THE VOLCANOES AND ROCKS OF PANTELLERIA

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PART III

PETROLOGY

Chemical characters.—All of my analyses of the Pantelleria rocks, with their norms, are given in Tables I and II. Those of Foerstner are omitted for reasons to be given later. They are sharply divided into a large group with high silica, varying from 63.30 to 72.21, and a smaller, the basalts, with about 46 per cent of silica. So far as known, from Foerstner's publications, my own observations, and Butler's collection, there are no rocks of intermediate composition.

Considering the larger group first, rather high alumina is found only in two or three cases, this constituent being in most of the rocks unusually low for rocks of such moderately high silicity—if the coining of a new word on the analogy of acidity and basicity be permissible. On the other hand, the iron oxides are distinctly high, especially in the pantellerites, going hand in hand with low alumina. Magnesia is uniformly low, as is lime, the latter rarely attaining more than 1 per cent. The alkalies are distinctly high, with soda dominant over potash, the latter being remarkably uniform. Titanium is remarkably high for rocks of this silicity and alkalinity. Phosphorus and manganese are both rather above the normal, but zirconia is low for sodic rocks, and only traces of barium are present. Traces of nickel seem to be commonly present, but tests failed to reveal the copper reported by Foerstner.

The basalts are very uniform in composition and show only one especially noteworthy character—the high titanium content.[1] Magnesia is not high for basalts of this general composition (camptonose) and alumina is distinctly low, much lower indeed than the

[1] H. S. Washington, *Q.J.G.S.*, LXIII (1907), 76.

TABLE I

Analyses of Pantellerian Lavas

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
SiO_2	65.27	63.43	63.30	64.54	63.77	72.21	70.14	69.79	67.32	69.91	66.07	69.33	67.85	46.40	46.22	45.72	44.83
Al_2O_3	13.50	16.31	16.38	11.49	11.18	9.72	8.61	11.91	9.55	8.58	11.74	8.62	12.87	14.34	12.23	12.45	11.73
Fe_2O_3	4.40	2.04	2.54	5.14	5.02	3.26	6.01	5.35	6.73	1.81	2.05	2.65	1.84	4.09	4.91	1.57	1.35
FeO	2.52	3.14	2.36	2.99	2.58	1.07	2.73	1.43	0.81	5.86	5.88	5.52	4.54	8.22	7.71	12.01	11.79
MgO	0.55	0.78	0.84	0.89	0.51	0.29	0.20	0.25	0.20	0.28	0.13	0.52	0.30	7.00	6.74	5.29	5.50
CaO	0.85	1.70	1.62	0.64	1.37	0.82	0.45	0.25	0.20	0.33	0.46	0.52	0.17	9.85	9.86	9.58	9.63
Na_2O	5.19	6.71	6.36	5.46	5.55	4.42	5.44	5.66	5.71	6.41	6.89	4.78	6.03	3.59	3.39	3.40	3.34
K_2O	4.21	4.31	4.41	4.66	4.35	4.98	4.20	4.59	4.48	4.71	4.80	4.71	4.83	1.00	1.13	1.08	1.40
H_2O+	1.98	0.18	0.83	1.11	2.72	1.96	0.35	0.17	3.15	0.22	0.43	2.35	0.13	0.14	0.17	0.40	0.81
H_2O-	0.14	0.26	0.10	2.12	1.28	0.24	0.17	0.04	0.49	0.13	0.03	0.27	0.02	0.08	0.05	0.01	0.10
TiO_2	1.09	1.19	0.71	0.90	0.94	0.62	0.86	0.89	0.59	0.75	0.92	0.85	0.83	4.54	5.68	6.43	6.88
ZrO_2	......	0.06	......	0.08	......	......	0.14	......	......	......	0.12	......	......	none	......	......	......
P_2O_5	0.17	0.20	0.30	0.16	0.14	0.10	0.12	0.13	0.08	0.16	0.18	none	0.08	0.85	1.46	1.54	2.14
SO_3	......	0.05	......	0.17	......	......	0.06	......	......	......	0.23	......	......	0.12	......	......	......
MnO	0.27	0.04	......	0.13	0.26	0.05	0.38	0.20	0.24	0.24	0.16	0.27	......	0.25	......	0.16	0.20
NiO	......	......	......	......	......	......	......	......	......	......	none	......	......	......	......	0.15	......
BaO	......	0.05	......	none	......	......	none	......	......	......	......	......	......	0.09	......	......	......
SrO	......	......	......	......	......	......	......	......	......	......	......	......	......	0.03	......	0.03	......
	100.14	100.45	99.75	100.48	99.67	99.74	99.86	100.66	99.55	99.39	100.09	100.39	99.49	100.59	99.55	99.82	99.70

