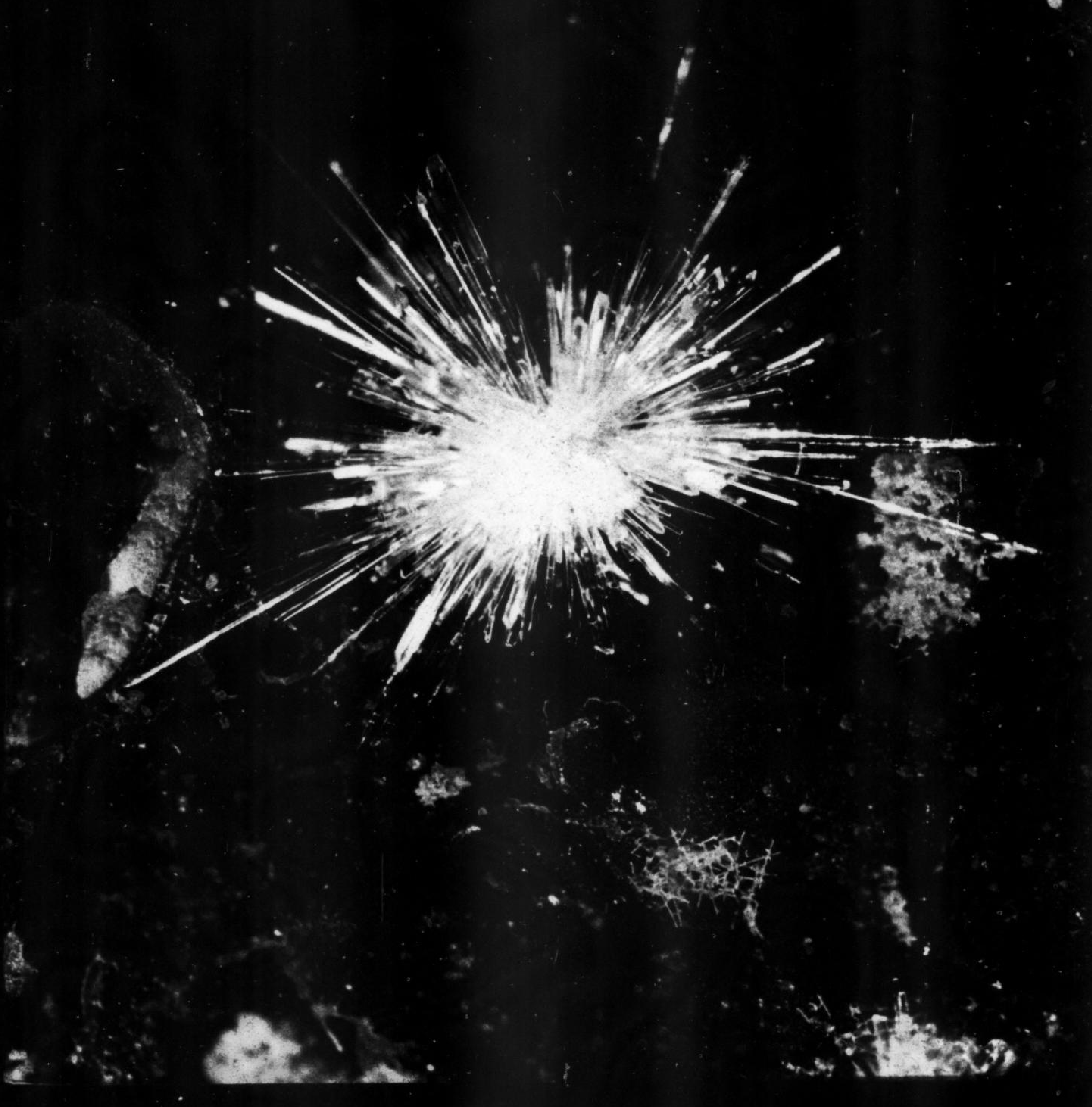
the Mineralogical Record

volume one • number one
SPRING 1970



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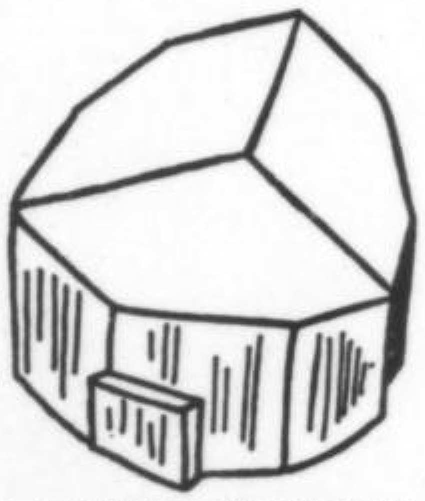

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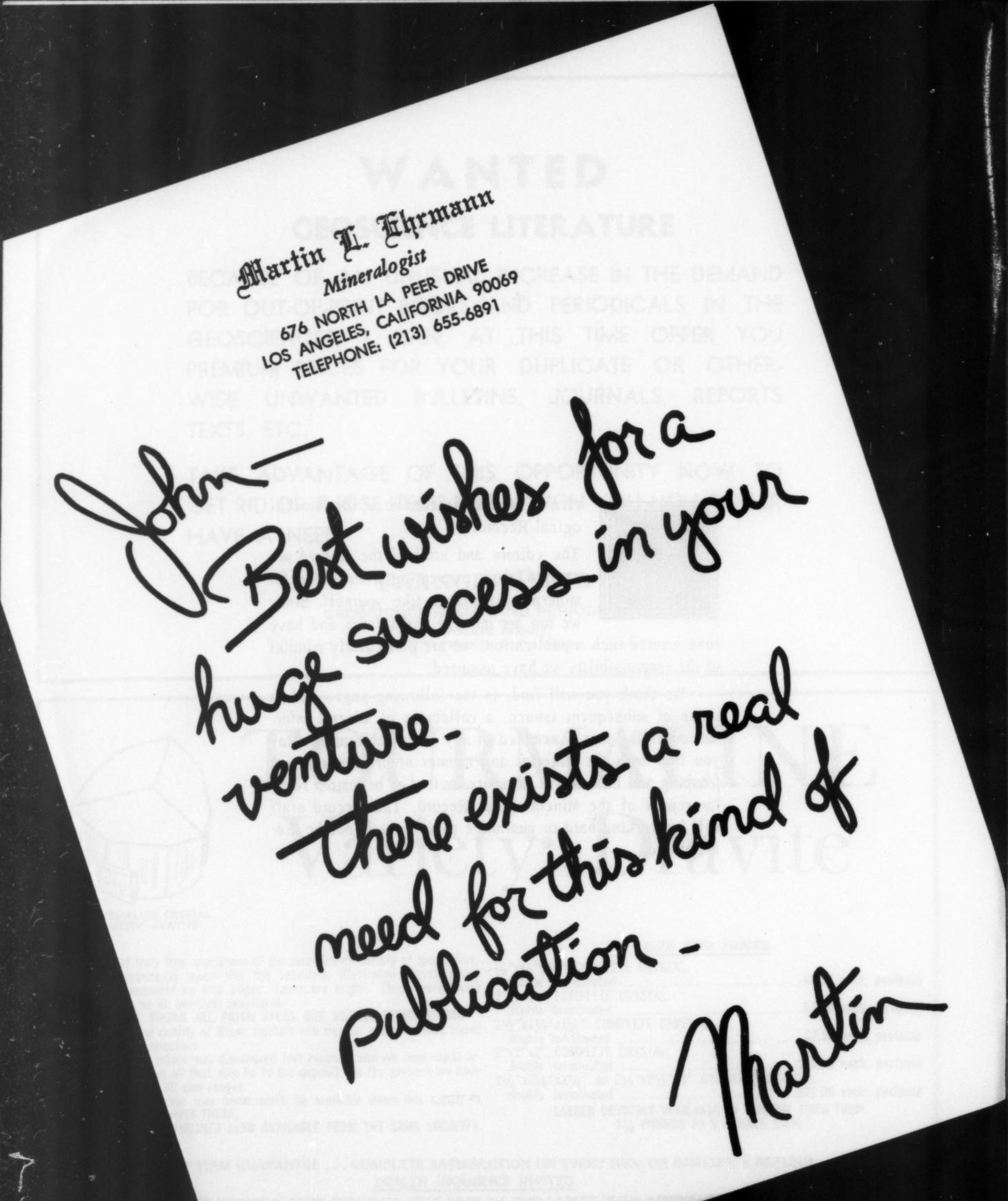
Welcome to your first issue of the Mineralogical Record.

The editors and staff of the Record are excited about presenting a magazine for mineral enthusiasts like yourself. Since we too are mineral enthusiasts and have long wanted such a publication, we are particularly mindful of the responsibility we have assumed.

We think you will find, in the following pages and in those of subsequent issues, a collection of mineral information unlike that assembled in any other publication. May you find both the material and manner of presentation refreshing and informative. You are invited to become a regular reader of the Mineralogical Record. The Record staff will be working hard to guarantee that you will not be disappointed.



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John —

Best wishes for a huge success in your venture — there exists a real need for this kind of publication —

Martin

the Mineralogical Record

volume one • number one
SPRING 1970

affiliated with the Friends of Mineralogy

feature articles

department

photograph by Jack Kath, Westfield, New Jersey

Photomicrograph of gypsum crystals from the Cornwall Iron Mine, Lebanon County, Pennsylvania. The entire cluster measures only 2 mm in diameter and is on a micromount in the collections of the U. S. National Museum of Natural History, Washington, D. C.

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editorial matter

Contributed manuscripts and news items are welcomed, but acceptance is subject to the approval of the editorial board. They should be mailed to the editor at the aforementioned address, and should be accompanied by a stamped, self-addressed envelope. No responsibility can be assumed for unsolicited material.

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friends of mineralogy

Twenty amateur and professional mineralogists met in Tucson, Arizona on February 13, 1970, to found an informal group dedicated to promoting better mineral appreciation, education and preservation. The name *Friends of Mineralogy* (FM) was chosen. The chief aims and activities of this group will include:

- Compiling and publicizing information on important mineral collections throughout the world.
- Encouraging improved educational use and far wiser conservation of mineral specimens, collections and localities.
- Supporting a semi-professional journal of high excellence and interest designed to appeal to mineral amateurs and professionals alike, also to undergraduates active in earth science, and through which FM activities may be circulated.
- Operating informally in behalf of minerals, mineral collecting and descriptive mineralogy, with dependence on voluntary support primarily by members and widest possible circulation of the journal.
- Functioning by means of fullest membership participation and majority decision, with responsibility for implementation of aims and activities channeled through an annually-selected regional committee willing to do the brunt of the work.
- Cooperating as fully as possible with the International Mineralogical Association and all mineral societies, professional and amateur, and guarding against overlap of functions performed by these groups.
- Building an active world-wide membership among amateur and professional mineralogists.

It is expected that membership will be kept small, limited to those believing in and best able to contribute to an unselfish cause, and approximately equal representation among amateurs and professionals with as many foreign participants as possible.

The Mineralogical Record has agreed to an affiliation with FM whereby it will publish its written material and news of its activities. FM will support the *Record,* since the aims of both are similarly educational and directed toward better coordination of the interests and efforts of amateurs and professionals throughout the world.

Inquiries as to FM program and membership may be sent to any member of the regional committee, preferably to the last-named, c/o Geology Dept., Lafayette College, Easton, Pennsylvania 18042.

FM Regional Committee

Joel Arem • Richard Bideaux • Ray Grant • Mike Groben
Arthur Montgomery

Paul Seel

(continued from page 31)

some of these diamond and quartz crystals. Since he is an accomplished draftsman he found it a natural thing to do. For his various mineral displays he has won numerous club, regional and National awards. Among them he holds three National awards in the categories of minerals, micromounts and educational exhibits. Although these are the areas of his highest awards, his interests range much more widely to include fossils, gems, plants or almost any subject you would care to mention and that he has time to pursue.

Paul is knowledgeable, enthusiastic and vocal about his hobby. He is often asked to give talks about it and can do then just as easily in German, if necessary. When pressed and given a few days to prepare, he might well do them in Spanish. I've never heard any of his large collection of very humorous stories told in anything but English. However, I have seen him on one occasion, in a poor Mexican village, entertaining the natives with harmonica solos, pleasant banter and then moving on to the miserable little school to give the children a demonstration on the use of that wonderful instrument – a pocket magnifier. Truly, Paul is one of the most unforgettable characters I have ever met and is a credit and example to the fraternity of mineral collectors.

IN THE NEXT ISSUE . . .

Feature articles now planned for Number 2, Volume I include the following:

"New Minerals from New England: a Survey"
Clifford Frondel

"A One-Circle Optical Goniometer"
Wm. A. Henderson, Jr.

"The Moctezuma, Sonora Tellurium Deposit"
Richard V. Gaines

"New Data on Plattnerite"
John S. White, Jr.

In addition you will find the regularly appearing columns about new mineral occurrences, micromounting, museum news, book reviews and the report from the Friends of Mineralogy

editorial page

It is with much pleasure that I am now able to put on paper the words which will introduce a new magazine for mineral collectors. Numerous personal acquaintances, in the mineral hobby and profession alike, have long spoken of a high quality publication to serve their needs and to satisfy a thirst for rewarding reading to nurture a love of minerals. Beginning collectors have floundered about in search of guidance and counsel, stumbling through the awkward process of acquiring the lore which experienced collectors tend to take for granted. Professional mineralogists perhaps have of necessity built an imposing wall of technology between themselves and knowledgeable collectors who might welcome glimpses into a fascinating world full of rich intellectual rewards, a world from which they have been systematically, albeit unintentionally, excluded. True there are some few collectors in close physical proximity to institutions where concerned professionals participate in programs designed to answer their needs, but what of the isolated majority? Where do the students now being introduced to earth sciences on the junior and senior high school level in great numbers seek advice about adopting mineralogy as a hobby as well as pursuing it as a career? *The Mineralogical Record* was conceived in response to a need.

The contents of this first issue speak of the magazine's philosophy and objectives. It is not designed to serve the interests of one level of understanding to the exclusion of others. However, it will speak only of minerals. Novices will find enough in its pages to entice them toward learning more about minerals. Knowledgeable collectors will find semitechnical articles that they can comprehend. Genuine news articles will be of general interest to all collectors. Professional mineralogists will find in it a vehicle for publishing valid descriptive work largely scorned by more technical journals. Those interested in the hobby will be able to keep in touch with what other hobbyists are doing. A panel of distinguished editorial assistants has agreed to help insure the continued high quality of contributions and the reliability of all information and data presented on its pages.

At times controversial matters will be presented editorially and a forum for debate will be provided through published letters. A medium now exists where opposing views on problems of vital interest to the great body of mineral collectors may be openly presented.

Several columns will be regular features of the Journal. A museum news column, by Paul Desautels, will present short notes about mineral museums, their major acquisitions, new exhibits, personnel changes and, if necessary, thefts. Neal Yedlin, known widely among mineral collectors, has volunteered to write the micromounting column. Look, too, for penetrating book reviews, abstracts of recent papers in which new minerals are described and older ones discredited, reports of exciting new mineral discoveries, biographical sketches of personalities within the science and hobby, and summaries of some of the activities of both professional and amateur societies.

The Mineralogical Record is not intended to be an "American only" publication, I am already making a major effort to give it international appeal and contributions of information from all countries are being sought.

The success of this journal depends entirely on the enthusiasm with which collectors greet it. It is the magazine you have been asking for. Your personal support in soliciting subscribers and in offering material for publication is needed. The editors intend to be responsive to the expressed desires of subscribers and they hope that you will always feel your opinions are welcome.

John S. White, Jr.

John Winthrop

Picture of John Winthrop the Younger
courtesy of the American Antiquarian Society

Early Mineral

by Clifford Frondel

In the early 1600's the pioneer settlers of the Atlantic seaboard, when not occupied with providing the necessities of life in the wilderness, undoubtedly picked up and saved specimens of rocks and minerals when the question of their possible value and utilization came to mind. The first known collections of minerals and ores in New England were those of John Winthrop the Younger (1606-1676) and of his grandson John Winthrop Jr. (1681-1747). Winthrop the Younger was the son of the first governor of the Massachusetts Bay Colony and eventually became the first governor of Connecticut.

The elder Winthrop was educated in Europe in natural science, medicine and law. He possessed a good library, and has been described as the leading scientific mind in the Colonies during his time.

Winthrop was active in the development of the mining industry in both Massachusetts and Connecticut, and brought about the first commercial iron mining and smelting operation in this country at Saugus, Massachusetts, in 1647. The history of this venture is explored by E.N. Hartley in his book *Iron work on the Saugus,* published in 1957.

It also appears that the first discovery of gold in New England was made by John Winthrop in the middle 1600's on Great Hill at Cobalt, which is south of Portland, Connecticut. This information is based on a statement by Ezra Stiles, then President of Yale University. Stiles, in his Literary Diary of 1787, mentioned that Governor Winthrop went to this place to, "roast ores and smelt gold."

No details concerning the mineral collection of John Winthrop the Younger are known, but a great deal is recorded about that of John Winthrop Jr. He possessed a large collection of objects of natural history including minerals and ores, which were perhaps in part inherited. At some time prior to 1717, at the solicitation of the theologian Cotton Mather, he is known to have sent specimens to England for examination by the English geologist John Woodward. Mineral specimens from New England, that presumably originated from Winthrop, are recorded in Woodward's book *A Catalogue of the Fossils of England,* published in 1728.

When the younger Winthrop was elected to the Royal Society in 1734, as his grandfather had been in 1663, he presented the Society with a collection of more than 600 specimens. This collection was made up of mostly minerals from New England, together with a catalogue of the specimens. The catalogue contains many interesting comments.

Many of Winthrop's specimens became incorporated into the collection of Sir Hans Sloan (1660-1753), President of

Collections In New England

Department of Geological Sciences, Harvard University

the Royal Society, and in 1753 this and other of Sloan's collections passed into the care of the British Museum.

Among the historic New England specimens in Winthrop's collection, still preserved in the mineral collection of the British Museum, is the original material in which the element columbium was discovered by the English chemist Charles Hatchett in 1802. The specimen was later re-examined by the chemist W.H. Wollaston in 1809 in connection with his work on the chemical nature of columbium and tantalum.

The mineral itself was named columbite, so-called from Columbia, a name for America. This particular specimen was found on an unknown date in Connecticut, at a place called Neatneague or Naumeag by the Indians. Unfortunately, the exact site cannot now be identified; although it almost certainly came from a pegmatite in the Middletown area. A colored lithograph of the specimen is included in a publication by J. Sowerby, *Exotic Mineralogy,* printed in London in 1811.

