NOTES AND NEWS

FELDSPARS IN THE ADIRONDACK ANORTHOSITE

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Barth's[1] article in the April number of the *American Mineralogist* on the composition of the feldspars of the Adirondack anorthosite, represents a beautiful piece of laboratory work. I am confident that his data will be a welcomed contribution. But as I find difficulty in accepting his conclusion that the labradorite and andesine grains are potash free, I feel called upon to review it and enlarge upon the problems there present. In the first place I feel that if we accept Barth's optical results as accurate, and interpret them on the basis of our present knowledge of the feldspars, I reach the conclusion the opposite to that stated by Barth. In other words, he, I think, failed to prove his point.

In the second place, Barth seems to have ignored the opinions of the Adirondack geologists who have faced this very problem for many years. Allow me briefly to review the literature.

Hawes[2] noted in thin sections of Adirondack anorthosites that a few feldspar grains failed to afford the twinned striations, which he, however, suspected of being plagioclase. Chemical tests demonstrate that they were dominantly soda-lime feldspars.

Cushing[3] says "The potash is in the labradorite (or other plagioclase), replacing a certain amount of soda" and "that analyses of this feldspar always show it."

Kemp[4] says "It [is] practically certain that the potash is in the orthoclase molecule and that this feldspar is in the rocks up to 5% or over." Kemp evidently at that time did not consider the possibility of orthoclase being in solid solution in the plagioclase.

Miller[5] says "The rather high percentage of potash in rocks of this character calls for explanation." He goes on to indicate that if potash feldspar is present as such he has been unable to demonstrate it in the thin sections which he has studied. Miller is uncertain whether this potash exists as a separate group of grains or forms part of the labradorite proper.

Kemp[6] took three analyses, two furnished by Leeds, and one by Joüet, and in recasting them it was necessary to employ orthoclase from 5 to 7%.

Kemp and Alling[7] show that an analysis of the Whiteface type made by Steiger on recasting produced a norm showing 66.12% of Or_5, Ab_{40}, and An_{55}, while an analysis of Leeds of the Mt. Marcy anorthosite gave 89.20% of Or_5, Ab_{25}, and An_{70}

Mawdsley[8] has studied forty thin sections of the anorthosite from the St.

[1] Barth, Tom. F. W., Mineralogy of the Adirondack Feldspars: *Am. Mineral.*, April **1930,** pp. 129–143.

[2] Hawes, G. W., *U. S. Nat. Mus. Proc.*, **1882,** Vol. 4, pp. 134–136.

[3] Cushing, H. P., *N. Y. State Mus. Bull.* 95, **1905,** p. 335.

[4] Kemp, J. F., *N. Y. State Mus. Bull.* 138, **1910,** p. 30.

[5] Miller, W. J., *Bull. Geol. Soc. Am.*, **1918,** Vol. 29, p. 406.

[6] Kemp, J. F., *N. Y. State Mus. Bull.* 229–230, **1920,** pp. 31–32.

[7] Kemp, J. F., and Alling, H. L., *N. Y. State Mus. Bull.* 261, **1925,** pp. 37–38.

[8] Mawdsley, J. B., St. Urbain Area, Charlesvoix District, Quebec: *Canada Geol. Surv. Mem.*, **152,** 1927, pp. 18–28.

Urbain Area in Quebec, and four complete chemical analyses made by Professor Phillips of Princeton University, where the alkalies were determined in duplicate. The composition of the feldspars as determined by chemical analyses is given below.

DETERMINED BY CHEMICAL ANALYSES

Or	Ab	An
4.7	57.7	37.6
1.3	58.9	39.8
2.0	41.5	56.5
1.9	37.4	60.7

Mawdsley[9] states "The low content of the orthoclase molecule as found by chemical analyses, considered in conjunction with the results obtained from optical analyses of the same materials, indicates the absence or virtual absence of orthoclase in solid solution in the plagioclase of three of the samples analyzed." The evidence of this conclusion appears to be that "the quantity of the orthoclase molecule indicated by chemical analysis to be present is far less than is required for the formation of the observed perthitic rods and interstitial grains of what *appears* as orthoclase." (My italics.)