A. Trachyte [I(II). 4. 1. (3) 4]. Costa Zichidi.
B. Trachyte [I (II). 5. 1. 4]. Montagna Grande.
C. Trachyte [I (II). "5. 1". "4]. Monte Gibele.
D. Pantelleritic trachyte [II. 4. 1. 3]. Costa Zeneti.
E. Pantelleritic trachyte [II. 4. 1. 3'']. Punta Pozzolana.
F. Comendite [(I) II. (3) 4. 1. 3]. Cuddia Nera.
G. Aegirite pantellerite [II. (3) 4. 1. 3]. Monte Sant' Elmo.
H. Aegirite pantellerite [II. 4. 1. 3]. Costa Zeneti.
I. Pantellerite pumice [II. 4. 1. 3]. Rione Buccarame.
J Hyalopantellerite [II. 3 (4). 1. (2) 3]. Monte Gelkhamar.
K. Hyalopantellerite [II. 4. 1. 3]. Khagiar.
L. Hyalopantellerite [II. 3 (4). 1. (2) 3]. Cantina Ziton.
M. Pantellerite obsidian [II. 4. 1. 3]. Costa Zeneti.
N. Basalt [III. 5. 3. 4]. Cuddia Ferle.
O. Basalt [III. 5. 3. 4]. Monte Sant' Elmo.
P. Basalt [III. 5. 3. 4]. Dike, Costa Zeneti.
Q. Basalt [III. 5. (2) 3. 4]. Foerstner Volcano, 1891.

TABLE II

Norms of Pantellerian Lavas

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Q	17.10	3.90	5.58	15.12	14.34	31.14	27.60	21.78	22.44	28.38	14.70	28.02	15.36	......	......	......	......
Or	25.02	25.58	26.13	27.80	26.13	29.47	25.02	27.24	26.69	27.80	28.36	27.80	28.36	6.12	6.67	6.12	8.34
Ab	44.01	56.59	53.97	33.01	33.01	22.01	20.44	35.63	24.10	17.82	33.54	17.82	39.30	28.30	28.82	28.82	28.30
An	0.83	1.67	3.06	......	......	......	......	......	......	......	......	......	......	20.02	14.73	15.57	12.79
Ne	......	......	......	......	......	......	......	......	......	......	......	......	......	1.14	......	......	......
Ac	......	......	......	11.55	12.47	9.24	17.56	10.63	19.40	5.08	6.01	7.85	5.54	......	......	......	......
Ns	......	......	......	......	......	1.10	1.34	......	0.49	7.08	4.15	3.17	1.22	......	......	......	......
Di	1.94	4.83	2.48	1.76	5.20	2.57	1.21	......	......	0.75	1.24	2.16	......	18.81	19.54	18.77	17.22
Hy	0.50	1.59	1.96	3.38	1.42	0.46	4.10	0.60	1.03	10.34	9.01	9.28	7.80	......	8.06	5.74	5.21
Ol	......	......	......	......	......	......	......	......	......	......	......	......	......	9.32	0.28	6.29	6.78
Mt	5.57	3.02	3.71	1.62	0.93	......	......	2.09	......	......	......	......	......	6.03	7.19	2.32	2.09
Il	2.13	2.28	1.37	1.67	1.82	1.22	1.67	1.67	1.42	1.37	1.82	1.67	1.52	8.66	10.79	12.16	13.07
Hm	0.64	......	......	......	......	......	......	0.32	......	......	......	......	......	......	......	......	......
Ap	0.34	0.34	0.67	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	......	0.34	2.02	3.36	3.36	5.04

general run of camptonose magmas. The iron oxides, lime, the alkalies, and manganese are about normal, while phosphorus is decidedly high.

The *norms* show some interesting features. The entire absence of anorthite, except in the most salic and most femic extremes, and the poverty in diopside, except in the basalts, are striking, as well as the abundance of excess silica (normative quartz) in all except the trachytes and basalts. Still more striking are the abundance of acmite and the prevalence of sodium metasilicate along with it in all except the extremes just mentioned, and the large amounts of ilmenite.

