Adams

FROM THE TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA
THIRD SERIES, VOLUME XX, SECTION IV, 1926

On Some Minerals from the Ruby Mining District of Mogok, Upper Burma

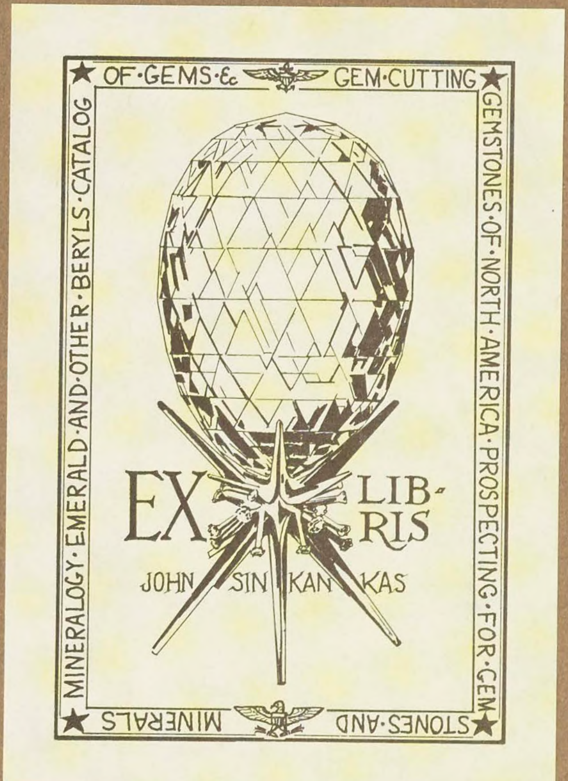
BY

Frank D. Adams, F.R.S., F.R.S.C. and R. P. D. Graham, F.R.S.C.

Topaz
sodalite
Chrysoberyl
sillimanite

OTTAWA
PRINTED FOR THE ROYAL SOCIETY OF CANADA
1926

Smithsonian Institution
Geol
National Museum


OF·GEMS·&c
GEM·CUTTING
GEMSTONES·OF·NORTH·AMERICA·PROSPECTING·FOR·GEM
STONES·AND
MINERALS
MINERALOGY·EMERALD·AND·OTHER·BERYLS·CATALOG
EX LIBRIS
JOHN SINKANKAS

Sinkankas
RR 018858

On Some Minerals from the Ruby Mining District of Mogok, Upper Burma

By Frank D. Adams, F.R.S., F.R.S.C. and R. P. D. Graham, F.R.S.C.

(Read May Meeting, 1926)

Introduction

While a few scattered papers have been published with reference to the minerals of this interesting area, no systematic account of them has yet appeared. Most of the papers in question are short and deal with the character of the rubies or with the methods of extracting them which have been employed.[1]

The most extended and important publications dealing with the mineralogy of the Mogok district which have appeared are the following:

Brown, C. B. and Judd, J. W.—The Rubies of Burma and Associated Minerals, their Mode of Occurrence, Origin and Metamorphoses (Phil. Trans., Vol. 187, 1896, pp. 151-228).

Penzer, N. W.—The Mineral Resources of Burma (Federation of British Industries: Intelligence Department)—George Routledge & Sons Ltd., London—1922, pp. 175.

Cotter, G. de P. (Superintendent, Geological Survey of India)—The Mineral Deposits of Burma—Government Printing Office, Rangoon—1924, pp. 53.

A brief description of the geology of this part of Burma has been given in a recent paper[2] which appeared in the *Transactions* of the Canadian Institute of Mining and Metallurgy. It will therefore here be necessary only to outline the geology of the district in so far as a knowledge of it is required for the purpose of understanding the manner in which the gems and other minerals described occur.

The dominant physiographic feature of Burma is the Irrawaddy river which, rising in the mountains along the Chinese border or in Thibet, runs in a southerly direction through the whole length of Burma, and is navigable from Bhamo to the sea—a distance of over 900 miles. In northern Burma it runs with a rapid current between low banks, through a wide plain underlain by rocks of Mesozoic and

---

[1]Bauer, Max—Ueber das Vorkommen der Rubine in Burma (Neues Jahr. f Min., II, p. 197), and others.

[2]Adams, Frank D.—A Visit to the Gem Districts of Ceylon and Burma (Trans. Can. Inst. Min. & Met., Vol. XXIX, 1926).

1/1/1971

Tertiary age. Rising from this back from the river, on the east toward the border of the Shan States and on the west towards the Arakan country, lines of hills can be seen conforming in a general way in their course to the north and south trend of the river. One of these lines of hills to the east of the river consists of a long and generally narrow belt of ancient pre-Cambrian (Archean) rocks which form the protaxis of the country and whose direction, like that of the lines of hills, follows the course of the river.

An excellent section across this Archean protaxis is seen along the road which runs from Thabeikkyin, a village on the east bank of the Irrawaddy about 70 miles above Mandalay, back into the country to the east, at right angles to the course of the Irrawaddy river, to Mogok near the border of the Northern Shan States, a distance of 60 miles on the road, or 40 miles as the crow flies. The rocks on this section are well exposed and present a most striking resemblance to those seen in sections through the Grenville series of the Canadian Shield. This section (Figure 1) shows alternating bands of gneiss and white crystalline limestone with some subordinate bands of quartzite.

The gneisses are in part reddish (sometimes greyish), garnetiferous, orthoclase-biotite gneiss, with many strings, streaks, and lenses of reddish pegmatite running parallel to the foliation, and closely resembling the gneiss of the Laurentian Plateau of Canada. The limestones, which occur in very thick bands over wide areas, are white and highly crystalline. Some bands are nearly pure calcite; others contain little grains of biotite, pyroxene, graphite, and other accessory minerals marking the lines of bedding, and are again identical in appearance with the crystalline limestone of the Grenville series in Canada. These limestones are in some cases more or less magnesian. The metamorphism to which the whole district has been subjected has been very intense and the limestones are in many places very coarsely crystalline.

The only occurrence of true granite which was seen in this district is a great intrusive mass which is crossed by the road just referred to about half way between Thabeikkyin and Mogok and which at one point towers up above the road in beetling crags. It is a rather fine-grained biotite granite which shows no sign of having undergone any movement during or since solidification, or of having been subjected to much pressure. Cutting as it does through a series composed of rocks in which great movements have taken place and which have been intensely metamorphosed, its character suggests that it may be of much more recent age than these and belonging possibly

