The use of alignment charts in crystal-optics.

(*With Plates VII and VIII.*)

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THE widespread use of methods based on total-reflection for finding the refractive indices of crystals either directly, by the Abbe-Czapski crystal reflectometer or by the Kohlrausch method, or indirectly by means of liquid mixtures of known refractive index which require to be verified and standardized from time to time, renders desirable a rapid graphical method of ascertaining with some accuracy the index of the substance under test, direct from the instrumental data without calculation.

An attempt in this direction was made by the author some years ago. The equation to be solved is $n' = n \sin\theta$, where n' is the index to be found, n that of the glass hemisphere, prism, or highly refracting liquid employed in the total-reflectometer, and θ the critical angle of total-reflection observed. A diagram was prepared in which the values of $\sin\theta$ were plotted as ordinates, values of n' as abscissae, and the corresponding values of n were given by a series of diagonal straight lines radiating from an origin situated outside the limits of the diagram. This solution of the problem was communicated to the Mineralogical Society[1] in 1911, and shortly afterwards F. E. Wright[2] published a number of diagrams designed on similar lines for the graphical solution of various problems which are met with in the optical investigation of crystals.

Although these diagrams are easy to construct and offer certain advantages fully discussed by F. E. Wright, yet they suffer from two defects which diminish their value and militate against their extended use. In the first place such arrangements of numerous vertical, horizontal, and diagonal lines are confusing and irritating to the eye, and

[1] A. Hutchinson, Min. Mag., 1912, vol. 16, pp. 236–238.

[2] F. E. Wright, Amer. Journ. Sci., 1913, ser. 4, vol. 36, pp. 509-539.

if mistakes are to be avoided demand an excessive amount of care, attention, and time in the reading. Secondly, if a tolerable degree of accuracy is aimed at, and reasonably open scales are used, the diagram becomes inconveniently large or the range of values covered is correspondingly restricted. The diagram published by the author in 1912, although useful within the limited field it covers, illustrates both these points particularly well. From the above-mentioned disadvantages the so-called 'alignment charts', which have in recent years found much favour with engineers, are to a large extent free. The principle on which they are based was alluded to by F. E. Wright in 1913, but for reasons given in his paper (loc. cit.), he regarded such charts as unsuited to his purpose and they do not appear so far to have been employed in crystallography and crystal-optics, although they have been adopted with success by H. S. Palmer[1] for solving certain problems met with in stratigraphical geology. His paper, entitled 'New graphic method for determining the depth and thickness of strata and the projection of dip', contains moreover a clear account of the principle on which the construction of his charts is based.

It would seem, however, that such charts may be used with advantage in the solution of certain simple optical problems, and as a step in this direction the author has prepared two diagrams (Plates VII and VIII), one for solving the total-reflection equation $n' = n \sin \theta$, and the other for solving the refractive index equation $\sin i = n \sin r$. By utilizing the device of folding, i. e. duplicating or triplicating some of the scales, it has been found possible to include within diagrams of moderate compass all values of the variables met with in practice and at the same time to employ scales open enough to be read easily to the degree of accuracy required.

Thus, in the case of the total-reflection equation, the upper scale of the chart (Pl. VII), which gives the values of n (the index of refraction of the hemisphere, prism, or highly refractive liquid used in the reflectometer), ranges from 1·620 to 1·900, and can be read direct to a single unit of the third decimal place, while the fourth figure may be estimated. The scales A_1, A_2, A_3, which give the values of n', the index to be found, range from 1·300 to 1·800 and can be read direct to two units of the third decimal place, while the values of the critical angle θ, scales B_1, B_2, B_3, can be read direct to 5′ over the range 43° to 60°, to 10′ for the range 60° to 80°, and to 20′ between 80° and 85°.

