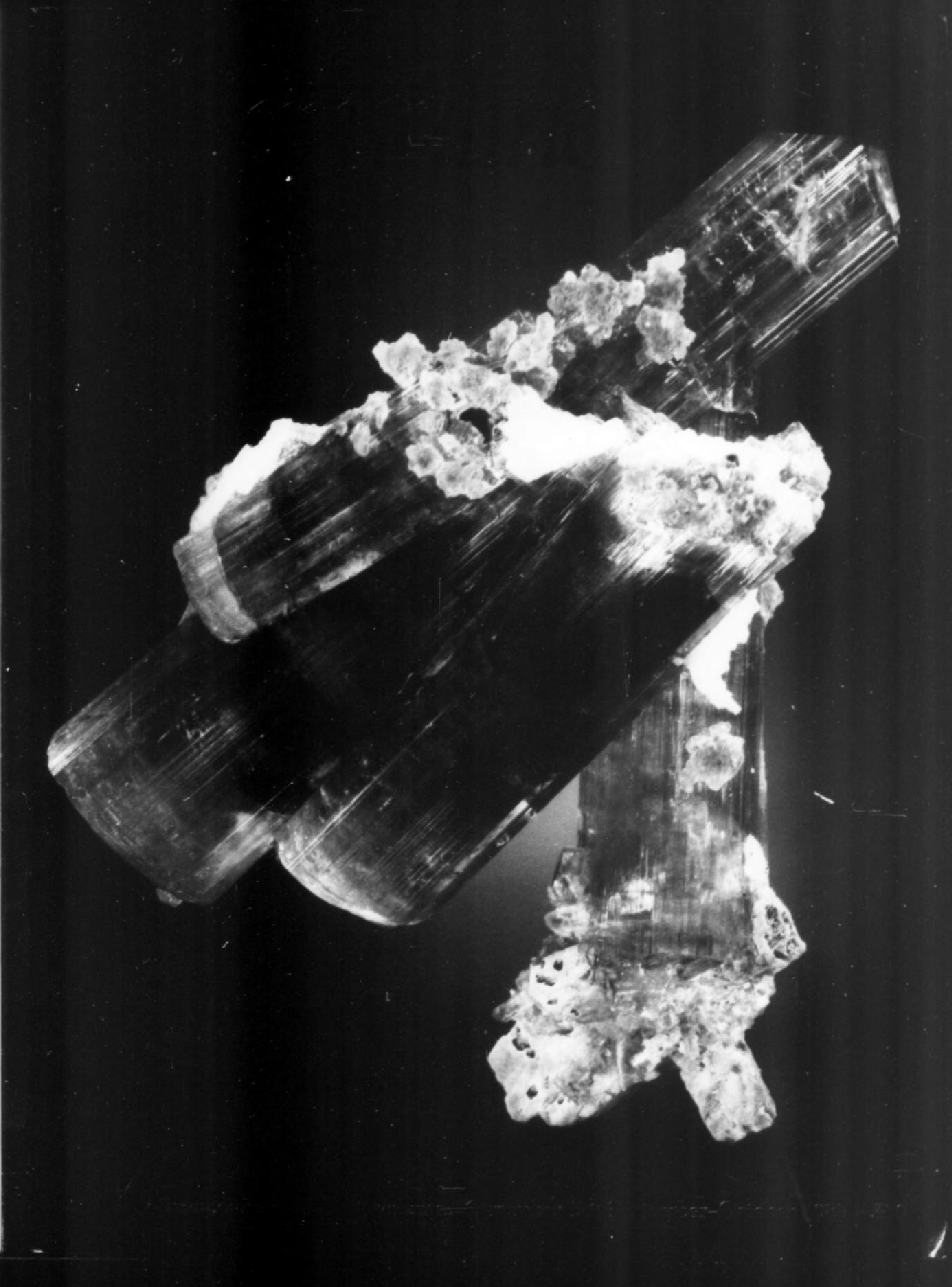


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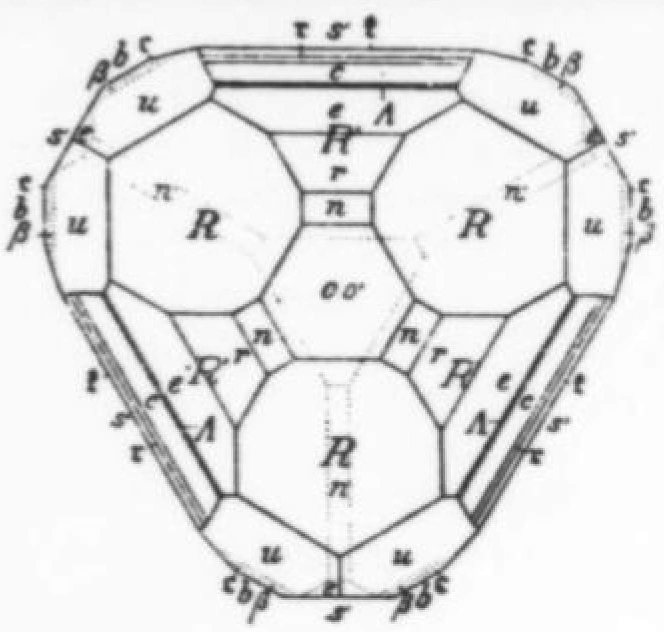
Tourmaline-1

the first special issue in the Gem Minerals Series

COVER: Tourmaline crystal group 9 cm long, with albite and lepidolite, mined recently at the Himalaya mine, Pala, California. William Larson collection; photo by Harold and Erica Van Pelt.

notes from the EDITOR



Tourmaline Issue

Welcome to the first issue (double-size!) in our projected series on the gem minerals. In this issue the focus is on tourmaline mineralogy and some of the important tourmaline localities worldwide. Of course we can't cover all the best localities in a single issue, so this should be considered as only the first of two or more special tourmaline issues; in fact, we already have a good start on *Tourmaline-II.*

Throughout this series some overlap of species will be inevitable; for instance, the Pakistan pegmatites covered here have also yielded superb aquamarine and could just as well have been included in the eventual Beryl Issue. Although discussion of the aquamarines may represent a minor conceptual digression for this particular issue, the entire series when complete will form a coherent whole. Certainly it will be several years before we've done it all, and I can't begin to predict how many special issues will be involved, but what a set they'll make!

Readers can rest assured that even though this series of special issues is based on the gem species, there will be precious little technical gemology included; plenty of references exist on that already. The occasional faceted stone will show up in an illustration here and there, but we are still the *Mineralogical* (not Gemological) *Record* and are happy remaining true to our niche. Readers interested in gemology are referred to our fine counterpart in the gem world, *Gems and Gemology* magazine. (A four-issue annual subscription is $29.50 in the U.S., $40 elsewhere, and well worth it; order from the Subscriptions Manager, Gemological Institute of America, 1660 Steward Street, Santa Monica, California 90404.)

Several noteworthy articles on tourmaline and its localities have appeared previously in the *Mineralogical Record.* A look back at the following might be interesting in the current context (some of these back issues* are still available from the Circulation Manager for $7 postpaid):

Locality—Minas Gerais, Brazil (by J. S. White)
[1970, vol. 1, no. 2, p. 73.]

Locality—Minas Gerais, Brazil: a response (by A. Lucio)
[1971, vol. 2, no. 1, p. 10–13.]

Gem tourmaline rediscovered at Newry (by D. A. McCrillis)
[1975, vol. 6, no. 1, p. 14–21.]

Elbaite from Newry, Maine (by P. J. Dunn)
[1975, vol. 6, no. 1, p. 22–25.]

Newry, Maine, a pegmatite phosphate locality (by V. T. King)
[1975, vol. 6, no. 4, p. 189–204.]

Famous mineral localities: the Pulsifer quarry (by W. E. Wilson)
[1977, vol. 8, no. 2, p. 72–77.]

Uvite, a new (old) common member of the tourmaline group and its implications for collectors (by P. J. Dunn, D. Appleman, J. A. Nelen and J. Norbert)
[1977, vol. 8, no. 2, p. 100–108.]

The dravite crystal bonanza of Yinnietharra, Western Australia
[1977, vol. 8, no. 2, p. 109–110.]

Famous mineral localities: the Himalaya dike system, Mesa Grande district, California (by E. E. Foord)
[1977, vol. 8, no. 6, p. 461–474.]*

The reopening of the Himalaya mine (by D. Eidahl)
[1977, vol. 8, no. 6, p. 475.]*

The best of San Diego County (by W. Larson)
[1977, vol. 8, no. 6, p. 507–515.]*

Famous mineral localities: the pegmatites of Laghman, Nuristan, Afghanistan (by P. Bariand and J. Poulen)
[1978, vol. 9, no. 5, p. 301–308.]*

New tourmaline discovered in [Itatiaia] Brazil (by A. Lallemant)
[1978, vol. 9, no. 5, p. 298–299.]*

More on rubellite from the Itatiaia mine, Brazil (by P. C. Keller)
[1979, vol. 10, no. 1, p. 33–34.]*

Famous mineral localities: the Cruzeiro mine [Minas Gerais, Brazil] (by J. P. and J. O. Cassedanne and D. A. Sauer)
[1980, vol. 11, no. 6, p. 363–367, 370.]*

The Urubu pegmatite and vicinity [Brazil] (by J. and J. Cassedanne)
[1981, vol. 12, no. 2, p. 73–77.]*

Famous mineral localities: the Virgem da Lapa pegmatites (by J. P. Cassedanne and J. Lowell)
[1982, vol. 13, no. 1, p. 19–28.]

The Jensen quarry, Riverside County, California (by F. DeVito and A. Ordway)
[1984, vol. 15, no. 5, p. 273–290.]*

Lest the reader be left with a burning question in his or her mind, I should mention before concluding this introduction that the *next* tourmaline issue will indeed be heavy with information and stunning photography on the subject of Brazilian tourmaline and its many famous deposits. Wild horses couldn't keep us away from that subject, but the project is large and complex, and requires some work yet before it will be ready for publication.

I should also mention the interesting little insert accompanying this issue, a flier for the forthcoming Munich Show. The show this year will feature tourmaline as the special topic, and show chairman Johannes Keilmann's clever flier (designed by Max Glas) can be cut out and folded into a three-dimensional model of a tourmaline crystal, an *impossible* tourmaline crystal that is, zoned with a different tourmaline color on each face!

A Special Thanks to our Anonymous Donor from Georgia for making this issue possible

Kunz book

To the gem and mineral connoisseur as well as the book lover, the name of George Frederick Kunz is well known. Dynamic, aggressive, voluble, self-educated and self-promoting, Kunz had enormous influence in the gem and mineral world. The lovely lilac-colored variety of spodumene, *kunzite,* is named for him, and his various books, especially *Gems and Precious Stones of North America* (1890) and *The Curious Lore of Precious Stones* (1913) are still widely read and collected. He was only 20 when, in 1876, he

George F. Kunz (1856–1932) examining a kunzite crystal from Pala, California.

sold Charles L. Tiffany a tourmaline, even though Tiffany and Company had never before marketed that gemstone. Soon Kunz was a "gem expert" working for Tiffany's, and eventually a vice president of the company. He received a wide range of medals, awards and honorary degrees from nations and institutions around the world, and was appointed "Special Agent of the U.S. Geological Survey" (in which capacity he wrote much on gemstone production and localities for the *Mineral Resources of the United States* series from 1885 to 1907). The "Kunz luck" followed him wherever he traveled, bringing hitherto unheralded gem and mineral finds to his attention, and great collections which he could buy.

Kunz died in 1932 at the age of 76, but a great deal of his fascinating correspondence has survived. He kept in touch with such notables as Edward S. Dana, Albert E. Foote, Charles Upham Shephard, Victor Goldschmidt, Washington Roebling, and also Clarence S. Bement, who built what is perhaps the finest private mineral collection ever assembled – over 16,000 specimens now in the American Museum of Natural History.

To salvage some of this rare and readable material, Lawrence Conklin (17 St. John Place, New Canaan, CT 06840 – 203-966-3590) is issuing a unique, privately printed limited edition (150 copies) of a compilation entitled *Letters to George Frederick Kunz*. Forty-three select letters, reproduced in facsimile with accompanying transcriptions, plus photographs, brief biographies of correspondents, and choice bits about their activities are included. Topping off the edition is a photographic color print (not a press print) of one of the world's finest kunzite crystals, taken by Harold and Erica Van Pelt.

The 43 letters were culled from a trove of more than 7000 pieces of Kunz correspondence, including letters between his emminent friends as well as to him. Of the 150 copies in the edition, 107 are bound in half-cloth and priced at $110. The remaining 43 are expensively bound in leather and each contains, in a pocket, one of the *original* 43 letters. If you have to ask the price on these you probably can't afford it. But even the cloth edition, at a mere 107 copies, will be highly collectible and constitutes a salutary addition to the mineralogical literature. Conklin should be congratulated for his efforts at private publishing; if only more people and organizations with access to rare information would do the same!

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Toramalli

A short history of the tourmaline group

Friedrich Benesch and **Bernhard Wöhrmann**
Abraham Wolf Strasse 46
D-7000 Stuttgart 70, West Germany

Though tourmaline is not among the classical precious stones it was indeed known in antiquity, and has been studied for centuries. Its attractive appearance, complex composition and interesting electrical and optical properties have endeared it to gemologists and mineralogists alike.

INTRODUCTION

Only a few gems and minerals were well known to the ancients. These generally fell into three categories: (1) raw materials for tools, such as flint and copper, (2) ornamental materials for making statuary, jewelry and religious accoutrements, and (3) materials thought to have mystical, therapeutic, magical or astrological value. Tourmaline was probably put to the latter two uses, though it was difficult to distinguish from other gems of similar color. A search of early writings reveals quite a number of interesting references to what was probably tourmaline.

LYNGOURION and LYCHNIS

Tourmaline is not normally counted among the classical gemstones such as emerald, ruby, sapphire and garnet, but there are clear indications in the writings of early Greek and Roman scholars that it was known in ancient times.

Theophrastus (372?–287 B.C.) described a substance called *lyngourion* in his treatise *On Stones,* the earliest known scientific work dealing expressly with minerals. He writes:

> Remarkable in its powers is the *lyngourion,* for seals are cut from this and it is very hard, like stone. It has the power of attraction, just as amber has, and some say that it not only attracts straws and bits of wood but also copper and iron if the pieces are thin. It is cold and very transparent. Those who are experienced find the stone by digging it up.
>
> (Edited from the Caley and Richards translation, 1956)

Although Theophrastus had been told that *lyngourion* was solidified animal urine, his description of its properties is fairly clear. The fact that it is cold to the touch (mistranslated until recently) and very hard, as well as its occurrence only in the ground argue against it being merely amber as some authors have suggested.

Pliny the Elder (A.D. 23–79), who used Theophrastus and a wide range of other works (many now lost) as sources, gives a somewhat different name and more information in his *Historia Naturalis*:

> To this same class of fiery red stones belongs the *lychnis,* so called because it is particularly beautiful by lamp light. It is found around Orthosia and throughout Caria and the neighboring regions, but occurs at its finest in India. I find that there are other varieties as well, one of which has a violet-red sheen and the other a rose-red color. These, when heated in the sun or rubbed between the fingers, are said to attract straws and papyrus fibers.
>
> (Edited from D. E. Eichholz's translation, 1971)

"Caria" is an ancient district in southwestern Asia Minor. The Indian stones Pliny refers to may have been rubies, and some of the Carian material may have been garnets, but his description of pyroelectricity unquestionably refers only to tourmalines. Ball (1950), commenting on his own translation, felt that even the Indian material of Pliny was most likely tourmaline, even though a precise locality is unknown. Perhaps the Indian stones actually had come from Ceylon. In any case, *lyngourion* and *lychnis* are apparently the earliest names applied to tourmaline.

CARBUNCLE

The earliest known tourmaline to have been mounted as jewelry is a rubellite cabochon set in a gold finger-ring of early Nordic origin; it has been dated at roughly 1000 A.D., and is currently in the H. Battke collection. Two other rubellite rings are known from the 13th and 14th centuries, further evidence that tourmaline (though unrecognized as such) was in use in the Middle Ages.

It is likely that the medieval term *Karfunkel* or *carbuncle* applied to red tourmaline as well as garnet and ruby; people of the time had no basis for making accurate mineralogical distinctions. The most famous tourmaline carbuncle, probably dating to the 1500s, is a 250-carat stone the size of a small hen's egg. Kaiser Rudolph II (died 1612), who was fond of gems and minerals, received it as a gift from his sister. Rudolph's physician, Anselmus Boetius de Boodt, mentioned the stone in his 1609 treatise *Gemmarum et Lapidum Historia.* At the end of the Thirty Years War in 1648 Sweden took Prague and claimed the stone as booty; it thereafter became part of the Swedish crown jewels, until Gustav III presented it to Catherine the Great of Russia in 1777. Throughout all this time the stone was thought to be a ruby, until the well-known Russian mineralogist Alexander Fersman identified it as a Burma tourmaline in 1925. Today it is kept in the treasure room of the Kremlin.

LA'L

The Arab scholars grew to prominence during the centuries of the Middle Ages. In one of their many books on stones, only translated relatively recently, is a description which could refer to tourmaline. Muhammad Ibn Mansur, in his book on gems entitled *Gawahirnama,* refers to a stone called *La'l.* Ibn Mansur lived in the late 1400s, and is thought to have used the writings of the 11th century scholar al-Birunis as a source. Ibn Mansur writes:

> La'l appears in four varieties: red, yellow, violet and green. The green is similar to emerald. Sometimes a La'l appears partly red and partly yellow [some translators say "green" in place of "yellow"]. Some gem specialists speak of La'l which are red, yellow and green, not in the sense of different varieties but meaning rather a combination of these colors in a single piece.
>
> There are eight types of red La'l: *Kuzdumki, Piyazaki, Tamri* (date-colored), *Lahmi* (flesh-colored), *Annabi* (wine-red), *Baqmi* (redwood color), *Idrisi* and *Akhab* (dark red). Kuzdumki is the most attractive, colorful and sparkling.
>
> The name La'l originated in Badakhschan* because La'l was found at localities there. [Following a severe earthquake], fragments of white rock were found in which La'l was embedded. When the rocks were split, La'l could be seen in the middle.
>
> (Edited from Ali Akbar Dehkoda Loghat-nama, 1955, Teheran)

SCHÖRL

The early mining literature of central Europe mentions a different type of tourmaline, a black variety called *schörl.* Around 1500 the first edition of Ulrich von Calw's *Ein nutzlich Bergbuchleyn* ["A useful book on mining"] was published, and in 1562 another book of mining information by Johann Mathesius of St. Joachimsthal was published. These books refer to a valueless black material which interfered with the purification of cassiterite tin ore; it was called *Schorlein, Schorleyn* or *Schürl.* Another early form of the name is *Schorlet,* mentioned in Zeisig's (1730) *Neues und curieuses Bergwerks Lexicon.*

Many attempts have been made to trace the derivation of this old term. One explanation refers to the old German word *Schor,* meaning garbage or waste. Others relate to the Wendic word *zorlin* and

Figure 1. **Title page of Ulrich Rülein von Calw's *Ein nutzlich Bergbuchleyn* (1500) and the portion of text *(opposite page)* referring to problems caused by schorl impurities in cassiterite tin ore.**

the German word *aufschirlin,* both meaning "to swell," in possible reference to a critical swelling phase in the cassiterite beneficiation process. Dana (1837) connects the name with Schorlaw, a village in Saxony which had afforded specimens.

As with colored tourmaline, confusion with similar minerals was a problem and it is likely that other blackish species such as rutile, augite, epidote, olivine and hornblende were sometimes called schörl.

SMARAGDUS BRESILICUS

In 1565 a book entitled *De rerum fossilium, lapidium et gemmarum* was published which dealt extensively with minerals and gems. The author was Conrad Gesner, a famous Zurich physician, natural historian and professor of philosophy. He describes some "cylindrical" (i.e., prismatic) crystals which he called *Smaragdus Bresilicus* or "Brazilian emerald." In addition to a description, Gesner provides a line-drawing of what is clearly a tourmaline crystal.

Johannes de Laet (1647), Rome de l'Isle (1772) and Zeisig's *Lexicon* (1730) contrast the two types of emerald, distinguishing between beryl ("oriental emerald") and tourmaline ("occidental emerald" from South America). It is believed that in the 1600s Jesuits operated a gem mine in Espirito Santo, Brazil, and produced green tourmaline.

These and a variety of other names were retained for tourmaline until the 19th century when modern mineralogy finally took hold.

---

*An area just north of Nuristan, Afghanistan, a famous tourmaline locality. See Bariand and Poullen (1978), *MR,* **9**, 301–308.

So aber die selbige klufft von dē gang eile ist zu-
besorgē das schwerlich etwas mercklichs darauff
zubauē stedt Es wer dan dz sie hinußwartz zuei-
nem anderenn gang eilte / darumb ist gar retlich
wu solche hengklufft die gedigē golt furen von dē
gang eylen vñ vallen dz man vff dz selbig ort mit
schurpfen ein erfarūg ader suchūg nach anderen
gengen thū vñ also mit vorsichtigkeit dy klufft ge
schick vnd die geng bey eynander erbawen

Das sechste capitel ist von

dem zynertz ❡ Das zynertz ader der zwitter
wirt gewirckt auß influs des planetē iupiter vō
reynē quecsilber vñ von wenigē schweffel vnd in
der vormischūg diser beiden werdē vndermengt
vnartige grobe schweyfelyge bradez dye sich mit
eynander incorperirē vñ voreinigē zueynē metal
zyn genand von welchen vnartigē bradē eyn ytz-
liches zyn starck richend knyrschigk vñ bruchigk
ist also dz es auch alle metal darvnder es gemēgt
wirt vnartig vñ bruchigk macht

❡ Item ein teil deß zwytters wirt geborē in dē
flyeß wie ytzundt oben berurt ist von dē golt dz in
dē flyeß gewirckt wirt vñ wirt etzlicheß gewasch
en groß kornig dē schorlein gleich vñ darauß wirt
das schonste vñ beste zyn dz man nēnedt saiphen
zyn wan seine materie wirt gar rein geleuttert vñ
durch die eigēschafft der stadt geadelt Auch wirt
etzlicher zynstein gewirckt in den bergen vñ gefun
den ganghafftig der selbig wirt besser vñ besser ge
acht nach dē er ferner vō den kyßgengē gefunden
wirt vñ weniger mit dē kyßwerck vormist / bsun-
derlichē mit gedichtē vñ kupperigem kyß der gar
schwerlich von dē zynstein kan gescheidē werdē
Sunder d taube kyß ist dē zynstein nicht also gar
schedlich / dan durch die scherpfe des feurs wirt
er gelichtert vñ geasschert also dz er auff den test
mit dē wasser von dez zynstein hynwegk weicht
Auch wirt der zwitter ader zynstein ein teyl ge-
funden in einē geschut nestigk vñ nicht ganghaff
tig vff dē bergk / diser zwytter ist aber leutterer
vñ besser nach dez er weytter von den kyßgengen
leydt vñ weniger mit eyserigē schweffel vormist
wirt ❡ Eyn anwysung zu disez zynstei ist Dz
er gemeyniglich an den tag bluet vñ geschub von
sich stost

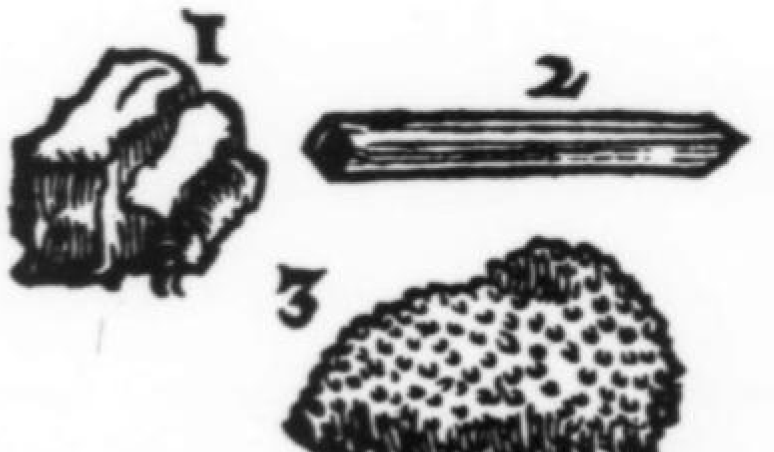
Das sibende capitel ist vō

dē kupfer ertz ❡ Das kupfer ertz ist gewirckt auß
einfluz veneris vō guttē vñ reynem quecksilber /

TORAMALLI

The origin of the name tourmaline can be traced to a manuscript of 1707 by Johann Georg Schmidt; he gave it the interesting title of *Curious Speculations during Sleepless Nights from a Lover who likes to Speculate*. This edifying little book covers many curious topics including magnetism, a subject of special interest at the time. Schmidt states that, in addition to the well known iron magnets, there is a gem named *Turmale, Turmalin* or *Trip* which exhibits a kind of magnetism. It was brought to Holland for the first time in 1703 by Dutchmen returning from East India. They found that, when laid in hot peat-coal, the stone not only attracted peat ashes but repelled them as well, a phenomenon that was "pleasant to watch." On this account the Dutch named the stone *Aschentrekker* or "ash-drawer." Its color was "pomegranate-red."

Schmidt used the name which the Dutch travelers had heard in Ceylon; the original Sinhalese spelling is *toramolli* or, in Tamil, *toramalli*, meaning "something little out of the earth." The French changed it to *tourmaline* and the Germans retained Schmidt's *Turmalin*. In Ceylon, of course, the term was merely a catch-all for any unidentified yellow, green or brown stone and, according to Eduard Gübelin, it is still used that way in Sri Lanka (Ceylon) today.



1 *Amiantus è Cypro.*
2 *Smaragdus Bresilicus, cylindri specie.*
3 *Hammites vel Ammonites, minor, minimis piscium ouis vel araneorum similis, velutiq; ex arenulis coagmentatus.*

Figure 2. **A portion of a page from Conrad Gesner's *De rerum fossilium, lapidum et gemmarum* (1565) showing the earliest published illustration of a tourmaline crystal ("2"). Gesner calls it *"Smaragdus Bresilicus, cylindri specie,"* or prismatic Brazilian emerald.**

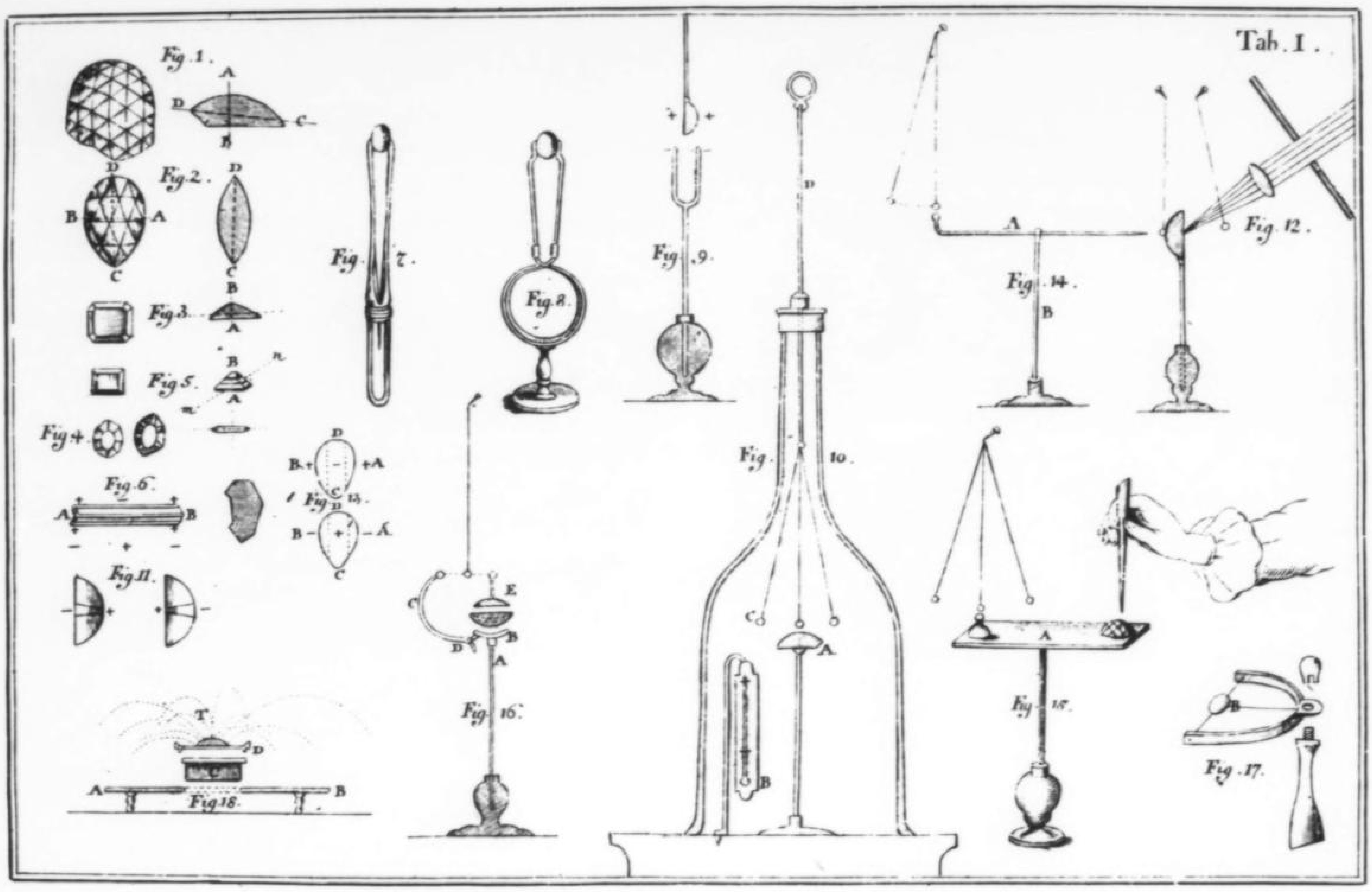


Figure 3. **Various experiments and apparatus involving tourmaline pyroelectricity (Wilke, 1768).**

LAPIS ELECTRICUS

Instead of attracting the attention of goldsmiths and jewelers, tourmaline soon acquired great importance in scientific circles due to its electrical properties. It was formally presented to the scientific community by Nicola Lemery at a meeting of the Royal Academy of Science in Paris in 1717. Following is a portion of those transactions (translated).

> There is another form of small magnet. It is a stone which can be found in a river on the island of Ceylon, and is the size of a denier [coin], round and brown. It sparkles and is as lustrous as if it were already cut and polished. It attracts, then repels small particles such as ashes, iron filings and bits of paper. It is quite scarce, and [the sample shown] cost 15 livres.

Following Lemery's presentation each and every researcher scrambled for a sample of the amazing gemstone for his experiments. A flurry of studies were soon published in the scientific journals of the time.

In 1756 Franz Ulrich Theodosius Aepinus published his "Memoire concernant quelques nouvelles experiences electriques remarquables" in the journal of the Royal Academy. He formulated his "law of the electricity of tourmaline" as follows:

> The tourmaline always has, at the same time, a positive and a negative electrical charge; that is, when one end is positive, the other is invariably negative.

Important writings followed in quick succession: Benjamin Wilson and John Canton (1759), Johann Carl Wilke (1759, 1766, 1768) and Torbern Bergman and Sven Rinman (1766). In 1763 Aepinus published a bibliography of articles on tourmaline up to that time.

It was Torbern Bergman who first noticed that *lapis electricus* (as Carl von Linne had called it in 1747) might also include schörl, a mineral having similar electrical characteristics. Romé de l'Isle (1772) had also observed the similarity. And so it was that the gap began to narrow between schorl and the rest of the tourmaline group.

Wondraschek (1797) attempted a chemical analysis of a tourmaline in 1790, identifying silica (46%), alumina (46%), Mg_2O_3 (4%), lime (2%) and water (2%).

INTO THE 19TH CENTURY

It remained for the great French mineralogist, René Just Hauy, to formalize the relationship of schorl to tourmaline in his *Traité de Mineralogie* of 1801. He also classified the well-known rubellite (formally described by Kirwan in his *Elements of Mineralogy,* 1794) as a tourmaline.

A number of new findings began to appear in the literature, as systematic research began to improve and accelerate. In 1800 d'Andrada described the colorless variety of tourmaline which he called *achroite*.

In 1802 the Count de Bournon described a remarkable and enormous specimen of rubellite which came to London as a gift from the King of Ava in present-day Burma. The specimen was pictured in James Sowerby's *Exotic Mineralogy* in 1817, as a hand-colored copper-plate engraving, reproduced here along with a facsimile of Sowerby's commentary. Count de Bournon described the piece thusly:

> This specimen, which is not accompanied by any kind of matrix, is nearly as large as a man's head; and is entirely composed of crystals layed by side of each other in a diverging

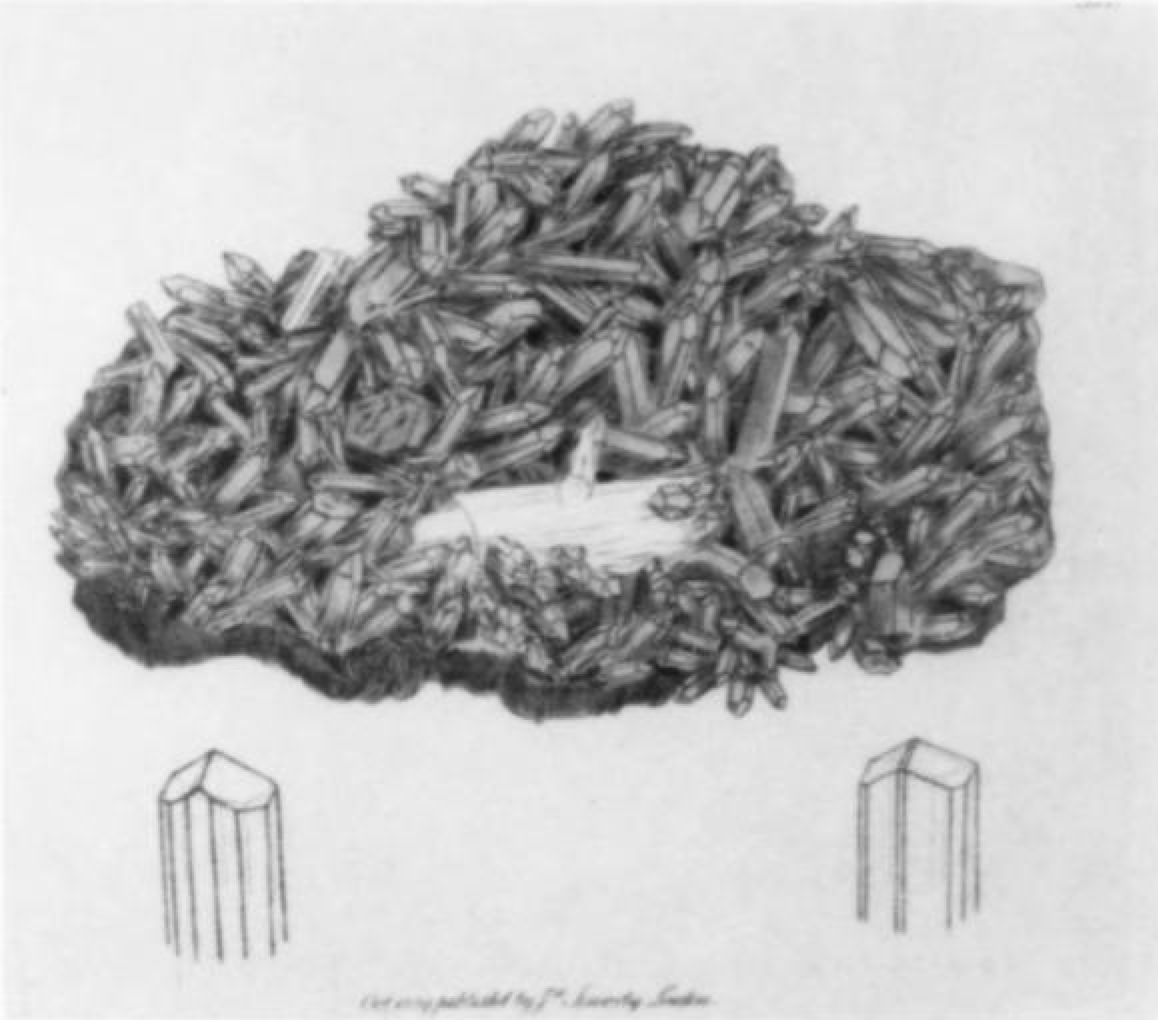


Figure 4. **Achroite or colorless tourmaline with quartz crystals from St. Just, Cornwall (from Sowerby's *British Mineralogy*, vol. 4, 1811).**

ARGILLA electrica, var. purpurea.
Tourmaline, var. Rubellite.

Syn. Rubellite, red schorl of Siberia. *Kirwan, 1.* 288.
Tourmaline Apyre? *Haüy, IV.* 401.
Tourmaline rouge de Sibérie. *Bournon,* 69.
Siberite, red schorl, &c.

Although Rubellite is only a variety of Tourmaline, it is such an interesting ore, that I have thought a figure of the most famous specimen yet known in the world, would be acceptable: it is that presented to Col. Symes by the King of Ava, in whose territories it was found. From Col. Symes it passed into the Grevillian collection, with which it was purchased, having been valued at £500,* for the British Museum, where it now stands, the pride of the mineral collection. It consists of a scopiform group of 9-sided prisms, terminated by trihedral pyramids, the prism in the centre of the group is the longest; on three sides of this the surrounding crystals are gradually shorter, forming a rugged trihedral pyramid, so obtuse as to resemble the corner of a cube: the edges of this pyramid are strongly defined by three rows diverging from the apex of more closely connected crystals than those upon the sides. The interior of the mass is of a deep reddish purple colour, and so intense as to be almost opaque; but the surface is of a yellowish brown colour; and between the two the crystals are transparent, and of a pink colour. I have added a crystal of a less rare variety of Rubellite from Siberia.

* I was told that it was once valued by an eminent Oryctognost at 1000 guineas.

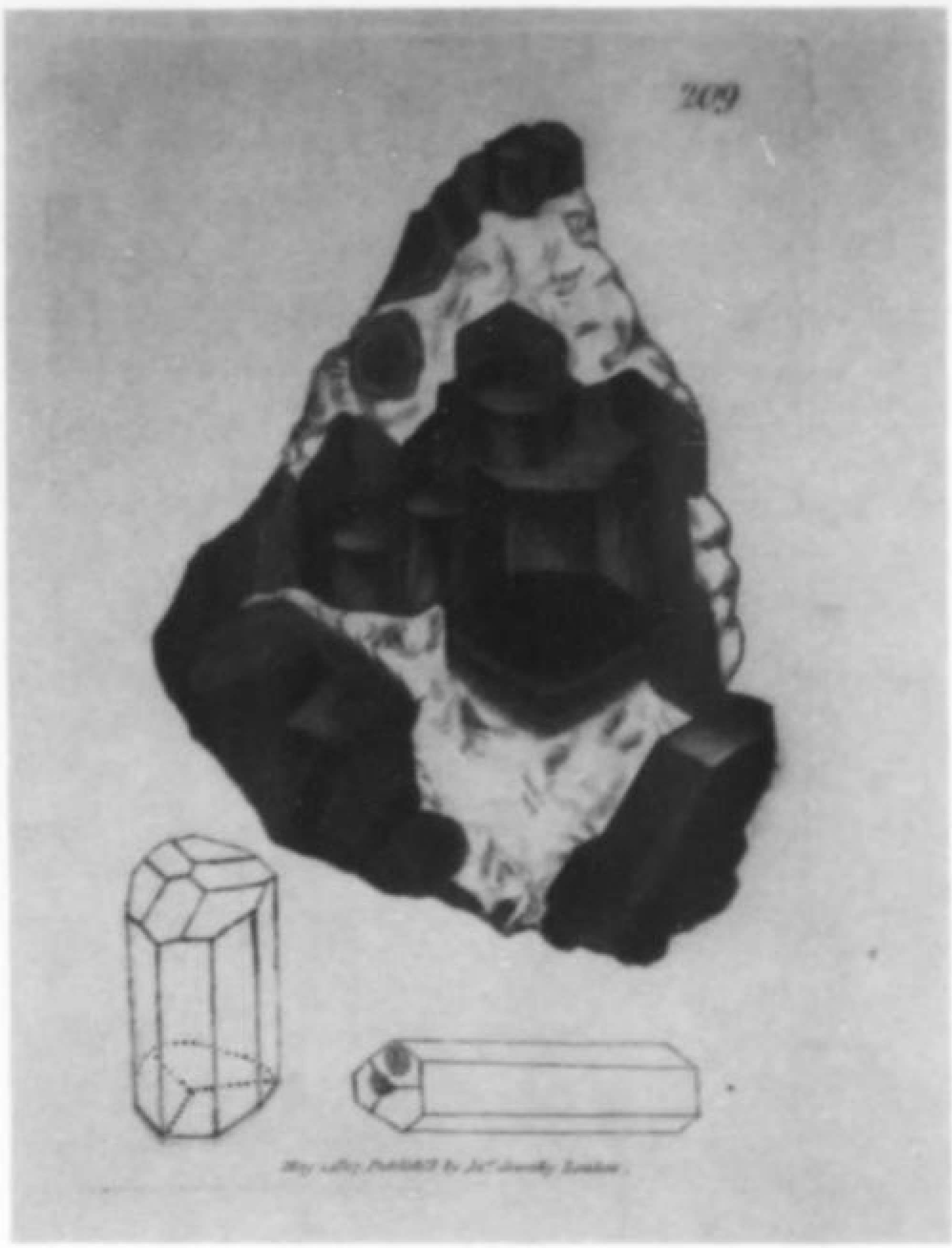
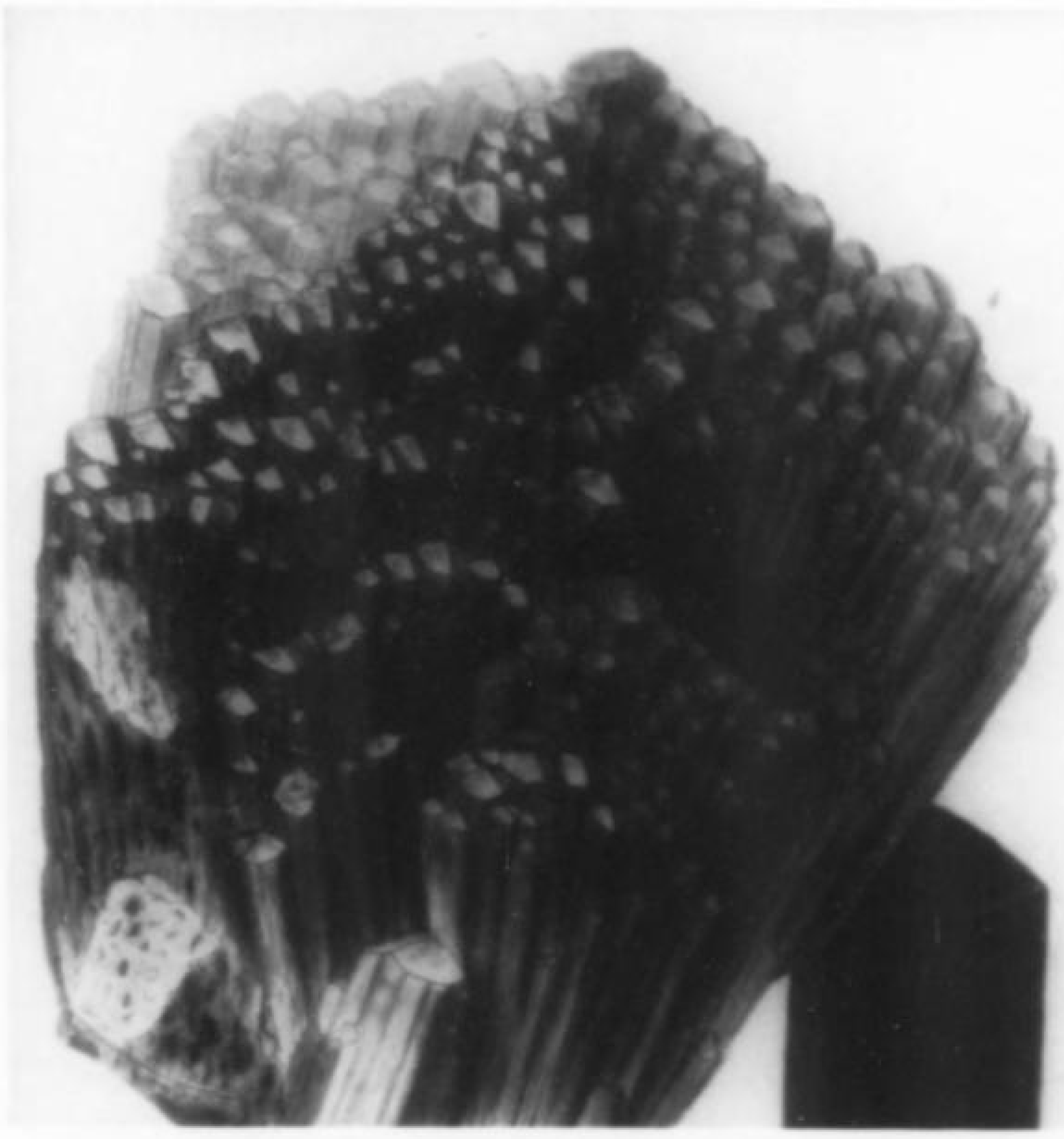


Figure 5. **Schorl crystals from Penzance, Cornwall (from Sowerby's *British Mineralogy*, vol. 3, 1809).**

Figure 6. **Rubellite tourmaline, a large cabinet specimen from Burma, illustrated in Sowerby's *Exotic Mineralogy* (1817) with Sowerby's accompanying text *(left)*.**



form, or rather penetrating each other at one of their extremities, and separating or diverging a little at the other extremity. Every one of these crystals, most of which are as long as the height of the specimen, is nearly as thick as the little finger.

All the crystals are relatively transparent and terminate on the top of the specimen.

> The greatest part of the specimen is the pale purplish red or flesh color; but, towards the base, this color grows much more deep so that, at last, it becomes absolutely black.

Tourmaline continued to be a mineral known almost exclusively to mineralogists until the second half of the 19th century, and only much later did it gradually acquire gemological importance. In 1865 Harry Emanuel, in his *Diamonds and Precious Stones,* declares that "the tourmaline has very little commercial value except for optical purposes." And as late as 1909 Max Bauer, in his *Precious Stones, their Characters and Occurrence,* wrote:

> To the ordinary jeweler the name tourmaline and the several variety names recognized by mineralogists are alike practically unknown. The gem varieties of tourmaline are distinguished by jewelers solely by their color, and are referred to by the names of better-known gems to which a qualifying prefix is added.

In 1813/14 Jean Baptiste Biot began investigating the polarization properties of tourmaline. In his *Traité de Physique* he was the first to describe the use of two thin tourmaline plates to construct a simple polariscope. In the following years David Brewster in Scotland made many important discoveries using Biot's tourmaline polariscope.

In 1818 Lampadius and Vogel discovered the presence of boron in tourmaline. In 1818 and 1820, respectively, Arfvedson and Gruner reported the presence of lithium. Elijah Hamlin discovered the first gem-grade North American tourmaline in Maine in 1820, and C. U. Shepard described them in 1831.

Parker Cleaveland (1816) reported colorless and black tourmaline from the island of Elba. In 1836 Gustav Rose published the first description of multicolored tourmaline from Penig in Saxony, and in 1845 Hermann described indicolite for the first time.

In 1837 James Dwight Dana published the first edition of his famous *System of Mineralogy* and presented a summary of previous analyses of black, green and red tourmaline by Gmelin and Arfvedon. In his third edition of 1850 he added analyses by such prominent mineralogists as Gruner, Klaproth and Buchholtz. Slowly a complex composition was revealing itself, consisting of at least 12 elements: Si, B, Al, Fe, Mn, Mg, Ca, K, Na, Li, H and O. Other properties including hardness, hemimorphism, dichroism, and a variety of crystal forms had become known.

In 1871 an extensive study of Russian tourmalines, including descriptions of many new forms, was published by M. Erofeev. Unfortunately it was published in Russian and the language barrier prevented it from being widely read.

Two years later, in 1873, Augustus Hamlin published his monograph on tourmaline occurrences (especially those in Maine) entitled *The Tourmaline.* It is a very original work, with several color illustrations of crystals. In his first chapter he states:

> The tourmaline, even at the present day, is but little known, except to the amateur or the mineralogist; yet it is, perhaps, the most interesting of all the gems, when we come to consider the beauty and diversity of its color, the complexity of its composition, and the wonders of its physical properties.

In 1872 gem tourmaline was found in Riverside County, California, on the southeast slope of Thomas Mountain, by Henry Hamilton. Then, in 1884, came the announcement that rubellite had been found in San Diego County, probably at the site of the present-day Stewart mine. Around this same time local residents had noticed tourmaline not far away at what was to become the famous Himalaya mine, officially laid claim to in 1898. Thus began the history of one of the most productive and interesting tourmaline districts in the world, one which still yields fine specimens today.

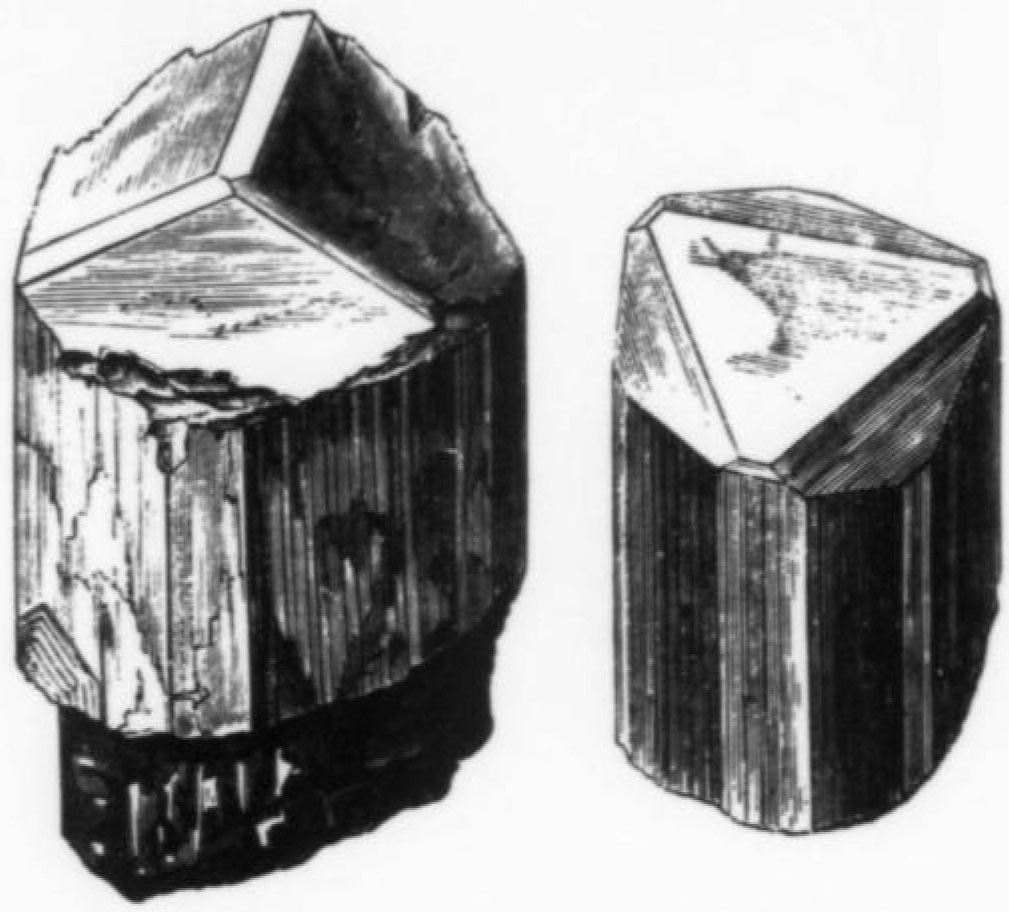


***Figure 7.* Black schorl (left) and translucent tourmaline from Siberia (from Amedee Burat's *Minéralogue Appliquée,* 1864).**

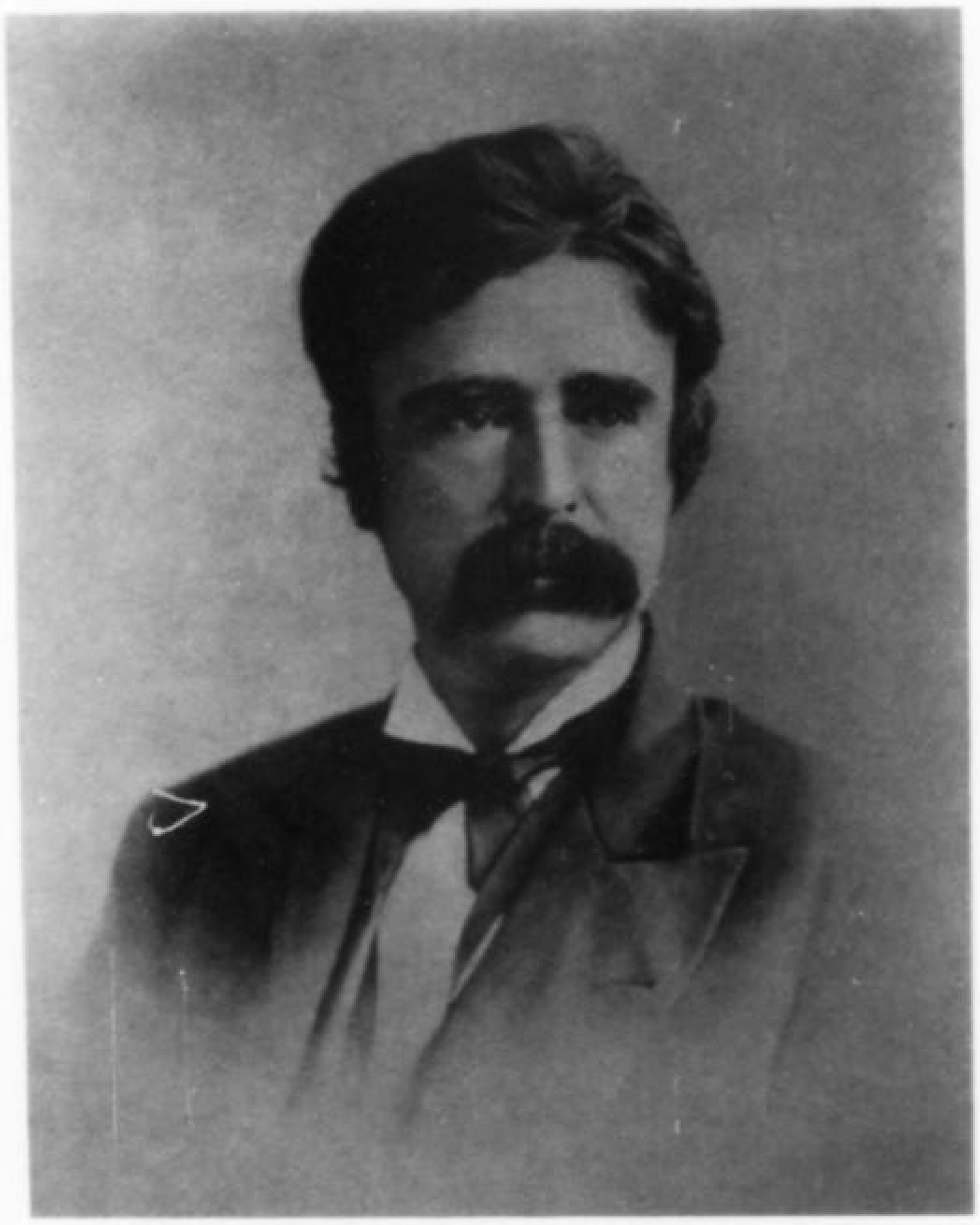


***Figure 8.* Augustus C. Hamlin, chronicler of the Maine tourmaline discoveries in his books *The Tourmaline* (1873) and *The History of Mount Mica* (1895).**

Piezoelectricity in tourmaline and quartz was discovered by the Curie brothers in 1880, and in 1883 Gustav Tschermak named a new species of tourmaline *dravite.* Dravite was found near the little village of Dobrava in Unterdrauberg (today known as Dravograd, in Yugoslavia), near a river called the Drau (Drava).

The second volume of Carl Hintze's *Handbuch der Mineralogie* was published in 1897, including no less than 57 pages on tourmaline and its localities. It is interesting to note that, until the turn of the century, many of what are today considered the great "classic" localities remained unknown or unmentioned. Areas like Minas Gerais in Brazil, San Diego County in California, Namibia, Mozambique and Madagascar are referred to little, if at all, in

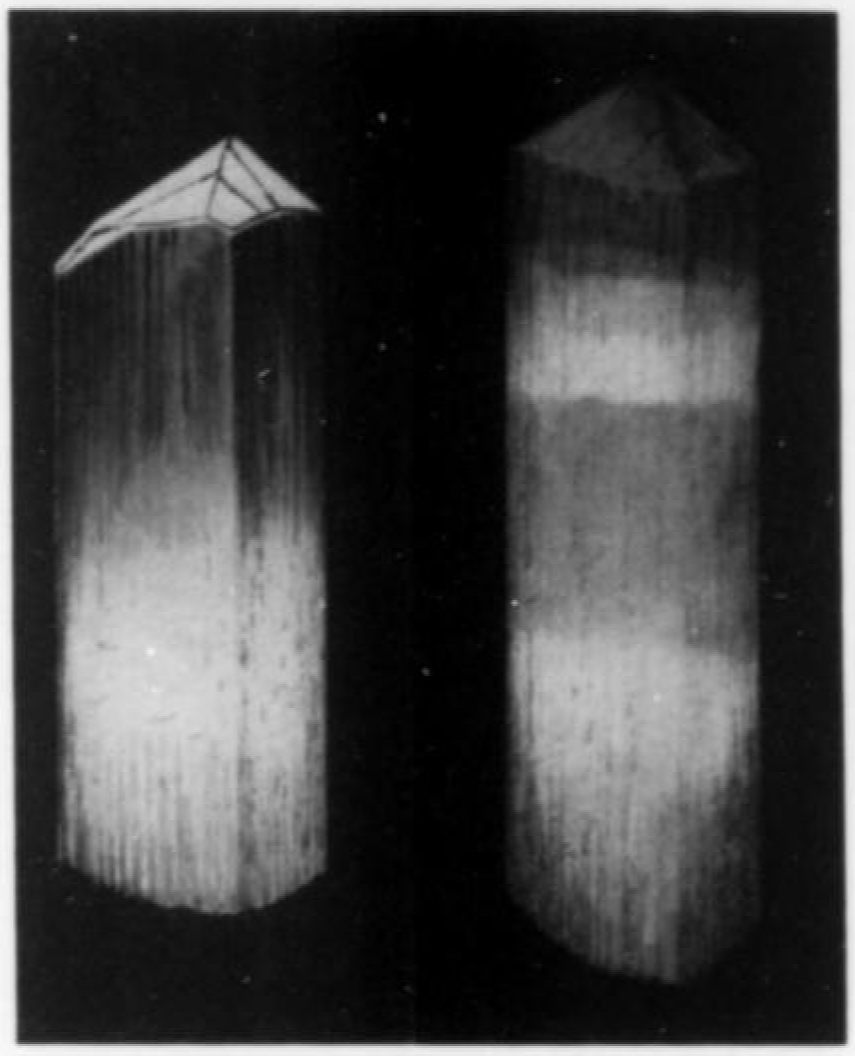
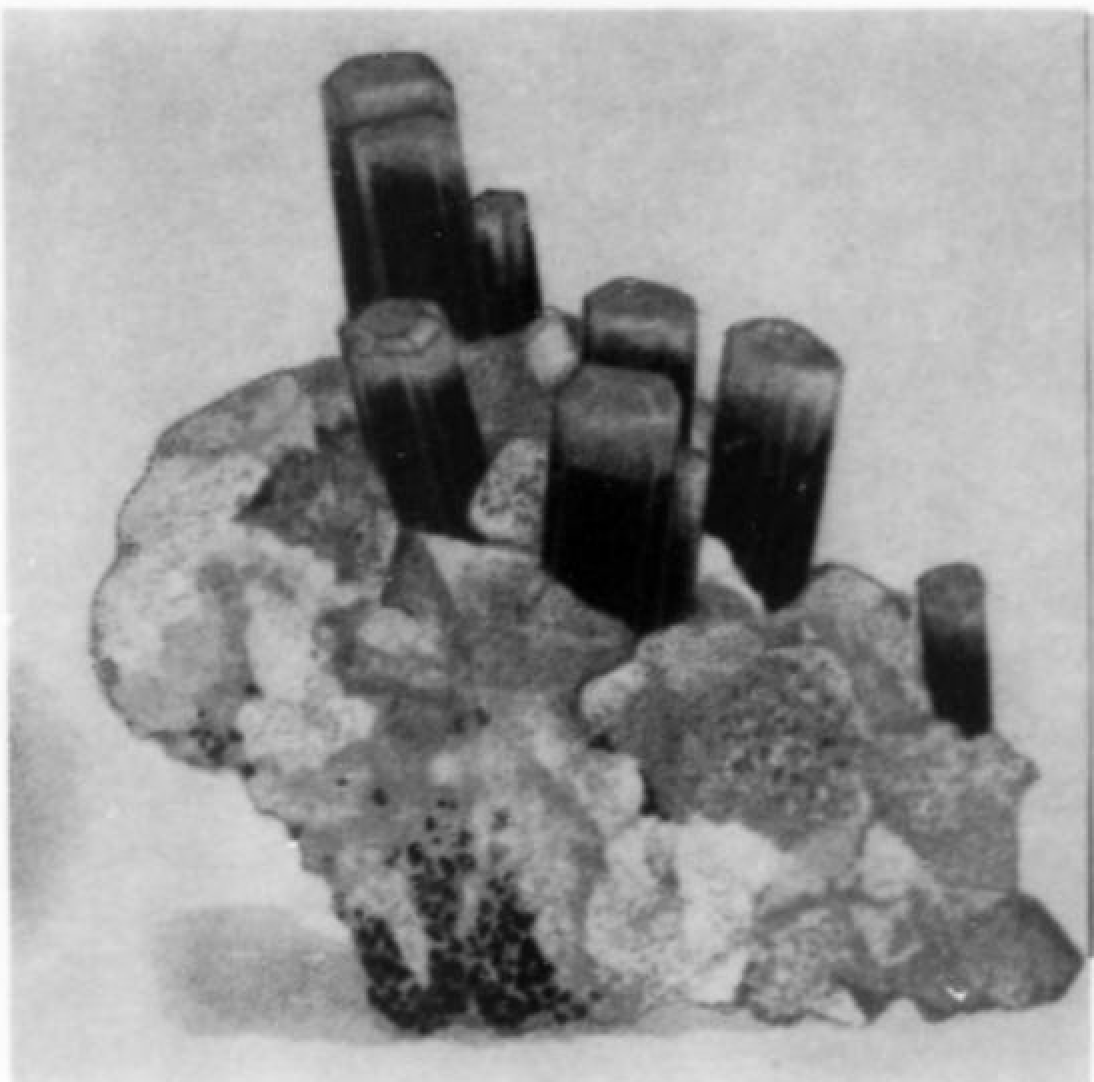
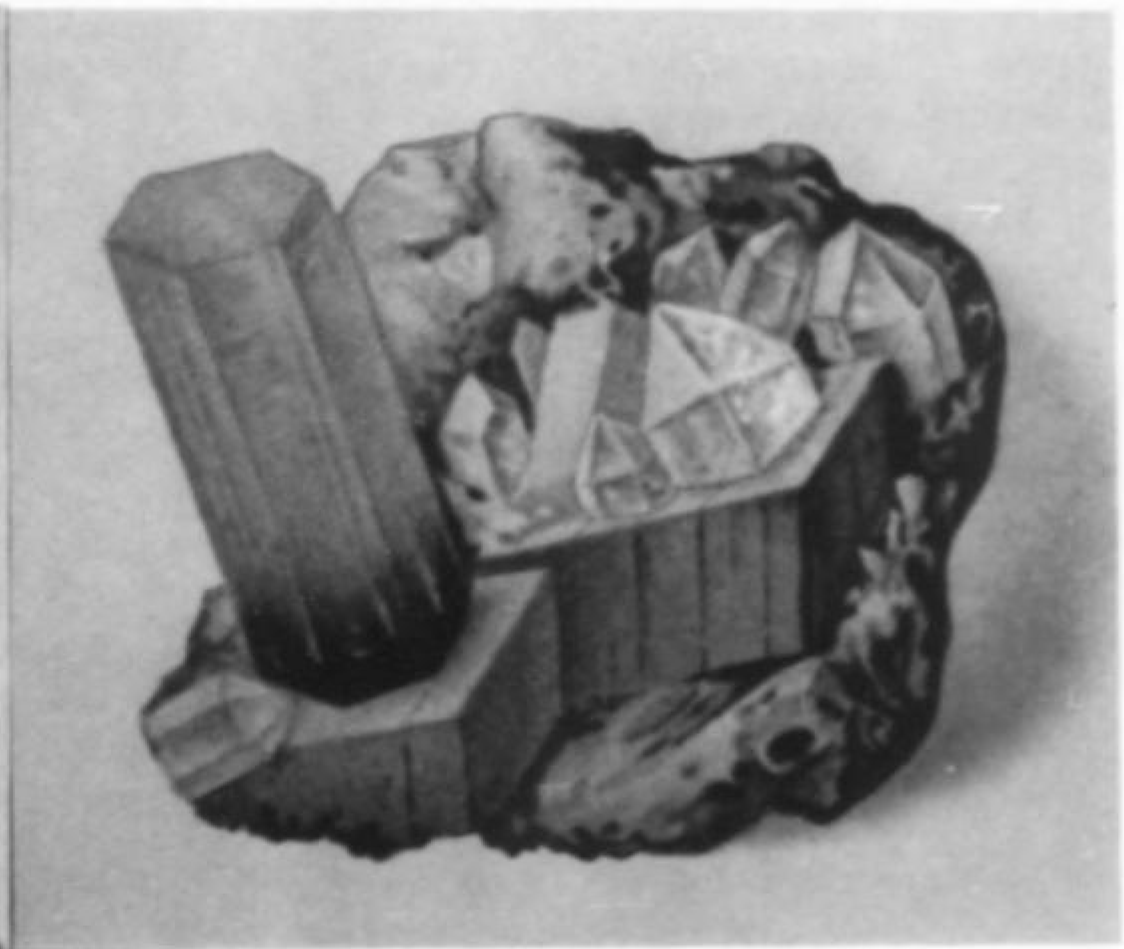


Figure 9. **Color-zoned Maine tourmaline, green at the top and red at the bottom, illustrated in Hamlin's *The Tourmaline* (1873).**

Figure 11. **Bright pink rubellite from the Himalaya mine, San Diego County, California (from Julius Wodiska's *Book of Precious Stones*, 1909).**

Figure 10. **Tourmaline specimens from Elba illustrated in Reinhard Brauns' *Das Mineralreich* (1903) (*left*) and Max Bauer's *Edelsteinkunde* (1896). The specimen at left has black crystals with greenish terminations, and the specimen at right has a pink crystal with green to black base.**





reference works of the time. Maine, Siberia, Burma and Ceylon were considered the most important localities.

INTO THE 20TH CENTURY

In 1899 and 1900, Penfield and Foote published important studies on the composition of tourmaline, summarizing all analyses made up to that time. Also in 1900, Victor von Worobieff published an extensive crystallographical study on a large number of Ceylon tourmalines having numerous crystal forms.

Exploration in a number of countries was intense around this time, and many discoveries of new tourmaline occurrences were made. Specimens had been coming out of Madagascar, in particular, and they attracted the attention of the French mineralogist Alfred Lacroix. His 1910 edition of *Minéralogie de la France et de ses colonies* includes a photo of a zoned tourmaline slab from Madagascar, and in 1922–1923 he published his monumental *Minéralogie de Madagascar,* covering a large number of tourmaline deposits which he had visited himself on an expedition there in 1911.

Perhaps the most spectacular tourmaline discovery in history was made in 1978, in Brazil, in the Itatiaia area. A walk-in pocket 3 meters in size was found which contained superb rubellite crystals up to an astounding 109 cm (3 feet, 7 inches) in size. Tons of

Figure 12. **Color-zoned slab of tourmaline (later described as the new species liddicoatite) from the Anjanabonoina pegmatite in Madagascar (from Lacroix, 1910).**

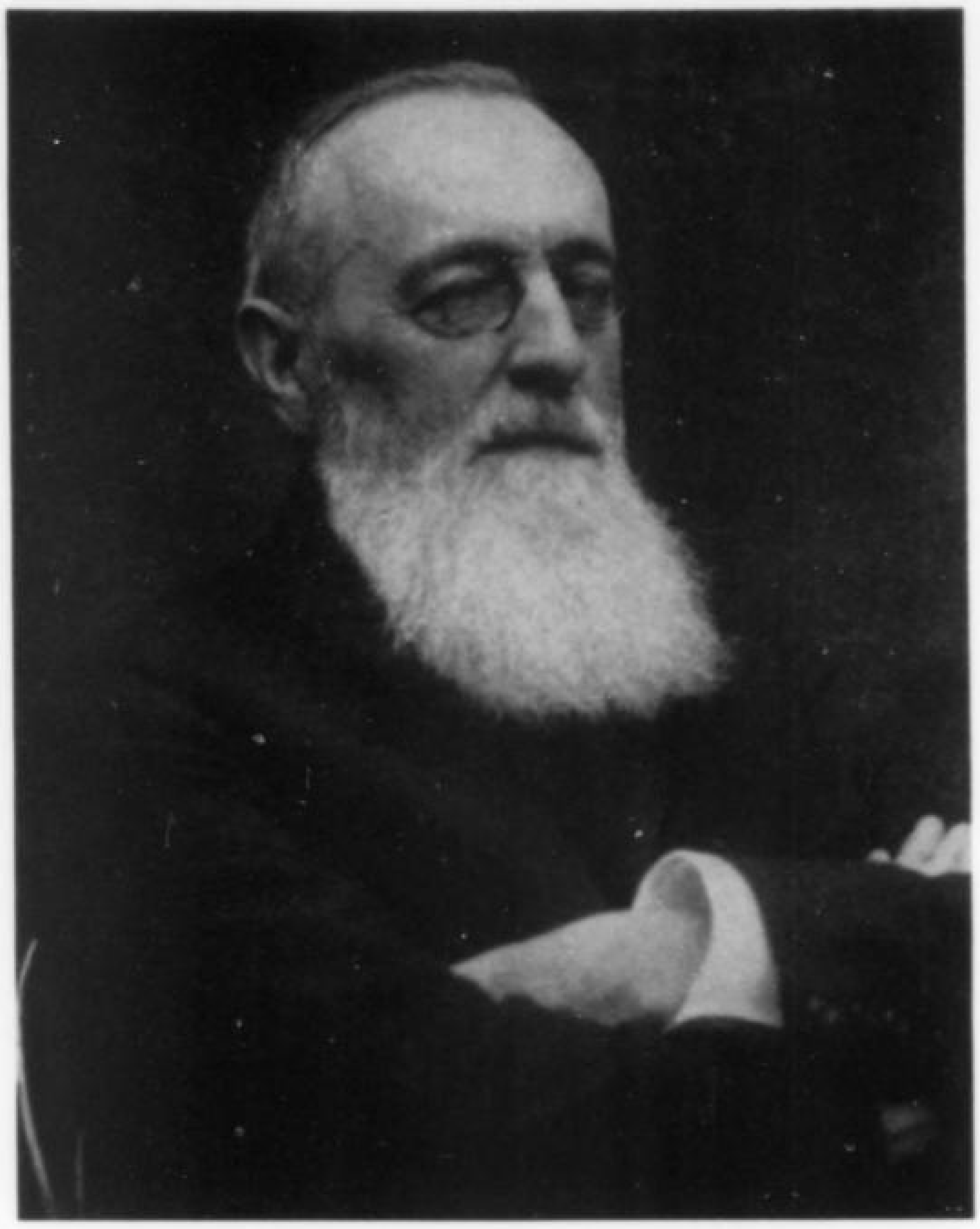


Figure 13. **Alfred Lacroix, French mineralogist and pioneering researcher on Madagascar tourmaline.**

specimens including large quantities of superb gem-quality and specimen-quality crystals were removed, some of which are the most valuable mineral specimens of any kind in the world today.

