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- lavender-gray, metallic luster, nearly pure

Pandaite

- hydrated barium strontium member of the pyrochlore-microlite series
- Panda Hill, Tanzania
- ref: E. Jager *et al*, Min. Mag. *32*, 10-25 (1959)
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the Mineralogical Record

volume one · number four
WINTER 1970

affiliated with the Friends of Mineralogy

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editorial matter

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Cover

A group of multicolored tourmaline crystals, embedded in a matrix of lepidolite. The specimen, only 2 inches in height, is in the collections of the Smithsonian Institution. This photograph was taken by Lee Boltin and first appeared in *The Mineral Kingdom*, by Paul E. Desautels.

fm friends of mineralogy

Educational Use of Minerals

Raymond W. Grant

One of the aims of *Friends of Mineralogy* is: "Encouraging improved educational use and far wiser conservation of mineral specimens, collections, and localities." To initiate the first part of this goal, that of improved educational use of mineral specimens and collections, *Friends of Mineralogy* is planning to establish a clearing center for information about available specimens for teaching, exhibit collections and the mineral needs of schools and museums.

For this effort to be successful, the following information is needed:

1. Names and addresses of collectors having good quality study material they would like to donate for educational purposes now or in the future.
2. Schools or museums having duplicate collections or substantial amounts of unused specimens they might be prepared to donate to other educational institutions or groups needing such material.
3. Collectors having mineral collections they would consider donating to educational institutions for exhibition only (not to be used in teaching).
4. Schools, museums, or educational organizations needing mineral specimens for teaching, study, or display.

This is a first request for information which may be sent to R. W. Grant, *Friends of Mineralogy*, Department of Geology, Lafayette College, Easton, Penn. 18042. DO NOT SEND SPECIMENS! *Friends of Mineralogy* will not handle specimens, but will try to get interested donors and recipients together. Material to be donated must be clearly characterized as to nature and quality. In the case of study material, detailed locality information is not essential. The Department of Geology at Lafayette College has already given study material to other schools and plans to continue this practice with other duplicate specimens.

In the future, *Friends of Mineralogy* hopes to be able to set up guidelines for the donation of specimens to educational institutions, with suggestions of possible agreements specifying how specimens are to be used and concerning their future preservation.

Comments on any of the above will be appreciated.

New Guidelines to Educational Exhibits to be Tested at Tucson, 1971

Robert W. Jones

Friends of Mineralogy is promoting a new concept in educational exhibit competition at Tucson, Arizona this winter. In the past educational competition has been handled much

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EDITORIAL PAGE

IF all who actively participate in the regular meetings of their mineral clubs should attempt an assessment of what the clubs offer to young people and highly motivated adults, I am afraid the assessment would be unsettling. The real strength of a mineral club, and any similar hobby organization, lies in a steady influx of new, usually young, members. If properly functioning, a club should indoctrinate and educate new members, motivating them to learn more about mineralogy. The process should elevate the level of understanding for all the members. Only through this kind of program can a feeling of participation in a productive and educational endeavor be instilled in a mineral club.

All too often, the opposite condition exists. I have not visited more than a few dozen different mineral clubs during meetings and cannot speak for all of them but many that have been visited seem to be in a state near suspended animation. They are, it seems, too much in the grip of those who have no real interest in knowing about minerals. Activities are limited to meetings for listening to an invited speaker, the planning of collecting trips, publishing a news bulletin or letter and, perhaps, sponsoring an infrequent show. More often than not, the show is infused with the same lack of originality and absence of concern for educational objectives that characterize the meetings.

It may be argued that many club members derive a great deal of benefit and enjoyment from a good lecture program. I agree. However, is this enough? Keen collectors and willing students of mineralogy can, and do, avail themselves of the opportunity to attend the better lectures yet often divorce themselves from all of the other responsibilities of club membership. They thereby deprive the rest of the group of their potential contributions. I suggest that merely lining up a cast of guest lecturers is taking the easy way out, or "copping out" in the parlance of the younger generation. It doesn't matter that more than half the audience may snooze through the talk and would give only blank stares if asked to summarize the contents of the speech. What seems to matter is that the president or program chairman can say, at the end of his term, that he was responsible for scheduling an impressive array of noted speakers. Never mind that few can remember what the speakers talked about.

The most stifling practice at meetings is to review interminable reports of various club officers. No law requires that a secretary's minutes must be read to the assembly. There is no reason why the treasurer's report cannot be reduced to something like, "We have a balance of $13.35 in the treasury." Instead, too many of these dreary accounts are inflated into lengthy monologues of little interest to anyone save the speaker. Probably the greatest annoyance accrues to the guest lecturer who is anxious to get on with the program.

The reaction of younger members and highly motivated adults alike, when they encounter this situation, is predictable. They are either lost to the hobby altogether or they are forced to seek the knowledge they desire outside of the club structure. At any rate, they find so little of value at meetings that they drop out. The clubs are thus deprived of an infusion of new and vital energy and ideas, remaining sheltered from anyone who would promote constructive change.

Is this a necessary condition? I would rather believe not but the prospects of changing this gloomy picture do not appear promising. The main reason for my pessimism is that in any given geographical area from which a club's membership is drawn there are only a few people with a strong interest in shaking a club from its lethargy. By driving away a single one of these, a continuing moribund state is practically assured.

What, then, might a mineral club do to enliven the meetings and increase the appeal of its offerings? As a beginning, the building of a mineral study collection would seem a must. Shouldn't mineral collectors be exposed to minerals? Sometimes the most unlikely place to see any mineral specimens is at a mineral club meeting. A collection project is much easier when the meetings are held in a room where the collection can be permanently housed but it is not impossible under other conditions. As an initial objective the membership might set for itself the goal of assembling good representative samples, not exhibit specimens, of the 100 to 200 minerals generally regarded as the most common or familiar to mineral collectors. While the collection is building meetings can be spent, in part, in a round-table discussion of the diagnostic properties of several of the minerals with lots of specimen handling, physical property testing, etc. Some members will quickly discover that they can easily learn to recognize dozens of minerals on sight. In the process they encourage others, less sure of themselves, to try harder. Periodic competitive testing may provide extra incentive to some to get a little more serious about it. It is altogether possible that, by being "put on the spot", some of the unmotivated may stop coming to meetings. The number of members listed on a club roster is one of the poorest measures of its strength. Far better, I say, to lose these than to lose members with a strong interest through boredom and frustration. In fact, the discovery by knowledgeable collectors that they can make a genuine contribution by leading others through the intricacies of mineral identification may provide the stimulus they need to remain active members.

(continued on page 178)

To The Editor . . .

Dear Sir:

It was very gratifying to see the introduction of the "Specimen Requests" column. This could be an excellent way for the collector to gain a sense of involvement in the science. Let us hope that the scientists will avail themselves of this opportunity to advertise their needs. Perhaps the service can be extended to include teaching and exhibit specimens for smaller schools lacking sufficient funds to buy what they need.

Samuel Greene

Dear Sir:

In the article about eakerite (Vol. 1, no. 3) the phonetic pronunciation is given as ĒKERAIT. According to my understanding of phonetics, this means the first syllable is pronounced as "eek" but I happen to know that Mr. Eaker pronounces it as to rhyme with "take".

Harry Mills

The phonetic eakerite was written in accord with the modified Royal Geographical Society System as adopted by Hey in *Chemical Index of Minerals, 2nd. Ed.* You are probably using the International Phonetic System. The first syllable of eakerite should rhyme with "take". Ed.

Dear Editor:

Congratulations on the fine publication *"The Mineralogical Record"*. It is the only magazine I know that can be read with interest by both the professional and the advanced amateur collector from cover to cover.

Davis M. Lapham
Chief Mineralogist
Topographic and
Geologic Survey
Harrisburg, Pennsylvania

Dear Editor:

I look forward to receiving *The Mineralogical Record* and I wonder if it would be possible to get some good dealers in micromount material to list themselves in the magazine. As now my buying experience with buying micromount material in the mail has been very poor. I don't think the dealers are trying to gyp me, I just don't think they know good micromount material.

How about some articles on basic crystallography? This would help us who are not experts in the field to improve ourselves.

Hope you have a very good *1971!* with *The Mineralogical Record.* I will push it all I can.

Carroll E. Withers
Lakewood, Colorado

We would appreciate recommendations from readers, of dealers who offer first-rate micromount material. We hope to include information on basic crystallography in future issues. Ed.

Dear Sir:

Will your magazine carry articles about the lapidary arts and the collecting of cutting and polishing material?

(Mrs.) Ernestine Cook
Miami, Florida

Decidely not! We feel that the lapidary arts are adequately covered by several other publications, but the popularization of mineralogy has been largely neglected. Ours is the latter objective. We may touch indirectly on lapidary subjects; for example, the article about Colombian emeralds in this issue. Ed.

First Mineralogy Published in the U.S.?

BY JOHN SINKANKAS

IN a catalog of secondhand books offered by a Philadelphia bookseller in early 1970, I noted two titles of interest, one being the classic mineralogical treatise of Charles Upham Shepard of 1838, and the other a work completely unknown to me on mineralogy and metallurgy with the imprint "Philadelphia, A. Bartram, 1798." My response to the catalog was not quick enough to secure the Shephard but I did get the second work, and, as it turns out, it may be of considerably more interest and value after all. The description of this book is as follows:

A
Compendious System
of
Mineralogy and Metallurgy
Extracted from
The Encyclopedia

Philadelphia·
Published by A. Bartram

1798

12°: iv + 505 pp. + [1] p. blank; signatures A-Ss^6, Tt^2. Contemporary calf, gold rules & letterpress on label on spine. P. size 6-7/8" x 4" (17-1/2 x 10 cm).

The work appears to be based on Cronstedt's *An Essay towards a System of Mineralogy by A. F. Cronstedt, translated from the original Swedish, with Annotations and an additional Treatise on the Blow Pipe, by G. v. Engestrom. II. Edition greatly enlarged and improved . . . by J. H. de Magellan.* vols. 1-2, London, 1788. 8°.

After a very brief introduction, the text begins with a section on the art of blowpiping, the preparation of samples, fluxing, and the interpretation of results, followed by a section on the blowpiping of ores and metallic substances, and a third section on the basic blowpiping laboratory, its equipment, accessories, and chemicals. The second part of the text begins with the "Arrangement of Mineral Bodies," with a footnote indicating that it is according to the system of Cronstedt which divides minerals into *earths, salts, inflammables,* and *metals* (p. 41-266). The "metallic substances" of this part (p. 184-266) begin with gold and end with manganese, and include detailed analysis and assaying instructions for 15 elements in native and combined states. An "Appendix of Saxa and Petrifications," p. 266-321, deals with common rocks ("saxa") and fossils and completes the mineralogical portion of the work.

The second part, on metallurgy (p. 323-505) briefly treats metals and their compounds, types of ores, pyritic ores, assaying and finishes with a lengthy dissertation on the ores of metals and specific methods for assaying each and smelting to extract the metals.

In the section describing the ideal blowpiping laboratory reference is made to two plates which, however, are not present in the copy in my possession for reasons which will be discussed presently.

Unfortunately, there is nothing in the book which accurately identifies the source of the text except the simple words "The Encyclopaedia." However, the time frame and the length of the articles appeared in keeping with the style and time of publication of the third edition of the Encyclopedia Britannica which when published was identified as *The Encyclopaedia; Or A Dictionary Of Arts, Sciences, And Miscellaneous Literature,* etc., the word "Britannica" not being applied until some time later. Accordingly, a copy of the third edition was located in the Library of the University of California at Los Angeles, and volume 12, containing the article on mineralogy was kindly supplied for personal examination.

It is now completely obvious that the work in question is an exact duplicate of the corresponding article in volume 12 of the third edition of the *Encyclopedia,* pp. 58-145, with Plate CCCXIII inserted between pp. 66-7. The print size of the *Encyclopedia* is 8-5/8" x 5-7/8" (21-3/4 x 15 cm) and the plate size is 9-1/2" x 7" (24-1/4 x 17-1/2 cm). The large size of the copper engraved plate, showing blowpiping apparatus and accessories, could not be accommodated within the book under discussion without folding, but since this was a common practice it is not understood why this and the other plate referred to in the text were not included unless it was a matter of keeping down expenses.

A close comparison of both works shows that the locked-up galleys of the *Encyclopedia,* printed in double-column, were used bodily for the *Compendium,* merely by discarding the marginal notes of the former and dividing the double-column format into the single-column format of the latter. By doing so, the page count was approximately doubled. Confirmation of this action was obtained by looking for broken type and other defects transferred without change from the *Encyclopedia* to the *Compendium;* these were found in abundance and there is no question that by some local agreement between the publisher of the *Encyclopedia,* a certain Thomas Dobson, "At The Stone House, N^{o}41, South Second-Street," in Philadelphia, and Mr. A. Bartram, the latter was enabled to send his printers over to South Second-Street and return with the galleys. There are minor changes as a result of this transfer, for example, use of different reference marks, and the need to completely reset footnotes which in the Encyclopedia are single-columned and therefore much too wide to be fitted into the space of the *Compendium's* pages.

I have not taken the trouble to look up the article on metallurgy which probably appears in the pre-

(continued on page 151)

MINERAL NOTES

NEW MINERALS

HENRITERMIÉRITE

C. Gaudefroy, M. Orliac, F. Permingeat and A. Parfenoff
Bull. Soc. fr. Mineral. Cristallogr., 92, 185-190, 1969.

Henritermiérite (named for Prof. Henri Termier of the Sorbonne, Paris) occurs with marokite, calcite, gaudefroyite and hausmannite in the Tachgagalt manganese deposits, Anti-Atlas, Morocco. The mineral is clove- to apricot-brown, with a vitreous luster, and occurs in grains up to 0.5 mm in size that display no cleavage. The fracture is conchoidal, hardness not determined.

Henritermiérite is a manganic hydrogrossular. Analysis gave an idealized formula $Ca_3(Mn_{1.5}Al_{0.5})(SiO_4)_2(OH)_4$ with Mn replacing Al rather than Ca. The resulting lattice distortion forces the mineral to crystallize in a tetragonal, deformed garnet structure. Strongest x-ray lines are 2.75 (10), 2.516 (9), 4.37 (8), 3.09 (8), 2.684 (7) and 1.614 (7).

Twinning on {101} produces aggregates that exhibit irregular birefringence and extinctions, but seem to have tetragonal outlines.

Tetragonal - space group $I4_1/acd$
a = 12.39, c = 11.91
G = 3.34 (meas.), 3.40 (calc.) Z = 8
$n\omega$ = 1.765 Uniaxial (+)
$n\epsilon$ = 1.800

NUFFIELDITE

P. W. Kingston
Can. Mineral., 9 (4), 439-452, 1968.

Nuffieldite, a sulfosalt, occurs in the Lime Creek stock near Alice Arm, British Columbia, as prismatic or acicular striated crystals up to 3 mm long but typically somewhat smaller. Bundles of parallel, unterminated crystals in vugs in quartz veins in a quartz diorite are also found.

The mineral has a metallic luster and lead to steel-grey color. The streak is dark greenish-grey to black, and crystals tarnish pale iridescent greyish-green to reddish-brown. Associated in quartz with nuffieldite are pyrite, molybdenite, cosalite and aikinite. Nuffieldite shows excellent cleavage (or parting between needles) //{001}; long needles are quite elastic, but the mineral is very brittle, fracture uneven to flat conchoidal, and even thin splinters are opaque.

Chemical analysis yields the empirical formula $Pb_{10}(Bi_{9.45}CU_{0.87}Pb_{0.22})Cu_4S_{26.73}$, idealized as $Pb_{10}Bi_{10}Cu_4S_{27}$. The strongest x-ray lines are 3.66 (10), 3.54 (10), 4.00 (9), 3.16 (8), 2.54 (7) and 1.871 (6). The powder pattern of nuffieldite bears only superficial resemblance to those of members of the bismuthinite-aikinite series.

The name is for Prof. E. W. Nuffield of the University of Toronto.

Orthorhombic - space group $Pnam$ or $Pna2_1$
a = 14.602, b = 21.344, c = 4.026
G = 7.01 (meas.) Z = 1

(continued next column)

FRIENDS OF MINERALOGY

(continued from page 132)

like other mineral competition, with only limited participation and success. To stimulate interest, Friends of Mineralogy will award cash prizes for the best educational exhibits entered at the Tucson Gem and Mineral Show, February 12 - 14, 1971, in Tucson, Arizona.

Emphasis of the competition will be on personally-collected minerals and hand-made materials in exhibits which develop a single valid concept in mineralogy. Once the exhibitor selects his concept he attempts to present it in such a way as to interest the viewer, educate him, and stimulate the viewer to further study. Presentation has to be clear, concise and factual.

There will be two categories of competition—senior and junior. Senior Division is open to anyone and prizes of $100 and $50 will be offered for the best exhibits. The Junior Division shall be open to anyone who has not reached his 16th birthday by showtime. We shall offer prizes of $50 and $25 for the two best exhibits.

People interested in competing in the special FM Educational Exhibit Competition at the 1971 Tucson Show should contact the Show Chairman, P.O. Box 6363, Tucson, Arizona 85716, or FM, C/O Robert W. Jones, 3520 N. Rose Circle Drive, Scottsdale, Arizona85251. ■

Mineral Notes continued

DISCREDITED MINERALS

ALLCHARITE = GOETHITE

F. Cech and Z. Johan
Bull. Soc. fr. Mineral. Cristallogr., 92, 99-100, 1969

Allcharite was named by Jezek in 1912 on the basis of crystallographic data alone. It was believed to be a sulfosalt because of its resemblance to stibnite and its occurrence with vrbaite, realgar and orpiment at Allchar, Macedonia. The type material was recently rediscovered and analysis and x-ray study of this material showed that, although the goniometry of Jezek is correct, the mineral is the iron oxide goethite. ■

WHO & WHAT	WHEN	WHERE	CONTACT
Southern California Micro-Mineralogists Sixth Annual Pacific Micromount Conf.	**Feb. 5 - 7**	Surf Rider Inn, 1700 Ocean Blvd., Santa Monica, Calif. 92625	**Wayne C. Leicht**, 482 Morning Canyon Road, Corona del Mar, Ca. 92625
Tucson Gem & Mineral Society, 17th annual show	**Feb. 12 - 14**	Fairgrounds, Tucson, Arizona	**Show Chairman**, P.O. Box 6363, Tucson, Arizona 85716
Nassau Mineral Club, 8th Annual Swapping Bee	**Feb. 21**	American Legion Hall, West Hempstead, Long Island, N.Y.	**Jack Andre**, 26 Browning Drive, Greenlawn, N.Y.
Geological Society of America, *North Central Section*, annual meeting	**Apr. 29 - May 1**	Lincoln, Nebraska	**W. J. Wayne**, Dept. of Geology, Univ. of Nebraska, Lincoln, 65808
Geological Assn. of Canada and Mineralogical Assn. of Canada, ann. mtg.	**May 13 - 18**	Sudbury, Ontario, Canada	**D. H. Williamson**, Dept. of Geology, Laurentian Univ., Sudbury, Ontario, Canada
Eastern Federation of Mineralogical and Lapidary Societies, annual show	**June 11 - 13**	Olympic Arena, Lake Placid, N.Y.	**M. F. Witherell**, Bristol, Vermont 05443
Calif. Fed. of Min. Societies, annual convention and show	**July 2 - 4**	Ventura Fairgrounds, Ventura, Calif.	**Bruno Benson**, 207 S. Pueblo, Ojai, Calif. 93023
Midwest Federation of Mineralogical & Geological Societies, convention and show	**July 22 - 25**	Richland Co. Fairgrounds, Mansfield, Ohio	**B. F. Parr**, 1488 Marion Ave. Rd., Mansfield, Ohio 44906
Mineralogical Soc. of America, summer mtg. (Pegmatite Phosphate Symposium), jointly with Clay Minerals Soc., ann. mtg., and North American Clay Minerals Conf.	**Aug. 8 - 12**	Rapid City, South Dakota	**D. H. Garske**, S. D. School of Mines, Rapid City, South Dakota 57701
Amer. Fed. of Min. Societies & Northwest Fed. of Min. Societies, annual show in conjunction with Seattle regional show	**Sept. 3 - 6**	Seattle Coliseum, Seattle, Wash.	**Ed Messerly**, 3017 N.E. 97th., Seattle, Wash. 98115
Rocky Mountain Federation Show	**Oct. 1 - 3**	Topeka, Kansas	**R. C. Roderick**, 2106 East 6th., Topeka, Kansas 66607
Geological Soc. of America and Mineralogical Soc. of America, ann. mtg.	**Nov. 1 - 3**	Washington, D.C.	**GSA Headquarters**, Box 1719, Boulder, Colorado 80302

FIRST ANNUAL MEETING

TUCSON - ARIZONA

Our readers are invited to attend the first get-together sponsored by *The Mineralogical Record.* Scheduled to coincide with the Tucson Gem & Mineral Show, the meeting will be on Saturday, Feb. 13, 1971, at the DESERT INN*, Tucson, Arizona, 8:00 P.M.

PROGRAM

- business meeting to select committee to plan next year's meeting
- lecture with slides
- 35mm mineral picture competition - 2 slide entries per contestant - $25.00 prize to winner - winning photo will be used on cover of *The Mineralogical Record.*

*Drinks available at pay bar.

Yedlin on micromounting

The 14th Annual Micromount Symposium of the Baltimore (Maryland) Mineral Society has come and gone (Sept. 26, 27) leaving an afterglow of satisfaction. The theme of the session was "Oddities of Crystal Growth", and from the first meeting of the first day, after symposium chairman Herbert V. Corbett opened the meeting at the auditorium of the Stemmers Run Jr. High School, to the end of the two-day conclave, there was almost frenzied devotion to the m/m art and to mineralogy. Lectures, demonstrations, show and tell sessions, slide programs, swaps, giveaways, mineral and book sales—all contributed to a packed weekend.

Over 100 enthusiasts attended, some 64 microscopes were set up for informal workshops, and the show went on. First, Dr. Joel Arem, staff crystallographer of the Smithsonian Institution, held forth on "Crystals: Perfect and Imperfect", indicating that a perfectly and ideally formed natural crystal, by the very nature of the structure and growth of the mineral, is a FREAK. He briefly told of the methods by which a crystal was formed and grew, and why certain peculiarities of habit were manifest.

After a session of workshop and sales, the subject of "Dendrites" was discussed by the founder of the Baltimore Mineral Society, and the organizer of the micromount symposia, Paul E. Desautels, Curator, Division of Mineralogy, Smithsonian Institution. The popular notion that a manganese dendrite is merely a treelike coating on quartz or feldspar, was dispelled. More properly, a dendrite is a single crystal, usually arborescent (whence its name), but also as a hopper crystal or other forms, caused by uneven growth, with consequent overdevelopment of some faces, resulting in distortions, treelike growths, aciculations, hopper growths and combinations of all of these. Notable examples are gold from Verespatak, Rumania; copper from the Mohawk mine, Michigan; cuprite (var. chalcotrichite) from Bisbee, Arizona; pyrite in basalt amygdules from Washington; and hopper halites from many localities.

The evening session was enlivened by Lou Perloff's Kodachromes, taken thru the 'scope, depicting distortions, unusual crystals, unfamiliar growth habits, and some new and rare minerals. The meeting adjourned at 10:00 P.M. and found its way back to the headquarters hotel, where several

(continued on page 139)

M.S.A. Meetings Planned Well In Advance

The annual meetings of the Mineralogical Society of America, held in conjunction with those of the Geological Society of America, for the next 6 years will be located as follows:

1971
Washington, D.C.

1972
Minneapolis, Minnesota

1973
Dallas, Texas

1974
Miami Beach, Florida

1975
Salt Lake City, Utah

1976
Denver, Colorado

It would be a nice gesture if mineral clubs in these cities, or regions, would volunteer to provide displays of local minerals for these meetings. Interested groups should write to:

G.S.A. Headquarters
Box 1719
Boulder, Colorado 80302

YEDLIN

(continued from page 138)

members held forth on some aspects of mineralogy and the micromount art. Perloff engaged the group with further slide displays of m/ms of some of the Foote mine, Kings Mtn., North Carolina minerals. Yedlin spoke on the history of mining and some of the minerals of Laurium, Greece, and several others displayed photographic skills by showing color slides of fine minerals.

The Sunday session began with Wayne Leicht, chairman, Pacific Micromounters Conference (all the way from southern Calif.), discussing the geology and mineralogy of the Grandview mine, Grand Canyon, Arizona. He displayed some of the available items, and had for distribution a number of superb m/ms.

A word about this and prior symposia. The thanks of all who attended are certainly due to the Baltimore Mineral Society, and the Maryland Academy of Sciences. And special mention to Jack Jedlicka, Principal of the Stemmers Run Jr. High School of Baltimore, who for years has provided the facilities of the school, necessary manpower and organization to make the meetings such an outstanding success.

NOTES: Torbernite, a new find. Chalk Mtn., near Spruce Pine, North Carolina. Superb, brilliant green, singly and in clusters, on white microcline and quartz. Forms include *c, e, o* and *m*. We think these are the best torbernites ever found in the U.S. They appear to be fully-hydrated torbernite for they are transparent and ultrabright. Whether or not they become metatorbernite in time remains to be seen. Some of the eastern dealers and collectors have this material. Get 'em.

NOTES: The mineral discussed on the last issue of the ***Record,*** from the Bell Pit, Newry, Maine, in white rhombs, exhibitng a triangular *"c"* face was checked at the Smithsonian—*goyazite*. Occurs with tan siderite, and at the contact between the muscovite and feldspar, occasionally with apatite. A good one to have from anywhere!