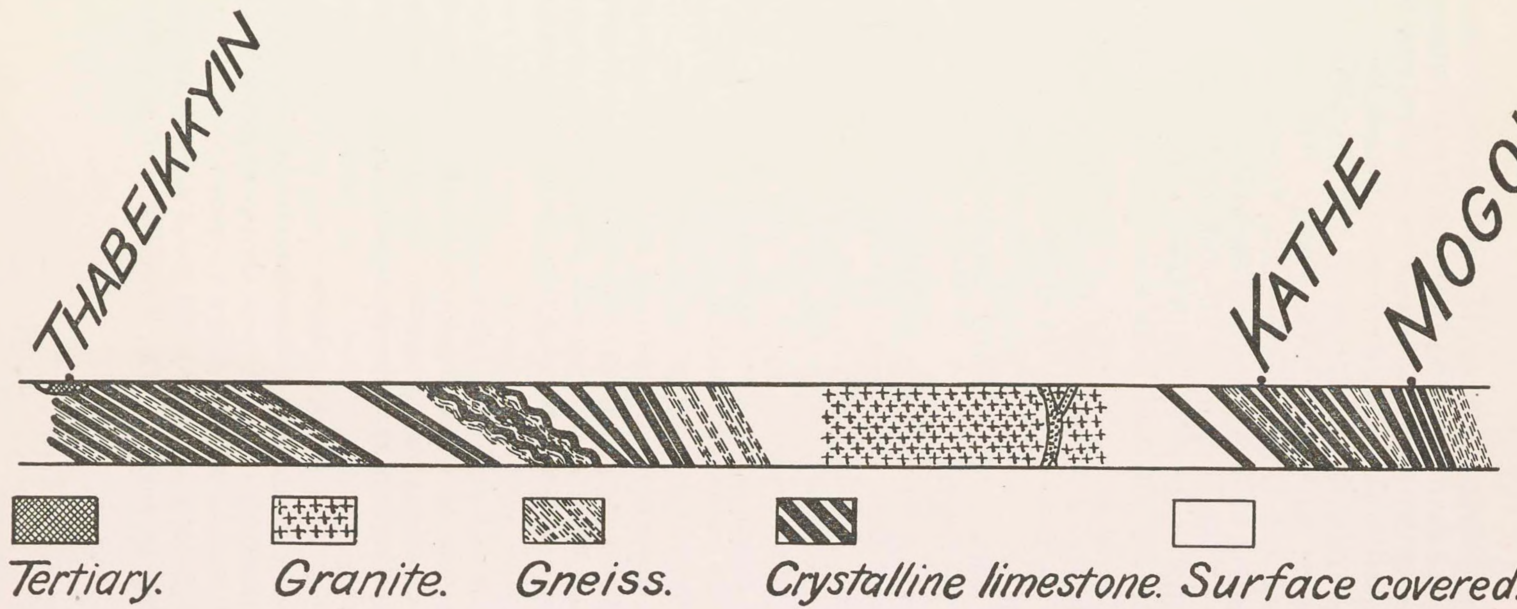


Fig. 1. Section from Irrawaddy River to Mogok.

to that series of granites of Mesozoic or even Tertiary age which have been found to the south-east in the Dutch East Indies. Just east of Sakangei, cutting this granite mass near its eastern border, is the enormous pegmatite dyke to which reference is made below.

The village of Mogok is beautifully situated in a valley near the eastern border of this belt of Archean rocks. The country rock consists of great beds of the white crystalline limestone interbedded with hard bands of white pyroxene-scapolite rock and allied varieties of rocks seen so frequently in the Grenville in Canada, the whole alternating with bands of the orthoclase gneisses and quartzites referred to above. All these rocks have been subjected to long continued subaerial decay and are in consequence largely mantled by red residual clay and other products of alteration. These, under the action of the torrential rains which fall in this region at certain seasons of the year, as well as through the transporting action of streams, are washed down, forming alluvial deposits on the hill slopes and in the valleys.

The rubies have their origin in the bands of crystalline limestone, especially where these have been subjected to the most intense metamorphism. As this limestone, more or less impure, dissolves away by the solvent action of the rain, the rubies accumulate in the residual and alluvial deposits which are thus produced. It is by washing and concentrating these residual and alluvial clays and gravels that the rubies are obtained by the Burma Ruby Mines Limited and by individual workers in the Mogok district.

The other minerals, to which reference will be made in the present paper, have in some cases been found with the rubies in these secondary deposits but, in other cases, have been obtained from the country rock, while some of them were taken from the great pegmatite dyke at Sakangei.

The authors desire to express their most sincere thanks to A. H. Morgan, Esq., and A. S. Wheeler, Esq., both officers of the Burma Ruby Mines Limited at Mogok, to whom they are indebted for some of the finest specimens of the minerals described in this paper.

Chrysoberyl

No specimens of this mineral have hitherto been described from Burma. In the lists of minerals from Burma given by Brown and Judd, or by Penzer, this species does not appear.

Cotter, however, mentions it in his list of Burmese minerals, the reference being as follows: "Chrysoberyl occurs at Mogok and neighbourhood but is rare." This is the only reference in literature to the occurrence of this mineral in Burma.

The two interesting crystals described below were presented to Adams by Mr. A. H. Morgan, when on a visit to Mogok in the spring of 1925. They came from Mogok, but whether they were obtained in the country rock or from the residual clay is not known. One is a simple crystal, and the other presents one-half of a trilling. Apart from the interest attaching to them by reason of their being from Burma, both are notable as unusually fine examples of the crystallization of chrysoberyl, and the simple crystal, a rarity in itself, is very rich in forms, many of which have not hitherto been recorded for this mineral.

The simple crystal has the sea-green colour of aquamarine, and is in part clear and transparent, and in part clouded. It is elongated in the direction of the vertical crystal axis and tabular parallel to b(010), with approximate dimensions 4 x 2.5 x 1 centimeters. It is thus an unusually large crystal of this variety of chrysoberyl.

The crystal, shown in Figure 2, is completely terminated at one end, and narrow pyramid and dome faces also appear as steps in parts near the other end. The prism zone also is complete at the terminated end of the crystal, but otherwise half of it is lacking where the crystal is bounded by a broken surface passing diagonally across its length. Indications of an imperfect cleavage parallel to (010) are to be seen on this broken surface, but for the most part it shows a conchoidal fracture or is uneven.

The faces in the prism zone are bright and lustrous, and the edges between them are without exception sharp. The pyramid faces also yield good reflections, but the dome faces and the basal plane are somewhat dull. Some of the edges and quoins between the faces of these latter forms are rounded and worn through abrasion.

Apart from the faces of the pinacoid b(010), parallel to which the crystal is tabular, the most prominent form in the prism zone is d(160). All four faces of this prism have a fair width, and one of them is about 1 cm. across. Actually, they are not so wide as they seem at first glance, as the apparently single face may consist of adjoining or alternating faces of the forms h(150), d(160), and δ(170), which lie nearly in a plane. Faces of the prisms r(130), s(120), and m(110) have a fair development, as also has one face of the pinacoid a(100). The remaining faces in this zone, which include a number of forms now recorded for the first time, are all narrow, or a series of such faces belonging to one form alternate with others of nearly related forms. As a result, the crystal has a somewhat rounded