As the 20th century has progressed, tourmaline has come into its own as a popular gemstone, and has also been at last properly characterized. Its crystal structure has been determined thanks to

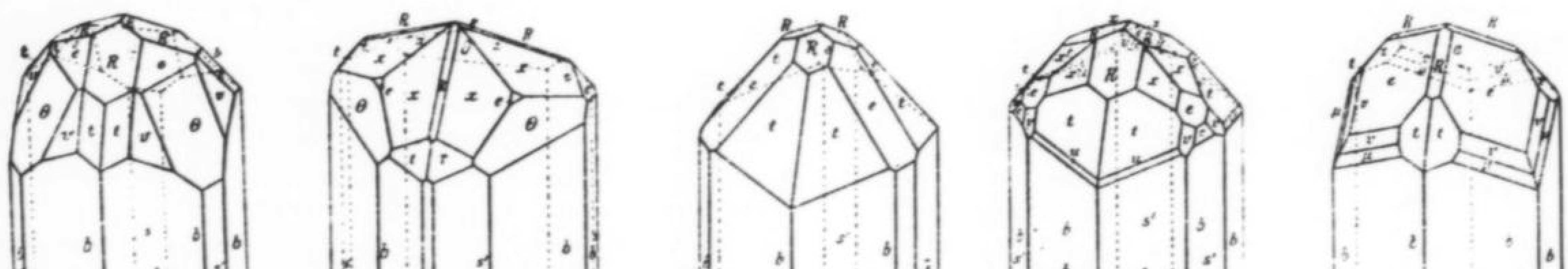


Figure 14. **Tourmaline crystals from Brazil, drawn by H. Müller in 1912.**

the development of X-ray technology, and its compositional variations refined into a number of distinct species: buergerite, chromdravite, dravite, elbaite, ferridravite, liddicoatite, schorl and uvite. The possibilities for chemical substitution in the structure allow for still more species which perhaps will be discovered in the future.

Two comprehensive surveys of the tourmaline group are to be published this year: *The Tourmaline Group* by R. V. Dietrich and *Der Turmalin* by Friedrich Benesch. These two works (to which the reader is referred for exhaustive bibliographies) complement each other ideally, and make available an immense diversity of information on this beautiful and most interesting group of minerals.

ACKNOWLEDGMENTS

Our thanks to Mokwang Doris Lima for preparing the English translation of this article, and to Johannes Keilmann for allowing simultaneous publication in the *Mineralogical Record* and in the show program for the Münchner Mineralientage. Wendell E. Wilson provided a number of additional illustrations.

the Tourmaline Group: A Résumé

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The tourmaline group of minerals contains some of the most attractive and interesting species known, differing widely in their complex compositions and occurring at a vast number of deposits worldwide. This résumé provides an overview of the systematic mineralogy of the group.*

NOMENCLATURE

The popular nomenclature for tourmaline is confusing. Along with a copy of the list published in *Dana's System of Mineralogy* (6th edition, 1892), *The Tourmaline Group* includes a list and definitions for 51 terms. Most of the terms that are still in use can be grouped into four chief categories:

1. Group one consists of the *currently acceptable names.* There are nine such terms – tourmaline for the group name and the eight accepted names for the species thus far found to occur naturally: buergerite, chromdravite, dravite, elbaite, ferridravite, liddicoatite, schorl and uvite. In light of the fact that these are the *only* currently acceptable names, everyone should diligently restrict their references to tourmaline-group minerals to these terms with or without appropriate (e.g., color) adjectives.

2. Group two, which includes such terms as "Ceylonese peridot," "Brazilian emerald" and chameleonite, is a legacy (curse!) from the gem trade. These terms should be abandoned; in fact, they should be outlawed as hoodwinking, fraudulent and deceptive!

3. Group three, which includes such terms as "tsilaisite" and "aluminobuergerite," proposed for hypothetical endmembers, is an abomination from professional mineralogists. These terms should also be abandoned. They have not been approved by the IMA Commission on New Minerals and Mineral Names because, to the present, no natural specimens have been found to have or even to approach the endmember compositions. (The Mn-bearing tourmaline from Zambia (Schmetzer and Bank, 1984) should not, in my opinion, be termed tsilaisite.) In fact, on the basis of what is now known about tourmaline group minerals, continued naming on the basis used to name endmembers, such as these, could become ridiculous – 96 to 448 endmember compositions, depending on one's viewpoint, could be so-named.[1]

4. Group four, which is made up of achroite, indigolite (or indicolite), rubellite and verdelite is also from scientists. These terms should also be abandoned although they might be retained as useful field terms if clearly redefined. One scheme, albeit poor, would be to use the terms to indicate tourmalines of appropriate colors as discerned macroscopically with *NO* species connotation. Then, for example, red tourmaline – be it elbaite, liddicoatite or dravite – could be termed rubellite if identified only by macroscopic means. It would appear to be much better, however, to abandon the terms as superfluous and just refer to such specimens as, for example, red tourmaline until they are identified as to species and then to name them appropriately as, for example, red elbaite, red liddicoatite or

*This résumé consists of synopses (including a few excerpts) of selected portions taken from *The Tourmaline Group* (Dietrich, 1985). References are kept to a minimum here in order to facilitate reading. Anyone desiring further documentation may consult the ≈1000-entry references section in the book and/or the ≈2600-entry card file bibliography from which the cited references were selected. The card file is available at the U.S. National Museum of Natural History in Washington, D.C.

[1] It would be best, in my opinion, not only to abandon these terms but also to give the corresponding natural representatives, if and when they are found, "new" names. This way, everyone would be better served because the renaming would reduce the chance for perpetuation of ambiguous perceptions.

red dravite. This latter scheme would be correct; its use would preclude the ambiguities and errors that sometimes result under current usage; and, it would also resolve problems such as the fact that there is no generic term, for, for example, black or brown tourmalines, *not* all of which are, as is often assumed, schorls and dravites, respectively.

Another aspect of tourmaline nomenclature relates to the fact that nearly all, if not all, natural tourmalines have compositions intermediate between two or more endmembers. Consequently, the question arises as to how specimens should be named. In my opinion, until a formal nomenclature scheme is codified and accepted by the IMA, it is best to name each specimen on the basis of its predominant constituent as determined chemically or by some other definitive means, and when possible to give its composition – for example:

merely

dravite

or

dravite – $(Na_{0.9}Ca_{0.08}K_{0.02})(Mg_{2.2}Fe^{+2}_{0.5}Fe^{+3}_{0.3})Al_6B_3Si_6O_{27}(O,OH)_4$

Still another aspect of nomenclature relates to my reason for italicizing the phrase "*currently acceptable names.*" The italics emphasize my belief that there are additional species of tourmaline yet to be found in nature. In fact, one of the new species predicted in the original manuscript for *The Tourmaline Group* has already been reported – the chromdravite reported by Rumantseva (1983) – and at least one other new tourmaline species is now being studied.

MORPHOLOGICAL CRYSTALLOGRAPHY

Tourmaline, which belongs to the trigonal subsystem of the hexagonal crystal system, is hemimorphic with *c* the polar axis. By definition, the positive end of the *c* axis is called the antilogous pole and the negative end, $\bar{c}$, is called the analogous pole. The identities of the poles can be established by structural analysis or etching or by determining pyroelectric or piezoelectric effects. In addition, several other features, some of which are relatively common and easily discerned, are typically, if not exclusively, associated with one end only. Two examples are: more acute (i.e., steeper) pyramidal faces are characteristic of the antilogous end (Fig. 1), and edges between $r\{10\bar{1}1\}$ terminations and $m\{10\bar{1}0\}$ prisms are parallel to (0001) nearer the antilogous end, whereas edges between $r'\{\bar{1}101\}$ terminations and *m* are at an angle to (0001) nearer the analogous end.

Three hundred twenty-nine (329) forms, of which sixteen (16) are "principal forms" in the sense of Goldschmidt (1922), have been recorded in the literature. Some individual crystals have been found to have as few as three forms and eight faces and a crystal from Ceylon (now Sri Lanka) has been reported to have 59 forms and more than 170 faces. Crystals from Yinnietharra, Western Australia, resemble isometric dodecahedrons (e.g., Bridge *et al.*, 1977); crystals from Hidrolandia, Goias State, Brazil (deCamargo and Souza, 1970) and Madagascar (Frondel *et al.*, 1966) appear, at first look, to be monoclinic.

Individual tourmaline crystals range in size from microscopic needles that comprise asbestiform tourmaline masses including some "mountain leather" and thin films that occur along, for example, mica cleavage surfaces[2] to crystals that are up to several centimeters across and approximately a meter long. Some composite masses are even larger; for example, "crude rosettes" of schorl up to about 2.2 meters in diameter are recorded from the Stewart pegmatite of San Diego County, California (Jahns and Wright, 1951).

[2] Stuker (1961) described some films from the vicinity of Brissaga, Switzerland, as "so dünn, dass sie auf dem Glimmer kaum einen Abdruck hinterlassen" – i.e., so thin that they scarcely leave an impression on the [underlying] mica.

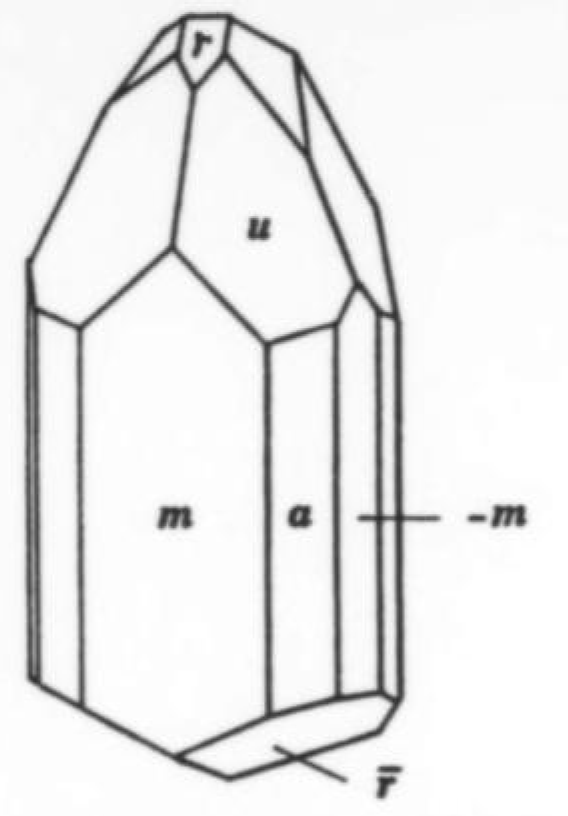


Figure 1. **Morphological expression of the antilogous (top) and analogous (bottom) ends of tourmaline crystals. Note difference in acuteness of terminations and other features mentioned in the text.**

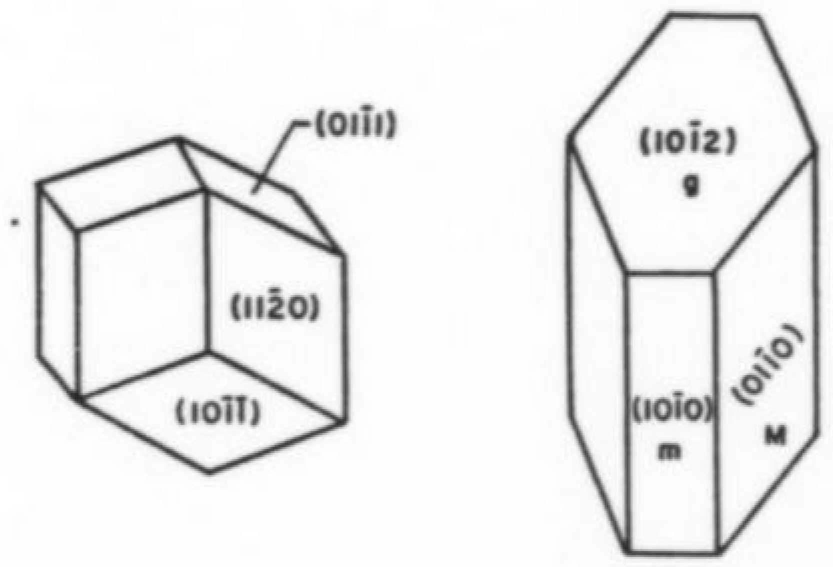


Figure 2. **A dravite crystal from Yinnietharra, Western Australia (*left*), resembling a rhombic dodecahedron, and a dravite from Hidrolandia (Goias), Brazil (*right*) of monoclinic appearance.**

In general, prismatic faces on crystals have vitreous to subadamantine lusters whereas terminations tend to have subvitreous to dull lusters. The typical grooved configuration of the prism faces on crystals having rounded triangular cross-sections perpendicular to *c* expresses trigonal prisms modified by hexagonal and/or ditrigonal prisms.

Some crystal faces, especially those that transect *c*, have sculptured and/or etched surfaces. For many of these faces it is difficult, if not impossible, to determine whether the surfaces originated as a result of growth, corrosion, or a combination of these processes.

Individual crystal habits range from equant to prismatic or even tabular. Crystal shape-to-species correlations have been made. However, most specimens upon which the correlations were based are collector's items that may not be truly representative, and there are known exceptions for all but the single locality species (i.e., the species thus far found as only one or a few specimens from only one locality). Indeed, a few investigators have directed attention to the absence of such shape (or habit)-to-species correlations. For example, Dunn *et al.* (1977) state that "Crystals of uvite do not exhibit any peculiar or diagnostic morphology which might aid in their identification." Nevertheless, it is noteworthy that among the hun-

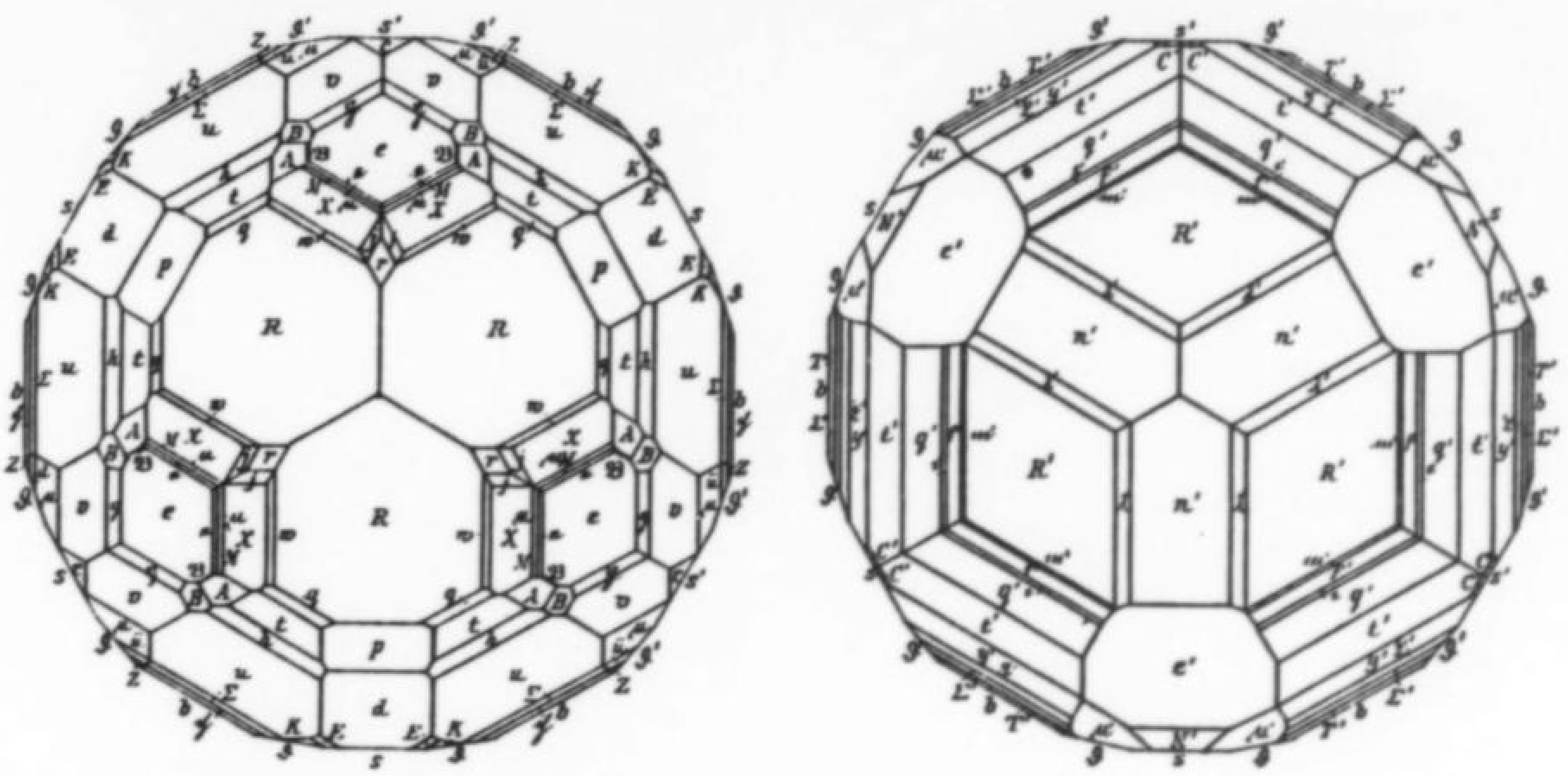


Figure 3. **Many-faced terminations on a tourmaline crystal from Ceylon (Sri Lanka) (Worobieff, 1900).**

Figure 4. **"Sculptured" surface on elbaite from San Diego County, California (13 mm across the view). Photo courtesy of E. E. Foord.**

Figure 5. **Pale gray, asbestiform tourmaline growing from a black single-crystal substrate. The view is about 4 cm across. Harvard Mineralogical Museum collection.**

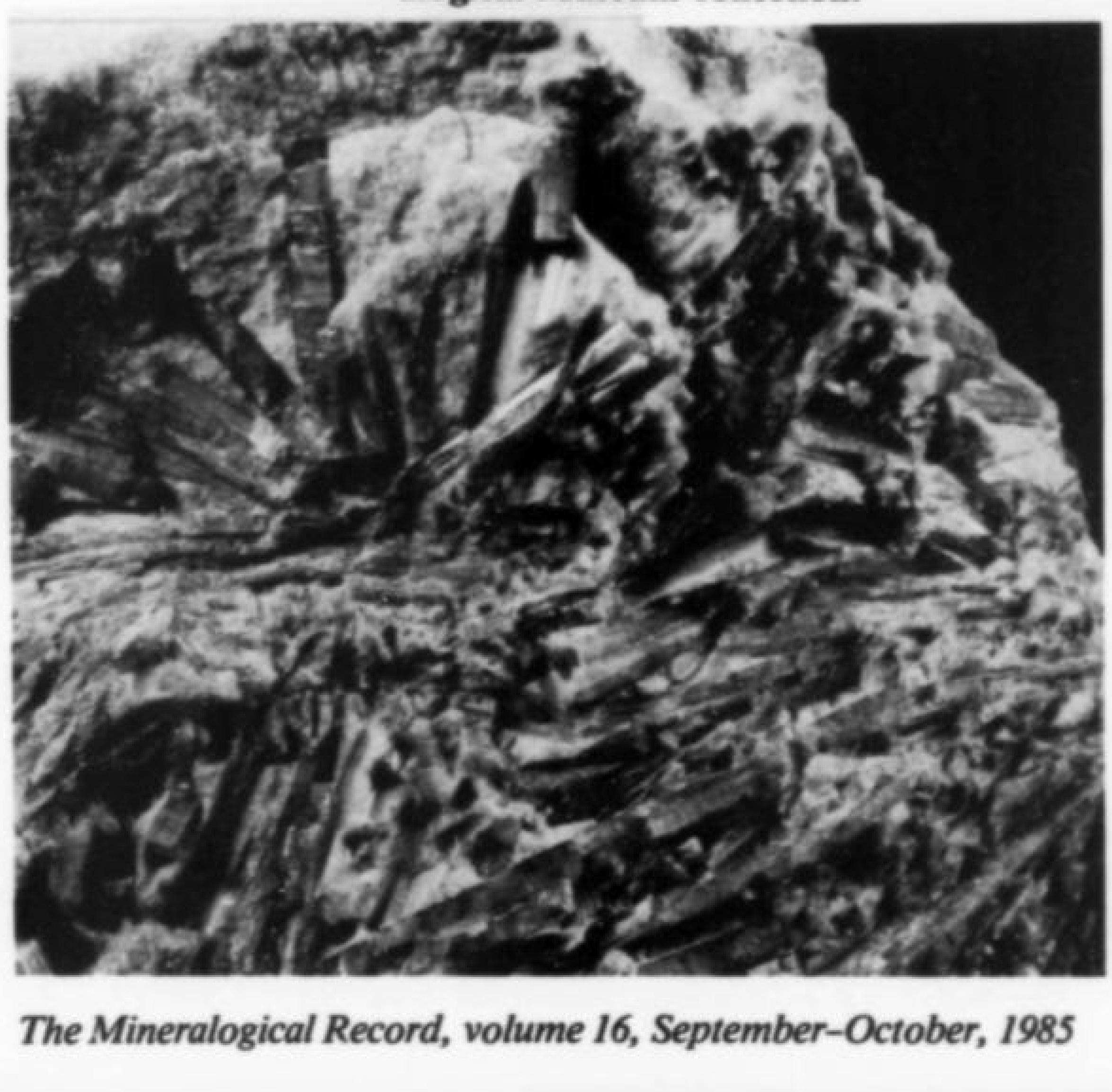


Figure 6. **Radial groups of pink elbaite imbedded in pale lavendar lepidolite from San Diego County, California. Werner Lieber photo.**

dreds of crystals I have seen, a large percentage of the elbaite, liddicoatite and schorl crystals are the just mentioned highly modified and grooved prisms whereas well over 50 percent of the dravite and uvite crystals are more nearly equant or prismatic with hexagonal cross-sections.

Much tourmaline occurs in parallel, divergent, or radial groups of crystals or as fibrous masses, some of which extend outwards

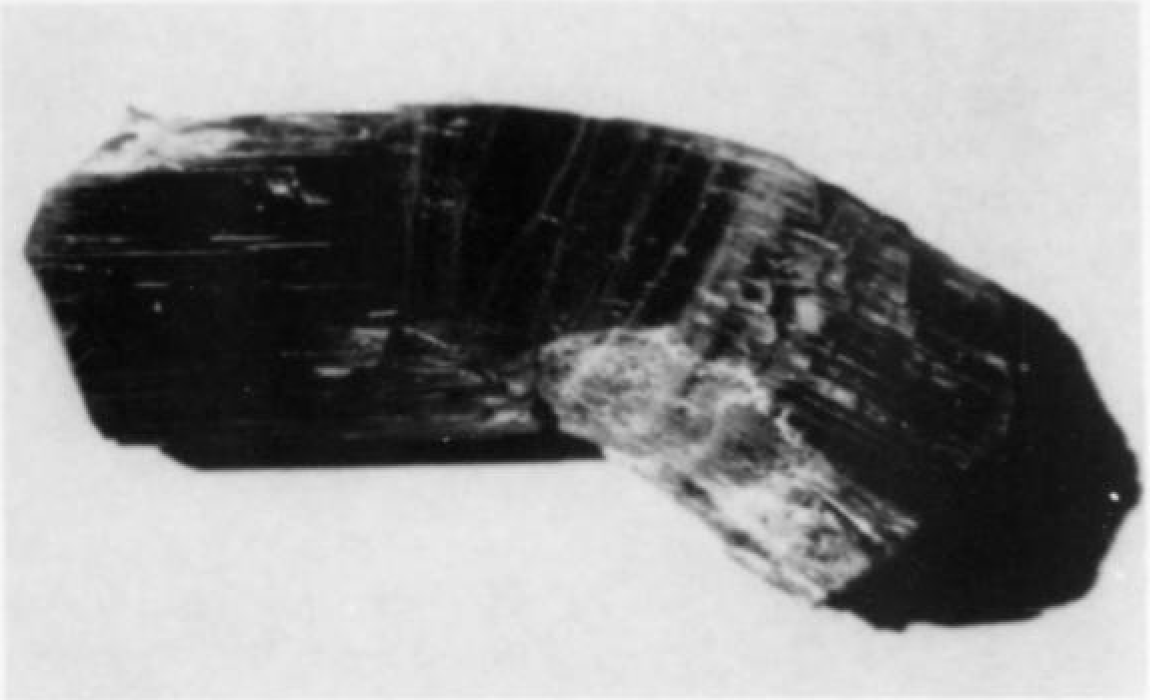


Figure 7. **"Bent" (fractured and rehealed) elbaite crystal, about 5 cm long, from San Diego County, California. Specimen and photo: E. E. Foord.**

from single crystal substrates. Groups that tend to flare or constitute "sunbursts" are also relatively common.

Bent and fractured crystals occur. Most "bent" crystals appear to have curved, but not twisted, *c* axes. In some of these crystals, the apparent bending represents closely spaced healed fractures; the "healing" material is typically fibrous tourmaline but, in some cases, it is another mineral such as quartz.

Tourmaline-bearing pockets in the pegmatites of, for example, Maine and San Diego County, California, commonly contain fragments of crystals that are separated up to several centimeters from their originally adjacent parts—they can be fit together like the pieces of jigsaw puzzles. Some pieces exhibit scratches apparently formed by natural abrasion; in fact, fragments that resembled tumbled pieces have been found in the few pockets in San Diego County. Some of the fragments exhibit post-separation overgrowths of tourmaline, especially on the antilogous ends.

Twinning is apparently rare, if indeed present, in tourmaline. That reported includes: simple twinning with twin planes $\{10\bar{1}1\}$ and $\{40\bar{4}1\}$; twinning with twin axis *c* and contact plane $\{10\bar{1}0\}$; and cruciform twinning with $\{10\bar{1}1\}$ as the twin plane.

Cleavage, although frequently said to be lacking, has been recorded for all species except ferridravite. The cleavages—parallel to $(11\bar{2}0)$, $(10\bar{1}1)$ and (0001)—are all termed indistinct (poor, very poor, difficult, etc.) except for the "distinct prismatic cleavage" reported by Donnay *et al.* (1966) for buergerite.

Fracture is usually recorded as conchoidal to uneven. Optical petrographers have long recognized a predominant fracture subparallel to {0001} as common. Fracturing around "nodules," which are prized by lapidaries because they constitute especially good gemstone material, occurs in many crystals, especially of elbaite and schorl (see photo in the article on Maine tourmaline elsewhere in this issue). Shepard (1830) described their quality as "of the finest water" and their shape as "gouttes de suif" (=drops of tallow). John Sinkankas (personal conversation, 1983) has stated that at some Brazilian deposits "miners have found long crystals of tourmaline cracked in sections that can be broken apart with the fingers and then 'peeled' like an onion to obtain the small clear nodules present in the core of each section."

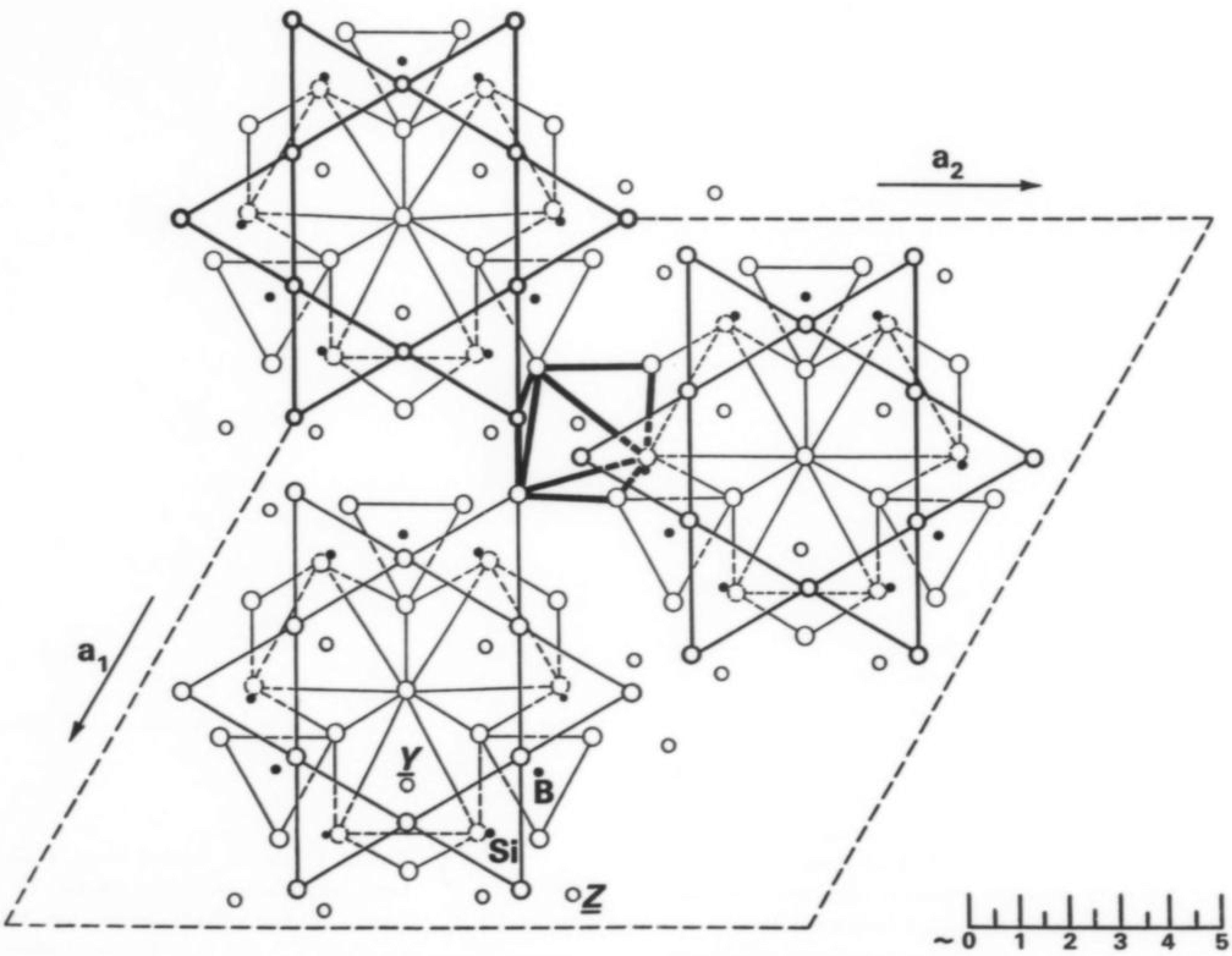


Figure 8. **Symmetry elements of the tourmaline structure and unit cell projected on (0001) showing linkage of structural "islands" (heavy tetrahedron) (modified after Barton, 1969).**

STRUCTURE

The structure[3] of tourmaline was first worked out by Ito and Sadanaga (1947) and independently by Hamburger and Buerger (1948). Their slightly different interpretations were reassessed and found to converge by Buerger *et al.* (1962). A third suggestion (see Belov and Belova, 1950) was concluded to be incorrect (Buerger *et al.*, 1962). Subsequently, several investigators have presented refined structures for different species of tourmaline and found the Buerger *et al.* model to be correct.

That structure, projected on (0001), is shown here. Each of the "islands" consists of, from top to bottom, a large cation that is along the central axis, an Si_6O_{18} ring with apices pointing downward toward the analogous pole, a layer made up of three *Y* and six *Z* octahedrons; and a layer with three BO_3 triangles. The "islands" are attached to one another by *Z* octahedra, which results in a screw-like arrangement.

Substitutions commonly occur in the large cation (*X*) site and in the *Y* and *Z* octahedrally coordinated sites (see the next section). On the other hand, there is a general lack of substitution in the Si-tetrahedral sites and the B-triangular sites. Common occupants of the *X*, *Y*, and *Z* sites are given on Table 1.

Table 1. **Common occupants of the *X*, *Y*, *Z*, and O_1 & O_3 (= OH) sites.** (Enclosing parentheses indicate that the element has been reported as a noteworthy but not predominant occupant; (□) indicates vacancy.)

X	*Y*	*Z*	*"OH"*
Na	Mg	Al	O
Ca	Fe^{+2}	Fe^{+3}	OH
(K)	Al	Cr^{+3}	F
(□)	Li	(Mg)	(Cl)
	Fe^{+3}	(V)	
	(Mn)	(etc.)	
	(etc.)		

[3] $R3m = C_{3v}^5$; $Z = 3$; $a = 15.676–16.23$ Å, $c = 6.86–7.47$ Å.

CHEMISTRY

The first known analyses of tourmaline were reported by Tobern Bergmann (1766). He reported specific percentages of "Argill," "Silex," "Calcereous-earth," and "Iron" for tourmalines from Tyrol, Ceylon (now Sri Lanka) and Brazil.

The first analysis in which boron was recorded was by Arfvedson (1818). His report is especially interesting in that the analyzed specimen was misidentified as "crystallized lepidolite"; fortunately, the correct identification as elbaite was given in an appendix by his professor, Berzelius. (This elbaite was, by the way, the one in which the element lithium was discovered.) Unfortunately, some subsequently recorded analyses of tourmaline have failed to show the presence of boron, and analysis for boron in the presence of silicon is to this day an apparent pitfall for some analysts (boron cannot be analyzed by microprobe).

Chemical compositions of the known naturally occurring tourmaline species, expressed in endmember terms, are as follows:

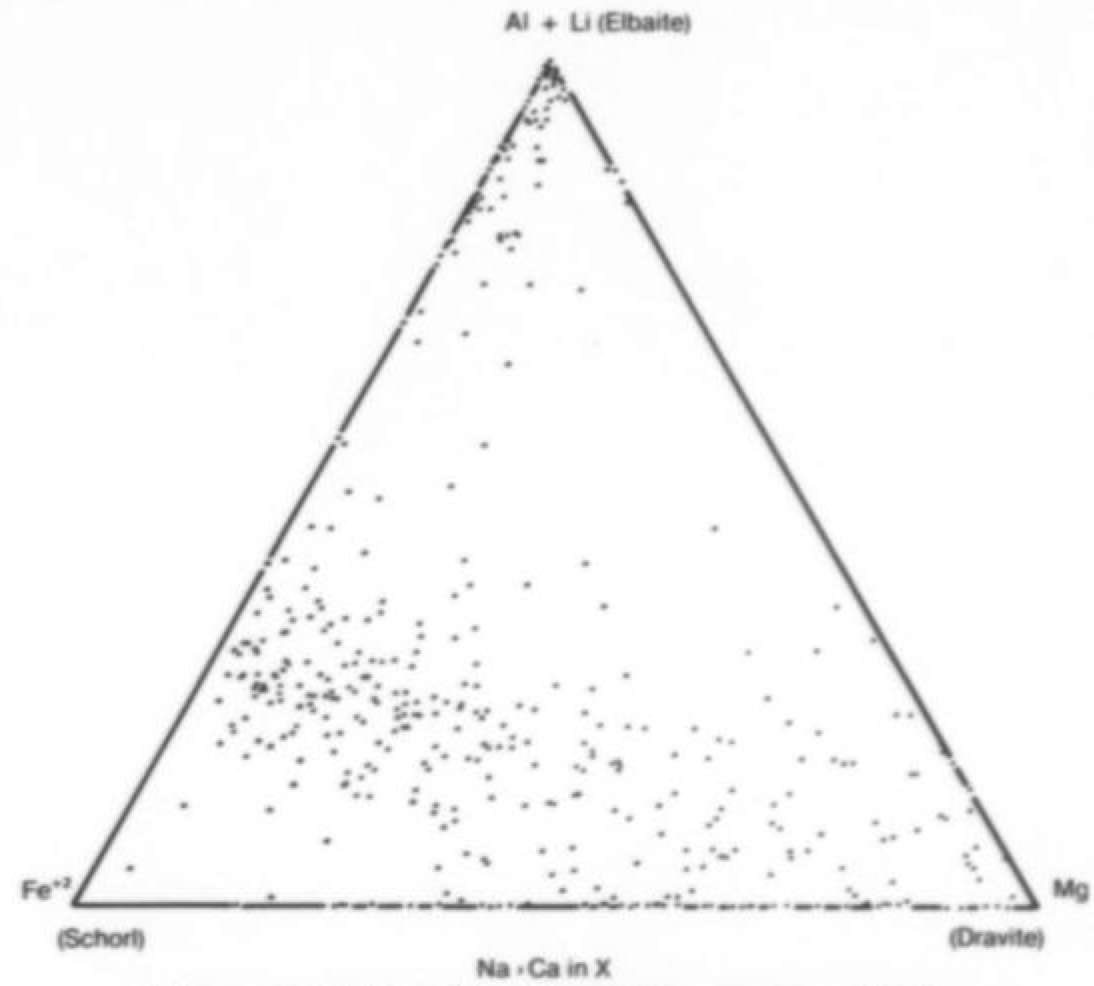


Figure 9. **Plot of high-quality analyses falling within the elbaite-schorl-dravite field.**

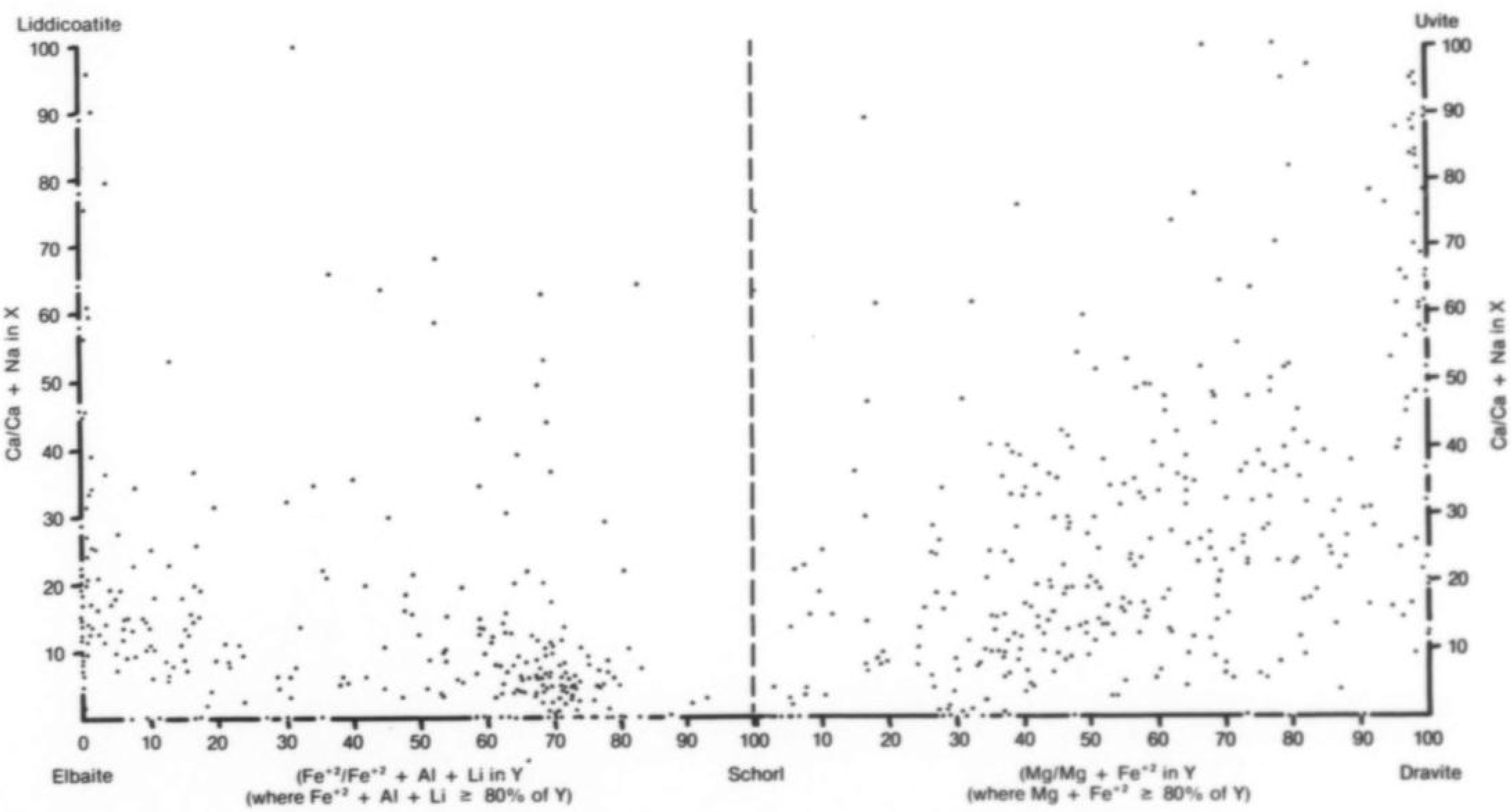


Figure 10. **Distribution of high-quality analyses in the liddicoatite-elbaite-schorl and schorl-dravite-uvite fields.**

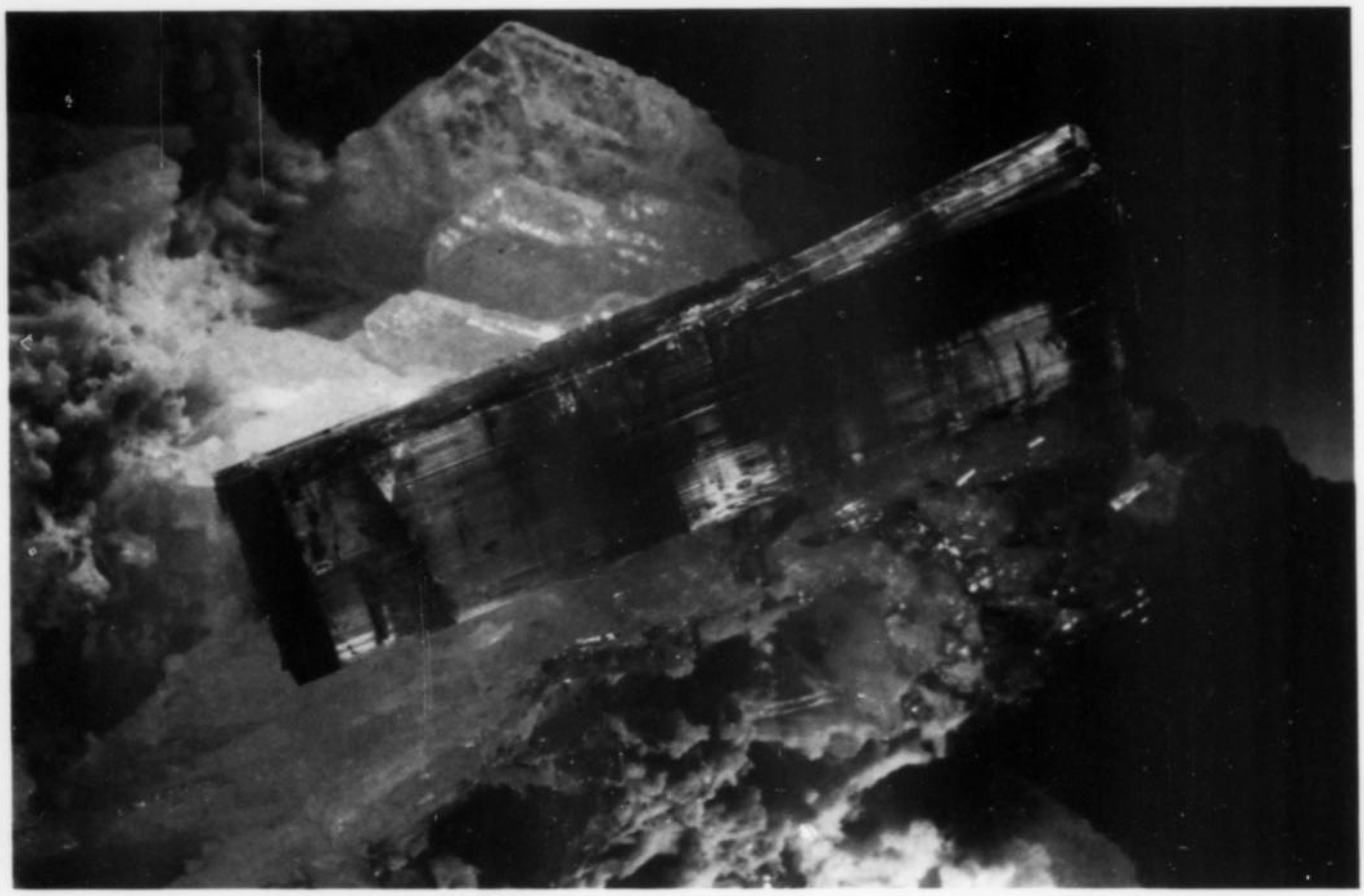
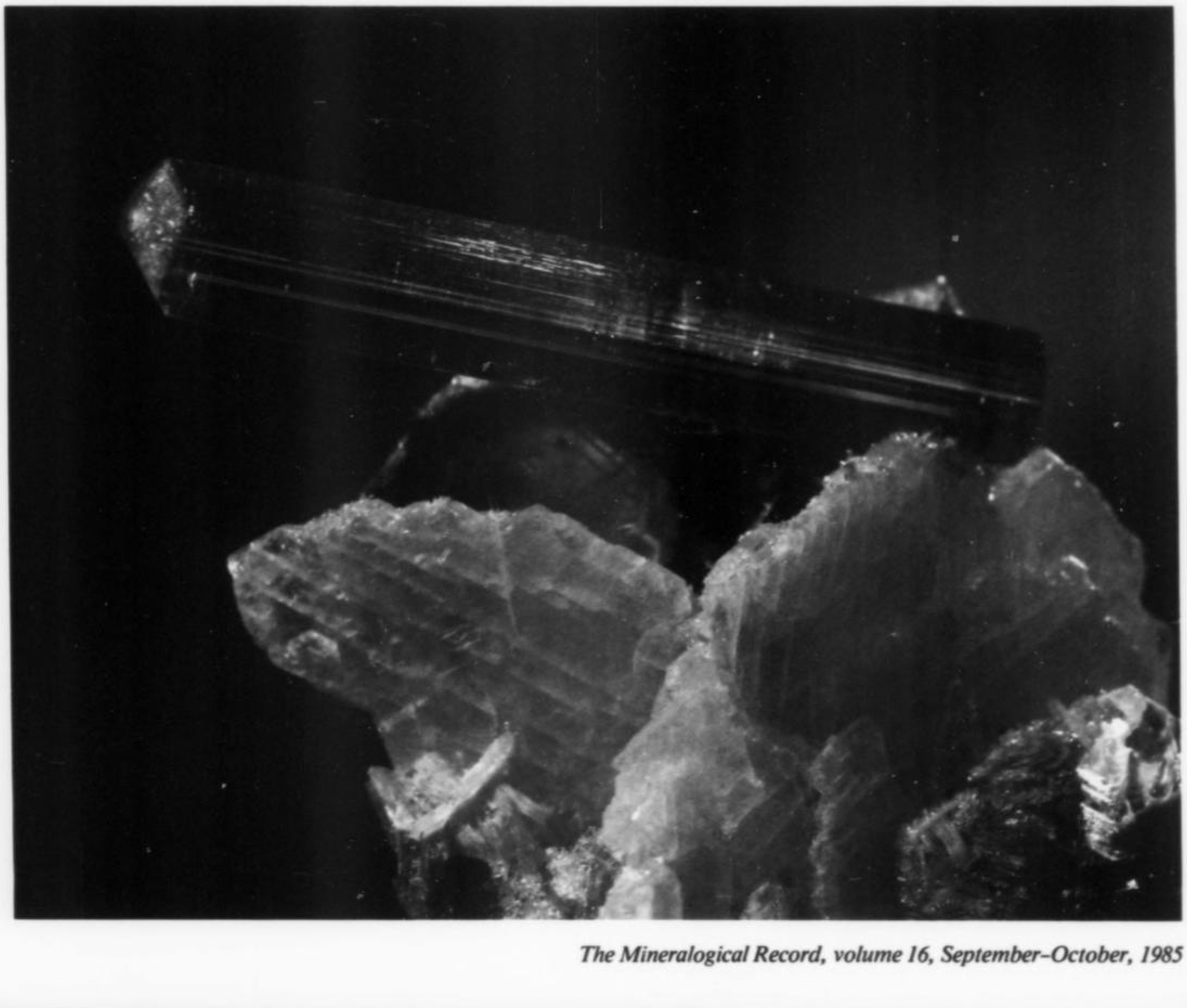


Figure 11. **A doubly terminated crystal of blue elbaite (indicolite) 6 cm long, from Minas Gerais, Brazil. Werner Lieber photo.**

Figure 12. **A doubly terminated crystal of cranberry-red elbaite (rubellite) 5 cm long, from the Jonas mine, Itatiaia, Brazil. William Larson specimen; Harold and Erica Van Pelt photo.**



	X	Y	Z	
Buergerite	Na	Fe_3^{+3}	Al_6	$B_3Si_6O_{27}O_3F$
Chromdravite	Na	Mg_3	Cr_5Fe^{+3}	$B_3Si_6O_{27}(O,OH)_3(OH,F)$
Dravite	Na	Mg_3	Al_6	$B_3Si_6O_{27}(O,OH)_3(OH,F)$
Elbaite	Na	$(Al,Li)_3$	Al_6	$B_3Si_6O_{27}(O,OH)_3(OH,F)$
Ferridravite	Na	Mg_3	Fe_6^{+3}	$B_3Si_6O_{27}(O,OH)_3(OH,F)$
Liddicoatite	Ca	$(Li,Al)_3$	Al_6	$B_3Si_6O_{27}(O,OH)_3(OH,F)$
Schorl	Na	Fe_3^{+2}	Al_6	$B_3Si_6O_{27}(O,OH)_3(OH,F)$
Uvite	Ca	Mg_3	Al_5Mg	$B_3Si_6O_{27}(O,OH)_3(OH,F)$

During the compilation of data for *The Tourmaline Group,* 788 of nearly 1000 analyses recorded in the literature were entered into a computer file for study. Partial analyses, obviously poor analyses, and analyses of apparently "oddball" (e.g., probably contaminated) tourmalines were not included. Each of the 788 analyses was converted to number of ions (i.e., subscripts in the formula) on the basis of 31 anions. After that conversion, several more analyses were deleted so far as inclusion on certain data plots; the basis for deletion was the character of the output and considerations of certain aspects of structural analyses and/or of known analytical pit-

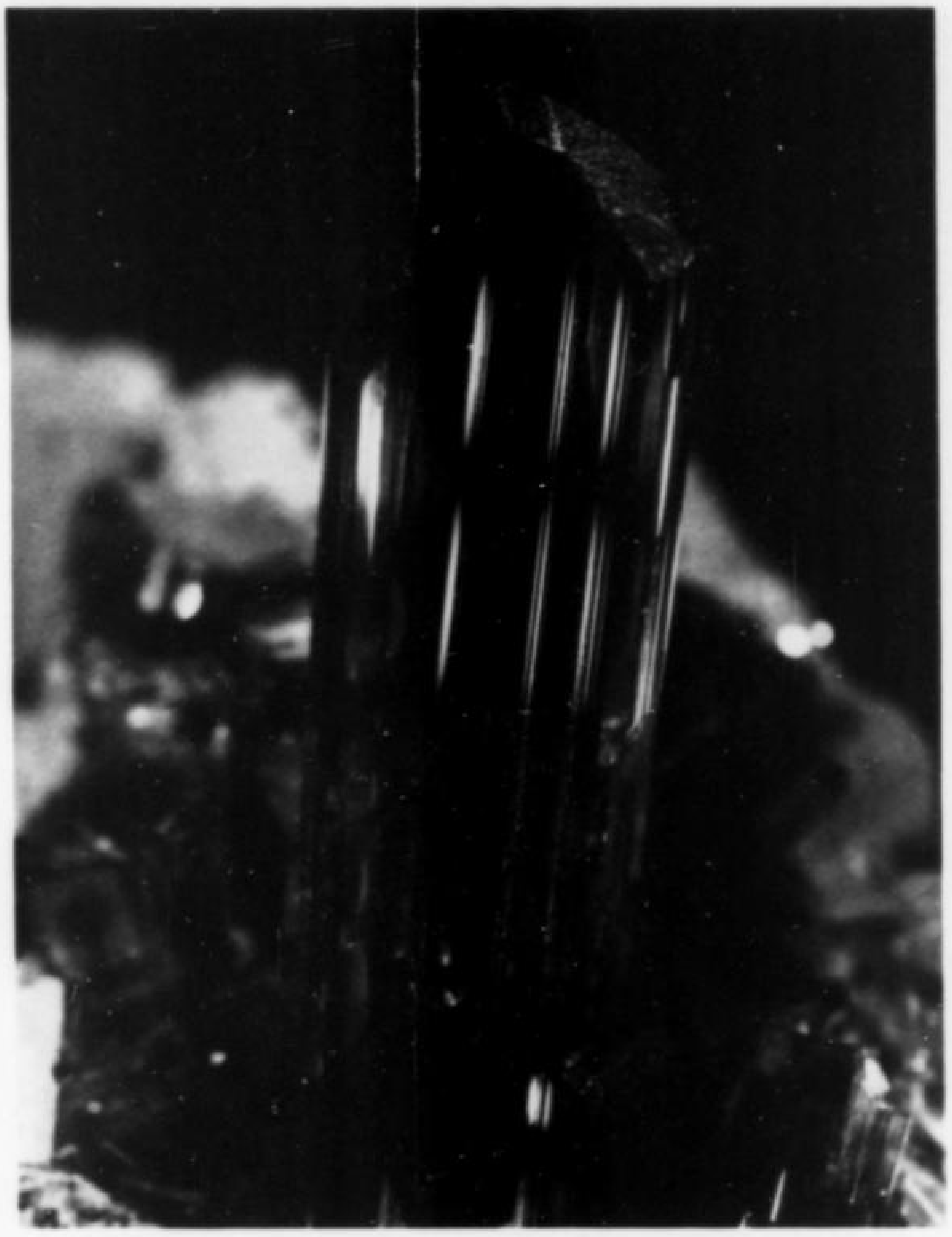


Figure 13. **Green elbaite crystal 5 cm tall from Minas Gerais, Brazil. Werner Lieber photo.**

Figure 14. **Brown dravite crystal 4 mm tall in a vug in dolomite from the Lengenbach quarry, Binntal, Switzerland. Eric Offermann photo.**

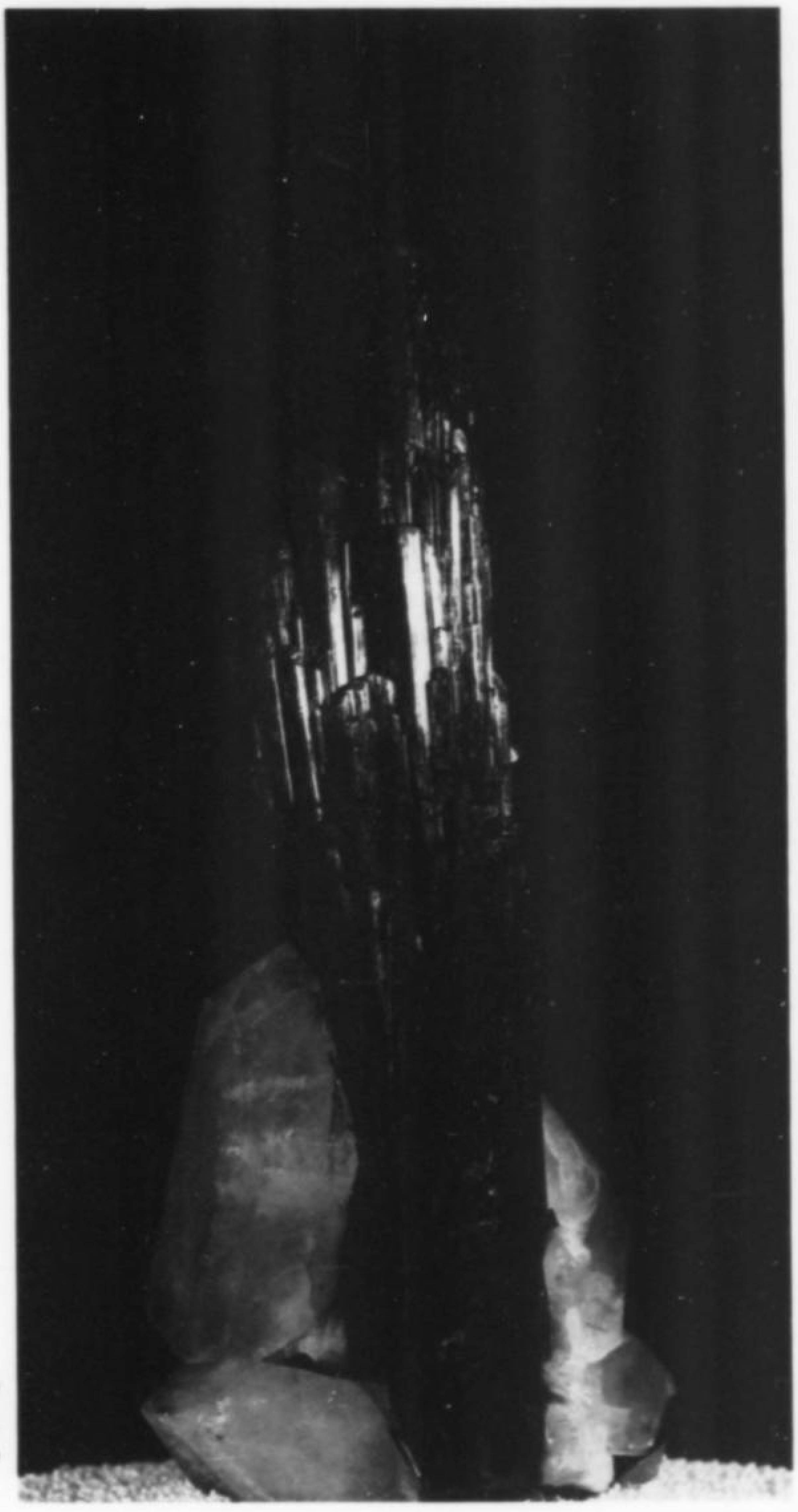


Figure 15. **"The Rocket," at 109 cm (43 inches) the largest fine crystal of tourmaline known; from the Jonas mine, Itatiaia, Brazil. Photo courtesy of Carlos Barbosa.**

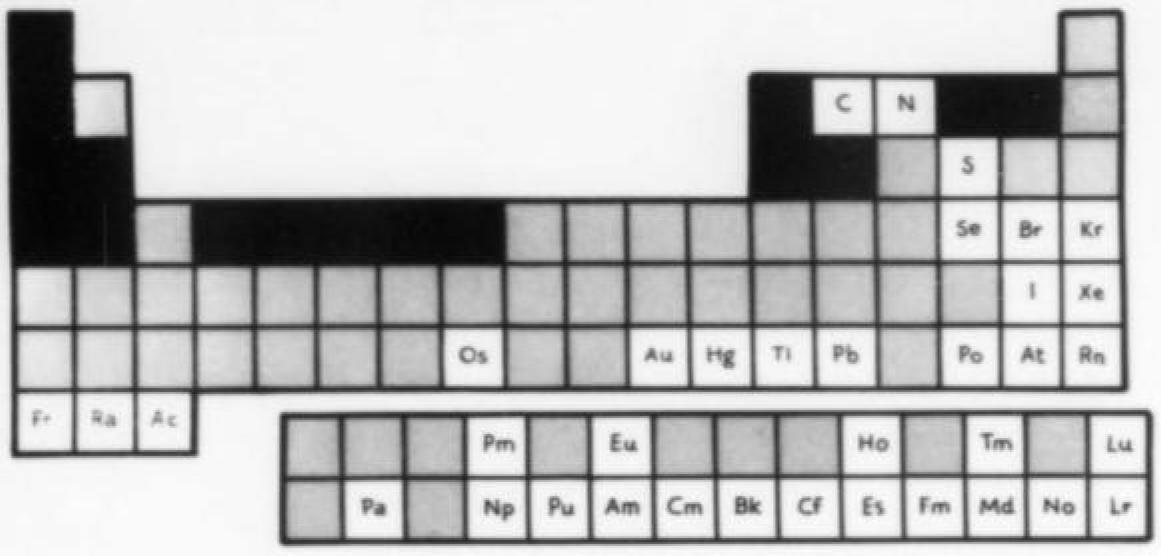


Figure 16. **Major elements (black) and trace elements (gray) recorded for tourmaline cover a significant portion of the periodic table. For references see Dietrich (1985).**

Figure 17. **"Siberite" (= red elbaite), the first color illustration of tourmaline ever published, from DeBuffon (1801).**

falls. Next, the data were correlated by programming several diverse plots, with the primary objective being the study of solid solution possibilities.

The following conclusions (none really new) are well supported by the plots:

1. Solid solution series based largely on *X*-site substitutions exist between elbaite and liddicoatite (nearly complete?), dravite and uvite (nearly complete) and schorl and the unnamed calcium analog of schorl (partial?).

2. Solid solution series based on *Y*-site substitutions exist between elbaite and schorl (nearly complete), dravite and schorl (nearly complete), elbaite and dravite (partial at best), and possibly between the Ca-analogs of these species.

3. Data are too few to tell whether there are solid solution series based largely on *Z*-site substitutions between dravite and ferridravite, dravite and chromdravite and ferridravite and chromdravite. Among other things, structural analyses showing the site location of Cr would be required before, for example, chromian dravites could be considered to be in a dravite-chromdravite series.

4. Data are also too few to put buergerite into any series although the existence of a schorl-buergerite series is suggested by several analyses.

5. Other schemes – for example, those suggested by Slivko (e.g., 1962), Foit and Rosenberg (1977), and Povondra (1981) – range from unacceptable to interesting and worthy of further consideration.

Published trace element and isotope contents were plotted for each species and also on an all-tourmaline basis. Among the several relations that became apparent are: (1) the number of elements recorded for tourmalines affords good support for Bragg's (1937) statement that "Tourmaline [is] one of nature's catchall or garbage-can minerals," and (2) as should be expected on the basis of their occurrence (typically, if not exclusively, in pegmatites), elbaites, as a group, contain more trace elements than the other species.

COLOR

The first colored picture of tourmaline in the literature is shown here. It appeared in DeBuffon's "Historie Naturelle des Mineraux" (volume 2), published in 1801.

In 1873, Hamlin stated: "The causes which give rise to the great variety of colors among tourmalines . . . form interesting themes of inquiry; and they are yet subjects of controversy among scientific men, and probably always will be." A 100-year later echo is provided in reports from two research teams: "The complex structure of tourmaline inevitably introduces a considerable speculative element into spectral interpretation" (Faye *et al.*, 1974); there have been "several mutually contradictory assignments of the main absorption bands . . . [by] different authors (and sometimes by the same authors at different times . . .)" (Smith and Strens, 1976); and "The optical absorption spectra continue to defy a satisfactory unified interpretation" (Faye *et al.*, 1974).

In any case, there are tourmalines of essentially all colors plus black, white, brown, and colorless, and many individual crystals exhibit zoning involving two or more hues and/or color saturations.

Causes suggested for the colors of tourmalines include: diverse concentrations of major elements, diverse concentrations of trace elements, combinations of concentrations of major and/or trace elements, structural imperfections (i.e., "color centers"), electron charge transfers, and combinations of these phenomena. Unfortunately, if applied generally, some of the causes suggested for individual colors are mutually exclusive and/or conflict with recorded data. However, considering the compositional variability of tourmalines, it may be that the apparent discrepancies exist only because unwarranted generalizations have been made from specific cases, i.e., some apparently identical colors may depend on different phenomena. Fortunately, the results of recent and ongoing research by Nassau (e.g., 1975) and by G. R. Rossman and S. M. Mattson (personal communications, 1984) appear to provide the bases for conclusions that will prove correct. (For a color by color summary, see Dietrich, 1985.)

Regarding color zoning, in the possibly first reference to tourmaline in the literature the tentative identification is made on the basis of tourmaline's rather common color zoning. Theophrastus, in his famous book *On Stones,* written about 315 B.C., may have been referring to tourmaline when he mentioned a stone from the Island of Cyprus that was emerald-green in color at one end and jasper-red at the other.

The color zoning in a given tourmaline may be perpendicular to *c*, parallel to *c*, parallel to pyramid faces, irregular or some combination of these arrangements. The transitions between differently colored zones range from abrupt ("razor-sharp") to gradational over a few microns to a few millimeters. Schorl, dravite and uvite, as well as elbaite and liddicoatite, commonly exhibit zoning.

A few investigators (e.g., Young *et al.*, 1969) have found different macromosaic textures to correspond to color differences in zoned crystals. Wagner *et al.* (1971) concluded that twinning, exsolution, compositional differences and deformation can be ruled out as responsible for these textural differences, and that "sudden drastic changes in conditions controlling growth are possible causes." Perhaps corroborative, Pollard and Wagner (1973) found the boundary zones to be the loci of microfaults and "lattice misorientations," and Foord and Mills (1978) found them to be manifested by biaxiality and extinction patterns resembling the grid twinning of microcline. To the present, however, no one has found any direct correlation between any particular color zoning and any of the textures, types of boundaries, biaxiality differences or extinction patterns.

Except for luminescence, other color characteristics (e.g., dichroism, chatoyancy, and the effects of heating and irradiation on color) are beyond the scope of this résumé. Luminescence is described briefly because it is frequently checked, especially by gemologists.

With one exception, no tourmaline has been recorded to fluoresce under any but shortwave ultraviolet radiation. (The exception is a pink elbaite that Bauer (1896) reported to fluoresce with a weak violet glow under X-rays; that specimen also exhibited phosphorescence after such exposure.) Under shortwave ultraviolet radiation, some tourmalines fluoresce but some do not; for those that do, the fluorescence differs from specimen to specimen both in color and intensity of color (see Table 2).

In addition, Krotova and Karasev (1953) have recorded a tourmaline, otherwise undefined, to emit light when cleaved in a vacuum – apparently a type of triboluminescence, termed by them "luminescence of mechanical breaking."

Table 2. **Tourmaline fluorescence under shortwave ultraviolet radiation.**

Specimen	*Fluorescence*	*Reference*
Dravite & Uvite (general; low in Fe)	Mustard-yellow	Dunn (1977)
Elbaite:		
pink – Newry, Maine	Chalky to strong blue	Beesley (1975)
pink – Brazil and Mozambique	None to faint chalky blue	Beesley (1975)
colorless – Afghanistan	Bright vivid violet	Dunn (1974)
pink – Afghanistan* & Newry, Maine*	Weak violet	Dunn (1974 & 1975)
green – Afghanistan* & Newry, Maine*	Faint chalky blue to weak violet	Dunn (1974 & 1975)

* Dunn (1974) reported that the depth of fluorescent color for these specimens varies indirectly with the depth of their color under white light. He also stated that the crystals with gradational zoning fluoresce more vividly than those with sharper zoning.

ELECTRICAL PROPERTIES

The fact that tourmaline exhibits readily observed electric properties has been known since at least 1703. The old name "aschentrekker" (meaning ash-drawer or ash attractant) dates back to at least that time (Schmidt, 1707). Lemery is generally credited with having first demonstrated tourmaline's pyroelectricity to the field of science in 1717. Æpinus' (e.g., 1756) work during the mid 1700s is especially noteworthy. As noted by Home (1976), Wilcke (1766) "held high hopes that . . . tourmaline would provide the key to a grand unification of the theories of heat, electricity and magnetism."

In any case, tourmaline, because of its pyroelectric properties, occupied the center of the scientific stage during much of the 18th century. In fact, a list of those who dealt with tourmaline and its pyroelectricity during that time constitutes a veritable "Who's Who" of the scientists of the period, and would include Lemery, Aepinus, Coulomb, Priestley, Benjamin Wilson and Franklin.

Jacques and Pierre Curie first reported piezoelectricity in 1880. Their primary example was tourmaline.

Both the pyroelectric and piezoelectric properties depend upon the fact that tourmaline is hemimorphic – i.e., it has only a single axis of symmetry and no center of symmetry. The effects are: During heating or tension (decompression) along *c*, the analogous end of a tourmaline crystal becomes charged positively while the antilogous end becomes charged negatively; and, during cooling or compression along *c*, the reverse effects develop. Furthermore, when an electric field is applied along *c*, heating or cooling and the development of appropriate stresses occur; these phenomena are termed converse pyroelectricity and converse piezoelectricity.

Five simple procedures have been outlined in the literature for testing or demonstrating the presence or absence of pyroelectric effects. One of these procedures, which is especially easy to follow, is attributed to Kundt (1883):

PROCEDURE

Heat the crystal to about 200° C;

Pass the heated crystal through a flame (to remove surface charge);

Shake a mixture of powdered sulfur and red lead, preferably through a brass sieve, onto the cooling crystal.

RESULT

As the crystal cools, the red lead is attracted to the negatively charged (analogous) end and the yellow sulfur is attracted to the positively charged (antilogous) end.

CAUTIONS

(1) Do not use schorl for such a demonstration – iron-rich tourmalines exhibit only weak, in some cases hardly detectable, electric effects. (2) Do not use a choice crystal – it might contain fluid inclusions that would expand and fracture the crystal.

To the present, the pyroelectric effect has found little use, whereas the piezoelectric effect (actually the converse piezoelectric effect) has found an ever-increasing number of real and suggested potential applications.

USES

Tourmaline has been used, or suggested for use, as a standard test material, as a component of several scientific and industrial instruments, as a gemstone and in the decorative arts, and for several other miscellaneous purposes.

As a standard test material tourmaline has been used because its physical properties are adaptable to (for example) calibrating pressure gauges, and because its chemical properties are such that it can (for example) serve as an "inert" boron-containing control in solubility tests involving such materials as boron-containing fertilizers.

As a component of scientific and industrial instruments, tourmaline found early use, in the 1820s, in tourmaline tongs and, since the late 1910s, it has been used or suggested for use in all sorts of devices, most of which take advantage of the converse piezoelectric effect. Examples of the latter include instruments to detect underwater obstructions (including submarines), depth-sounding apparatuses, transducers to detect and measure pressure differences produced by explosions (explosions ranging from nuclear blasts to the "firing" in internal combustion engines), motors for converting electrical into mechanical energy, generators for the opposite conversion, capacitors for storing electrical energy, frequency control devices, and spark generators. (Along this line, the late mineral dealer Martin Ehrmann was involved in some cloak-and-dagger work during World War II because of tourmaline. As a member of the U.S. Intelligence Service, he went "into German-occupied France . . . [to] bring out several tons of Madagascar tourmaline urgently needed for piezoelectric plates for making pressure gauges" (Switzer, 1974).)

Figure 18. **Elbaite crystal 9 cm tall from the Stewart mine, San Diego County, California, showing color zoning parallel to *c*. Werner Lieber photo.**

As a gemstone and in the decorative arts, tourmaline has probably been used since at least the early days of the Roman Empire. This conjecture is based on tourmaline's association with other gems and decorative stones in several of the deposits in the Orient that are known to have been in production at that time. In any case, it is known for certain that tourmaline has been used for adornment and small carvings for more than the last two centuries (see, for example, Brückman, 1773).

Today, tourmaline is the most popular of all colored gemstones, and currently its annual sales run into millions of dollars. Tourmaline's chief appeal is its availability of stones of nearly all readily distinguishable color hues and saturations and also as parti-colored stones and attractive "cat's eyes."

Most of the tourmaline used in gems is elbaite, but gem-quality liddicoatite, dravite, uvite and schorl have also been used.

A few tourmaline gemstones have gained special attention. Noteworthy are: the 255-carat red pendant shaped roughly like a bunch of grapes that was given to Catherine II of Russia by Gustav III of Sweden in 1777 (see, for example, Donova, 1972); a heart-shaped, 50.59-carat, blue-green stone fashioned from Mount Mica, Maine, tourmaline (Graves, 1967); and the 25-carat Rozek tourmaline also cut from a Mount Mica tourmaline. So far as I have been able to determine, the largest cut and faceted tourmaline is a 509-carat, "highly flawed," pink stone fashioned from a crystal from the Tourmaline Queen mine of San Diego, California (Sinkankas, 1976).

There are also some well-known tourmaline necklaces. Probably the most famous is the Hamlin necklace, made from Mount Mica tourmalines in the late 1800s – it is now in the Harvard Museum. Another especially noteworthy necklace is the State of Maine necklace, which consists of stones from the 1972 find at Newry.

In addition, both solid color and multicolored tourmaline crystals have been carved. Carvings with the shapes of leaves, butterflies and bunches of grapes are especially common. A few of the carvings have been fashioned rather interestingly from the black-topped ("mohrenkopf") crystals so the black portions have become, for example, the hair on the heads of miniature busts. Multicolored tourmaline crystals are sometimes carved into small birds (e.g., hummingbirds, parrots and birds of paradise) or animals (e.g., fish, porpoises and seals). A few of the figurines have been carved from single crystals; others are composites.

