THE MORPHOLOGY OF PHENACITE FROM TWO NEW OCCURRENCES

FREDERICK H. POUGH, *Harvard University, Cambridge, Mass.*

In the course of an extended morphological study of phenacite, it was found that two new and as yet incompletely described localities had been discovered in the past few years. This paper is a

TABLE I

REVISED ANGLE-TABLE FOR PHENACITE

No.	Letter	G_2 Symbol	Bravais	ϕ	ρ
1.	**c*	0	0001	00°00′	00°00′
2.	*a*	$\infty 0$	$11\bar{2}0$	00 00	90 00
3.	*k*	2∞	$5\bar{1}\bar{4}0$	40 54	90 00
4.	*m*	∞	$10\bar{1}0$	30 00	90 00
5.	*K*	$\frac{1}{2}\infty$	$41\bar{5}0$	19 06	90 00
6.	*P*	10	$2\bar{1}\bar{1}3$	60 00	23 47
7.	*p*	01	$11\bar{2}3$	00 00	23 47
8.	**H*	$\frac{3}{2}0$	$2\bar{1}\bar{1}2$	60 00	33 28
9.	0	20	$4\bar{2}\bar{2}3$	60 00	41 23
10.	*o*	02	$22\bar{4}3$	00 00	41 23
11.	*d*	$\frac{1}{2}$	$10\bar{1}2$	30 00	20 53
12.	*d*·	$-\frac{1}{2}$	$01\bar{1}2$	−30 00	20 53
13.	*r*	1	$10\bar{1}1$	30 00	37 21
14.	*r*·	−1	$01\bar{1}1$	−30 00	37 21
15.	μ·	−2	$02\bar{2}1$	−30 00	56 46
16.	*N*	$\frac{1}{4}1$	$21\bar{3}4$	10 53	26 47
17.	ν	$1\frac{1}{4}$	$3\bar{1}\bar{2}4$	49 07	26 47
18.	**I*	$\frac{1}{2}1$	$41\bar{5}6$	19 06	30 14
19.	**i*	$1\frac{1}{2}$	$5\bar{1}\bar{4}6$	40 54	30 14
20.	**L*	$1\frac{3}{2}$	$71\bar{8}6$	23 25	43 51
21.	**l*	$\frac{3}{2}1$	$8\bar{1}\bar{7}6$	36 35	43 51
22.	Λ	$1\frac{5}{2}$	$31\bar{4}2$	16 06	54 00
23.	*S*	14	$21\bar{3}1$	10 53	63 39
24.	*s*	41	$3\bar{1}\bar{2}1$	49 07	63 39
25.	Σ	17	$32\bar{5}1$	6 35	73 16
26.	*B*	$\frac{1}{4}\frac{7}{4}$	$32\bar{5}4$	6 35	39 45
27.	*b*	$\frac{7}{4}\frac{1}{4}$	$5\bar{2}\bar{3}4$	53 25	39 45
28.	*z*·	$-\frac{5}{4}\frac{1}{2}$	$13\bar{4}4$	−16 06	34 32
29.	*X*·	$-\frac{1}{2}2$	$\bar{1}3\bar{2}2$	−49 07	45 17
30.	*x*·	$-2\frac{1}{2}$	$12\bar{3}2$	−10 53	45 17
31.	γ·	$-\frac{7}{2}\frac{1}{2}$	$23\bar{5}2$	− 6 35	58 59
32.	**V*·	$-\frac{2}{5}\frac{3}{5}$	$\bar{1}8\bar{7}5$	−36 35	21 01
33.	**v*·	$-\frac{3}{5}\frac{2}{5}$	$17\bar{8}5$	−23 25	21 01
34.	Ξ·	−25	$\bar{1}4\bar{3}1$	−43 54	70 02
35.	ξ·	−52	$13\bar{4}1$	−16 06	70 02

portion of the longer work; its purpose is to put the characteristic habits of the crystals from these localities on record.

The two new localities are Klein-Spitzkopje, Southwest Africa, and the Morefield mine, near Winterham, Amelia County, Virginia. Through the kindness of Alexander Hahn, of Idar-on-the-Nahe, Germany, a complete suite of specimens and loose crystals was available for the study of the first locality. From the latter locality, several specimens were available, three of which were loaned by Dr. W. F. Foshag of the U. S. National Museum, and five by Miss Jewel J. Glass of the U. S. Geological Survey. The greater part of the work was done in the Victor Goldschmidt Institut für Kristallforschung, Heidelberg, Germany.

