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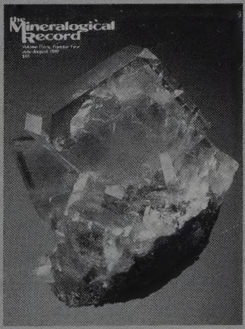

COVER: BARITE, 17 cm, from the Miekle mine, Nevada. (See the article in the previous issue.) Keith Proctor collection; Jeff Scovil photo.

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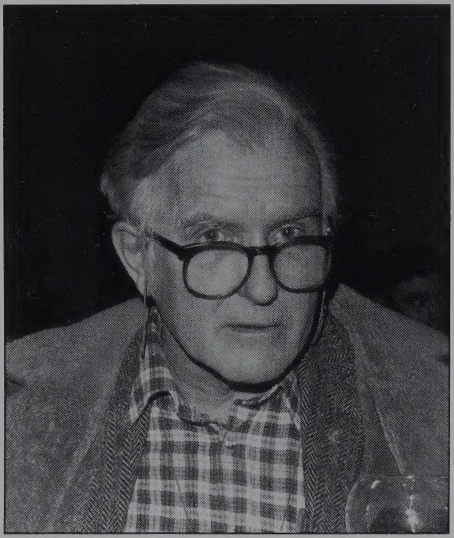

Kent England

Richard V. Gaines, 1917–1999

NOTICES

Died, Richard Venable Gaines, 81, from cerebral vascular complications on January 21st, 1999.

Richard was born on the 25th of January, 1917, in Poughkeepsie, New York. His mother was Elizabeth Castle Gaines and his father was Clement Carrington Gaines. He grew up in the town of Beacon, New York (Mitchell, 1988).

While attending a summer camp in Maine, at the age of nine, Richard found specimens of mica and garnet that initiated his enduring interest in mineralogy. Thereafter, with the encouragement of the curators of minerals of the American Museum of Natural History in New York, Herbert P. Whitlock and Frederick H. Pough, he visited the zeolite areas of Patterson, New Jersey. During subsequent Maine vacations he continued to explore the Maine pegmatites. In 1930, on a transatlantic ship with his mother and siblings, bound for one year at a Swiss boarding school, he met the exploration geologist, Robert Overbeck, whose fascinating stories of a professional life combined with world-wide travel influenced his career decisions from that time on.

Richard attended the Massachusetts Institute of Technology as a freshman and then transferred to the Colorado School of Mines where he received the degree of Engineer of Mines in 1940. This was followed by employment at the New Jersey Zinc Company at Sterling Hill, where he worked until February 1942. At that time he entered service with the United States Army and, as a Warrant Officer in the Corps of Engineers, was involved in the construction of airports in North Africa and India. He had diversified assignments, such as working in a cement plant in Eritrea, a half year in Cairo, and then a year in Calcutta where he secured a three-week leave to trek to the sapphire mines of Kashmir (see Gaines, 1946, 1951). He was finally discharged from the U.S. Army in November 1945.

Richard's years in the service as an engineer, while not entirely to his liking, had a positive effect on his future. He realized that he really wanted to study mineralogy because engineering offered little opportunity to work as a geologist. He enrolled as a graduate student at Harvard University and had the good fortune of working as a museum assistant under Clifford Frondel and as a teaching assistant under Hugh McKinstry, eminent professors of mineralogy and economic geology respectively. Richard received his Master's Degree in 1949 and his doctorate in 1951. The title of his dissertation was "The Mineralogy, Synthesis and Genetic Significance of Luzonite, Famatinite and Some Related Minerals." After he completed his graduate work at Harvard, he obtained an enviable job as a professional mineralogist at the renowned lead-zinc mines at Joplin, Missouri, and subsequently worked in uranium exploration while living in Grand Junction, Colorado.

In 1959 Richard moved with his family to Mexico where he spent eight and a half years exploring for economic minerals in the states of Sonora, Chiapas, Sinaloa, Guerrero, and Veracruz. It was during this period that he rediscovered the Moctezuma mine that was first opened for gold in 1937. This mine, though small, provided many new mineral species. Dr. Gaines wrote a comprehensive review of this mine for *The Mineralogical Record* early in its first year of publication in 1970. He named seven of these new species: burchardite, carlfriesite, cliffordite, moctezumite, poughite, schmitterite, and sonoraite. To facilitate this work, Richard received an appointment as research mineralogist at the Instituto de Geologia, Universidad Nacional Autonoma de Mexico. As one can see from the names he gave to these minerals, he was honoring many of the mineralogists who influenced his life's work.

Toward the end of 1966, Dr. Arthur Montgomery, chairman of the geology department at Lafayette College and a long time friend, informed him of an opportunity to appraise some pegmatites for tantalum. This resulted in his moving to Pottstown, Pennsylvania, in the employ of the Kawecki Chemical Company, later known as Cabot Resource Development. Here he became more focused on tantalum and beryllium deposits worldwide. This assignment led to extensive travels beyond North America and Europe, to such places as Brazil, French Guiana, Australia, Africa, China, and, of course, Madagascar. In fact, when we first met in 1972, he had just returned from a collecting trip to Brazil with John White, Wendell Wilson and Paul Moore, where Richard's fluency in Portuguese and his many Brazilian friends facilitated their travels. His trips provided great opportunities to acquire rare and classic mineral specimens which were attractively displayed in his homes, first in Pottstown, then in Earlysville, Virginia, where he moved upon retirement from the Cabot Corporation in 1987.

In 1975 Dr. Gaines was invited to join the editorial board of the *Mineralogical Record,* and served in that capacity until 1983.

Even though Richard sold many of his beautiful specimens to finance the construction of his new home in Earlysville, he retained his remarkable collection of beryllium, tantalum, niobium, and lithium specimens, along with garnets and some classic topaz crystals and members of the tourmaline group that he associated with his memorable trips to Brazil and Madagascar.

For what seemed like a millennium, Richard served as the senior author of *Dana's New Mineralogy,* the eighth edition of Dana's *A System of Mineralogy,* with H. Catherine Skinner, the late Eugene E. Foord, Brian Mason, and Abraham Rosenzweig. It was finally published by John Wiley & Sons in New York in 1997 as one volume of 1,819 pages. Dana's first edition was printed in 1837, just 22 years before Darwin's *On the Origin of Species.*

Thanks to the persistence of Dr. Paul B. Moore, a new zirconium beryllium phosphate mineral, found at the Nevel quarry an Newry, Maine, was given the name gainesite in 1983.

Richard was a long-time member of the New York Mineralogical Club, a fellow of the Mineralogical Society of America, a member of the Mineralogical Society of Great Britain, the Mineralogical Association of Canada, the Society of Economic Geologists, and served as president of the second oldest United States mineral society, The Philadelphia Mineralogical Society.

Richard is survived by his wife of twelve years, Denise "Nina" Martin Gaines, a retired professor of Italian at Northern Illinois University and a Dante scholar. Also surviving are the four children by his first marriage: Elizabeth Castle, David Nathaniel, Leslie Ann, and Richard Venable III, and their mother, Dorothy B. Gaines; a grandson, Arman, three step-children and three step-grandchildren.

John D. Hallahan

REFERENCES

GAINES, R. V. (1946) The Kashmir sapphire mines. *The Himalyan Journal,* **13**, 73–77.

GAINES, R. V. (1951) The sapphire mines of Kashmir. *Rocks and Minerals,* **26**, 464–472.

GAINES, R. V. (1970) The Moctezuma tellurium deposit. *Mineralogical Record,* **1**, 40–43.

MITCHELL, R. S. (1988) Who's who in mineral names: Richard Venable Gaines, Robert Ferguson. *Rocks & Minerals,* **63**, 304–306.

MOORE, P. B., ARAKI, T., STEELE, I. M., SWIHART, G. H., and KAMPF, A. R. (1983) Gainesite, sodium zirconium beryllophosphate: a new mineral and its crystal structure. *American Mineralogist,* **68**, 1022–1028.

PANCZNER, W. D. (1985) Miguel Romero and the Romero Mineralogical Museum. *Mineralogical Record* **16**, 129–136.

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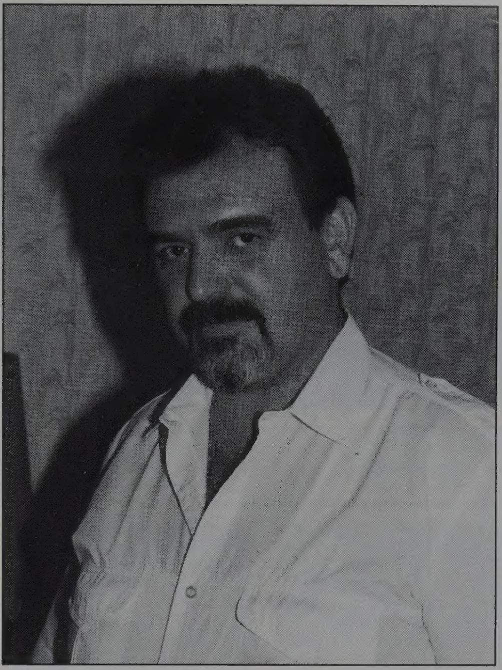
Died, Luis Antonio Bravo Teixeira Leite, 56, prominent mineral dealer after whom *leiteite* was named, in Bahia, Brazil. Luis Leite was born on July 5, 1942, in Lisbon, Portugal, the son of José Rodrigues and Gloria de Jesus Bravo Teixeira Leite (Mitchell, 1988). A small mineral collection given to him when he was 12, by an assistant at the Faculdade de Ciencias in Lisbon, kindled his interest in mineralogy.

In 1959 his parents moved to Lourenço Marques, the capital of Mozambique (at that time known as Portuguese East Africa, a Portuguese overseas province until achieving independence in 1975). There he completed high school, and then studied paleontology and archeology at the Museum of Science in Livingstone, Zambia. During eight years spent primarily in Mozambique he worked variously as a professional crocodile hunter and safari guide, a mud-logger with Gulf Oil Company, a geological assistant at Dr. Alvaro de Castro's museum in Lourenço Marques, and as a curator of the mineralogical museum at the University of Lourenço Marques, while also serving as an archeology assistant at the Instituto de Investigação Cientifica de Moçambique. He loved sports, played soccer and handball for many years, and taught swimming in Mozambique.



Kent England

Luis T. Leite, 1942–1999

Luis moved to Pretoria, South Africa, where he ran a mineral business, *Mara Gems and Minerals* (named for his wife, Mara Catharina Magdalena Prinsloo, m. 1967), from 1968 through 1976. He traveled extensively on collecting trips throughout Africa, visiting sites in Rhodesia, Zambia, Angola, Morocco, Malawi, Mozambique, South Africa, and South-West Africa (Namibia), where he discovered a new mineral species at Tsumeb that was later named *leiteite* in his honor (Cesbron *et al.*, 1977).

In 1976 Luis returned to Portugal where he opened a restaurant called the *Vila Real de Santo Antonio* (1979–1982), a mineral shop in Lisbon (1983–1985), and a business dealing in rare postage stamps. In 1985 he began serving as a volunteer at Lisbon's Museu de Faculdade de Ciencias, in gratitude for the role its members had in inspiring his childhood interest in mineralogy, and was promoted to honorary curator. He and Mara also owned and operated a big-game park in Portugal from 1992 to 1996.

During his life he assembled and sold at least three personal collections of fine minerals, the most recent one sold to Albert Chapman in Australia. He was a popular conference speaker, and the author of a number of articles on pegmatite localities in Mozambique, published in the *South African Lapidary Journal.* He was well-known to mineral collectors world-wide as a supplier of beautiful and rare species, particularly through his motel rooms at the Desert Inn and (later) the Executive Inn during the annual Tucson Show. He had an eye for color, and a visitor's first impression of his display stock was always to marvel at the beautiful array of colorful, well-crystallized minerals. He died March 2, 1999, in Porto Seguro, Bahia, Brazil, and was buried in Governador Valadares, Minas Gerais, Brazil.

Wendell E. Wilson

REFERENCES

CESBRON, F. P., ERD, R. C., CZAMANSKI, G. K., and VACHEY, H. (1977) Leiteite, a new mineral from Tsumeb. *Mineralogical Record,* **8**, 95–97.

MITCHELL, R. S. (1988) Who's who in mineral names: Luis Antonia Bravo Teixeira Leite. *Rocks & Minerals,* **63**, 478–479.

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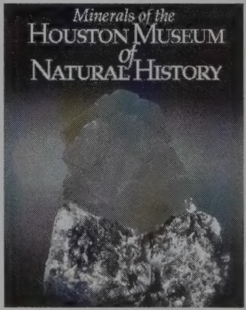

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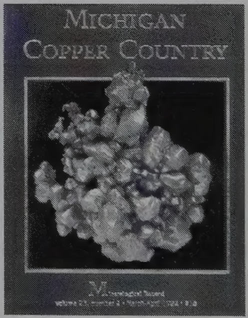

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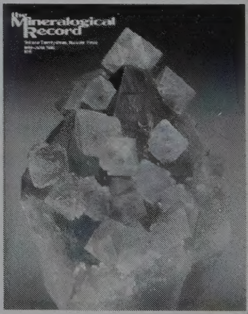

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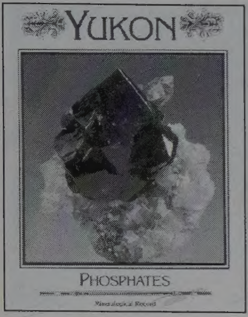

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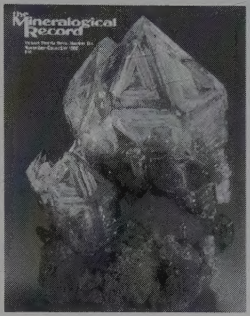

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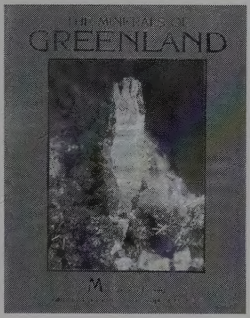

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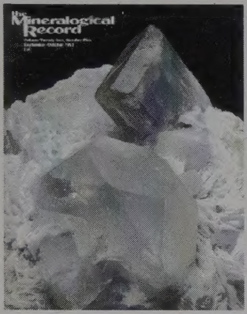

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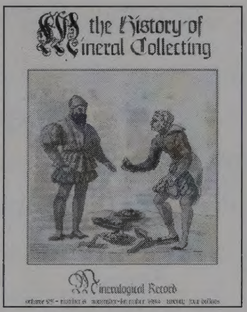

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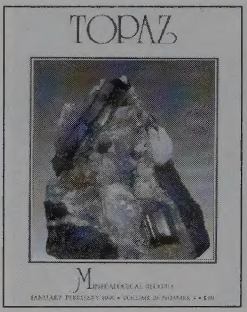

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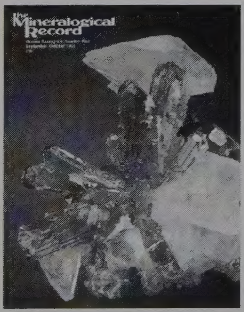

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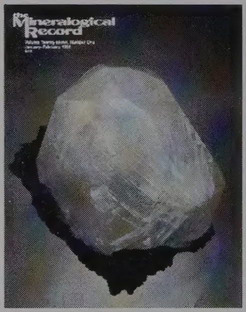

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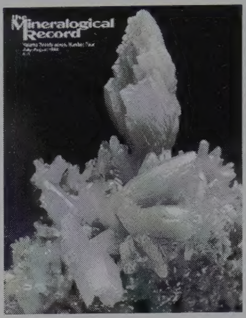

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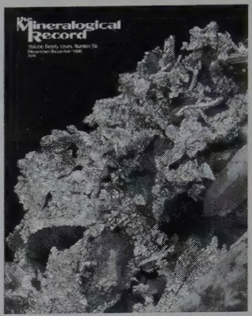

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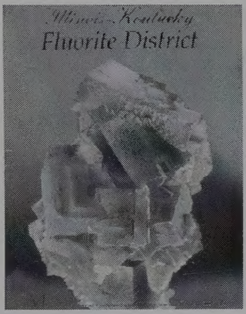

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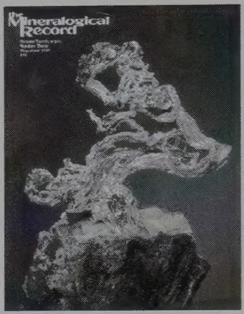

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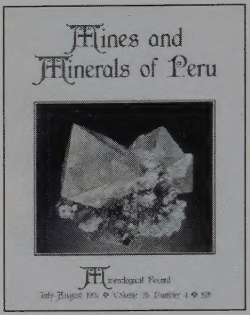

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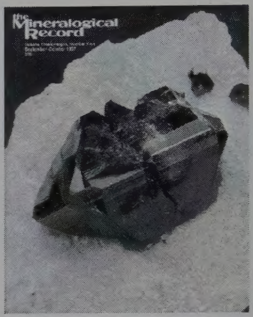

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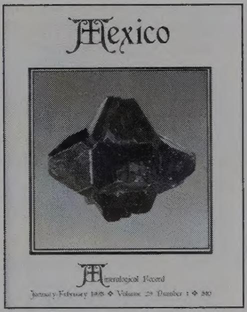

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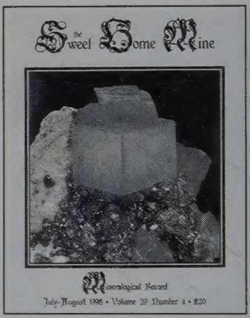

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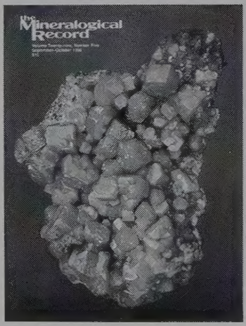

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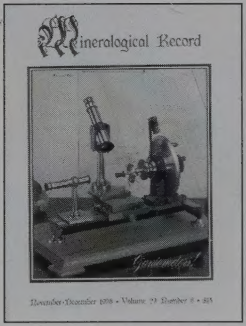

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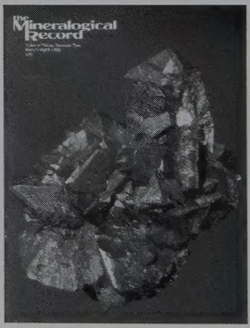

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COBALT MINERALS OF THE KATANGA CRESCENT, CONGO

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Cobalt, copper and uranium are the important ore metals in a large number of deposits within and near the "Katanga Crescent." Many beautiful cobalt-containing minerals have come from this famous area, including carrollite, cattierite, siegenite, comblainite, heterogenite, kolwezite, oursinite, sphaerocobaltite, and brilliant pink cobaltoan calcite and dolomite.

HISTORY OF COBALT

Unlike copper, which has been known for millennia, metallic cobalt was not definitely isolated until the 18th century. The coloring properties of its oxides have nonetheless been known since the most ancient times, particularly in the Middle East, Egypt and China. Materials as varied as pottery, earthenware, glass, enamelware and pearls were tinted every shade of blue by heating with cobalt oxides at high temperatures in clay furnaces. Objects could also be decorated with paints derived from these same cobalt oxides.

The cobalt ores used initially came from Persia and Burma. After roasting at red heat, followed by fine grinding, a pigment with a very high coloring capacity was obtained; the "Egyptian blue" and the "China blue" of those times were simply "cobalt blue."

It is likely that the alchemists of the Middle Ages, who had mastered the technique of roasting sulfide ores, followed by reduction to obtain the native elements, produced cobalt under another name well before the 13th century. Subsequent to the Middle Ages and in Central Europe, cobalt ores closely associated with silver, lead, nickel and bismuth ores were extracted from mines in Saxony and Bohemia. Since cobalt was not of any economic value at that time, it posed a considerable problem in the metallurgical processing of the so-called "useful" metals. In addition, since the cobalt was associated with sulfur and arsenic, the roasting process released noxious fumes. As a result, this mineral was regarded by the miners as a divine curse.

The term "cobalt" comes from the German *Kobold,* which means "demon," or, according to an old Germanic legend, the evil-minded gnome-like spirits of the mines. The etymology that evokes goblins or gnomes also raises another possibility. The origin of the word is perhaps to be found in the height of the miners. Perhaps the exploitation of the mines in Saxony required workers of small size, as it did earlier in the ancient mines of Laurium in Greece.

In any case, the name *cobalt* appeared in the literature on mining for the first time (in the Latin forms *cobaltus* and *cobaltum*) in the celebrated treatise on the mining operations in Saxony and Bohemia entitled *De Re Metallica* (1556) by Georgius Agricola. It was not until 1735 that the Swedish chemist Georg Brandt isolated cobalt as a pure element. The research subsequently undertaken on this new element led to industrial applications that were far more important than its simple use as a coloring agent.

COBALT MINING WORLDWIDE

By the early 19th century, cobalt deposits had been found more or less everywhere in the world, particularly in Germany (the Black Forest, Harz, Hesse), Norway, Sweden, Transylvania (now part of Romania), France, Spain, England, Chile, Argentina, Tasmania, etc. The chronology of the most recent discoveries of large deposits is as follows:

1874: New Caledonian deposit
1904: Ontario deposits (Canada)
1907: Katanga deposits (Democratic Republic of the Congo)
1930: Bou Azzer deposit (Morocco)
1933: Deposits of the Zambian Copperbelt which overlaps southeastern Katanga
1939: Outokumpu deposits (Finland)

Other deposits of varying importance have also been discovered in the United States (which is also the leading consumer of cobalt), in Kazakhstan, in Azerbaijan, and in the lateritic soils of Cuba.

Cobalt has been mined intermittently in the United States for more than a century, at localities in Idaho, Maryland, Missouri, Pennsylvania, Virginia and Wisconsin. Known reserves are abundant but generally too low-grade to be economical. Today only a few mines in Pennsylvania are producing cobalt, as a byproduct of iron mining.

The old Blackbird mine in Idaho is among those that once produced cobalt, despite a very low ore grade (0.015% Co). Reserves there are extensive, consisting primarily of copper ore with trace amounts of cobalt. The mine was shut down for purely environmental reasons.

At best, domestic U.S. production of cobalt has rarely exceeded 1,000 tons per year. Consequently, the United States remains heavily dependent upon foreign producers for the roughly 20,000 tons of cobalt it consumes each year.

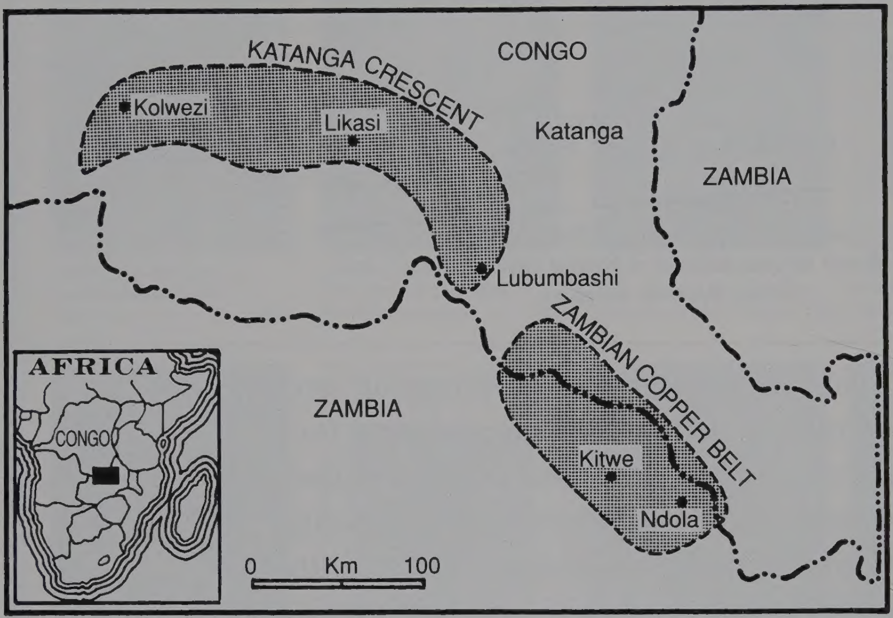

Figure 1. **Location map.**

Cobalt production worldwide is almost invariably a byproduct of mining for other metals, and ore grades are typically very low (a few hundredths to a few tenths of a percent Co). The rare exceptions where ore containing over 1% Co is found include Bou Azzer, Morocco; the hydrothermal veins in the Cobalt-Gowganda area, Ontario; and of course the Katanga Crescent copper-cobalt deposits. High-grade cobalt ores in Katanga occur mainly in the upper enrichment zones of oxidized orebodies. Despite the enrichment, cobalt content alone is generally too low to make mining profitable; as elsewhere, the cobalt has in the past been produced primarily as a byproduct, in this case of copper mining.

The most important producers of cobalt today are Zambia, Canada, Kazakhstam and Azerbaijan. Congo was the leader until the 1970's, producing up to 16,000 metric tons per year. At present, cobalt production in Congo is negligible; but with reserves estimated at 600,000 tons of metallic cobalt, and with good market conditions forecast, Congo may soon be a major cobalt producer once again.

KATANGA COBALT DEPOSITS

All cobalt produced in Katanga is taken from stratiform deposits. Thus far it has been a byproduct of copper production, but plans for the future call for cobalt to be extracted as the main ore metal, with copper as the byproduct. In the Katanga Crescent, the Union Minière du Haut-Katanga (U.M.H.K.), which operated mines there from 1906 to 1966, has identified over 100 deposits containing both cobalt and copper. The size and grade of the orebodies vary over a substantial range, but they are always in the form of continuous layers in the lower part of the Roan System (R.2 group). The R.2 group has been dislocated and fragmented to some extent by tectonic movements and separated by breccias, some of which are also mineralized (by Cu or Cu+Co). Where cobalt is found, it is always associated with copper, both in the primary ores and in the oxidation zone.

There are two principal strata which tend to be mineralized (known generally as the "upper" and "lower" orebodies). The mineralization is always parallel to the stratification and somewhat patchy in distribution, with cobalt-rich patches overlapping copper-rich patches. Patches are typically separated by barren or very low-grade zones. Individual patches range from a few hundred meters to several kilometers in maximum dimension.

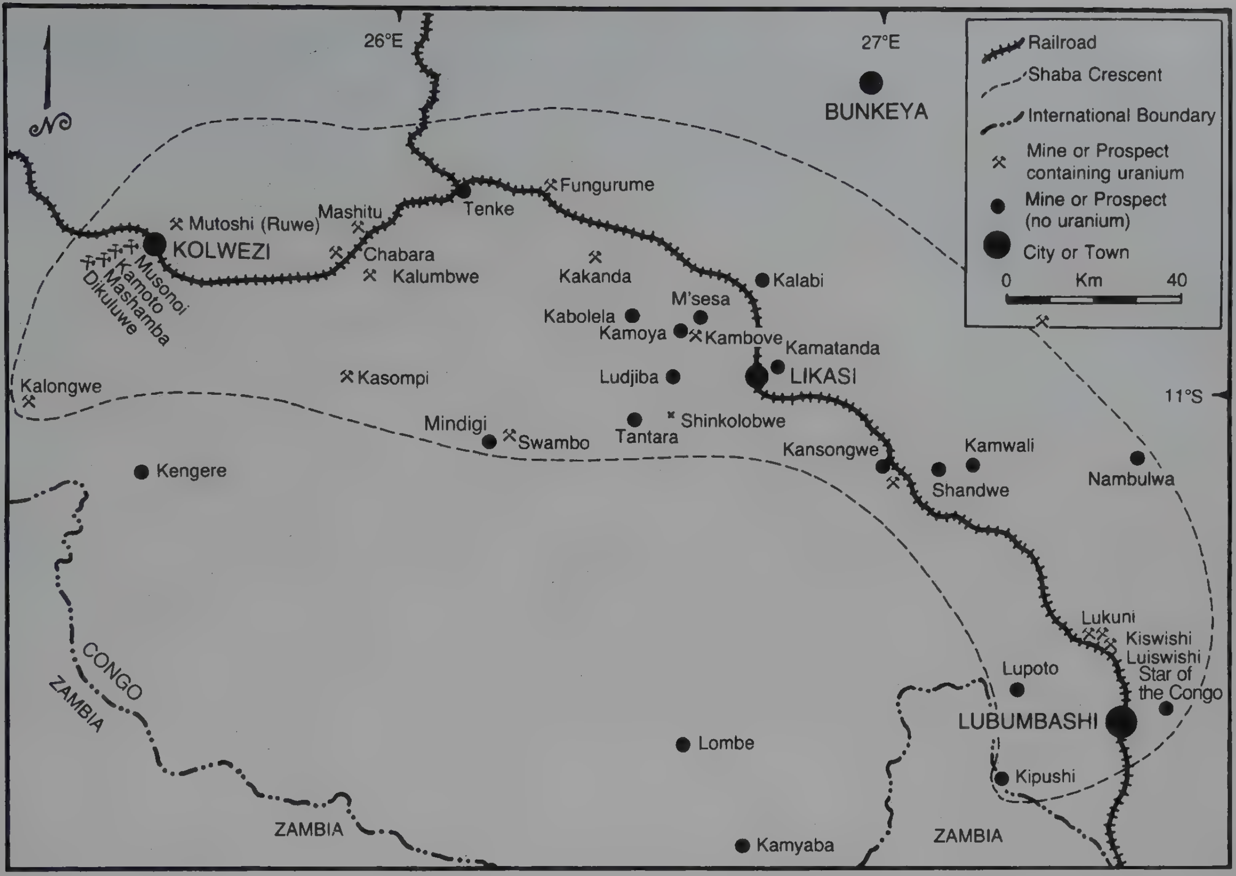

Figure 2. **Location of mines in the Katanga Crescent.**

In general the upper orebody is richer in cobalt, but the lower orebody is thicker and more extensive (except at sites such as Kambove West). Cobalt-rich patches are generally smaller in extent than copper-rich patches. Cobalt distribution is somewhat irregular; in the huge Kolwezi Klippe (in which there are many mines including the Musonoi, Kamoto, Mutoshi, Mupine, Mashamba and Dikuluwe) cobalt content decreases steadily from south to north, disappearing entirely in the northern half of the Klippe. Cobalt content is generally lower than copper, though still substantial relative to other world deposits (see Table 1).

Cobalt recovery in Katanga began in 1925 at the Panda-Likasi electrical refinery. An iron-cobalt mixture called "white alloy" was produced from this pilot plant. Regular production began in the 1940's, at the Shituru-Likasi electrolytic plant, and in the 1960's at the Luilu-Kolwezi plant.

Actual production of cobalt ore first began in 1907 with the opening of the famous Star of the Congo mine near Lubumbashi, the capital of Katanga province. Table 1 shows the ore grades for Cu and Co at mines in the Katanga Crescent which contain at least 0.3% cobalt.

It should be noted that in the upper portion of the oxidized zones of the deposits there are local enrichments, mainly of cobalt, in which a heterogenite heap is more resistant than the copper oxides to being washed out by meteoric waters. This is the case in particular, at an outcropping of the Musonoi deposit, where exploitation of the particularly well developed "cobalt cap" was begun in 1940–41, while the mine itself did not begin operation until 1945. It is also the case with the upper zone of the Oliveira fragment, in the K.O.V. (Kamoto-Oliveira-Virgule) deposit, also in the western sector, where there is a superficial enrichment of cobalt, while the copper has been entirely leached away.

During World War II, cobalt became an important strategic metal. From 1939 to 1943, the U.M.H.K. increased substantially its cobalt ore production with the opening of the rich cobalt mines of Kasombo (southern sector), Mindigi and Kabolela (central sector), Kingamyambo, and the gossan zone of the Kamoto mine (western sector).

COBALT MINERALS

Although more than 400 mineral species containing essential copper are known (worldwide), the total number of cobalt species barely exceeds 50. Only 15 of these have thus far been reported from Katanga, 14 from the Cu-Co stratiform deposits and from vein deposits at Shikolobwe, and one from the pipe-like Kipushi deposit. The stratiform deposits have yielded carrollite, linnaeite, trogtalite, cobaltomenite, heterogenite (both 3R and 2H polytypes), julienite, kolwezite and sphaerocobaltite. The Shinkolobwe mine has yielded cattierite, carrollite, linnaeite, penroseite, siegenite, comblainite, oursinite and heterogenite (3R). And the Kipushi mine has produced colbaltite. Julienite (a thiocyanate of cobalt) has been found only at the Shamitumba deposit outcrop and may be quite recent in origin. Bieberite (cobalt sulfate) has formed as a post-mining mineral on timbering in old stopes above the water table.

It should also be noted that the alteration of carrollite (virtually the only primary cobalt ore mineral in the stratiform deposits) proceeds far more readily than the alteration of primary copper sulfides. Consequently, even where alteration of copper and cobalt sulfides begins simultaneously, and copper sulfides significantly exceed carrollite, the concentration of Co ions in solution will dominate during the deposition of Co-Cu secondary minerals until the carrollite has been exhausted. Thereafter only copper second-

Figure 3. **The Mashamba West mine, Katanga. Photo by Armand François.**

Figure 4. **Collecting at the Mindigi mine. Photo by Joseph Lhoest.**

ary minerals will form. This dephasing of the Co and Cu secondary minerals is particularly obvious at one of the Fungurume outcrops where (secondary Co) heterogenite is found associated with (primary Cu) chalcocite; unaltered carrollite is only found at a depth of about 300 feet below the outcrop.

The relatively small number of secondary cobalt species is a result of the limited compatibility and affinity of Co^{2+} and Co^{3+} ions for other possible ions in solution. The affinities are restricted to S, Se, and to a lesser extent Cu and Ni (for primary minerals), and O^{2-}, OH^-, CO_3^{2-} and to some extent Cu and Ni (for secondary minerals). Physiochemical characteristics of the alteration environment may further restrict the possibilities. Cobalt, however, can replace copper, calcium and perhaps also magnesium to a limited degree in such minerals as cobaltiferous malachite and cobaltoan calcite and dolomite.

Katanga is the type locality for five of the known cobalt species: cattierite (from Shinkolobwe), comblainite and oursinite (from Shinkolobwe), heterogenite (the 2H polytype, from Mindingi) and kolwezite (from Musonoi).

