# PEGMATITE MINERALS OF POLAND, MAINE

HARRY BERMAN AND F. A. GONYER, Harvard University

In 1911, Professor Palache visited the Berry quarry at Poland, Maine, already long abandoned. He found there a small group of specimens which had been taken from this quarry, but concerning the relative occurrence of which nothing could be learned. In them were noted a number of rare phosphates first found at Branchville, Conn., and up to that time not found elsewhere. These phosphates have, however, now been found at Newry, Maine, and Buckfield, Maine, but since they are still rare a description of them seems worth while. One of them, eosphorite, has been completely described[1] by Dr. Drugman who had separated the other minerals of the group for analysis and had begun their study but never completed it on account of the outbreak of the war. The specimens were subsequently returned to Harvard where the study was resumed by the authors.

The chief information concerning this locality is contained in Bastin's well-known account of the Maine pegmatites[2] from which we here abstract a short description of the quarry.

The Berry quarry is located in the town of Poland, across the Little Androscoggin River from Mt. Apatite. It was at no time worked extensively, the quarry consisting mainly of a few scattered openings in the pegmatite ledge. The main mass of the pegmatite is essentially like that of Mt. Apatite, across the river, *i.e.*, a graphic intergrowth of quartz and microcline with some orthoclase. Other minerals of the solid pegmatite reported by Bastin are: muscovite, biotite, albite, beryl and amblygonite. Pocket minerals reported by Bastin are: lepidolite, vari-colored gem tourmaline, herderite and lavender colored apatite. In addition to Bastin's list must be mentioned alkali-beryl, the so-called pocket beryl, which is said to contain caesium. A handsome crystal of this type of beryl from this quarry is in the Harvard collection.

The Berry quarry has also been mentioned by Landes in his paper on the pegmatites of the region.[3]

---

[1] Drugman, J. On childrenite from Crinnis Mine, Cornwall, and Eosphorite from Poland, Maine, *Min. Mag.*, **17**, 81, 1915, pp. 193–201.

[2] Bastin, E. S. Geology of the Pegmatites and Associated Rocks of Maine, *Bull.* **445**, *U. S. G. S.*, 1911.

[3] Landes, K. K. The Paragenesis of the Granite Pegmatites of Central Maine, *Am. Mineral.*, **10**, 1925, pp. 355.

The minerals here described are of a later stage in the mineralization of the pegmatite than those of Bastin's list and are especially interesting in that they represent an uncommon period in the paragenesis of lithia pegmatites. Landes has referred to this phase at Buckfield as the intermediate hydrothermal stage.

## General Description of the Specimens

The half dozen specimens studied consisted of buff colored microcline much stained by manganese oxide, in which are small pockets of the later minerals. These pockets, about 3 or 4 inches in largest dimension are rimmed by a narrow band of amblygonite, approximately a half inch wide, next to the feldspar. Within this band is a somewhat wider irregular layer of rhodochrosite with numerous small cavities into which project small etched crystals of the same mineral. Cutting the rhodochrosite are small veinlets made up of small doubly terminated quartz crystals. These veinlets form a network in the inner portions of the pockets, from which the rhodochrosite has been partially removed by the solutions which later deposited the phosphate minerals. Manganese oxide, a late product of alteration, stains or coats almost all the cavity minerals as well as the adjacent microcline.

## Paragenesis of the Phosphate Minerals

The sequence of events leading to the deposition of the cavity minerals seems to be somewhat as follows. The feldspar was replaced first by amblygonite, which may have filled the entire pocket. Then manganese rich solutions replaced the greater part of the amblygonite with rhodochrosite which in turn was cut by veinlets of quartz. Later manganese solutions attacked the rhodochrosite leaving central cavities in the pockets into which were introduced the manganese phosphates, eosphorite, reddingite, dickinsonite and fairfieldite, followed by apatite. Last of all supergene alteration changed the reddingite to landesite; and a general manganese staining was the final step.

It is probable that the lithiophilite, of which there was a single large cleavage block was formed at about the same time as the amblygonite, and had filled a pocket in the microcline.