NOTES: A new box has just made its appearance. Plastic, clear, somewhat larger than the standard m/m box, it is 1 x 1 x 7/8 inch in size. Beautifully fashioned, it has an unusual feature. The cover has been molded into a 3X magnifier. The advantages are manifest. Excellent for quick selective scanning, for casual observation, and for competition, it adds a new dimension to the hobby. Another thing we discovered is the box is so well made, and so clear, that it can be used as a pocket magnifier. The focal length of the lens cover is exactly 7/8th inch, so that when the box is assembled and placed on a flat surface, anything (small print, coins, stamps, or boxed m/ms) can be seen at 3 or 4 magnifications. By removing the cover it can be used as a hand lens. Cost about 10 cents each in hundred lots.

The Canadian Micro Mineral Association held its 7th annual workshop in Brantford, Ontario, October 24 and 25, 1970. The theme of the two-day affair was "The Minerals of Mont St. Hilaire, Quebec". Bob Gait, of the Royal Ontario Museum, undertook the arrangements and programming in the absence of George Huff, the association president, who was ill. The attendance was 85, including Henry Budgen of Montreal, and Cliff Vickery and Larry LaChapelle of Toronto, experts on the St. Hilaire locality. Del Oswald, of Pittsburgh, lectured on the minerals of San Benito County, California, and the Ross Andersons exhibited color slides of St. Hilaire and some of its minerals. Fascinating was the projection by Cliff Vickery of a suite of unknown minerals from this locality, from unk. #2 to unk. #20. Imagine seeing pictures, in color, of a series of, as yet unidentified and unnamed, minerals! Mont St. Hilaire, and Kings Mtn., N.C., are perhaps the two most prolific collecting areas in eastern North America. The profusion of new minerals, the unusual habits of rare as well as common species, make these areas "demand" localities.

In the early 1930s Harvard College worked a fabulous find at Fisher's Lodge, Topsham, Maine. Recovered from a vast pocket in the pegmatite were such minerals as topaz, beryl (etched), garnet, tourmaline, herderite (the world's largest and finest), and many others (Palache, *Am. J. Sci.*, (5), 27, 37-48). Fine green "gahnites" were included in the report of the find, and it was not until some years later that these were reexamined and determined to be microlite (*Amer. Min.*, 25, 411, 1940).

We were fortunate in acquiring a couple of m/ms of this mineral from the late Herb Haven, of Portland, Maine, Just recently we got some more. These we had to dig for, not in the field, but under about 30X magnification in our basement, and this is how it came about. Joe Pollack, Harrison, Me., sent us a pound or so of sand taken from the locality. He took the stuff from below the original pit, and wherever the Harvard crowd had dumped the tailings. The sand was made up of particles of albite, quartz, some mica, garnet and tourmaline. It was alleged that loose tiny green microlites were included. This is the recovery technique. 1. Pour contents into bucket of soapy water, stirring by hand to free bits of wood, grass, seeds, mica, snakeskin (yep) and mud. 2. Place bucket under running faucet until water runs clear. 3. Decant, put sand on tilted tray to permit it to drain, and dry for a day or two, or place in a warm oven to dry. 4. Sift through mosquito screen. 5. Go through all larger fragments under 'scope to highgrade for possible m/m material, and, hopefully, big green microlites (no luck). 6. Go through fine material sifted through screen by putting a pinch at a time into a 3 x 4 inch mineral tray previously ruled with lines 1/2 inch apart, running lengthwise, and scattering sand so that it is 1 layer thick. 7. Scan along lines under 30X, picking up tiny terminated blue tourmalines, fine garnets, 2 monazites, 4 cassiterites, and, YES, 16 green octahedral microlites, 4 of which are perfect, and the balance in fragmented crystals. Sure, it is a long, drawn out process, but very relaxing after a hard day at the boiler factory. And where else can you get green microlite?

And buy and use a good mineral book.

Neal Yedlin

Second Occurrence of Benstonite

JOHN S. WHITE, JR., and EUGENE JAROSEWICH

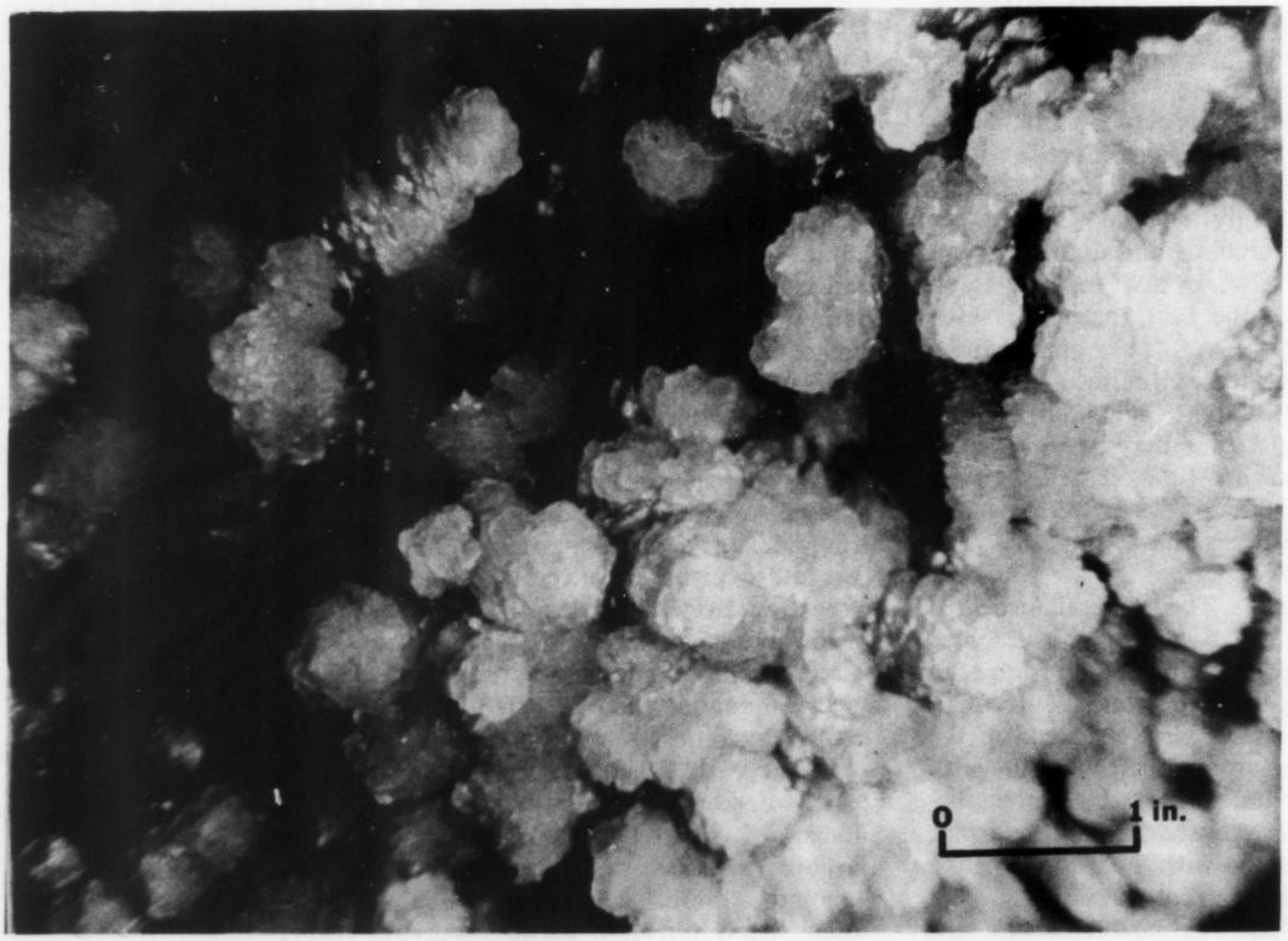
Friedrich Lippmann first described benstonite in short papers in *Fortschritte der Mineralogie* (1961) and *Die Naturwissenschaften* (1961). A longer, more detailed description by the same author followed in the *American Mineralogist* (1962). Benstonite is one of three minerals having the general formula $BaCa(CO_3)_2$; the others are barytocalcite and alstonite, monoclinic and orthorhombic, respectively. Benstonite is hexagonal (rhombohedral) and its formula, as reported by Lippmann, is $(Ca,Mg,Mn)_7\ (Ba,Sr)_6(CO_3)_{13}$ which may be simplified to $Ca_7Ba_6(CO_3)_{13}$ or possibly $MgCa_6Ba_6(CO_3)_{13}$. Structurally benstonite bears a strong resemblance to calcite, having a distinct rhombohedral cleavage at about the same angles. Its effervesces in dilute hydrochloric acid so that a cursory examination would probably lead the unsuspecting to label it calcite.

Lippmann's benstonite was found in irregular white veins up to a few inches thick in a fine-grained, grey-colored barite rock about 2-1/2 miles ENE of the igneous complex at Magnet Cove, Hot Spring County, Arkansas. It is associated with milky quartz, barite and calcite as snow-white to ivory-colored cleavable masses with cleavages up to about 1/2 inch across. Benstonite from this locality fluoresces red under both short and long wave ultraviolet radiation.

In late 1965 one of the authors (JSW) received a specimen for identification from Mr. Harry Sering of Indianapolis, Indiana. It looked in all respects like calcite but the specific gravity was too high. The x-ray powder pattern was found to match perfectly that of benstonite, a mineral which had not received much attention prior to that time, due undoubtedly to the massive and unspectacular appearance of specimens from the type locality.

The new benstonite was found in the Minerva mine, Cave in Rock, Hardin County, Illinois. It occurs as flat, unmodified rhombohedral crystals which appear to be arranged epitaxially around spinelike crystals of calcite. Benstonite has apparently grown as a single layer of rhombohedra oriented on and mimicing the overall form of a calcite crystal substrate. The benstonite occurs in

Fig. 1. A portion of a large benstonite specimen from Cave in Rock, Illinois. Smithsonian Institution specimen.



sectors outlining calcite scalenohedron faces, with their *c* axes parallel to one another in a sector, and parallel to the underlying calcite face. Further, the benstonite *c* axes are aligned parallel to the alternate, more acute of the two kinds of calcite scalenohedron edges which run from the girdle of the calcite crystal to its apex. Thus the benstonite crystals are slightly tilted with respect to those on an adjacent calcite scalenohedron face, allowing easy recognition of the underlying calcite crystal's form. Benstonite crystals usually cover the calcite completely so that the relationship of the two minerals is revealed only when these fingerlike growths are broken. The "fingers" reach 1-1/2 inches in length and 3/4 inch in width. Minerva mine benstonite is very pale yellow to pale yellowish brown in color; the associated calcite is much the same color, but darker. Benstonite not associated with calcite tends to form crusts of interlocking saddle-shaped crystals. Individual crystals do not exceed 1/2 inch across.

Many specimens are superficially chalk-white due to a thin coating of drusy barite. Associated minerals include yellow, blue, brown and purple fluorite, sphalerite and calcite, all of which crystallized before benstonite.

Unlike Arkansas benstonite these crystals do not fluoresce uniformly, but irregular areas emit a very weak red or yellow fluorescence. The measured specific gravity (pycnometer) of Minerva mine benstonite is 3.66; that of Lippmann 3.596. A semiquantitative spectrographic analysis showed:

Ca	major	Mn	.01 %
Ba	major	Pb	.005 %
Mg	2.0%	Si	.001 %
Sr	1.0%	Al	.001 %
Zr	.07%		

The low manganese content may explain the failure of this benstonite to fluoresce more intensely. Type benstonite contains 0.35% MnO and Lippmann suggested that manganese is responsible for its red fluorescence.

The remarkable similarity between the magnesia content of the two benstonites and that calculated from the formula $MgCa_6Ba_6(CO_3)_{13}$ (Table 1.) suggests very strongly that magnesium is an essential constituent to the extent of one atom per formula unit and is not simply substituting for calcium. The excellent agreement of the analyses with the chemistry predicted from this formula argues forcefully for its acceptance as the proper formula for benstonite.

TABLE 1. Chemical Analyses of Benstonite

	1.	**2.**	**3.**
BaO	49.23	44.9	43.05
SrO	-----	2.2	4.02
CaO	18.00	19.2	19.52
MgO	2.16	2.1	1.69
R_2O_3	-----	0.1	-----
MnO	-----	Tr	0.35
Co_2	30.61	30.7	31.35
	100.00	99.2	99.98

1. $MgCa_6Ba_6(CO_3)_{13}$. 2. Cave in Rock, Illinois*. 3. Hot Spring County, Arkansas. *Analysis by Eugene Jarosewich

It would be impossible to determine how many benstonite specimens from the Minerva mine were labelled calcite before their true identity was revealed. Several dozen specimens have been seen by the authors. A magnificent specimen, measuring 10 inches by 6 inches, of sharp crystals stacked around calcite crystals on blue and yellow fluorite is in the mineral collections of the National Museum of Natural History, Smithsonian Institution (Fig. 1.).

The authors are indebted to J. L. Harris and W. B. Crandell, of the United States Geological Survey, for the semiquantative spectrochemical analysis.

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_____ (1961), Benstonite, $Ca_7Ba_6(CO_3)_{13}$, ein neues mineral. *Die Naturwissenschaften, 48,* 550-551.

_____ (1962), Benstonite, $Ca_7Ba_6(CO_3)_{13}$, a new mineral from the barite deposit in Hot Spring County, Arkansas. *Amer. Mineral., 47,* 585-598.

Note added in proof. The occurrence of benstonite at Långban, Sweden, reported by N. Sundius in 1965 (*Ark. Mineral. Geol. 4,* 279), was not known to the authors until it was observed in reading the manuscript of Paul Moore, "Mineralogy and Chemistry of Långban-type Deposits in Bergslagen, Sweden" (see article, this issue).

Emerald Mining in Colombia: History & Geology

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Introduction

Emerald is the deep green variety of the not uncommon mineral beryl. Where transparent and free of flaws, emerald commands a price per carat not equalled by any other gemstone. A large emerald of fine color and quality carries as much as three times the value of a flawless white diamond of the same weight.

The overwhelming bulk of the world's emeralds, and virtually all those mined today, have been won from mines on steep Andean mountainsides in the Republic of Colombia, South America. Elsewhere, production has been reported from the Urals, the Salzburg Alps, India, Norway, Southern Rhodesia, Egypt, Brazil, and North Carolina. However, both in aggregate production and in quality, emeralds from these localities are thoroughly eclipsed by those from Colombia.

In the following paragraphs will be given a brief summary of the history of the Colombian emerald and its exploitation, a thumbnail sketch of the unusual if not unique geologic setting of these gemstones and their associated minerals, a few words on how the emeralds are mined, and a review of theories on their origin.

History of the Colombian Emerald

Emeralds were known long before the discovery of the New World. Their documentation from ancient writings, however, is made difficult by imprecise terminology; emeralds bore no name distinct from a variety of other green minerals such as malachite, jade, and serpentine. It was only with the Spanish conquest of South and Central America in the 16th century that the lore and the lure of the emerald became firmly established.

Perhaps the discovery most surprising to the Spanish *conquistadores* of the New World was the great wealth in emeralds that they found from Mexico to Peru. It is hard to imagine what must have been Cortes' reaction when in 1519 he met Montezuma bedecked from head to foot in a shimmer of deep green emeralds. Or Pizarro's reaction a few years later when he seized the Inca hoard of emeralds from Atahualpa (Morello, 1957, p. 512), a hoard so large that in 1533 Pizarro was able to send four chests full of these precious stones to the king of Spain.

Both Cortes and Pizarro thought the emeralds of their finding to be of local derivation. Pizarro in particular expended considerable energy and money in a futile search for the source mines in the Peruvian Andes. Unknown to both men was that the emeralds had been mined thousands of kilometers away by the Chibcha and Muzo Indians in what today is the Republic of Colombia, and had been bartered during centuries of trade up and down the Andes and through Central America.

As stated earlier, Colombian mines are virtually the exclusive source of good quality emeralds. One might expect that the geologic accident which restricted the occurrence of these much sought and very expensive green stones to a single nation would have been an act most favorable to that nation. Unfortunately, it has not been so. The presence of these riches has offered open stimulus to dishonesty and expedient opportunism, to bribery and corruption in both government and business through more than four centuries. It has fostered a greed in the hearts of many individuals who are connected directly or indirectly with the emerald business, a greed known in Colombia as "emerald fever" or "green fever". An unpublished memo by the Colombian Government's "Colombian Center" in New York City ("Notes on emerald mining activities in Colombia", 1966, 7p.) states: "Facts on emerald mining in Colombia constitute good material for a newspaper story, but hardly for a public relations publication. There are many sordid details". The memo further points out that only an estimated 10 percent of the Colombian emerald production is mined, cut, and sold legally, a quantity sufficient only for the local market, which of course is swelled by the many purchases by international tourists. Rafael Domínguez A., author of the most comprehensive work on the Colombian emerald,

Most mining at Chivor is by hand, because of the fragile nature of the emeralds. When necessary a limited amount of drilling and light blasting is done.

places Colombia's emerald misfortunes in a historical perspective when he writes (Dominguez A., 1965, p. 155): "If it were possible to know the weight of all the gems taken from (the mines of) Muzo and Cosquez since the year 1832, those gotten from the mines of Chivor, from the deposits of Gachalá and Buenavista, from clandestine exploitations at the Peñas Blancas mine and many others, known and unknown to the general public, it would be necessary to express the weight in tons. Such is the great emerald wealth of Colombia that has been used so improperly". Anguish, both public and private, over the politics and economics of the "National Emerald Domain" (essentially the Muzo district, discussed below) is common, and a statement on financial losses incurred by the Muzo mine issued by the National Treasury of Colombia a half century ago is equally true today: "This rich property of the State has been a genuine burden, a hotbed of unending trouble and embarrassment for the public administration" (Dominguez A., 1965, p. 154).

Colombian emeralds come entirely from two mining districts, Chivor and Muzo, each located north of the capital city of Bogotá in the eastern Andean cordillera (Fig. 1). Both districts were worked for gems by the indigenous population long before the establishment of Spanish colonialism early in the 16th century.

The Chivor district

The Chivor emerald district, named after the town of the same name, is perched on the humid eastern slopes of the Andes about 75 km airline east-northeast of Bogotá (Fig. 1). The district occupies about 100 square kilometers of exceedingly rugged country cut in places by canyons 1000 m or more deep. The Chivor mine, for example, is located high on an east-facing mountainside at an elevation of 2300 m above sea level. Only 2 km to the east, and in sight of the mine, the Río Guavio slices through an even higher ridge at an elevation of only 700 m in a dark craggy canyon so narrow and with walls so precipitous that it more resembles the product of an artist's imagination than an accomplishment of erosion. Beyond that, and visible through the gap cut by the Guavio, lie the vast plains of the Orinoco drainage. Much of the Chivor district is covered by dense and scrubby vine-choked cloud forest rich in parasitic plants. The two currently active and most important mines in the Chivor district are the Chivor and the Gachalá (Vega de San Juan).

Chivor mine

The Chivor mine, already long worked by the Chibcha Indians, was discovered by the *conquistadores* in 1537 or 1538 under Gen. Jiménez de Quesada, perhaps in company with Capt. Pedro Fernández de Valenzuela (Morello, 1957; Johnson, 1961, p. 127). Early exploitation by the Spaniards used Indian slave labor so harshly and cruelly that it threatened to decimate the local population and led directly to a series of laws beginning in 1593 that offered some protection for the Indians (Johnson, 1961, p. 128). By the close of the 16th century, following the Spaniards' discovery of the richer Muzo mine, Chivor went into eclipse. Exploitation became desultory, mostly the efforts of individuals granted rights by the Spanish Crown. In 1675 the mine was abandoned and, quickly covered by the lush cloud forest, it became lost (Johnson, 1961, p. 128).

In 1888 the Colombian mining engineer Don Francisco Restrepo found in a Dominican convent in Quito, Ecuador, a careful description of an emerald mine "in a region of Nueva Granada called Chivor" written 300 years earlier by Fray Martín de Aguado (Domínquez A., 1965, p. 164). In the description was noted that the site of the mine was the only place where from within the Andes one could see, through a gap, the *llanos* or great plains of the Orinoco to the east. Restrepo began his search, and in 1896 (Johnson, 1961, p. 129) or 1904 (Domínguez A., 1965, p. 251), found the lost mine. The gap of the description proved to be the craggy canyon of the Guavio portrayed above.

The Chivor mine. Through the gap in the far ridge may be seen the "Plains of the Orinoco", the clue that led to the discovery of the mine in 1537 or 1538.

From its discovery to the present day, the Chivor mine has been worked by a succession of privately financed foreign companies under concessions granted by the Colombian Government. The first of these companies was masterminded by Fritz Klein, a German mining engineer, and began operations in 1912. It was under Klein that the Patricia, perhaps the best-known uncut emerald, was found. This richly colored though much flawed euhedral prism weighs 632 carats and is currently at the American Museum of Natural History in New York City.

The company later passed to American hands where it has been ever since. Certainly the most colorful era at Chivor was in the late 1920s and 1930s under the stewardship of Peter Rainier as mine manager. This period included a series of civil disorders from 1932 to 1936 during which mining frequently had to be suspended for shoot-outs with marauding bandits. These and other events form the background of Rainier's well-known suspenseful book "Green Fire" (Rainier, 1942).

The departure of Rainier and his firm administration at the outbreak of World War II brought on new harassment by bandits and caused the collapse of the company. A complete reorganization soon followed and the present "Chivor Emerald Mines, Inc." was chartered in 1947. The new company's success was threatened at the outset by dishonesty, corruption, and high living among many of its officials, both at the mine and in Bogotá. Production went astray and accounts were falsified. Debts skyrocketed and soon Colombian creditors filed suits to recover overdue accounts "in all the courts of the capital (Bogotá) and neighboring towns" (Domínguez A., 1965, p. 166). Faced with insolvency, the company made two unsuccessful attempts to sell its holdings to the Colombian Government (Domínguez A., 1965, p. 166). Management of the company was then assumed by a committee of creditors and a succession of trustees under supervision of the Colombian courts. In May, 1970, the last of the outstanding debts were liquidated and the company came out of receivership.

Gachalá mine

The other mine currently active in the Chivor district is the Gachalá (Vega de San Juan). Reportedly the discovery of emeralds at the site was made by a woodcutter. Apparently he was unable to keep his secret, and as Domínguez A. (1965, p. 161) reports: "In only a single day the place was invaded by men of all classes mounted on horseback, firing shots in the air, and with greed and lust reflected in their faces according to the testimony of witnesses, put themselves to digging the earth with whatever tools were available that the urgency of the task called for". This took place not a century or two ago, but in 1953.

This mine has produced what is perhaps the finest known uncut emerald. Appropriately named the Gachalá, the 858-carat stone is well colored, relatively clear, and carries an unusually complex array of crystal faces. It is displayed in the National Museum of Natural History, Washington, D.C., gift of Harry Winston.

The Muzo district

The Muzo district comprises a tract of 360 square kilometers centered 105 km north of Bogotá (Fig. 1) on the west flank of the eastern Andean cordillera facing the Magdalena valley (Restrepo A., 1959, pl. 1). The district lies at a much lower elevation and has far less local relief than the Chivor district. The Muzo mine, for example, is only about 700 m above sea level and maximum local relief is less than 500 m. The climate is correspondingly hot and commonly has been described as "unhealthy". The landscape of the district is broken and much of it is cloaked with tropical rainforest. The district takes its name from the small and sleepy unkempt town of Muzo, which although most unpretentious, is truly the "Emerald Capital of the World".

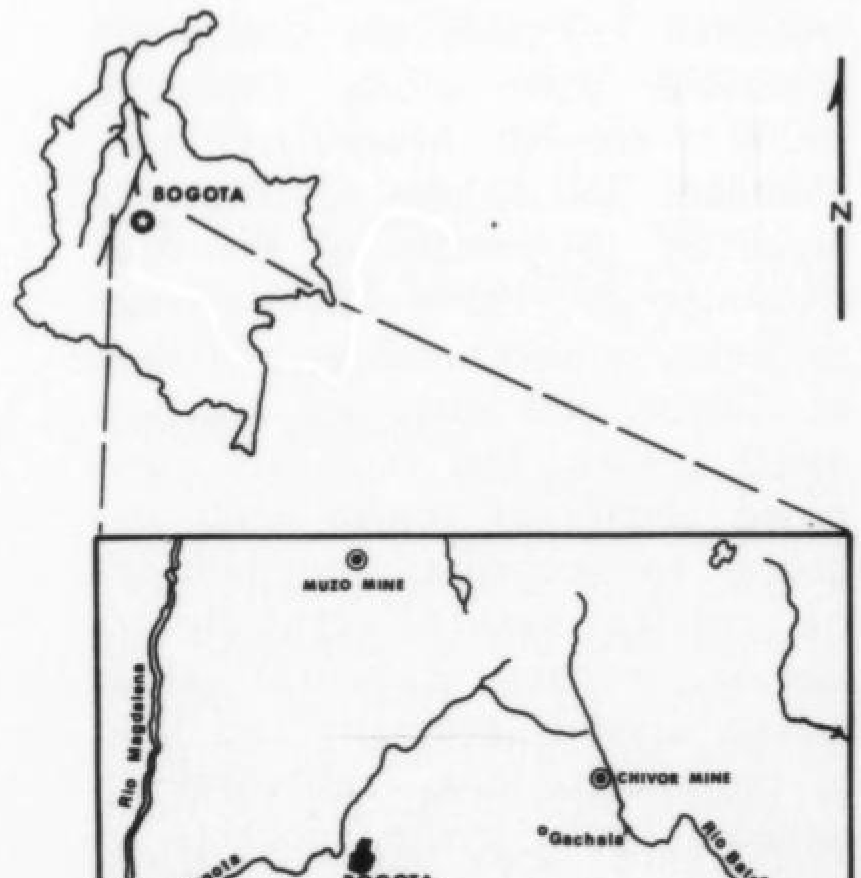
Three mines are currently active in the district: the Muzo, Coscuez, and Peñas Blancas. By law, all emerald production from within the Muzo district, which became known as the "National Emerald Domain" in 1871, is under the direct control of the Colombian

Government. This policy has had a checkered history to the present day.