Primary Minerals—Stratiform Deposits

Cu-Co sulfide mineralization in Katanga is localized into two orebodies. The so-called "lower" orebody of stratified, siliceous dolomite 10 to 15 meters thick, and the "upper" orebody of stratified, sandy, dolomitic shale 5 to 10 meters thick. These two major layers are separated by a massive, barren dolomite (the RSC

Figure 5. **Giant carrollite crystal cluster about 30 cm across, from the Kambove mine. Photo by E. Van Der Meersche.**

Figure 6. **Carrollite crystals to 1.5 cm on matrix, from the Kambove mine. Smithsonian collection; photo by Wendell E. Wilson.**

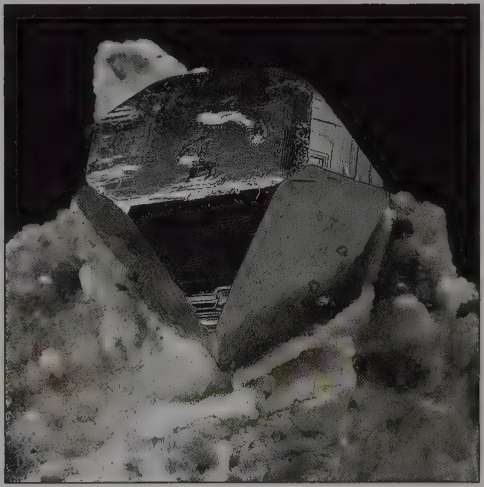

Figure 7. **Carrollite crystal, 1.3 cm, on matrix from Terry Wallace collection; photo by Wendell E. Wilson.**

Formation) of variable thickness ranging from a few meters to several tens of meters. The two orebodies are located at the base of the R_2 Group, an Upper Proterozoic member of The Roan Supergroup. The only cobalt sulfides present are carrollite and linnaeite, but the selenide trogtalite is also associated.

Carrollite $Cu(Co,Ni)_2S_4$

Katanga carrollite contains 36% Co and virtually no Ni, so the formula can be simplified to that of the pure end-member: $CuCo_2S_4$ (except at Luishia, where a little nickel is found). Carrollite is the principal primary cobalt mineral in the stratiform deposits. It generally occurs in massive form, associated with massive copper sulfides such as chalcopyrite, chalcocite and bornite. Well-formed crystals have developed in the dolomitic beds of both main orebodies, in calcite veins crossing these dolomites, and in fissures

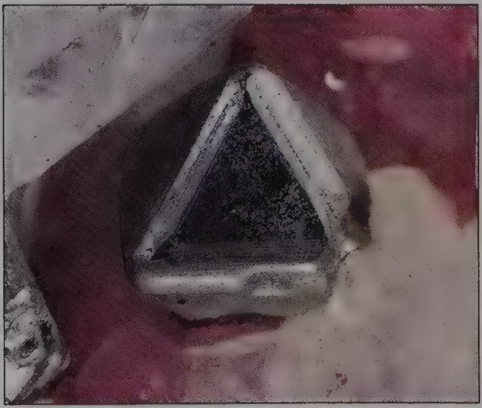

Figure 8. **Carrollite crystals to 9 mm, with quartz and cobaltoan dolomite, from the Kambove mine. Photo by E. Van Der Meersche.**

and vugs in the walls of the lodes. The most common crystal forms are the cube and the octahedron in some combination; the cube or octahedron alone are exceedingly rare. Unaltered crystals are steel-gray to silvery white with a bright metallic luster. Altered crystals are dull and frosty, gray to black in color, and may bear a thin coating of heterogenite.

Remarkable crystals of carrollite have been found at four mines. The Musonoi open pit has yielded crystals to 5 cm on an edge. The Kambove West (underground) mine produced a 10-cm crystal which was unfortunately broken by blasting; nice twins 3 to 4 cm in size have also been found there. And the Kamoto (underground) workings have been the source of perfect octahedrons and exceptional cubes to 3 cm on calcite. At the Luishia open pit, tiny, perfect, lustrous crystals have been found on a bed of magnesite. These are superb octahedrons nicely modified by truncated edges and low-angle tetrahexahedron faces. Unlike carrollite from other stratiform deposits, the crystals from Luishia contain several percent nickel. In the Shinkolobwe vein deposits a nickeliferous carrollite has also been found, but crystals there are exceedingly rare. Alteration of carrollite above the water table and on the dumps has often led to the deposition of sphaerocobaltite on skeletal, etched carrollite.

Linnaeite Co_3S_4

Linnaeite, with a cobalt content of 58%, is very rare in Katanga, and occurrences in The Katanga Crescent are few. Not a single crystal visible to the naked eye has been found during more than 90 years of exploitation of the stratiform deposits. Linnaeite has been identified primarily in polished sections of massive sulfide ore from the Luishia and Kabolela open pits, in association with carrollite and copper sulfides.

Trogtalite $CoSe_2$

Cu-Pd-rich trogtalite has been found at the Musonoi-Extension mine in the Kolwezi Klippe (Johann *et al.,* 1970). It occurs in close association with oosterboschite, $(Pd,Cu)_7Se_5$, and secondary selenium minerals such as marthozite, demesmaekerite and derriksite in U-Se-rich portions of the oxide zone. The two selenides form porous, blackish nuggets resembling heterogenite, but distinguished from it by their yellowish metallic luster. The mixed nodules are found sporadically throughout the deposit.

When examined in polished section, the patches of trogtalite may measure up to a millimeter in diameter. They reveal an orthogonal network of polysynthetic twins. The trogtalite appears pinkish brown, in contrast to the creamy white of the oosterboschite. The cobalt content is 17%, with 9% copper and 4.7% palladium.

Primary Minerals—Vein Deposits

The second type of deposit in southern Katanga is vein-like in character, but is genetically related to the stratiform deposits of the Katanga Crescent. The Shinkolobwe-Kasolo vein-like deposit is located at the far eastern end of a long anticlinical zone extending to Kalongwe on the west, and on through Swambo, Mindigi and Kasompi along the Monwezi fault. This zone is characterized by cuprocobaltiferous deposits that are richer in nickel, and are often also uraniferous.

The Shinkolobwe-Kasolo deposit is genetically related to the stratiform cuprocobaltiferous deposits in the Katanga Crescent, but the intense local tectonics, accompanied by a later remobilization of sulfide minerals and uranium oxides, have given the deposit a typical veined appearance. This characteristic is clearly seen in the geometry of the mineralized body, and in the mineralization itself. The mine was basically exploited for uranium, associated with high grades of cobalt and nickel; copper is not very abundant. It should be remembered that uranium is not unusual in the Cu-Co deposits in the Katanga Crescent (Gauthier *et al.,* 1989). However, although it is generally only a minor byproduct of copper production from the stratiform deposits (with no economic interest, the grade and the quantity being too low), it was the main mineralization in the vein-like deposit of Shinkolobwe, with high levels of cobalt and nickel. The mineralization at Shinkolobwe also contains selenium, as does that of the Musonoi-Extension uranium deposit in the Kolwezi Klippe.

Before taking up the copper sulfide minerals at Shinkolobwe, it is worthwhile to devote a few lines to the history of this great deposit. Shinkolobwe is the name of a small river that has its source at the base of a high hill. The summit of the hill was chosen as a geodesic signal point during the triangulation of South Katanga by the "Comité Spécial du Katanga" (the C.S.K.), the state landlord of the Katanga Crescent. This hill was identified as Shinkolobwe-Signal for reference purposes. It was a protruding outcrop in the eroded area of a Cu-Co deposit, about 3 km east of the native village of Kasolo. In 1915, Major Sharp, one of the U.M.H.K. prospectors, noticed at Kasolo an almost vertical cliff several meters high. It was a steep outcropping of hard, cellular siliceous rock (the RSC Formation, well-known throughout the Katanga Crescent) considerably more resistant to erosion than the surrounding sedimentary beds. The RSC Formation is the great reference mark for finding the stratiform orebodies: at depth, it is the barren massive dolomite separating the two orebodies in the alteration zone, this formation is completely silicified and full of cavities, showing frequently the remnants of the Roan Collenias fossils (stromatoporidae-like algal formations). The big Collenias colonies are the only visible fossils in the formation.

At the foot of this cliff, Sharp identified solid blocks of uraninite associated with curite. But it was not until 1920 that the U.M.H.K. decided to register the deposit at the C.S.K. office in Lubumbashi, under the name "Kasolo deposit" with the mention of "radium" (not uranium!) as the ore metal.

Strangely, this mine was opened by the U.M.H.K. in 1924 under the name of "Shinkolobwe." Logically, it should have been named "Kasolo," or at least "Shinkolobwe-Kasolo," to avoid any confusion with the Shinkolobwe-Signal deposit.

Linnaeite Co_3S_4

Linnaeite is present only in the form of massive ore, in association with other sulfides. It can only be identified with certainty by observation in polished section. There are no idiomorphic crystals in Shinkolobwe.

Cattierite CoS_2

Cattierite in Katanga has been identified only from the Shinkolobwe mine, which is the type locality (Kerr, 1945). In the ore mass, the cattierite forms mixed associations with linnaeite. The two sulfides form gray to bronze patches with a metallic luster, associated with chalcopyrite, in crystallized pink dolomite. The cattierite may contain up to 0.5% copper and up to 4% nickel.

Beautiful cubes of cattierite have been found in vugs. The crystals measuring 1–5 mm, have sharp edges and a definite cleavage parallel to the faces of the cube. Their color is a metallic gray with purplish glints. With oxidation in the air, the crystals take on a characteristic tobacco-brown color.

Carrollite $Cu(Co,Ni)_2S_4$

Unlike the carrollite in the stratiform deposits, Shinkolobwe carrollite contains nickel. It is very rare in Shinkolobwe.

Siegenite $(Ni,Co)_3S_4$

The cobalt content of Shinkolobwe siegenite is 26%. Centimeter-size octahedral crystals with brilliant faces are found at a number of points in the Shinkolobwe deposit. The mineral is generally associated with masses of gray siegenite and black vaesite. Massive veins of siegenite have resulted from the replacement of vaesite or cattierite veins.

In the lower part of the Shinkolobwe oxidation zone, siegenite rich in selenium is also found, in close association with penroseite (described below).

Penroseite $(Ni,Co,Cu)(Se,S)_2$

Penroseite was discovered in the oxidation zone of the Shinkolobwe deposit (Deliens, 1975), in association with seleniferous siegenite and molybdenite. Thus it is not a primary mineral, properly speaking, but rather a species belonging to the upper enrichment zone of the deposit. It is nevertheless being mentioned in this category because it is chemically analogous to the primary sulfides. Penroseite and the associated sulfides form mixed clusters measuring up to several cm^3 within a gray vuggy dolomite rich in microcrystals of barite and anhydrite. In polished section, the penroseite appears pale gray, in contrast to the creamy white siegenite and the dark gray molybdenite. The penroseite contains 2.6% cobalt, 26% nickel and 1% copper. The unusual characteristic of Shinkolobwe penroseite is its high sulfur content, which, in part, replaces the selenium: 5.8% sulfur, and 66.6% selenium.

Secondary Minerals

The alteration of primary sulfide minerals in Katanga has led to secondary associations that differ greatly in quality and in copper/cobalt ratio. One of the principal characteristics of the oxidation zones in the southern Katanga deposits, whether in the stratiform layers or the vein beds, is the lack of diversity in the cobalt mineral assemblages as compared to the very broad range of copper minerals. From this point of view, the cobalt more resembles nickel, a rarer metal in Katanga, but one that, where it is present (Shinkolobwe, Mindigi), is only involved in the formation of secondary minerals in exceptional cases.

Another notable fact is the extreme development of the oxidation zone of the Katanga deposits. It is not uncommon to observe thicknesses of several score, or even 100 meters (Kambove, for example). The oxidized ores are found at a great depth below the current water table, which suggests an oxidation prior to a new rise in the hydrostatic level. This phenomenon is explained by major climatic variations during the Pleistocene epoch. Moreover, erratic oxidation phenomena independent of depth can be observed. They are directly linked with the permeability (porosity and fissuration) of the host rocks and the lode wall rocks. The presence of numerous faults and impermeable obstacles amplifies the anomalies.

From the genetic point of view, it is believed that the leaching of the primary sulfides created sulfate solutions that have reacted with the dolomitic rocks to produce secondary carbonates (malachite, sphaerocobaltite), and with the siliceous rocks to produce silicates, such as chrysocolla, plancheite, shattuckite and dioptase. More generally, however, the cobalt tends to accumulate in the form of hydrous oxides associated with siliceous rocks, but frequently retaining the indices of the primitive carbonate rock. Katanga malachites may contain an appreciable percentage of cobalt (up to 6.5%). In the western mines (Musonoi, Kamoto), a double carbonate of copper and cobalt (kolwezite) has been found which belongs to the rosasite structural group and contain nearly 20% cobalt (Deliens and Piret, 1980).

Calcite $CaCO_3$, and **Dolomite** $CaMg(CO_3)_2$

Tiny pink crystals of cobaltoan dolomite on gray dolomite have come from deposits in the Kakanda area, and are well-known on the mineral market. The Mashamba West, Mupine and Mindingi deposits produced pink cobaltoan calcite, and generally in much bigger crystals. The large, pink scalenohedrons of cobaltoan calcite from the Mashamba West mine are the most beautiful in the world; some crystals also have a partial kolwezite coating. Like Shinkolobwe, the Mashamba West mine has also produced spectacular cobaltoan calcite in pink hexagonal prisms to several centimeters, with three-faced rhombohedron terminations.

Energy-dispersive X-ray and X-ray diffraction analyses by Dave Douglass (personal communication, 1998) have confirmed that the larger, paler pink crystals are cobaltoan calcite, whereas the more vividly colored druzes and botryoidal crusts are cobaltoan dolomite. The dolomite crystals tend to be magnesium-rich (Mg:Ca up to 3:1), and in fact are so supersaturated with Mg that they should have spontaneously broken down into a mixture of normal dolomite and magnesite. This appears not to have occurred, since X-ray diffraction analyses show only dolomite being present.

Cobaltoan calcite and dolomite, though brightly colored, actually contain only a very small percentage of cobalt. A series does not exist between sphaerocobaltite (50% Co) and calcite or dolomite (0.5 to 1.5% Co) because the Co^{2+}/Ca^{2+} substitution is so limited.

It should also be mentioned that the Tantara mine has yielded spectacular, massive but *gemmy* cobaltoan calcite, sometimes in association with dioptase. One such example is displayed in a showcase of the U.M.H.K. Company in their Brussels office, and others are currently on exhibit in the Sengier-Cousin Museum in Likasi, Katanga.

Cobaltite $CoAsS$

Cobaltite has never been reported from the stratiform and vein-like deposits of Katanga; there is practically no arsenic present in those orebodies. However, cobaltite has been found in the massive ore of the Kipushi mine, a pipe-like deposit similar to the one at Tsumeb, Namibia.

Cobaltomenite $CoSeO_3\cdot 2H_2O$

Cobaltomenite has been found on the 2,400 level of the Musonoi-Extension mine. Seleniferous digenite is the main primary sulfide of copper here, in association with primary uraninite (UO_2). The alteration of these minerals has yielded rare selenites of copper (chalcomenite, $CuSeO_3\cdot 2H_2O$) and of cobalt (cobaltomenite). The cobaltomenite occurs as very small, purplish crystals on altered digenite.

Alteration in an environment rich in selenium and uranium at Musonoi has led to the formation of other rare minerals including demesmaekerite, derriksite, guilleminite and marthozite.

Comblainite $(Ni^{2+}_x,Co^{3+}_{1-X})(OH)_2(CO_3)_{(1-x/2)}\cdot yH_2O$

Comblainite, an oxycarbonate of nickel and cobalt, has been found in the uraniferous Shinkolobwe deposit in association with heterogenite-3R and secondary cobalt minerals such as rutherfordine, becquerelite and masuyite. Comblainite is found in millimeter-thick beds of turquoise-blue masses, and also yellow to yellowish green masses in association with gummite. Under the microscope, irregular crystals up to 10 microns in size can be seen (Piret and Deliens, 1980).

From the chemical point of view, all of the cobalt in comblainite is in trivalent form, whereas the nickel is bivalent. The highest cobalt content observed is 14.6%. Structurally, comblainite belongs to the hydrotalcite group. The X-ray diffraction pattern is very close to that of takovite. $Ni_6Al_2(OH)_{16}(CO_3,OH)\cdot 4H_2O$, which belongs to the same structural group. Comblainite is very rare at Shinkolobwe, and has only been found in a few specimens.

Figure 9. **Cattierite crystals to 6 mm, with cobaltoan calcite, from the Shinkolobwe mine. Sorbonne collection, Paris; photo by Nelly Bariand.**

Figure 10. **Cobaltoan calcite crystal, 3 cm, from the Mupine mine. Photo by E. Van Der Meersche.**

Figure 11. **Cobaltoan calcite crystals with cobaltiferous malachite, 3 cm, from the Mupine mine. Photo by E. Van Der Meersche.**

Heterogenite CoOOH

The compact or powdery black oxyhydroxides of cobalt are by far the preponderant secondary minerals in the supergene alteration zones of the sulfide deposits of cobalt throughout the world. They were given the name "heterogenite" (literally "of a different nature") by Frenzel in 1872 in order to distinguish them from the black oxides of manganese (which have the same appearance) obtained from the cobalt, nickel and manganese ore at the Maasen mine in Schneeberg (Saxony, Germany).

Since their discovery, the black oxides of cobalt have posed a mineralogical problem that is particularly difficult to resolve. For more than a century, material obtained from various deposits has been studied. More than 20 different chemical formulae have been proposed, and a number of names were given to them (including *boodtite, heubachite, lubumbashite, mindigite, schulzenite, stainierite, transvaalite, trieuite* and *winklerite*). In 1962, Max Hey came to the conclusion that the heterogenites all have a single formula, CoOOH, analogous to that of manganite (MnOOH) and goethite (FeOOH). Deliens (1974), who studied the southern Katanga heterogenites, confirmed Hey's views and retained the

Figure 12. Cobaltoan dolomite crystals to 2 mm, from the Kakanda area. Photo by E. Van Der Meersche.

Figure 13. Cobaltoan dolomite crystals to 2 mm, from the Kakanda area. Photo by E. Van Der Meersche.

Figure 14. Cobaltomenite crystals to 2 mm, from the Musonoi-Extension mine. Photo by E. Van Der Meersche.

Figure 15. Heterogenite crystals to 1 mm, from the Mindigi mine. Paul De Bondt collection; E. Van Der Meersche photo.

Figure 16. Heterogenite with malachite, 23.3 cm, from Dikuluwe. J. Lhoest collection; Jeff Scovil photo.

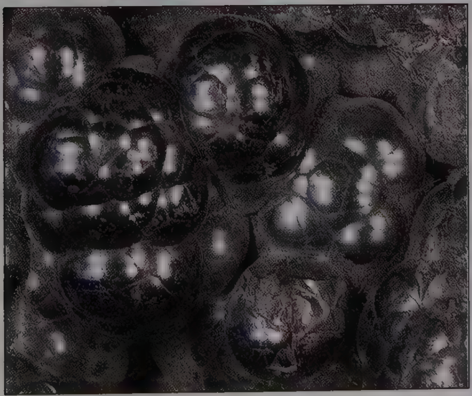

Figure 17. Lustrous, botryoidal heterogenite, 2 cm across, from Kabolela. Brussels Museum collection and photo.

single name "heterogenite" to describe the hydrated black oxides of cobalt. This latter author also revealed the existence of a hexagonal polytype, which he called "heterogenite 2H" (Deliens and Goethals, 1973). Since then, common heterogenite has been termed heterogenite 3R in mineralogical treatises, in order to distinguish it from the 2H polytype.

Heterogenite 3R, which occurs with the widest variety of appearances, is the heterogenite most commonly found in southern Katanga. The following habits are well known:

(1) Microgranular kidney-shaped nodules and irregular masses streaked with little veins that have a metallic luster. These crystallized masses were known in Katanga by the name "stainierite."

(2) Kidney-shaped or botryoidal masses with very shiny jet-black surfaces. The fracture resembles that of anthracite. This heterogenite is found in concentric superposed layers in the outcrops. In Katanga it was known as "trieuite."

(3) Earthy encrustations with subconchoid fractures (formerly "mindigite").

(4) Stalactites, draperies, scoria and oolitic formations.

The principal differences between the crystalline varieties that have a metallic luster and the cryptocrystalline varieties that are rich in copper are discussed below. The data are taken from the work of Deliens (1974).

When examined by X-ray diffraction, the material with a metallic luster yields a spectrum made up of sharp peaks, whereas the kidney-shaped masses produce patterns characterized by relatively feeble peaks, or indeed mere undulations reflecting a cryptocrystalline state.

Microscopic examination of polished sections in reflected light shows a very clear relationship between the degree of crystallinity and the reflectivity value. The value of the upper reflective index is nearly 25% for the crystalline material, while it ranges between 15% and 10% for the other specimens.

From the chemical point of view, three factors characterize the difference between the habits with a metallic luster and the other heterogenites. They are the cobalt valence, the presence of copper, and the water content.

The crystalline varieties are almost exclusively made up of trivalent cobalt (Co^{3+}). They contain very little copper (maximum 3.8%), and the H_2O content is approximately 1%. In addition, they contain a low percentage of nickel (not over 1.5%). The formula representing them is $CoO \cdot OH$, or, in another form, $Co_2O_3 \cdot H_2O$.

The kidney-shaped or earthy cryptocrystalline habits contain between 14% and 25% bivalent cobalt (Co^{2+}) associated with 25% to 37% trivalent cobalt (Co^{3+}). The copper content is always appreciable, and may reach 15%; nickel is absent. The H_2O content ranges between 2.5% and 9%. Thermogravimetric analysis curves (percentages of weight lost during the heating of the minerals) are particularly significant. The general formula arrived at for the poorly crystallized habits containing cobalt in its two valence states and copper is: $(Co_2O_3 \cdot CoO \cdot CuO) \cdot H_2O$, or again, $CoO \cdot OH + nCo(OH)_2 + mCu(OH)_2$. The $Co(OH)_2$ and $Cu(OH)_2$ phases cannot be detected by X-ray analysis. They are, therefore, amorphous, and are not regarded as a part of the heterogenite structure, although they do constitute a factor hindering crystallization. That is why the general formula $CoO \cdot OH$ is valid for all of the heterogenites. The term "cupriferous" can be added to the cryptocrystalline varieties.

Experiments in synthesizing hydrated oxides of cobalt under normal temperature and pressure conditions have clearly confirmed the role of copper in limiting the degree of crystallinity in the heterogenites, whereas the presence of a little nickel favors crystallization.

The most beautiful heterogenites in the world have been collected at the Kabolela mine. They are found there in botryoidal masses, in stalactites, and in cavern draperies. Some museum specimens measure several tens of centimeters.

Mammillary specimens of good quality are obtained from the Star of the Congo, Luishia, Kalabi, Likasi and Mindigi mines. Stalactitic habits are rarer. In Mindigi, for example, pseudostalactites (stalactites without a feeder canal) with a core of heterogenite (3R) and with concentric areas of malachite on the exterior, have been found.

Heterogenite 2H is a hexagonal polytype of rhombohedral heterogenite 3R. It is very closely associated with the crystals of heterogenite 3R in the little veins with a metallic luster found in certain specimens obtained from the oxidation zone of the Mindigi mine. The polytype 2H crystals appear as flattened prisms with regular hexagonal contours. They are black in color with a bright metallic luster. The largest do not measure more that 1 mm.

Chemical analysis of the 2H polytype reveals the presence of 88% Co_2O_3, 2% nickel and 10% water. The formula is thus identical to that for heterogenite 3R: $CoO \cdot OH$. The nickel content is too low to justify its inclusion in the formula. However, it nonetheless plays an equally important role here in determining the degree of crystallinity.

The maximum reflective capacity measured on a polished section was 23.5%, which is slightly less than that for the polytype 3R (25%).

The clearest distinction between the two polytypes is obtained by means of X-ray diffraction. If the *a* parameters of the links in the two polytypes have the same value (2.85 Å), the *c* parameter of the heterogenite 2H (8.81 Å) is only two-thirds of that for the heterogenite 3R (13.16 Å). This is reflected in perceptible variations in the spectral lines revealed by diffraction.

The 2H polytype is rare in comparison to the 3R, which is almost always present in the oxidation zones of the Cu-Co deposits in southern Katanga. To date, it has been found only in Mindigi, and only in association with the crystallized habits that have the metallic luster of heterogenite 3R. These habits are themselves uncommon in comparison to the large quantities of earthy or reniform material in the deposit.

Julienite $Na_2Co(SCN)_4 \cdot 8H_2O$

Julienite has only been found on the surface at the Cu-Co deposit in Shamitumba, located at the center of the Kambove-Likasi-Shinkolobwe triangle. This thiocyanate of sodium and copper is organically formed and can very easily be synthesized. Since its formation depends upon biological action, this species does not entirely meet the definition of a mineral. Julienite is a mineralogical curiosity in Katanga. The bright blue orthorhombic prismatic crystals may reach several millimeters in length. They form intergrowths on the surface of specimens of dolomite. Julienite is also found in masses filling small fissures.

Kolwezite $(Cu,Co)_2(CO_3)(OH)_2$

Kolwezite (Deliens and Piret, 1980) is a member of the rosasite group, which also includes the mineral glaukosphaerite, $(Cu,Ni)_2(CO_3)(OH)_2$; the latter has been found in stratiform deposits at the Kasompi mine. Kolwezite is a typical secondary cobalt mine in the western sector, occurring at several deposits in the Kolwezi Klippe. It forms hemispheres to 1 cm, and blackish brown to pale tan reniform crusts. The knobs can display a range of differently colored zones. The mammillary surfaces are generally lusterless to powdery and occasionally velvety.

Kolwezite appears commonly as a late-stage coating and, more rarely, as layers inside banded concretions of other minerals. It is often associated with very dark green cobaltiferous malachite, and can be distinguished by its invariably tan streak in comparison to

Figure 18. **Julienite crystal, 10 mm, from Shamitumba. Brussels Museum collection and photo.**

Figure 19. **Kolwezite hemispheres to 5 mm, on matrix, from the Mashamba West mine. Brussels Museum collection and photo.**

Figure 20. **Sphaerocobaltite rosettes to 6 mm, from the Kakanda mine. Photo by E. Van Der Meersche.**

Figure 21. **Sphaerocobaltite crystals to 3 mm, from the Kakanda mine. Photo by E. Van Der Meersche.**

the green streak of malachite. Other associations include black heterogenite masses and knobs, pink cobaltoan calcite and cobaltoan dolomite.

The Co content of kolwezite ranges from 14.75 to 18.50%, with a Cu:Co ratio of 2:1; this is the maximum cobalt content for the species. Cobaltiferous malachite never contains more than 6.5% Co. Thus there is a gap in cobalt content (6.5 to 14.75%) between the two species.

The most important localities for kolwezite are the Musonoi Principal, Kamoto, Mupine and, especially, the Mashamba West mine. At Mashamba West, kolwezite is found as beautiful groups of stalactites. In 1997 it was discovered in a large vug on the upper

Table 1. **Cu-Co deposits in the Katanga Crescent.**

Sector	*Deposit*	*% Co*	*% Cu*	*Remarks*
South	Kasombo	4.9	8.1	High Co %
	Luiswishi	1.9	3.6	
	Lupoto	0.6	0.9	
	Ruashi	0.6	3.4	
	Star of the Congo	0.4	7.0	First UMHK mine
Central	Fungurume	0.5	1.5	Future exploitation
	Kabanbankola	1.5	1.5	Cu = Co
	Kabolela	0.7	3.8	
	Kakanda East	0.5	4.3	
	Kakanda South	0.3	3.7	
	Kambove West	0.3	5.4	
	Kamfundwa	0.3	2.6	
	Kasompi	1.8	1.2	
	Kazibizi	0.6	2.8	
	Luishia	?	?	
	Mindingi	?	?	Local contractor
	Saafi	0.3	0.3	Cu = Co
	Shamitumba	0.7	3.3	
	Shinkolobwe	1.0	3.0	
	Tenke	?	?	Future exploitation
West	Kamoto East	0.3	5.2	
	Kamoto Etang	0.5	2.1	
	Kamoto Principal	0.3	4.3	
	Kamoto Fond (undergr.)	?	?	
	Mashamba East	1.1	?	
	Mupine	0.6	2.6	
	Musonoi F.N.S.R.	0.4	5.4	
	Musonoi Deep	0.6	3.9	
	Oliveira	0.5	3.5	
	Virgule	0.3	4.9	KOV mines
Copper-Only Mines				
South	Karavia	0	10.0%	Highest copper
Central	Kamatanda	0	4.9	
West	Kolwezi	0	6.0%	
	Mutoshi Breccia	0	1.5%	(= Ruwe Breccia)
Cobalt-Only Mines				
West	Kabulungu	1.0%	0	near Mashamba East
	Nyoka	0.8%	0	South of Musonoi
Known Reserves:				
Star of the Congo, Ruashi, Luiswishi Lupoto, Kasombo		0.54	3.65	(Lubumbashi Dist.)
Kambove West, Kamoya, M'Sesa Kazibizi, Kamfundwa, Shangulowe		0.30	2.76	(Kambove Dist.)
Kakanda East, North, South, Saafi Bangwe, Kiwana, Luita, Disele		0.17	3.31	(Kakanda Dist.)
Fungurume, Kwatebala, Fwalu, Shimbidi, Goma, Kabwelunono, Kakavilondo		0.32	4.42	(Fungurume-Tenke Dist.)
Fungurume IIh and VII		4.00		(rich, hand-sorted ore)
Kolwezi, Mutoshi, Musonoi, Nyoka East & West, Dima (Dikuluwe-Mashamba), K.O.V., Mupine, Kamoto Prin., North & Etang, Mashamba East, West		0.36	4.30	

level, as part of a botryoidal succession beginning with heterogenite at the base, then a layer of kolwezite up to 2 cm thick, followed finally by a top layer of cobaltiferous malachite with surface coatings of chrysocolla and kolwezite knobs. Such concretions are exceedingly rare. A partial coating of kolwezite on groups of large, rose-red cobaltoan calcite crystals from Mashamba West is also quite aesthetic.

Oursinite $(Co,Mg)(UO_2)_2Si_2O_7 \cdot 6H_2O$

Oursinite is the only secondary uranium mineral in southern Katanga containing cobalt in any appreciable quantity (5.2%). The mineral belongs to the uranophane structural group, and is analogous to sklodowskite (with magnesium) and cuprosklodowskite (with copper). It has been found only in secondary ores at the Shinkolobwe mine (Deliens and Piret, 1983).

Oursinite occurs in flexible to rigid fibers of a pale to whitish yellow color measuring up to 1 mm in length, with a diameter of 0.02 mm. The fibers are grouped in tufts or rosettes. More rarely, oursinite fibers are found closely intermingled with needles of lepersonnite-(Gd).

Oursinite is associated with a whole series of other secondary uranium minerals such as curite, becquerelite and kasolite. One characteristic of the association that might serve as a guide in the detection of oursinite is the frequent black pigmentation caused by hydroxides of cobalt in the accompanying minerals mentioned above. While cobalt is an integral component of oursinite, it is nothing more than pigmentary impurity in the other species.

Table 2. **Cobalt minerals from Katanga.**

	Katanga Crescent		*Outside of Katanga Cresent*
	Stratiform Cobalt Deposits	*Vein-like Cobalt Deposits**	*Cobalt Deposits***
Primary Minerals	Linnaeite Carrollite	Linnaeite Carrollite Cattierite Siegenite Trogtalite Penroseite	Linnaeite Carrollite Cobaltite
Secondary Minerals	Heterogenite-3R Heterogenite-2H Kolwezite Sphaerocobaltite Cobaltomenite Julienite	Heterogenite-3R Oursinite Comblainite	Heterogenite-3R

*Shinkolobwe
**Kipushi

Wherever the black coloring is present in minerals that are usually yellow or orange, there is an excellent likelihood that the radial aggregates resembling sklodowskite and uranophane are in fact oursinite.

Sphaerocobaltite $CoCO_3$

Sphaerocobaltite occurs in most of the Katanga Crescent Cu-Co deposits, but only sparsely. Unlike the carbonate of copper, malachite, it never occurs in botryoidal concretions and masses. In rare case, massive, fine-grained, rose-red to purple sphaerocobaltite has been found at the Kambove, Kabolela, and Kamoto Fond ("Fond" = "underground") mines typically as an *in situ* alteration of massive, lenticular beds of carrollite. The reason for the scarcity of sphaerocobaltite is its easy solubility, making it prone to replacement by the more stable heterogenite.

Sphaerocobaltite occurs mainly in the transition zone between primary and secondary ores, and in carrollite-bearing dolomites high in the oxide zone. Outside of these favorable zones it dissolves readily. Sphaerocobaltite specimens commonly contain remnant carrollite. Although found most often as microscopic inclusions coloring dolomite, or as shapeless, vaguely drusy aggregates, sphaerocobaltite also has been found locally as idiomorphic crystals, always with curved, lustrous faces.

Sphaerocobaltite crystals have been found in the Kambove, Musonoi, Mupine, Kamoto Principal (underground), and Kakanda mines. At Kakanda, crystals reach 3 mm is size and show a discoidal, pseudo-hexagonal habit; groups of singles and twins cluster together, sometimes forming delicate rosettes. Their color is deep rose to deep red, the darkness and intensity of which serve to distinguish to from associated pink cobaltiferous calcite and dolomite. Perfectly shaped crystals to 5 mm have been found at the Kakanda South mine. At the Kambove mine it forms aggregates and tiny crystals on superb carrollite crystals.

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REFERENCES

DELIENS, M., and GOETHALS, H. (1973) Polytypism of heterogenite. *Mineralogical Magazine,* **39**, 152–157.

DELIENS, M. (1974) Les oxydes hydratés de cobalt du Shaba méridional. *Annales Museé royal Afrique Centrale Tervuren,* série in −8°, Sc. géol., **76**, 80 p.