The following list gives the probable sequence of the minerals occurring in the pockets:

> Amblygonite
> Lithiophilite
> Rhodochrosite
> Quartz
> Eosphorite
> Reddingite
> Dickinsonite
> Fairfieldite
> Apatite
> Landesite
> Yellowish brown globules
> Manganese oxide

## DESCRIPTION OF THE MINERALS
### AMBLYGONITE

The amblygonite forms a tough compact rim around the pockets and grades into the feldspar which it undoubtedly replaces since remnants of the feldspar are found remaining in the amblygonite. There is a peculiar green stain in some portions of the amblygonite for which an explanation has not been found. The amblygonite was identified optically.

### LITHIOPHILITE

The single specimen of lithiophilite studied was a cleavage block, associated with reddingite, which replaced it along cleavage cracks and in cross-cutting veinlets. In this replacement the lithiophilite has evidently exercised an orientating force on the reddingite since the latter comes to extinction simultaneously over a large section of the field under the microscope. The reddingite makes up perhaps ten per cent of the total mass of the lithiophilite specimen.

The following analysis of lithiophilite, by Gonyer, was made on about a gram of pure material, light brown in color. The deepness of the color seemingly is a good criterion for judging the amount of the triphylite admixture in the isomorphous series.

ANALYSIS OF LITHIOPHILITE

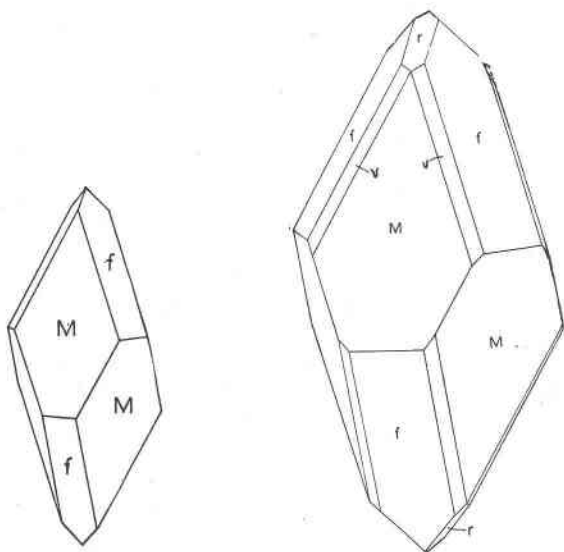| | PER CENT | MOLECULAR RATIOS | |
|---|---|---|---|
| FeO | 10.96 | .1525 ⎱ | .6022 = 2 x 3011 |
| MnO | 31.90 | .4497 ⎰ | |
| $Na_2O$ | 0.30 | .0048 ⎱ | .3243 = 1 x 3243 |
| $Li_2O$ | 9.55 | .3195 ⎰ | |
| $H_2O+$ | 0.40 | .0222 | |
| $P_2O_5$ | 46.35 | .3262 | .3262 = 1 x 3262 |
| Insol. | 0.16 | | |
| | 99.62 | Sp. gr. = 3.481 | |

The ratio of $Mn:Fe=3:1$ in this lithiophilite is much like that of the Branchville material. The formula deduced from the analysis is $2(Mn, Fe)O.Li_2O.P_2O_5$.

The optical properties were determined on material from the analyzed sample and are as follows:

Bx$(+)$, $2V=60° \pm$.  $\rho > v$ fairly strong

$\alpha$ and $\gamma$ parallel to cleavages.
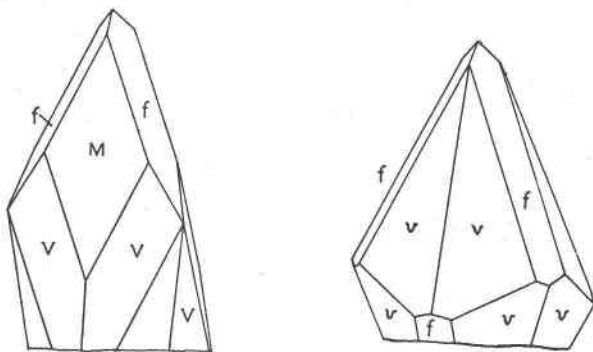
$\alpha = 1.675, \beta = 1.679, \gamma = 1.688$.



