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XII.—*Further Improvements in studying the Optical Characters of Minerals.*

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IN the following short paper I propose to describe what I have lately done in improving the method of studying the optical characters of the minerals which I treated at greater length in my address last year at annual meeting at Plymouth.

It is a curious example of how a method may be invented, and then lost sight of, that the determination of the index of refraction in the way there described was proposed by a French savant upwards of a hundred years ago. I have not yet consulted the original publication, but I very strongly suspect that the proposal was more theoretical than practical, and that with the instruments then at disposal the results were found to be so inexact that the whole system became obsolete and practically forgotten. I may, however, claim to have so modified the method, and brought the instrumental means to such perfection, as to make it fully equal to the requirements of practical mineralogy. Whilst speaking on this point it may be well to give an illustration of the accuracy with which it is possible to measure the index with the apparatus which I have now at disposal. Thus, in the case of a specimen of quartz, about ·372 inch thick, five different determinations of the index of the ordinary ray for the light transmitted by red glass, which corresponds to the solar line c, were

1·5513, 1·5531, 1·5524, 1·5531 and 1·5513, so that no observation differed more than an unit in the third place of decimals from the mean value, which may, therefore, be looked upon as true to the third place of decimals, assuming that the equation $\mu = \frac{T}{T-d}$ needs no correction.

There was no difficulty in thus proving that there is a slight but well-marked difference in the index for different specimens. The mean for five was 1·5543, whereas, according to Rudberg, it is 1·5418. In a similar manner I found that my method invariably gave too high a result in the case of other minerals. After many very careful measurements I came to the conclusion that this can be satisfactorily attributed to the spherical aberration due to the introduction of a transparent plate in front of the object glass, as suggested by Professor Stokes. The amount of this error depends partly on the index of refraction, and partly on the special correction of each particular object glass, and when great accuracy is desired it is necessary to construct a small table showing the amount that must be deducted in each case. I thus find that, when using my $\frac{2}{3}$ object glass, if the index is about 1·5 I must deduct ·0100, and, when 2·0, must deduct ·0180.

Having thus shown how accurately the index may be measured, it may be well to briefly allude to some improvements in the apparatus. I find two cross lines in the focus of the eye lens very useful in keeping constant the focal adjustment of the eye itself. In adjusting the focus of any object it is always arranged so that the cross lines are also in sharp focus. Without this precaution there may be an important difference, according as the focus is adjusted by moving the object glass up or down. I have also found it desirable to take the means of two or more sets of measurements made in slightly different parts of the scale, so as to eliminate any error due to imperfect graduation. This is easily managed by moving the fine adjustment. It is by adopting these precautions that I have been able to make such concordant and accurate measurements as those given above in the case of quartz, and to prove that the limit of error may be made very small.

When first I commenced to apply my method to the study of various minerals, with the view of comparing mathematical theory with observation, I soon found that there were a few discrepancies. For some time I thought it just possible that these might be due to errors in the measurements, but I found that these discrepancies became the more and more marked as by degrees I was able to remove every apparent source of error. The principal discrepancy is in the case of bi-axial crystals like aragonite, but some are also met with in the case of uniaxial crystals. I have not yet been able to thoroughly ascertain the laws which govern these special peculiarities, and no kind of explanation has yet suggested itself either to Professor Stokes or myself; and therefore it appears to me undesirable to enter more fully into the question, which relates more to the mathematical theory of light than to practical mineralogy. It may, however, be well to say that the discrepancy to which I refer is in the ratios of the values of the real and apparent indices.

My attention has been so much devoted to these interesting and important matters of detail, that I have had but little opportunity to further apply the method to the identification of doubtful minerals. It may, however, be well to give one illustration.

I had in my collection two six-sided prismatic crystals with oblique terminations. They had the general aspect of calcite, but then the six angles were obviously unequal, and polarized light at once showed that the axes of elasticity were very far from parallel and perpendicular to the axis of the prism. On examining them by my method I at once saw by the character of the images that I had before me an uniaxial crystal with powerful double refractions, and that the direction in which I could observe the indices was such as would give their true values, since there was no material lateral displacement of the images. I give below the three apparent indices, two real, and one only apparent, and compare them with calcite :—

	ORDINARY RAY.	EXTRAORDINARY RAY.	
		Real.	*Apparent.*
Observed mineral	1·674 ..	1·503 ..	1·859
Calcite	1·665 ..	1·494 ..	1·855
	·009	·009	·004

There cannot, therefore, be the slightest doubt that the crystals are an unusual secondary form of calcite, possibly containing some impurity which makes the indices rather higher than for Iceland spar. Though I have not had occasion to put the method to many other practical tests, yet I feel fully convinced that it would give equally satisfactory results in the case of any mineral having parallel faces, and sufficiently transparent over some small area to enable us to see through it the image of the cross lines of the grating.