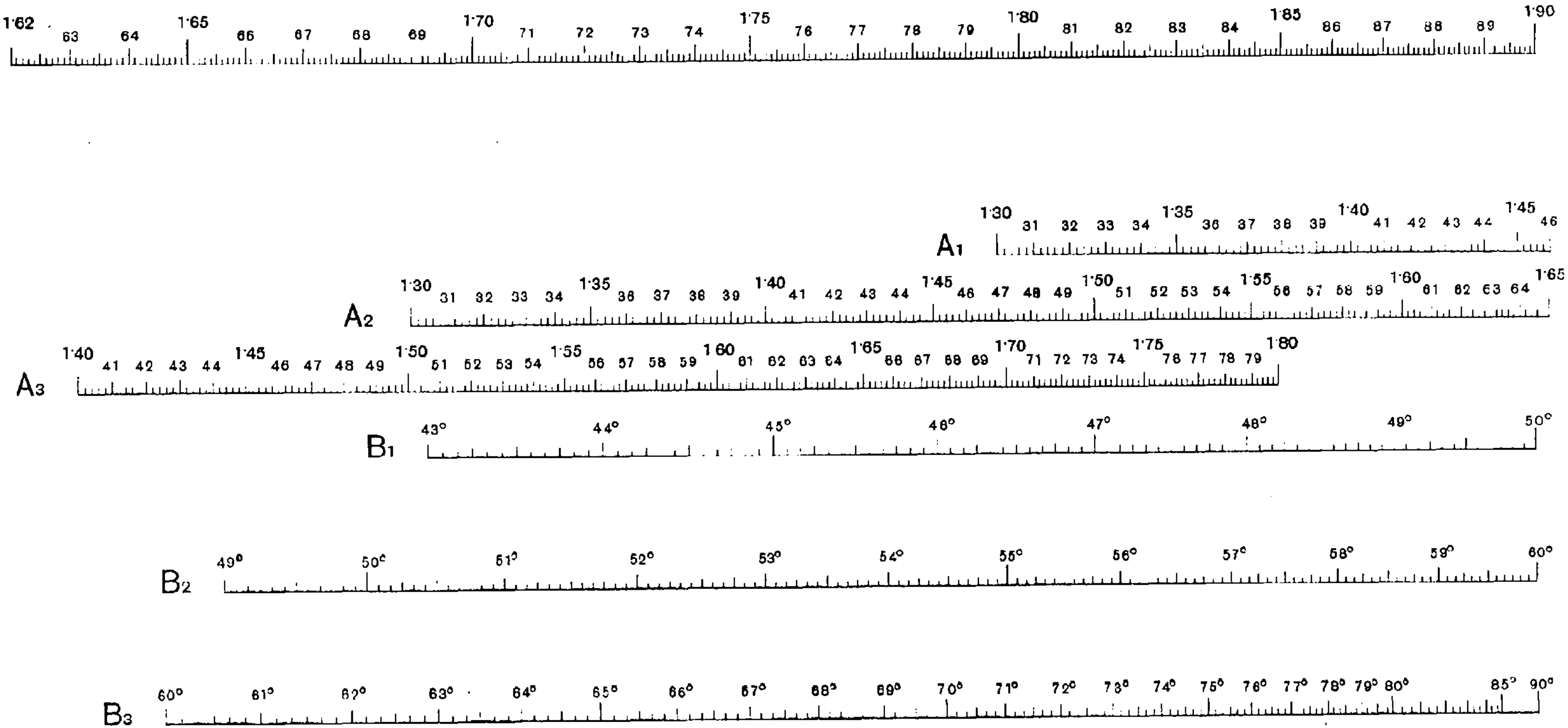
[1] H. S. Palmer, Professional Paper U.S. Geol. Survey, 1918, no. 120-G, pp. 123-128.

Similarly, in the refractive index chart (Pl. VIII) the values of n can be read direct to two units of the third decimal place, the angles of incidence i can be read to 5′ over the range 6° to 30°, to 10′ for the range 30° to 50°, and to 20′ between 50° and 75°, the same closeness of graduation being adopted for the angles of refraction r.

The charts can be most conveniently read by means of a narrow strip of stout celluloid down the centre of which a fine straight line has been engraved, but a thin black thread stretched between the observed points will serve nearly as well, or an ordinary straight edge may be used.