Figs. 1 and 2. Rhodochrosite, Poland, Maine.

### Rhodochrosite

The main mass of the rhodochrosite is a compact aggregate of rather small grains with an occasional cleavage piece a centimeter across imbedded in the small grains. Small crystals protrude into the cavities in the granular rhodochrosite. The crystals are etched, sometimes to the extent of obliterating the crystal outlines. The unit rhombohedron ($r$) is not etched whereas the rhombohedron ($f$) and the steeper form ($M$) always are. The scalenohedron ($v$) rarely present, is also unattacked. The various habits of the rhodochrosite crystals are illustrated in figures 1 to 4. Figure 1 is the dominant habit. The forms found on rhodochrosite from this locality are: $r(10\bar{1}1)$, $M(40\bar{4}1)$, $f(02\bar{2}1)$, $v(21\bar{3}1)$, $V(62\bar{8}1)$.

The optical properties of the rhodochrosite indicate that it is almost pure $MnCO_3$.



FIGS. 3 and 4. Rhodochrosite, Poland, Maine.

## QUARTZ

The quartz occurs as minute transparent doubly terminated crystals strung together to form tiny veinlets in the rhodochrosite. The two rhombohedrons are.equally well developed, with no prism present.

## EOSPHORITE

Eosphorite from this locality has been adequately described by Drugman[4] who has discussed the composition, crystallography and optical properties. It is the only phosphate of the cavities which occurs as well formed unetched crystals. The crystals are, for the most part, embedded in the rhodochrosite but occasional prismatic crystals, well terminated, protrude into the cavities in the rhodochrosite. The general relations indicate that eosphorite is one of the earliest phosphates to form in the pockets.

## REDDINGITE

This rare phosphate is found in two different associations at this locality. It replaces rhodochrosite as granular crystalline masses, and, as stated above it replaces lithiophilite. The mineral varies from almost colorless to a deep brownish red, the depth of color seemingly dependent on the degree of alteration of the material. In some cases the reddingite has been completely altered to a

[4] *Loc. cit.*

mineral which is probably closely related to sicklerite which is here called landesite.

The material used for analysis was fairly light in color but not entirely free from altered grains.

ANALYSIS OF REDDINGITE

|  | PER CENT | MOLECULAR RATIOS | |
|---|---|---|---|
| $Fe_2O_3$ | 0.95 | .0059 | |
| FeO | 12.68 | .1763 | |
| MnO | 38.36 | .5410 | .7173 = 3 x .2391 |
| CaO | 0.15 | .0027 | |
| $Na_2O$ | trace | | |
| $K_2O$ | trace | | |
| $H_2O+$ | 13.16 | .7304 | .7304 = 3 x .2435 |
| $P_2O_5$ | 34.52 | .2429 | .2429 = 1 x .2429 |
| Insol. | 0.45 | | |
|  | 100.27 | Sp. gr. = 3.136 | |

The material analyzed yields the formula, $3(Mn, Fe)O.P_2O_5.3H_2O$ with the ratio of $Mn:Fe = 3:1$, which is similar to the composition of the Branchville reddingite.

The optical properties are as follows:

$$Bx(+).\quad 2V = 65°±.\quad \rho > v \text{ perceptible.}$$
$$\alpha = 1.655,\quad \beta = 1.662,\quad \gamma = 1.683.$$

There were no crystals found suitable for crystallographic measurements. The grains were usually bounded by contact faces with only an occasional crystal boundary.

## DICKINSONITE

Dickinsonite is the rarest of the phosphates occurring here. It has been reported from one other locality, Branchville, Conn. The material is rather variable in color ranging from a dark brownish green to a yellowish green, suggesting common epidote at first sight. The crystals are small, tabular, and highly etched. Fairfieldite is nearly always associated with the dickinsonite and definitely later than the latter mineral. In some places there is a strong indication that the dickinsonite has been altered to fairfieldite probably by a leaching out of the alkalies and addition of lime. This alteration probably explains the rarity of dickinsonite. In this connection it is interesting to note that "a yellowish to olive green alteration product" is present in some of the fairfieldite at

Buckfield,[5] according to Landes. This "alteration product" is probably residual fragments of dickinsonite.

