

## PETALITE AND AMBLYGONITE FROM KARIBIB, SOUTH WEST AFRICA\*

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### ABSTRACT

A detailed description of the physical and chemical properties of petalite  $[\text{LiAl}(\text{Si}_2\text{O}_6)_2]$  and amblygonite  $[\text{LiAlPO}_4(\text{OH},\text{F})]$  from the Karibib district of South West Africa is given here for the first time. Both these minerals constitute potential lithium ores in this area.

### INTRODUCTION

Petalite and amblygonite are known in Southern Africa only from the lepidolite deposits in the Karibib district, South West Africa. The lithium minerals occur in pegmatite bodies which are genetically related to the Salem granite. In this area both the granite and the pegmatite invade the rocks of the Damara System which consists of metamorphosed sediments, now represented by quartzite, marble and biotite schist.

In 1940 C. M. Schweltnus and H. D. le Roex† reported on the lithium mineral deposits of the Karibib district. They found that lepidolite, sometimes containing up to 6%  $\text{Li}_2\text{O}$ , is the most common lithium mineral. Amblygonite and petalite with approximately 9%  $\text{Li}_2\text{O}$  and 4%  $\text{Li}_2\text{O}$  respectively, also constitute potential lithium ores.

In discussing the mode of occurrence of these minerals, they state that: "The lithium-bearing minerals all occur in quartz blows. . . . Amblygonite essentially occurs as completely isolated blebs within the quartzose part of the pegmatite bodies. The individual blebs vary in size from less than an inch to a few feet across and have been found in places to yield as much as five tons of massive amblygonite. Unfortunately the blebs are very erratic both in size and distribution . . . ."

"Petalite occurs in much lesser quantities than the lepidolite, but certainly in much greater abundance than the amblygonite. It is usually confined to the quartz and occurs mostly in close proximity to amblygonite. Huge massive blocks of this material (i.e. the petalite) can be seen in most of the deposits."

### PETALITE

A specimen of petalite from the farm Kaliombo 42, approximately 20 miles east of the village of Karibib, South West Africa, was made avail-

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† Departmental report.

able for study through the courtesy of Mr. H. D. le Roex, formerly of the Geological Survey.

The petalite is massive, gray-white in colour and mainly translucent. The cleavage (001) is well developed, while there is sometimes the tendency to split along (201) when struck with a hammer. On (001) the lustre is pearly, otherwise it is usually vitreous. The mineral crystallises in the monoclinic system.

The specific gravity, determined by suspension of pure fragments of petalite in a solution of bromoform and alcohol, is  $G_4^{14} = 2.422 \pm .005$ . The hardness on the (001) cleavage plane is  $\pm 6.5$ .

According to most textbooks on mineralogy, petalite emits a blue "phosphorescent" light when gently heated. Both finely powdered petalite and a single piece of about half a cubic inch were at first gently and later more strongly heated on a hot plate: in no case was any thermoluminescent effect observed. Exposing the unheated and heated petalite to sunlight and to radiation from a quartz mercury lamp failed to produce any phosphorescence. Petalite from Sweden also gave negative results under the same conditions.

A fine-grained isotropic white mineral, probably an alteration product, is sparsely distributed through the petalite. This mineral, which is both too fine grained and too sparingly present to permit identification by ordinary chemical or microscopic methods, is probably the cause of the observed translucence of the petalite. It may be of interest to mention here that Quensel (1) records montmorillonite as an alteration product of petalite from the Varuträsk pegmatite, Sweden.

In thin section cut parallel to (001), the massive petalite is seen to be composed of irregularly shaped individuals differing very slightly in optic orientation, so that extinction is not obtained simultaneously on all these components. From sections cut approximately parallel to (100) and (010) it could be established that these components, which are roughly lath-shaped, have their longest direction approximately parallel to the crystallographic axis  $c$ , and their shortest direction approximately parallel to  $b$ .

### *Optical Properties*

The refractive indices of the petalite (and that of the amblygonite described in this paper) were determined according to a single variation method. The mineral grains were brought to the desired orientation on a universal stage (2, p. 18) and the refractive indices matched at room temperature with those of mixtures of suitable immersion liquids of high dispersion, by adjusting the wavelength of the monochromator. The refractive indices of the petalite are given in Table 1.