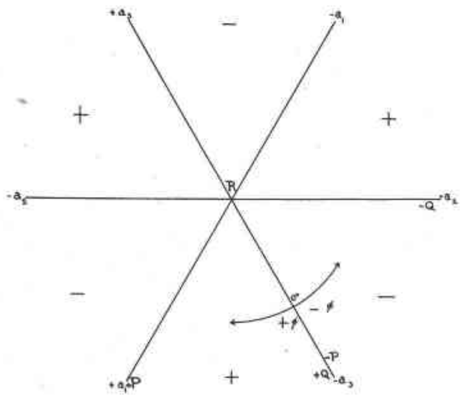

FIG. 1. Diagram showing the manner of listing of the ϕ angles in the new angle-table.

The angle-table gives the new forms found in the complete study and includes those which are new on the crystals from the two localities. The forms whose letter is preceded by an asterisk are new. The symbols and co-ordinate angles are calculated on the generally accepted elements.

$$c = 0.6611 \text{ (Koksharov)}$$
$$p_0 = 0.4407$$

As shown in Fig. 1, the azimuth angles ϕ refer to the negative end of the a_3- axis as prime meridian, reading from 0° to +60° and 0° to −60° in the adjacent positive and negative sextants, respectively. Positive forms thus receive positive azimuth angles and negative forms negative azimuths. This convention has been adopted to obtain exact correspondence between the position angles and the Bravais symbols.

With the polar axes P, Q designated as in Fig. 1, the Goldschmidt symbol p, q defines the position of a pole in the right or left part of the sextant enclosed by the polar axes. A negative sign prefixed to the symbol p, q places the pole in the negative sextant. The Goldschmidt symbol p, q is related to the Bravais symbol ($hk\bar{i}l$) by the following equation:

$$p=(h-k)/l \qquad h/l=(2p+q)/3$$
$$q=(h+2k)/l \qquad k/l=(q-p)/3$$

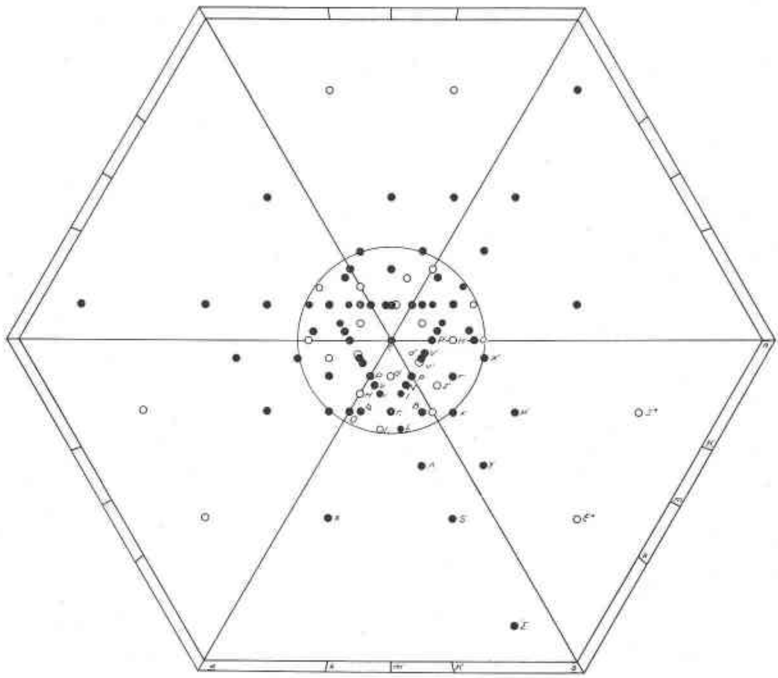

FIG. 2. Gnomonic projection of all the certain forms of phenacite.

The equations are strictly true in the positive sextant. In the negative sextant the indices and sign of the Bravais symbol must be appropriately interchanged.

A convention has been adopted in the lettering of the forms for the new angle-table. All right forms are distinguished by capital letters and left forms by small letters. Forms lying in the negative sextant are distinguished from those in the positive sextant by dots which follow the letters of the negative forms. Fig. 2 is a gnomonic projection showing all of the established forms of phenacite, derived from the study of all of the occurrences.

