XXIX.—*Description of the Lithoscope, an Instrument for distinguishing Precious Stones and other bodies.* By Sir DAVID BREWSTER, K.H., F.R.S. (Plate XIX.)

(Read 18th January 1864.)

In examining the light reflected from the surface of calcareous spar, when in contact with different fluids, I observed several phenomena, both of light and colour, which led me to make the same experiments on the natural and artificial surfaces of the precious stones and other minerals. In these experiments, the intensity of the reflected pencil varied, as might have been expected, with the refractive power of the fluid; but I was not prepared for the curious fact, that when the reflective power of the surface was reduced almost to nothing, the surface was no longer able to reflect white light, but reflected pencils of different colours, depending on the approximation of the refractive power of the fluid to that of the solid. When the crystal had much double refraction, the colour of the reflected light varied with the inclination of the plane of reflection to the plane passing through the axis of the crystal.

In making these experiments, a drop of fluid is placed upon the surface of the body to be examined, and upon this drop is laid the broad surface of a rectangular prism of glass. A parallel film of fluid will thus be formed between the crystal and the prism, and any luminous image reflected from the two combined surfaces will consist of two images superposed, one reflected from the common surface of the crystal and the fluid, and the other from the common surface of the fluid and the glass. By a slight inclination of the prism, the two images are separated, so that we can examine and compare them, the pencil from the prism and fluid surface being a standard light, with which the pencil reflected from the common surface of other crystals and the same fluid may be compared, in reference to colour and intensity of light.

By the use of fluids, therefore, of known refractive power, we can distinguish precious stones and other minerals, the standard of intensity and of colour being the invariable pencil reflected from the prism and fluid surface. A continuous scale of refractive power, embracing a great variety of minerals and other bodies, may be obtained, by mixing fluids in different proportions. The fixed oils combine readily, not only with one another, but with many of the volatile oils; and the aqueous solutions of alcohol and sugar, will to some extent, be useful auxiliaries in reducing the refractive power of the surfaces on which they are placed.

This method of distinguishing bodies is not limited to those which are solid. By standard prisms of crystals, or of different kinds of glass, we may distinguish fluids of *all* kinds, because the range of refractive powers from tabaheer to

diamond and chromate of lead, is much greater than from water to oil of cassia. In this case, a standard pencil will be obtained from a standard fluid of a known refractive power, placed on a surface of the same glass as the prism, as will be presently explained. Impurities in oils and other substances may be thus detected, and specific gravities approximately ascertained.

In order to make these experiments easily and correctly, I contrived the instrument now on the table, which was constructed for me many years ago by the late Mr DOLLOND, and which may be called a *Lithoscope*, from its application to the discrimination of precious stones.

It consists of a rectangular prism PR, mounted as shown in Plate XIX., where AB is a pillar, carrying the horizontal and vertical branches CD, CE. The prism turns vertically round a joint at E, and may be lifted round that joint by the hand, from its horizontal position, or raised slowly by the milled-head F of a screw FG, resting at G upon the branch CD. A small circular plate H, at the top of a screwed rod I, is made to rise or fall by means of the milled head KL; and has also a motion of rotation round the top of the rod. Two steel rods *de*, *cf*, carry two small aperture tubes *e*, *f*, through one of which, *f*, the incident pencil falls nearly perpendicularly upon one side of the prism, and at an angle of 45° upon its base. These rods, with their tubular apertures, slide through short tubes at *m* and *n*, in order that they may receive the incident and reflected pencils. Bottles containing oil of cassia and other standard oils are placed at *a*, *b*, *c*.

In using the Lithoscope, the mineral upon whose surface the observation is to be made is attached, if necessary, by cement or otherwise to the plate H. A drop of the proper oil is then put upon the surface of the mineral, and the prism brought into a horizontal position. If it does not touch the oil, it is brought into contact with it by the milled head KL, which raises the plate H. A plate or film of oil, with parallel surfaces, is thus formed between the mineral and the prism; and if we now view the image of the sun or of a small bright flame, transmitted through the aperture *f*, reflected from the film, and reaching the eye through the aperture *e*, we shall see one image consisting of two coincident images, the one reflected from the surface of the prism and the oil, and the other from the surface of the oil and the mineral. In order to separate these images, the prism is slightly raised round the joint at E, by turning the milled head F. The prism image will then appear at the right hand of the other image; and by a comparison of the colour and intensity of these images, we obtain the information we desire.

