

than the cube or the tetrahedrons. The cube, likewise, forms at a slightly higher temperature than the \pm tetrahedrons, and the combination of the \pm tetrahedrons forms at a higher temperature than the single tetrahedron. The rate of evaporation for each case is considered "slow."

A combination of crystal forms, in the light of the above experiments, may for some crystals be considered to be the result of a successive change of conditions. If conditions favorable to any one crystal form exist for a sufficiently long period of time that form will be the dominant form or it may even grow as a single form to the exclusion of all other forms. This result has been obtained in the case of the cube. The most favorable temperature for the cube of barium nitrate seems to be about 23°C. If this temperature can be successfully maintained for a period of three days, the majority of the barium nitrate crystals in the mother liquor will be cubes. Such results have been obtained repeatedly.

(To be continued)

EUHEDRAL OLIGOCLASE OF PERICLINE HABIT FROM MEDICINE BOW MOUNTAINS, WYOMING

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INTRODUCTION

The purpose of this article is to place on record an American occurrence of oligoclase crystals of pericline¹ habit, an unusually rare form of a common mineral. They occur at Gold Hill, Wyoming, on the west flank of Medicine Bow Mountains or Snowy Range, about three miles due west of Medicine Peak. Specimens were collected by the writer in July, 1925, while acting as field assistant to Professor Eliot Blackwelder. These were studied in the mineralogical laboratory at Stanford University and this article prepared under the direction of Professor Austin F. Rogers, whose stimulating criticism is gratefully acknowledged.

OCCURRENCE

The oligoclase lines the walls of an irregular vein in an altered pre-Cambrian dike, a dark-colored, mediosilicic rock, typical of many similar dikes which here traverse the ancient sediments.

¹ Pericline is a variety of albite in which the crystals are elongated parallel to the *b*-axis. The variety of albite with this habit should not be confused with the twinning-law bearing the same name. No necessary connection exists.

The latter are thoroughly recrystallized and are almost exclusively metaquartzite² though, a few miles to the east, they grade into argillaceous and calcareous strata. An abandoned prospect furnished the material³ for this study.

A chemical analysis of the dike rock has not been made, but a petrographic study of thin sections shows that it is probably a metadiorite. It is completely recrystallized and the various constituents are intergrown, usually occurring in aggregates rather than in units of definite orientation. More than half of the rock is made up of plagioclase feldspar which gives, by the statistical method of Michel-Lévy, a maximum extinction angle of about 13° (measured in the albite twinning lamellae), and thus corresponds to Ab₇An₃. Due to the dearth of albite twinning and the abundance of included matter, no high degree of accuracy can be claimed for this determination. It suggests that the plagioclase of the dike is slightly more calcic than that in the vein, but since they are alike in the prevalence of twin-seams after the pericline law, in the scarcity of albite twinning lamellae, and in the abundance of minute inclusions, it is believed that they may be identical.

No typical microcline appears to occur in the dike, but a carnegieite-like⁴ mineral with a peculiar double polysynthetic twinning is sparingly present. Its index of refraction seems too high for microcline, and there occurs an occasional large twin-seam after the pericline law. This suggests that the mineral may be another phase of the plagioclase already described.

² This term was suggested by Van Hise ("A Treatise on Metamorphism," *U. S. Geol. Sur. Mon.*, 47, p. 776, 1904) to describe a quartzite "again metamorphosed." It was later applied by Blackwelder ("The Wasatch Mountains Revisited." Abstract. *Bull. Geol. Soc. Amer.*, 36, 1, 1925) to a quartzite that had been thoroughly recrystallized. Blackwelder (in a paper soon to be published) would reserve the term quartzite for a rock derived from sandstone through simple cementation by silica. Some such distinction as this seems advisable as the term quartzite has been used ambiguously by various authors to cover either or both of these rock types. The prefix meta- commends itself because it is already in common use before the names of igneous rocks to signify analogous changes.

³ This material consists of a single large specimen of the dike containing a portion of the principal vein with numerous minor ramifications. The largest oligoclase crystal present is more than an inch in the longest direction, but there are all gradations to crystals an eighth of an inch.

The specimen is believed to be typical, but the circumstances under which it was collected prevented a detailed study in the field.

⁴ Washington and Wright: *Am. Jour. Sci.*, [4], 29, 52 (1910). See Figs. 2 and 3.