Muzo mine

Like the Chivor mine, the Muzo mine was long worked by the indigenous population prior to the arrival of the *conquistadores*. A rich lore surrounds this period of the mine's history (Otero M., 1948, p. 21-25; Domínguez A., 1965, p. 4-11). Legend has it that the Spaniards found the mine on 9 August, 1564 (26 years after their finding of Chivor), when a horseman riding around the plaza of the newly settled town of Muzo saw green flashes coming from one of the hoofs of his steed. Dismounting to investigate, he dislodged an emerald that had become wedged between hoof and shoe. Questioning Indians, he learned that these green stones were found 7-1/2 km from the town (Domínguez A., 1965, p. 30-31). The story is probably apocryphal, however, for a letter to the King of Spain dated 1 January 1564 and written in Bogotá by Andrés Diez Venero de Leiva, mentions the discovery of emeralds 150 km from the colonial capital by Capt. Juan de Penagos (Domínguez A., 1965, p. 31).

Little is known of the early exploitation of Muzo by the Spaniards, which began in 1567 (Domínguez A., 1965, p. 251), except that the initial production of emeralds overshadowed that of Chivor. Production declined in the 1600s, however, and by mid century the Muzo mine had fallen into decay and disuse (Domínguez A., 1965, p. 39). Interest in the mine was revived a century later, and in 1764 mining experts brought from Mexico and Peru once again had Muzo in production. Nevertheless, exploitation proved costly, and associated banditry, thievery, and corruption reached intolerable proportions, and in 1792 the Muzo mine was ordered closed by Madrid, to be leased to the highest bidder. No bidders came forth, and by 1796 the mine was being worked by numerous individuals, probably armed bandits (Domínguez A., 1965, p. 41-47).



Map—Index map showing locations of the Chivor and Muzo emerald districts, Colombia.

Colombia achieved independence from Spain in 1819, and five years later the young country entered the emerald business based on its holdings in the Muzo district. The Chivor mine had by now been lost for a century and a half. The new government was to follow two distinct paths in working its holdings: by contract to outside interests, and by direct exploitation (Domínguez A., 1965, p. 47-128).

The contract method, used extensively in the last century, appears to have been the more favorable for the government which received 5 percent (10 percent from 1824 to 1828) of the proceeds from the sale of recovered emeralds. Some contractors sought to stabilize the price of emeralds by selling them through a single controlled market, generally in Europe. Nevertheless, the contract method was not without shortcomings. Most contracts offered fodder for political disputes within the Colombian Government and some, such as the 30-year contract let in 1909 with the "Colombian Emerald Company", had to be dissolved owing to knotty legal problems.

Direct exploitation has been mostly at a loss to the government's coffers. Widespread and at times quite open corruption and thievery was possible within a government which until recently enjoyed little stability. Direct exploitation prior to 1939 (in the years 1848-1849, 1903, and 1933-1938) was under the National Treasury. In 1939 the Muzo mine was closed pending a reorganization. A year later the Ministry of Mines was created and immediately assumed authority over the National Emerald Domain. In 1944 the Ministry let the first of several contracts to the Colombian National Bank (Banco

An older section of the Chivor mine showing how the mining is carried out by terracing. Water is released from a reservoir at the top of the ridge to wash waste rock into the valley below.

de la República). The first contract was solely for the cutting and sale of rough emeralds in the government's possession in Bogotá. Subsequent contracts allowed the bank to work the mine at Muzo (and later at Coscuez) as well as to continue stewardship of cutting and sales. Excluding the years 1949 and 1950 when operations at Muzo were suspended owing to civil war, this arrangement was continued through 1969 when all exploitation, cutting, and sales of stones from the National Emerald Domain passed to the "Colombian Emerald Enterprise", a new bureau in the Ministry of Mines and Petroleum. This transfer, largely completed by mid-1970, was welcomed by the bank, whose directors long had felt that the emerald business, a consistent money loser, was in any case too far removed from the mission of the bank.

Coscuez mine

Located 12 km north of the Muzo mine, the Coscuez mine is reputed to have been discovered by Capt. Francisco de Ovalle in June 1646. However, he had actually purchased the mine clandestinely several years earlier from Spaniards (Domínguez A., 1965, p. 40). It is not known if the mine was worked prior to Spanish colonization.

The relatively hard bedrock and scarcity of water at Coscuez made mining there difficult and underground methods were used (*see* Mining methods, below). This was hazardous as the principles of tunnelling and rock support were poorly understood in the 17th century. For example, a single cave-in is reputed to have taken the lives of more than 300 miners (Domínguez A., 1965, p. 41). More accidents and difficulty of access plagued operations and gradually the mine fell into decay. It was essentially abandoned before the end of the century although it continued to be worked by individuals and bandit groups in a desultory fashion through the succeeding three centuries. Coscuez was not again officially or legally exploited until 1960 when the Banco de la República began operations there after long having claimed inadequate facilities to rid the area of illegally installed miners, to clear the dense forest, to build adequate access, or to provide enough water for mining (Domínguez A., 1965, p. 142-143). Today Muzo and Coscuez, under the administration of the Colombian Emerald Enterprise, are the only mines legally being worked in the National Emerald Domain.

Peñas Blancas mine

The existence of emeralds at Peñas Blancas, tucked away in a remote corner of the National Emerald Domain about 20 km northeast of the Muzo mine, has been known for a century or more (Domínguez A., 1965, p. 145). The history of the Peñas Blancas mine though, is an unhappy one, for the mine is not now nor has it ever been exploited officially by the government. It has never even been under the control of the government. Production on a large scale began about a decade ago when hundreds of heavily armed men on the fringes of the law or far beyond moved into the Peñas Blancas area and began working the ground for emeralds, defending their "holdings" with hot lead. Attempts by the government to oust these miners with soldiers resulted only in the corruption and demoralization of one batallion after another. Bribery and bloodshed are still ways of life at Peñas Blancas. Even under these uncontrolled conditions the production of emeralds must be appreciable judging by the large quantity of contraband emeralds on the market both in Colombia and the gem capitals of the world. The success of the new Colombian Emerald Enterprise to some measure is threatened by activities at Peñas Blancas.

Geologic Setting of Colombian Emeralds and Their Associated Minerals

Bedrock at both Colombian emerald districts consists exclusively of fine-grained clastic marine sedimentary rocks of Cretaceous age. The rocks of the Chivor district differ markedly from those of the Muzo district. At Chivor the rocks are gray gritty shales and siltstones to fine-grained feldspathic sandstones with black shales. At Muzo the rocks are black calcareous shales rich in organic matter. In both districts the rocks are intensely deformed, fractured, and locally brecciated.

Colombian emeralds occur as a sparse accessory mineral in more or less randomly oriented veins and pockets apparently only locally in physical continuity with one another. The enclosing sedimentary rocks are not altered, bleached, or changed in any other way at contacts with veins. Weakly colored poorly crystallized anhedral smears of emerald with little commercial value, known locally as *moralla,* have a far wider distribution in the veins than does subhedral to euhedral clear and darkly colored gem emerald. The best emeralds are found in pockets, commonly with open centers. Some pockets are merely local dilatations of veins, but others are isolated and apparently not continuous with veins.

The mineral composition of the veins rather closely reflects the composition of the enclosing rocks, and veins at Chivor are quite unlike those at Muzo. Veins at Chivor are not abundant (they constitute only a percent or two of the rock) and rarely exceed 8 cm in thickness (Rainier, 1929). They are composed of glassy euhedral albite crystals less than 5 mm long, quartz, and euhedral to subhedral pyrite. The pyrite predates the emerald (it is a common inclusion in Chivor emeralds), and the albite postdates it; fractured emeralds are commonly cemented with albite (Mentzel, 1929). Veins at Muzo are more abundant and locally constitute as much as 10 percent of the rock (Restrepo A., 1959). Their average thickness is also much greater than at Chivor, and some are nearly a meter across. The veins are composed chiefly of coarse white euhedral to subhedral rhombohedra of calcite several centimeters across, etched euhedral clear quartz crystals generally less than a centimeter long, subhedral to anhedral pale pyrite, pockets of organic material, and sparse quantities of the unusual minerals parisite (a rare earth halide-bearing carbonate) and codazzite (a rare earth ankerite). Feldspar is mentioned in some descriptions (Barriga V., 1948, p. 100; Restrepo, A., 1959).

Gem emeralds from both districts occur as relatively simple subhedral to euhedral stubby prismatic crystals, generally with abundant internal fractures, flaws, and inclusions. These imperfections, collectively known as *jardín* (= garden), serve to diminish the value of emeralds as gemstones. Unusual emeralds with crystallographically oriented inclusions - "trapiche emeralds" - occur in both districts (Nassau and Jackson, 1970). The nature of the *jardín*, and particularly the inclusions, allows the provenance of many emeralds to be established with considerable precision. For example, whereas Chivor stones generally carry euhedra of pyrite, those from Muzo contain dispersed organic material. Emerald from plutonic terrains, such as those from the Urals or Brazil, carry needles of amphibole or flakes of mica, both unknown in Colombian emeralds.

The green color of Colombian emeralds is attributed to chromium, but little agreement exists on how much, and the relation of chromium content to depth of coloration remains unstudied. Single stones of uneven coloration occur in both districts. It is the most deeply and evenly colored stones, of course, that have the greatest value per carat.

Speculation on the relative merits of gems from the two Colombian districts is common. It is a subjective topic. A prevailing conclusion is that Muzo emeralds are the more richly colored, but that they lack the brilliance, or "fire", of stones from Chivor (Morello, 1957, p. 515).

Mining Methods

Colombian emeralds are mined exclusively by open cut methods that differ little from those used by the Spaniards in the 16th century. Nearly all work is by hand. The bedrock is generally soft and explosives are used only rarely to break vein-free rock. Small bulldozers are used sparingly to remove some broken rock. The mines are haphazard and unspectacular in appearance and more resemble road metal quarries than gem mines (Fig. 2).

Emeraldiferous strata on steep mountainsides are cut into steps

Q/A column

I have changed my labels from: octahedrite to anatase, titanite to sphene, and vesuvianite to idocrase. Now I am advised that some of these are to be changed back to original names. Please tell me which, and why.

Also, in the garnet group I am told the variety names have been changed to almandine, spessartine and grossular, but that andradite, uvarovite and pyrope remain the same. Why these changes and inconsistencies? I see that many museums carry the old names. What is the amateur collector to do?

Wendel Harvey, Caribou, Maine

Much of the synonomy of mineral names dates back far beyond the introduction of x-ray techniques to mineral identification when differences in habit were sometimes interpreted as indicating different species. Also many duplicate names for the same species have been carried to the present through popular usage in different countries. In recent years the New Minerals and Mineral Names Commission of the International Mineralogical Association has been trying to eliminate much of the synonomy by putting a preferred name up for vote among its members. In general, the rule of priority is followed but priority cannot always be clearly established. Further, it has been agreed that the Commission would make a recommendation only when there was a strong preponderance of opinion; when the vote has shown a small majority, the problem has been deferred.

Of those you have inquired about, the Commission has chosen anatase, titanite, grossular and spessartine. The idocrase-vesuvianite and almandine-almandite synonomies have not yet been resolved. There does not appear to be any real problem with pyrope and uvarovite, as no alternate names are in widespread use. Please note that pyrope, uvarovite, grossular, etc. are not varieties *of garnet, they are different garnets, that is, different minerals.*

Just as the news of these changes did not reach you as soon as they occurred, it hasn't reached the curators of many museums either. As these changes are better publicized, we hope the old labels will be updated. The best the amateur can do is keep in touch through the Mineralogical Record.

My problem is stilbite-epistilbite-desmine-epidesmine. I have specimens of a white zeolite, obviously stilbite, but because of the squared-off terminations it was labelled epistilbite. Years ago, from Moore's Station, New Jersey, a flat-topped stilbite was called epistilbite. All white or clear, more or less isolated crystals are labelled epistilbite to this day if they appear to resemble Figs. 28 and 31, Table 26, Vol. 3 of *Goldschmidt's Atlas der Kristallformen*. It is interesting to note that Goldschmidt labels his figures desmine, and a few pages further, calls the other mineral epistilbite. Is there any way of identifying these minerals visually, without the use of optical equipment? Has desmine been discredited in favor of stilbite? Thank you for your assistance in this matter.

John A. Webber, Philadelphia, Pa.

Stilbite and epistilbite are distinct and different minerals. They cannot be readily distinguished on sight. Desmine is synonomous with stilbite and its use should be abandoned in accord with the recommendation of the New Minerals and Mineral Names Commission. Most authorities regard epidesmine as synonomous with stilbite but according to Pabst, Amer. Min. 24, *63, 1939, epidesmine "though truly monoclinic, (is) both optically and morphologically pseudo-orthorhombic." These observations have led some authors to conclude that epidesmine is not identical with stilbite.* ■

about two meters high and three or four meters wide by gangs of miners using picks and crowbars. Where veins strike into hillsides, terraced notches are cut to follow the veins (*see* Rainier, 1929). Literally every cubic meter of rock is examined and recovery of emeralds approaches 100 percent. Broken waste rock is removed mostly by flushing with water. Large reservoirs (*tambres*) on hills above the mines are filled directly by streams or by water diverted from distant sources by dug canals, some of which at Chivor are more than 10 km long. The reservoirs can be emptied rapidly through large gates. The rush of water so generated is directed to the area to be flushed by ditches and trenches cut high on the hillsides and where discharged, effectively washes away all broken rock in its path.

As the emeraldiferous veins and pockets are not regularly arrayed, and their locations are not predictable, mining cannot be selective. The tenor of the "ore" (rock and contained veins) mined for emeralds, therefore, is fantastically low, probably lower than that of any other commercially mined mineral commodity. A recent unpublished report on the Chivor mine by Dewitt, Smith, and Company, states that one carat of emerald is won from every 15 cubic meters of ore. Assuming a bulk density of 2.2 gm/cm3, the ratio emerald to ore is 1:165 million, and the tenor of the ore is 0.0000006%! This is more than ten times leaner than the tenor of South African diamantiferous kimberlites. Tenor of ore at Muzo is probably comparable with that at Chivor.

The great value of the emerald makes security at the mines a problem. Members of the National Police guard and oversee operations at all legally worked emerald mines in Colombia. At Chivor, the salaries of these men are paid by the mine company, which also has its own staff of private guards. Thievery by miners is further discouraged by the payment of bonuses to miners who report smears of *moralla* or other signs that lead to the discovery of a productive vein or pocket. A month or more of mining commonly separates such discoveries which may contain, each in a volume not much larger than that of a softball, gems worth from a few thousand to a million dollars. Once found, such a discovery is traditionally covered with mud in which the mine superintendent or other responsible official inscribes his signature. The site is then covered with tons of broken rock debris. Immediately other mine officials and government representatives are summoned to be present when the debris is cleared, the signature is checked to see if tampering has taken place, and the vein or pocket is cleaned out. In the case of the Muzo or Coscuez mines, for example, the men summoned would include the mine superintendent, and representatives of the Colombian Emerald Enterprise, the Ministry of Mines and Petroleum, and the National Treasury. The emeralds are then weighed, described, and sealed in canvas bags at the mine office for shipment to Bogota.

Annual production of emeralds in Columbia is imperfectly known, and the officially reported figures are probably but a fraction of actual production, owing chiefly to the clandestine operations at Peñas Blancas. Average yearly production from 1964 through 1967 as reported in the 1968 U.S. Bureau of Mines "Minerals Yearbook" is 325,000 carats. The bulk of this is *moralla* and low-grade stones. Total production by the Banco de la República at Muzo and Coscuez from the inception of their mining activities in 1947, through 1962 (excluding *moralla*) is 229,000 carats (Domínguez A., 1965, p. 159). Also excluding *moralla,* total production at Chivor from 1926 through 1962 was 508,000 carats, and at Gachalá through 1959 was 37,000 carats (Domínguez A., 1965, p. 162, 167).

A Review of Theories on the Origin of Colombian Emeralds

Nearly all theories proposed on the origin of Colombian emeralds have been powerfully influenced by the nearly universal and classical occurrence of beryl as a high-temperature mineral associated with granites and pegmatites (Deer and others, 1962, p. 263-264). The emeraldiferous veins at Chivor, for example, have been ascribed to the action of pegmatites or pegmatite-derived solutions by Gilles (1930), and to the action of magmatic fluids or vapors of unspecified source by Johnson (1961). Veins at Muzo have been ascribed to pegmatitic, anatectic, or pneumatolytic action by Oppenheim (1948) and Restrepo A. (1959), to emanations from ultramafic intrusions by Bürgl (1956), or interpreted as hydothermal carbonate veins by Beus (1962, p. 44-45).

The working face at the Muzo mine lies at the foot of a large, steep open cut. Emerald veins occur very sparsely in the soft, black shale.

Few geologists have given sufficient weight to the unusual if not unique geologic setting in which the Colombian emeralds are found. To relate the origin of these gems to the classical occurrence of beryl seems unwarranted and for the following reasons is here discarded. In the first place, there are no associated igneous rocks. The nearest known granitic rocks of Cretaceous age or younger are small bodies of andesite, dacite, and rhyolite south of the town of Paipa (Saramiento Soto, 1942, p. 17, 41-43), 100 km or more from either Chivor or Muzo. Bürgl (1956) emphasizes the presence of ultramafic intrusions in Cretaceous rocks in the Muzo district reportedly found by Gansser, but these intrusions have never been documented and furthermore would be unlikely source-rocks for beryl mineralization. The assumption of hidden igneous rocks at depth offers little comfort, especially in the Chivor district where erosion has cut more than a kilometer and a half below the emeraldiferous veins that failed to lay bare igneous rocks or evidence of their possible presence nearby. Certainly the emeraldiferous veins themselves can in no way be construed as pegmatites, even though those at Chivor and some at Muzo contain feldspar. The texture, composition, and prevailing thinness and blindness of the veins forbid this. Finally, the complete absence of contact effects on the enclosing sedimentary rocks at vein borders (stressed only by Mentzel (1929) and Gilles (1930) at Chivor, but equally true at Muzo) argues strongly, if not conclusively, that the veins formed at a low temperature, possibly no higher than that to which were subjected the enclosing sedimentary rocks at their deepest burial.

An imaginative theory on the origin of Colombian emeralds not involving igneous rocks was proposed by a Bogotá high school teacher, Miguel Gutiérrez, S. J., and published locally in 1913 (*in* Domínguez A., 1965, p. 211-219). Referring himself to observations made at Muzo, Gutiérrez envisioned fractures in the rocks that became partly or wholly filled with calcite and emerald by a process of lateral secretion from enclosing rocks. In his own words (*in* Domínguez A., 1965, p. 214): "A small quantity of the elements that comprise emerald were present disseminated in the calcareous rock. Mineralizing waters, which circulated through the fractures of the rock, freed these elements and recombined them in the fractures where the silicate of aluminum and beryllium was deposited, from which were formed the precious crystals. Commonly the emeralds are found in geodes lined with crystals of calcite and emerald". Gutiérrez' theory deserves serious consideration because it is nicely consistent with such field observations as the absence of igneous rocks, the apparent low-temperature origin of the veins, the common isolation of emeraldiferous pockets and lack of physical connection between veins, and perhaps most important, the similarity of composition between vein and enclosing rock.

Heretofore the birthplace of beryl has been considered limited to hot plutonic—chiefly igneous—terrains. Perhaps beryl, like cristobalite, danburite, anorthite, and other minerals once believed exclusively the products of high temperatures, similarly has a low temperature metastable paragenesis. Metastable crystallization of Colombian emeralds could explain the frequency and severity of internal flaws even in euhedral crystals which grew in open cavities patently unaffected by post-crystallization mechanical deformation. The absence of distinctive optical or physical properties of beryl, and the difficulty of recognizing beryllium in routine chemical analyses, conspire to make the detection of pale or colorless beryl particularly difficult. It is a mineral easily overlooked and may be present elsewhere in low-temperature environments where its presence is unsuspected.

Acknowledgments

Part of the present paper is based on a trip to the emerald mines at Chivor and Muzo in October 1968 with Dr. George Switzer and Mr. Martin Ehrmann. The trip was made possible only by the splendid cooperation of Chivor Emerald Mines, Inc. and the Banco de la República, and the generous loan of a field vehicle by the Colombian Institutú Nacional de Investigaciones Geológico-Mineras. Fruitful discussions with George Switzer and permission to use the photograph (Fig. 2) are gratefully acknowledged. Most of the bibliography for this paper was done during part of my tenure as a Visiting Research Fellow in the Department of Mineral Sciences, Smithsonian Institution.

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The Record Bookshelf

Renaissance Of Mineral Collecting In Britain

A COLLECTOR'S GUIDE TO MINERALS, ROCKS AND GEMSTONES IN CORNWALL AND DEVON. Cedric Rogers, publ. by D. Bradford Barton Ltd., Truro, Cornwall, England, 1968. Center-stapled pamphlet: 48 + 1 pp., text sketches, maps. P. size 8-1/2" x 5-1/2" (21-1/2 x 14 cm). Price 8s. 6d. ($1.00, U.S.) Available from the publishers at 18 Frances Street, Truro 2815, or from Truro Bookshop, same address.

The astonishing rise in amateur mineralogy and lapidary in England within the space of a few recent years is a welcome if puzzling phenomenon. Why should these earth science hobbies suddenly "take off"? Why hadn't they "taken off" many years ago?

Some say the economic stresses of the post World War II period prevented it, but this seems less than a satisfactory explanation in view of the fact that collecting minerals from the many splendid deposits in the British Isles poses no real problems either in respect to transportation or expense. Lapidary is another matter since some machinery is most desirable, if the hobby is not to become sheer drudgery in shaping and polishing gemstones.

Whatever the real explanation, it is all different now. A definite atmosphere of bustle, of businesslike approach to the needs and fulfillment of amateur needs is everywhere evident. Clubs are starting up all over, manufacturers have organized to fill equipment demands, and naturally enough, qualified writers have appeared to provide the necessary home literature, for example, the fine booklet here reviewed.

Of all the works published on topographic mineralogy of the British Isles, three stand out as being particularly useful to the collector. The earliest is *Manual of the Mineralogy of Great Britain and Ireland,* by R. P. Greg and W. G. Lettsom, published in 1858, followed by the less useful but still valuable *The Mineralogist's Directory: or, a Guide to the Principal Mineral Localities in the United Kingdom of Great Britain and Ireland,* by Townshend M. Hall, published in 1868, and finally, for Cornwall and Devon alone, *A Handbook to the Mineralogy of Cornwall and Devon . . .* by J. H. Collins, published in 1871. It is understood that republication of the last is underway (now available; D. Bradford Barton; reprint of 2nd ed., 1892, 108 pp., 10 pl.; 1969, 48s.—Ed.) but in my view at least, the Greg & Lettsom easily deserves to be reprinted also, and perhaps some publisher in England will take note and do so.

The present work by Cedric Rogers naturally takes some material from these earlier works but brings it all up to date by indicating the status of the various mines, quarries, cliffs, etc., at the present time. Rogers is familiar with his country as is readily apparent from his descriptions of collecting sites, hints as to where to collect and what to look for, and specific directions, both verbal and by means of a series of sketch maps within the text. He does not fall into the all too common pitfall of describing rather indifferent materials in glowing terms, leading the naive reader into the belief that a veritable bonanza awaits merely his picking. Further, he specifically cautions readers as to sites where entry is refused.

In regard to content, the booklet begins with an elementary treatment of mineralogy designed to acquaint the less knowledgeable with the minerals of the region and their identification. Some very attractive (and accurate!!) sketches of mineral specimens and classic mining sites adorn the text in this section. Next comes the treatment of collecting sites grouped into common areas, followed by 9 sketch maps showing roads and collecting points. After the sketch maps appear an identification chart of minerals, the quartz "family tree", minerals grouped according to classes, a hardness table, and a list of localities and mines, with ordnance survey chart grid reference numbers. An interesting table shows old and new names for minerals, e.g., "mispickel" = arsenopyrite, etc. There is a brief list of references, scales of maps, and a list of shops specializing in minerals and equipment, also remarks on museums and clubs, the inevitable collecting warnings, and a request for corrections to be directed to the author.

All in all, this booklet seems just the thing for any would-be Cornwall or Devon collector and is recommended without reserve for those contemplating a visit to this world famous collecting region. ■

JOHN SINKANKAS

(continued from page 135)

vious volume of the *Encyclopedia,* and presume that it was treated in the same manner as the article on mineralogy.