It was by an apparatus of this kind, furnished with a graduated circle, that I discovered the influence of the doubly refracting force in polarising common light in planes inclined to the plane of reflexion. These experiments were published in the "Philosophical Transactions" for 1819, and have led several distinguished mathematicians—Professor MACCULLAGH of Dublin, M. SEEBECK of Berlin, and

Professor NEUMANN of Königsberg—to important extensions of the Undulatory Theory. I shall have occasion, in another paper, to submit to the Society a series of experiments on the influence of the doubly refracting force in turning the planes of polarised light out of the plane of incidence and reflexion; but at present I confine myself to the consideration of the intensity and colour of the reflected pencils.

The following observations were made chiefly with oil of cassia and oil of anise seeds, on account of their great refractive power, and will be sufficient to show the use and application of the Lithoscope:—

With Oil of Cassia.

DIAMOND.—The colour from the crystal is *yellow*, and the intensity of the pencil *four* or *five* times greater than that of the pencil from the prism. The Diamond may therefore be easily distinguished from *Quartz* and from Glass of very high refractive power, for which it is often mistaken.

ZIRCON.—The colour from the crystal is white, and the intensity of the pencil *two* or *three* times greater than that of the pencil from the prism.

RUBY, *Oriental*.—The colour from the crystal is *yellow* in artificial light, and the intensity of the pencil nearly double that from the prism.

CHRYSOBERYL, *Cymophane*.—The colour from an artificial face in candle-light is *yellowish*, and the intensity of the pencil greater than that from the prism.

BERYL.—The colour from the crystal is *slightly blue*, and fainter than the pencil from the prism.

BLUE TOPAZ.—The colour from the crystal is a *brilliant lilac*, approaching to *blue*, when the plane of reflexion passes through the axis of the prism, and the surface is *artificially polished*. On the same face, and in a plane at right angles to this, the colour of the pencil is *bluish pink*. The intensity of the pencil is two or three times less than that of the pencil from the prism.

Upon a *natural face*, the colour of the pencil is *bright blue* in every azimuth.

Above the polarising angle, the reflected pencil consists of polarised *red* light and of unpolarised *blue* light.

TOPAZ from *Brazil*, *colourless*.—The colour from a cleavage plane is a brilliant *blue*, in every direction.

TOPAZ, *yellow*, from *Brazil*.—Upon natural and artificial faces, the colour is a *faint red*, and the image scarcely perceptible. On another specimen, I found the colour to be a *bright pink*, the intensity being much less than that of the pencil from the prism.

CINNAMON STONE.—On an artificial surface of this variety of garnet, the colour of the pencil was *yellowish red*, and its intensity less than that from the prism.

GARNET, *precious*.—The colour of the pencil is *reddish yellow*, and its intensity a little greater than that from the prism.

GARNET, *from Elie, in Fife*.—The colour of the pencil is *reddish yellow*, but the intensity very much less than that from the prism.

PERIDOT.—The colour of the pencil is *brownish yellow*, and its intensity much less than that from the prism.

EUCLASE.—The colour of the pencil is *brilliant yellow*, and its intensity less than that from the prism.

PREHNITE.—The colour of the pencil is *blue*, but brighter than that from topaz.

QUARTZ.—The colour of the pencil is a *faint blue*, both on natural and artificial faces, and its intensity less than that from the prism.

AMETHYST.—The colour of the pencil is a *faint blue*, as in quartz, and its intensity less than that of the prism.

DICHOITE.—The colour of the pencil is a *blue*, fainter than in quartz, and its intensity less than that of the prism.

BLACK TOURMALINE.—The colour of the pencil in a plane perpendicular to the axis is a *brownish yellow* in candle-light, and its intensity much less than that from the prism.

AUGITE.—The colour of the pencil, in candle-light, is *yellow*, and its intensity less than that from the prism.

SULPHATE OF BARYTES.—The colour of the pencil is *brick-red*, less faint than in topaz, and the same at all incidences and in all azimuths. The intensity of the pencil is very much less than that from the prism.

SULPHATE OF LEAD.—The colour of the pencil, in candle-light, is *brilliant yellow*, and its intensity twice as great as that from the prism.

LEELITE.—The colour of the pencil is *greenish blue* when the oil is warm, the intensity of the pencil increasing with the incidence.

JET.—The colour of the pencil is a very faint *yellowish red*, and the same at all incidences.

The following experiments were made with *Oil of Anise Seeds*, a less refractive oil than *Oil of Cassia*:—

QUARTZ, on a face of the prism. When the plane of reflexion passes through the axis, the image of a candle is just perceptible, and of a *brick-red* colour.

In sun-light the colour is *blue*, of little intensity, but *pink* when the oil is first put on!