Foerstner's analyses.—It is always an unpleasant task to criticize adversely the work of another, but in the present case such a course seems to be unavoidable, as Foerstner's analyses, especially of the pantellerites, have been widely quoted and accepted as accurate, being the only ones heretofore available for these rocks. The numerous new analyses, most carefully made according to modern methods, indicate that those given by Foerstner are incorrect and incomplete in certain important particulars, and that many of them are subject to errors, apparently systematic in character. The comparison is shown in the accompanying table,

TABLE III

COMPARISON OF OLD AND NEW ANALYSES

		1	2	3	4	5	6	7	8	9	10
SiO_2...	F	61.43	61.47	67.48	70.30	69.61	68.75	68.33	49.87	49.35	44.64
	W	65.27	63.43	70.14	69.79	66.07	69.91	69.33	46.40	46.22	44.83
Al_2O_3..	F	17.51	18.09	9.70	6.32	8.02	5.91	10.94	14.80	15.71	12.74
	W	13.50	16.31	8.61	11.91	11.74	8.58	8.62	14.34	12.23	11.73
Fe_2O_3..	F	5.11	5.14	7.42	9.23	7.17	5.81	3.74	8.25	7.44	4.21
	W	4.40	2.04	6.01	5.35	2.05	1.81	2.65	4.09	4.91	1.35
FeO...	F	2.30	3.06	2.21	1.40	2.83	5.33	5.41	6.88	6.96	11.17
	W	2.52	3.14	2.73	1.43	5.88	5.86	5.52	8.22	7.71	11.79
MgO..	F	0.54	1.32	0.77	0.89	0.65	0.08	0.16	6.77	5.71	5.82
	W	0.55	0.78	0.20	0.25	0.13	0.28	0.52	7.00	6.74	5.50
CaO...	F	2.45	3.00	1.45	0.84	0.88	2.11	1.36	9.36	9.80	10.12
	W	0.85	1.70	0.45	0.25	0.46	0.33	0.52	9.85	9.86	9.63
Na_2O..	F	6.22	5.85	7.21	7.70	7.47	7.52	7.09	2.81	2.96	4.31
	W	5.19	6.71	5.44	5.66	6.89	6.41	4.78	3.59	3.39	3.34
K_2O...	F	3.95	2.83	2.94	2.50	2.88	4.28	4.08	0.68	1.31	1.41
	W	4.21	4.31	4.20	4.59	4.80	4.71	4.71	1.00	1.13	1.40
TiO_2...	F	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	5.86
	W	1.09	1.19	0.86	0.89	0.92	0.75	0.85	4.54	5.68	6.88

1, 2. Trachyte
3, 4. Aegirite pantellerite
5, 6, 7. Hyalopantellerite
8, 9, 10. Basalt

in which, so far as possible, analyses by both of us of rocks from the same locality or flow are incorporated.

Foerstner's ferric oxide, lime, and soda are uniformly, and often much, higher than mine, except for the lime and soda in the basalts, and the tendency of his magnesia is also to run higher. His alumina is distinctly higher than mine in the trachytes, while in the pantellerites it is generally lower, as it would also be in his basalts were the 4 or 5 per cent of titanium dioxide and phosphoric oxide present subtracted. His potash is markedly lower in the salic group. Only his figures for silica and ferrous oxides run about the same as mine, though even here some great discrepancies are to be noted.

These differences, especially those in ferric oxide, lime, soda, potash, and alumina, are very striking, and so uniformly in the same respective directions as to suggest systematic errors in his analytical methods as the explanation. What these have been it is difficult, if not impossible, to decide definitely, but, without entering into a detailed discussion, they may be ascribed to the inadequate methods prevailing at the time (prior to 1883), and probably in part to impurities in his reagents. It will be noted that his latest analysis, that of the lava of 1891, most closely resembles the corresponding one of mine.

Whatever be the explanation, the discrepancies here pointed out are, for the most part, so serious and so systematic, and the incompleteness so marked, especially as regards titanium, phosphorus, and water, that Foerstner's analyses of the Pantellerian rocks must be considered as of inferior quality and doubtful utility.

