Pyroxenes from the Lower Carboniferous basalts of the Old Pallas area, Co. Limerick.

By the late D. F. ASHBY,[1] B.Sc., A.R.C.S., F.G.S.

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(The author commenced his study of the Lower Carboniferous and interbedded volcanic rocks of the Old Pallas area in 1935. Four years later he published a short account of the geology of the district.[2] Just before his death the author had almost completed his laboratory work on the porphyritic pyroxenes in three of the basalts, and the paper now presented, which is admittedly incomplete, has been assembled from his notes. Mr. F. G. H. Blyth has most generously given of his time to determine with the universal stage the 2V and $\gamma{:}c$ values, and has checked the manuscript. Acknowledgement is also made to the Royal Society for a grant to meet the cost of chemical analyses.—W. F. Whittard.)

THE most complete succession of Carboniferous rocks found in Co. Limerick crops out in the Limerick basin, which is situated between Limerick and Tipperary. The zonal ranges of the chief lithological divisions of the Lower Carboniferous rocks have been determined, and two volcanic episodes, represented by the Lower and the Upper Volcanic Groups, are now known to have occurred early in S_1 and early in D_1 times. The porphyritic pyroxenes have been isolated from representatives of the lower group, which 'constitute a graded series of olivine-basalts, trachybasalts, trachyandesites and trachytes, comparable with

TABLE I. Analyses of rocks. (Analyst, Geochemical Laboratories.)

	I.	II.	III.		I.	II.	III.
SiO_2	44·43	45·26	51·13	MnO	0·25	0·17	0·19
Al_2O_3	12·74	14·87	16·58	CO_2	1·28	2·58	0·56
Fe_2O_3	7·41	3·34	4·14	S	—	0·06	0·04
FeO	5·34	8·38	6·22	Cr_2O_3	—	0·012	0·012
MgO	6·43	4·51	2·73	V_2O_3	—	0·020	0·009
CaO	12·05	9·81	6·11	NiO	—	0·01	nil
Na_2O	2·85	2·70	4·24	CoO	—	0·004	nil
K_2O	1·42	1·58	2·89	BaO	—	0·04	0·05
$H_2O+105°$ C.	1·77	2·02	1·92	SrO	—	*nil*	*nil*
$H_2O-105°$ C.	0·46	0·38	0·41				
TiO_2	3·45	3·45	2·22		100·31	99·956	99·991
P_2O_5	0·43	0·76	0·54	Less O for S...	—	0·03	0·02
						99·926	99·971

I, Olivine-basalt, Dunsapie type, 4160 feet N. 20½° E. of Pallas Grean railway station from Lower Volcanic Group exposed in canal cutting.

II, Olivine-basalt, 1000 feet E. 10° N. of Brackyle school, Pallas Grean, Lower Volcanic Group.

III, Olivine-trachybasalt, 300 feet W. 6° S. of summit of Derk Hill, Lower Volcanic Group.

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[1] Donald Frederick Ashby was accidentally drowned in Barmouth estuary on July 31, 1943, and a promising career was cut short at the age of 28. He was born at Parson's Green, London, on October 10, 1914. In 1938 he was geologist on the University of London Arctic Expedition to Jan Mayen Island, and the same year was appointed assistant lecturer in geology in the University of Bristol. He joined this Society in 1938. Obituary notices in Quart. Journ. Geol. Soc. London, 1945, vol. 100 (for 1944), p. lxi, and Proc. Geol. Assoc. London, 1944, vol. 55, p. 38.

[2] D. F. Ashby, The geological succession and petrology of the Lower Carboniferous volcanic area of Co. Limerick. Proc. Geol. Assoc. London, 1939, vol. 50, pp. 324–330.

the Lower Carboniferous Scottish suite. Among the olivine-basalts, all the Scottish types have been recognised, with the exception of Craiglockhart type and mugearite. Macroporphyritic basalts akin to Dunsapie or Markle types are conspicuous among the earlier flows, while among the later ones microporphyritic types predominate, of which the Dalmeny type is the commonest' (loc. cit., p. 327).

The porphyritic pyroxenes of two olivine-basalts and an olivine-trachybasalt were selected for investigation. The rocks were crushed, the sieved fractions treated with heavy liquids, and the denser constituents further separated electro-magnetically into groups. The pyroxene concentrates were picked over under a binocular microscope and samples of the pure mineral prepared for chemical analysis; the parent rock was analysed in each case. The refractive indices were determined by the single variation method, using a monochromatic illuminator of variable wave length and a refractometer (Tables I, II).