Another famous old New England specimen in Sloan's collection did not come out of a mineral collection, but rather from Benjamin Franklin's pocket – it is a purse woven from asbestos fibers. Sloan purchased it from the famous American in 1725, when, as a less than famous youth of 19 years, Franklin was visiting London to obtain material to establish a printing shop in Philadelphia but ran out of funds when he failed to receive a promised letter of credit.

A letter from Franklin to Sloan along with an entry in the catalogue of Sloan's collection indicate that the purse and an accompanying piece of the matrix stone came from New England (Sweet, 1952). The exact locality may have been the asbestos deposit at Pelham, Massachusetts, which produced fibers up to two feet in length. Incidently, the purse is still preserved in the British Museum.

Undoubtedly many other accumulations of minerals, ores, rocks and natural curiosities were made in New England in the 17th and 18th centuries for which no record exists. This assumption is very likely well founded since there were numerous, although in most instances quite small, metal mines in New England prior to 1800. These mines chiefly were worked for copper and lead ores. During this early period, and for a long time after, there was also a thriving iron mining and iron smelting industry in Massachusetts and other New England states. What must have been an important 18th century collection was made by Hugh Orr, master iron-worker of Bridgewater, Massachusetts. According to Thacher (1804), "His (Orr's) knowledge of minerals and ores was so extensive that from nearly every newly discovered mine in the country he was immediately furnished with specimens of its quality, and a few years previous to his death [in 1798] he was in possession of a valuable mineral collection."

A collection of minerals and plants also is known to have been made by William Douglass, a physician of Boston, prior to 1721.

The interest in minerals from Colonial up through Revolutionary times in New England was practical in nature. The development of the mineral resources was almost wholly accomplished by experts brought from Europe for the purpose, by importing skilled workmen, and by shipping ores abroad for treatment. A formal education in mineralogy or metallurgy could only be obtained by study in Europe.

The systematic study of minerals as objects of interest in and of themselves, and the beginning of college instruction in mineralogy, geology, chemistry and related sciences first began in New England in the decades immediately after 1800. This scientific activity stemmed partly from the rapid rise of mineralogy and chemistry as formal sciences in Europe in the latter 18th and early 19th centuries. It was also encouraged by increasing material wealth and leisure in New England during this general period. This relatively affluent atmosphere, of course, contributed to the support of intellectual and scientific activities.

The geological sciences flourished in the colleges, with leading centers of activity at Bowdoin, Amherst, Brown, Harvard and, in particular, Yale. These developments were accompanied by the formation of a number of motable mineral collections.

One of the most important early 19th century collections in the New England region was that of Colonel George Gibbs (1776-1833) of Newport, Rhode Island. This collection primarily contained identified and labelled specimens that had been bought in Europe. It was displayed at Yale University in 1825 and purchased for the then very considerable sum of $20,000. It is still on exhibit and in use.

A competent judge, Professor George J. Brush of Yale, whose own fine collection later went to Yale, said that the Gibbs collection " . . . did more to create an interest in and disseminate a knowledge of Mineralogy in this country than any other single agency." The Gibbs collection was significant because it placed an invaluable store of correctly labelled teaching and reference material at the disposal of Benjamin Silliman, J.D. Dana and other leading workers of the time.

One gathers that the early American mineral collections were not reliably labelled. Before the accession of the Gibbs collection, the Yale minerals were taken in a candle box to

Excerpts from the catalogue of the mineral collection of John Winthrop, Jr. (1681-1747)

72. A flesh-colored earth from the Gay-head, where are divers coloured ochres. [Martha's Vineyard]

109. A bright shining flakey mineral like burnished steel from the woods at Tantinsquese. [graphite from Sturbridge]

118. A stone used in building, containing granates [garnets] from Connecituct Island in Narraganset Bay.

158. The stone, between which the Alumen plumosum [asbestos] is found. It makes the best furnaces that can be, bearing the fire beyond any thing known. It is found near Plainfield, on Quinebauge River, and also in several other parts of the country. [The reference is to soapstone, widely used in Colonial times and later for hearthstones, furnaces, etc.]

207. Fragments of dark reddish and black spars, from Clam-Pudding Pond, in Plymouth colony.

227. Clay generated in the form of horse shoes, from the bottom of Connecticut River. [Concretions].

236. Yellow crystals in pointed squares, from the high white rock called Lanthorn Hill. [Probably stained quartz crystals with pseudocubic terminations, from the quartz deposit at Lantern Hill, Connecticut.]

262. Sulphur from the inland parts near the great high mountain, Monadnuck. It is apprehended that hereafter, by some accident or other a volcano will break out thereabouts. There is sulphur earth in many other parts of the country, the effects of which may have been the cause of several earthquakes which have happened there. [Mount Monadnock, New Hampshire; numerous earthquakes are noted in early Colonial records, the first in 1638. The mineral probably was not sulfur but some sort of a sulfate efflorescence.]

Philadelphia to be identified by Adam Seybert, a skilled mineralogist who had been trained by Werner in Freiberg and Haüy in Paris.

Another noteworthy early 19th century collection belonged to Parker Cleaveland (1780-1858) of Bowdoin College in Maine. This collection was rich not only in European material, but also in specimens from localities throughout the Atlantic states. These specimens had been obtained by exchange and as gifts from other collectors, including Robert Gilmor Jr. of Baltimore.

Gilmor, a wealthy merchant who collected both minerals and oil paintings, was the first person in this country to find and correctly identify a uranium mineral – a specimen of autunite from Baltimore found about 1814. Specimens of this uranium mineral were transmitted to Cleaveland, whose collection is still preserved at Bowdoin, but they cannot now be found.

Cleaveland's collection is especially interesting when taken in context with his excellent *Treatise on Mineralogy and Geology*, published in Boston in 1816 with a second edition in 1822. This was the standard American textbook on minerals for many years.

Another early American book, of special interest to mineral collectors then and now, was Samuel Robinson's *Catalogue of American Minerals with their Localities*, published in Boston in 1825. It very briefly mentions the minerals found in the towns of the various states and of the Canadian provinces.

A small *Catalogue of Minerals found in the State of Vermont and in the Adjacent States* was published by Frederick Hall in 1824, and numerous short lists of the minerals found at various localities, either privately printed or published in early volumes of the American Journal of Science or in other journals, appeared during this general period.

Many of the localities mentioned in the early lists cannot now be precisely located, or have long since been exhausted; but it is stimulating to read commentaries regarding the discovery by our forefathers of such specimens as spinel crystals 16 inches around the base, emerald crystals six inches long, and fine amethysts by the bushel.

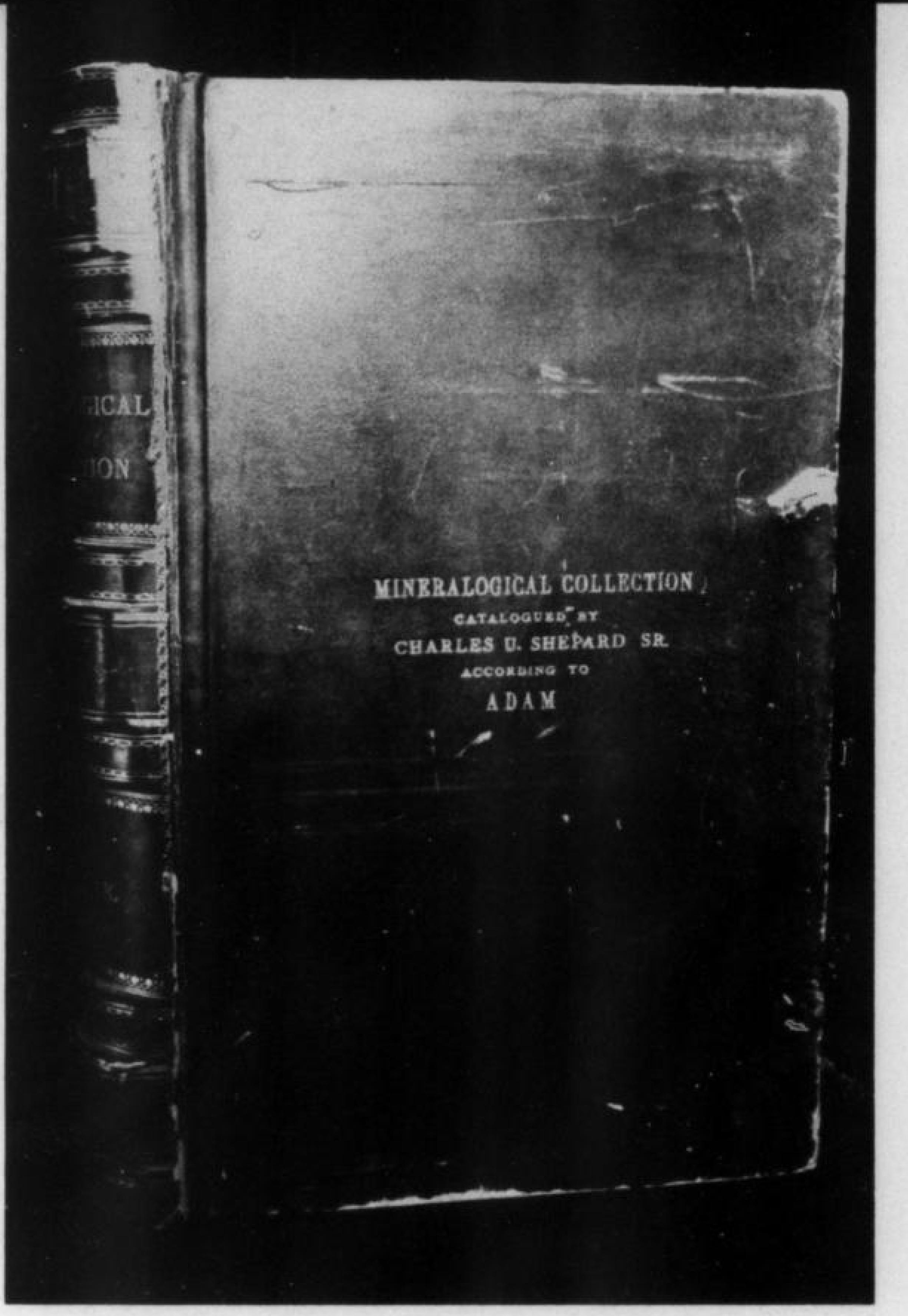
Another important early college collection in New England was possessed by Amherst. It was started after the Yale and Harvard collections but by the middle of the 19th century was one of the best in the country. The collection was compiled primarily by Charles Upham Shepard (1804-1886) with later additions by Edward Hitchcock (who conducted the first state geological survey of Massachusetts, in 1830-1833) and others.

A collection of meteorites developed by Shepard at Amherst was the first, and for a long period, the largest in the country. It totaled 151 specimens in 1861. Unfortunately most of the Amherst collections were lost by fire in 1882. Although some of the material from the Shepard collection is preserved in the National Museum of Natural History.

Harvard University's mineral collection was begun in 1784 with "a half peck of minerals" belonging to Benjamin Waterhouse and is the oldest continuously maintained collection in the United States. An earlier collection at Harvard of objects of natural history that presumably included minerals was destroyed by fire in 1764.

The original basis of the Harvard mineral collection was principally the result of gifts from European collections, including 700 specimens from J.C. Lettsom of London in 1793, 200 specimens from the French Republic transmitted by the French consul in Boston in 1795, and a small collection of building stones purchased in Italy by James Bowdoin and donated in about 1795. Most of these specimens are still preserved.

A major acquisition was made in 1820 when a large collection of European minerals was purchased from C.A. Bloede of Dresden, Germany. The mineral collections of Harvard, Yale and the other colleges of the region have continued to grow down through the years.



The catalogue for the Charles Shepard Collection is extremely unusual in that he attempted to fit the various types of minerals into biological categories.

Notably, the only other important mineral collections in the United States in the early 1800's were those of Archibald Bruce and Adam Seybert. Bruce, who established the American Mineralogical Journal in 1810, acquired a valuable collection during a tour of Europe from 1801 through 1803. This collection was kept in New York City but the final disposition is unknown.

Seybert's collection, also of European minerals, was brought to Philadelphia about 1795 and is still preserved in the original cabinets at the Philadelphia Academy of Natural Sciences. There were numerous smaller private mineral collections in the country in the decades around 1800, but little is now known of their contents or of the contest in which they were used. Among them were those of David Hosack of Columbia College in New York City, which was given to Princeton in 1821; Silvanius Godon of Philadelphia, which was presented to the Academy of Science in 1816; Hoseph Sansom of Philadelphia, given to Haverford College about 1832; and a reputedly fine collection belonging to Joseph A. and J. Randolph Clay of Philadelphia.

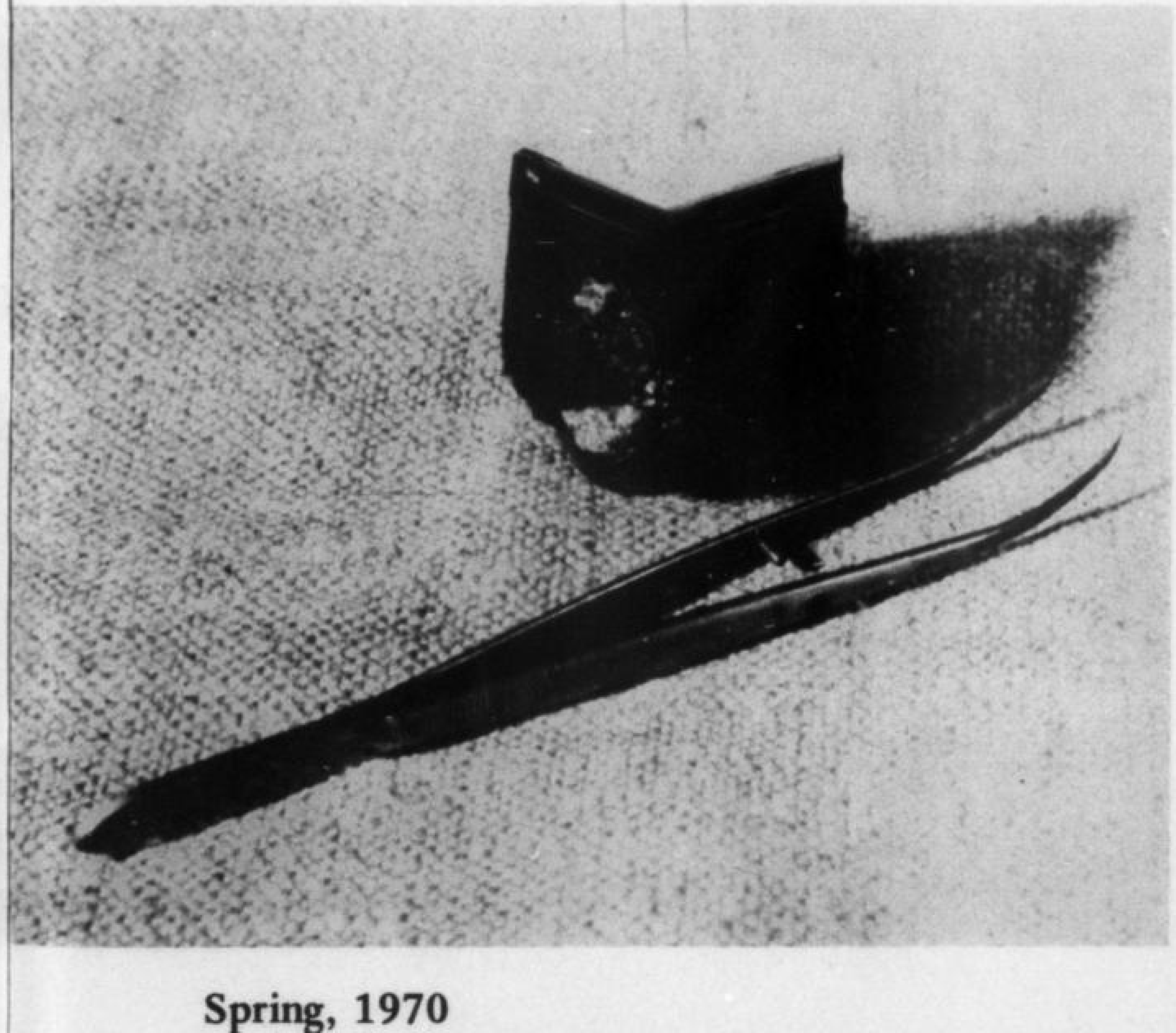
The main period of development of American mineral collections was between the end of the Civil War and the first decade or so of the 20th century.

Recognition should be given to the innumerable amateur collectors who, over the years, have helped find and make known the minerals of New England. The bulk of the fine specimen material from the pegmatites and other mineral occurrences of the region has come directly or indirectly through the interests of such people. There is often no written record of their work and collections, other than that which is pieced together from the accession catalogues of museums, and from brief acknowledgements given in scientific papers. For the most part their industry and love of minerals is preserved only in memory.

Benjamin K. Emerson, in a monograph on the geology of western Massachusetts which was published in 1898, paid tribute to the many physicians, teachers and laymen who in the early 1800's contributed to the mineralogy of Massachusetts. "Men without learning, books or assistance, who, from a strong love of the quest, roamed over the hills hunting for minerals, and became as acute and skillful in the search as their neighbors did in hunting and fishing," according to Emerson. Among the men of this ilk was David Hunt, a physician of Northampton. Amos Eaton said, in 1820, that Hunt had every mineral of the state at his call.

A number of these enthusiastic students of mineralogy both past and present have contributed accounts of the minerals of New England to the scientific literature. One of them, Alanson Nash, about whom nothing is known other than the comment by B.K. Emerson that he was a shoe cobbler, in 1827 published the best existing account of the

(continued on page 10)



This fine twinned cassiterite specimen from Schlaggenwald, Bohemia, Czechoslovakia is one of the many superb specimens in the Charles U. Shepard mineral collection residing in the National Museum of Natural History, Smithsonian Institution.

Yedlin on micromounting

In the past few years the collector of micromounts has come to the fore at a pace far exceeding statistical expectations. The reasons are many, and in no small measure reflect a growing sophistication in his tastes, and a growing dissatisfaction with the scarcity of fine mineral materials, presently available only at tremendous prices. This has resulted in a quest for small superb specimens, common and rare, and a banding together of enthusiasts devoted to this phase of the mineral art.

Collecting areas are closing. Insurance companies are insisting that mining and quarrying operators bar potential trouble-makers (in this case accident and legal prone collectors). The horde of specimen-gatherers descending upon any rock removing operation is so large and persistant that it interferes with mining operations. Ergo the closures and refusals. Fine specimens are yet available, from far off places, thru dealers in minerals, from the dissemination of old collections and such, but the joys of field work are fading.

