

ORDINARY MEETING, APRIL 5TH, 1878.

Professor MORRIS, F.G.S., President, in the Chair.

The following Donations were announced :—

“Abstracts of the Proceedings of the Geological Society of London,” Nos. 349 and 350; from that Society.

“Proceedings of the Warwickshire Natural History and Archæological Society,” 1877; from that Society.

“Journal of the Society of Arts,” Nos. 1320-4; from that Society.

“Proceedings of the Nova Scotian Institute,” Vol. iv., pt. 3; from Dr. Honeyman.

“Transactions of the Geological Society of Glasgow,” Vol. v., pt. 2; from that Society.

“Proceedings of the Literary and Philosophical Society of Liverpool,” Vol. xxxi., 1876-7; from that Society.

“On Fossil Lepidoptera,” by the Rev. P. B. Brodie, M.A.; from the Author.

United States Geological Survey, &c. “1st. Descriptive Catalogue of the Photographs of North American Indians.”—2nd. “Preliminary Report of the Field Work, for the Season of 1877.”—3rd. “Bulletin;” Vol. iv., No. 1.—4th. “Report” [Monographs], Vol. vii.; from Dr. F.V. Hayden.

The following were elected Members of the Association :—

J. W. Judd, Esq., F.R.S., F.G.S., Professor of Geology in the Royal School of Mines; W. J. Sollas, Esq., B.A., F.G.S.

The following Paper was read :—

ON SOME PHYSICAL PROPERTIES OF PRECIOUS STONES.

By PROFESSOR A. H. CHURCH, M.A., F.C.S.

Of the various physical properties which may be used to distinguish and identify those minerals which are called gems or ornamental stones, I wish to direct your special attention to two only, to-night, namely pleochroism and specific gravity. I thus limit myself for several reasons. I have some new facts to communicate on these points: these two properties are easily tested without injury to the specimens examined; and the results are obtained in

a decisive form with the simplest apparatus and by inexperienced manipulators. Not that I would wish for a moment to disparage other means and methods of identifying transparent minerals. In the cases to which the process is applicable, what can be more exquisite than Mr. Sorby's new plan for the determination of refractive indices under the microscope? How valuable in certain instances is the aid of the spectroscope, which furnishes us at a single glance with proofs of a stone being a red garnet or a red spinel, a yellow chrysoberyl or a yellow jargoon, though in each case the colour and outward appearance might deceive. The nature of the polished surface of different species of gems offers also another indication of value. This indication may be secured by the sense of touch, at least in some cases. Let the inner aspect of a well-educated human thumb be passed firmly over a polished facet of topaz; it glides softly and uninterruptedly to the end. Substitute as fine a surface of quartz as is attainable by skill of lapidary, and the motion becomes an alternation of slipping and stopping, stopping and slipping, like the crisp feel of starch granules between the fingers. But the nature of these polished surfaces may be investigated by other and more delicate methods than the above rule of thumb. We can determine the polarizing an les* of such surfaces; we can ascertain the distance at which a point of standard light, or a reflected image of some small object (a black triangle being very suitable) becomes extinguished; we can learn by a simple contrivance of moveable plate and graduated arc at what angles the stability of a small weight placed on polished level surfaces of different materials will be overcome. And not to lengthen the list of available properties too much, I can but mention one other characteristic of certain gems, namely, their development of polar electricity by the action of heat.

PLEOCHROISM.—I now propose, in the first place, to enter into more complete details concerning the property of pleochroism, noting, as a preliminary, the construction of the instrument by which it may be most conveniently studied. This instrument, the dichroscope, was devised by Haidinger, and is now made for about 15 francs by

* Such angles measured from normals are :—

Glass	...	...	...	...	54°	35'
Rock Crystal...	...	...	...	...	57	22
Topaz	...	...	...	...	58	40
Spinel	...	...	...	...	60	16
Zircon	...	...	...	...	63	8
Diamond...	...	...	...	...	68	2

several opticians in Paris. It is, in fact, a double-image prism of calc-spar, fitted into a tube of about $2\frac{1}{4}$ inches in length, one end of this tube being furnished with an adjustable stop, having a square opening in its centre—and the other end being completed by a simple eye-piece, the focus of which is such that it gives a distinct image of the above-named square opening. The length of one edge of the cleavage-rhombohedron of Iceland-spar used is about 1 inch, the other edges being about $\frac{1}{3}$ of an inch each. In the original instrument compensating glass prisms of 18 degrees were cemented to each small end-face of the calcite rhombohedron; but this addition is quite unnecessary if the ends in question be ground perpendicular to the axis of the instrument, and then polished. Thin squares of microscopic covering glass, cemented to the polished faces, and to the inner aspect of the square opening, will preserve the apparatus from injury and dust.