The following analysis was made by Gonyer on half a gram of fairly pure material.

ANALYSIS OF DICKINSONITE

| | PER CENT | MOLECULAR RATIOS | |
|---|---|---|---|
| FeO | 12.33 | .1716 ⎫ | |
| MnO | 31.83 | .4488 ⎬ | 7 x .0945 |
| MgO | 1.67 | .0414 ⎭ | |
| CaO | 2.01 | .0353 | ½ x .0706 |
| Na₂O | 7.41 | .1195 ⎫ | |
| K₂O | 1.73 | .0184 ⎬ | ¾ x .0962 |
| Li₂O | 0.20 | .0067 ⎭ | |
| H₂O | 1.82 | .1010 | 1 x .1010 |
| P₂O₅ | 40.78 | .2870 | 3 x .0957 |
| Insol. | 1.00 | | |
| | 100.78 | Sp. gr. = 3.266 | |

The analysis of dickinsonite yields a formula similar to that of the Branchville type material. The formula is as follows: $7(Mn, Fe)O.2(Na_2, K_2, Ca)O.3P_2O_5.H_2O$; with CaO in relatively small amount as compared with the type material, and a correspondingly greater amount of the alkalies.

The optical properties are as follows: Bx(+), 2V near 90°. $\rho > v$ easily perceptible.

$$\alpha = 1.648 \pm .003,$$
$$\beta = 1.655 \pm .003,$$
$$\gamma = 1.662 \pm .003.$$

The indices of refraction vary somewhat in the various grains increasing with the depth of color of the mineral.

### FAIRFIELDITE

Fairfieldite occurs as white foliated plates in rhodochrosite, and, in one specimen, as a pseudomorph after rhodochrosite. As stated above it also is found as a soft platy material on dickinsonite, probably as an alteration of the latter.

The following analysis was made on the freshest portions of the fairfieldite, by Gonyer:

[5] Landes, K. K. *Loc. cit.*

ANALYSIS OF FAIRFIELDITE

| | PER CENT | MOLECULAR RATIOS | |
|---|---|---|---|
| FeO | 4.75 | .0661 } | 1 x .2750 |
| MnO | 14.82 | .2098 } | |
| CaO | 30.85 | .5502 | 2 x .2751 |
| Na$_2$O | 0.41 | .0066 | |
| K$_2$O | none | | |
| H$_2$O | 9.70 | .5384 | 2 x .2692 |
| P$_2$O$_5$ | 39.55 | .2784 | 1 x .2784 |
| Insol. | 0.50 | | |
| | 100.58 | Sp. gr. = 3.016 | |

The analysis gives the usual formula for fairfieldite, that is $(Mn,Fe)O.2CaO.P_2O_5.2H_2O$.

The fairfieldite from this locality has a ratio of $Mn:Fe = 3:1$ which seems to be the same for all the manganese-iron phosphates of the locality. The optical properties of Fairfieldite are difficult to determine by ordinary microscopic methods since the mineral is triclinic. By the use of the Fedorow stage, however, it becomes a comparatively simple operation to correctly determine the position of the optic planes with respect to the prominent cleavages. Figure 5 is a stereographic projection of the cleavages and the poles of the three major optic planes as found by the use of the Fedorow stage. The positions of the poles can then easily be expressed in terms of the coordinates using the well-known $\phi$ and $\rho$ angles. The angle table for the optic elements of fairfieldite is here given using the method outlined below

| | | $\phi$ | $\rho$ |
|---|---|---|---|
| $b$ (010) best cleavage | | 0 | 90°00' |
| $a$ (100) inferior cleavage | | 78° | " |
| | X | −44° | 56° |
| | Y | +156° | 36° |
| | Z | +56° | 79° |

Figure 6 is a projection of the optical elements on the side pinacoid which is the cleavage upon which most grains lie under the microscope.