Modal characters.—Leaving the basalts out of consideration the lavas of Pantelleria show some very striking modal characteristics. The small amount of quartz, considering the silicity of the rocks, and its great rarity as phenocrysts, are very unusual. Its small amount is, of course, due to the abundance of alkali feldspar and of aegirite. As Na_2O in aegirite takes up four times its amount of silica (molecularly), much less silica is left uncombined than would be the case in a rock of the same silicity but carrying only ordinary pyroxenes in which the ratio of RO to SiO_2 is 1 to 1.

The exclusively alkalic character of the feldspars, and the absolute lack of nephelite and soda-lime plagioclase are very striking. The soda-microcline phenocrysts very seldom show multiple twinning lamellae or the usual grating structure, but Carlsbad twins of simple individuals are common. The composition, judging from the rock analyses and norms, is somewhat variable, between Or_3Ab_2 to Or_2Ab_3, but will average somewhere about Or_1Ab_1.

Since this paper was written, Dr. H. E. Merwin has very kindly examined optically the feldspar phenocrysts of some of the lavas. In the pantellerites of Zeneti, Khagiar, Gelkhamar, and Cuddia Nera, he finds they have refractive indices (α=about 1.527) corresponding to an albite content of not more than 30 to 40 per cent. We have seen that the average feldspar of these rocks, while somewhat variable, is about Or_1Ab_1, which indicates that the small feldspars of the groundmass are much higher in albite than in orthoclase. The phenocrysts of the Montagna Grande trachyte, however, are relatively higher in albite and approach more nearly to the average composition, Or_1Ab_1. The study of these feldspars is, as yet, but preliminary, and a chemical and optical investigation will be taken up in detail in the near future, but the evidence goes to show that the soda tends to remain in solution longer than the potash.

The abundance of sodic pyroxenes and hornblendes, namely, aegirite, aegirite-augite, cossyrite, and possibly kaersutite, and the poverty in non-sodic augite and hypersthene are also notable. It is also interesting to remark on the absence of *blue* sodic hornblendes, as riebeckite, arfvedsonite, or crossite, riebeckite especially being commonly found in sodic rocks of high silicity. A paper by Murgoci,[1] in which he correlates the presence of riebeckite with zirconium and fluorine as "mineralizers," and katoforite (and cossyrite) with titanium, is interesting in this connection, since on Pantellaria we find titanium high and zirconium low, with no evidence of the presence of fluorine.

It is also noteworthy that only a small part of the aegirite and cossyrite is in the form of phenocrysts, the greater part of these minerals being in the groundmass, or, as is well seen in the hyalopantellerites, not crystallized at all. Here we see the same tendency of the soda to remain in solution as was observed with the feldspars.

[1] G. M. Murgoci, *Am. Jour. Sci.*, XX (1905), 133.

The complete absence of biotite and the great poverty or generally absolute lack of the more salic rocks in magnetite and ilmenite are very characteristic. The rather common presence, though in very small amounts, of olivine in these rocks is interesting. The investigation of Soellner,[1] with analysis by Dittrich, shows that it is an almost purely ferrous fayalite. As is well known, the olivine found elsewhere in highly silicic rocks, as granite and rhyolite, is always fayalite, not common olivine or the magnesian forsterite. The entire absence of nephelite tephrites and basanites is remarkable in view of the highly sodic character of the general magma.

Norm and mode.—The rocks show some interesting relations between the norm and mode. They are quite normative as regards the quartz and feldspars, both soda-microcline and andesine-labradorite, and only slightly abnormative as regards the augite of the trachytes and basalts, and the aegirite of the aegirite pantellerites. The departure of the mode from the norm is, however, very marked in the presence of the sometimes abundant cossyrite and the presence of small amounts of fayalite in the pantellerites.

It is interesting to note that the presence of the soda-hornblende, cossyrite, goes hand in hand with normative sodium metasilicate. In some cases, as in the trachytes, a very little cossyrite is present with neither acmite nor sodium metasilicate in the norm, but in general the amount of this mineral is correlated directly with that of sodium metasilicate in the norm, the rocks richest in cossyrite, especially as phenocrysts, showing most excess of soda over alumina. On the other hand, the rocks, in which aegirite is largely dominant over cossyrite, the aegirite pantellerites, and comendites, show very little or no sodium metasilicate, but, in general, large amounts of acmite in the norm.

This relation between sodium metasilicate and cossyrite, the norm of which shows 8.66 per cent of sodium metasilicate, furnishes an instructive commentary on Harker's[2] criticism that the norm may contain compounds "which are foreign to igneous rocks and some of which are not known in nature." Cross[3] has briefly dis-

[1] J. Soellner, *Zeits. Kryst.*, XLIX (1911), 138.