Klein-Spitzkopje, Southwest Africa

Klein-Spitzkopje, formerly called Kainsberg or Keinsberg, is situated 100 km. northwest of Swakopmund, Southwest Africa. For several years it has been the source of beautiful, well-terminated aquamarine crystals. The occurrence has been briefly described by Reuning.[1] Topaz from the same occurrence has been described by Hintze[2] and Himmelbauer.[3] Recently, Spencer[4] has described two crystals from the locality, indicating two habits. The phenacite probably occurs in the same dikes as the beryl, but in only one specimen had the crystals actually grown upon a beryl crystal. The study showed that the phenacite crystals from this locality are of two distinct types, apparently originating in two different, although closely associated pegmatite dikes.

The specimens of type 1 consisted of ninety-eight small, loose crystals and two matrix specimens. The loose crystals are prismatic in habit and many are doubly terminated. Commonly these show no signs of attachment and appear to have been found loose in pockets of clayey mud, remnants of which is to be seen on the crystals. Some have grown together into small groups with random orientations. The matrix specimens show a gangue of quartz with a few attached crystals of phenacite and several small brownish feldspar crystals. These specimens have a slightly weathered apappearance, in contrast to the freshness of the specimens of type 2.

Of the second type of material, forty-three specimens were studied. These are strikingly different in habit, being lenticular and almost without prism faces. All of these crystals are small and attached to matrices of microcline or smoky quartz, with associated muscovite, topaz, tourmaline, and siderite. The quartz and feldspar are often coated on one or more sides with black tourmaline needles, but in no case do these needles cover the phenacite crystals. In one or two cases, however, it was noted that the ends of the tourmaline needles are included by the outer portions of the

[1] Reuning, E., Pegmatit und Pegmatitmineralien in Südwest Afrika: *Zeit. Krist.*, vol. **58,** pp. 448–459, 1923.

[2] Hintze, C., Ueber Topas aus Südwest Afrika: *Zeit. Krist.*, vol. **15,** pp. 505–509, 1889.

[3] Himmelbauer, A., Kristallographische Untersuchungen an einigen Afrikanischen Topasvorkommen: *Festschrift V. Goldschmidt,* Heidelberg, pp. 147–153, **1928.**

[4] Spencer, L. J., Some Beryllium Minerals from Southwest Africa: *Mineralog. Mag.*, vol. **23,** pp. 616–623, 1934.

phenacite crystals. Another specimen shows a small phenacite crystal entirely included within a large topaz crystal. The same specimen shows mutual interference between the topaz and quartz.

The suite is sufficiently diverse to allow one to draw some conclusions concerning the order of crystallization. From the specimens described, it is clear that quartz was the earliest mineral to form, followed closely by muscovite, microcline, topaz and then phenacite. The tourmaline may have preceded the phenacite, but it is also possible that it developed later, replacing small portions of the

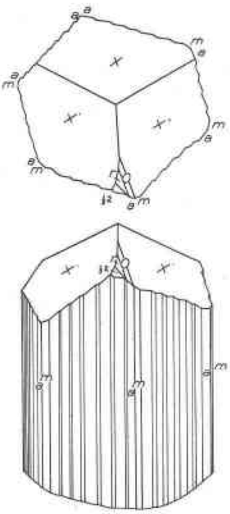

FIG. 3. Lower end of a Klein-Spitzkopje crystal of type 1, showing the form $\frac{1}{3}2$ and the striated appearance.

earlier crystals of quartz and feldspar in growing upon their surfaces. All of the minerals show widely overlapping relationships.

The prismatic crystals of type 1 are of variable apearance, ranging from transparent and colorless to an opaque gray which is probably caused by the inclusion of impurities. None attains great size, the largest group being but 20 mm. long. One of the largest single crystals measures 15 by 7.5 mm.; the average size is approximately 10 by 4 mm. The crystals are fresh in appearance and but slightly etched, giving bright though diffuse signals on the goniometer. They are remarkably uniform in habit and poor in forms. The resemblance of these crystals to some of the Mt. Antero, Colorado, crystals is striking.

As in the Mt. Antero crystals, the prism zone, with strong vertical striations is dominant (Fig. 3). These striations result in a rounding of this zone and a lack of well-defined, sharp-edged prism faces. Therefore, the signal on the goniometer is a continuous train-of-reflections[5] extending from *a* $(11\bar{2}0)$ to *m* $(10\bar{1}0)$. It contains no particularly strong point which would correspond to another prism form.