Not so with the micromount enthusiast. No deserted quarry, no road cut, no building excavation in rocky area is so barren that it will not produce adequate (and often superb) mineral specimens of this type, lining minute cavities and seams, and ideal for viewing under low magnification, preferably in stereo. Both the scientific and artistic needs of the enthusiast are satisfied: – the seeking, selecting and determining of the mineral, and the creating of an exquisite work of art, a fine mineral micromount.

What is a micromount? From early times and early collectors – Rakestraw, Fiss, Bement, et. al. – it has meant the assembling and preserving of specimens of minute crystals of minerals, observed and appreciated only by viewing thru a magnifier. The nomenclature indicates a fixed holder of some kind – a mount – to help preserve the specimen and present its "best face forward". Thru the years containers have varied – from glass microscope slides

(continued on page 11)

collections

(continued from page 9)

lead veins of the Northampton district in Hampshire County, Massachusetts in the American Journal of Science.

James Dwight Dana, the editor of the Journal, later commented on the difficulty he had in "deciphering the crabbed script of the author and in bending his sentences to the common rules of grammar." Nash's paper, incidentally, was the first effort made in this country to explain the origin of an ore deposit.

The names of some of the private mineral collectors of older times have been given to new mineral species found in New England. Among them are amesite, named in 1876 for James T. Ames, proprietor of an iron foundry in Chicopee. Ames was also part owner of the Chester emery deposit.

Hamlinite is named for Augustus Choate Hamlin (1829-1905) of Bangor, Maine. Hamlin, a doctor with a distinguished career in the Army medical service during the Civil War, developed the Mount Mica pegmatite for gem tourmaline.

Dickinsonite was named in 1878 for the Reverend John Dickinson, who made a collection of the minerals of the Branchville, Connecticut, pegmatite. Gibbsite honors Colonel George Gibbs, and fillowite is for Mr. A.N. Fillow of Branchville. Other names given to minerals from New England, including cleavelandite, bowenite, danaite, sillimanite and cookeite honor early scientific workers. May the list long increase.

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YEDLIN

(continued from page 10)

with a cemented glass cover; a sealing wax or metal collar, also glass covered, on the slide, to accommodate small clusters of crystals; oblong paper boxes; square paper ones; and finally to the present day square plastic box.

Rules and regulations have from time to time established the box size, methods of mounting and labeling, single crystals or minute matrix specimens, etc. There are no laws or regulations for the individual. It is true that if he wants to enter a club competition he must comply with the requirements of the club. This is axiomatic. Beyond this there are no restrictions. He mounts as he chooses. From this there may be adduced sufficient data to formulate a workable definition. How's this? – "Micromount, a natural mineral, in crystals, permanently mounted, properly labeled, requiring magnification for proper observation". No limitations here as to size, "carpentry," quantity of enlargement or non-essential details. Box – your choice. Technique – your choice. Size – your choice, just so long as the focal point of interest requires magnification for proper observation.

Rambling Of A Micromounter

Just returned from Tucson, Arizona and Santa Monica, California, where we attended the Rocky Mountain (and American) Federation, and the Pacific Micromount Conference meetings, respectively. Had a ball. Details in future columns, but we must give some of the highlights.

The profusion of exhibits and educational materials, among which shone those of the Smithsonian Institution and British Museum, the latter with some of the famous Cornwall specimens, and with the Curator of Minerals, Peter Embrey, there to discuss them.

Minerals acquired by us from dealers, at most reasonable prices, because of size requirements: – Mexican milarite; Brazilian euclase; legrandite; a new boleite from Montana; heubnerite; papagoite; shattuckite from Ajo, Ariz.; adamite from a new pocket at Mapimi, (superb and most reasonable); annabergite from Laurium; minute clear crystals of arsenolite from Manhattan, Nevada; four-

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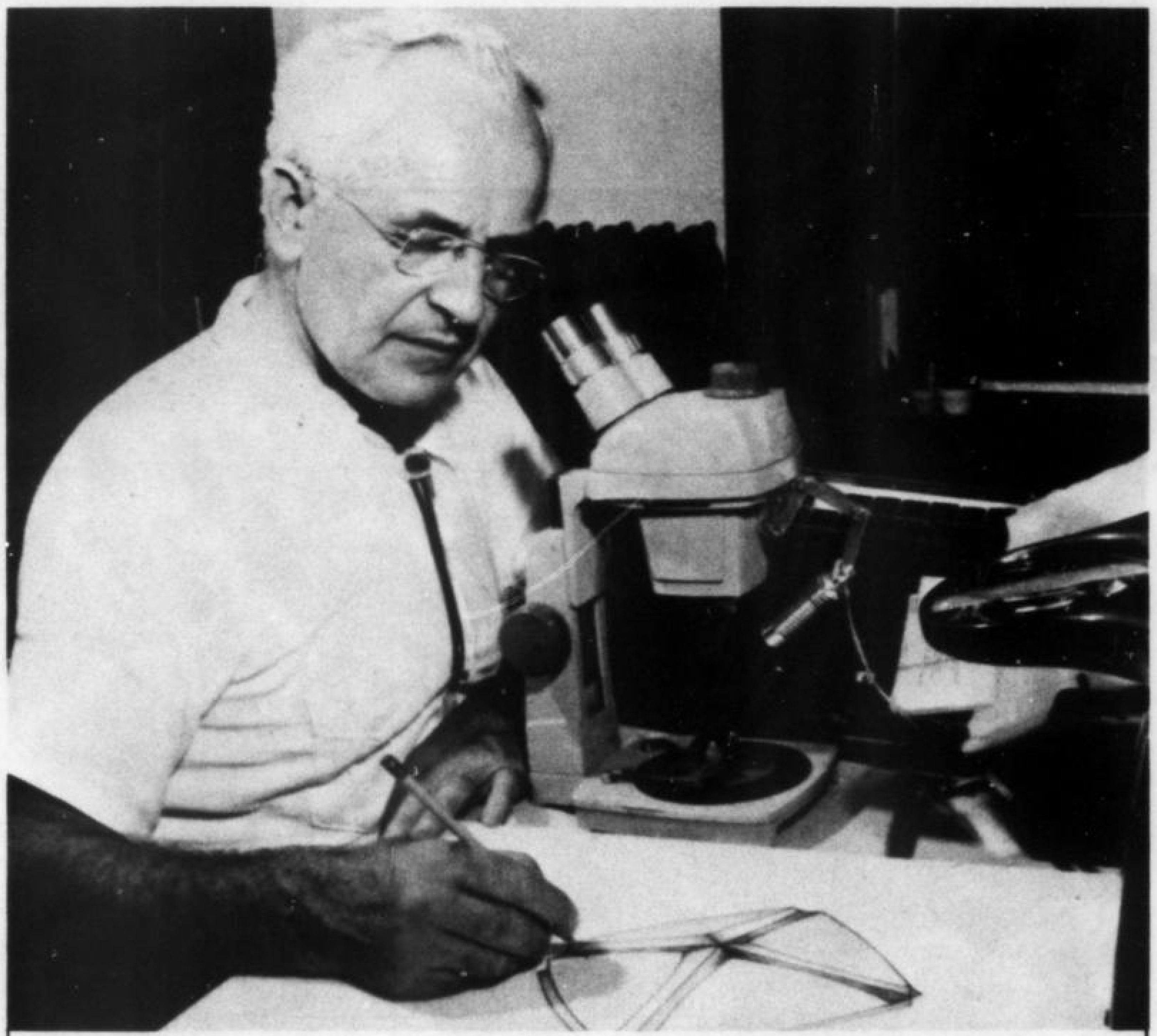

Paul Seel –
gentleman, scholar & mineral collector

by Paul E. Desautels
the Smithsonian Institution

To sit around for a long pleasant evening of listening while Paul Seel spins tales of mineralogy and mineral collecting is a rare treat indeed! He tells of events and of the legendary mineralogical giants associated with them. What's more, he tells of them with authority because he has known many of them personally. How many of us can claim knowing all the founders of the American Mineralogist and being a personal friend of the first editor, Dr. Edgar T. Wherry, for years? How many mineral collectors can claim successful completion of a college course in crystallography taken for the purpose of supporting a hobby interest? Paul Seel can claim all of this and much more in the way of experiences gathered from his enthusiastic pursuit of the mineral collecting hobby. His contributions to the hobby are just as numerous.

Paul was born in 1904 in Silesia, Germany. His home town of Breslau, sitting on ancient sand and gravel beds, was the source of his first collected specimens – some pretty pebbles. By 1925 he had earned a college degree in Civil Engineering and in 1926 left Germany to start life in the United States. Starting work with the

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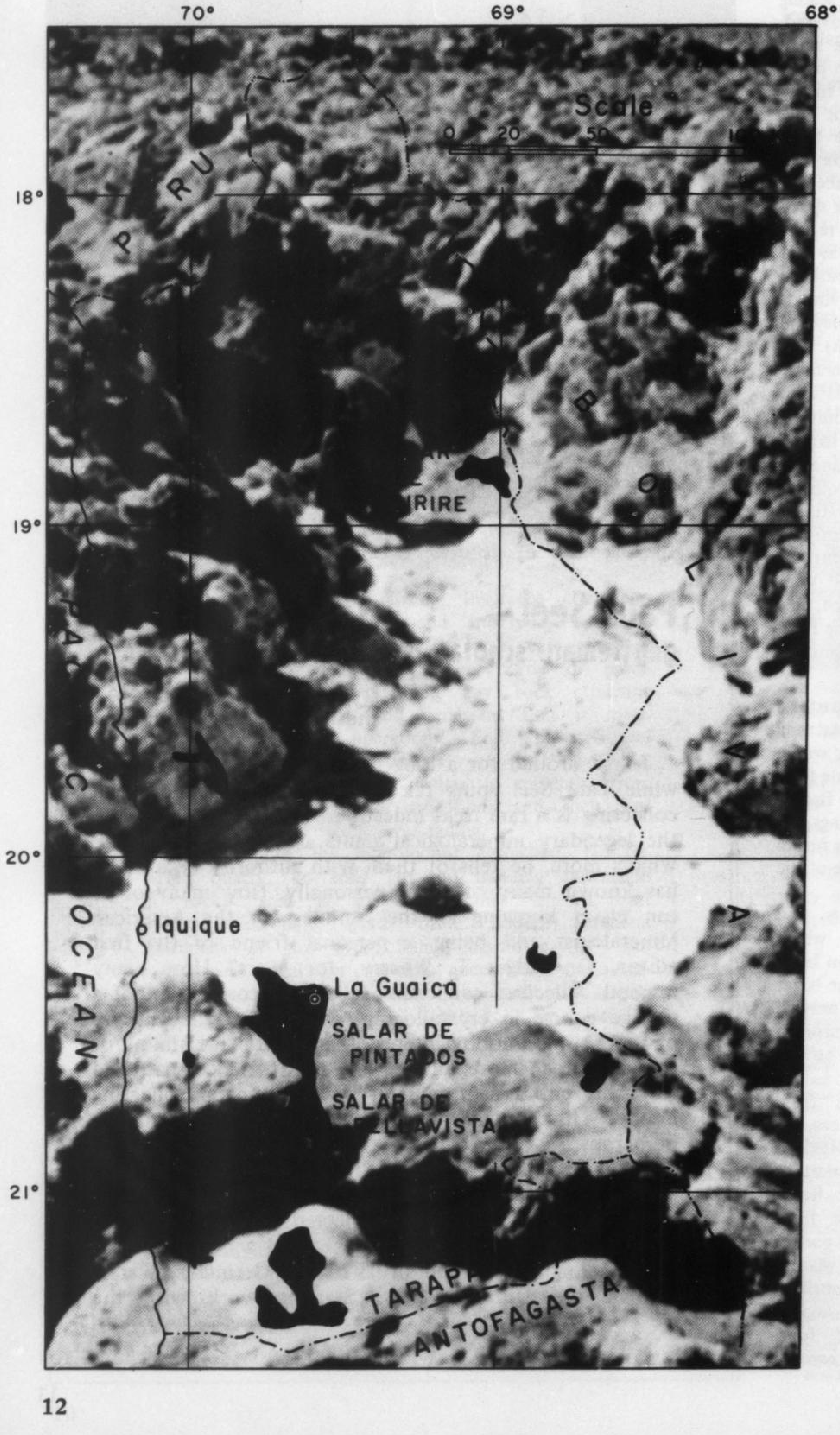

ice-clear

from Salar de Pintados northern CHILE

Publication authorized by the Director, U.S. Geological Survey

mirabilite

by

George E. Ericksen • Mary E. Mrose • Joseph J. Fahey

Abstract

Unusual deposits of high-purity, clear, coarsely crystalline mirabilite are found in the northeastern part of Salar de Pintados, a large salt pan in the Atacama Desert of northern Chile. The mirabilite occurs as discontinuous lenticular layers, as much as 40 cm thick, beneath a hard rubbly permanently dry salar crust that consists chiefly of halite. It was deposited by capillary evaporation of saline ground water from the underlying water-saturated silts and clays.

X-ray powder diffraction patterns of this mirability were obtained for sealed mounts of material that was pulverized at freezing temperatures. These patterns, the most detailed yet obtained for natural mirabilite, show the following strong lines: (hk , d(meas.), I): 200, 5.48 Å (100); 023, 3.20 Å (71); $\bar{2}04$ and 311, 3.09 Å (71); $\bar{1}31$, 3.26 Å (50); 223, 2.515 Å (50); 102, 4.76 Å (42); 132, 2.797 Å (42).

The X-ray powder data and crystallographic data derived from them are in good agreement with those reported for synthetic mirabilite.

Introduction

Lenticular layers of massive coarsely crystalline mirabilite, $Na_2SO_4 \cdot 10H_2O$, resembling clear ice, occur in the northeastern part of Salar[1] de Pintados, near the village of La Guaica, Tarapacá Province, northern Chile (Fig. 1).

Salar de Pintados is in the Pampa del Tamarugal, a segment of the Central Valley of northern Chile that is bordered on the west by the low Coastal Range and on the east by the high Andes Mountains. It is at an altitude of about 1,000 meters, and is in the Atacama Desert, which is probably the driest in the world.

The mirabilite is exposed in pits and trenches over an area of several square kilometers, where it has been mined sporadically for more than 50 years as a source of sodium sulfate for local industry. Similar deposits of mirabilite also have been mined in the southeastern part of Salar de Bellavista (Fig. 1).

Mirabilite also occurs in salars of the high Andes of northern Chile where freezing temperatures are common in contrast to Salar de Pintados where the temperature rarely, if ever, drops to 0°C. In the winter (June) of 1967, we found mirabilite at the surface of Salar de Surire (Fig. 1), as scattered crystals 1- to 5-mm long, as discontinuous blebby crusts 1- to 3-mm thick, and as lenticular dense crystalline masses as much as 2 meters in diameter and 20 cm thick.

Here the lenticular masses are aggregates of small crystals of mirabilite, not massive crystalline material like that in Salar de Pintados.

To our knowledge, layers of coarsely crystalline mirabilite as part of a permanently dry salt pan crust have not been reported elsewhere. Salt pans, playas, and saline ponds or lakes in western United States locally contain mirabilite as surface efflorescences and as single crystals and layers of crystals that formed in playa muds or in open saline water (for examples see Wells, 1923, p. 18-32; Smith and Haines, 1964, p. 30; Jones, 1965, p. A45; Hardie, 1968, p. 1288). Bedded mirabilite deposits, such as those in the Great Plains of Western Canada (Cole, 1926, p.81-82), consist of aggregates of crystals that settled out of saline lakes and ponds. Coarsely crystalline mirabilite, which evidently also accumulated in saline ponds, has been found in Antarctica as surface layers as well as layers and crystals in ice and moraines (David and Priestly, 1914, p. 277; Black and Bowser, 1968, p. 228).

Very little published data are available about mirabilite occurrences in Chile. Ericksen (1963, p. 129) briefly described the mirabilite in Salar de Pintados. Vila (1953, p. 376-377) also described these deposits and stated that similar deposits occurred in Salar de Bellavista and in several other salars in northern Chile. Brüggen (1918) and Gale (1918) discussed the potash deposits in Salar de Pintados; they mention, but do not describe, the sulfate deposits near La Guaica.

Occurrence and Origin

The saline crust of Salar de Pintados, in the vicinity of the La Guaica sulfate deposits, is generally about a meter thick, and consists of three distinct layers. The mirabilite layer, at the bottom of the crust (Fig. 2), ranges from a few centimeters to about 40 centimeters in thickness.

It rests on moist to water-saturated silts and clays containing thin layers, pods, and blebs of fine-grained gypsum. It is overlain by a layer of porous to cavernous, granular white thenardite and admixed halite, locally containing large (as much as 20 cm long) prismatic thenar-

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[1] Salar, as used in Chile and in this report, designates a salt pan, a flat undrained area covered with a salt crust generally not more than a meter or two thick.

dite crystals. This layer, which evidently formed in part by desiccation of mirabilite, is commonly 20-30 cm thick.

The uppermost layer of the crust, ranging from 30 to 75 cm in thickness, consists of large flat cakes and smaller rubbly fragments of halite with admixed reddish-brown clay and silt from the underlying sediments and small amounts of thenardite and gypsum.

The mirabilite locally contains admixed clay and silt from the underlying sediments and sparse amounts of gypsum, halite, and the recently defined mineral hydroglauberite, $5Na_2SO_4 \cdot 3CaSO_4 \cdot 6H_2O$ (Slyusareva, 1968). This is the second authenticated occurrence of hydroglauberite.

The mirabilite layers evidently were formed, and continue to form today, by capillary evaporation of saline ground water at or near the base of the salt pan crust. The separation of the mirabilite from the other saline components in the ground water suggests a delicate balance between evaporation of the ground water to concentrate a brine, and temperature changes,[2] diurnal and annual, to precipitate the mirabilite. A separation of the saline components on the basis of solubility is indicated by a concentration of gypsum (much less soluble than mirabilite) in the clays and silts below, and of halite (more soluble) in the salar crust above the mirabilite.

Accumulation and preservation of the mirabilite as part of a relatively thin, permanently dry salt pan crust can be attributed to an unusual climatic and hydrologic environment that has the following main characteristics: 1) paucity of rainfall; 2) relatively cool climate (for a desert of low latitude and altitude); and 3) abundant near-surface high-sulfate ground water, and 4) absence of surface runoff or accumulation.