[2] A. Harker, *Natural History of Igneous Rocks*, London, 1909, p. 365.

[3] W. Cross, *Q.J.G.S.*, LXVI (1910), 499.

cussed this point, and points out that the great majority of the normative mineral molecules are those that Harker himself would necessarily choose.

In many of the rocks now under discussion accurate chemical analysis shows that more than enough soda is present to combine with silica and alumina, or with silica and ferric oxide, as potential or actual albite or aegirite respectively. This excess of soda is an important chemical feature of the rocks and, as among rock-making minerals we find soda always as silicates (except in the sodalite group), it is natural and justifiable to state this excess in the norm as Na_2SiO_3, of course without the implication that a mineral of this composition actually exists. When we find, as we do here, that the rocks showing this sodium metasilicate in the norm are likewise rich in cossyrite, and that this mineral itself contains a large excess of soda, presumably as metasilicate, the procedure adopted seems amply justified. A similar reasoning applies to the other "unnatural minerals" objected to by Harker, kaliophilite, akermanite, wollastonite, and potassium metasilicate. The last of these, by the way, is present in the norms of only three rock analyses.

TABLE IV

AVERAGES OF ROCK TYPES OF PANTELLERIA

	I*a*	I	I*b*	II*a*	II	II*b*	III
SiO_2.....	66.85	69.30	71.75	63.46	66.27	69.08	46.09
Al_2O_3....	11.82	11.02	10.23	16.36	13.47	10.58	12.77
Fe_2O_3....	5.29	5.12	4.94	2.29	2.20	2.11	2.95
FeO......	2.91	2.12	1.33	3.26	4.38	5.50	9.99
MgO.....	0.73	0.49	0.25	0.81	0.56	0.31	6.17
CaO......	1.04	0.78	0.52	1.66	1.02	0.37	9.82
Na_2O....	5.32	5.25	5.18	6.55	6.32	6.10	3.43
K_2O.....	4.71	4.69	4.67	4.37	4.60	4.82	1.16
TiO......	0.96	0.88	0.80	0.95	0.90	0.85	5.91
P_2O_5.....	0.16	0.14	0.12	0.25	0.18	0.11	1.51
MnO.....	0.21	0.21	0.21	0.04	0.10	0.17	0.20

Succession of magmas.—The change in composition of the magma during the successive eruptive phases offers some features of interest. The averages of the analyses of the several types—each representing a distinct volcanic episode—are shown in Table IV.

They are calculated to 100, free from water and the very minor constituents. The analyses of the comendite and of the Zichidi trachyte are not included, as their place in the succession is uncertain.

I*a* and I*b* are the averages respectively of the early pantelleritic trachytes and the aegirite pantellerites, I being the average of these, representing the composition of the first phase. II*a* and II*b* are the averages of the trachytes and the hyalopantellerites, II being the average of these and representing the composition of the second phase. III is the average of the final basalts, including that of 1891.

The first two phases show a marked repetition in the magmatic succession, a beginning of which is apparently repeated in the basaltic phase. Starting with the pantelleritic trachytes, there is first a rise in silica and a fall in the other constituents (that in K_2O being slight) to the pantellerites which formed the last flows of this phase. After the formation of the caldera the magma returns toward or beyond its original composition, as shown in the fall in silica (and potash) and the rise in the others. Then the change shown in the first phase is repeated, silica and potash rising and the others falling in the hyalopantellerites. After the cessation of these flows the basalts show a change in the magma in the same directions (except the alkalies) but to a greater extent as between phases I and II. The iron oxides do not conform to the courses of the other oxides, but there is a steady increase in the ratio of ferrous to ferric oxide, and first a decrease and then an increase in their total amount. The averages of the whole phases (I and II) show the general trend of the magma to a more femic composition.

In the absence of any accurate data as to the relative volumes of the various types no satisfactory estimate can be made at present of the average Pantellerian magma, but a general consideration of the various flows and cones suggests that probably the average I*a* roughly represents this. If this be so, the order of succession corresponds well with that enunciated by von Richtofen and Iddings, namely: beginning with the mean and ending with an extreme (generally the most femic) after few or more alternations.