The termination is always dominated by $X\cdot$ $(\bar{1}3\bar{2}2)$, again just as in the case of the Mt. Antero crystals. Of the secondary forms the most common is *r* $(10\bar{1}1)$, and in diminishing frequency *S* $(21\bar{3}1)$, *s* $(3\bar{1}\bar{2}1)$, $d\cdot$ $(01\bar{1}2)$, and lastly *p* $(11\bar{2}3)$ and *P* $(2\bar{1}\bar{1}3)$, always as small narrow faces. The form $r\cdot$ $(01\bar{1}1)$, though a common form elsewhere, was not observed.

It was noted that the rarer forms on the cloudy and gray crystals lie between $X\cdot$ and the prisms, while on the clear crystals they lie near the apex, as faces of $d\cdot$, *p*, and *P*. This suggests the possibility that the inclusions have influenced the development of the crystals.

The form $X\cdot$ exhibits clear-cut accessories, in most cases covering the entire face. Similar accessories were noted in other occurrences on the same form. They consist of small rounded hillocks, which sometimes give reflections from the bounding planes corresponding to $d\cdot$, *p*, *P* and the prism faces. The edge between two $X\cdot$-faces often shows small planes parallel to *r*, resulting from the intersection of the accessories on $X\cdot$.

The faces of the other rhombohedrons are usually small and even giving good signals. The prisms are narrow and have no outstanding accessories, their striations have little similarity to the Framont-Mt. Antero type, except that they both give continuous trains through one side of a sextant, This train usually extends from *a* to *m*, with the adjoining half sextant dark, with the train recommencing at *a*.

Reflections in the position of the base, *c* (0001), a new form for phenacite, were found three times upon etched crystals. They result from corrosion figures on $X\cdot$. On the goniometer it was further observed that three trains extend from the base to the position of $d\cdot$. The surfaces giving these reflections have also originated through etching.

One probable new form, $\frac{1}{3}2$ $(8\cdot 5\cdot \overline{13}\cdot 9)$ was observed as a small face to the right of *r* on three of the crystals. It was dull and gave

[5] German: *Lichtzug, Reflexzug.*

unsatisfactory readings. The form is shown on the lower end of a crystal in Fig. 3, but it requires confirmation.

Measured: $\phi = 7°26'$ Calculated: $\phi = 7°35'$
$\rho = 43°40'$ $\rho = 43°56'$

The new form *V*·, $-\frac{23}{55}$ ($\bar{1}\cdot 8\cdot \bar{7}\cdot 15$) was observed once as a small face intergrown with *d*·. Since it has commonly been found on crystals from other localities, it may be considered certain.

Measured: $\phi = 35°42'$ Calculated: $\phi = 36°35'$
$\rho = 21°35'$ $\rho = 21°01'$

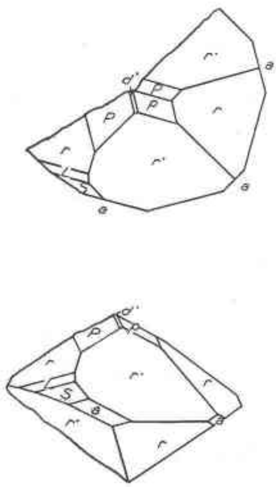

FIG. 4. Klein-Spitzkopje crystal of type 2, showing the new form *L*.

In summary, a statistical survey of the forms present on the crystals of type 1 show: *a*, *m*, and *X*· to be dominant, *r*, *S*, *s*, *d*·, *p*, and *P* moderately frequent in their occurrence and all others to be very rare.

The crystals of type 2 range in size from very minute up to a maximum diameter of 13 mm., with a thickness of 6 mm. The average diameter is about 5 mm. They vary from quite colorless and transparent to milky and translucent, and they are free from chloritic and hematitic inclusions. Although the crystals are bright and fresh, many of them show the effects of etching, the edges being frequently rounded, particularly near the equatorial zone. All the crystals of this type have similar habits, and resemble rhombohedral crystals from Ilmengebirge, Florissant, and New Hampshire.

On these crystals the forms of the prism zone are often absent, and when present they play but a minor role. The forms *a* and *m* were both observed, but no other prism forms were found. The faces are smooth and free from accessories.

Of the terminal forms, *r* and *r*· are dominant; *P* and *p* are also common, occasionally equalling *r* and *r*· in size and even, in one or two cases, becoming dominant. Other forms, most frequently *S* and *s*, then *d*·, and least often *X*· and *x*·, were also observed, but always as small facets.