Collection specimens are well included in this decorative use category. Tourmaline mineral specimens have been considered to be a valuable commodity since at least the late 1700s. For example, Greene and Burke (1978) found that "In 1780, Archduchess Marie-Anne of Austria, who had formed an extensive cabinet, presented several beautiful specimens of the tourmaline of Tyrol to Duke Charles of Lorraine to enrich his collections." Today, several tourmaline specimens are widely known, and a few have been given names. Examples of the latter are: the *Jolly Green Giant* and the *Cloven Hoof* from Newry, Maine; *The Candelabra* and *Crowning*

Figure 19. **Crystal slab cut parallel to *c* showing color zoning; 7 cm across, from Brazil. B. Wöhrmann collection, photo by Karl Hartmann.**

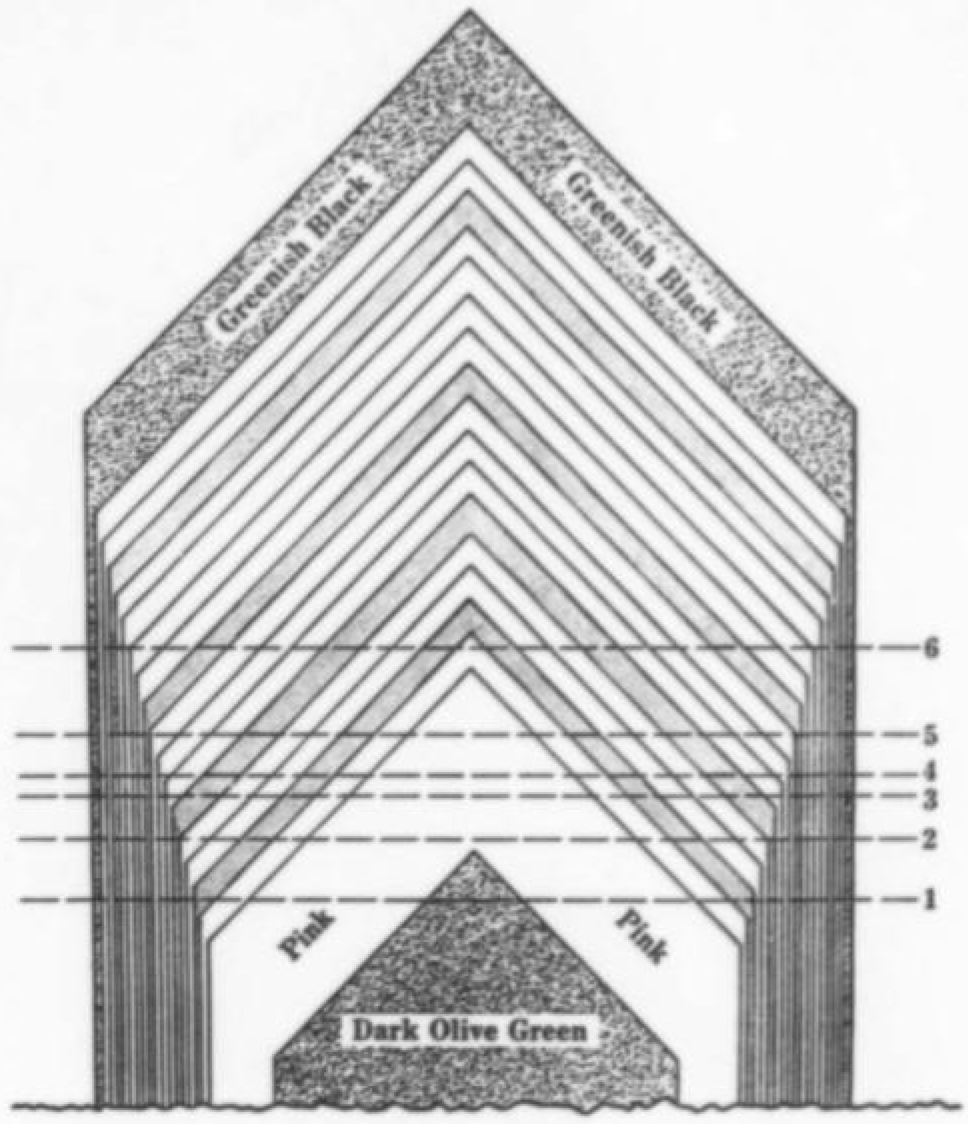


Figure 20. **Diagram illustrating the way crystal slabs cut parallel to *c* intersect zoning parallel to the prism face on liddicoatite from Anjanabonoina, Madagascar (redrawn from Althaus, 1979). (See Fig. 12, p. 338.)**

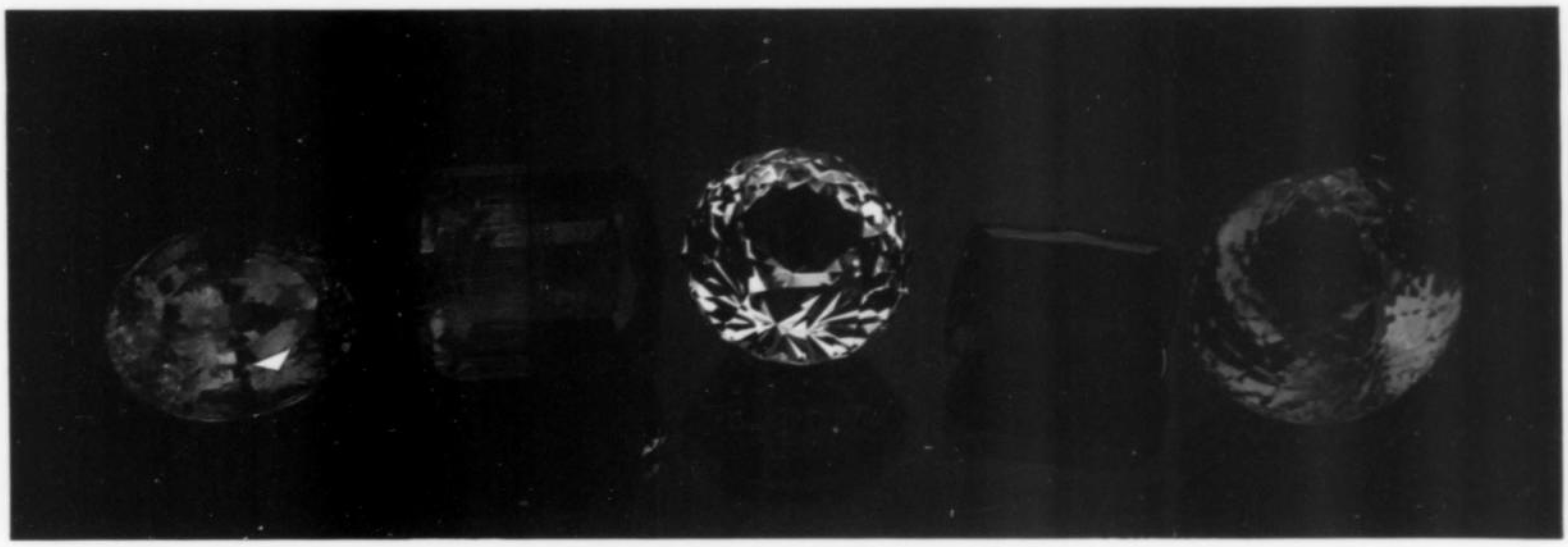


Figure 21. **Faceted elbaite from the Smithsonian collection. Photo by Dane Penland.**

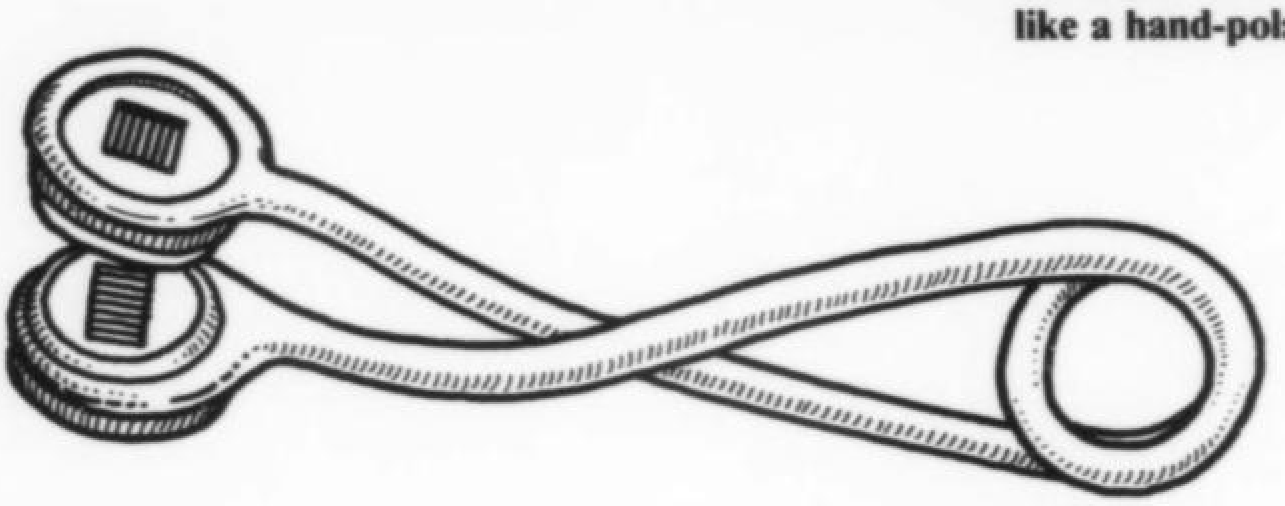
Glory from the Tourmaline Queen mine in San Diego County, California; the *Steamboat* from the Tourmaline King mine in San Diego County, California; and *Flor de Liz, Foguete* ("The Rocket"), and *Joninha* from the Jonas mine, Itatiaia, Minas Gerais, Brazil. (Richard V. Gaines (personal communication, 1984) has said that the "Joninha" specimen is perhaps the one most valuable mineral specimen in the world.)

The miscellaneous uses and suggested potential uses for tourmaline include: for the manufacture of Al_2O_3, borax, and boric acid; as the source of H_3BO_3 for the manufacture of ampule glass; as a component of certain specialty concretes for nuclear (neutron) reactor shields; as a flux for welding and in blast furnace production of low-sulfur pig-iron; as a track detector for differentiating heavier ions and energies; and as a thermal dosimeter to measure the intensity of radium and/or neutron irradiation.

OCCURRENCE AND GENESIS

The several uses and widespread occurrence of tourmaline-group minerals have prompted investigations dealing with its occurrences and geneses (e.g., Henry and Guidotti, 1985; and Jolliff *et al.*, 1985) and also with its possible synthesis (e.g., Voskresenskaya and Ivanova, 1975; and Werding and Schreyer, 1977). These subjects

Figure 22. **Tourmaline tongs (redrawn from Haidinger, 1845). A sample is placed between the heads and the device is held up to the light like a hand-polariscope.**



are, however, beyond the scope of this résumé. A few of the more famous localities are described in this special issue of *The Mineralogical Record.* Diverse kinds of occurrences and geneses are treated at length and a fairly comprehensive list of localities is given by Dietrich (1985). Suffice it to say here that one or another of the tourmaline group minerals occurs in essentially all kinds of rocks, and that for other than the apparently rare species: *schorl* is a common accessory mineral in some granites, griesens, gneisses and schists, veins and pegmatites; *dravite* and *uvite* are most common in metamorphosed carbonate rocks, especially those that have undergone metasomatism; and *elbaite* and *liddicoatite* are nearly restricted to complex (typically zoned), Li-rich pegmatites.

With regard to synthesis, tourmaline has been synthesized in a few laboratories. To the present, however, tourmaline has apparently not been synthesized on a commercial scale.

ACKNOWLEDGMENTS

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REFERENCES

ÆPINUS, F. U. T. (1756) Mémoire concernant quelque nouvelles expériences électriques remarquables. *Histoire de l'Académie Royale des Sciences et Belles Lettres, Berlin,* **12**, 101–121.

ALTHAUS, E. (1979) Wassermelonen und Mohrenköpfe. *Lapis,* **4**, 8–11.

ARFVEDSON, A. (1818) Undersökning af nagra vid Utö jernmalmsbrott förekommande fossilier och af ett deri funnet eldfast alkali. *Afhandlungen i Fysik, Kemi och Mineralogi,* **6**, 145 (ns).[4]

BARTON, R., Jr. (1969) Refinement of the crystal structure of buergerite and the absolute orientation of tourmalines. *Acta Crystallographica,* **B25**, 1524–1533.

BAUER, M. H. (1896) *Precious Stones* (1904 translation by L. J. Spencer). C. E. Tuttle, Rutland, Vermont, 627 p.

BEESLEY, C. R. (1975) Dunton mine tourmaline: an analysis. *Gems & Gemology,* **15**, 19–24.

BELOV, N. V., and BELOVA, E. N. (1950) Structure of tourmaline. *Doklady Akademii Nauk SSSR,* **75**, 807–810.

BERGMANN, T. (1766) Commentarius de indole Electrica Turmalini. *Philosophical Transactions of the Royal Society of London,* **56**, 236–243.

BRAGG, W. L. (1937) *Atomic Structure of Minerals.* Cornell University Press, Ithaca, New York, 292 p.

BRIDGE, P. J., DANIELS, J. L., and PRYCE, M. W. (1977) The dravite crystal bonanza of Yinnietharra, Western Australia. *Mineralogical Record,* **8**, 109–110.

BRÜCKMAN, V. F. B. (1773) *Abhandlung von Edelsteinen.* Mansenhaus, Braunschweig, Germany, 256 p.

BUERGER, M. J., BURNHAM, C. W., and PEACOR, D. R. (1962) Assessment of the several structures proposed for tourmaline. *Acta Crystallographica,* **15**, 583–590.

CURIE, J., and CURIE, P. (1880) Développment par compression de l'ectricité polaire dans les cristaux hémièdres à faces inclinées. *Bulletin de la Soçiété Mineralogie de France,* **3**, 90.

DeBUFFON, G. L. L. (1801) *Histoire Naturelle des Minéraux.* Vol. 2, Deterville, Paris, 327 p.

deCAMARGO, W. G. R., and SOUZA, I. M. (1970) Nôvo Hábito da Turmalina. *Academia Brasileira de Ciencais* (Rio de Janeiro), *Anais,* **42**, 219–222.

DIETRICH, R. V. (1985) *The Tourmaline Group.* Van Nostrand Reinhold, New York, 296 p.

DONNAY, G., INGAMELLS, C. O., and MASON, B. (1966) Buergerite, a new species of tourmaline. *American Mineralogist,* **51**, 198–199.

DONOVA, K. V. (1972) Sokrovishcha Almaznogo fonda SSSR (kamalog vystavki). *Isobrazitelbnoe Iskysstvi,* 55 p.

DUNN, P. J. (1974) Gem spodumene and achroite tourmaline from Afghanistan. *Journal of Gemmology,* **14**, 170–174.

DUNN, P. J. (1975) Elbaite from Newry, Maine. *Mineralogical Record,* **6**, 22–25.

[4] (ns) = not seen by the writer.

DUNN, P. J. (1977) Chromium in dravite. *Mineralogical Magazine,* **41**, 408–410.

DUNN, P. J., APPLEMAN, D., NELEN, J. A., and NORBERG, J. (1977) Uvite, a new (old) common member of the tourmaline group and its implications for collectors. *Mineralogical Record,* **8**, 100–108.

FAYE, G. H., MANNING, P. G., and GOSSELIN, J. R. (1974) The optical absorption spectra of tourmaline; importance of charge-transfer processes. *Canadian Mineralogist,* **12**, 270–380.

FOIT, F. F. Jr., and ROSENBERG, P. E. (1977) Coupled substitutions in the tourmaline group. *Contributions to Mineralogy and Petrology,* **62**, 109–127.

FOORD, E. E., and MILLS, B. A. (1978) Biaxiality in "isometric" and "dimetric" crystals. *American Mineralogist,* **63**, 316–325.

FRONDEL, C., BIEDL, A., and ITO, J. (1966) New type of ferric iron tourmaline. *American Mineralogist,* **51**, 1501–1505.

GOLDSCHMIDT, V. (1922) *Atlas der Kristallformen.* Carl Winters Universitätsbuchhandlung, Heidelberg, Germany, **IX**, 16–36.

GRAVES, S. G. (1967) A tourmaline bonanza at old Mt. Mica, Maine location. *Lapidary Journal,* **21**, 10, 12–13, 16–17.

GREENE, J. C., and BURKE, J. G. (1978) The science of minerals in the Age of Jefferson. *Transactions, American Philosophical Society,* **68** (4), 113 p.

HAIDINGER, W. (1845) Über den Pleochroismus der Krystalle. *Abhandlungen, Gesellschaft der Wissenschaften* (Prag), **3**, 7.

HAMBURGER, G. E., and BUERGER, M. J. (1948) The structure of tourmaline. *American Mineralogist,* **33**, 532–540.

HAMLIN, A. C. (1873) *The Tourmaline.* J. R. Osgood, Boston, 107 p.

HENRY, D. J., and GUIDOTTI, C. V. (1985) Tourmaline as a petrogenetic indicator mineral: an example from the staurolite-grade metapelites of NW Maine. *American Mineralogist,* **70**, 1–15.

HOME, R. W. (1976) Aepinus, the tourmaline crystal, and the theory of electricity and magnetism. *Isis,* **67**, 21–30.

ITO, T., and SADANAGA, R. (1947) A Fourier analysis of the structure of tourmaline. *Acta Crystallographica,* **4**, 385–390.

JAHNS, R. H., and WRIGHT, L. A. (1951) Gem and lithium-bearing pegmatites of the Pala district, San Diego County, California. *California Department of Natural Resources,* Special Report 7-A, 72 p.

JOLLIFF, B. L., PAPIKE, J. G., SHEARER, C. K., and LAUL, J. C. (1985) Tourmaline as a recorder of pegmatite evolution: Bob Ingersoll pegmatite, Black Hills, South Dakota. Manuscript submitted to *American Mineralogist.*

KROTOVA, N. A., and KARASEV, V. V. (1953) Investigation of electron emission upon cleavage of solids in vacuum. *Doklady Akademii Nauk SSSR,* **92**, 607–610.

KUNDT, A. (1883) Ueber eine einfache Methode zur Untersuchung der Thermo-, Actino- un Piëzoëlektricität der Krystalle. *Weidmann Annalen der Physik und Chemie,* **20**, 592–601.

LEMERY, L. (1717) Diverses observations de physique générale. *Histoire de l'Academie Royale des Sciences* (Paris), **7** (ns).

NASSAU, K. (1975) Gamma ray irradiation induced changes in the color of tourmalines. *American Mineralogist,* **60**, 710–713.

NEIVA, A. M. R. (1974) Geochemistry of tourmaline (schorlite) from granites, aplites and pegmatites from northern Portugal. *Geochimica Cosmochimica Acta,* **38**, 1307–1317.

POLLARD, C. Jr., and WAGNER, C. (1973) Strains associated with chemical boundaries in a sector-zoned elbaite tourmaline crystal (Abstract). *Southeastern Section, 22nd Annual Meeting, Geological Society of America, Abstracts,* **5** (5), 426.

POVONDRA, P. (1981) The crystal chemistry of tourmalines of the schorl-dravite series. *Acta Universitatis Carolinae, Geologica,* **3**, 223–264.

RUMANTSEVA, E. V. (1983) Chromdravite, a new mineral. *Zapiski Veseoyuznogo Mineralogischeskogo Obshchestva,* **112**, 222–226.

SCHMIDT, J. G. (1707) *Curiöse Speculationen bei schlaflosen Nächten.* Leipzig and Chemnitz. (This item was published under the pen-name "Immer Gern Speculirt.")

SHEPARD, C. U. (1830) Mineralogical Journey in the northern parts of New England. *American Journal of Science,* **18**, 289–303.

SINKANKAS, J. (1976) *Gemstones of North America.* Van Nostrand-Reinhold, New York, **2**, 494 p.

SLIVKO, M. M. (1962) Chemical composition and isomorphic replacement in tourmalines. *Mineralogicheskii Sbornik, L'vovskii Gosodarstuennyi Universitet,* **16**, 113–129.

SCHMETZER, K., and BANK, H. (1984) Crystal chemistry of tsilaisite (manganese tourmaline) from Zambia. *Neues Jahrbuch für Mineralogie (Mh.),* **1984**, 61–69.

SMITH, G., and STRENS, R. G. J. (1976) Intervalence-transfer absorption in some silicate, oxide and phosphate minerals *in* Strens, R. G. J., ed., *The Physics and Chemistry of Minerals.* Wiley, New York, 583–612.

STUKER, P. (1961) Feldergeteilter Turmalin in Pegmatit von Brissago. *Schweizerische Mineralogische und Petrographische, Mitteilungen,* **41**, 489–492.

SWITZER, G. S. (1974) Memorial of Martin L. Ehrmann, August 9, 1903 – May 18, 1972. *American Mineralogist,* **59**, 414–415.

THEOPHRASTUS (~315 B.C.) περι λιθων. [See, for example, Caley, E. R., and Richards, J. F. C., *Theophrastus On Stones.* Ohio State University Press, Columbus, Ohio, 1956.]

VINOKUROV, V. M., and ZARIPOV, M. M. (1959) Magnetic properties of tourmaline. *Kristallografiya,* **4**, 873–877.

von WOROBIEFF, W. (1900) Krystallographische Studien über Turmalin von Ceylon und einigen anderen Vorkommen. *Zeitschrift für Kristallographie und Mineralogie,* **33**, 263–454.

VOSKRESENSKAYA, I. E., and IVANOVA, T. N. (1975) [Study of tourmalines obtained by synthesis.] *Akademiya Nauk S.S.S.R. Mineralogicheskii Muzei,* **24**, 20–30.

WAGNER, C. E., POLLARD, C. Jr., YOUNG, R. A., and DONNAY, G. (1971) Texture variants in color-zoned tourmaline crystals. *American Mineralogist,* **56**, 114–132.

WARNER, T. W. Jr. (1935) Spectroscopic analysis of tourmalines with correlation of color and composition. *American Mineralogist,* **20**, 531–536.

WERDING, G., and SCHREYER, W. (1977) Synthese von borhaltigem Kornerupin und Turmalin im System MgO-Al_2O_3-B_2O_3-SiO_2-H_2O. *Fortschritte der Mineralogie* (Jena), **55**, 152–154.

WILCKE, J. C. (1766) Geschichte des Tourmalin. *Abhandlungen der Königlichen Schwedischen Akademie der Wissenschaften,* **27**, 89–115 (ns).

YOUNG, R. A., WAGNER, C. E., POLLARD, C. O., and DONNAY, G. (1969) Crystalline heterogeneity, evidence from source-image distortion. *Carnegie Institute of Washington Year Book,* **67**, 220–221.


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minerals of the Elba Pegmatites

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Elba, historically remembered as the island where Napoleon was exiled, is also world famous as a source of superb hematite and pyrite specimens and pegmatite minerals, and as the namesake for the most important of the tourmaline species, elbaite. The pegmatites remain open to collectors and continue to yield interesting material, including five species here reported from Elba for the first time.

INTRODUCTION

Elba, the largest island in the Tuscan Archipelago, is located off the west coast of Italy, about 10 kilometers southwest of Piombino, the nearest point on the mainland. It is about 27 kilometers long in the east-west direction, with a complex, boot-like shape and an area of about 220 square kilometers. It forms part of a sunken mountain range extending towards Corsica and Sardinia. The highest point on the island is Monte Capanne (1028 meters; 3340 feet).

Above the major port of Portoferraio on the north coast, between the forts of Stella and Falcone, is the Villa dei Mulini where Napoleon was exiled in 1814 and 1815. The area is today a popular tourist attraction.

Collections the world over contain fine specimens of Elba hematite and pyrite crystals from the ancient iron mines, as well as beautiful crystals of elbaite tourmaline in a variety of colors. Only the gem pegmatites will be dealt with in this article.

HISTORY

Elba has been famous since ancient times primarily for its iron deposits. Early smelting furnaces on the island gave it its Greek name of Athalia ("soot island"). The iron deposits have been known and worked for over 2000 years, by the Etruscans, Romans, and many subsequent owners. The gem pegmatites, however, are rarely mentioned in the literature and appear to have been actively worked only since the 1850s (Sinkankas, 1981). Cleaveland (1816) quotes Dolomieu (?) as having noted both colorless and black tourmaline from Elba.

Antonio d'Achiardi (1873) reports that the first prospecting work at Monte Capanne was done in 1825 by Giovanni Ammannati, a mineral collector and a lieutenant in the First Royal Infantry Regiment stationed in Portoferraio. After discovering the pegmatite veins at Grotta d'Oggi, he purchased the property and began mining for specimens. Ammannati's prospect was probably the first locality in Italy to be mined for specimens only.

The Speranza vein, near the village of San Piero in Campo, was first worked by Captain G. Pisani, who dug an 8-meter trench. A local collector, Raffaello Foresi, excavated an area nearby which has come to be called "Masso Foresi."

Collectors have continued to frequent the various pegmatite veins and still turn up interesting specimens.

GEOLOGY

Monte Capanne, a granodiorite stock, forms the western half of the island. Hundreds of pegmatite bodies of vein-like form occur along a north-south interlaminated contact between the granodiorite and various schists, gabbros and calc-silicate rocks on the eastern margin of the stock. The pegmatite bodies, rarely exceeding 1 meter in thickness, generally strike approximately north-south and dip 50–90°.

Editor's note: This is a revised and enlarged translation of an article which appeared in the October-December 1983 issue of *Rivista Mineralogica Italiana,* and is presented here with the kind permission of editor Erberto Tealdi. The English translation is by Renato Pagano. Additional illustrations have been provided by Werner Lieber, Harold and Erica Van Pelt and Wendell E. Wilson.

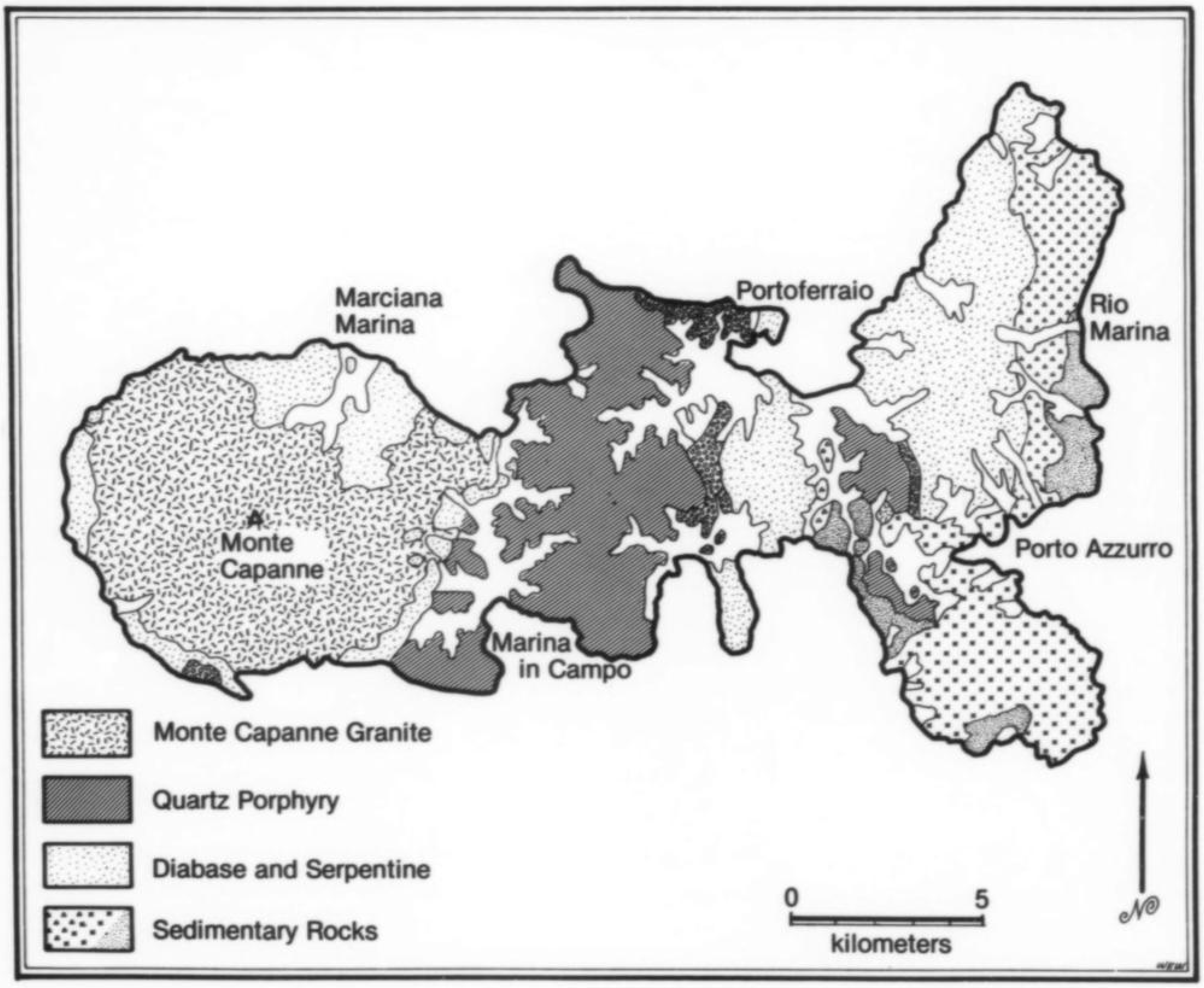
The important pegmatites at Grotta d'Oggi, Speranza, Facciatoia and Fonte de Prete are all within a thousand meters of each other but are not mineralogically equivalent. The Grotta d'Oggi vugs, for example, contain no pollucite, petalite or zeolites, yet these minerals are abundant in the Speranza vein.

Although a large number of pegmatite veins have been worked and exhausted, others remain relatively untouched and the extensive dumps still contain interesting microminerals. Many localities are heavily overgrown with dense, thorny brush and are difficult to find and work.

Field collectors with experience at Elba look first for pegmatites that are relatively vuggy rather than tight and solid, since the best crystals come only from the pockets. Snow-white orthoclase is a guide to yellow, brown and green tourmaline and beryl; pink orthoclase is associated more with pink and purple tourmaline, lepidolite and morganite (Lareida, 1979). The pegmatites, though overgrown, are commonly visible as ridges 5 to 30 meters high and half a meter in width, some weathered and others relatively fresh.

Because the pegmatites are so extensive in their occurrence, even new roadcuts may yield crystals. And particularly observant collectors have noticed that a high-stemmed white flowering plant grows only on lithium-rich soil and rock . . . another clue to the presence of productive pegmatites.

Figure 1. **Location map and geology of Elba (Lareida, 1979).**



Schorl is almost universally present, as are quartz, orthoclase and albite. Elbaite, lepidolite, and a variety of rare species have been found as superb crystals in pockets. Some pegmatites show a well-developed, symmetrical zoning, with most of the more interesting species (tourmaline, garnet, beryl, pollucite, petalite, cassiterite, etc.) concentrated in the core.

LOCALITIES

The most important pegmatite localities on Elba are the following:

Grotta d'Oggi (Oggi Cave)

Located on Monte Capanne about 2 km northeast of San Piero

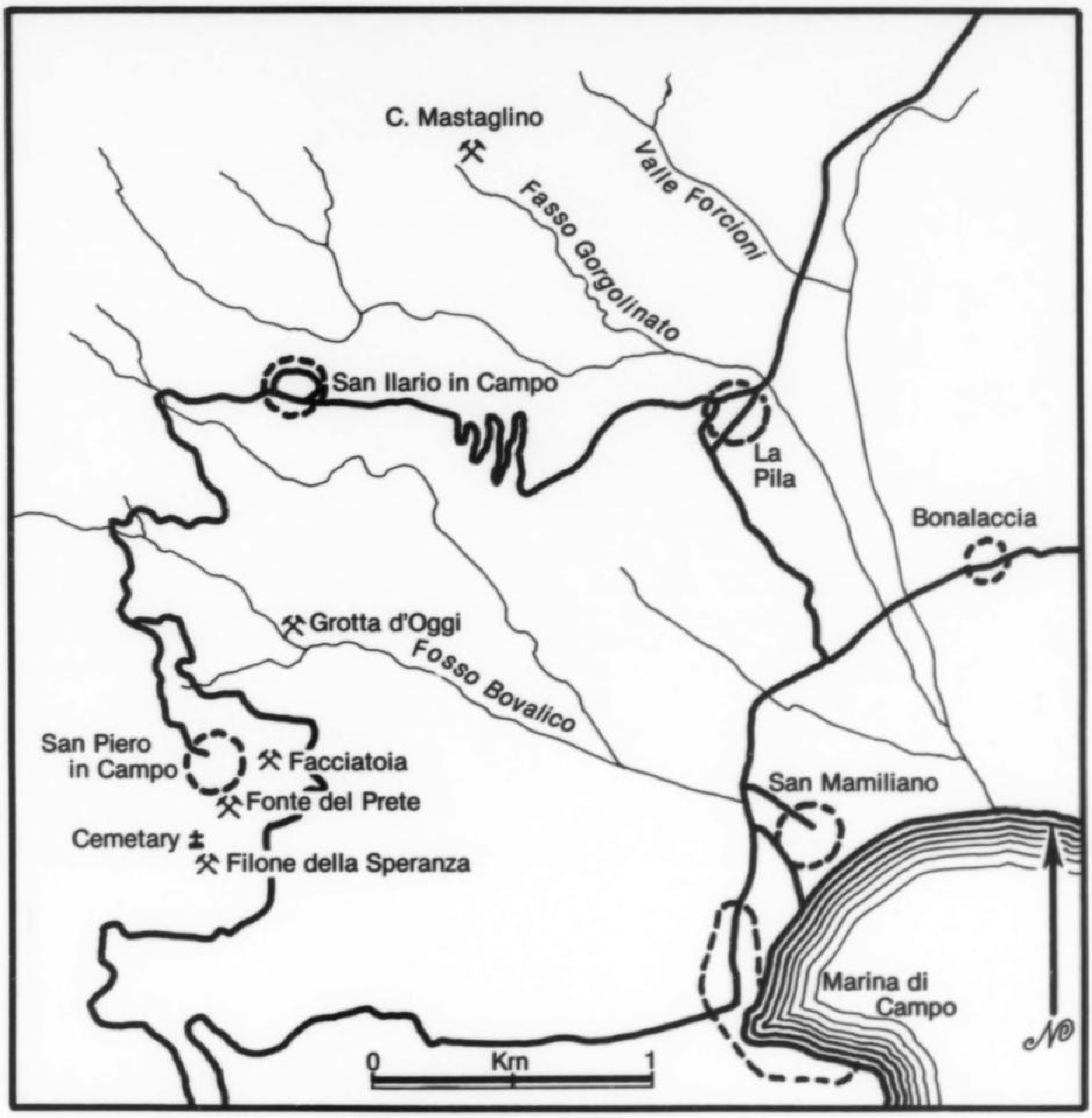


Figure 2. **Location map for important deposits in the San Piero in Campo–San Ilario in Campo area.**

in Campo, Grotta d'Oggi is among the most famous Elba occurrences. The veins, situated in the valley of Fosso Bovalico Creek, are still visible today. Five principal veins, more or less parallel and dipping 60–65° northwest, penetrate a granodiorite cliff, the largest vein being about a meter across. These veins are largely worked out, but the huge dump has provided occasional specimens. Colored tourmalines here are found only in the vugs of narrow veins; in thick veins the tourmaline is black.

Fonte del Prete (Prete Springs)

Located south of the village of San Piero in Campo at the town outskirts, this vein has produced many fine specimens, but collectors are not welcome there, and the locals use the area for a garbage dump.

Filone della Speranza (Speranza Vein)

The Speranza vein is located by the San Piero in Campo town cemetery, and has been very productive of fine specimens. "The Four Evangelists" are four large Speranza specimens, each having outstanding crystals of tourmaline, beryl, petalite and pollucite. These, along with many other fine Elba specimens, are on exhibit in the Mineralogical Museum of the University of Florence.

Other localities

Another interesting locality, Facciatoia, is located near the esplanade of the San Piero belvedere. Le Fate, I Canili, Prato alla Valle and Fosso Stabbiali are productive localities in the San Piero in Campo area. Gorgolinato, Catri, Mastaglino, Graziano and I Forcioni are occurrences in the San Ilario in Campo area. Others are mentioned below in the discussions of individual species.

Collectors should be advised that scorpions live in the rocks, and so gloves should always be worn when mucking about. Poisonous adders and aspis vipers also infest the area but are generally too shy to present a problem.

MINERALS

More than thirty species have been identified from the Elba pegmatites, including five which are reported here for the first time: ilmenite, ilmenorutile, manganotantalite, metatorbernite and rutile. Special attention is given here to those species of greatest collector interest. Most of the species discussed can still be collected today, as confirmed by field work (PBS) and interviews with reliable collectors.

Albite $NaAlSi_3O_8$

Albite is one of the most common minerals in the pegmatite veins. Beautiful crystal groups have been found, and can still be obtained, with colors ranging from white to pale green, pale pink and light blue. It is often found in parallel growths on quartz and orthoclase crystals. Albite crystals are rarely larger than 1 centimeter.

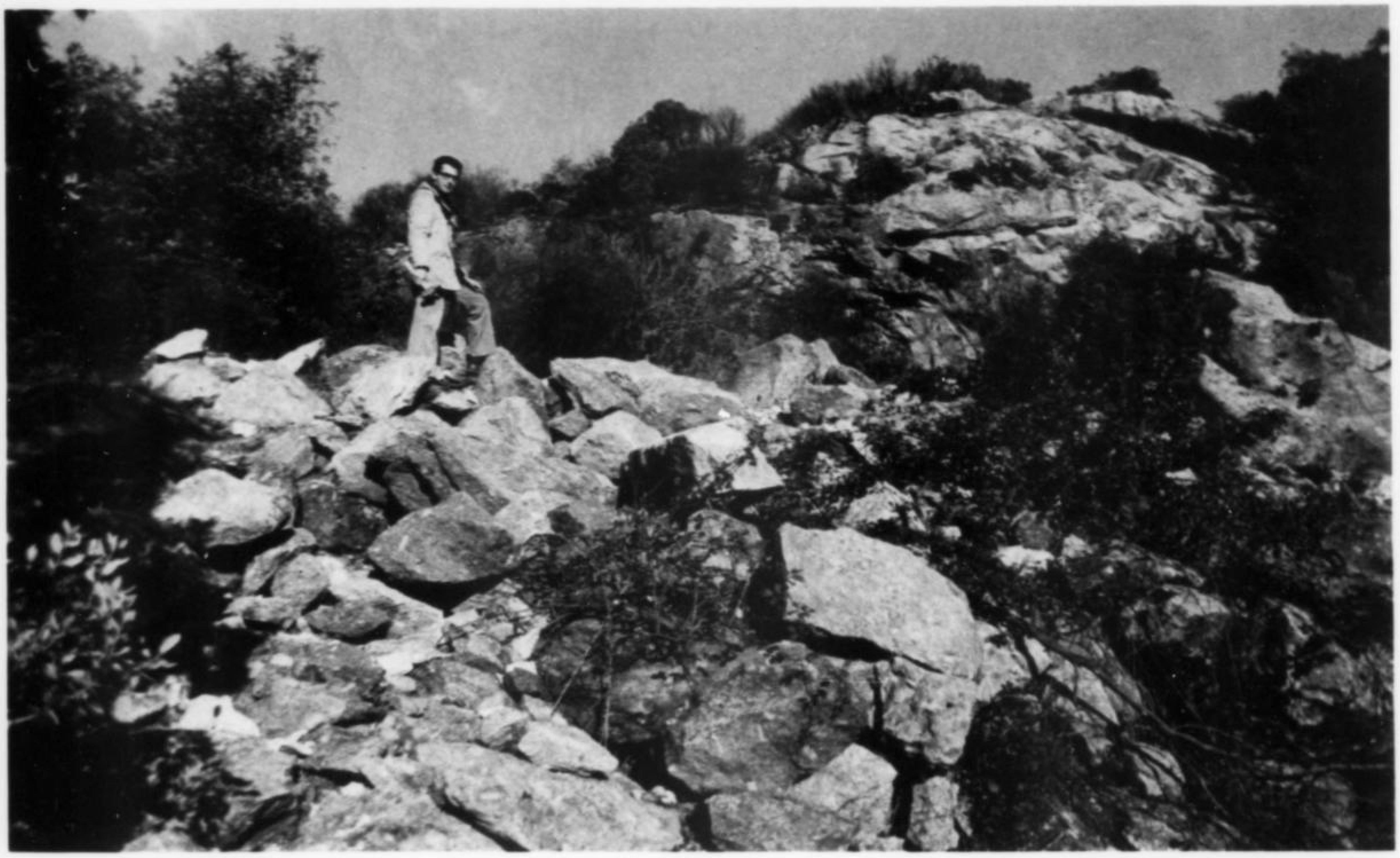


Figure 3. **Grotta d'Oggi in 1979.**

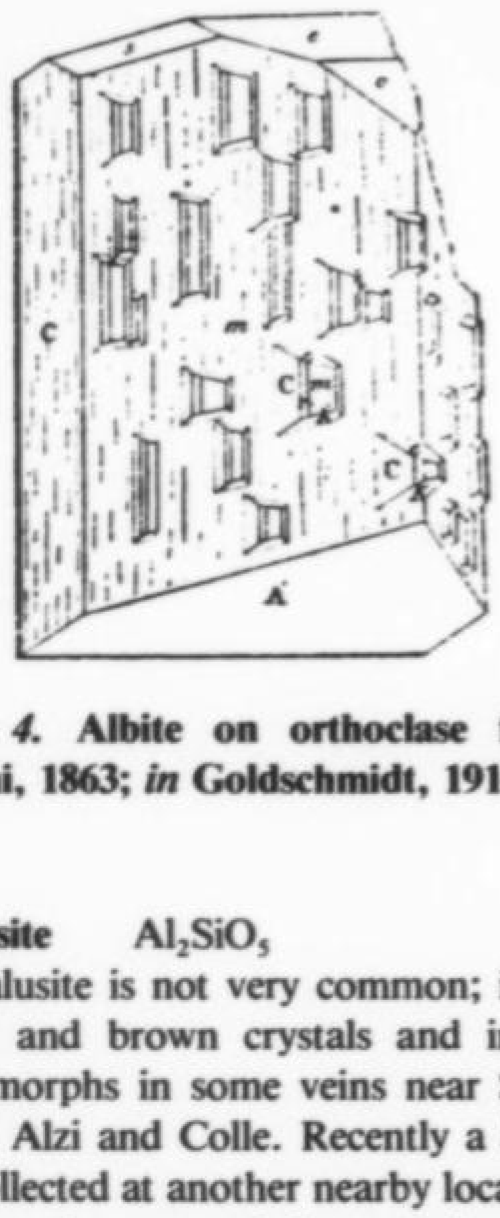


Figure 4. **Albite on orthoclase from Elba (Scacchi, 1863; *in* Goldschmidt, 1916, q.v.).**

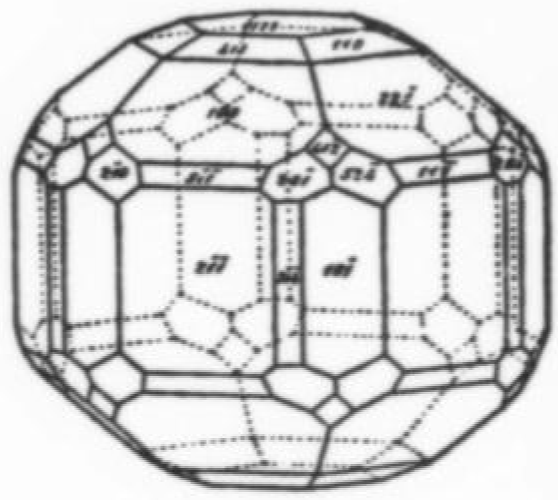


Figure 5. **Apatite from Elba (Artini, 1895; *in* Goldschmidt, 1913, q.v.).**

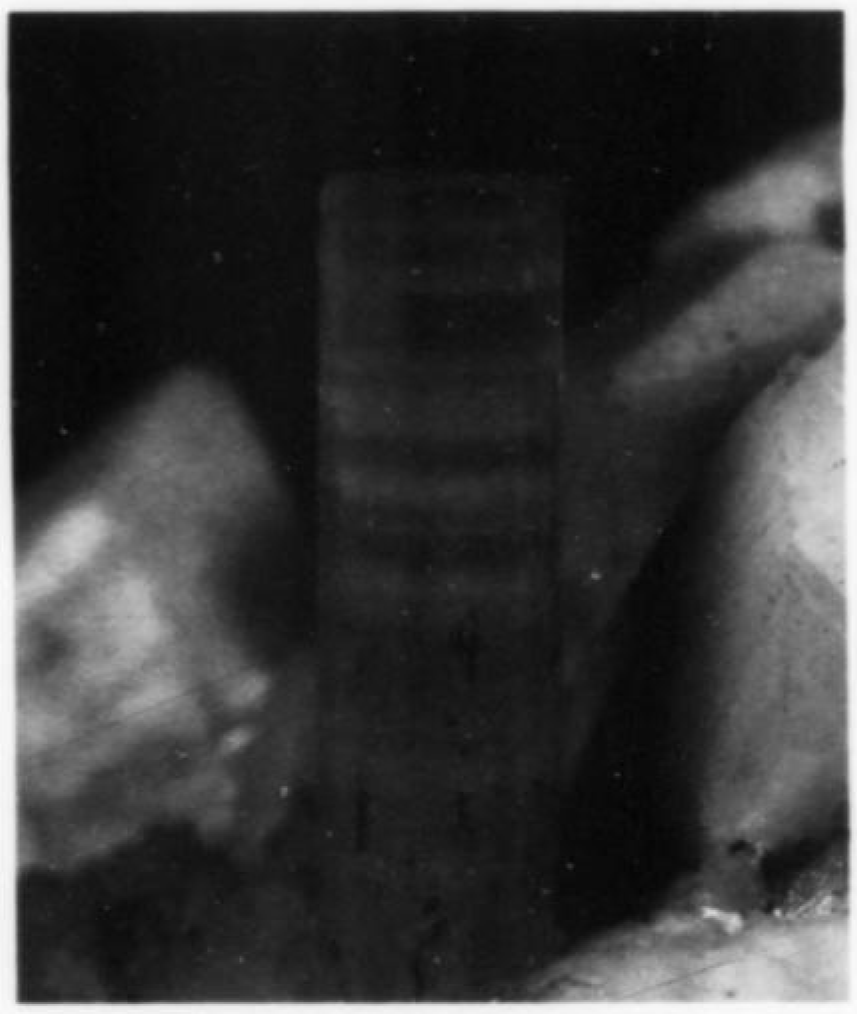


Figure 6. **Aquamarine beryl crystal 2 cm tall, from San Piero in Campo. Florence Mineralogical Museum specimen; photo by P. B. Scortecci.**

Andalusite Al_2SiO_5

Andalusite is not very common; it has been found in distinct, pinkish and brown crystals and in reddish masses with mica pseudomorphs in some veins near San Piero in Campo at Facciatoia, Alzi and Colle. Recently a few beautiful specimens have been collected at another nearby locality, Grotta al Guerrino, with pink, 3 to 4-cm crystals in a granite matrix.

Apatite Group

Apatite is not very common on Elba. It has been found in splendid tabular crystals, colorless or pale purple to very pale pink. The best specimens come from localities near San Piero in Campo: Fonte del Prete, Madonna delle Grazie and Santa Lucia.

Beryl $Be_3Al_2Si_6O_{18}$

Beautiful crystals of beryl occur at Monte Capanne, ranging from the colorless (*goshenite*) to pink (*morganite*) and pale blue (*aquamarine*). Elba beryl is very pure, therefore the colorless variety predominates, and the morganites and the aquamarines are all very light-colored.

The crystals typically have a prismatic, elongated habit but sometimes tabular crystals, called "rosterites," are found. The crystal terminations may show the basal pinacoid alone; more frequently, the pinacoid is accompanied by various hexagonal bipyramidal faces.

Figure 7. **Fonte del Prete in 1979.**

The crystals range from microscopic sizes up to a few centimeters in length.

Commonly the prism faces are striated lengthwise. Various inclusions, such as tourmaline, quartz and other minerals, are common and are especially easy to see in the colorless beryls.

Elba beryl tends to be particularly rich in crystal forms. D'Achiardi (1904) listed at least 18 identified with certainty; Millosevich (1911) added nine more, three of which were new for the species.

Vom Rath (1870) described a superb pink crystal of tabular habit and hexagonal outline, 5 cm (2 inches) across and 1 cm thick. Another crystal, from a Turin collection, appears from Vom Rath's description to be an example of lepidolite epitaxially oriented on beryl, with the lepidolite cleavage parallel to the beryl (0001) plane.

Figure 8. **Morganite beryl crystal 3.5 cm long, from San Piero in Campo. Florence Mineralogical Museum specimen; photo by P. B. Scortecci.**

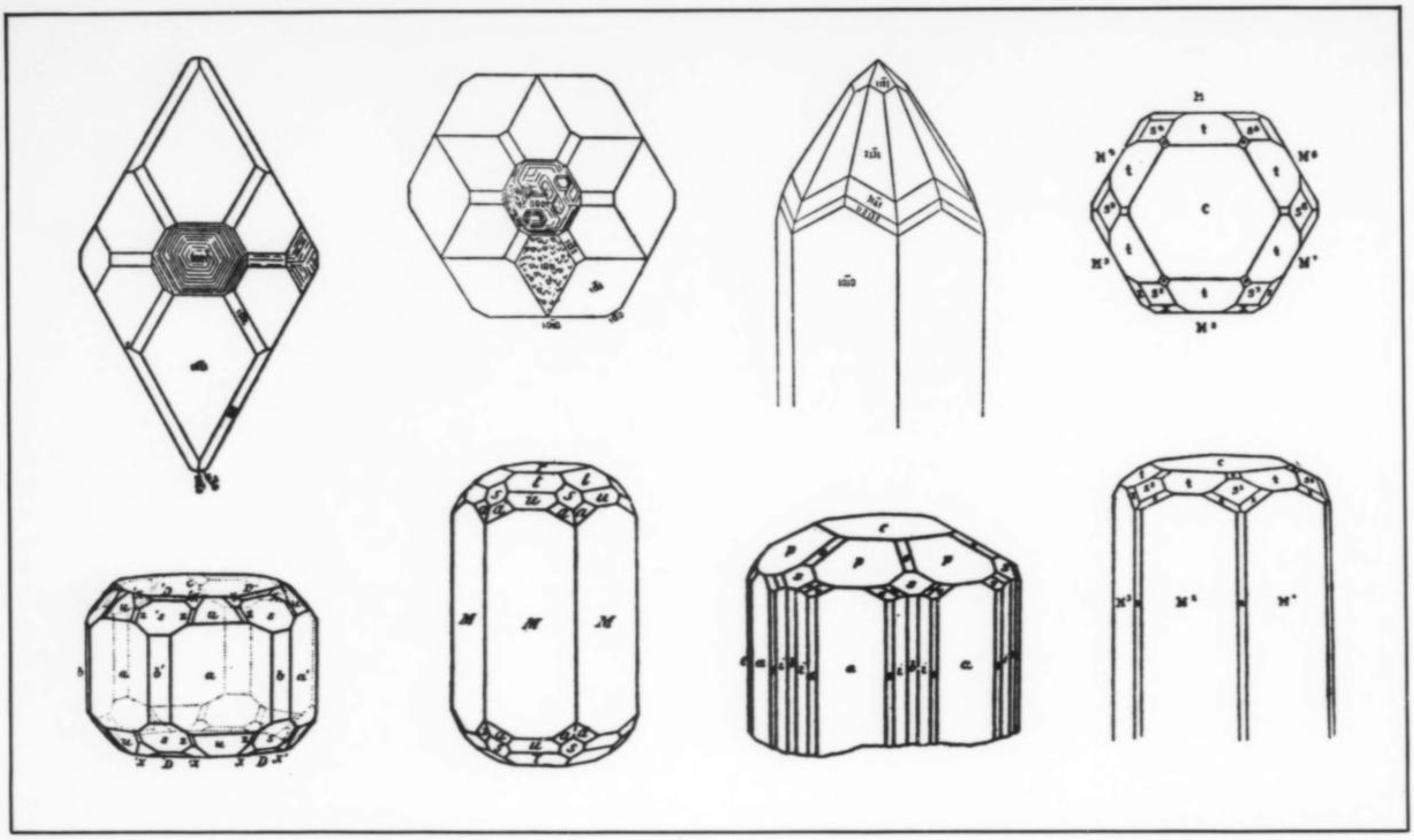


Figure 9. **Beryl from Elba (Rath, 1870; Schrauf, 1873; Busz, 1890; d'Achiardi, 1904; *in* Goldschmidt, 1913, q.v.).**

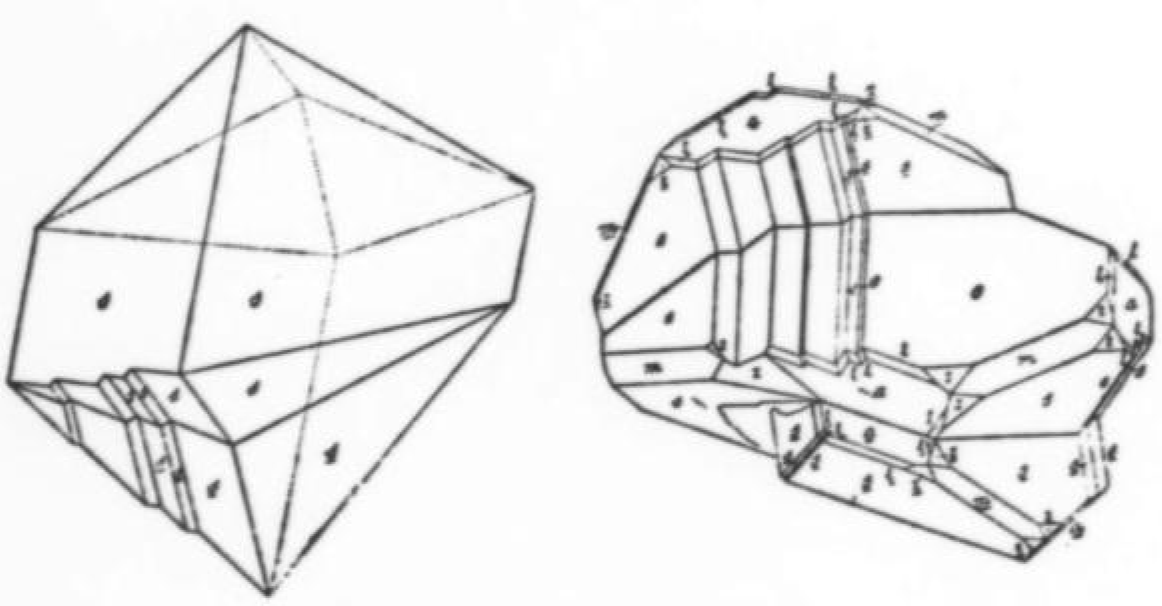


Figure 10. **Cassiterite from San Piero in Campo (Aloisi, 1910; *in* Goldschmidt, 1923, q.v.).**

Cassiterite SnO_2

Cassiterite has been found frequently in vein pockets at Monte Capanne, and can still be found in the dump material at several localities, especially at Grotta d'Oggi and Fonte del Prete.

The crystals are stout prismatic, commonly isolated, normally shiny black and almost always twinned on {101}. In the past most of the cassiterite specimens were collected at the I Canili and Facciatoia localities, and also at the two localities mentioned above. Elba cassiterite is often mistaken for schorl.

Chabazite $CaAl_2Si_4O_{12}{\cdot}6H_2O$

Chabazite occurs at Masso Foresi as small, white to yellowish rhombohedral crystals. A few 1 to 2 millimeter crystals have also been found at Filone della Speranza and in the dumps nearby.

Dachiardite $(Ca,Na_2,K_2)_5Al_{10}Si_{38}O_{96}{\cdot}25H_2O$

This is the rarest among the zeolites reported from the pegmatite veins of Monte Capanne. It was found originally associated with mordenite, stilbite and heulandite in the Speranza vein by Giovanni d'Achiardi (1905) and was named in honor of his father Antonio d'Achiardi. Dachiardite occurs as typical white crystals, very frequently in multiple twins of eight individuals with the characteristic pseudo-octagonal, hopper habit.

The best specimens, with crystals up to 5 millimeters and more, occur in the Speranza vein, but good material was also found at Fonte del Prete, Masso Foresi and Grotta d'Oggi.

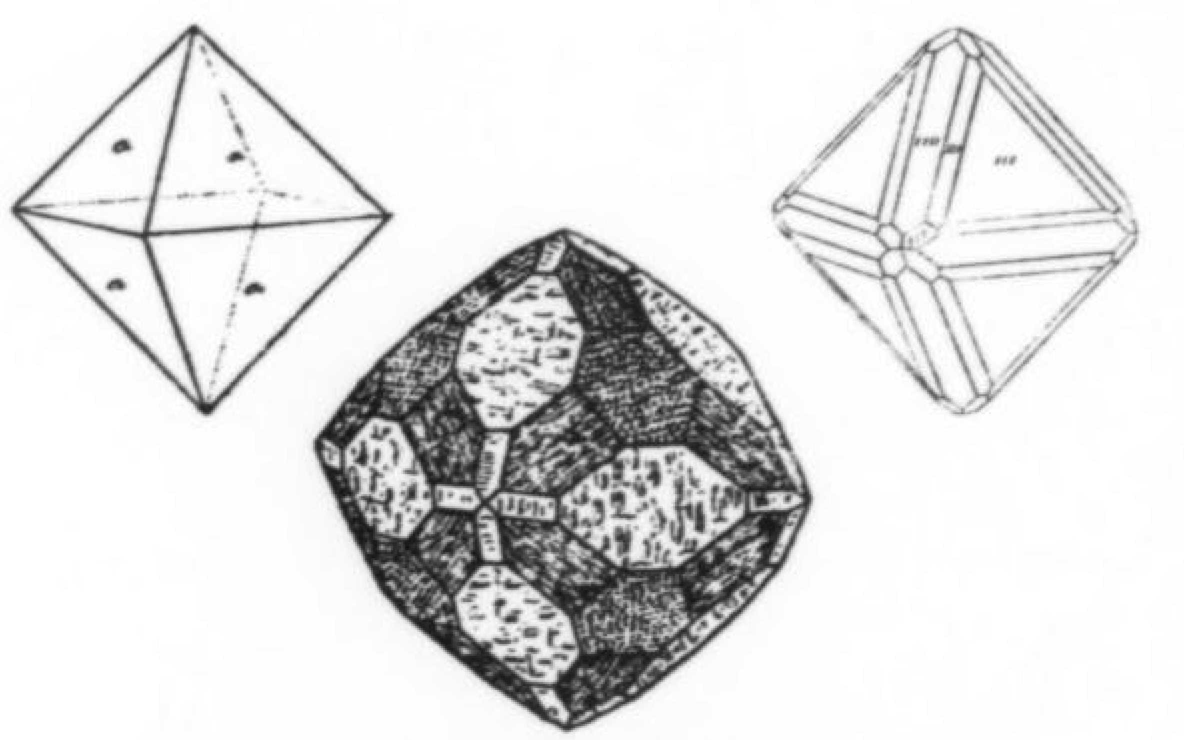


Figure 11. **Garnet from San Piero in Campo and Affaccata (Bauer, 1874; Bombicci, 1874; d'Achiardi, 1896; *in* Goldschmidt, 1918, q.v.).**

Garnet Group

Famous specimens of grossular in *octahedral* crystals have been found in the contact area between the country rocks and the Monte Capanne granodiorite.

In the veins, excellent crystals of spessartine occur, with fine honey-yellow, reddish yellow to hyacinth-red colors. The most common forms are the dodecahedron and trapezohedron; less common are trisoctahedron and tetrahexahedron. The crystal size is normally less than 5 millimeters, but exceptionally can reach 3 centimeters. Beautiful specimens have been collected at Grotta d'Oggi and in the San Ilario area at Catri and Gorgolinato.

Hambergite $Be_2BO_3(OH)$

This species was identified in 1977 by C. M. Gramaccioli and T. Pilati in a specimen collected from a small vein near the road fork between San Ilario and San Piero in Campo. It occurs as whitish, elongated, striated prismatic crystals up to a few millimeters in size. Hambergite is a rather unobtrusive mineral which can be easily mistaken for albite; thus it may have gone unnoticed at other localities. In this vein, hambergite is associated with microscopic crystals of pink tourmaline, microlite, feldspar and quartz.

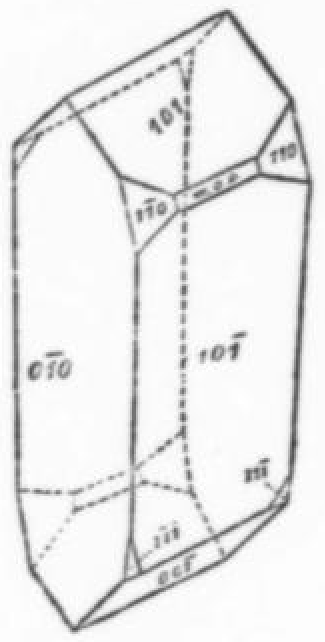


Figure 12. **Heulandite from San Piero in Campo (d'Achiardi, 1874; *in* Goldschmidt, 1918, q.v.).**

Heulandite $(Na,Ca)_{2\text{-}3}Al_3(Al,Si)_2Si_{13}O_{36}\cdot 12H_2O$

Heulandite can be found especially at Masso Foresi and Fonte del Prete with several other zeolite minerals. The crystals are about 1 millimeter in size, pale yellow to honey-yellow with pearly luster, and commonly associated with petalite, pollucite, quartz, orthoclase and tourmaline.

Ilmenite $FeTiO_3$

Ilmenite has recently been identified by X-ray powder diffraction in a specimen from Grotta d'Oggi. A qualitative X-ray fluorescence analysis has confirmed the presence of iron and titanium. The ilmenite crystals are in a small vug, associated with quartz, orthoclase and albite crystals, and with rosettes of an apple-green mineral identified as a chlorite. The ilmenite crystals are up to 2 mm across, and show a lamellar habit with predominant basal pinacoid and rhombohedron.

Ilmenorutile $(Ti,Nb,Fe)_3O_6$

Ilmenorutile has been identified by X-ray diffraction using a Gandolfi camera. An X-ray fluorescence analysis, performed on the same crystal fragment, has shown the presence of titanium and also of niobium, the latter not as traces, but as one of the main components. Tantalum was found to be absent. The cell parameters obtained by refining with the least squares method the data of the powder diffractograms were: $a = 4.627(8)$; $c = 2.987(8)$Å.

The crystals are small, up to 1 or 2 mm, but very beautiful, with a bipyramidal habit determined by {111}. Other forms which were observed as modifications on bipyramids are the basal pinacoid {001} and prism {100}.

The Elba ilmenorutile, always in association with schorlite, is dark gray with a metallic luster. The material examined was found for the first time by Mr. M. Retali at Grotta del Guerrino near San Piero in Campo. Reportedly in this locality minute crystals of rutile, anatase and brookite were also found.

Laumontite $CaAl_2Si_4O_{12}\cdot 4H_2O$

Laumontite was first reported in 1966 by M. De Fino and S. Menchetti from a find in the eurites of Marciana Alta. It also occurs as microscopic, white, very fragile crystals on black and green tourmaline specimens from Fonte del Prete, associated with orthoclase and quartz.

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

Lepidolite is abundant in all the veins, as single crystals or in rosettes and aggregates of lamellar crystals ranging in color from yellowish white to gray-white, pinkish white and pink. The crystals are normally a few millimeters in size, but in some cases reach 1 centimeter or larger. Lepidolite crystals are normally implanted on quartz, orthoclase and tourmaline, and sometimes are associated with pollucite.

Manganotantalite $MnTa_2O_6$

This species was identified in pegmatite specimens from Facciatoia as prismatic, elongated, slightly flattened crystals, orange-brown in color and measuring about 1 mm, implanted on quartz and orthoclase crystals. The following cell parameters have been obtained by X-ray powder diffraction, based on twelve reflections indexed: $a = 14.435(5)$, $b = 5.771(2)$, $c = 5.103(2)$Å. The identification by X-ray diffraction has been confirmed by a qualitative chemical analysis performed using the EDAX equipment in association with an electron microprobe at the Institute of Mineralogy of the University of Florence. The elements indicated by this analysis are: manganese, niobium, tantalium and zinc.

Metatorbernite $Cu(UO_2)_2(PO_4)_2\cdot 8H_2O$

Metatorbernite has been identified on specimens from Facciatoia by X-ray powder diffraction using a Gandolfi camera. It occurs in flattened, tabular crystals with a square outline, emerald-green in color and smaller than 1 mm. The crystals are implanted on quartz and orthoclase or, rarely, on manganotantalite crystals.

A qualitative chemical analysis was performed on a small crystal fragment using the electron microprobe of the Institute of Mineralogy, University of Florence. Uranium, copper and phosphorous were determined, thus confirming the identification by X-ray diffraction.

Microlite $(Na,Ca)_2Ta_2O_6(O,OH,F)$

Splendid crystals of microlite occur especially at Grotta d'Oggi, with sizes up to a few millimeters, color yellow, green, red or dark red to brown, on albite, orthoclase, quartz and tourmaline. Normally the crystals are octahedral, but sometimes cube and dodecahedron faces can be observed.

Mordenite $(Ca,Na_2,K_2)Al_2Si_{10}O_{24}\cdot 7H_2O$

This is one of the most common zeolites in the pegmatite veins. It occurs in the tourmaline-rich vugs as acicular crystals or white to slightly grayish radiating aggregates. The best specimens have been collected near San Pietro in Campo at Cava Pisani and Fonte del Prete.

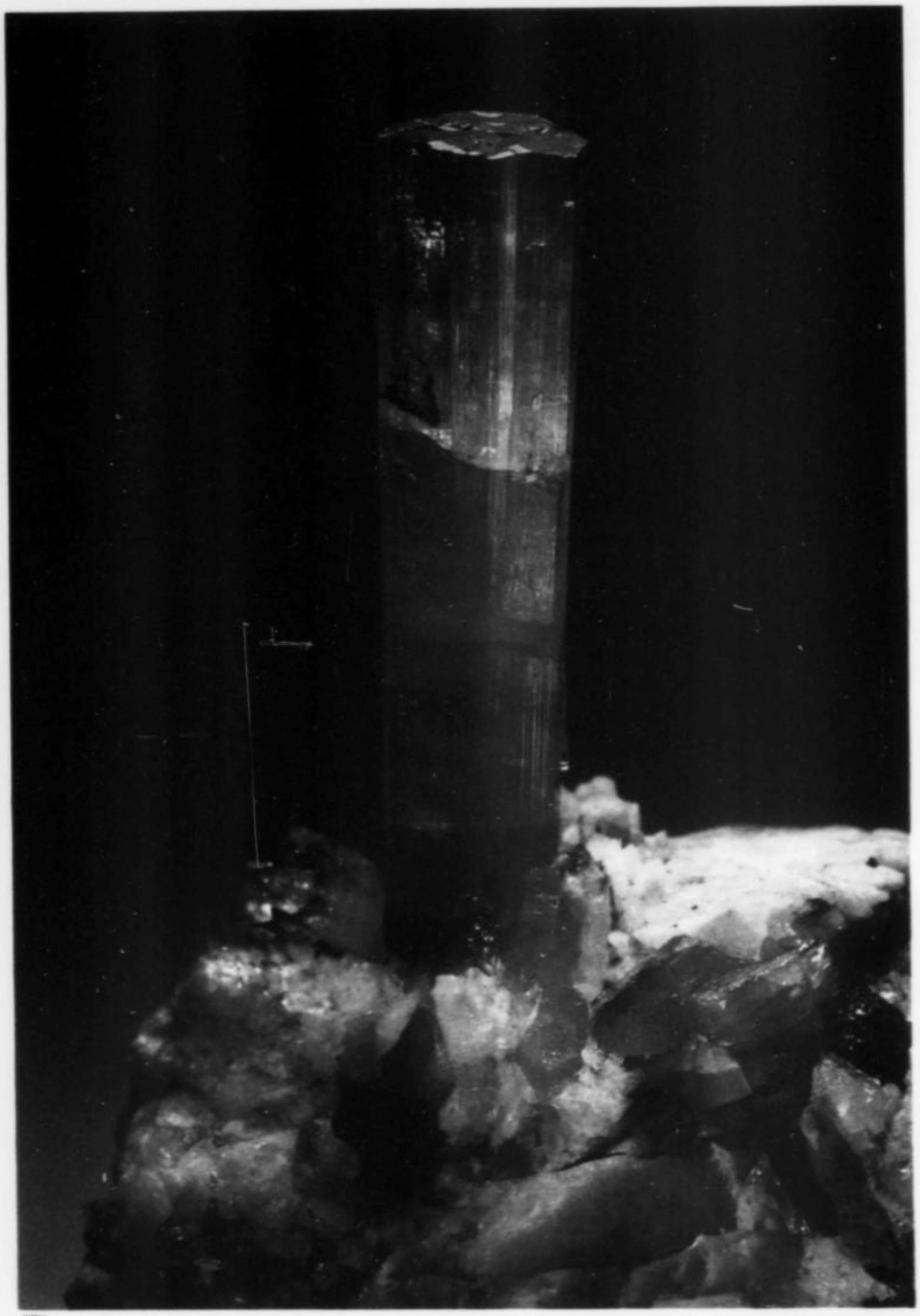
Orthoclase $KAlSi_3O_8$

Orthoclase is the most common component of the vein material. Beautiful specimens have been recovered at Grotta d'Oggi, with crystals reaching very large sizes, up to 10 x 10 centimeters.

The color ranges from a fine ivroy-white to yellowish, gray and pale pink. Carlsbad twins occur more frequently than Baveno twins, while Manebach twins are rather scarce. Many crystals, and especially secondary crystals grown on the first-generation orthoclase, show the typical adularia habit. Adularia occurs especially at Facciatoia, Vallicella Bassa, Valle agli Alzi and Secchetto, all in the San Piero in Campo area; and at Catri, Gambale and Confessionario in the San Ilario area.