DELIENS, M. (1975) Replacement partiel du sélénium par le soufre dans la penroséite $(Ni,Co,Cu)(Se,S)_2$ de Shinkolobwe (Zaire). *Bulletin de la Société française de Minéralogie et Cristallographie,* **98**, 347–350.

DELIENS, M., and PIRET, P. (1980) La kolwézite, un hydroxy-carbonate de cuivre et de cobalt analogue à la glaukosphaerite et à la rosasite. *Bulletin de Minéralogie,* **103**, 179–184.

DELIENS, M., and PIRET, P. (1983) L'oursinite, nouveau minéral de Shinkolobwe, Shaba, Zaire. *Bulletin de Minéralogie,* **106**, 305–308.

GAUTHIER, G., FRANÇOIS, A., DELIENS, M. and PIRET, P. (1989) Famous mineral localities: the uranium deposits of the Shaba [= Katanga] region, Zaire. *Mineralogical Record,* **20**, 265–288.

HEY, M. H. (1962) Cobaltic hydroxide in nature. *Mineralogical Magazine,* **33**, 253–259.

JOHAN, Z., PICOT, P., PIERROT, R., and VERBEEK, T. (1970) L'oosterboschite, $(Pb,Cu)_7Se_5$, une nouvelle espèce minérale et la trogtalite-cupro-palladifère de Musonoi (Katanga). *Bulletin de la Société française de Minéralogie et de Cristallographie,* **93**, 476–481.

KERR, P. F. (1945) Cattierite and vaesite, new Co-Ni minerals from the Belgian Congo. *American Mineralogist,* **30**, 483–497.

PIRET, P., and DELIENS, M. (1980) La comblainite, nouveau minéral du groupe de la pyroaurite. *Bulletin de Minéralogie,* **103**, 113–117.

PYRITE on CALCITE, 2.75 inches, Naica, Mexico, from Arthur Court, June 1974

COBALTOAN CALCITES AND DOLOMITES FROM KATANGA

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INTRODUCTION

It was pointed out by Douglass (1992) that most mineral specimens labeled as "cobaltoan calcite" are actually "cobaltoan dolomite." In many cases the magnesium content is greater than the calcium content. During the past several years analyses have been performed on various minerals supplied by Gilbert Gauthier. This paper summarizes work on numerous mineral specimens from the Democratic Republic of the Congo along with a few others from localities other than the Congo.

The original motivation for this work was to determine the amount of cobalt required for the vivid pink coloration. Most specimens analyzed are dolomite, but a few are clearly calcite. The analyses led to the conclusion that the dolomite is generally vivid, "electric" pink (see Fig. 7), whereas the calcite is a much duller, more subtle pink (Fig. 8). Furthermore, the dolomite is generally in smaller crystals which exist as a druse or botryoidal crust. The calcite exhibits larger crystals. In some cases, sphaerocobaltite (Figs. 5 and 6) is present as small, more deeply colored particles on the minerals studied.

EXPERIMENTAL PROCEDURES

Energy-dispersive X-ray analyses (EDX) were performed in a scanning electron microscope (SEM), and ZAF (atomic number absorption fluorescence) corrections were made *in situ* in the unit. No standards were used. The lower limit of detection of an element is probably about 0.5 atom %, depending upon the take-off angle, excitation voltage (20kv), distance, etc. The accuracy is probably about ±0.5 atom %. It should be mentioned that the specimens are quite heterogeneous, as demonstrated by the multiple analyses taken at various locations on a given specimen. Values reported are not average values, but rather they simply represent the results obtained at a given spot.

EDX analysis does not detect the light elements oxygen and carbon, and thus only cations are detected in carbonates. Further, impurities such as Si, S, K, P, etc. are always present and detected. The compositions obtained in the initial study, shown in Table 1, include the impurities detected. A second batch of samples supplied by Gauthier in 1992 was studied, the results being listed in Table 2, which includes various impurities. A third batch of specimens, supplied by Gauthier in 1993, was analyzed and the results (Table 3) were normalized by eliminating the various impurities and recalculating the cation fractions on the basis of 100%. Iron and manganese impurities were treated as if they were cobalt, based on their similar ionic sizes, chemistry and phase equilibria. The reason for this was to enable the result to be plotted on an isothermal section of a ternary carbonate system as will be explained subsequently.

Small fragments were removed from several specimens, and were then ground into powder and analyzed with an X-ray diffractometer using filtered-Cu radiation. The patterns obtained were compared to those in the ICCD file. Excellent matches were obtained between the experimental patterns and those of known compounds, i.e., calcite, magnesite, dolomite, and sphaerocobaltite.

RESULTS

The most surprising result of the analyses was that specimens thought to be calcites are actually dolomite, and the magnesium content is greater than the calcium content. The amount of cobalt required to cause the pink color is apparently quite low, and in some cases is below the detection limit. Other specimens have appreciable cobalt, up to 5.8 atom %. A true dolomite was also examined (Guanajuato, Mexico) in which the calcium content is considerably greater than the magnesium content. Dolomite specimens from the Congo usually exhibit a magnesium content exceeding that of calcium.

One of the five specimens supplied in 1993 was labeled as "sphaerocobaltite," and another specimen has an interesting banded structure. This consists of alternating concentric rings of pink material between purple material. The banded structure was subjected to line-traverse analysis, and the results are shown in Fig. 1. The light-colored regions are higher in calcium than in magnesium, whereas the dark regions show the reverse. No cobalt was detected.

X-ray diffraction confirmed the EDX results, although there were some surprises here also. Sample 4, Table 3, contains about 75 atom % magnesium and, according to the calcite-magnesite phase diagram (Fig. 2), should consist of about 50% dolomite and 50% magnesite upon application of the lever law. However, XRD showed only dolomite; no magnesite was detected, which is inconsistent with the composition and the phase diagram which shows that this composition should be in the center of the dolomite + magnesite field.

The nodules on sphaerocobaltite were identified by XRD as magnesite, and the matrix is clearly dolomite. The magnesite structure of the nodules is consistent with the EDX results, and since considerable cobalt and calcium are present, the proper name for the nodules is cobaltoan-calcian magnesite.

Table 1. **EDX analyses of various so-called "cobaltoan calcites," dolomite and rhodochrosite.**

			Cations, atom %					
	Source	*Specimen Descriptions*	*Mg*	*Ca*	*Co*	*Mn*	*Fe*	*Si*
1	Unknown mine, Congo	Brilliant pink crystals about 4–6 mm in size	50.2	49.8	trace	—	—	—
			46.0	54.0	trace	—	—	—
			64.6	35.4	trace	—	—	—
			59.0	35.4	1.4	—	—	4.2
			55.2	42.1	2.7	—	—	—
2	Unknown mine, Congo	Dark, pink burgundy crystals about 1–3 mm in size	54.5	45.5	n.d.*	—	—	—
3	Kamoto mine, Congo	Brilliant pink crystals about 1–2 mm in size	58.1	41.9	n.d.	—	—	—
4	Kamoto mine, Congo	Large, rhombohedral, single crystal with cleavage facets; brilliant pink about 3 x 4 x 8 cm	n.d.	100.0	n.d.	—	—	—
5	Kamoto mine, Congo	Botryoidal druse (hillocks 5–7 mm) with mini facets; some malachite balls	56.5	37.8	5.7	—	—	—
6	Unknown mine, Congo	Magenta druse with facets and malachite balls	53.5	46.5	trace	—	—	—
7	Unknown mine, Congo	Brilliant pink, botryoidal druse with 2–3 mm rhombs	56.0	41.1	29.9	—	—	—
			62.8	37.2	n.d.	—	—	—
8	Unknown mine, Congo	Pink-purple crystals about 10 mm in size, cleaved appearance	64.6	35.4	n.d.	—	—	—
9	Guanajuato, Mexico	**Dolomite**—light beige-pink rhombohedral crystals about 6–12 mm	36.5	62.0	n.d.	—	1.5	—
			42.6	55.6	n.d.	—	1.8	—
10	Santa Rita, Peru	**Rhodochrosite**—medium pink crystals about 4–7 mm, rhombohedral form	8.7	—	n.d.	91.3	—	—
			8.2	—	n.d.	91.8	—	—

*n.d. = not detected

Table 2. **EDX analyses of specimens supplied by G. Gauthier, February, 1992.**

		Cations, atom %					
Source	*Specimen Descriptions*	*Mg*	*Ca*	*Co*	*Na*	*Al*	*Si*
Bou Azzer, Morocco	Dull, violet-pink crystals, ~3–4 mm	3.2	90.0	n.d.*	—	3.5	3.3
		3.0	91.5	n.d.	—	3.5	2.0
		3.6	87.2	n.d.	—	6.2	3.0
		4.4	88.4	n.d.	—	4.1	3.1
Kakanda, Congo	Bright pink, magenta drusy crystals, 1 mm	60.8	34.2	n.d.	—	—	5.0
		66.5	26.5	n.d.	—	—	7.0
		66.5	26.5	n.d.	—	—	7.0
		62.1	25.1	n.d.	—	—	12.8
Unknown	Dull pink, rhombohedral crystals, 10 x 15 mm cleaved	4.6	85.3	n.d.	4.9	2.4	2.8
		0.0	93.1	n.d.	—	—	6.9
		6.8	84.6	n.d.	—	4.4	4.2
		0.0	87.0	n.d.	—	—	13.0
		11.6	88.4	n.d.	—	—	—
		8.0	83.7	n.d.	—	3.4	4.9

*n.d. = not detected

DISCUSSION

The phase diagram, Fig. 2, clearly shows that dolomite is a line compound at temperatures below about 650°C. However, most EDX analyses have shown that more magnesium is present than calcium, and thus XRD should show both dolomite and magnesite with the dolomite content being greater than the magnesite content. Either the phase diagram is erroneous, or invalid for the system, or the dolomite formed under conditions for which a wide solubility existed, and this supersaturation was retained upon cooling from high temperature.

Dolomite is actually very difficult to produce, as shown by Graf and Goldsmith (1956) who found that temperatures above 500°C were required to form the ordered line compound. Protodolomites were formed at lower temperatures, and these materials did not show the superstructure reflections. These observations can be understood in terms of the crystal structure of dolomite. It is an

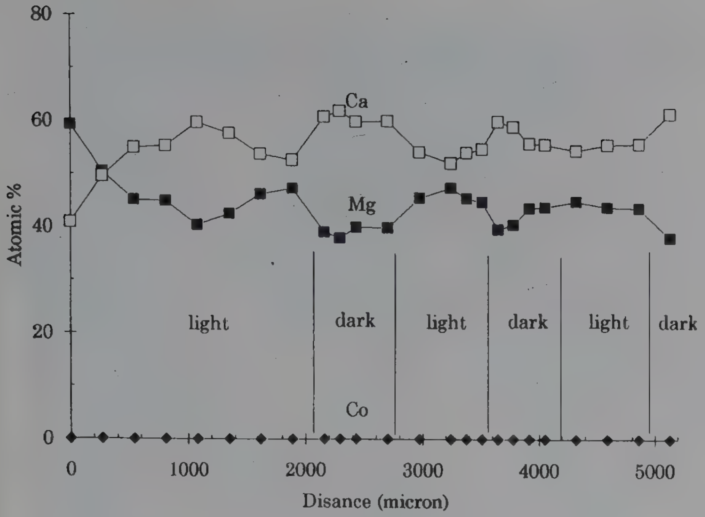

Figure 1. **EDX analysis of banded cobaltoan calcite/dolomite from Kakanda, Katanga, Congo.**

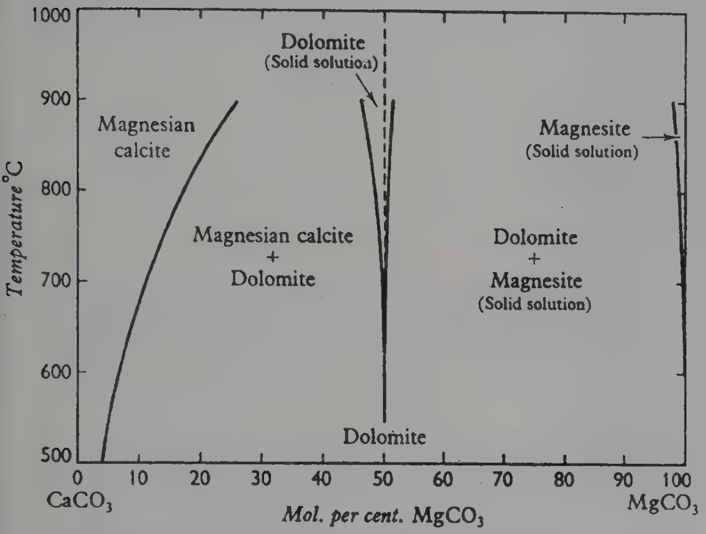

Figure 2. **The $CaCO_3$–$MgCO_3$ system at CO_2 pressure sufficient to prevent decomposition of the carbonates (Harker and Tuttle, 1955).**

ordered compound with alternating layers of Ca ions and Mg ions between planar layers of CO_3 groups, Figure 3, as described by Putnis (1992). The structure develops from a disordered solid solution at high temperatures, the ordering process reducing the symmetry from the rhombohedral space group $R\bar{3}c$ to $R\bar{3}$. The formula is given by $CaMg(CO_3)_2$. A comparable mineral, kutnohorite, $CaMn(CO_3)_2$ forms as an intermediate phase in the $CaCO_3$–$MnCO_3$ system, but ankerite is erroneously reported as a species. Goldsmith (1959) notes that ankerite is really a ferroan dolomite because no ordering occurs, as verified by the absence of superlattice reflections in XRD patterns. Ferroan dolomites form by the replacement of Fe^{2+} for Mg^{2+}. The iron does not substitute for calcium. The difference between end-member rhombohedral, calcite-type carbonates and dolomite-type structures is that the calcite structures consist of alternating layers of Ca^{2+} and CO_3^{2-} ions, but dolomite has alternating layers of Ca and Mg ions. Random solid solutions occur readily in calcite-type structures by substitution of various cations for Ca^{2+}.

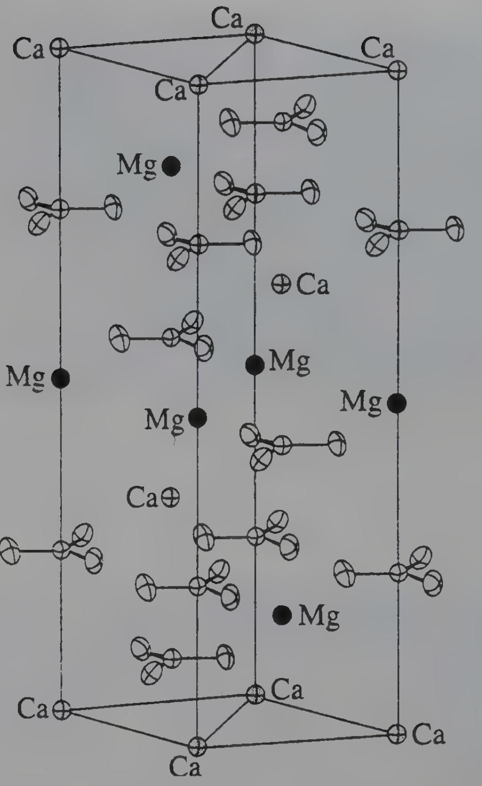

Figure 3. **Dolomite crystal structure showing the ordered nature, with alternating layers of Ca and Mg atoms between the planar carbonate clusters.**

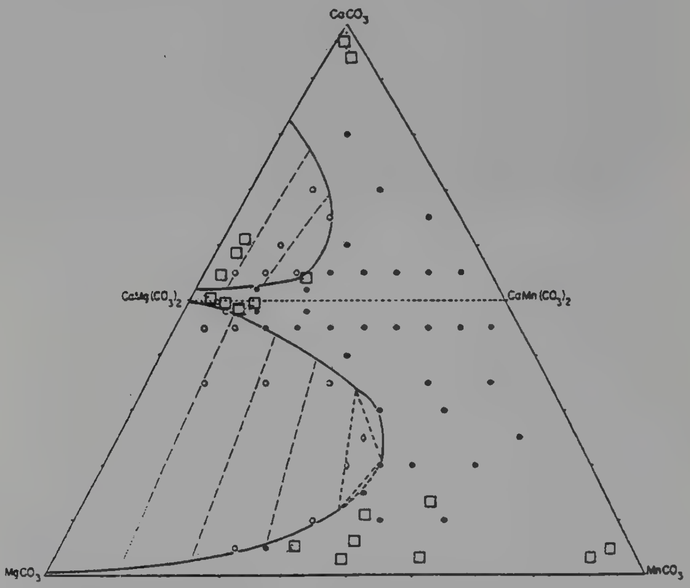

Figure 4. **Ternary Ca-Mg-Mn carbonate system at 800°C. Black dots are single-phase points; circles are two-phase points; squares represent EDX analyses of various cobaltoan calcite/dolomite specimens.**

Dolomite structures form because there is a significant difference in the ionic size of the two cations. The size difference results in low solubility limits of Mg in calcite and of Ca in magnesite. However, at high temperatures a more expanded and open structure results, thus reducing the importance of ionic-size differences. In

Figure 5. **Sphaerocobaltite crystal clusters, 2–3 mm, on pink cobaltoan dolomite, from Kakanda, Katanga, Congo. D. L. Douglass specimen; Wendell Wilson photo.**

Figure 6. **Sphaerocobaltite crystals to 1 mm (dark magenta color) intergrown with pink cobaltoan dolomite crystals, from Kakanda, Katanga, Congo. D. L. Douglass specimen; Wendell Wilson photo.**

Figure 7. **Cobaltoan dolomite druse, 3.6 cm, from Kakanda, Katanga, Congo. D. L. Douglass specimen; Wendell Wilson photo.**

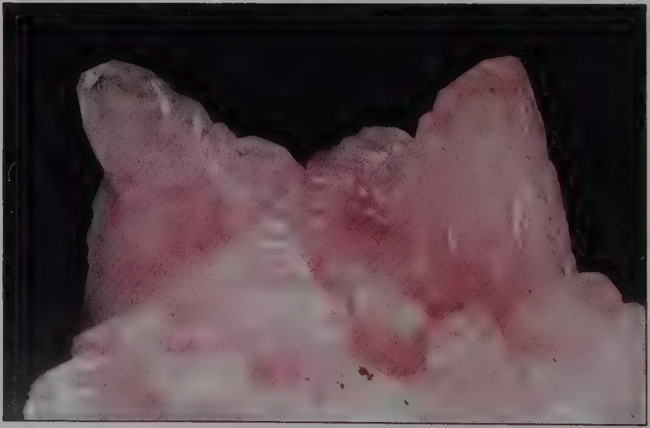

Figure 8. **Cobaltoan calcite crystal cluster, 2.5 cm, from Kakanda, Katanga, Congo. D. L. Douglass specimen; Wendell Wilson photo.**

fact, at very high temperatures dolomite becomes disordered, and a complete series of solid solutions forms between calcite and magnesite, as seen in the phase diagram (Fig. 2).

There are no ternary phase diagrams for carbonate systems in which $CoCO_3$ exists. However, extensive studies have been made on the phase equilibria in the $CaCO_3$–$MgCO_3$–$MnCO_3$ system (Goldsmith and Graf, 1960). Thus, in the absence of phase equilibria involving $CoCO_3$, the $CaCO_3$–$MgCO_3$–$MnCO_3$ system was selected because the ionic sizes of Co^{2+} and Mn^{2+} are similar, the crystal structures of the respective carbonates are identical, and their lattice parameters are very similar.

The compositions obtained by EDX analyses of a third lot of specimens supplied by Gauthier in 1997 are plotted on a ternary isotherm at 800°C in the calcite-magnesite-rhodochrosite system, Figure 4, assuming that sphaerocobaltite acts similarly to rhodochrosite with respect to the phase equilibria. The data points superimposed on the ternary isotherm were "normalized" as mentioned previously. For the most part the compositions are in the single-phase solid-solution region. However, this is a disordered structure and would not be considered as a dolomite. The problem that cannot be solved is how the disordered solid solution can order into a dolomite and not form two phases upon cooling. High-temperature solid solutions can be readily obtained at low temperatures by rapid cooling, but in order for the metastable solid solution to form dolomite, solid-state diffusion of Ca and Mg is required. However, such a process would enable the solid solution to separate into the two phases shown in the phase diagram. It would thus appear that the formation of the supersaturated dolomites found in this study would not likely occur by high-temperature processes and subsequent cooling.

The "dolomite problem" has been puzzled over for more than two hundred years. Recently, Presier (1996) suggested that sulfate-consuming bacteria can form dolomite, based on studies by

Table 3. **EDX analyses of Kakanda, Katanga, Congo, specimens supplied by G. Gauthier, February, 1993.**

	Source	*Specimen Description*	*Cations, atom %* *Mg*	*Ca*	*Co*
1	Kakanda, Katanga, Congo	Lavender, scalenohedral crystals, ~2 mm thick, 4–5 mm long	57.4	42.6	n.d.*
			62.3	37.7	n.d.
			51.7	48.3	n.d.
			56.4	43.6	n.d.
2	Kakanda, Katanga, Congo	Banded structure, fine grain	See Fig. 1		
3	Kakanda, Katanga, Congo	Dark, brownish pink euhedral crystals, ~1–2 mm	63.1	36.9	n.d.
			69.7	30.3	n.d.
			67.3	32.7	n.d.
			69.8	30.2	n.d.
4	Kakanda, Katanga, Congo	Bright, deep pink violet euhedral crystals, ~2–4 mm	76.2	23.8	n.d.
			72.0	28.0	n.d.
			75.2	24.8	n.d.
			Nodules		
5	Kakanda, Katanga, Congo	Sphaerocobaltite—purple nodules ~1–8 mm on magenta, drusy matrix	72.2	11.6	16.2
			61.2	7.1	27.6
			69.0	24.4	6.6
			Matrix		
			48.2	42.8	9.0
			51.0	41.9	7.1
			55.5	44.5	n.d.

*n.d. = not detected

McKenzie of the Swiss Federal Institute in Zurich, Switzerland. McKenzie used bacteria from the Lagoa Vermelha near Rio de Janeiro and mixed them into a sludge of sand, nutrients, sulfate and the ingredients to make dolomite. The mixture was refrigerated for one year, following which an examination showed that the bacteria had indeed produced dolomite. Bacteria-free mixtures showed no dolomite. It is difficult to imagine how enough bacteria could have been present to account for the Dolomite Mountains in Northern Italy; but the dolomite crystals formed by the bacteria could conceivably act as heterogeneous nucleation sites upon which natural processes could then form dolomite. Thus, the high degree of ordering to form dolomite can be achieved or at least initiated by a biological factor.

CONCLUSIONS

EDX analyses and XRD have shown that cobaltoan calcites are really cobaltoan dolomites in most instances. The former are pale pink with larger crystals, and the latter tend to be drusy or botryoidal and have a vivid, "electric" pink color. The dolomites tend to be magnesium-rich and in some instances contain 75 atom % magnesium. According to the calcite-magnesite phase diagram, such a composition should consist of a 50-50 mixture of dolomite and magnesite, but XRD shows only dolomite. The existence of "supersaturated" dolomite, normally a line compound, was discussed on the basis of phase equilibria in the calcite-magnesite-rhodochrosite system since no data are available for the calcite-magnesite-sphaerocobaltite system. The analyzed compositions fall within the solid-solution region at high temperature, 800°C, but in order to form dolomite, ordering of the calcium and magnesium is required, a solid-state diffusion process that would also lead to dissociation of the solid solution into a mixture of dolomite and magnesite. XRD clearly shows that this did not occur. Thus, high-temperature processes seem to be ruled out. An alternative process to form such supersaturated dolomites might exist with an assist from sulfate-reducing bacteria which have been shown to form dolomite at low temperatures. There is no evidence presently to support this hypothesis for dolomites found in Katanga, but it seems more likely than the high-temperature scenario.

ACKNOWLEDGMENTS

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REFERENCES

DOUGLASS, D. L. (1992) Letter to the editor, "Cobaltoan Calcite = Cobaltoan Dolomite." *Mineralogical Record*, **23**, 445.

GOLDSMITH, J. R. (1959) Some aspects of the geochemistry of carbonates. In *Researches in Geochemistry,* John Wiley & Sons, Inc., New York, 336.

GOLDSMITH, J. R., and GRAF, D. L. (1960) Subsolid relations in the system, $CaCo_3$–$MgCO_3$–$MnCO_3$. *Journal of Geology*, **68**, 324.

GRAF, D. L., and GOLDSMITH, J. R. (1956) Some hydrothermal syntheses of dolomite and protodolomite. *Journal of Geology*, **64**, 173.

HARKER, R. I., and TUTTLE, O. F. (1955) *American Journal of Science*, **253**, 279.

PRESIER, R. (1996) The dolomite problem. *Discovery*, **17**, no. 7, 32.

PUTNIS, A. (1992) *Introduction to Mineral Sciences.* Cambridge University Press, Cambridge, England, 296.

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The Zapot pegmatite is currently being mined for mineral specimens (chiefly amazonite, topaz and smoky quartz in miarolitic cavities), for gemstones (topaz and smoky quartz) and for decorative rock (amazonite). The deposit is owned and operated by Harvey Gordon Minerals *of Reno, Nevada, and is the only amazonite-topaz mining operation in the state. Thousands of specimens from this operation have reached the collector market.*

INTRODUCTION

The Zapot pegmatite is the largest of several pegmatites enclosed in plutonic igneous rocks which crop out in the Gillis Range about 25 km (16 miles) northeast of Hawthorne, Nevada (Fig. 1). Most pegmatites in the area are simple narrow veins and dikes containing amazonite (or tan microcline), smoky quartz and minor topaz. The multistage Zapot pegmatite is unique because it is much larger and more complex than the other pegmatites in the area. Known pegmatites are largely confined to a relatively small area measuring 300 meters in diameter (Fig. 2).

HISTORY

The original discovery of amazonite and smoky quartz in the Zapot area is now lost to history. On the basis of persistent rumors, a few known mineral specimens, and discussions with prospectors and various other individuals over a period of years starting in the early 1960's, D. J. (Jerry) Gray of Reno, Nevada, compiled the accumulated information on a map and set out to rediscover the source. After a brief airborne reconnaissance of the general area, he began a ground search on foot and, after a series of long traverses, was attracted to some "reddish iron stains in a limestone"; during examination of the area he discovered "amazonite and smoky quartz among large granitic boulders" (D. J. Gray, personal communication, 1995). Based on this discovery, Gray staked the *Sun 5*

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*Deceased.

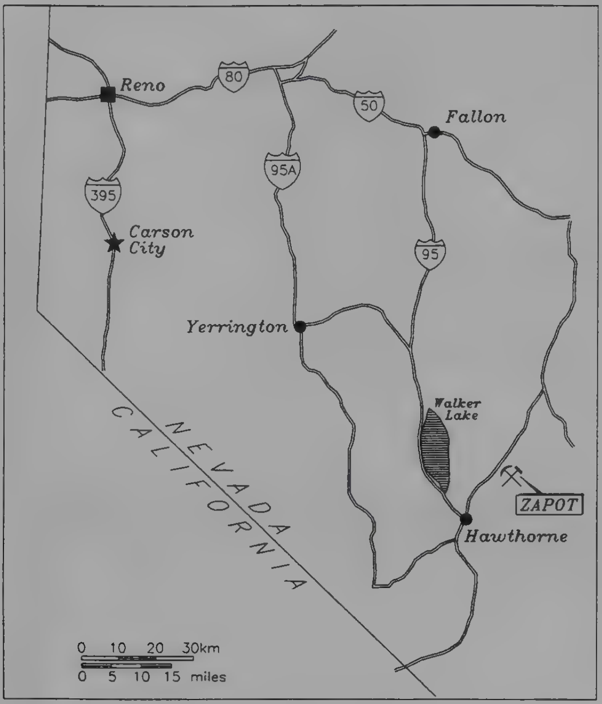

Figure 1. **Map showing location of the Zapot pegmatite northeast of Hawthorne, Nevada.**

claim in 1984. Later he took Harvey Gordon to this claim, where they collected crystals of amazonite, smoky quartz and topaz. Harvey Gordon was so impressed with the area that in 1986 he bought the claim, renamed it the Zapot (topaz spelled backwards) Pegmatite, and began to explore.

Early progress was hampered by difficult access; however, later improvement in the roads allowed access by mechanical equipment, and serious surface exploitation followed. Since that time hundreds of crystals of amazonite, smoky quartz, and topaz have been removed from the pegmatite and offered for sale on the mineral market. It is estimated that less than 1% of the topaz mined has been of gem-quality, largely due to intense fracturing of the pegmatite by faulting. The largest known faceted stone is 53 carats. In addition, several tons of bulk amazonite have been sold for decorative rock.

GENERAL GEOLOGY

The intrusive rocks in the western part of the Gillis Range are part of a large unnamed batholith of Jurassic-Cretaceous age (Ekren and Byers, 1985). Amazonite-topaz pegmatites, one of which is the Zapot pegmatite, occur in a reddish-gray medium-grained quartz monzonite. The reddish-gray quartz monzonite contains sparse, small miarolitic cavities lined with quartz (sometimes smoky) and tan to pink microcline with occasional albite, epidote and pale yellow to greenish muscovite. Calculations from chemical analyses of the quartz monzonite, using the classification

Figure 2. **View of the Zapot pegmatite area. Excavations of the Zapot pegmatite (right) and the West Area (left).**

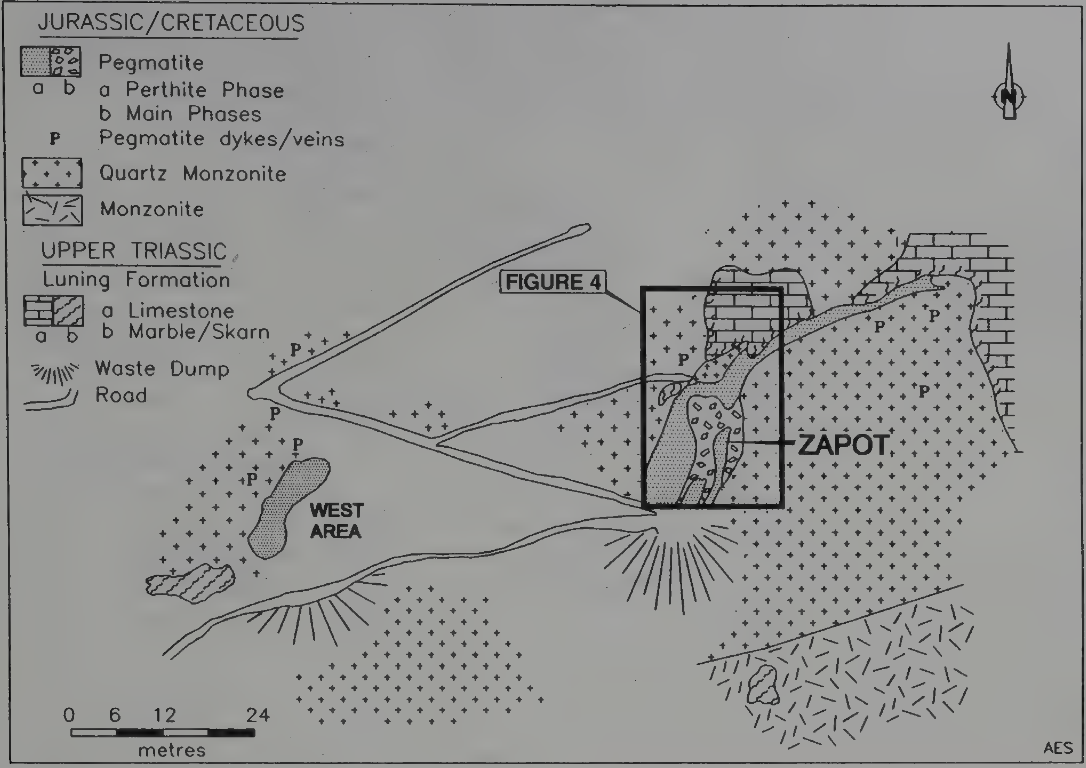

Figure 3. **Geologic map of the Zapot pegmatite and the West Area (A. E. Soregaroli).**

scheme of De La Roche *et al.* (1980), show that the host rock is a quartz syenite close to the field of quartz monzonite. A gray, medium-grained phase is exposed southeast of the reddish-gray quartz monzonite.

Limestones of the Upper Triassic Luning Formation have been intruded and altered by the batholithic rocks and the pegmatites. Large areas of limestone have been recrystallized, especially east and northeast of the pegmatites. The limestones south and west of the pegmatites have been converted to finely crystalline skarns with variable composition, dominantly vesuvianite, garnet and diopside. The garnet deserves special mention because it occurs in various forms and environments. Dark brown trapezohedra as large as 1 cm across have been observed in fine-grained, recrystallized limestones; very fine-grained, olive-green to brownish grossular is a major part of most skarns; and emerald green grossular occurs as a minor part of some fine-grained skarns and on fractures in skarn as gemmy dodecahedra as large as 1.5 mm. Analytical studies by G. Robinson (A. E. Seaman Mineralogical Museum, Houghton, MI), confirmed these gemmy crystals as grossular with small amounts of vanadium, which perhaps could be called tsavorite. An intensive search of the area resulted in the discovery of only a few samples containing microcrystals of the emerald-green grossular.

In addition, the skarns contain sporadic, irregular patches and veinlets of pink zoisite (thulite), epidote, wollastonite, magnetite, dark green chlorite, and serpentine.