Average annual rainfall at Salar de Pintados may be less than 1 mm per year, as indicated by incomplete records cited by Fuenzalida (1966, Table 1). It is not uncommon for measurable rainfall to occur only once every 5-10 years at any given locality in the Atcama desert, and during one 17-year period, 1942-1959, a rain-gauging station at Canchones, near La Guaica, recorded no rainfall (Castillo, 1960, p. 25).

Fuenzalida (1965, p. 123-124) reported the average annual temperature at Canchones to be 16.7°C; February, the warmest month, averaged 21.2°C; June, the coldest month, 12.9°C. Diurnal temperature changes of at least 40°C (with a minimum of about 5°C) have been reported at Canchones (Castillo, 1960, p. 11).

In spite of low rainfall, the ground-water table is at or near the surface over much of Salar de Pintados, and the saline crust is actively being built up with saline material deposited by capillary evaporation of this ground water. The ground-water supplies in the salar are maintained by surface and underground flow of water from the Andes, where rainfall is much greater. There is no evidence of surface flow or ponding of surface water in the vicinity of La Guaica, although surface water does accumulate periodically in the eastern and lower part of the salar.

Sodium sulfate and the other salines in Salar de Pintados were derived chiefly from rhyolite tuffs of late Tertiary age, which are extensive in the northern Chilean Andes. These tuffs contain water-soluble salts, commonly in amounts of as much as 1/4 percent, with Cl^- and SO_4^{--} as the principal anions (Ericksen, 1963, p. 142).

The salines in the tuffs are leached by rain water and carried by surface runoff and ground-water flow into the La Guaica area. Analyses of ground water in the immediate vicinity of the mirabilite deposits are not available. The sample of water from a well in La Guaica (Table 1), which

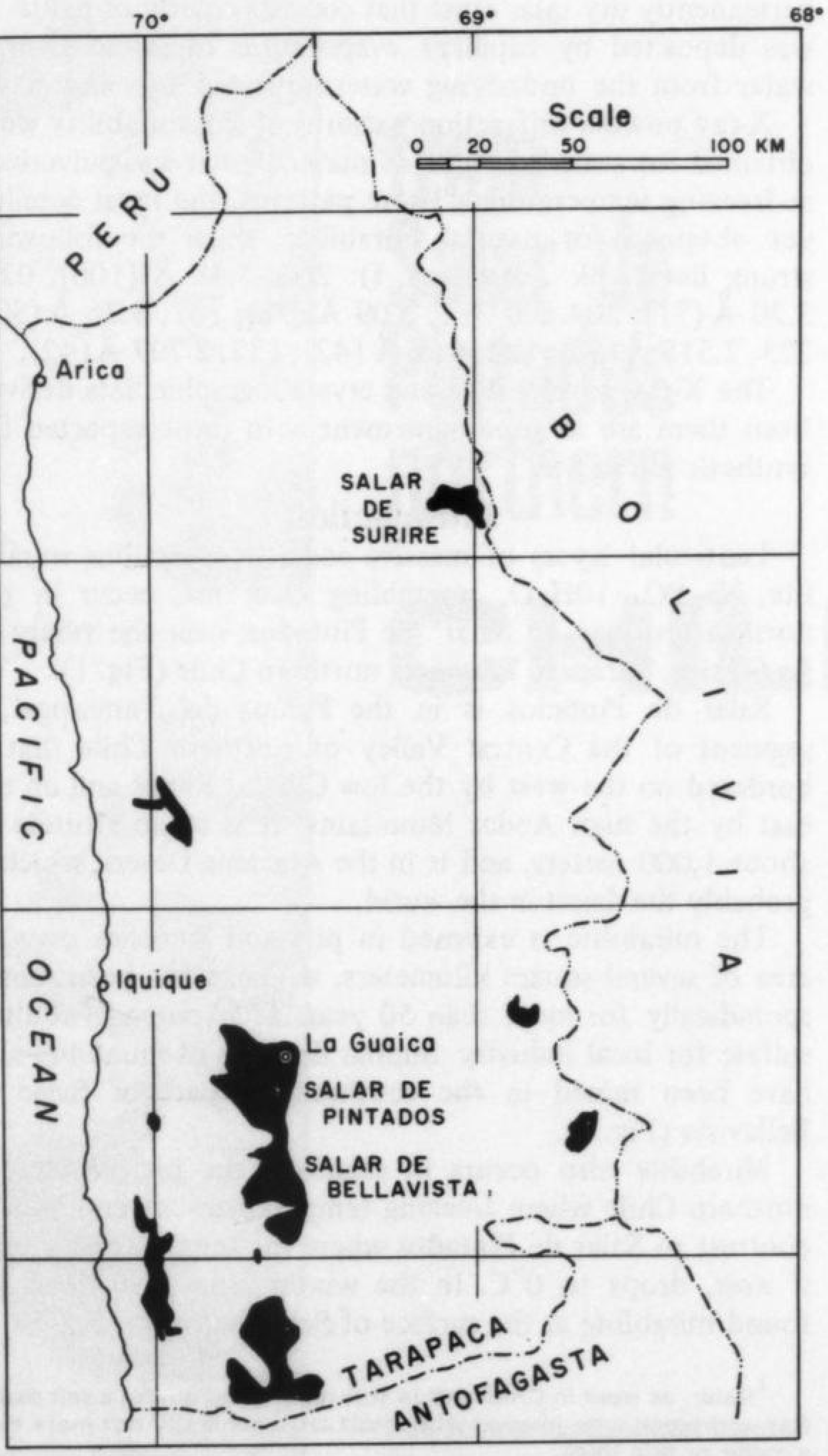

Figure 1. Index map showing salars (black) in Tarapaca Province, northern Chile

[2] The transition temperature of mirabilite to thenardite is 32.38°C in a pure sodium sulfate solution. It is lowered by the presence of other ions; for example, it is 17.5°C in a saturated solution containing 7.57 percent sodium sulfate and 22.3 percent sodium chloride (Chrétien, 1929, p. 139). Furthermore, the solubility of mirabilite decreases markedly with decrease in temperature.

Figure 2. Mirabilite layer covered with 1-5 cm of white powdery thenardite (a desiccation of the mirabilite), exposed in a newly opened trench, Salar de Pintados, near La Guaica. The mirabilite layer is 20-30 cm thick. It rests on water-saturated clay and silt and is overlain by a rubbly salar crust, as can be seen in the trench walls, which consists chiefly of halite and admixed silt and clay.

is about half a kilometer from the nearest mirabilite deposit, may be similar (though less concentrated) to the saline ground water from which mirabilite is now crystallizing.

Physical and Optical Properties

The material utilized in this study consists of massive to vesicular mirabilite resembling clear ice. Specimens consist of large interlocking anhedral crystals of mirabilite, which, as indicated by cleavage planes, are commonly 10 centimeters or more in diameter. Some of the mirabilite contains abundant round to tubular or irregular brine-filled cavities that are 1-20 mm in longest dimension.

The mirabilite from Salar de Pintados shows three directional cleavages: (100) perfect; (010) and (001) fair to good. The (011) clevage reported by Rosicky (1908) was not observed. Fracture is conchoidal and the luster is vitreous. Hardness is about 2½. Specific gravity calculated from X-ray data is 1.467 (Table 2), essentially the same as that (1.464) measured by Meulendijk (1956). This mirabilite does not fluoresce in either long- or short-wave ultraviolet radiation.

The refractive indices for mirabilite were not determined in this study because of difficulty in handling the material at room temperature and because the optical characteristics for mirabilite are well-defined in the literature (Larsen, 1921, p. 111; Schaller *in* Schaller and Henderson, 1932, p. 81).

The main refractive index for the Chilean mirabilite, calculated by the Gladstone-Dale law, is 1.391. This value is in very good agreement with the measured mean refractive index 1.396, based on Larsen's data, α=1.394, β=1.396 and γ=1.398; and 1.394, obtained from Schaller's data, α=1.391, β=1.394, and γ=1.396

X-ray Study

A major purpose of our X-ray study was to develop techniques that would give reliable powder diffraction data, for both camera and diffractometer work, under normal operating conditions of X-ray machines. Because mirabilite is unstable in dry air at normal room temperature the main problem was to develop a method for pulverizing the mirabilite and protecting it during an X-ray run.

Such techniques would be of aid in the search for mirabilite in natural mixtures of saline minerals where it is commonly overlooked because it desiccates to thenardite during normal sample preparation. It was found that crushed mirabilite was stable in air at near-freezing temperatures and remained stable in X-ray mounts at room

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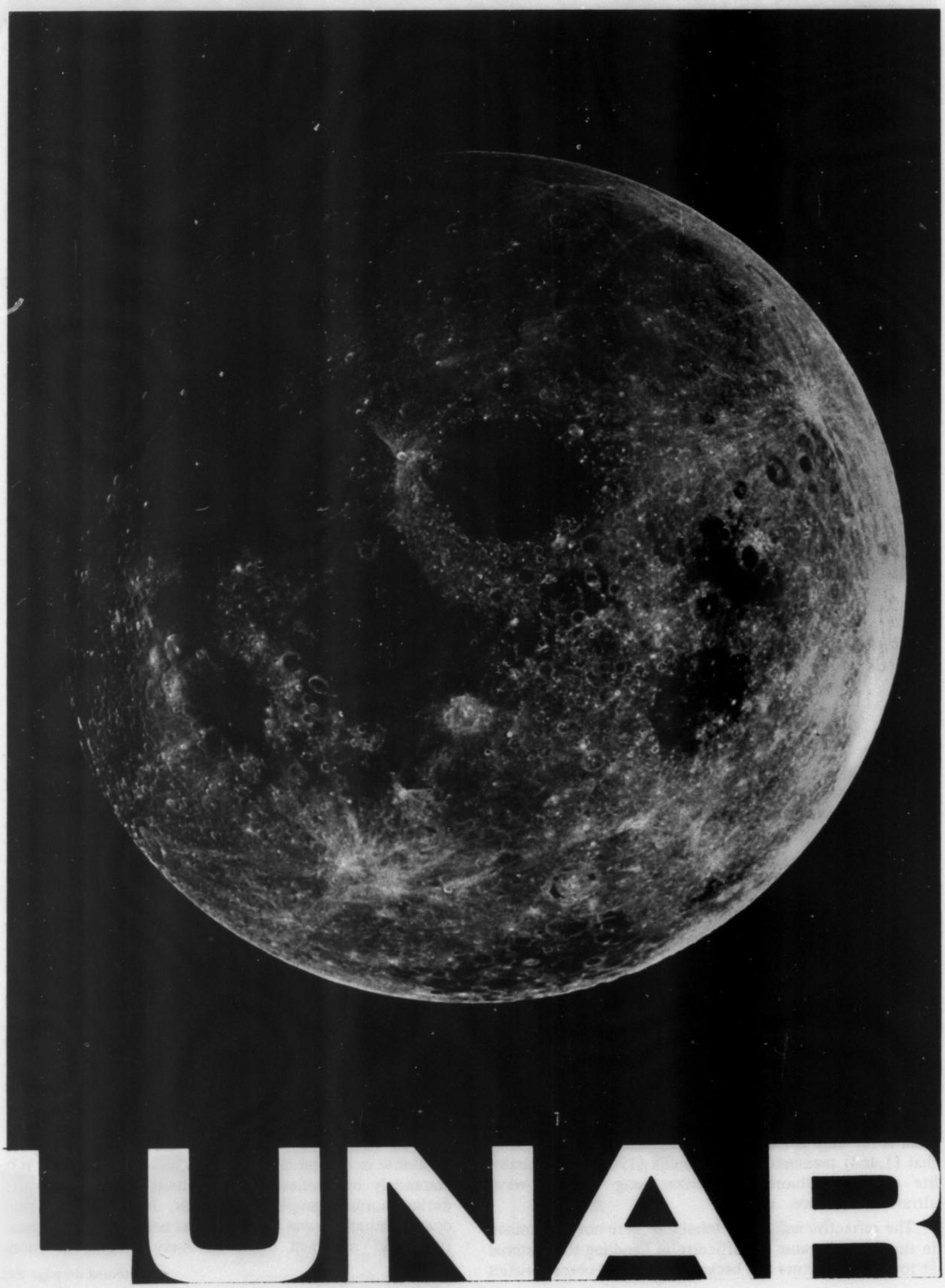


LUNAR M

MINERALOGY

by
Brian Mason
the Smithsonian Institution

Compared to terrestrial rocks, the mineralogy of the lunar samples so far collected is quite limited. This is partly caused by the extremely limited size of the areas in which these samples were collected. Evidently, however, they include material ejected from other areas of the Moon and material introduced by impacting meteorites.

The limited mineralogy can also be ascribed in part to the limited range in chemical composition of Moon materials, and in part to the absence of water and weathering processes on the Moon. By contrast, on the earth these processes result in the formation of a great variety of hydrated minerals from the comparatively few primary minerals of igneous rocks.

The accompanying table of lunar minerals has been compiled from the numerous reports made on the Apollo 11 materials. Division of the table into major, minor, and accessory minerals is convenient but is also, to some extent, arbitrary. For example, in some rocks ilmenite and pyroxene are only minor constituents. In others iron and nickel-iron may slightly exceed 1%. Some of the minor and accessory minerals are not widely distributed but appear only in certain specific rock types.

In addition to the minerals listed in Table 1, a few more have been tentatively identified. Further information is needed before their occurrence as lunar materials can be accepted as certain. These include aragonite, $CaCO_3$; chalcopyrite, $CuFeS_2$; magnetite, Fe_3O_4; an amphibole mineral; a mineral of the mica group; graphite, C; and native copper, Cu.

Information now available on Apollo 12 collections indicates that the mineralogy of these newer samples is not significantly different from those of Apollo 11, even though the proportions of the individual minerals in these rocks may be very different. Olivine is a major mineral in many of these rocks, and ilmenite is a minor, rather than a major constituent, as it was in Apollo 11 samples.

The Preliminary Examination Team at the Lunar Receiving Laboratory in Houston classified the Apollo 11 collec-

(continued on next page)

Minerals In Lunar Materials

Name	Formula	Crystal System
Major		
(greater than 10%)		
Pyroxene	$(Ca,Fe,Mg)_2Si_2O6$	Monoclinic
Plagioclase	$(Ca,Na)(Al,Si)_4O_8$	Triclinic
Ilmenite	$FeTiO_3$	Hexagonal
Minor		
(between 1 and 10%)		
Olivine	$(Mg,Fe)_2SiO_4$	Orthorhombic
Cristobalite	SiO_2	Isometric
Tridymite	SiO_2	Hexagonal
Pyroxferroite	$CaFe_6(SiO_3)_7$	Triclinic
Accessory		
(less than 1%)		
Iron	Fe	Isometric
Nickel-iron	(Fe,Ni)	Isometric
Schreibersite	$(Fe,Ni)_3P$	Tetragonal
Cohenite	Fe_3C	Orthorhombic
Troilite	FeS	Hexagonal
Quartz	SiO_2	Hexagonal
Armalcolite	$(Fe,Mg)Ti_2O_5$	Orthorhombic
Ulvospinel	Fe_2TiO_4	Isometric
Chromite	$FeCr_2O_4$	Isometric
Spinel	$MgAl_2O_4$	Isometric
Perovskite	$CaTiO_3$	Isometric
Rutile	TiO_2	Tetragonal
Baddeleyite	ZrO_2	Monoclinic
Zircon	$ZrSiO_4$	Tetragonal
Apatite	$Ca_5(PO_4)_3(F,Cl)$	Hexagonal
Whitlockite	$Ca_3(PO_4)_2$	Hexagonal

An Apollo astronaut gathers Lunar mineral samples with some very sophisticated collection equipment.

photo courtesy of NASA

tions into four types, a classification that also applies to the Apollo 12 materials. These four types are as follows:

Type A: fine-grained vesicular crystalline igneous rocks, analogous to terrestrial basalt

Type B: medium-grained vuggy crystalline rocks analogous to terrestrial dolerite

Type C: microbreccias, consisting of small rock and mineral fragments in a groundmass of comminuted material

Type D: fines, material smaller than 1 cm. in diameter.

The individual minerals and mineral groups identified through examination of the lunar material are classified into the following categories.

Pyroxene

Pyroxenes with a wide range of compositions are the principal phases in most of the lunar materials. In the coarser-grained rocks this mineral is readily distinguished with the naked eye as cinnamon-brown lustrous grains up to 2 mm across. In thin sections under the microscope the color is usually pale buff, sometimes with a pink tint.

Overlooking their minor content of titanium and aluminum, lunar pyroxene compositions can be expressed in terms of the three components $CaSiO_3$, $MgSiO_3$, and $FeSiO_3$. Many names have been applied to different pyroxene compositions, but the current standard nomenclature is illustrated in Fig. 3; the shaded areas in this figure indicate compositions for which natural pyroxenes have not been found. (Interestingly enough, the composition of the new mineral pyroxferroite falls within the shaded area near the $FeSiO_3$ apex).

Individual compositions of lunar pyroxenes are shown on Fig. 3. Most of them fall within the composition fields of augite and ferroaugite; some are pigeonites, frequently occurring as cores mantled by augite. Exsolution of hypersthene or clinohypersythene is rarely visible in microscopic examination, but is frequently detected by x-ray diffraction or electron microscopy.

The range in compositions illustrated in Fig. 3 may be observed in a single crystal, zoned from a magnesium-rich core to an iron-rich margin. Sometimes the pyroxene is rimmed with pyroferroite, indicating that when the iron to magnesium ratio exceeds a certain value a structural change is induced, forming this new mineral.

Pyroxferroite

The Preliminary Examination Team observed a yellow mineral in the coarser-grained Apollo 11 rocks which they recognized as a probable new mineral. They noted that it seemed to be concentrated in vuggy areas of the rocks, evidently forming in a late stage of crystallization. This yellow mineral was subsequently examined by several groups of investagators and it proved to be structurally identical with the terrestrial mineral pyroxmangite.

Pyroxmangite is essentially a manganese silicate in which some of the manganese is replaced by a ferrous iron. The

Figure 1. The broken surface of a Type B (medium-grained) lunar basalt, shows the granular texture and presence of numerous vugs, some of which are lined with crystals of plagioclase and pyroxene. The specimen is about 4 cm long. (NASA photograph S-69-45585).

lunar mineral in contrast is essentially a ferrous silicate with only minor amounts of manganese, so it merits a specific name. Pyroxferroite was selected because it indicates its composition as well as its relationship to pyroxmangite.

The mineral occurs mostly as anhedral grains, occasionally as euhedral crystals, up to a few tenths of a mm in size. It has been observed mantling a core of pyroxene. Individual grains are yellow, but it is almost colorless in thin section. It is triclinic, and has perfect (110) and $(1\bar{1}0)$ and poorer (100) clevages. The density is 3.83.