Several new forms were found, but none, with the exception of H$(2\bar{1}\bar{1}2)$, *L*$(71\bar{8}6)$ and *l*$(8\bar{1}\bar{7}6)$, found elsewhere as well, can be called certain. The forms *L* and *l* lie above *S* and *s* in the zones [*aSr*] and [*asr*], as narrow faces giving good signals; they were each seen twice (Fig. 4). The angles for the form are:

	Measured:		Calculated:	
L$(71\bar{8}6)$	$\phi=23°00'$		$\phi=23°25'$	
		$\rho=44°46'$		$\rho=43°51'$
l$(8\bar{1}\bar{7}6)$	$\phi 37°00'$		$\phi=36°35'$	

The new form *H*, $0\frac{3}{2}(2\bar{1}\bar{1}2)$ was observed three times on one crystal. It lay exactly in the [*Pa*] zone and gave poor measurements.

Measured:		Calculated:	
	$\phi=60°00'$		$\phi=60\ 00'$
	$\rho=32°46'$		$\rho=33°28'$

The surface of the *r*·-faces is distinctive in its appearance and a glance at the accessories usually suffices to distinguish the form from *r*. The accessories on *r*· are well-developed, the face being commonly covered with many small oval hillocks, whose long axes lie in the zone [*rm*] (Fig. 5). Because of the character of this surface, the face usually appears dull and gives blurred signals. The faces of *r*, on the other hand, are usually brilliant and distinctive accessories are rare. When present, they usually take the form of a single central mound, larger than those of *r*· but similar in form. The faces of *P* and *p* were, in several instances, observed to have small rounded mound-like accessories (Fig. 6) but they are much rarer than those on *r*· and therefore the danger of confusing the forms is not great. The faces of the other forms are all small and brilliant, without distinctive accessories.

Many of the crystals appear to have been somewhat etched, about half of them showing this phenomenon. The results of this attack are quite distinctive and different from that seen on crystals from other localities. The etching is to be observed only upon the faces lying near the prism zone; it has resulted in a rounding off of the edges in most cases without regard to the positive or negative character of the rhombohedron so attacked. Although the surfaces developed in this manner are smooth, no satisfactory measurements or symbols were obtained. In several cases the etching has taken the form of a shallow trenching along the equatorial edges. However, the faces themselves have not been appreciably etched and the *rr* edges are always sharp.

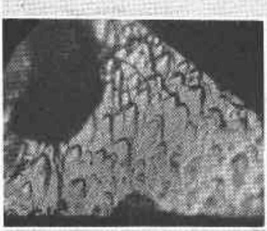

FIG. 5. Klein-Spitzkopje crystal of type 2, showing mound-like accessories on *r*·.

FIG. 6. Klein-Spitzkopje crystal of type 2, showing ridges on *P*.

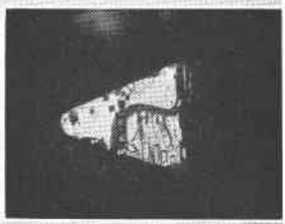

FIG. 8. Amelia Courthouse crystal, showing etch pits on *a*.

The crystals show another peculiarity in their tendency to be distorted near the contacts with the matrix. Faces of the same form near the contact have variable ρ angles, with the portion in contact often showing more deviation from the normal position than the more distant part.

A statistical summary of the 44 crystals studied shows *r* and *r*· to be invariably present. On 26, *r* is dominant and determines the habit; *r*· is dominant on but 4 crystals, and *p* and *P* likewise on 4 crystals. On 9 crystals *r* and *r*· were so equally developed that it was not possible to say which was the more important, and in one case, *p* and *P* are equal to the former pair in their importance.

Crystallographically, the two types of phenacite from Klein-Spitzkopje are distinct and definitely non-gradational. Because of their close geographic occurrence they must have a genetical relationship, and a study of the actual field relationships of the pegmatites in which they occur should give some interesting information upon the relation of crystal habit to the conditions of crystallization.

Morefield Mine, Amelia County, Virginia

The second new phenacite find of the past few years is not far distant from the occurrence partially described long ago by Yeates.[6] The specimens mentioned by Yeates were found at the Rutherford Mine, near Amelia Courthouse, but not far from Winterham, the nearest town to the Morfield deposit.