Chlorite is the mineral second in abundance and gives the dark color to the dike. There are two kinds of chlorite. The most common is the ordinary green variety, with very low birefringence and slightly anomalous interference colors. It occurs in spherulitic and irregular aggregates, often showing polysynthetic twinning parallel to the cleavage, which is also the direction of extinction. The second is a pleochroic brown variety with decidedly anomalous (ultra blue through lavender, straw, brownish-yellow, and orange-red) interference colors. Its birefringence is considerably greater than that of the first variety, and its occurrence in small patches around the edges and along the cleavage planes of the green chlorite suggests that it is possibly an alteration product of the green variety.

Clinozoisite, biotite, a very pale green amphibole, and titanite named in order of abundance, are present in considerable quantities. The clinozoisite, which is very granular, is embedded in the plagioclase and occurs in all gradations from irregular aggregates that can be easily recognized to individual particles of sub-microscopic size. The biotite is very dark, has strong absorption, and contains numerous pleochroic halos surrounding small crystal inclusions. The amphibole is almost colorless and is undoubtedly a recrystallization product. Both biotite and amphibole occur intergrown with chlorite, but it is doubtful if the chlorite has been derived from either. Other constituents of the dike are tourmaline, apatite, muscovite, sericite, calcite, and quartz, but they are present only in very small amounts.

CHARACTER OF THE VEIN

The oligoclase-bearing vein is irregular and full of cavities. Small ramifications project from the principal fissure into the walls of the dike where they connect with secondary vugs and gash veinlets. In fact, the dike in the vicinity of the vein is itself very porous and contains a great deal of subhedral oligoclase in the partly filled cavities. The boundary between the dike and the vein is thus often indefinite, so that even under the microscope it is impossible to determine where the plagioclase in the vein ends and the plagioclase of the dike begins. Quartz, however, which occurs very sparingly in the dike, is present in the vein in scattered subhedral crystals an inch or more in length. Minute chlorite flakes dust the surface of both quartz and oligoclase, but

beneath this dirty greenish-gray veneer the oligoclase is usually white; occasionally it is nearly salmon pink.

CRYSTALLOGRAPHY

Although varied, most of the crystals are somewhat tabular, elongated in the direction of the b -axis, and thus show a pericline habit. The largest and most typical crystal collected is shown in Fig. 1. (This plan and clinographic projection were drawn from a gnomonic projection by Goldschmidt's method.⁵)

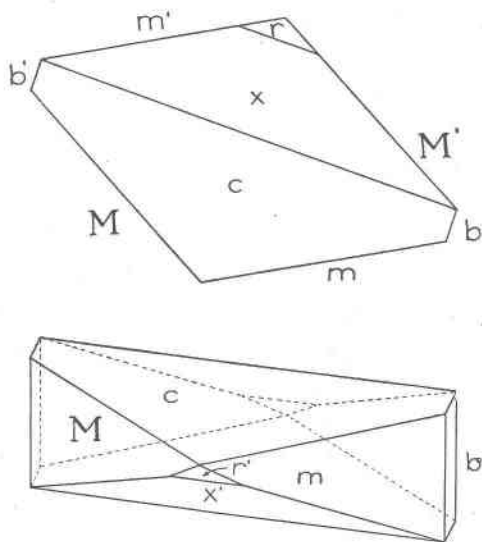


FIG. 1. Plan and clinographic projection of an oligoclase crystal of pericline habit from Gold Hill, Wyoming.

With a hand lens the principal forms are evident by inspection. Some difficulty was encountered, however, in checking these determinations by measurements. The crystals were either too small or too embedded to use a contact goniometer with any degree of precision; and the faces were so covered with bits of chlorite that no reflection image could be obtained. Nevertheless, by mounting a small crystal on a one-circle reflection goniometer, using the converging or low power microscope lens, carefully adjusting the crystal so that all the edges in a zone were parallel to the vertical cross-hair, and recording the position on the

⁵ A good description of this method is given in English by Miss Mary Porter, "Practical Crystal Drawing," *Am. Mineral.*, 5, 88 (1920).

graduated circle at which each succeeding face became parallel with the line of sight, values were obtained for the interfacial angles which approximate to within one degree those recorded in Dana's "System of Mineralogy" for the respective angles.

The principal forms are: $c\{001\}$, $b\{010\}$, $m\{110\}$, $M\{\bar{1}\bar{1}0\}$, $x\{\bar{1}01\}$, and $r\{\bar{4}03\}$. Some minor forms, such as $o\{\bar{1}\bar{1}1\}$, $p\{\bar{1}\bar{1}1\}$, $f\{130\}$ and $z\{1\bar{3}0\}$, are believed to occur on some crystals, but they are small, much rounded, and cannot be surely identified. Usually, as in Fig. 1, the forms m and M are equally developed, x is nearly as large as c , while r is either small or absent. Two common variations from this habit are illustrated in Figs. 2 and 3. In Fig. 2, the crystal still has a pericline habit, but c is developed at the expense of the other faces and the individual is thin and tabular. In Fig. 3, c is not so prominent, the faces in the zone

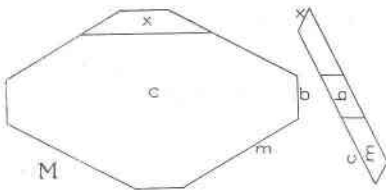


FIG. 2. Plan and projection on (010) of a tabular oligoclase crystal of pericline habit.

