

*The chemical composition and optical properties of
a basaltic hornblende from Hungary.*

By MIKLÓS VENDL, Ph.D.

Professor of Mineralogy and Geology in the Mining Academy
of Sopron, Hungary.

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ALTHOUGH there is an extensive literature on the amphiboles, especially those of the monoclinic series, there appear to be only few records for basaltic hornblendes in which the physical properties and the chemical composition have been determined in detail on the same sample of material. Mention may be made of the later papers by S. L. Penfield and F. C. Stanley,¹ S. Kreutz,² W. E. Ford,³ and H. Kűchler.⁴

The basaltic hornblende described in the present paper is found in the volcanic tuff-breccias of Pliocene age in the neighbourhood of Lake Balaton. The locality is near the small village of Balatoncsicso on the southern slope of the 'Fenyves' hill, the top of which is capped with basalt. The hornblende is found as loose crystals in the tuff-breccia and also in blocks rich in olivine. Specimens of some size, up to 2 or 3 cm. in length, may be collected. In bulk, they are black in colour with bright vitreous to sub-metallic lustre on the cleavages. A bronze-like lustre is sometimes shown by altered specimens. The crystals show no terminal faces. Measurement of the cleavage-angle made on six fragments gave the mean value $(110):(1\bar{1}0) = 55^{\circ} 44\frac{1}{3}'$.

¹ S. L. Penfield and F. C. Stanley, On the chemical composition of amphibole. Amer. Journ. Sci., 1907, ser. 4, vol. 23, pp. 23-51; translation in Zeits. Kryst. Min., 1907, vol. 43, pp. 233-260.

² S. Kreutz, Untersuchung der optischen Eigenschaften von Mineralien der Amphibolgruppe und ihrer Abhängigkeit von der chemischen Zusammensetzung. Sitzungsber. Akad. Wiss. Wien, Math.-naturw. Kl., 1908, vol. 117, Abt. 1, pp. 875-970.

³ W. E. Ford, A contribution to the optical study of the amphiboles. Amer. Journ. Sci., 1914, ser. 4, vol. 37, pp. 179-193; translation in Zeits. Kryst. Min., 1914, vol. 54, pp. 1-16.

⁴ H. Kűchler, Chemische und optische Untersuchungen an Hornblendenden und Augiten aus dem Diorit-Gabbro-Massiv des oberen Veltlin. Chemie der Erde, 1914, vol. 1, pp. 58-100. [See also A. N. Winchell, 1924; Min. Abstr., vol. 2, p. 304.]

This value lies between those ($55^{\circ} 40'$ to $55^{\circ} 50'$) determined by K. von Kraatz-Koschlau¹ for basaltic hornblendes. Sections parallel to (010) show the perfect prismatic cleavage, and sometimes also a system of cracks as short interrupted lines inclined at 50° – 60° to the *c*-axis on the side of the acute angle β and near the direction of (201). [Calculated (100):(201) = $50^{\circ} 34\frac{3}{4}'$]. This latter cleavage or parting is shown only by altered specimens and is never seen in fresh fragments. The thin sections of the altered material also show minute grains of an opaque mineral and rusty spots along the cleavage-cracks.

For the purpose of the chemical analysis and the determination of the optical properties carefully selected fragments only were used, which under the microscope were perfectly clear and free from inclusions.

The chemical analysis was carried out by the usual methods. The determination of the water was made in a tube of silica-glass placed in an electric furnace, the water being carried by a current of dry air into a spiral tube containing concentrated sulphuric acid. The results are as follows:

		Percentage.		Molecular ratios.		
SiO ₂	...	40.17	...	0.6662	}	0.7134
TiO ₂	...	3.78	...	0.0472		
Al ₂ O ₃	...	15.09	...	0.1476	}	0.1820
Fe ₂ O ₃	...	5.49	...	0.0844		
FeO	...	5.99	...	0.0834	}	0.5941
MnO	...	0.09	...	0.0013		
CaO	...	11.21	...	0.1999	}	0.9458
MgO	...	12.48	...	0.3095		
Na ₂ O	...	2.27	...	0.0366	}	0.1697
K ₂ O	...	1.55	...	0.0166		
H ₂ O + 110°	...	2.10	...	0.1165		
H ₂ O - 110°	...	0.25				
		100.47				

The analysis shows that the chemical composition of this hornblende cannot be calculated as consisting of normal metasilicates, since the metallic oxides and water in the form of metasilicates would require $\text{SiO}_2 + \text{TiO}_2 = 1.3098$, whilst only 0.7134 is shown in the analysis. In explaining the chemical composition of the augites F. Zambonini² has advocated the assumption of aluminate molecules in place of Tschermak's hypothetical compound. The same idea can be applied

¹ H. Rosenbusch, *Mikro. Phys. Min.*, 1905, vol. 1 (2), p. 226.