For the information of readers, the following is the title of the *Encyclopedia,* third edition, and the first American edition, 1798:

Encyclopedia
Or, A
Dictionary
Of
Arts, Sciences
And
Miscellaneous Literature;
Constructed on a Plan,
By Which
The Different Sciences And Arts
Are Digested into the Form of
distinct Treatises or Systems,
. . .

The First American Edition,
In Eighteen Volumes, Greatly
Improved.

Illustrated With Five Hundred
And Forty-Two Copperplates
. . .

Philadelphia:
Printed By Thomas Dobson,
At The Stone-House,
n^{o} 41, South Second-Street
M.DCC.XCVLLL.

[Copy-Right secured according
to law.]

The work described herein appears to be rare, and I can find no reference to it in G. P. Merrill's "Contributions to the History of American Geology," in *Report, U.S. National Museum,* Washington, D.C., 1906, pp. 189-733. It antedates the first mineralogy written by a native American, Parker Cleaveland's *Elementary Treatise on Mineralogy and Geology,* 1816. There is no indication of an author for the *Encyclopedia* articles and perhaps, as was the custom, the two articles were actually written by the editor, Colin MacFarquhar, who, in 1793, died at the age of 48, "worn out by fatigue and anxiety of mind" (*Encyclop. Britt.,* 14th edit., v. 8, p. 430). In any event, and while not written by a native, and extracted from another work, this book appears to be the first independent treatise on mineralogy published in the United States. ■

what's new in minerals

Polydymite

Mr. Robert Francis of the Science Department at Oak Street Middle School, Burlington, Iowa has discovered a new occurrence of the rare mineral polydymite. This occurrence, however, is more than just a new find as the crystal habit is much different than any reported for the mineral and quite unlike that which one would expect for an isometric mineral. The crystals consist of long, gently curved fibers with smaller fibers randomly protruding from the sides all along their length and thus resembling very long, thin bottle brushes. The crystals are black and are enclosed in transparent calcite. They were found in a limestone at Gray's quarry on the southern edge of Hamilton, Hancock County, Illinois. Preliminary identification was based on an x-ray diffraction pattern of a powdered sample. X-ray fluorescence analysis revealed that the metal is mostly nickel with minor cobalt (Ni:Co = 25:1) and only a trace of iron, so the mineral is a rather pure polydymite.

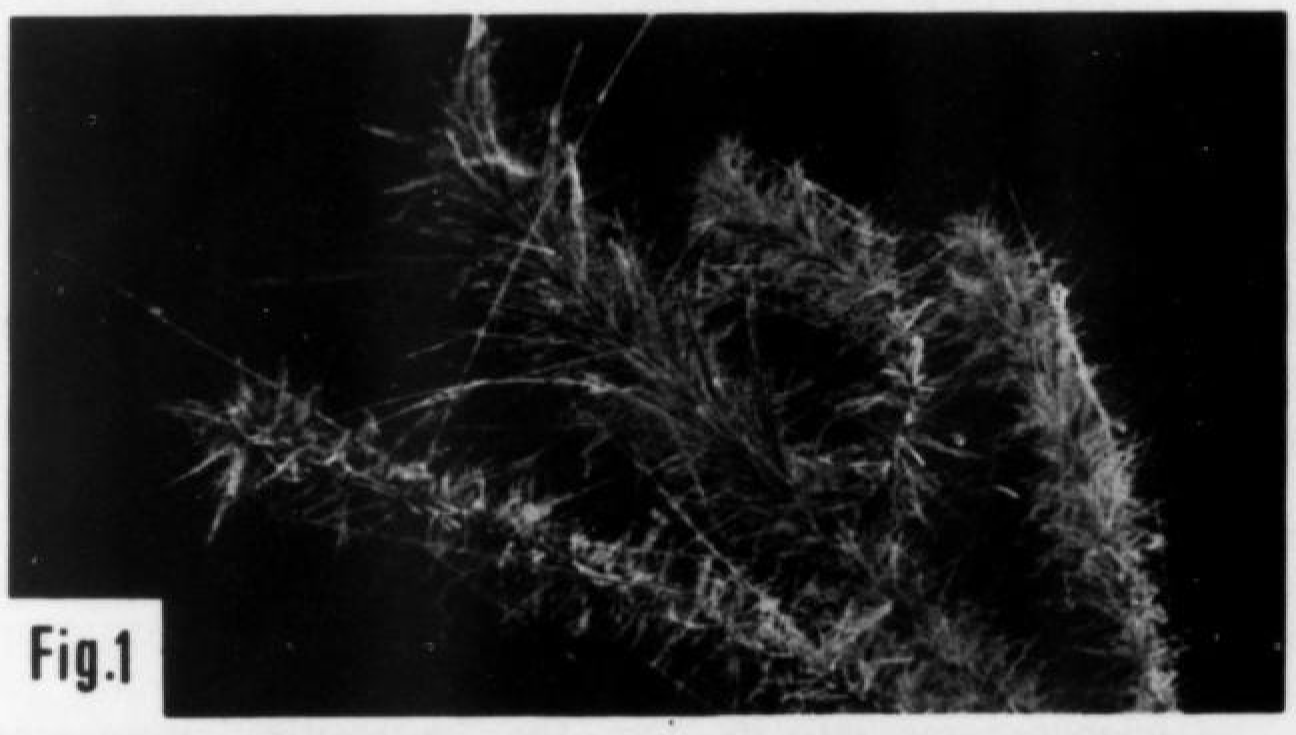


Fig.1

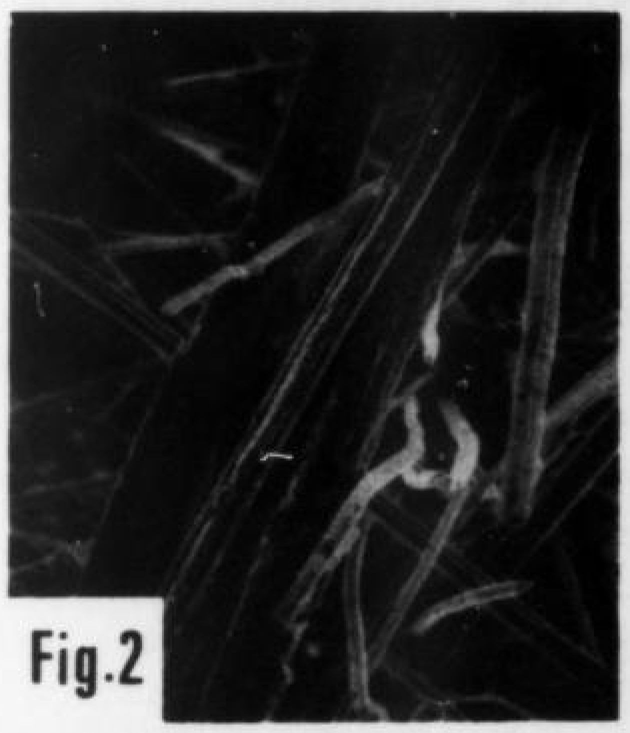


Fig.2

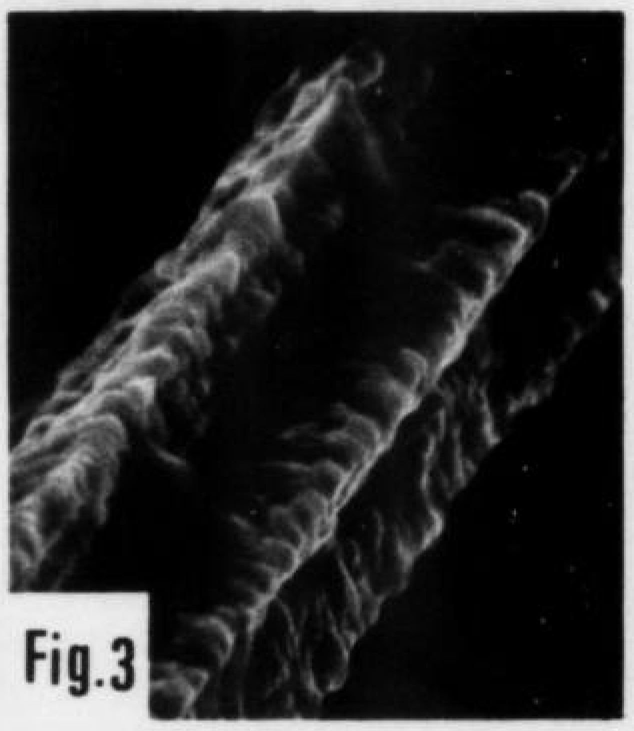
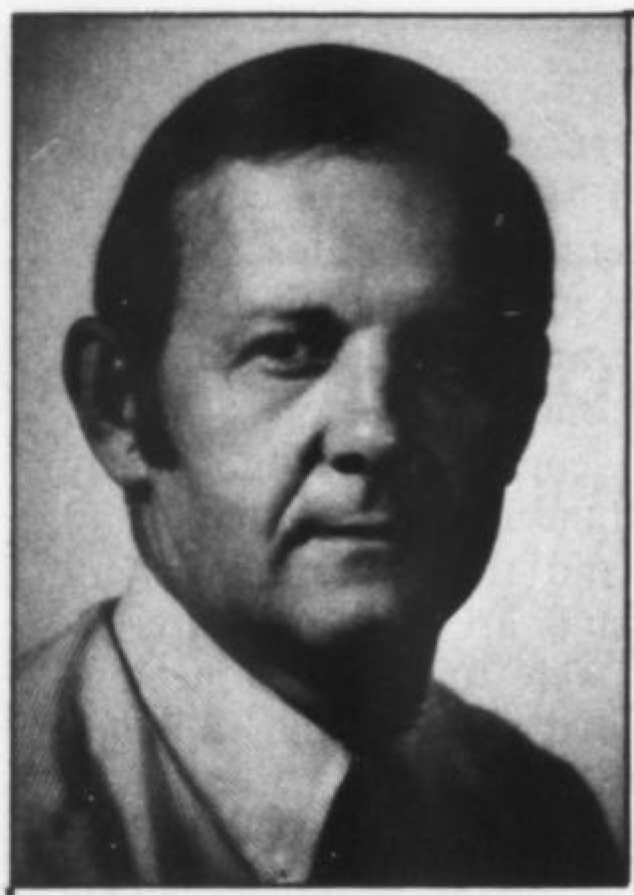


Fig.3


Fig.4

(continued on page 173)



the museum record

BY PAUL E. DESAUTELS

There are some vexing problems facing mineral museums these days that are not directly related to their financial resources. Primary among these problems is the decision facing directors of museums of every sort. It is a matter of objectives. What are the objectives of a mineral museum and what sorts of exhibits will lead to their attainment?

In a previous generation the answer was simple. The objective of any mineral museum was to show the public as many mineral specimens of as high quality as possible, in some orderly and attractive array. This was, and is, the plan for almost all the larger European mineral museum collections. Their origins were among the "cabinets of natural curiosities" assembled in the early days of enthusiasm over new discoveries of natural objects. True, when natural science came into its own, the "curiosities" were arranged and rearranged in increasingly rational, and thus instructive, groupings. It was at this later stage that the great mineral museums of the United States were established and, by and large, they show clearly their European origins. Instruction is derived by exposure of the visitor to these collections. His own previous learning and self motivation provides the key for unlocking the storehouse of information assembled row upon row.

Today in museum circles, at least in the United States, the feeling seems to be developing that this is not enough. Museums are now feeling that they must be educational institutions in almost every sense. As the concept goes, exhibits must be planned to lead or even entice visitors into a learning situation and to spell out carefully each lesson that should be carried away. Specimen accumulations, and even instructional exhibits, are somewhat out of fashion. The educational process becomes of prime importance. By this last rationale the choice of specimens for public exhibition is made solely on the basis of their ability to contribute to the process.

The museum director, then, is faced with assuming one of perhaps three stances. His mineral exhibits, if there are to be any in the grand educational plan, will be: 1/ a fine showing of the treasures of the mineral kingdom arranged in some rational and attractive way (the systematic collection), 2/ arranged in a series of instructional units selected to fit available suites of specimens (the topical exhibit in crystallography, fluorescence, physical properties, mineral genesis, etc.) or 3/ a series of expositions of major themes to be learned about man, his origins, environment or activities as illuminated by selected studies of the mineral kingdom.

(continued in next column)

Of course, this is a gross simplification of the question and it would be impossible to probe all its ramifications in this single column. Obviously, the answers are not all one way or the other. Eventually, I suspect, each mineral museum, wherever it may be, will have to question its goals in the light of local interests, the historical accidents of its position in the museum spectrum, the nature and size of its collections and, finally, within the limits of its space and financial resources. Having seen various solutions, I think it is safe to say that space and financial considerations carry the same weight no matter which plan is followed. In the long run they are constant factors. It is the collections and a sensitivity to the public need that will probably determine the course to follow.

For a small group of institutions—such as the American Museum of Natural History, the Harvard University Geological Museum, the National Museum of Natural History (Smithsonian) in the United States, the British Museum (Natural History), the Natural History Museum in Paris, the Natural History Museum in Vienna and others—it is mandatory that comprehensive systematic collections be exhibited. They must do it because they are the only ones with the capacity. History, in endowing them with great collections, has selected their role. Strong arguments can also be advanced for the establishment of similar collections elsewhere—in California for example—to make significant minerals, like significant art, available for more people to see. Unfortunately, in our time, the cost of such a project is almost prohibitive. A 2 or 3 million dollar gift to buy a single painting is not uncommon in the art world. It has never happened for mineral specimens. Such a gift could buy a fairly respectable collection.

Most museums, without the collection resources, must necessarily

(continued on page 174)

Natrolite and Analcime from Eckman Creek Quarry, Waldport, Oregon

by MIKE GROBEN

The occurrence of crystallized natrolite and analcime at the Eckman Creek quarry near Waldport, Lincoln County, Oregon, is not well known. Although both minerals found here are well crystallized, the vugs containing good crystals are few in number and it is only on rare occasions that material is available.

The quarry is east of Waldport and south of the Alsea River on Eckman Creek. (Fig. 1). To reach it, start from the junction of Routes 101 and 34 in the center of Waldport. Proceed eastward on Route 34, 2.6 miles to the road junction on the east side of Eckman Lake. Turn south at this junction and follow the county road 1.6 miles to the Eckman Creek quarry. The quarry lies on the east side of the road. There are several other quarries on the same side of the road which can be confused with the Eckman Creek quarry if the directions are not followed carefully.

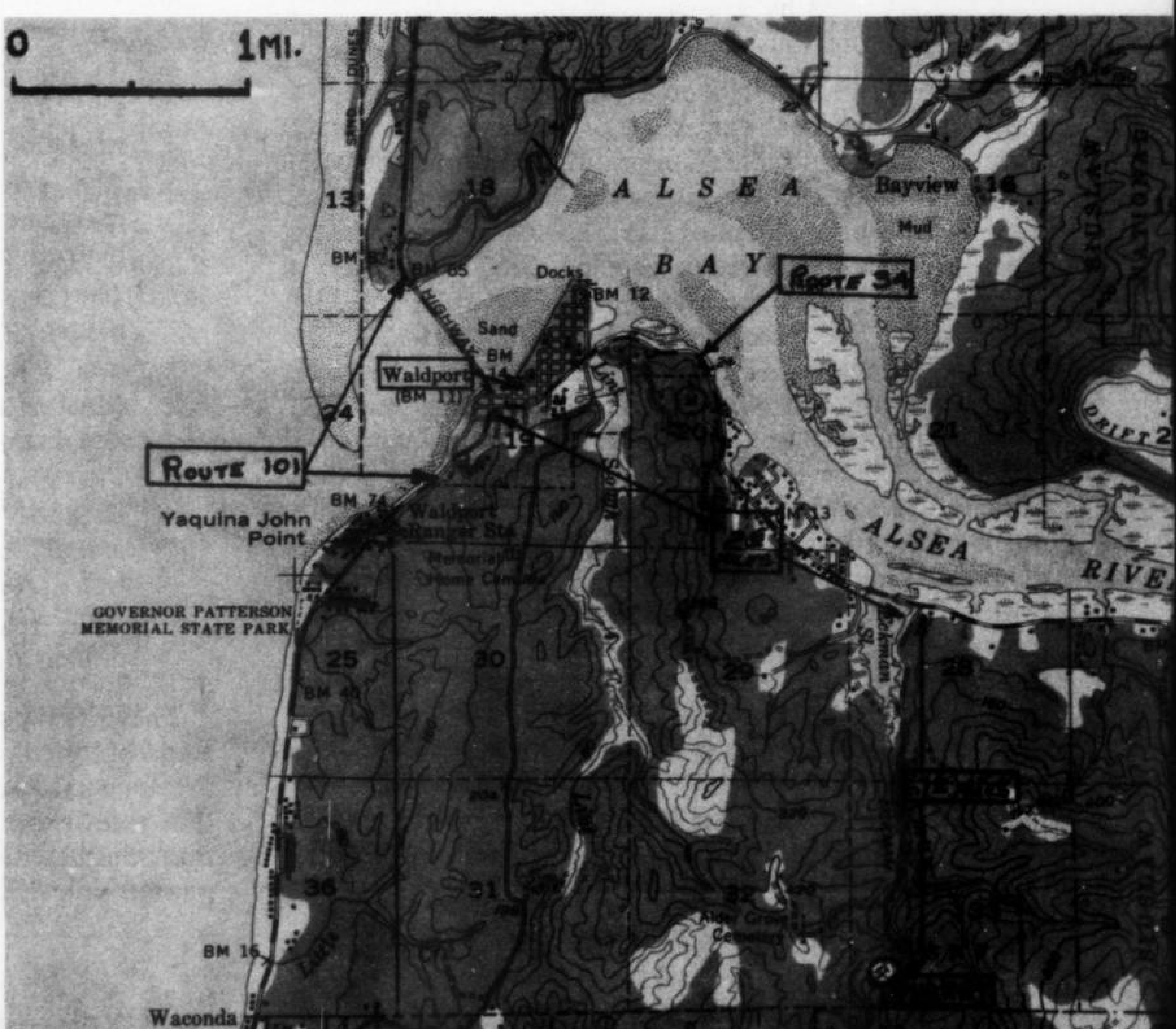
The quarry is a fairly large one compared to others in this part of Oregon. The rock is used primarily as road surfacing material for logging roads. It is also the source of rip-rap for the banks along the Alsea River and other tidewater areas. The quarry is owned and operated by Lawrence Kauffman of Waldport and, as of this time, there are no restrictions on collecting providing permission is requested.

The geological history of the area is relatively simple. The rock in the immediate vicinity of the quarry consists of basalts which originated at the beginning of Late Eocene time, approximately 58,000,000 years ago. During that particular epoch of time, the western land mass of Washington and Oregon was the floor of the shallow eastern edge of the Pacific Ocean. (Fig. 2). Intermittent volcanism occurred at various places underneath this shallow sea, extruding lavas which flowed laterally over the sea floor to form pillow basalts and breccias. In a few isolated areas such as the site of the Eckman Creek quarry, the flows continued to build upward until they protruded out of the sea to form islands. (Fig. 3). Evidence of this can be found in the Eckman Creek quarry where subaerial flows of columnar basalt overlie pillow lavas. These same subaerial flows may be traced laterally until they grade into pillow lavas at the places where they flowed off the island and into the sea. (Snavely & Wagner 1963).

It is in these pillow lavas where the zeolites formed and crystallization occurred. This concurs with the findings of C. N. Fenner (in Lindgren 1913, p. 396-8) who investigated the basalts of New Jersey and concluded that zeoliti-

(continued on page 173)

Fig. 1. Map showing location of Eckman Creek quarry.



Mineralogy & Chemistry of Långban-type Deposits in Bergslagen, Sweden

By PAUL B. MOORE

INTRODUCTION

Långban, in the Swedish province of Värmland, is the most remarkable mineral locality on Earth. A source of peculiar species since the earliest stages of mineralogical research, more kinds of compounds have been described from this one small mine than any other location. Approximately one-tenth of all known mineral species have been recorded from Långban and at least fifty species are found nowhere else.

It is no surprise that Långban is a sacred word among the more serious connoisseurs of minerals and that the locality has provided the earth scientists with an immense storehouse of information concerning the chemical behavior of earth materials over a great range of temperature. Species diversity, indeed, not only makes a locality interesting, but also provides us with insights concerning the behavior of cations and anions over a range of conditions.

But Långban is only one of several central Swedish locations which bear the mark of mineral assemblages formed under "peculiar" conditions. Insight into the general problem of Långban-type ores and associated minerals is brought into finer focus by considering these genetically related orebodies. Since Långban is the most studied of the localities, I shall refer to them collectively as Långban-type ore deposits. These include Långban, Pajsberg and Harstigen (near Filipstad); the Sjö mine (near Grythyttan); and the Jakobsberg, Eastern Moss and Brattfors mines (near Nordmark). The localities are situated within a radius of 20 miles from each other, whose center is 60 miles north-east of Karlstad, a city on the northernmost tip of Lake Vänern, Sweden's largest lake. The smaller towns of Filipstad and Nordmark are situated on the easternmost portion of the province of Värmland and Grythyttan is situated at the westernmost portion of the adjacent province of Örebro. The area is located in a geological district with a fascinating mining history called "Bergslagen." No less than 1000 iron mines, nearly all of them long-abandoned, are located within this district. Figure 1 outlines the locations and their routes of access.

The Långban-type ore deposits with their diverse mineralogy are subordinate to the iron ore deposits. Only a handful of iron ore deposits are known to have associated manganese ores. The Långban-type ore deposits all share several features in common, which collectively offer us clues to their origin.

1. The country rocks are leptites, granites and dolomitic marble.
2. The manganese and iron ores occur within the marbles and usually show a banded appearance.

3a. The manganese and iron ores are usually in proximity to each other but are well-separated.

3b. The iron ores were situated below the manganese ores, at least during original deposition.

4a. The manganese ores consist of granular hausmannite, braunite and minor manganosite.

4b. Carbonates associated with the manganese ores are enriched in barium.

5. The leptites act as damming areas for the ores and reveal metasomatic exchange with the neighboring skarns.
6. The great diversity of species occurs in the manganese ores and associated skarns and hydrothermal veins.
7. The crystallization temperatures of the assemblages—ores, skarns and veins—ranged from at least 650°C to room temperature.
8. Most of the "rare" minerals occur in the fissures and formed at low temperatures.
9. The great species diversity is due to the presence of certain cations not usually found in association with each other, such as Mn^{2+}, Mn^{3+}, Sb^{5+}, As^{3+}, As^{5+}, Pb^{2+}, Ba^{2+} and Be^{2+}.
10. In a relative sense, the deposits are of small dimension.

These ten points are very important to our discussion, but first some definitions are required. Leptites are unusual rocks and must have played some important role in ore formation since they occur at all locations discussed here. They are believed to be metamorphosed volcanic rocks such as rhyolites, ash flows and tuffs, and consist of fine-grained quartz, plagioclase feldspar, some potash feldspar and muscovite. They are among the oldest rocks (Precambrian) and probably were associated before metamorphism by solutions, volcanic in origin, carrying significant concentrations of iron (and manganese). The dolomites, also Precambrian, are metamorphosed limestones with composition nearly $CaMg(CO_3)_2$, though an excess of calcium over magnesium is most typical. The later rocks, granitic intrusives, provided heat for metamorphism. Regional folding also provided some energy for certain metamorphic and metasomatic reactions, and all rocks earlier than these intrusives show extensive folding and fracturing. For this reason, the geology of the region is very complex and must be mapped very carefully. Iron and manganese oxide "proto-ores," in the presence of siliceous material and enclosed in a good flux and reactive material like carbonates, will react at high-grade metamorphic temperatures to form silicates. These silicates are observed to encompass the ore pods and often display a texturally and compositionally banded appearance. Such reaction products are called "skarns," a Swedish term meaning waste or trash, since they are of little benefit to the mining industry. Hydrothermal veins, which appeared after the apex of thermal metamorphism and probably after folding, are located in fracture systems where minerals stable at lower temperatures have crystallized from aqueous solutions.