TABLE 1

	<i>F</i> (486 m $\mu$ )	<i>D</i> (589 m $\mu$ )	<i>C</i> (656 m $\mu$ )
$\alpha$	1.512	1.507	1.505
$\beta$	1.517	1.512	1.510
$\gamma$	1.523	1.518	1.516
(all values correct to $\pm .001$ )			
Birefringence ( $\gamma - \alpha$ ) = .011			
Dispersion ( $\beta_F - \beta_C$ ) = .007			
$2V_\gamma$ (calculated) = $84^\circ$			
$2V_\gamma$ (observed) = $82^\circ \pm 1^\circ$			
Optic axial plane $\perp$ (010)			
Extinction $X/a = 2^\circ \pm 2^\circ$ .			

There is no noticeable dispersion of the optic axes in petalite. In thin section of standard thickness examined conoscopically and on the universal stage by monochromatic light of different wavelengths, no dispersion could be observed. The value of  $2V_\gamma$  is constant, within experimental error, for light from 480–650 m $\mu$ . The petalite shows marked conical refraction in thin section of standard thickness.

*Chemical Properties*

The spectrographic and chemical analyses of the petalite listed below were done on specially selected fragments which were examined microscopically and found to be free from impurities.

TABLE 2. CHEMICAL ANALYSIS

<i>a.</i>		<i>b.</i>	<i>c.</i>		<i>d.</i>		
SiO <sub>2</sub>	77.18	1.2850	Si	1.2850	15.90	Si	15.90 (16)
Al <sub>2</sub> O <sub>3</sub>	16.04	0.1573	Al	0.3146	3.89	Al	3.99 (4)
Fe <sub>2</sub> O <sub>3</sub>	0.64	0.0040	Fe	0.0080	0.10		
CaO	0.22	0.0039	Ca	0.0039	0.05	Li	4.20 (4)
MgO	0.26	0.0064	Mg	0.0064	0.08		
Na <sub>2</sub> O	1.14	0.0184	Na	0.0368	0.46		
Li <sub>2</sub> O	4.36	0.1459	Li	0.2918	3.61	H	0.58
H <sub>2</sub> O+	0.40	0.0233	H	0.0466	0.58		
H <sub>2</sub> O-	0.02		O	3.2518	40.42	O	40.24 (40)
Total	100.26						

- a.* Chemical analysis by C. J. Liebenberg.
- b.* Molecular proportions.
- c.* Atomic proportions.
- d.* Calculation of the unit cell formula from the relationship.

## QUALITATIVE SPECTROGRAPHIC ANALYSIS

*Present* Li, Al, Si, Mg, Na, Ca, Fe.*Trace* B, F, Ga, Mn, Cr.*Absent* K, Ge, Tl, Sr, Ba, Cs, Be, Ti, Rb.

ANALYST: B. Wasserstein.

Number of ions of each element in the unit cell =

$$\frac{\text{Unit cell volume} \times \text{Avogadro's Number} \times \text{Atomic Ratio} \times \text{Density}}{\text{Sum total of the chemical analysis}}$$

The unit cell volume ( $abc \sin \beta = 844.8 \text{ cu. } \text{\AA}$ ) was obtained from the unit cell dimensions of petalite from Elba, given by Gossner and Mussnug (3, p. 64) viz:

<i>a</i>	11.77 $\text{\AA}$
<i>b</i>	5.13 $\text{\AA}$
<i>c</i>	15.17 $\text{\AA}$
<i>B</i>	112°44'

Assuming that these dimensions are reported in Siegbahn units, a value of  $(6.0597 \pm 0.0016) \times 10^{23}$  is used for Avogadro's number (4, p. 110). The density of the petalite is 2.422.

The unit cell formula of petalite may therefore be expressed as  $\text{Li}_4\text{Al}_4\text{Si}_{16}\text{O}_{40}$ , that is, the unit cell contains four molecules with the composition  $\text{LiAl}(\text{Si}_2\text{O}_5)_2$ , which agrees with the results first obtained by Gossner and Mussnug. As can be seen from Table 2, column *d*, the amount of water present in the unit cells is too low to be considered in the formula. The ratio of Li to Na is 7.93:1.

In conclusion it may therefore be stated that the petalite from Karibib, South West Africa, does not differ markedly in physical and chemical properties from petalite reported from other parts of the world.

## AMBLYGONITE

The massive amblygonite (Geological Survey Museum No. 6614) has a well developed cleavage, and is white with a bluish tinge in patches where the mineral is perfectly fresh. The lustre is vitreous to greasy. Polysynthetic twinning, frequently reported in amblygonite, is sporadically developed in the numerous thin sections examined. Amblygonite crystallises in the triclinic system.