Some descriptions of the newly opened deposit have appeared. The first reference to it was in a brief note by the owner[7] and since then Glass[8] has published a description of the rare earth minerals of the dike and has a longer paper in preparation upon the same aspects.[9] The pegmatite is apparently the same sort of dike as those of the Ilmengebirge, Florissant, and Klein-Spitzkopje. The principal associates of the phenacite are microcline, beryl, quartz, topaz and a mica said to have the composition of zinnwaldite. Many other minerals are found in small quantities in the dike.

About fifteen specimens of phenacite from the locality were available for the study. The largest consists mainly of beryl, with some quartz, microcline, and muscovite, and several embedded white translucent anhedrons of phenacite about 2 cm. in length. A similar specimen has several embedded crystals of phenacite, one of which shows some free faces. The crystal is rough and dull and permits only approximate contact goniometer measurements. The forms present are: *a* (large), *m* (medium), *r* (medium), *P* and *p* (the dominating forms), and *d·* (small). The faces are dulled by etching, but are without distinctive etch figures. Several other crystals of this type were seen and all present the same aspect and forms.

Although the small crystals show the same forms in the same relative development, they are very different in their appearance. The crystals of this group are small, the largest not exceeding 4 or

[6] Yeates, W. S., New Localities for Phenacite: *Am. Jour. Sci.*, Ser. III, vol. **40**, p. 259, 1890.

[7] Morefield, S. V., Letter in *Rocks and Minerals*, vol. **8**, pp. 143–144, 1933.

[8] Glass, J. J., Rare Chemical Constituents of the Amelia Pegmatite Dikes and their Mineral Sources: *Trans. Am. Geophys. Un.*, 15 Meet., **1934.**

[9] Glass, J. J., The Pegmatite Minerals from near Amelia, Va.: *Am. Mineral.*, vol. **20**, pp. 741–768, 1935.

5 mm. in diameter, and are colorless and transparent. They are found completely embedded in microcline, and the crystal form is very well developed on most. Ten of these crystals were measured on the goniometer. All are short prismatic and show both *a* and *m* in the prism zone. The forms *r*, *P* and *p* are invariably present, usually with *r* dominant and *P* and *p* smaller but nearly equal in size (Fig. 7). Etching has rounded some of the edges, but in two cases *d*· is unmistakably present. The *r*-faces are small, occurring

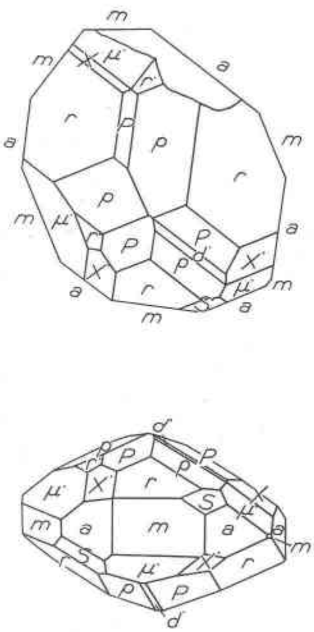

Fig. 7. Typical Amelia Courthouse, Virginia, crystal.

three times on the ten crystals. *S*, *X*· and *z*· were each seen once. One possible new form, lying in the [*z*·*a*] zone was observed as a single small face on one crystal, (U. S. N. M. #96749). Its symbol would correspond most nearly to (3·11·$\overline{14}$·12). The angles are:

Measured: $\phi = -12°27'$ Calculated: $\phi = -12°10'$
$\rho = 43°10'$ $\rho = 42°03'$

All of the crystals show considerable etching, sometimes over the entire crystal and sometimes over only the upper or lower portion. The etched faces give somewhat diffuse signals, many parts of their surfaces giving reflections corresponding to other forms. Reflections of this sort from *P* and *p* correspond to *d*·, *r*, and *r*·; those from *r*· correspond to *d*· and *μ*·; and those from *r* to *S* and *s*. Distinctive etch pits of the type seen upon the Brazilian crystals upon *a* were observed (Fig. 8), although they were not common.

Summary

In the study of these two new localities we find crystals representing all three of the habits found to be common to phenacite: prismatic, short prismatic, and rhombohedral. The customary relations exist, that is, the rhombohedral and prismatic crystals are not found in close association. The matrix of the rhombohedral crystals seems typically to contain no beryl, a phenomenon noted at other occurrences as well. The rarity of the form *d*· on crystals from the Morefield mine is noteworthy, for it is usually a dominant form. The tetartohedry is pronounced on all the crystals and several new forms, *V*·, *H*, *L* and *l*, were observed.