Petalite $LiAlSi_4O_{10}$

Petalite is one of the rarest minerals in the Monte Capanne veins;



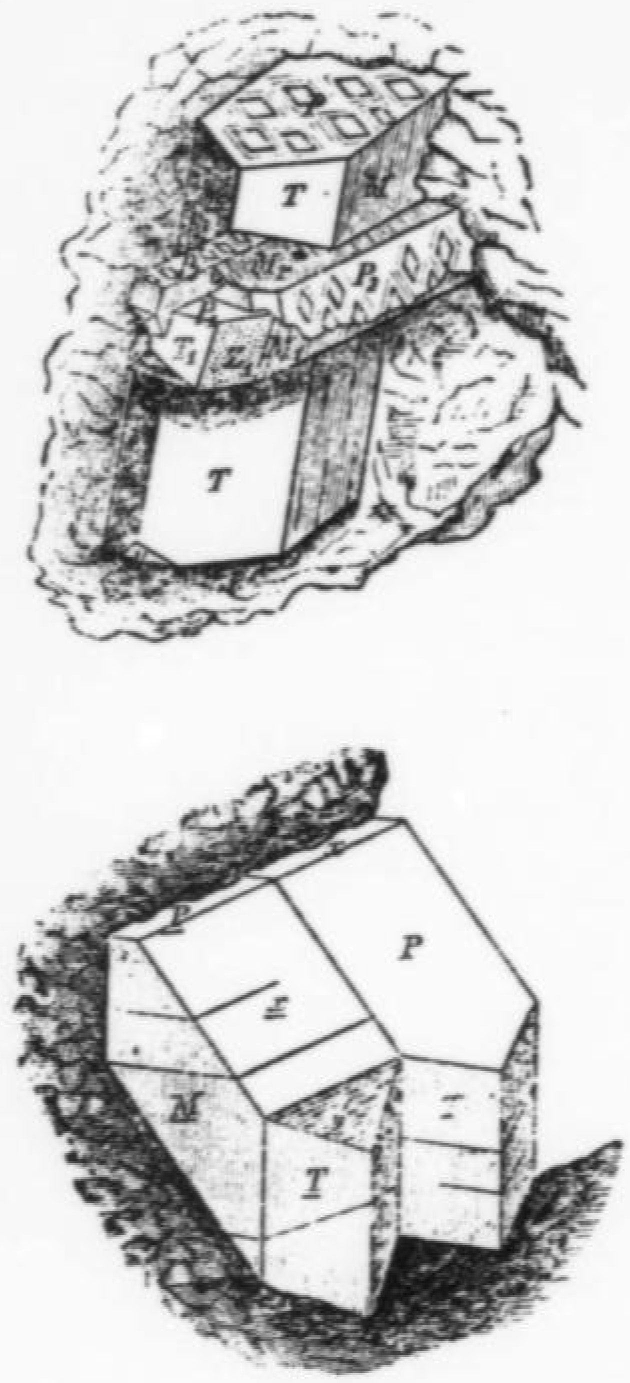


Figure 13. **Orthoclase from Elba (Baumhauer, 1889; Bartalini, 1901; *in* Goldschmidt, 1916, q.v.).**

Figure 14. **Elbaite crystal *(left)*, 4 cm tall, on quartz and feldspar matrix. Harvard University collection.**

Figure 15. **Elbaite crystal, 3 cm, with black termination (known as "moor's heads"); Werner Lieber photo.**

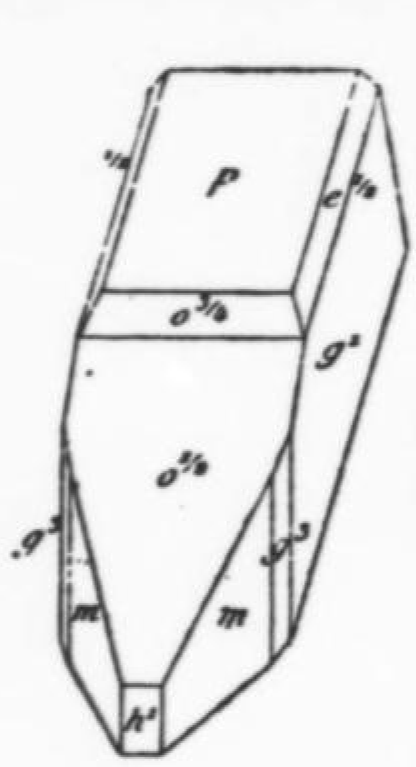
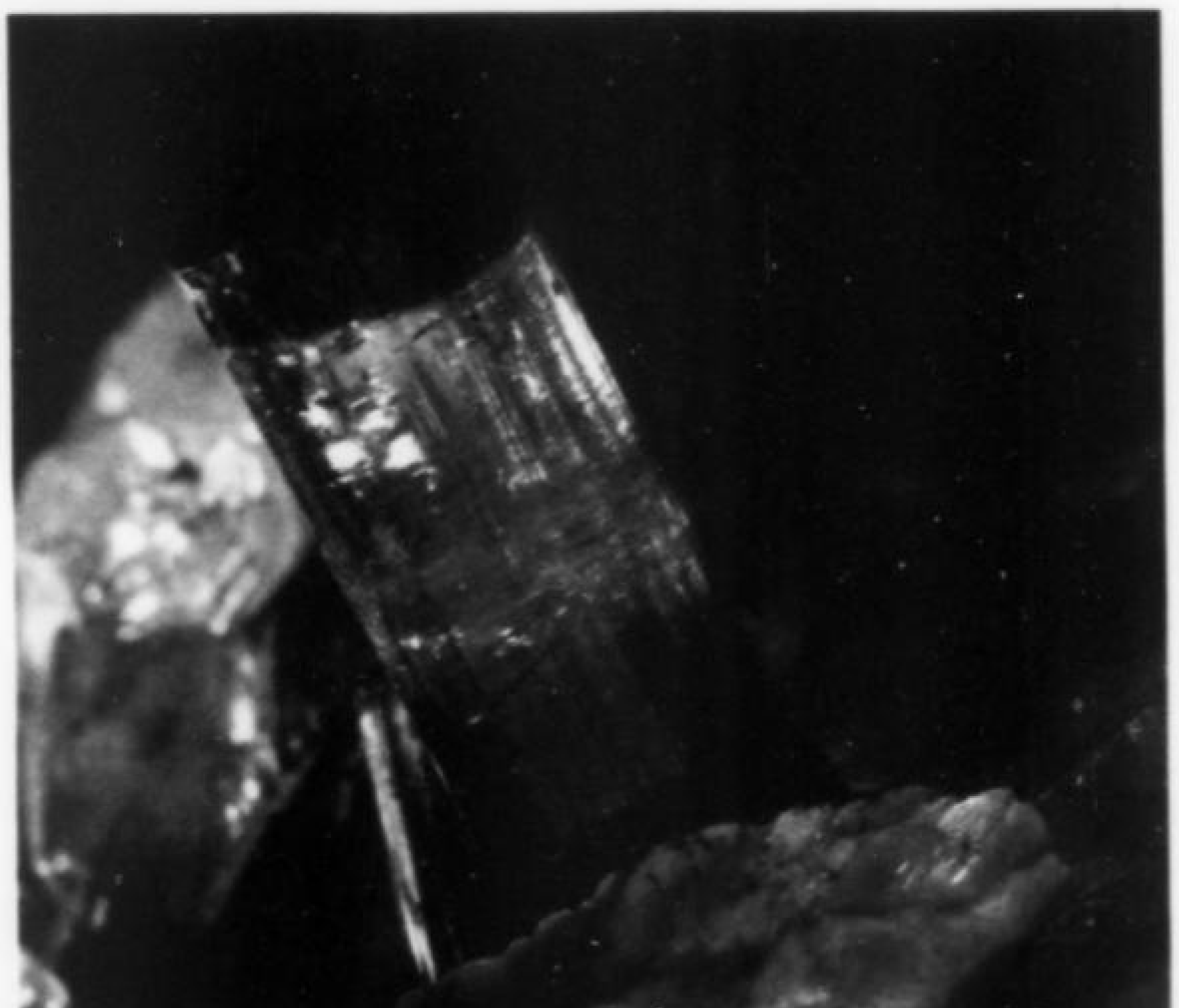


Figure 16. **Petalite from Elba (Descloizeaux, 1864; *in* Goldschmidt, 1920, q.v.).**



the specimens from this locality are famous for their beautiful crystals. Petalite occurs especially at Fonte del Prete and Masso Foresi as monoclinic, irregular crystals, flattened on {010}; as columnar aggregates or, more commonly, colorless or whitish to gray masses which can be easily mistaken for orthoclase. Recently,

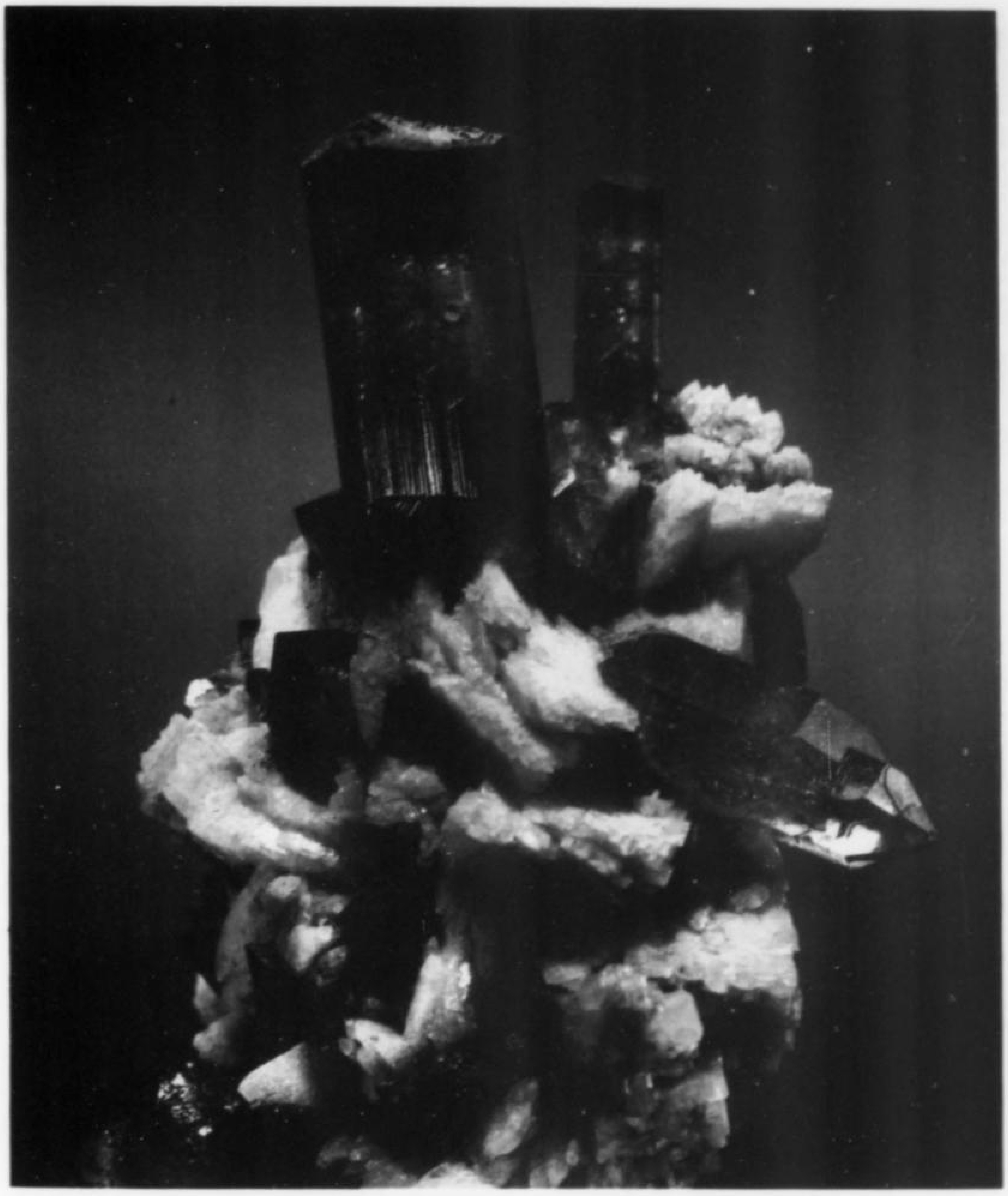


Figure 17. **Elbaite with smoky quartz and elbaite, 6 cm tall, from Grotta d'Oggi. David Eidahl specimen; Harold and Erica Van Pelt photo.**

splendid crystals over 1 cm in size have been found associated with quartz, orthoclase and tourmaline.

Pollucite $(Cs,Na)_2Al_2Si_4O_{12}\cdot H_2O$

Pollucite has been found in splendid specimens, especially at Masso Foresi. It occurs as crystalline masses, often rather large and full of cavities. Sometimes fairly distinct crystals, colorless, whitish or gray, with a glassy luster, can be found. The crystal habit is characterized by a combination of trapezohedron {211} and cube, and commonly shows many different crystal faces.

Grotta d'Oggi has also supplied excellent specimens. Here the crystals are usually well formed and lie on orthoclase or in close association with lepidolite rosettes.

Quartz SiO_2

Quartz is extremely common in all the veins of Monte Capanne. The crystals are mostly clear, and rich in faces; normally, the prism is almost completely embedded in the feldspar matrix, so that just the rhombohedral faces protrude. Lightly colored, yellowish to smoky crystals are not uncommon; smoky to black crystals occur especially at Grotta d'Oggi. The quartz crystals are never very large, up to 3 or 4 cm as a maximum; sometimes they contain inclusions, mostly of green or black acicular tourmaline crystals.

Rutile TiO_2

Rutile was mentioned by Giovanni d'Achiardi (1904) as doubtfully present in specimens from Fonte del Prete. The rutile crystals we have found are stout prismatic, about 1 mm long, dark brown to black with a metallic luster, and are associated with quartz, orthoclase and albite.

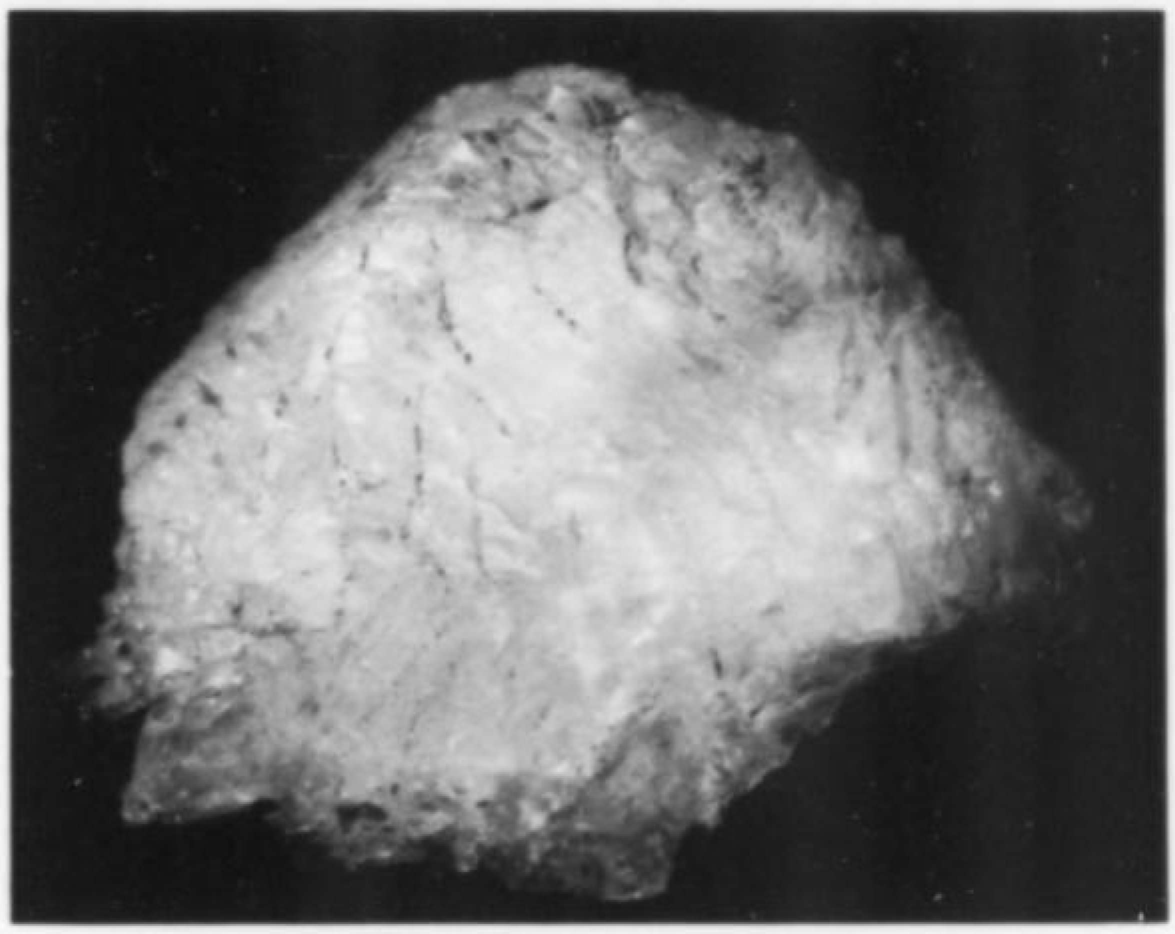


Figure 18. **Colorless pollucite crystal group, 3.5 cm, from San Piero in Campo. Florence Mineralogical Museum specimen; photo by P. B. Scortecci.**

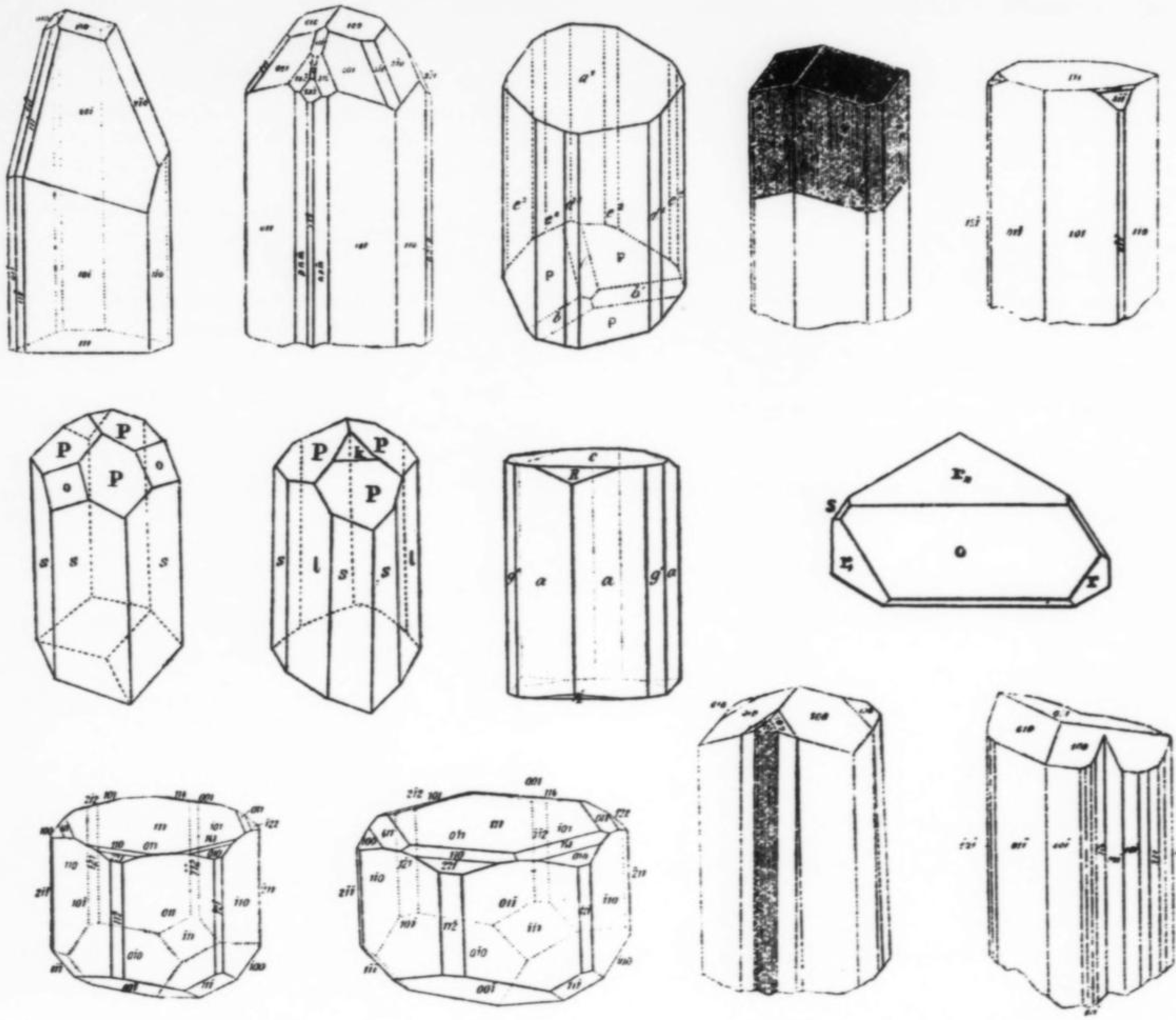


Figure 19. **Tourmaline from Elba (Soret, 1822; Rose, 1836; Dufrenoy, 1856; Jenzsch, 1861; d'Achiardi, 1893; Viola and Ferrari, 1911; *in* Goldschmidt, 1923, q.v.).**

Stilbite $NaCa_2Al_5Si_{13}O_{36} \cdot 14H_2O$

This zeolite has been found in good specimens at Masso Foresi and Fonte del Prete. It occurs as typical spherical or sheaf-like aggregates, about 1 cm in size; the color is white or light yellowish. Stilbite occurs associated with tourmaline, lepidolite, quartz, orthoclase, petalite and pollucite.

Topaz $Al_2SiO_4(F,OH)_2$

Although topaz is not rare in the Elba veins, it is easily mistaken for quartz, especially when it occurs in clear, colorless crystals. The best crystals, sharp and transparent, are found at Graziano near San Ilario in Campo. Crystals reach about 1 cm.

Tourmaline Group

Tourmalines are the most important and famous minerals of Monte Capanne, occurring in all veins as prismatic, often deeply striated or fasciculated crystals with a rhombohedron or pedion termination. The crystals can reach a length of 10 cm and a width of about 1 cm.

The colors vary widely: colorless (*achroite*), pink, yellow, green, blue (*indicolite*), purple-red (*rubellite*) and brown to black. The lithium-rich pink, green and blue tourmalines are elbaite. A peculiar feature of some of these tourmalines, especially from the Graziano veins near San Ilario in Campo, is their black termination while the rest of the crystal is pink, green or colorless. These tourmalines are called *testa di moro* in Italian and *Mohrenkopf* in German ("moor's head").

Recently, various interesting finds have been made. Two collectors from Tuscany, while digging out the remainder of a vein at Fonte del Prete, discovered a pocket containing many color-zoned elbaite crystals, pale pink at the tip and green at the base, 1 to 4 cm long.

Zircon $ZrSiO_4$

Zircon is rather rare on Elba, but is found in excellent, pale green crystals with an elongated prismatic habit and tetragonal bipyramid terminations. The crystals normally lie on orthoclase and are associated with microlite, cassiterite, lepidolite, albite, beryl and tourmaline.

Many of the crystals are of microscopic size and escaped the attention of the early collectors, so that zircon specimens can still be found on the dumps.

IMPORTANT COLLECTIONS

The most beautiful collection of Monte Capanne minerals is preserved in the Mineralogy Museum of Florence University. A number of spectacular specimens are on exhibit. More specimens, also of great interest, are in storage; these, unfortunately, cannot be seen by the general public.

Some of the specimens were damaged during World War II; at that time the curator, Professor G. Carobbi, hid most of the collection in the terreplein under the museum floor, where the Medici's stables used to be.

Another important collection is at the Mineralogy Museum of Pisa University, which includes specimens of great value and esthetic quality as well as several rarities from Monte Capanne.

ACKNOWLEDGMENTS

The authors wish to thank Ornella Donato for her cooperation and assistance during their visit at the Mineralogical Museum of the Florence University where several specimens were photographed. Also, the authors are grateful to Mauro Retali for information and material supplied.

BIBLIOGRAPHY

BUSATTI, L. (1891) Sopra un aspetto nuovo del berillo elbano. *Processi Verbali della Societa Toscana di Scienze Naturali in Pisa,* 7, 299–302.

CLEAVELAND, P. (1816) *An Elementary Treatise on Mineralogy and Geology*. Boston, 262.

D'ACHIARDI, A. (1872–1873) *Mineralogia della Toscana,* Pisa. Reprinted in 1973 by Nistri, Firenze.

D'ACHIARDI, G. (1904a) Di alcuni minerali dei filoni tormaliniferi nel granito di S. Piero in Campo (Elba). *Processi Verbali della Società Toscana di Scienze Naturali, Pisa,* **14**, 89–96.

D'ACHIARDI, G. (1904b) Forme cristalline del berillo Elbano. *Processi Verbali della Societa Toscana di Scienze Naturali in Pisa,* **14**, 75–83.

D'ACHIARDI, G. (1905) Zeolite probabilmnete nuova dell'Isola d'Elba. *Processi Verbali della Società Toscana di Scienze Naturali,* Pisa, **14**, 150–156.

DE FINO, M., and MENCHETTI, S. (1966) Laumontite di Marciana (Isola d'Elba). *Rendiconti della Società Mineralogica Italiana,* **22**, 59–71.

GOLDSCHMIDT, V. (1913–1923) *Atlas der Krystallformen.* Carl Winters Universitätsbuchhandlung, Heidelberg.

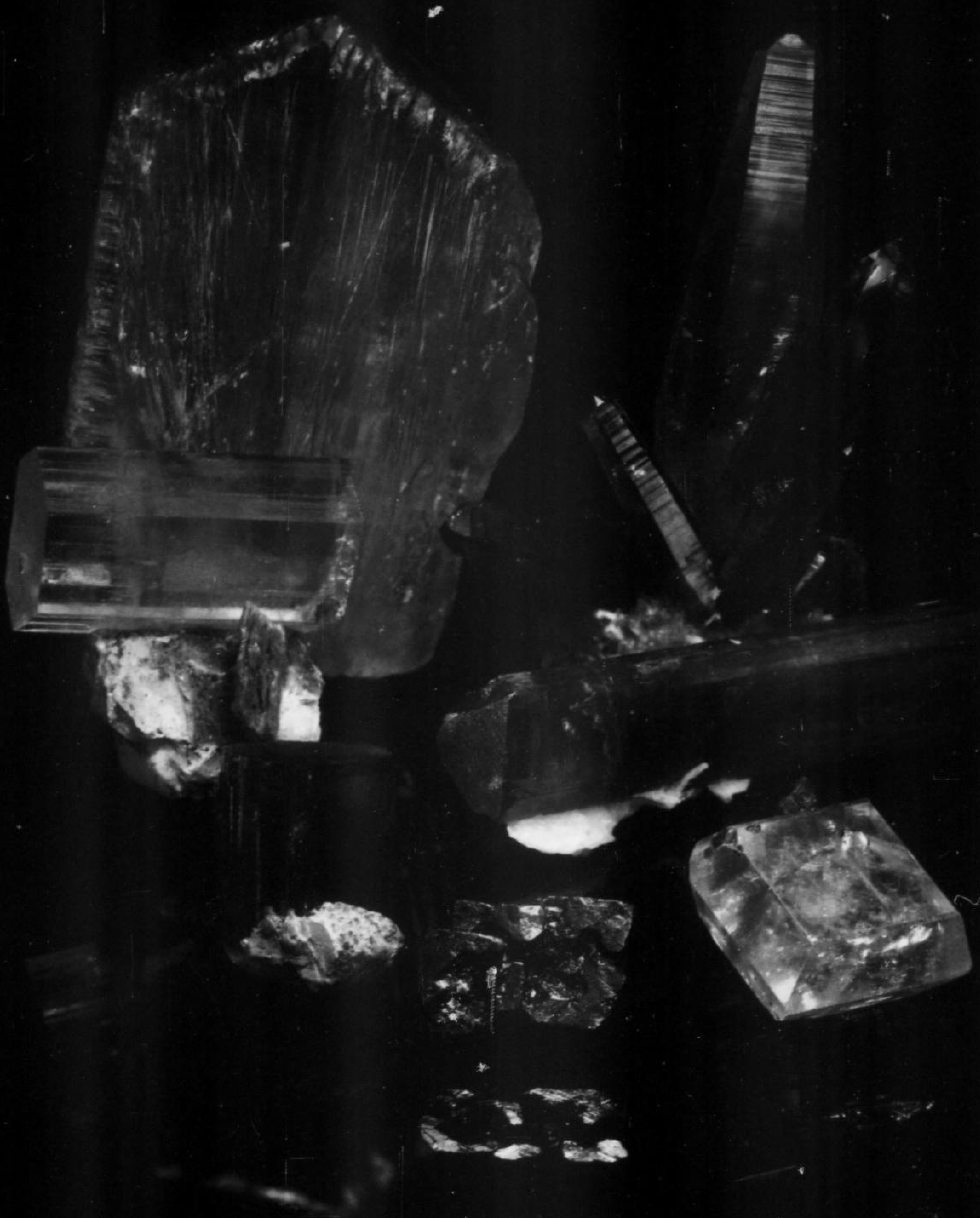
GRAMACCIOLI, C. M., and PILATI, T. (1977) Hambergite dell'Elba. *Periodico di Mineralogia,* **46**, 5–9.

LAREIDA, S. (1979) Man mietet sich einen Esel . . .: Die Turmalin-Pegmatite der Insel Elba. *Lapis,* **4**, 14–19.

MILLOSEVICH, F. (1911) Forme nuove del berillo elbano. *Atti della Reale Accademia Nazionale dei Lincei,* **20**, 138–144.

RATH, G. vom (1870) Geognostische-mineralogische Fragmente aus Italien. VIII. Die Insel Elba. *Zeitschrift der deutschen geologischen Gesellschaft* (Berlin), **22**, 591–732.

SINKANKAS, J. (1981) *Emerald and other beryls.* Chilton, Radnor, Pennsylvania, 458–462.



Maine Tourmaline

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Granitic pegmatites are the focus of mineral collecting activity in Maine; nearly half of all the species known from the state have been found in the pegmatites of Androscoggin, Oxford and Sagadahoc counties. Elbaite, the state gem, has remained Maine's most sought-after mineral since its discovery at Mount Mica in 1820.

INTRODUCTION

Contemporary collectors are familiar with the fine tourmaline crystals, brilliant gems and beautiful carvings resulting from the 1972 discovery at Newry. This find was an absolute bonanza that fully merited all the exuberant publicity it received. In contrast, collectors, especially those from outside the New England region, are less familiar with Maine's numerous other tourmaline occurrences; none of the older finds was as prolific as Newry and specimens dispersed long ago are rarely available on the market today.

Three tourmaline species are associated with Maine pegmatites. Dravite, the magnesium tourmaline, is the rarest, occurring in the contact zone at Black Mountain and the Dunton mine where pegmatites intruded mafic schists. Elbaite, the lithium tourmaline, is restricted to the albitized portions of complex lithium-rich pegmatites. Schorl, the common iron tourmaline, is widespread in Maine pegmatites. Each species is described below, along with its occurrences.

ELBAITE $Na(Li,Al)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

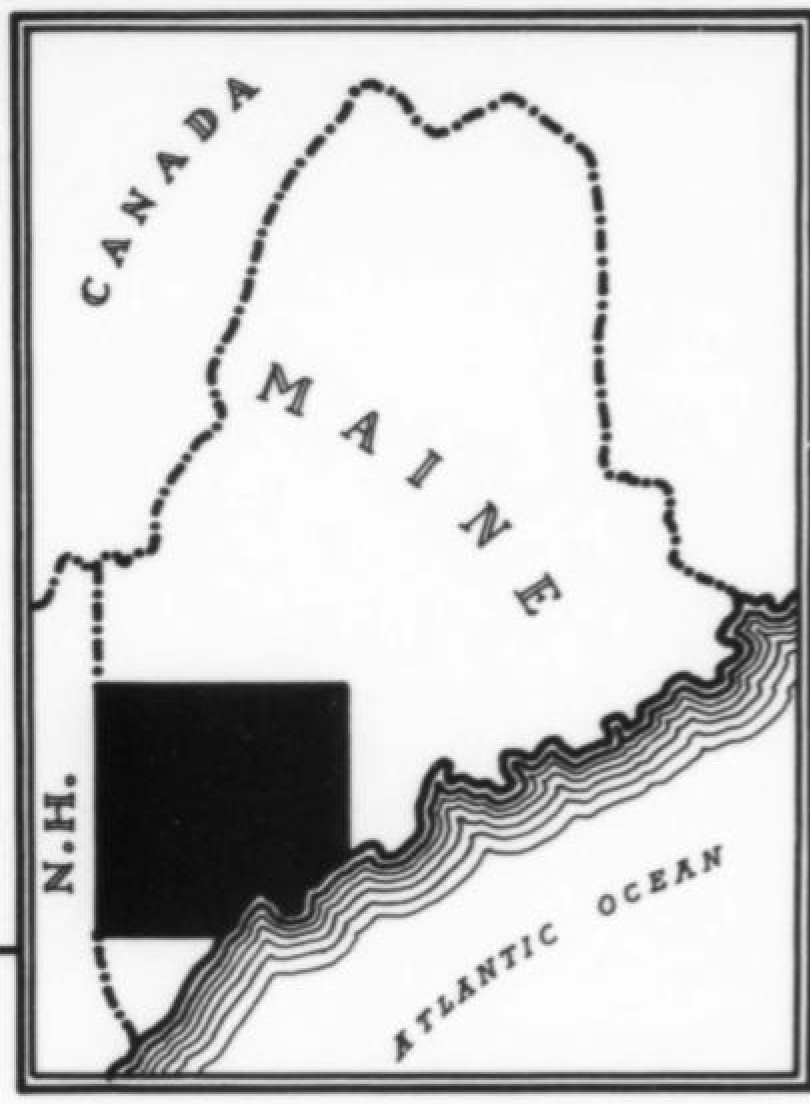
Elbaite occurs in complex, lithium-rich pegmatites which in Maine lie in a narrow belt trending northwest from Georgetown on the coast to Newry near the Maine–New Hampshire border. When the fluids from which these deposits were crystallized became depleted in iron, the growing crystals of tourmaline took up aluminum and lithium in its place. This transition is marked by a color change and a species change from black schorl to blue or green elbaite. The appearance of elbaite as green blades in muscovite, rubellite fans in lepidolite, or watermelon crystals in cleavelandite is an indication of pockets nearby. Unfortunately, the crystallization process does not usually end with the growth of beautiful, free standing gem crystals. These are in turn often coated with the lithium chlorite, cookeite, and then partially dissolved leaving etched fragments and pseudomorphs. Alternatively, explosive rupturing of the pocket in some cases allowed the late stage, corrosive fluids to drain away but also shattered the gem crystals. Larger pockets typically have collapsed by the spalling of pieces from pocket roof and walls and are infilled with mud carried by seeping ground water.

Mount Mica, Paris, Oxford County

Mount Mica, North America's first gem tourmaline locality, is located 1.5 kilometers east of the lovely village of Paris Hill. The story of its discovery and early development was recounted by Augustus C. Hamlin, son of the discoverer, in his book *The Tourmaline* (1873) and later in *The History of Mount Mica of Maine, U.S.A. and Its Wonderful Deposits of Matchless Tourmalines* (1895). The latter, with its detailed history and coloritype plates depicting 57 elbaite crystals, is as desirable a collector's item as actual crystals.

Briefly, Elijah L. Hamlin and Ezekiel Holmes found a transparent green crystal near dusk in the late autumn of 1820 on the west facing slope of a small hill now known as Mount Mica. A heavy snowfall that night and subsequent snow cover prevented further examination of the site until the following spring when some thirty crystals were collected on the surface. Specimens sent to Yale University were identified by Professor Benjamin Silliman as tourmaline. Hamlin's description of additional specimens sent to Silliman in November of 1822 and belatedly published in what was popularly known then as "Silliman's Journal" (Hamlin, 1826) reveal Hamlin to have been a competent amateur mineralogist. Two years after the discovery Hamlin's younger brothers, Cyrus and Hannibal (later Vice President to Abraham Lincoln), made a crude blast and opened "a large cavity of two or more bushels' capacity" in the solid ledge.

News of the tourmaline discovery circulated rapidly in the scientific community via correspondence. Professors Thomas Nuttal, Charles U. Shepard and John W. Webster all visited Mount Mica at least once before Hamlin's notice was published in 1826. Shepard (Francis, 1974; Roe, 1975) later described Mount Mica as "a locality of minerals yielding in interest to none in North America, if we take into view the variety and richness of the specimens it has afforded in times past, or those which it still produces in the greatest abundance" (Shepard, 1830). The first specimens of tourmaline, quartz and lepidolite were found on the surface or by superficial digging. Just a few years later Shepard wrote, "these, however, have long since wholly disappeared; and the collector who is now in search of these minerals is obliged to lay open the solid rock by the aid of gunpowder . . . Mr. Chesley, with the same liberality which characterized his father while living, is always ready, in the most obliging manner, to promote the objects which the visitors of his place have in view; and for a very reasonable compensation is accustomed to undertake the necessary drilling and blasting." Would that all property owners were as obliging today!



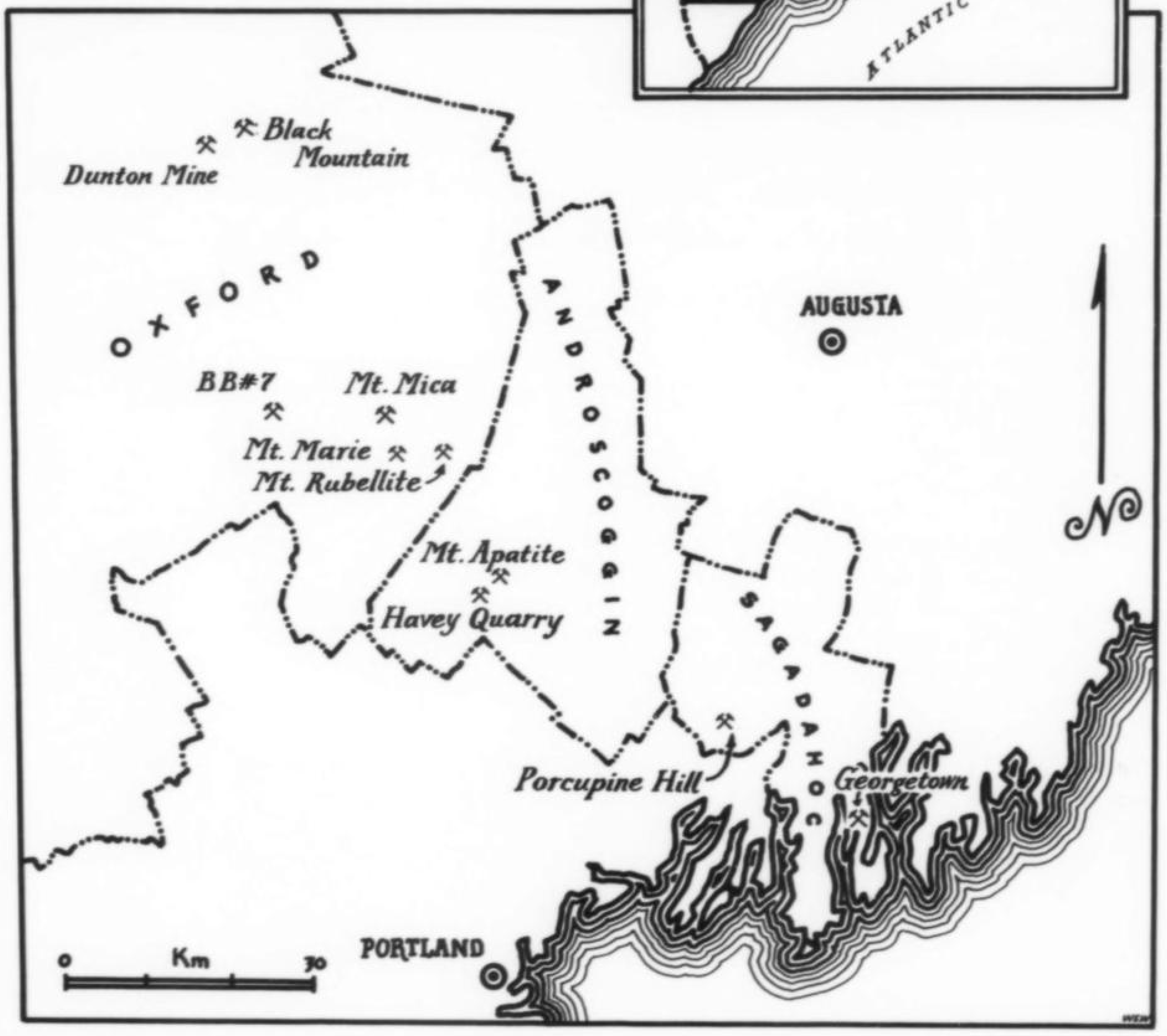


Figure 1. **Map of southwestern Maine showing the location of tourmaline pegmatites.**

The pocket that Shepard opened in September, 1825 produced a number of elbaite specimens of which he described seven in some detail. His somewhat awkward crystal drawings are based on actual goniometric measurements. The red and green "broaches" cut for Shepard by Messrs. Montanye & Mason, Lapidaries, 93 Reed Street, New York, must be among the earliest of our indigenous gemstones. Nearly 50 years later, George F. Kunz, America's great gem expert, praised them. "Some of the finest of the cut rubellites and green tourmalines are in the possession of Prof. C. U. Shepard and members of his family. One of the most magnificent known green tourmalines is . . . 1 inch long, ¾ inch broad, and 1 inch thick, and finer than any of the Hope gems" (Kunz, 1885).

Although unrecorded, other people undoubtedly visited Mount Mica from time to time. In 1863 Professor Sanborn Tenny of Williams College accidently discovered a small pocket containing several tourmalines. Samuel R. Carter of Paris, made extensive excavations the following summer without success. In 1866 a large cavity was opened by Bowker, the property owner. It was this discovery that probably motivated Augustus Hamlin, together with his father, to reinvestigate the locality in 1868. Until then all of the tourmaline pockets discovered were in a small open cut about 2 meters deep and 5 meters in length. Subsequent work by the Hamlins and others greatly enlarged the excavation. This period of activity (1868–1890) is here termed the "Hamlin Period" and a chronology of it, based largely on the somewhat contradictory data in *The History of Mount Mica,* is summarized in Table 1.

Table 1. **Chronology of the "Hamlin Period" at Mount Mica. The cavity numbers and plate numbers refer to *The History of Mount Mica* (Hamlin, 1895).**

1868	First cavity (no. 2) discovered by A. C. Hamlin. It contained smaller crystal in plate 6 (AMNH). Cavity no. 3 opened by father, E. L. Hamlin. A light green 6 carat oval gem now in the Hamlin necklace and two pendants of 5 carat are from these pockets (Hamlin, 1890).
1869	Cavity no. 5 opened by A. C. Hamlin; no. 6 by E. L. Hamlin.
1870	Cavity no. 7 yielded Hamlin and Prof. Joseph Leidy achroite of plates 8 (H88248) and 11 (owned by E. Schernikow c. 1895). Mica miners exposed cavities no. 9–12.
1871	Small cavity (no. 8) at a depth of about 2 meters contained only the crystal of plate 7.
1873	Cavity no. 18 discovered by Hamlin. A 9.15 carat light crimson rubellite oval cut and set with New Mexico turquoise (Hamlin, 1890).
1878	Cavities no. 14 and 15 blasted out by Bowker and Perry. A 3.6 carat pink tourmaline from this season is in the Hamlin necklace (Hamlin, 1890).
1879	Cavity no. 13 found by Hamlin produced the small etched green crystals in plate 20 (AMNH). A crystal section found in the soil is depicted in plate 12. Cavity no. 16 produced two crystals for Hamlin and Vaux. A grass green 28 carat gem cut by Samuel Reynolds of Boston considered one of three finest found and valued at $500 to $1000 (Hamlin, 1890).
1880	Cavity no. 27 yielded Bowker and Perry the prism section in plate 27.
1881	The Mount Mica Tin and Mica Company organized. Indicolite of plate 21 (H92102D) found by Hamlin's son F. C. Hamlin in cavity no. 17. Cavities 19 and 20 opened by Carter produced crystals of plates 15, 16, and 17 (AMNH).
1882	Cavity no. 21 opened by Carter. Kunz (1883) reported value of season's production as "something over $2000." A major exhibit of Mount Mica tourmalines held in September at Academy Hall in Paris.
1884	The mine was not operated. That summer the 1882 production offered for sale at Bar Harbor (Kunz 1885). The company's inventory of gemstones was valued at $2683 for the tourmalines ($10–$500 each) and $1062 for the beryls ($5–$50 each). Uncut specimens were valued at $400.
1885	Overburden removed June-August (Kunz, 1886).
1886	A large but poor cavity (no. 22) was opened by Carter in May. In September an important cavity (no. 23) discovered and represented by plates 14 and 30. The latter, 25 cm long and 5 cm in diameter, Hamlin (1895) considered "the largest transparent crystal of green tourmaline known." The central 34.25 carat pendent of the Hamlin necklace valued at $1000 came from this find. In October another important cavity (no. 24) represented by plates 18 and 19 was discovered. Kunz (1887) reported that the entire find of about 100 crystals would yield cut gems valued about $5000 and specimens valued at $1000.
1889	Gems from the 1886 discoveries exhibited at the World's Fair in Paris by Tiffany and Company.

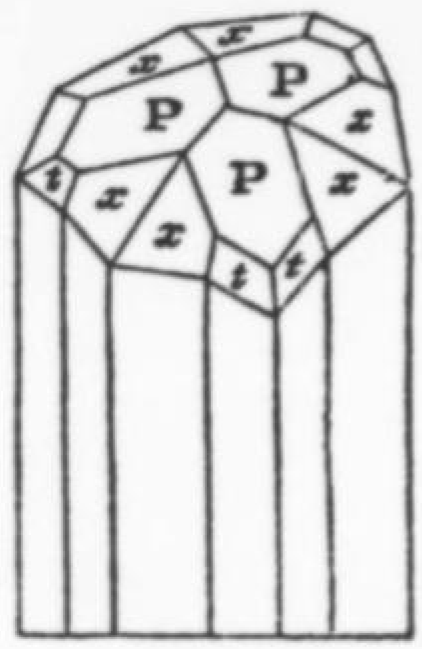


Figure 2. **Crystal drawing of Mount Mica elbaite by C. U. Shepard (1830).**

The substantial but irregular recovery of elbaite crystals led to the organization in 1881 of the Mount Mica Tin and Mica Company with A. C. Hamlin, the principal stockholder, as President and Samuel R. Carter as Superintendent. The company's activities and production are prominently mentioned in the early "Precious Stones" reports by George F. Kunz which appeared in the U.S. Geological Survey publication *Mineral Resources of the United States* beginning in 1882. A total of 27 pockets discovered during the Hamlin Period are described and located on a map in *The History of Mount Mica.* A quaint photograph showing two farmer-miners and the positions of numerous pockets probably dates from this time.

In 1890 the rights to operate Mount Mica were purchased by Loren B. Merrill and L. Kimball Stone from the Mount Mica Company initiating the "Merrill & Stone Period" (Table 2). In September 1891 Merrill and Stone moved the excavations eastward about 15 meters to the point of the original discovery. By May 1895 some 59 cavities had been opened in the new pit (Hamlin, 1895).

Merrill mined for about 25 summers at Mount Mica. Drilling the holes for blasting was done by hand and a one-horse windlass powered the derrick used to move the waste rock away from the working face and dump it in the abandoned workings. The pegmatite dips gently into the hillside so as mining progresses, the working face moves eastward, the thickness of the overlying schist increases and so does the cost of mining. Merrill ceased mining circa 1915. In his memorial of Merrill, Palache (1930) called "the cut on the top of Mount Mica and the great pile of waste taken from it . . . the best monument to his tireless energy."

The finest piece of gem rough mined by Merrill is a flawless green prism section that forms the end of a disintegrated crystal 20 cm long (Bastin, 1911). Palache (1930) soberly recalled the crystal:

> He kept in his possession for many years and to the end of his days a tourmaline crystal which he considered the finest he had ever found among the hundreds he took from the gem pockets of Mt. Mica. This crystal he had agreed to cut for the Harvard collection and a large price was agreed upon for the gem and the work. But he could not bring himself to cut it and I have before me his last letter to me in which he asked to be freed from his engagement as he feared the crystal might be shattered if cut in so large a form as we had planned.

After Merrill's death this specimen passed through Stanley Perham's hands. In the September, 1934 issue of Benjamin Burbank's short-lived *Maine Minerals,* it was illustrated and advertised for sale by the Stephen Varni Company, Inc. of New York with these words: "It would be a sacrilege for this tourmaline to be cut

Figure 3. **View of Mount Mica when the pocket zone was very near the surface. Markers indicate the locations of pockets. After Bastin (1911).**

Figure 4. **Loren B. Merrill posing in the largest pocket he ever excavated at Mount Mica (Bastin, 1911).**

Figure 5. **View of Merrill's operations at Mount Mica in November, 1908. Bottom, left of center is a large pocket (Bastin, 1911).**

up for jewelry, thereby destroying forever a splendid and historic specimen which should be kept intact in the State of Maine. Is there not someone in the State of Maine who will present it to one of her museums or put it in one of her fine collections?" The present whereabouts of this crystal section is unknown and it is presumed to have been cut.

Palache had undoubtedly hoped to match the large gem Merrill was to have cut with a remarkable specimen he'd previously purchased. This crystal was a gem nodule of 584 carats that can be fitted both to the termination and the lower prismatic section. There is a museum tradition that this was Merrill's "pocket piece," something that he frequently carried with him and probably used in the manner of a "worry stone." Such gem nodules are the very best of cutting rough, and apparently are unique to tourmaline. Neither quartz nor beryl, which occur with approximately the same frequently and abundance in the same geological environment, show such nodules nor does any other species known to the writer. Although gem nodules are found in tourmalines from around the world, no explanation of their genesis has been offered. The problem is not an easy one but some progress has been made by X-ray source-image distortion (SID) studies of tourmaline micro textures (Wagner *et al.*, 1971).

Mount Mica was sold in 1926 by Hamlin's heirs to the General Electric Company which in turn sold it to Howard Irish of Buckfield. Although the mine was not actively worked, its fame continued to draw collectors (e.g., Manchester and Bather, 1918; Cloud, 1934; Hoadley, 1935).

In 1949 the United Feldspar Company while mining "spar" at the northeast end of the pegmatite opened the third largest pocket (1.2 x 1.5 x 6.2 m) ever found at Mount Mica. Lacking elbaite it would have been described as barren by Hamlin or Merrill but, far from being barren it produced groups of distinctive, chisel-shaped albite crystals and perhaps the most morphologically interesting beryl crystals known. These crystals have such bizarre shapes that they were not initially recognized as beryl. A laboratory investigation by Hurlbut and Wenden (1951) established their identity and offered a fascinating explanation for their shapes. These are fragments of a large milky crystal that shattered. Subsequent overgrowth of colorless, alkali-rich beryl attempted to heal the irregular fracture surfaces. The resulting crystals are lustrous, asymmetric and bounded by faces that have such unlikely Miller indices as $\{33.11.\overline{44}.6\}$ and $\{19.4.23.4\}$.

Another important pocket beryl specimen was stolen from the mine. It was purchased for the Maine State Museum by the Federation of Maine Mineral and Gem Clubs when it appeared on the market in 1970. It is an impressive aquamarine crystal about 25 cm in diameter, 25 cm tall and 13.5 kg in weight. The prism faces are etched but the terminal pinacoid has a fine luster.

Frank C. Perham, of the well-known Oxford County pegmatite mining family (Dunn, 1975b), leased Mount Mica from Sarah Spencer, Howard Irish's widow, in 1965. That spring he began mining where Loren Merrill had quit 50 years before. On Sunday, June 6th, with several onlookers present, Perham opened and excavated a group of three, small, mud-filled gem pockets. A lively eyewitness account (Graves, 1967) and a later description by Stevens (1972) document this discovery.

The tourmalines were typical of the locality—color zoned, striated prisms about 2 cm in diameter that were completely shattered. Two reconstructed crystals were originally 12 and 20 cm long. From a section of the former a superb, green, heart-shaped gem was cut. At 50.59 carats it was regarded as the third largest gem from Mount Mica. A 25 carat square stepcut gem named the Rozek

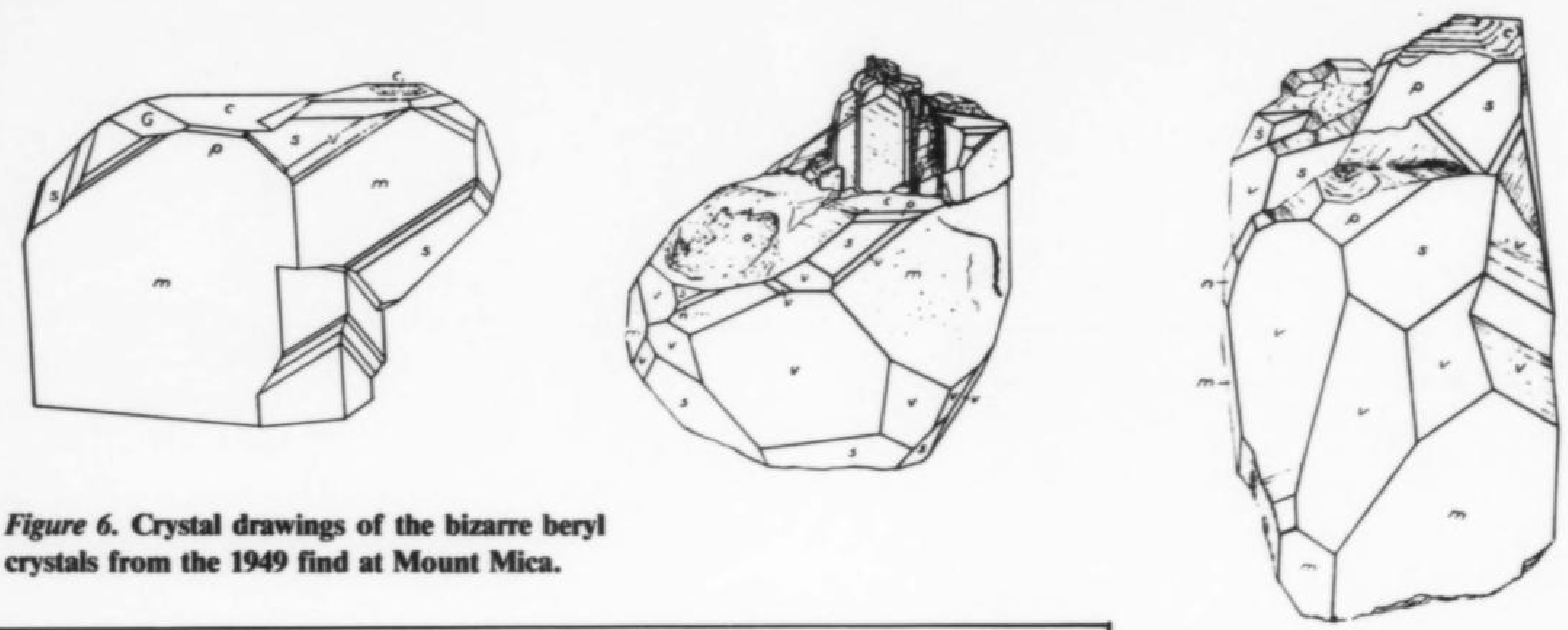


Figure 6. **Crystal drawings of the bizarre beryl crystals from the 1949 find at Mount Mica.**

***Table 2.* Chronology of the "Merrill Period" at Mount Mica.**

1890	L. B. Merrill and L. K. Stone purchased rights to operate Mount Mica (and Mount Rubellite) from the Mount Mica company (Bastin, 1911) and recovered "over $2000 worth of fine gems" (Kunz, 1892b).
1891	In June a cavity (no. 26) containing more than 30 indicolites including the crystals in plates 26–29 was found. A new pit about 16 meters to the east was begun in September where the green crystals in plates 33 and 37 were found. In October the crystals in plates 31 and 32 were collected. The curved crystal in plate 34 also found.
1892	Work resumed in May. Many pockets proved barren. The crystals in plates 35 and 36 were discovered in July and those in plate 33 in September.
1893	Plates 38–40 depict crystals found in June. An important find made in November yielded the crystals in plates 41–43. A flawless green gem of 63.50 carats cut from this material was sold to the Tiffany Collection. The value of the production was estimated at $3,000 (Kunz 1894).
1895	Fifty-nine cavities, many of them barren, had been opened in the new pit prior to May (Hamlin, 1895).
1896	In August a 5 x 7 x 18 cm green crystal was discovered and sold for an outrageous $300 to Harvard (H88250).
1900	"The results of the mining . . . were not as extensive as those of previous years." (Kunz, 1901).
1904	June pockets described by Bastin (1911) yielded large compound crystal (H119777).
1905	Numerous pockets including one 1 x 2.5 x 3 meters opened. Elbaites mostly small and pale green (Kunz, 1906).
1908	The dimensions of the pit in November were 6 x 15-30 x 45 m (Bastin, 1911).
1910	The pit was about 10 m high and 90 m long by July visit of W. H. Emmons.
1913	No work in progress during June visit of Sterrett (1914).
1914	Four months work produced only one pocket containing a few green crystals (Sterrett, 1916).
1915	Worked about four months (Manchester and Bather, 1918).

Tourmaline and eight somewhat smaller stones in heart, rectangular and tear shapes were also cut from this material. Specimens from this find can be viewed in the museum section of Perham's Maine Mineral Store at Trap Corner in West Paris.

Perham renewed his lease and returned to mine Mount Mica in 1966 but his initial success was not repeated. One small tourmaline cavity was found but the crystals were too dark to warrant cutting (Stevens, 1972).

The property was purchased from Mrs. Sarah Spencer by the Mount Mica Land Company in the spring of 1973. That summer an enormous bulldozer was used to push Merrill's dumps away from the outcrop at the southern end of the pegmatite. The northern end where feldspar was mined in the late 1940s was also cleaned up. Frank Perham did the mining with the assistance of Leonard Pearson and James Archer. In 1976 Rene Dagenais of South Paris took over the mining. He was assisted by Irving Groves of Poland and Dwight Mills of Bryant Pond. Some mining took place each summer from 1973 until 1979 in what almost seemed like a return to the turn-of-the-century "Merrill Period." Pockets were encountered regularly but some seasons were more productive than others. Dean McCrillis summarized it as a "nip and tuck" operation with sales only just repaying mining costs.

In 1976 the "tangerine pocket" yielded two dozen small but superb gemmy crystals that sold quickly at Tucson the following winter. Dagenais mined the Bowker rose quartz prospect the following summer producing several schorl specimens mentioned below. In 1978 in a grapefruit-sized cavity, Dagenais, like Merrill, found a particularly memorable piece of cutting rough. From it Arthur Grant of Hannibal, New York, faceted the magnificent 256 carat flawless blue-green gem (illustrated in Bancroft, 1984, p. 12) which is four to five times larger than the previous "biggest-best" gems (all green) from this locality. One of the many pockets found in 1979 contained a crystal whose habit is reminiscent of the great compound crystal found by Merrill in June, 1904. As mining was beginning to wind down that fall another giant pocket, the "Dagenais" pocket, was breached.

The Dagenais pocket proved to be the largest (4 x 5.5 x 16 m) yet encountered at Mount Mica. It was a collapsed and mud-filled cavity that required two months to excavate (Perham, 1980). Being open that long, many who had never before had an opportunity to see a gem pocket were able to examine a colossal one. The visitors included a Harvard mineralogy class, and the author brought along

Figure 7. **Elbaite (9.5 cm tall) reminiscent of the large compound crystals from Merrill's June 1904 pocket. Mined at Mount Mica in 1979 from where the tractor in Figure 8 is sitting.**

Figure 8. **The Mount Mica pegmatite and overlying schist in late autumn 1979. Portal of "Dagenais" pocket is behind tractor's bucket. Author's photograph.**

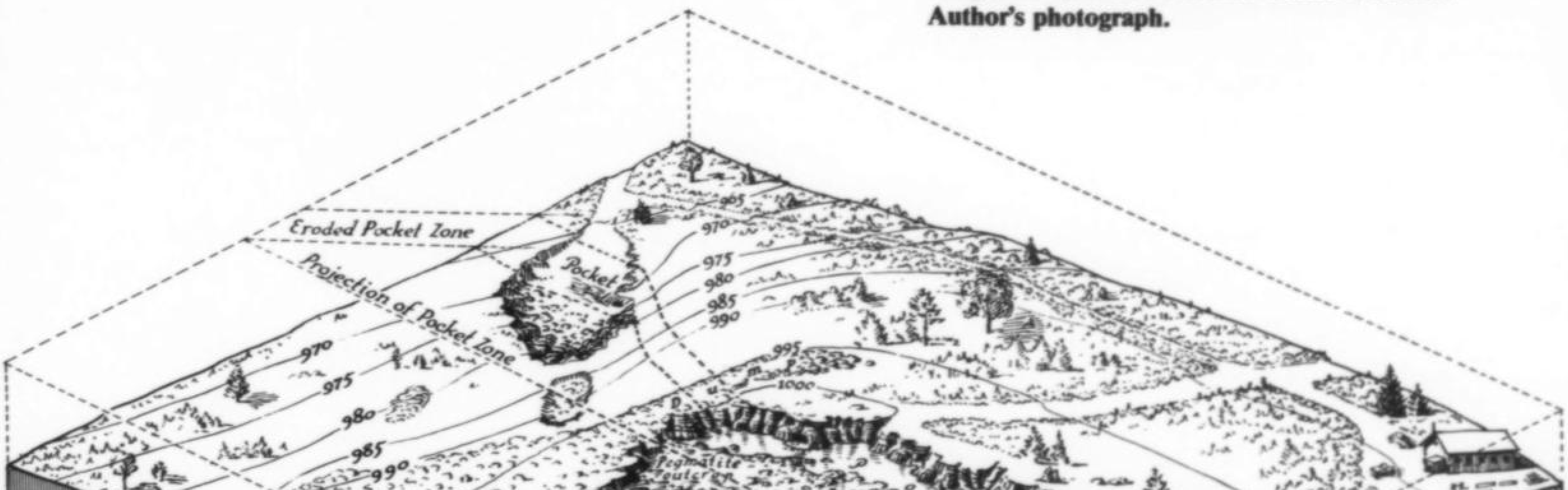


Figure 9. **Block diagram depicting the geology of Mount Mica after Hurlbut and Wenden (1951).**

Table 3. **Minerals from Mount Mica, Oxford County.**

Species	*Formula*	*Notes*
Albite	$NaAlSi_3O_8$	Lamellar "cleavelandite" habit abundant in the pocket-bearing zone. Uncommon as specimens except as matrix of other species. Chisel-shaped crystals to 5 cm from large 1949 pocket (H108565).
Almandine	$Fe_3Al_2(SiO_4)_3$	Trapezohedra rimmed by indicolite characteristic of "garnet line" at base of pocket-bearing zone (H125864).
Arsenopyrite	FeAsS	Easily mistaken for loellingite but included by Winchell (1938) on the basis of a closed-tube test for sulfur.
Bertrandite	$Be_4Si_2O_7(OH)_2$	Colorless plates with siderite (Winchell, 1938).
Beryl	$Be_3Al_2Si_6O_{18}$	Occurs in both solid pegmatite and pockets. A notable occurrence in the 1949 pocket.
Biotite	$K(Mg,Fe)_3(Al,Fe)Si_3O_{10}(OH,F)_2$	Common in the wall and outer intermediate zone (Thomssen, 1981).
Brazilianite	$NaAl_3(PO_4)_2(OH)_4$	S. A. Williams identification in Thomssen (1981).
Cassiterite	SnO_2	Iridescent, black twinned crystals from the pocket zone (H125868).
Cookeite	$LiAl_4(AlSi_3)O_{10}(OH)_8$	White to golden micaeous coatings on elbaite in pockets with quartz. Type locality (Brush, 1866).
Elbaite	$Na(Li,Al)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$	Crystals both in solid pegmatite and free growing (but often broken) in cavities (Hamlin, 1895).
Ferrocolumbite	$(Fe,Mn)(Nb,Ta)_2O_6$	Black, tabular crystal in microcline (P. Cerny, pers. comm.) (H121044).
Fluorapatite	$Ca_5(PO_4)_3(F,OH)$	Blue crystals dominated by third order dipyramid (Dana, 1884); 1 cm prismatic crystal on albite from 1949 cavity (H125875).
Graphite	C	Black with elbaite and cookeite (Winchell, 1938) (H125876).
Hydroxyl-herderite	$CaBe(PO_4)(OH)$	Golden on smoky quartz (Stevens, 1972) (H102316); white, twinned crystals on quartz from 1979 pocket.
Loellingite	$FeAS_2$	White metallic masses, with indicolite (H125884).
Lepidolite	$K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$	Fine grained, micaceous, purple. Characteristic of pocket areas. Also as pseudomorphs after elbaite.
Mangancolumbite	$(Mn,Fe)(Nb,Ta)_2O_6$	Black mass with red rim against lepidolite (P. Cerny, pers. comm.) (H87822).
Microcline	$KAlSi_3O_8$	A principal constituent of the sill. Euhedral crystals in pockets (H125943).
Montebrasite	$LiAl(PO_4)(OH,F)$	Opaque white masses (H60481-2) and crystals to 15 cm (Brownlow Thompson collection).
Montmorillonite	$(Na,Ca)_{0.33}(Al,Mg)_2Si_4O_{10}(OH)_2nH_2O$	Pinkish clay mineral from cavities (H125885).
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	Abundant in several zones. Also in crystal cavities (H125863).
Palermoite	$(Li,Na)_2(Sr,Ca)Al_4(PO_4)_4(OH)_4$	S. A. Williams identification in Thomssen (1981).
Pollucite	$(Cs,Na)_2(Al_2Si_4)O_{12}H_2O$	Somewhat altered, granular, vitreous masses (H125887-9).
Pyrite	FeS_2	Anhedral masses, uncommon (Winchell, 1938) (H125890).
Quartz	SiO_2	Abundant in most zones. Crystals very common in cavities (H125945), also rose colored crystals (H125891).
Siderite	$FeCO_3$	Replacement of triphyllite.
Schorl	$NaFe_3^{+2}Al_6(BO_3)_3Si_6O_{18}(OH)_4$	Common iron-bearing accessory. Crystals may reach a meter in length (H125034-5).
Spodumene	$LiAlSi_2O_6$	Pinkish cleavages (H125899-901).
Tantalite	$Fe(Ta,Nb)_2O_6$	Specimens in Brush collection, Yale University from L. K. Stone described by Warren (1898).

and displayed on the dump the Hamlin necklace (Stevens, 1972) so that the students might fully appreciate the gem potential of the pocket they'd just seen. Curved, yellow-green elbaite crystals with a waxy appearance suggesting incipient alteration (Harvard collection no. 117387) were found at the entrance and a very large compound crystal was discovered in the rubble on one side of the pocket. Unfortunately, it was much too dark to cut. Lepidolite had replaced another big tourmaline crystal which is described further under pseudomorphs. Rusty, translucent quartz crystals were so abundant and often so large and unwieldly that John Marshall remarked, "The collectors won't even steal them!" If the pocket can be said to have held a prize, it was the three etched beryl crystals. The largest (14 x 20 x 26 cm) is comparable to the Maine State Museum specimen. It is incomplete with only three of the prism faces preserved. It contains a gemmy core of tawny morganite that is overgrown with a fev centimeters of palest aquamarine. This specimen was presented to the Harvard Mineralogical Museum by Nina C. Bushnell in 1982. The smaller (8 cm diameter), more complete crystals lack the morganite zone. Littered about the entrance to the pocket and on the nearby dump were albite crystals, almandine, cookeite pseudomorphs, hydroxyl-herderite twins on quartz, masses of lepidolite, loellingite, large diamond-shaped muscovite books, and quartz crystals which were collected by the writer without much effort.

Mount Mica, of all of Maine's pegmatites, has the greatest potential for additional production of crystals and gemstock but now lies idle because of the economic uncertainties of mining.

The rudiments of the geology of Mount Mica are well known (Bastin, 1911). The pegmatite is a sill of undetermined thickness that strikes N 50 to 60° E and dips 20 to 30° SE. The contact with the overlying schist is sharp and conformable with an abundance of almandine in the schist near the contact. The pocket-bearing portion, a pervasive but irregular layer varying from 0.2 to 2 meters thick, lies near the top of the sill and was exposed at the surface accounting for the deposit's early discovery and development. A curious horizon characterized by numerous small garnets is observed both here and in the Pulsifer pegmatite on the west side of Mount Apatite. This feature is locally known as the "garnet line" and is believed to mark the base of the pocket bearing zone. Mining ceases when the garnet line is reached.

Mount Mica is so closely identified with elbaite that most collectors don't own and can't even recall specific specimens of other species from this famous locality. Good to fine cabinet specimens of elbaite, beryl, cassiterite, fluorapatite, hydroxyl-herderite, quartz and schorl are in the Harvard University Collection. Table 3 summarizes the mineralogy in more detail but no comprehensive modern mineralogical study (i.e., since the widespread availability of X-ray powder diffraction apparatus) has been made of Mount Mica or any of Maine's other gem pegmatites except the Dunton mine (King, 1975). This list is probably complete for the most abundant minerals of the pegmatite. Work on the niobium-tantalum oxides is in progress but the secondary phosphates and pocket clays are yet to be investigated.

Mount Rubellite, Hebron, Oxford County

The unusual minerals found at Mount Rubellite in Hebron attracted the early attention of Professor G. J. Brush of Yale's Sheffield Scientific School. Papers on "amblygonite" (= montebrasite) (Brush, 1862), the first North American occurrence of "childrenite" (= eosphorite) (Brush, 1863; Cooke, 1863), the new species cookeite (Brush, 1866; Penfield, 1893), "herderite" (= hydroxyl-herderite) (Wells and Penfield, 1892; Penfield, 1894) and the second world occurrence of pollucite (Wells, 1891) by Brush and his colleagues may have done more to establish Mount Rubellite's reputation as a mineral locality than did its actual production of gem tourmaline.

Hamlin (1873) credits Luther Hills, "an itinerant lecturer and strolling preacher," with the discovery of this pegmatite. Apparently Hills observed a boulder of lepidolite on a stone fence, recognized its unusual nature, and traced it to its source on a nearby hillside.

Bastin (1911) states that the locality "was formerly worked to a slight extent for its gems and rarer minerals by Augustus Hamlin, of Bangor, and Loren B. Merrill, of Paris. The pegmatite resembles in a general way that at Mount Mica, but has yielded few pockets, Mr. Merrill reporting the occurrence of only three or four, one of which was about 18 inches deep, 3 feet wide and 6 feet long" (0.5 x 1 x 1.8 m). The recovery of some "exceptionally fine gem pink tourmaline crystals and some green crystals" that Merrill faceted into gems is mentioned by Stevens (1972). The pink 13.2 mm diameter stone to the left of the central pendant in the "Hamlin necklace" is described by Hamlin (1890) as being a 7 carat "rose tourmaline . . . changed by heat from a smoky brown" that was mined at Hebron in 1891.

Following the period of general inactivity coinciding with World War I, pegmatite mining resumed in Maine during the 1920s, partly for feldspar and partly in response to a demand for pollucite created by the improved efficiency of cesium filaments in radio vacuum tubes (Fairbanks, 1928). The occurrence of pollucite is restricted to lithium-rich pegmatites. Consequently, the gem-pegmatites of Oxford County were reexamined and specimens of rare minerals, a normal byproduct of pegmatite mining, again became available.

Professor Palache of Harvard University obtained numerous fine specimens from William D. Nevel of Andover including several from Mount Rubellite. In a letter dated December 6, 1927 Nevel offered Palache specimens of cookeite and elbaite:

Dear Dr. Palache:

The G. E. Company permitted Mr. Merrill to work the Hebron mine two weeks this Fall at his request. He worked there last year but found nothing of value. Just before snow came he opened a small cavity that produced a few matrix specimens. I picked out ten of these last week and I must say they are the finest for their kind I have seen from Maine. The material is mostly cookeite with some small qtz. but they are so clean and the cookeite so white and silvery that they are wonderfully pleasing and the small Xls. of bright but broken tourmaline and the rich flecks of lepidolite make them well worthy of examination even where one has an absence of tourmaline. From the ten I selected I have discarded three and I would be glad to mail these seven to you at practically Mr. Merrill's prices which were $1.50 to $3.00. I have added just enough to cover postage. I told him I would submit his prices to you. I think you will not regret having them sent. They are beautiful. May I have your permission?

[Signed] W. D. Nevel

As Nevel had anticipated, Palache did not regret the offer. Three specimens of cookeite incrusting green and watermelon tourmalines were acquired (H90163). However, neither Nevel nor Palache could have foreseen that after almost seventy years of mining at Mount Rubellite the best was yet to come. almost exactly a decade later, on May 4, 1938, Nevel penned a letter to W. E. Richmond, Palache's student assistant, that would quicken the heart of any collector or curator:

Dear Mr. Richmond,

I've put in so much on the mineral stock that I have responded to a strong urge of a day or two and want to attempt to sell, if I can, the suite of 3 tourmaline xls. we found at Hebron four years ago. These are the best ever found there. They turned up the third (last) year it was worked. I sunk a lot there and am sure nothing but a WPA can ever work it again. These crystals, at least the large one, is also better than anything found at Mt. Mica during the last number of years it was worked. Think it was back in the '90s when anything comparable was last found. The large one nearly 3" long shows 3 or 4 color changes and in central section has a clear area that should yield an 80 ct. flawless stone. The middle size shows a larger proportionate area of clearness and the small one is about all clear as I remember. They are over to the house in safe but can have them mailed on approval if you have any interest in examining them. I know that tourmalines are not and have long ceased to be, the rare bird of years ago but these xls are really extraordinary. There is nothing so clear in the Havey suite as even the middle size. Had that they should bring $300 without the feeling of profiteering coming in to the transaction but these are not good times and if you care to look them over I would like to have you appraise them. Could you please let me know as soon as possible and oblige.

Yours very truly,
[Signed] W. D. Nevel

Outside of the knowledge of the man working for me at Hebron and one or two local parties I've never made known the find.

Professor Palache promptly offered $150 for the larger crystal and $50 for each of the smaller ones (Fig. 12). On May 16, 1938 Nevel accepted. His reply reads in part, "I consider Dr. Palache's valuation of the crystals most liberal. To retrieve at this particular time a large portion of the loss I sustained at Hebron is extremely satisfying."

Nevel must have been satisfied indeed for he then offered to complete the cutting of a green nodular crystal fragment from the same pocket and to sell it to Harvard to add to the Hebron suite for the $2.00 per carat cost of cutting! This 27.75 carat cushion cut stone (H94102) is certainly one of the local prizes in the Harvard gem collection. It and the aforementioned rubellite in the Hamlin necklace are the only faceted elbaites from Mount Rubellite known to the writer.

The most recent mining attempt was made in the upper pit during the summer of 1980 by the Plumbago Mining Corporation. A single pocket containing a couple of handfuls of small, colorless quartz crystals (H123913) was the meager reward for their efforts.

Specimens from Mount Rubellite were never abundant and are hardly ever seen in contemporary collections. Representative suites are to be found among the collections of Harvard and Yale Universities, the American Museum of Natural History, and the U.S. National Museum.