Analyses show a somewhat variable composition, as follows (weight per cent): SiO_2 44.7-47.1, TiO_2 0.3-0.7, Al_2O_3 0-1.2, FeO 44.6-47.7, MgO 0.3-1.2, MnO 0.6-1.0, CaO 4.7-6.3, Na_2O 0-0.1, K_2O 0-0.1. In terms of the principal components, then, the formula can be written $CaFe_6(SiO_3)_7$.

This formula is consistent with the pyroxferroite crystal structure, the principal feature of which is a single chain of SiO_4 groups linked through common oxygen atoms (giving the SiO_3 composition), the chain having a 7-unit repeat. The usual pyroxene chain has a 2-unit repeat. Minerals having SiO_3 chains but with different repeat numbers are known as pyroxenoids. Pyroxferroite can thus be classed as a pyroxenoid.

Plagioclase

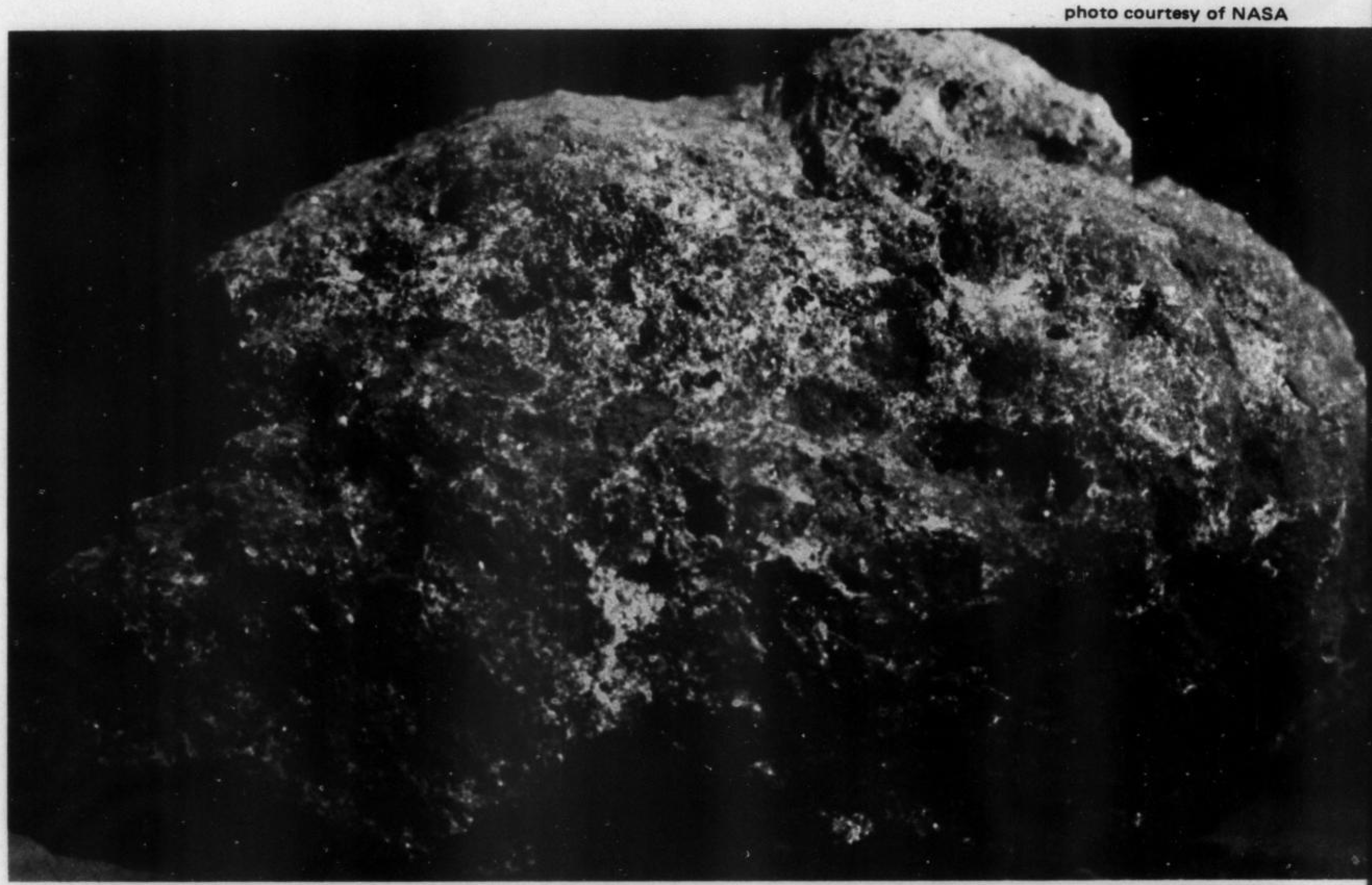
After pyroxene, plagioclase feldspar is the most abundant mineral in the Apollo 11 rocks, making up 20-40% of the volume of most of them, and somewhat less by weight. Some rock fragments in the lunar breccias and soil consist almost entirely of plagioclase. In the coarser-grained rocks it is seen as white granular aggregates or as platy crystals tabular parallel to (010) with individual crystals ranging up to about 1 mm in length. In thin sections the mineral is colorless and usually shows albite type twinning.

The crystals are sometimes hollow, which is a feature characteristic of relatively rapid growth. The tubular growth cavities are filled with a fine-grained material which evidently represents the last liquid to crystallize.

Plagioclase can be considered a solid solution of the components albite, $NaAlSi_3O_8$ (Ab) and anorthite, $CaAl_2Si_2O_8$ (An). Individual plagioclase grains in the lunar rocks show a range of composition from about 60% anorthite to nearly pure anorthite with the commonest composition being near An_{90}. Thus most of the lunar plagioclase crystals fall within the composition range of anorthite (An_{90-100}) and bytownite (An_{70-90}); a few fall in the range of labradorite (An_{50-70}). Individual plagioclase crystals may be zoned, becoming more albitic from core to margin.

In the lunar breccias and soils the plagioclase grains frequently have a chalky appearance and are very friable. In thin sections under the microscope these grains no longer show the characteristic birefringence of plagioclase, and

photo courtesy of NASA



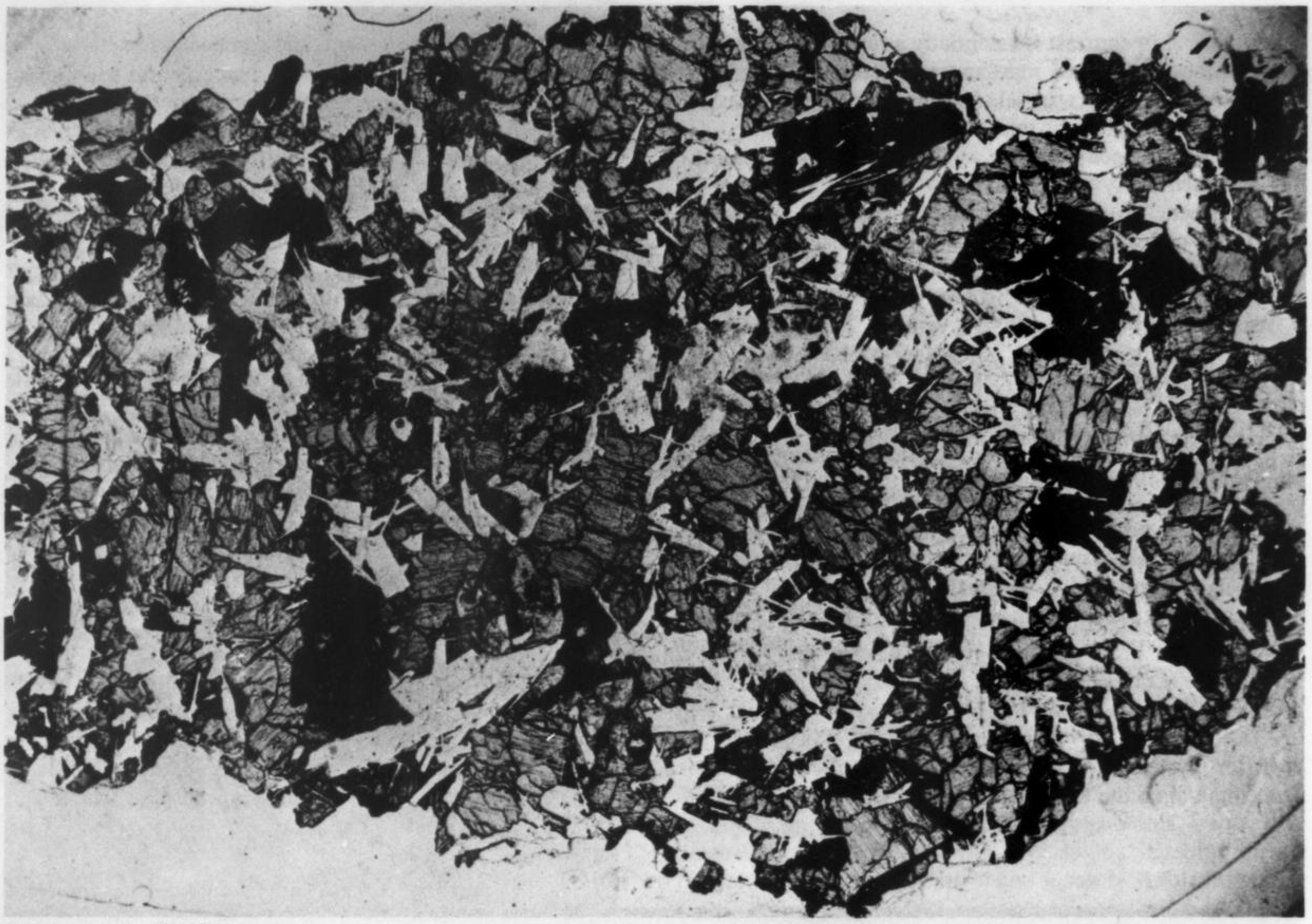


photo courtesy of NASA

Figure 2. This photomicrograph in transmitted light of a thin section of a Type B lunar basalt, shows laths of plagioclase (white, up to about 1 mm long), together with pyroxene (grey) and ilmenite and other opaque minerals (black).

some of the material has become completely isotropic and amorphous to x-rays.

Isotropized plagioclase was first observed in the Shergotty meteorite many years ago and was named maskelynite. It is now known that this isotropization is produced by extreme shock and, as evidence, maskelynite has been identified in rocks associated with terrestrial meteorite craters and in those exposed to nuclear explosions. The presence of maskelynite in lunar breccias and soils is therefore good evidence for shock metamorphism caused by meteorite impacts on the lunar surface.

Potash feldspar

Potash feldspar has been recognized as an accessory constituent in the lunar samples. Potassium is a minor constituent of the lunar rocks (0.1-0.2%), and some of this is combined in the plagioclase feldspar. Part of it, however, evidently concentrated in the residual melt after most of the plagioclase, pyroxene, and ilmenite had formed, and crystallized as small grains of potash feldspar. It probably contains much of the rubidium, cesium, and barium originally present in the magma from which the rocks formed.

Ilmenite

One of the most remarkable features of the rocks recovered by Apollo 11 is the presence of ilmenite. Ilmenite is common in terrestrial basalts, seldom exceeding 5%, but it makes up 10-20% of the lunar rocks. In the coarser-grained rocks it can be recognized with the naked eye as black lustrous grains or platy crystals up to 2 mm long.

Chemical analyses and Mössbauer spectra show that the composition of the lunar ilmenite is close to the ideal formula $FeTiO_3$. Unlike terrestrial ilmenite, the specimens from the Moon contain no detectable ferric iron. Some magnesium (up to about 6% MgO) substitutes for ferrous iron in lunar specimens.

Olivine

This mineral is a minor constituent (up to 5%) in some of the Apollo 11 rocks, and a major constituent of many of the Apollo 12 rocks. In thin sections it is seen as colorless grains usually mantled by augite.

The composition is usually around Fa_{30} (i.e., 30 mole per cent of the Fe_2SiO_4 (fayalite) component), but may range from about Fa_{20} to Fa_{50}. In comparison to most terrestrial olivine it has notably high calcium (0.2-0.4%) and chromium (0.1%), and contains very little nickel (up to about 0.05%); other minor elements are manganese (0.2-0.3%), titanium (0.1-0.2%), and aluminum (about 0.05%).

Cristobalite, Tridymite, Quartz

These three polymorphs of SiO_2 have all been recognized in the lunar materials. Cristobalite and tridymite are minor constituents (up to 5%) of some of the lunar basalts, whereas quartz is rare. In thin sections cristobalite is easily recognized as a colorless mineral with very low birefringence, occurring as granular aggregates interstitial to the major minerals. It is evidently one of the last minerals to crystallize. Tridymite is associated with the cristobalite, occurring as thin platy crystals tabular on (0001).

Naturally occurring cristobalite and tridymite are seldom if ever pure SiO_2, since their structures can accommodate small amounts of other elements, especially alkalies and aluminum. Quartz, on the other hand, usually contains only minute traces of other elements. Lunar cristobalite is reported to contain 0.4-0.8% Al, 0.1% Fe, 0.1-0.2% Ca, 0.1% Na, and 0.2-0.3% Ti.

Troilite

Troilite is the only sulfide thus far positively identified in the lunar samples. It is universally present in small amounts (up to about 0.7%). It usually occurs as small rounded blebs up to 3 mm across, which probably originated as immiscible droplets in the lunar magma. These blebs frequently contain inclusions of metallic iron. Its composition is close to pure FeS. Minor amounts of titanium (0.3%), manganese (0.1%), chromium (0.03%) and nickel (0.02%) have been reported.

Iron, Nickel–Iron

Metallic iron is present in the lunar materials in at least two distinct forms. One is inherent to the lunar rocks, while the other is introduced by impacting meteorites. In the crystalline rocks it occurs within the troilite blebs, usually as rounded inclusions but occasionally showing cubic crystal forms.

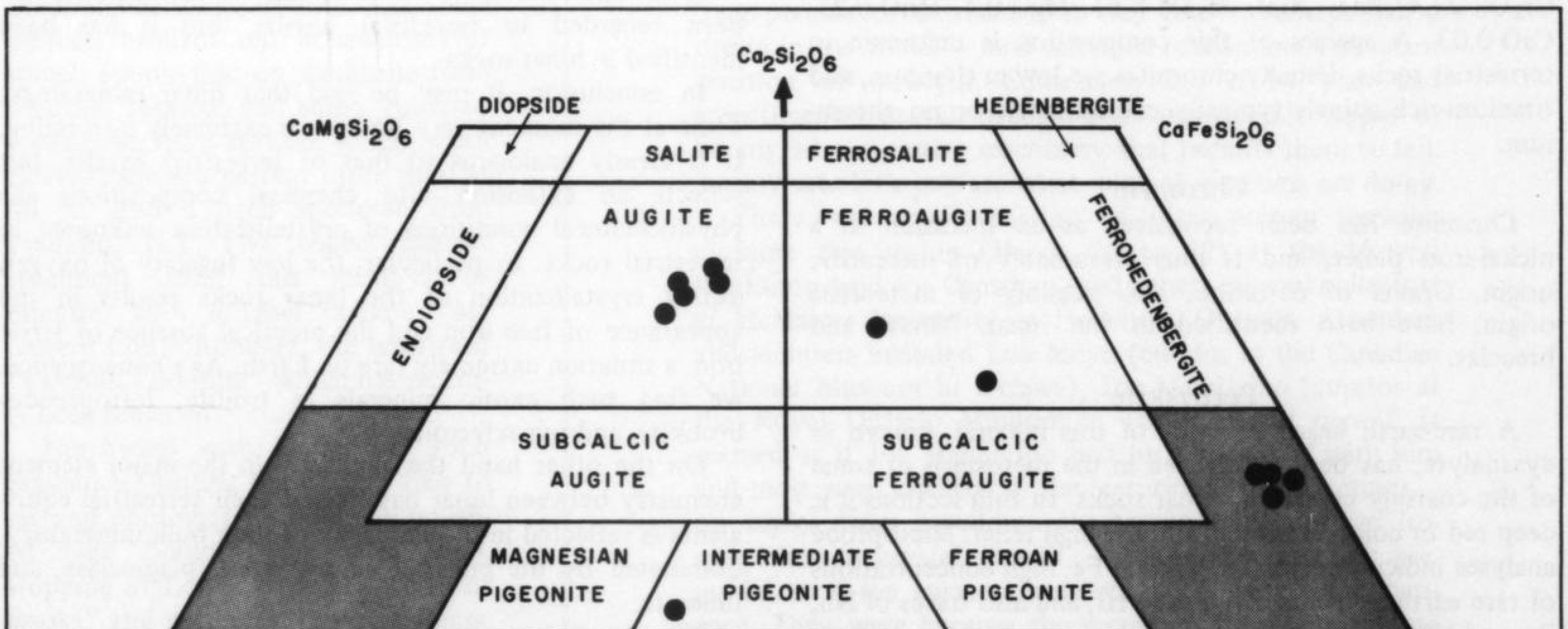
The proportion of metal to sulfide, about 1 : 6, is close to the composition of the Fe-FeS eutectic, and the association indicates that the metal and troilite separated simultaneously from the silicate magma as immiscible droplets. This metal is almost pure Fe, with very little nickel (0.1% or less) in solid solution. The breccias and the lunar soil contain a nickeliferous iron, usually as irregular fragments up to a few mm across, but sometimes as spherical or lensoid droplets. This metal is sometimes accompanied by troilite, and may contain up to 30% Ni and 1% Co. The composition of this metal, and the fact that it is confined to the breccias and soil, indicate that it is extra-lunar, i.e. meteoritic in origin.

A probable third form of metallic iron is almost universally present in the lunar glasses as minute particles and thin films. The mode of occurrence of this metal suggests that it formed by the direct dissociation of iron-bearing compounds at the high temperatures of glass formation.

Cohenite, Schreibersite

Cohenite, the iron carbide and schreibersite, the nickel-iron phosphide, have been recognized in trace amounts associated with nickel-iron in breccias and soils, and are

Figure 3. The dots represent pyroxene compositions in the lunar rocks, and the composition of the new mineral pyroxferroite in the shaded field, a compositional region for which natural pyroxenes do not occur.



presumable of meteoritic origin. Trace amounts of cohenite or another iron carbide have been identified in the metal-troilite blebs of the crystalline rocks.

