# *On Sericite from North Wales and on Penninite and Labradorite from Ireland.*

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FOR the first of the three minerals to be described in the following pages we are indebted to Mr. W. G. Fearnsides, who collected it in North Wales in the autumn of 1908, and we desire to express our best thanks to him for the readiness with which he placed at our disposal enough suitable material for a complete analysis. The other two minerals were collected by ourselves.

## 1. Sericite from North Wales.

This mineral occurs in an old road-metal quarry, one mile west of Tan-y-Bwlch, Merioneth, North Wales. It is found in open joints and veins in quartz strings which transgress a dolerite sill and extend into the country-rock, a hard member of the Lingula Flags. The mineral forms irregular talc-like aggregates readily cleaving into very small plates. The colour is pale green, thin flakes being almost colourless.

The specific gravity was found by suspension in a heavy liquid to be 2·798, as compared with water at 4° C. Two refractive indices, $\beta$ and $\gamma$, measured by Schroeder van der Kolk's method on cleavage fragments, were found to be 1·589 and 1·594 respectively. Cleavage flakes show a biaxial interference-figure, the acute bisectrix being normal to the cleavage. The sign of the double refraction is negative. Dispersion weak, $\rho > v$. The angle 2E between the optic axes in air was found by measuring the distance between the optic eyes by means of a micrometer eye-piece provided with a travelling cross-wire. A value for E was then obtained by Mallard's formula $D = K \sin E$, the value of K for the microscope being determined by the aid of minerals of known optic axial angle, near to that of the sericite. The mean of several determinations gave $2E = 68^\circ\ 50'$ for sodium-light. A percussion-figure was obtained in which the leading-ray was at right angles to the plane of the optic axes.

Great care was taken in selecting material for analysis, and under the microscope it was seen to be free from quartz and to contain no inclusions. Total water was determined on about one gram of the fine powder by strong ignition in a current of dry air, the platinum boat containing the sample being placed in a tube of silica glass which was enclosed in a furnace made from a plumbago crucible and heated over a powerful blast. The water was absorbed in a weighed U-tube containing concentrated sulphuric acid. After the total water had been determined, the powder was fused with sodium carbonate and the other constituents estimated by the methods described by Hillebrand and Washington. Alkalis were determined on 0·8 gram by the method of Lawrence Smith. Samples of 0·5 gram were used for the estimation of ferrous iron, while hygroscopic water was determined by heating one gram of the powdered mineral in a toluene bath.

The results of two concordant analyses are given in columns I and II of the table below. Column III gives the mean of these, column IV the corresponding ratios, while in columns V and VI are quoted for comparison analyses by Fraatz[1] of a sericite from Werlau, and by S. Blau[2] of a muscovite from Bengal; a very similar analysis to the last has been published by L. Sipöcz.[3]

| | I. | II. | III. | IV. | V. | VI. |
|---|---|---|---|---|---|---|
| $SiO_2$ | 46·50 | 46·51 | 46·51 | 0·7702 | 45·58 | 45·57 |
| $Al_2O_3$ | 36·63 | 36·52 | 36·58 | 0·3580 | 36·76 | 36·72 |
| $Fe_2O_3$ | 0·54 | 0·48 | 0·51 | 0·0032 | 1·13 | 0·95 |
| FeO | 0·49 | 0·46 | 0·48 | 0·0067 | — | 1·28 |
| CaO | 0·42 | 0·46 | 0·44 | 0·0078 | — | 0·21 |
| MgO | 0·44 | 0·48 | 0·46 | 0·0114 | 0·85 | 0·38 |
| $K_2O$ | 7·79 | 7·89 | 7·84 | 0·0831 | 9·29 | 8·81 |
| $Na_2O$ | 1·71 | 1·84 | 1·77 | 0·0283 | 1·36 | 0·62 |
| $H_2O$ + | 4·92 | 5·14 | 5·03 | 0·2793 | 5·16 | 5·05 |
| $H_2O$ (105°) | 0·11 | 0·11 | 0·11 | — | | |
| F | — | — | — | — | — | 0·15 |
| $Li_2O$ | — | — | — | — | — | 0·19 |
| Total | 99·55 | 99·89 | 99·73 | – | 100·13 | 99·93 |
| Sp. gr. | — | — | 2·798 | — | 2·875 | 2·831 |

The results given above show that silicon and oxygen are present in

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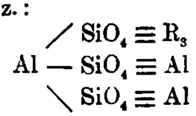
[1] A. Groddeck, Neues Jahrb. Min., 1883, Beil.-Band ii, p. 90.