Explanations for the origins of the exceedingly complex mineralogy of the Långban-type ore deposits are many and somewhat speculative, but I shall state a few which probably play a major role. These explanations are not only compatible with the field observations but also conform to our understanding of the chemistry involved. First, solutions of volcanic origin are usually strongly acidic, and cations such as Fe^{2+} and Mn^{2+} are highly mobile, behaving essentially as ionic systems. Carbonates serve as good neutralizing agents of such acidic solutions, *viz.* $2H^+ + (CO_3)^{2-} \rightarrow H_2O + CO_2\uparrow$. The transition metal cations (such as Fe^{2+} and Mn^{2+}) associated with solutions of successively diminishing hydrogen ion concentration with time, eventually form relatively insoluble complexes through chemical bonding with water molecules and hydroxyl groups and are precipitated. Complexing agents which afford the unshared electron pair, such as $(OH)^-$ and (H_2O), are called *ligands*. Other examples of ligands in mineralogical systems include $(PO_4)^{3-}$, $(AsO_4)^{3-}$, $(SO_4)^{2-}$ etc. As carbon dioxide gas is released, the precipitating oxyhydroxides of the transition metals replace almost volumetrically the space remaining. Furthermore, the formation of insoluble iron complexes, particularly if the ferric state is involved, tends to occur under more acid conditions than those necessary for formation of the Mn^{2+} complexes. In addition, Fe^{2+} is more easily oxidized than Mn^{2+}. These observations account for points 2 and 3. The precipitated and subsequently desiccated complexes we shall call "proto-ores"; they have formed prior to thermal metamorphism. The phenomenon of precipitation, along with the separation of the iron complexes from the manganese complexes, would exhibit a sedimentary appearance. Point 4 requires some further observations. It is well-known that typical low-temperature iron and manganese oxyhydroxides (the so-called "bog ores"), whether formed by chemical or organic precipitation, usually include the species goethite ($FeO(OH)$, often called "limonite"), and various manganites and manganates such as pyrolusite (MnO_2), manganite ($HMnO_2$), and psilomelane ($BaMn_{16}O_{32}$-(H_2O)). Thermal metamorphism of these proto-ores followed by dehydration lead to the familiar iron oxides hematite (Fe_2O_3) and magnetite ($Fe_2^{3+}Fe^{2+}O_4$) and the manganese oxides hausmannite ($Mn_2^{3+}Mn^{2+}O_4$) and braunite ($Mn^{2+}Mn_6^{3+}SiO_{12}$). Hausmannite can be derived from psilomelane according to the following reaction:

$$\underset{\text{psilomelane}}{3BaMn_{16}O_{32}(H_2O)} + \underset{\text{dolomite}}{3CaMg(CO_3)_2} \rightarrow \underset{\text{hausmannite}}{16Mn_3O_4}$$

$$+ \underset{\text{norsethite}}{3BaMg(CO_3)_2} + \underset{\text{portlandite}}{3Ca(OH)_2} + \underset{\text{gas}}{140_2\uparrow}$$

A similar equation can be written for braunite formation, using a psilomelane-hollandite mixed proto-ore:

$$\underset{\text{“wad”}}{BaMn_7O_{14}(H_2O)} + \underset{\text{quartz}}{SiO_2} + \underset{\text{dolomite}}{2CaMg(CO_3)_2} \rightarrow$$

$$\underset{\text{braunite}}{Mn_7SiO_{12}} + \underset{\text{norsethite}}{BaMg(CO_3)_2} + \underset{\text{calcite}}{2CaCO_3}$$

$$+ \underset{\text{brucite}}{Mg(OH)_2} + \underset{\text{gas}}{1/2\ O_2\uparrow}$$

The equations account for the presence of barium in the carbonates associated with the manganese ores, and the confirmation of norsethite in carbonates surrounding a braunite ore (Sundius, 1965) is gratifying. We can gain further insight into the problem by examining the analysis of typical braunite-hausmannite ore in Table 2. This analysis, by A. Bygdén, appears in Magnusson (1930, p. 76). Assuming MnO and Mn_2O_3 as the constituents of braunite and hausmannite, their contribution to the analysis amounts to 59.5% by weight. Assuming BaO and PbO in the norsethite, its contribution is 10.8%. The remainder is approximately 27.1% calcite and 2.7% periclase. We now assume that BaO originally occurred in psilomelane proto-ore. The psilomelane composition is $BaMn_{16}O_{32}(H_2O)$ with a computed 8.9% BaO by weight. If the braunite-hausmannite was originally psilomelane, the amount of contained BaO would be $.595 \times 8.9 = 5.3\%$ BaO, in very good accord with the analysis.

These reactions and the interpretation of the analysis for braunite ore accommodate point 4. Since psilomelane and hollandite ores (collectively called "wad") usually contain barium and some lead, the carbonates are enriched in these cations since the higher temperature oxide structures like hausmannite and braunite cannot accommodate these large cations.

Point 5 accounts for the observation that the ores are predated by the volcanic equivalents of the leptites, since the precipitative reactions took place in the limestone. Points 6 and 7 result from two facts. ***First,*** a great range of temperature was involved in the total mineral assemblages of the Långban-type deposits. Many phases in the ores and skarns, in particular such dissociation products as manganosite (MnO) and

TABLE 1. MINERALOGY OF LÅNGBAN-TYPE ORE DEPOSITS

(Species known only from these deposits have asterisks)

Species	Formula	Location (see text)	Paragenesis	Comment	Reference
ELEMENTS					
copper	Cu	J,L,P,H	A?,D	Common at J with plumboferrite	Flink(1923), p. 364
silver	Ag	L,H	D	Very rare	Flink(1923), p. 364
lead	Pb	L,H,P,J,S	C,D	Most common element at L	Flink(1923), p. 363
bismuth	Bi	L	D	Very rare	Flink(1923), p. 363
antimony	Sb	L	D	Very rare	
arsenic	As	L	D	Rare	Aminoff(1931), p. 50
CHALCOGENIDES					
galena	PbS	H,L,P,J	C,D	Uncommon	Flink(1923), p. 365
sphalerite	ZnS	B,L,H,J,P,S	C,D	Uncommon	Flink(1923), p. 364
realgar	AsS	L	C	Uncommon	Aminoff(1925a)
orpiment	As_2S_3	L	D	Uncommon	
pyrite	FeS_2	L,H,J,S	C	Infrequent; in veins with other sulfides	Flink(1923), p. 365
molybdenite	MoS_2	L,J	C	Rare; with other sulfides	Flink(1923), p. 364
chalcocite	Cu_2S	L	C	Uncommon	Flink(1923), p. 365
chalcopyrite	$CuFeS_2$	L,J	C	Rare	Flink(1923), p. 372
α-domeykite	Cu_3As	L	D	Very rare	Aminoff(1931), p. 49
algodonite	Cu_6As	L	D	Very rare	
bornite	Cu_5FeS_4	L	C	Uncommon	Flink(1923), p. 365
tennantite	Cu_3AsS_{4-x}	L	D	Very rare	Flink(1910)
OXIDES AND HALIDES (SIMPLE)					
periclase	MgO	L,B,P,J	A	Early dissociation product of dolomite	Magnusson(1930), p. 38
manganosite	MnO	B,L	A	Granular; common at B	Magnusson(1930), p. 38
bromellite*	BeO	L	C	Very rare	Aminoff(1925b)
litharge	PbO	L,P	D	Oxidation of Pb; as coatings	
quartz	SiO_2	L,J,H,S,P,B	A,B,C,D	Ubiquitous, especially with Fe ores	Magnusson(1930), p. 31
rutile	TiO_2	L,J	B,C	Rare, in sköls	Magnusson(1930), p. 66
hematite	Fe_2O_3	L,B,J,H,S,P	A,B,C,D	Major ore of Fe	Magnusson(1930), p. 31
bixbyite	$(Mn,Fe)_2O_3$	L	B	Cubes with manganophyllite	Mason(1942)
cuprite	Cu_2O	J,P,L	D	Oxidation of copper	Boström(1965)

TABLE 1 (Continued)

Species	Formula	Location (see text)	Paragenesis	Comment	References
senarmontite	Sb_2O_3	L	D	Minute octahedra; very rare	Boström(1965)
valentinite	Sb_2O_3	L	D	Rare crystals with nadorite	
brucite	$Mg(OH)_2$	J,H,L,P	C	Common at J ("manganbrucite")	Magnusson(1930), p. 39
pyrochroite	$Mn(OH)_2$	L,B,S,P,H,J	D	Common open fissure mineral, usually with native Pb. ("basiliite", "bäckströmite")	Flink(1923), p. 366
feitknechtite	$MnO(OH)$	L,B,S,P,H,J	D	Oxidation product of pyrochroite	
manganite	$HMnO_2$	L,H,S	D	Uncommon, with pyrochroite	Flink(1919)
fluorite	CaF_2	L,J,B	D	Rare, often with barite	Flink(1923), p. 367
OXIDES AND HALIDES (COMPLEX)					
spinel	$(Al,Fe)_2(Mg,Mn)O_4$	L,B	B	Rare skarn product	Magnusson(1930), p. 62
galaxite	Al_2MnO_4	B	B	Red granular with manganosite	Moore(1970a)
magnetite	Fe_2FeO_4	L,B,J,S,H,P	A,B,C,D	Major ore of Fe	Magnusson(1930), p. 31
jacobsite	Fe_2MnO_4	J,L	A	Common ore at J	Flink(1923), p. 369
magnesioferrite	Fe_2MgO_4	L	A	Common on dumps at L	Van de Pijpe Kamp, et al(1969)
hausmannite	Mn_2MnO_4	L,B,J,H,P,S.	A,B,C,D	Major ore of Mn	Magnusson(1930), p. 37
α-vredenburgite	$(Mn,Fe)_3O_4$	L	B	With bixbyite	Mason(1942)
pyrophanite	$MnTiO_3$	L,J,H	C	Deep-red platy in sköl rocks	Magnusson(1930), p. 56
melanostibite*	Mn_2SbFeO_6	S	B	Very rare; deep black	Moore(1968a)
magnetoplumbite*	$PbFe_{12}O_{19}$	L	B	Common in manganophyllite skarn	Aminoff(1925c)
plumboferrite*	$Pb_4Fe_{21}O_{36}$	J	B	Large plates embedded in ore	Aminoff(1925d)
hematophanite*	$Pb_4Fe_3ClO_8$	J	C	Brown plates with plumboferrite, rare	Johansson(1928)
crednerite	$CuMn_2O_4$	L	D	Black thin platy crystals, very rare	
braunite	$MnMn_6SiO_{12}$	L,S,H,P,B	A,B	Major ore of Mn	Flink(1923), p. 368
manganostibite*	Mn_7SbAsO_{12}	B	B	Black grains with sonolite, very rare	Moore(1970a)
catoptrite*	$Mn_{13}Al_4SB_2Si_2O_{28}$	B,S,L	B	Black micaceous prisms with sonolite; ("hematostibiite")	Moore(1970a)
parwelite*	$Mn_5Sb(Si,As)_2O_{10}$	L	C	Resinous brown with långbanite, spessartine	Moore(1968b)
långbanite*	$Mn_4Mn_9SbSi_2O_{24}$	L,S	B	Black hexagonal prisms, var. "ferrostibian"	Moore(1970a)
stenhuggarite*	$Ca_2Fe_2Sb_2As_4O_{15}$	L	C	Orange crystals, very rare	Moore(1970c)
quenselite*	$Pb(OH)\ MnO_2$	L	D	Shiny black tabular, rare	Flink(1925a)
roméite	$(Ca,Pb)\ (OH)Sb_2O_6$	L,J,H	C	Yellow to brown octahedra	Aminoff(1918a), p. 540
bindheimite	$Pb(OH)\ Sb_2O_6$	L,J	C	("weslienite", "atopite")	

TABLE 1 (Continued)

Species	Formula	Location (see text)	Paragenesis	Comment	References
swedenborgite*	$NaSb\ Be_4O_7$	L	C	Colorless "quartzoids", rare	Aminoff(1924)
wickmanite*	$Mn\ Sn(OH)_6$	L	D	Yellow octahedra, rare	Moore and Smith(1967)
sjögrenite	$Mg_6Fe_2(CO_3)(OH)_{16}\cdot 4H_2O$	L,B,J	D	Tan plates with native lead, uncommon	Aminoff and Broomé(1931)
pyroaurite	$Mg_6Fe_2(CO_3)(OH)_{16}\cdot 4H_2O$	L,B,J	D	Dimorph of sjögrenite	Aminoff and Broomé(1931)
wermlandite*	$Ca_2Mg_{14}Al_4(CO_3)(OH)_{42}\cdot 30H_2O$	L	D	Green plates with calcite, rare	Moore(1970d)
thaumasite	$Ca_3(CO_3)(SO_4)Si(OH)_6\cdot 12H_2O$	L	D	Fissure fillings with Pb silicates	Flink(1923), p. 374
blixite*	$Pb_4Cl_2O_3$	L	C	Greenish yellow, rare	Gabrielson, Parwel and Wickman(1953)
mendipite	$Pb_3Cl_2O_2$	L	C	Greenish cleavages, very rare	Goñi and Guillemin(1953)
CARBONATES					
calcite	$CaCO_3$	L,B,H,J,P,S	A,B,C,D	Ubiquitous	Aminoff(1918b)
aragonite	$CaCO_3$	L,H	D	Late stage mineral, rare	Flink(1910)
siderite	$FeCO_3$	L	D	Very rare	Flink(1923), p. 368
cerussite	$PbCO_3$	L,J,P,S,H	D	With native lead	
dolomite	$CaMg(CO_3)_2$	L,B,P,S,H,J	A,B,C	Most common mineral and principal gangue; rare in fissures	Magnusson(1930), p. 63
barytocalcite	$BaCa(CO_3)_2$	L	B	With dolomite in Mn ores	Sjögren(1877)
benstonite	$Ba_3Ca_2Mg(CO_3)_6$	L	B	With calcite in hausmannite ore	Sundius(1965)
norsethite	$BaMg(CO_3)_2$	L	B	Mixed with dolomite in braunite ore	Sundius and Blix(1964)
azurite	$Cu_3(OH)_2(CO_3)_2$	L,J,H,P	D	Oxidation product of copper	Flink(1923), p. 368
malachite	$Cu_2(OH)_2(CO_3)$	L,J,H,P,S	D	Oxidation product of copper	Flink(1923), p. 368
hydrocerussite	$Pb_3(OH)_2(CO_3)_2$	L,H,P	D	With native lead, thin plates	Aminoff(1926)
plumbonacrite*	$Pb_{10}O(OH)_6(CO_3)_6$	L	D	With hydrocerussite, thick hexagonal plates	Moore and Söderquist (1968), unpublished
SULFATES					
anhydrite	$Ca(SO_4)$	L	C	Relatively rare	Igelström(1865)
barite	$Ba(SO_4)$	L,H,J,P,S,B	C,D	Very common fissure mineral. Classic study by Aminoff	Aminoff(1918)
gypsum	$Ca(H_2O)_2(SO_4)$	L,H	D	Relatively rare	Flink(1923), p. 369

TABLE 1 (Continued)

Species	Formula	Location (see text)	Paragenesis	Comment	References
lanarkite	$Pb_2O(SO_4)$	L	D	Brilliant colorless crystals with finnemanite	
ARSENATES, ARSENITES, PHOSPHATES, ETC.					
stolzite	$Pb WO_4$	L	D	Very rare small crystals	Boström(1965)
apatite	$Ca_5(OH,F,Cl)(PO_4)_3$	L,J	C	Rare	Magnusson(1930), p. 66
hedyphane	$(Ca,Ba,Pb)_5 Cl[AsO_4]_3$	L,S,J,H	B,C	Yellowish greasy, most common arsenate	Flink(1923), p. 370
svabite	$CaF[AsO_4]_3$	L,H,J	C,D	Grey prisms, common	Flink(1925b)
mimetite	$Pb_5Cl[AsO_4]_3$	L,H,J	C,D	Yellowish, confused with hedyphane	Lindgren(1880)
tilasite	$CaMgF[AsO_4]$	L	C	Garnet pink granular, common on dump	Aminoff(1923a)
adelite	$CaMg(OH) [AsO_4]$	L,B,J	C	Pale green to yellow granular	Sjögren(1892)
gabrielsonite*	$PbFe(OH) [AsO_4]$	L	D	Black granular, very rare	Moore(1967c)
pyrobelonite*	$PbMn(OH) [VO_4]$	L	D	Red prisms with lead, very rare	Moore(1967c)
berzeliite	$(Ca,Na)_3(Mg,Mn)_2 [AsO_4]_3$	L,S	B,C	Common orange masses	Blix and Wickman(1959)
manganberzeliite	$(Ca,Na)_3(Mn,Mg)_2 [AsO_4]_3$	L,S	B,C	Common deep orange	Blix and Wickman(1959)
caryinite*	$(Ca,Na,Pb)_2 (Mn,Mg)_3[AsO_4]_3$	L,S	B	Orange-brown, confused with berzeliite	Moore(1967d)
ekdemite	$Pb_3Cl_2[AsO_4]$	L,J,H	C	Greenish-yellow, perfect cleavage	Nordenskiöld(1877)
sahlinite*	$Pb_8O_6Cl [AsO_4]$	L	C	Pale yellow bladed masses	Aminoff(1934)
sarkinite	$Mn_2(OH) [AsO_4]$	L,H,B,S	C,D	Pale pink to red, ("pleurasite", "chondrarsenite")	Aminoff(1931), p. 56
eveite*	$Mn_2(OH) [AsO_4]$	L	D	Pale green tabular, very rare	Moore(1968c)
arsenoclasite*	$Mn_5(OH)_4[AsO_4]_2$	L	C	Looks like sarkinite, rare	Aminoff(1931), p. 52
allactite	$Mn_7(OH)_8[AsO_4]_2$	L,B,S,H	D	Pink laths with pyrochroite, ("chloroarsenian")	Flink(1923), p. 371
brandtite	$Ca_2Mn(H_2O)_2[AsO_4]_2$	H,L	D	White tufts with sarkinite	Boström(1965)
akrochordite*	$Mn_4Mg(OH)_4(H_2O)_2 [AsO_4]_2$	L	D	Pink laths, brown hemispheres, very rare	Moore(1967d)
flinkite*	$MnMn_2 (OH)_4[AsO_4]$	H	D	With sarkinite, very rare	Moore(1967a)
retzian*	$\gamma Mn_2(OH)_4[AsO_4]$	B	D	With allactite, very rare	Moore(1967a)
hörnesite	$Mg_3(H_2O)_8[AsO_4]_2$	L	D	White tufts, rare	Gabrielson(1951)
manganhörnesite	$Mn_3(H_2O)_8[AsO_4]_2$	L	D	White tufts, rare	Gabrielson(1951)

TABLE 1 (Continued)

Species	Formula	Location (see text)	Paragenesis	Comment	References
magnussonite	$Mn_5(OH)[AsO_3]_3$	L,B	C,D	Orange to green with trigonite (at L)	Moore(1970c)
finnemanite*	$Pb_5Cl[AsO_3]_3$	L	D	Grey-black hexagonal pyramids	Aminoff(1923b)
trigonite*	$Pb_3Mn[AsO_3]_2[AsO_2(OH)]$	L	D	Brownish-yellow with magnussonite	Flink(1920)
armangite*	$Mn_3[AsO_3]_2$	L	D	Black prisms, very rare	Aminoff and Mauzelius(1920)
synadelphite*	$Mn_9(OH)_9[AsO_4]_2[AsO_3]$	B,L	D	Deep red prismatic with allactite	Moore(1970b)
dixenite*	$Mn_6(OH)_2SiO_4[AsO_3]_2$	L	C	Bronze micaceous with adelite	Wickman(1950)
hematolite*	$Mn_4Al(OH)_2[AsO_4][AsO_3]_2$	B,L	D	Deep red tabular with allactite	Wickman(1950)
nadorite	$Pb[ClSbO_2]$	L,J,H	D	Bright yellow tablets	Aminoff(1931)
perite*	$Pb[ClBiO_2]$	L	D	Yellow tablets	Gillberg(1960)
BORATES					
pinakiolite*	$(Mg,Mn)_2MnO_2[BO_3]$	L	C	Black platy with phlogopite, uncommon	Randmets(1960)
orthopinakiolite*	$(Mg,Mn)_2MnO_2[BO_3]$	L	C	Black prisms with phlogopite, rare	Randmets(1960)
SUBDIVISIONS OF THE SILICATES					
NESOSILICATES				Colorless crystals in manganophyllite skarn	
forsterite	$(Mg,Fe)_2[SiO_4]$	L,B	B,C	Common in Mn-skarns; grey greenish	Flink(1923), p. 372
tephroite	$Mn_2[SiO_4]$	L,H,S,J,P,B	B,C	Tawny grains in dolomite	Flink(1917), p. 134
chondrodite	$Mg_5(OH)_2[SiO_4]_2$	L,B	B	With chondrodite	Magnusson(1930), p. 62
clinohumite	$Mg_9(OH)_2[SiO_4]_4$	L	B	Brown massive ("hydrotephroite")	Moore(1970e)
leucophoenicite	$Mn_7[SiO_4][(SiO_4)(OH)_2]$	P	C		
sonolite	$Mn_9(OH)_2[SiO_4]_4$	L,B	B,C	Brown complex crystals with sarkinite	Moore(1967b)
manganohumite*	$Mn_7(OH)_2[SiO_4]_3$	B	C	Brown grains with catoptrite	Moore(1970e)
welinite*	$MnMn_3O_3[SiO_4]$	L	C	Black with sarkinite	Moore(1967b)
andradite	$Ca_3Fe_2[SiO_4]_3$	L,H,J,S,P,B	B,C	Common skarn product	Magnusson(1930), p. 34
spessartine	$Mn_3Al_2[SiO_4]_3$	L,H,J,S,P,B	B,C	Minor garnet in skarns	Moore(1968b)
andalusite	$Al_2O[SiO_4]$	L,H,J	B	Constitutent of leptites	Magnusson(1930), p. 64

TABLE 1 (Continued)

Species	Formula	Location (see text)	Paragenesis	Comment	References
sillimanite	$Al_2O[SiO_4]$	L,H,J,S	B	Constituent of leptites	Magnusson(1930), p. 64
SOROSILICATES					
idocrase	$Ca_{10}Mg_2Al_4$ $(OH)_4\ [Si_9O_{34}]$	J,L	B	Relatively rare. Variety "cyprine"	Flink(1923), p. 372
epidote	$Ca_2(Al,Fe)Al_2O(OH)$ $[Si_2O_7]\ [SiO_4]$	L,J,S,P,H,B	B,C	Common skarn and slickenside product	Flink(1923), p. 371
piemontite	$Ca_2(Al,Mn)Al_2O(OH)$ $[Si_2O_7]\ [SiO_4]$	J,S,L	C	Brick-red bladed	Magnusson(1930), p. 70
julgoldite*	$Ca_2FeFe_2(OH)_2(H_2O)$ $[Si_2O_7]\ [SiO_4]$	L	D	Black bladed with apophyllite	Moore(1970f)
barylite	$BaBe_2\ [Si_2O_7]$	L,J	C	Like barite, but much greater hardness	Aminoff(1923c)
aminoffite*	$Ca_6(BeOH)_4[Si_3O_{10}]_2$	L	D	Very rare	Hurlbut(1937)
harstigite*	$MnCa_6(Be_2OOH)_2$	H	D		
	$[Si_3O_{10}]_2$			Very rare	Moore(1968d)
kentrolite	$Pb_2(MnO)_2\ [Si_2O_7]$	L,P,H,J	B		
melanotekite	$Pb_2(FeO)_2\ [Si_2O_7]$	L,P	B	Common, dense black massive	Flink(1917), p. 136
nasonite	$Pb_6Ca_4Cl_2\ [Si_2O_7]_3$	L	C,D	Black, like kentrolite	Flink(1917), p. 138
ganomalite*	$Pb_6Ca_4(OH)_2$	J,L	B	Dense pearly white curved plates	Aminoff(1916)
	$[Si_2O_7]_3$			Colorless grains. Common skarn at J	Aminoff(1916)
barysilite	$Pb_8Mn[Si_2O_7]_3$	L,H,P,J	C		
ericssonite*	$Ba_2MnFeO(OH)$	L	B	Pink platy masses	Aminoff(1918a)
	$[Si_2O_7]$			Rare deep brown plates in tephroite-schefferite skarn	Moore(1970g)
orthoericssonite*	$Ba_2MnFeO(OH)$	L	B		
	$[Si_2O_7]$			Intergrown with ericssonite	Moore(1970g)
welshite*	$Ca_2Mg_4SbFeO_2$	L	C		
	$[Be_3Si_3O_{18}]$			Rare deep brown prismatic with adelite	Moore(1968), unpublished
CYCLOSILICATES					
cordierite	$Mg_2Al_3[AlSi_5O_{18}]$	L,J,H	B	Infrequent rock-former	Magnusson(1930), p. 66
hyalotekite*	$PbBaCa_2(BO_2F)$ $[Si_6O_{15}]$	L	C	Rare white massive with barylite	Lindström(1887)

TABLE 1 (Continued)

Species	Formula	Location (see text)	Paragenesis	Comment	References
margarosanite	$Pb(Ca,Mn)_2[Si_3O_9]$	L	C	Uncommon large bladed masses	Aminoff(1918a)
kainosite	$Ca_2Y_2(CO_3)$	B	C	Only one known crystal	Nordenskiöld(1886)
	$[Si_4O_{12}]\cdot H_2O$				
jagoite*	$Pb_8FeO_2(Cl,OH)_3$	L	C	Rare green micaceous with melanotekite	Blix, Gabrielson and Wickman(1957)
	$[Si_3O_9]_3$				
INOSILICATES				Ubiquitous in Fe skarns	Magnusson(1930), p. 62
diopside	$CaMg\ [Si_2O_6]$	L,H,J,S,P,B	B,C	Common in Mn-Fe skarns	Flink(1923), p. 373
schefferite	$Ca(Mn,Mg,Fe)$	L,H,J,S,P	B,C		
	$[Si_2O_6]$			Common in Mn skarns	Sundius(1931)
rhodonite	$CaMn_4\ [SiO_3]_5$	L,H,S,P,J,B	B,C	Much rarer than rhodonite	Sundius(1931)
bustamite	$(Ca,Mn)_2[Si_2O_6]$	L,H,S	B	Pink bladed aggregates	Aminoff(1918a)
inesite	$Ca_2Mn_7(OH)_2(H_2O)_6$	L,H,J,S	C,D		
	$[Si_{10}O_{28}]$			Fibrous with Pb silicates	Flink(1923), p. 373
pectolite	$NaCa_2H[Si_3O_9]$	L,J	C	Ubiquitous Fe silicate skarn, var. "actinolite"	Magnusson(1930), p. 62
tremolite	$Ca_2Mg_5(OH)_2[Si_8O_{22}]$	L,H,P,J,S,B	B,C	Common in Mn silicate skarns	Magnusson(1930), p. 62
richterite	$(Na,Ca)Ca_2(Mg,Mn)_5$	L,H,P,J,S	B,C		
	$(OH)_2[(Si,Al)_8O_{22}]$			Rare black prisms with schefferite	Moore(1969)
joesmithite*	$PbCa_2Mg_4Fe(OH)_2$	L	C		
	$[Si_6Be_2O_{22}]$				
PHYLLOSILICATES				Common skarn product, var. "manganophyllite"	Magnusson(1930), p. 62
biotite	$K(Mg,Mn,Fe)_3(OH)_2$	L,H,J,P,S,B	B		
	$[AlSi_3O_{10}]$			Constituent of leptites and sköls	Magnusson(1930), p. 65
muscovite	$KAl_2(OH)_2[AlSi_3O_{10}]$	L,H,J,P,S,B	B	Skarn product in dolomite	Magnusson(1930), p. 62
phlogopite	$KMg_3(OH)_2[AlSi_3O_{10}]$	L,H,J,P,S	B,C	Slickensides and alteration of skarns	Magnusson(1930), p. 93
serpentine	$(Mg,Fe)_6(OH)_8\ [Si_4O_{10}]$	L,H,J,P,S	B,C,D		
talc	$Mg_3(OH)_2[Si_4O_{10}]$	L,H,J,P,S,B	C	Minor alteration product of skarns	Flink(1923), p. 372
gonyerite*	$Mn_6(OH)_8[Si_4O_{10}]$	L	C	Brown radial aggregates with inesite	Frondel(1955)
caryopilite*	$Mn_6(OH)_8[Si_4O_{10}]$	H,L	D	Replaces rhodonite; related to bementite	Hamberg(1889)
bementite	$Mn_{14}(OH)_{14}[Si_2O_5]_7$	L	C,D	Brown scales, needs further study, var. "ektropite"	Aminoff(1918a), p. 545