Armalcolite

This mineral was so named to honor the three Apollo 11 astronauts, Neil Armstrong, Edwin Aldrin, and Michael Collins. Is is isostructural with the terrestrial mineral pseudobrookite. Pseudobrookite usually occurs as minute crystals in cavities in volcanic rocks; its composition is ferric titanium oxide, Fe_2TiO_5. Armalcolite is a ferrous titanium oxide with considerable magnesium substituting for iron; its formula is $(Fe,Mg)Ti_2O_5$. Electron microprobe analyses give (weight per cent): TiO_2 70.3-73.4; FeO 11.3-18.0; MgO 5.5-11.1; Al_2O_3 1.0-2.2; Cr_2O_3 1.0-2.2; Mn, Ca, and V have been detected in minor amounts (0.1-0.5%). Armalcolite is orthorhombic; the calculated density, for $(Mg_{0.5}Fe_{0.5})Ti_2O_5$, is 4.64.

The mineral occurs in the lunar basalts as minute black opaque grains (up to 0.3 mm across), usually as cores to crystals of ilmenite. It is evidently the first oxide mineral to crystallize, and its crystallization ceased after a short time, being followed by that of ilmenite.

Ulvöspinel

This mineral has been recognized as a rare accessory in the lunar material. It occurs as tiny grains, and may be intergrown with ilmenite, possibly as a replacement. A microprobe analysis gave the following results (weight per cent): FeO 62.2, TiO_2 32.7, Cr_2O_3 3.5, Al_2O_3 1.88, MnO 0.22, MgO 0.04, CaO 0.03. This composition is very close to the ideal formula Fe_2TiO_4. Terrestrial specimens on the contrary usually have considerable amounts of Fe_3O_4 in solid solution.

In addition to this nearly pure Fe_2TiO_4, another spinel, intermediate in composition between it and $FeCr_2O_4$ (chromite), has been found in lunar basalts as euhedral grains 0.1-0.2 mm across, forming about 10% by volume of the iron-titanium oxides in the rock. Many of the grains are mantled by ilmenite.

The composition is (weight per cent): FeO 42.1, Cr_2O_3 23.5, TiO_2 20.9, Al_2O_3 8.61, MgO 0.4, MnO 0.25, CaO 0.03. A species of this composition is unknown in terrestrial rocks. Usually chromites are low in titanium, and titanium-rich spinels typically contain little or no chromium.

Chromite

Chromite has been recognized as an inclusion in a nickel-iron pellet, and is thus presumably of meteoritic origin. Grains of chromite, also possibly of meteoritic origin, have been identified in the lunar "fines" and breccias.

Perovskite

A rare-earth bearing variety of this mineral, known as dysanalyte, has been recognized in the mesostasis of some of the coarsely crystalline lunar rocks. In thin sections it is deep red in color, isotropic, and has high relief. Microprobe analyses indicate major Ca, Ti, and Fe, high concentrations of rare earth elements, Zr, Y, and Hf, and also traces of Nb, Ba, and Na.

Perovskite occurs as an accessory in a few terrestrial igneous rocks which are generally of unusual composition. They have high magnesium to iron ratios and low silicon percentages (i.e., ultrabasic, and enriched in Ti). The late crystallization of perovskite in the lunar rocks probably indicates that nearly all the iron has been removed by the formation of pyroxene and ilmenite, thus promoting the formation of a calcium titanium oxide.

Rutile

Minute inclusions of this mineral have been recognized in ilmenite, either produced by exsolution or possibly by local reduction ($FeTiO_3$=Fe+TiO_2+O).

Baddeleyite

Small grains of this zirconium mineral have been identified in some of the lunar crystalline rocks, and in high-density concentrates from the breccias and "fines". The mineral is rich in hafnium (about 2%) and contains other minor elements such as the rare earths. Its presence as thick, tabular, untwinned grains is quite different from its terrestrial occurrences.

Zircon

This mineral appears to be rarer than baddeleyite in the lunar materials. Very small amounts have been found in high-density fractions of the lunar "fines", as colorless grains. They are somewhat cloudy with microfractures, are uniaxial or slightly biaxial, and have refractive indices ω=1.869, ϵ=1.901. Terrestrial zircon is frequently metamict (i.e., the crystal structure has broken down, probably caused by the disintegration of uranium and thorium in solid solution). The lunar zircon has not undergone this breakdown, which suggests that its radioactive element content is very low.

Apatite

As with terrestrial basalts, apatite is the usual phosphate mineral in the lunar rocks. It is an accessory mineral present in amounts of 0.2-0.4% in the crystalline rocks. It occurs as small colorless prisms up to about 0.2 mm long in the interstitial material. Apparently, it varies somewhat in composition, especially in the relative amounts of fluorine and chlorine.

Whitlockite

A common accessory in meteorites, whitlockite has not been recorded in terrestrial basalts, but it has been identified in lunar rocks.

In conclusion, it may be said that lunar mineralogy, while at the moment very limited, is extremely interesting. It is clearly analogous to that of terrestrial basalts, but reflects an extension into chemical compositions ans physiochemical conditions of crystallization unknown in terrestrial rocks. In particular, the low fugacity of oxygen during crystallization of the lunar rocks results in the appearance of free iron and the practical absence of ferric iron, a situation extremely rare on Earth. As a consequence, we find such exotic minerals as troilite, ferropseudobrookite, and pyroxferroite.

On the other hand the similarity in the major element chemistry between lunar basalts and their terrestrial equivalents is reflected in the similarity of their bulk mineralogy, dominated by the presence of pyroxene, plagioclase, and ilmenite.

The detailed reports of the investigators of the Apollo 11 collections were published in the January 30, 1970 issue of SCIENCE (vol. 167, no. 3918), and additional details on the lunar mineralogy and petrology can be found therein.

YEDLIN

(continued from page 11)

marierite; francevillite; hematite on red cassiterite; roselite; and many others.

A meeting at the Bideaux home, where Dr. Arthur Montgomery presided, forming the nucleus of a society for the preservation of mineral specimens, and where details of this publication were discussed.

Visits to George Bideaux and Suzie Davis, where some of the above listed specimens were acquired. Phyllis Sonnenberg's conducting of the m/m session at the show, and Lou Perloff, Julie Weber and I taking over and showing photos of micromounts for the entire session.

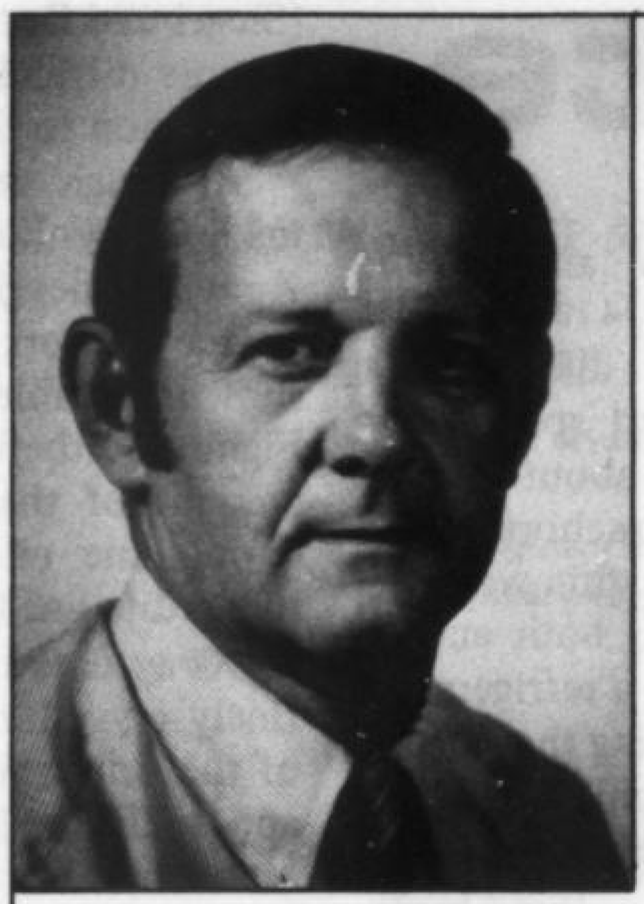
Viewing the University of Arizona's mineral collection, rich in copper minerals, naturally. And all the while meeting old friends, (never DID get to see everything at the show) arranging swaps, back room sessions after hours to settle the world's mineralogical problems and to drown the accumulated dusta of a frenzied day – memories and impressions.

Then westward along Rte 80 thru Yuma to San Diego, to visit with John Sinkankas, his family, his books and his minerals. All four terrific. One of the finest collections of gem literature extent, and superb minerals in addition. And a swell family, warm and hospitable. We latched on to John's duplicate set of Tagore's "Mani Mali" for our own library, as well as some other standards. From him, too, some perfect, brilliant red octahedrons of spinel; apophyllite on danburite from Charcas, Mexico; and some rutilated topaz, also from Mexico, which, when cleaved, showed perfect rutile rings at 30 X. And a hand specimen from Franklin, N.Y. (We collect cabinet specimens from this locality) of esperite, with a label marked "Mc Govern Coll." Actually, the label read "Calcium Larsenite" which has recently been renamed.

Northward with Marge and John Sinkankas, visiting the Pottery Fair to see and photograph a naturally polished jade boulder (no m/m this), stopping at Long Beach at "Acres of Books" and getting a couple of items, and then on to Santa Monica.

The fifth annual Pacific Micromount Conference was a winner. Old

(continued on page 30)



the museum record

by Paul E. Desautels
the Smithsonian Institution

In the same way that the fortunes of mineral specimen collecting ebb and flow with changes in economic and social climates, so the health measurements of museum mineral collections tend to rise and fall. The museum collections react this way because they are, in fact, merely an institutionalization of the private collector's methods, goals and successes (or failures).

True, the mineral museum historically seems to lag well behind any concerted movement which develops among mineral collectors. This results in a constant race among museums to catch up with things during good times. Conversely, in bad times, the museum acts as a buffer. It offers a (more or less) safe repository for objects liable to be lost for lack of interest. The world is full of examples of mineral museums that have tried half-heartedly to function or that haven't tried at all. Usually, these are indistinguishable in the long run because both kinds end up in ruin with loss of interested staff and gradual but final deterioration of the collections.

I think it is safe to say that most mineral museums have followed this path to oblivion. Some few, however, have shown their vitality by coming suprisingly to life again after long periods of dormancy. A very few – perhaps half a dozen in the world – have managed to maintain a constant position of strength. Sometimes this is by plan and sometimes by default because there just doesn't happen to be any administrative machinery that permits them to fail. At any rate let's just see what mineral museums are doing.

There was much sharing of ideas among museum curators this spring (March 20 to 22) at the Mineral Workshop held for Canadian (and other) mineral collectors at McMaster University in Hamilton, Ontario. Attendees and lecturers included Lou Moyd (curator at the Canadian National Museum in Ottawa), Joe Mandarino (curator at the Royal Ontario Museum in Toronto) and myself. It seemed as if Joe Mandarino had his entire staff with him and most were involved in the lecturing. All the lectures – on topics from pseudomorphs to schiller and from isomorphism to crystal growth – were enthusiastically presented as if the curators were really enjoying the experience. They were because the reception from a full house was also enthusiastic.

(continued on page 29)

mirabilite

(continued from page 15)

temperature (and operating temperature of an X-ray machine) if properly sealed off from air.

The mirabilite sample for X-ray powder diffraction study was prepared by crushing a refrigerated specimen out-of-doors on a cold winter day (temperature about 4°C). The sample was crushed under cold carbon tetrachoride to obtain a thick sludge that was forced into a thin-walled glass capillary tube, which was then sealed at both ends with Tackiwax. This capillary was inserted into a refrigerated powder camera. Several films were made using the same capillary spindle-mount, the camera being chilled in a refrigerator between exposures, before the mirabilite in the capillary began to desiccate to thenardite.

A satisfactory X-ray diffractometer mount was prepared at room temperature by pulverizing refrigerated mirabilite in a deep thick-walled refrigerated mortar (which remained cold during pulverizing), then mounting the cold powdered mirabilite in a refrigerated window-type diffractometer mount that was faced with Mylar. The Mylar was sealed to the front of the mount with immersion oil and held in place with a glass slide while the mount was filled from in back.

Less material is required if the pulverized mirabilite is spread on a frosted-glass slide and covered with Mylar (Siegel and Dort, 1968), but the smaller amount of material is more difficult to work with and there is greater danger of desiccation to thenardite.

TABLE 1.
CHEMICAL ANALYSIS OF DISSOLVED SOLIDS IN WELL WATER FROM LA GUAICA, CHILE

(FROM CASTILLO, 1960, TABLE 5)

Composition in parts per million	
SiO_2	63
Ca^{--}	164.3
Mg^{--}	28.2
Na^{-}	143
K^{-}	26.8
HCO_3^{-}	72
SO_4^{--}	451.5
Cl^{-}	245.5
NO_3^{-}	5
Total	1,199.3

Although several X-ray diffraction studies have been made on synthetic crystals or mirabilite, the only published X-ray powder data for naturally occurring mirabilite known to the authors are those of Alietti (1959). Alietti's data, shown in Table 3, are based on a study of mirabilite from Figno, northern Italy. This material may contain a small amount of thenardite, as indicated by the exceptionally strong line cited for d = 2.78 Å, which is the strongest thenardite line (Table 3).

X-ray data reported for so-called mirabilite, occurring as finely crystalline coatings or druses on the walls of tunnels of the Anna mine, near Přibram, Czechoslovakia (Dubanský and Jedlička, 1956), are unquestionably those for thenardite. Inasmuch as the chemical analysis shows that this material was mirabilite when collected in the mine (Dubanský and Jedlicka, 1956, p. 784), it seems probable that desiccation took place during sample preparation. As a consequence, not even the strongest line for mirabilite appears in the X-ray powder data of the material from the Anna mine.

X-ray powder diffraction data for the mirabilite from Salar de Pintados (Table 3) were determined from a pattern taken in a Debye-Scherrer camera (114.59 mm diameter) that was fitted with a Wilson adapter to permit film measurements using the Straumanis technique. Exposure was 12 hours with Cu/Ni radiation; the pattern showed no thenardite lines.

These powder data show good agreement with those reported by de Wolff (1961) for synthetic mirabilite (Table 3). Final indexing of the powder diffraction data for mirabilite was fixed by relating the observed intensities of lines on the film to the observed and calculated structure factors, F_o and F_c respectively, given for sodium sulfate decahydrate, $Na_2SO_4 \cdot 10H_2O$ (Ruben *et al.*, 1961, ADI 6418).

Crystallographic data for the mirabilite from Salar de Pintados are compared in Table 2 with published data for synthetic mirabilite. The unit cell constants of natural mirabilite (Table 2) were derived by a least-squares refinement of the X-ray powder diffraction data of the Chilean material that are listed in Table 3, using for the initial parameters those given by Ruben *et al.* (1961) for synthetic mirabilite (Table 2). We did not attempt a single-crystal X-ray investigation of the Chilean mirabilite.

The several references in the literature citing crystallographic data obtained by single-crystal X-ray study of synthetic mirabilite (de Wolff, 1961; Cocco and Rossetti, 1959; Alietti, 1959; and Meulendijk, 1956) are comparable to those of Ruben *et al.* (1961) cited in Table 2. The crystal structure of $Na_2SO_4 \cdot 10H_2O$ was determined by Ruben *et al.* (1961) and by Cocco (1962).

Chemistry

A chemical analysis of the mirabilite from Salar de Pintados (Table 4) is very near the calculated composition of $Na_2SO_4 \cdot 10H_2O$. A semiquantitative spectrographic analysis of the same material made by Joseph L. Harris of the U. S. Geological Survey shows, within the limits of detectability of the method, that the material is relatively free of trace elements. Only the following elements were

TABLE 2. CRYSTALLOGRAPHIC DATA FOR MIRABILITE AND ITS SYNTHETIC EQUIVALENT

	Present Study[1]	Ruben et al. (1961)	Rosicky (1908)
Locality	Salar de Pintados, Chile	Synthetic crystal	Synthetic crystals
Habit	Massive; clear	Crystal grown in capillary tube	Commonly prismatic to acicular, *b*; also thin tabular (100) or (001)
Space Group	$P2_1/c$	$P2_1/c$	---
***a* (Å)**	11.506 ± 0.002	11.51 ± 0.01	---
***b* (Å)**	10.377 ± 0.002	10.38 ± 0.01	---
***c* (Å)**	12.827 ± 0.002	12.83 ± 0.01	---
	107° 45′ ± 7′	107° 45′ ± 10′	107° 45′ (gon.)
a* : *b* : *c	1.1088 : 1 : 1.2361	1.109 : 1 : 1.236	1.10964 : 1 : 1.23882 (gon.)
Cell volume ($Å^3$)	1459	1460	---
Cell contents	$[4/Na_2SO_4 \cdot 10H_2O/]$	$[4/Na_2SO_4 \cdot 10H_2O/]$	---
Sp. gr. x-ray	1.467	1.466	---
meas.	---	1.4661, at 24° C[2]	1.490
Mean calc. *n*	1.391[3]	1.391[3]	---
Mean meas. *n*	1.396[4]; 1.394[5]	---	---

[1] Unit-cell data from least-squares refinement of the powder diffraction data of Table 3, by method of Evans *et al.* (1963).

[2] Determined by Andreae (1913)

[3] Calculated by present authors, using the Gladstone-Dale law.

[4] Calculated by the present authors from optical data of Larsen (1921, p. 111).

[5] Calculated by the present authors from optical data of Schaller *in* Schaller and Henderson (1932, p. 81).

detected and reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, etc.: Mg 0.003%, Ca 1%, Cu 0.007%, and Sr 0.0015%.

Acknowledgments

The study of the mirabilite deposits of Salar de Pintados was carried out in cooperation with the Instituto de Investigationes Geológicas of Chile. Jaime Sayez and Nelson Bravo of that institution assisted during field work. We wish to thank Dr. František Čech of the Department of Mineralogy, Charles University (Prague, Czechoslovakia), for his translation of the paper by Dubanský and Jedlička; Joseph L. Harris of the U. S. Geological Survey, for the spectrographic analysis of the mirabilite from Salar de Pintados; and Judith Konnert, also of the Geological Survey, for the refinement of the X-ray powder diffraction data.