PEGMATITES

The Zapot pegmatite and neighboring pegmatites have been emplaced into a quartz monzonite phase of a large Jurassic/Cretaceous batholith (Fig. 3). In addition, veins, dikes and irregular bodies, some with open cavities, cut the batholithic rocks in the West Area. As mentioned above, the host rocks to the Zapot pegmatite are chemically quartz syenite according to the classification of De la Roche *et al.* (1980) but plot close to the quartz monzonite field. Previous investigators, without benefit of chemical analyses, have termed the host rocks monzonite and quartz monzonite and these terms are used in this paper. Two X-ray fluorescence (XRF) analyses yielded (weight %): SiO_2 68.2, 68.3; Al_2O_3 16.8, 17.2; Fe_2O_3 (total Fe reported as Fe_2O_3) 1.21, 1.8; MgO 0.25, 0.25; CaO 1.04, 1.02; Na_2O 5.22, 5.28; K_2O 5.48, 5.14; TiO_2 0.22, 0.21; P_2O_5 0.06, 0.08; MnO 0.06, 0.06; LOI (920°C) 0.20, 0.08; Σ98.74, 99.33. Trace elements (by inductively-coupled plasma atomic emission spectroscopy, (ICP-AES)) on one sample include (ppm): Ba 1300, Be 4, Ce 63, Ga 19, La 37, Li 34, Nb 9, Nd 24, Pb 15, Sc 5, Sr 100, Th 11, V 11, Y 9, Yb 1, Zn 18.

Dikes and veins in the West Area generally are irregular in strike and dip with the dominant orientation being N50–80°E, and 60°S to vertical dips. Minor orientations are N to N25°E with near-vertical dips. The largest and finest topaz, amazonite, and smoky quartz crystals were found in the Zapot pegmatite, but for size alone the largest amazonite crystal was found in the West Area (Fig. 3). Paucity of outcrop and the abundance of large transported boulder cover prevent a detailed geological account of the West Area; only the Zapot pegmatite has received detailed study.

Zapot Pegmatite

The multi-zoned Zapot pegmatite, within the quartz monzonite, is unusual in size and mineralogy and no comparable bodies have been encountered in the area. The pegmatite is shaped somewhat like a tadpole with a 1 to 3-meter-wide tail extending northeasterly for about 35 meters and a "head" on the southwestern end which is exposed over an area measuring about 18 × 15 meters and a vertical depth of 6 meters. The pegmatite can be separated into two parts: (1) a northern near-vertical perthite dike which strikes N50–60°E and (2) a southern wider, more complex and multi-zoned dike with a N20°E strike, containing coarsely crystalline amazonite, topaz, smoky quartz, zinnwaldite and ferroan lepidolite (Fig. 3). Dimensions of the pegmatite, as currently exposed, are 53 meters long by 1–15 meters wide with a vertical range of 50–60 meters. Miarolitic cavities, some of which are collapsed, are as large as 2 × 1.5 × 0.5 meters. The pegmatite is enriched in Li-F-Rb, and contains anomalous amounts of Pb-Bi-Sb which have crystallized

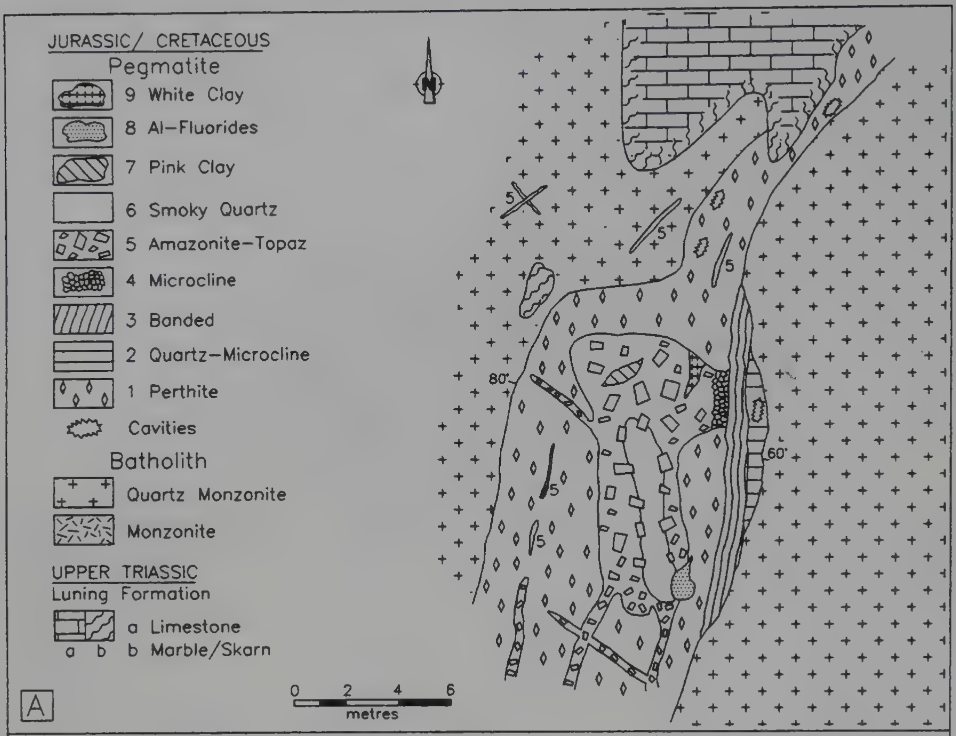

Figure 4a. **Geologic map of the Zapot pegmatite showing the host rocks and the nine zones of the pegmatite (A. E. Soregaroli).**

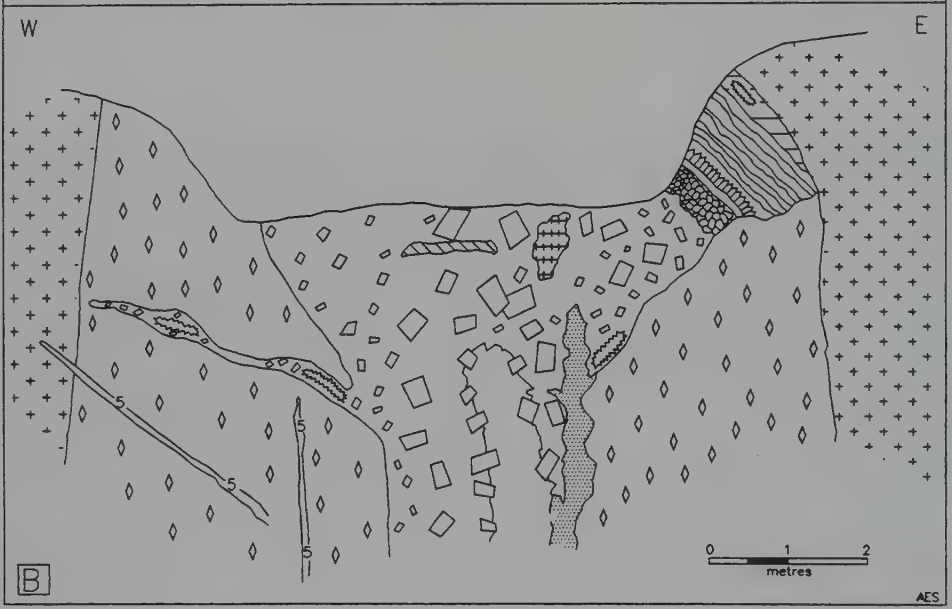

Figure 4b. **Schematic cross-section through the Zapot pegmatite (A. E. Soregaroli).**

as part of Nb-Ti-Ta oxides, but REE's (Rare Earth Elements), B and Be are extremely low. Some Pb is also incorporated into amazonite. The pegmatite displays aspects of both LCT (Li-Cs-Ta) and NYF (Nb-YF) types.

Nine zones have been mapped in the Zapot pegmatite. Vuggy, cockscomb-layering of quartz-microcline-albite exists on the hangingwall of the pegmatite and represents episodic loss of volatiles from the system. An outermost and earliest perthite zone forms the northeasterly tail and outer shell of the southwestern end of the pegmatite. The eight other zones form an asymmetrical funnel-shaped body enclosed within the perthite zone (Figs. 4a and 4b).

Late fracturing has reduced smoky quartz, topaz and albite in the central part of the pegmatite to sand-sized fragments which generally are less than 3 mm in diameter. Fracturing in amazonite is largely expressed by closely spaced cleavage development. This fracturing has destroyed many crystals.

Near the center of the pegmatite, at the upper contact of the amazonite-topaz zone with the overlying perthite zone, a small area approximately 1 × 1.6 meters in size contained a concentration of coarsely crystalline ilmenite (to 10 cm), magnetite, zircon, rutile and several other minerals. Such an association has not been observed elsewhere in the pegmatite.

Figure 5 is a view of the pegmatite taken in June, 1994.

Perthite Zone

The earliest and most extensive zone of the pegmatite is in contact with the quartz monzonite phase of the batholith and is in intrusive contact with limestones of the Luning Formation. Complex intergrowth of individual plumose-shaped microcline perthite crystals up to 9 cm × 15 cm dominate most of the zone. The groundmass and interstices consist of albite, microcline, quartz and fine-grained black biotite. Zircon and manganocolumbite are rare constituents. The zone contains occasional cavities lined with microcline (pink to creamy), smoky quartz, schorl and rare topaz. The number of cavities increases toward the main amazonite-bearing zone and in these areas may contain amazonite.

Amazonite-smoky quartz-topaz veins cut the perthite zone and near-vertical lenses (1–3 cm wide by 1–5 cm long) occupy a zone up to 40 cm wide adjacent to the amazonite-smoky quartz-topaz zone. All other zones cut the perthite zone.

Quartz-Microcline Zone

This is the outermost of the main zones, and formed at the contact with the host quartz monzonite and the perthite zone. The unit dips easterly 60° and varies in thickness from a maximum of 50 cm to zero where it pinches out down the dip and along strike. This zone is present only on the east side of the pegmatite and near the coarsely crystalline amazonite-bearing zone. Miarolitic cavities up to 1 meter × 35 cm × 20 cm contain white to clear quartz, creamy microcline and pale yellowish green muscovite. This zone has been totally removed by mining. The contact with the quartz monzonite phase of the batholith is sharp to gradational.

Banded Zone

Immediately adjacent to and west of the quartz-microcline zone is a 1 to 2-meter-thick unit of banded rock with comb-structured quartz bands in a white microcline, albite, and quartz groundmass. These quartz bands are irregular and sometimes discontinuous (Fig. 6). Some bands are distorted and display foldlike features. The bands are composed of quartz crystals which have grown upward from a sharp, essentially planar lower contact and have euhedral to subhedral upper contacts. Individual quartz bands range in thickness from 1 to 11.5 cm and may form cavities at their upper contact which are lined with quartz, microcline, albite, needle-like black schorl, rare topaz and occasional pink beidellite. The groundmass is an interlocking mosaic of microcline, albite and quartz. Like the quartz-microcline zone, the banded zone occurs only adjacent to the amazonite-bearing zone and terminates laterally and downward against the perthite zone.

Microcline Zone

Between the banded zone and the amazonite-topaz zone is an irregular and discontinuous 0 to 40-cm-wide, interlocking mosaic of 6 to 10-cm anhedral to subhedral crystals of pinkish-gray microcline. The microcline zone is a monomineralic unit displaying a sharp planar contact with the overlying banded zone and an irregular, sharp contact with the amazonite-topaz zone.

Amazonite-Topaz Zone

The most important and colorful zone in the Zapot pegmatite is the amazonite-topaz zone which is somewhat funnel-shaped in cross-section (Fig. 4b) with the east side dipping 60° westerly and the west side dipping 70–80° easterly. Both sides become vertical at about 4 meters below the surface and then the west side again flares outward.

The amazonite-topaz zone is finer grained at its sharp contacts with the surrounding perthite zone. A border 2 to 4-cm at the contact is white in color and consists of 1 to 2-cm white microcline and albite crystals plus minor smoky quartz and zinnwaldite. Inward from this thin border area the microcline is green in color and the crystal size rapidly increases to 6 to 8-cm for a width of about 10 to 15 cm and then again abruptly increases in crystal size to as much as 50 cm.

This zone of the pegmatite contains amazonite, smoky quartz, topaz, albite and zoned zinnwaldite-ferroan lepidolite as the dominant minerals (Fig. 7). Minor minerals include hematite, metamict plumbopyrochlore grading to other members of the pyrochlore group showing distinct alteration haloes, and zircon plus thorite near the contacts.

Crystal-bearing cavities occur throughout the amazonite-topaz zone, especially at inflections in strike or dip of the pegmatite contact and near the hangingwall contact with the overlying perthite stage. Such cavities (pockets) may be lined with amazonite, smoky quartz, and topaz crystals of various sizes. Schorl occurs intergrown with smoky quartz and on the surfaces of other minerals. Most cavities are filled with pink to tan-pink clay (beidellite-montmorillonite).

A white mica (discussed under lepidolite) in the coarsely crystalline central part of the amazonite-topaz zone is rare and occurs in small cavities (several cm in maximum dimension) as rosette-like clusters of small (to 5 mm across), euhedral, pseudohexagonal plates on pale blue, granular albite and topaz. Dikes of amazonite-topaz cut the perthite zone as well as the quartz monzonite host rocks.

Smoky Quartz Core Zone

Massive intergrown smoky quartz forms a core which has been exposed over an area 7 meters long, up to 1.5 meters wide and about 3.0 meters vertically. The zone is enclosed within the amazonite-topaz zone, from which euhedral amazonite, albite and topaz crystals extend into the smoky quartz core.

Of particular note in the quartz core is the presence of large euhedral to subhedral, polysynthetically twinned, light tan or buff to white colored hambergite crystals (Fig. 8). Cavities filled with pink beidellite-montmorillonite and metamict pyrochlore-group minerals also occur within the core.

Beidellite-Montmorillonite

Irregular cavities and early fractures filled with pink beidellite are found in all stages of the pegmatite but are especially abundant in the amazonite-topaz zone and in the quartz core. Such pockets may be as much as 1 meter × 2 to 20 cm × 2 to 10 cm. Euhedral topaz, amazonite, and smoky quartz crystals as well as ovoid masses of metamict plumbopyrochlore (and related species) may be found in clay-filled cavities.

Alumino-Fluoride Zone

One cross-cutting, white to creamy white, pipe-like body containing alumino-fluoride minerals and fluorite was found at the southeastern corner of the exposed smoky quartz core (Fig. 9). The pipe measured 10 to 25 cm in diameter and was exposed for a vertical distance of 2.7 meters. Minerals identified in the pipe are: cryolite, cryolithionite, elpasolite, pachnolite, prosopite, ralstonite, thomsenolite, weberite and a new mineral with the composition Na_2LiAlF_6 that has been named simmonsite. Green and bright golden orange fragments of fluorite are enclosed within the primary alumino-fluorides and small, colorless to purple euhedral fluorite crystals line some secondary vugs. Areas of extremely fine-grained prosopite-pale purple fluorite are also present. A few fragments of amazonite, topaz, and smoky quartz occur within the pipe.

Mining has completely removed the pipe.

Kaolinite

Kaolinite may be slightly younger or older than the alumino-fluoride zone. Snow-white kaolinite fills irregular fractures and cavities and some replacement of feldspar has also occurred. The white kaolinite occurs on the outer edges of some masses of pink beidellite-montmorillonite where it appears to replace these pink clays. The kaolinite masses occasionally have finely crystalline purple fluorite on fracture surfaces which suggests a possible relationship with the alumino-fluoride zone.

Figure 5. **Exposure of the Zapot pegmatite in June, 1994.**

Figure 6. **Vuggy cockscomb-layering of quartz-K-feldspar-albite in the banded zone of the Zapot pegmatite.**

Figure 7. **View of a portion of the amazonite-topaz zone showing amazonite-topaz and quartz. A = amazonite, T = topaz, Q = quartz. Hammer shows scale.**

PEGMATITE MINERALOGY

The mineralogy of the Zapot pegmatite is both simple and complex. It is simple because relatively few, only about 38, minerals have been thus far identified from the pegmatite. On the other hand, it is complex because of the 38 minerals, nine are alumino-fluorides. Furthermore, several rare or new minerals which include hambergite, plumbopyrochlore and other members of the pyrochlore group, a polymorphous form of Na_2LiAlF_6 (simmonsite), a hydrated Nb-oxide, and a yellow U-Bi-Nb-Ca-Ti silicate also occur.

Albite $NaAlSi_3O_8$

Albite, ranging from An_5 to An_1 occurs ubiquitously in the pegmatite. The mineral is white and occurs generally interstitial to microcline and quartz, as an exsolution product within microcline crystals, and in irregular masses as much as 30 cm in maximum dimension. Euhedral, prismatic, single crystals or crystal aggregates of albite occur in small cavities in the banded zone. These crystals may be 4 mm long, 1 mm wide and 0.05 mm thick. The bladed and radiating variety, cleavelandite, occurs within miarolitic cavities with amazonite, smoky quartz, and topaz.

Beidellite-Montmorillonite

$(Na,Ca_{0.5})_{0.3}Al_2(Si,Al)_4O_{10}(OH)_2 \cdot nH_2O$ to
$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$

Masses of pale to dark pink to buff-colored beidellite, as much as 1 meter long, 30 cm wide, and 20 cm thick fill late topaz-bearing cavities within the amazonite-topaz and the quartz core zones. White clay (a mixture of beidellite and kaolinite) surrounds and is intergrown with some of the masses of pure pink beidellite. The beidellite is of hydrothermal origin and with continued decrease of

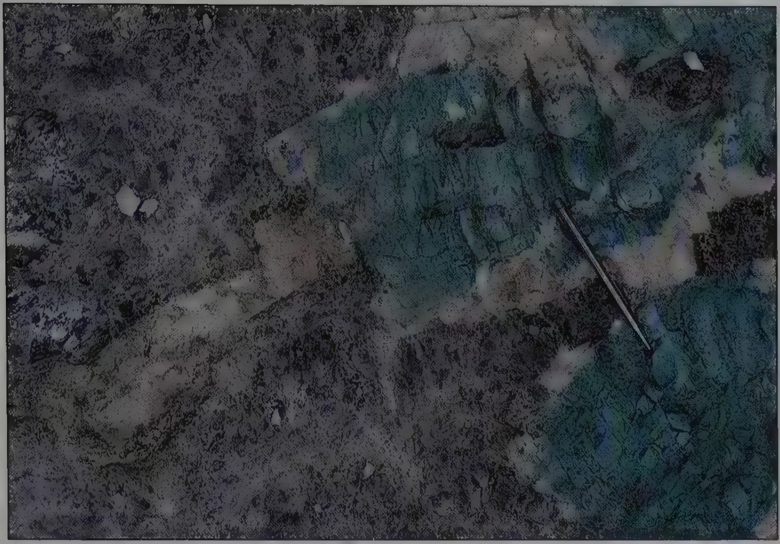

Figure 8. **Crystals of amazonite, albite, and a crystal of hambergite projecting into the quartz. Pen shows scale.**

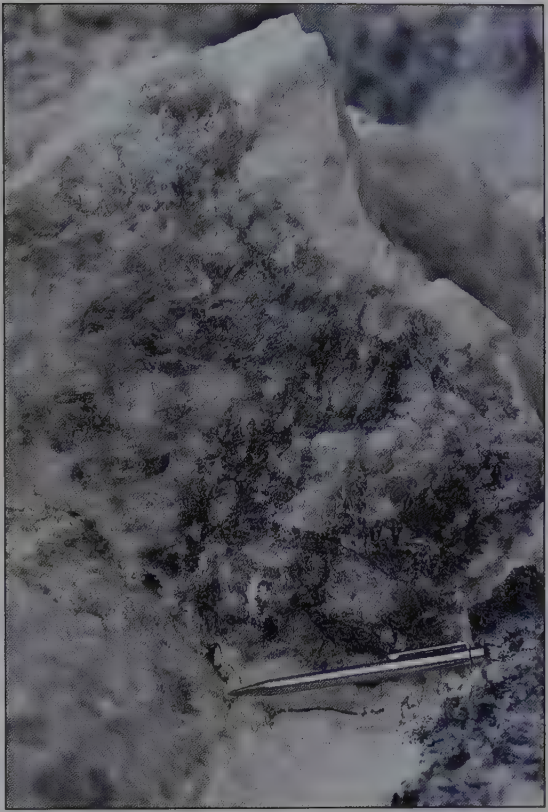

Figure 9. **Primary alumino-fluoride breccia pipe with cross-cutting late-stage white secondary alumino-fluorides. Pen shows scale.**

Figure 10. **Amazonite, a euhedral crystal, 10 cm, showing mottled and striped appearance. Harvey Gordon specimen; Jeff Scovil photo.**

Figure 11. **Phenakite crystal, 1.2 cm. A. E. Soregaroli specimen, M. Mauthner photo.**

Figure 12. **Metamict pyrochlore-betafite crystal and radiation halo at the contact of the quartz core and the amazonite-topaz zone. Dime for scale.**

temperature, kaolinite became stable. An XRF analysis for the waxy beidellite gave (weight %): SiO_2 47.7, Al_2O_3 27.5, Fe_2O_3 <0.03, MgO 3.26, CaO 0.98, Na_2O <0.1, K_2O 0.1, TiO_2 <0.01, P_2O_5 0.13, MnO 0.12, LOI (925°C) 19.8, Σ99.59. ICP-AES analyses agree closely with the XRF values. Additional trace and minor elements include: 180 ppm Ba, 6 ppm Be, 190 ppm Li, 10 ppm Nb, 44 ppm Pb, 75 ppm Sc, and 170 ppm Sr. The pink color of the beidellite is due to the presence of small amounts of manganese. The color is darker pink or reddish to brownish adjacent to masses of metamict pyrochlore group minerals. The analysis of the Zapot beidellite is similar to analyses of beidellites from San Diego County which were examined in detail by Foord *et al.* (1986).

Calcite $CaCO_3$

Small quantities of white, tan, or gray calcite fill late-stage fractures throughout the pegmatite. Some open fractures are lined with microcrystalline groups of white calcite rhombohedra to 1 mm across. Calcite is a minor constituent of the pegmatite and probably is unrelated to pegmatite genesis. The mineral fluoresces white in shortwave ultraviolet light.

Fluorite CaF_2

Fluorite occurs chiefly in the alumino-fluoride pipe and the amazonite-topaz zone. Anhedral to botryoidal colorless fluorite, generally brightly fluorescent yellow green in shortwave ultraviolet light, fills vugs and fractures in the alumino-fluoride masses. This fluorite also phosphoresces for several seconds. Medium to dark purple microcrystalline fluorite is younger than the colorless variety. The microcrystalline (less than 0.5 mm) purple fluorite occurs as simple octahedra with some dodecahedral faces, and is most common; it coats late-stage alumino-fluoride minerals which have formed as alteration and reaction products of early alumino-fluorides. Thin, purple coatings of fluorite also occur on amazonite, albite, and white clay (generally kaolinite).

Purple fluorite was also observed within the alumino-fluoride pipe as cryptocrystalline, weakly banded, irregular, tabular lenses and veinlets which measure up to 12 cm long, 10 cm wide, and 2 cm thick and are intimately intergrown with alumino-fluorides. Such a tabular fluorite mass was observed near the base of the pipe.

Fragments of bright apple green, translucent to nearly transparent fluorite, as much as 2 cm across, are a minor constituent within the alumino-fluoride pipe. One fragment of translucent, bright orange to red-orange fluorite was also observed. The fragments are parts of single crystals and crystal masses, and generally are elongate with irregular, but sharp contacts with the alumino-fluorides. The largest fragment measures 2.1 × 1.3 × 1.0 cm. All fragments fluoresce bright yellow in SW UV light and are phosphorescent for 1–2 seconds.

Grayite $(Th,Ca)(PO_4,SiO_4)\cdot H_2O$

Sparse amounts of Ce-bearing grayite occur as an alteration product of thorite. The grayite is fine-grained, pale yellowish gray, and occurs as a partial coating on crystals of thorite.

Hambergite $Be_2BO_3(OH,F)$

Creamy tan to white, euhedral to subhedral, tabular hambergite crystals of unusually large size (as much as 6 × 9 × 30 cm) (Fig. 8) are enclosed by massive smoky quartz in the core of the pegmatite. The tabular form and polysynthetic twinning of the crystals resemble plagioclase feldspar, except for the color, which is unlike the albite in the deposit, and the earthy to silky luster. Such characteristics prompted sampling for XRD identification. Several crystals of various size were found during the mapping and mining activity. All crystals are intensely shattered as is the host smoky quartz, making it impossible to collect intact one of these large crystals, which are among the largest ever reported for hambergite. Where the hambergite is in contact with amazonite or albite of the amazonite-topaz zone, the mineral is silky white in color and is difficult to identify except for the long, splintery and acicular bundles of white cleavage fragments.

Refractive index determinations on one sample of hambergite indicate that approximately 0.5 (atomic) of the O(4) site is occupied by F (Novak *et al.*, in press). Thus the hambergite from Zapot is a high-F hambergite.

Hambergite is a rare mineral and has been reported from fewer than about 25 world wide localities.

Hematite Fe_2O_3

Hematite occurs as a primary mineral in the Zapot pegmatite as bright, lustrous, euhedral plates as much as 2 mm × 2.5 × 4.5 cm. Most plates are elongated and, when dull, have the appearance of columbite; however of the several which have been analyzed and X-rayed, all are hematite. Some plates exhibit three sets of striae reflecting the trigonal symmetry. The mineral generally is enclosed in amazonite or albite, but is also found partially enclosed by smoky quartz or rarely topaz. It occurs widely disseminated throughout the body and is most abundant in the amazonite-topaz zone. An LA-ICP-MS analysis of the hematite showed: Fe—major, TiO_2 1.08 weight %, MnO 0.52, Nb_2O_5 0.02, SnO_2 0.20, Sb_2O_5 0.17, Ta_2O_5 0.02. The contained trace elements are typical for an evolved pegmatite.

Ilmenite-Pyrophanite $FeTiO_3$-$MnTiO_3$

Sparse, 5-mm to 10-cm long crystals of ilmenite grading to pyrophanite were found at the upper contact of the amazonite-topaz zone with the perthite zone, in association with microcline, quartz, magnetite, zircon and thorite. Some crystals are 50:50 ilmenite:pyrophanite. The ilmenite contains trace to minor amounts of Nb.

Kaolinite $Al_2Si_2O_5(OH)_4$

Kaolinite, admixed with beidellite-montmorillonite, rims and replaces pink beidellite in the amazonite-topaz zone of the Zapot pegmatite. The mixture is white, and is somewhat hard and compact. An XRF analysis of a bulk sample (approx. half montmorillonite and half kaolinite) showed (weight %): SiO_2 46.2, Al_2O_3 35.4, Fe_2O_3 0.04, MgO 1.60, CaO 0.30, Na_2O <0.05, K_2O 0.06, TiO_2 <0.01, P_2O_5 <0.02, MnO <0.01, LOI (925°C) 16.1, Σ99.70. ICP-AES determinations agree closely with the XRF values. Additional trace and minor elements include: 24 ppm Ba, 10 ppm Be, 170 ppm Li, 10 ppm Nb, 17 ppm Pb, 11 ppm Sc, and 44 ppm Sr.

Lepidolite (ferroan) $K(Li,Al,Fe)_3(Si,Al)_4O_{10}(F,OH)_2$

Pale tan ferroan lepidolite occurs as outer portions of color-zoned mica 'books' within the coarse-grained, central amazonite-topaz zone. The 'books' may be more than 20 cm across and 2 cm thick. A partial composite chemical analysis of this material yields (weight %): SiO_2 48.0, Al_2O_3 18.8, Fe_2O_3 5.80, MgO <0.05, CaO 0.06, Na_2O 0.30, K_2O 9.12, TiO_2 0.12, P_2O_5 <0.02, MnO 4.07, F 7.0, Rb_2O 3.3, Cs_2O 0.1, Li_2O 6.2, BeO 0.035, B_2O_3 0.01, Ga_2O_3 0.02, ZnO 0.20, Σ103.135, O for F 2.95, Cor. Σ100.18. Trace elements present include: Sn 60 ppm, Sr 24 ppm, Nb 25 ppm, Ba 170 ppm. Total iron was reported as Fe_2O_3. The high MnO content (4.07 weight %) is noteworthy and represents solid solution towards masutomilite.

A still younger generation of lepidolite that crystallized in small miarolitic cavities is characterized by high concentrations of Li, F, and Rb. Visually it closely resembles muscovite but is an overgrowth on pale brownish tan ferroan lepidolite. Such crystals were identified in one small area of the pegmatite. These crystals of low Fe-bearing lepidolite are essentially colorless or very pale tan. An XRF analysis for major elements for the lepidolite gave (weight %): SiO_2 50.2, Al_2O_3 17.0, Fe_2O_3 4.31, MgO 0.18, CaO 0.05, Na_2O 0.34, K_2O 7.48, TiO_2 0.05, P_2O_5 0.05, MnO 2.02, LOI (920°C) 2.31, Total 84.0. Additional elements determined by ICP-AES (P. H. Briggs, USGS) include Li_2O 4.5, Rb_2O 3.4, ZnO 0.04, Nb 75 ppm, Pb 150 ppm, Be 61 ppm. This lepidolite melted at a temperature less than 920°C.

Magnetite Fe_3O_4

Magnetite in black, subhedral crystals to 1 cm was found intergrown and associated with ilmenite, microcline, zircon, rutile and thorite in one area of the pegmatite: at the upper contact of the amazonite-topaz zone with the overlying perthite zone.

Manganocolumbite $MnNb_2O_6$

Manganocolumbite, containing some Ta, is a rare mineral in the pegmatite. It generally occurs in albite or microcline within the perthite zone as black, sometimes lustrous, prismatic, flattened on {010}, in crystals that may be 3 mm long and 1 mm wide.

Microcline (including amazonite) $KAlSi_3O_8$

Microcline, one of the dominant minerals, occurs in the main body and in miarolitic cavities. Except for the amazonite variety in the amazonite-topaz zone and in the West Area, the microcline is pinkish tan, tan or gray, and forms crystals as large as 15 cm in length. Such crystals are intimately intergrown with smoky or colorless quartz crystals.

Two elongated, pale gray, euhedral Baveno-twinned microcline crystals were found on different occasions in broken debris in the Zapot pit. Both were in the center of the amazonite-topaz zone near the upper contact with the perthite zone.

Euhedral amazonite crystals as large as 50 × 50 cm have been recovered from pegmatites in the West Area. Amazonite crystals in the Zapot pegmatite rarely exceed 8 × 10 cm in size (Fig. 10). Most crystals are mottled with considerable quantities of white to pale green, elongate patches of microcline, while others are uniformly blue-green.

Groundmass amazonite in the Zapot pegmatite has also been observed in subhedral crystals as much as 50 cm in length enclosed in quartz, albite and topaz.

Two distinct generations of amazonite are present in the Zapot pegmatite: a first generation of pale blue-green amazonite and a second generation of deep blue-green amazonite. Both generations of amazonite are perthitic. The pale blue-green amazonite occurs in the outer part of the amazonite-topaz zone whereas the deep blue green amazonite occurs in the coarser crystalline inner part of the zone. Bulk chemical analyses (major elements by XRF, Pb and Rb by ICP-AES) for the first and second generations respectively are (weight %): SiO_2 64.6, 64.5; Al_2O_3 18.6, 18.6; Fe_2O_3 0.13, 0.07; MgO <0.02, <0.02; CaO 0.02, 0.03; Na_2O 2.47, 2.14; K_2O 12.6, 12.6; TiO_2 <0.02, <0.02; P_2O_5 <0.05, <0.05; MnO <0.01,<0.01; PbO 0.02, 0.03; Rb_2O 1.08, 1.53; LOI (920°C) 0.08, 0.06 Σ99.44, 99.56. Empirical formulas of the bulk crystals (on the basis of 8 oxygen atoms) are: $(K_{0.74}Na_{0.22}Rb_{0.03})_{\Sigma 0.99}Al_{1.01}Si_{2.99}O_8$ and $(K_{0.75}Na_{0.19}Rb_{0.05})_{\Sigma 0.99}Al_{1.02}Si_{2.99}O_8$.

Amazonite of the youngest generation occurs in miarolitic cavities in the amazonite-topaz zone of the main Zapot pegmatite as well as in the West area. Figure 8 shows a typical crystal exhibiting a striped appearance. Both generations of amazonite fluoresce magenta-red under shortwave ultraviolet light, which is characteristic of much amazonite, particularly from alkalic rocks.

Cretaceous age amazonite is rare, most being Precambrian in age. Sparse amounts of additional Cretaceous amazonite in pegmatite occur in Nevada between Round Mountain and Manhattan, Nye County (D. R. Shawe, U.S.G.S., personal communication, 1980).

Muscovite (including sericite) $KAl_2(Si_3Al)O_{10}(OH,F)_2$

White mica occurs in cavities within the quartz monzonite host, as well as in the quartz-microcline and perthite zones. Micas (as sheets 0.5 to 1.5 cm across) occur in cavities with microcline (tan to pink) and colorless quartz. SEM-EDS analysis of the muscovite shows that it is iron-bearing but is otherwise normal.

Phenakite Be_2SiO_4

One euhedral crystal of phenakite was found in a miarolitic cavity in the perthite zone north of the amazonite-bearing part of the pegmatite. The 1.1 cm long by 5-mm-diameter, striated, translucent to transparent creamy yellow crystal (Fig. 11) occurred with pale gray microcline and smoky quartz crystals.

Plumbopyrochlore (and other members of the pyrochlore group: e.g. plumbobetafite, bismutobetafite and betafite)
$(Pb,Y,U,Ca)_{2-x}Nb_2O_6(OH)$

Chocolate brown to nearly black anhedral to subhedral masses of metamict plumbopyrochlore grading to plumbobetafite and other members of the pyrochlore-microlite group are present in the amazonite-topaz and smoky quartz zones of the pegmatite. The masses may be as much as 7 × 9 cm and typically are enclosed in feldspar or in pink beidellite. Distinctive reddish brown and yellow diffuse halos are present around the masses. A pattern of shrinkage cracks also extends away from the metamict minerals (Fig. 12). A red-brown coloration of the feldspar is due to radiation damage and a yellow coloration of the feldspar and beidellite is due to secondary Bi and U oxides (?) produced by alteration of the primary plumbopyrochlore.