TABLE 1 (Continued)

Species	Formula	Location (see text)	Paragenesis	Comment	References
pennine	$(Mg,Al)_6(OH)_8[(Si,Al)_4O_{10}]$	L	C	Pink plates scattered in dolomite	Eckermann, H. von(1927)
ganophyllite	$NaMn_3(OH)_4[(Si,Al)_4O_{10}]$	H,S	C	Brown brittle platy	Hamburg(1890)
oeblingite	$Pb_2Ca_7(OH)_9(SO_4)_2[Si_2O_5]_3$		C	Locally abundant pink platy, var. "lamprophane"	Blix(1931)
molybdophyllite*	$Pb_8Mg_{10}(CO_3)_2(OH)_8[Si_9O_{30}]$	L	C	Colorless plates, needs further study	Aminoff(1918a)
apophyllite	$KCa_4F[Si_4O_{10}]_2 \cdot 8H_2O$	L,H	C,D	Fissure-filling mineral	Flink(1917)
prehnite	$Ca_2Al(OH)_2[AlSi_3O_{10}]$	L,J	C,D	Relatively rare pale green radial	Magnusson(1930), p. 93
neotocite	hydrated manganese silicate	L,H,J,P,S	D	Replaces rhodonite, colloidal black, var. "hisingerite"	
	TEKTOSILICATES				
phenakite	$Be[BeSiO_4]$	L,J	C	Rare colorless with trimerite	Aminoff(1931)
trimerite*	$CaMn_2[BeSiO_4]_3$	L,J,H	C	Pale pink complex crystals, rare	Flink(1923), p. 372
banalsite	$BaNa_2[Al_2Si_2O_8]_2$	L	C	Pink massive, rare	
celsian	$Ba[Al_2Si_2O_8]$	L,J	B	Relatively rare in skarn	
hyalophane	$(K,Ba)[(Si,Al)_4O_8]$	L,J	B	Uncommon in Mn-rich skarns and sköls	Magnusson(1930), p. 70
microcline	$(K,Na)[AlSi_3O_8]$	L,H,P,S,J,B	B,C	Skarn product and constituent of leptites	Magnusson(1930), p. 70
plagioclase	$(Ca,Na)[Si,Al)_4O_8]$	L,H,P,S,J,B	A,B	Major rock-former	Magnusson(1930), p. 70
scapolite	$Na_8(Cl_2,SO_4)[AlSi_3O_8]_6$	L,J	B	Skarn product	Magnusson(1930), p. 64
harmotome	$Ba[Al_2Si_6O_{16}] \cdot 6H_2O$	L	D	Rare in fractures in leptite	
chabazite	$(Ca,Na_2)[Al_2Si_4O_{12}] \cdot 6H_2O$	L	D	In fractures in leptite	
natrolite	$Na_2[Al_2Si_3O_{10}] \cdot 2H_2O$	L	D	Fractures in sköl rocks	
thomsonite	$NaCa_2[Al_3Si_2O_{10}]_2 \cdot 5H_2O$	L	D	Fractures in sköl rocks	

periclase (MgO), indicate temperatures whose maxima were at least 650°C. The fissure and hydrothermal vein assemblages range from somewhat lower temperatures to room temperature, with an especially diverse suite of species occurring at the low-temperature range. This is due to the relative stability of water molecules and hydroxyl groups at lower temperatures, which bond as ligands to the transition metals and contribute to a variety of coordination complexes, as well as the accompanying phenomenon of ligand stereoisomerism, as discussed by Moore (1970h). Consequently, point 8 is understandable. ***Second,*** manganese exhibits a remarkable crystal-chemical behavior: it can occur in the valence states Mn^{2+}, Mn^{3+} and Mn^{4+} and in coordination numbers ranging from four to eight with respect to oxygen. Manganese is crystal-chemically one of the most diverse elements in the periodic system, possessing greater diversity than the more abundant iron. This is why manganese occurs in so many species in the mineral kingdom.

Point 9 is more difficult to discuss even though these cations, in conjunction with point 7, would lead to a mineralogical diversity of unusual complexity since their mutual association in a lithophile environment is unusual. This fragment of the puzzle is difficult to decipher since it was obliterated during the ensuing thermal metamorphic and metasomatic processes. I would conjecture that such an association is indicative of a proto-ore which also included subordinate amounts of cations such as Sb^{5+} and As^{5+} which precipitated through complex formation under similar conditions. Some oxides and sulfides such as stibnite, antimony oxides, realgar and orpiment could have been deposited in limited amount by fumarolic activity. Selective replacement of carbonates by antimony oxides is well-documented. The author has seen extensive deposits of this type in the Sierra de Catorce, State of San Luis Potosí, Mexico. The range also includes large deposits of manganese oxides of low grade; though not in immediate relation with the antimony oxide deposits, the manganese ores occur in association with beds of carbonates of similar character. Beryllium was certainly introduced in limited amount at a later stage during the granitic intrusive activity and was not originally associated with the proto-ores. The observed beryllium minerals post-date the period of skarn formation.

Intense thermal metamorphism at shallow depths would lead to oxidation of any sulfides, followed by gross recrystallization. Relatively immobile cations, such as Mn^{2+}, Mn^{3+}, Fe^{2+} and Fe^{3+} remained, leaving their impressions of the original sedimentary aspect of the proto-ore, occurring as granular bands of the oxide ores and as pod-like replacement units in the limestone. Antimony, arsenic, and lead, mobile and reactive at high temperatures, migrated outward and reacted with the silicate-rich enclosing masses, forming a spectrum of unusual lead silicates, arsenates, arseniosilicates, antimonates and antimoniosilicates. It is worthy of note that some cations which would usually occur together with lead, antimony and arsenic as sulfides, such as zinc and copper, are very rare at Långban. It is unlikely for this reason that these deposits resulted from the oxidation of pre-existing sulfide ores, since the prevailing cationic distributions are grossly unlike those in any typical sulfide ore deposit.

Much has been said about the relationship,—more pointedly, kinship—between the Långban and Franklin, New Jersey deposits. There seems to be little ground in support of a common heritage since the differences are the greatest where we would expect them to be the least. Similarity in the mineralogy at the final stage of metamorphism between deposits does not presuppose a common origin of the proto-ore: it merely means that similar reaction temperatures and compositions were encountered during metamorphism. However, even here the differences between the two deposits are too great to be ignored. At Långban-type deposits the iron and manganese ores are differentiated, at Franklin, they occur together (along with zinc) in the spinel franklinite. The Franklin deposits have so far not revealed any equivalent of the leptites. Even the lead silicates at Franklin have a texture and paragenesis distinct from the lead silicates at Långban.

Point 10 is interesting, since all the Långban-type deposits, with the exception of Långban, are very small. Even Långban is small in a relative sense: up until 1929, already past the heyday of mining activity, accumulatively 680,000 tons of iron and manganese ores had been mined. This amounts to a cube approximately 200 feet on an edge, a very small dimension for typical present-day iron and manganese oxide ore reserves. It is remarkable that the crystal chemistries of these deposits are so similar, even to the level of the textures of the ores and skarns and the mineral parageneses, and we must conclude that their origins were also very similar.

The Långban-Type Orebodies

Harstigen. Harstigen, near Persberg, was a small deposit mined in the 19th Century. It consisted of two parallel ore bands embedded in dolomites and associated with potassic leptite. To the east were the manganese ores and the iron ores appeared on the west flank. The manganese silicate skarns were in contact with the iron silicate skarns, the former consisting of hard compact masses of richterite-manganophyllite-schefferite-garnet-rhodonite. Only 153 tons of manganese ore was mined and the small narrow excavation can still be seen. Fractures in the skarns allowed passage of retrograde solutions and subsequent crystallization of several basic manganese arsenates and lead silicates. The rhodonite which crystallized in vuggy cavities in the vicinity of the fissures occurs as clear crystals of great beauty up to one inch across and can still be collected on the moss-covered dumps. Flinkite and harstigite are two rare species peculiar to this locality.

Pajsberg. Pajsberg was another small deposit situated near Harstigen and mined about the same time. The manganese ore consisted entirely of banded granular hausmannite in dolomite. Rhodonite, schefferite and manganophyllite form the associated skarns. The iron ore, which was situated stratigraphically beneath the manganese ore, consisted of quartz-bearing hematite, thermally metamorphosed in part to magnetite, and enclosing diopside-tremolite-andradite skarns. Native lead and pyrochroite were first discovered at Pajsberg, where they occurred in late stage fracture systems. Approximately 3,500 tons of manganese ore and 8,500 tons of iron ore were recovered.

Nordmarks Odalfält. Nordmarks orefield consisted of a steeply dipping hook-shaped mass of ore dammed up on the convex side by leptite and embedded in dolomite on the concave side. Dikes of lamprophyres cut the orebodies, which consisted mainly of iron ores. The manganese ores were small local pods in the dolomite and consisted of hausmannite, manganosite and pyrochroite. Two mines—the Eastern Moss mine and the Brattfors mine—intersected these pods at a depth of about 140 meters. The pyrochroite ore, a retrograde product derived from manganosite, contained numerous pockets lined with ruby-red crystals of rare basic manganese arsenates and arsenites such as hematolite, synadelphite, allactite and retzian. These attractive species, often crystallized upon a background of snow-white barite, were collected by Sjögren (1878) who described their paragenesis and morphology in considerable detail. The Brattfors mine is the type locality for catoptrite, $Mn_{13}Al_4Sb_2Si_2O_{28}$,

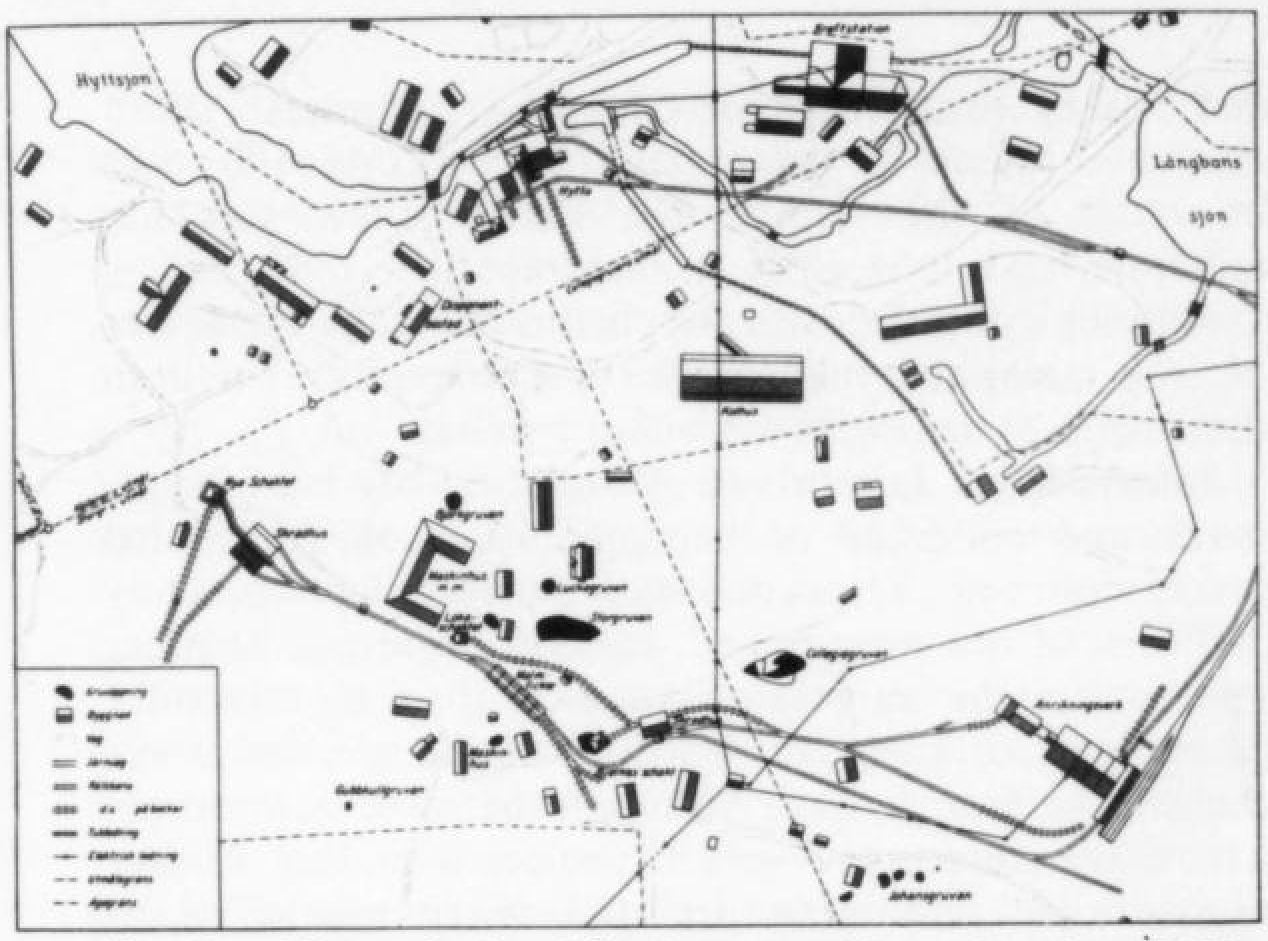


Fig. 2. Plan of the Långban workings in the 1920s. The sketch is from Magnusson (1930). Translation of legend: mine opening; building; road; railroad; tram; ditto, on trestle; pipeline; electric line; mine boundary; property boundary. Other translations: hytta = smelter; skrädhus = mine shed; schakt = shaft; malmfickor = ore bins; disponent bostad = mine offices; kraftstation = power station; kolhus = coke and coal storage; anrikningsverk = mill.

Fig. 1. Route and location map of the Långban-type deposits. The key deposits are circled.

and manganostibite, Mn_7SbAsO_{12}, unusual skarn minerals. Masses of decomposed pyrochroite still occur in some of the dumps but the unstable arsenate minerals have long since disintegrated.

Although the deposits supplied significant quantities of iron ores, the manganese ores were too small in dimension to be of any economic value.

Jakobsberg. Jakobsberg is one mile south of Nordmark and consisted of hausmannite-jacobsite banded ore in dolomite, associated with potassic leptites. Only 380 tons of ore were mined, but Jakobsberg is of great interest to the mineralogist since it is a miniature counterpart of Långban. Portions of the ore and skarn can still be seen *in situ*. Although the mine is presently a garbage dump, a research project including further exposure of remaining ore and skarn would reveal much information of the character of Långban-type deposits. Black platy masses of plumboferrite occurred locally with hausmannite and minor native copper. Hematophanite, the only known specimen of which was lost many years ago, was "rediscovered" recently on the moss-covered dumps. The skarns consist of dense schefferite-garnet-manganophyllite with large quantities of ganomalite (a lead silicate) occurring at one location. Although the dump specimens are unspectacular, they are classic examples of banded reaction skarns involving minor amounts of elements not usually considered lithophilic, such as lead and copper.

Sjö Mine. The Sjö mine, near the village of Grythyttan in the neighboring province of Örebro, is another mineralogical curiosity. Knowledge of its complex mineralogy was provided by the eccentric mineralogist-chemist L. J. Igelström. In the 1880s, he named no less than twenty "new" species such as basiliite, chloroarsenian, ferrostibian, lamprostibian, etc. Recent study by the author reveals that nearly all these "species" are in fact mixtures of more properly defined species such as pyrochroite, allactite, berzeliite, caryinite, långbanite, etc. The deposit occurs on the south-east shore of Söder Älgen Lake and can be reached by rowboat. The ores consisted of hausmannite and braunite adjacent to hematite-quartz ("bloodstone") ore within tightly banded tephroite-rhodonite-schefferite-garnet skarns in dolomite bounded by leptite. The dumps still yield masses of berzeliite and caryinite (the variety "arseniopleite"). The rare mineral, melanostibite, Mn_2FeSbO_6, is peculiar to this locality.

The orebody was very small and only a few tons of ore were mined.

THE LÅNGBAN MINES

The Långban mines and the neighboring mines at Gåsborn possess a very rich natural as well as technical-economic history, so remarkable in fact that an extensive book by Carlborg (1931) is devoted to this very subject. Figure 2 shows the layout of the Långban workings as of the 1920s.

The iron ores along with small lenses of sulfide ores were apparently discovered during the period of the Black Death, about 1350. Actual mining operations in the Långban complex began in 1711, at the location which was eventually called the Stor (= large) mine. Its present remnant is an opening, largely caved in and inaccessible. In 1725, the Kollegii (= collegium) mine was begun and was operated intermittently until the 1870s when further access to the ore proved impractical. In 1877 the Nya (= new) shaft was sunk and remained the central access to the underground workings and the shaft from which ore was hoisted throughout the future mining history of Långban. Other shafts, the Bjelkes and Loka shafts, sunk in 1882 and 1905 respectively, afforded access for the water pumps, ventilation and personnel.

The history of mining at Långban was fraught with uncertainties. The best years were certainly 1880-1930. During this time, up to 75 workers were employed, averaging 23 underground, 17 above ground, 16 in the machine shops and 20 in the concentration mill. From the beginning through 1929, over 540,000 tons of iron ore and 160,000 tons of manganese ore were mined. Although the iron ore contributed only a fraction of a percent of Sweden's production, the manganese ore accounted for up to 60% of total national production in the 1920s, doubtless leading to the popular misconception that Långban was essentially a manganese mine. Typical prime iron ore ran 60% iron by weight, whereas prime manganese ore ran 38% manganese by weight.

The manganese ores did not assume importance until the 1870s, since before that time they were overlooked or mistaken for magnetite. According to Sjögren (1910),

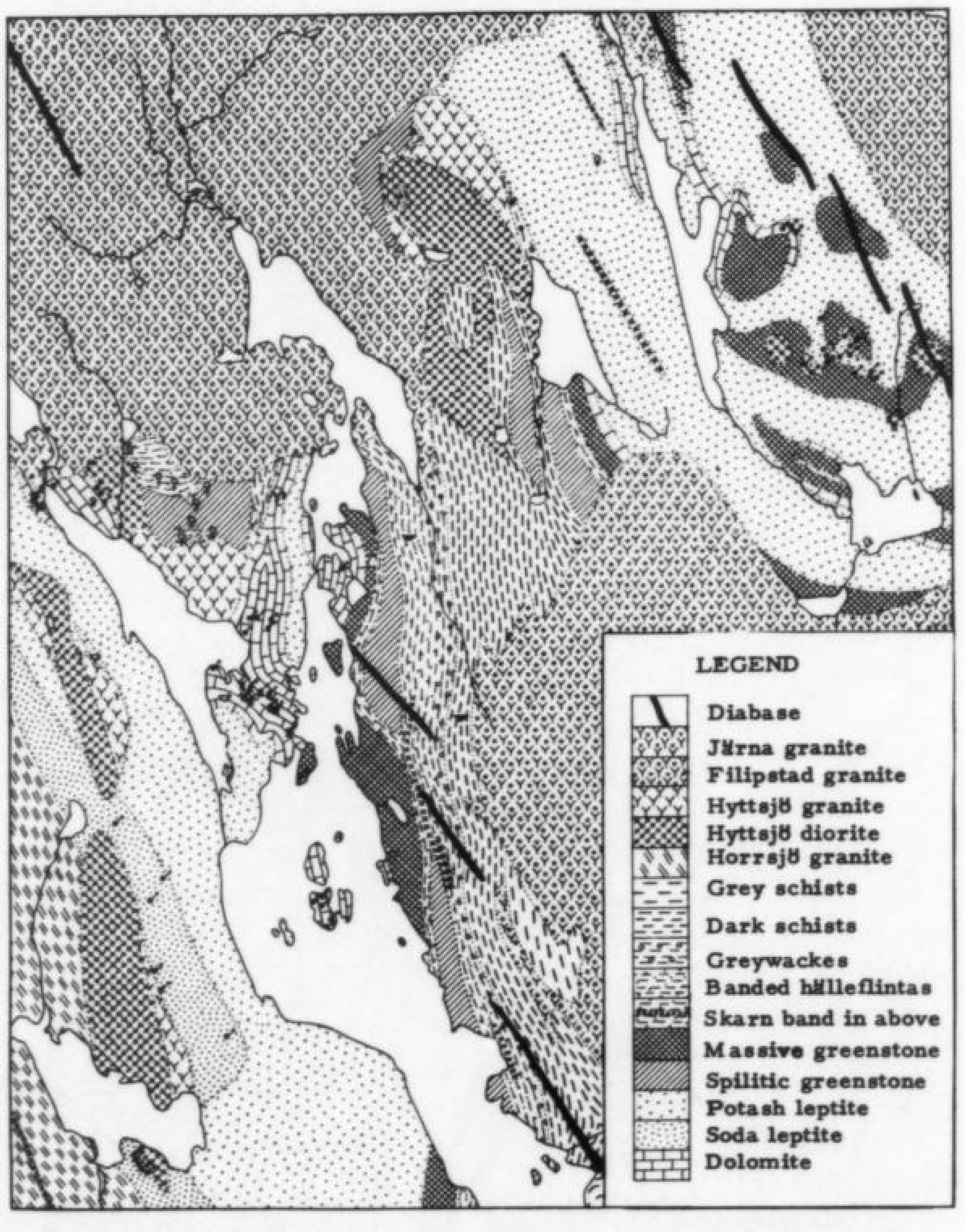


Fig. 3. Surface geology of the Långban mines. The ore deposits are shown as the alchemical symbols for iron and manganese. The Långban mines appear at the densest clustering of the symbols on the isthmus west of the word "Legend." The Gåsborn mines are to the north of that word in the dolomite. The map is from Magnusson (1930).

TABLE 2.
ANALYSIS OF BRAUNITE-HAUSMANNITE ORE AND ITS INTERPRETATION

	1	2	3	4	5	6	7
SiO_2	2.49	41	-	-	-	-	-
TiO_2	0.01	-	-	-	-	-	-
Al_2O_3	0.21	2	2	2	2	2	2
Fe_2O_3	0.47	3	3	3	3	3	3
Mn_2O_3	40.62	257	134	-	-	-	-
MnO	12.44	175	134	-	-	-	-
MgO	5.56	138	138	138	95	81	68
CaO	14.65	261	261	261	261	261	-
BaO	5.68	37	37	37	-	-	-
PbO	1.34	6	6	6	-	-	-
CuO	0.03	-	-	-	-	-	-
Na_2O	0.04	1	1	1	1	1	1
K_2O	0.02	-	-	-	-	-	-
As_2O_5	0.27	1	1	1	1	1	1
Sb_2O_5	0.04	-	-	-	-	-	-
P_2O_5	0.03	-	-	-	-	-	-
CO_2	15.72	360	360	360	274	274	-
H_2O	0.26	14	14	14	14	-	-
SO_3	0.05	1	1	1	1	1	1
	99.93	1297	1092	824	652	624	76

[1] Weight percentage. Analysis of Bygdén in Magnusson (1930).

[2] Molecular fraction × 1000.

[3] Removal of braunite, $Mn^{2+}Mn_6^{3+}SiO_{12}$. The weight percentage of braunite is 28.8%.

[4] Removal of hausmannite, $Mn_2^{3+}Mn^{2+}O_4$. The weight percentage of hausmannite is 30.7%.

[5] Removal of norsethite, (Ba, Pb) $Mg(CO_3)_2$. The weight percentage of norsethite is 10.8%.

[6] Assuming $H_2O = OH^-$ in brucite, $Mg(OH)_2$. The weight percentage of brucite is 0.9%.

[7] Removal of calcite, (Ca, Mg) $(CO_3)_2$, as the remaining carbonate. Its weight percentage is 27.1%. The final remainder is periclase with weight percentage 2.7%.