The point seems to be what is the actual nature of these interstitial grains, as well as the actual thickness and size of the blebs. Mawdsley suggests anorthoclase, which if I take the usual meaning of the word to apply here, is a soda-rich potash feldspar something of the order of K-feld. 45, Na-feld. 53, Ca-feld. 2. Whatever may be the exact composition of these interstitial grains, anorthoclase or untwinned plagioclase, it is pretty certain that it is not pure orthoclase. Furthermore, my studies of antiperthitic labradorites show that the blebs are relatively thin, thinner than many thin sections, and hence, any graphic quantitative analysis would exaggerate their bulk. I question Mawdsley's statement "The only possible explanation is that the plagioclase present has practically no orthoclase in solid solution" . . . . "the plagioclase feldspars of the St. Urban anorthosites in some, perhaps in most cases, contain practically none of the orthoclase molecule in solid solution."

Mawdsley suggests that it is "probable that the process of exsolution was so facilitated (perhaps by the plagioclase crystals being kept for a long time at a temperature close to the inversion point[10] of the solid orthoclase from the solid plagioclase),[11] that almost complete exsolution of the orthoclase from the plagioclase in the anorthosite rocks took place."

Bowen[12] notes these antiperthitic grains in the Adirondacks and suggests that either the potash feldspar blebs were "originally in solid solution in the plagioclase and that on separating from solid solution it left the plagioclase poorer in potash feldspar and therefore of higher refraction" . . . . or "that the potash feldspar

[9] *Ibid.*, p. 6.

[10] I question whether the word "inversion" is correctly used here. I believe that the word "boundary-curve" between two solid phases would be more accurate. See Fenner, C. N., *Jour. Geol.*, Vol. 33, **1930,** pp. 159–165.

[11] Mawdsley, J. B., St. Urbain Area, Charlesvoix District, Quebec: *Canada Geol. Surv. Mem.*, 152, **1927,** p. 27.

[12] Bowen, N. L., *Jour. Geol.*, Vol. 25, **1917,** p. 221.

[blebs] . . . . formed from the portion which remained liquid last and was introduced into the plagioclase by a sort of replacement."[13]

Such suggestions are quite in conformity with the views I have expressed,[14] but none of the thermal diagrams that have been proposed show a complete separation of potash feldspars from plagioclase. That is, all of them show that plagioclase must be represented by an area and not a line. Plagioclase is in truth a ternary and not a binary system. If these blebs of the antiperthite have been introduced, the problem is complicated thereby; I am not sure if this changes my opinion of the composition of the plagioclase, however.

Barth[15] says "facts will be presented that prove the non-existence of an admixture in solid solution of potash feldspar (as well as of carnegieite.)" He suggests that chemical studies of this feldspar are difficult because of the presence of the perthites and other intergrowths which make it impossible to get pure material for the analyses. This is perfectly obvious to anyone who has studied the Adirondack feldspars. Barth used the Fedorow stage and determined the axial angle and the position of the indicatrix of 15 different crystals and plotted these in Figure 2 of the above mentioned paper. He states that he has compared these results with the position of the indicatrix of "normal" plagioclase. "All of the measurements agree with the curves for the normal plagioclase within the limits of error."[16] "It is highly improbable that an appreciable amount of either the potash feldspar or carnegieite would not cause an observable alteration of the shape of the indicatrix, and throw it far out of its normal position."

It is not entirely clear to me what Barth means by "normal position" of "normal" plagioclase. In his figure he reproduces "the positions of the optical elements in the normal plagioclase series (according to Duparc and Reinhard)." If Barth has drawn his figure on the basis of Duparc and Reinhard[17] and calls the feldspar studied by these Swiss mineralogists "normal," then it is reasonable, from a study of the chemical analyses of the feldspars (given below) to definitely conclude that "normal" plagioclase contains the potash end member.[18]

However, Duparc and Reinhard's data are based upon old analyses, the accuracy of which I have recently questioned.[19]

Barth calls the interstitial feldspar comparatively pure orthoclase, and yet records the extinction angle normal to (010) from 1° to 3°. This suggests to Barth,

[13] See Colony, R. J., *Jour. Geol.*, Vol. 31, **1923,** p. 170, fig. 1.

[14] Alling, H. L., Mineralography of the Feldspars, Part 2, *Jour. Geol.*, 31, **1923,** pp. 288–290.

Mäkinen Eero, Über die Alkalifeldspäte, *Sonderabd. aus. Geol. Föreningens. Förhandle.*, XXXIX, H. 2 (February **1917**), 149.

[15] Barth, Tom. F. W., Mineralogy of the Adirondack Feldspars: *Am. Mineral.*, April **1930,** pp. 129–143.

[16] I am unable to find where the limits of error are given.