Mount Marie, Paris, Oxford County

There are numerous small openings on Little Singepole Mountain in the southeastern part of Paris (Cameron *et al.*, 1954). The single lithium-bearing pegmatite on Little Singepole is located on the eastern knoll known as Mount Marie. According to Stevens (1972) the locality yielded a "powder keg full of gem tourmaline" that was sold to Loren Merrill. Ownership was acquired by Harold C. Perham in the late 1920s and then passed to the United Feldspar and Minerals Company in 1940. It was operated for feldspar in 1948 by the Pechnik brothers. That summer a pocket containing beryl, "a pint of broken pink, blue and green tourmaline crystals," and smoky quartz crystals was opened on a field trip of the Oxford County Mineral and Gem Association.

James Mann of Bethel mined Mount Marie during the summers of 1974 to 1976. A suite of his specimens preserved in the Harvard Mineralogical Museum includes albite, almandine, beryl, cassiterite, cookeite, elbaite, purple fluorapatite, lepidolite, muscovite, petalite, and a superb scepter quartz crystal. The elbaite is corroded with only small green and red fragments remaining (H124439).

A thumbnail-size crystal of elbaite—green with an intense red cap—from Philip Morrill's collection of gem minerals (H122387) labeled "Little Singepole Mountain, Hebron" is so similar in its coloring to the crystals mined by Nevel at Mount Rubellite that it causes one to question the veracity of its label, but this is a familiar curatorial dilemma.

Mills Quarry, Hebron, Oxford County

In 1901 the Mount Marie Mining Company began operations for feldspar on the north slope of No. 4 Hill in Hebron (Bastin, 1911). Although both pits were abandoned when Bastin visited the pegmatite in 1906, several pockets were exposed in the larger pit where a few transparent tourmalines of gem quality had been found during the mining operations. The Mills quarry was again worked in 1911 but no mention of it is made by Cameron *et al.* (1954) or Stevens (1972) and specimens are almost never encountered in collections.

Mount Apatite, Auburn, Androscoggin County

Mount Apatite, a hill in the western part of the city of Auburn, is a bona fide topographic term that, unlike the names Mount Mica and Mount Rubellite, does not uniquely specify a single quarry or even a single pegmatite. The old Hatch farm on the east side of Mount Apatite is the site of the earliest tourmaline discoveries and of the principal feldspar quarries. To the west of the present-day Hatch Road is the old Pulsifer farm where several small quarries were opened on a single, shallow dipping pegmatite sill. The best known of these is the Pulsifer quarry, famous for its royal purple fluorapatite crystals.

Although State Geologist Charles T. Jackson added specimens of tourmaline from Auburn to the state collection in 1839 (Stevens, 1972), Hamlin (1873) and most subsequent authors (e.g., Kunz, 1884; Bastin, 1911) credit Luther Hills with the recognition in 1868 of a curiosity on the mantle of a Minot home as a specimen of green tourmaline and the discovery of its source on the Hatch farm. The initial exploration by Hamlin on the Hatch farm produced little and was abandoned. Nathaniel H. Perry of South Paris first found elbaite in place on Mount Apatite in 1883. Nearly 1500 pale colored crystals were collected from a 3 x 3 x 7 meter pit near the Hatch farmhouse. "They differ in general appearance from the other Maine tourmalines, and are as a rule somewhat lighter in color and of more brilliant polish. They are found colorless, light pink, light blue, light puce colored, bluish pink, and light green, and at times nearly all these colors are found in one crystal" (Kunz, 1884).

In 1884 G. C. Hatch and Thomas F. Lamb of Portland found "much darker material . . . especially the green colors, some of which equals anything found at Mount Mica" (Kunz, 1885). Their production for 1886 was valued at $500 (Kunz, 1886). In the fall of 1887 "$200 worth of tourmalines and $400 worth of other minerals were found" (Kunz, 1888). "The operations carried on by private parties yielded during 1890 about $1,000" (Kunz, 1892a). In 1891 the Mount Apatite Mining Company was organized and that summer mined "a large quantity of material in the form of mineral specimens, but few gems of any value" (Kunz, 1892a).

The Maine Feldspar Company opened quarries on the Hatch farm in 1902 to supply feldspar to their mill at Littlefield Station where the feldspar, actually an intergrowth with quartz known as graphic granite, was ground and then shipped by rail to potteries at Trenton, New Jersey and East Liverpool, Ohio. At the time of Bastin's visits in 1906 and 1907 the workings comprised numerous small pits averaging 6 meters wide, 3 to 7 meters deep, and 25 to 35 meters long. Feldspar production from Mount Apatite continued into the 1930s eventually resulting in the excavation of the large Greenlaw, Maine Feldspar and Smith quarries at the east end of the summit.

Bastin (1911) observed that pockets are "of rather rare and irregular occurrence and are found only in the coarser portions of the deposit." None have been well documented (e.g., Stoddard, 1922) but Mount Apatite's largest pocket of gem tourmaline is notorious for being blasted to smithereens in 1927 by feldspar miners who didn't want to be inconvenienced by the delays of excavating a "worthless cavity of quartz crystals" (Szenics, 1968; Stevens, 1972). That pocket contained a wealth of tourmaline, tiny shards of which could still be found in the dirt on the opposite side of the Maine Feldspar quarry in June, 1983.

Pitt P. Pulsifer opened a quarry on his farm in 1901 and there discovered the "royal purple" fluorapatite crystals first described and figured by Wolff and Palache (1902). Pulsifer must have been a disciplined man for mining would commence after haying season and would abruptly cease when one hundred dollars was spent (Stevens, 1972). After three seasons the mine was leased to William Rogers Wade's Maine Tourmaline Company for ten years. In August, 1906 Bastin (1911) found two pits, the original Pulsifer quarry (3 x 8 x 8 m) and the Wade quarry (8 x 10 x 25 m). The more westerly Wade quarry, which was apparently only worked in 1904 and 1905 (Wade, 1909) is now a shady goldfish pond dwarfed by the adjacent Pulsifer quarry which was much enlarged in 1966 and 1967 by Terry Szenics and Frank C. Perham (Szenics, 1967, 1968). The apatite and tourmaline pockets found at this classic locality were reviewed by Wilson (1977) and no discoveries have been made since.

The Keith quarry is located east of the Pulsifer on the same pegmatite. It was opened in April of 1907 by John Seaver Towne of Brunswick and operated for feldspar by the Maine Feldspar Company. Towne handled the sale of specimens and gem material. By October of 1907 two cavities had been found. One bore dark grass-green tourmaline, the other light green elbaite tipped with thin opaque pink caps (Bastin, 1911). A good suite of these distinctive crystals is preserved at the American Museum of Natural History (A12327-31). In 1912 Palache purchased from Towne four specimens of pencil-like green elbaite attached to quartz crystals. One is now in the James Mann collection and a similar specimen is in the collection of Raymond Woodman of Auburn. These are among the very few cabinet-size matrix specimens from Mt. Apatite known to the author. Another hand specimen from Towne clearly illustrates the paragenetic sequence cleavelandite + lepidolite matrix → green elbaite + quartz pocket crystals → a cookeite coating → glassy, colorless hydroxyl-herderite crystals (H62492A). Several exquisitely beautiful specimens in miniature to micro sizes are labeled Moulton mine, which is synonymous with the Keith quarry. These etched, blue-green crystals are still partially encased in molds of pocket clay (H105191, 124437). Topaz, which is generally rare in Maine pegmatites, was encountered by Towne in at least one tourmaline pocket (H90571). A unique 43.75 carat gem cut from this find was sold to the U.S. National Museum (S2047) (Nevel, 1928).

Martin L. Keith, a prominent gemcutter from Auburn, purchased the quarry from Pulsifer in June, 1916 and worked it sporadically until his death in 1948. He opened two outstanding tourmaline pockets that yielded an estimated 10,000 carats of green and pink gemstock in June, 1917 (Stevens, 1972). The quarry was studied in the late 1930s by John B. Hanley (1939) whose map shows two pits. The smaller and more easterly may be the one Morrill (1959) referred to as the Fisher quarry. Mr. and Mrs. Irving Groves of Poland purchased the quarry from the Keith heirs in 1970. "Duddy" Groves and Frank Perham, dubbing themselves the "Destitute Mining Company," cleaned out the pit in October, 1971 and on the 27th opened a pocket containing blue-green and lilac zoned elbaites, light purple and yellow fluorapatite, and hydroxyl-herderite (Stevens, 1972).

Despite some distinct differences in the pocket minerals from quarry to quarry, the overall mineralogy of the Pulsifer pegmatite seems well established. The species are: albite, almandine, beryl, biotite, cassiterite, cookeite, elbaite, ferrocolumbite, fluorapatite, gahnite, hydroxyl-herderite, lepidolite, lithiophilite, microcline, montebrasite, montmorillonite, muscovite, quartz, schorl, topaz and triplite.

Havey Quarry, Poland, Androscoggin County

A feldspar quarry variously known as the Berry, the Havey, or the Berry-Havey quarry is located in Poland just across the Androscoggin River from Mount Apatite. It was opened in 1900 by A. R. Berry and was operated for feldspar which was sold to the Maine Feldspar Company mill at Littlefield Station 4.8 km away. The following clipping from the *Lewiston Journal* is copied from the 1904 prospectus of The Maine Tourmaline Company.

> Mr. A. R. Berry of East Poland, who is mining a large amount of feldspar, opened a pocket of herderite last week worth perhaps a hundred dollars. Mr. Berry also finds many beautiful gem tourmalines both green and pink. He has had a number cut and they are beauties. The valuable gem mines of Maine are paying better than many of the great puffed-up western gold and silver mines are.

In 1906 the "quarry" comprised numerous shallow irregular pits that covered an area of two acres. The occasional occurrence of pocket minerals including green and pink elbaite, purple fluorapatite and hydroxyl-herderite as well as beryl, montebrasite and schorl from the solid pegmatite is reported by Bastin (1910, 1911).

The mining rights to the adjoining Brown Farm were leased in 1902 by Forrest L. Havey. In 1910 he purchased the property and, employing a gang of ten to twelve Italian laborers, reopened his earlier excavations. In late August three pockets were opened that contained a total of 8,000 carats of elbaite crystals. "Chance blast reveals $100,000 in gems and makes tourmaline mine treasure store" shouted the *Boston Sunday Post* of September 4, 1910. Based on correspondence with George R. Howe of Norway, Sterrett (1911) reported, "The features of these tourmalines are the predominance of green and the fine quality and clearness of the gem material. Of a representative collection containing 108 crystals, chosen from the output of the mine, 98 crystals are of gem quality and weigh 3,231 carats. It is estimated that this should yield 1,000 carats of cut gems." Additional pockets were found in 1911 and 1912. Sterrett (1913) recorded, "Mr. Havey reports a production of 25,000 carats of fine green crystals, which it is estimated, will cut into about 7,000 carats of gems." The phrasing suggests that 25,000 carats is the cumulative total for the three years and that little or none of it had been cut. What has become of this material is something of a mystery. Nevel in the previously quoted letter of May, 1938 spoke of the "Havey suite" in the present tense. Exactly three years later Harvard purchased from M. Sutherland (a jeweller?) of Portland four crystals at $2 per carat and a 2-carat gem at $10. Comparable material was not located in any of the collections examined by the writer.

Professor Palache visited the locality in 1911 and obtained a small suite of phosphates reminiscent of the assemblage from Branchville, Connecticut, which was later investigated by Berman and Gonyer (1930). The described species, listed in paragenetic order, are: montebrasite, lithiophilite, rhodochrosite, quartz, eosphorite, reddingite, dickinsonite, fairfieldite, fluorapatite and the new mineral landesite. The quarry, mapped in 1942 (Cameron *et al.* 1954), is now owned by Terry "Skip" Szencis, who mined the nearby Pulsifer quarry with spectacular success in 1966 and 1967. Small pink and blue-green elbaite crystals were collected here by Szenics in 1977 (H119342).

Norway, Oxford County

Kunz (1883, 1888 and 1892) mentioned Norway as a source of colored tourmalines. These are, apparently, references to Tubbs Ledge which is 2 kilometers northwest of Norway village. Bastin (1911) describes it as "a pegmatite mass which has been blasted at several localities in a pasture" and further remarks that "the presence of lepidolite, colored tourmalines, and cleavelandite shows that the locality is a favorable one for further prospecting for gem tourmalines." In 1973 Jim Mann collected specimens of albite, elbaite, lepidolite and schorl from the ledge. Today Tubbs Ledge has a house built on it.

Of far greater importance but not widely appreciated is the tourmaline pocket found at the BB #7 quarry in Norway on August 13, 1954. This pocket, known as the "Friday the 13th Pocket," was discovered during feldspar operations by Stanley I. Perham and is unusually well documented by his daughter Jane (Stevens, 1972) who was present and vividly recalls the excitement surrounding "the removal of between eight and ten thousand carats of gem quality green tourmaline crystals." In addition, a "substantial amount of indicolite" and a few pink (nongem) tourmaline crystals were found.

Many of the green crystals were terminated, the longest being 7 cm. The largest gem crystal was found in two sections and weighed 27.5 grams. Four fine green gems weighing 43.13 carats were cut from it. The largest, a 23.67-carat triangular stone, was set in a pendant. It and a necklace made with 18 heart-shaped gems of 2 to 5 carats each are illustrated in Stevens (1972).

The pocket was found behind a single book of muscovite "five feet square" and beneath a schorl crystal "two and one half inches thick and three feet long"! The other species mentioned by Stevens: albite, almandine, botryoidal beryllonite (hydroxyl-herderite?), cassiterite, columbite, cookeite, lepidolite, pollucite and quartz are typical of lithium-rich pegmatites in Oxford county. A small suite of pocket material is preserved in the collections of the American Museum of Natural History (A23644-5). Matrix specimens are exhibited at Perhams, and others might be available for sale.

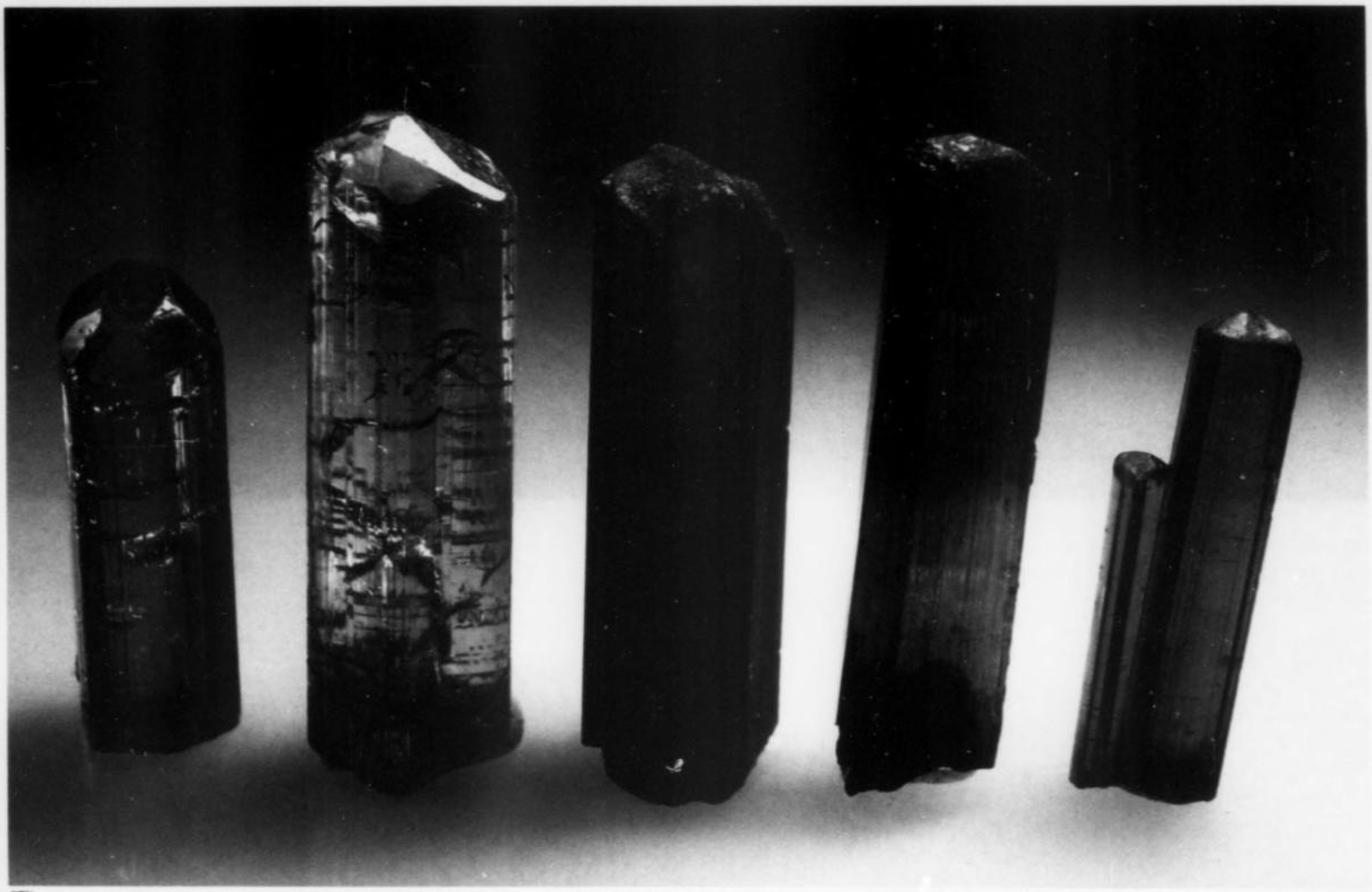


Figure 10. **Suite of elbaite crystals from Mount Mica (*left to right* S. Pelles collection, H126025A, H126026 (4 cm tall), H119529, and H126027).**

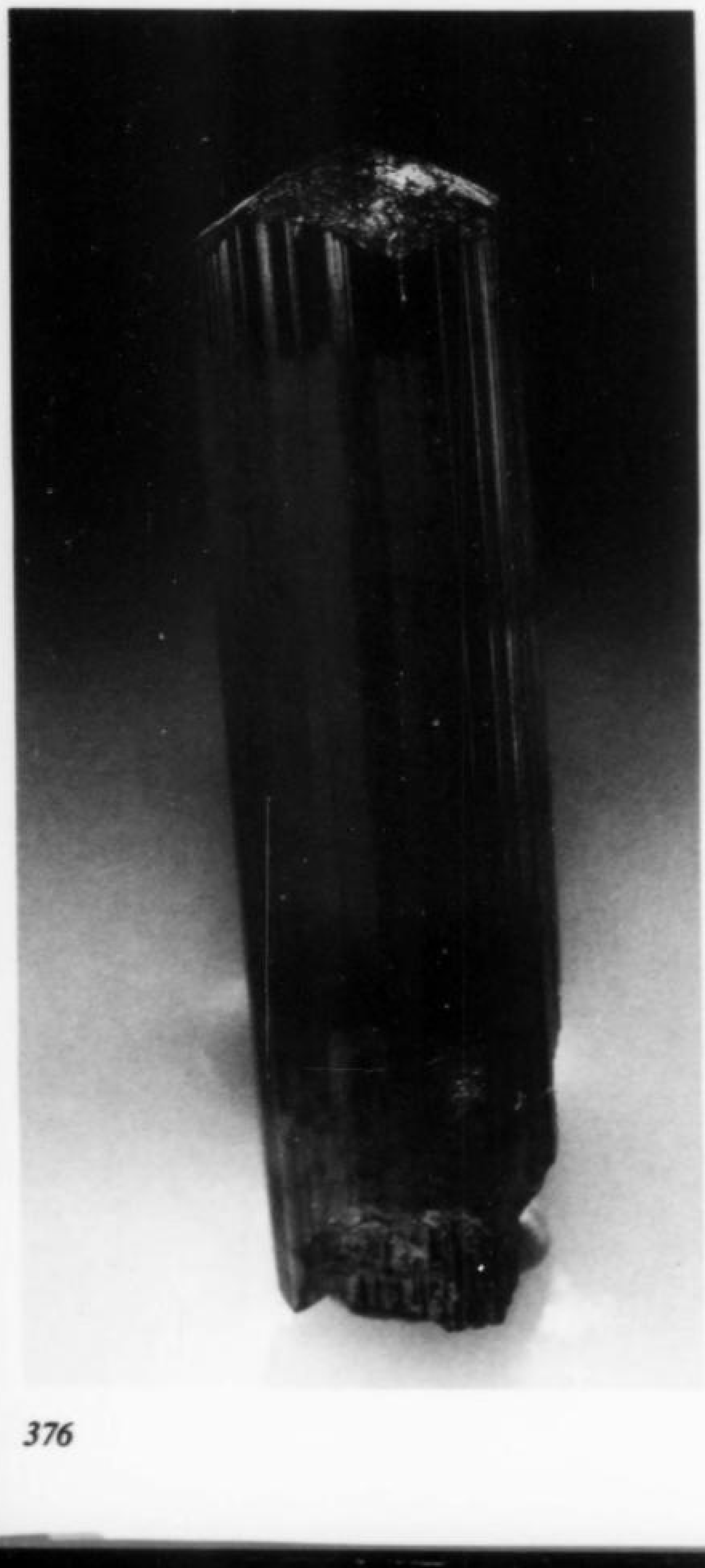


Figure 11. **Elbaite crystal from Mount Mica (U.S. National Museum specimen).**

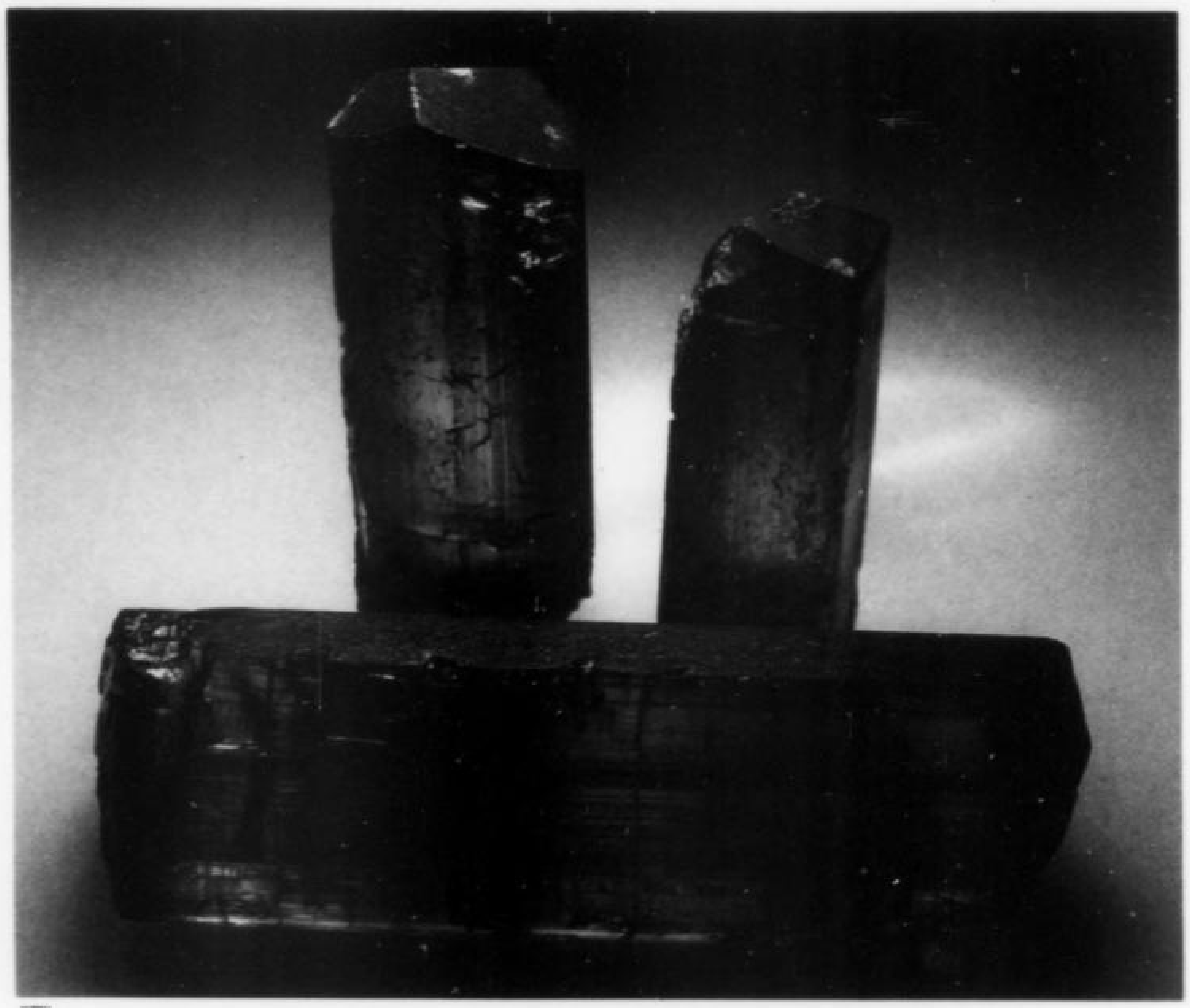
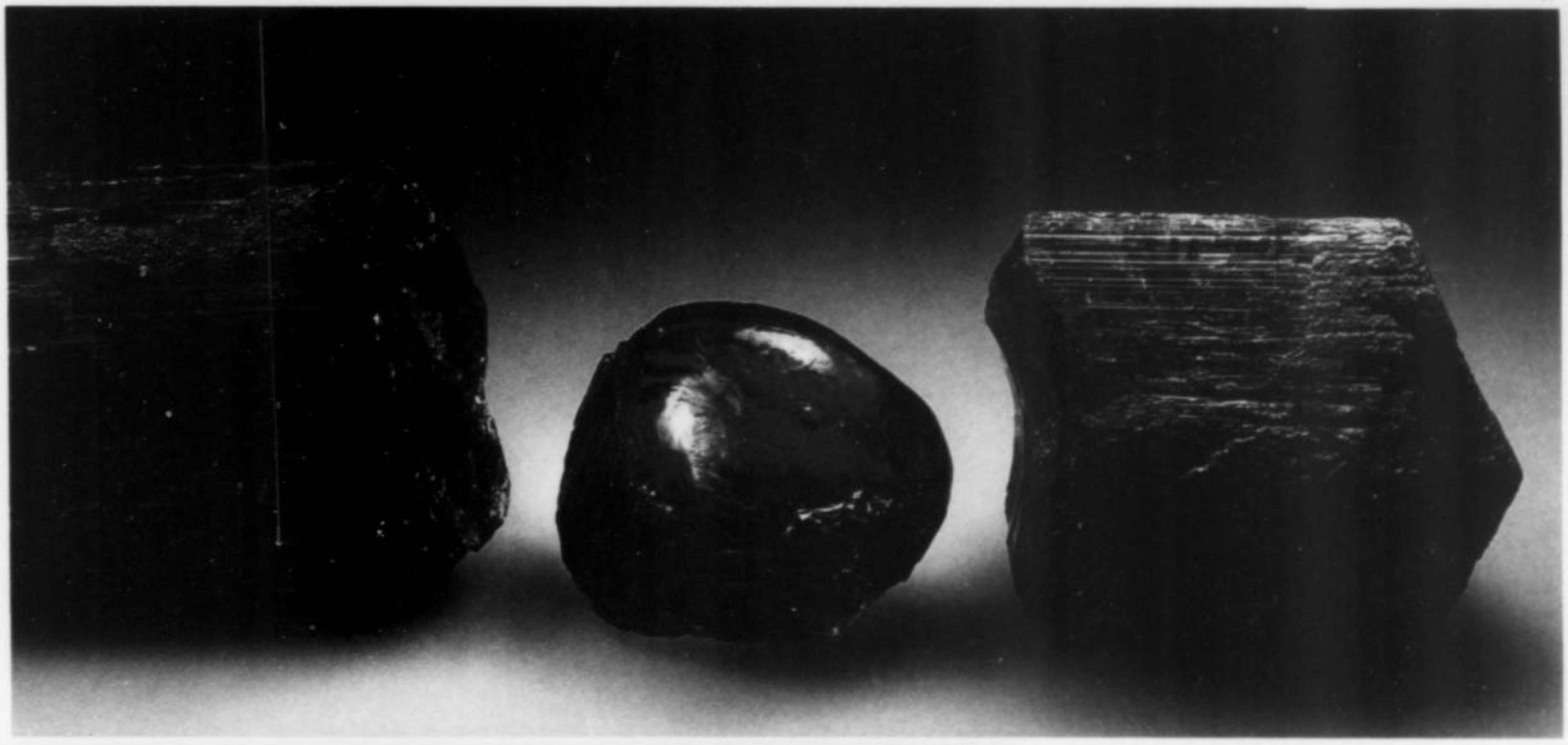


Figure 12. **The best elbaite crystals preserved from Mount Rubellite. Mined by W. D. Nevel in 1934. Horizontal crystal is 7 cm long (H94101).**



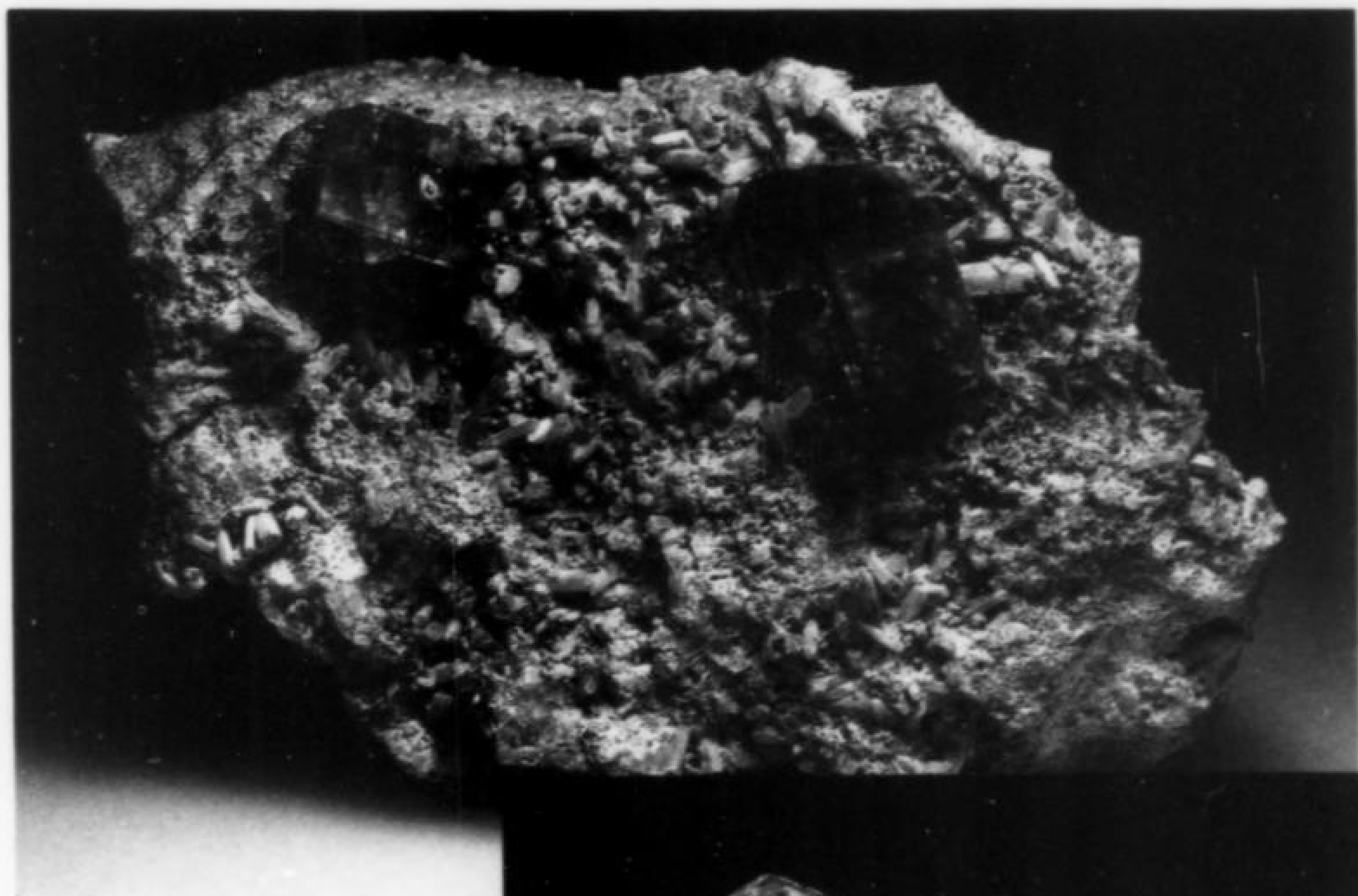


Figure 13. Mount Mica elbaite with a gem nodule (4 cm across). Purchased from L. B. Merrill in 1923 for $1000, the gem value of the nodule (H81170).

Figure 14. Purple fluorapatite crystals on matrix (13 cm across) from the Pulsifer quarry (H93796).

Figure 15. Elbaite crystals from Mount Apatite (the left crystal measures 4.5 cm) (Harvard collection).

Figure 16. **Stanley I. Perham emptying the "Friday the 13th" pocket at the BB #7 quarry in August of 1954. C. S. Hurlbut, Jr. photograph.**

Standish, Cumberland County

Kunz (1885) records that, "Mr. Lucien Holmes, of Standish, Maine, found crystals of green, red and blue tourmaline on the Hussey farm, but they were not of gem quality, although very good as crystals. The specimens at Bates College, Lewiston, labelled 'Baldwin,' are supposed to have been found at this locality." Presumably this is the locality referred to by Morrill (1959) as the "old Spar mine" that is almost 1 kilometer north of Steep Falls and just east of Route 11. Kunz's suggestion that "this locality might improve by development" probably remains sound.

Black Mountain, Rumford, Oxford County

The pegmatites on Black Mountain in the northern part of Rumford were discovered by Edmund M. Bailey of Andover in 1878 (Stevens, 1972). Exploration for gem tourmaline was begun in conjunction with A. C. Hamlin in 1884 (Kunz 1885) and continued in conjunction with N. H. Perry for the next two years (Kunz, 1886, 1887). No gemstock was found but specimens of rubellite, lepidolite and spodumene were abundant. Professor Samuel L. Penfield from Yale visited the locality in 1885 and collected the rare minerals manganocolumbite, microlite and pollucite (Foote, 1896).

William McCrillis purchased the property from Bailey in 1899 and mined it for scrap mica. Although Bastin (1911) and Stevens (1972) disagree on historical details, Black Mountain was principally mined for scrap mica at the turn of the century. Caesari Trusiani of Brunswick recovered beryl, spodumene, lepidolite and feldspar during the summers from 1938 to 1942. Because of the wartime demand for beryl, the Black Mountain area was carefully mapped by the U.S. Geological Survey and drilled by the Bureau of Mines in the 1940s (Cameron *et al.*, 1954).

Black Mountain is known primarily for its sprays of pink elbaite embedded in lepidolite that are somewhat reminiscent of the material from the Stewart Lithia mine at Pala, California. Nice examples include a large specimen with two fans in the American Museum (A30876) and an 11 x 16 x 26 cm specimen at Harvard (H92071). Indicolite occurs as stout prisms (2 cm diameter) in matrix (A39337-9) and occasionally in the cores of the rubellite sprays (Perham's Museum). The large masses of lepidolite are also notable. Harvard has a polished slab 2 x 31 x 57 cm of coarsely crystalline lepidolite associated with quartz (H126023) and another polished specimen 10 x 23 x 38 cm of finely crystalline lepidolite associated with albite (H108339). A surprising by-product of Truziani's feldspar mining in the upper pit was a profusion of cabinet-size eosphorite specimens (H104601) and some roscherite.

Topsham, Sagadahoc County

Several dozen feldspar quarries lie in the north-south trending belt about 1.5 km wide through the center of the town of Topsham (Shainin, 1948). Most have relatively simple mineralogies but the Fisher quarry is noted for a large, topaz-bearing pocket that was excavated by Professor Palache and Forrest Gonyer in 1933 (Burbank, 1934; Palache, 1934). Thin blue crystals of elbaite about 2 or 3 cm in length were found heavily coated by pocket clay. During the 1960s the Trebilock family of Topsham dug out the pocket and in a "leader" to it found larger pencils of indicolite, at least one of which has a pink cap. Kenneth Grover of Poland also collected indicolite at the Fisher quarry. His are larger but more brush-like compound crystals.

There is an etched 5 cm crystal in the Harvard Mineralogical Museum (H92173) labelled Porcupine Hill, the noted schorl locality. Edith Trebilock suggested that it may have come from pockets with quartz crystal from the lower end of the quarry.

Georgetown, Sagadahoc County

Located on the coast at the mouth of the Kennebunk River, Georgetown is remote from the previously known gem pegmatites of Oxford and Androscoggin Counties. Here fine pink and green

Figure 17. **Reconstructed elbaite crystals from Georgetown collected by R. Woodman in June, 1961 (l. 9.7 cm, H119338, r. S. Pelles collection).**

tourmalines were found (Schaller, 1917). In the late spring and early summer of 1961 a small, unnamed pit about 100 meters east of the large Consolidated Feldspar quarry produced pocket tourmalines for at least five collecting parties. The discovery was a serendipitous one made by a Massachusetts collector on his way to Nova Scotia to collect zeolites. A second pocket was opened in June by Raymond Woodman of Auburn. All of the crystals were broken into sections but Woodman successfully reconstructed several of them by matching striations on the prism faces. The crystals are strongly color zoned in the sequence blue, colorless, pink, and yellow-green. Seymour Butters, Dean McCrillis and Addison Saunders spent nearly ten days camped at the site while they excavated a series of nine small pockets. A year or so later Frank Perham was hired to collect on behalf of the Harvard Mineralogical Museum. Regrettably only a handful of centimeter-size tourmaline fragments were recovered (H108277) and nothing has since been found. These pockets are significant not only for their elbaite but also their etched crystals of gemmy spodumene, which are pale blue or green and photosensitive (H119339-41).

Dunton mine, Newry, Oxford County

The Dunton mine, Maine's most prolific gem pegmatite, was discovered by Edmund Bailey about 1898. The mineral rights were acquired by H. C. Dunton of Rumford Falls and it was operated by him between 1902 and 1904 by Hiram F. Abbott and C. L. Potter (Shaub, 1960). The locality was called Rumford Falls in an erroneous report by Kunz (1904) and early specimens (H86281, H86290) are so labelled. Later Kunz (1906) correctly described the character of the occurrence:

> At Newry a good deal of tourmaline has been found, some of the crystals very large, up to 4 inches in diameter; but at that place the crystals are not in pockets, but traverse the pegmatite in the manner of beryls, and hence are liable to much breakage. At this locality pink tourmaline predominates over green.

Bastin (1911) also described the pegmatite and noted that "no pockets have been encountered."

The mine was idle until the summer of 1926 when William Nevel

Figure 18. **Watermelon elbaite (l. 8 cm across) from Nevel's operations at the Dunton mine in the late 1920s (l. H126033, r. H90158).**

***Figure 19.* Doubly terminated elbaite crystal (3 cm) on quartz crystal from the Keith quarry. Purchased from J. S. Towne in 1912 (H43777).**

***Figure 20.* Elbaite crystals (r. 5 cm tall) and 2 carat gem from the Havey quarry (H95820).**

***Figure 21.* Elbaite from the Dunton mine (back row l. H125523, c. H125525, r. H125526; front row l. pair H94100, 26.5 carat H1132, 59.6 carat, 19.6 carat, r. H125526).**

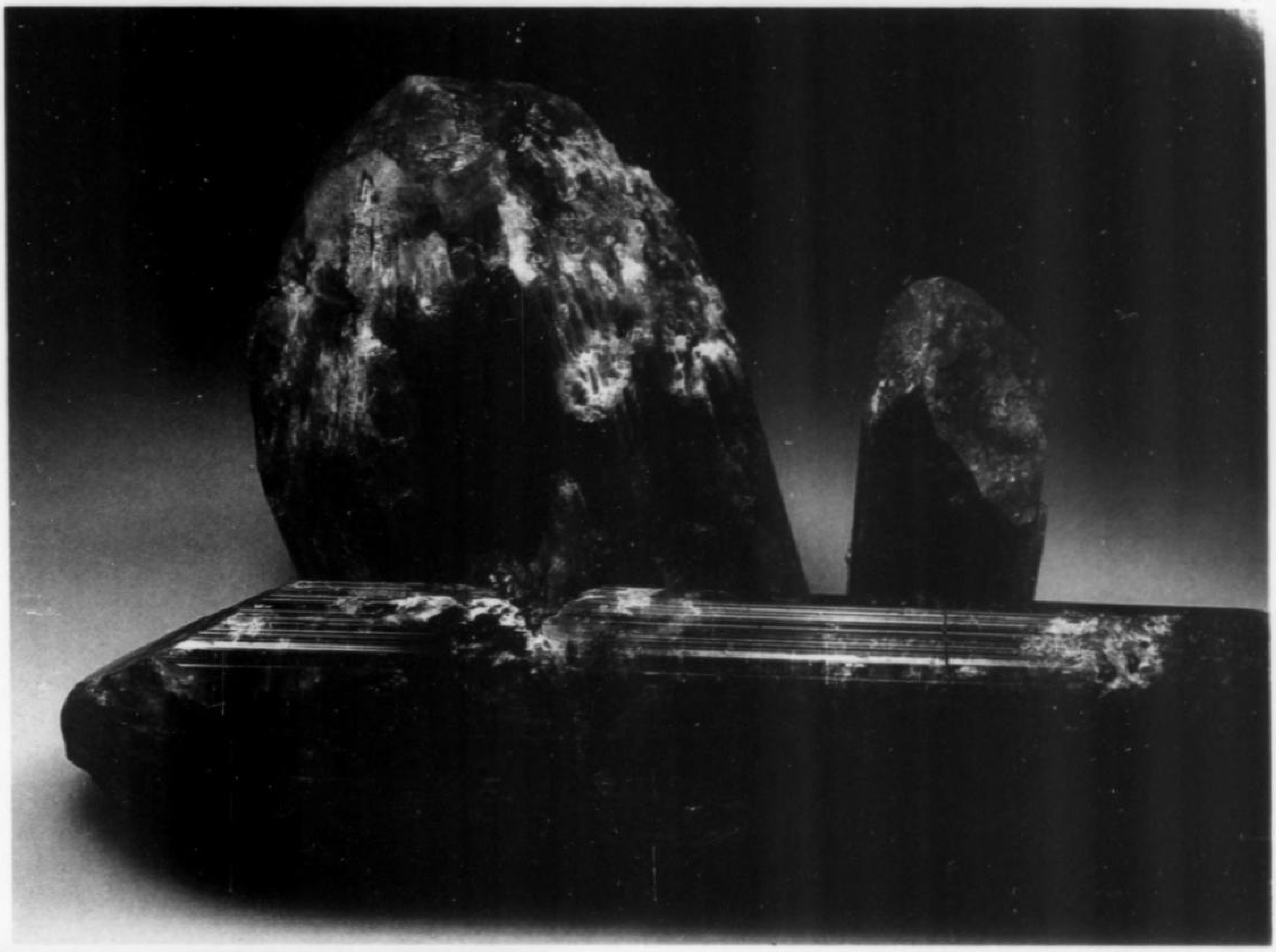


Figure 22. Elbaite from the 1972 find at the Dunton mine (l. Plumbago Mining Corporation specimen, r. H125523, front H125528).

Figure 23. Elbaite (9 cm tall) on matrix from the Dunton mine (H125524).

Figure 24. Elbaite with an atypical termination from the Dunton mine (10 cm, W. Larson collection). Harold and Erica Van Pelt photo.

began supervising the mining of pollucite for the General Electric Company. Being a mineral dealer as well, Nevel carefully saved specimen material which he later supplied to museums and researchers. On the basis of specimens received by Harvard, Palache and Shannon (1928) described the phosphates beryllonite (second world occurrence), eosphorite and hydroxyl-herderite, and Fraser (1930) described the paragenesis of the pegmatite.

The typical good Dunton tourmaline specimens from this period are translucent to opaque watermelon crystal sections, either free or in matrix. Terminated crystals (BMNH 84004, H90160) and especially those in matrix (H90154) are decidedly scarce. A letter to Palache from Nevel describes the quality of gems and pocket crystals available at that time.

December 14, 1927

Dear Professor Palache,

I have now gotten ready the largest and best of the gems from Newry—four tourmalines of various shades and one pale bluish caesium beryl. The latter is the first gem cut from this material from Newry. We found a number of these crystals or broken pieces of same but all were opaque. I had hoped to get a ten carat gem but when the flaws were ground out it reduced it to about 4 carats.

The four tourmalines were found in little cavities in the same area that produced the eosphorites, the only pockets formed in the entire ledge. The largest is of 15½ carats weight and much the largest ever found at Newry that I know anything about. Mr. Merrill told me the largest gem he ever saw from there was a pink stone that weighed 1¼ carats. This was a fragment broken out from the pink center of one of those big "watermellon" crystals that they found 25 years ago but no pocket material was taken out. The several tiny cavities I found this Summer were at the opposite end of the vein from where they worked years ago. The largest cavity was 4 inches across.

The gems consist of one sapphire blue, one dark blue-green, one fine pink and the large green stone of 15½ carats beside the cut beryl. I consider the large one worth $8.50 per carat in view of its brilliancy and exceptional size from that locality. The pink one at $10.00. It weighs about 1 carat and is fine color. I have a large piece of pink I intend to cut but there will be flaws in it.

Very truly yours,
[Signed] W. D. Nevel

At least 1600 kg of pollucite were mined in the late 1920s by Nevel. He also reworked the dumps for montebrasite, plagioclase and spodumene in 1935. The geology of the small (3 x 60 m), lens-shaped Dunton pegmatite was studied as part of the wartime effort by the U.S. Geological Survey to investigate domestic sources of strategic minerals (Cameron *et al.*, 1954; Shainin and Delwig, 1955) and now, it is the best-studied of Maine's gem pegmatites (King, 1975). The Whitehall Company and Harvard University jointly explored for commercial feldspar and gem tourmaline in 1949 without success. Richard "Robbie" Robinson of New Hampshire discovered a gem pocket here in 1967 (Stevens, 1972). With the permission of International Paper Company and the assistance of Frank Perham, the pocket produced blue-green elbaite "pencils" and "popcorn" lepidolite (H117487). This was much richer than the pockets found by Nevel but merely a precursor to the fabulous find a meter below it in 1972.

The now-famous discovery was made by George Hartman, Dale Sweatt and James Young in August, 1972. After the material from this "pre-lease" pocket was divided, Hartman, Sweatt and Dean McCrillis organized the Plumbago Mining Corporation. A lease was obtained from International Paper Company, Frank Perham was hired, and exploration for gem tourmaline was resumed. In late October a second series of pockets was discovered that proved richer than any previously discovered in Maine and, perhaps, anywhere in the world. These exciting events were recounted by McCrillis (1975) with rare detail.

The characteristics of the new crystals were described by Dunn (1975a) and are sufficiently distinctive that they shouldn't be confused with crystals from earlier finds at the Dunton or elsewhere in Maine. Typical specimens are the green terminations and watermelon "logs" from large naturally broken crystals. Acute trigonal pyramids are the dominant terminal forms. Ditrigonal pyramids and the pedion are less common. The only large crystal on matrix is both repaired and reattached to the cleavelandite.

The full gem potential of these crystals was not appreciated until John White observed that the obvious flaws in the logs were confined to the green rinds and that the cores were almost flawless. Maine had never produced such amounts or quality of rubellite. The largest rubellite cut for Plumbago Mining is 60 carats (H119102). Gems in the 20-40 carat range were routine and small stones were abundant. Lesser material was carved or cabbed (Stevens, 1973, 1979). The total amount of tourmaline is not accurately known. In November of 1972 when John Marshall bought Hartman's interest in Plumbago, there was more than 1 metric ton of ungraded tourmaline (no matrix) stored in the vault of the Casco National Bank! This was only the production from the October, 1972 find; pockets found in May of 1973 and July of 1974 were also important producers.

Plumbago did not ignore the rare species found in the pockets with albite and elbaite. The writer, in August 1973, purchased two pale green montebrasite crystals at the Rumford office. Harvard Professors Frondel and Hurlbut collected beryllonite which hadn't been available since the 1920s (H110048). A large, colorful specimen of beryllonite associated with cleavelandite and elbaite was later acquired by Harvard (H119587). Examining the beryllonite assemblage closer, John Stewart and Palmer Sevrens discovered the second world occurrence of uralolite (Dunn, 1978). Some thumbnail-size single beryllonite crystals and eosphorite on elbaite were also marketed. The dumps, too, produced rare phosphates. Steven Garza, a central Massachusetts collector who bicycled to Newry in July 1982 to collect at the Dunton mine, discovered 5-mm rhombohedral whitlockite crystals (H119585) associated with xanthoenite.

At the cessation of mining in 1974, the Dunton was fairly honeycombed with tunnels. To eliminate this attractive hazard and potential liabilities the International Paper Company arranged for Jim Mann, a blasting contractor as well as a mineral dealer, to collapse the Plumbago workings. In the course of this work he discovered a small (1 m) pocket of blue tourmaline. The pencil-like crystals were all broken into 2 cm sections. The one crystal Mann successfully reconstructed is doubly terminated and 11.3 cm in length (H119903). Although the color of this 1500 carats of elbaite is unsuitable for faceting, it is evident that the last word on Dunton mine tourmaline isn't yet in!

SCHORL $NaFe_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Schorl is an abundant accessory mineral in Maine's granites and granitic pegmatites. In simple pegmatites it frequently occurs as lustrous, well-formed prismatic crystals frozen in a matrix of white to buff-colored feldspar and gray, granular quartz. Interesting morphological variations result from different combinations of the common crystal forms. Almandine trapezohedrons, chrysoberyl twins and pseudohexagonal muscovite books may be associated. In complex pegmatites schorl is an important petrologic component. At Mount Mica for example, schorl accompanies almandine in that pervasive horizon known as "the garnet line" below which pockets are almost never found. At both Mount Mica and Mount

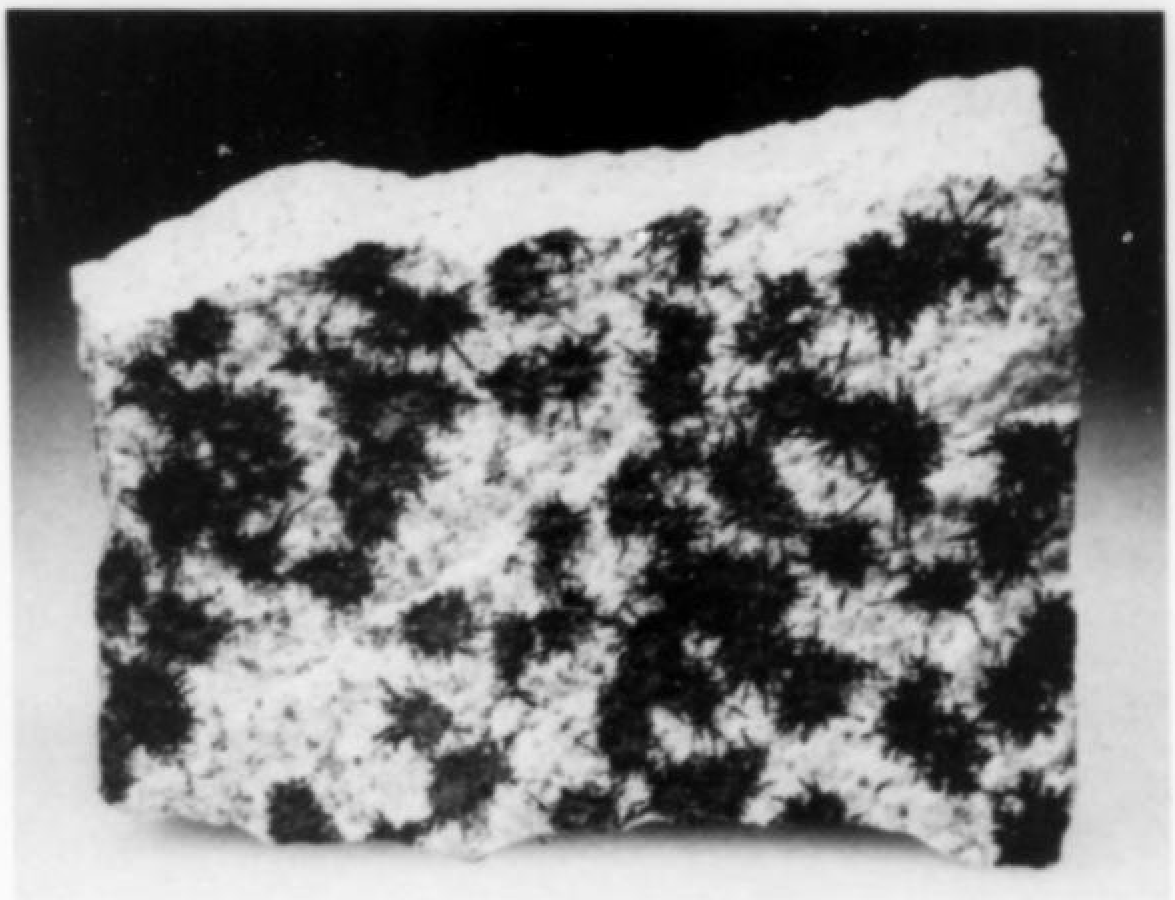


Figure 25. **Radial clusters of schorl on granite gneiss (10 cm across) from the Municipal quarry, Portland (H91928).**

Rubellite crystals longer than a meter have been exposed but, being brittle, have not survived extraction. Specimen crystals are usually less than 10 centimeters in length. Crystal groups are uncommon and pocket specimens are rarely seen.

Porcupine Hill, Topsham, Sagadahoc County

Perhaps the state's premier schorl locality is the narrow quarry on Porcupine Hill in Topsham where unusually large and stout crystals were collected by William Brookes. A recent letter from Wil DeGraff, of Fargo, North Dakota, Brookes' collecting partner, recounted details of their discovery:

> For your records, Bill and I hacked it out of a rock-face of white albite feldspar in the Porcupine Hill Quarry near Topsham, ME on July 18, 1935. This information comes from my specimen notebook in which I still have listed the 35 specimens I collected from both Porcupine Hill and the Standpipe Hill quarries.
>
> As I recall it, we got the directions from Stan Perham's Rock Shop in Brunswick. For both of us it was our first unaccompanied field trip after having taken 1st year Geology in our respective colleges.
>
> Lying loose in that pit was another schorl measuring 6 x 5½ x 5½ inches and a 6 x 3½ inches ⅔rds of a lovely aquamarine beryl crystal, most of it full of internal fractures thanks to the dynamite. Still have them.

The field trip diaries of Herbert M. W. Haven (1886–1949) were edited by Bill Brookes and Philip Morrill and privately published under the title of *Tales of a Homemade Naturalist* (Havens, 1966). This delightful book describes a June 7, 1936 field trip of the Maine Mineralogical and Geological Society which included Porcupine Hill on its itinerary:

> We next went to the feldspar openings on Porcupine Hill. I collected some columbite on feldspar. They thought this was a very fine locality as it had been operated the year before and everything was fresh and clean.
>
> Ben Burbank dug out a wonderful Black tourmaline crystal fully five inches across and 8 inches deep. Willis True dug out one 4½ inches in diameter and 4½ deep with perfect double terminations. McKay found another double terminated and about an inch long in feldspar matrix. Nice specimens of several other minerals were found. Same quarry where Wm. J. Brookes found two Black tourmalines 7 inches in diameter and about 7 inches long – described by Dr. Palache as the largest up to that time ever found in the world.
>
> Most of the crowd now left for Ben Burbank's house in Brunswick. Dr. Berman cut his head on the top of my Reo.
>
> Ike Skillin and I remained to chisel out a fine group of Black tourmaline crystals. We had to remove a lot of matrix from the bottom before the tourmalines were exposed. When we reached the crystals, they broke all to pieces.

Figure 26. **Schorl crystal (17 cm tall) from Porcupine Hill (H92331). Alphonse Coleman photograph.**

Many fine schorl specimens have been collected at Porcupine Hill by (and may be available from) Clifford and Edith Trebilcock, who have a small shop on Tedford Road in Topsham. Schorl was still abundant on the dumps when the writer accompanied Woody Thompson and Ray Woodman to the locality in July of 1982.

Whispering Pines quarry, Paris, Oxford County

Although best known for its gem quality rose quartz, the Whispering Pines quarry is also a notable schorl locality (Stevens, 1972). A large matrix specimen containing a lustrous, sharp, terminated crystal 8 x 8 x 20 cm in size was collected there by the late Robert Davis about 1960. This extraordinary specimen is displayed at Perham's store in West Paris, where permission to visit the quarry may be obtained. Smaller crystals of similar quality are preserved in the collections of Bruce Wadleigh and Ray Woodman.

Non-Lithium Pegmatites

Many other non-lithium pegmatites have produced interesting specimens of schorl over the years. A handsome matrix specimen from Owl's Head in Buckfield was acquired for Yale's Brush Collection in 1871. Another is labeled "Speckled Mountain near Paris." Crude crystals in quartz were found at Eagle Point, Patch Mountain in Greenwood (H125362). A nineteenth century specimen of fine microcline and schorl crystals in the American Museum of Natural History (A9225) is from an unspecified location in Stoneham. The Melrose prospect, also in Stoneham, is famous for its aquamarine and beryllonite. Here Skip Szenics and Ray Woodman collected somewhat crude but interesting crystals in the 1960s. A markedly hemimorphic crystal in matrix from this prospect is in the Harvard collection (H119554). Perham's Maine Mineral Store displays crystal groups from the Bumpus quarry in Albany and the A. C. Perham quarry in West Paris in their museum. Elongated prisms in flesh-colored feldspar were collected at the LaFlamme mine in Minot during the late 1950s and early 1960s. Also during the 1960s many well-terminated crystals were collected by Ray Woodman from the Tryon Mountain quarries in Pownal. Crystals from the lower quarry are associated with almandine and beryl in quartz while those from the upper quarry occur in feldspar. For the past two or three years Daniel Studley of Portland has been intermittently mining these for exchange and sale. A lustrous 1 x 3 cm crystal from a small pocket in feldspar was collected in 1970 at the LaChance quarry in Brunswick by Eugene Bearss of Sanford. The Bowker rose quartz prospect on the Mount Mica property was reopened by Rene Dagenais in 1977. Several fine schorls with associated almandine trapezohedrons were produced. A lustrous 4 x 7.5 cm schorl crystal from a rose quartz prospect within 300 meters of the Mount Marie quarry on Little Singepole Mountain (H120485) was collected by Jim Mann.

Chrysoberyl-bearing pegmatites, Oxford County

Schorl is a frequent accessory in Maine's numerous chrysoberyl occurrences (Jacobson, 1982). Probably the most prolific chrysoberyl locality is the narrow pegmatite on the rugged southwest face of Ragged Jack Mountain in Hartford. Palache (1924) describing the mineralogy of this simple pegmatite remarked, "crystals as much as six inches in length were seen and from that they show every gradation to slender needles, but the mineral is not abundant in the dike." Frank Perham mined the little-known Nubble quarry in Greenwood for mica in 1960 and produced some superb schorl crystals (Perham, 1960). A doubly terminated thumbnail crystal from this occurrence in the Harvard collection (H117825) is so sharp and lustrous that on casual inspection it can easily be mistaken for an uvite from Pierrepont, New York! A fine suite of almandine, chrysoberyl, muscovite and schorl crystals from the Wheeler mine in Gilead graces the collection of Raymond Woodman of Auburn. A July 1982 climb to the Wheeler mine with Woodman and Thompson was rewarded with good exercise and a fine view but no specimen worth bringing home. Mrs. Adriane Saunders, who used to work at the mine and now runs a mineral shop on Route 2 in Bethel, still has Wheeler specimens available.

Lithium-bearing pegmatites, Oxford County

Schorl is abundant in lithium-bearing pegmatites but fine examples are surprisingly uncommon. A striated 3 x 5 cm terminated prism from Mount Apatite was recently acquired by Harvard from Professor Philip Scalisi, but was probably collected many years ago. In 1951 Dick Dwelley opened a pocket on the westerly edge of the Greenlaw quarry that contained a small quantity of schorl. The crystals are etched and show a deep purple color on thin edges (R. Woodman, personal communication). Schorl is occasionally found as flattened crystals within muscovite books. An example from Auburn (H126021) shows both longitudinal and cross sections. The American Museum of Natural History has a 1 cm, flattened crystal in muscovite from Mount Mica (A12339). A 1.5 cm doubly terminated crystal in the Holden collection at Harvard (H86278) shows hexagonal and ditrigonal prisms and a simple pyramid while a 4 cm crystal in the Hamlin collection (H86276A) shows a striated hexagonal prism terminated by two pyramids and a pedion. A terminated 5 cm crystal from the Harvard quarry in Greenwood (H123063) was added to the Harvard University collection in 1983. Crude, barrel-shaped crystals broken and recemented by quartz were collected by Ray Woodman at the B.B. #7 quarry in Norway about 1958. The unexpected association of schorl with spodumene occurs at Newry (H126022).

WEW

Figure 27. **Schorl (4.5 cm long) with almandine and muscovite crystals in quartz from the Bowker prospect. Rene Dagenais specimen.**

DRAVITE $NaMg_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Magnesium-rich members of the dravite-schorl solid solution series are a widespread constituent of metamorphic schists in Maine (Henry and Guidotti, 1985). Dravite has even been suggested as a prospecting guide to massive base-metal sulfide deposits in the Penobscot Bay area (Slack, 1980). It also occurs as a contact mineral in some of the pegmatite quarries. Bastin (1911) records, "the abundant development of prisms of cinnamon-brown tourmaline from one-fourth to one-half inch long and one-sixteenth to one-eighth inch in diameter in certain of the more muscovitic layers" in the immediate vicinity of the Black Mountain pegmatite in Rumford. This occurrence has apparently been overlooked by

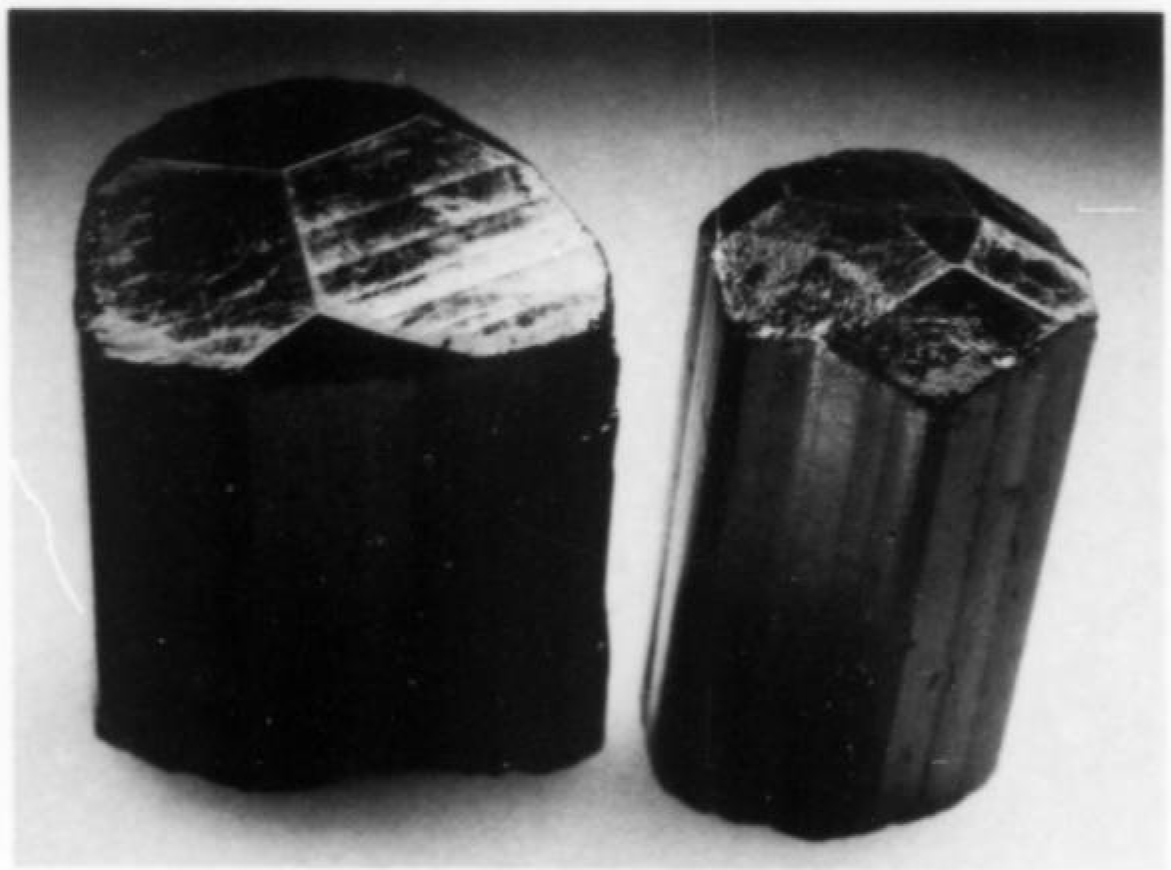


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Figure 28. **Schorl crystals from Mount Apatite (l. 3 cm across, H117813) and Mount Mica (r. 4 cm tall, H82676A).**

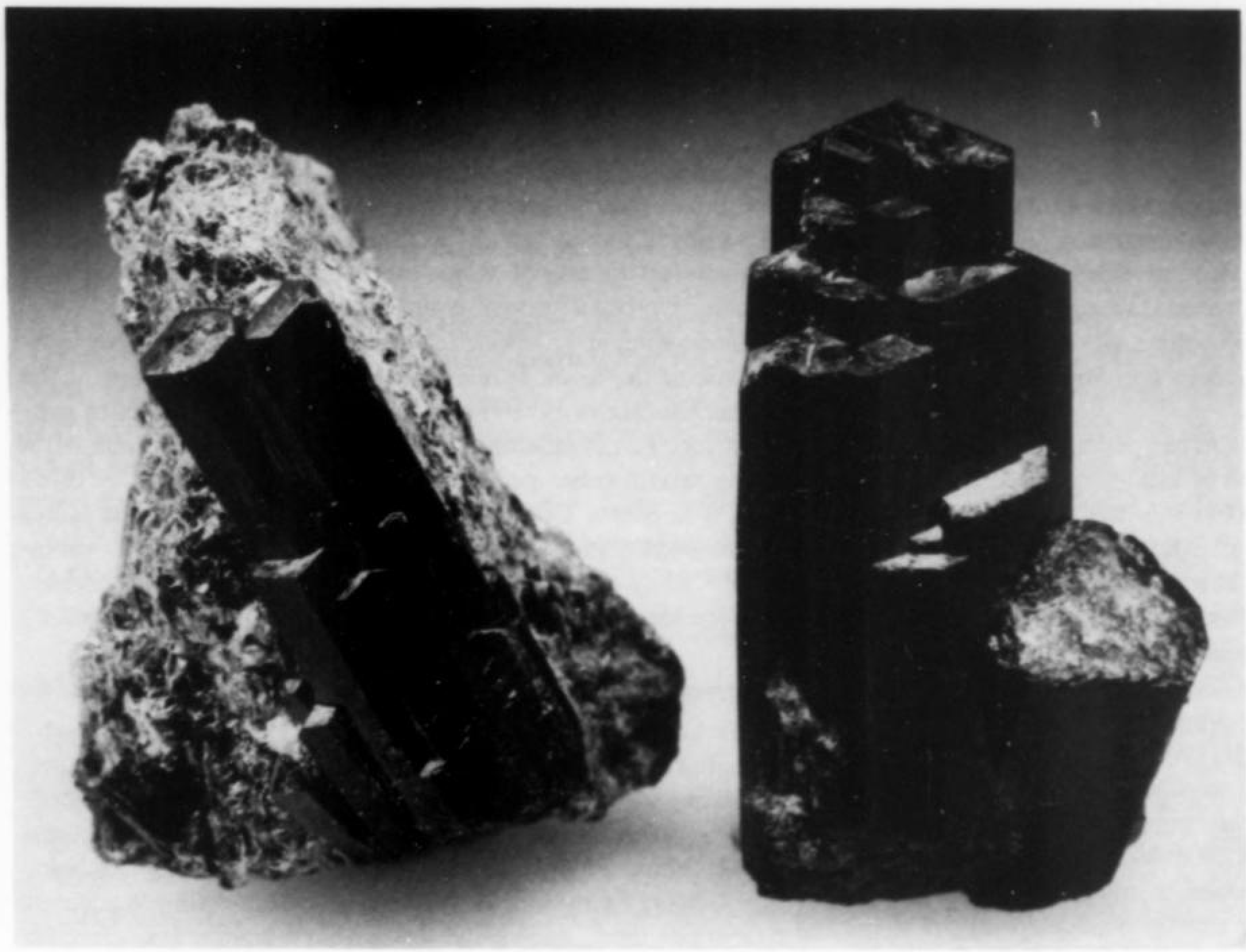

Figure 29. **Dravite crystal groups (l. H120922, r. 4 cm tall, H126024) collected by Jim Mann at the Dunton mine.**

collectors, even those as talented as Charles Marble of Buckfield (Marble, 1927), as no examples were encountered in the collections surveyed. Tourmaline specimens from the actinolite schist adjacent to the Dunton pegmatite at Newry (Shanin and Delwig, 1955) are not uncommon in collections but are rarely labeled as dravite. The finest specimens seen are two small groups of crystals in parallel position that were collected by Jim Mann. Dravite should be readily collectible at the Dunton mine and perhaps elsewhere but careful excavation of the matrix is normally required to reveal good terminated crystals.

TOURMALINE PSEUDOMORPHS

Tourmaline is generally resistant to chemical and mechanical breakdown as demonstrated by its common occurrence as detritial grains in sediments, sedimentary rocks and their metamorphosed equivalents. However, tourmalines in granitic pegmatites may be etched, heavily corroded or completely dissolved away leaving only molds as evidence of their former presence. Occasionally, partial or complete replacement pseudomorphs are found.

Unusually sharp pseudomorphs of muscovite after schorl were collected by Rene Dagenais last fall from a ledge on Noyes Mountain in Greenwood. These crystals are doubly terminated, occur in feldspar, and may reach 4 cm in length. An X-ray powder pattern revealed that two distinct polytypes, the $2M_2$ and 3T polytypes, of muscovite are present in these pseudomorphs (H124638). This finding was sufficiently interesting to encourage the examination of another muscovite pseudomorph, a partial crystal (H123037), from Mount Apatite, probably from the Maine Feldspar Company quarry, but it is apparently composed of a single polytype. Similar pseudomorphs were collected at the Ohtonen quarry in Greenwood (H123943). Specimens of silvery muscovite replacing dark blue tourmaline were collected on Plumbago Mountain in Newry (the Dunton mine?) by Charlie Marble (H97748).

The colorful elbaites from the zone of "lithium bloom" in solid pegmatite surrounding the pockets may be altered to lepidolite. Such specimens preserve the radiating, columnar structure of the elbaite but lose the rich color as the replacement becomes more complete. Lepidolite pseudomorphs may be readily distinguished from the primary tourmaline by a scratch test. Elbaite is very hard, number 8 on the Mohs scale, while fine grained lepidolite is quite soft and is readily scratched with a pin or pocket knife. Specimens of this type of pseudomorph can probably be found at most of the elbaite-bearing pegmatites in Androscoggin and Oxford Counties. Examples from Mount Apatite, Mount Mica and Mount Rubellite are represented in the Harvard collection.

The huge Dagenais pocket at Mount Mica excavated in the fall of 1979 produced a lepidolite pseudomorph which rivals in size any elbaite yet known from Maine (H117486). It is roughly cylindrical, about 25 cm in diameter and 25 cm tall. With very irregular surfaces, a flat top and vertical grooves this extraordinary specimen resembles a weatherbeaten stump.

Pocket crystals of elbaite may be overgrown by cookeite and quartz. Should the elbaite be dissolved, hollow molds result. Golden cookeite pseudomorphs of this type were abundant in Frank Perham's 1966 pocket at Mount Mica, a superlative example of which is prominently displayed in the museum section of Perham's shop at Trap Corner.

PRESENT COLLECTIONS AND FUTURE PROSPECTS

No collection, public or private, has a monopoly on Maine's tourmaline treasures. The museums of the Northeast, by virtue of their age and proximity to the pegmatites, have better representations than most. The Smithsonian Institution holds about a dozen premier specimens and three large drawers of systematic material. Their near-gem-quality, terminated, blue-green crystal from Arthur Montgomery's collection is the finest Mount Mica crystal seen by the writer. A somewhat longer achroite crystal is displayed in their mineral gallery. The polished slice of sapphire-blue elbaite from Mount Mica is also extraordinary! The 27 cm "Jolly Green Giant" (Dunn, 1975, Fig. 1), probably the most widely known specimen of Maine tourmaline, is the centerpiece of the suite from the Dunton mine donated by International Paper Company. The blue-green etched fragment from Mount Apatite and crystal section from Georgetown are also notable.