Detailed microprobe analyses (for 21 elements) (by P. A. Wolpert, USGS) indicate that at least four other oxide minerals are intergrown with the dominant plumbopyrochlore (section 1) while a second section consisted of single-phase Bi-dominant betafite-pyrochlore. Chemical analyses for the six minerals found are given in Table 1. The most abundant mineral is a plumbo-bismuto-pyrochlore-betafite that is tantalian, uraniferous and siliceous. Solid-solution between pyrochlore and betafite is indicated by the microprobe analyses. The bismuth-dominant betafite in section 2 is also Si- and U-bearing. Small inclusions and segregations of an Fe-Sn-Nb-Ti-Ta oxide mineral are present in section 1 along with very sparse inclusions of a Pb-Sb-Nb-Ti-Ta mineral and what is probably a uranium dominant betafite-pyrochlore. Silica is absent from the Fe-Sn-Nb-Ti-Ta oxide and the U- dominant betafite-pyrochlore.

The substantial (7.1–11.0 weight %) SiO_2 content of the pyrochlore group minerals is noteworthy. Crystalline (non-metamict) Nb-Ti-Ta oxides very rarely contain SiO_2 and metamict examples also usually contain low to extremely low levels of this oxide. Reaction of what presumably was non-silica bearing betafite-pyrochlore with late-stage silica-rich solutions has occurred in the Zapot pegmatite. Because of this, meaningful empirical formulas cannot be calculated for the various minerals. An additional feature is the presence of variable major amounts of Pb, Sb, Bi, U and Sn in addition to the normal Nb, Ti and Ta. A bismuth-dominant betafite has previously been reported from the Malkhan pegmatites, Transbaikalia (Zagorsky and Peretyazhko, 1992). Additional Sb-bearing and Bi-bearing members of the pyrochlore group were also reported and, unlike the Zapot material, do not contain major amounts of SiO_2. Complete description of "bismutobetafite" from Malkhan is currently being completed (V. Ye. Zagorsky, personal communication, 1997).

Electron-microprobe analyses by T. S. Ercit (Canadian Museum of Nature) of two samples (Z-11 and Z-6) showed Si-bearing bismutobetafite (Z-11) and Si-bearing uranpyrochlore (Z-6).

X-ray diffraction studies show the masses to be metamict. Heating at greater than 700°C for several hours in a reducing atmosphere produces material which gives a pattern matching plumbopyrochlore and stibiobetafite plus several additional minor peaks.

Quartz SiO_2

Quartz is ubiquitous in the Zapot pegmatite and occurs in all zones except for the microcline zone. Most quartz is present as anhedral to subhedral intergrowths with microcline and albite and as the major constituent of the smoky quartz core. Euhedral, smoky quartz (Fig. 13) occurs in most miarolitic cavities. Crystals as large as 17.5 × 60 cm have been collected from the amazonite-topaz zone; anhedral crystals in the smoky quartz core and in the amazonite-topaz zone matrix measure as much as 40 cm in length. The most common forms observed include $m\{10\bar{1}0\}$, $r\{10\bar{1}1\}$ and $z\{01\bar{1}1\}$, with small modifying faces of the forms $s\{11\bar{2}1\}$ and $x\{51\bar{6}1\}$.

Smoky quartz crystals in the West Area often occur as parallel groups, the largest observed single crystal measuring 8 by 24.5 cm. Colorless to white euhedral quartz crystals were observed in cavities in the quartz-microcline zone and in the northeastern part of the perthite zone.

Rutile TiO_2

Small amounts of niobian rutile occur intergrown with ilmenite

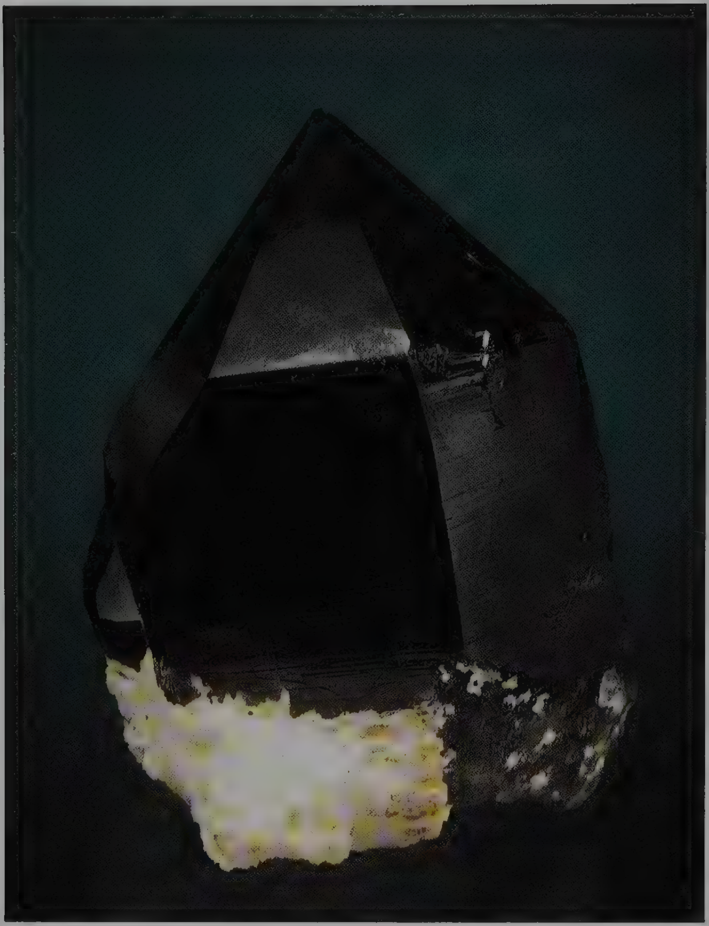

Figure 13. Smoky quartz crystal, 6.3 cm, from a miarolitic cavity. Harvey Gordon specimen, Jeff Scovil photo.

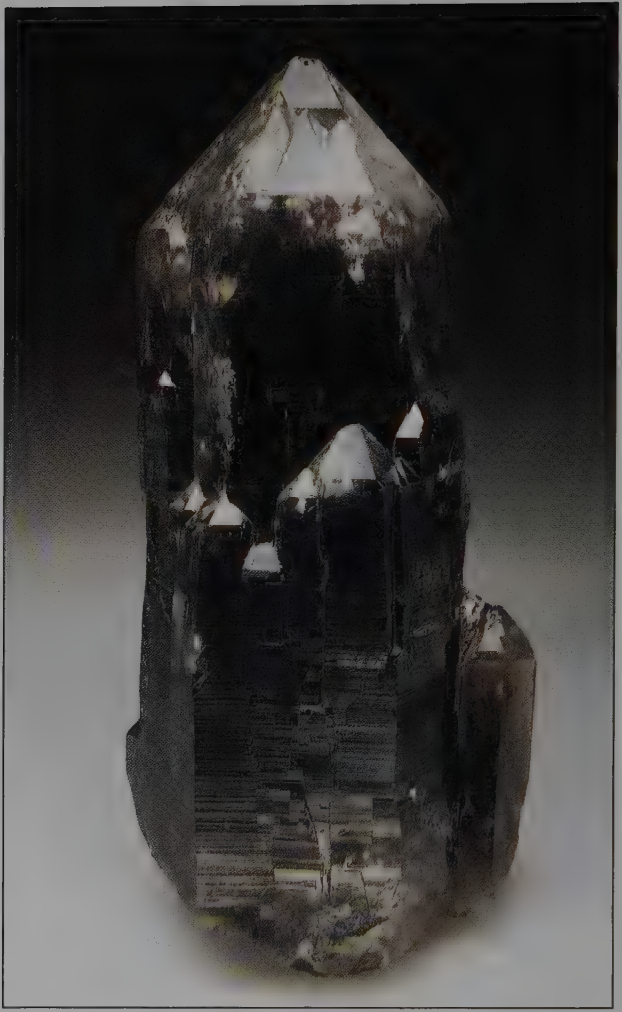

Figure 14. Smoky quartz crystal, 24.2 cm. Harvey Gordon specimen; Jeff Scovil photo.

Figure 15. Smoky quartz (center crystal 2.4 cm long) on microcline. Harvey Gordon specimen; Jeff Scovil photo.

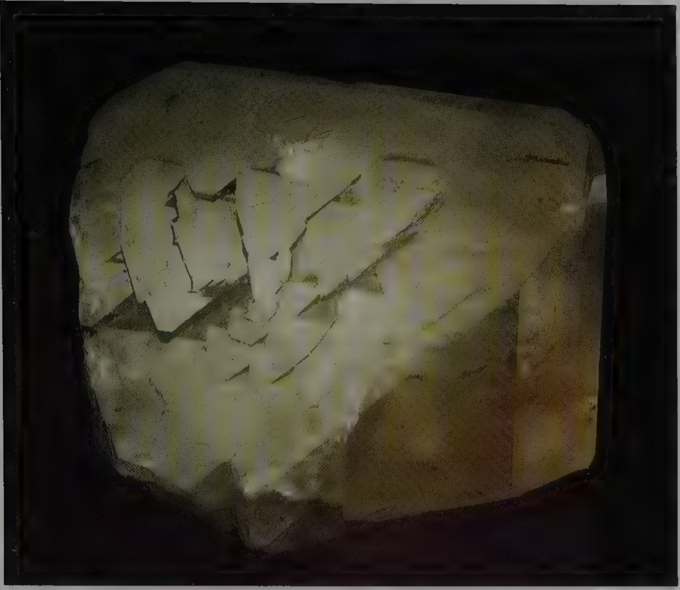

Figure 16. **Topaz crystal, 7.9 cm wide, from a miarolitic cavity. Harvey Gordon specimen, Jeff Scovil photo.**

Figure 17. **Gem-quality crystal of topaz, 2.6 cm, showing multiple forms. Collin Young specimen, Jeff Scovil photo.**

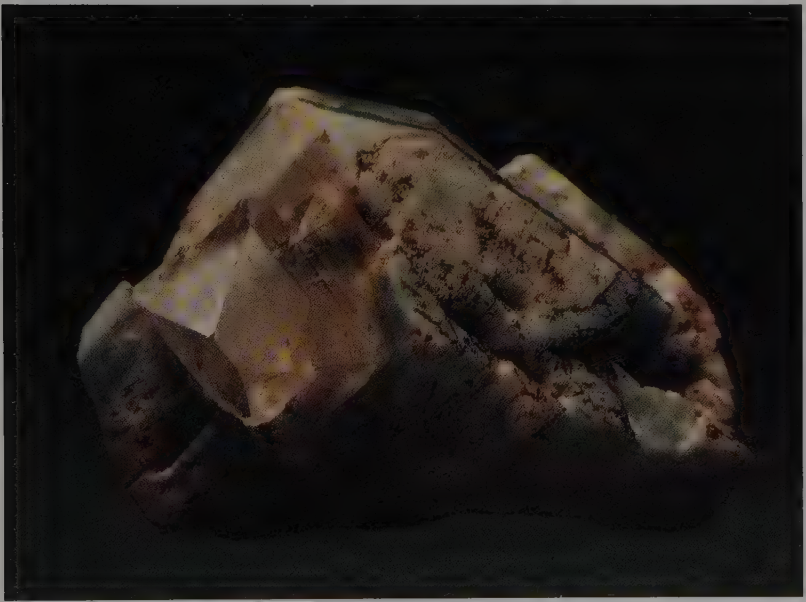

Figure 18. **Topaz crystal, 3 cm, on mottled amazonite, 7.2 cm, with tiny (0.2–1.0 mm) black crystals of schorl on the upper crystal face of the amazonite. A. E. Soregaroli specimen; Mark Mauthner photo.**

Figure 19. **Faceted colorless topaz (3.4 cts., 3.6 cts) from the Zapot pegmatite. Harvey Gordon specimens: Jeff Scovil photo.**

and magnetite, associated with zircon, thorite, microcline and other minerals at the upper contact of the amazonite-topaz zone and the overlying perthite zone.

Schorl $NaFe_3^{2+}Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Small, black (rarely dark green in strong transmitted light) prisms, needles, and radiating clusters of schorl grading towards elbaite have grown on and in the outer few millimeters of both quartz, microcline (amazonite and other colors) and albite in miarolitic cavities. Most schorl crystals are small (1 to 10 mm) but needles as long as 4 cm have been observed, especially in radiating sheaves of crystals.

Spessartine $Mn_3Al_2Si_3O_{12}$

Orange-red to reddish-orange, euhedral, trapezohedral, Fe-bearing spessartine was found in one miarolitic cavity in the West Area associated with smoky quartz, very pale green amazonite and schorl. Crystals typically range from 0.1 to 2 mm in diameter.

Thorite $ThSiO_4$

Thorite is a rare mineral in the amazonite-topaz zone, and was also found associated with ilmenite, magnetite and zircon at the upper contact of the amazonite-topaz zone with the perthite zone. Crystals are reddish brown to brown, may be several mm across, and are partially metamict.

Topaz $Al_2SiO_4(F,OH)_2$

Colorless, yellowish, pale green and medium blue or bluish-green topaz crystals and anhedral masses as much as 25 cm across occur interstitial to amazonite, albite and smoky quartz. Specimen-grade to gem-quality crystals of topaz occur in beidellite-filled

Table 1. **Electron-microprobe analyses of metamict pyrochlore group minerals and associated oxide minerals from the Zapot pegmatite.**

Section no.	*(1)*	*(1)*	*(2)*	*(1)*	*(1)*	*(1)*
Oxide	*Pb-Bi-Ti-Nb-Ta*	*Pb-Bi-Ti-Nb-Ta*	*Bi-Pb-U-Ti-Nb*	*Fe-Sn-Nb-Ti-Ta*	*Pb-Sb-Nb-Ti-Ta*	*U-Pb-Bi-Nb-Ti*
PbO	19.0	8.6	5.7	0.4	39.5	9.0
Bi_2O_3	14.5	7.5	31.6	0.0	1.8	7.4
Na_2O	0.1	0.0	0.0	0.0	0.7	0.0
CaO	2.7	4.0	2.4	0.0	0.0	3.5
TiO_2	6.5	16.4	11.0	14.0	7.4	9.9
Nb_2O_5	18.5	18.3	14.8	40.0	21.4	15.4
Ta_2O_5	10.0	9.1	1.6	8.5	4.4	6.1
FeO	0.8	1.3	1.8	23.5	2.0	0.5
MnO	0.8	0.1	2.9	1.0	1.0	0.0
F	0.0	0.0	0.0	0.0	0.0	0.0
UO_2	5.0	4.3	7.4	0.2	0.8	24.7
ThO_2	0.3	0.6	0.7	0.0	0.0	0.5
SiO_2	8.0	11.0	7.1	0.0	0.0	7.6
P_2O_5	0.6	0.0	0.3	0.0	0.0	0.3
K_2O	0.1	0.0	0.15	0.0	0.0	0.1
V_2O_3	0.1	0.2	0.2	0.15	0.0	0.1
SnO_2	2.5	2.4	2.1	5.2	1.8	1.4
Sb_2O_3	0.1	0.0	0.9	3.0	14.6	0.0
MgO	0.5	0.75	0.4	0.0	0.0	0.55
Sc_2O_3	0.0	0.0	0.0	0.4	0.0	0.0
ZrO_2	0.3	0.0	0.1	0.4	0.0	0.0
H_2O	9.5		9.5			
Total	99.9	84.55	100.6	96.95	95.4	87.05
Name	Plumbo-bismuto-pyrochlore-betafite (uraniferous) (Si-bearing)	Plumbo-bismuto-betafite-pyrochlore (uraniferous) (Si-bearing)	Bismuto-betafite-pyrochlore (Si-bearing)	Ferro-columbite plus ?	Plumbo-stibio-pyrochlore?	Betafite-pyrochlore (Si-bearing)
No. of points	83	21	20	16	4	3

Notes: H_2O determined by TGA (average of three determinations on different specimens). LA-ICP-MS analyses show approx. 1 weight % of SrO and RE_2O_3. (1) and (2) refer to different samples analyzed.

Table 2. **Alumino-fluoride minerals from the three known North American localities: St. Peter's Dome, the Morefield mine and the Zapot pegmatite.**

Mineral	*Formula*	*St. Peter's Dome*	*Morefield mine*	*Zapot pegmatite*
Chiolite	$Na_5Al_3F_{14}$	—	X	—
Cryolite	Na_3AlF_6	X (1)	X (2)	X (1)
Cryolithionite	$Na_3Li_3Al_2F_{12}$	—	—	X (1)
Elpasolite	K_2NaAlF_6	X	X	X
Pachnolite*	$NaCaAlF_6 \cdot H_2O$	X	X	X
Prosopite	$CaAl_2(F,OH)_8$	X	X (1)	X
Ralstonite	$Na_xMg_xAl_{2-x}(F,OH)_6H_2O$	X	X	X
Thomsenolite*	$NaCaAlF_6 \cdot H_2O$	X	X	X
Gearksutite	$CaAl(OH)F_4 \cdot H_2O$	X	—	—
Weberite	Na_2MgAlF_7	X	—	X
Simmonsite	Na_2LiAlF_6	—	—	X (1)
Total species:		8	7	9

X = present, — = absent (not reported), * = dimorphous forms, (1, 2) = most abundant and second most abundant mineral miarolitic cavities (Figs. 16–18). The clay in the cavities protected the crystals from crushing as in the case of massive topaz and quartz. Habit is typical for that of pegmatitic topaz. The dominant forms in decreasing order of abundance are: {201}, {401}, {110}, {001}, {011}, {012}, and {120}. The blue color is most common near metamict minerals. Maximum crystal size is 6 × 8 cm. Unfractured crystals are not fluorescent in shortwave or longwave ultraviolet light. However, clear, colorless fragments in the alumino-fluoride pipe fluoresce a dull red-orange and some fractured topaz crystals exhibit a creamy yellow fluorescence, probably due to impurities on the fractures.

Water determinations for a clear blue crystal fragment showed: H_2O^+ 0.37 weight % and H_2O^- <0.05 weight %. ICP-AES analysis of the same sample showed all elements except for Al and Si to be below the respective limits of detection. Topaz from the Zapot pegmatite is similar in composition to that reported for topaz from other granitic pegmatites.

Two faceted topazes are shown in Fig. 19.

Figure 20. **Nb-oxide (hydrated) alteration product of pyrochlore-betafite. SEM photo; crystals are 2 to 8 µm.**

Unknown New Pale Blue Discontinuous Nb-Oxide Coating

A discontinuous, pale blue coating of variable thickness often is present as an alteration product on fracture surfaces of the metamict brown to black plumbopyrochlore-betafite. X-ray diffraction studies (114.6 mm Gandolfi camera) produced a pattern that cannot be matched with any known mineral or inorganic compound: (d-spacing in Å, intensity I/I_o) 11.5, 100; 7.5, 40; 4.7, 15; 4.15, 15; 3.71, 25; 3.55, 5; 3.38, 50; 3.20, 75; 3.01, 15; 2.80, 10; 2.60, 10; 2.56, 10; 2.45, 25; 2.08, 5; 2.03, 30; 1.89, 10; 1.81, 5; 1.74, 10; 1.64, 10; and 1.61, 10. SEM-EDS examination shows the mineral to be a Nb-oxide, and probably hydrated. The mineral is microcrystalline (Fig. 20), and forms euhedral crystals that are typically 3–4 microns across. This and the following mineral require further study and complete characterization.

Unknown New U-Bi-Nb-Ca-Ti-Si Mineral

A second alteration product of the brown to black masses of plumbopyrochlore-betafite also forms discontinuous coatings and fracture fillings. The mineral is conspicuous because of its bright lemon yellow to orange yellow color. X-ray diffraction studies indicate that this mineral is the same as a new mineral reported as small nodules to 3 mm from a granitic pegmatite east of Tanti, Department of Punilla, Province of Córdoba, Argentina (Arcidiacono and Bedlivy, 1976). The mineral was not completely described because of extremely small crystal size (1 × 0.1 microns) and difficulty in obtaining quantitative chemistry.

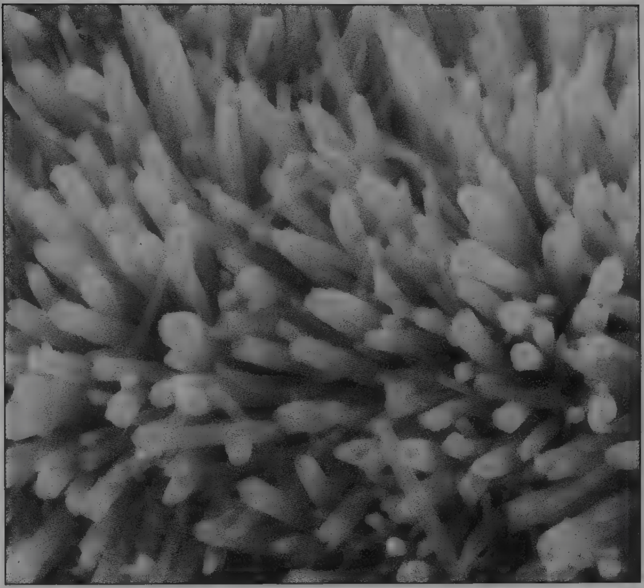

Figure 21. **Yellow U-Bi-Nb-Ca-Ti-silicate alteration product of pyrochlore-betafite. SEM photo; crystals are 2 µm.**

A large (*a* 14.03A, *b* 15.37A, *c* 16.53A) orthorhombic cell was reported for the Argentinian material. Single-crystal studies are not possible on the Zapot material because of extremely small crystal size (typically 0.3 × 2 microns, Fig. 21). Elements determined to be present in the Tanti material were: U, Th, Y, Cu, Nb, Ta, Pb, and Zn as well as Ca, Si, P and As. The Zapot material contains major amounts of U, Bi, Nb, Ca, and Ti with minor amounts of Mg, Al and Ce.

Powder diffraction lines and intensities observed for the Zapot material are: (d in Å, I/I_o) 8.35, 50; 7.13, 80; 5.17, 5; 4.30, 5; 4.18, 100; 3.76, 10; 3.54, 5; 3.43, 5; 3.33, 50; 3.04, 80; 2.93, 50; 2.80, 50; 2.58, 40; 2.31, 5; 2.04, 5; 2.02, 5; 1.88, 20; 1.82, 30; 1.72, 5; 1.58, 5; plus additional lines.

Zinnwaldite (see also lepidolite) $KLiFe^{2+}Al(AlSi_3)O_{10}(F,OH)_2$

Pale brown zinnwaldite occurs in miarolitic cavities with smoky quartz and amazonite. The "books" of zinnwaldite are euhedral and may be as much as 7 cm across. An electron-microprobe analysis of this material showed (in weight %): Na_2O 0.18, Al_2O_3 20.5, SiO_2 44.8, K_2O 9.6, CaO 0.0, MgO 0.02, FeO (all Fe as FeO) 10.1, MnO 3.55, TiO_2 0.3, F 8.3, O for F 3.47, total 93.8.

Large (to 2 × 20 cm) "books" of zoned zinnwaldite-ferroan lepidolite (from core to rim) occur in the amazonite-topaz zone of the pegmatite. A composite analysis of dark to medium brown core zinnwaldite is (weight %): SiO_2 47.1, Al_2O_3 18.8, Fe_TO_3 (total Fe as Fe_2O_3) 7.28, FeO 4.88, Fe_2O_3 1.86, MgO <0.10, CaO 0.02, Na_2O 0.36, K_2O 9.19, TiO_2 0.22, P_2O_5 <0.05, MnO 4.30, H_2O^+ 0.30, H_2O^- 0.05, F 6.9, Rb_2O 2.40, Cs_2O 0.07, Li_2O 4.52, BeO 0.035, B_2O_3 0.01, Ga_2O_3 0.01, ZnO 0.24, Σ101.265, O for F 2.90, Cor. Σ98.365. Trace elements present include: Sn 65 ppm, Sr 23 ppm, Nb 49 ppm, Ba 160 ppm.

Zircon $ZrSiO_4$

Small, reddish brown to gray brown, euhedral crystals of zircon

(Fe-, REE-, U-, and Th-bearing) occur chiefly in the perthite zone and in the amazonite-topaz zone. Crystals are partly metamict and range from 1 to 3 mm. Zircon also occurs with ilmenite, magnetite, rutile and other minerals at the upper contact of the amazonite-topaz zone with the perthite zone.

BRECCIA PIPE MINERALOGY

A sinuous, near-vertical, pipe-like body as much as 25 cm across and 2.7 meters long cuts across the Zapot pegmatite. The body is composed almost entirely of alumino-fluoride minerals with exotic fragments of fluorite, feldspar, topaz and quartz.

The Zapot pegmatite represents the third known occurrence of the alumino-fluoride minerals cryolite, elpasolite, pachnolite, prosopite, and ralstonite in North America. It also hosts the first occurrence of cryolithionite and simmonsite, and the second known North American occurrence of weberite. Similar mineral assemblages have been reported from pegmatites (e.g., Eureka Tunnel) at St. Peter's Dome, El Paso County, Colorado (Cross and Hillebrand, 1883, 1885) and the Morefield pegmatite, Amelia County, Virginia (Kearns, 1993, 1995; Raade and Haug, 1980) (Table 2). The presence of cryolithionite and simmonsite (both absent at Morefield or St. Peter's Dome) and the presence of lepidolite and zinnwaldite at Zapot is indicative of higher Li content relative to the Morefield pegmatite.

Within the pipe, there appears to be a distinct segregation of the alumino-fluoride minerals. The main mass of the breccia pipe is made up of colorless to white or pale tan, vitreous to greasy, homogeneous-appearing material. X-ray diffraction, optical, and electron microprobe studies show that this material is actually composed of four different alumino-fluoride minerals: roughly equal amounts of cryolite, cryolithionite, a new mineral having the composition Na_2LiAlF_6 (simmonsite), and less than 1% anhedral elpasolite disseminated throughout the other minerals. A first stage of alumino-fluoride deposition consisted of Li-Na-Al-K species. A younger, second stage, generally white, and sometimes containing voids with euhedral crystals, contains Ca and Mg in addition to Na, Al and F. Li was remobilized and recrystallized as a second generation of cryolithionite. The presence of Ca and Mg indicate exchange and interaction with the host rocks. Minerals in the younger, secondary stage include: fluorite, pachnolite, prosopite, ralstonite, thomsenolite, and weberite. Replacement of the primary assemblage by the secondary assemblage is also evident. Replacement reactions also have been reported for alumino-fluorides from the Morefield mine and from St. Peter's Dome.

The massive, greasy mixture of cryolite-cryolithionite-simmonsite fluoresces yellow-orange under shortwave ultraviolet light, but is not phosphorescent. The patchy and non-uniform fluorescence may be related to incipient alteration. The masses are not fluorescent under longwave ultraviolet light. A second generation of clear and colorless cryolite-cryolithionite fluoresces white-pale cream under both shortwave and longwave ultraviolet light, and phosphoresces for several seconds.

Cryolite Na_3AlF_6

Cryolite, along with cryolithionite and a monoclinic form of Na_2LiAlF_6 (simmonsite), forms the bulk of the alumino-fluoride breccia pipe. The three minerals occur in roughly equal amounts when integrated over a large surface area. These minerals cannot be distinguished from one another in hand specimen. All are pale cream-buff to colorless, very soft, and translucent, with similar luster.

Electron microprobe data (low totals) suggest that OH may be present. Under the electron beam (10 Kv and 40 micron spot) the mineral rapidly shows beam damage.

Figure 22. **Cryolithionite crystal. SEM photo.**

Cryolithionite $Na_3Li_3Al_2F_{12}$

Cryolithionite is one of three dominant alumino-fluoride minerals, the others being cryolite and simmonsite, in compact, vitreous, white to pale cream-tan masses.

Under the electron beam (10 Kv and 40 micron spot), the mineral shows no visible signs of damage, even after several minutes of exposure. Electron microprobe analyses confirm the presence of this mineral. A cell-refinement of 114.6 mm Gandolfi camera X-ray data for the cryolithionite yielded a cell edge (a_o) of 12.13(1)Å indicating a nearly ideal composition of $Na_3Li_3Al_2F_{12}$.

Fig. 22 shows discrete crystals of recrystallized cryolithionite.

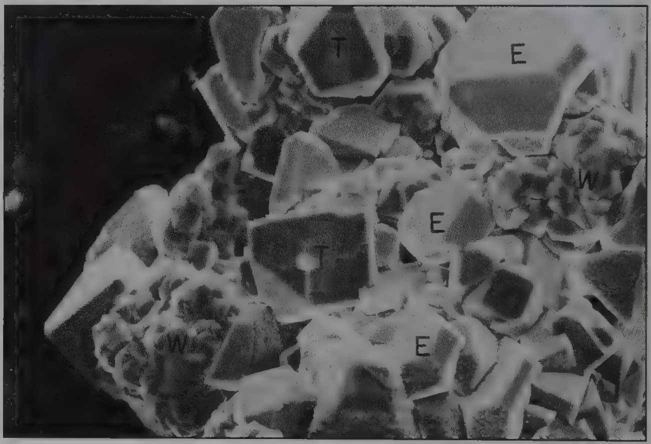

Figure 23. **Elpasolite (E), weberite (W) and thomsenolite (T) crystals. SEM photo; crystals are 20 to 50 µm.**

Elpasolite K_2NaAlF_6

Elpasolite has two modes of occurrence: (1) as very small oval or circular (in cross-section) anhedral grains less than 20 micrometers across, enclosed in early stage Al-F minerals and (2) as one of several late-stage vug-filling alumino-fluoride minerals cutting the primary mixture of cryolite-cryolithionite-simmonsite. Electron-microprobe analyses of the anhedral grains confirm its composition. No beam damage was noted to occur during analysis. The late-stage crystals of elpasolite range from 5 to 20 microns across.

Pachnolite $NaCaAlF_6{\cdot}H_2O$

Pachnolite occurs as fine-grained, soft, snow white masses to 1 cm associated with other late-stage alumino-fluorides.

Prosopite $CaAl_2(F,OH)_8$

Prosopite, another late-stage alumino-fluoride, occurs chiefly associated with fluorite in fine-grained, moderately hard, pale purple to white masses as much as 10 cm across. These masses break with a subconchoidal fracture.

Ralstonite $Na_xMg_xAl_{2-x}(F,OH)_6 \cdot H_2O$

Small amounts of ralstonite were found associated with other secondary alumino-fluorides replacing and veining primary alumino-fluorides. Identity of the mineral was established by Jerry Van Velthuizen and George Robinson (X-ray diffraction and SEM-EDS analysis).

Simmonsite Na_2LiAlF_6 (new mineral species)

Under the electron beam (10 Kv and 40 micron spot), simmonsite shows some evidence of beam damage after 1–2 minutes. A LA-ICP-MS analysis of a bulk sample of the vitreous pale tan to white primary alumino-fluoride mixture showed major Na and Al, 0.21% K (chiefly as elpasolite inclusions), 2.6% Li, 100 ppm Rb, 13 ppm Sc, and all other elements were less than 10 ppm. Electron microprobe and X-ray diffraction analyses of the mixture revealed four minerals to be present: about equal amounts of cryolite, cryolithionite, simmonsite, and trace amounts (about 1%) of elpasolite.

Simmonsite is the monoclinic polymorphous form of Na_2LiAlF_6 that is stable at room temperature. A cubic form is stable at greater than about 400°C but was not found at Zapot. The new species and minerals associated with it will be treated in a separate paper. The name and species status for simmonsite have been approved by the IMA Commission on New Minerals and Mineral Names.

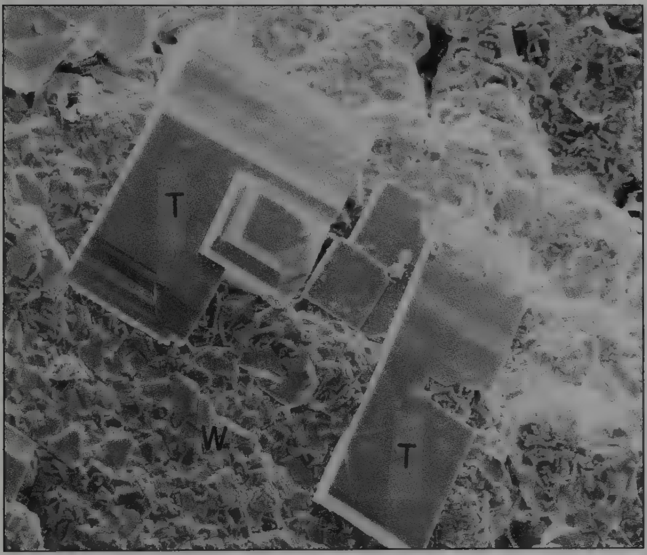

Figure 24. **Thomsenolite (T) crystals on weberite (W). SEM photo; crystals are 200 µm.**

Thomsenolite $NaCaAlF_6 \cdot H_2O$

Thomsenolite was identified by X-ray diffraction and SEM-EDS analysis as part of an intimate admixture of the late-stage alumino-fluoride assemblage. Crystal size is typically 5 to 20 microns.

Weberite Na_2MgAlF_7

Weberite is a sparse mineral occurring with other secondary alumino-fluorides. Microscopic, euhedral crystals are present in vug-fillings in massive cryolithionite-cryolite-Na_2LiAlF_6.

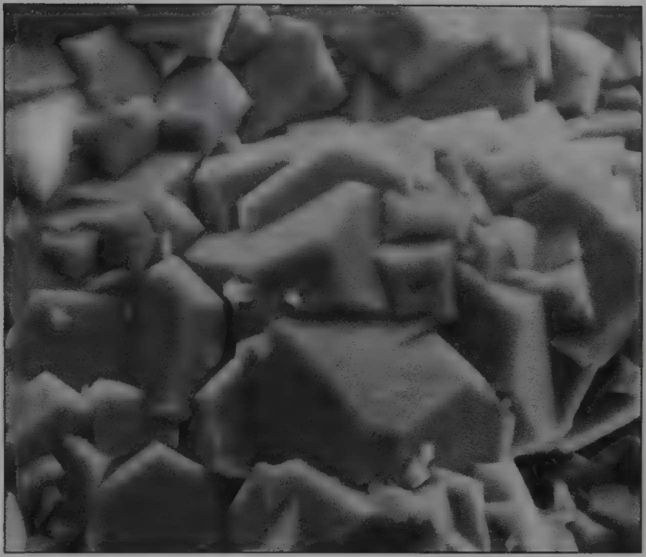

Figure 25. **Weberite crystals. SEM photo; crystals are 10 to 30 µm.**

CONCLUSIONS and GENESIS

The Zapot pegmatite is one of the youngest known amazonite-bearing pegmatites in the world. The pegmatite represents the final stages of crystallization from a batholithic igneous host. As mentioned above, the pegmatite displays geochemical and mineralogical features that are characteristic of both Li-Ce-Ta and Nb-Y-F-type pegmatites (Černý, 1991). The Zapot pegmatite is enriched in Li-F-Nb.