[17] Duparc and Reinhard, La Determination des plagioclases dans coupe minces: *Mem. Soc. phy. et d'hist. nat. Geneve*, Vol. **XL,** p. 134.

[18] Alling, H. L., Indices of Refraction of the Plagioclase Feldspars: *Jour. Geol.*, Vol. 37, No. 5, July–August **1929,** p. 475.

[19] Alling, H. L., *Jour. Geol.*, 37, **1929,** pp. 462–482.

TABLE I

COMPOSITION OF PLAGIOCLASES USED BY DUPARC AND REINHARD.

NAME	LOCALITY	COMP. AS GIVEN		DATE OF ANALYSIS	COMPOSITION AS RECAST			TOTAL FELDSPAR
		Ab.	An.		K-Feld.	Na-Feld.	Ca-Feld.	
Albite	Greenland	99.5	0.5	1908	2.	98.	N.D.	98.78
Oligoclase	Bamle, Norway	87.	13.	1869	2.	84.	14.	—
Oligoclase	Bakersville	80.	20.	1888	3.3	74.5	22.2	98.07
Basic Oligoclase	Tvedestrand	75.	25.	1845	7.45	69.62	22.93	—
Andesine	Hohenstein	65.	35.	—	2*	61.	37.	98.92
Bytownite	Narodal	27.	73.	1869	2*	24.	74.	—

* K_2O not determined. Assumed 2% K-Feld., and subtracted it from Na-Feld.

as it does to me,[20] anorthoclase. But Barth is uncertain "whether the potash feldspar is pure or whether it is an anorthoclase." How can it be a pure[21] monoclinic feldspar with an extinction angle 1° to 3°? He says some grains show an extinction of 4° to 5° and microcline cross-hatching. He gives me the impression that he calls this feldspar microcline, without realizing that many anorthoclases exhibit this type of twinning. Twinning alone is no safe criterion.[22]

Barth measured the indices of refraction of "crystals . . . . said to consist mainly of orthoclase." His results with sodium light are: $N_g = 1.5288$, $N_m = 1.5270$, $N_p = 1.5230$.

In applying these results to the diagrams furnished by Winchell[23] and modified by Alling,[24] difficulty is experienced in making them fit. It makes no difference what series is attempted. The γ-feldspars: sanidine-barbietite, the β-feldspars: orthoclase-albite, or the α-feldspars: microcline-analbite. In any case, it is impossible to obtain results from Barth's determinations that in any way approach pure potash feldspar. Applying it to the orthoclase-albite system, ignoring for the moment any lime component, results crudely approximate Or_{50}, Ab_{50}, and if applied to the γ-feldspars, results are in the neighborhood of microcline 75, and analbite 25.

[20] Alling, H. L., *Jour. Geol.*, Vol. 29, **1921,** p. 231.

[21] Meaning 100% $KAlSi_3O_8$?

[22] Alling, H. L., *Jour. Geol.*, Vol. 31, **1923,** pp. 357–358, 374.

[23] Winchell, A. N., *Jour. Geol.*, 33, **1925,** pp. 714–727.

[24] Alling, H. L., *Jour. Geol.*, 34, **1926,** p. 604.

Barth gives indices of refraction for the "microcline" which gives the extinction angle on the (001) phase, 15°, as follows: $N_g = 1.5293$, $N_m = 1.5268$, $N_p = 1.5225$. In applying these data to the microcline-analbite system it shows a very high percentage of soda.

Barth's conclusions are as follows, to which I have added my comments:

1. That there are two clearly separate stages of crystallization. To this I agree.
2. The andesine-labradorite is potash free. To this I do not agree.
3. Late stage feldspar; potash free oligoclase and comparatively *pure* (my italics) potash feldspar. This I cannot accept.
4. Pure labradorite melts at about 1300° C. This is true in *dry* melts at *normal* pressure which Barth recognizes.
5. Potash feldspar melts at about 1000° C. Morey and Bowen[25] have shown that potash feldspar has no true melting point; it melts incongruently.

My Conclusions

1. The plagioclase of the Adirondack anorthosites consists of labradorite grading into andesine with an appreciable though small percentage of potash feldspar in solid solution.
2. Late stage interstitial feldspars are soda-rich anorthoclases and potash bearing oligoclases. The latter may be untwinned.

[25] Morey, G. W., and Bowen, N. L., *Am. Jour. of Sci.*, (5), Vol. 4, **1922**, pp. 1–22.