[2] S. Blau, Tschermak's Min. Mitt., 1873, p. 32.

[3] L. Sipöcz, ibid., 1878, p. 31.

almost exact orthosilicate ratios, the mineral conforming closely to type 1 of Clarke's formulae,[1] viz.:



It can be represented as a combination of this type with small quantities of types 3 and 4.

## 2. PENNINITE FROM RECESS, COUNTY GALWAY, IRELAND.

This mineral occurs in veins and joints in the ophicalcite, the so-called 'Connemara marble', which is quarried at Recess, County Galway.

It forms hexagonal plates which are sometimes 1 cm. across. These plates are flexible but not elastic, they possess a perfect basal cleavage, and are transparent and colourless to pale brown. The specific gravity is 2·619 as compared with water at 4° C. The double refraction is weak and the optical properties often vary even in the same plate, for though usually optically positive and sensibly uniaxial, plates are found which exhibit biaxial portions, while other plates again are negative in character. The plates give a percussion-figure whose leading-ray is parallel to the optic axial plane in the biaxial portions. A determination of the index of refraction for sodium-light by a total reflection method gave a value of 1·551.

When heated before the blowpipe the mineral glowed strongly, remained white, and did not swell up. It was just fusible when in thin flakes.

Carefully selected material was used for the analyses, which were carried out by the methods described above. Fluorine and lithium were tested for but proved to be absent. The precipitates of aluminium hydroxide and of magnesium ammonium phosphate were purified by three precipitations. The results of the analyses are given in columns I and II, the mean of these in III, and the ratios in columns IV and V.

| | I. | II. | III. | IV. | V. |
|---|---|---|---|---|---|
| $SiO_2$ | 34·85 | 34·78 | 34·81 | 0·5763 | 0·5763 |
| $Al_2O_3$ | 16·43 | 16·00 | 16·21 | 0·1586 | 0·1654 |
| $Fe_2O_3$ | 1·05 | 1·13 | 1·09 | 0·0068 | |
| FeO | 0·36 | — | 0·36 | 0·0050 | 0·7630 |
| CaO | 0·95 | 0·55 | 0·75 | 0·0134 | |
| MgO | 30·03 | 30·07 | 30·05 | 0·7446 | |
| $K_2O$ | 1·71 | 1·99 | 1·85 | 0·0196 | 0·7251 |
| $H_2O+$ | 12·70 | 12·72 | 12·71 | 0·7055 | |
| $H_2O$ (105°) | 1·82 | 1·97 | 1·89 | 0·1051 | |
| | | | 99·72 | | |

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[1] F. W. Clarke, Amer. Journ Sci., 1889, ser. 3, vol. xxxviii, p. 385.

It does not appear possible to deduce any satisfactory formula from these numbers, but if the water driven off below 105° is omitted and $Fe_2O_3$, FeO, CaO, and $K_2O$ are replaced by equivalent quantities of $Al_2O_3$, MgO, and $H_2O$ respectively, then the empirical composition of the substance is approximately represented by the formula $H_{23}Mg_{12}Al_5Si_9O_{49}$.

On comparing the composition of this mineral with that of other members of the chlorite group, it will be seen that it presents the greatest analogy to a compact variety of penninite called pseudophite,[1] from which, however, it differs in that it occurs in fairly developed crystals.

## 3. LABRADORITE FROM COUNTY DOWN, IRELAND.

Among the many dykes intruded in the slates and exposed along the shore of County Down two in particular long ago attracted attention on account of the extraordinary size of their felspar phenocrysts, which are often 5 to 6 cm. long and 3 to 4 cm. wide, and sometimes attain much greater dimensions. These dykes occur just below the lighthouse at St. John's Point near Ardglass, and were briefly described by Traill and Egan[2] in 1871. They vary in width from four to six feet, and it is in their wider parts that the porphyritic habit is best developed.