"The occurrence of braunite was not established before 1878; it had earlier been mistaken for magnetite and some of the so-called magnetite of Långban had consequently not enjoyed a particularly good reputation."

The mines were worked to a depth of 750 feet. The ores, which occurred as irregular pod-like concentrations, were mined in stopes of greatly varying dimension and regularity. These stopes were fondly given such location names as "Hindenburg," "Japan," "Amerika," "Norrbotten," "Allaktitorten" (allactite location), etc.

By modern standards, Långban (often called Långbanshyttan or "Långban's smelter"; compare with Franklin Furnace!), was a small mine. Discoveries throughout the world of large sources of manganese ore in the 1930s combined with gradual exhaustion of the Långban ore reserves led to the abandonment of iron and manganese ore mining in 1946. Today, the mine still operates, but only for the pure dolomite, and no ore has subsequently been encountered. The only testament to the remarkable ores and mineralogy in the area are the surficially blackened waste heaps which still yield unusual species to the fortunate and perspicacious collector.

The detailed geology of Långban was the subject of many papers, the most outstanding of which are those of Sjögren (1910) and Magnusson (1930). N. H. Magnusson, who still remains an influential figure in the interpretation of Central Swedish iron ore deposits, also co-authored with P. Geijer a voluminous monograph on the geology of these deposits (Geijer and Magnusson, 1944). This treatise, written in the Swedish and describing over 1500 deposits, stands out as one of the most noteworthy achievements in descriptive economic geology.

The geology of Långban is very complex and can only be briefly discussed. Figure 3 presents a geological map of the Långban surface geology and interested readers are further referred to Magnusson (1930), which includes a summary in English. The rocks belong to four periods, in order of decreasing age: the supercrustals, the older Archean granites and greenstones, the younger Archean granites and greenstones, and diabase dikes. The supercrustal rocks consist of leptites, spilitic greenstones, and dolomitic marbles. The leptites, which are relicts intimately related to the ore genesis, correspond to metamorphosed volcanic flows and tuffs. The leptites occur as bands and lenses intermingled with the dolomite. Intrusion of the older Horrsjö granite compounded with contemporaneous folding contributed to the profound metamorphism of the ash flows, proto-ores and limestone into leptite, recrystallized ores and marble. The ores are wholly enclosed in the limestone, in places dammed up by the leptites. Intrusion of younger granites derived from a common parent magma—the Filipstad, Järna and Hyttsjö granites—contributed to a further stage of metamorphism.

Earliest formed products of thermal metamorphism were recrystallized ores derived from the proto-ores (here postulated as basic ferrites and manganates, such as goethite, psilomelane and hollandite), which upon reaction with residual and introduced siliceous matter produced the skarns. In a similar manner, the tuffs and lava flows were converted to leptites. Later metamorphism led to metasomatic exchange between skarns and leptites when, according to Magnusson, SiO_2, Al_2O_3, K_2O and Na_2O were added to the skarns by subtraction from the leptites and MgO, CaO, FeO and MnO were added to the leptites by subtraction from the skarns. Throughout this process, water was introduced. The rocks, intermediate to the skarns and leptites, are called "sköls" and consist of biotite-rich rocks displaying a schistose texture.

Prograde metamorphism of the hematite ores led to the formation of magnetite, *viz.* hematite + quartz + impure dolomite → magnetite + iron silicate skarn + pure dolomite

and

braunite + quartz + impure dolomite → hausmannite + manganese silicate skarn + pure dolomite.

Consequently, it is generally observed that magnetite replaces hematite and hausmannite replaces braunite, with the hematite and braunite occurring in the inner portion of the ore pods.

The remarkable separation of ores and skarns of iron from those of manganese led Sjörgren (1910) to conclude that the iron ores were of a different age than the manganese ores. Magnusson (1930) does not agree and believes the separation to have resulted from the surface oxidation of ore solutions in what were apparently shallow deposits. I have earlier suggested a related mechanism for such a separation, which must have occurred during the earliest stage of proto-ore deposition.

The skarns are quite characteristic markers of their associated ores. Iron skarns consist of brown-black garnet (andradite), diopside and tremolite. The manganese skarns consist of the pyroxenoid rhodonite, the olivine tephroite, yellow garnet (spessartine), schefferite (manganoan diopside), richterite (alkali manganoan tremolite) and manganophyllite (manganoan biotite). Rarely do the iron and manganese skarns come in contact with each other; when they did, extensive exchange of iron and manganese took place, especially between the garnets and pryoxenes. Since Långban has been a cornucopia for rare minerals, the more important rock-forming minerals have not received the attention they deserve, and much research remains to be done on the skarns. Rarely, the manganese ores came in contact with the iron ores, which resulted in the formation of jacobsite, $Fe_2^{3+}Mn^{2+}O_4$, a common ore at Jakobsberg. It is predicted that the $Mn^{2+}Fe^{3+}$ garnet (calderite) should occur in its associated skarn but so far no systematic studies have been undertaken on the garnets at Långban.

New light is being shed on such skarn assemblages through recent finds elsewhere. Recently, Klein (1966) and Babcock (1970) have described mixed Fe-Mn silicate skarns in iron formations of metamorphic grade somewhat lower than at Långban. Babcock (pers. comm.) presented the author with a remarkable specimen from the Champion Iron Mine, Champion, Michigan, representing an unusually high grade of skarn within the Marquette Range Iron Formation. It consists of grains of jacobsite, magnetite and calderite surrounded by rhodonite, kutnahorite and schefferite, with textures closely mimicking typical Långban mixed Fe-Mn silicate skarns. Quite remarkable is the presence of small quantities of such unusual minerals as powellite and molybdenite. Suffice it to say that the Långban-type ore and skarn assemblages are not unique but are unusual only in their coarse-grained appearance. The skarns and ores make up only a small fraction of the total species described from the Långban-type deposits and it now remains to discuss the more peculiar aspects of the Långban geochemistry and mineralogy, which make the locality so unusual.

GEOCHEMISTRY AND MINERALOGY

Publications by Aminoff (1918a, 1931) Magnusson (1930) and Mason (1943) presented aspects of the distribution and paragenetic settings of the chemical elements at Långban. Magnusson (1930) has proposed four principal paragenetic settings for the Långban deposits and these are broadly enough based that I shall apply them to the other deposits as well. To period A, he places the primary ores and earliest skarns. The bulk of the skarn products belong to period B. The period of "sköl" formation (including local invasion of some sulfides) corresponds to period C and period D corresponds to the low-temperature fissure-filling or hydrothermal products.

Table 3, a crude outline of the elemental frequencies at Långban, reveals 32 elements which are present in major quantities in at least one mineral species. Quantitative estimates of elemental frequencies are most difficult to obtain, since a bias factor is present which results from the selective preservation of the rarer species and the lack of any systematic study of trace element distributions among the species of greater frequency, such as the carbonates, ores and skarns. The major rock-forming elements—H, C, O, Mg, Al, Si, Ca, Na and K—predominate along with the ore elements Fe and Mn. In terms of the atomic abundances in the greater than 10% range, the Långban ore deposit is not unusual. It is an interesting fact that, although Fe and Mn occur in practically equal frequency at Långban, no less than 60 distinct species containing major manganese are known whereas only about 25 species containing major iron have been recorded. This is a consequence of the great crystal-chemical diversity of manganese, resulting from its greater crystal radius and ability to occur in a great variety of coordination complex clusters, involving oxygen, over a wide range of temperature.

What is unusual are the elemental abundances in the 1-10% range, including As, Ba and Pb. Arsenic occurs in the manganese-rich skarns, substituting for silicon and occurring in its own species of which hedyphane, caryinite and berzeliite are noteworthy. Locally abundant masses of tilasite, $CaMgF(AsO_4)$, many tons in weight, were once encountered in the Långban workings and large granular masses of garnet-orange color can still be seen on the dumps. In the low temperature open fissures, a great diversity of basic manganese arsenates and arsenites occur in association with a highly reduced assemblage including barite, native lead and pyrochroite. These arsenates are believed to have formed by the digestion of pyrochroite by retrograde solutions rich in the $(AsO_4)^{3-}$ anion. Typical species in this assemblage include allactite, synadelphite, sarkinite, hematolite, and trigonite. An assemblage, apparently representative of a higher temperature of formation, includes adelite, tilasite, sarkinite, and arsenoclasite occurring with tephroite, sonolite and barite.

Lead, likewise, occurs in species representative of a wide temperature interval. It occurs in the carbonates associated with the manganese ores, but is particularly conspicuous in the manganese-rich skarns and sköls, occurring in the minerals magnetoplumbite, hedyphane and caryinite and as the lead-bearing silicates kentrolite, melanotekite and ganomalite which sometimes occurred locally in considerable abundance. Fissure-filling assemblages of the C- and early D-periods consisting of platy lead silicates as sole minerals include margarosanite, barysilite and roeblingite. In the low temperature fissure assemblages of the late D-period, lead occurs overwhelmingly as the native element in masses up to several hundreds of pounds in weight, along with barite and pyrochroite. Complex arsenites of lead, such as finnemanite and trigonite, are rare and very local in occurrence.

Barium occurs conspicuously in two associations: as

TABLE 3.

FREQUENCIES OF CHEMICAL IONS AT LÅNGBAN IN IONIC FRACTIONS.

Letters A,B,C,D refer to the paragenetic classification of Magnusson (1930))

	>10%	1-10%	<1%
H^+	D	B,C	A
Be^{2+}			C
B^{3+}			C
C^{4+}	A,B,C,D		
O^{2-}	A,B,C,D		
F^-		C (locally, in tilasite)	C,D
Na^+		B,C	A,D
Mg^{2+}	A,B	C	D
Al^{3+}		A,B,C	D
Si^{4+}	A,B,C	D	
P^{5+}			C
S^{6+}		D (in barite)	C
Cl^-		C	B,D
K^+		B,C	D
Ca^{2+}	A,B,C,D		
Ti^{4+}		B	C
V^{5+}			D
Mn^{2+}	A,B	C,D	
Mn^{3+}	A,B		C,D
Fe^{2+}	A,B,C	D	
Fe^{3+}	A,B,C	D	
Cu^0			D
Cu^{2+}			C,D
Zn^{2+}			B,C
Ge^{4+}			C
As^0			D
As^{3+}			D
As^{5+}		B,C (locally, in tilasite)	A,C,D
Mo^{4+}			C
Y^{3+}			D
Ag^0			D
Ag^{1+}			C
Sn^{4+}			D
Sb^{3+}			D
Sb^{5+}		C	A,B,D
Ba^{2+}		B,D (in barite)	C
$R.E.^{2+,3}$			C
W^{6+}			C,D
Pb^0		D	
Pb^{2+}			B,C
Bi^0			D

carbonates with the manganese ores and as the ubiquitous sulfate, barite, in the low temperature fissure systems. It is also noted in skarns, as a constituent of hedyphane and magnetoplumbite, and in a few rare silicates such as ericssonite and hyalotekite.

Antimony is noteworthy, occuring throughout all paragenetic settings as a minor element which has contributed to the formation of several exotic species. It occurs in the Sb^{5+} state and is crystallochemically akin to Fe^{3+} in its behavior, occurring as $(SbO_6)^{7-}$ octahedra. Charge difference accounts for the unusual behavior of antimony with respect to iron in these assemblages (Moore, 1968a). The antimoniosilicates, långbanite and catoptrite, are examples of B-period minerals. Roméite and its varieties "weslienite" and "atopite" occur in C-period assemblages, and in the low temperature fissure assemblages, antimony occurs in the minerals nadorite and valentinite in the Sb^{3+} state associated with highly reduced vein minerals mentioned earlier.

There also occur several elements which are inconspicuous, except for some very local assemblages. These elements are typical "pneumatolytic" cations and anions and probably derived from the local granitic intrusions. Boron occurs in the C-period in the minerals pinakiolite and orthopinakiolite, the former a locally fairly abundant species. Beryllium appears in several unusual minerals, such as swedenborgite (an antimonioberyllate!), trimerite, joesmithite, welshite and barylite.

A comprehensive outline of the minerals of the Långban-type ore deposits appears in Table 1. I have attempted to remain faithful to the present crystal-chemical interpretations of the formulae and have offered a few comments on each species. Magnusson's paragenetic classification is used as well as alphabetic symbols for the localities. This list is relatively incomplete since many of the more well-known species (such as barite, fluorite, etc.) have not been investigated in as much detail as the more unusual ones and since literally hundreds of unknown minerals still remain to be investigated. References are also cited; these represent only a fragment of the total published research output covering Långban-type ore deposits, but afford a retrieval for other references. Pihlström (1965) lists no less than 270 titles concerning the Långban deposit alone and that paper renders a great service to the students of Långban mineralogy.

LÅNGBAN: RESEARCH AND COLLECTIONS

Personalities

Few localities in the world have been studied in greater detail than the Långban mines. Its students were many and a review of all the research efforts would be impossible. Most noteworthy were the mineralogical studies at the Mineralogical Section of the Swedish Natural History Museum in Stockholm. The list of directors and their tenure is impressive: Adolf Erik Nordenskiöld (1858-1901†), Hjalmar Sjögren (1901-1923†), Gregori Aminoff (1923-1947†), Frans E. Wickman (1948-1965, now at the Pennsylvania State University) and Eric Welin (1965-). Although research on the Långban-type ore deposits consumed a good portion of their time, they are especially known in the scientific community for other accomplishments. Axel Hamberg, another noteworthy contributor to Långban mineralogy, first described the fascinating mineralogy of Harstigen. Nordenskiöld engaged in early Arctic and Spitsbergen explorations and was the first to sail around Asia, through the Northeast Passage; Sjögren was an early student of ore deposits and amassed a cabinet of high quality specimens from all over the world, many of them personally collected; Aminoff was a profound influence in the development of X-ray spectroscopy.

Two personalities are especially prominent in Långban research and deserve special note: Gustav Flink (b. 1849-1931†) and Gregori Aminoff (b. 1883-1947†).

Gustav Flink (Fig. 4) was a schoolteacher with a deep interest in minerals. He held the position of assistant keeper of the cabinet at the Swedish Natural History Museum, and contributed more to the preservation, study and description of Långban specimens than anyone else. When retired and active as a mineral dealer, he singled out no less than 520 distinct unknown specimens for further research. Research up to the present on this unique collection has revealed no less than twenty species new to science and literally dozens new to Långban. Over 10,000 Långban specimens were assembled by Flink with the assistance of local miners, especially those employed in the hand-sorting of ores. The outstanding personality among them was K. J. Finneman whose keen eye spotted exceptional finds when they reached the surface before tossed on the waste heaps. Flink published no less than forty papers on Långban alone.

Gregori Aminoff (Fig. 5) was a "Renaissance man" of unusual talent. His contributions to mineralogy were manifest after a deep training and pursuit of the arts: he was a violinist and portraitist as well, both interests extending beyond mere hobbies. His status in each was that of a professional and his interests in art led him to Paris where he studied under Matisse. An obvious love of minerals and crystal forms was to influence his research in science. The paper on the morphologies of calcite and barite from Långban (Aminoff, 1918b) is a classic study in paragenetic mineralogy and crystal projection, and the paper on the chemical aspects of Långban (Aminoff, 1918a) is noteworthy in light of its date. He studied and named many Långban species, including armangite, finnemanite, bromellite, swedenborgite, magnetoplumbite, arsenoclasite, and sahlinite. "Bäckströmite" still remains an enigma, but present research indicates that it is an altered pyrochroite. In the scientific community, he is probably best known for contributions in electron diffraction, high dispersion X-ray spectrography and crystal structure analysis.

Collections

The Mineralogical Section of the Swedish Natural History Museum houses by far the most extensive collection of Långban minerals, probably the largest collection of single locality specimens in the world, since no less than 30,000 specimens are included. Of these, 10,000 require further study. The large specimens, including a special arrangement of Långban minerals, appear in the display area of the museum which is open to visitors. Most of the specimens, however, are filed away in the basement and arranged according to an efficient system of retrieval. Unknowns, beside the Flink collection, are arranged according to their colors or specialized physical properties. The most prized jewels of the Långban legacy include a specimen the size of a shoebox showing inch-long allactite crystals which are green in daylight but purple in artificial light, implanted upon snow-white barite and calcite crystals; a swedenborgite crystal two inches long; a ten-pound mass of bladed margarosanite; a långbanite group with lustrous hexagonal crystals up to an inch in length; and large tan pyroaurites, grouped like roses on a calcite block a foot on an edge. Similar descriptions of items of interest to the micromounter are endless.

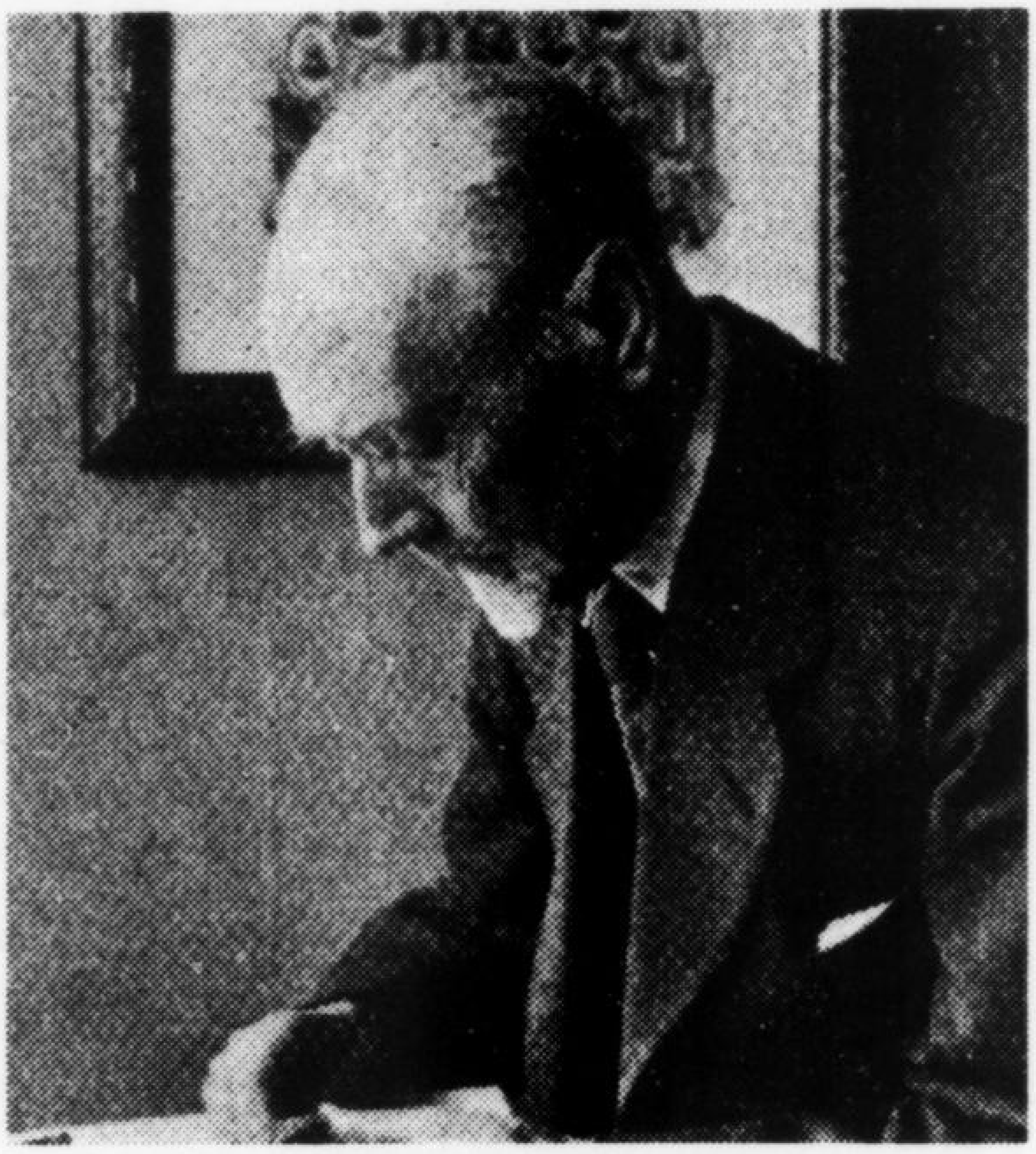


Fig. 4. Gustav Flink. The photograph was taken in the early 1920s.

It is general policy of the museum to refrain from exchanging Långban specimens, since the systematic suite is indispensible in piecing together the complex history of the deposit. It would be foolhardy to exchange the femur of a single dinosaur skeleton, just as continued preservation of the Långban specimens is necessary and in the best interests of science.

Some exceptional Långban specimens found their way to other collections, especially when the mines were still active. It was fitting that Flink was to assemble a duplicate collection of his unknown minerals for the eminent American mineralogist Charles Palache. In 1924, Palache returned from Stockholm with a representative Långban suite, probably the second-best Långban collection, which presently resides in the Geological Museum at Harvard University. Other museums which have preserved Långban specimens include those at the Universities of Stockholm and Uppsala, the Mineralogical and Geological Museum at Oslo, the British Museum of Natural History, the American Museum of Natural History and the U.S. National Museum of Natural History.

Fig. 5. Three students of Långban mineralogy: from the reader's left: Dr. F. E. Wickman, Mr. K. J. Finneman, and Prof. G. Aminoff. The photograph was taken at Långban in 1939.

Unlike collectors of Franklin, New Jersey specimens, there does not appear to be any private individual who has arranged even a partially systematic Långban collection, with the possible exception of Mr. J. B. Jago of San Francisco. This may have arisen from a long-standing policy in Sweden which discourages private collections of irreplaceable natural objects such as minerals. To this day, collectors visiting Sweden will be struck by the reluctance of mine and quarry owners to offer permission to collect minerals except for research purposes. Only the most serious collectors would find a collecting trip to Sweden rewarding in the first place and they should follow the proper procedures for obtaining advance permission.

The waste heaps will reveal, however, remnants of some of the most remarkable deposits on Earth. Here, the experienced observer will see the relationships among the differentiated iron and manganese oxide ores and their associated skarns and gangues. A close inspection of these "open-air" museums will present the keeneyed with many jigs to fit together into a puzzle which may yield further understanding of the remarkable yet explicable chemical and geological processes of the past. These insights into Nature's personality are the most rewarding collecting experiences of all.

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Biographical Sketch

Dr. Paul B. Moore is Associate Professor of Mineralogy and Crystallography in the Department of the Geophysical Sciences, The University of Chicago. His academic training has been in the fields of chemistry and physics, and his interest in minerals stems from childhood. Dr. Moore's avocations include the interpretation and performance of German Baroque and Romantic organ music, and the study of Scandinavian intellectual history.

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WHAT'S NEW IN MINERALS

(continued from page 151)

Scanning electron microscope (SEM) photographs were taken (by Walt Brown, of the Smithsonian Institution) of some of these crystals that were dissolved out of the calcite with dilute hydrochloric acid. The group in Fig. 1 measures about 2 mm in length (magnification = 50X). Fig. 2 shows some of the crystal fibers at a magnification of 900X, Fig. 3 the details of a portion of a fiber (8,200X) and Fig. 4 the termination of a fiber (9,000X).

This mineral was originally tentatively identified as millerite so it should be looked for in the many other localities where nickel sulfides are found with calcite.

Minerals of the Route 80 Roadcut, New Jersey

The following information about the minerals of the Route 80 roadcut comes from Thomas A. Peters, a geology student at Lehigh University, Bethlehem, Pennsylvania.

> "Early in the summer of 1969, work began towards the completion of Route 80 near Paterson, New Jersey. The roadcut trends in an east-west direction roughly parallel to New Street, Paterson, and cuts through the northern back portion of the Old Lower New Street quarry. The minerals are found in gas pockets in the basalt of the First Watchung Mountain, which is the oldest of three lava flows of Late Triassic age. Alternating with the flows are continental sediments consisting of interbedded arkosic sandstones and shales known as the Brunswick formation of the same age. Mason (in *Trap Rock Minerals of New Jersey,* State Dept. of Conservation and Economic Development, Bull. 64, 1960) did an excellent job of summarizing the geology and mineralogy of the rocks and associated secondary minerals found in this area and similar occurrences elsewhere in New Jersey. Listed below are brief descriptions of the minerals that have been found at this roadcut as of August, 1970:

pyrite—irregular grains or small crystals coating many of the other minerals. Common.

chalcopyrite—brass-yellow crystal plates and irregular grains usually coating quartz. Common.

greenockite—a small (1 - 2 mm) yellow-brown crystal of greenockite was found by Mr. Neil Foglia of Paterson. This rare mineral was found associated with prehnite, pectolite, natrolite, laumontite and quartz.

chalcocite and bornite—reported but not verified. Rare.

hematite—small black rosettes usually implanted on quartz and calcite. Scarce.

calcite—rhombohedral crystals up to an inch in diameter, associated with prehnite. Calcite from this area also occurs with quartz and, in this association, may form very complex crystals. Abundant.

malachite—occurs as an alteration product of chalcopyrite. Common.

quartz—in crystals up to an inch in diameter. Magnificent amethyst and smoky quartz have been found. Clear and milky quartz are common. Quartz is also found as pseudomorphs after anhydrite and glauberite.

analcime—small (1/2 inch or less) white or red trapezohedra associated with pectolite. Scarce.