The American Museum of Natural History has two important suites of Maine tourmaline. In the 1940s K(atherine?) B. Hamlin presented twelve specimens that included the original crystal discovered by E. L. Hamlin in 1820 (!) and several illustrated in the *History of Mount Mica.* Two Newry crystals in the gem gallery and an exquisite rubellite in cleavelandite matrix (A40726) are part of the suite given by International Paper Company. A green 4 cm crystal from Mount Apatite (A37986), an esthetic little specimen from Stoneham (A12334) and representative suites from Mount Apatite, Harvard quarry, Mount Rubellite, BB #7, Mount Mica, Black Mountain and the Fisher quarry in Topsham round out their holdings.

The Harvard Mineralogical Museum has perhaps the best collection of Maine tourmalines if breadth of locality representation and quality of documentation are factored into the judging. My particular favorites are: (1) the Mount Mica crystal with the gem nodule, (2) Nevel's crystals from Mount Rubellite, (3) a crystal (H125523) and slice from the Dunton mine, (4) the Havey quarry pair, (5) a Mount Mica achroite with nodular end (H92102), (6) another Mount Mica crystal (H126025A), (7) the matrix specimen from the Keith quarry (Fig. 19), (8) a doubly terminated indicolite crystal from the Dunton quarry (H119903), (9) the Georgetown crystal, and (10) an etched green crystal from Porcupine Hill (H92173). Three large specimens are important: the compound crystal from Merrill's June, 1904 pocket at Mount Mica (H119777); a very large watermelon crystal section in matrix from pre-1972 Dunton mine (H119592); and cleavelandite studded with "tooty-fruity" tourmalines, lepidolite and beryllonite from the 1972 Dunton find (H119587).

The relatively new State of Maine Museum in Augusta has a suite of Dunton mine specimens received from International Paper in the mid 1970s. The Boston Museum of Science (formerly Boston Society of Natural History) had an important collection of New England minerals assembled by Edward Wigglesworth that included the collection of Thomas F. Lamb of Portland (Stevens, 1972). Much of this material has been transferred to Harvard. The suite of Hebron material in the Brush Collection at Yale University includes a nice matrix rubellite specimen. Other Maine specimens might be expected to be in the New York State Museum in Albany, the Academy of Natural Sciences in Philadelphia, the Field Museum in Chicago, the British Museum (Natural History) in London and a few of the European museums. The collection at Perham's store in West Paris is the only one of the many private collections mentioned that is publicly displayed.

Maine's reputation for tourmaline rests largely on the sustained production of crystals and gems from Mount Mica and Hamlin's history of it. Despite the important production from Mount Apatite and the Havey quarry in the early part of this century, Maine elbaite was eclipsed by the finds in southern California and Brazil. Nevertheless, the field collector should be encouraged by the pockets discovered in the last 25 years at Georgetown, Mount Mica, Mount Apatite, the Havey quarry and the Dunton mine. Those who mostly wield the "silver pick" should also be encouraged. In the past eight years the writer has seen for sale or been offered (and in some cases purchased) good to fine quality elbaites from the following localities: Mount Apatite, the Bennett mine in Buckfield, Georgetown, the Harvard mine in Greenwood, Dunton mine, BB #7, Mount Mica, Havey quarry and the Fisher quarry in Topsham! Collectors of either ilk should find solace in this verse:

> First and foremost
> Keep in mind
> Tourmalines
> Are hard to find.
>
> S. B. Graves (1967)

A NOTE ON LABELING

Well-labeled specimens often assume the role of historical documents in the preparation of articles such as this because the written record is usually insufficient. Regrettably, labels too are often incomplete. Precise specification of the locality is essential. Additional notes on the collector, date of discovery, paragenetic observations, subsequent owners, etc. add interest and value to specimens. In the case of Maine tourmalines, labels should include the mine or prospect, town, county, state and whatever additional information might be available. Older specimens often carry only the name of the town. While that may have been adequate at the time, such localities as "Hebron" and "Paris" can no longer be considered specific designations for Mount Rubellite and Mount Mica because several other pegmatites have now been mined in those towns. The Maine Geological Survey's index of pegmatite mines and prospects (Anonymous, 1957) and the field guide by Philip Morrill (1959), both of which show the locations on topographic maps, are helpful aids to labeling.

ACKNOWLEDGMENTS

One's knowledge of a mining district is accumulated slowly by reading the literature, visiting the localities, studying the specimens, and talking with the local experts. I am particularly indebted to Rene Dagenais, Irving and Doris Groves, Jim Mann, Dean and Ann McCrillis, Philip McCrillis, Frank Perham, Jane Perham, Terry Szenics, Edith and Clifford Trebilcock and Ray Woodman for sharing their knowledge of Maine's pegmatites. Specific assistance with various aspects of the preparation of this article was rendered by George Harlow, Vandall King, John Marshall, William Metropolis, Joseph Peters, Richard Thomssen, John White, Wendell Wilson and especially my secretary Helen Foley.

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BIBLIOGRAPHY

ANONYMOUS (1957) Maine pegmatite mines and prospects and associated minerals. *Maine Geological Survey, Mineral Resources Index,* 1.

BANCROFT, P. (1984) *Gem & Crystal Treasures.* Western Enterprises-Mineralogical Record, Fallbrook, CA, 488 p.

BASTIN, E. S. (1910) Feldspar deposits of the United States. *U.S. Geological Survey Bulletin* **420**.

BASTIN, E. S. (1911) Geology of the pegmatites and associated rocks of Maine. *U.S. Geological Survey Bulletin* **445**.

BERMAN, H., and GONYER, F. A. (1930) Pegmatite minerals of Poland, Maine. *American Mineralogist,* **15**, 375–387.

BRUSH, G. J. (1862) On amblygonite from Hebron in Maine. *American Journal of Science,* **34**, 243–245.

BRUSH, G. J. (1863) On childrenite from Hebron in Maine. *American Journal of Science,* **36**, 257.

BRUSH, G. J. (1866) On cookeite a new mineral species. *American Journal of Science,* **41**, 246–248.

BURBANK, B. B. (1934) Topaz and herderite at Topsham, Maine. *Rocks and Minerals,* **9**, 125–131.

CAMERON, E. N., LARRABEE, D. M., McNAIR, A. H., PAGE, J. J., STEWARD, G. W., and SHAININ, V. E. (1954) Pegmatite investigations 1942–45 New England. *U.S. Geological Survey Professional Paper* **255**.

CLOUD, P. E. (1934) Mineral collecting in the vicinity of Paris, Maine. *Rocks and Minerals,* **9**, 183–185.

COOKE, J. P. (1863) Crystallographic examination of the Hebron mineral, and comparison of it with the childrenite from Tavistock. *American Journal of Science,* **36**, 257–258.

DANA, E. S. (1884) Apatite. *American Journal of Science,* **27**, 480.

DUNN, P. J. (1975a) Elbaite from Newry, Maine. *Mineralogical Record,* **6**, 22–25.

DUNN, P. J. (1975b) Personality sketch: Frank Perham. *Mineralogical Record,* **6**, 105.

DUNN, P. J. (1978) Uralolite from the Dunton gem mine, Newry, Maine: A second world occurrence. *Mineralogical Record,* **9**, 99–100.

FAIRBANKS, E. E. (1928) The importance of pollucite. *American Mineralogist,* **13**, 1–25.

FOOTE, H. W. (1896) On the occurrence of pollucite, manganocolumbite and microlite at Rumford, Maine. *American Journal of Science,* **1**, 457–461.

FRANCIS, C. A. (1974) Development of the Amherst College Collection. *Mineralogical Record,* **5**, 190–192.

FRASER, H. J. (1930) Paragenesis of the Newry pegmatite. *American Mineralogist,* **15**, 349–364.

GRAVES, S. B. (1967) A tourmaline bonanza at old Mt. Mica, Maine location. *Lapidary Journal,* **21**, 10–17.

HAMLIN, A. C. (1873) *The Tourmaline.* J. R. Osgood & Co., Boston, 107 p.

HAMLIN, A. C. (1890) *Catalogue of gems, jewels and tourmaline crystals.* Manuscript notes owned by F. Pough.

HAMLIN, A. C. (1895) *The History of Mount Mica of Maine, U.S.A. and Its Wonderful Deposits of Matchless Tourmalines.* Privately Published, Bangor, Maine, 72 p.

HAMLIN, E. J. (1826) Miscellaneous localities of Minerals. 4, Paris, Maine. *American Journal of Science,* **10**, 14–18.

HANLEY, J. B. (1939) Geology of the Poland Quadrangle, Maine. Unpublished Ph.D. dissertation. Johns Hopkins University.

HAVENS, H. M. W. (1966) *Tales of a Homemade Naturalist.* Winthrop Mineral Shop, Winthrop, Maine, 153 p., edited by Philip Morrill.

HENRY, D. J., and GUIDOTTI, C. V. (1985) Tourmaline as a petrogenetic indicator mineral: an example from the staurolite-grade metapelites of NW Maine. *American Mineralogist,* **70**, 1–15.

HOADLEY, C. W. (1935) A recent visit to Maine. *Rocks and Minerals,* **10**, 37–38.

HURLBUT, C. S., Jr., and WENDEN, H. E. (1951) Beryl at Mount Mica, Maine. *American Mineralogist,* **36**, 751–759.

JACOBSON, M. I. (1982) Chrysoberyl: A U.S. Review. *Rocks and Minerals,* **57**, 49–57.

KING, V. T. (1975) Newry, Maine: a pegmatite phosphate locality. *Mineralogical Record,* **6**, 189–204.

KING, V. T. (1982) World news on mineral occurrences. *Rocks and Minerals,* **57**, 31–34.

KUNZ, G. F. (1883) American gems and precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1883**, 483–499.

KUNZ, G. F. (1884) On the tourmaline and associated minerals of Auburn, Maine. *American Journal of Science,* **27**, 303–305.

KUNZ, G. F. (1885) Precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1883** and **1884**, 723–782.

KUNZ, G. F. (1886) Precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1885**, 437–444.

KUNZ, G. F. (1887) Precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1886**, 595–605.

KUNZ, G. F. (1888) Precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1887**, 555–579.

KUNZ, G. F. (1892a) *Gems and Precious Stones of North America.* The Scientific Publishing Company, 2nd ed. [Dover Publication #21855-4, 1968].

KUNZ, G. F. (1892b) Precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1889** and **1890**, 445–448.

KUNZ, G. F. (1893) Precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1891**, 539–551.

KUNZ, G. F. (1894) Precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1893**, 680–702.

KUNZ, G. F. (1901) Precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1900**, 749–778.

KUNZ, G. F. (1904) Gems and precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1903**, 911–977.

KUNZ, G. F. (1906) Gems and precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1905**, 1323–1358.

MANCHESTER, J. G., and BATHER, W. T. (1918) Famous mineral localities: Mt. Mica, Mt. Apatite and other localities in Maine. *American Mineralogist,* **3**, 169–174.

MARBLE, C. F. (1927) The Black Mountain Mica Mine – Maine. *Rocks and Minerals,* **2**, 6.

McCRILLIS, D. A. (1975) Gem tourmaline rediscovered at Newry. *Mineralogical Record,* **6**, 14–21.

MORRILL, P. (1959) *Maine Mines and Minerals.* Vol. **1**, *Western Maine.* Winthrop Gem & Mineral Shop, 80 p.

NEVEL, W. D. (1928) Large topaz crystal from Maine. *American Mineralogist,* **13**, 75.

PALACHE, C. (1924) The chrysoberyl pegmatite of Hartford, Maine. *American Mineralogist,* **9**, 217–221.

PALACHE, C. (1930) Memorial of Loren B. Merrill. *American Mineralogist,* **15**, 277–279.

PALACHE, C. (1934) A topaz deposit in Topsham, Maine. *American Journal of Science,* **27**, 37–48.

PALACHE, C., and SHANNON, E. V. (1928) Beryllonite and other phosphates from Newry, Maine. *American Mineralogist,* **13**, 392–396.

PENFIELD, S. L. (1893) On cookeite from Paris and Hebron, Maine. *American Journal of Science,* **45**, 393–396.

PENFIELD, S. L. (1894) On the crystallization of herderite. *American Journal of Science,* **47**, 329–339.

PERHAM, J. (1980) New adventures in Maine tourmaline. *Lapidary Journal,* **33**, 2114–2118 and 2142–2152.

PERHAM, S. I. (1960) 1960 locality notes. *Oxford County Mineral and Gem Association Yearbook* **1960**, 35.

ROE, A. (1975) The C. U. Shepard Mineral Collection and the Two Drs. Shepard. *Mineralogical Record,* **6**, 253–257.

SCHALLER, W. T. (1917) Gems and precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1915**, 856.

SHAININ, V. E. (1948) Economic geology of some pegmatites in Topsham, Maine. *Maine Geological Survey Bulletin* **5**.

SHAININ, V. E., and DELWIG, L. F. (1955) Pegmatites and associated rocks in the Newry Hill area, Oxford County, Maine. *Maine Geological Survey Bulletin,* **6**, 58 p.

SHAUB, B. M. (1960) Notes on the Dunton Gem Mine, Newry Hill. *Oxford County Mineral and Gem Association Yearbook,* **1960**, 27–32.

SHEPARD, C. U. (1830) Mineralogical journey in northern parts of New England, *American Journal of Science,* **18**, 293–303.

SLACK, J. (1980) Tourmaline – A prospecting guide for massive base-metal sulfide deposits in the Penobscot Bay Area, Maine. *Maine Geological Survey Special Economic Studies Series,* 8.

STERRETT, D. B. (1911) Gems and precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1909**, 739–800.

STERRETT, D. B. (1913) Gems and precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1912**, 1023–1060.

STERRETT, D. B. (1914) Gems and precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1913**, 688–692.

STERRETT, D. B. (1916) Gems and precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1914**, 331.

STEVENS, J. P. (1972) *Maine's Treasure Chest: Gems and Minerals of Oxford County.* Privately published, 216 p.

STEVENS, J. P. (1973) Striking it rich with Maine tourmaline. *DownEast,* May issue, 42–47, 74.

STEVENS, J. P. (1979) The Gerhard Becker miniatures in Maine tourmaline. *Lapidary Journal,* **32**, 2122–2128 and 2154–2160.

STODDARD, B. H. (1922) Gems and precious stones. *U.S. Geological Survey Mineral Resources of the United States,* **1919**, 178–179.

SZENICS, T. (1967) The richest find of royal purple apatite in more than 50 years! *Lapidary Journal,* **21**, 1177–1189.

SZENICS, T. (1968) Emerald-green tourmaline found at Pulsifer quarry, Mt. Apatite, Auburn, Maine. *Lapidary Journal,* **21**, 96–110.

THOMPSON, W. B. (1977) Maine tourmaline localities and their relevance to the critical areas program. *Maine State Planning Report,* **31**, 38 p.

THOMSSEN, R. W. (1981) Evaluation of Mt. Mica mine for future gem tourmaline production potential. Private report for Plumbago Mining Corporation, 9 p. with map.

WADE, W. R. (1909) The gem bearing pegmatites of western Maine. *The Engineering and Mining Journal,* **87**, 1127–1129.

WAGNER, C. E., POLLARD, C. O., Jr., YOUNG, R. A., and DONNAY, G. (1971) Texture variations in color-zoned tourmaline crystals. *American Mineralogist,* **56**, 114–132.

WARREN. C. H. (1898) Crystallized tantalite from Paris, Maine. *American Journal of Science,* **6**, 123.

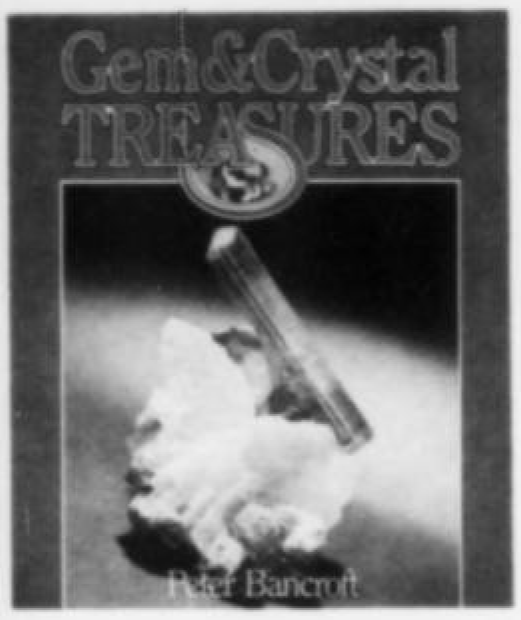
WELLS, H. L. (1891) On the composition of pollucite and its occurrence at Hebron, Maine. *American Journal of Science,* **41**, 213–220.

WELLS, H. L., and PENFIELD, S. L. (1892) On herderite from Hebron, Maine. *American Journal of Science,* **44**, 114–116.

WILSON, W. W. (1977) Famous Mineral localities: The Pulsifer Quarry. *Mineralogical Record,* **8**, 72–77.

WINCHELL, H. A. (1938) Paragenesis of the pegmatite at Mount Mica, Maine. Unpublished term paper for Professor Palache's Advance Mineralogy course.

WOLFF, J. E., and PALACHE, C. (1902) Apatite from Minot, Maine. *Proceedings of the American Academy of Arts and Sciences,* **37**, 517–529.



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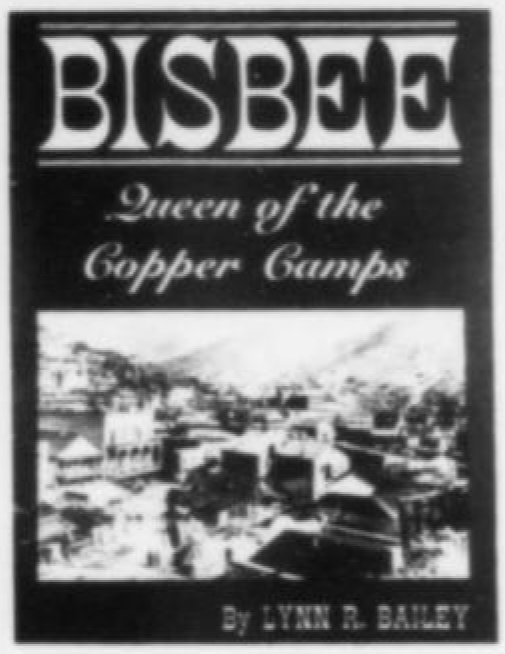

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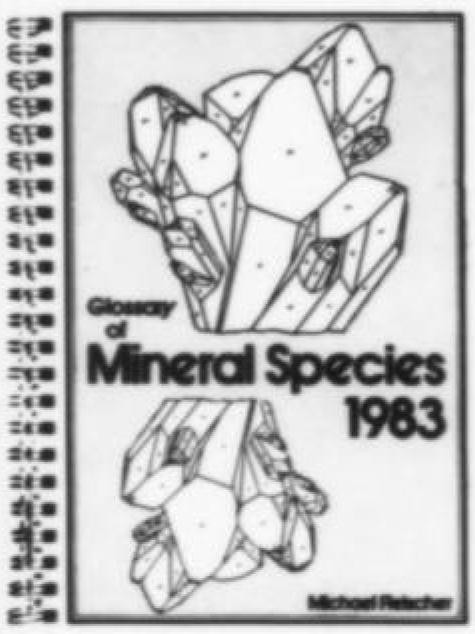

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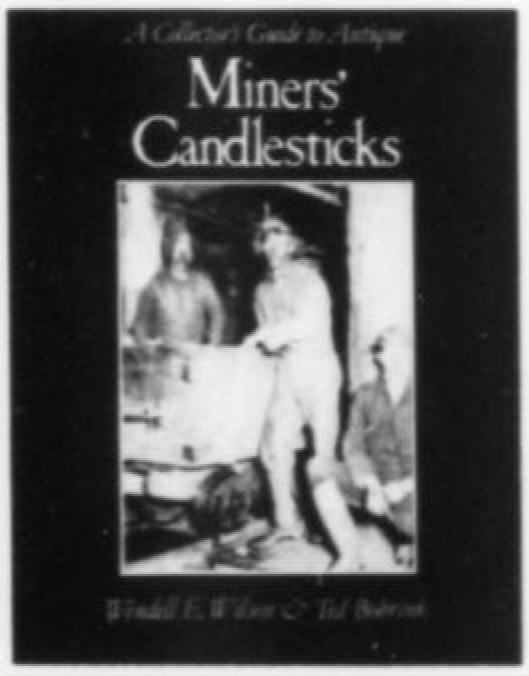

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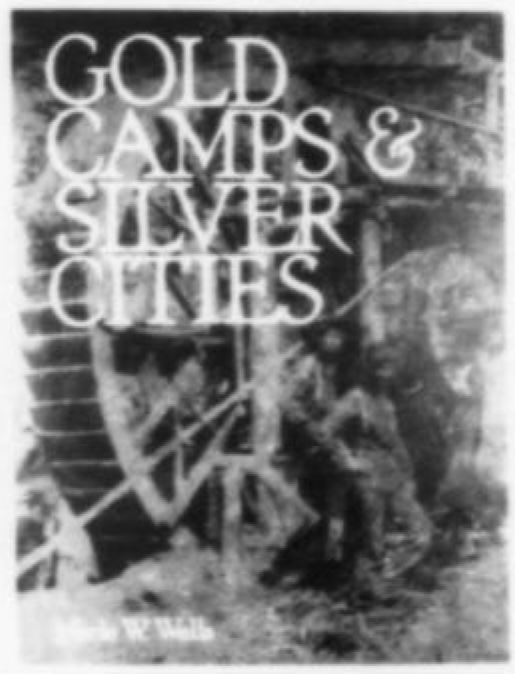

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Gem pegmatites of the Shingus-Dusso area
Gilgit, Pakistan

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Pegmatites in the Gilgit division of northern Pakistan have yielded exceptionally fine specimens of multicolored tourmaline, aquamarine beryl, sherry colored topaz and almandine-spessartine garnet. The deposits are located in the Western Himalayas near some of the highest mountain peaks in the world.

INTRODUCTION

The Gilgit division of northernmost Pakistan has common boundaries with India, China and Afghanistan, while the Russian border with Afghanistan runs nearly parallel to its northern margin along the Oxus River, barely 64 kilometers to the north. The lofty Karakoram Range (highest elevation, Mt. Godwin Austin (K_2) 8,612 meters; 28,250 feet) covers its northern part, whereas the Nangaparbat Range (Nangaparbat peak 8,115 meters; 26,660 feet) forms its southern margin. This region contains some of the highest mountain peaks in the world. It forms the upper catchment of the mighty Indus River which has carved out the deepest canyon in the world, the spectacular Indus Canyon, which is more than 6,100 meters deep near Chilas.

Gilgit, the divisional headquarters, is a small frontier town, located approximately 280 km northeast of Islamabad. It may be approached by a good paved, all-weather road, the Karakoram Highway, constructed along the Indus canyon, through some of the most rugged mountainous terrain in the world. The Pakistan International Airlines operates a daily passenger service to Gilgit from Islamabad.

The known and productive gem pegmatites of the Gilgit division are located in the vicinity of Shingus village, about 80 km southeast of Gilgit, and near Dusso village about 200 km southeast of Gilgit and 80 km north of the town of Skardu. Both of these localities are easily accessible by road.

PREVIOUS INVESTIGATIONS

Middlemiss and Parshad (1918) first mentioned the occurrence of gem pegmatites and aquamarine in the Gilgit region. They reported that villagers made the initial discovery of aquamarine near Dusso in 1912. Parshad reported that he "had the satisfaction of coming upon beautifully clear aquamarine crystals . . . 2 or 3 inches thick and 2 to 6 inches long . . . in a thick vein of pegmatite, at the village of Daso (Dusso), lying a few miles south of and under Ganchan peak." Ivanac *et al.* (1956) investigated aquamarine-bearing pegmatites reported in the Hunza (50 km northeast of Gilgit) and Haramosh areas (same as Shingus). They state that "One beryl-bearing pegmatite with pale, blue-green crystals of beryl ⅓ to ¼ inch in diameter was examined, and this deposit was the only one known to the villagers. Only two crystals of beryl were seen. Further investigation of beryl deposits seems unwarranted, because beryl-bearing pegmatites are apparently very rare, and are likely to be snow-covered for most of the year." Gübelin (1981) noted that colorless goshenite and pale blue aquamarine crystals "are found in great quantity . . . at Dusso in the area of Skardu."

One of us (HO) travels to Pakistan several times a year in search of display-quality mineral specimens for museums and private collections and has visited the gem pegmatites near Shingus and Dusso. Detailed work on these pegmatites has been done by the Gemstone Corporation of Pakistan, under the guidance of one of us (AHK).

REGIONAL GEOLOGY

The Shingus-Dusso area is located in one of the most geologically dynamic environments in the world—at the suture zone along which the Indo-Pakistan and Asian crustal plates have collided. This area encompasses three major crustal elements or domains.

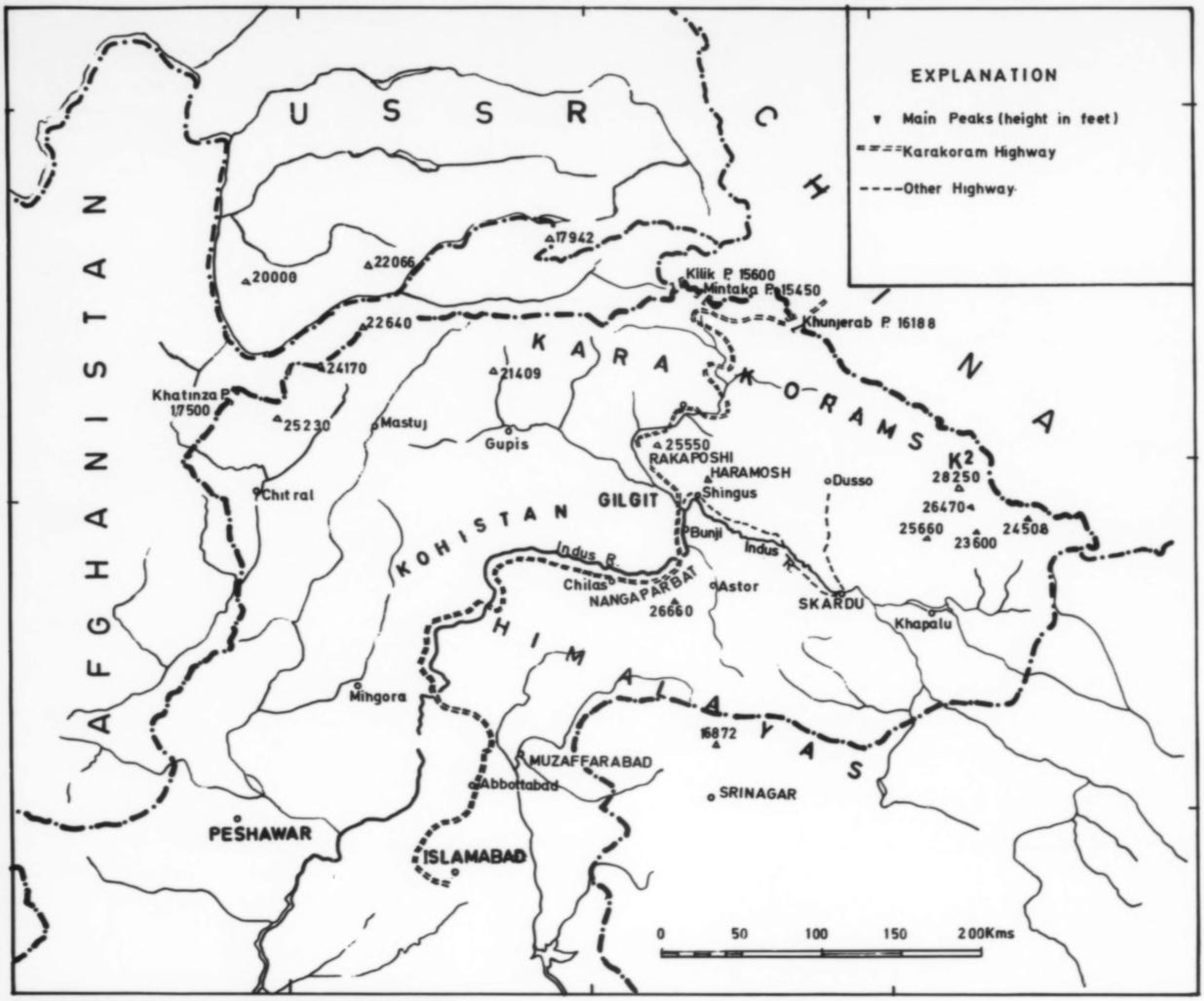


Figure 1. **Location map of the Gilgit division of Pakistan.**

From north to south, these are: (a) the components of the Asian plate which are thrust over the andesitic Kohistan Island Arc, their boundary being marked by the Main Karakoram Thrust or MKT (Tahir Kheli, 1979), (b) the Kohistan Island Arc which has been obducted onto (c) elements of the Asian plate. The boundary between the latter two components is marked by a great thrust fault, the Main Mantle Thrust or MMT (Jan, 1977; Jan and Symes, 1977; Tahir Kheli, 1979; Tahir Kheli *et al.*, 1979) which is the location of a past subduction zone and is the western continuation of the Indus-Tsangpo suture zone (Kazmi *et al.*, 1984; Lawrence *et al.*, 1983). The MKT and MMT are characterized by outcrops of ophiolitic and metavolcanic rocks (Stocklin, 1977; Gansser, 1981; Kazmi *et al.*, 1984) which record the suturing of the Kohistan Arc to the Asian continent to the north and to the Indian subcontinent to the south.

The rock sequence exposed in the Shingus-Dusso area is summarized in Table 1. The table also cites the major publications on the geology of this area.

GEM-BEARING PEGMATITES OF THE SHINGUS REGION

The Shingus area comprises the southern part of the lofty Haramosh mountains (Haramosh peak 7,399 meters; 24,270 feet). The Indus River flows through this region and has cut a narrow 6,100-meter deep canyon near Shingus. An all-weather road linking Gilgit with Skardu runs through the area on the bank of the Indus. The MMT forms a narrow u-shaped loop in this region giving rise to a structural feature commonly referred to as the Nangaparbat-Haramosh syntaxis. The Precambrian Nangaparbat gneissic complex and associated late stage granitic intrusions are exposed in the

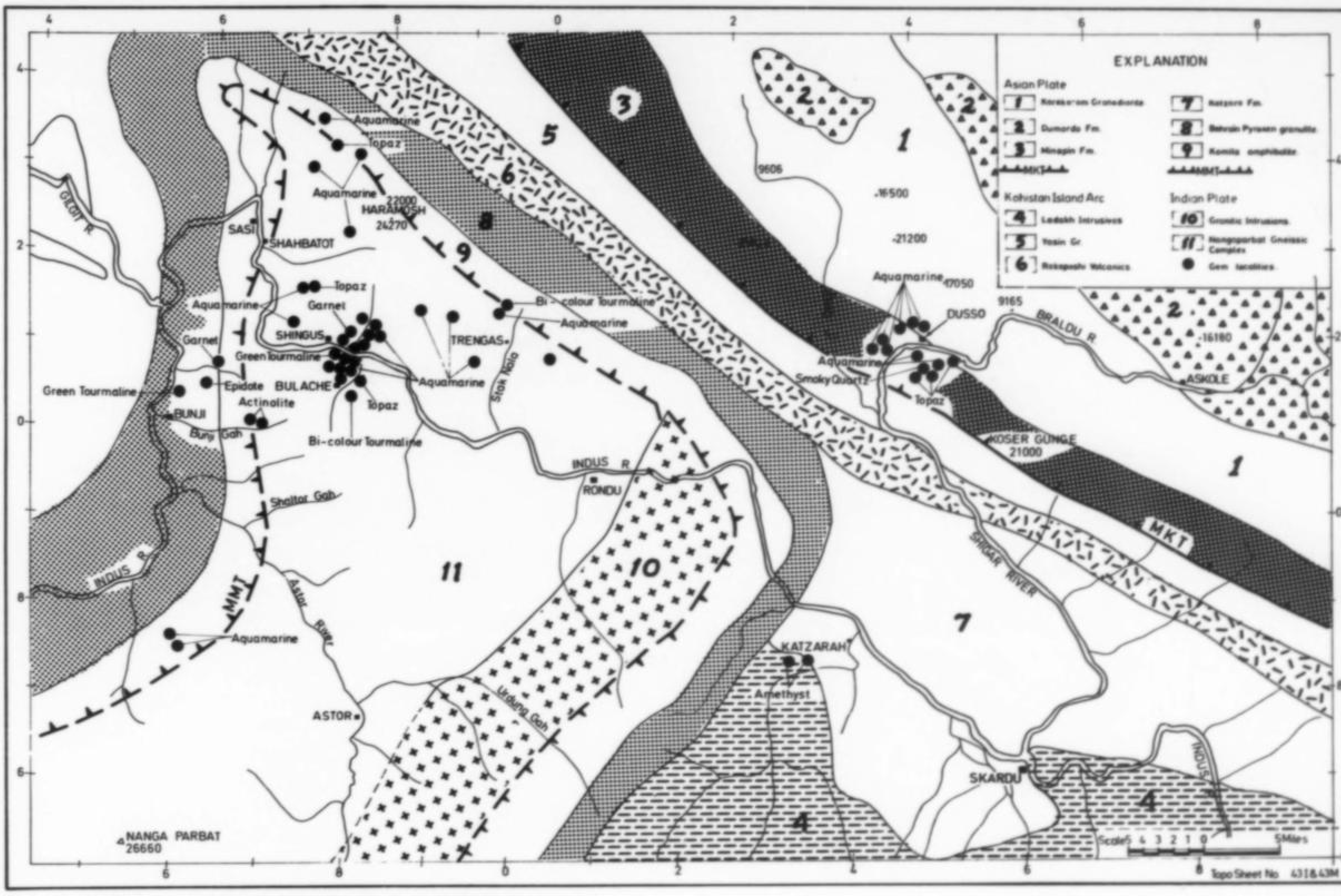


Figure 2. **Sketch map showing pegmatite gem deposits in the Shingus-Dusso area of Gilgit, Pakistan.**

Table 1. **Stratigraphic sequence in the Shingus-Dusso area of Gilgit Division**

	AGE
ASIAN PLATE	
Main Karakoram Batholith	
Granite, granodiorite with some basic plutonic rocks. (Desio, 1964).	Miocene to Pliocene
Dumordo Formation	
Marble interbedded with garnetiferous calc. schists and gneisses. (Schneider, 1957; Desio, 1963, 1964, 1974, 1979).	Triassic to Cretaceous
Minapin Formation	
Slates, phyllites, schists, metaconglomerates and marbles. (Tahir Kheli, 1982).	Precambrian to Lower Paleozoic
Main Karakoram Thrust (MKT)	
KOHISTAN ISLAND ARC	
Ladakh Intrusives	
Granite, granodiorite to diorite. (Jan, 1977; Bard *et al.*, 1980, Tahir Kheli, 1982).	Late Upper Eocene to Lower Miocene
Dras Volcanics*	
Pyroxenite, serpentinite, norite, pillow basalt, pyroclastics, hornfels and amphibolite. (Wadia, 1937; Zanettin, 1964; Desio, 1979).	Cretaceous to Eocene
Burji Formation*	
Fossiliferous limestone and shale. (Desio, 1964; Casnedi, 1976).	Cretaceous to Tertiary
Hornfels*	
Yasin Group	
Inconsistently fossiliferous slates, quartzites, metaconglomerates, limestones and volcanics. (Hayden, 1916; Ivanac *et al.*, 1956; Tahir Kheli *et al.*, 1979).	Upper Cretaceous
Rakaposhi Volcanic Complex	
Metamorphosed basalt-andesite-dacite-rhyodacite flows with quartzite and marble. (Ivanac *et al.*, 1956; Stauffer, 1968; Tahir Kheli, 1982).	Late Lower Cretaceous
Katazara Formation	
Slates, phyllites, quartzites and garnetiferous schists. (Casnedi and Ebblin, 1977).	Late Upper Eocene to Lower Eocene
Bahrain Pyroxene Granulite (Jan, 1977; Tahir Kheli *et al.*, 1979).	Early to Lower Cretaceous
Kamila Amphibolite (Jan, 1977; Tahir Kheli *et al.*, 1979).	Jurassic to Lower Cretaceous
Main Mantle Thrust (MMT)	
INDIAN PLATE	
Granite Intrusions	Late Upper Eocene to Lower Miocene
Nangaparbat Gneiss Complex	
Gneisses and schists. Metamorphosed sediments of Salkhala formation. (Wadia, 1932; Tahir Kheli *et al.*, 1979).	Upper Cretaceous

*Outcrops outside of area mapped in Fig. 2.

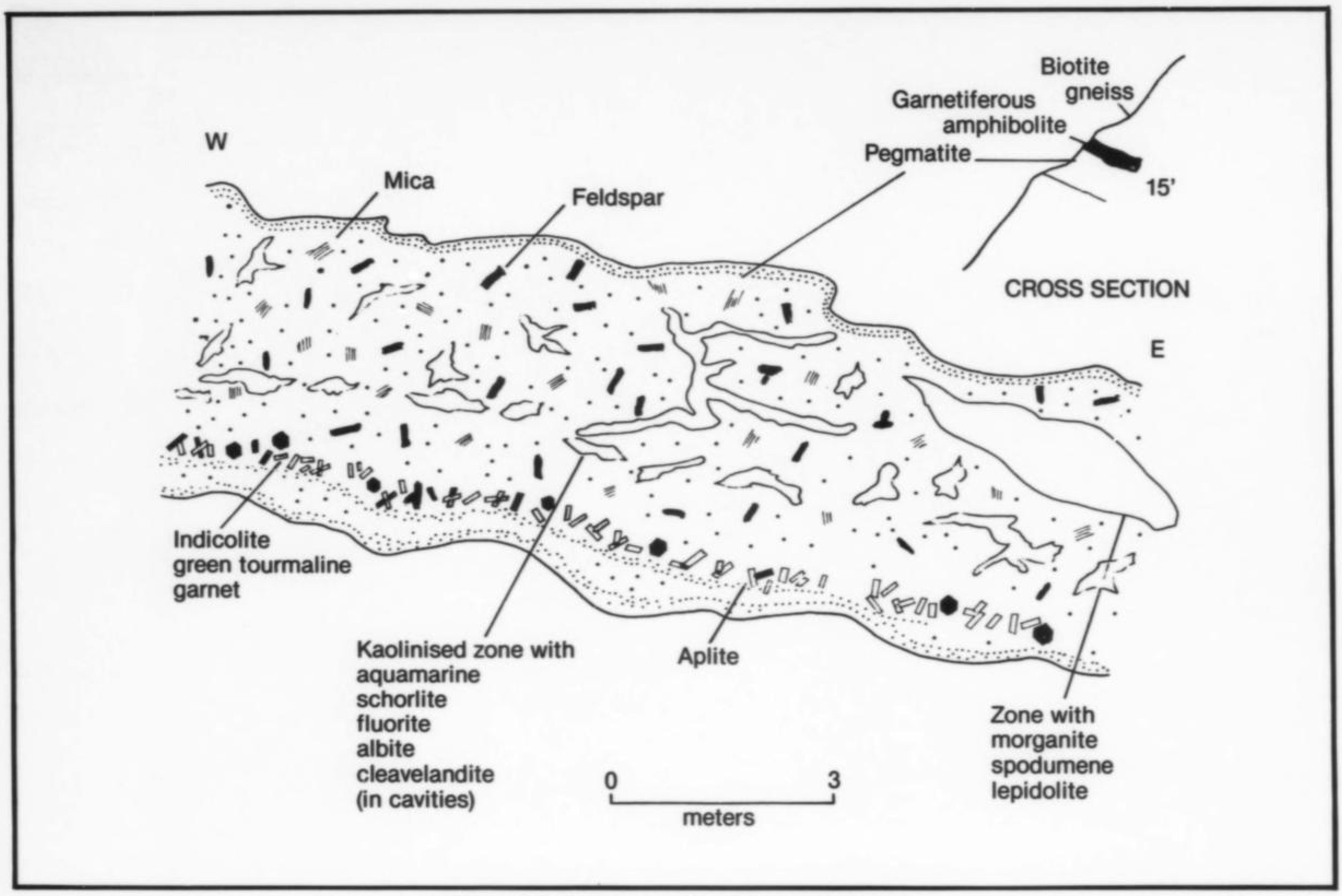


Figure 3. **Strike section of the Shingus pegmatite (diagrammatic).**

core of this loop which is bounded by the MMT, forming an anticline. It contains elements of the Indian crustal plate which have been subducted beneath the rocks of the Kohistan Island Arc, a wide belt of amphibolites and pyroxene granulites wrapped round the Nangaparbat-Haramosh genissic complex. Extensive swarms of pegmatites are seen in this gneissic complex and this area comprises one of the major pegmatite districts in Pakistan.

In this region the gem-bearing pegmatites occur at four principal localities:

1. In the vicinity of the Haramosh peak.
2. Near Shingus village, on the north bank of the Indus.
3. Near Bulechi village, on the south bank of the Indus.
4. In the Stak Nala, near Ghorapa village in the shadows of Paraber peak (6,323 meters; 20,740 feet).

In the Shingus area, the Nangaparbat gneissic complex contains the following major lithologic units:

Leucocratic Biotite-Muscovite Gneiss

This unit occurs interlayed with quartzite and has been intensely dissected by stringers and veins of pegmatite. It contains a few basic dikes and sills. Augen structure and segregation banding (5–15 centimeters) of mica and feldspar are common features. Pegmatites in this unit have a random occurrence. Most of them are concordant and show gradational contact. Most are composed of feldspar (65–70%), quartz (20%), biotite and muscovite (5%) and schorl (1%).

Biotite Gneiss

The biotite gneiss is intensely deformed and foliated, pale gray, weathering to yellowish gray, fine-grained, hard and compact. It contains layers of feldspar and mica. Garnet, tourmaline and augens of quartz and feldspar are also present. In places it is graphitic and contains layers, lenses and sills of amphibolites and other basic rocks. The pegmatites intruded in this unit are discordant with sharp contacts with the host rock. The biotite gneiss has a gradational contact and apparently overlies the leucocratic biotite-muscovite gneiss.

Granite Gneiss

The granite gneiss is mainly composed of feldspar, quartz and biotite with trace amounts of muscovite and garnet. It is pale gray, fine-grained, hard, compact and massive. It is well-jointed and fractured and has been intruded by mafic sills and granite pegmatite bodies.

Amphibolites

These are largely para-amphibolites and occur as large layers, interfoliated with gneisses. They are dark gray, medium-grained, garnetiferous and are also intruded by pegmatite dikes. These amphibolites form extensive outcrops near Shingus.

Pegmatites

The pegmatites in the Haramosh, Shingus, Bulechi and Stak Nala localities form extensive swarms, with outcrops extending up to a few kilometers and ranging in thickness from a few centimeters to several meters. They occur in a variety of shapes, forming a network of parallel veins, with some veins intersecting each other. They also occur as arcuate or crescentic lenses. The pegmatites are commonly discordant, though some show a concordant relationship.

At Shingus they have been emplaced along two distinct sets of

Figure 4. **The trail to Stak Nala. David P. Wilber photo.**

Figure 5. **Gemstone Corporation employees at Stak Nala. David P. Wilber photo.**

Figure 6. **The Stak Nala pegmatite. David P. Wilber photo.**

joints, one striking east-northeast and the other west-northwest. The pegmatites have been physically deformed by folding, offset by faulting and, in places, have been mylonitized. Slow cooling has created perthitic textures in some portions of the pegmatites. Alteration of feldspar to kaolinite and seam-filling with limonite is commonly observed.

The Bulechi pegmatites are similar to those at Shingus and have been intruded into thinly-foliated augen gneiss and banded biotite gneiss. In some places these cut across garnetiferous amphibolites. The pegmatites range in thickness from a few centimeters to several meters and vary in length from a few meters to a 100 meters or more. They largely cut across the foliation and have been intersected and offset by a number of right lateral wrench faults. A few smaller, satellite pegmatites run parallel to the foliation.

Most of the Shingus, Bulechi and Haramosh pegmatites are zoned and consist of an outer fine-grained granitoid or aplitic zone and an inner coarsely-grained pegmatitic zone with vugs and cavities ranging from 5 centimeters to almost 1 meter across. Often the central zone is kaolinized. Near the outer margins of a few pegmatites is a thin zone of radiating schorl crystals or crystals of blue (indicolite variety) and green (verdelite variety) elbaite with garnet. Other pegmatites lack this zone and contain randomly distributed vugs and cavities.

In general the Shingus, Bulechi and Haramosh pegmatites are composed of feldspar (largely albite and microcline, 60%), quartz (10–15%), biotite and muscovite (5–10%) and schorl (1–5%). Almandine garnet occurs in a few pegmatites. Beryl commonly occurs as phenocrysts in the groundmass. Beautiful euhedral crystals of feldspar, quartz, tourmaline, mica and gem grade aquamarine occur in vugs and cavities, grown on and between plates of albite. The aquamarine crystals are commonly pale blue, 2.5 to 10 centimeters long and are occasionally intergrown, forming radiating sprays. The goshenite and morganite varieties of beryl are also present in small quantities. A few pegmatites contain sparsely-distributed, euhedral crystals of colorless topaz, green elbaite (verdelite) and large euhedral crystals of bicolored (brown and clear) elbaite. Some of the Bulechi pegmatites also contain lepidolite and spodumene.

The Stak Nala pegmatites are located opposite Kongo Dass village, about 60 meters above Stakgah at an elevation of approximately 3,050 meters. The larger pegmatites are 1.2 to 1.8 meters thick and up to 15 meters long. These pegmatites have become famous for euhedral crystals of bicolored and tricolored tourmaline which occur in vugs and cavities intergrown with quartz, feldspar and mica, commonly jacketed by platy albite (cleavelandite) crystals. The elbaite crystals are typically zoned; the base of the crystals are opaque and colored black, brown or dark green; the terminations are translucent to transparent and colorless, pink or blue. Occasionally, well-developed, euhedral crystals of green fluorite or violet to pink fluorapatite are also found intergrown with other crystals in the cavities.

GEM-BEARING PEGMATITES OF THE DUSSO REGION

The Dusso area is located on the southern slope of the main Karakoram Range, near the confluence of the Basha and Braldu

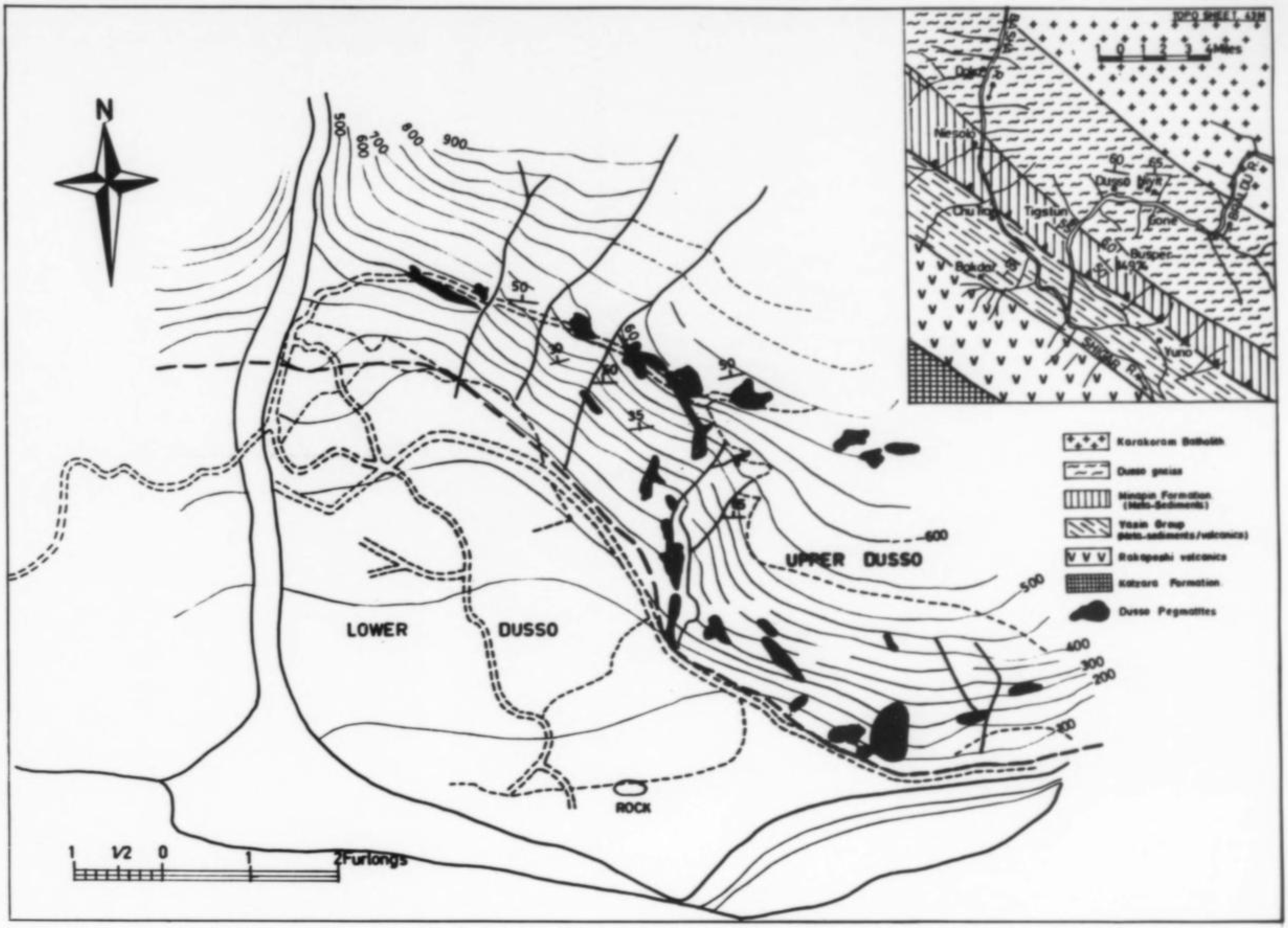


Figure 7. **Sketch map showing location of Dusso pegmatites.**

rivers at an altitude of about 2,590 meters. This area encompasses metasediments of the Minapin formation and granitic rocks of the Karakoram Batholith which form the leading edge of the Asian crustal plate and have been pushed over the metasedimentary and volcanic rocks of the Kohistan Island Arc by the Main Karakoram Thrust. The MKT passes within 8 km of Dusso which itself is located close to the contact of the Minapin formation and the granodioritic Karakoram Batholith. The Minapin formation, which contains Precambrian to Lower Paleozoic slates, phyllites, schists and marbles, extends in a bank between the Karakoram Batholith and the MKT. The Karakoram Batholith is largely composed of granite, granite gneiss and granodiorite but also contains relatively small outcrops of more basic plutonic rocks. It is interpreted to have been emplaced above a north-dipping subduction zone on the leading edge of the Asian continent prior to the final suturing of the Indo-Pakistan Plate to the Asian Plate. Desio *et al.* (1964) have given the age of this batholith as Miocene to Pliocene, but according to Tahir Kheli (1982) an older age will ultimately be determined.

At Dusso, near the contact of the Minapin formation and the Karakoram Batholith, a considerable thickness of biotite gneiss and biotite schist, with a few marble bands is exposed. The biotite gneiss grades into biotite schist and epidote-hornblende gneiss. These rocks are commonly banded and have been intruded by ultrabasic dikes as well as pegmatite veins.

The Dusso area contains the other major pegmatite field in Pakistan. Swarms of pegmatite dikes occur in this region, principally clustered around the following localities:

1. At Dusso village.
2. Near Niyit Bruk village, 8 km northeast of Dusso.
3. Near Gone, 8 km east of Dusso.
4. Near Tisgtung village, 5 km southwest of Dusso.

The Dusso pegmatites are exposed on the hill slope just above (northeast of) Dusso village. Dikes, lenses and irregularly-shaped pegmatites intrude biotite gneiss and vary in size from a few meters across to up to 8 meters thick and 45 meters long. They contain an outer, fine-grained aplitic zone and an inner coarsely-grained pegmatitic zone containing vugs and cavities. The main constituents of these pegmatites are plagioclase, quartz, muscovite, biotite, beryl and schorl. The vugs contain euhedral crystals of pale blue gem-grade aquamarine with quartz, feldspar and mica. Some of the pegmatites contain massive rose quartz while other show banding with zones of beryl and mica and zones of schorl. At places, the pegmatites have been sheared and along these fracture planes garnet, galena and pyrite have formed.

The Niyit Bruk pegmatites occur south of Niyit village, across the Braldu River at an altitude of about 4,270 meters, approximately 1,740 meters above the river bank. The pegmatites occur in biotite gneiss and have become famous for fine, clear, euhedral, gem-grade crystals of brown topaz. So far only one of the pegmatite veins has proved to be productive. It is a tabular and discordant body 0.4 to 0.7 meters thick, about 42 meters long, striking northeast and dipping 35° northwest. It has a fine-grained aplitic outer zone (2.5 to 7.5 cm thick), followed by an intermediate zone of coarsely-grained pegmatite (17.5 to 22.5 cm) and an inner, kaolinized zone full of vugs and cavities (25 to 30 cm thick). The

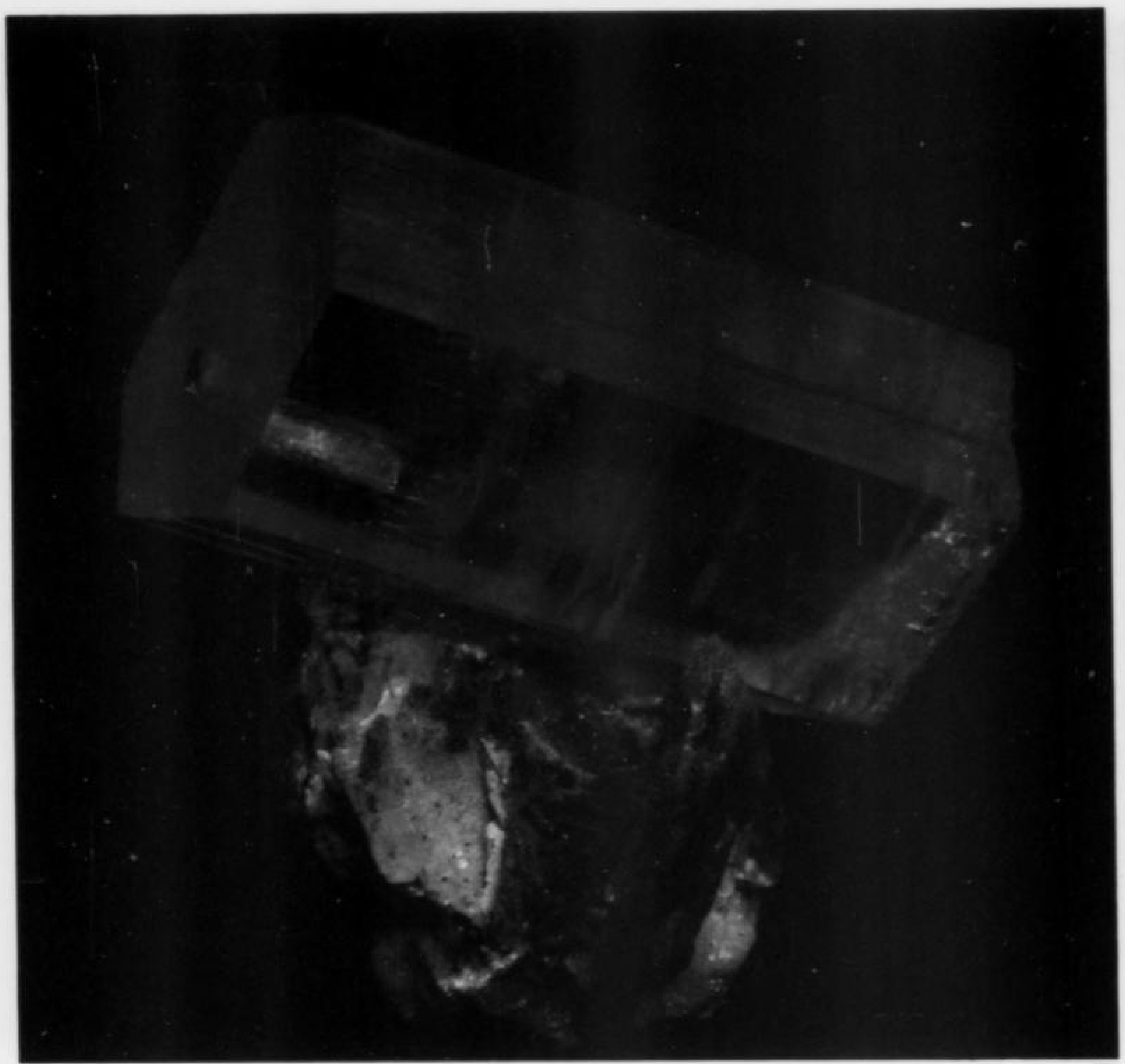


Figure 8. **Pale blue, doubly terminated beryl variety aquamarine crystal 4.8 cm long associated with silvery brown muscovite and white albite, from near Dusso, Gilgit division, Pakistan. Eugene Schlepp specimen.**

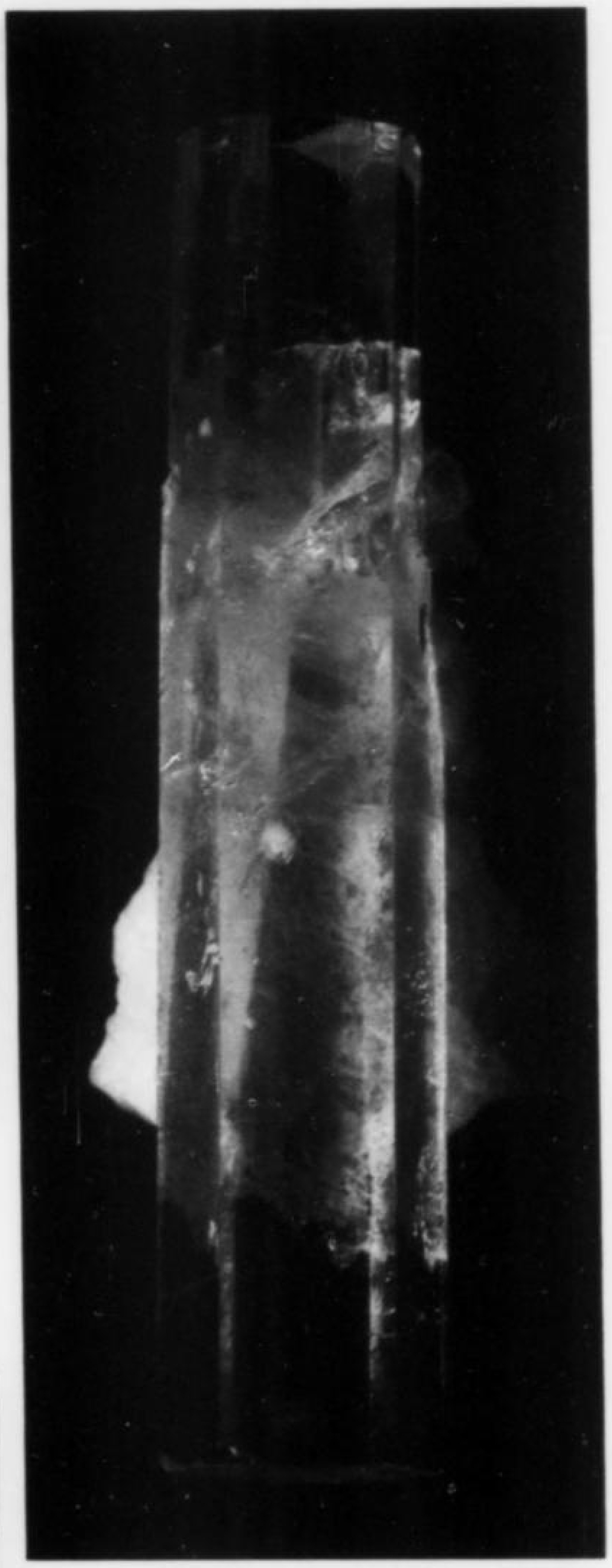


Figure 9. **Pale blue, hexagonal beryl variety aquamarine crystal 7.5 cm long associated with white albite, from near Dusso, Gilgit division, Pakistan. AMNH 92128; photo by Olivia Bauer and Jackie Beckett.**

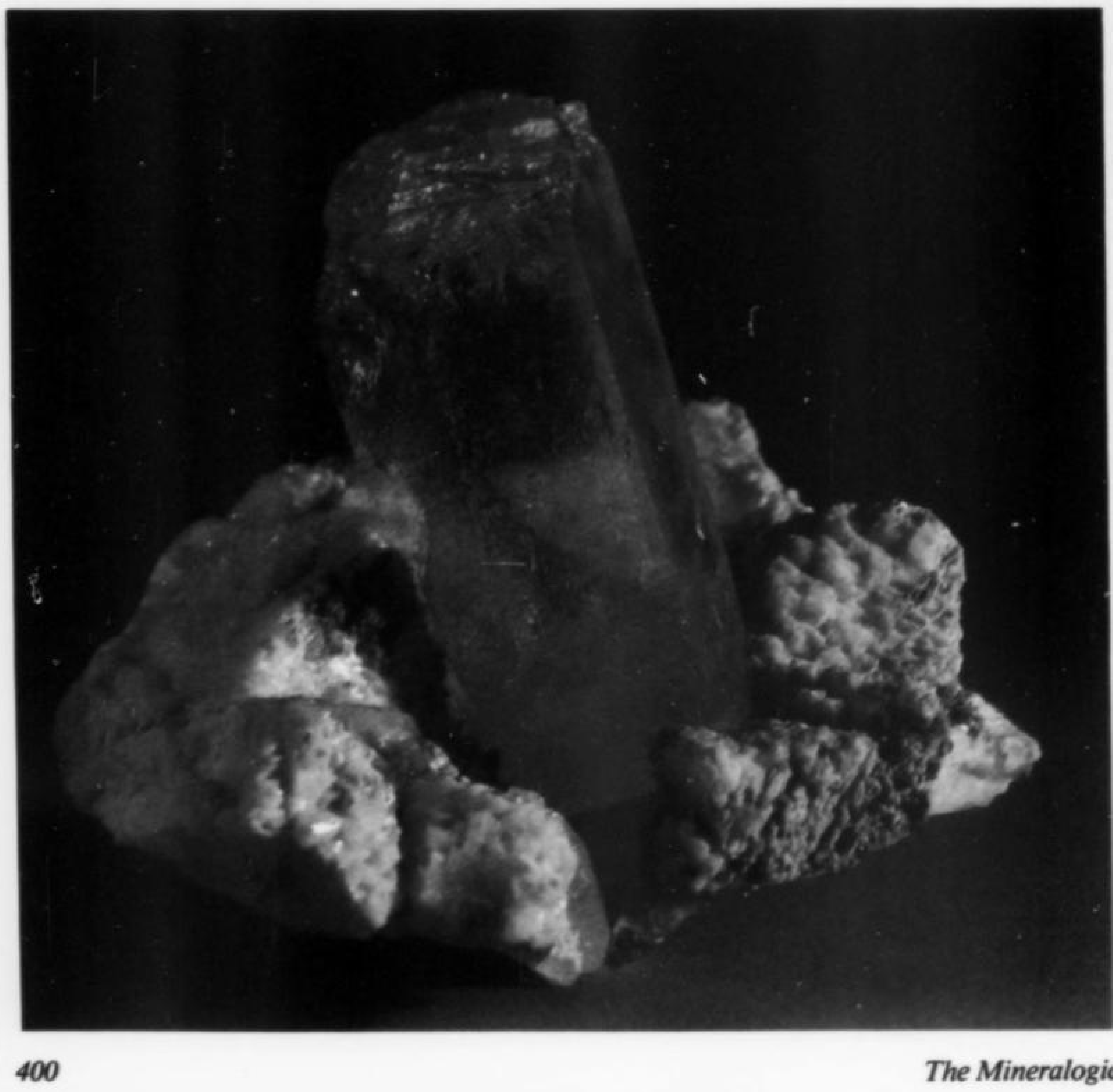


Figure 10. **Pale blue, etched beryl variety aquamarine crystal 8 cm long associated with white albite, from near Dusso, Gilgit division, Pakistan. AMNH 95607; photo by Olivia Bauer and Jackie Beckett.**

Figure 11. **Magnificent group of pale blue, hexagonal beryl variety aquamarine crystals (two views). This is one of the finest crystal groups collected from the Dusso pegmatites during the past decade. The specimen measures 7.0 cm by 16.0 cm and currently resides in the James A. Gibbs collection. Photo by Olivia Bauer and Jackie Beckett.**

Figure 12. **Inky blue, hexagonal crystals of beryl 2.5 cm long on matrix of grayish white calcite with minor silvery brown muscovite, from the Haramosh Mountains, near Skardu, Gilgit division, Pakistan. AMNH 97489; photo by Olivia Bauer and Jackie Beckett.**

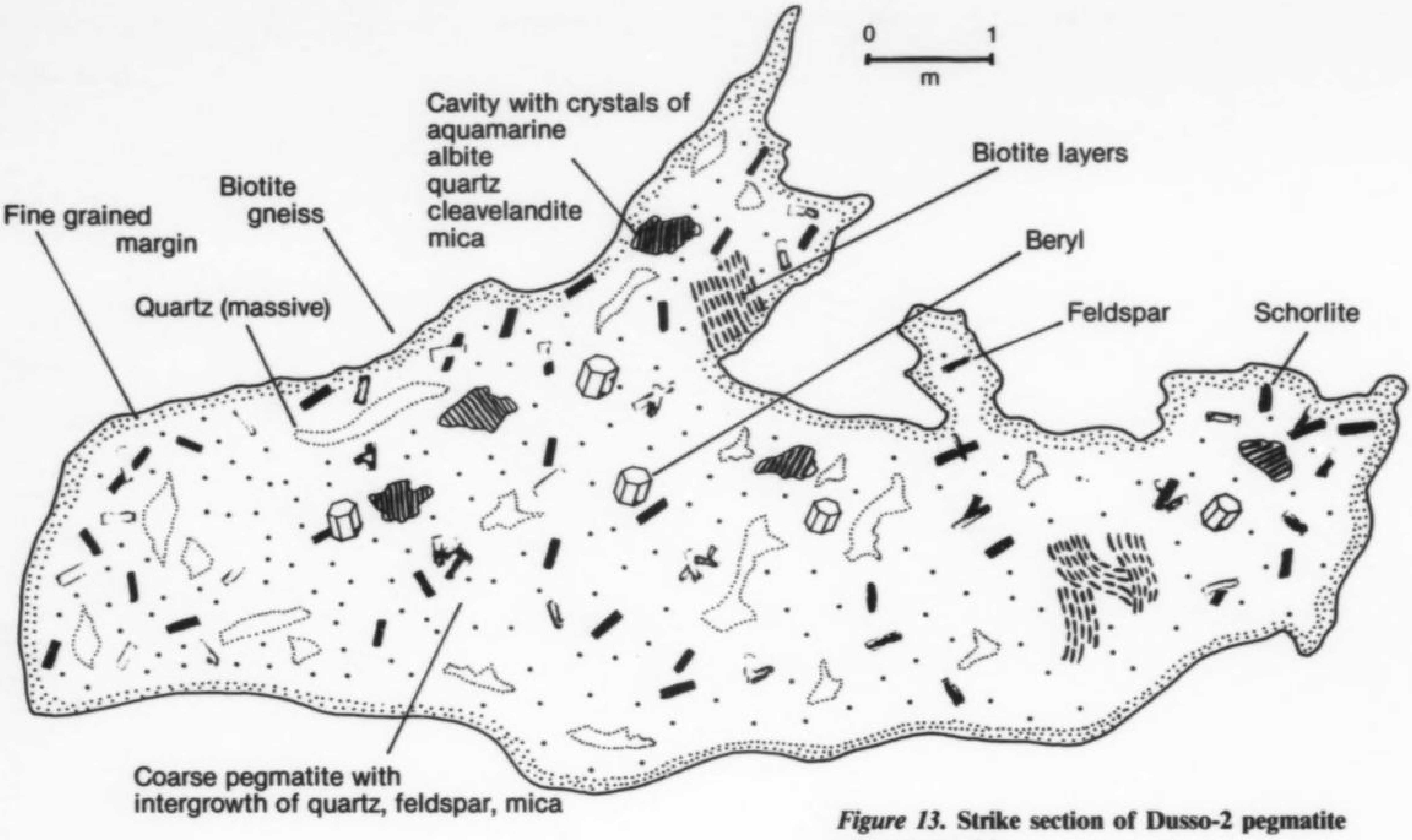


Figure 13. **Strike section of Dusso-2 pegmatite (diagrammatic).**

pegmatite contains plagioclase, quartz, tourmaline and muscovite.

Topaz occurs mainly in vugs and cavities in the center of the pegmatite. It is transparent, colorless or light to medium brown and occurs as well-formed, perfectly euhedral, prismatic, doubly-terminated crystals. Crystals range in weight from 5 to 200 grams and are usually clear, transparent and flawless. It is associated with euhedral crystals of quartz and feldspar and rosette-like groupings of white, platy albite crystals. Green, transparent to translucent crystals of hydroxyl-herderite are also found occasionally.

The Gone pegmatites are located on the southern bank of the Braldu River about 8 km east of Dusso. They intrude the Karakoram granodiorite and have a fine grained outer margin and a coarse-grained central pegmatitic zone containing vugs and cavities. Transparent, colorless to brown euhedral crystals of gem-grade topaz and pale blue crystals of gem-grade aquamarine occur in vugs associated with plagioclase, orthoclase, quartz, muscovite and schorl. Fluorite is rare and occurs in the groundmass, not in the vugs. These pegmatites produce good collector-quality specimens.

The Tisgtung pegmatites occur northeast, northwest and east of Tisgtung village, about 5 km southwest of Dusso. They intrude biotite gneiss and, like other pegmatites in this region, possess a fine-grained outer zone and a coarse-grained pegmatitic inner zone containing vugs and cavities in their central portion. They contain plagioclase, quartz, muscovite, biotite, schorl and beryl variety aquamarine. The pegmatites east of Tisgtung also contain beryl and garnet.

MINERALOGY

Specimens from Gilgit-area pegmatites represented in the mineral collection of the American Museum of Natural History, New York, are described in detail. Important AMNH specimens have been photographed, along with a few specimens from other collections. Brief descriptions of specimens housed at the British Museum (Natural History) are also provided. The following descriptions are heavily skewed toward gem-quality crystals or esthetic specimens as this type of specimen preferentially reaches museums and private mineral collectors. Unless otherwise noted, all specimens are thought to have crystallized within vugs and cavities located near the center of the pegmatites. Precise localities for the AMNH specimens described below are lacking. Most of these specimens were originally obtained by one of us (HO) from local Pakistani prospectors who may have deliberately provided misleading information to prevent others from exploiting productive pegmatites. However, the localities cited below are thought to be reasonably accurate.

Albite $NaAlSi_3O_8$

Albite (var. cleavelandite) is found associated with microcline, schorl, elbaite and muscovite at Dusso, Stak Nala and most other Gilgit-area pegmatites. It typically occurs at Stak Nala in the form of white, centimeter-sized, curved plates coating elbaite crystals.

Beryl $Be_3Al_2Si_6O_{18}$

Middlemiss and Parshad (1918) reported that translucent to transparent aquamarine crystals from Dusso typically measured from 5 to 15 cm in length and 1 to 7.5 cm in width, while transparent crystals were 5 to 7.5 cm in length and 1 to 3 cm in width. Transparent, pale aquamarine crystals from Dusso-area pegmatites collected since 1980 are larger, typically 5 to 8 cm in length and 1 to 3 cm in width. One especially large aquamarine crystal group obtained by one of us (HO) and now in the James A. Gibbs collection measures 16 cm long and 7 cm wide.

Many of the aquamarine crystals collected at Dusso-area pegmatites are associated with albite. The middle portion of these aquamarine crystals is enveloped in an albite "jacket," while the terminations are not. Curiously enough, nature has also "fitted" the tourmaline crystals of the neighboring Stak Nala pegmatite with these feldspar "jackets." This type of association appears to be the rule, rather than the exception, and it can be an aid in determining whether a particular beryl or tourmaline specimen originated from the Gilgit area.