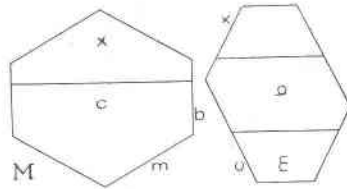


FIG. 3. Plan and projection on (010) of a stout oligoclase crystal.

$[001]$ are better developed and the elongation in the direction of the b -axis is less marked.

Although the majority of crystals are not twinned, pericline twinning is represented by simple twins, twin-seams, and polysynthetic twins. Of these, crystals with a twin-seam, Fig. 4, appear to be the most common. Albite twinning is seldom present, but when it does occur it is polysynthetic.

A parting⁶ parallel to the pericline twinning is frequently well developed as illustrated in Fig. 4.

The angle of the rhombic section, that is, the angle between the $(001):(010)$ edge and the trace of the pericline twinning

⁶ Parting parallel to pericline twinning was noted by Penfield and Sperry, *Am. Jour. Sci.*, [3], **34**, 390 (1887), and later emphasized by Rogers, *Jour. Geol.*, **21**, 202 (1913). It has since been observed by MacKenzie, *Am. Mineral.*, **8**, 193 (1923). This parting is perhaps the only one on record which is not parallel to a crystallographic direction (see A. F. Rogers, "Introduction to the Study of Minerals and Rocks." 2nd ed., p. 132, *New York*. 1921.)

lamellae (Fig. 4) was measured on several specimens. This was accomplished by mounting the crystals and using the microscope as a goniometer. Twenty readings, taken on the best three specimens, gave a mean value of $+7^{\circ}52'$ with extremes of $+6^{\circ}40'$ and $+9^{\circ}0'$.

The angle of the rhombic section may vary⁷ from $+22^{\circ}$ for albite to -18° for anorthite, Fig. 5. The angle obtained for the Gold Hill plagioclase is well within the limits usually assigned⁸ to oligoclase.

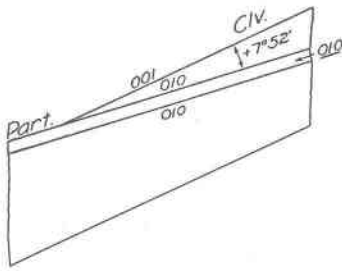


FIG. 4. Projection of a Gold Hill oligoclase cleavage fragment on (010), showing a twin-seam, (according to the pericline law), (001) cleavage, parting parallel to the pericline twinning, and the angle ($+7^{\circ}52'$) of the rhombic section.

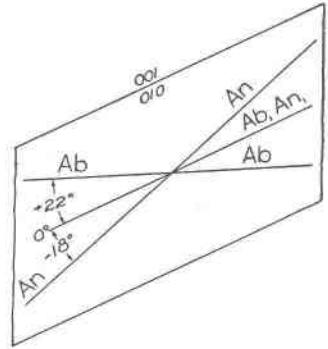


FIG. 5. Projection of a plagioclase cleavage fragment on (010), showing the position of the pericline twinning lamellae for pure albite Ab ($+22^{\circ}$), andesine-labradorite Ab_1An_1 (0°), and pure anorthite An (-18°).

OPTICAL PROPERTIES

EXTINCTION ANGLES: Twenty readings on a good (010) cleavage flake gave a mean value of $+3^{\circ}40'$, with extremes of $+2^{\circ}0'$ and $+4^{\circ}30'$, for the extinction angle measured against the trace of the (001) cleavage. This, according to Wright⁹ corresponds to an oligoclase of $Ab_{76}An_{24}$ composition.

⁷ See Penfield and Sperry, *loc. cit.*

⁸ It seems unfortunate that this comparatively simple method for the identification of the various plagioclase feldspars, practically the only one that can be used megascopically, has received so little attention. Since the investigation of Penfield and Sperry in 1887 it seems that nothing has been done to correlate the angle of the rhombic section with chemical analyses.