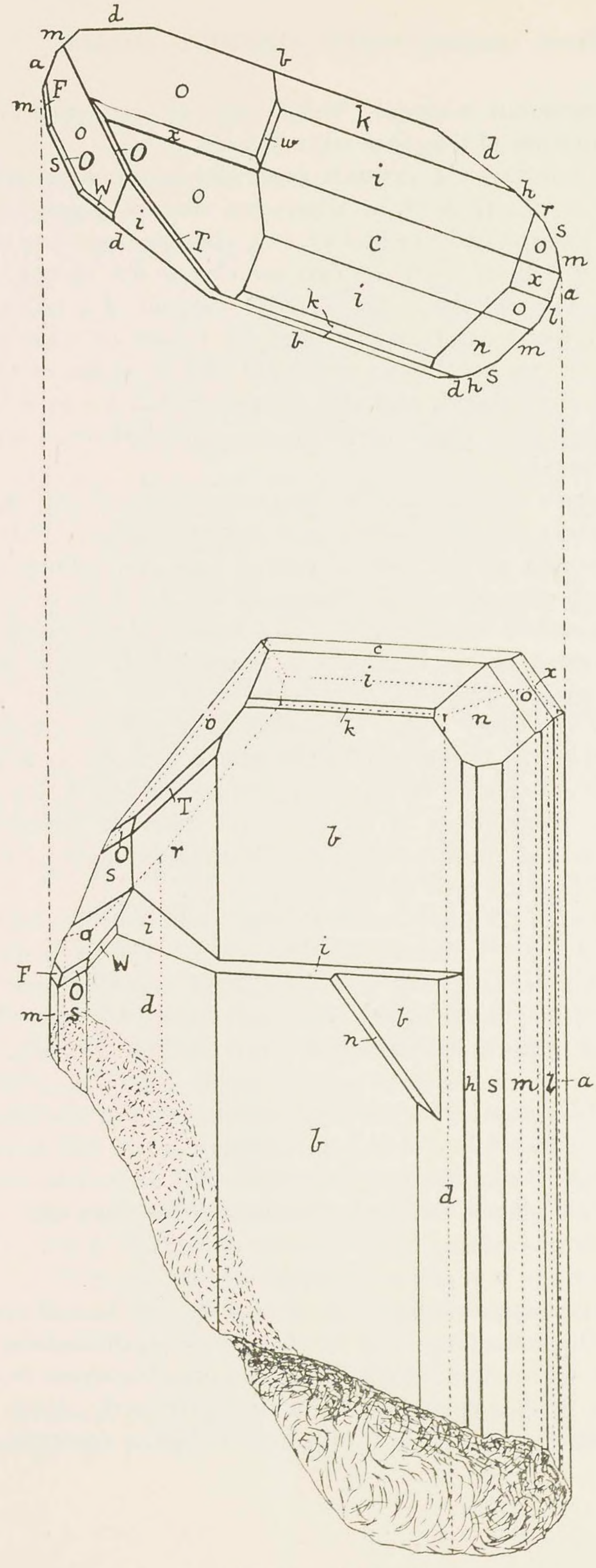


Fig. 2. Chrysoberyl from Mogok.

outline towards the extremities of the *a* crystal axis, and the prism zone here appears heavily striated vertically.

The main terminal forms are those usually present on crystals of chrysoberyl having the habit of that here described, but there are in addition a number of new pyramids. Faces of the unit pyramid o(111) are pitted with etched figures, which are described in detail below.

The habit of the crystal, and the relative development of the principal forms present, are shown in Figure 2. Following is a list of the forms observed, those marked with an asterisk being new:

a 100	*λ 530	*R 250	i 011	w 122
b 010	*N 430	r 130	k 021	v 211
c 001	*M 540	f 270	x 101	*F 221
*A 710	m 110	q 140	*ν 151	*G 332
*B 610	*μ 670	*H 290	n 121	*O 342
*C 510	*χ 450	h 150	o 111	*P 453
*D 410	*ξ 570	d 160	*U 656	*T 352
*E 310	s 120	*δ 170	*V 323	*W 5.10.4
*L 520	*S 490	*γ 1.10.0	h 313	
l 210				

Measured and calculated angles for the new forms are as follows:

Angle	Calculated	Measured	Remarks
a:A 100:710	3° 51′	3° 41′	
B :610	4 29	4 10	
C :510	5 23	5 55	Mean of 5° 52′, 5° 59′.
D :410	6 43	6 20	Mean of 3; 6° 11′-6° 27′.
E :310	8 55	9 07	
L :520	10 40	10 49	Mean of 4; 10° 24′-11° 08′.
λ :530	15 47	15 17	Mean of 15° 11′, 15° 22′.
N :430	19 27	19 39	
M :540	20 38	21 11	
μ :670	28 47	28 26	Mean of 28° 15′, 28° 36′.
χ :450	30 29	30 16	
ξ :570	33 24	33 33	
S :490	46 39	46 35	Mean of 3; 46° 16′-46° 51′.
R :250	49 39	49 34	Mean of 49° 28′, 49° 40′.
H :290	64 44	64 24	
δ :170	73 07	73 11	Mean of 4; 73° 00′-73° 26′.
γ :1.10.0	78 00	77 35	
b:ν 010:151	28 39	29 38	Truncating edge 111:010.
o:U 111:656	3 01	3 08	Replacing edge 111:$1\bar{1}1$.
V :323	6 24	6 23	
F :221	16 07	17 16	Replacing edge 111:110.
G :332	10 12	10 07	
O :342	13 05	13 16	Replacing edge 111:120.
P :453	9 41	9 44	
T :352	28 06	28 44	Truncating edge 111:130.
W :5.10.4	18 58	18 01	Truncating edge 111:160.

While the new prisms listed above are all present as narrow, and some of them as very narrow, faces, these yield well-defined images, and there is, in general, a close correspondence between the measured and calculated angles. In the case of many of them the well-defined image is accompanied by a string of others which are less bright, and readings for the most prominent of these latter yielded results as follows:

Angle on a(100)	Index	Calculated angle
8°10′	10. 3.0	8° 02½′
12° 05′, 12° 03′	20. 9.0	11 58
12° 39′, 12° 20′	15. 7.0	12 23½
14° 41′	20.11.0	14 31
22° 56′	10. 9.0	22 58
53° 19′	5.14.0	52 49
72° 30′, 72° 12′, 72° 11′	3.20.0	72 19½

In view of the indefinite character of the images upon which these angles and indices are based, all these faces are perhaps best to be regarded as vicinal. None of the forms listed have been recorded for chrysoberyl, although 11.3.0 (angle on 100 = 7° 19′) has been noted on crystals from New York City.[3]

The remaining new forms are all pyramids. Two of these, U(656) and V(323), occur, together with h(313) and x(101), as narrow faces replacing the edge between the two large unit pyramid faces. The remainder are present as narrow faces replacing the edges in which the faces of this pyramid meet the several forms of the prism zone, as noted in the table. Some of these narrow faces are rather dull, or are curved and yield a series of images, but as the table shows, there is in general a fair agreement between the measured angles and those calculated for the forms named.

The two large faces of the unit pyramid are pitted with etched figures, which are especially sharp and well developed on the smaller of these two faces. These figures are five sided in outline, and are symmetrically disposed on the pyramid faces. They are bounded by two principal edges in the zone $111:1\bar{1}1$, or $[10\bar{1}]$, and are terminated at the lower end by an edge in the zone $[1\bar{1}0]$ or $[\bar{1}10]$, and at the upper end by two edges in the zones containing the pyramids and the domes (011) and $(0\bar{1}1)$ respectively (see Figure 3).

The minute facets of these etched figures are in general flat and

[3]H. P. Whitlock, N.Y. State Mus. Bull., CLVIII, 1912, p. 185.