The specific gravity of the amblygonite was determined on carefully selected fragments by suspension and gave  $G_4^{14} = 3.085 \pm .005$ . The hardness is  $\pm 5.5$ . Finely powdered amblygonite does not readily dissolve on boiling in either concentrated or 1:1 HCl,  $\text{H}_2\text{SO}_4$  or  $\text{HNO}_3$ . A sufficient amount of the mineral does, however, go into solution with boiling concentrated  $\text{HNO}_3$  to give the phosphate test with ammonium molybdate.

*Optical Properties*

In thin section it could be established that two cleavage directions (100) and (011)\* are represented, with the former direction more prominently developed. By means of these cleavages the optic orientation of the amblygonite could be established on the universal stage. This orientation (7, p. 42) is given in Table 3, together with the position of

TABLE 3

	$\phi$	$\rho$
X	19°	69°
Y	-78°	72°
Z	156°	28°
100	110°	90°
011	162°	24°
100 $\wedge$ 011	75°	

the two cleavages already mentioned. The positions of X, Y and Z are stated correct to 2°.

Further optical data are given in Table 4.

TABLE 4

	F (486 m $\mu$ )	D (589 m $\mu$ )	C (656 m $\mu$ )
$\alpha$	1.599	1.594	1.592
$\beta$	1.613	1.608	1.606
$\gamma$	1.621	1.616	1.614
(all values correct to $\pm .001$ )			

Birefringence ( $\gamma - \alpha$ ) = .022

Dispersion ( $\beta_F - \beta_C$ ) = .007

2V $\alpha$  (calculated) = 74°

2V $\alpha$  (measured) = 75°  $\pm$  2°

No dispersion of the optic axes could be observed.

*Chemical Properties*

The spectrographic and chemical analyses of the amblygonite were done on material free from impurities.

\* Richmond and Wolfe (5, p. 41) recently proposed a new crystallographic orientation, based on x-ray studies, for amblygonite. Transformation formula: Dana to Richmond and Wolfe 001/011/100. This new orientation is used in this paper.

## QUALITATIVE SPECTROGRAPHIC ANALYSIS

*Present* Li, Al, P, Na.*Trace* Ga, Ca, Mg, Fe, Mn, K.*Absent* Ba, Rb, Cs, Tl, Ti, B, Be, V, Ni,  
Co, Sr, Si, Rare earths.ANALYST: *B. Wasserstein*

TABLE 5. CHEMICAL ANALYSIS

<i>a.</i>		<i>b.</i>	<i>c.</i>		<i>d.</i>	
Al <sub>2</sub> O <sub>3</sub>	35.19	0.3452	Al	0.6904	2.06 Al	2.06 (2)
P <sub>2</sub> O <sub>5</sub>	47.54	0.3347	P	0.6694	2.00 P	2.00 (2)
Li <sub>2</sub> O	9.65	0.3230	Li	0.6460	1.93	
Na <sub>2</sub> O	0.43	0.0069	Na	0.0138	0.04	
K <sub>2</sub> O	0.10	0.0011	K	0.0022	0.01	Li 2.00 (2)
MgO	0.33	0.0082	Mg	0.0082	0.02	
F	5.40	0.2842	F	0.2842	0.85	
H <sub>2</sub> O+	3.26		H	0.3664	1.09	OH+F 1.94 (2)
H <sub>2</sub> O-	0.04	0.1832				
			O-F	2.9473	8.80 O*	7.71 (8)
	101.94					
Less O for F	2.27					*After an equivalent amount of O has been subtracted for F.
	99.67					

*a.* Chemical analysis by C. J. Liebenberg. (Fluorine determination by P. J. Hamersma).

*b.* Molecular proportions.

*c.* Atomic proportions.

*d.* Calculation of the unit cell formula, using a unit cell volume of 159.11 cu. Å (5, p. 47) and a specific gravity of 3.085 as determined on the Karibib amblygonite. The calculation is made on the same basis as that of the petalite formula.

The unit cell formula of the amblygonite is therefore 2[LiAlPO<sub>4</sub>(OH,F)] which is the same as that obtained by Richmond and Gonyer (5, p. 47) on amblygonite from Hebron, Maine. The ratio of OH to F is approximately 1.30:1.

The composition of the amblygonite may also be expressed in terms of the end members of the series, namely, 44% amblygonite (LiAlPO<sub>4</sub>F) and 56% montebasite (LiAlPO<sub>4</sub>OH). There is a reasonably good agreement between the refractive indices of the Karibib amblygonite and the values given by Winchell (6, p. 248) in his diagram for the amblygonite-montebasite series, for amblygonite of the composition stated above. Winchell does not claim his diagram to be highly accurate, and since its publication in 1926 there is still the need for chemical analyses,

coupled with physical data, of members of the amblygonite-montebbrasite series.

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