(continued on page 174)

ECKMAN CREEK

(continued from page 153)

zation took place in pillow lavas in the floor areas that were formerly occupied by shallow lakes. The deposition of the zeolites took place in the rocks as they cooled and while the flow was quiet. The outside waters cooled the surface of the flow while the interior was still hot. This initiated a system of circulation from hot to cold causing the aqueous solutions to percolate through the flow along seams, joints, and gas pockets. The flow contributed various constituents to the percolating sublimates and as the solution continued to cool, zeolites were deposited. In the area of the Eckman Creek quarry, gas pressure in the flow resulted in the formation of small pockets. The large amount of sea water present in proportion to the flow volume caused the basalt to cool rapidly and prevented the occurrence of larger pockets. This is unfortunate for the mineral collectors because the small size of the pockets adds to the difficulty in acquiring hand-size cabinet specimens. Most of the pockets are about 3x3x3" although occasionally a larger one is uncovered. The largest crystallized vug noted so far was about 3x5x10".

Analcime and natrolite are the only zeolites observed at this locality to date. Analcime was the first of the zeolites to crystallize. The analcime crystals are somewhat unusual in that they do not turn white after they are removed. They are perfectly clear when first exposed, but as time elapses, they become cloudy in appearance due to the loss of water causing what appear to be internal fractures. Ordinarily analcime occurs as solid aggregates of well-developed trapezohedra lining the vugs, although, in a few instances individual crystals are found on drusy calcite. The crystals vary in size from microscopic to 1/2", although they are normally 1/8" to 5/16". (Fig. 4 & 5).

Natrolite was the second zeolite to crystallize at this locality. Whenever analcime and natrolite are present in the same pocket, natrolite has crystallized on analcime.

(continued on page 176)

WHAT'S NEW IN MINERALS

(continued from page 173)

chabazite—small colorless, white, red, or brown rhombohedra associated with quartz and calcite. Scarce.

gmelinite—small pyramidal growths frequently intermixed with chabazite. Rare.

heulandite—canoe-shaped crystals up to 3 inches in length. They may be colorless, white, pink, brown, or green. Common.

stilbite—clear or brown spheroidal masses and small tabular individual crystals. Much of the stilbite found here was eroded and therefore not suitable for specimens. Common.

thomsonite—small rosettes or radiating aggregates associated with prehnite. It is white or pink to brown in color. Rare.

laumontite—small colorless or white prismatic crystals usually in the form of radiating aggregates of crystals implanted on prehnite. Common.

natrolite—white silky prismatic crystals usually in radiating aggregates and associated with prehnite or analcime. Mr. Lenny Currell found a magnificent radiating group 5 inches long.

mesolite—exceedingly fine hair-like crystals associated with prehnite. Common.

apophyllite—colorless or white crystals usually associated with pectolite or calcite. One single crystal found, had it not shattered, would have measured about 8 inches across. Scarce.

datolite—small white or light green crystals usually associated with calcite, laumontite and prehnite. Scarce.

prehnite—very abundant at the roadcut, ranging in color from golden (rare), many shades of green, and blue (rare). Distinct crystals, although rare, have been found. Specimens of prehnite up to 5 feet across have been found. The prehnite occurs as botryoidal masses, as finger-like or stalactitic masses, and as scepter growths replacing anhydrite. The stalactitic masses are the result of the replacement of long prismatic crystals of anhydrite. Associated with prehnite are laumontite, natrolite, mesolite, datolite, calcite, chlorite and pectolite.

pectolite—white to pink globular, radiating masses up to 6 inches in diameter. It has also been found as silky terminated crystals. It is associated with prehnite, calcite and apophyllite. Abundant.

stevensite—a clay mineral pseudomorphous after pectolite. It is pink to brown in color. Common.

tremolite—sponge-like matted fibers associated with badly eroded prehnite. This variety is sometimes called ***mountain leather*** and is a pinkish-brown in color. Rare.

babingtonite—small bluish-black crystals usually implanted on quartz. Scarce.

chlorite—small, velvety masses coating traprock and commonly coating many of the other secondary minerals.

chrysocolla—occurs as an alteration product of chalcopyrite. Scarce.

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MUSEUM RECORD

(continued from page 152)

find their places with some sort of reasonable combination of systematic, instructional and educational mineral exhibits. There is nothing to prevent the big museums from offering combinations also, but only after meeting their mandatory exhibit requirements. I think our readers would be very interested in knowing of some of the ways in which the various mineral museums have approached the problem. It would be a pleasure to report here any local solutions or even any refutations of my own assumptions about mineral museums.

Incidentally, in this vein, I mentioned in this column (Summer, 1970) the problems of the Museum of North Carolina Minerals. Its story fits exactly what I have been trying to say. My earlier remarks about this museum resulted from a summation of my own feelings about it and those of a number of concerned visitors. As a direct result there has been some pleasant and interesting correspondence with Mr. Granville Liles, Superintendent of the Blue Ridge Parkway in which the museum is located. According to Mr. Liles, the original building and its exhibits were a direct gift to the Federal Government by the State of North Carolina. To be perfectly honest, the museum does exactly as was intended. The exhibits were purposely planned to introduce tourists to the general geology of North Carolina and especially to the State's mineral industry. The criticisms through the years seem to come mostly from a feeling among many that the original emphasis was misplaced. At any rate, Mr. Liles was delighted to tell me that "our correspondence coincides with recent Blue Ridge Parkway planning which identifies and recommends a complete exhibit revision." To me it seems he is obviously quite interested in making this facility as interesting and as useful as possible to visitors who pass through it in enormous numbers each year. This seems to be the time—during the planning pe-

(continued on page 175)

(continued from page 174)

thaumasite—large white compact masses associated with minor pectolite and laumontite. Scarce.

It should be noted that the roadcut is now complete and collecting is no longer permitted. Anyone caught in the process of collecting minerals will be subject to arrest by the local police!

Torbernite

The best torbernite locality in the United States is producing specimens once again, and in considerable numbers. Recent feldspar mining at Chalk Mountain, about 2 miles southwest of Spruce Pine, Mitchell County, North Carolina exposed open fissures coated with lovely, dark grass-green torbernite crystals. While most of the crystals range from micromount size up to 1/8 inch, specimens have been found with crystals between 1/8 and 1/4 inch across. Cabinet size specimens with numerous crystals scattered over a flat surface are being recovered in quantity. The individual crystals are thick and cloudy, only rarely are they transparent. The cloudiness may be due to partial dehydration forming metatorbernite but, if so, this alteration does not markedly reduce their stability. The crystals appear to be able to withstand considerable shock without shattering or breaking free from the maxtrix.

Although permission can be obtained to collect, a shovel operator who works in the quarry has a virtual monopoly on the best material so the chances of finding outstanding specimens that he may have missed are not good. ■

(continued from page 174)

riod—when any local mineral enthusiasts should make their suggestions known to the National Park Service. Mr. Liles' office can be reached through P.O. Box 1710, Roanoke, Virginia 24008. ■

In the Next Issue . . .

"Calcian Ancylite from Pennsylvania: New Data"
F. A. Keidel, A. Montgomery, C. W. Wolfe and R. P. Christian

"Mineral Auctions at Sotheby's of London"
Brian Lloyd

"Locality—Minas Gerais, Brazil"
Alvaro Lucio

"Mineral Collecting at Monte Redondo, Portugal"
Richard V. Gaines

ECKMAN CREEK

(continued from page 173)

The crystals occur as clear well-developed prisms averaging 1/16" to 1/2" in size although excellent terminated crystals as large as 1/8" x1-1/4" have been observed. All of the natrolite crystals have terminations which can readily be seen without magnification. They occur either in masses of individual crystals completely lining the vugs or as isolated radiating sprays im-

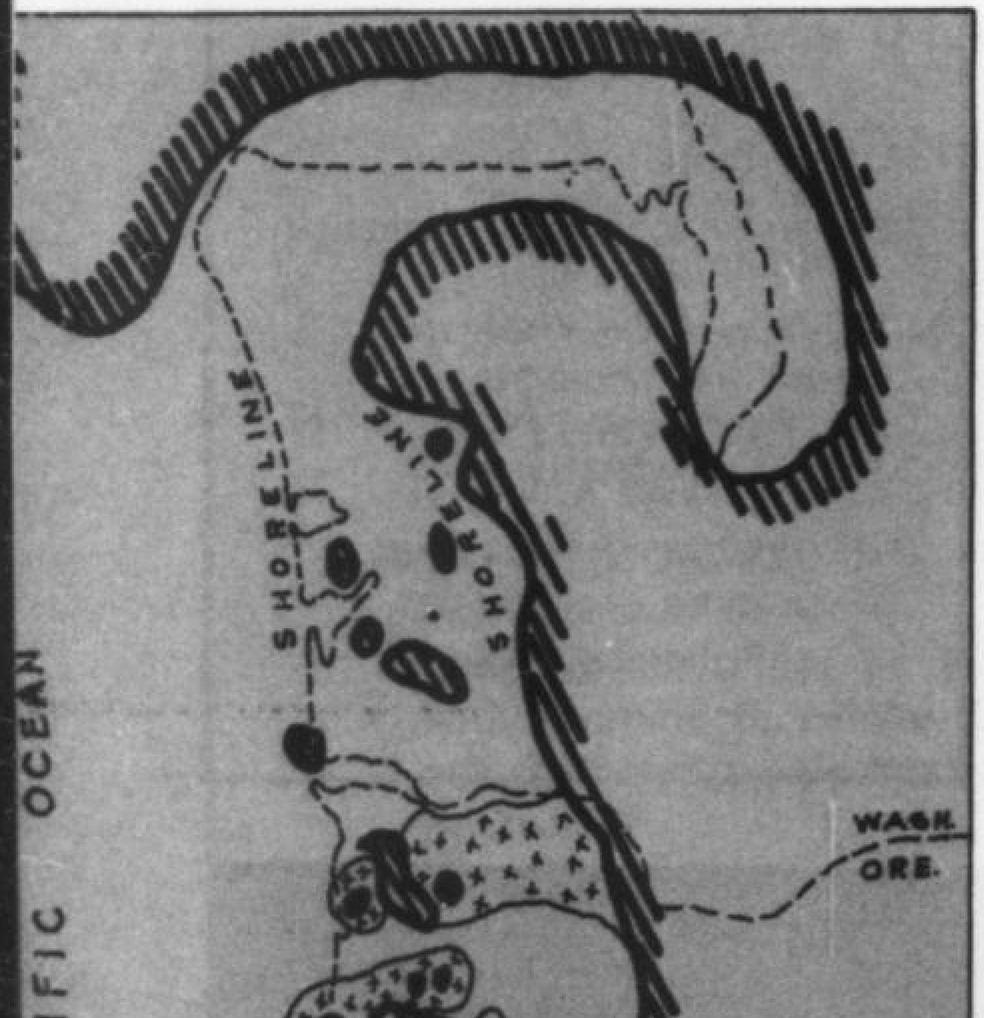

Fig. 2. Map showing coastline of Oregon and Washington during Late Eocene time. (Snavely & Wagner, 1963).

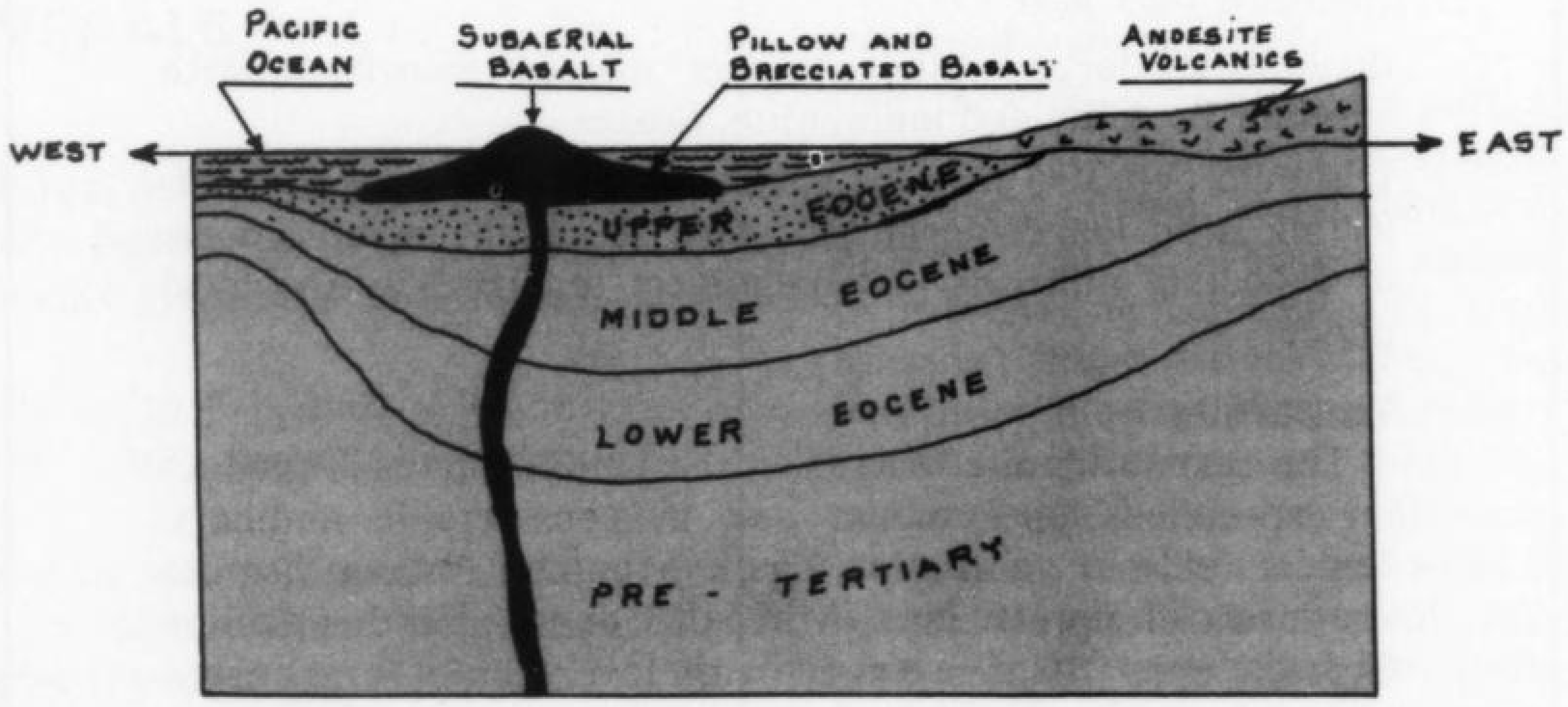

Fig. 3. Cross-section of Oregon in vicinity of Waldport during Late Eocene time. (Snavely & Wagner, 1963).

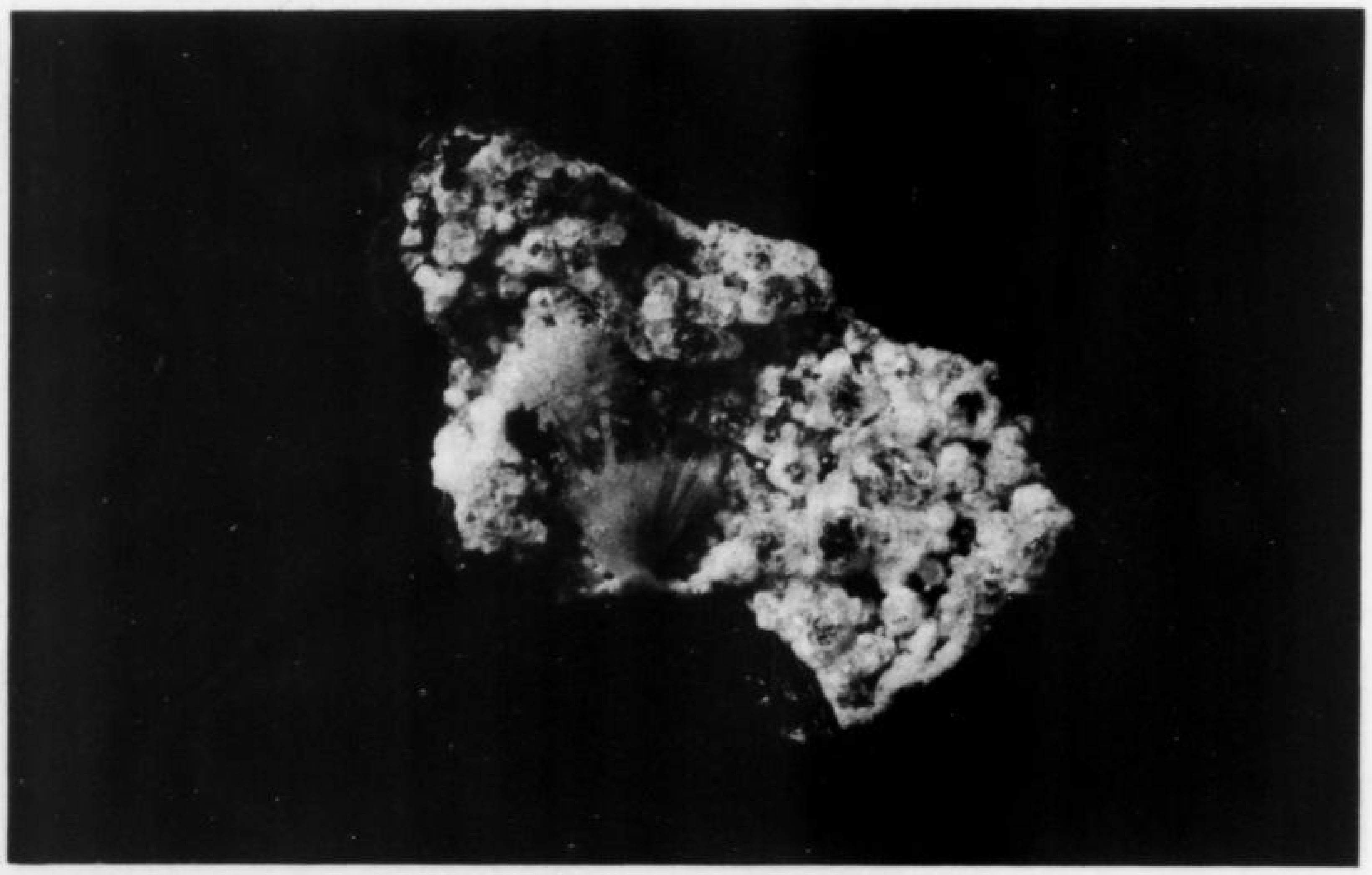

Fig. 4. Natrolite and analcime. Size of specimen 3"x5". Collection of M. M. Groben. (Photo courtesy Ward Robertson, Coos Bay, Oregon).

Fig. 5. Natrolite spray on light brown calcite. The natrolite crystals are about 1/2" in length. Collection of M. M. Groben. (Photo courtesy Ward Robertson, Coos Bay, Oregon).

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Z

Eckman Creek

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planted on analcime or calcite. (Fig. 4, 5 and 6). The latter are the most eye-appealing cabinet specimens from this area.

The attractiveness of the specimens from this quarry is enough to lure many crystal collectors. However, anyone who intends to visit this locality should be aware that good specimens are difficult to acquire. The crystallized pockets are small and sporadic in their occurrence. It is not unusual to visit the quarry many times before finding a good crystallized pocket. The climate also works adversely for the collector. As soon as the crystals are exposed after a blast, they are subject to weathering, losing their luster and becoming dull quite rapidly. Even more detrimental is the fact that the heavy rainfall of the coastal area causes silt, soil and clay to be deposited around the tightly packed sprays of natrolite crystals. This material is unsightly and is extremely difficult, if not impossible, to remove even with an ultrasonic cleaner.

I should like to express my gratitude to Dr. Lloyd W. Staples and A. L. McGuinness for their suggestions and help in reading this paper and to Dr. Arthur Montgomery for his assistance and careful editing of the final report.

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EDITORIAL

(continued from page 133)

Another possible project, in which all of the members can participate, is to build mineral sets, for both study and display, to be given to local schools and colleges. Field trips, which usually are not too productive of fine cabinet specimens, can supply many pounds of excellent specimens of common minerals for teaching. These can be taken to the meetings, broken into small pieces and pasted or placed in flat boxes appropriately labelled and distributed to schools. Schools can also make good use of any printed material prepared by clubs about nearby mineral localities.

A variation on the practice of inviting a lecturer might be to schedule a field trip, conducted by a geologist, or mineralogist, who can describe features of interest in the field. His talk is automatically illustrated with examples for everyone to see and touch and even attack with a hammer.

These are only a hint of the ways in which new life can be pumped into stagnating mineral clubs. I am sure our readers can add many other ideas. Please remember that I am eager to publish your letters and suggestions. I am looking forward to your willingness to share your ideas and opinions so that we can all do our best to improve our clubs. ■

JOHN S. WHITE, JR.

ERRATA

The following errors and omissions in Vol. I, no. 3 should be noted:

"Mineral Rings and Cylinders" by R. A. Bideaux

pp. 108-109, Figs. 5 & 6—the boulangerite specimens belong to Neal Yedlin, not William Pinch.

although most SEM photos require that the subjects be gold-coated, the specimens in Figs. 3-9 were not, as they are naturally conductive.

"Some Possible New Minerals Not Yet Found" by Michael Fleischer

(Table of Contents and p. 121) author's name should be spelled Fleischer, not Fleisher.

"Mineral Notes"—Kinoite (p. 125)

second author's name should be spelled Laughon, not Langhon.

"The Record Bookshelf" (p. 129)

the review were written by Joel A. Arem.

"Eakerite—a New Tin Silicate" by Leavens, White and Hey (p. 92)

the photograph of eakerite (p. 93) is by Ben Kinkead, Kingsport, Tennessee.

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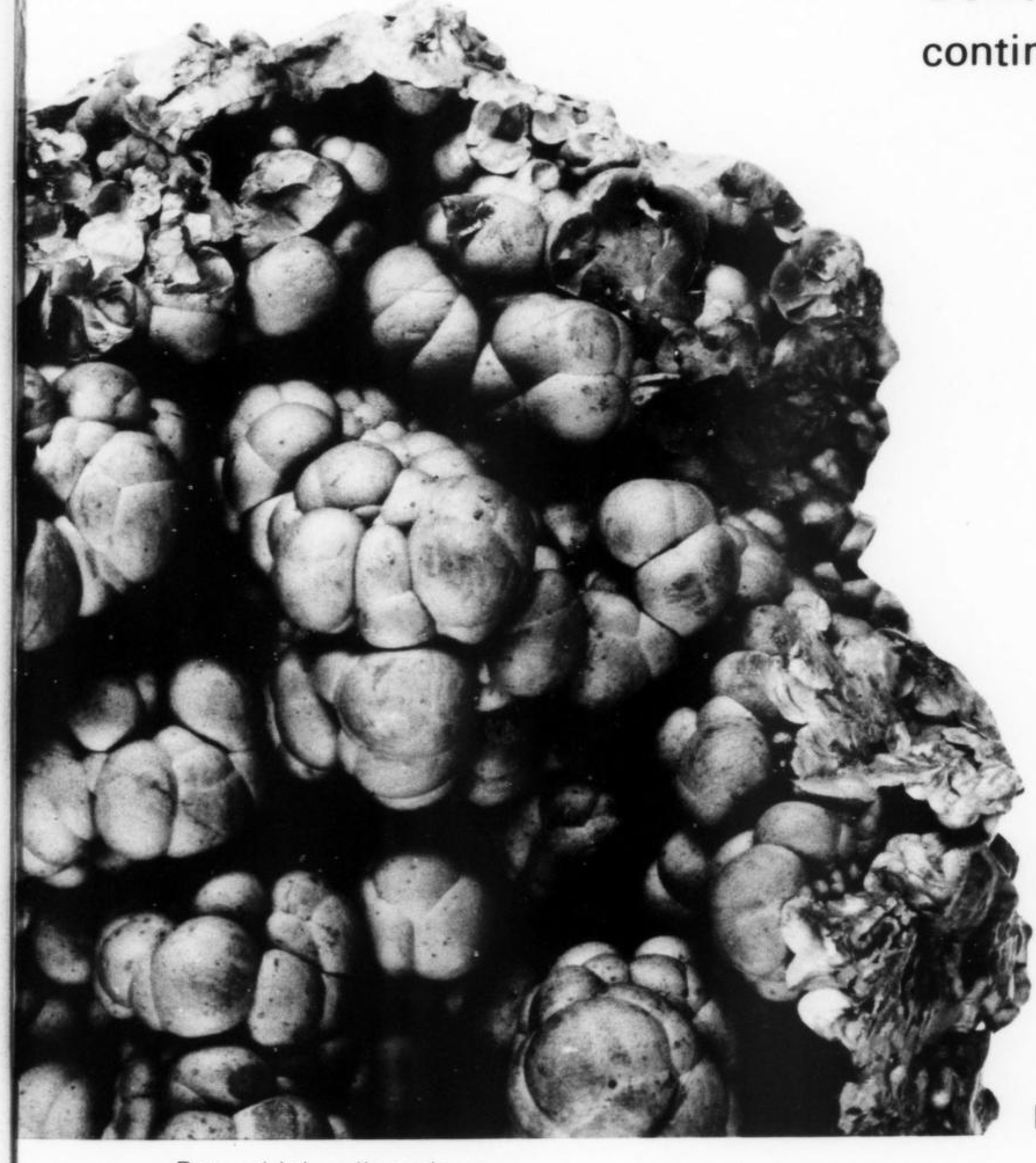
For most of our readers it is subscription renewal time. With the close of our first year of publication you have been treated to 178 pages of substantial information about minerals. Don't risk a delay in the continuing flow of issues by failing to renew in time.



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