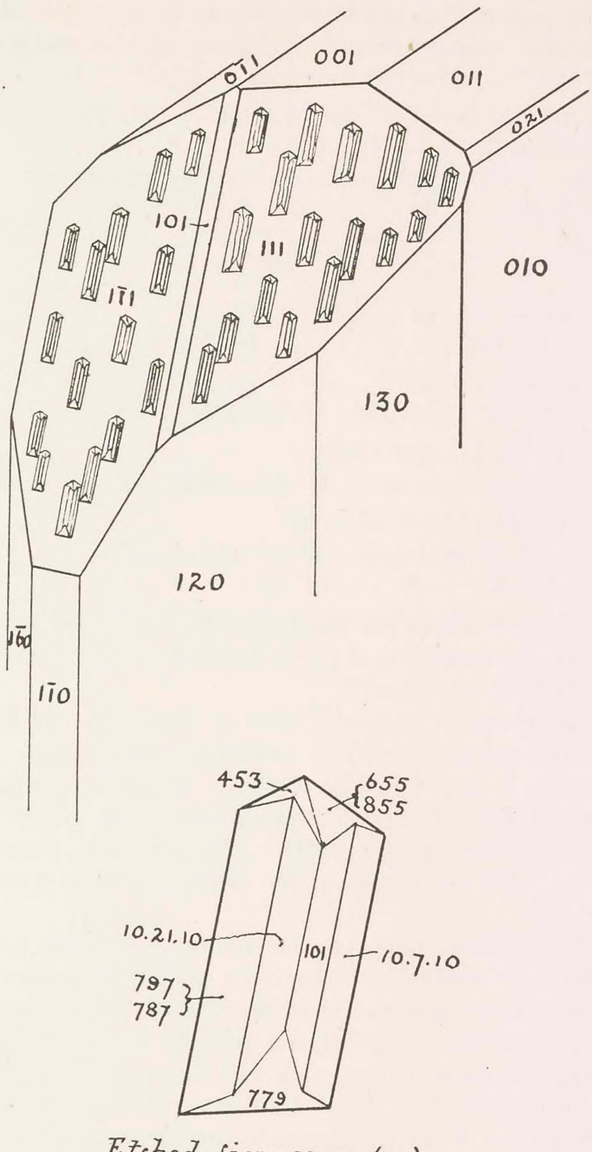


Fig. 3. Etched figures on Chrysoberyl from Mogok.

yield sharp and fairly bright reflections, but the images obtained from them on the goniometer are faint, as was to be expected owing to their small size. Measurements for those on the smaller pyramid face, taken as (111), gave the following results:

Zone $[\bar{1}01]$, giving, in order, the faces $[1\bar{1}1$, *101*, *10.7.10*, 111, *787*, *797*, *10.21.10*, 010].

111:*101*	20° 00′	measured	20°, 06′	calculated
:*10.7.10*	5 39	"	5 44	"
:*787*	2 36	"	2 36	"
:*797*	5 03	"	5 06	"
:*10.21.10*	17 40	"	17 27	"
(for 111:121,			16 06	"

Zone $[1\bar{1}0]$, or [111:*779*:001]

111:*779* 7° 07′ measured, 7° 04′ calculated

Zone $[\bar{2}11]$, or $[0\bar{1}1$:111:*453*:120]

111:*453* 9° 41′ measured, 9° 41′ calculated

Zone $[01\bar{1}]$, or [011:111:*655*:*855*:100]

111:*655*	5° 22′	measured,	5° 10′	calculated
:*855*	12° 50′	"	12° 47′	"

In the above, indices for the facets of the etched figures are in italics. With the exception of (*101*), forms having these indices have not been noted on chrysoberyl.

The twin crystal is shown in plan in Figure 4. It has a wine-yellow colour, and is beautifully clear and transparent. Regarded as a gemstone, it is practically flawless. It presents one-half of a very symmetrically developed trilling, the twin plane being the general one for chrysoberyl, (031). The principal dimensions are 2.1 x 1.0 cm., and the depth, in the direction of the *a* crystal axis, is 0.9 cm.

The twin junctions between the several individual parts of the pinacoid (100) are marked by sharp lines, or, rather, narrow V-shaped channels. On these faces also are some fine, discontinuous striations, or minute etched figures, elongated parallel to the *c* crystal axis, but they are not conspicuous, and they have been omitted in the drawing. Otherwise the crystal faces are remarkably perfect, and have a high lustre. Without exception, the edges are slightly rounded and dull, through abrasion, and this feature is especially pronounced around what may be referred to as the girdle of the crystal, where there remain only two partially roughened brachy-dome faces, these being adjacent to the re-entrant angle between two of the twinned individuals.

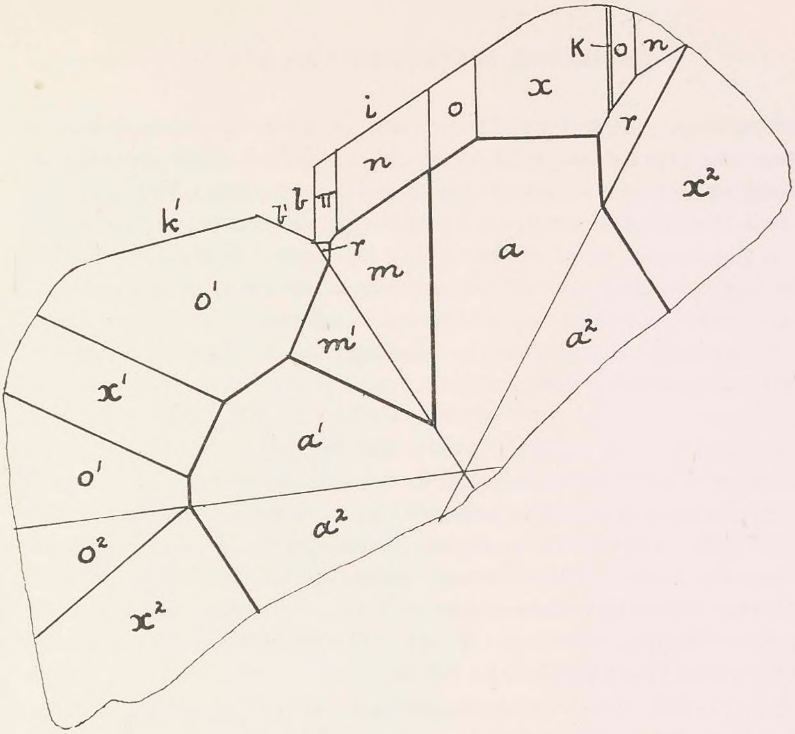


Fig. 4. Twinned Chrysoberyl from Mogok.