$$Bx(+). \quad 2V = 86° \pm 1°,$$
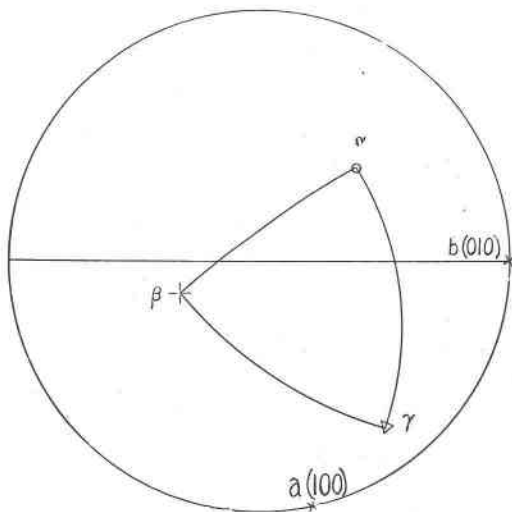$$\alpha = 1.640; \ \beta = 1.650; \ \gamma = 1.660. \ \text{All} \ \pm .002$$

FIG. 5.



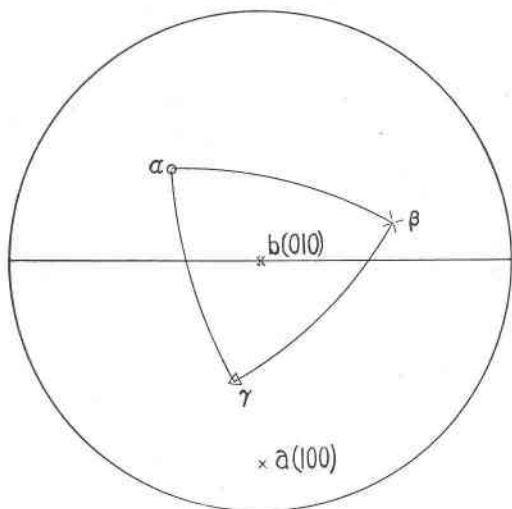FIG. 6.

FIG. 5. Stereographic projection of the axes of the optical indicatrix. Projection on plane normal to $c$-axis. $\odot = \alpha$; $\dashv\vdash = \beta$; $\triangle = \gamma$; $\times$ = pole of cleavage.

Fig. 6. Projection on best cleavage, $b(010)$.

## APATITE

Apatite occurs as one of the latest of the phosphate minerals, resting on the rhodochrosite and occasionally on the other phosphates as small "nailhead" crystals, (Fig. 7.) slightly etched. Some
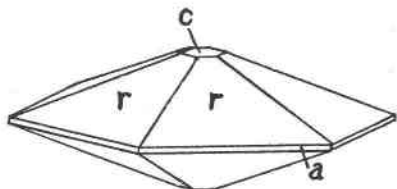


FIG. 7. Apatite, Poland, Maine.

specimens show apatite crystals of the normal habit, elongated parallel to the $c$ axis. On these crystals the prism zone remains unattacked by the etching solutions while the pyramids are deeply etched.

## LANDESITE A NEW MINERAL

The reddingite as stated above, has been altered to a brown mineral related to salmonsite. The crystals are rough, octahedral development suggesting in form the unit pyramid of reddingite. No adequate crystallographic data could be obtained on the rough crystals so that a close angular agreement between the supposed pseudomorph and reddingite could not be obtained. The crystals possess a good cleavage in the position of $b(010)$ of reddingite and an inferior cleavage at right angles to the first. It is uncertain whether the first cleavage coincides with the cleavage position in reddingite.

### ANALYSIS OF LANDESITE

| PER CENT | | MOL. RATIOS | |
|---|---|---|---|
| $Fe_2O_3$ | 13.91* | | |
| $Mn_2O_3$ | 2.69 | .0869 | $= 3 \times .0290$ |
| MnO | 33.65 | | |
| MgO | 3.07 | .5763 | $= 20 \times .0288$ |
| CaO | 1.39 | | |
| $H_2O$ | 13.60 | .7556 | $= 27 \times .0280$ |
| $P_2O_5$ | 31.94 | .2248 | $= 8 \times .0281$ |
| Insol. | 0.13 | | |
| | 100.38 | | Sp. gr. $= 3.026$ |

* $Fe_2O_3 + FeO$, (FeO not determined).