Beryl (var. goshenite) has been reported from the Dusso area by Gubelin (1981). One specimen preserved at the AMNH (AMNH

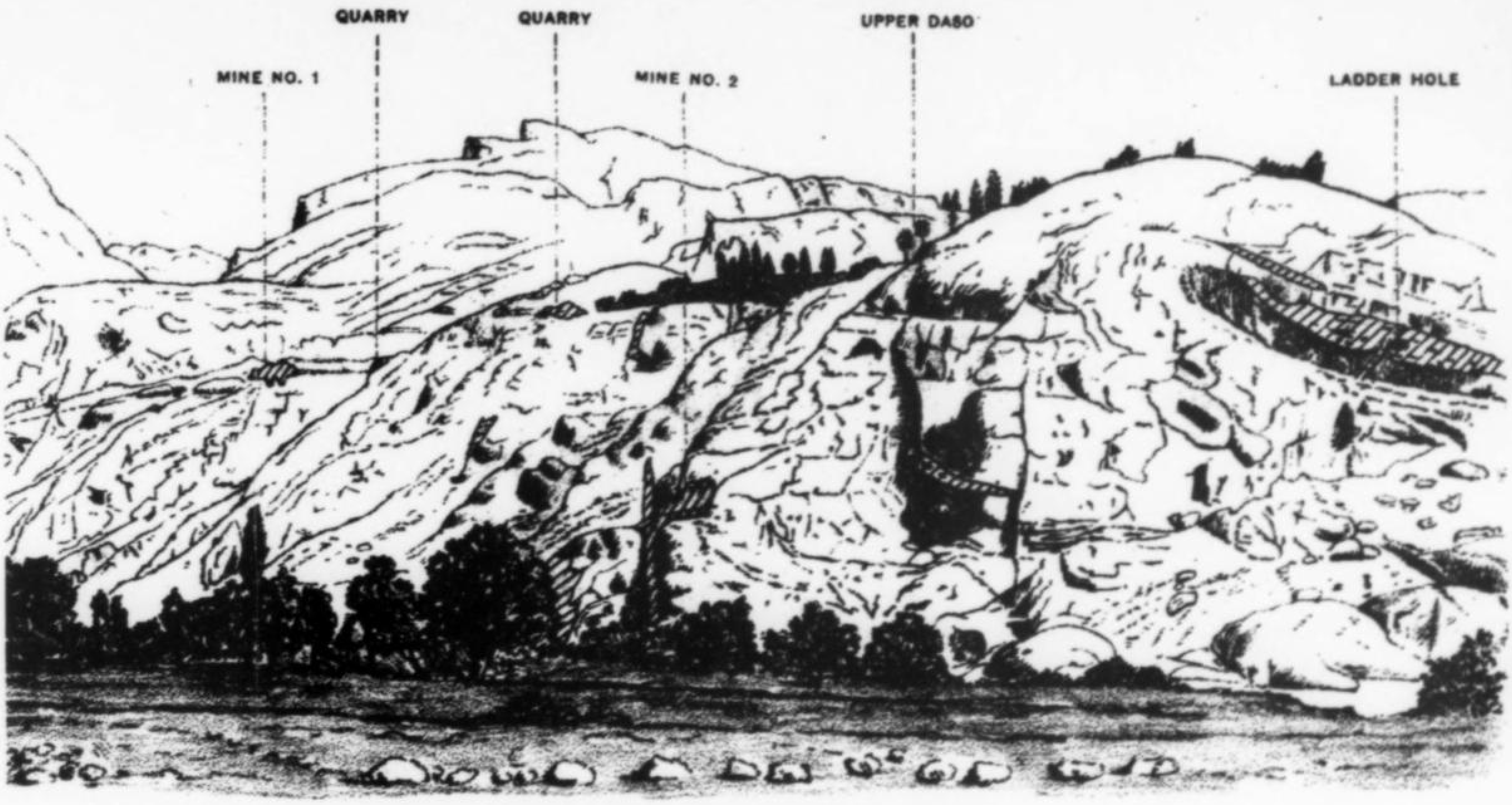


Figure 14. **Plan view of the Dusso aquamarine mines (reproduced from Middlemiss and Parshad, 1918).**

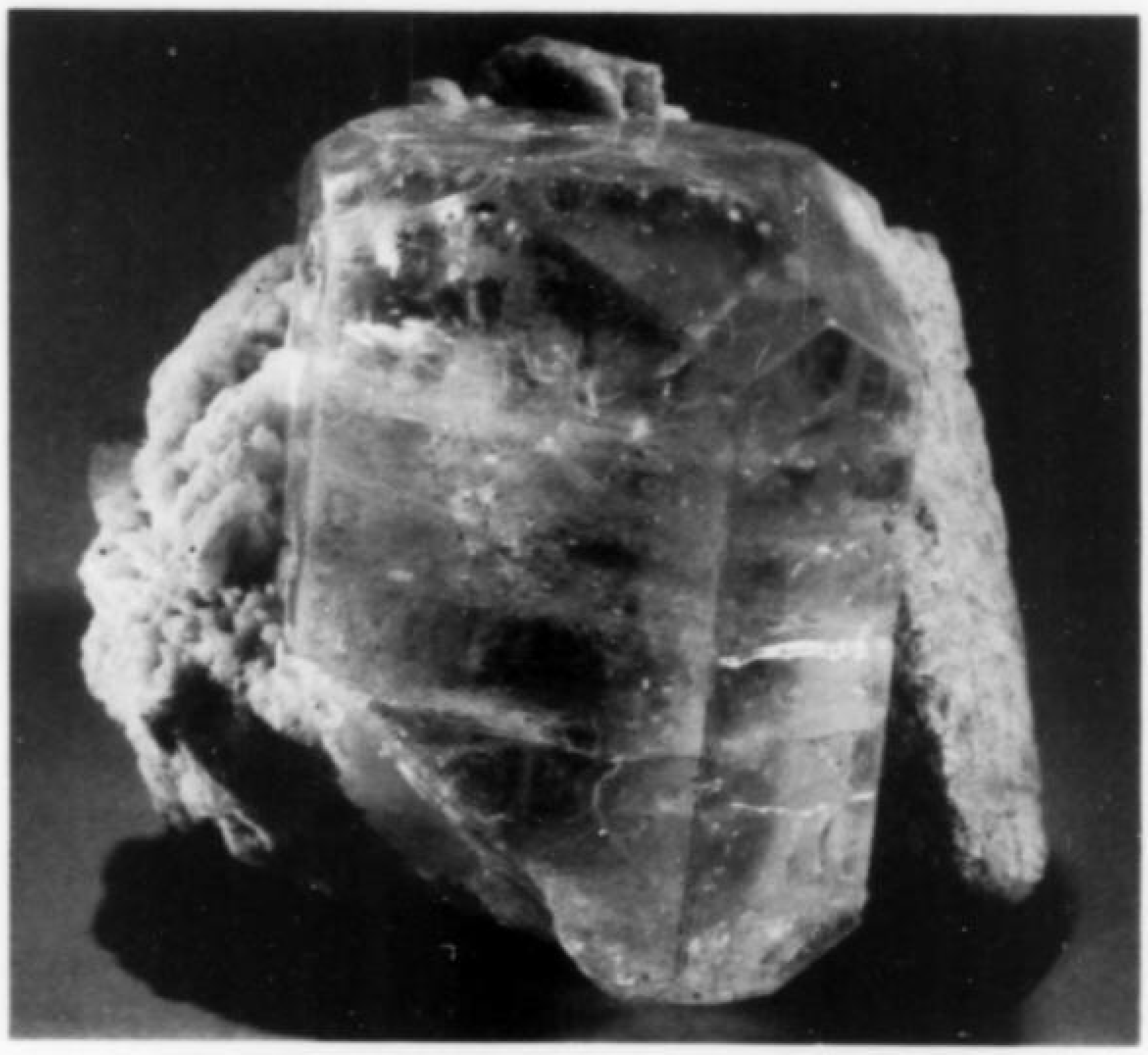


Figure 15. **Colorless to white, hexagonal crystal of beryl variety goshenite 8.0 cm high associated with white albite, from the Haramosh Mountains, near Skardu, Gilgit division, Pakistan. AMNH 48837; photo by Olivia Bauer and Jackie Beckett.**

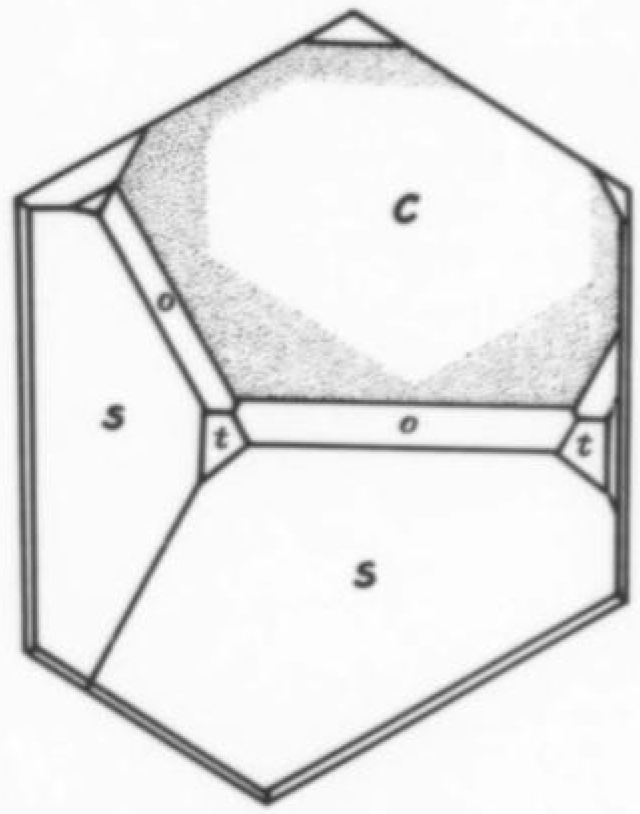


Figure 16. **Terminal faces on a beryl crystal. Gene Schlepp collection. Sketch by Wendell E. Wilson.**

48837) consists of a well-formed, colorless to white crystal 8 cm tall associated with albite.

An unusual specimen consisting of inky blue crystals of beryl (average 1 cm long) on a calcite matrix was collected in the Haramosh region. Shams (1963) reported finding similar material in the Swat area. Fragments of the deeply-colored Haramosh material have been examined optically and by Gandolfi X-ray diffraction techniques to ascertain whether this coloration is intrinsic or caused by microscopic inclusions of another phase. X-ray analysis failed to reveal any contaminating phase. Microscopic examination revealed that the beryl fragments have no visible inclusions and are strongly pleochroic (deep inky blue to almost colorless) which leads us to believe the color of this material is intrinsic.

Calcite $CaCO_3$

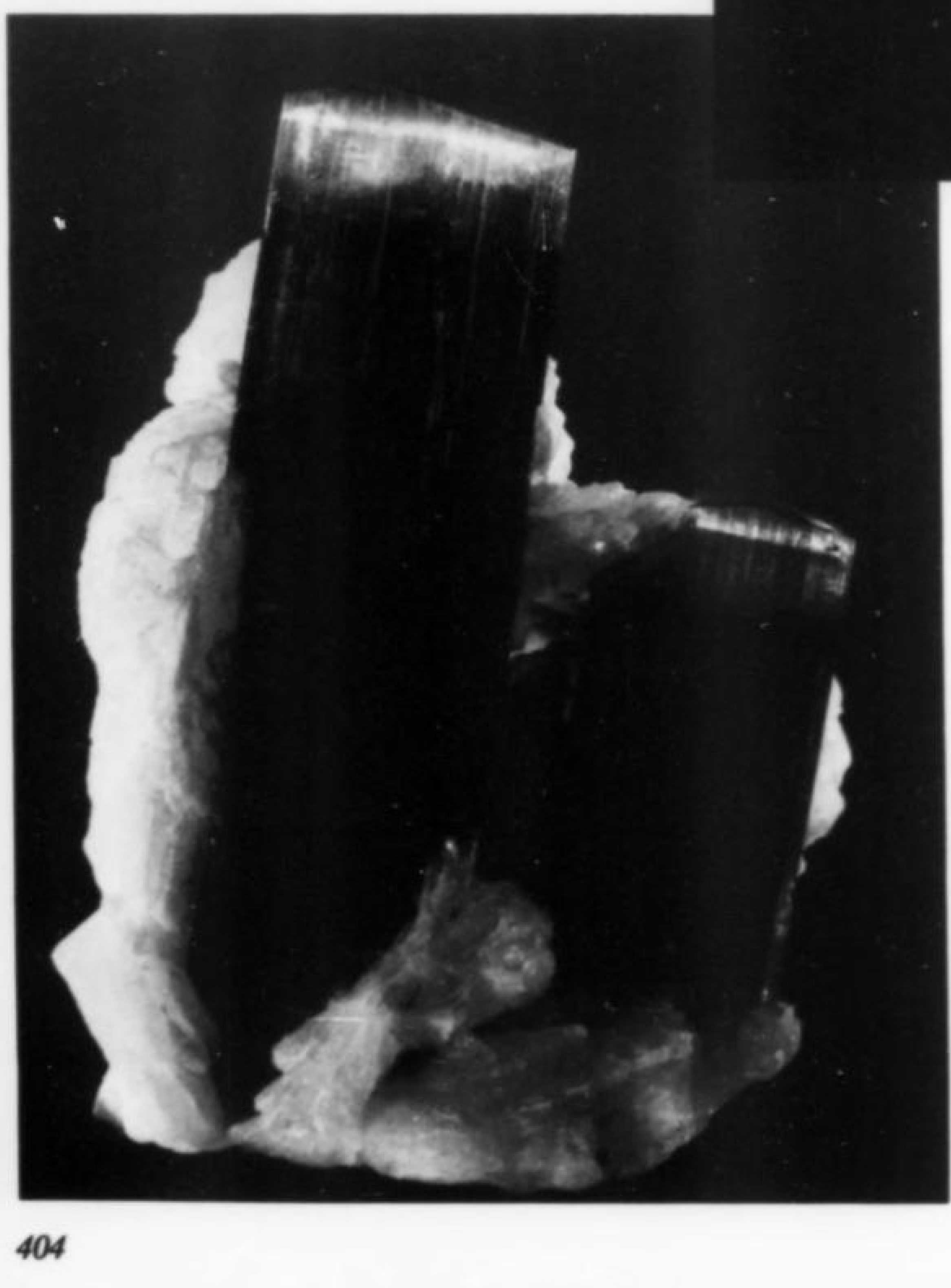
Calcite rarely occurs in pegmatites. However, one pocket in the Haramosh region produced specimens of grayish white calcite associated with inky-blue beryl crystals.

Cassiterite SnO_2

Small (average 1 to 2 cm) crystals of lustrous, black cassiterite associated with muscovite, albite and elbaite have been found at Stak Nala.

Figure 17. **Tricolored (black-dark green-pink) elbaite crystals 6 cm long, with quartz and albite, from near Stak Nala, Gilgit division, Pakistan. William Larson specimen; photo by Harold and Erica Van Pelt.**

Figure 18. **Tricolored (black-green-pink) elbaite crystals (largest 6.5 cm) associated with white albite, from near Stak Nala, Gilgit division, Pakistan. AMNH 95614; photo by Olivia Bauer and Jackie Beckett.**



Elbaite $Na(Li,Al)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Elbaite is a common pocket-zone phase at the Stak Nala pegmatite, where it is associated with quartz, muscovite, microcline and albite. As mentioned earlier, the elbaite crystals from this pegmatite are usually found wearing albite "jackets." The crystals are almost invariably color-zoned, the lower portions of the crystals being black or dark green in color and opaque, the terminal faces are translucent and colored grass green, pink or blue. Crystals are well-formed, with either flat or prismatic terminations and average between 5 to 6 cm in length and 1.5 cm in width.

Fluorapatite $Ca_5(PO_4)_3F$

Superb crystals of doubly-terminated, hexagonal fluorapatite have been collected from pegmatites on the Skardu road near Dusso. The crystals are light pink in color and measure up to 3 cm across. They typically consist of the dominant first order prism {1010} with basal pinacoids {0001}. Attractive specimens consisting of pale pink fluorapatite crystals atop pale blue beryl variety aquamarine crystals have been found near Dusso.

Fluorite CaF_2

Loose, green crystals of fluorite associated with elbaite, quartz and albite have been collected at the Stak Nala pegmatite. The crystals, measuring up to 6 cm across, consist of the dominant octa-

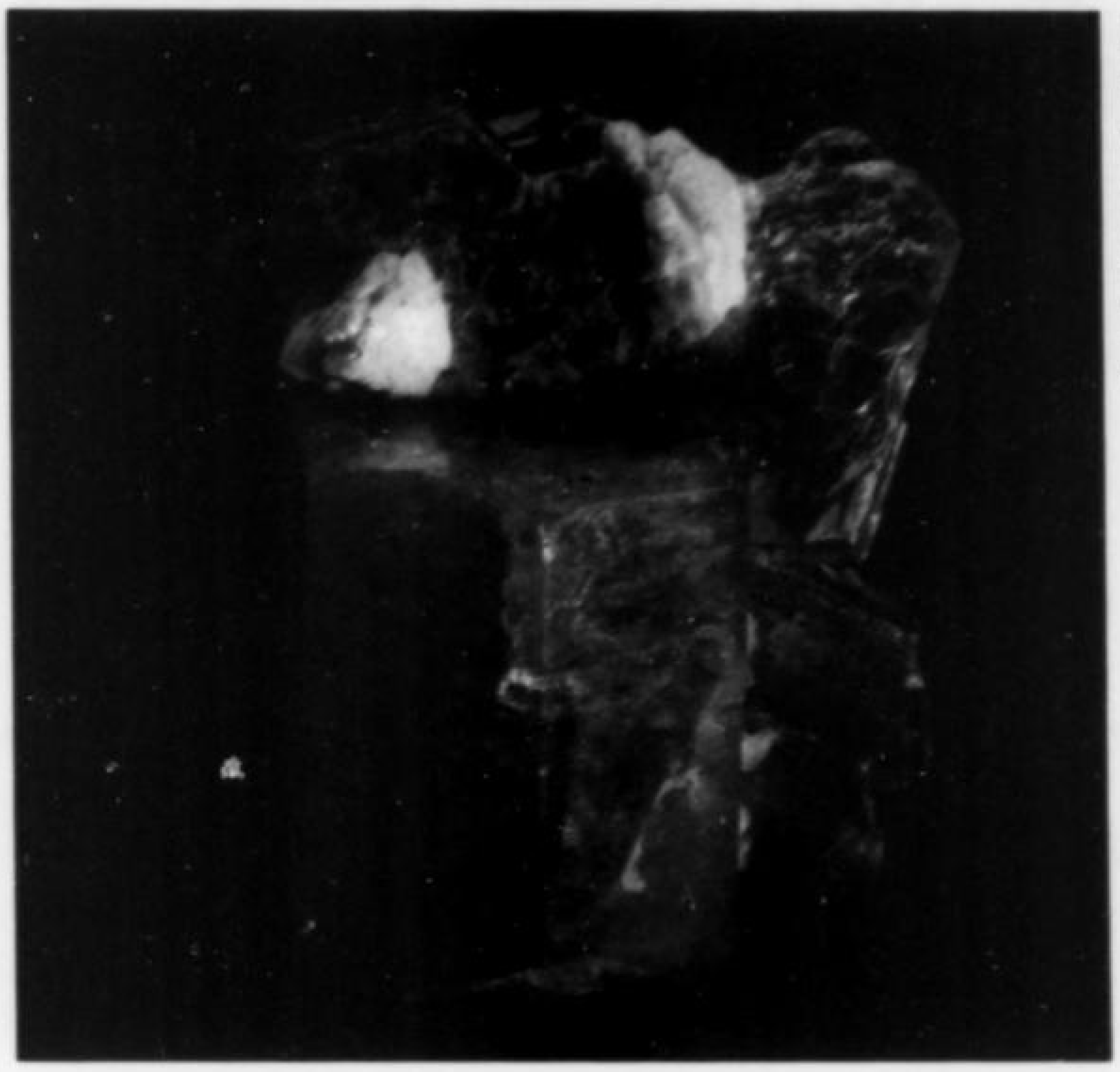


Figure 19. Pink, hexagonal crystal of fluorapatite 3 cm across showing dominant first order prism {1010} and basal pinacoids {0001}. Associated species are silvery brown muscovite and white albite, from near Dusso, Gilgit division, Pakistan. Donated to AMNH by David Eidahl. AMNH 48784; photo by Olivia Bauer and Jackie Beckett.

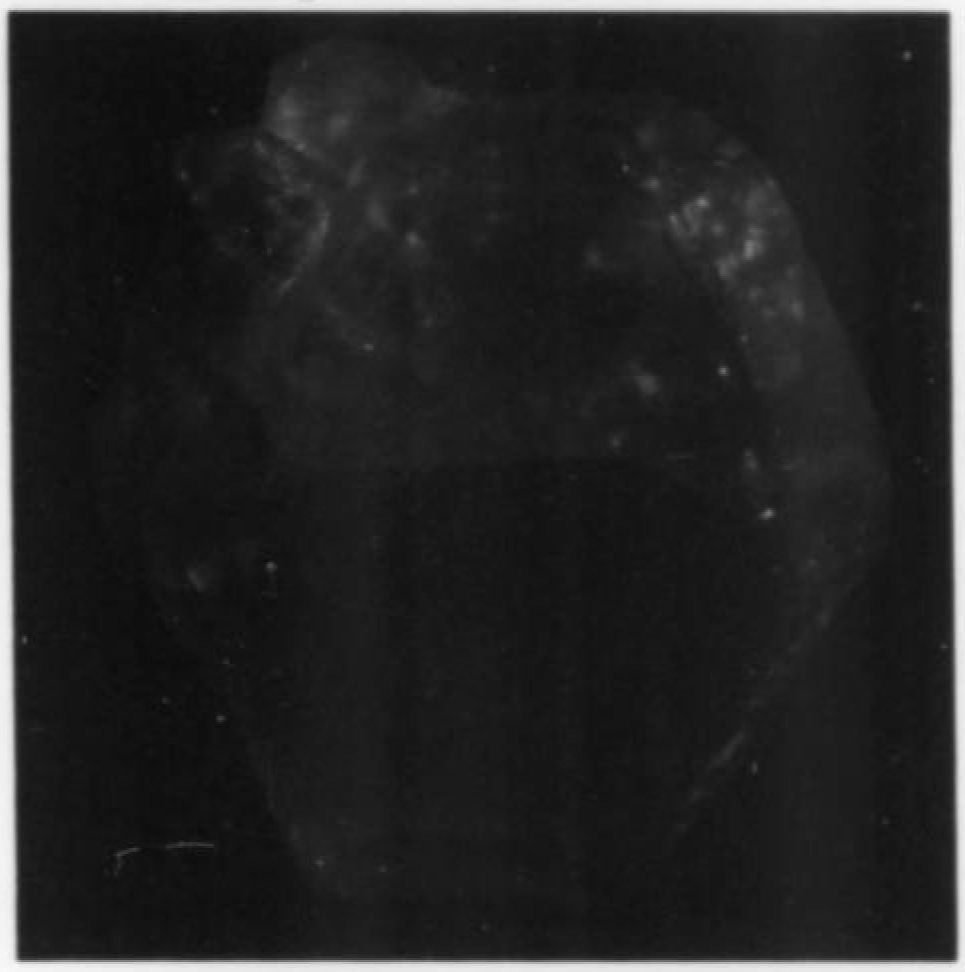


Figure 20. Loose, green crystal of fluorite 6 cm across showing the dominant octahedron {111} modified by dodecahedron {110} and cube {100}, from near Stak Nala, Gilgit division, Pakistan. AMNH 97485; photo by Olivia Bauer and Jackie Beckett.

Figure 21. Elbaite crystal 8.3 cm long wearing typical albite "jacket," from near Stak Nala, Gilgit division, Pakistan. Herbert P. Obodda specimen; sketch by Wendell E. Wilson.

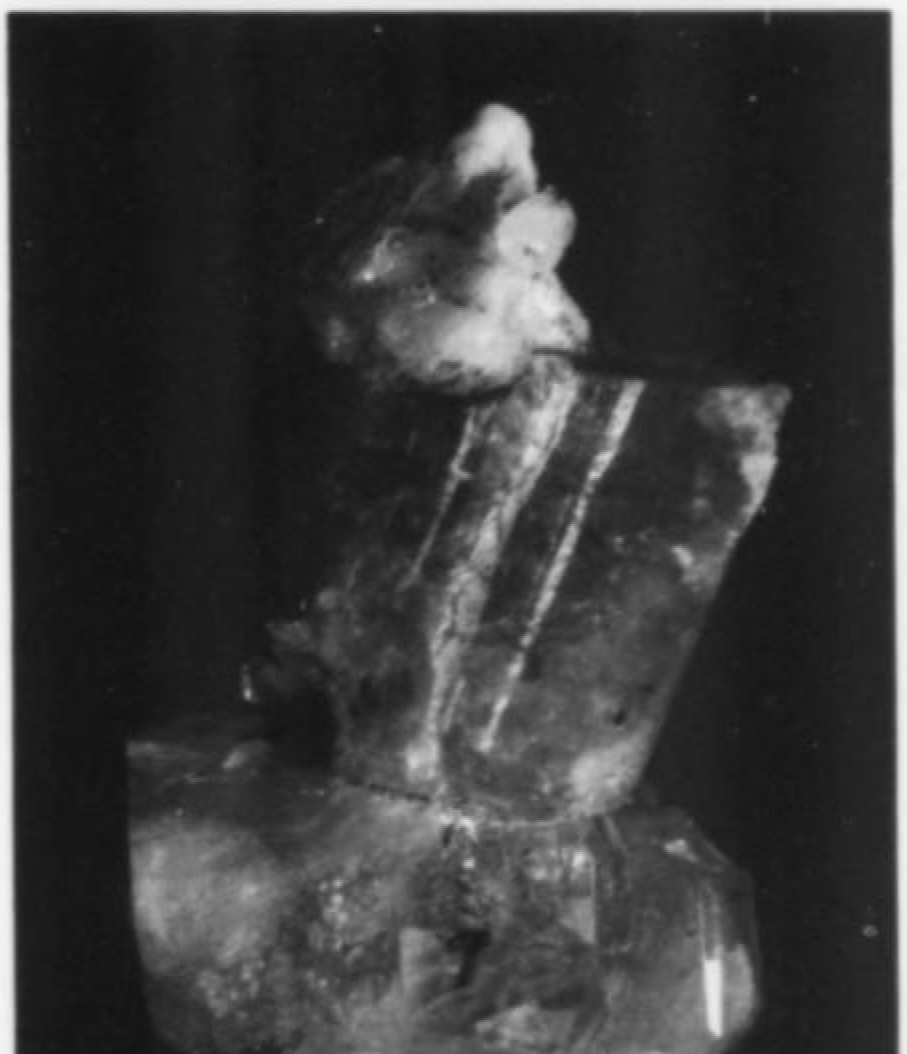


Figure 22. Apple green, striated, wedge-shaped crystal of hydroxyl-herderite 2 cm across associated with pink fluorapatite and white albite, from near Dusso, Gilgit division, Pakistan. AMNH 95604; photo by Olivia Bauer and Jackie Beckett.

hedron {111} modified by cube {100} and dodecahedron {110}. Green, cuboctahedral crystals of fluorite (1–2 cm across) associated with topaz were collected recently at pegmatites near the village of Niyit Bruk.

Garnet Group
Almandine $Fe_3Al_2(SiO_4)_3$
Spessartine $Mn_3Al_2(SiO_4)_3$

Translucent, reddish brown crystals of almandine and spessartine garnet associated with albite, schorl and microcline have been collected at pegmatites near Dusso and Shingus. The crystals typically measure between 1 and 2 cm across, although crystals up to 5 cm across have been collected. Crystal forms observed include the trapezohedron {211} and the dodecahedron {110}, the latter form usually modifying a dominant trapezohedron. An unusual, highly-distorted, spindle-like crystal of reddish brown spessartine with an inner core of gray quartz collected from a pegmatite in the Haramosh area is present in the AMNH collection.

Semi-quantitative analyses were obtained on four garnet specimens from the Gilgit region (AMNH 96214, 48836, 97505 and 92596) using an ARL SEMQ microprobe equipped with a Tracor Northern energy dispersive spectrometer (EDS). The composition of the garnets was relatively uniform from the center of the crystals to their margins (not chemically zoned) and the following Mn/Fe weight ratios were obtained: AMNH 96214: 1:1; AMNH 48836: 2:3; AMNH 97505: 2:3 and AMNH 92596: 2:1. Magnesium (Mg) was also detected in all of the garnets, but no effort was made to quantify the amount present. Based on these analyses, it would appear that both almandine and spessartine are common constituents of gem pockets in the Gilgit area.

Hambergite $Be_2BO_3(OH)$

Hambergite occurs at Stak Nala as small, translucent white crystals associated with elbaite and albite. Crystals average 1 cm or less, although some crystals recovered measured 2.5 cm in length. One of us (HO) has examined thousands of mineral specimens from Stak Nala and has noted hambergite crystals on perhaps a dozen of the specimens. Two crystal habits occur at Stak Nala. The first habit is tabular or rectangular in shape and the dominant forms are, *a*{100}, *b*{010}, and *c*{001} pinacoids. The second habit is dipyramidal, frequently twinned, and features a dominant dipyramid, *p*{111}.

Hydroxyl-herderite $CaBe(PO_4)(OH)$

A single specimen from a Dusso-area pegmatite is preserved in the AMNH collection (AMNH 95604). It consists of an apple green, striated, wedge-shaped crystal measuring 2.5 cm across associated with crystals of pink fluorapatite and white albite. Refractive index measurements show that β is approximately 1.610, which yields an (OH) mole % of 53 to 59 (Leavens *et al.*, 1978), placing it near the mid-point between pure end-members hydroxyl-herderite, $CaBe(PO_4)(OH)$ and herderite, $CaBe(PO_4)F$. Leavens, *et al.* (1978) reports hydroxyl-herderites with similar compositions from Epprechstein, Germany, San Diego County, California, and Waldstein, Germany.

Manganotantalite $MnTa_2O_6$

Two specimens of manganotantalite identified by microprobe analysis (Fuller, personal communication, 1984) from the Gilgit area are preserved in the mineral collection of the British Museum (Natural History) (BM 1980,31). They consist of dark reddish black, striated crystals (up to 5 mm) partly enclosed within pale beryl variety aquamarine prisms 1 cm wide by 4.5 cm long and 0.8 cm wide by 5.0 cm long, respectively. Manganotantalite has also been collected from the mineralogically-similar pegmatites at Nuristan, Afghanistan.

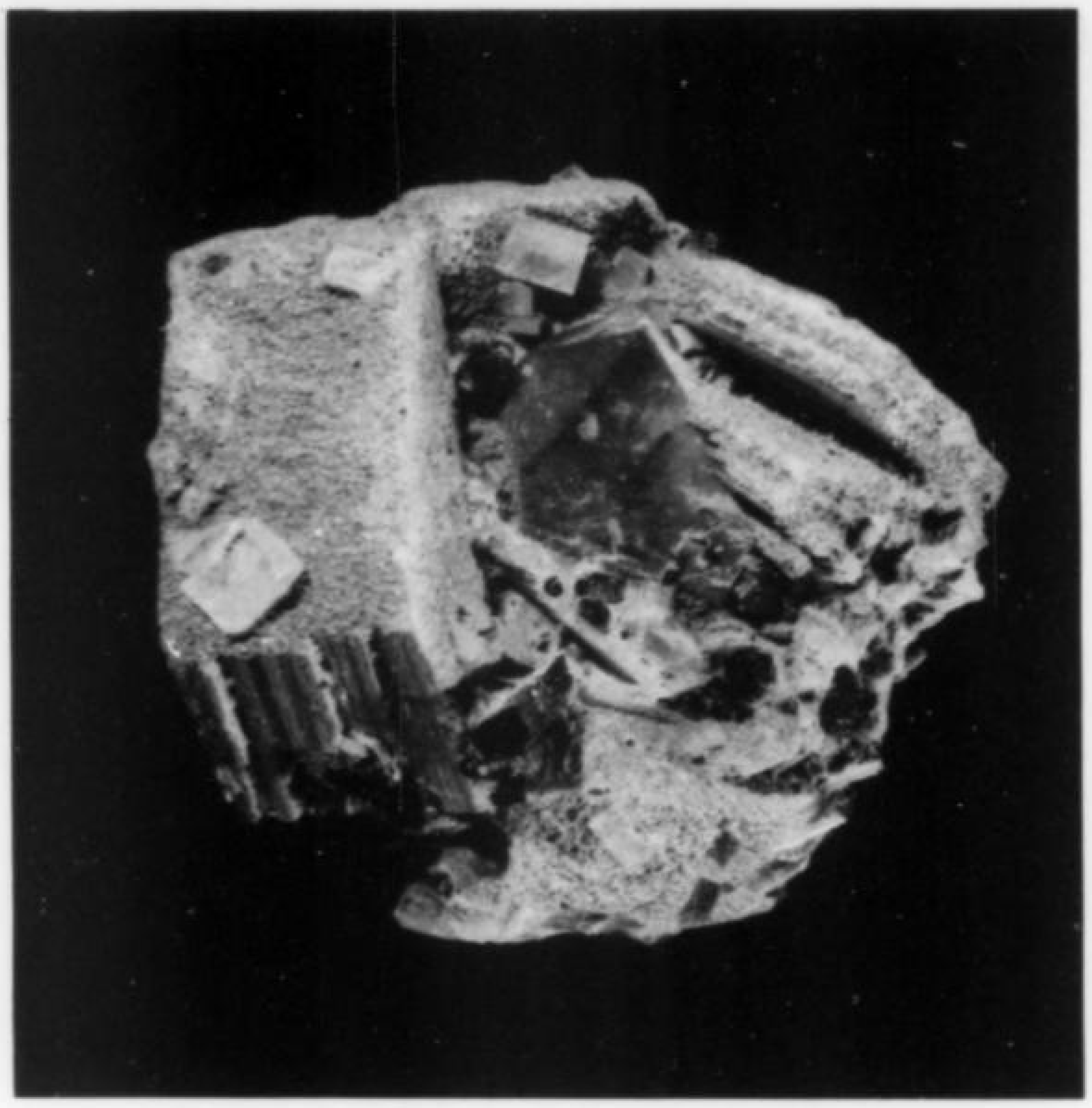


Figure 23. **Translucent, white, tabular crystals of hambergite (average 0.5 cm across) scattered atop perfect books of muscovite, from near Stak Nala, Gilgit division, Pakistan. AMNH 97984; photo by Olivia Bauer and Jackie Beckett.**

Figure 24. **Colorless hydroxyl-herderite crystal, 2 cm, from near Dusso. Obodda specimen.**

Microcline $KAlSi_3O_8$

Microcline is found at several gem-bearing pegmatites located in the Haramosh Mountains region. Specimens of unattractive, blocky perthite crystals have been collected from pegmatites exposed on the Karakoram highway between Skardu and Gilgit.

Montmorillonite $(Na,Ca)_{0.33}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$

Montmorillonite has been found at Stak Nala. It occurs there as white balls (average 3 mm in diameter) encrusting crystals of elbaite and albite. A Gandolfi X-ray pattern of this material indicates that it is a mixture of montmorillonite and other (unknown) phases.

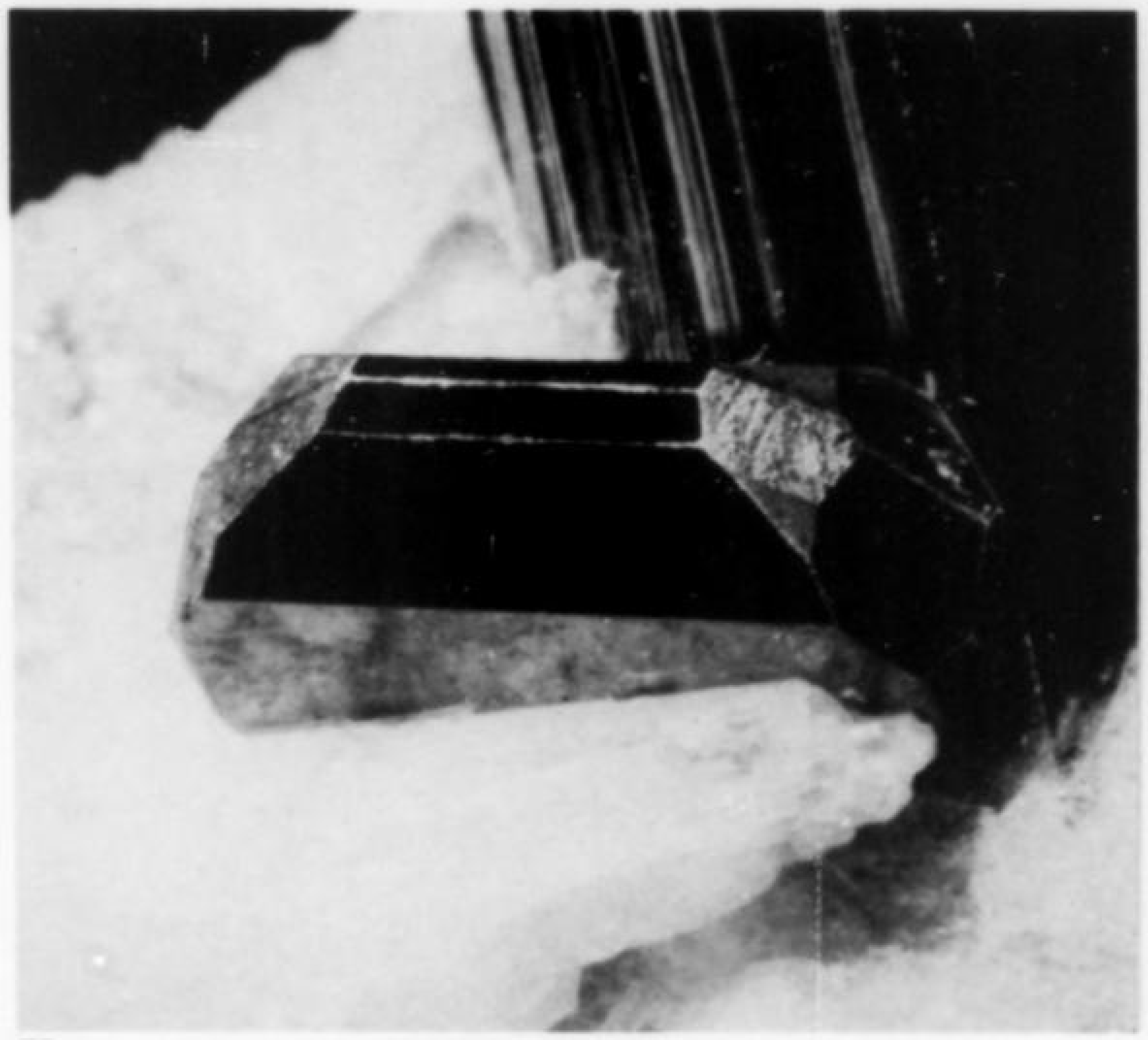


Figure 25. **Manganotantalite crystal, 5 mm, with dark green elbaite from Stak Nala. Gene Schlepp specimen.**

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

Muscovite is one of the most common minerals present in the pocket zone at Dassu and Stak Nala. Most matrix specimens contain at least a few books of silvery brown muscovite.

Orthoclase $KAlSi_3O_8$

An orthoclase specimen from the Gilgit area is present in the mineral collection of the British Museum (Natural History) (BM 1980,292). It is a white crystal, 4.5 by 6.5 by 7.5 cm, associated with a pale beryl variety aquamarine crystal, 5.5 cm long. The identification of this specimen was made by X-ray (Fuller, personal communication, 1984). Interesting orthoclase specimens have been collected in the Doksun Mountain area, near the village of Bungla. One specimen preserved in the AMNH collection consists of a doubly-terminated, white, transparent to translucent crystal 3 cm across intergrown with a pale blue beryl crystal 3 cm tall. The orthoclase also contains visible, needle-like inclusions of a black mineral, possibly schorl. Middlemiss and Parshad (1918) reported "orthoclase, white or cream-colored, in great poikilitic plates from a few inches to a foot or more across" from Dusso pegmatites.

Schorl $NaFe_3^{+2}A_{16}(BO_3)_3Si_6O_{18}(OH)_4$

Schorl crystals occur in gem pockets and scattered in the groundmass of pegmatites located within both major pegmatite fields (Dusso and Shingus). Good specimens associated with beryl variety aquamarine, microcline, albite, muscovite and quartz have been collected at pegmatites near Dusso. One especially nice specimen from this occurrence consists of black, sub-parallel bundles of schorl up to 10 cm long. Large black, striated crystals of schorl associated with pink fluorapatite, curved plates of cream-colored albite and drusy, clear topaz crystals have been collected at pegmatites located near Shingus.

Topaz $Al_2SiO_4(F,OH)_2$

Colorless and sherry-colored topaz crystals have been found at many pegmatites in the Gilgit region. These complex, highly modified crystals are recovered as loose crystals weighing up to 400 grams. Topaz crystals on matrix are less common. Those found consist of isolated crystals on a microcline-quartz-muscovite matrix. Beryl variety aquamarine and schorl crystals from Shingus-area pegmatites are frequently coated with drusy crystals of topaz.

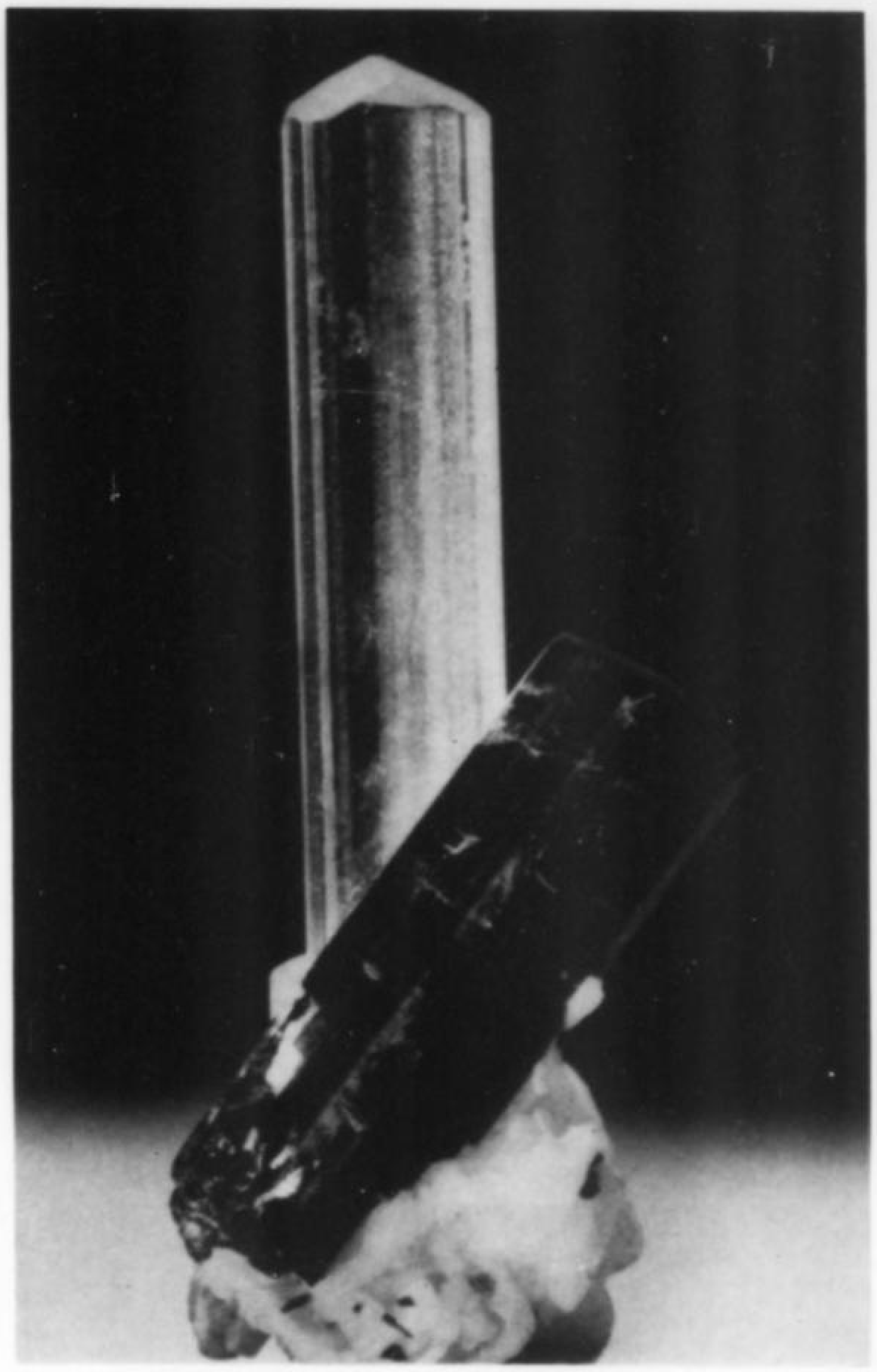


Figure 26. **Small (2 cm) black schorl crystal attached to a slender, water-clear crystal of aquamarine 4.5 cm long, from near Dusso, Gilgit division, Pakistan. Herb Obodda specimen; photo by Olivia Bauer and Jackie Beckett.**

Zircon $ZrSiO_4$

An isolated occurrence of zircon associated with microcline and elbaite has been found in a pegmatite cropping out near Stak Nala. The zircon crystals are yellowish green in color and average 1.5 cm in height. They form sub-parallel aggregates with individual crystals exhibiting tetragonal prism {110} and dipyramid {111} faces. Zircon crystals associated with beryl have been reported from pegmatites in the Gilgit region.

CHARACTER AND AGE OF PEGMATITES AND HOST ROCKS

The Shingus-Dusso pegmatites form only a small part of the vast pegmatite fields that occur in the Nangaparbat-Karakoram ranges. In fact, it would be reasonable to estimate that this region contains tens of thousands of pegmatites. Most of these are inaccessible as they occur at altitudes of between 3,660 and 4,270 meters, cropping out on bare vertical cliffs with sheer drops of thousands of meters.

The structure, composition and mineral association of these pegmatites indicate that they are largely miarolitic (Cerny, 1982) having formed at shallow depths (1.5 to 3.5 km). They are related to a very late stage of the syntectonic phase of granitic intrusions in the Himalayas and the Karakorams. The Gilgit area has been subjected

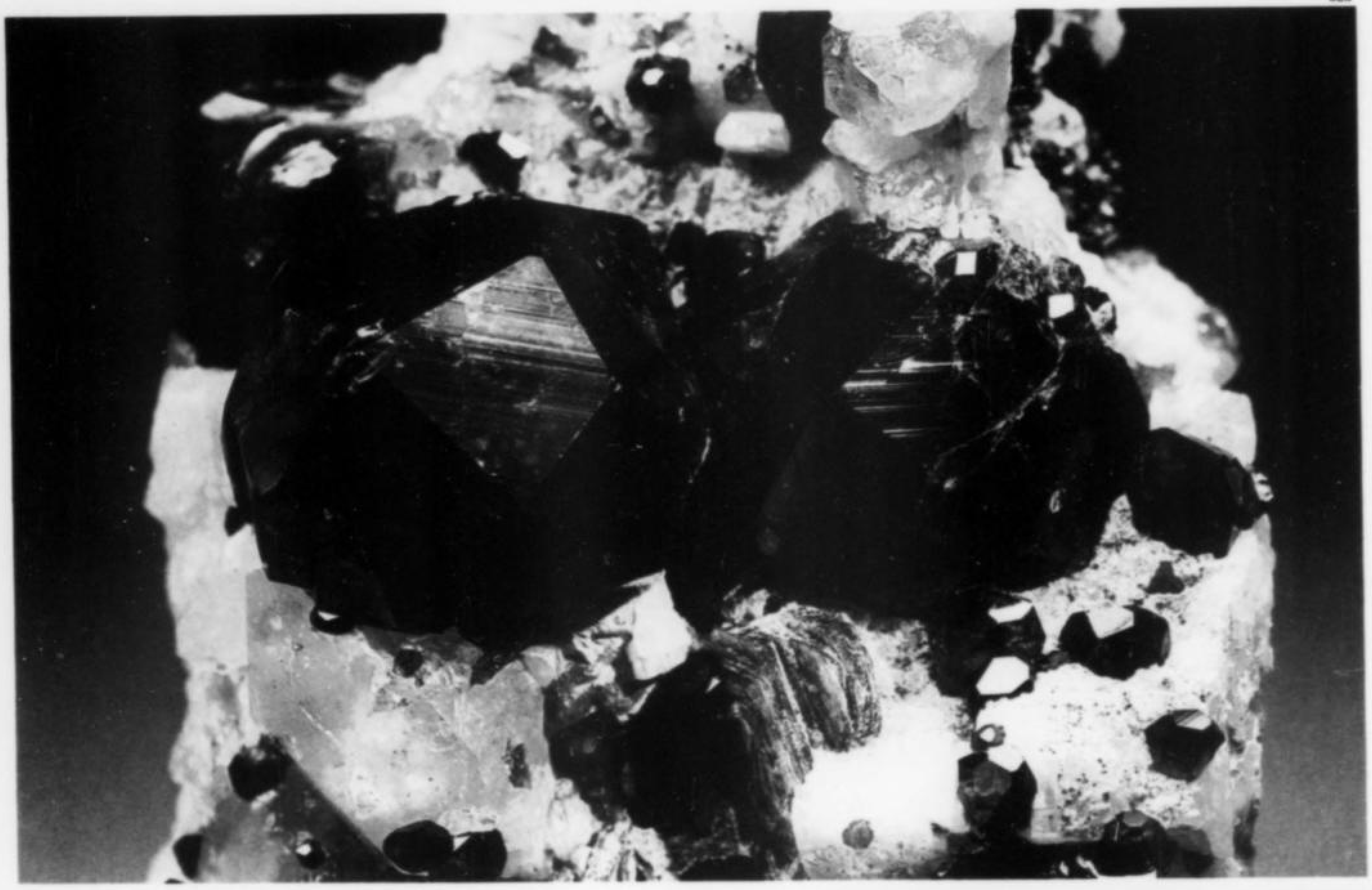


Figure 27. **Spessartine garnet crystals to 2.4 cm on feldspar, from near Gilgit.**

Figure 28. **Large (4.2 cm) crystal of spessartine with muscovite, from the Haramosh Mountains region. Gene Schlepp specimen.**

to intermittent orogenic and tectonic activity ever since the collision of the Asian and Indo-Pakistan plate and this region is tectonically active even today as evidenced by high seismicity (Seeber *et al.*, 1980), the presence of active faults (Lawrence and Ghauri, 1983), and the rapid and continued uplift of the Nangaparbat massif (Zeitler *et al.*, 1982). It is, therefore, not surprising that the granitic intrusions in this region range from Paleocene to Pliocene.

Earlier, Desio (1964) reported a K-Ar date of 8.6 million years on one sample from the Karakoram Batholith collected from the Hunza Valley. More recently, according to Tahir Kheli (1982), Windley and Jan have indicated the following dates on some of the granites in this region:

1. Sample from Yasin Valley – 4.7 m.y.
2. Sample from granite intruded in metasedimentary rocks (Baltit group), north of Minapin (Hunza Valley) – 17 m.y.
3. Sample from Karakoram Batholith (Upper Hunza Valley) – 52 m.y.

Matsushita *et al.* (1965) have reported the following two K-Ar determinations for samples from the Shigar Valley (Baltistan):

1. Sample from a pegmatite near Dusso – 27 m.y.
2. Sample from a leucocratic granite near Dusso – 30 m.y.

According to Tahir Kheli (1982), these dates suggest protracted multi-phase magmatism in the Karakorams which started in the Late Eocene and lasted until Early Pleistocene.

The Nangaparbat-Haramosh massif, the northeastern part of which contains the Shingus group of pegmatites, is believed to contain Precambrian metasediments (Salkhala formation) and granite gneiss (Wadia 1932; Misch 1949; Desio 1976). According to Misch (1949), there has been progressive granitization from low-grade metamorphism of Salkhala slates to complete metasomatic and migmatitic changes in the inner part of the massif.

There is no definitive data on the possible age of the Shingus pegmatites. It may be speculated that these pegmatites are related to the granitic rocks which form the northeastern part of the Nangaparbat massif, near Rhondu, and that this granite is linked to the larger, more extensive Ladakh granite (Frank *et al.*, 1977; Sharma *et al.*, 1978), which crops out only a short distance east of Rhondu and forms an extensive belt in the Ladakh range along the entire length of the Indus Suture Zone. This plutonic complex has intruded Cretaceous volcanics (Dras formation) and unconformably underlies the Miocene Kargil formation. Desio (1979) reported

Figure 29. **The Dusso topaz mine. Photo by David P. Wilber.**

Figure 30. **Topaz crystal, 3.5 cm, with quartz from Niyit Bruk near Dusso. Obodda specimen.**

Figure 31. **Reddish brown, elongated spessartine crystal 3 cm high with core of gray quartz, from the Haramosh Mountains region, near Gilgit, Pakistan. AMNH 92596; photo by Olivia Bauer and Jackie Beckett.**

Figure 32. **Yellowish green, sub-parallel aggregate of zircon crystals (average 1.5 cm) on a matrix of buff-colored albite crystals. Individual crystals exhibit tetragonal prism {110} and dipyramid {111} faces; from near Stak Nala, Gilgit division, Pakistan. AMNH 97490; photo by Olivia Bauer and Jackie Beckett.**

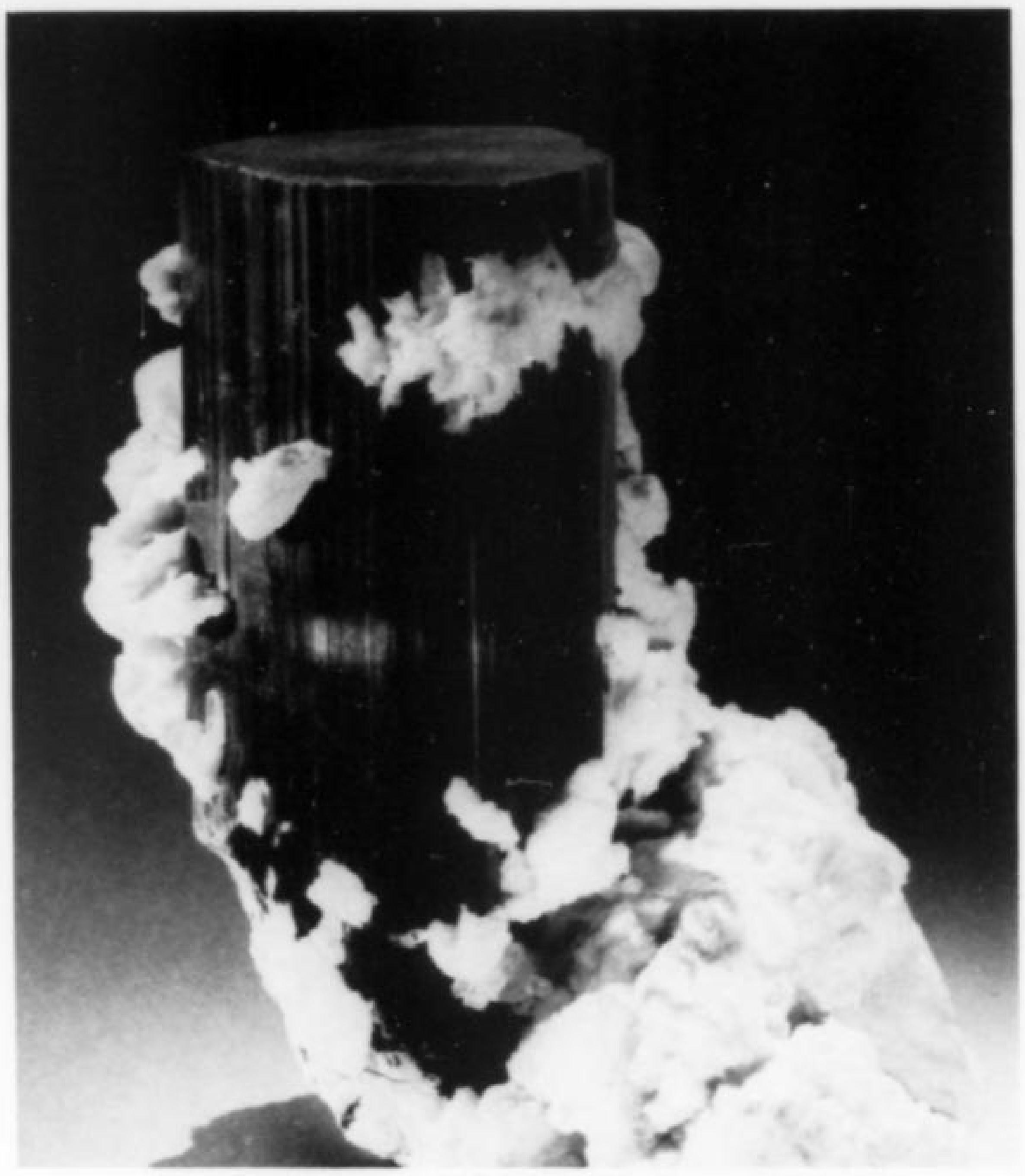


Figure 33. **Large black schorl crystal 11.5 cm high associated with pink fluorapatite, clear, mm-sized topaz crystals and rosette-like plates of cream-colored albite, from the Shingus area, Gilgit division, Pakistan. AMNH 97505; photo by Olivia Bauer and Jackie Beckett.**

K-Ar ages of 39 m.y. and 45 m.y. for these rocks. It is, therefore, likely that the Shingus group of pegmatites are somewhat older in age than the Dusso pegmatite group which occurs in a different domain related to the granites of the Karakoram Batholith.

LOCALITY SPELLINGS

English transliterations of Urdu locality names used in this article are those adopted by the Pakistani Geological Survey. The *Official Standard Names Gazetteer (Pakistan)* lists alternate spellings (e.g., Dusso, Dassu, Dasu; and Shingus or Shengus).

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REFERENCES

BARD, J. P., MALLUSKI, H., MATTE, P. H., and PROUST, F. (1980) The Kohistan sequence: Crust and mantle of an obducted island arc. In *Geodynamics of Pakistan* (Farah, A. and DeJong, K. A., eds.), Geological Survey of Pakistan, 87–94.

CASNEDI, R. (1976) Geological reconnaissance in the Yasin Valley, NW Pakistan. *Rendiconti Accademia Nazionale dei Lincei,* Roma, **8**, 792–799.

CASNEDI, R., and EBBLIN, C. (1977) Geological notes on the area between Astor and Skardu, Kashmir. *Rendiconti Academia Nazionale dei Lincei,* Roma, **9**, 61.

CERNY, P. (1982) Granitic pegmatites in science and industry. *Mineralogical Society of Canada, Short course handbook,* **8**, 555 p.

DESIO, A. (1963) Review of the geologic "Formations" of the Western Karakoram, Central Asia. *Rivista Italiana di Paleontologia e Stratigrafia,* **69**, 475–501.

DESIO, A. (1964) Tectonic relationship between the Karakoram, Pamir and Hindu Kush, Central Asia. *Proceedings of the 22nd International Geological Congress,* New Delhi, **2**, 192–213.

DESIO, A. (1974) Karakoram Mountains. In *Mesozoic-Cenozoic Orogenic Belts Data for Orogenic Studies* (Spencer, A. M., ed.). Geol. Soc. London, Spec. Pub. No. 4, 255–266.

DESIO, A. (1976) Some geotectonic problems of the Kashmir Himalaya-Karakoram-Hindu Kush-Pamir Orogenic Belts International Coll. on the geotectonics of the Kashmir Himalaya etc., Rome, 1974, *Atti dei Convegni Lincei,* **21**, 9–13.

DESIO, A. (1979) Geologic evolution of the Karakoram. In *Geodynamics of Pakistan* (Farah, A. and DeJong, K. A., eds.), Geological Survey of Pakistan, 111–124.

DESIO, A., TONGIORGI, E., and FERRARA, G. (1964) On the geological age of some granites of the Karakoram, Hindu Kush and Badakhshan (Central Asia). *Proceedings of the 22nd International Geological Congress,* New Delhi, **11**, 479–496.

FRANK, W., GANSSER, A., and TROMMSDORFF, V. (1977) Geological observations in the Ladakh area (Himalayas) – a preliminary report. *Schweizer Mineralogische und Petrographische Mitteilungen,* **57**, 89–113.

GANSSER, A. (1981) The geodynamic history of the Himalaya. In *Zagros-Hindu Kush-Himalaya Geodynamic Evolution* (Gupta, H. and Delaney, F., eds.). American Geophysical Union Geodynamics Series, **3**, 111–121.

GÜBELIN, E. (1981) Pakistan enters the gem scene. *Gems and Gemology,* **17**, 180–181.

HAYDEN, H. H. (1916) Notes on the geology of Chitral, Gilgit, and the Pamirs. *Records of the Geological Survey of India,* **45**, 271–335.

IVANAC, J. F., TRAVES, D. M., and KING, D. (1956) The geology of the NW portion of the Gilgit Agency. *Records of the Geological Survey of India,* **82**, 1–29.

JAN, M. Q. (1977) The Kohistan basic complex, a summary based on recent petrological research. *Geological Bulletin University of Peshawar,* **9–10**, 36–42.

JAN, M. Q., and SYMES, R. F. (1977) Piedmontite Schist from upper Swat, NW Pakistan. *Mineralogical Magazine,* **41**, 37–54.

KAZMI, A. H., and RANA, R. A. (1982) Tectonic Map of Pakistan (1:2 million). *Geological Survey of Pakistan,* Quetta.

KAZMI, A. H., LAWRENCE, R. D., DUAD, H., SNEE, L. W., and HUSSAIN, S. S. (1984) Geology of the Indus Suture Zone in the Mingora-Shangla area of Swat. *Geological Bulletin University of Peshawar,* **17** (in press).

LAWRENCE, R. D., and GHAURI, A. A. K. (1983) Evidence of the active faulting in Chilas District, Northern Pakistan. *Geological Bulletin University of Peshawar,* **16**, 185–186.

LEAVENS, P. B., DUNN, P. J., and GAINES, R. V. (1978) Compositional and refractive index variations of the herderite-hydroxyl-herderite series. *American Mineralogist,* **63**, 913–917.

MATSUSHITA, S., and HUZITA, K. (1965) *Geology of the Karakoram and Hindu Kush.* Kyoto University, Japan, 151 p.

MIDDLEMISS, C. S., and PARSHAD, L. J. (1918) Note on the aquamarine mines of Daso on the Braldu River, Shigar Valley, Baltistan. *Records of the Geological Survey of India,* **45**, part 3, 160–172.

MISCH, P. (1949) Metasomatic granitization of batholithic dimensions. *American Journal of Science,* **247**, 673–705.

SCHNEIDER, H. J. (1957) Tectonic and magmatism in NW Karakoram. *Geologische Rundschau (Stuttgart),* **46**, 426–476.

SEEBER, L., QUITTMEYER, R., and ARMBRUSTER, J. (1980) Seismotectonics of Pakistan: A review of results from network data and implications for the Central Himalaya. Proc. Int. Comm. Geodynamics, Gr. 6 meeting, Peshawar, 1979. *Geological Bulletin University of Peshawar,* **13**, 151–168.

SHAMS, F. A. (1963) An inky blue beryl from Swat State. *Geological Bulletin University of Punjab,* 3, 31.

SHARMA, K. K., and GUPTA, K. R. (1978) Some observations on the geology of the Indus and Shyok Valleys between Leh and Panamik, district Ladakh, Jammu 7, Kashmir, India. *Recent Research in Geology,* **2**, 133–143.

STAUFFER, K. W. (1968) Geology of the Gilgit-Hispar area, Gilgit Agency, W. Pakistan. *U.S. Geological Survey Project-Report,* **(IR) PK-10**, 42 p.

STOCKLIN, J. (1977) Structural correlation of the Alpine ranges between Iran and Central Asia. *Societe Geologique de France,* Hors Series, **8**, 333–353.

TAHIR KHELI, R. A. K. (1979) Geology of Kohistan and adjoining Eurasian and Indo-Pakistan continents, Pakistan. *Geological Bulletin University of Peshawar,* **11**, No. 1, 1–30.

TAHIR KHELI, R. A. K. (1982) Geology of the Himalaya, Karakoram and Hindu Kush in Pakistan. *Geological Bulletin University of Peshawar,* **15**, 51 p.

TAHIR KHELI, R. A. K., MATTAUER, M., PROUST, F., and TAPPONNIER, P. (1979) The Indian-Eurasian Suture zone in northern Pakistan: Synthesis and interpretation of data at plate scale. In *Geodynamics of Pakistan* (Farah, A. and DeJong, K. A., eds.). Geological Survey of Pakistan, Quetta, 125–130.

WADIA, D. N. (1932) Note on the geology of Nanga Parbat and adjoining portions of Chilas, Gilgit District. *Records of the Geological Survey of India,* **66**, 212–234.

WADIA, D. N. (1937) The Cretaceous volcanic series of Astor-Deosai, Kashmir, and its intrusions. *Records of the Geological Survey of India,* **72**, 151–161.

ZANETTIN, B. (1964) Geology and petrology of Haramosh-Mango Gusor Area. Scientific Reports Desio's Exped. Karakoram and Hindu Kush, **1**, Brill, Leiden, The Netherlands.

ZEITLER, P. K., JOHNSON, N. M., WAESER, G. W., and TAHIR KHELI, R. A. K. (1982) Fission-track evidence for Quaternary uplift of the Nanga Parbat region, Pakistan. *Nature,* **298**, 255–257.

the Tourmalines of Nepal

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Fine, multihued, well terminated tourmaline crystals up to 20 cm (8 inches) in length have been produced from two pegmatite mines in the Sankhuwa Sabha district, Kosi Zone of eastern Nepal. The most distinctive tourmalines from Nepal are bright grass-green elbaite, yellow to amber manganese-rich elbaites, and pink, lemon-yellow and green tricolored and watermelon crystals.

INTRODUCTION

Nepal is a small mountain kingdom just one-third the size of California, located between China and India on the southern slope of the Himalayas. The average yearly income for the population of 13 million people is just over $100 per person. Nepal has only recently become famous for its tourmalines. The country was almost totally unknown to the outside world until 1950 when, for the first time in over a century, foreigners were permitted to enter. It was not until the 1960s that the first crystals began to appear in mineral collections, and they remain to this day rather rare items as nearly all of the production has gone to India for faceting, and there has been little or no production for the past two decades. Unless the problems are somehow overcome (mining in remote, rugged, mountainous areas subject to severe landslides, where leeches are uncomfortably abundant) these beautiful crystals will remain hard to obtain and highly prized.

About two dozen or more gem pegmatites are now known in Nepal, but two have yielded virtually the entire tourmaline production: the Hyakule mine and the Phakuwa mine.

HISTORY and PRODUCTION

It is difficult to reconstruct the history of the Hyakule mine with verbal reports that vary from person to person and from time to time, dealing with secrecy and two different calendars (1985 = 2041). Probably the discovery was made in 1934 after the great Bihar earthquake (magnitude 8.4) rocked all of eastern Nepal causing many landslides in the steep mountains and exposing the white rock of the pegmatite. A crystal was taken to the wealthy Prime Minister of Nepal who recognized it as a gemstone. He had the pegmatite mined for about six years, yielding over 90 kg of gem crystals, and then abandoned it, probably due to continuing landslides. During the eight years from 1956 to 1964 about a ton of tourmaline was mined, and since then only sporadic efforts to rework old dumps have been undertaken; the main pegmatite body has been buried by landslides. Most of the good crystals available in the past 15 years have come from private stashes retained since the 1950s by those who worked in the mine, and there is no way to guess how much, if any, remains.

Over the period of 50 years since the discovery of the Hyakule pegmatite, a fairly well documented yield of at least 1300 kilograms (2800 pounds) of gem tourmaline has been produced, but estimates run into tens of tons, with no way to know what percentage was of gem quality; an optimistic estimate would be 10%, to judge from what can be seen.

GEOLOGY

In eastern Nepal, small swarms of pegmatite dikes cut discordantly across the foliation and bedding of a metamorphic sequence of marbles, dolomites and schists, with quartzite layers, named the Khitya Khola formation by Andrews (1984), that lies directly below the Main Central Thrust of the Himalayas. This formation extends in a belt that snakes across at least 48 km of mostly unexplored territory in a pair of north-plunging folds with axes transverse to the general east-west strike of the Himalayan formations. The topography is reversed in these large folds, with the western anticline breached by the Arun River Valley, and the eastern syncline forming the high ridge of the Jaljale Himal. The Hyakule and Phakuwa deposits lie in the northeast-dipping strata of the limb between these folds.

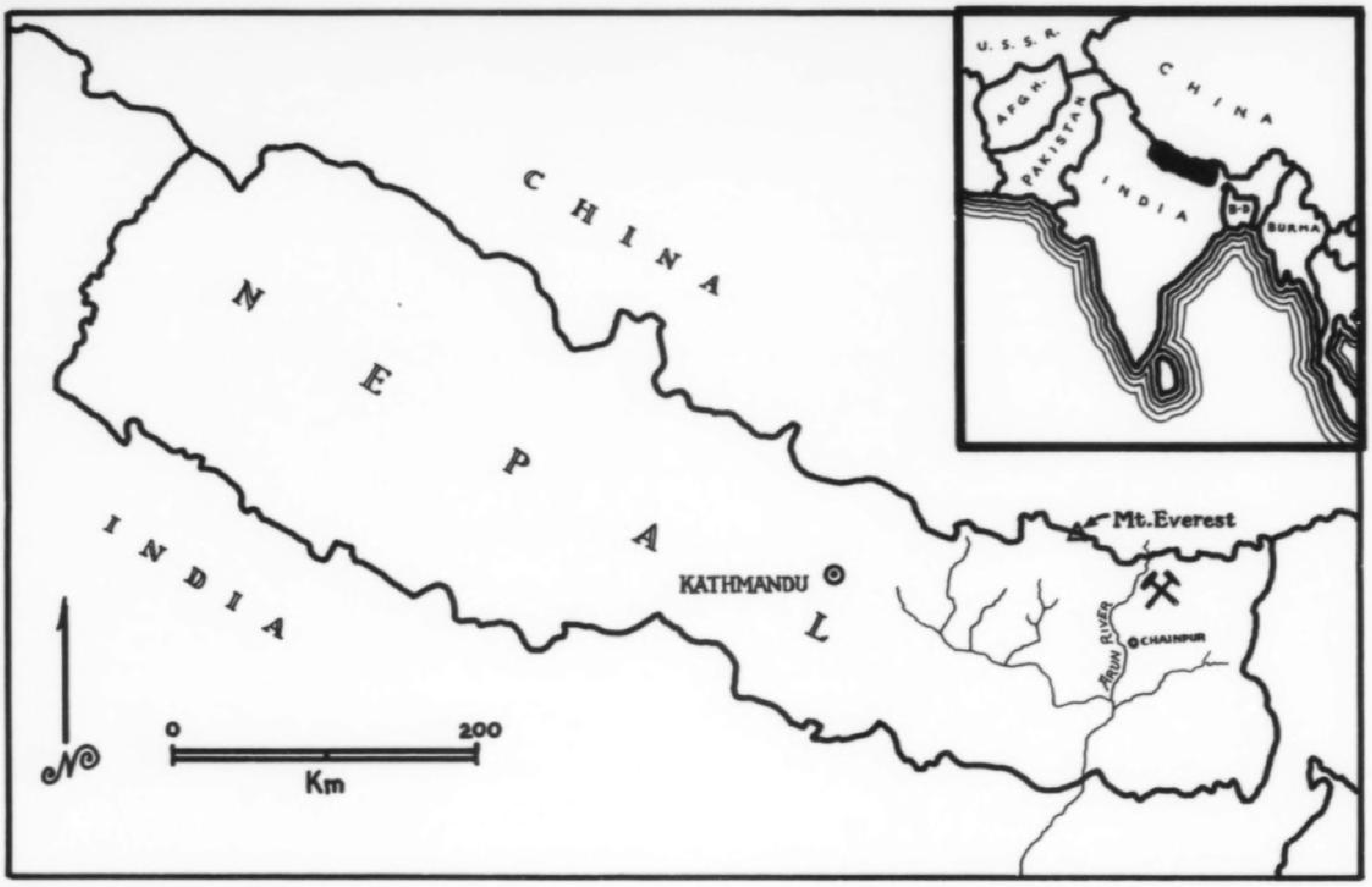


Figure 1. **Location map showing the Sankhuwa Subha district just 60 km south-southeast of Mount Everest. Kathmandu is the only major city in Nepal.**

The absence of any known plutonic body from which the pegmatites might have been derived, and their occurrence in the uppermost formation of a series of similar metamorphosed stratigraphic sequences, stacked one above the other by imbricate thrusting, suggest that the origin of the pegmatites may not be from residual fluids of a parental granitic pluton, as is thought true for most pegmatites. Their presence just below the major plane of thrusting in the Himalayas suggests the possibility of an origin related to the heat generated by a crustal shortening of hundreds of kilometers along that thrust plane as the Indian subcontinent underthrust the Asian continent in a major plate collision that is probably still active.