Lead is also enriched in the Zapot pegmatite and is contained predominantly in amazonite and plumbopyrochlore-betafite. Lead and OH substitute for K in microcline and together produce the characteristic blue-green color of amazonite. Because the lead content is sufficiently high, it can be deduced that crystallization of amazonite ensued shortly after initial crystallization of the pegmatite.

Another element showing some enrichment is manganese. This is manifested in the crystallization of Mn-rich zinnwaldite-ferroan lepidolite, manganocolumbite (rather than ferrocolumbite), and very late Mn-bearing beidellite and black Mn-oxides.

Enrichment in Li and F, along with Rb and Cs, is shown by the progression of zinnwaldite to ferroan lepidolite to low-iron lepidolite. The low-iron lepidolite (about 4 weight % Fe_2O_3) contains major Li, F and appreciable Rb and Cs. Li and F were further concentrated in the early cryolithionite, simmonsite, cryolite and later alumino-fluorides making up much of the sinuous pipe-like body composed of alumino-fluoride minerals and fluorite.

Pb, Bi, Sn, U and Sb have their principal residence in the masses of metamict pyrochlore group minerals and associated oxide phases in the amazonite-topaz zone. Pb is also incorporated in amazonite.

Boron and beryllium, on the other hand, are depleted in the Zapot pegmatite. Beryl has not been found in the pegmatite; B and Be were present only at the final core-stage of crystallization and were incorporated into a few, large crystals of hambergite. A small amount of B also was incorporated into schorl which crystallized in miarolitic cavities in several zones of the pegmatite. Likewise, an even smaller amount of Be was incorporated into phenakite. An alkalic affinity is shown by the high alkali (K + Na) content of the host rocks relative to Ca, Mg, and Ti.

The Zapot pegmatite was the result of crystallization of a residual volatile-rich, and rare-element-rich magma derived from the host granitic rocks. Each of the zones distinguished in the pegmatite reflect the continuing evolution and fractionation of the hyperfusible and volatile-rich (H_2O, F) pegmatite magma.

The alumino-fluoride pipe postdates at least six of the nine zones of the pegmatite, and field evidence is lacking as to whether the pipe is younger or older than the hydrothermal beidellite-montmorillonite and kaolinite. It would stand to reason that the clays are younger. Ca and Mg in the clays (and alumino-fluorides) most likely represent contamination from and interaction with the host rocks. Circulating hydrothermal water provided a medium of transport and subsequent deposition of the alkaline earths. The primary alumino-fluorides are Li-Na-K bearing and the secondary (fractures, vugs, replacements) alumino-fluorides are Na-K-Ca-Mg-bearing with some recrystallization of cryolithionite and cryolite (Na-Li). Purple and colorless fluorite postdates both the alumino-fluoride minerals and the hydrothermal clays.

In terms of the major minerals and the alumino-fluoride mineral assemblage present (Table 2), the Zapot pegmatite most closely resembles the Morefield pegmatite, Amelia district, Virginia (Kearns, 1993, 1995).

ACKNOWLEDGMENTS

Many people have been instrumental in the discovery, exploration and study of the Zapot pegmatite. Jerry Gray is acknowledged for his perseverance in the rediscovery of the pegmatite. Bob Driscoll has had a continual presence and his untiring exploration efforts and uncanny nose for "pockets" have been an inspiration to keep digging when little was being found. Rex and Gary Harris provided the first machine excavation of the area, tutored H. Gordon and B. Driscoll in the philosophy and use of such machinery and provided advice on the solution to many problems. Paul Gordon provided yeoman service in the excavation of the Zapot pegmatite, the West Area and in building access roads.

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REFERENCES

ARCIDIACONO, E. C., and BEDLIVY, D. (1976) Datos preliminares sobre el hallazgo de un nuevo mineral de uranio, en Tanti. *Associación Geológica Argentina, Revista,* **31**(3), 232–234.

ČERNÝ, P. (1991) Rare-element granitic pegmatites, part 1: Anatomy and internal evolution of pegmatite deposits. *Geoscience Canada,* **18**, 49–67.

CROSS, W., and HILLEBRAND, W. F. (1883) On minerals of the cryolite group recently found in Colorado. *American Journal of Science,* **26**, 271–294.

CROSS, W., and HILLEBRAND, W. F. (1885) II. Minerals from the neighborhood of Pike's Peak, *in* Cross, W., and Hillebrand, W. F., *U.S. Geological Survey Bulletin* **20**, p. 258–292.

DE LAROCHE, H., LETERRIER, J., GRANDCLAUDE, P., and MARCHAL, M. (1980) A classification of volcanic and plutonic rocks using R_1-R_2 diagram and major-element analyses—its relationship with current nomenclature. *Chemical Geology,* **29**, 183–210.

EKREN, E. B., and BYERS, F. M., Jr. (1985) Geologic map of the Win Wan Flat, Kinkaid NW, Kinkaid, and Indian Head Peak Quadrangles, Mineral County, Nevada. *U.S. Geological Survey Miscellaneous Investigations Series,* Map I-1578.

FOORD, E. E., STARKEY, H. C., and TAGGART, J. E., Jr. (1986) Mineralogy and paragenesis of "pocket" clays and associated minerals in complex granitic pegmatites, San Diego County, California. *American Mineralogist,* **71**, 428–439.

KEARNS, L. E. (1993) Minerals of the Morefield pegmatite, Amelia County, Virginia. *Rocks and Minerals,* **68,** 232–242.

KEARNS, L. E. (1995) Alumino-fluorides from the Morefield pegmatite, Amelia County, Virginia. *Mineralogical Record,* **26**, 551–556.

NOVAK, MILAN, BURNS, P. C., and MORGAN VI, G. B. (in press) Fluorine variation in hambergite from granitic pegmatites. *Canadian Mineralogist.*

RAADE, G., and HAUG, J. (1980) Rare fluorides from a soda granite in the Oslo Region, Norway. *Mineralogical Record,* **11**, 83–91.

ZAGORSKY, V. Ye., and PERETYAZHKO, I. S. (1992) *Pegmatites with Gemstones of Central Transbaikal.* Novosibirsk, "Nauka," 222 p.

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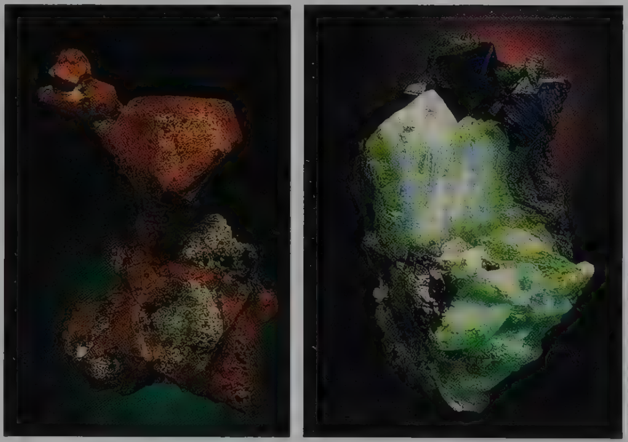

Left: Copper
Michigan 5.1 cm
Right: Anglesite
Tsumeb 6.2 cm

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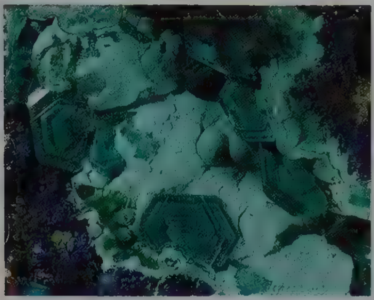
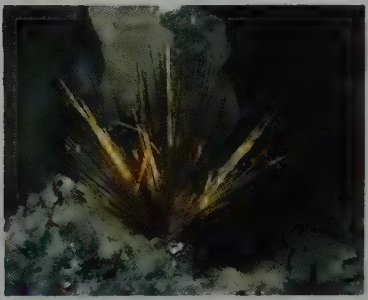


Chalcophyllite - Rancagua, Chile



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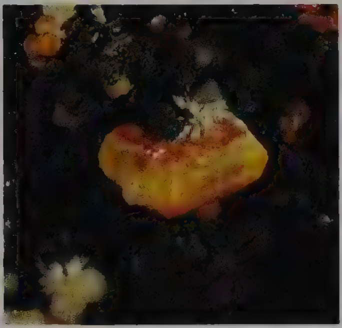

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PART I. WDS AND EDS

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In order to identify obscure and unusual species today it is usually necessary to go well beyond the "classical mineralogy" techniques many of us learned in past decades. Wavelength Dispersive Spectroscopy and Energy Dispersive Spectroscopy are among the most useful modern techniques.

INTRODUCTION

While one's powers of observation are still fundamentally critical, simple physical properties are usually insufficient to accurately assign a species name to many specimens. Perhaps the greatest limiting factor (at least in my own case) is my own increasing curiosity regarding smaller and smaller areas of a given sample. Yes, some rapid identifications can be made with large, well-crystallized, homogeneous minerals. But it's those tiny little "whatsthat" crystals we see in vugs under the microscope, or those nondescript crusty masses of oddly colored "grunge" on matrix that really challenge our use of otherwise fairly reliable classical indicators such as specific gravity, optical properties, blowpipe and bead test reactions or other microchemical observations. When these techniques simply won't produce a satisfactory result because of species complexity or specimen paucity, what *will* work?

Contrary to popular belief, there really aren't any foolproof, single technological innovations that can produce an accurate identification *every* time for *every* mineral. Frequently, two or more confirming techniques are needed to ascertain a mineral's identity with some confidence.

CHEMISTRY vs. STRUCTURE

It is convenient to broadly categorize identification techniques into those that focus upon either a mineral's chemistry or its structure. Early naturalists relied upon simple observations of color, habit, streak and other physical properties to classify and often name a mineral. These observed physical properties were the result of a mineral's chemistry or structure, but it was not until much later that classical mineralogists made this connection and expanded upon these simple observations to include a mineral's reaction to chemical reagents, the specimen's apparent chemical make-up (as evidenced by blowpipe and similar analyses) and the mineral's optical properties. Many of these processes were time-consuming, error-prone or subjective in nature, but trained mineralogists and chemists produced remarkably accurate results with these techniques. While most of these methods are still useful and can produce valid results for many mineral species, modern mineralogists utilize more sophisticated techniques to solve a mineral's identity.

STRUCTURE by X-RAY DIFFRACTION

We've often heard, "*it's been X-rayed, so it has to be* ———" as substantiation of a mineral's identity. While this has traditionally come to imply some form of X-ray diffraction analysis, there are many different techniques that utilize X-rays (either as input or output) as an identification tool. Some of these deal with structure, others with chemistry; an unqualified statement of "*X-ray identified*" fails to clarify the specific technique and therefore its applicability and reliability in establishing a particular mineral's identity. Although it is an extremely powerful technique, X-ray diffraction cannot differentiate many minerals from many others

Figure 1. **Typical Scanning Electron Microscope equipped with Energy Dispersive Spectroscopy system.**

(for example, gold from silver), and a chemical analysis or other supporting method is often needed to assure proper identification. The topic of X-ray diffraction is a complex one and may be discussed in greater detail in a future article.

CHEMISTRY by X-RAY MICROANALYSIS

Many classical techniques employed for the chemical analysis of minerals have fallen into disuse with the advent of sophisticated spectroscopic methods and equipment. Two methods of chemical microanalysis that utilize electron beams have become popular mainstays of modern scientists: *Wavelength Dispersive Spectroscopy* (WDS) and *Energy Dispersive Spectroscopy* (EDS). In both EDS and WDS, the electron beams can be generated in an electron probe microanalyzer (EMPA, or "microprobe") or a scanning electron microscope (SEM). A typical arrangement is shown in Figure 1. Regardless of the instrument employed, of particular interest are the X-ray photons that are emitted by the bombarded specimen, since these emissions are indicative of the atomic make-up of the specimen and can be measured and quantified utilizing sophisticated detectors and computer systems. Both methods are usually non-destructive and similarly employ a high-voltage electron beam focused on a small area of a specimen. These focused electrons create a number of different specimen/beam interactions that provide information to the investigator and provide the basis for microanalysis.

SPECIMEN/BEAM INTERACTIONS

The equipment operator has control of the electron beam prior to its impact on the specimen surface. The beam diameter, its electrical current and its convergence can all be carefully regulated with high accuracy. However, once the electron beam impacts on the specimen, several complex but useful specimen/beam interactions occur that provide a great deal of information about the specimen being studied. It is important to note that these interactions are not only occurring at the surface of the specimen, but also in a pear-shaped region called the *interaction volume* that projects into the specimen (see Fig. 2).

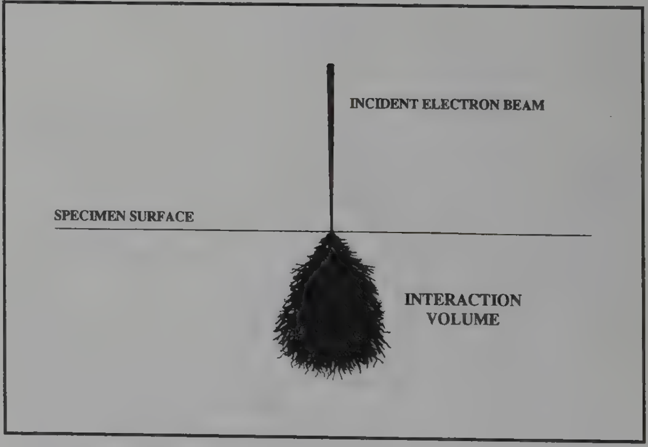


Figure 2. **Sketch showing interaction volume in a specimen being bombarded by electrons. The area subject to electron beam interactions is typically pear-shaped and below the surface of the specimen.**

Upon entry, the incident electron beam undergoes numerous scattering effects which are broadly categorized as *elastic* or *inelastic* scattering. Elastic scattering affects the trajectories of the entering beam electrons, but there is no appreciable energy loss in the incident electrons. Those electrons which enter a specimen, are diverted within it, and ultimately emerge again from the specimen

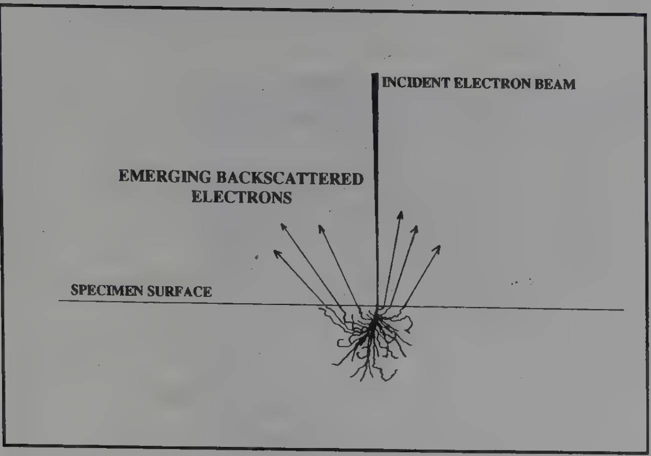


Figure 3. **Sketch showing path of backscattered electrons. Those electrons which enter the specimen, are subsequently diverted, and then emerge again are called backscattered electrons.**

are called *backscattered electrons* (see Fig. 3). These backscattered electrons are very useful for imaging in an SEM, since they are influenced by surface topography. Further, the atomic number and crystallography of the target area also greatly affect backscattering, and backscattered images can often be useful maps defining mineral species boundaries in a flat, polished section, as shown in Figure 4.

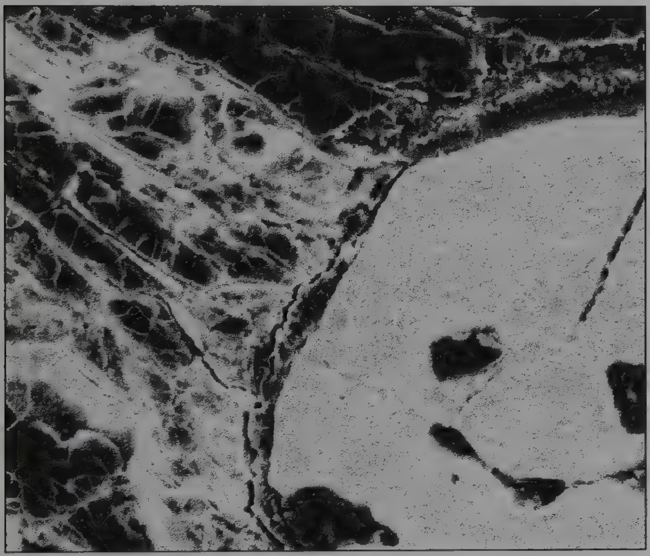


Figure 4. **Backscattered electron image showing mineral phase boundaries in a polished section.**

Conversely, inelastic scattering phenomena involve the transfer of energy from beam electrons to the specimen. As a result, inelastic scattering generates numerous energy transfers in the form of secondary electrons, Auger electrons, continuum and characteristic X-rays, several forms of electromagnetic radiation and lattice vibrations (heat) as well. Of greatest interest to the investigator are the *secondary electrons* and *characteristic X-rays* produced in the specimen.

Secondary electrons are *electrons from the specimen* (as opposed to electrons from the incident beam) that are ejected from the sample area. They are usually weakly bound or *outer-shell valence electrons*, and they are generally not atomic number-dependant like backscattered electrons. However, they are also particularly useful in SEM imaging since they are generated at very shallow depths within the specimen, yielding excellent topographical information.

Two types of X-rays are also produced within a specimen when it is bombarded by an electron beam and subjected to inelastic scattering. First, *characteristic X-rays* are generated when *inner shell electrons* are ejected by the incoming beam electrons, and outer shell electrons consequently drop to fill the inner shell vacancies. The X-ray photons emitted during this de-excitation transition are characteristic of the element being excited because their wavelengths and energies are specific and sharply defined. In X-ray microanalysis techniques, EDS measures the photon energies, WDS measures their wavelengths.

Secondly, when the beam electrons undergo velocity deceleration in the Coulombic field of an atom, the energy loss is emitted as a photon of electromagnetic energy, called the *Bremsstrahlung* or "braking radiation." The random nature of the deceleration can result in any amount of energy loss, thereby forming a continuous electromagnetic spectrum. It is this X-ray continuum that forms the background spectra underlying the peaks of interest in X-ray microanalysis spectra (see Fig. 5).

ENERGY DISPERSIVE SPECTROSCOPY

In Energy Dispersive Spectroscopy (EDS), an electron beam (measured in keV, or thousands of electron volts) bombards a minute area of a specimen. Specialized liquid nitrogen-cooled detectors capture the emitted photons, convert charge pulses to voltage pulses in a preamplifier, then measure and amplify the resulting signal, all while the associated analog-to-digital converter and computer system collect and sort these amplified signals by the specific energy range of each absorbed photon. As noted under Specimen/Beam Interactions, photons emitted by specific elements have specific energies, and over a short period of time, an EDS spectrum can be produced that identifies the elements detected in the sample.

Determination of the specific elements present in a sample is termed qualitative analysis, while a precise determination of the amount of each present is termed quantitative analysis. When this technology was first introduced fewer than 30 years ago, early detectors were barely able to differentiate adjacent elements in the periodic table. Since that time, dramatic improvements in detector technology and associated computer systems have made remarkable strides in light-element detection (down to beryllium), spectral peak resolution and complex matrix corrections for quantitative analysis.

WAVELENGTH-DISPERSIVE SPECTROSCOPY

In wavelength dispersive spectroscopy, the mechanics of beam generation and specimen/beam interaction are the same as in the EDS scenario described above. However, instead of measuring the *energy* of emitted photons, the WDS system measures the *wavelength* of this form of electromagnetic radiation.

This is accomplished through an elaborate and relatively time-consuming process in which a series of individual analyzing crystals are used to diffract the characteristic X-rays which are emitted from the specimen. These diffracted X-rays are subsequently captured in a gas-filled proportional counter, the detector signal is amplified, converted to a standard pulse size, and then counted. The nature of the analyzing crystals only enables one element at a time to be studied. To overcome this problem, multiple spectrometers, each containing several different crystals, are neces-

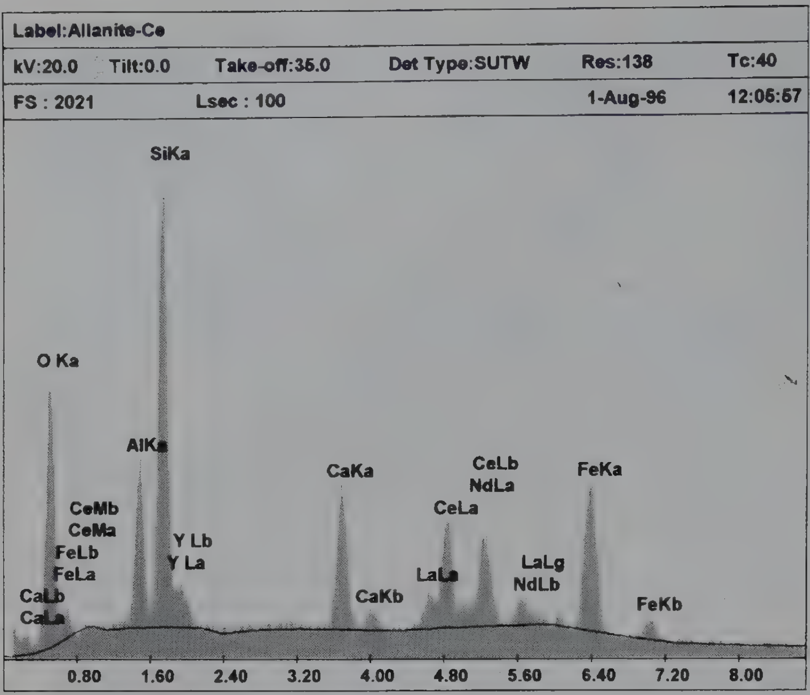


Figure 5. **A sample X-ray spectrum showing background and characteristic peaks.**

sary to not only speed the analysis, but also to optimize performance along a wider range of wavelengths.

QUANTITATIVE ANALYSIS

The discussion thus far has primarily dealt with fairly rapid *qualitative* analysis. However, both EDS and WDS can be used for *quantitative* analysis as well, and the procedures are fundamentally similar for both technologies. The essential procedural difference between qualitative vs. quantitative analysis is the use of appropriate standards to which the unknown sample can be compared. A general outline for a quantitative analysis is as follows:

(1) **Perform** an accurate qualitative analysis in order to identify the elements present in the sample being studied. If this initial analysis is not correctly performed, gross errors in the eventual outcome are assured!

(2) **Select** standards that are chemically and structurally as close as possible to the qualitatively studied sample. These standards must not only be known compounds, but they must also be highly homogeneous down to the microscopic level.

(3) **Obtain** X-ray spectra of both the sample and the standard under identical, reproducible conditions. This means that spectrometer efficiency, take-off angle, resolution and calibration are identical, as well as the beam energy and electron dose (beam current multiplied by the spectral accumulation time).

(4) **Remove** the background resulting from the X-ray continuum, for both sample and standard, so that the spectra consist only of the characteristic X-ray signals. Background removal can be performed by linear interpolation, mathematically complex background modeling, or background filtering procedures such as Fourier analysis. (A detailed discussion of these procedures is beyond the scope of this article.)

(5) **Compare** the X-ray intensities between sample and standard by developing X-ray intensity ratios for each element present in the sample.

(6) **Calculate** matrix corrections to arrive at the quantitative concentration values. Matrix corrections account for the effects of atomic number in X-ray generation, absorption effects and X-ray fluorescence. These calculations are critical in arriving at an accurate quantitative analysis; they are quite complex and are usually accomplished by computer programs within larger analytical modules.

SUMMARY: EDS VS. WDS

Wavelengths Dispersive Spectroscopy has a longer history of use among mineralogists than the newer Energy Dispersive Spectroscopy technology. As noted earlier, however, dramatic improvements in detector technology and associated computer systems now make these two techniques complementary, and for routine qualitative analysis, EDS is considerably faster, with detection limits around 0.1% by weight for most elements. While WDS detection limits can approach the hundreds of parts per million range, the value of this level of trace element detection capability must be weighed against the time required to achieve it.

EDS has superior geometrical collection efficiency, speed of acquisition, spectral acceptance range and a quantum efficiency that is three times better than WDS. However, the resolution capability, i.e., the ability to easily isolate and identify elemental peaks with a minimum of overlaps is far superior in WDS detector systems. In addition, spectral artifacts are common in EDS, and these can further complicate interpretation of the resulting spectra. Elaborate software programs are now offered by leading detector manufacturers such as EDAX International to assist the analyst in overcoming these complexities. To effectively compliment the strengths and weaknesses of these two technologies, several vendors are now offering instruments with dual EDS/WDS capability as well.

REFERENCES

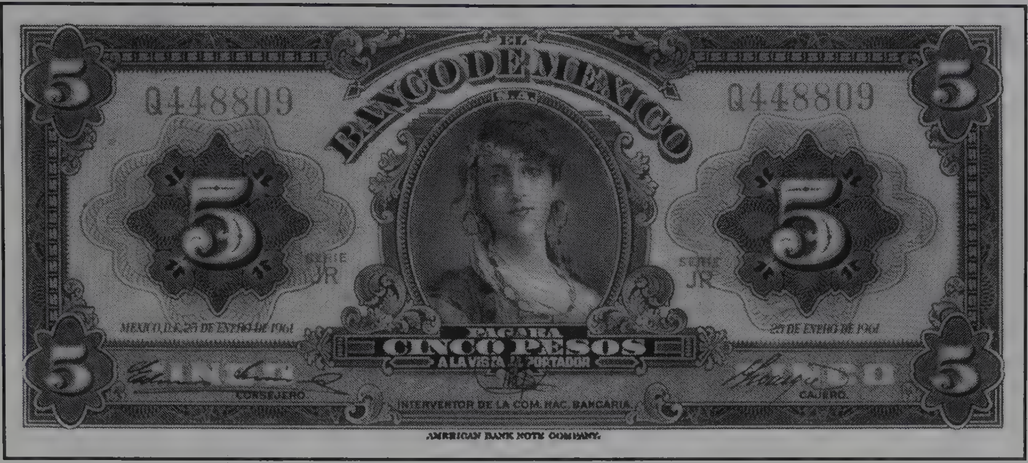
GOLDSTEIN, J. I., NEWBURY, D. E., et al. (1992) *Scanning Electron Microscopy and X-Ray Microanalysis*. Second Edition, Plenum Press, New York.

HAWTHORNE, F. C., editor. (1988) *Spectroscopic Methods in Mineralogy and Geology: Reviews in Mineralogy*. Volume 18. Mineralogical Society of America, Washington, D.C.

HURLBUT, C. S. (1971) *Dana's Manual of Mineralogy*. 18th Edition. John Wiley & Sons, New York.

PUTNIS, A. (1992) *Introduction to Mineral Sciences*. Cambridge University Press, Cambridge.

WINCHELL, A. N., and WINCHELL, H. (1951) *Elements of Optical Mineralogy*. Fourth Edition. John Wiley & Sons, New York.



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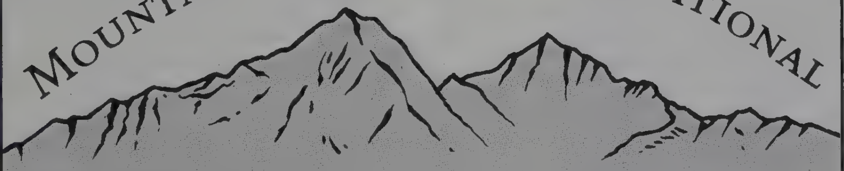

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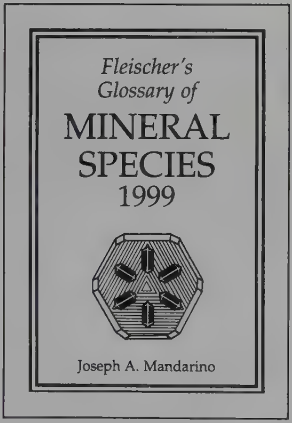

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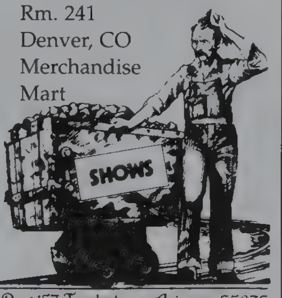

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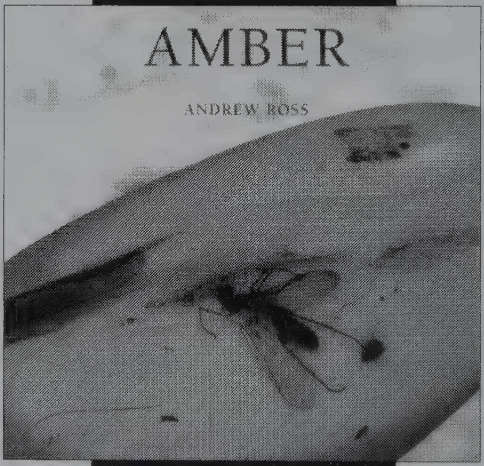

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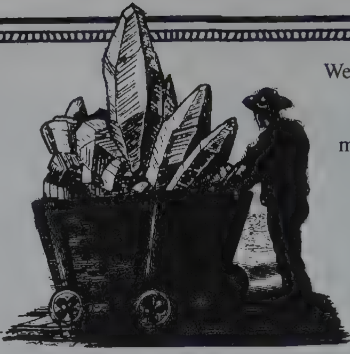

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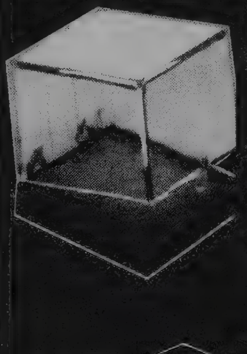

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Show promoter and mineral collector par excellence, *Martin Zinn is one of those people everybody seems to know. Personable and efficient, he has changed the face of the mineral world through the events he has pioneered and the project he has supported at the Sweet Home mine. At the forthcoming 1999 Springfield Show he plans to go a step further and exhibit hundreds of specimens from his personal collection to the public, filling more than 50 exhibit cases!*

If you have attended a major mineral show in the United States during the last decade, you have probably benefitted from the work of Martin Zinn: odds are that he was the promoter behind that show, or a "satellite" show associated with it. If you have been especially fortunate, you may at some time have received an invitation to his home outside Denver, and seen his extraordinary mineral collection. Whether collecting minerals himself or facilitating the collecting activities of the rest of us, Marty Zinn is an energetic and positive force in the mineral world.

Martin Zinn III (he has no middle name) was born June 2, 1941, in Lake Charles, Louisiana, the eldest son of Martin Zinn Jr. and Ray Elizabeth Halff. The name *Zinn,* of course, is German for "tin," suggesting that his ancestors in the middle ages were tin miners in west-central Europe. His parents divorced in 1948, his mother remarrying a year later to George W. Llewellyn. George brought five children to the marriage, including James Llewellyn, whose interest in minerals soon absorbed the entire family. Each of the children developed a specialty, but in the end only Marty and his mother pursued their interest in minerals throughout the succeeding years. His mother, known to the mineral world as Betty Llewellyn, was awarded the James Smithson bronze and silver medals by a grateful Smithsonian Institution in recognition of her philanthropy, not just to that institution but to others as well. She continued to enjoy gem and mineral collecting until passing away in 1995, at the age of 83 (Wilson, 1995; Llewellyn, 1984).

Marty's first interest was more lapidary than mineralogical, but


Kent England

Figure 1. **Marty Zinn, at the 1985 Tucson Show.**

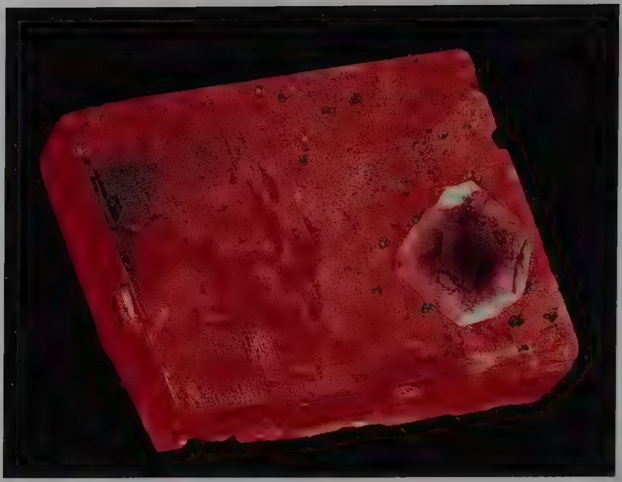

Figure 2. Rhodochrosite, 3 cm, with fluorite, from the Sweet Home mine, Alma, Colorado. Zinn collection; photo by Harold and Erica Van Pelt.

Figure 3. Fluorite, 11 cm, from the American Tunnel mine, Silverton, Colorado. Zinn collection; photo by Harold and Erica Van Pelt.

Figure 4. Beryl crystal, 2.8 cm, from the Wah Wah Mountains, Utah. Zinn collection; Jeff Scovil photo.

Figure 5. Smithsonite, 7.7 cm, from the Kelly mine, Magdalena, New Mexico. Zinn collection; Jeff Scovil photo.

he soon saw the error of his ways and became a hard-core collector of crystal specimens. Betty and George had bought many fine specimens in the 1950's from the prominent suppliers of the day (e.g., Scott Williams in Arizona, Oscar Giesler's son in Las Vegas, and Professor Woodhouse in Santa Barbara). They divorced in 1965, and Betty and Marty "curated" the collection thereafter.