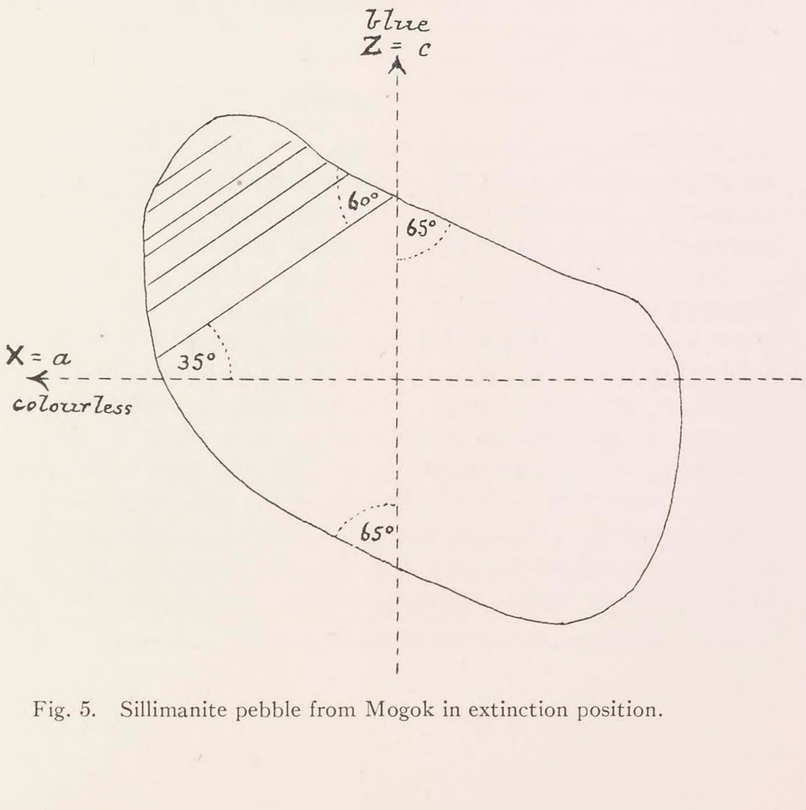


Fig. 5. Sillimanite pebble from Mogok in extinction position.

In breaking, either from its matrix or from a more complete specimen, the crystal has split along the imperfect (010) cleavage of one of the three individuals of which it is composed. The plane of cleavage has passed almost exactly through the central point or line in which the several parts of the trilling intersect. Although the face itself is fairly smooth and bright, its edges are worn by abrasion to about the same extent as are all the other edges on the crystal, from which it may be concluded that the specimen was broken to its present size before it became a rolling stone.

The forms exhibited are: a(100), b(010), r(130), m(110), i(011), k(021), x(101), π(131), n(121), o(111), and K(434).

The form K(434) has not hitherto been recorded for chrysoberyl. On the present crystal it is represented by a single narrow face truncating the edge (101):(111), as shown in the figure. It may be noted, also, that the form π(131) was not observed on the simple crystal from Burma described above, but it has been noted by Liffa[4] as occurring on chrysoberyl from Ceylon. The measured and calculated angles for these two forms are as follows:

o:K=111:434 . . .	4° 45′ measured,	4° 43′ calculated	
b:π=010:131 . . .	42° 21′ "	42° 19′ "	

The remaining forms are those commonly present on crystals of chrysoberyl. Their relative development on the Burma specimen is shown in the figure.

Sillimanite

Sillimanite, or fibrolite, occurs very rarely as rolled pebbles accompanying the ruby and associated minerals in the gem deposits at Mogok. Its occurrence here does not appear to have been hitherto described, or even recorded in geological literature.

The specimen examined is part of a flat pebble, with main dimensions 1.7 x 1.0 cm., and about 3 mm. thick. The two principal edges by which it is bounded are nearly parallel and fairly straight, suggesting that they have the directions of the original edges of a crystal of prismatic habit. The flattening is parallel to the side pinacoid b(010), which, in sillimanite, is a plane of very perfect cleavage; and it is along this plane that the pebble has been split, the part examined evidently having about half the thickness of the original pebble. The specimen must have been split into two parts after it was collected, since the cleavage plane has the lustre and brilliance of a highly polished surface. Otherwise, the surface is

[4]A. Liffa, Zeits. f. Kryst., XXXVI, 1902, p. 606.

rounded and water-worn, though still fairly smooth, and the lustre is pearly, especially on the nearly flat surface parallel to the cleavage.

The specimen is perfectly transparent, and, even when viewed in the ordinary way, it is seen to be very noticeably pleochroic, ranging from practically colourless to pale sapphire blue.

The specific gravity, as determined by the hydrostatic method, is 3.266, which is somewhat higher than the value (3.243 to 3.250) given by Melczer for sillimanite from Ceylon. The mineral scratches feldspar with ease, but will not scratch quartz, indicating a hardness nearer 7 than 6.

When the pebble, lying on the nearly flat natural surface or on the cleavage plane, is examined between crossed nicols under the microscope, it is found that it does not extinguish along its principal, and nearly straight and parallel, edges, as it would do if these represented the prismatic edges of an orthorhombic crystal. Instead, the extinction is inclined, at an angle of about 25 deg. (or 65 deg.).

On the cleavage surface, near one end of the pebble, there is a series of conspicuous cracks, perfectly straight and parallel to one another. Actually, the cleavage has not followed one continuous plane, but the surface descends at these cracks in extremely shallow steps to successively lower levels. The cracks thus have all the appearance of traces of a fair cleavage, possibly at right angles to the perfect (010) cleavage. They are inclined to the principal edges of the pebble at an angle of about 60 deg., and the extinction, measured with reference to them, is 35 deg. These relations are illustrated in the accompanying sketch (Figure 5).

In view of the fact that distinct terminal faces have never been observed on crystals of sillimanite, such a cleavage, presumed to be parallel to a macro-dome, would be of interest, since it would permit of a determination being made of the relative length of the vertical crystal axis, at present not known. Thus, assuming these cracks to be the trace of the plane (101) on the (010) cleavage face, the axial ratio $c:a=\tan 35°=0.70$, and $a:b:c=0.97:1:0.68$.

That this axial ratio does actually represent, at least approximately, the relative lengths of the crystal axes in sillimanite seems very probable, since it is in close correspondence with the axial ratios of the related minerals andalusite and cyanite, which are, respectively, 0.986:1:0.702 and 0.899:1:0.709.

The unsymmetrical elongation of the pebble recalls the fact that sillimanite was formerly regarded as monoclinic; and it is a matter of common observation that prisms of sillimanite, when examined under the microscope in thin sections of rocks containing the mineral, frequently have inclined extinction, and the stouter individuals, at least, commonly exhibit fairly straight transverse cracks, which as often as not cut obliquely across the direction of elongation.

As already stated, the crystal exhibits very strong pleochroism. Viewed normal to the cleavage plane, the observed colours in the two extinction positions are sapphire-blue and practically colourless, or with a faint yellowish tint. This feature has been used as a basis in orienting the pebble, it being assumed that it has the general optical character of sillimanite, with $X=a$, $Y=b$, $Z=c$, and absorption $Z>Y>X$. The pleochroism in this specimen is similar to that of the sillimanite from Ceylon.