The phenocrysts are set in a black, very compact groundmass, in which a few round patches of black glass, about 1 mm. in diameter, are the only constituents which can be made out with the naked eye. Under the microscope this groundmass is seen to consist very largely of short laths of plagioclase felspar showing albite-twinning. These give a maximum extinction angle of 30°, corresponding to labradorite. The interstices between the felspars are filled up by augite, magnetite, and green glass. The augite occurs, not as granules, but as groups of closely packed and strictly parallel straight rods of a pale violet colour bordered by minute cubes of magnetite. There is no apparent relation between the orientation of these rods in the separate groups. Similar growths of augite and magnetite have been observed in many basic rocks, some peculiar forms

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[1] Compare analyses by: R. v. Drasche, Tschermak's Min. Mitt., 1873, p. 126; W. Gintl, ibid., 1874, p. 7; K. v. Hauer, Sitz.-Ber. Akad. Wien, 1855, vol. xvi, p. 170; V. Wartha, Zeits. Kryst. Min., 1887, vol. xiii, p. 72; P. von Groth, ibid., 1877, vol. i, p. 509; E. Cohen, ibid., 1888, vol. xiv, p. 409; M. F. Heddle, Mineralogical Magazine, 1880, vol. iii, p. 188; H. Fox, ibid., 1892, vol. ix, p. 275.

[2] W. A. Traill and F. W. Egan, Mem. Geol. Surv. Ireland, 1871, sheets 49, 50, and part of 61, p. 58.

having been described recently by Bailey[1] from Argyllshire and by Prior[2] from Natal. In the present case, however, none of these complex branching growths occur, only simple straight rods being observed. The round patches of glass mentioned above are very irregularly distributed, two or three often occurring close together. They consist of a dark brown or green, almost opaque glass showing incipient devitrification. They no doubt represent segregations of the glassy residue left after the separation of the crystalline constituents.

The phenocrysts of plagioclase all show albite-twinning frequently combined with Carlsbad-twinning. Zonary banding is almost entirely absent, but near the borders there are often lines of very small inclusions of augite and magnetite which follow the outline of the crystal. The crystals occasionally contain irregular patches of the groundmass, and sometimes present rounded edges. On the whole, however, the felspar of the phenocrysts is seen to be of a high degree of purity, and therefore affords excellent material for optical and chemical investigation.

In the hand-specimens the phenocrysts are of a greenish-yellow tinge. They are invariably tabular parallel to *b*(010), and are terminated by faces which are probably *c*(001) and *x*($\bar{1}$01). The cleavages parallel to *c*(001) and *b*(010) are both perfect, and give faces which afford good reflections on the goniometer. The angle (001) : (010) is 85° 57′. On twinned fragments the angle between the two *c* cleavages was found to be 8° 8′, corresponding to 85° 56′ for (001) : (010).

The extinction-angles measured on cleavage fragments are:

On *c*(001), −11° to the trace of the *b* cleavage.
On *b*(010), −23° ,, ,, ,, *c* ,,

Two plates were cut as nearly as possible parallel to *b*(010), and these were carefully polished on one face. The position of the polished face was verified by measurements on to the cleavages *c*(001) and *m*(110). On examination in convergent light it was found that one optic axis emerged just outside the field of view.

The refractive indices were measured on these two plates by means of an Abbe-Pulfrich total-reflectometer. In each case the glass hemisphere of the refractometer was rotated through 360°, readings being taken at intervals of 10° with the telescope first on one side and then on the other. Both limits of total reflection pass through a maximum and a minimum, which were determined as accurately as possible. The positions of these maxima and minima give four angles $\theta_\gamma$, $\theta_\beta$, $\theta_n$, and

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[1] E. B. Bailey, Trans. Edinburgh Geol. Soc., 1904, vol. viii, p. 366.