TABLE II. Analyses and optical data of pyroxenes. (Analyst, Geochemical Laboratories.)

		I A.	II A.	III A.
SiO_2		50·23	45·86	48·77
Al_2O_3		5·29	8·30	4·18
Fe_2O_3		1·16	2·08	2·03
FeO		4·48	7·03	9·34
MgO		14·74	12·65	12·48
CaO		20·50	20·23	20·49
Na_2O		0·70	0·68	0·51
K_2O		0·10	0·11	0·02
$H_2O+105°$ C.		0·66	0·54	0·98
$H_2O-105°$ C.		0·03	0·02	
TiO_2		0·92	2·34	1·59
P_2O_5		0·05	0·05	nil
MnO		0·25	0·17	0·11
CO_2		0·68	0·20	—
		99·79	100·26	100·50
Weight per cent.	Wo.	47·5	48·3	46·8
	En.	43·4	36·6	34·2
	Fe.	9·1	15·1	19·0
Refractive indices*	α'	1·685	1·707	1·699
	β	1·690	1·714	1·706
	γ'	1·706	1·727	1·722
	$\gamma'-\alpha'$	0·021	0·020	0·023
2V (+)	range	46–52°	46–49°	52–53°
	mean	49°	48°	52°
$\gamma':c$†		53°	55°	44°

* The author contemplated correcting his determination of α' by $-0·004$ and of γ' by $+0·004$. The calculated value of 2V would then be much higher than the observed one and the uncorrected determinations for the refractive indices are therefore preferred.

† The extinction-angles here given were measured by Mr. Blyth on sections nearly parallel to (010). Further measurements were made by him with the universal stage, using Burri's method, which gave an unsatisfactorily wide range of values for I A and II A, and in the case of III A a range of 38–49°; it appears probable that for pyroxene III A, $\gamma:c$ lies between 44° and 49°.—W. F. W.

After allowing in the pyroxenes for small amounts of such impurities as calcite, apatite, and chlorite (probably a ferruginous pennine) which are indicated by the presence of CO_2, P_2O_5, and $H_2O+105°$ C., and which can be identified in thin slices of the pyroxenes, the constitutions and formulae of the three types can be computed as shown in Table III.

TABLE III. *Calculation of the formulae of pyroxenes.*

	I A.				II A.				III A.			
	Mol. ratios.	No. metal atoms when O=6.			Mol. ratios.	No. metal atoms when O=6.			Mol. ratios.	No. metal atoms when O=6.		
SiO_2 ...	0·8060	1·913		2·00	0·7380	1·744		2·00	0·7694	1·880		2·00
Al_2O_3 ...	0·0448	0·213	0·087 0·126	1·983	0·0755	0·357	0·256 0·101	2·012	0·0315	0·154	0·120 0·034	1·987
Fe_2O_3 ...	0·0053	0·025			0·0111	0·052			0·0096	0·047		
FeO ...	0·0513	0·122			0·0888	0·210			0·1149	0·281		
MgO ...	0·3316	0·787			0·2852	0·674			0·2617	0·639		
CaO ...	0·3488	0·828			0·3564	0·842			0·3654	0·893		
Na_2O ...	0·0113	0·054			0·0110	0·052			0·0080	0·039		
K_2O ...	0·0011	0·005			0·0012	0·006			0·0002	0·001		
TiO_2 ...	0·0115	0·027			0·0292	0·069			0·0199	0·049		
MnO ...	0·0040	0·009			0·0024	0·006			0·0016	0·004		

I A. ... ... $(Ca,Mg,Fe'',Mn,Al,Fe''',Na,K,Ti)_{1\cdot983}[(Si,Al)_2O_6]$
II A. ... ... $(Ca,Mg,Fe'',Mn,Al,Fe''',Na,K,Ti)_{2\cdot012}[(Si,Al)_2O_6]$
III A. ... ... $(Ca,Mg,Fe'',Mn,Al,Fe''',Na,K,Ti)_{1\cdot987}[(Si,Al)_2O_6]$

The analyses accord with Barth's view that the early precipitated pyroxene of basalts is enriched in lime and magnesia relative to iron,[1] and demonstrate the small extent to which aluminium replaces silicon.

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[1] T. F. W. Barth, Crystallization of pyroxenes from basalts. Amer. Min., 1931, vol. 16, pp. 195–208. [M.A. 5–219.]