Material for analysis was carefully picked but it was found impractical to get it entirely free of impurities since there was not much available. The above analysis was made by Gonyer on a gram sample.

This analysis yields the formula $3Fe_2O_3 \cdot 20MnO \cdot 8P_2O_5 \cdot 27H_2O$, which comes closest to salmonsite, described by Schaller, from Pala, as an oxidation and hydration product of hureaulite. The optical properties, however, indicate that the mineral is very different. It was at first supposed that this alteration of reddingite was closely related to sicklerite, another alteration product, from Pala, since the optical properties of the two are quite similar. The chemical analyses of the two are, however, different. This mineral seems to represent a new species for which the name landesite is here proposed in honor of Professor Kenneth K. Landes who has done much work on the pegmatites of Maine.

The optical properties of the analyzed material are as follows:
Bx $(-)$. 2 V large. $\dot{Z} \perp$ to best cleavage and $X \perp$ to an inferior cleavage. Pleochroism, $X =$ dark brown, $Y =$ light brown, $Z =$ yellow. $\alpha = 1.720$, $\beta = 1.728$, $\gamma = 1.735$. It is interesting to note, in connection with this occurrence that Landes[6] has also reported an oxidation product which he believes related to sicklerite.

## CASSITERITE

This mineral has been found in the study series on only one specimen. There are residual fragments of rhodochrosite within it but some veinlets of the carbonate seem to cut it also so that the two are probably nearly contemporaneous. The material was identified optically from the following data:

Uniaxial $(+)$, $\omega = 2.01 =$ light green; $\epsilon =$ brown.
The strong pleochroism of the cassiterite is worthy of note since that property is rarely mentioned in the literature for this mineral.

## BERYL

A single large, bluish white crystal of beryl from this locality is in the Harvard Collections. Although it is not a part of the phosphate suite of minerals, with which this paper is mainly concerned, it merits description because of the excellent etch figure developed on the base. The crystal has been eaten away in greater part by the

[6] Landes, K. K. *Loc. cit.*

etch solutions, the base, however, is still present and deeply pitted by negative solution crystals. These etch faces forming the negative crystals are of the simple forms $p(10\bar{1}1)$ and $s(11\bar{2}1)$, and give excellent reflections. This is somewhat unusual since etch forms usually have a complex relationship to the crystal axes. The forms developed on the prism and pyramid $s$ are too curved to measure, their general character only being indicated in fig. (8).
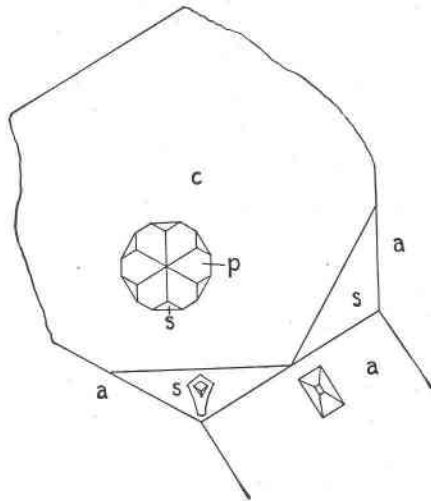


FIG. 8. Etched Beryl, Poland, Maine.

The index of refraction ($\omega = 1.585$) indicates that this beryl is rather high in alkalies and probably contains caesium. Landes places this type of beryl in the second phase, the hydrothermal phase, of his classification so that it is probably earlier than the above mentioned phosphates.

CONCLUSION

From the foregoing description of the minerals and their probable sequence, it is seen that the solutions leading to their formation were essentially of manganese phosphate with carbonate and water, lithia-rich in their earlier phase and calcium rich toward the end of the deposition. These same conditions were presumably present at Buckfield, Maine, Newry, Maine, and Branchville, Conn., since the same minerals were formed in essentially the same general

sequence. This remarkable similarity of four localities at which lithia-pegmatites have been studied seems to require a closed system, with no ingress of new material into the pegmatite solutions.