

Pyroxene from the Squilver dolerite, south Shropshire.

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THE andesine-dolerite of Squilver Hill, situated nearly 3 miles due north of Bishops Castle, has been described in another place.¹ This somewhat coarse-textured rock, with a distinctive greenish-blue colour, contains up to 20 per cent. of a fresh monoclinic pyroxene as crystals of irregular shape, many of which are about a millimetre in length. The rest of the rock consists of saussuritized plagioclase, some interstitial chlorite and prehnite, and accessory apatite, sphene, magnetite, and ilmenite; the unaltered nature of the pyroxene is noteworthy.

The pyroxene was separated from the crushed rock by the use of bromoform and methylene iodide; the grains passed a 60-mesh sieve and at no stage did they come into contact with water before analysis. The larger grains of the final sample were hand-picked in order to avoid including any that were obviously composite. The composition of the mineral together with its optical data, specific gravity, and formula calculated to a basis of O = 12, are given in table I. The analysis of the dolerite from which the pyroxene was obtained is given in table II and has been reproduced by permission of the Council of the Geological Society of London.

The pyroxene is a diopsidic augite; it has a small content of aluminium, the greater part of which is substituted for silicon in the crystal structure. When molecular proportions of Wo, En, and Fs are computed and plotted in the usual triangular diagram, the point obtained falls within the salite field as defined by Hess² and Poldervaart.³

The chemical analysis, however, shows a water content of 1.70 % (H₂O+); many pyroxene analyses show up to 0.5 % of water, in some cases more, which is rarely commented upon. In the present case the water might be accounted for in various ways: (i) it may be due to

¹ F. G. H. Blyth, *Intrusive rocks of the Shelve area, south Shropshire*. *Quart. Journ. Geol. Soc. London*, 1944, vol. 99 (for 1943), pp. 169-204.

² H. H. Hess, *Amer. Min.*, 1941, vol. 26, pp. 515, 573. [M.A. 8-233.]

³ A. Poldervaart, *Min. Mag.*, 1947, vol. 28, p. 159.

chlorite associated with the pyroxene; (ii) it may (in part) be water adsorbed on the surface of cracks in the mineral; or (iii) the pyroxene may be hydrous. This last possibility is not borne out by considerations of specific gravity. Thin sections of the dolerite reveal that some of the

TABLE I. Analytical and optical data.
(Analysis by Geochemical Laboratories.)

			Atomic ratios	Atomic ratios	Atomic ratios	Number of atoms
			ratios.	after deduction	for chlorite.	when O = 12.
SiO ₂	48.50	Si ^{iv} 0.8075	0.7367	3.822	4.000
Al ₂ O ₃...	...	4.50	Al ⁱⁱⁱ 0.0883	0.0411	0.213
Fe ₂ O ₃	1.36	Fe ⁱⁱⁱ 0.0170	0.0170	0.088	3.992
FeO ...	...	8.18	Fe ⁱⁱ 0.1139	0.0864	0.448
MgO ...	...	15.06	Mg ⁱⁱ 0.3735	0.2831	1.469
CaO ...	...	19.32	Ca ⁱⁱ 0.3445	0.3445	1.787
Na ₂ O ...	...	0.32	Na ⁱ 0.0103	0.0103	0.053
K ₂ O ...	...	0.17	K ⁱ 0.0036	0.0036	0.019
H ₂ O+	...	1.70	Ti ^{iv} 0.0134	0.0134	0.070	
H ₂ O-	...	0.15	Mn ⁱⁱ 0.0042	0.0042	0.022	
TiO ₂ ...	...	1.07	Cr ⁱⁱⁱ 0.0001	0.0001	0.001
MnO ...	...	0.30	H ⁱ 0.1887	—	—
Cr ₂ O ₃...	...	0.01	O ^v 2.7374	2.3129	12
BaO	nil				
		100.64				

Formula: (Ca,Mg,Feⁱⁱ,Na,K,Ti,Mn,Feⁱⁱⁱ,Al)₂(Si,Al)₂O₆.

Colour of grains: pale green. Specific gravity 3.38.

Refractive indices: α 1.673, β 1.678, γ 1.705. γ-α 0.032.

2V 48-49°, positive. γ: c 42°.

Weight % (neglecting sesquioxides, titania, and alkalis): { Wo = 49.8
En = 35.4
Fs = 14.8

TABLE II. Analysis of dolerite, Squilver Hill quarry.

SiO ₂ ...	49.19	K ₂ O ...	0.91
Al ₂ O ₃ ...	19.47	H ₂ O+ ...	3.63
Fe ₂ O ₃ ...	2.35	H ₂ O- ...	0.16
FeO ...	5.04	TiO ₂ ...	1.00
MgO ...	4.48	P ₂ O ₅ ...	0.30
CaO ...	8.67	MnO ...	0.11
Na ₂ O ...	4.48	CO ₂ ...	0.01
		Total	99.80

pyroxene grains, although themselves fresh, enclose small crystals of an earlier mineral phase now pseudomorphed by chlorite, which may represent an earlier pyroxene. The total amount of the chlorite pseudomorphs is small, but their presence probably largely accounts for the water shown by analysis, and this explanation is regarded as more

probable than either of the others mentioned above. Further, a rough estimate from thin sections of the proportion of the chlorite relative to pyroxene gives a result of the right order of magnitude. In calculating the formula of the pyroxene, therefore, a clinocllore composition has been assumed for the chlorite, and the necessary amounts of its constituents, including hydroxyl, have first been deducted, as shown in table I.