The action of this dichroscope will be best explained by an illustrated example. We will take the sapphire as our test-object. A slice of this mineral, showing a blue colour, is cut parallel with the principal axis of the prism. We will assume this specimen (and all others spoken of to-night) to be so orientated as to have the principal axis perpendicular to the axis of our dichroscope. On looking through the instrument we perceive two images of the square opening, the left-hand image being of a pale-greenish yellow, the right-hand image being of a pure velvety ultramarine blue. The light of these images consists of oppositely-polarized and differently-coloured pencils—the two pencils into which the ordinary light transmitted through the rhomb is separated by double refraction. Now the extraordinary ray of these two forms the blue image; the ordinary ray the greenish-yellow image. The latter image consists of light polarized in a plane through the short diagonal of the rhomb while the greenish-yellow image consists of light which is polarized in a plane through the longer diagonal of the rhomb.* Both images together contain the whole transmitted light, but as they share it between them, if the images be made to overlap the part where they coincide, they will not

* The image formed by the pencil of ordinary rays may also be known by its appearing larger and nearer the eye than the other image—the ordinary ray being more lifted up than the extraordinary ray by refraction. If the dichroscope be furnished with a fine adjustment, and the upper surface of the section of the mineral under examination be ruled or marked, a measurement of this difference between the two rays may be made by focussing the rules or marks in each image.

only reproduce the original colour of the sapphire, but will also be more brilliant or luminous. This experiment may be shown by rotating the stop, when the neighbouring angles of the two images of its square opening will overlap, and the original light and colour will be reproduced.

Now let us consider how the above phenomena may be utilized in the discrimination of the various transparent blue substances which simulate more or less closely the true sapphire, and which might be mistaken for it. We may dismiss at once from our view the glass or paste and the blue spinel, since these two substances do not polarize the light through them in any direction, and consequently will give two images of identically the same hue in the dichroscope. But with blue tourmalines and iolites, the case is different. The latter stone images, the iolite or dichroite, shows indigo blue and a buff—the crystal or the instrument requiring with this mineral to be turned through 45° to develop the greatest difference between the two colours. With some blue tourmalines indigo blue and inky grey or greyish-green images are produced, while with those tourmalines which are strongly absorptive of light, the images may alternately disappear during rotation.

A few words concerning the red variety of corundum or ruby may fitly be here introduced. This stone, when of the proper pigeon's blood colour, gives two differently coloured images when viewed in the same way as the sapphire. The ordinary ray is of a flame or aurora-red; the extraordinary ray gives a crimson or carmine image. Red glass, red spinel, and all the varieties of red garnet, including the beautifully coloured "Cape rubies," so-called, give in each instance two images identical in hue. Now that the ingenious plan has been adopted of mounting a well-cut garnet of blood-red colour between two excellent diamonds, and so arranging a handsome combination where the genuineness of the costly diamonds carries off the falsity of the spurious ruby, it is well to apply the dichroscope to jewellery of this kind, before giving twice or thrice its retail value for a specimen.

The emerald, and, indeed, all the coloured varieties of beryl, afford excellent specimens for the dichroscope. A fine emerald is so rare and costly a stone, that it is worth while to know an immediate method of recognizing it, and of detecting the difference

between it and green paste and green garnet. With the emerald the ordinary ray forms a beautiful bluish-green image—like the colour called “viridian”—the extraordinary ray gives an image of a decidedly yellowish-green. With blue beryls the colours are azure and sea-green; with aquamarines green-blue and straw-white. That the two colours of the emerald are distinct, and easily seen, is shown not only by the varied and shifting hues of a well-cut stone of this gem, but also by such observations as the following:—In the magnificent suite of precious stones comprised in the Townshend bequest to the South Kensington Museum, is a splendid faultless emerald (No. 1284), which reveals to the dichroscope the two hues, although two sheets of glass and a considerable space intervene between the specimen and the instrument. On the other hand one has no difficulty in affirming that a little stone, a so-called emerald, in Mr. J. B. Hope’s loan of jewels to the same museum, is nothing but a bit of green glass! A sapphire in the same collection (No. 42), may be similarly proved to be equally worthless.