The interesting feature about the present case is that the most abrupt changes in the magma seem to be correlated with maxima of intensity in vulcanicity, marked by the caldera formation and the dislocation of the Montagna Grande block. Far too little systematic study has as yet been made at any volcano of the change in the chemical characters involved in the succession of flows, in connection with variations in the intensity of the volcanic action, to permit any proper discussion or generalization. It may be said, however, that a causal connection between the two seems to be possible.

The general succession is strikingly like that seen in Sardinia, the rocks of which will be described in forthcoming papers. Here we find the pre-Tertiary sheets beginning with rhyolites, passing to trachytes, and apparently ending with basalts. The later large volcanoes of Monte Ferru and Monte Arci also poured out first trachytes and rhyolites, followed by large flows of basalt, which also forms the product of the most recent small cones.

Comparison with other regions.—Rocks analogous to the pantellerites, comendites, and trachytes of Pantelleria are not very abundant, but are quite widely distributed over the earth. The region most nearly like it is that of Afarland and French Somali described by Arsandaux.[1] The resemblance is very close and is emphasized by Arsandaux, who was able to study specimens from Pantelleria also. He describes both lithoidal and glassy pantellerites, which correspond to the two main types on Pantelleria, except for the irregular occurrence of quartz phenocrysts; and also "microgranites," trachytes, and glassy rhyolites with aegirite, riebeckite, and some cossyrite. Except for the occasional presence of quartz phenocrysts and the replacement of cossyrite by riebeckite, the resemblance between these rocks and those of Pantelleria is most striking, extending even to details such as the felt of aegirite needles and small areas of micropoikilitic quartz. Associated with these rocks are basalts of ordinary feldspathic types.

In their chemical features the Somali rocks are like those of Pantelleria, the only notable difference being the smaller amount of soda. Arsandaux did not determine titanium, so we are ignorant as to this.

[1] H. Arsandaux, *L'Étude des roches alcalines de l'Est-africain,* Paris, 1906, pp. 39, 45.

It is of special additional interest to note that, analogously to Pantelleria, the Somali lavas are divided into a large group of pantellerites, rhyolites, and trachytes, with silicity from 76.0 to 66.5 per cent, and a smaller of basalts, the silicity of which runs from 50.1 to 46.2; and that there are no phonolites, kenytes, or other intermediate types here. A further resemblance is that the basalts are "always the most recent of the volcanic series to which they belong." The general silicity of the Somali rocks is higher than that of Pantelleria.

Another analogous region is that of British East Africa, including the Rift Valley, described by Prior,[1] and Mt. Kenya described by Gregory.[2] Both of these geologists call attention to the resemblance of some of the more silicic lavas to those of Pantelleria. These highly sodic rocks are accompanied by plagioclase basalts of ordinary types, though no analyses were made of them. At Mt. Kenya these basalts are the last eruptive products. This region differs from Pantelleria and Somali in the abundance of phonolite, kenyite, and other nephelite-bearing lavas.

Similar rocks have also been described from Eritrea, Abyssinia, Masai Land, Madagascar, Aden, and Sokotra; and farther away they have been met with in Japan, Australia, New Zealand, Germany, and Texas.

Closely allied to the Pantellerian lavas, both chemically and modally, but of paleotypal habit and occurring as intrusive dikes and other bodies, are grorudites, sölvsbergites, and paisanites of Greenland, Norway, Massachusetts, Texas, and elsewhere.

It is a noteworthy fact, bearing on the discussion of the norm on a previous page that sodium metasilicate usually appears in notable amount in the norms of these rocks which carry arfvedsonite, while it is either less or absent in the norms of those which contain only aegirite or aegirite-augite.

Attention may also be called to a feature of igneous rocks which carry aegirite or sodic hornblende, which is in accord with the principles adopted in establishing the norm. This is that such rocks

[1] G. T. Prior, *Min. Mag.*, XIII (1903), 228.

[2] J. W. Gregory, *Q.J.G.S.*, LVI (1900), 205. No analyses given.

only rarely contain soda-lime feldspars, the felsic minerals being almost without exception alkali feldspars, with or without quartz or nephelite. Corresponding to this, the norms of such rocks seldom show anorthite, the apparent presence of this in some cases being certainly due to a too high figure for alumina because of the non-determination of titanium and phosphorus. The norms of such rocks very frequently show acmite, and less often sodium metasilicate, or would show it were the alumina correctly low, while acmite seldom occurs in the norms of any but such sodic pyroxene and amphibole-bearing rocks.