[2] G. T. Prior, Annals Natal Museum, 1910, vol. ii, p. 146.

$\theta_\alpha$. Three of these are the critical angles corresponding to the principal indices: the angle to be rejected $\theta_n$ is that maximum or minimum for which the vibration-direction is in the plane of incidence.[1]

The critical angles obtained from the two plates using sodium-light were:

| | Plate I. | Plate II. |
|---|---|---|
| $\theta_\gamma$ | 56° 15′·25 | 56° 15′·5 |
| $\theta_\beta$ | 55 58·25 | 55 59·75 |
| $\theta_\alpha$ | 55 46·25 | 55 46·75 |

Each of these values represents the mean of four readings. The refractive index of the glass hemisphere of the refractometer was found by measuring the critical angles for glasses of known refractive indices, ear those of the felspar.

The values thus obtained for the refractive indices are:

$$\alpha = 1{\cdot}5630, \quad \beta = 1{\cdot}5665, \quad \gamma = 1{\cdot}5712.$$

The calculated value for 2V obtained from these figures is 81° 48′, the felspar being optically positive.

The material used for analysis was very carefully selected, and consisted of small water-clear cleavage fragments in which no trace of inclusions could be perceived with a lens, though it is probable that the iron found was derived from small specks of magnetite or thin incrustations of hydrated oxide which had escaped notice. The mean specific gravity of the mineral analysed was 2·706, compared with water at 4° C. The determination was made by the suspension method in a mixture of bromoform and xylol. Particles of density greater than 2·71 or less than 2·70 were rejected.

The analyses were made on quantities of from 0·5 to 1·0 gram in the Mineralogical Laboratory of the University of Cambridge, I and II by Mr. G. G. Knighton, III by Mr. M. C. Burkitt, and to these gentlemen we desire to express our thanks for the care they gave to their execution. Column IV of the table below gives the mean of the three analyses, the determination of alumina of analysis III being, however, omitted as probably too low; column V the percentage composition of the felspar, on the assumption that the water lost on ignition and the ferric oxide found are adventitious constituents. Column VI gives the ratios obtained when the percentages of column V are divided by the molecular weights of the oxides.

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[1] C. Viola, Zeits. Kryst. Min., 1902, vol. xxxvi, p. 245.

| | I. | II. | III. | IV. | V. | VI. | VII. |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 52·22 | 52·32 | 52·44 | 52·33 | 52·57 | 0·8704 | 52·48 |
| $Al_2O_3$ | 30·34 | 30·10 | (29·93) | 30·22 | 30·36 | 0·2971 | 30·22 |
| $Fe_2O_3$ | 0·42 | 0·39 | — | 0·40 | — | — | — |
| CaO | 12·37 | 12·79 | 12·39 | 12·52 | 12·58 | 0·2242 | 12·70 |
| $K_2O$ | 0·70 | 0·79 | 1·07 | 0·85 | 0·85 | 0·0090 | 0·85 |
| $Na_2O$ | 3·92 | 3·57 | 3·36 | 3·62 | 3·64 | 0·0586 | 3·74 |
| Ign. loss | — | — | 0·36 | 0·36 | — | — | — |
| | | | | 100·30 | 100·00 | | |

Now in anorthite lime, alumina, and silica are in the ratio 1 : 1 : 2, while in albite and orthoclase the ratios of alkalis, alumina, and silica are as 1 : 1 : 6. If then we take the ratios of column VI and remove anorthite, we find that the alkalis are to the residual alumina and silica as 0·0676 : 0·0729 : 0·4220, instead of in the ratio 0·0703 : 0·0703 : 0·4220, the values which should be obtained if the residual silica were entirely present as albite or orthoclase.

The above results lead to the conclusion that this felspar can be represented as $33NaAlSi_3O_8.5KAlSi_3O_8.62CaAl_2Si_2O_8$. The theoretical percentages for a felspar of this formula are given in column VII and exhibit a good agreement with the observed values.