I must not leave the subject of pleochroism without a reference to the topaz, the chrysoberyl, the amethyst, and the tourmaline. A rich sherry-coloured topaz from Brazil gives two very different hues, one a rose-pink, the other a straw-yellow. The former colour becomes more pronounced, and the latter less so, after the stone has been heated or “pinked,” as the lapidaries term the process. If a burnt cairngorm or beryl, or a piece of burnt quartz, be similarly examined, the coloured images are quite different. A chrysoberyl in my collection shows two colours, a greenish-yellow and a golden-brown. A fine dark amethyst shows two hues of purple, one with more blue in it than the other. But the most dichroic of all stones, too distinctly so to need the instrument, is the tourmaline. Many green and brown tourmalines are opaque in the direction of the principal, which is also the optic axis, to light polarized, except what is polarized in a plane perpendicular to that of the axis.*

* Such a tourmaline plate, cut with its face parallel to its optic axis, will divide the ray of common light into two, but the ordinary ray (O) will be completely absorbed, and only the extraordinary ray (modified in colour by the colour of the tourmaline) will be transmitted. The one emergent beam (E) will be polarized in a plane perpendicular to the axis of tourmaline.

The following list includes several examples of dichroism :—

	O.	E.
Sapphire	green-yellow	blue.
Ruby	aurora-red	carmine-red.
Emerald	bluish-green	yellowish-green.
Topaz	rose-pink	straw-yellow.
Peridot	sea-green	brown-yellow.
Aquamarine	grey-blue	straw-white.
Blue Beryl	azure	sea-green.
CRYSTALS.		
UNIAXIAL.*		BIAXIAL.
<i>Positive.</i>	<i>Negative.</i>	Chrysoberyl.
Zircon.	Tourmaline. }	Topaz.
Quartz.	Rubellite. }	Iolite.
	Sapphire. }	Peridot.
	Ruby. }	
	Beryl.	

A good notion of the variety of twin colours, shown by individual specimens of tourmaline, may be gathered from the following list :—

Pistachio-green and bluish-green.
 Greenish-yellow and reddish-brown.
 Rose-pink and salmon.
 Umber-brown and columbine-red.

A properly-cut orange-brown tourmaline shows, from each facet in succession, as it is turned round, a greenish-yellow tint passing into an orange and a brown.

SPECIFIC GRAVITY.—Thanks to Mr. Sonstadt, we have now been in possession for a few years of a ready method of distinguishing many minerals from one another by their specific gravity. To determine this property of a gem by the ordinary method, requires a good balance and a careful experimenter, but Sonstadt's solution enables us to separate from each other, as well as to distinguish, almost any two minerals differing in specific gravity, providing neither exceeds 3.

Sonstadt's solution is made by dissolving mercuric iodide and potassium iodide alternately in a saturated solution of the latter salt, until the liquid refuses to dissolve any more of either. A little powdered potassium iodide and a few drops of mercury are then added, the mixture shaken, and, after some hours' rest, filtered

* In these the ordinary ray is always more refracted than the extraordinary.

if not clear. The sp. gr. of such a solution slightly exceeds 3. I find it convenient to prepare two other strengths of Sonstadt's solution.

A. sp. gr. about 2.63.

B. „ „ 2.67.

In solution A minerals lighter than quartz, such as the felspars, float; solution B serves to separate beryl, which sinks therein, from quartz; while in the saturated solution, C, all the minerals heavier than beryl sink.

Before giving special illustrations of the results obtained by the use of Sonstadt's solution, permit me to draw your attention to the claims of two recent writers as to the origination of this method of separating minerals differing in specific gravity. In the "Comptes Rendus" for the 18th February, 1878, we have a M. Thoulet recommending a solution of iodide of mercury in iodide of potassium, for the separation of the non-ferruginous minerals of rocks, provided their sp. gr. lie between 2.2 and 3. But M. Thoulet would seem to be perfectly ignorant of all that has been done by Sonstadt and myself working in this direction. He does not even know how to prepare the solution properly, for his greatest density is but 2.77 at 11° C. He clearly is ignorant that Sonstadt pointed out the solubility of K I in the solution having that density, nor the further solubility of Hg I₂ in the liquid thus obtained. But if it takes four years for a method to reach France, there is no excuse for Mr. E. T. Hardman, F.C.S., of the Geological Survey of Ireland, announcing, as a discovery of his own, the applicability of Sonstadt's solution, as I have named it, to the separation of mixtures of minerals. I have used it for years for that purpose, a purpose flowing out of Sonstadt's original statements and suggestions.