Marty earned his Bachelor of Science degree in Business Management from the University of Colorado in 1964, then joined the Army Corps of Engineers and served a tour of duty in Vietnam ending in 1966. After the service he worked for his father's wholesale clothing business for several years, then worked his way up at Emery Air Freight, from Salesman (1969) to International Sales Coordinator (1981). During the late 1970's he dabbled on the side as a mineral dealer, selling off excess specimens from the family collection at the Tucson Show, the Dallas Intergem shows, and other venues (collectors may recall the metal oil well sculptures he had which sold better than the minerals). In 1982 he gave up dealing in order to start Martin Zinn Expositions, and has earned his living promoting mineral and fossil trade shows ever since. He is also one of the founders of the Mineralogical Association of Dallas, and a past-president of the Dallas Gem and Mineral Society.

Figure 6. **Marty Zinn, 1964.**

Marty's serious field collecting adventures began when he and his wife bought a promising property near Florissant, Colorado, and worked it quite successfully for amazonite and quartz. He has collected brookite at Magnet Cove, Arkansas; wavellite at Mauldin Mountain; quartz at Coleman's mine in Jesseville, Arkansas; blue barite at Stoneham, Colorado; pyrite at the Dallas–Fort Worth Airport; clear barite at Grand Junction; quartz at Herkimer, New York; red beryl at the Wah Wah Mountains in Utah; topaz and pseudobrookite at Topaz Mountain; and tourmaline at the Himalaya mine in California.

Marty and his wife Judy (they married in 1969) revitalized the family collecting hobby, initially focusing on wulfenite and thumbnails. Over the years their specializations broadened to include the building of suites centering on tourmaline, calcite, Mexico, Utah, Russia, Pakistan, India, and Colorado specimens. A particular specialty was fine miniatures. His most recent passion has been stalactitic (a more precise term might be "stalactiform") minerals. He and Rock Currier mounted a fascinating and, as far as I know, unique exhibit of stalactites and stalagmites of various species at the 1998 Denver Show. His connoisseurship having evolved somewhat beyond specific specialties, he is today concentrating primarily on the acquisition of superb small-cabinet specimens from localities worldwide. His collection currently numbers over 2,000 thumbnails and 2,000 miniatures and small-cabinet specimens. The "mineral room" in his home is a treasure-house of beautiful specimens arrayed in well-lit glass cases and drawers of cotton-lined boxes. And he has no aversion to owning several specimens of the same thing if all of them please him. The drawers are arranged systematically, although the emphasis is definitely more in favor of aesthetics than species rarity. The walls are covered with framed published photos of his specimens, and with mineral art (much of it mine, God bless him). Going through this superb collection is a wonderful experience indeed.

During their 29 years of marriage Judy and Marty had three great children and lots of good times. Having achieved many honors as an Eagle Scout in his youth, he became heavily involved for many years as a Scoutmaster in the Boy Scouts of America, as his two sons were growing up. Judy and Marty divorced amicably in 1998, the mineral collection remained with him (along with the collection of his mother which he inherited in 1995). A portion of it has been set aside in trust for their children.

For many years Marty has also been involved part-time in managing the Texas-based family business known as the "Halff Interests." These consist primarily of petroleum and natural gas properties, leases and joint ventures owned collectively by some 26 Halff descendants. Grandpa Halff had owned a grocery store in Midland, Texas, during the Depression, and when folks couldn't pay their grocery bill he accepted mineral rights in exchange. Thus grew the family fortune, or so the story goes, anyway.

Marty's career in show promotion began shortly after his move from Dallas to Evergreen, Colorado. In 1983, show promoter and mineral wholesaler Tom Palmer ("Independent Dealers Mineral Shows") and mineral dealer Harvey Gordon asked Marty to help out in the creation of a satellite show in conjunction with the Denver Show. They started out with a dozen dealers at the Holiday Inn North; in just a few years Marty was able to buy out Palmer's interest and has since made the operation (the *Colorado Mineral and Fossil Show*) into one of the largest satellite shows in the business. The *Colorado Fossil Expo* (a second satellite) was added in 1998.

Next he established the *East Coast Gem, Mineral and Fossil Show* in Springfield, Massachusetts, in 1988 (at first in partnership with Ron Bentley, until his death in 1991). This was not a "satellite" show but rather a major convention-center exhibition. Keith Williams and the Rocksmiths were the first dealers to sign up. It is currently held in the Eastern States Exposition Grounds (since the Springfield Convention Center revealed an inconvenient tendency to flood during heavy rainstorms!). Approximately 200 dealers show their merchandise to nearly 10,000 visitors each year.

Marty moved on, in 1990, to tackle the awesome phenomenon known worldwide as the *Tucson Show.* A change in the ownership

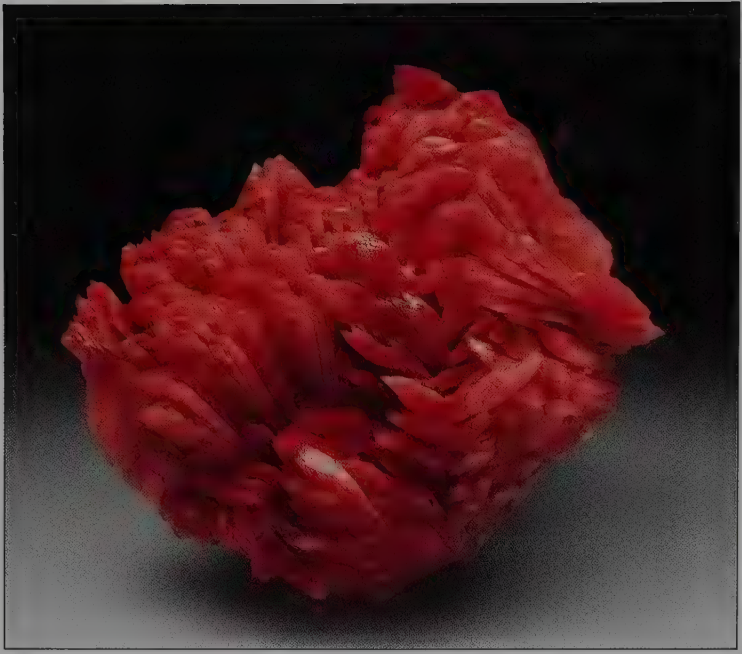

Figure 7. Rhodonite, 6.7 cm, from the Chiurucu prospect, Huanuco, Peru. Zinn collection; Jeff Scovil photo.

Figure 8. Brazilianite, 6.3 cm, from Corrego Frio mine, near Linopolis, Minas Gerais, Brazil. Zinn collection; Jeff Scovil photo.

Figure 9. Beryl (emerald) crystal, 2 cm, from the Chivor mine, Muzo, Colombia. Zinn collection; Jeff Scovil photo.

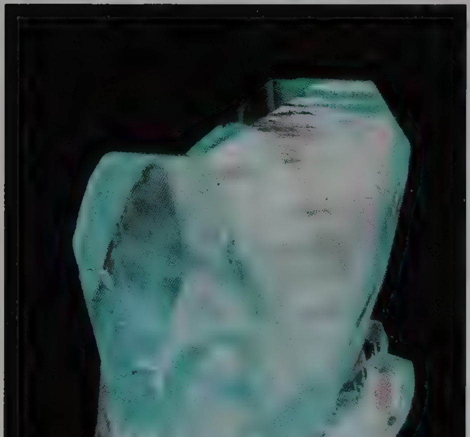

Figure 10. Phosphophyllite, 3 cm, from the Kraus vein, Unificada mine, Cerro Rico de Potosí, Bolivia. Zinn collection; Jeff Scovil photo.

Figure 11. Proustite, 3.6 cm, from Freiberg, Saxony. Zinn collection; photo by Harold and Erica Van Pelt.

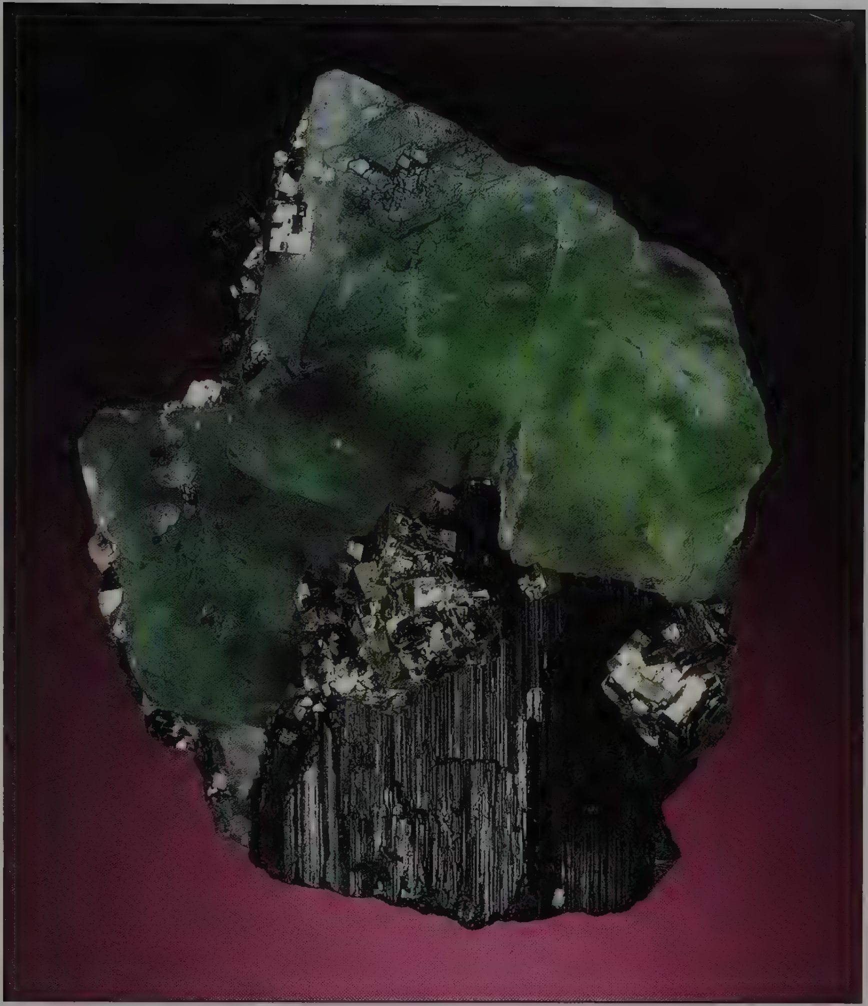

Figure 12. Fluorite on ferberite, 6.8 cm, from Kara Oba, Kazakhstan. Zinn collection; Jeff Scovil photo.

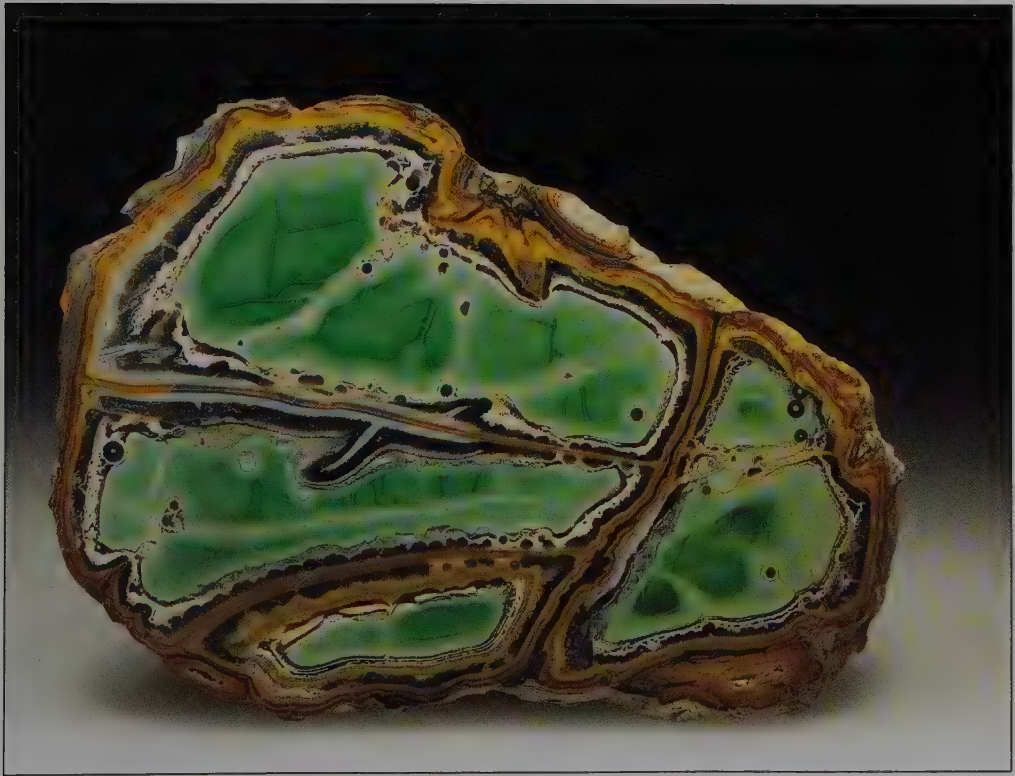

Figure 13. Variscite nodule slab, 15.3 cm, from Fairfield, Utah. Zinn collection; Jeff Scovil photo.

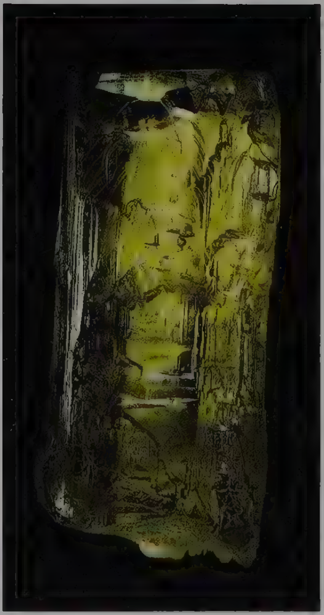

Figure 14. Beryl, 10 cm, from Volodarsk Volynsk, Ukraine. Zinn collection; Jeff Scovil photo.

of the Desert Inn, long the site of the most revered satellite mineral show of all time (see Wilson, 1996), had been accompanied by some serious management and maintenance problems which had the dealers there worried. The writing was on the wall that the venerable Desert Inn's days were numbered, and that *someone* was needed to reorganize the mineral dealers at a different location. Into the breach stepped Marty, who signed a long-term agreement with the Best Western Executive Inn a short distance away and began taking on refugee dealers from the sinking ship that was the Desert Inn. The show was so successful that in 1994 it expanded into the Quality Inn (now the Ramada Inn–University) just around the corner, and in 1998 also the InnSuites Hotel (formerly the Ramada Inn–Downtown). In 1999 more than 400 dealers took part in Marty's three hotels, known collectively as the *Arizona Mineral and Fossil Show.*

In 1995 Marty established the Costa Mesa show in California, now called the *West Coast Gem & Mineral Show,* held the weekend after Mother's Day.

One of the most remarkable chapters in the life of Marty Zinn has been his involvement with Bryan Lees' project at the Sweet Home mine, as a principal investor. Marty was the one who got Lees and mine owner Leonard Beach together, and Marty was the first investor. From its shaky and speculative beginning in 1990, it blossomed into one of the most extraordinary mineral collecting adventures of all time, as illustrated by the July-August 1998 issue of the *Mineralogical Record*: the 192-page Sweet Home Mine Issue. Without Marty's enthusiastic support throughout, there is reason to wonder if it ever would have been such a success. And so, in yet another way, Marty's work has directly benefitted the collections of thousands of mineral collectors and museums worldwide.

In August of this year the general public will have the unique opportunity to view a major part of Marty's mineral collection, around 400 of his best pieces! At the *East Coast Gem & Mineral Show* he will commandeer over *50 exhibit cases* in order to accommodate the specimens. Nothing on this scale has ever been attempted at any mineral show. In order to give a preview, some of his specimens are pictured here, and readers may wish to look up those specimens of his which have previously been published (see list).

In conclusion, I might ask the reader to imagine placing a little "Thanks Marty" tag or label next to every specimen acquired at one of his shows, and every specimen from the Sweet Home mine. I think the drawers and display cases of many of us would be littered like confetti with those little tags. If that is not impressive enough, imagine the logistical and labeling difficulties that will be involved in filling 50 exhibit cases at the Springfield Show, not to mention the hazards involved in specimen handling, packing and shipping. And all of this is simply to have the pleasure of sharing his collecting with us. Truly, for the many opportunities he has given us in mineral collecting, we all owe Martin Zinn III a tip of the hat and a grateful "Thanks, Marty!"

Table 1. **List of illustrated specimens from the Martin Zinn Collection.**

Beryl	*Rocks & Minerals,* cover, Sept.-Oct. 1993
Emerald	*AJM Magazine,* cover, Feb. 1995
Emerald	*Lapis,* cover, Oct. 1998
Fluorapatite	*Mineralogical Record,* v. 21, p. 407
Fluorite	*Mineralogical Record,* cover, v. 28, n. 4
Fluorite	Denver Show poster 1987; *Rocks & Minerals,* cover, v. 62, n. 4
Fluorite	*Lapidary Journal,* October 1991, pp. 25–27
Fluorite	*Lapis,* cover, Special Issue n. 4
Garnet	*Mineralogical Record,* cover, v. 24, n. 1
Gold	*Rocks & Minerals,* cover, Nov.-Dec. 1994
Phosphophyllite	*Rocks & Minerals,* cover, Sept.-Oct. 1994
Proustite	*Mineralogical Record,* cover, v. 20, n. 3
Quartz (Rose)	*Mineralogical Record,* cover, v. 18, n. 2
Rhodochrosite	*Lapidary Journal,* cover, October 1991
Rhodochrosite	*Mineralogical Record,* v. 22, p. 55
Rhodochrosite	*Rocks & Minerals,* cover, Sept.-Oct. 1996
Rhodochrosite	*Compressed Air,* cover, March 1994
Topaz	*Rocks & Minerals,* cover, Nov.-Dec. 1992
Tourmaline	*Rock & Gem,* cover, October 1979
Wulfenite	*Mineralienweit,* cover, March 1995

REFERENCES

LLEWELLYN, E. H. (1984) *I Can't Forget.* (Autobiography.) Privately published.

WILSON, W. E. (1995) Died, Betty Halff Llewellyn, 83. *In* Notes from the Editor, *Mineralogical Record,* **26**, 434.

WILSON, W. E. (1996) Demolished, The Desert Inn. *In* Notes from the Editor, *Mineralogical Record,* **27**, 403.

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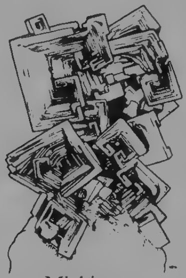

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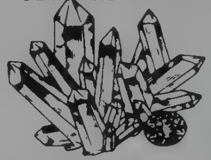

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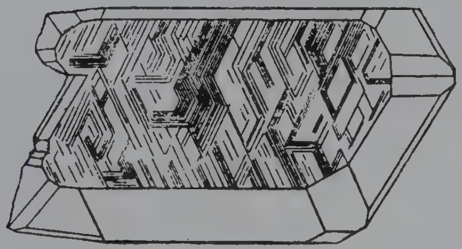

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The information given here is provided by the Commission on New Minerals and Mineral Names, I.M.A. for comparative purposes and as a service to mineralogists working on new species.

Each mineral is described in the following format:

Chemical Formula

Any relationship to other minerals

Crystal system, space group. Unit cell parameters. Color; luster; diaphaneity. Optical properties. Strongest lines in the X-ray powder diffraction pattern. IMA No.

The names of these approved species are considered confidential information until the authors have published their descriptions or released information themselves.

NO OTHER INFORMATION WILL BE RELEASED BY THE COMMISSION.

1998 PROPOSALS

$\mathrm{Cu_3(AsO_4)_2\cdot 4H_2O}$

New structure type

Orthorhombic: *Pnma*. *a* 5.6906, *b* 17.061, *c* 9.732 Å. Bottle green; vitreous; transparent. Biaxial (-), α 1.745, β 1.755, γ 1.760, 2*V*(meas) 71°, 2*V*(calc) 70°. 8.52(100), 3.721(60), 3.221(90), 3.102(40), 2.817(35), 2.795(35), 2.350(25). IMA No. 98-001.

$\mathrm{Ca_3Ge(OH)_6(SO_4)(CO_3)\cdot 12H_2O}$

A member of the ettringite group; structure

Hexagonal: *P*6$_3$*/m*. *a* 11.056, *c* 10.629 Å. White; vitreous; transparent. Uniaxial (-), ω 1.509, ε 1.479. 9.57(vs), 5.53(s), 3.83(s), 3.56(ms), 3.44(m), 2.74(ms), 2.53(m). IMA No. 98-002.

$\mathrm{(Ca,Fe^{3+})_2Cu_5(Bi,Cu)(PO_4)_4(H_2O,OH,Cl)_{13}}$

The Bi-P-dominant analogue of rechelsdorfite

Monoclinic: *C*2*/m*. *a* 14.200, *b* 13.832, *c* 14.971 Å, b 102.08°. Honey-brown; resinous; translucent. Biaxial (-), α 1.718, β 1.748, γ 1.748, 2*V*(calc) 0°. 14.57(100), 6.95(40), 6.28(40), 3.469(30b), 3.104(30), 2.816(40), 2.506(30), 2.452(30). IMA No. 98-003.

$\mathrm{Pb_{32}As_{40}S_{92}}$

A member of the rathite (sartorite) group

Monoclinic: *P*2$_1$. *a* 8.368, *b* 115.75, *c* 7.903 Å, β 90.11°. Lead-gray; metallic; opaque. In reflected light: deep red, anisotropic. R_{min} & R_{max}: 37.9, 41.8% (470 nm), 36.5, 40.8% (546 nm), 35.0, 39.7% (589 nm), 32.7, 37.7% (650 nm). 3.663(70), 3.216(48), 2.978(100), 2.872(48), 2.735(60), 2.713(50), 2.339(65). IMA No. 98-004.

$\mathrm{MnPO_4\cdot H_2O}$

Related to the kieserite group

Monoclinic: *C*2*/c*. *a* 6.914, *b* 7.468, *c* 7.364 Å, β 112.29°. Dark brown to dark greenish black; adamantine; translucent. Biaxial α 1.75, β 1.79, γ > 1.79. 4.856(12), 4.633(15), 3.503(100), 3.271(10), 2.957(10), 2.516(19), 2.104(12). IMA No. 98-006.

$\mathrm{(\square, Na)_1Ca_2(Mn^{2+},Mg,Fe^{2+})_2(Fe^{3+},Mg,Al)_2\text{-}Mn^{2+}_2(PO_4)_6(H_2O)_2}$

Isostructural with wicksite and grischunite; structure

Orthorhombic: *Pcab*. *a* 12.559, *b* 12.834, *c* 11.714 Å. Very dark brown to black; vitreous; transparent. Biaxial (-), α 1.729, β 1.738, γ 1.741, 2*V*(meas) 54°, 2*V*(calc) 60°. 6.419(31), 3.006(67), 2.927(78), 2.856(31), 2.814(35), 2.768(100), 2.110(33). IMA No. 98-007.

$\mathrm{Cu_3O[(Mo,S)O_4SO_4]}$

Unique combination of elements; structure

Orthorhombic: *Pnma*. *a* 7.420, *b* 6.741, *c* 13.548 Å. Olive-green; vitreous; transparent. Average refractive index 1.925 (calculated from reflectance). 3.391(60), 3.342(60), 3.077(100), 2.542 (60), 2.500(60), 2.275(60). IMA No. 98-009.

$\mathrm{Ca_4Al_6Si_6O_{24}(SO_4)}$

A member of the scapolite group; structure

Tetragonal: *I*4*/m*. *a* 12.182, *c* 7.604 Å. Colorless to slightly yellow; subvitreous; transparent. Uniaxial (-), ω 1.585, ε 1.553. 3.83(20), 3.46(100), 3.08(40), 3.05(15), 2.70(15). IMA No. 98-010.

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$Cu_3(OH)_2(As_2O_7)$

Related to olivenite; structure

Orthorhombic: *Pmma*. *a* 8.3212, *b* 2.9377, *c* 4.6644 Å. Dark pistachio green; vitreous to adamantine; translucent. Biaxial (+), α 1.81, β 1.82, γ 1.86, 2*V*(meas) 57°, 2*V*(calc) 54°. 3.104(100), 2.486(70), 2.400(25), 1.672(30), 1.596(25), 1.330(25). IMA No. 98-012.

$Cu_4Al_3(OH)_{14}F_3 \cdot 2H_2O$

New structure type

Monoclinic: *C2/m*. *a* 12.346, *b* 2.907, *c* 10.369 Å, β 97.90°. Bright blue; vitreous; translucent. Biaxial (+), α 1.585, β 1.615, γ 1.648, 2*V*(calc) 89°. 10.29(80), 5.589(90), 4.232(100), 2.828(90), 2.362(100), 2.006(100), 1.871(80). IMA No. 98-013.

$Pb(Zn,Fe,Cu)_2(AsO_4)_2(OH,H_2O)_2$

The Zn-dominant analogue of gartrellite; structure

Triclinic: $P\bar{1}$. *a* 5.550, *b* 5.620, *c* 7.621 Å, α 68.59, β 69.17, γ 69.51°. Green-yellow; vitreous; transparent to translucent. Biaxial (-), α 1.91, β 1.94 (calc), γ 1.97, 2*V*(meas) 87°. 4.731(74), 4.669(86), 3.283(89), 3.252(91), 2.999(100), 2.894(74), 2.880(70). IMA No. 98-014.

$Pb(Co,Ni,Zn,)_2(AsO_4)_2 \cdot 2H_2O$

The Co-dominant analogue of helmutwinklerite; structure

Triclinic: $P\bar{1}$. *a* 11.216, *b* 10.604, *c* 7.618 Å, α 100.10, β 110.26, γ 98.87°. Red to red-brown; vitreous; translucent. Biaxial (+), α 1.85(calc), β 1.87, γ 1.90, 2*V*(meas) 85°. 4.670(97), 3.256(100), 3.170(29), 3.072(56), 2.890(40), 2.760(37), 2.568(46). IMA No. 98-015.

$Mg(H_2O)_6[Sb(OH)_6]_2$

The Mg-dominant analogue of bottinoite; structure

Trigonal: *P*3. *a* 16.114, *c* 9.863 Å. Colorless; vitreous; transparent. Uniaxial (-), ω 1.570, ε 1.569. 4.946(50), 4.636(100), 4.217(20), 3.392(70), 2.595(20), 2.356(40), 2.103(20). IMA No. 98-017.

$(Na,Ca,Bi)_2Ta_2O_6F$

A member of the microlite group; structure

Cubic: *Fd3m*. *a* 10.4451 Å. Green; adamantine; transparent. Isotropic, η > 2.0, 2.03(calc). 6.023(31), 3.148(33), 3.015(100), 2.610(27), 1.846(59), 1.574(47), 1.198(23). IMA No. 98-018.

$Na_{3-x}(Ti,Nb)_2[Si_4O_{12}](OH,O)_2 \cdot 3\text{–}4H_2O$

The Ti-dominant analogue of nenadkevichite; structure

Orthorhombic: *Pbam*. *a* 7.349, *b* 14.164, *c* 7.130 Å. Colorless; vitreous; transparent. Biaxial (+), α 1.646, β 1.654, γ 1.763, 2*V*(meas) 30°, 2*V*(calc) 32°. 7.09(72), 6.53(85), 3.262(100), 3.180(52), 2.553(56), 2.075(57), 1.735(50). IMA No. 98-019.

$(Ni,Fe)_3P$

The Ni-dominant analogue of schreibersite

Tetragonal: $I\bar{4}$. *a* 8.99, *c* 4.396 Å. White with pinkish yellow-tint; metallic; opaque. In reflected light: weak anisotropy in oil, in yellowish-pinkish colors. R_{min} & R_{max}: 42.3, 43.9% (460 nm), 45.7, 47.5% (540 nm), 47.6, 49.1% (580 nm), 50.3, 51.7% (640 nm), 2.17(10), 2.13(5), 2.08(5), 1.955(7). IMA No. 98-023.

$(Fe^{3+},Zn)_{12}(As^{3+},Si)_8O_{30}$

New structure type

Hexagonal: $P6_3mc$. *a* 12.771, *c* 5.051 Å. Brownish black; vitreous; transparent. Uniaxial (+), ω ~ 1.99, ε ~ 2.08. 6.37(80), 3.221(100), 2.531(40), 2.420(70), 1.788(40), 1.672(50), 1.507(50). IMA No. 98-024.

$NaCa_2Al_2(AsO_4)[AsO_3(OH)](OH)_2F_4(H_2O)$

New structure type

Monoclinic: $P2_1/m$. *a* 9.687, *b* 10.7379, *c* 5.5523 Å, β 105.32°. Pale blue-green; vitreous; transparent to translucent. Biaxial (-), α 1.580, β 1.588, γ 1.593, 2*V*(meas) 74°, 2*V*(calc) 76°. 5.364(80), 4.796(80), 3.801(80), 3.527(90), 2.966(100), 2.700(90), 2.246(60). IMA No. 98-025.

$[Zn_{1-x}Al_x(OH)_2][(SO_4)_{x/2}(H_2O)_n]$ $x = 0.33$, $n \approx 0.96$

A member of the hydrotalcite group; polytype 1*T*

Trigonal: $P\bar{3}$. *a* 3.063, *c* 8.91 Å. Pale blue; waxy; translucent. Uniaxial, η(max) 1.558. 8.81(100), 4.406(2.5), 2.654(4), 2.545(5). IMA No. 98-026.

$[Zn_{1-x}Al_x(OH)_2][(SO_4)_{x/2}(H_2O)_n]$

$x = 0.32\text{–}0.50$, $n \approx 0.59$

Polytype 3*R*

Trigonal: $R\bar{3}m$. *a* 3.065, c 25.42 Å. Pale bluish to bluish-white; waxy; translucent. Uniaxial, ω 1.5636. 8.50(100), 4.248(33), 2.600(5), 2.354(4). IMA No. 98-026.

$(Al,Mg,Fe)_{16}(Al,Si,Be)_{12}O_{40}$

A member of the sapphirine group

Monoclinic: $P2_1/c$. *a* 9.9000, *b* 14.369, *c* 11.2537 Å, β 125.53°. Very dark green; vitreous; transparent. Biaxial (-), α 1.725, β 1.740, γ 1.741, 2*V*(meas) 34°, 2*V*(calc) 29°. 2.985(38), 2.834(30), 2.826(45), 2.566(36), 2.445(100), 2.439(44), 2.340(43). IMA No. 98-027.

$Fe^{2+}Ti(Ta,Nb)_2O_8$

A member of the wodginite group

Monoclinic: *C2/c*. *a* 9.402, *b* 11.384, *c* 5.075 Å, β 90.33°. Very dark brown to black; opaque; submetallic. In reflected light: creamy white, very abundant internal reflections, anisotropic, moderate pleochroism. R_{min} & R_{max}: 18.2, 18.7% (470 nm), 18.1, 19.1% (546 nm), 16.9, 17.9% (589 nm), 15.6, 16.4% (650 nm). 3.626(70), 2.963(100), 2.939(90), 2.484(45), 1.759(45), 1.715(50), 1.711(45). IMA No. 98-028.

$Ca(HCOO)_2$

β-calcium formate

Tetragonal: $P4_12_12$. *a* 6.770, *c* 9.463 Å. White, light-blue; vitreous; transparent. Uniaxial (+), ω 1.553, ε 1.573. 5.54(90), 3.40(100), 3.19(60), 2.859(80), 2.196(70), 2.046(50), 1.947(60). IMA No. 98-030.

$(MoO_2)_2As_2O_5 \cdot 3H_2O$

New structure type

Monoclinic: $P2_1/c$. *a* 7.0516, *b* 12.0908, *c* 12.2190 Å, β 101.268°. Green to grey-green; vitreous, translucent. Biaxial (+), α 1.757, β 1.778, γ 2.04, 2*V*(calc) 35°. 6.92(26), 6.05(100), 3.457(16), 3.325(59), 2.624(15), 2.593(12), 2.264(19). IMA No. 98-031.

$Cu_{10}(AsO_4)_4(SO_4)(OH)_6 \cdot 8H_2O$

Structure

Monoclinic: *C2/c*. *a* 21.778, *b* 12.317, *c* 10.716 Å, β 92.81°. Green with a bluish tint; vitreous; transparent. Biaxial (-), α 1.590, β 1.740, γ 1.744, 2*V*(meas) 18°, 2*V*(calc) 17°. 10.8(100), 5.43(50), 4.90(30), 3.625(50), 3.090(40), 2.675(40), 2.630(60). IMA No. 98-032.

$Zn_2AlSb(OH)_{12}$

Related to cualstibite; structure

Trigonal: *P*312. *a* 5.327, *c* 9.792 Å. Colorless; vitreous; transparent. Optical properties could not be measured. 4.897(100), 4.615(35), 4.180(57), 3.366(18), 2.667(31), 2.342(88), 1.887(10). IMA No. 98-033.

$SrAl_2Si_2O_7(OH)_2 \cdot H_2O$

A member of the lawsonite group

Orthorhombic: *Cmcm*. *a* 6.031, *b* 8.945, *c* 13.219 Å. Blue; vitreous; transparent. Biaxial (+), α 1.664, β 1.674, γ 1.688, 2*V*(calc) 81°. 4.68(s), 4.26(vs), 3.31(vs), 2.75(vs), 2.68(vvs), 2.63(s), 2.50(s). IMA No. 98-034.

$Pb_{10}(SO_4)O_7Cl_4 \cdot H_2O$

Related to the nadorite and kombatite groups; structure

Triclinic: $P\bar{1}$. *a* 8.796, *b* 10.768, *c* 13.096 Å, α 68.87, β 86.52, γ 75.79°. Venetian pink; vitreous; translucent. In reflected light: colorless or pale pink, anisotropic. R_{min} & R_{max}: 14.3, 14.6% (470 nm), 13.6, 13.9% (546 nm), 13.4, 13.75% (589 nm), 13.3, 13.55% (650 nm). 6.573(4), 3.768(4), 3.286(9), 2.955(9), 2.911(10), 2.793(8). IMA No. 98-035.