It is interesting to notice that two somewhat similar felspars have been recently described, one by Ford and Bradley,[1] the other by Bonillas.[2] The first specimen occurred in rolled fragments and came from the Altar Mountains, Mexico, the second from the basalts of Pinacate, Altar district, Sonora. The compositions of these minerals are as follows, the figures given for the specimen from the Altar Mountains, A, being the mean of two concordant analyses; B is the mineral from Pinacate.

| | $SiO_2$. | $Al_2O_3$. | $Fe_2O_3$. | FeO. | CaO. | MgO. | $K_2O$. | $Na_2O$. | Ign. |
|---|---|---|---|---|---|---|---|---|---|
| A. | 51·24 | 30·84 | 0·73 | — | 13·59 | — | 0·17 | 3·76 | 0·24 |
| B. | 50·58 | 29·43 | 2·71 | 0·34 | 12·62 | 0·31 | 0·50 | 3·17 | 0·35 |

For the sake of comparison with one another, and with the theoretical composition of mixtures of albite and anorthite, our analysis and the two above quoted have been calculated to 100, potash being supposed to be replaced in each case by an equivalent amount of soda. The results are tabulated below, the composition and physical properties of the felspars

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[1] W. E. Ford and W. M. Bradley, Amer. Journ. Sci., 1910, ser. 4, vol. xxx, p. 151. Here 'Altar' is printed incorrectly as 'Altai'.

[2] Y. S. Bonillas, Parergones Instit. Geol. Mexico, 1910, vol. iii, p. 427. As pointed out by Bonillas (p. 432), these two descriptions probably refer to the same occurrence.

from Ireland, the Altar Mountains, and from Pinacate being given under I, II, and III respectively; while under I a, II a, and III a are to be found the calculated data for felspars of the compositions 38 Ab 62 An, 34 Ab 66 An, and 32 Ab 68 An.

| | I. | II. | III. | I a. | II a. | III a. |
|---|---|---|---|---|---|---|
| $SiO_2$ | 52·73 | 51·47 | 51·87 | 52·63 | 51·63 | 51·13 |
| $Al_2O_3$ | 30·44 | 30·98 | 31·63 | 30·81 | 30·98 | 31·32 |
| $CaO$ | 12·62 | 13·66 | 13·46 | 12·74 | 13·52 | 13·92 |
| $Na_2O$ | 4·21 | 3·89 | 3·54 | 4·32 | 3·86 | 3·62 |
| Sp. gr. | 2·706 | 2·718 | 2·731 | 2·704 | 2·711 | 2·714 |
| Ext. on *c* | −11° | −12° 13′ | −12° 40′ | −10·3° | −12·5° | −13·8° |
| Ext. on *b* | −23° | −24° 37′ | −26° 3′ | −23·7° | −25·5° | −26·5° |
| $\alpha$ | 1·5630 | — | — | 1·5630 | — | — |
| $\beta$ | 1·5665 | — | — | 1·5667 | — | — |
| $\gamma$ | 1·5712 | — | — | 1·5715 | — | — |

The calculated specific gravities given above are based on the values 2·605 and 2·765 assigned by Day and Allen to albite and anorthite respectively. If the values 2·624 and 2·758 adopted by Wülfing are made the basis of calculation, slightly higher values, 2·707, 2·7125, and 2·715 are obtained. The other results, quoted for comparison, are taken from the charts given in 'Rock Minerals' by J. P. Iddings, 2nd edit., 1911, p. 223; and in 'Elements of Optical Mineralogy' by N. H. and A. N. Winchell, 1909, p. 200.

It will be seen that the felspar from St. John's Point is a basic labradorite, and that its physical properties are quite in accord with the place in the plagioclase series to which it must be assigned on account of its chemical composition.

NOTE.—In the abstract which appeared in 'Nature', 1912, vol. xc, p. 375, the indices of this felspar were erroneously given as $\alpha = 1{\cdot}5598$, $\beta = 1{\cdot}5648$ and $\gamma = 1{\cdot}5694$. The correct values now published are the result of two highly concordant series of observations made, one with an Abbe-Pulfrich reflectometer as described above, the other with a Kohlrausch total-reflectometer provided with an attachment for rotating the plate in its own plane when immersed in bromonaphthalene.