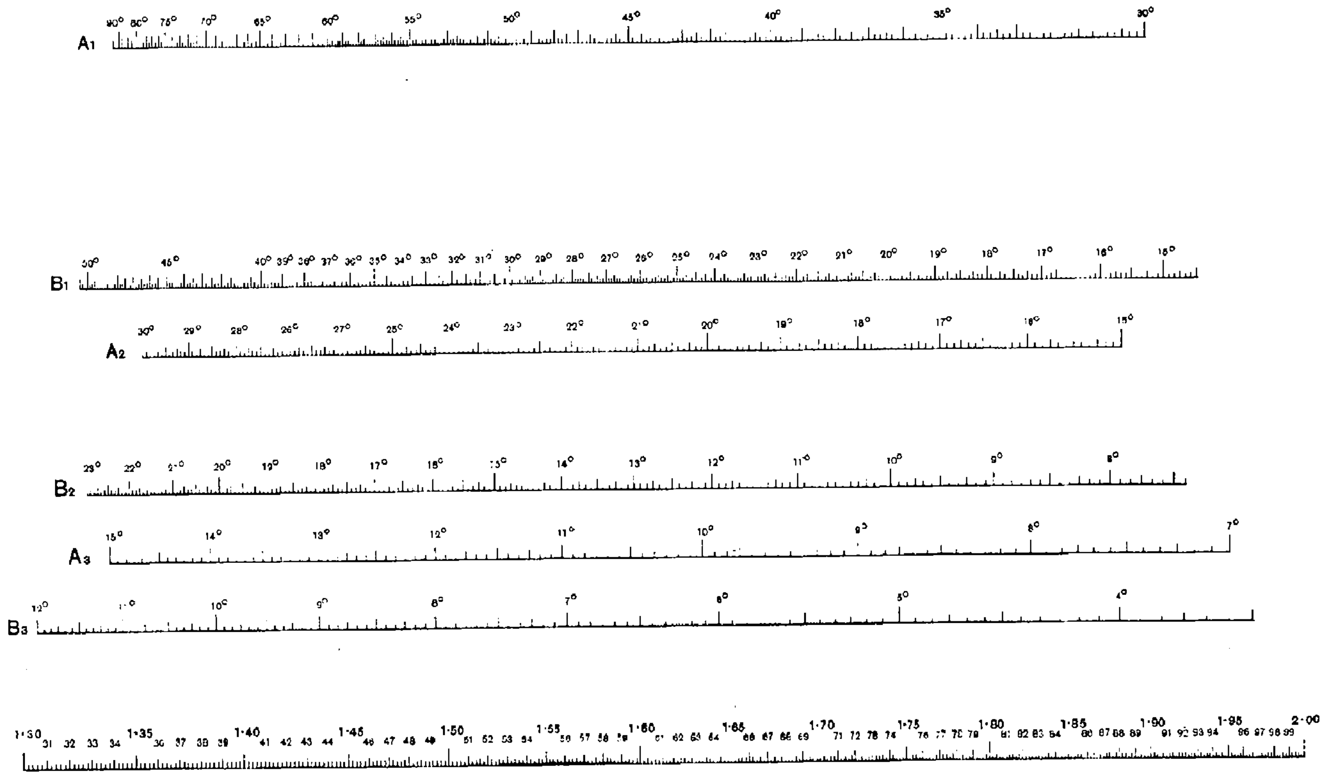
The principle on which these charts are constructed was enunciated so far back as 1884 by Maurice d'Ocagne and is fully explained in chapter 3 of his 'Traité de nomographie', Paris, 1899, and his methods have in recent years formed the subject of numerous text-books. English readers will find full information in the following works: John B. Peddle, 'The construction of graphical charts', New York (McGraw-Hill Book Co.), 1910; Carl Runge, 'Graphical methods', New York (Columbia University Press), 1912; S. Brodetsky, 'A first course in nomography', London (G. Bell & Sons), 1920. Reference may also be made to E. S. Andrews, 'Alignment charts', London (Chapman & Hall), or to W. N. Rose, 'Line charts for engineers', London (Chapman & Hall), 1923.

A. Hutchinson: Chart for solving the total-reflection equation, $n' = n \sin \theta$.



Join the value of n read on the upper scale to the value of θ read on the scales B_1, B_2 or B_3.
The intersection of this line with the corresponding A scale gives the value of n'.

A. Hutchinson: Chart for solving the refractive index equation, $\sin i = n \sin r$.



Join the value of the angle of incidence i read on the scales A_1, A_2 or A_3 to the value of the angle of refraction r, read on the corresponding scales B_1, B_2 or B_3. The intersection of this line with the bottom scale gives the value of n, the index of refraction.