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TABLE 3. X-RAY POWDER DIFFRACTION DATA FOR MIRABILITE, $Na_2SO_4 \cdot 10H_2O$, and THENARDITE, Na_2SO_4

Mirabilite
Monoclinic, $P2_1c$; $a = 11.506 \pm 0.002$ Å,
$b = 10.377 + 0.002$, $c = 12.827 + 0.002$, $\beta = 107\ 44.7' + 7.0'$

Thenardite

	Salar de Pintados, Chile			Synthetic		Figno (Scandiano, Reggio E.)		Synthetic Swanson and Fuyat (1953)	
	Present Study			De Wolff (1961)		Alietti (1959)			
	Calculated[1]	Measured[2]		Measured[3]		Measured		Measured[4]	
hk	d(Å)	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I
100	10.958								
011	7.909								
110	7.535	7.53	3	7.55	1				
$\bar{1}11$	7.114	7.12	6	7.11	3				
$\bar{1}02$	6.199								
002	6.109	6.11	35	6.11	17	6.10	10		
111	5.886	5.89	13	5.89	9				
200	5.479	5.48	100	5.49	100	5.52	100		
$\bar{1}12$	5.322	5.32	25	5.32	25				
012	5.264								
020	5.189	5.19	3	5.17	5				
$\bar{2}11$	4.988								
$\bar{2}02$	4.886	4.89	18	4.88	20				
210	4.845								
021	4.775								
102	4.755	4.76	42	4.77	45	4.79	70		
120	4.690							4.66	73
$\bar{1}21$	4.583								
$\bar{2}12$	4.420								
112	4.323	4.32	25	4.32	20	4.33	30		
121	4.199								
$\bar{1}12$	3.979								
022	3.955								
$\bar{1}13$	3.945	3.95	13	3.95	15				
$\bar{2}21$	3.834	3.84	35	3.83	40	3.83	50	3.84	18
013	3.791								
220	3.767	3.77	6	3.77	9				
$\bar{3}02$	3.666	3.67	6	3.67	7				
300	3.653								
$\bar{2}13$	3.638								
$\bar{3}11$	3.597			3.60	9				
202	3.573	3.57	25	3.58	17	3.58	25		
$\bar{2}22$	3.557								
122	3.506								
$\bar{3}12$	3.456	3.46	9	3.46	9				
310	3.446								
221	3.405	3.40	25	3.40	17	3.36	25		
212	3.379			3.38	5				
031	3.328								
113	3.305	3.31	6	3.31	5				
130	3.299								
$\bar{1}23$	3.295								
$\bar{1}31$	3.261	3.26	50	3.26	60				
$\bar{1}04$	3.206								
023	3.204	3.20	71	3.21	75	3.22	100	3.178	51
131	3.114								
$\bar{2}23$	3.109								
$\bar{3}13$	3.108								
$\bar{2}04$	3.100	3.09	71	3.11	60	3.10	100		
311	3.092			3.10	7				
$\bar{3}21$	3.084			3.07	3			3.075	47
$\bar{1}14$	3.063			3.06	3			3.075	47
$\bar{1}32$	3.021	3.02	13	3.02	9				
032	3.010								
$\bar{2}14$	2.970			2.975	5				
222	2.943	2.943	18	2.943	13				
123	2.894	2.892	4	2.896	3				
$\bar{4}02$	2.844	2.843	18	2.847	20				
132	2.797	2.797	42	2.801	30B	2.78	100		
302	2.784							2.783	100
$\bar{4}12$	2.743	2.742	13	2.743	13				
314	2.704	2.706	2	2.706	7				
312	2.689	2.688	18	2.687	11				
114	2.644							2.646	48
040	2.594			2.592	3				
$\bar{3}31$	2.569	2.567	13	2.569	13	2.58	8		
041	2.538			2.535	3				
223	2.515	2.515	50	2.516	35	2.52	10		
$\bar{1}15$	2.482	2.481	9	2.485	20				

---

[1] All possible calculated d's are listed for $d \geqslant 2.000$ Å.

[2] Camera diameter, 114.59 mm; Ni-filtered Cu radiation (λ CuKα = 1.5418 Å). Measurements corrected for expansion. Lower limit measurable for 2θ, approximately 6.6° (14 Å). Intensities estimated visually by direct comparison with a calibrated intensity film strip of successive step-line exposures related to each other by a factor of $\sqrt{2}$. D = diffuse.

[3] Guinier camera; camera diameter, 114.06 mm. Copper radiation. Cut-off, 50 Å. Intensities determined by photometer. B = broad.

[4] High-angle Geiger-counter spectrometer. Copper radiation (λ CuKα = 1.5405 Å) at 25° C. Internal standard, tungsten

TABLE 3. X-RAY POWDER DIFFRACTION DATA FOR MIRABILITE, $Na_2SO_4 \cdot 10H_2O$, and THENARDITE, Na_2SO_4

Mirabilite

Monoclinic, $P2_1/c$; a = 11.506 ± 0.002 Å,

b = 10.377 ± 0.002, c = 12.827 ± 0.002, β = 107° 44.7′ ± 7.0′

Salar de Pintados, Chile Present Study Calculated[1]		Salar de Pintados, Chile Present Study Measured[2]		Synthetic De Wolff (1961) Measured[3]		Figno (Scandiano, Reggio E.) Alietti (1959) Measured		Thenardite Synthetic Swanson and Fuyat (1953) Measured[4]	
hk	d(Å)	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I
$\bar{4}04$	2.443	2.444	35	2.444	25	2.45	7	2.329	21
420	2.423			2.425	<1				
042	2.388	2.388	13	2.386	7	2.34	5		
$\bar{3}31$	2.364	2.365	9	2.364	5			2.329	21
$\bar{2}25$	2.280	2.280	9	2.282	7	2.278	5		
$\bar{4}21$	2.263	2.264	9	2.265	9				
$\bar{4}31$	2.207			2.208	3	2.212	5	2.211	5
115	2.193	2.194	4	2.196	3				
332	2.169	2.169	21	2.168	11	2.171	5		
243	2.157			2.157	1				
430	2.149								
$\bar{1}34$	2.148			2.146	<1				
$\bar{2}06$	2.133			2.135	<1				
504	2.111			2.114	3				
242	2.099	2.100	30	2.099	22	2.103	8		
$\bar{4}22$	2.069	2.070	18	2.071	15				
$\bar{1}35$	2.056	2.053	18	2.057	7				
$\bar{3}04$	2.055								
$\bar{2}35$	2.046			2.047	1				
150	2.039			2.038	7				
006	2.036								
$\bar{1}51$	2.030	2.030	9	2.029	7	2.023	5		
314	2.016	2.015	13						
		1.989	9						
		1.966	15			1.965	5		
		1.916	18			1.916	8	1.915	4
		1.880	4					1.891	4
		1.865	9			1.868	10	1.864	21
		1.828	6					1.841	6
		1.809	6					1.798	4
		1.786	11			1.789	5		
		1.762	3						
		1.744	9			1.738	5		
		1.728	11						
		1.710	9						
		1.700	3						
		1.680	4			1.680	5	1.680	12
		1.664	4			1.663		1.662	8
		1.643	7						
		1.628	2						
		1.616	2						
		1.602	4					1.605	5
		1.581	3					1.589	3
		1.568	3						
		1.554	5			1.549	5	1.553	10
		1.541	6					1.537	<1
		1.528	5						
		1.511	3					1.512	2
		1.496	3					1.497	5
		1.482	4						
		1.467	4					1.465	<1
		1.452	5						
		1.428	4					1.429	5
		1.411	2						
		1.401	2						
		1.393	4						
		1.381	3					1.386	3
		1.370	6						
		1.361	2						
		1.340	2						
		1.323	2					1.324	3
		1.310	5					1.304	3
		1.294	4					1.297	6
		1.279	4					1.279	5
		1.263	3						
		1.256	6					1.258	1
		1.247	2					1.233	1
		1.201	3					1.214	1
		1.193	2					1.1922	<1
		1.172	2D					1.1654	<1
								1.1345	3

[2] Camera diameter, 114.59 mm; Ni-filtered Cu radiation (λ CuKα = 1.5418 Å). Measurements corrected for expansion. Lower limit measurable for 2θ, approximately 6.6° (14 Å). Intensities estimated visually by direct comparison with a calibrated intensity film strip of successive step-line exposures related to each other by a factor of $\sqrt{2}$. D = diffuse.

[3] Guinier camera; camera diameter, 114.06 mm. Copper radiation. Cut-off, 50 Å. Intensities determined by photometer. B = broad.

[4] High-angle Geiger-counter spectrometer. Copper radiation (λ CuKα = 1.5405 Å) at 25° C. Internal standard, tungsten. Intensity values measured as peak height against background; expressed as percentages of the strongest line.

TABLE 4.
CHEMICAL ANALYSIS AND COMPOSITION OF MIRABILITE

(Analyst: Joseph J. Fahey)

	Ice-clear mirabilite, Salar de Pintados, Chile (weight percent)	$Na_2SO_4 \cdot 10H_2O$ Calculated Composition (weight percent)
Na_2O	19.09	19.24
K_2O	.04	––
CaO	.16	––
SO_3	24.82	24.85
Cl	.01	––
H_2O	55.73	55.91
Total	99.85	100.00

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museum record

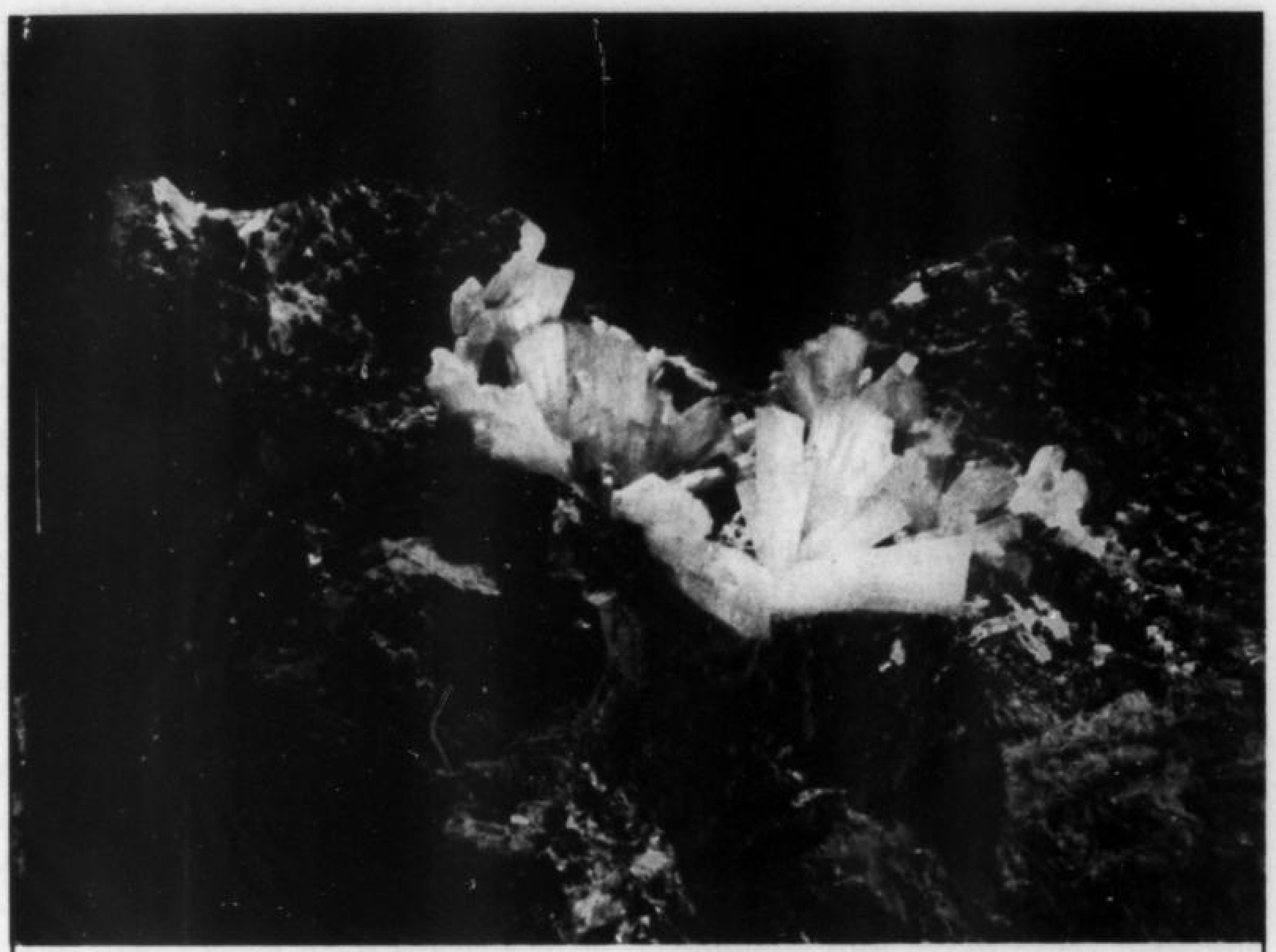
(continued from page 23)

Lou Moyd reports, incidentally, that the Victoria Memorial Museum in Ottawa – which houses the collections and exhibits of the National Museum of Natural Sciences of Canada – has been closed to permit structural improvements. During the renovation period, in order to keep all the mineral collectors happy, fifteen cases of minerals selected from the National Mineral Collections of Canada are being displayed in Logan Hall. This Hall is the public exhibit gallery of the Geological Survey of Canada at their headquarters at 501 Booth Street in Ottawa.

Vince Manson (curator of Minerals at the American Museum of Natural History in New York) stopped in at the office for a visit during the American Geophysical Union April meetings in Washington. He and John White and I had a little time to talk between moments when Vince was busy scouting out meteorites in the collection. According to Vince, the new exhibit of minerals is definitely underway. As a matter of fact, preliminary discussion is finished and ideas are starting to appear on paper. This is the most difficult part of any such project because lofty ideas and brilliant suggestions must finally be reduced to specifications on paper that any electrician, designer, carpenter, etc. can follow. Fortunately, the new installation will be on another floor of the building so that it may be possible to keep at least some sort of display for the crowds of collectors who look forward to their visits with this fine collection.

Ray Buyce (associate curator at the New York State Museum in Albany) phoned a couple of weeks ago to discuss a problem in locality identification. This reminded me that it is imperative to get to Albany to see the new exhibit hall entitled "The World of Gems" that Ray planned and that has now been opened to the public. There is an excellent article about the museum's history, the present gem exhibit and future plans for the museum written by Ray for the April 1970 issue of the Lapidary Journal. I have no intention of devoting much space in this column to gems per se. However, this superb exhibit includes

(continued on page 31)



Legrandite - Mapimi, Durango, Mexico

What's New In Minerals

In the history of mineral collecting there have been long dry periods when it seemed that there were almost no new mineral specimen discoveries to brighten the scene. However, in the last few years a large number of extraordinary specimens have appeared. The following brief survey shows a remarkable range of choice items and gives a fair idea of new specimens coming to light.

Mexico often seems to be trying to surpass itself in producing incredibly fine and progressively better mineral specimens – continuing to amaze even those accustomed to its mineralogical surprises. The classic adularia (valencianite) specimens from the old silver mines of Guanajuato suddenly began to appear with lime-green milarite crystals nestled attractively among the white crystals of feldspar and quartz.

Long considered a rare mineral, milarite has been found in recent years in rather large amounts, in excellent specimens from Rossing, Swakopmund, Southwest Africa and in lesser quantities from the Foote Mineral Company spodumene mine, Kings Mountain, North Carolina.

Creedite, previously little-known except to micromounters, has been found in some quantity as sprays and clusters of large crystals, with individuals exceeding an inch in length, at Santa Eulalia in Chihuahua. Most of the crystals are colorless but, to gild the lily, many are a lovely amethystine color.

From other countries, newly available and desirable mineral specimens include suites of apatite, arsenopyrite and cassiterite along with superb, splendent wolframite crystals from the tungsten mines near Panesqueira, Portugal. Bou Azzer, Morocco has been producing record-setting specimens of roselite, beta-roselite and skutterudite.

(continued on page 32)

Mineral Notes

NEW MINERALS

BEHOITE

Arthur J. Ehlmann and Richard S. Mitchell
Amer. Mineral., v. 55, pp. 1-9, 1970

The new mineral behoite β-Be(OH)$_2$, is found in pseudo-octahedral, colorless crystals up to 1 mm in size in altered zones or rinds around masses of vitreous gadolinite from the Rode Ranch pegmatite, Llano County, Texas. Spectrographic analysis revealed Be as the only major element present. The mineral is identical with synthetic β-Be(OH)$_2$, a polymorph of metastable tetragonal Be(OH)$_2$. Behoite is orthorhombic, $P2_1 2_1 2_1$ with axial ratio 0.658:1:0.645. The strongest x-ray lines are 3.88 (vs), 3.83 (vs), 2.39 (vs), 2.95 (m), 2.79 (m), 1.99 (m) and 1.96 (m). Optically behoite is biaxial negative α1.533, β1.544, γ1.548, 2V=82°, $r<v$ (strong), density 1.92 ± 0.01, hardness about 4. The name is for the composition.

The mineral was earlier reported by Montoya *et al,* (U. S. Bur. Mines Rep. Invest., *6408,* 1-11, 1964) in Honeycomb Hill, Jaub County, Utah.

AGARDITE

Jacques-E. Dietrich, Marcel Orliac and Francois Permingeat
Bull. Soc. fr. Mineral. Cristallogr., v. 92, pp. 420-434, 1969

Agardite, $(Y,CaH)Cu_6[(AsO_4)_3(OH)_6]\cdot 3H_2O$, is the yttrium analog of mixite $(Bi,CaH)Cu_6[(AsO_4)_3(OH)_6]\cdot 3H_2O$. The hexagonal cell is a = 13.55 ± 0.05 and c = 5.8 ± 0.02 Å. The mineral is uniaxial positive, $n\omega = 1.701 \pm 0.005$, $n\epsilon = 1.782 \pm 0.005$, G(meas.) = 3.72± 0.05, G(calc.) = 3.66 ± 0.04. The strongest x-ray lines are 11.73 (10), 2.938 (8), 2.451 (8), 4.43 (7) and 3.54 (7). Agardite occurs as very thin acicular, green-blue crystals up to a few mm. in the oxidation zone of the Bou-Skour copper deposit, Morocco, associated with azurite, malachite, cuprite, native copper and quartz. The authors have identified the mineral on specimens from at least five other localities, from which most specimens were formerly labelled either mixite or chlorotile. The name is for J. Agard, former chief of the Service d'Etudes des gites mineraux of the Geological Survey of Morocco.

DISCREDITED MINERALS

BIALITE = WAVELLITE

P. G. Embrey and E. E. Fejer
Min. Mag., v. 37, pp. 123-127, 1969

Type bialite from Mushishimano, Katanga, Congo is shown to be wavellite on the basis of its x-ray and optical characteristics.

YEDLIN

(continued from page 23)

friends and correspondents. Loads and loads of give-aways. Fine arrangements. Talks by Sinkankas, Bill Wise, Chodos, Desautels, Marshall and Hill, on subjects dealing in mineralogy, equipment and identification methods. Evening sessions after hours, with Pough, Godshaw, Blackford, Curtis, Leicht, Parnau, Oswald, Perloff, Seel, McGuinness, Embrey, Kokinos, Robertson, Hunt, Desautels, Sinkankas, Wise and many, many others.