Measurements of $2V$ and $\gamma:c$ were made on thin sections with the universal stage. In obtaining the extinction angle Burri's method¹ was first used, but the results showed considerable variation even on carefully selected sections: eight determinations gave a range from 30 to 45° , four values being less than 40° . An alternative method, described by Turner² and due to Nemoto,³ involves measurements on twin crystals; this method was eventually used, several suitably sectioned twins being available, and gave consistent results.

Refractive indices were determined by immersion of grains in mixtures of methylene iodide and α -monobromonaphthalene, the values being read with a Bellingham and Stanley refractometer. Specific gravity was obtained from Clerici solution diluted to match the density of grains of the pyroxene immersed in it.

Comparisons and discussion.—For purposes of comparison, the composition (in terms of Wo , En , and Fe) and optical properties of two other pyroxenes are tabulated with the Squilver pyroxene in table III. The

TABLE III. Comparison with other pyroxenes.

	Wo .	En .	Fs .	$2V$.	$\gamma:c$.	α .	β .	γ .	$\gamma-\alpha$.
A. ...	49.8	35.4	14.8	48°	42°	1.673	1.678	1.705	0.032
B. ...	46.8	34.2	19.0	52°	44°	1.699	1.706	1.722	0.023
C. ...	46.6	34.0	19.4	43°	41°	1.695	1.702	1.722	0.027

A. Pyroxene from the Squilver dolerite (this paper).

B. Pyroxene IIIA, from olivine-trachybasalt, Pallas Green, Co. Limerick (D. F. Ashby, *Min. Mag.*, 1946, vol. 27, p. 196).

C. Pyroxene IA, from hypersthene-olivine-gabbro (4077), Skaergaard intrusion, Greenland (L. R. Wager and W. A. Deer, *Meddel. om Grønland*, 1939, vol. 105, no. 4, p. 77. [M.A., 8-27.]).

three minerals have similar compositions but considerable differences in refractive index and $2V$.

Curves for optical properties drawn on a composition diagram have

¹ C. Burri, *Schweiz. Min. Petr. Mitt.*, 1931, vol. 11, p. 285. [M.A. 5-71.]

² F. J. Turner, *Amer. Journ. Sci.*, 1942, vol. 240, p. 571. [M.A. 8-350.]

³ T. Nemoto, *Journ. Fac. Sci. Hokkaido Univ.*, 1938, ser. 4, vol. 4, p. 107.

been given by Winchell,¹ Wager and Deer,² and others. The value of $2V$ for the Squilver pyroxene (A), as read from such curves, is too high when compared with the measured value; this is true also of pyroxenes B and C, table III. There is less discrepancy in refractive index values, in the case of pyroxene A.

The discrepancies in $2V$ may be attributed to the influence of constituents such as Al, Fe⁺⁺⁺, Ti, which are present in the minerals, but are not taken into account when the composition is expressed in terms of Wo, En, and Fs. Thus, Winchell (1935, loc. cit.) states that variation in optical properties from those shown in his diagram indicates differences in composition, for example, the presence of alumina; he adds that alumina has little effect on the optic angle and refractive indices but considerable effect on extinction angle. This does not seem to be borne out in the three cases quoted above.

A consideration of the available data, which is scanty, leads the writer to suggest tentatively that differences in $2V$ (between measured values and those estimated from the curves) may be explainable by reference to that part of the Al which is *not* in 4-co-ordination positions in the crystal structure, together with Fe⁺⁺⁺,—as distinct from the total (Al,Fe⁺⁺⁺)-content of the minerals. But it is difficult to establish this definitely until more analyses of pyroxenes of similar composition are available.

Finally, when the proportions of CaO, MgO, and FeO in the Squilver pyroxene and in the rock in which the mineral occurs are compared, it is apparent that the pyroxene is richer in CaO than the rock-melt from which it separated. Such a relationship was pointed out by Kennedy³ as indicating an olivine-basalt magma parentage, in contrast to a tholeiitic magma, which yields a pyroxene poorer in lime. The affinities of the Squilver dolerite with rocks of olivine-basalt type have already been demonstrated (Blyth, loc. cit.).

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¹ A. N. Winchell, *Amer. Min.*, 1935, vol. 20, p. 562. [M.A. 6-294.]

² L. R. Wager and W. A. Deer, *Min. Mag.*, 1938, vol. 25, p. 15.

³ W. Q. Kennedy, *Amer. Journ. Sci.*, 1933, ser. 5, vol. 25, p. 239.