⁹ F. E. Wright, "A Graphical Plot for Use in the Microscopical Determination of the Plagioclase Feldspars." See curve No. 6, *Am. Jour. Sci.*, [4], 36, 541 (1913).

Extinction angles on good (001) flakes measured against the trace of the (010) cleavage are practically 0° . A plagioclase with a 0° extinction angle on (001) would be $\text{Ab}_{70}\text{An}_{30}$, according to Wright's curve No. 5. Following Calkins' nomenclature¹⁰ a feldspar with this composition would fall on the oligoclase-andesine line. However, the curve for extinction angles on (010) changes much more rapidly for sodic plagioclases than does the curve for extinction angles on (001). The extinction angles on (010) are therefore more reliable as indicators of composition and it is probable that $\text{Ab}_{76}\text{An}_{24}$ is nearer the real composition than is $\text{Ab}_{70}\text{An}_{30}$.

INDEX OF REFRACTION: Crushed fragments immersed in liquids of known index of refraction gave values varying from $1.540 \pm .001$ for n_1 to $1.551 \pm .001$ for n_2 . Using the minimum as suggested by Tsuboi¹¹ a composition of $\text{Ab}_{77}\text{An}_{23}$ is indicated. As the indices given above vary between wider limits than should exist if there were present only perfect (001) and (010) cleavage flakes, it is probable that the above minimum is slightly too low and therefore the plagioclase may be a little more calcic.

DISCUSSION

In summarizing the optical data, the index of refraction and the extinction angle on (010) cleavage flakes are regarded as the two most reliable determinations. These give $\text{Ab}_{77}\text{An}_{23}$ and $\text{Ab}_{76}\text{An}_{24}$, respectively. Both of these values are very close to Ab_3An_1 , and since this formula is more in keeping with the degree of accuracy of the determination as a whole, it may be regarded as the nearest approximation justified.

The Alpine type of veins from Tyrol, Switzerland, and the French Alps, with its characteristic assemblage of minerals, have furnished so many examples of beautiful albite crystals elongated in the direction of the *b*-axis that this particular (pericline) habit has come to be associated in the minds of mineralogists with albite feldspar in Alpine veins. Here is an example of pericline habit with a feldspar not albite and in a vein not of the usual Alpine type.

¹⁰ F. C. Calkins, "A Decimal Grouping of the Plagioclases." *Jour. Geol.*, **25**, 157 (1917).

¹¹ *Mineral. Mag.*, **20**, 93 (1923).

Although exceedingly common as embedded rock-forming minerals, the intermediate members of the isomorphous albite-anorthite series, unlike albite, are seldom found as attached euhedral crystals in veins. Further, among all the plagioclase crystals found attached to the walls of veins, those of pericline habit are confined to relatively few localities, and in these localities a disproportionately large ratio of them are albite in composition. Of the 324 albite crystals figured by Goldschmidt in his *ATLAS DER KRYSTALLFORMEN*, about ten per cent have the typical pericline development, while of 117 figures illustrating the entire transition series from oligoclase to bytownite there are only three figures which show this habit. These three were described from Sweden by Flink¹² in 1914. So far as the writer is aware no American occurrence of euhedral oligoclase of pericline habit has previously been described.

From the foregoing it is evident that at Gold Hill an extremely common mineral occurs in an unusually rare form. To the collector, such specimens are always fascinating.

RELATIONS BETWEEN PROPERTIES AND COMPOSITION IN THE AMBLYGONITE-MONTEBRASITE SERIES

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Amblygonite is a lithium aluminum fluophosphate whose formula is commonly written as LiAlFPO_4 . Penfield¹ demonstrated that hydroxyl can proxy for any part or all of the fluorine in this substance, thus forming a series from amblygonite proper, LiAlFPO_4 , to montebasite, LiAlOHPO_4 . Furthermore, sodium can proxy for lithium up to about twenty (molecular) percent, as shown by many analyses; according to Schaller² sodium can displace lithium (almost) entirely, as in "fremontite," but there is no evidence that NaAl(OH,F)PO_4 is miscible in more than limited amounts with LiAl(F,OH)PO_4 .

¹² *Arkiv Kemi Min. Geol.* (1914), cited by Goldschmidt, "Atlas der Krystallformen," Band III, Heidelberg (1916). The three figures referred to (Figs. 113, 114 and 115, Tafel 206, Goldschmidt) would serve equally well to illustrate the variations in the habit of the Gold Hill material, except for the minor forms.

¹ *Am. Jour. Sci.*, CLXVIII, 297 (1879).

² *U. S. Geol. Surv. Bull.*, 610, 141 (1916); see also: *Am. Jour. Sci.*, CLXXXI, 48 (1911).