A determination of the refractive indices by the total reflection method gave, for sodium light, $\alpha=1.6578$, $\beta=1.6590$, $\gamma=1.6776$. These are in close agreement with the values found by Zimanyi for sillimanite from Chester, near Saybrook, Conn., and by Lacroix and Melczer for the Ceylon material:

Burma	$\alpha=1.6578$	$\beta=1.6590$	$\gamma=1.6776$	Graham
Saybrook	1.6570	1.6583	1.6770	Zimanyi
Ceylon	1.658	1.659	1.678	Lacroix
"	1.6562	1.6577	1.6766	Melczer

Nepheline

One mile north of the 47½ mile post on the main road from Thabeikkyin to Mogok, and some 13 miles from the latter place, is the mining camp of Sinkwa, which was opened up in 1925. On the road going into Sinkwa, Adams found by the roadside, and closely associated with the highly crystalline limestone, a most interesting occurrence of nepheline-bearing rock of the variety known as urtite. In a note received, for which the authors are indebted to A. S. Wheeler, Esq., M.I.M.M., Chief Engineer of the Burma Ruby Mines Limited, this occurrence is referred to as follows: "The specimen came from a fresh exposure where we had blasted out for a roadway through some pinnacly limestone country. It was near one of the most variegated and interesting contacts we had in the locality. Mr. Morgan [the General Manager of the Burma Ruby Mines Limited] and I discussed that particular rock on several occasions because it was different from anything we had yet found. . . . It represented the nearest approach to a basic igneous rock we had obtained in the district and we regarded it as a dyke or intrusion. If I remember aright there were several distinct bands of it at intervals of a few hundred feet apart having a vertical attitude and up to two or three feet in width."

The specimen collected by Adams and referred to above is of a rather coarse-grained rock, dark in colour and showing an indistinct banding. It is composed essentially of greenish-yellow elaeolite and a black aegerine-augite. It also contains a considerable amount of primary calcite and resembles very closely certain varieties of the nepheline rocks which are found in association with the Grenville limestones of the Bancroft district in Ontario.[5] Under the microscope, it is seen to contain as accessory constituents a greyish-brown sphene in rather large grains enclosed in both the augite and the nepheline, as well as a little microcline, apatite, and black iron ore. The occurrence of the rock at this locality is of interest, not only as affording the first recorded occurrence of the mineral nepheline in Burma but also as affording another instance of the association of nepheline rock with bodies of limestone, so strikingly seen in the Ontario occurrences to which reference has just been made, as well as in a large proportion of the occurrences of similar nepheline rocks in other parts of the world.

Sodalite

A very interesting nepheline-bearing rock also occurs at the Tajonngnadine mine at Mogok. A specimen from this mine, given to Adams by Mr. Wheeler, was found on examination to be composed of nepheline and sodalite, with some associated colourless calcite. The nepheline is pale greenish, and similar to that in the urtite just described, but the sodalite is remarkable in having a beautiful purple or deep lilac colour, so different from ordinary sodalite that it was not at first recognized as that mineral. The rock has the coarsely crystalline appearance of a pegmatite, both the nepheline and sodalite forming irregular patches up to two inches or more in diameter. In the specimen examined, sodalite is in excess of nepheline. The contrast between the deep lilac and pale greenish colours of the constituent minerals gives the rock a very striking appearance.

The specimen is described as coming from a band in the crystalline limestone. The common association of nepheline-bearing rocks with bodies of limestone has already been commented on in the description of the Sinkwa urtite.

The sodalite is quite coarsely crystalline, some individuals, as seen by the continuity of the cleavage, having a diameter of nearly an inch. Two very minute partially terminated crystals were noted

---

[5]Adams and Barlow, Geology of the Haliburton and Bancroft areas, Province of Ontario, Geological Survey of Canada, Memoir 6, 1910.

on the specimen. They are simple dodecahedra with some of their edges modified by narrow faces, which, however, yielded such faint images that the forms to which they belong could not be determined. The specific gravity of these crystals is 2.295-2.30.

Cleavage pieces have sufficiently bright faces to be used for the determination of the refractive index by the total reflection (immersion) method. The value found, for sodium light, is 1.479.

The general blowpipe characters, and behaviour with acids, are the same as for ordinary sodalite. Qualitative tests for sulphur yielded negative results.

When warmed, even very slightly, the purple colour immediately disappears and the material becomes white. The colour fades somewhat on long exposure to light, but it has not yet been observed to become entirely bleached in this way. It also seems that material that has been exposed to light for some time regains its original tint after being kept in darkness.

Pink coloured sodalite has been described from several localities, but in every case so far recorded the colour either disappears instantly, or fades very rapidly, on exposure to bright daylight.

In the original sodalite from Kangdluarsuk, Greenland, first described by Thomson in 1810, Giesecké, who collected the material, had already observed (in 1806) that a freshly broken surface of the material had a peach-blossom-red colour, which immediately disappeared on exposure.[6] The same feature was observed by Thomas Allan, as is noted by Robert Allan in his *Manual of Mineralogy* (1834).

A somewhat similar sodalite was described in 1904 by Vredenburg[7] from Kishengahr state in Rajputana. The sodalite occurs there in a nepheline pegmatite, and it is in part blue and in part, under ordinary conditions, colourless and transparent. If the latter material is kept in the dark for some weeks, however, it assumes a pink colour, which again disappears on exposure to light, and almost instantaneously in direct sunshine. Holland[8] also has described a bright carmine-red sodalite from Rajputana that loses its colour on exposure to light, turning a dull grey, but regaining its pink colour in the dark.

More recently, Walker and Parsons[9] have drawn attention to the fact that a sodalite occurring near Bancroft, Ontario, displays similar properties. On a freshly broken surface, it has a fine pink colour which disappears in from ten to thirty seconds in direct sunshine.

---

[6]Note by Currie in Nature, 74, p. 564, 1906.

[7]Rec. Geol. Surv. India, 31, 43, 1904; Zs. Kr. 42, 390.

[8]Nature, 74, p. 550, 1906.

[9]Univ. of Toronto Studies, Geol. Series No. 20, 1925.

In this case, also, the colour gradually returns if the specimen is kept in the dark, but apparently never regains its original intensity.

The species described by Borgström[10] under the name hackmanite behaves similarly. Here again the bright reddish-violet colour of the freshly-broken material bleaches rapidly in daylight. Hackmanite is a member of the sodalite group, but differs from sodalite in containing 0.39 per cent of sulphur. As already stated, the Burma sodalite contains no sulphur.

Although there are many points of resemblance between the several occurrences of pink sodalite referred to and the Burma material, it seems evident that in the latter the colour is much more permanent than in any of the others.

Forsterite

Reference has already been made to the fact that the Archean crystalline limestone of Burma bears a very striking resemblance to the crystalline limestone of the Grenville series in Canada, and this similarity extends to the accessory minerals commonly present in certain bands of the rock.

In some specimens of a rather coarsely crystalline phase of the rock, collected by Adams in some abandoned workings in the village of Mogok, the accessory minerals include graphite, phlogophite, colourless diopside, sphene, apatite, and pink spinel, all distributed through the rock in small crystals or rounded grains. In addition, there are numerous minute colourless grains, usually ellipsoidal rather than spherical, of forsterite.

When crushed under oil and examined under the microscope, the majority of the fragments are found to be lying on the imperfect b(010) cleavage. These exhibit a negative interference figure, with the obtuse bisectrix emerging normally. They thus have the usual optically positive character of forsterite. From approximate measurements of the angle between the optic axes as they emerge from a (010) cleavage face of a fragment immersed in oil, the obtuse axial angle, $2V_{ob.}$, was calculated as 93° 40′.