² F. Zambonini, *Osservazioni sulla composizione chimica di alcuni minerali. Atti R. Accad. Sci. fis. mat. Napoli*, 1916, ser. 2, vol. 16, No. 2, pp. 1-25; translation in *Zeits. Kryst. Min.*, 1915, vol. 55, pp. 132-155.

in the present case, as shown below. Water above 110° C. is regarded as an essential constituent, as shown by Penfield and Stanley, and more recently by Kùchler. The calculation gives the following compounds :

	R ₂ O.	RO.	R ₂ O ₃ .	(Si, Ti)O ₂ .	Mol. %.
CaSiO ₃	...	0.1999	...	0.1999	25.09
MgSiO ₃	...	0.1604	...	0.1604	20.14
Fe''SiO ₃	...	0.0834	...	0.0834	10.47
MnSiO ₃	...	0.0018	...	0.0018	0.16
Na ₂ SiO ₃	0.0366	...	...	0.0366	4.59
K ₂ SiO ₃	0.0166	...	...	0.0166	2.08
H ₂ SiO ₃	0.1165	...	...	0.1165	14.62
Al ₂ (SiO ₃) ₃	...	...	0.0329	0.0987	4.13
MgAl ₂ O ₄	...	0.1147	0.1147	...	14.40
MgFe''' ₂ O ₄	...	0.0344	0.0344	...	4.32
Totals	0.1697	0.5941	0.1820	0.7134	100.00

The agreement is very close, and shows that the composition can be expressed by the isomorphous mixture of simple metasilicates and aluminates. The outstanding features of the present analysis, which is very close to that of a basaltic hornblende analysed by C. Schneider,¹ are the high contents of sesquioxides, especially alumina, and of titanium dioxide, thus showing some relation in the direction of kaersutite. The amounts of alkalis and of water are also high, suggesting a weak alkaline character.

The *specific gravity* of the mineral, determined with a pyknometer on 1.5175 gram of material, gave the value 3.178 (mean of two determinations, 3.179 and 3.177) at 20° C.

Optical properties.—The determination of the three principal indices of refraction was made on an Abbe-Pulfrich-Zeiss total-reflectometer at 20°-20.5° in sodium-light. A carefully polished plate parallel to the cleavage (110) was used. The edges of the shadows of total-reflection were very sharp, especially for α ; for β and γ a nicol was used. Since the three values were determined on a single plate, a confirmation of the value for β was made by comparing the measured optic axial angle with that calculated from the three indices. The results obtained from the means of ten measurements taken on either side are :

$$\begin{aligned} \alpha &= 1.6698 & \gamma - \alpha &= 0.0231 \\ \beta &= 1.6825 & \gamma - \beta &= 0.0104 \\ \gamma &= 1.6929 & \beta - \alpha &= 0.0127 \end{aligned}$$

¹ C. Schneider, Zur Kenntniss basaltischer Hornblend. Zeits. Kryst. Min., 1891, vol. 13, pp. 579-584.

The plane of the optic axes is parallel to the plane of symmetry (010) and the positive bisectrix γ lies near the vertical axis c . Since terminal faces are present on none of the crystals it was not possible to determine directly whether the γ direction lies in the obtuse or the acute axial angle β (Dana's orientation, $\beta = 73^\circ 58\frac{1}{4}'$). The dispersion of this bisectrix though not strong is quite perceptible, the angle being greater for red than for blue, $c:\gamma_\rho > c:\gamma_v$. According to the connexion between the dispersion of the bisectrices and the optical orientation of the hornblendes, as established by F. Becke,¹ this shows that γ lies in the obtuse angle β . The mean of ten double measurements made in daylight in plates cut accurately parallel to (010) gave the values $c:\gamma = +8.7^\circ$ to $+8.8^\circ$.

The optic axial angle was measured in a plate cut very nearly perpendicular to the acute bisectrix a . The accuracy of the orientation was controlled by goniometric measurements from the prismatic cleavages, and a slight difference—less than 1° —was observed between a and the normal to the plate. This was eliminated as far as possible by adjusting the refractive index of the Thoulet solution in which the plate was immersed. The measurement was made on the large Fuess apparatus, and in sodium-light gave the value $2V_{Na} = 82^\circ 45'$, which agrees closely with the value ($84^\circ 0'$) calculated from the three refractive indices. The dispersion of the optic axes is small and $v > \rho$.

The extinction-angle on the cleavage-plane determined in daylight on four flakes gave the mean value 7.6° to the vertical axis. This corresponds very closely with the value (7.4°) calculated for sodium-light from the positions of the optic axes.

The pleochroism as observed under the microscope is given below; and the absorption is $\beta \geq \gamma > a$, the difference between β and γ being very slight, but perhaps β is the darker.

- a , pale-yellow with a tinge of brown,
- β , dark-brown,
- γ , dark olive-green with a tinge of brown.

The above study was carried out partly in the Laboratory of Mineralogy and Petrography of the Pázmány University in Budapest and partly in the Laboratory of Mineralogy and Geology of the Mining Academy at Sopron.

¹ F. Becke, *Gesteine des Columbretes*. Tschermaks Min. Petr. Mitt., 1896, vol. 16, p. 159.