A more plausible alternative is that under the conditions of intense shearing of the abundant paragneisses in the area, alkali elements and water enabled a lower melting point to cause partial anatexis or localized granitization. Such small, rather diffuse patches of coarse pegmatitic granite with black tourmaline are seen today in the sheared gneisses. These mobile components may have been squeezed out and up, collecting into large enough quantities to crystallize as pegmatites when they encountered the carbonate rocks just below the Main Central Thrust with which they seem to be associated. The gem pegmatites are clearly intrusive, with thin contact metamorphic borders and xenoliths contained within them, and are not of the diffuse granitization type.

However, the area has not been mapped in sufficient detail to eliminate the possibility that parent granitic plutons exist but have not been found, nor can the possibility be overlooked that such plutons exist at depth but are nowhere exposed at the surface despite deep erosion.

In any event, because all enclosing rocks are severely foliated and lineated due to the intense thrust shearing and pressures of deep burial, whereas the pegmatites are not at all, it is believed that these pegmatites are much younger than the adjacent metamorphism, perhaps the youngest pegmatites exposed anywhere in the world. They are probably of late Tertiary age, following most of the mountain-building forces of the Himalayas, but no radiometric dates have been obtained specifically on these pegmatites. Many K/Ar dates on metamorphic rocks of eastern Nepal fall in the range of 9 to 20 million years, but "the extremely young ages (3.7, 5.5 m.y.) determined near the Main Central Thrust are a manifestation of the very late cooling (or the very high temperature gradient) present around this most important feature of the Himalayan Range, on which movements are still continuing today" (Krummenacher, *et al.*, 1978).

HYAKULE and PHAKUWA MINES

The Hyakule and Phakuwa dike swarms are about 5.6 km apart at approximately 27°28′ N. latitude and 87°23′ E. longitude, in the Sankhuwa Sabha district, Kosi Zone, eastern Nepal, at an altitude of around 2150 meters (7000 feet). They are both reached by steep climbs after three or four days of trekking up the Sabhaya Khola River from the grass STOL air strip of Tumlingtar on the east bank of the Arun River. The strip is one hour flying time from the capital, Kathmandu, or two days hike from the end of the nearest road at Dhankuta. The area near both mines is practically uninhabited, but many small farming villages scattered through the Himalayan mid-hills lie within a few kilometers below the mines. Although the administrative center of Khadbari is more accessible to the mines, they are often reported as being near Chainpur, a town about 19 km away. English is not spoken in these hills and the mines could not be found without a knowledgeable guide. (For a more detailed adventure story of access and conditions at the mines, see Bassett, 1979.)

At Hyakule, two parallel pegmatites about 62 meters apart strike northwest. The upper, northeastern pegmatite, 150 meters in length, contains no gem tourmaline but has abundant blue beryl, some of which is relatively transparent, pale blue aquamarine.

Many years ago a tunnel was driven about 30 meters into the length of this pegmatite by the Nepal Department of Mines and Geology to appraise the beryl resources. The lower, southwestern pegmatite has been intermittently worked for gem tourmaline since its discovery in 1934. Since the pegmatite was last worked intensively many years ago, it has been buried almost completely by the debris of landslides that occur annually during the heavy monsoon rains of summer, and at present is nowhere exposed in place; therefore its dimensions are not known. It is believed to have a width of approximately 9 meters at its widest bulge and to taper to dikes of 2-meter widths at the extremities of its 90-meter length. The country rock above the upper pegmatite and below the lower pegmatite is a mica schist, but the rock between them is a foliated wavy dolomite, strongly suggesting that the pegmatites were influenced in their emplacement by the boundaries of the dolomite layer.

At Phakuwa, several pegmatites of various orientations, sizes, and shapes have been opened by crude mining, and, though most of them contain tourmaline, very little of gem quality has been found. Most of the tourmaline is brown and green in opaque crystals with multiple color bands, but some strongly dichroic yellow-green to emerald-green clean crystals have been found, and a very few of the distinctive grass-green crystals. All work has been abandoned at the Phakuwa pegmatites as the owners found too little to justify continued mining.

MINERALOGY

Elbaite

Color

Most fine, terminated tourmaline crystals from the Hyakule gem pockets are predominantly pink with bands, at the positive termination ends, of yellow, colorless, bright green, and rarely light orange. Although sometimes these color bands are repeated a couple of times, most typically a terminated crystal will have the upper 10 to 20% of its length banded from pink through a colorless or yellow band to a final band or rhombohedral phantom of green. In some instances the green is capped by a thin surface of pink again. When faceted with the table perpendicular to the long axis of pink crystals, these gems are a very attractive rose color. The base of the pink crystals is often a dark olive-green, usually not of gem clarity, with a dark brown to amber core. In the solid pegmatite rock, larger opaque tourmalines generally have a color sequence outward from a black or very dark brown core through yellow-brown and yellow-green bands to pink edges. Watermelon crystals of many color combinations occur commonly, but the ones of gem clarity are usually lemon yellow with a pink rim, or pink with a lemon-yellow or colorless rim; green and pink "watermelons" are very rare. White-rimmed gray and green-rimmed brown crystals are abundant, but not of gem quality. Transparent crystals of deep olive-green to dark emerald-green are less common here than the pink crystals.

Figure 2. **Deteriorating entrance adit to the Hyakule mine.**

At the Phakuwa mine most material is opaque dark brown, ochre, and yellow-green, through fine crystals of vivid grass-green to strongly dichroic emerald-green have been found. These are usually too dark to transmit light along the *c*-axis and require steep-sided pavilion angles. One cut stone in the author's collection, faceted from a Phakuwa fragment, is virtually indistinguishable in color from a fine peridot.

Pleochroism

Pleochroic effects are striking in Nepal tourmalines; they are strongly dichroic. Pink crystals, even when only a pale to medium pink, appear a rich violet-rose when viewed parallel to the *c*-axis. Large, flattened, pink crystals appear to be distinctly trichroic: true pink when viewed through the thinnest direction, medium orange-yellow without a trace of pink viewed through the thickest direction, and a deep violet rose viewed parallel to the long axis. Since tourmaline cannot be trichroic, it is presumed that the dichroic yellow in some pink crystals completely masks the pink when thick enough. When a pink crystal has a bright green band, the *c*-axis color becomes a deep orange to rose-orange. The bright green bands in pink crystals, when viewed through a dichroscope, are either blue and yellow or blue-green and yellowish pink. A dichroic combination of taupe and yellow causes a distinctive smoky or dusky rose color that occurs particularly in the choice, perfectly clean, 2.5-cm crystals which are 3 to 12 mm in diameter, that have a single light green band near the sharp rhombohedral terminations.

The usual green tourmalines of Nepal, as elsewhere, have either total absorption along the *c*-axis, or a dark muddy brown to amber, and require good judgment in faceting. Even with steep pavilion sides, any internal inclusions will pick up a sharply contrasting amber or brown color. The yellow to amber crystals with no trace of green when viewed parallel to the *c*-axis, often appear a true green when viewed across the *c*-axis. The least dichroism, except for the achroic tourmaline, is in the lemon-yellow, which may be only faintly greenish perpendicular to the *c*-axis.

Physical properties

The indices of refraction (measures on a GIA refractometer) of faceted pink and green elbaites from Hyakule and Phakuwa, are consistently in the range $O = 1.640$ to 1.645, E = 1.618 to 1.625, except for the dark yellow and amber manganese-rich tourmalines that run as high as 1.655 and 1.635, respectively.

Specific gravities range widely from a low of 2.99 for the dusky rose, 3.04 for the typical pink elbaites, 3.05 for the lemon-yellow, 3.06 for the green, to 3.14 for the high-manganese amber tourmalines, all readings measured on a gem scale by immersion in water on several unflawed crystals or cut stones of each color.

Crystals from Hyakule are most commonly rounded trigonal prisms, or compound trigonal and hexagonal (nine-sided) prisms. These usually have either a rhombohedral termination or a pedion,

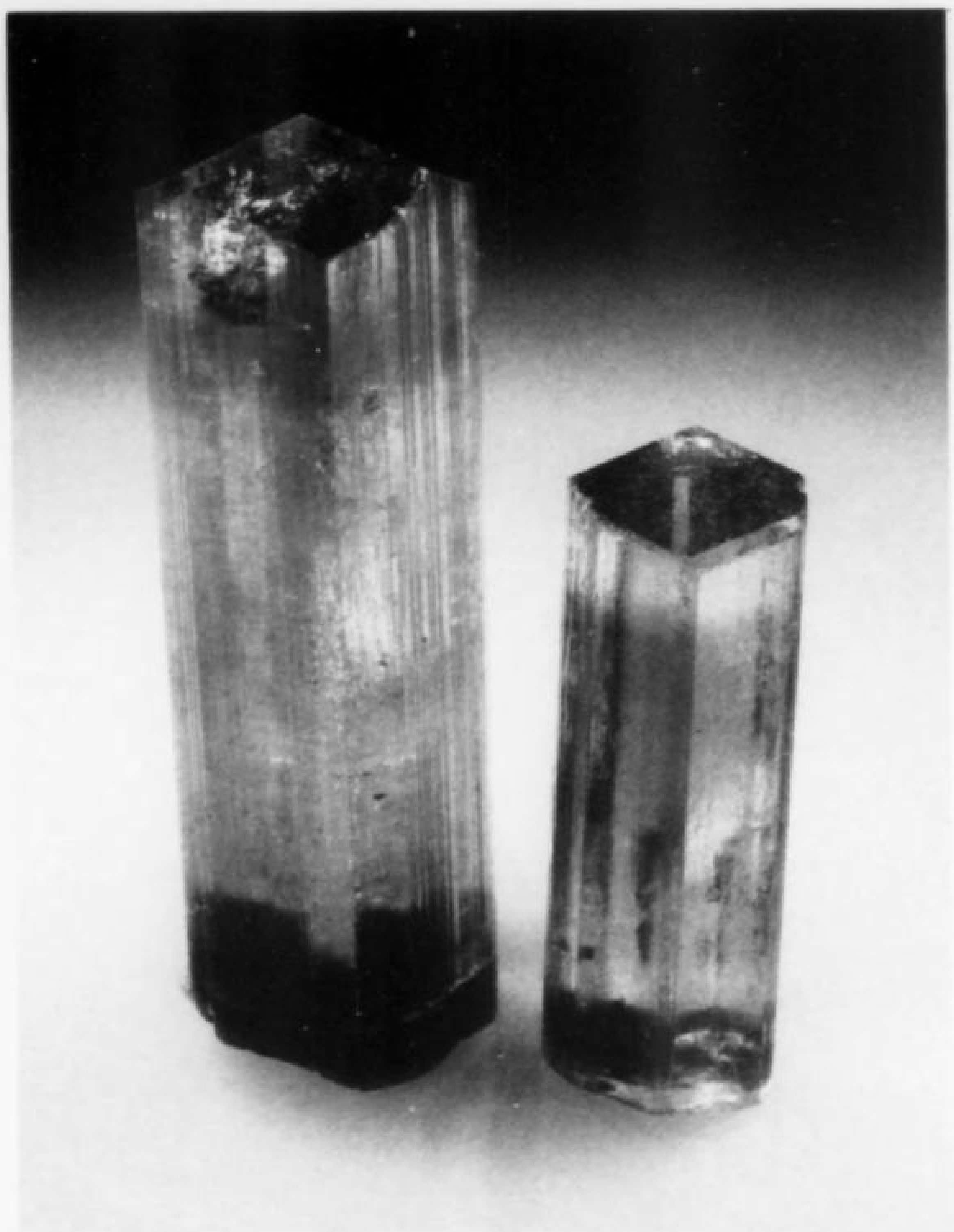


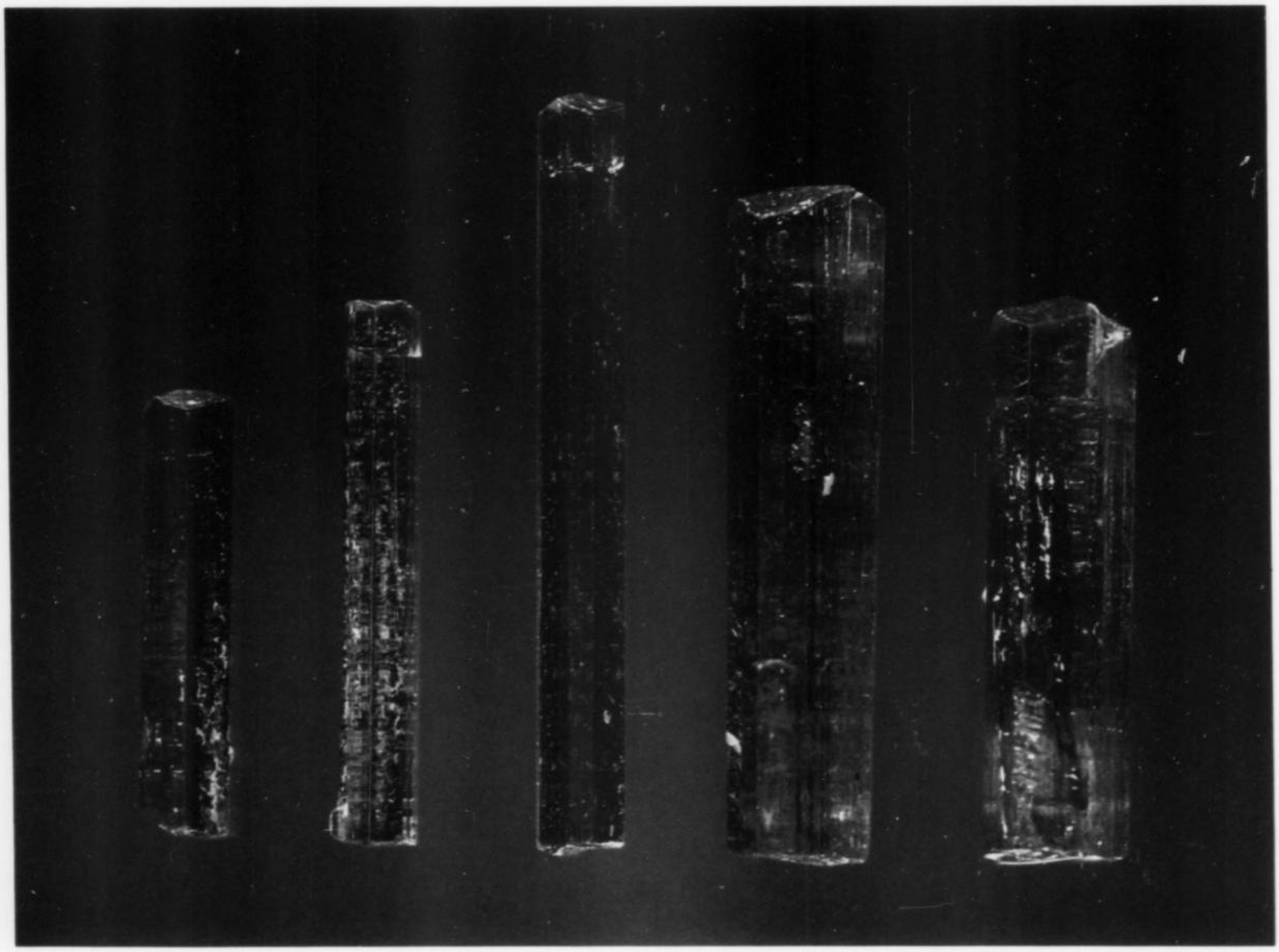
Figure 3. **Two small (3 cm and 4.5 cm) color-zoned tourmaline crystals from the Hyakule mine, Nepal. The larger one is doubly terminated. William Larson collection.**

and sometimes both, but several additional scalenohedral faces are noted at steeper angles on the positive end of the crystals. Generally imperfect and undecipherable faces, always inclined only slightly from the basal pedion, are typical of the negative ends of doubly terminated crystals. All the crystals from Phakuwa are terminated by the pedion, only rarely modified by small rhombohedral faces.

Yellow manganese-rich elbaite

Distinctive lemon-yellow, chrome-yellow, and amber-colored tourmalines from the Hyakule mine have been analyzed by wet chemical and microprobe methods, yielding results of high manganese content, usually between 3 and 6% MnO (Bassett, 1984), while the pink and green tourmalines are devoid of any manganese. These high-manganese yellow tourmalines have a chemical formula, based on the work of F. Cesbron at the University of Paris, of: $(Na,Ca)(Al,Mn,Li,Fe,Ti)_3Al_6(Si_6O_{18})(BO_3)_3(OH)_4$, making them a particularly good example of Ruskin's now famous comment that the chemistry of tourmaline is like a medieval doctor's prescription.

Figure 4. **Crystals of tourmaline from the Hyakule mine, Nepal, the largest measuring 5 cm in length. Houston Museum of Natural Science collection; photo by Ron Bentley.**



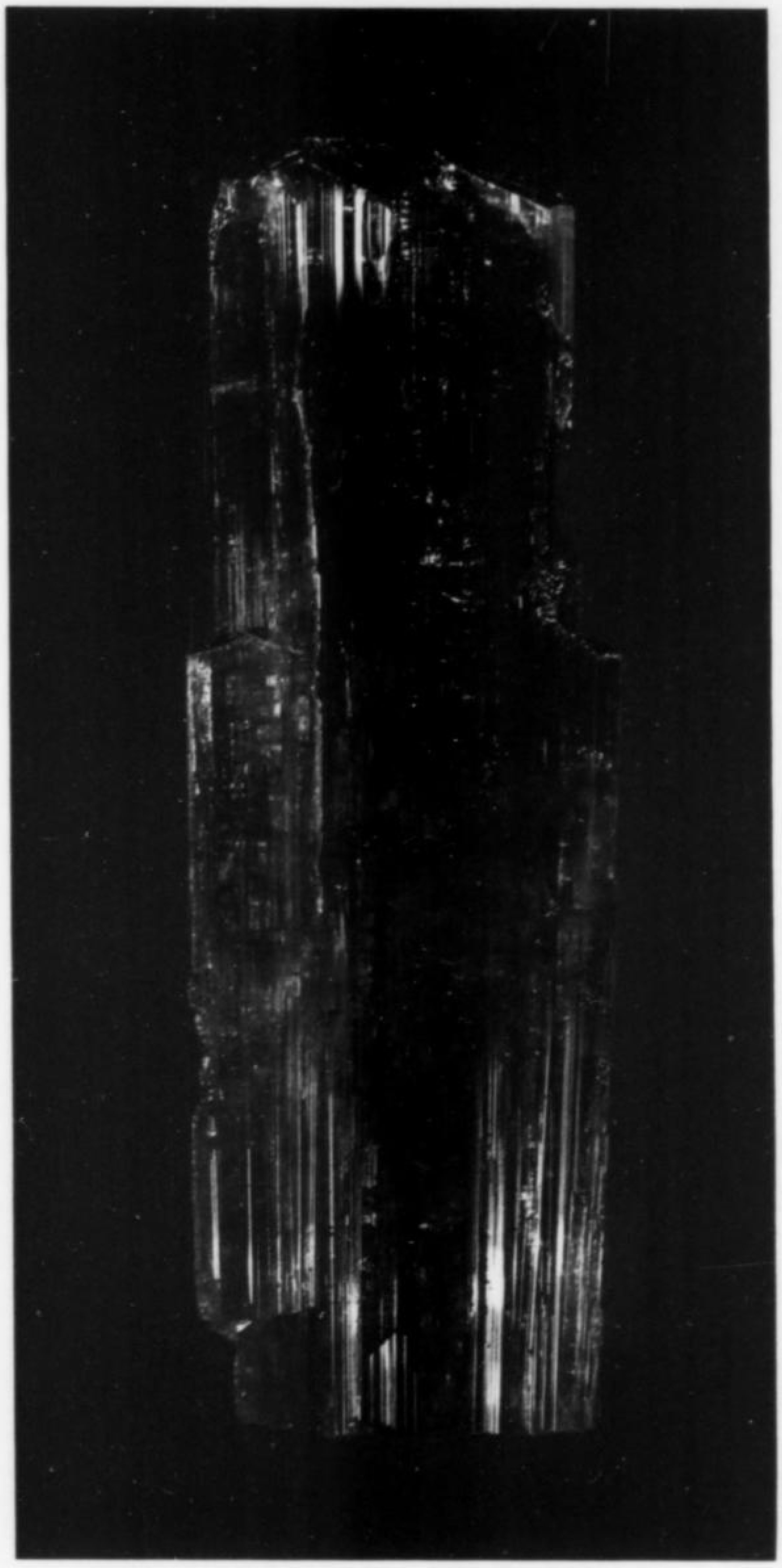


Figure 5. **Large crystal of tourmaline from the Hyakule mine measuring 13.1 cm, the finest known. Houston Museum of National Science collection; photo by Ron Bentley.**

Although the name *tsilaisite* has been applied to manganese-rich tourmalines (Kunitz, 1929; Slivko, 1961), there is some question as to whether this is appropriate inasmuch as aluminum predominates over manganese up to approximately 11% MnO, suggesting that the designation manganese-rich elbaite for these yellow Nepal tourmalines is preferable until such time as *tsilaisite* is officially defined.

Associated minerals

Because the author has never been able to see the Hyakule pegmatite in place, due to landslides, the zoning of the pegmatite and the positions of other minerals have not been worked out, but it is presumed that most of the unusual minerals were formed in gem pockets in the core of the pegmatite midway between the walls. Associated pocket minerals include clusters of pink lepidolite crystals in well formed, often concave, hexagonal plates up to 2.5 cm in diameter, sometimes attached to tourmaline crystals; danburite in finely terminated, transparent colorless to pale yellow crystals usually 2.5 cm long with almost square cross-sections, that test as niobian by XRF analysis; hambergite in 2.5 to 5-cm tabular white or colorless crystals, in rare instances of sufficient clarity to facet one-carat stones; apatite in glass-clear colorless well-formed crystals about 1.5 cm long that seem to be yttrian by XRF analysis; spessartine crystals seldom of gem quality; transparent etched colorless beryl prisms; blue-green amazonite microcline; clear quartz crystals; muscovite and cleavelandite. Neither topaz nor spodumene have yet been noted. The pegmatite rock is moderately coarse-grained with tapered prisms of blue beryl and a striking abundance of rectangular biotite plates several cm across, in graphic intergrowhts of quartz and feldspars.

Specimens of tourmaline on matrix are exceedingly rare, all gem crystals having been broken off by the miners or formed free of matrix, probably in pocket clay long ago washed away. Many of the tourmaline crystals are coated with fine muscovite (sericite) in which tiny pink tourmaline crystals of 1 mm or less are frequently embedded. Removing this coating is sometimes difficult, as the tiny crystals are also embedded in the surface to the host tourmaline crystal.

OTHER NEPAL TOURMALINE LOCALITIES

In addition to the gem elbaites of Hyakule and Phakuwa, and a few sparse crystals in nearby pegmatites, pink tourmalines are reported to occur in central Nepal in the Langtang Valley, and green tourmalines are found near Jajarkot, north of Surkhet in western Nepal. From western Nepal, also near the town of Surkhet, transparent medium yellow-brown to orange uvites (?) in good but not sharp doubly terminated crystals from 2.5 to 5 cm in length occur in dolomite marble. Though their color is quite unusual, these are generally too fractured to be faceted successfully. Small translucent to opaque, dark brown, perfectly formed, euhedral crystals of dravite occur in some abundance in far eastern Nepal north of Taplejung. They are usually between 6 and 12 mm in length, doubly terminated and of such sharp crystal perfection as to make nice thumbnail specimens. From a locality in Nepal that the owner has not been willing to divulge, is available a good supply of black tourmaline, probably schorl, in unusually crisp and perfect, doubly terminated crystals of a fairly uniform 5-cm length.

The author has seen no indicolite (blue elbaite) among thousands of fragments from Hyakule and Phakuwa, but many years ago a large 500-carat crystal of fine indicolite was reported to have been bought from a Hyakule miner and sold in Germany. This and other indicolites of true medium to dark blue, without any green, usually not of faceting quality, have probably come from the Chokte pegmatite about 16 km southeast of the two principal tourmaline pegmatites.

A single 21.50-carat chrome-yellow or chartreuse faceted tourmaline obtained in Nepal, and supposedly from a Nepal crystal, is in the collection of E. Gubelin who had it analyzed. According to the data he has kindly supplied (personal communication, 1980) the $\approx 5\%$ MnO and $\approx 11\%$ MgO without CaO or Li_2O and only $\approx 2\%$ Na_2O could make it a gem manganoan dravite. The author does not know of any other gem tourmaline chemically like it from Nepal even though the color is characteristic of the manganese-rich elbaites of Hyakule that contain no magnesium in their composition (Bassett, 1984).

CONCLUSION

It seems certain that if the Hyakule pegmatite were ever reopened by removing the tons of landslide material under which it is now buried, unusually fine collector's specimens could be expected. In

Nepal, it is not possible for westerners to own or operate such a property, nor does it seem likely that any Nepali will invest the considerable sum necessary to reopen the pegmatite in the near future. Such crystals as now exist in private or museum collections should be regarded as uncommon specimens from a locality that is probably defunct. For collectors of rare and fine tourmalines from unusual localities, these are now prized possessions.

ACKNOWLEDGMENTS

My thanks to Wendell E. Wilson and Ron Bentley for the specimen photography, and to William Larson for the loan of specimens pictured.

REFERENCES

ANDREWS, E. (1984) Geology and gemstone deposits of the Sabhaya Khola region, Sankhuwa Sabha district, eastern Nepal. *Journal of Nepal Geological Society,* Kathmandu, Nepal, **3**.

BASSETT, A. M. (1979) Hunting for gemstones in the Himalayas of Nepal. *Lapidary Journal,* **33** (no. 7, October), 1492–1520.

BASSETT, A. M. (1984) Chemical and microprobe analyses of yellow Mn-bearing tourmalines from Nepal. *Gems and Gemology.*

KRUMMENACHER, D., BASSETT, A. M., KINGERY, F. A., and LAYNE, H. F. (1978) Petrology, metamorphism and K/Ar age determinations in eastern Nepal. In: *Tectonic Geology of the Himalayas,* Editor P. Saklani, New Delhi, 151–166.

KUNITZ, W. (1929) Die Mischungsreihen in der Turmalingruppe und die genetischen Beziehungen zwischen Turmalinen und Glimmern. *Chemie der Erde,* **4**, 208–251.

SLIVKO, M. N. (1961) Manganese tourmalines. *International Geological Reviews,* **3**, 195–201, translated from the Russian article of 1959.

Recent work at the Himalaya Mine

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The world-famous Himalaya mine was the world's principal source of gem-grade and carving-grade tourmaline from its opening in 1898 until 1914. Today it is again producing fine gems and crystal specimens in abundance.

INTRODUCTION

The Himalaya mine is located on the Himalaya pegmatite-aplite dike system in the Mesa Grande mining district 83 km (52 miles) northeast of San Diego, California. The Mesa Grande, Pala, Rincon and Ramona districts collectively comprise San Diego County's main gem-pegmatite area.

A sizeable body of literature exists on San Diego County pegmatites. Readers are referred to the important studies by Donnelly (1935) and Foord (1976) for detailed bibliographies. Foord (1976) gives a comprehensive account of the mineralogy and petrogenesis of dikes in the Mesa Grande district, especially at the San Diego and Himalaya mines. An excellent review was published in the *Mineralogical Record* (Foord, 1977).

HISTORY

Local Indians were probably the first to find tourmaline in the Mesa Grande area, and Kunz (1905) tells of pegmatite minerals being found in old Indian graves. It has even been suggested that the Indians did a little surface mining using primitive techniques.

The Mesa Grande locality appears to have been found in 1889 by a prospector searching for lepidolite. He came across gem-quality tourmaline, quartz and lepidolite in float on the flanks of Mesa Grande Mountain. The discovery sparked interest in the area, and additional prospecting turned up more occurrences.

In 1898 the Himalaya mine opened and from that time until 1914 it was the world's leading supplier of tourmaline. Most of the mine's production was purchased by the Imperial Chinese government as carving material. The Boxer Rebellion and subsequent collapse of the government brought an end to this important market, and large-scale mining at the Himalaya mine ceased.

During those early years the Mesa Grande district yielded over 100 metric tons of marketable tourmaline valued then at over $750,000. In 1906 alone over 50 tons were produced (Jahns, 1982). There is no telling what this material would have been worth today.

The Himalaya mine was worked intermittently on a small scale for many years but production was minor. In 1952 Ralph Potter purchased the property. During the following 12 years he reopened old workings and began new ones, operating more or less full time until 1964. In 1963 the Himalaya Gem Mines Corp. was formed, composed of ten shares divided among nine owners.

In 1977 Pala International took a lease on the property and began an adit on the east side of the mountain. At a distance of about 160 meters into the mountain they struck a richly mineralized zone of the pegmatite and have been removing fine specimens and gem material for the last several years. Over 680 meters of workings have been developed in the pegmatite vein here, with the result that the Himalaya mine has once again become North America's leading supplier of tourmaline.

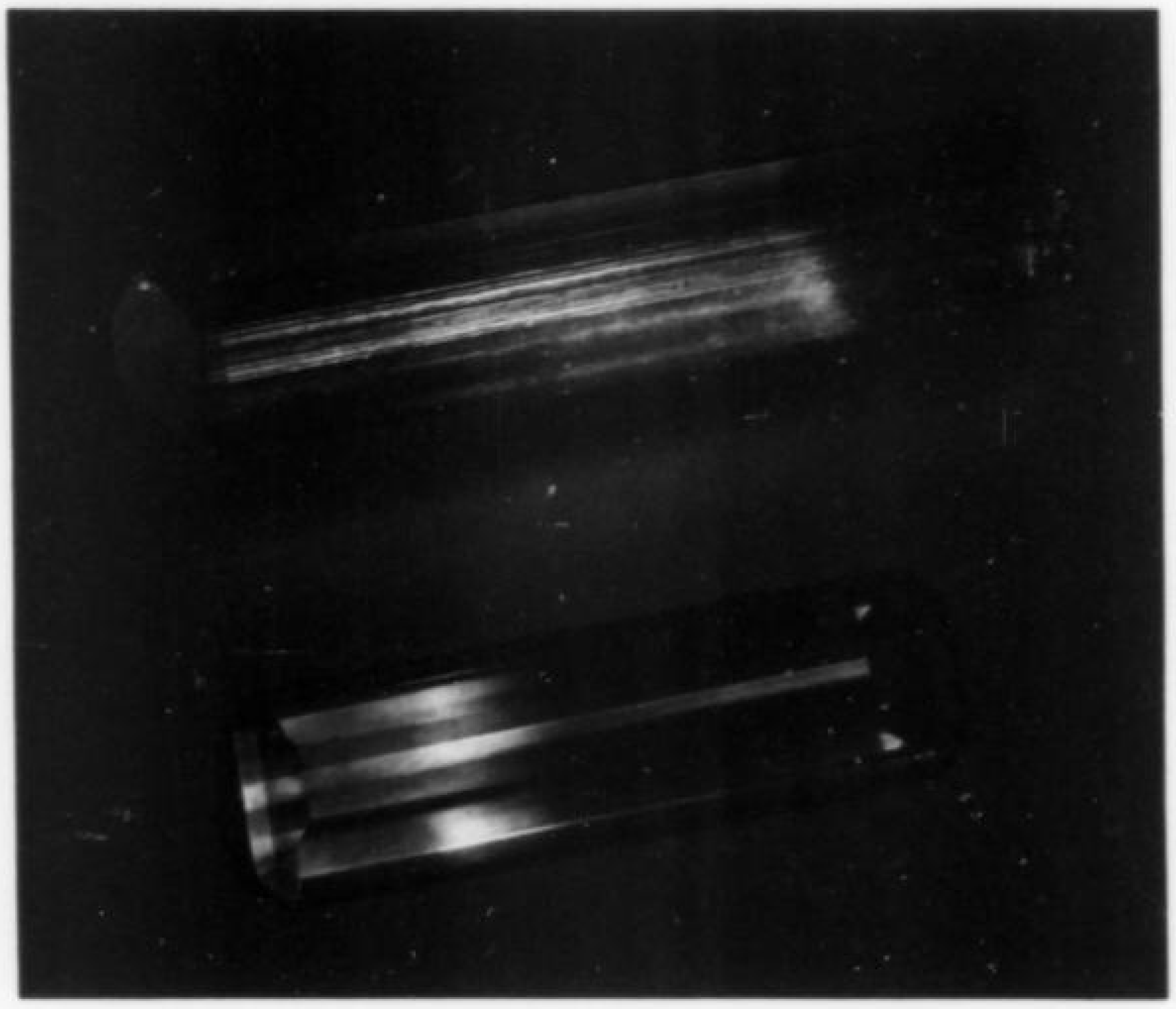
GEOLOGY

Pegmatites in the Mesa Grande area lie within the Cretaceous Peninsular Ranges batholith. This intrusion and its associated pre-batholithic rocks form a northwest to north-northwest-trending linear belt extending from Riverside County, California, to the southern tip of Baja California, Mexico. The batholith is a complex of many hundreds of plutons and forms a major segment in the circum-Pacific chain.

The Mesa Grande gem-bearing pegmatites lie within the western portion of the batholith and intrudes a norite member of the San Marcos gabbro (Larson, 1948). The pegmatite dikes parallel a prominent set of joints in the gabbro, and follow the joints where they penetrate neighboring igneous rock units (Jahns, 1979). Jahns believed these joints were the result of contraction associated with cooling of the batholith.

Figure 1. **Two multicolored tourmaline crystals 5 cm tall, with albite. Photo by Harold and Erica Van Pelt; William Larson collection.**

Figure 2. **Himalaya mine bicolored tourmaline crystal 3.5 cm long with faceted stone. Photo by Harold and Erica Van Pelt; William Larson collection.**



Pre-batholithic rocks of the area consist primarily of quartz-mica schists, sillimanite schists and "hybrid gneisses" which Weber (1963) described as an intimate mixture of migmatitic gneiss and various metamorphic and igneous rock types.

The Pegmatite Body

Two pegmatite-aplite dikes and their related stringers comprise the Himalaya dike system. These two sub-parallel dikes crop out on the eastern slope of Gem Hill. To the south the dikes merge in the area of the San Diego mine (Foord, 1976). The upper dike has historically been the major producer, and is the focus of current operations.

The dike averages about 46 cm in thickness but is quite variable. It strikes northwest and ranges in dip from a gentle 18° to 53°. Contacts with the norite are generally sharp but may be locally convoluted and complex. In places the dike encloses markedly altered xenoliths or "horses" of norite, and in these areas the dike often bulges and becomes convoluted, thickening noticeably on one side of the inclusion. These areas of thickening typically contain a concentration of gem-bearing pockets.

The density and orientation of joints in the host norite appear to be the primary control for dike structure and pocket distribution

R. Bentley

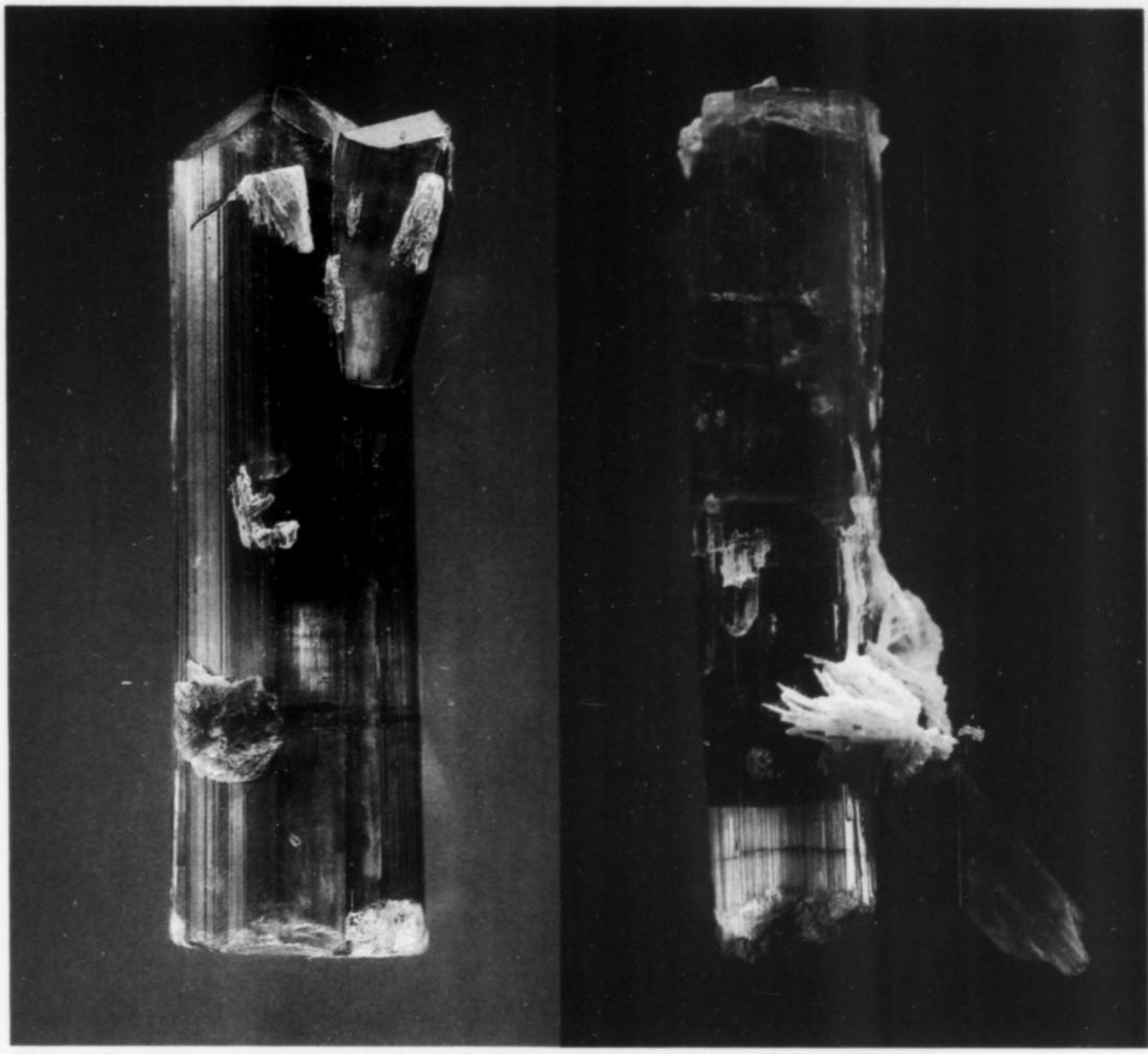


Figure 3. **Tourmaline crystals 14 and 11.5 cm tall. Houston Museum of Natural Science collection.**

Figure 4. **Fluorapatite crystal 1.5 cm across on quartz. Note chatoyant pale green zone parallel to termination. William Larson collection.**

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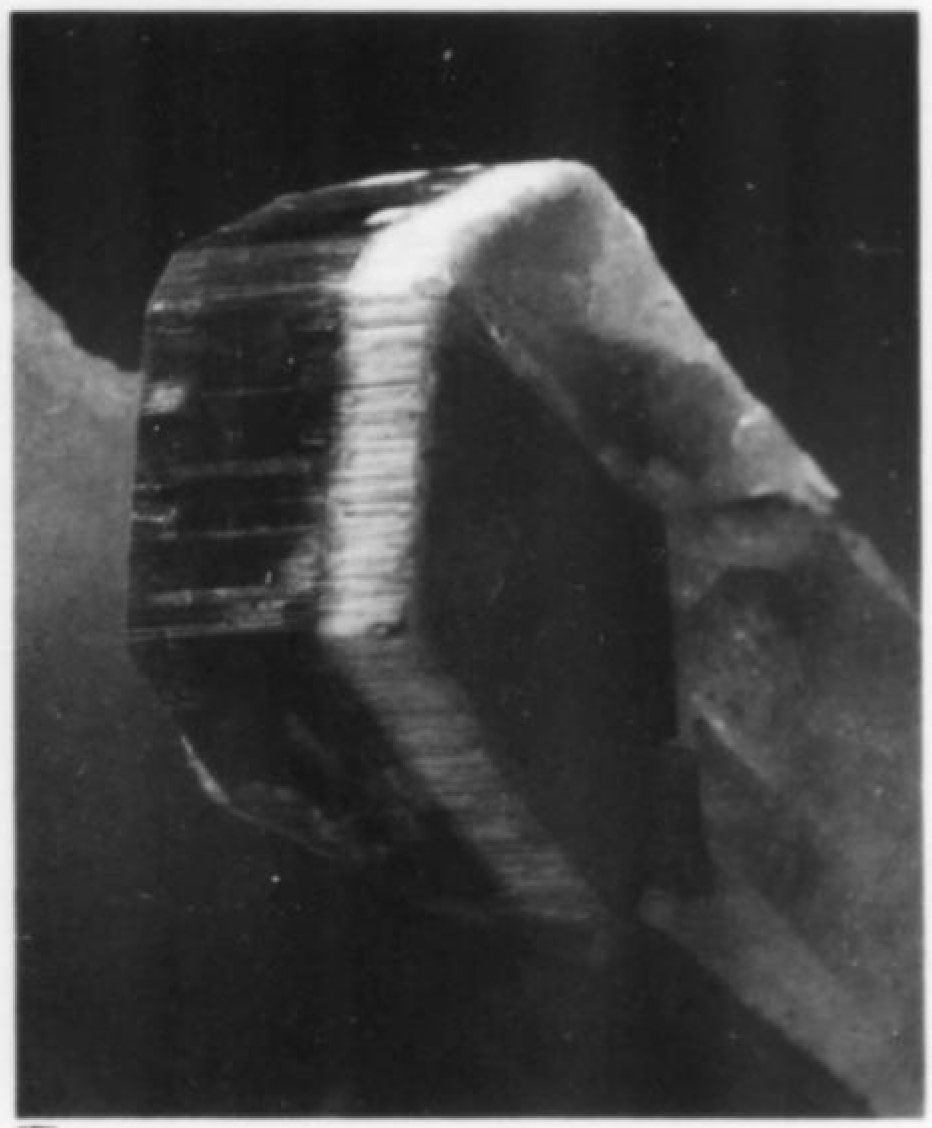
Figure 5. **Doubly terminated rubellite crystal 2.1 cm long on microcline with stilbite. William Larson collection.**



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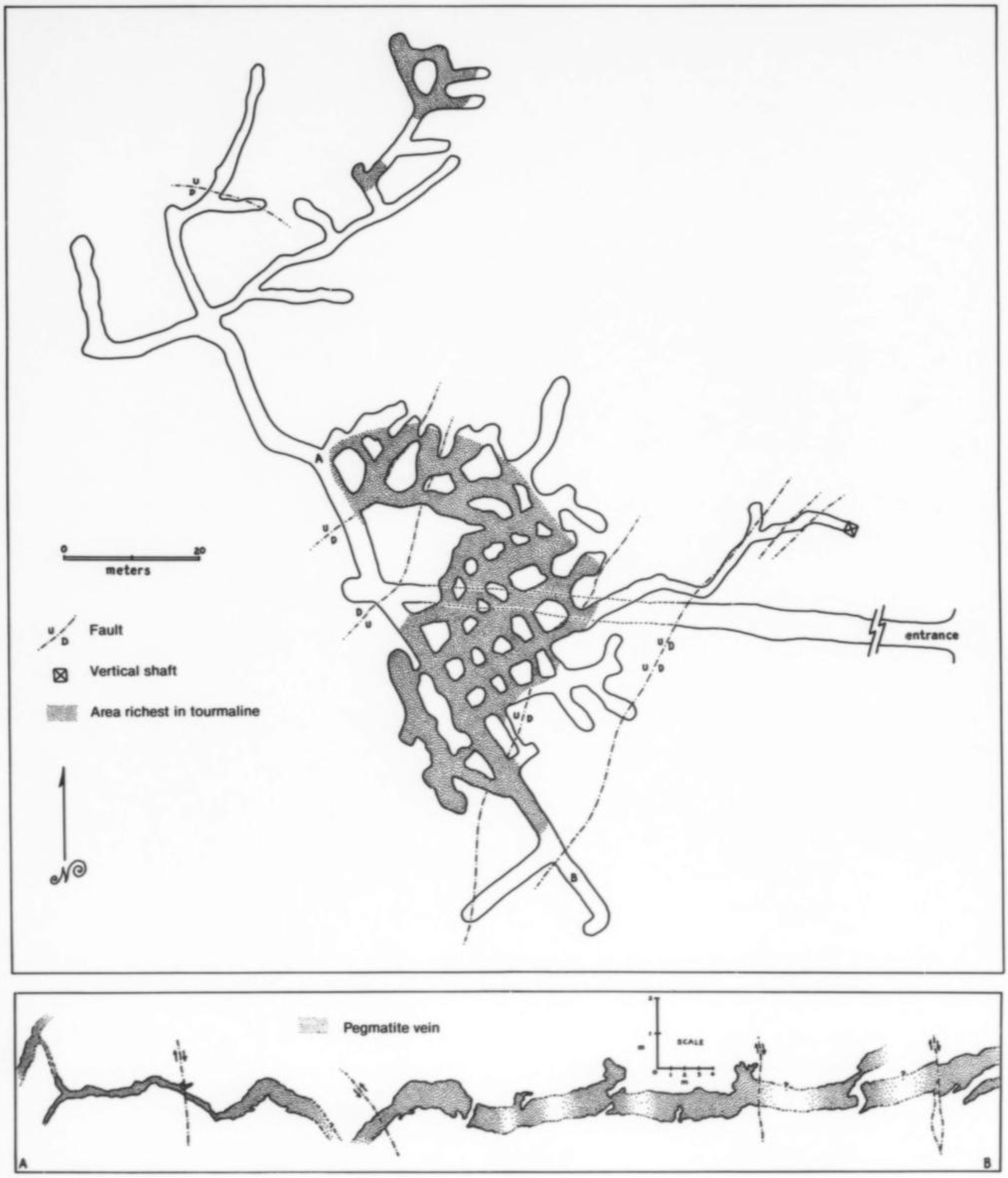

Figure 6. **Post-1977 underground workings at the Himalaya mine (Marcusson, 1985). Plan view *(top)* shows the areas of tourmaline mineralization. Approximately 130 meters of the entrance adit are omitted at the break. Vertical section *(bottom)* shows the conformation of the vein between points A and B on the plan view. Lighter areas are inferred; vertical scale is exaggerated; surrounding country rock is norite.**

(Marcusson, 1985). An optimum ratio appears to exist between joints paralleling the dike and joints intersecting the dike at roughly 90°; where this ratio is maintained the dike retains its thickness and productivity. Where the ratio favors joints parallel to the dike the pegmatite splinters, narrows and becomes unproductive. Too many joints at right angles to the dike result in kinking and forking and, once again, the pegmatite becomes unproductive.

The occurrence of gem-grade and specimen quality tourmaline, generally in shades of pink and green, is limited to the central pocket-forming zones of the dike. Here many of the tourmaline crystals contain gemmy, unfractured areas. Collector-quality specimens consist of single crystals, crystal groups and associations with other species including quartz, lepidolite, microcline and albite (cleavelandite). Less common associations are fluorapatite, calcite, stilbite and an interesting array of tantalum-niobium minerals.

The author recently completed mapping of the new (post-1977) underground workings. As can be seen on the accompanying map, the main adit undercuts the upper dike to a northwest-southeast crosscut, and from there a system of galleries or stopes have been excavated in the dike. The main productive zone is still yielding tourmaline on the southwest (down-dip) face, and a separate productive zone has just recently been opened at the extreme northern end of the workings. The mine has been particularly productive

Figure 7. **A section of the pegmatite dike. Photo by Harold Van Pelt.**

during the last 15 months or so and a great many fine specimens have reached the market.

MINERALS

The following descriptions refer only to material mined in the last few years.

Elbaite $Na(Li,Al)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Elbaite tourmaline is found throughout the mine, but specimen-quality material is limited to the central pocket zone of the dike. The tourmaline crystals are typically elongated, striated and prismatic, resembling crystals found during earlier decades.

As shown on the mine map, two areas are currently producing specimens. The northern area contains tourmaline in a fairly wide range of colors (red, burgundy, green, grayish green, in zones parallel to the *c* face, and ranging in size from 1 to 23 cm in length and up to about 5 cm in diameter. Radiating groups and single crystals, sometimes doubly terminated, occur with quartz, cleavelandite, microcline and lepidolite. In the southern area very large, deep pink crystals have been found which measure up to 13 cm in length and 7.5 cm in diameter. Some crystals are bicolored deep pink and green with a sharp transition between colors.

Recent years have seen the production of some of the finest tourmaline-calcite-cleavelandite associations ever to come from the mine. Specimens having white stilbite crystals are also particularly attractive.

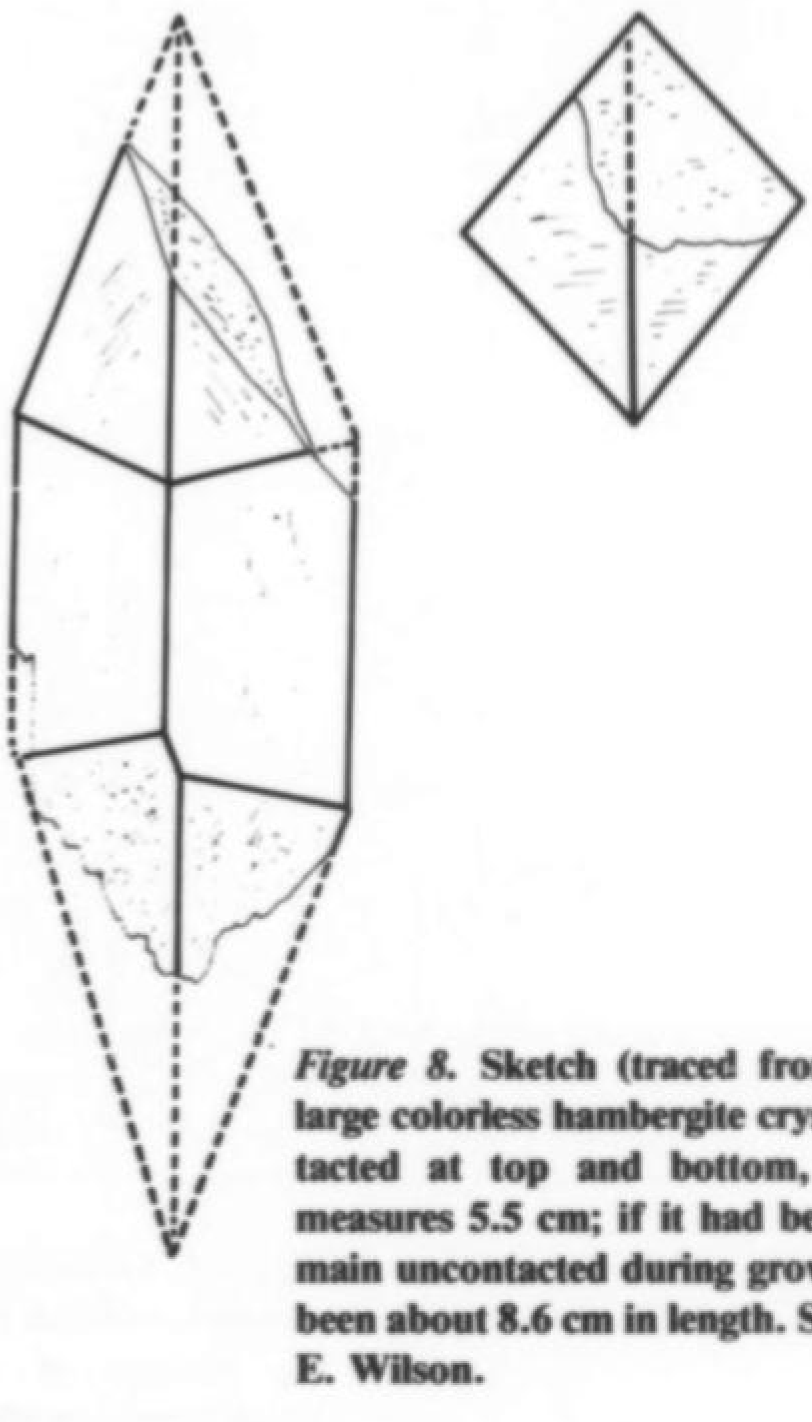

Figure 8. **Sketch (traced from a photo) of a large colorless hambergite crystal. Though contacted at top and bottom, the crystal still measures 5.5 cm; if it had been allowed to remain uncontacted during growth it would have been about 8.6 cm in length. Sketch by Wendell E. Wilson.**

Fluorapatite $Ca_5(PO_4)_3F$

Though rather rare, some attractive and interesting specimens of pale blue to reddish violet fluorapatite have been found recently. The crystals are stubby in habit, sometimes shorter along *c* than along *a*. The prism faces on some crystals are sharp and lustrous whereas the terminations are frosty and poorly formed, in some cases actually concave. They have been found as singles only, on quartz crystals.

Hambergite $Be_2BO_3(OH)$

Very recently large hambergite crystals have been found, some over 5 cm in length. The crystals are colorless with a little orange iron staining here and there. Some areas are quite gemmy but others are heavily fractured to the point of milkiness. The faces are sharp but have a slightly etched and frosty appearance. Some crystals show twinning on (110).

Malayaite $CaSnSiO_5$

Very small amounts of this rare mineral were collected at the Himalaya mine recently by Garth Bricker, and were subsequently identified by E. E. Foord (personal communication; Foord *et al.*, 1986, in press). The mineral occurs as tiny white hemispheres and rosettes to 0.2 mm in size, on elbaite, quartz, cleavelandite and K-feldspar crystals of the pocket zone. This is the first reported occurrence of malayaite in the United States.

Stibiotantalite-Columbotantalite $SbTaO_4$-$SbNbO_4$

The Himalaya dike system is well known for its stibiotantalite-columbotantalite, and has recently produced some particularly fine specimens. The crystals are dark mahogany-red to amber-yellow in color, and tabular in habit; maximum crystal size is about 2 cm.

Stilbite $NaCa_2Al_5Si_{13}O_{36}\cdot 14H_2O$

Stilbite and also other zeolites including laumontite and thompsonite are found as coatings and overgrowths on pocket minerals. The stilbite is particularly attractive, often forming snow-white crystals and sheaves which make a nice complement to bright pink and green tourmaline. Crystals of stilbite exceeding 4 cm have been found.

CONCLUSIONS

The operations at the Himalaya mine are currently productive, and a potentially very great portion of the pegmatite dike under Mesa Grande Mountain remains to be explored. Considering that workings on opposite sides of the mountain have proved extremely rich in tourmaline, there is every reason to believe that the intervening area will be yielding fine tourmaline for several years to come.

ACKNOWLEDGMENTS

My thanks to William Larson of Pala International for allowing access to the Himalaya mine and providing specimens for study and photography, and to E. E. Foord for providing additional data on some of the minerals. Thanks also to Harold and Erica Van Pelt, Ron Bentley and Wendell E. Wilson for help with the illustrations.

REFERENCES

DONNELLY, M. G. (1935) The lithia pegmatites of Pala and Mesa Grande, San Diego County, California: Unpublished Ph.D. dissertation, California Inst. of Technology.

FOORD, E. E. (1976) Mineralogy and petrogenesis of layered pegmatite-aplite dikes in the Mesa Grande district, San Diego County, California. Unpublished Ph.D. thesis, Stanford University. 326 pp.

FOORD, E. E. (1977) The Himalaya Dike System, Mesa Grande District, San Diego County, California. *Mineralogical Record,* **8**, 461–474.

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

JAHNS, R. H. (1979) Gem-bearing pegmatites in San Diego County, California: The Stewart Mine, Pala district and the Himalaya Mine, Mesa Grande district; in: *Mesozoic Crystalline Rocks: Peninsular Ranges batholith and pegmatites, Point Sal ophiolite;* P. L. Abbott and V. R. Todd, eds., Geological Society of America Annual Meeting, San Diego (1979), San Diego State University, California, 3–38.

LARSON, E. S., Jr. (1948) Batholith and associated rocks of Corona, Elsinore, and San Luis Rey quadrangles, southern Califormia. *Geological Society of America Memoir,* **29**, 182 pp.

MARCUSSON, C. R. (1985) Horizontal and vertical zonations within the Himalaya dike system, Himalaya Mine, Mesa Grande, California: Unpublished B.S. thesis, San Diego State University, 66 pp.

WEBER, F. H. (1963) Geology and Mineral Resources of San Diego County, California. *California Division of Mines and Geology County Report 3,* 309 pp.

Wright's ROCK SHOP

★ NEW CATALOG $2 ★

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Uvite, Brumado mine, Brazil; Crocoite, Red Lead mine, Tasmania; Tourmaline, Brazil; Hematite, Spain; Hematite on Quartz, Switzerland

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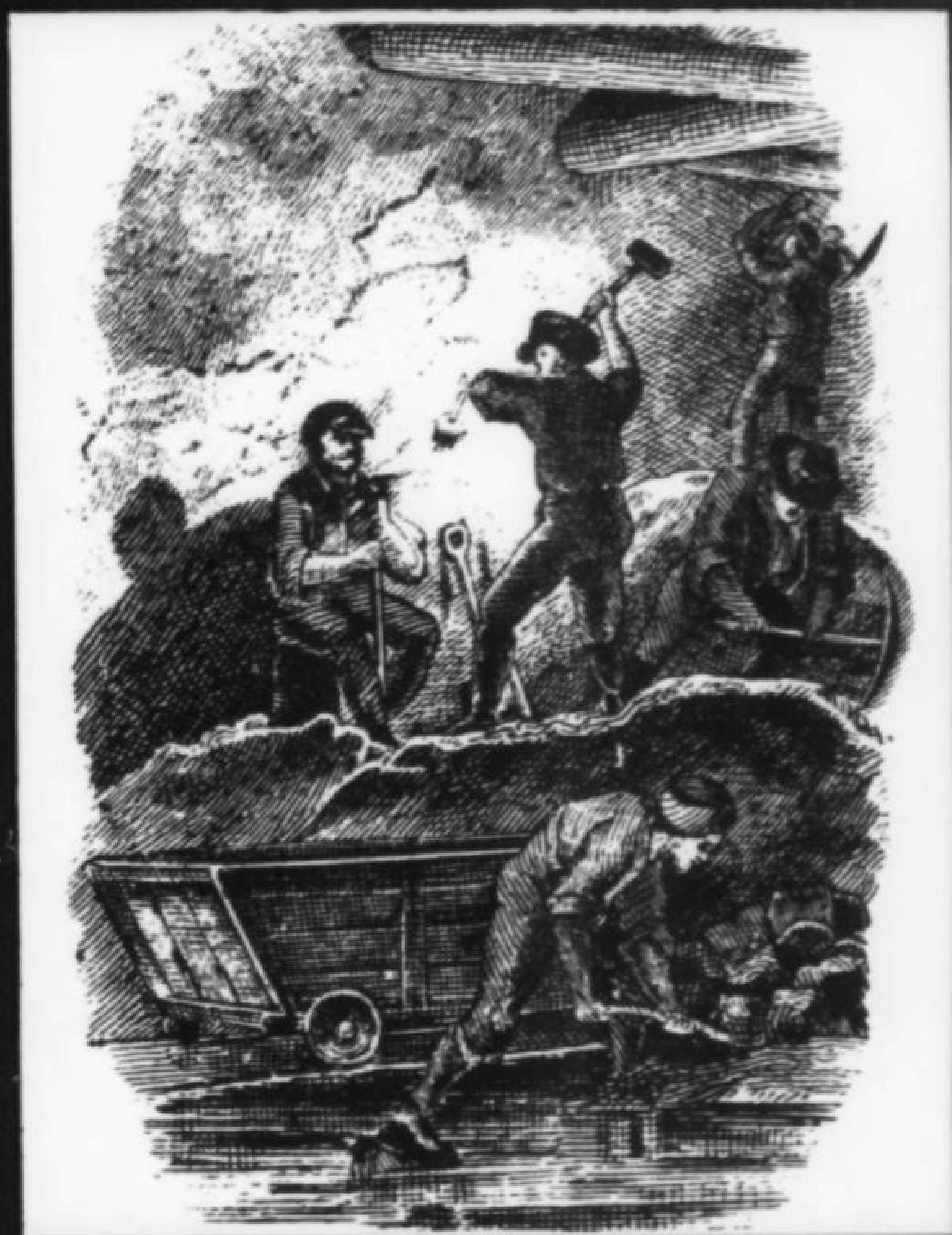

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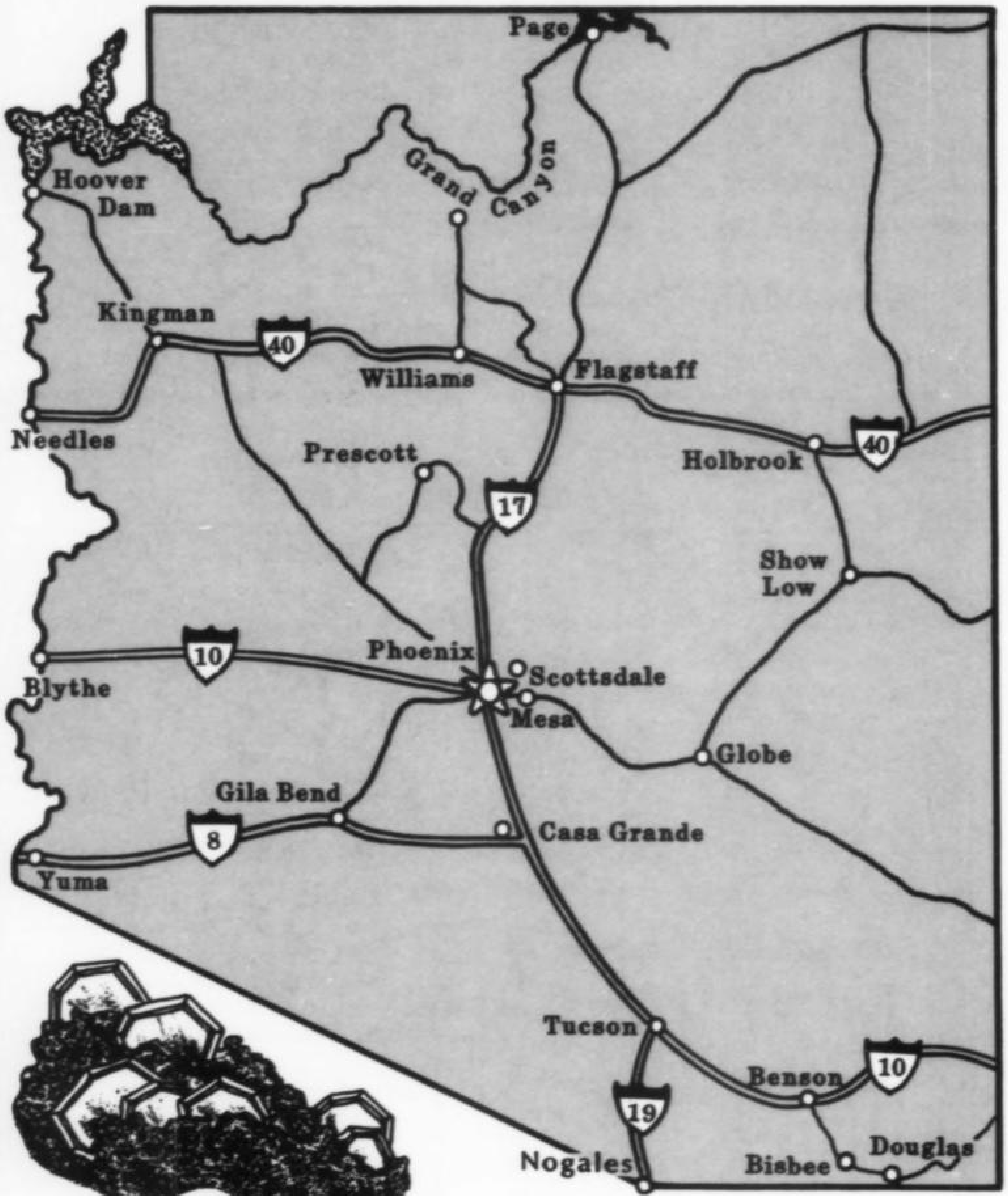
Arizona Mineral Dealers

Arizona Is Fast Becoming The Center For Dealers of Minerals & Supplies!



Throughout Arizona there are numerous mineral dealers and field collectors who sell wholesale, retail or both. We encourage you to visit Arizona and our many fine dealers.

Below, a few of us are listed: Appointments prior to visits are recommended (dealers tend to travel often).

Kino Rocks & Minerals
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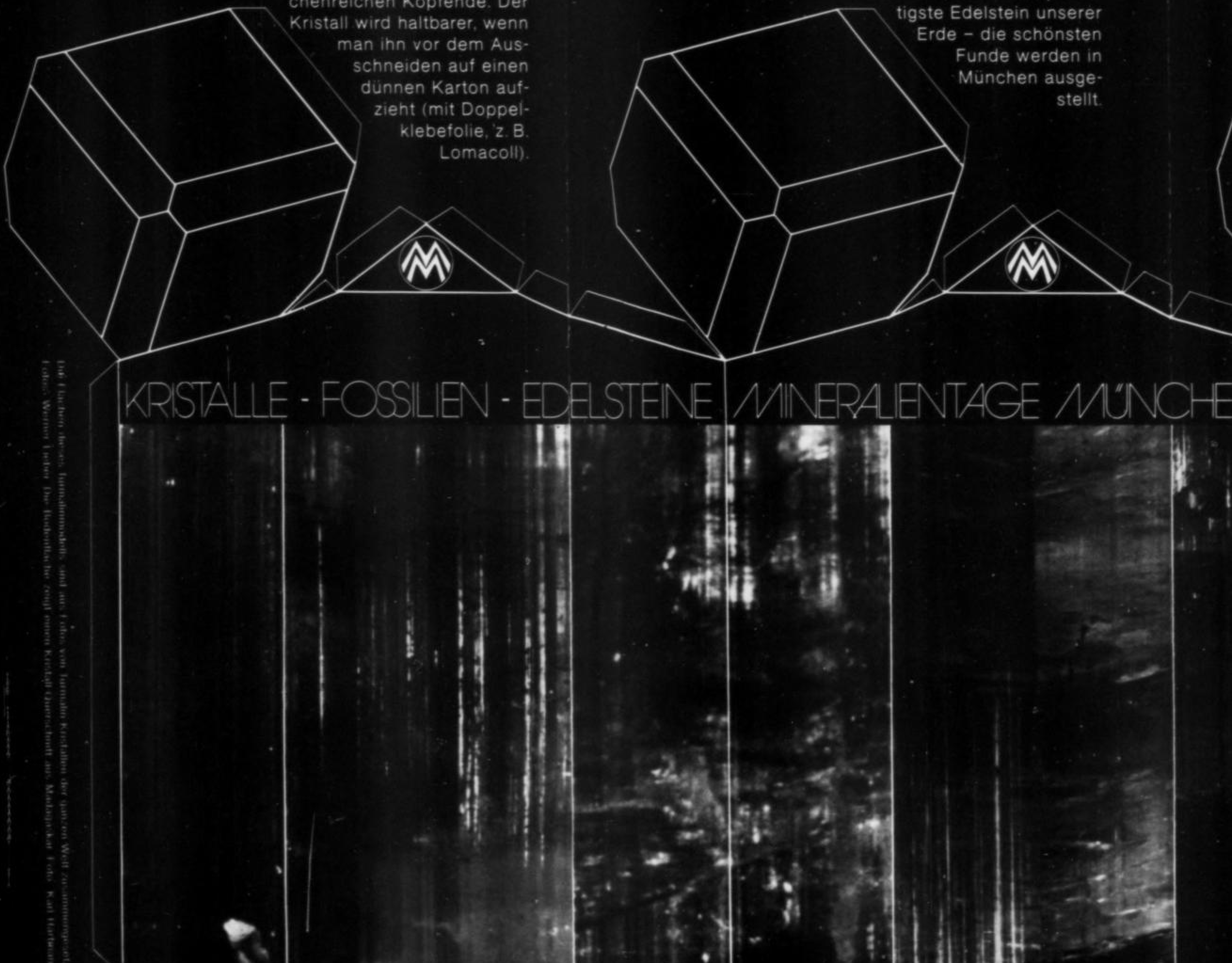


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the Munich Show

MUNICH

Munich is one of Europe's great cities, and home to well over a million people. It began sometime before the year 800 as a small settlement of Benedictine monks; it was known then as *Munichen* or *zu den Mönchen* ("at the monks"). Both namens have endured, as Munich and München, though Germans use the latter almost exclusively and refer to residents as Münchners.

It would make no sense at all to travel all the way to Munich and not see the city as well as the mineral show. Start with the modest mineral collection on exhibit in the Ludwig-Maximilian University, indicated on some city maps as the Mineralogische Staatssammlung, the State Mineral Collection. Of particular interest here are four huge platinum nuggets from Nishne Tagilsk, Soviet Union, measuring from 3.5 to 10 cm across. And it's difficult to miss the 30-cm plate of emerald crystals on schist matrix from Takowaja, Soviet Union.

The other stop which no mineral collector should miss is the Deutsches Museum, the largest science and technology museum in the world. Here you'll find an enormous mining exhibit consisting largely of recreated underground environments from many mines, countries and eras. Imagine spending more than half an hour just walking through mine after mine, up inclines, past stopes and shafts, around miners and mining equipment; and the wall rock changes to correspond to each mining area depicted as you move along. Three cases of superb antique mine lamps highlight the whole presentation.

Finally there is the site of the show itself, the Munich Messegelände or Fair Grounds. The enormous show hall is Halle 16, only one of 20 major structures in a vast complex of show buildings arranged in a U-shape around a park. Opposite Halle 16 at the far end of the park stands the 20-meter brass statue known as *Bavaria,* a rather husky, toga-clad goddess overlooking Therese's Meadow where the Oktoberfest spreads out every year.

THE MUNICH SHOW

From its modest beginning in 1964, when 300 people attended the show, the Mineralientage München has grown into a mineralogical event of worldwide stature.

The Munich Show: the first day of the show, Friday, is the designated wholesale *day* for *all* dealers. This day is referred to as the GEOFA or Geofachmesse (Geo-trade show), and only visitors presenting a GEOFA card are admitted. How does one obtain such a card? All you need do is write to the show office well in advance, on company stationery demonstrating that you are somehow "in the business". Museum curators, professional mineralogists, jewelers, dealers and their purchasing agents and guests, goldsmiths and silversmiths, stone carvers, craftspeople and miners are all permitted. Then, on Saturday and Sunday, the entire show is open to the public.

The Munich Show caters to everyone, but is primarily directed toward the mineral collector. Fossil collecting is more popular in Europe than in America, so you also see a surprising number of fossil dealers. The numbers for 1983 show this clearly: 180 mineral dealers, 52 fossil dealers, 55 gemstone dealers, 14 dealers in jewelry findings, and seven magazines *(Der Aufschluss, Emser Hefte, Lapis, Magma, Mineralein Magazin, Mineralogical Record* and *Schweitzer Strahler).* Also included are scattered dealers in stamps (mineral theme), postcards, calendars, used books and collecting gear. The German post office even sets up a booth where showgoers can have mail stamped with the show's own postmark!

There's no doubt about it: the Munich Show merits the highest recommendation. The city of Munich provides a wealth of fascinating sites and delicious food, good shopping and friendly people . . . and ideal setting for a mineral show. Visitors willing to range a bit more widely can visit any number of castles and palaces in Bavaria, and can reach the Alps in little over an hour. My special recommendation: a short jaunt over to Salzburg to tour the famous salt mines and enjoy the city's wonderful ambiance, shopping, music and chocolate desserts.

For more information on the Munich Show write to Johannes Keilmann, Mineralientage München, Postfach 60, D-8024 Oberhaching, West Germany (Telephone 089/6 13-47 11). The theme for the 1984 show will be Alpine minerals. For more information on Munich and on traveling in Germany write to the German Tourist Office, suite 1714, 700 South Flower Street, Los Angeles, California 90017. Tourist guides and maps of Germany are available in many bookstores.

This is a report by the editor of the most prominent Mineral-Magazin, who was visiting the Munich Mineral Show in 1983.

Wendell E. Wilson
The Mineralogical Record, May–June, 1984

The 22nd annual

MUNICH

Mineral & Gem & Fossil-Show

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- **The Great International Show**
  with the Victor-Goldschmidt-Prize 1985
- **German Gem Museum Idar-Oberstein**
  Sculptures in Tourmaline

Show-Dates '85:

GEOFA	Friday	October 18th	9 am – 6 pm
SHOW	Saturday	October 19th	9 am – 6 pm
	Sunday	October 20th	9 am – 6 pm

Munich Tourist Office

For hotel reservation write to:
Fremdenverkehrsamt München, Rindermarkt 5,
D-8000 München 2, Telephone (0 89) 23 91-2 36.

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