Analysis of these colourless grains (Sp.G. = 3.22) gave the following result (column 1):

	Burma	Vandry, Que.
SiO_2	41.72	41.31
Al_2O_3	.....	trace
FeO	1.11	7.42
CaO	.....	....
MgO	57.83	51.48
	100.66	100.21

[10]Geol. För. Förh., 23, p. 563, 1901; Zs. Kr. 37, 284.

As further indicating the very close resemblance between this limestone and the Grenville limestone in Canada, it is of interest to note that Bancroft[11] found minute spherical grains of forsterite in an occurrence of Grenville limestone near Vandry station on the Canadian National railway in northern Quebec. The result of an analysis, by Professor N. N. Evans, of the Vandry forsterite (Sp.G. = 3.283) is given in column 2 above.

Minerals in the Great Pegmatite Dyke at Sakangei

As mentioned above, a great pegmatite dyke cuts the great granite intrusion on the Thabeikkyin-Mogok road near its eastern border about mile-post number 42 (see Figure 1). This dyke is at least 100 feet wide, although it may have a greater width since only one wall is seen, the wall-rock being granite, which is here much decomposed.

This granite intrusion and its accompanying tin-bearing pegmatite, probably mark a northerly extension of that great series of granite intrusions which occur in a long line following the coast of Lower Burma, Siam, and the Malay States to Singapore, Banka, and Billiton and which, in the southern portion of its course, has given rise to the most extensive bodies of tin ore hitherto discovered in the area.

The dyke consists essentially of orthoclase—which has been almost completely changed to kaolin—and quartz, the latter mineral occurring sometimes intergrown with the orthoclase forming a graphic granite, and sometimes in the form of large, colourless, transparent crystals. Crystals up to seven inches in diameter were found at the abandoned workings, but individual crystals as much as four feet long and a foot in diameter were obtained from the vein. These transparent quartz crystals found a ready market in China and were sought for by the Chinese traders. One fine crystal collected by Adams is of interest as exhibiting the steep pyramid f($40\bar{4}1$). The specimen is a hexagonal prism terminated at one end by the usual pyramidal faces, and measuring 2½ inches in diameter by 4 inches long. It exhibits one imperfect face of the right-handed trapezohedron x($51\bar{6}1$). Both the prism and the pyramid faces are marked with an irregular pattern of streaks and blotches, alternately bright and dull, showing that the crystal is an interpenetrant twin, about the vertical axis, of two right-handed individuals. All six faces of the steep pyramid f($40\bar{4}1$) are well developed, with a width of half an inch or more.

This dyke was opened up by the Burma Ruby Mines Limited some

[11]Annual Report, Mines Branch, Dept. of Mines, etc., Quebec, 1916, p. 148.

years ago, but work has now been discontinued and the workings are filling in under the action of the heavy tropical rains.

In addition to the two minerals which made up the greater part of the vein, a number of other minerals were found in much smaller amount. Chief among these were lepidolite, muscovite, biotite, topaz, and cassiterite.

Lepidolite

The lepidolite is of especial interest owing to the very large size of the individuals, and also owing to the fact that, so far as can be ascertained, this species has never before been mentioned as occurring in this vein; nor has the mineral ever been described before from any point in Burma.

The specimen collected is rudely circular in outline, with diameter about six inches, and a maximum thickness of half an inch. It has apparently broken, or been broken, from a thicker platy crystal, since both the upper and the lower surfaces display an interrupted cleavage, and both have a fresh appearance and bright vitreous lustre. Around one half of the margin of the specimen, however, and extending inward for about an inch, the material is bleached white and has a pearly lustre. This evidently represents the part that was exposed to weathering agencies while the crystal as a whole was yet attached to its matrix by the other, and still fresh, part. Any natural faces which may originally have bounded the crystal have been destroyed during this exposure.

Except where bleached, the colour is a uniform and fairly deep shade of lilac, which is to be seen especially well by transmitted light; for even in its thicker parts the specimen is, in places, comparatively clear and transparent.

Heated before the blowpipe, flakes of the material fuse easily, with intumescence, at the same time colouring the flame intensely crimson (lithium).

Examined in convergent light, cleavage flakes exhibit the usual negative interference figure of mica, with no marked dispersion. The optic axial angle in air, 2E, for sodium light, was measured as 60° 54′. This may be compared with the value recorded for lepidolite from Penig (59° 24′) and Wolkenburg (57° 10′), both in Saxony. However, the axial angle in lepidolite has a very wide range, doubtless due to variations in chemical composition. In this particular occurrence, the axial angle in air is smaller than that commonly assigned to the species (about 76°), but it is still far above the value (36° to 32°)

which Bauer found for a deep pink variety from Penig. The acute bisectrix is inclined at $1\frac{1}{2}°$ to the plate normal.

The percussion figure, made on a cleavage flake in the usual way, has one of its rays parallel to the line joining the optic axes. The axial plane thus coincides with the plane of symmetry, and the lepidolite is brachydiagonal (mica of the second class) and not macrodiagonal, as is more usual. In this respect the Burma lepidolite resembles that from Schüttenhofen in Bohemia. Bowman has described both brachydiagonal and macrodiagonal lepidolite from the well-known Haddam Neck, Conn., locality.

Moderately thin cleavage flakes appear nearly colourless and not perceptibly pleochroic, but when the transparent patches in the specimen, with a thickness of a quarter of an inch or more, are examined, either with the dichroscope or under the microscope, the material is found to have a fairly strong pleochroism, from faint pink to a rather deep lilac, with absorption $Z > Y$.

A plate mounted with the plane of the optic axes first horizontal, and then vertical, and immersed in Thoulet solution, gave refractive indices as follows, using sodium light:

	Axial plane horizontal	Axial plane vertical
Nicol at 0°	1.535	1.534
Nicol at 90°	1.558	1.561

From $\beta = 1.558$, $2E = 60°\ 54'$, and $\text{bx.} \wedge \text{normal to } c = 1\frac{1}{2}°$, the true optic axial angle, 2V, is calculated as $37°\ 57'$. A similar calculation from the measured angle $2H = 34°\ 10'$ in Thoulet solution gives $2V = 37°\ 51'$.

Muscovite

The muscovite is a pale green variety, and in the specimen examined has the form of platy crystals aggregated together into a more or less compact mass. Some of the smaller crystals are bounded by fair faces of the prism and other forms, where their edges project freely from the main mass. For the most part, however, the plates have no crystal outline. They are superposed with the basal planes not quite in parallel, in such a way that they form wedge or fan-shaped aggregates. As a result of the overlapping of the plates, the cleavage surfaces have a plumose waviness, and a pearly lustre. The optic axial angle in air, 2E, was measured as $74°\ 00'$, which is about the same as in some muscovite from Schüttenhofen ($2E = 73°\ 52'$).