When the plane of reflexion is perpendicular to the axis, the image of a candle is distinctly visible, and of a *brick-red* colour. In sun-light the colour is *red*, but *yellow* when the oil is first put on.

On a face perpendicular to the axis of the crystal, the colour in sun-light is *blue*.

On a face of the pyramid, the colour is *pink* in a plane passing through the axis, but *light red* in a plane perpendicular to the axis.

AMETHYST.—The colour of the pencil is a *fine blue* at all incidences and in all azimuths.

DICHOITE.—The colour of the pencil varies from *reddish yellow*, when the oil is warm, to a *bluish* colour when the oil is cold, the intensity being the same at all incidences.

OPALS, *Common and Precious*.—The colour of the pencil a *pale yellow*, but bright.

BLOODSTONE.—Colour of the pencil *lemon yellow*.

LEELITE.—Colour of the pencil *purple*, becoming *bluish* at great incidences.

LABRADOR FELDSPAR.—Colour of the pencil *sky blue*.

ROCK SALT.—The colour of the pencil *blue*, at all incidences.

The following experiment was made with *Sulphate of Lime* :—

With *Balsam of Capivi* the pencil was colourless, and faint at all incidences.

With *Castor Oil*, the pencil was colourless at all incidences.

The following experiments were made on *Quartz* with pencils of polarised light, O and E, polarised in planes + and — 45° to the plane of reflexion :—

On the face of the *prism*, and in a plane passing through the axis of the crystal, with *Canada Balsam*, E was *orange yellow*, and not so bright as O, E being polarised at a greater incidence than O.

In a plane at right angles to this O=E, and both vanish together.

On the face of the *pyramid*, and in a plane passing through the axis of the crystal, O is *bluish* and E a *straw yellow*, O being much brighter than E, and both vanishing together.

In order to reduce the reflective power of the *quartz*, I mixed *Oil of Sassafras* and *Oil of Anise Seeds*, in such proportions that the combination had nearly the same refractive power as the mineral. The image of a candle placed a few inches from the reflecting surface was scarcely visible.

In sun-light, however, and on a face of the prism in a plane passing through the axis, the pencil E was a bright *greenish blue* at incidences below the polarising angle, and it consisted of two pencils of different colours, the one a *bright blue*, polarised in the plane of reflexion, and the other a *yellow*, polarised in a plane perpendicular to it.

In a plane perpendicular to that passing through the axis, the colour of E was a *bright purple* at various incidences.

On the face of the pyramid, the colour was *blue* in the one plane, and *purple* in the other.

The use of the Lithoscope, in distinguishing both solids and liquids, may be extended in two ways—

1st, By dividing the reflecting surface of the prism into two, three, or more parts, by means of grooves, so that two, three, or more oils may be used at once; and,

2d, By using a prism composed of two, three, or more portions of glass with different refracting powers.

By either of these means, or by the two in combination, the experimental results may be more readily and accurately compared.

In the preceding experiments our attention is called to two different phenomena—the intensity and the colour of the reflected pencil. When the pencil is colourless, which is generally the case when one of the surfaces is that of glass, its intensity depends on the index of refraction of the surfaces in contact, which is always equal to the quotient of the greater index of refraction divided by the lesser.

The phenomena of colour produced by feebly reflecting surfaces, and first described in my paper of 1819, already referred to, arise from two different causes—

1st, In doubly refracting crystals, from the influence of the doubly refracting force in turning through different angles the planes of the polarisation of the differently coloured rays; and,

2d, In the same class of bodies, and in those which have no double refraction, from the different dispersive powers of the surfaces in contact, and also from the irrationality of dispersion, in consequence of which the coloured spaces in different spectra have not the same proportion to each other.

To the subject of crystalline reflexion in which the phenomena of colour are exhibited, I shall have occasion to direct the attention of the Society in another paper. When the colour is produced by difference of dispersive power, or by irrationality in the spectra, it is easily explained. In a combination, for example, of flint glass and oil of cassia, the index of refraction for red light is the same in both bodies, but different for all the other colours. The *red* light, therefore, in a perfectly colourless beam, will pass through the surface of the oil and the glass, without suffering reflexion; and, consequently, the light reflected must be *bluish*, while the transmitted light will be *yellowish*. As there is no reason for believing that in any two bodies, whether gaseous, fluid, or solid, the dispersive powers are exactly the same, or the coloured spaces exactly proportional, we may assert that when pure white light is either transmitted by, or reflected from, bodies perfectly colourless, the transmitted and reflected pencil must be coloured, however inappreciable the colour may be.*

* See "Memoirs of the Life and Writings of Sir ISAAC NEWTON," vol. i. p. 163. Second edition.