Mr. Hardman says that he does not gather from my paper that the solution has been "practically used for analytical purposes." In the paper of mine, from which he quotes,* I state—"A few repetitions of this process seldom fail in effecting such a separation in an hour, as would have taken days, or have been impossible by the ordinary method of mechanical selection." If this statement does not involve the experimental application of Sonstadt's solution to analytical purposes, I am at a loss to know what words should be used to convey the meaning intended. Chemists are not in the

* "Mineralogical Magazine," Nov., 1877.

habit of laboriously separating powdered or crushed mixtures of minerals into their constituent species, except for the purposes of analysis.

I have before me two different strengths of Sonstadt's solution. This one, which we will call C, has the sp. gr. 3, the other, B, is about 2.67—the latter we will use for our experiments. First of all, let us introduce a piece of pure rock crystal—this just floats; so does a bit of yellow cairngorm. An amethyst sinks, a dark one very decidedly. Beryl sinks more distinctly still, while topaz and sapphire sink like lead, not only in this solution, but also in solution C. In the case of a parti-coloured amethyst crystal—one end dark and the other light-coloured, the dark end will be the lower. Opals are quite buoyant in solution B, and even milky quartz, which contains a few per cents. of opal, and has the sp. gr. of about 2.64, floats easily. Here are a few specific gravities of varieties of quartz :—

Milky	...	...	...	...	2.642.
Pure Rock Crystal	...	...	...	...	2.650.
Brown Cairngorm...	...	...	...	...	2.656.
Amethyst	...	...	...	...	2.659.
Very dark ditto	...	...	...	...	2.662.

A very instructive experiment consists in heating the solution in which are a number of minerals just floating, just suspended or just sunk. The coefficients of expansion of the liquid and of the several minerals being different, the alterations of position which occur are very striking.

The study of our diagrams of sp. gr. afford materials for other experiments with Sonstadt's solution in addition to those I have named. Solution C. often also enables us to distinguish between minerals which may be easily confused together, such as nephrite and jadeite, or euclase and triphane.

Leaving Sonstadt's solution, let us consider for a few minutes some improvements in the ordinary method of taking specific gravities by weighing the substance in air and then in water. If we attempt such determinations with a delicate balance, we shall find an insuperable difficulty in the viscosity of the water. Long before the sensibility of the balance is exhausted, the oscillations of the beam cease. By substituting alcohol of such a strength that it has no tendency to absorb water or lose spirit, this difficulty may be overcome, the sp. gr. of a large supply of this alcohol at

various temperatures ranging between 10° and 20° C ; these determinations are made in Sprengel's apparatus. The pan of the balance for holding the mineral is of German silver ; it is suspended from an upper pan (for holding the counterpoise necessary on the immersion of the lower pan) by a single fibre of strong unspun silk ; one such thread has been in use for four years in my laboratory. The balance I have employed is one of Oertling's finest assay balances. The sp. gr. of fragments weighing up to about 2 grams. may be taken. The balance will distinctly show the 40th part of 1 milligram ; the errors of the specific gravities lie probably within 0.005.

Speaking of specific gravities I am reminded of a plan of getting rid of adherent air by means of CO_2 and a faintly alkaline liquid.

When a solid or a powder is not easily wetted by water, we may first surround it with pure carbonic acid gas, then absorb that compound by means of a very dilute solution of caustic soda. Pure water may then be gradually substituted for the alkaline liquid, and the determination of the sp. gr. completed by weighing in the usual manner.

Professor Church concluded his paper by some references to the value of the dichroscope, and of Sonstadt's solution in the microscopic study of rocks : he also referred to various public collections of precious stones. The well-arranged series of the British Museum and the Jermyn-street Museum were named, but particular attention was directed to the Townshend jewels in the South Kensington Museum. He pointed out, in detail, the numerous and absurd mistakes in the authorized catalogue of that collection — mistakes repeated in successive editions, although attention had been drawn to them in 1871 in "The Spectator," and "The Quarterly Journal of Science." All the corrections then made were afterwards (1874) adopted by Mr. Hodder M. Westropp in his revised list of the Townshend Collection.