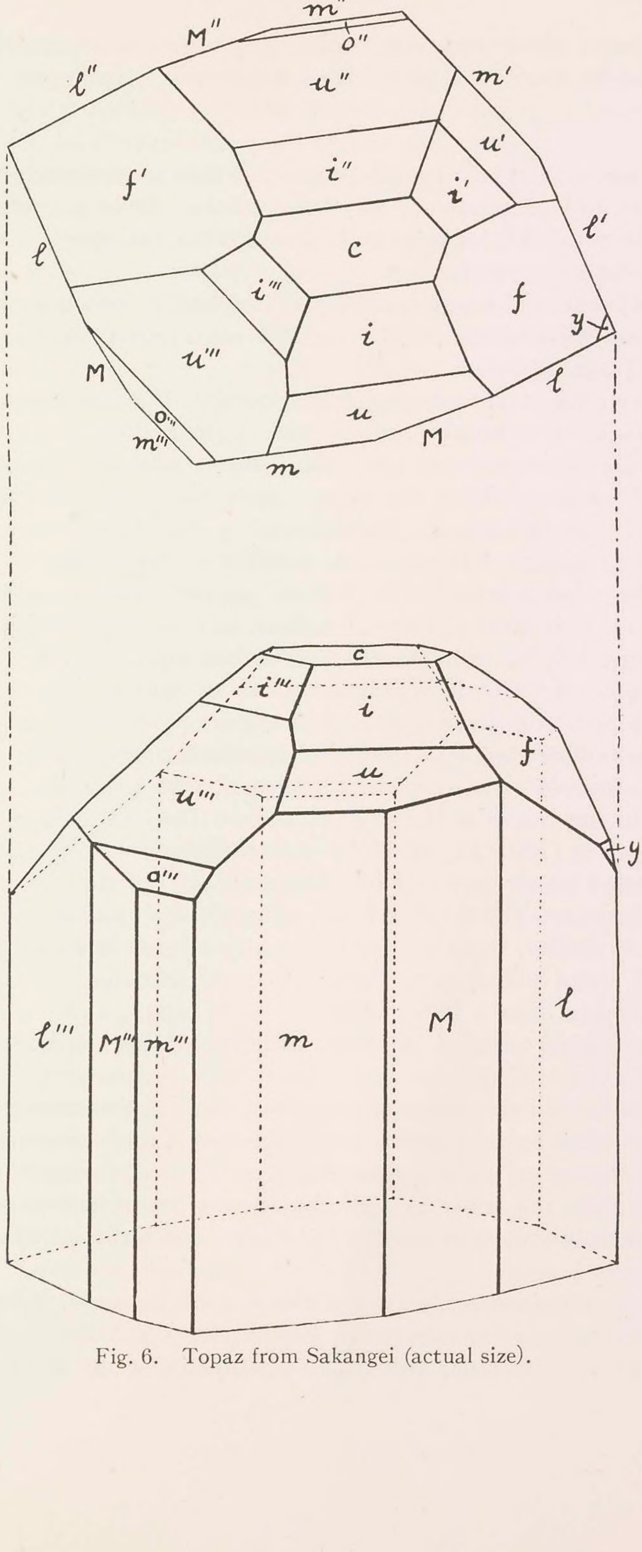


Fig. 6. Topaz from Sakangei (actual size).

This mica apparently contains no lithium. It is quite infusible before the blowpipe, and gives no pronounced flame colour.

Topaz

The topaz in the Sakangei pegmatite vein is remarkable for the large size and transparence of the crystals. It is a colourless or very pale yellowish variety and occurs often intimately associated with the quartz crystals.

A very fine and exceptionally large crystal is shown in Figure 6. The lateral dimensions are 6.5 and 8.5 centimeters, and the length is about 7.5 centimeters.

The crystal is colourless and transparent, but not entirely clear owing to several internal fractures, mainly parallel to the basal cleavage. These fractures are coated in places with a film of yellow hydroxide of iron. With the exception of the basal plane, which is pitted with etched figures, the faces all yield sharp reflections and have a high lustre. The crystal is completely terminated at one end and at the other is bounded by a plane parallel to the basal cleavage. This plane is in part a natural crystal face, since one half of it is smooth and bright, and covered with etched figures. The other half is rougher, and is clearly a broken surface produced when the crystal was detached from its matrix. The etched figures are very regular in outline and arrangement. They have the form of shallow negative rhombic pyramids, whose edges of intersection with the basal plane are parallel to the traces of the prism l(120). They thus have a nearly square outline ($120:\bar{1}20 = 86° 49'$), with their longer diagonal at right angles to the longer diagonal (the *b* crystal axis) of the crystal. The etched figures on the smaller basal plane at the opposite end of the crystal are similar, but they are not nearly so well-defined. On each face they range in size up to about 1 mm. in diameter.

The crystal has a habit common with topaz, and exhibits the following forms: c(001), m(110), M(230), l(120), f(021), y(041), i(223), u(111), o(221).

In addition to the forms enumerated, there are narrow faces of a number of other prisms, and as a consequence of their presence certain parts of the prism zone appear heavily striated vertically; but it was, of course, not possible with the contact goniometer to make the angular measurements necessary to identify the forms to which these narrow faces belong.

The most interesting feature of this crystal is the large basal face which terminates it at one end. Judging by the lustre and general appearance of this face, and especially the presence of the etched figures, there can apparently be no doubt that it is a natural crystal face and not merely a basal cleavage plane. If this interpretation is correct, the crystal has a very striking polar or hemimorphic development in the direction of the vertical axis, and topaz must be assigned, not to the normal, but to the calamine (hemimorphite) class of the orthorhombic system.

Doubly terminated crystals of topaz are rare, but some have been described that are apparently polar. In such cases, however, the polar character has consisted in a difference in the relative development of the faces of certain forms at opposite ends of the crystal rather than in the presence of a different combination of forms. In no recorded case has the polarity been so extreme as it appears to be in the present crystal.

From other considerations it has long been suspected that topaz crystals are polar. Generally, though not always, they are pyroelectric, and the absence of this feature in some crystals has been explained on the assumption that such crystals are possibly twinned about the basal plane. P. and A. Curie,[12] in the course of their work on the piezo-electric properties of crystals, examined topaz, among other minerals, and were of opinion that it exhibits the effect. They stated, however, that it would be advisable to repeat the experiment on a crystal which has an undoubted polar character. With this in view, Dr. D. A. Keys of the department of Physics, McGill University, kindly undertook to examine the Burma crystal. His experiments, using a quadrant electrometer, indicate that the crystal almost certainly has piezo-electric properties, but that the constants are much less than those of tourmaline or quartz. It is hoped that, with more refined apparatus, it will be possible to determine the constants for topaz shortly.

Cassiterite

Cassiterite occurs in the vein only in small amount, in little scattered segregations. The specimens examined consist of fine granular massive cassiterite grading into coarser material from which groups of well-formed and sometimes doubly terminated crystals project. Some of the very small crystals have a brown colour and are more or less transparent. These have a prismatic habit. Otherwise, the material is black, and in mass appears quite opaque.

The crystals of this black variety range up to one-third of an inch in diameter, and have the form of simple unit bi-pyramids, s(111). In some the edges of the unit pyramid are truncated by

[12]Compt. Rend., XCI, p. 383, Aug., 1880.

narrow imperfect faces of the second order pyramid e(101), but none were observed to exhibit faces of the prism. There is a tendency for each unit pyramid face to be replaced by a pair of vicinal faces, inclined at about 6°, belonging to a di-tetragonal pyramid. The crystals interfere with, and interpenetrate, each other at all angles, but there is a complete absence of the knee-shaped or stellate twins so common in cassiterite. Except where coated with a thin reddish film of earthy material, probably iron oxide, the faces of the crystals have a brilliant adamantine lustre.