The acquiring of specimens of many zeolites; wickenbergite; choice ilvaite; tunellite; woodhouseite; Hagendorf phosphates; a Majuba Hill suite; a Grandview, Ariz., group; pink spinel from Riverside, Cal. (Dosse); St. Gotthard material from Lobel and more. To Jack Streeter's book collection at Altadena – very fine and most complete. Came away with Tavernier's "Travels," some Kunz items, Sowerby, and others. To Santa Barbara with Kokinos, stopping for 10 minutes at Aguera, and collecting much ferrierite and clinoptilolite. Met C. G. Woodhouse, a wonderful gentlemen, who insisted we'd met some 30 years ago. (A long time between hellos.) To the Ehrmanns in Beverley Hills, old friends, and long talks anent the Calvert Collection, the Lord Baltimore assemblage that Martin E. had brought to the U.S. 35 years ago.

We'd been going thru old mineralogical magazines, and came upon an item that may be of interest. In the "Mineral Collector," November, 1904 issue, Elmer Benge, of Philadelphia, gave a 5 page report on micromounts. This is part of his essay: –

"One by this agency (microscope) will find perfect crystals, and when I say perfect, let it be understood that I mean it to be taken literally . . . where the lustre is untarnished, the faces without blemish, and the lines clean, clear cut and sharp." He goes on – "Determination requires close observation, as well as knowing the physical properties of minerals. You may have the most perfect form presented for study, and this may prove a handicap, for your experience has not been obtained from specimens of this degree of perfection, and so you may be led astray . . ."

Buy and USE a good mineral book.

Neal Yedlin, the Micromounter

Paul Seel

(continued from page 11)

Pennsylvania Railroad Company in 1929 he finally left them 35 years later in 1964 to become a consultant on high-speed transportation. He is an expert on engineering specifications, inspection and testing procedures for suburban transportation systems, Metroliners and jet turbine cars.

In 1933 he took time out for a degree in Education at the University of Pittsburgh. Three years later, during a visit to the Olympics in Berlin, he married Hilde whom he had first met fifteen years before in Germany. They had a mineralogical honeymoon visiting Vesuvius and collecting specimens of crystallized volcanic species at Pozzuoli and elsewhere in Italy. Paul has since travelled extensively through all of the States in the United States, has also travelled the full length of Canada twice, visited 24 of the 29 States in Mexico and has even been snorkeling off the coast of Yucatan. On one particular trip we were able to spend almost three weeks together in the southern part of Mexico centering our activities around Oaxaca City. It was a delightful and memorable experience. Paul often tells of his trips, speaking wistfully of experiences such as his trip down the San Juan and Colorado Rivers in 1948 with Norman Nevills the "great white water man". This included many rugged experiences such as the 14 mile hike from the Colorado to climb the Rainbow Bridge and then 14 miles back to the boats again.

Starting in 1936, when Paul was transferred to Philadelphia, he joined the old and prestigious Philadelphia Mineralogical Society. Later he was to become the president of the venerable Leidy Microscopical Society and is currently curator of the important Keeley Micromount Collection. As a charter member of the Pennsylvania Mineral Society he volunteered to attend Eastern Federation meetings as a delegate, began working on Federation committees and eventually became president of the Eastern Federation. For seven years he served as Eastern Federation Rules Committee chairman. His work with the Advisory Committee to the U.S. Bureau of Land Management during the critical period of establishing rules for collecting petrified wood on government lands led to his ascension through the ranks of officialdom in the American Federation of Mineralogical Societies. From Regional Vice President he advanced to Secretary, Treasurer, Executive Vice President and is expected this year to assume the duties of President of the American Federation. He still maintains hobby connections with his early mineral collecting friends through participation in local society activities, support of the annual Baltimore Micromounting Symposium and so on. As a side duty he acts as Trustee and Vice President of the Wagner Free Institute of Sciences in Philadelphia.

You would almost assume that collecting trips and society and committee affairs would distract Paul's attention from the minerals. On the contrary, he uses his time so well that more than ever is spent working with his collections. Among the people he met, on joining the Philadelphia Mineralogical Society in 1936, was Bill Van Horn who had worked with Dr. Wills on micromounts. Dr. Wills was the author of the first authoritative article on micromounting and was a friend and associate of the early renowned micromounters, Rakestraw, Fiss, Keeley, Bement, Jefferis and others. Paul was quickly converted to micromounting and acquired his first microscope in 1938. To further his understanding of the subject he took a course in crystallography at the University of Pennsylvania in 1944 under Professor A. Williams Postel. At the time I was a student in chemistry at the University but was working part time with the mineral collection. There we became good friends and my own conversion to micromounting took place through Paul's efforts. This eventually led me from a career in chemistry to one in mineralogy. How many others must he have influenced in this way!

A burgeoning interest in morphological crystallography has led this tireless collector to specialization in the collecting of diamond crystals and quartz crystals. The diamond collection alone contains hundreds of crystals, each illustrating some morphological fact. Without doubt it is the finest and largest collection of diamond crystals in existence. For exhibit purposes Paul has made many large-scale sketches and drawings of

(continued on page 4)

museum record

(continued from page 29)

some superb display and instructional material of immediate interest to mineral collectors. It also indicates what is to come in the future when the New York State Museum staff gets around to the mineral collection display. It will surely be one of the most attractive and informative mineral displays ever assembled.

For sheer beauty and impact it will be difficult to improve over the new presentation of fine mineral specimens planned and executed by Pierre Bariand (curator of Minerals at the Sorbonne in Paris). I was fortunate enough to see the new exhibit room approaching completion last fall and have seen the small but fine collection of minerals several times. The latest communication tells me that the minerals and exhibit hall are now joined in the new building of the Faculte des Sciences in the Jardin des Plantes in Paris. I'm sure we'll be hearing more about this collection later.

It is to the whole gamut of museums – weak, strong, moribund or thriving that this column addresses itself. I hope to keep up a steady flow in these lines of information about any event which reflects the state of affairs among the ultimate conservers of mineral specimens. Be sure to let me know of any thoughts or experiences or events connected with your museum that you want to share.

The Mineralogical Society of America reports that its officers for 1970 are:

William F. Bradley,
President,
University of Texas

Francis J. Turner,
Vice President,
University of California

Arnulf Muan,
Secretary,
Pennsylvania State University

Alvin Van Valkenberg, Jr.,
Treasurer,
National Science Foundation

The Record Bookshelf

Mineralien. Prof. Dr. Helmut Schrocke and Dr. Karl Ludwig Weiner. Illustrated with paintings by Claus Caspari. Hamburg: Kronen-Verlag Erich Cramer, 1969. 69 pp. 162 separate plates. $48.00. In U.S., Francis Paul, 49 Fourth Avenue, Mt. Vernon, N. Y. 10550.

When this reviewer was a young art student there were spirited discussions concerned with the anomaly of distortions of the environment as depicted in the art work at the turn of the century. Why did they paint like that? The ready reply of the cynic was that these artists could do no better. Others, however, pointed to the appearance on the scene of the camera which could copy nature better than any artist. Why try to compete with the camera?

In this second half of the twentieth century it comes then as something of a shock to discover a publication, one purpose of which is to provide accurate representations of mineral species, with reproductions of *paintings* of mineral specimens. Why resort to paintings when the camera can report so much more accurately what it views?

One can scarcely imagine that such questions were not raised about the comparable advantages of paintings and photographs, when the publication of a volume on mineralogy was being considered. Once the initial surprise had subsided, it became clear that the choice to use paintings was a wise one.

Appropriately lighted, excellent photographs can be made of single crystals and even some specimens with clusters of discrete crystals. However, the characteristics of some specimens defy all but the exceptional photographer to record them accurately. Problems associated with depth of field, illusory effects created by light properties as well as properties of the minerals themselves, chatoyancy and diffraction for example, tend to create difficulties for the individual who would wish to distinguish clearly the characteristics of particular mineral species. Such problems are more readily controlled by the skilled artist who copies faithfully at the same time that he exercises an editorial discretion. Reflections can be suppressed or enhanced to highlight the idiosyncrasies of a species or of a particular crystal.

These advantages of the paintings are clearly manifest in 162 plates printed on matte finish cards about 7½ x 10½ inches. The visual properties of the minerals are faithfully rendered and, indeed, some illustrations are remarkable for the illusion created of luster and surface texture and of color lurking below the surface of the crystals. The opacity, translucency and transparency of the crystals is realistic enough to tempt one to touch the plate for corroboration.

On several plates the printing register was slightly off so that the generally excellent reproduction quality was lessened, but the problem was detected apparently by the publishers and new plates run to replace the unsatisfactory ones.

Each plate depicts one specimen except where varieties of the same species are shown. For *Garnet,* the variety spessartine is most prominent surrounded by six other varieties somewhat smaller in size and, as with all the other plates, bears the name of the species. The back of each plate presents data which are similar to those provided in most mineral textbooks, but alas! the only words in English to be found are "Printed in Germany". For this reviewer the German text was only occasionally intelligible. Of the specimens depicted 60% came from European localities, 23% from the Western Hemisphere, 8% from the African continent, 7% from Asia, and 2% were of uncertain origin. It may be of interest to some statistically minded individuals to compare this distribution with that found in large representative collections.

One may wish, perhaps, to quarrel not only with the representative minerals selected but also with the quality of the specimens. For the discriminating collector some of the specimens may not be up to his standard of quality. However, few if any are uncharacteristic of the species and so the intent of the authors may have been achieved.

Unfortunately, this linguistically handicapped reviewer could not be certain of the authors' objectives. The separate plates are packed loose in a linen case which contains a slender volume of introductory text and several indices for locating and grouping the plates.

Obviously, the plates are meant to be handled but the matte finish tends to collect dirt and stains very easily. If they are to be used in conjunction with a course, they should be sprayed or protected by plastic sleeves. One would wish that line renderings of the crystal habit had been inserted in the corner of each plate. The mineral collector and educator alike may enjoy these plates for their esthetic and descriptive qualities. Would that an English language version were available, also.

Paul Yaffe, Ed. D.

What's new

(continued from page 29)

The vanadinite specimens coming from Mibladen, Morocco are perhaps the finest ever produced anywhere. Large as these crystals are, they are very sharply defined in habit and run a gamut of colors from bright red to rich brown. It is imperative, too, to mention the magnificent clear rhombs of dolomite from Eugui, Navarra, Spain, superb tourmaline groups from Santa Rosa, Minas Gerais, Brazil, eosphorite on rose quartz from Taquaral, Minas Gerais, Brazil and, of course, the exciting new gem crystals of zoisite (tanzanite) from near Arusha, Tanzania.

Of course, this is an incomplete list but it includes some of the headliners. Several of these, and others as they come to our attention, will be described later in this column.

Figure one

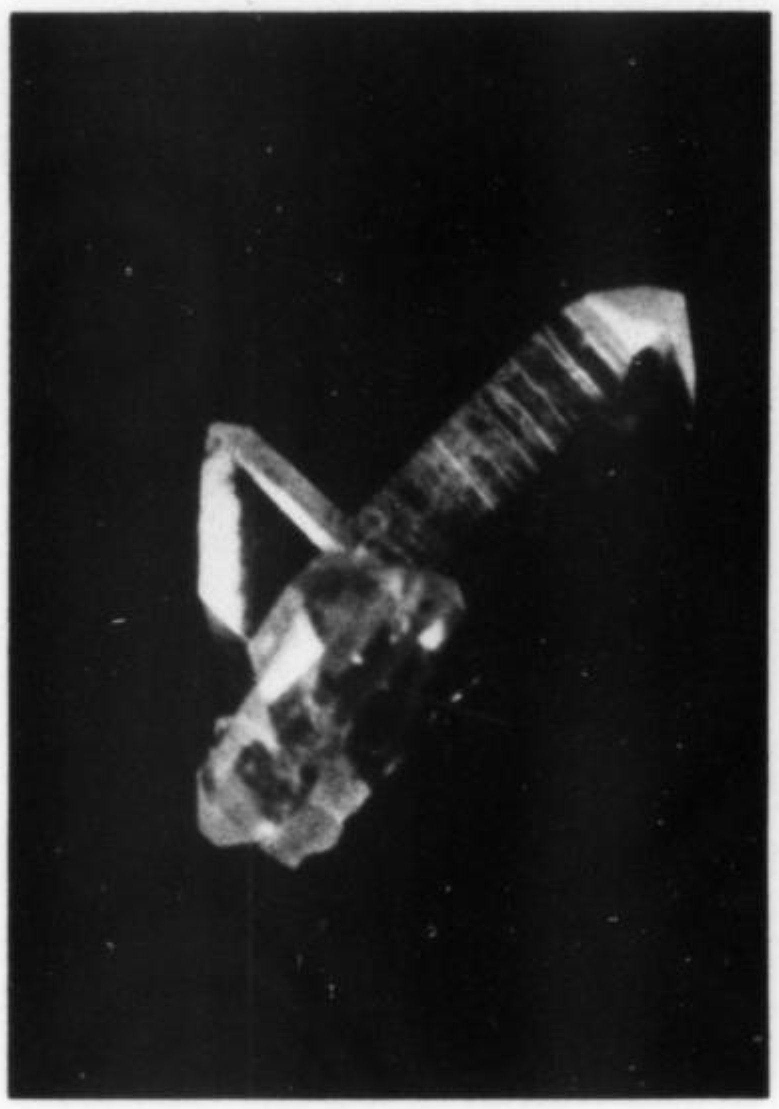


Figure two

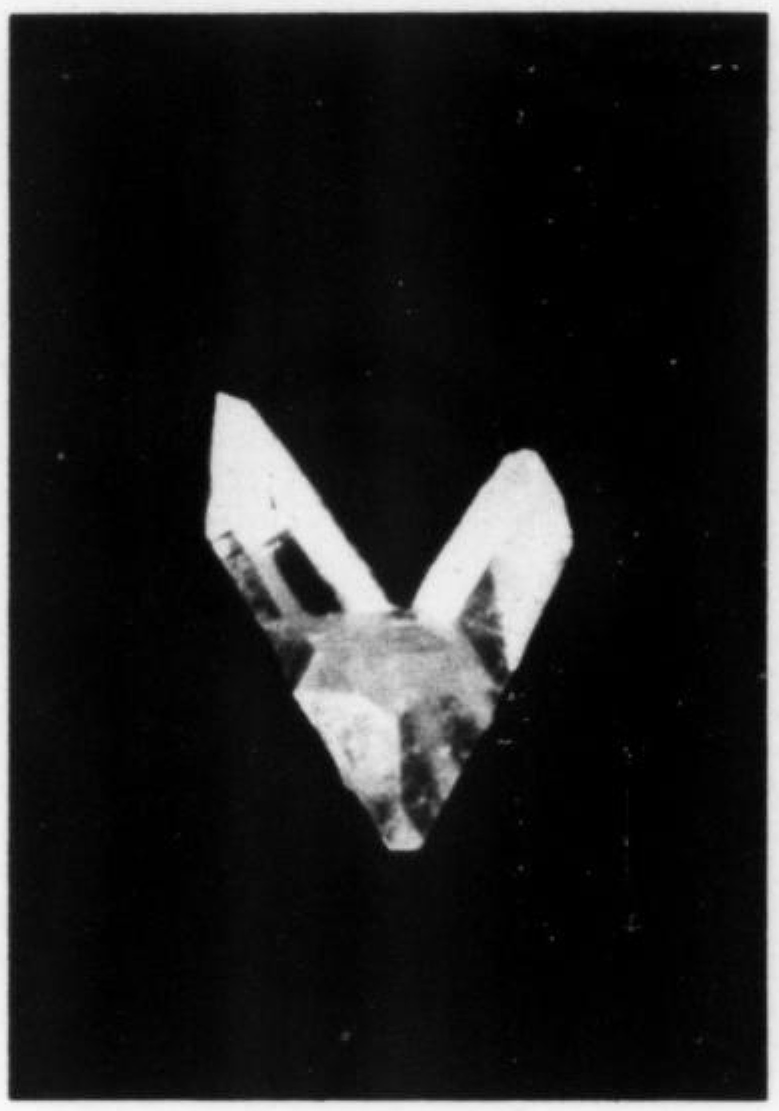


Figure three

A Multiple Japan Law Quartz Twin

by Richard A. Bideaux

Contact twins of quartz with composition plane (1122), opposed sets of coplanar prism faces, and c-axes inclined at 84’ 33’ are collectively known as Japan law twins. The accompanying photographs illustrate a group of three quartz crystals related by an instance of multiple Japan law twinning.

The central individual, I, to which each of the other two individuals are twinned, is about 5 mm. long and doubly terminated. One end shows multiple terminations perhaps due to secondary growth. This crystal is slightly tapering, somewhat triangular in cross-section by suppression of alternate prism faces, and is prominately striated in the plane of its a-axes.

Individual II, the upper-rightmost crystal in Fig. 1, is about 1/3 the length of I and shows only a single termination. Individual III, the left-uppermost crystal in Fig. 2, is slightly smaller than II, and is also singly terminated. Fig. 1 is taken nearly perpendicular to the plane of the c-axes of I and II; Fig. 2 is oriented similarly for I and III.

II and III are each apparently twinned to I according to the Japan law, but the composition faces are adjacent prism faces of I. This “Siamese” relationship is seen in Fig. 3, which shows the group viewed approximately down the c-axis of I. There is no twin relationship between II and III. Both II and III are slightly flattened along their a-axes perpendicular to the c-axis of I. This flattening is a common characteristic of Japan law twinning.

The group was measured on a two-circle reflecting goniometer with disappointing results. Unexpected poor reflections were obtained especially from II and III, apparently the result of curved faces, striations and matte crystal surfaces. Sufficient observations to accurately establish the interaxial relationships between I, II and III were impossible to obtain. The few measurements which could be approximated were within about 1° of their expected theoretical positions.

Forms or natural etching diagnostic of hand are not evident. Thus the relative hands of the crystals or the existance of further twinning according to any of the parallel axis laws could not be ascertained.

Other examples of multiple Japan law quartz twins are not known (C. Frondel, pers. comm.).

This crystal group was collected, free of matrix, on a mine dump near the Yankee Boy mine, about six miles easterly from Mayer, Gila County, Arizona. Other small Japan law twins have been collected from this locality also. It is in the collection of Mrs. Donald C. Sonnenberg, Phoenix, Arizona, to whom I am indebted for the opportunity to examine, photograph and describe it.


The Mineral Kingdom
by Paul E. Desautels