$Pb_4^{2+}(S^{6+}O_3S^{2-})O_2(OH)_2$ or $Pb_4(S_2O_3)O_2(OH)_2$

New structure type

Triclinic: $P\bar{1}$. *a* 7.455, *b* 6.496, *c* 11.207 Å, α 114.33, β 89.65, γ 88.69°. Beige-cream to colorless; vitreous to pearly; opaque to transparent. In reflected light: light grey with yellow-brown internal reflections, bireflectant and slightly pleochroic. 10.13(100), 5.93(50), 4.401(35), 3.414(100), 3.198(80), 2.889(35), 2.805(35), 2.622(40). IMA No. 98-036.

$(Mg_2Al)Al_6(Si_6O_{18})(BO_3)_3(OH)_4$

A member of the tourmaline group; structure

Trigonal: *R*3*m*. *a* 15.884, *c* 7.178 Å. Bluish grey; dull; transparent. Uniaxial (-), ω 1.650, ε 1.624. 6.366(6), 4.211(9), 3.969(10), 3.470(6), 2.949(7), 2.567(10), 2.037(5). IMA No. 98-037.

$Pb_3Cl_4(SeO_3) \cdot H_2O$

Structure

Triclinic: $P\bar{1}$. *a* 8.115, *b* 8.433, *c* 9.242 Å, α 62.52, β 71.87, γ 75.01°. Colorless to white; vitreous to silky, diaphaneity not given. η 1.96, birefringent. 3.548(m), 3.258(s), 3.188(s), 2.728(m), 2.365(s), 2.298(m). IMA No. 98-038.

$Sr_2Fe(Fe,Mg)_2Al_4(PO_4)_4(OH)_{10}$

New structure type

Triclinic: $P\bar{1}$. *a* 5.455, *b* 9.118, *c* 9.769 Å, α 108.48, β 91.62, γ 97.38°. Pale blue to dark-yellow green; vitreous; transparent to translucent. Biaxial: α 1.660, γ 1.684. 4.473(47), 3.596(75), 3.470(45), 3.215(100), 3.132(75), 3.016(54), 2.878(43), 2.811(60). IMA No. 98-039.

$Na_{12}Sr_3Ca_6Fe_3WZr_3(Si_{25}O_{73})(O,OH,Cl)_5 \cdot (H_2O)$

A member of the eudialyte group; structure

Trigonal: *R*3*m*. *a* 14.2958, *c* 30.084 Å. Orange-red; vitreous; transparent to translucent. Uniaxial (-): ω 1.6279, ε 1.6254. See X-ray powder data for IMA No. 98-043. IMA No. 98-042.

$Na_{12}Sr_3Ca_6Mn_3WZr_3(Si_{25}O_{73})(O,OH\ Cl)_5 \cdot (H_2O)$

A member of the eudialyte group

Trigonal: *R*3*m*. *a* 14.282, *c* 30.12 Å. Orange; vitreous; transparent to translucent. Uniaxial (-): ω 1.629, ε 1.626. 11.50(90), 9.535(70), 6.452(50), 6.072(50), 5.735(50), 3.406(50), 3.213(50), 3.167(50), 2.980(100), 2.856(80). IMA No. 98-043.

$PbMn_2^{3+}(VO_4)_2(OH)_2$

A member of the tsumcorite group; structure

Monoclinic: *C*2/*m*. *a* 9.275, *b* 6.284, *c* 7.682 Å, β 117.97(4)°. Dark brown to black; vitreous to adamantine; translucent to opaque. In reflected light: light grey to light brownish grey, strong anisotropism (dark metallic blue to light purplish brown-grey), distinct bireflectance, slight pleochroism. R_{min} & R_{max}: 15.8, 19.2% (470 nm), 14.8, 17.8% (546 nm), 14.4, 17.3% (589 nm), 14.1, 16.8% (650 nm). 4.695(34), 3.388(95), 3.270(100), 2.946(51), 2.850(49), 2.491(93), 1.869(35), 1.697(83), 1.6378(31). IMA No. 98-044.

$Pb_6^{2+}Sb_6^{3+}S_{14}^{2-}S_2^{1-}S^0$

Structure

Orthorhombic: $P2_122_1$. *a* 5.328, *b* 4.0400, *c* 23.054 Å. Black; metallic; opaque. Reflectance data could not be obtained. 3.724(ms), 3.559(m), 3.427(s), 3.232(m), 3.047(ms), 2.952(m), 2.844(ms), 2.779(ms), 2.753(ms), 2.422(m). IMA No. 98-045.

$NaNa_2(Mg_3Fe^{3+}Ti^{4+})Si_8O_{22}O_2$

A member of the amphibole group; structure

Monoclinic: C2/*m.a* 9.795, *b* 17.949, *c* 5.290 Å, β 104.19(2)°. Pink; vitreous; transparent. Biaxial (-), α 1.643, β 1.657, γ 1.670, 2*V*(meas) 81°, 2*V*(calc) 87°. 8.414(100), 4.467(50), 3.390(60), 3.117(50), 2.705(70), 2.531(50). IMA No. 98-046.

$Ba(V^{4+}OPO_4)_2 \cdot 4H_2O$

The Ba-dominant analogue of sincosite

Tetragonal: *P*4/*n* or *P*4/*nmm*. *a* 9.031, *c* 12.755 Å. Pale green; vitreous; transparent. Uniaxial (-), ω 1.721, ε 1.715. 5.722(100), 4.519(40), 3.548(30b), 3.192(60), 3.101(40), 2.858(50), 2.794(50), 2.375(70), 2.022(50). IMA No. 98-047.

$BaV_3^{3+}(PO_4)_2(OH,H_2O)_6$

A member of the crandallite group

Trigonal: $R\bar{3}m$, *R*3*m* or *R*32. *a* 7.258, *c* 17.361 Å. Black; adamantine to semimetallic; opaque. Uniaxial (-). ω 1.858, ε 1.817. 5.90(9), 3.627(4), 3.073(10), 2.301(4), 1.971(5), 1.814(4). IMA No. 98-048.

$YbPO_4$

A member of the xenotime group

Tetragonal: $I4_1/amd$. *a* 6.866, *c* 6.004 Å. Colorless to slightly yellow or brown; vitreous; transparent. Uniaxial (+), ω 1.717, ε 1.802. 4.515(7), 3.437(10), 2.730(3), 2.556(8), 2.138(3), 1.760(5). IMA No. 98-049.

$Cu(OH)Cl$

Monoclinic: $P2_1/a$. *a* 5.552, *b* 6.668, *c* 6.124(2) Å, β 115.00(3)°. Yellowish-green to olive-green; vitreous; transparent to translucent. Probably biaxial, η > 1.8. 5.553(100), 2.785(14), 2.516(18), 2.241(27), 1.996(12), 1.851(21), 1.869(16). IMA No. 98-054.

$Sr_4ZrTi_4Si_4O_{22}$

The Sr-Zr-dominant analogue of perrierite

Monoclinic: $P2_1/a$. *a* 13.97, *b* 5.675, *c* 11.98 Å, β 114.26(8)°. Dark brown; adamantine; diaphaneity not given. Optical properties could not be measured. 4.15(m), 3.20(m), 3.12(s), 3.05(vvs), 2.99(vs), 2.84(s), 2.78(m), 2.74(s), 2.51(m), 2.30(m), 1.967(m). IMA No. 98-055.

$NaNa_2Mg_4Fe^{3+}(Si_8O_{22})(F,OH)_2$

A member of the amphibole group

Monoclinic: *C*2/*m*. *a* 9.81,*b* 18.05, *c* 5.29 Å, β 103.9(2)°. Grey; vitreous; transparent to translucent. Biaxial (-), α 1.618, β 1.629, γ 1.633, 2*V*(meas) 54°, 2*V*(calc) 61.8°. 8.42(34), 3.264(23), 3.129(100), 2.804(28), 2.716(10), 2.708(10), 1.895(10), 1.654(10). IMA No. 98-056.

$(Ba,K,Pb)_4(Y,Ca)_2Si_8(B,Si)_4O_{28}F$

The Y-dominant analogue of hyalotekite; structure

Triclinic: $I\bar{1}$. *a* 11.181, *b* 10.850, *c* 10.252 Å, α 90.64, β 90.05, γ 89.97°. Light pink to white; vitreous; translucent. Biaxial (+), α 1.637, β 1.628, γ 1.624, 2*V*(meas) 69°, 2*V*(calc) 67°. 7.79(65), 3.773(100), 3.742(70), 3.493(56), 2.936(50), 2.921(37), 2.912(42), 2.564(35). IMA No. 98-057.

$K_2(Mn,Fe)Ti_4[Si_4O_{12}]_2(OH)_4 \cdot 5H_2O$

A member of the labuntsovite group; structure

Monoclinic: *C*2/*m*. *a* 14.369, *b* 13.906, *c* 7.812 Å, β 117.09°. Yellow; vitreous; transparent. Biaxial (+), α 1.683, β, 1.687, γ 1.775, 2*V*(calc) 25°. 7.00(9), 6.33(8), 4.86(7), 3.17(10), 3.08(5), 2.58(4), 2.47(4), 1.551(4). IMA No. 98-058.

$(Bi,U,Ca,Pb)_{1+x}(Nb,Ta)_2O_6(OH) \cdot nH_2O$

A member of the pyrochlore group

Metamict, Cubic after heating: *Fd*3*m*. *a* 10.41 Å. Dark greenish-brown to brown; vitreous; translucent. Isotropic, η 2.10. 5.98(4), 2.967(10), 2.614(7), 1.848(9), 1.569(9), 1.500(4), 1.195(8), 1.145(5). IMA No. 98-059.

$PbBi_4S_7$

Orthorhombic: *Bbmm*. *a* 13.18, *b* 37.4, *c* 4.05(3) Å. Silver grey; metallic; opaque. In reflected light: white, distinct anisotropism (without color effects), very weak bireflectance, nonpleochroic. R_{min} & R_{max}: 35.8, 40.2% (460 nm), 35.3, 40.6% (540 nm), 35.0, 40.6% (580 nm), 34.8, 40.1% (640 nm). 3.80(10), 3.58(3), 3.40(2), 3.30(3), 2.95(4b), 2.92(2), 2.81(2), 2.34(4b), 1.917(2b). IMA No. 98-060.

$Na(LiNa)(Fe_2^{3+}Mg_2Li)Si_8O_{22}(OH)_2$

A member of the amphibole group; structure

Monoclinic: *C2/m*. *a* 9.536, *b* 17.789, *c* 5.277 Å, β 102.53°. Green; vitreous; translucent. Biaxial (+), α 1.694, β 1.698, γ 1.702, 2*V*(meas) 83°, 2*V*(calc) 85°. 8.25(24), 4.45(22), 3.396(28), 3.057(100), 2.749(54), 2.699(60), 1.920(20), 1.639(44), 1.396(23). IMA No. 98-061.

$(Zn,Mn)(Mn^{2+},Mg,Fe^{3+},Al)_{14}(As^{3+}O_3)(As^{5+}O4)_2(OH)_{23}$

New structure type

Monoclinic: *Cc*. *a* 14.236, *b* 8.206, *c* 24.225 Å, β 93.52°. Red-brown to orange-brown; resinous to submetallic; opaque. Biaxial (-), α 1.723, β 1.744, γ 1.750, 2*V*(meas) 44°, 2*V*(calc) 56°. 12.07(100), 6.05(100), 4.12(30), 9.04(90), 3.148(30), 3.030(70), 2.411(40), 1.552(70). IMA No. 98-062.

$Na_{15}Ca_3Mn_3Fe_3Zr_3Nb(Si_{25}O_{73})(O,OH,H_2O)_3(OH,Cl)_2$

A member of the eudialyte group; structure

Trigonal: *R*3. *a* 14.192, *c* 29.983 Å. Yellowish brown; vitreous; transparent to translucent. Uniaxial (-), ω 1.6450, ε 1.6406. 11.35(44), 7.10(33), 6.02(36), 5.68(31), 4.29(36), 3.389(43), 3.199(31), 3.150(35), 3.013(30), 2.964(100), 2.844(89) . IMA No. 98-064.

$Mg_9[Si_4O_{16}](OH)_2$

A member of the humite group; structure

Monoclinic: $P2_1/b$ (unique axis *a*). *a* 4.7480, *b* 10.2730, *c* 13.6894 Å, α 100.72°. Yellow-orange; vitreous, transparent. Biaxial (+), α 1.631, β 1.641, γ 1.664, 2*V*(meas) 70°, 2*V*(calc) 68°. 5.05(70), 4.46(52), 3.35(64), 2.772(91), 2.748(50), 2.551(80), 2.516(93), 2.365(50), 2.269(100), 2.259(95), 1.747(79), 1.485(51). IMA No. 98-065.

$CaMg(VO_4,AsO_4)(OH)$

A member of the descloizite group; structure

Orthorhombic: $P2_12_12_1$. *a* 7.501, *b* 9.010, *c* 5.941 Å. Orange to orange-brown; adamantine; transparent. Biaxial, α 1.797, β 1.805-1.815, γ 1.828. 4.50(72), 4.14(32), 3.170(100), 2.972(20), 2.785(30), 2.639(27), 2.596(21), 2.523(30), 1.733(20), 1.614(41). IMA No. 98-066.

$Cu[AlAsO_5]$

New structure type

Monoclinic: $P2_1/c$. *a* 7.314, *b* 10.223, *c* 5.576 Å, β 99.79°. Light green; vitreous; translucent. Biaxial (-), α 1.672, β 1.718, γ 1.722, 2*V*(calc) 32°. 7.20(100), 4.84(9), 4.33(23), 3.604(10), 3.125(20), 2.656(6), 2.458(8). IMA No. 98-067.

$K_2MnV_4O_{12}$

New structure type

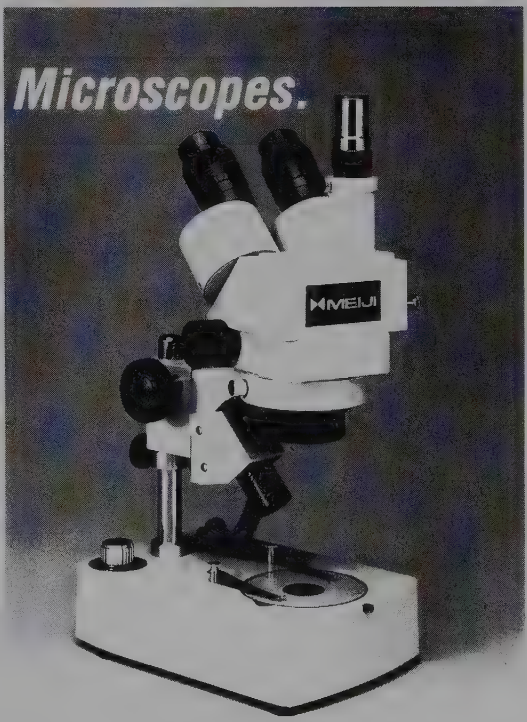
Monoclinic: $P2_1/n$. *a* 8.173, *b* 9.243, *c* 8.640 Å, β 109.70°. Reddish brown; adamantine; translucent. Biaxial, α 1.925 β 1.960, γ > 1.988, 2*V*(meas) 82°. 6.86(25), 5.91(27), 5.51(32), 3.957(25), 3.701(55), 3.336(100), 3.118(50), 3.000(36), 2.878(64), 2.752(68), 1.968(28), 1.860(28). IMA No. 98-069.

PROPOSALS FROM PREVIOUS YEARS APPROVED IN 1998

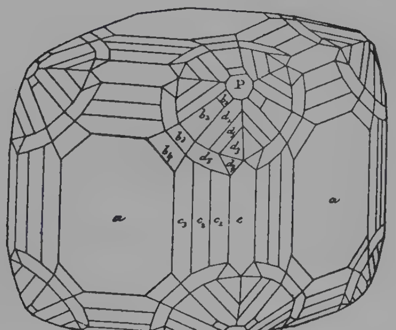
$(Mn,Fe,Mg)Al_2(PO_4)_2(OH)_2\cdot 8H_2O$

Polymorph of mangangordonite

Triclinic: $P\bar{1}$. *a* 7.0102, *b* 10.2050, *c* 10.5040(7) Å, α 71.82, β 89.62, γ 69.90(1)°. Colorless to beige; vitreous; translucent to transparent. Biaxial (-), α 1.5665, β 1.5740, γ 1.5815, 2*V*(meas.) 94.7°, 2*V*(calc.) 90.6°. 9.92(85), 6.54(100), 5.80(55), 4.746(85), 4.577(35), 3.885(30), 3.001(70), 2.900(30), 2.773(35) . IMA No. 97-033.



ABSTRACTS OF NEW MINERAL DESCRIPTIONS



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Quintinite — Hexagonal and Hexagonal (trigonal)

$Mg_4Al_2(OH)_{12}CO_3 \cdot 3H_2O$

Locality: (1) The Jacupiranga mine, Jacupiranga, São Paulo, Brazil (the *-2H* polytype); (2) Demix Quarry, Mont Saint-Hilaire, Rouville County, Quebec, Canada (the *-3T* polytype).

Occurrence: (1) (the *-2H* polytype): In vugs in dolomitic carbonatite. Associated minerals are: dolomite, magnetite, fluorapatite, phlogopite, pyrite, calcite, chalcopyrite, and pyrrhotite. (2) (the *-3T* polytype): In miarolitic cavities and in pegmatite bodies within nepheline syenite. Associated minerals are: analcime, natrolite, tetranatrolite, aegirine, calcite, siderite, fluorite, pyrite, biotite, donnayite-(Y), and ancylite-(Ce); in another occurrence it is associated with muscovite.

General appearance: The *-2H* polytype as equant crystals (up to 5 mm across) and prismatic crystals (up to 3 mm long); the *-3T* polytype as tabular crystals (up to 1 mm across), commonly forming rosettes, also in epitactic relationship with donnayite-(Y).

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* deep orange-red to orange to pale brown (*-2H*) and bright to pale yellow (*-3T*). *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* about 2. *Tenacity:* brittle. *Cleavage:* {001} perfect. *Fracture:* uneven. *Density:* 2.14 g/cm^3 (meas.), 2.14 g/cm^3 (calc.). ***Crystallography:*** Hexagonal (*-2H*), $P6_322$, a 10.571, c 15.139 Å, V 1465 Å^3, Z 4, c:a = 1.4321; hexagonal (trigonal) (*-3T*), $P3_112$ or $P3_212$, a 10.558, c 22.71 Å, V 2192 Å^3, Z 6, c:a = 2.1510. Morphology: forms, {001}, {100}, and a trigonal trapezohedron {hkl}. Twinning: none observed. ***X-ray powder diffraction data:*** The *-2H* polytype, 7.63 (100), 3.785 (100), 2.603 (15), 2.496 (15), 2.341 (15), 2.166 (15), 1.991 (15), 2.825 (20), 1.495 (15); the *-3T* polytype, 7.57 (100), 3.778 (90), 2.570 (40), 2.281 (40), 1.932 (40), 1.524 (20), 1.493 (20). ***Optical data:*** Uniaxial (+) (*-2H*), Uniaxial (+ or –) (*-3T*); for both polytypes the indices of refraction are the same, ω 1.533, ε 1.533, pleochroism O = yellow, E = lighter yellow (*-2H*); nonpleochroic to pleochroic with O = dark green, E = light green (*-3T*). ***Chemical analytical data:*** For the *-2H* polytype, means of four sets of electron microprobe data: MgO 33.19, FeO 0.74, Al_2O_3 20.52, Fe_2O_3 1.15, CO_2 (9.17), H_2O (33.80), Total 98.57 wt.%. CO_2 and H_2O by stoichiometry. Empirical formula: $(Mg_{3.95}Fe_{0.05})_{\Sigma 4.00}(Al_{1.93}Fe^{3+}_{0.07})_{\Sigma 2.00}(CO_3)_{1.00}(OH)_{12.00} \cdot 3.00H_2O$. For the *-3T* polytype, means of three sets of electron microprobe data: MgO 34.08, FeO 0.29. Al_2O_3 21.14, Fe_2O_3 0.80, CO_2 (9.35), H_2O (34.43), Total 100.09 wt.%. CO_2 and H_2O by stoichiometry. Empirical formula: $(Mg_{3.98}Fe_{0.02})_{\Sigma 4.00}(Al_{1.95}Fe^{3+}_{0.05})_{\Sigma 2.00}(CO_3)_{1.00}(OH)_{12.00} \cdot 3.00H_2O$. ***Relationship to other species:*** The Mg-dominant analogue of caresite and charmarite. Structurally and chemically related to the hydrotalcite and manasseite groups. The difference between this group of minerals and the hydrotalcite and manasseite groups is the ratio of 2+ cations to 3+ cations. In this group the ratio is 4:2 and in the hydrotalcite and manasseite groups it is 6:2. Also, the octahedrally coordinated cations are ordered in the 4:2 compounds but not in the 6:2 compounds.

Name: For Quintin Wight of Ottawa, Ontario, Canada. ***Comments:*** IMA No. 92-028 and 92-029. Note that the *-2H* and *-3T* polytypes are known.

CHAO, G. Y. and GAULT, R. A. (1997) Quintinite-*2H*, quintinite-*3T*, charmarite-*2H*, charmarite-*3T* and caresite-*3T*, a new group of carbonate minerals related to the hydrotalcite-manasseite group. *Canadian Mineralogist* **35**, 1541–1549.

Rossmanite — Trigonal

$(\square LiAl_2)Al_6(Si_6O_{18})(BO_3)_3(OH)_4$

Locality: The Hradisko quarry, near Rožná, western Moravia, Czech Republic.

Occurrence: In a pegmatite. Associated minerals are: lepidolite, albite, elbaite, "apatite", topaz, beryl, amblygonite-montebrasite, manganocolumbite, and cassiterite.

General appearance: Striated prismatic crystals (up to 25 x 5 mm).

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* transparent to translucent. *Color:* pale pink to colorless. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* about 7. *Tenacity:* brittle. *Cleavage:* none. *Fracture:* not mentioned. *Density:* 3.00 g/cm^3 (meas.), 3.04 g/cm^3 (calc.). ***Crystallography:*** Trigonal, *R3m*, *a* 15.788, *c* 7.089 Å, *V* 1530.5 Å^3, Z 3, *c:a* = 0.4490. Morphology: no forms were mentioned. Twinning: none mentioned. ***X-ray powder diffraction data:*** 4.181 (58), 3.950 (100), 3.434 (52), 2.924 (56), 2.552 (93), 1.898 (72). ***Optical data:*** Uniaxial (-), ω 1.645, ε 1.624, nonpleochroic. ***Chemical analytical data:*** Means of fourteen sets of electron microprobe data: Li_2O 1.13, Na_2O 1.43, B_2O_3

10.88, Al_2O_3 44.60, SiO_2 38.10, H_2O 3.70, F 0.20, sum 100.04, less O = F 0.08, Total 99.96 wt.%. Empirical formula: $(\square_{0.57}Na_{0.43})_{\Sigma 1.00}(Li_{0.71}Al_{2.17})_{\Sigma 2.88}Al_{6.00}(Si_{5.92}O_{18.00})(B_{2.92}O_{9.00})[(OH)_{3.83}F_{0.10}O_{0.07}]_{\Sigma 4.00}$. ***Relationship to other species:*** A member of the tourmaline group.

Name: For Dr. George R. Rossman (1945–), California Institute of Technology, for his work on the spectroscopy of tourmaline minerals in particular and his wide-ranging contributions to mineralogy in general. ***Comments:*** IMA No. 96-018.

SELWAY, J. B., NOVÁK, M., HAWTHORNE, F. C., ČERNÝ, P., OTTOLINI, L., and KYSER, T. K. (1998) Rossmanite, $\square(LiAl_2)Al_6(Si_6O_{18})(BO_3)_3(OH)_4$, a new alkali-deficient tourmaline: description and crystal structure. *American Mineralogist* **83**, 896–900.

Rubicline Triclinic

$(Rb,K)AlSi_3O_8$

Locality: San Piero in Campo, Elba, Italy (probably from the pegmatite known as La Speranza).

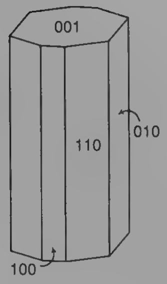
Occurrence: In a pollucite-bearing rare-element pegmatite. Specifically in 1 to 2 cm wide veins of rubidian microcline that crosscut pollucite. Associated minerals are: rubidian microcline, albite, muscovite, quartz, and "apatite".

General appearance: Abundant small grains (< 20 to 50 µm).

Physical, chemical and crystallographic properties: *Luster:* probably vitreous. *Diaphaneity:* transparent. *Color:* colorless. *Streak:* not mentioned but probably white. *Luminescence:* not mentioned. *Hardness:* could not be determined. *Tenacity:* brittle. *Cleavage:* {001} perfect and {010} good (by analogy with microcline. *Fracture:* not given. *Density:* could not be determined, 2.75 g/cm³ (calc.) (see comments). ***Crystallography:*** Triclinic, probably $P\bar{1}$, *a* 8.81, *b* 13.01, *c* 7.18 Å, α 90.3°, β 115.7°, γ 88.2°, *V* 741 Å³, Z 4, *a:b:c* = 0.6772:1:0.5519. Morphology: no forms were mentioned. Twinning: none. ***X-ray powder diffraction data:*** The usual data could not be determined. The following calculated interplanar spacings are given: 5.814, 5.775, 4.607, 3.855, 3.616, 3.596, 3.588, 2.938, 2.653, 2.633, 2.607, 2.562. ***Optical data:*** Biaxial (sign unknown), indices of refraction could not be measured but are slightly higher than those of the host microcline, 2V could not be measured; no other optical properties could be determined. ***Chemical analytical data:*** Electron microprobe data (of the structurally characterized mineral): K_2O 6.23, Rb_2O 17.47, Cs_2O 0.92, Al_2O_3 16.48, Fe_2O_3 0.12, SiO_2 58.68, Total 99.90 wt.%. Empirical formula: $(Rb_{0.57}K_{0.41}Cs_{0.01})_{\Sigma 0.99}Al_{0.99}Si_{3.00}O_{8.00}$. ***Relationship to other species:*** It is the rubidium-dominant analogue of microcline.

Name: For the compositional relationship to microcline. ***Comments:*** IMA No. 96-058. Because of the very small grain size, many of the usual physical and optical properties could not be determined. Strangely, no calculated density is given in the paper; the value given above was derived from the chemical and unit cell data given in the paper.

TEERTSTRA, D. K., ČERNÝ, P., HAWTHORNE, F. C., PIER, J., WANG, L.-M., and EWING, R. C. (1998) Rubicline, a new feldspar from San Piero in Campo, Elba, Italy. *American Mineralogist* **83**, 1335–1339.



Sodic-ferri-clinoferroholmquistite

Sodic-ferri-clinoferroholmquistite Monoclinic

$Li_2(Fe^{2+},Mg)_3Fe^{3+}_2Si_8O_{22}(OH)_2$

Locality: The Arroyo de la Yedra Valley in the eastern part of the Pedriza Massif, Sierra de Guadarrama, Spanish Central System, Spain.

Occurrence: In episyenites. Associated minerals are: albite, "augite-aegirine," titanite, andradite, magnetite, and "apatite." The mineral also occurs as micro-inclusions in microcline and quartz.

General appearance: Crystals up to 0.5 mm long.

Physical, chemical and crystallographic properties: *Luster:* vitreous. *Diaphaneity:* translucent. *Color:* black. *Streak:* grey. *Luminescence:* not mentioned. *Hardness:* 6. *Tenacity:* brittle. *Cleavage:* {110} perfect and {001} parting. *Fracture:* splintery. *Density:* 3.19 g/cm³ (meas.), 3.25 g/cm³ (calc.). ***Crystallography:*** Monoclinic, C2/m, a 9.472, b 17.844, c 5.276 Å, β 101.97°, V 872 Å³, Z 2, a:b:c = 0.5308:1:0.2957. Morphology: forms, {110}, {001}, {100}, and {010}. Twinning: not mentioned. ***X-ray powder diffraction data:*** 8.222 (61), 4.458 (19), 3.044 (100), 2.741 (53), 2.712 (14), 2.341 (14), 1.433 (46), 1.392 (14). ***Optical data:*** Biaxial (+), α 1.699, β 1.703, γ 1.708, 2V(meas.) 72°, 2V(calc.) 83°; dispersion r < v, magnitude not mentioned; strong pleochroism X = yellow green, Y = indigo blue, Z = green blue; Y ∧ c = 10° (in obtuse angle β), Z = b. ***Chemical analytical data:*** Means of six sets of electron microprobe data: Li_2O 3.75, Na_2O 2.66, K_2O 0.17, MgO 5.72, CaO 0.25, MnO 0.57, FeO 11.29, ZnO 0.16, Al_2O_3 1.19, Fe_2O_3 14.37, SiO_2 56.15, TiO_2 1.16, H_2O (1.66), F 0.93, sum 100.03, less O = F 0.39, Total (99.64) wt.%. Water was calculated to give OH + F = 2.00. The proportions of Fe^{2+} and Fe^{3+} were calculated and confirmed by a redox determination. Empirical formula: $(Na_{0.44}K_{0.03})_{\Sigma 0.47}[Li_{2.15}(Fe^{2+}_{1.35}Mg_{1.22}Mn^{2+}_{0.07}Zn_{0.02})_{\Sigma 2.66}(Fe^{3+}_{1.54}Al_{0.20}Ti_{0.12})_{\Sigma 1.86}]_{\Sigma 6.67}Si_{8.00}O_{22.00}[(OH)_{1.58}F_{0.42}]_{\Sigma 2.00}$. ***Relationship to other species:*** A member of the amphibole group.

Name: Based on the 1997 amphibole classification. ***Comments:*** IMA No. 95-045. The name given in the paper, "ferri-clinoholmquistite," does *not* conform with the IMA approved system of nomenclature by Leake *et al.* (1997). Dr. Bernard E. Leake and Dr. Joel D. Grice confirmed my derivation of the correct name which is given here. The authors of the paper probably are blameless in this regard, because their paper probably was "in press" when the new amphibole classification by Leake *et al.* (1997) was published in the *American Mineralogist*. It is unfortunate that the editors of that journal did not catch this error. The crystal drawing which accompanies this abstract was produced with the assistance of Dr. Caballero to whom I express my thanks.

CABALLERO, J. M., MONGE, A., LA IGLESIA, A., and TORNOS, F. (1998) Ferri-clinoholmquistite, $Li_2(Fe^{2+},Mg)_3Fe^{3+}_2Si_8O_{22}(OH)_2$, a new ^BLi clinoamphibole from the Pedriza Massif, Sierra de Guadarrama, Spanish Central System. *American Mineralogist* **83**, 167–171.

Sorosite Hexagonal

Cu(Sn,Sb)

Locality: The Baimka gold placer deposit, western Chukotka, Russian Far East, Russia.

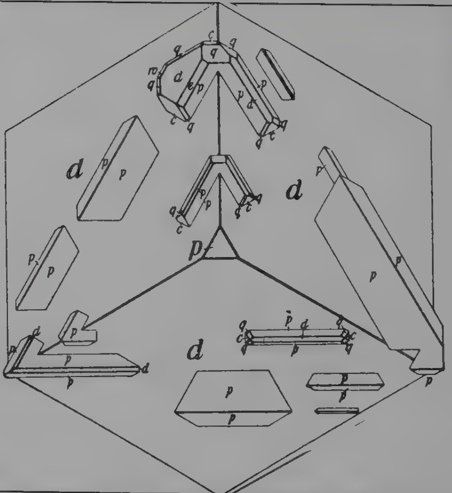
Occurrence: A placer deposit. Associated minerals are: tin, stistaite, herzenbergite, cassiterite, and lead.

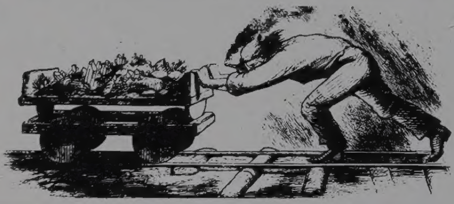
General appearance: Subhedral to euhedral crystals (up to 0.4 mm long) in tin.

Physical, chemical and crystallographic properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* not given. *Streak:* not given. *Hardness:* $VHN_{40;50}$ 443.7 kg/mm^2. *Tenacity:* very brittle. *Cleavage:* none observed. *Fracture:* not given. *Density:* could not be determined, 7.57 g/cm^3 (calc.). ***Crystallography:*** Hexagonal, probably $P6_3/mmc$, *a* 4.217, *c* 5.120 Å, *V* 78.85 Å^3, Z 2, *c*:*a* = 1.2141. Morphology: no forms were observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 2.970 (10), 2.112 (8), 2.094 (9), 1.487 (5), 1.218 (5), 1.212 (5). ***Optical data:*** In reflected light: white with a pinkish tint, distinct to moderate anisotropism, typically not bireflectant but some weak to distinctly bireflectant grains are present, pleochroism not mentioned. R_1, R_2; $^{im}R_1$, $^{im}R_2$: (74.0, 74.4; 62.3, 64.2 %) 470nm, (76.9, 77.2; 64.0, 66.4 %) 546nm, (77.8, 78.1; 65.1, 67.3 %) 589nm, (78.0, 78.6; 66.09, 68.1 %) 650nm. ***Chemical analytical data:*** Means of nine sets of electron microprobe data: Cu 35.33, Fe 1.18, Sb 4.77, Sn 58.18, Total 99.46 wt.%. Empirical formula: $(Cu_{1.00}Fe_{0.04})_{\Sigma 1.04}(Sn_{0.89}Sb_{0.07})_{\Sigma 0.96}$. **Relationship to other species:** none apparent.

Name: For George Soros (1930–), American financier, in recognition of his support to science in republics of the former Soviet Union. ***Comments:*** IMA No. 94-047.

BARKOV, A. Y., LAAJOKI, K. V. O., GORNOSTAYEV, S. S., PAKHOMOVSKII, Ya., and MEN'SHIKOV, Yu. P. (1998) Sorosite, Cu(Sn,Sb), a new mineral from the Baimka placer deposit, western Chukotka, Russian Far East. *American Mineralogist* **83**, 901–906.





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