ON THE

OPTICAL PHENOMENA AND CRYSTALLISATION

OF

TOURMALINE, TITANIUM, AND QUARTZ,

WITHIN

MICA, AMETHYST, AND TOPAZ.

BY

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WITH A PLATE.

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XXXVII.—*On the Optical Phenomena and Crystallisation of Tourmaline, Titanium, and Quartz, within Mica, Amethyst, and Topaz.* By Sir David Brewster, K.H., D.C.L., F.R.S., and V.P.R.S. Edin. (With a Plate.)

(Read 4th January 1853.)

The existence of certain minerals imbedded in others,—the optical phenomena which they exhibit,—their form and mode of distribution, and the mechanical influence which has been exerted during their formation on the mineral that contains them, are among the most curious and instructive facts in physical science.

The dissemination of perfectly-formed crystals of titanium, both in the form of *titanite* and *anatase*, in Brazilian crystals of quartz, is a fact so well known that I shall take no farther notice of it, but shall proceed to give an account of a series of facts of a much more general and interesting character, which I have had occasion to observe, during an extensive examination of minerals, undertaken with a different object.

1. *On the Distribution of Tourmaline in Mica.*

When fluids and condensed gases are imprisoned in the cavities of *topaz* and other hard minerals, they retain their place till some powerful agent releases them from confinement, or till heat gives them such an expansive force as to burst the mineral. In *mica*, however, where the laminæ of which it is composed are held together by a very feeble cohesive force, the fluids in their cavities, and the extraneous materials which were present at their formation, have experienced no difficulty in quitting their place, and spreading themselves between the plates of the mineral.

Tourmaline and *quartz*, though thus distributed between the laminæ of mica subsequent to its crystallisation, have yet found a place in it contemporaneously with the crystallisation of the mica itself. In this case they are large crystals, equivalent in thickness to many laminæ, and may be taken out and subjected to examination. Some of the crystals of tourmaline are so large, indeed, that I have used them with their own natural faces as analysing prisms; and the quartz crystals, which are amorphous, and very irregularly formed, occupy a still greater space. In both cases, however, the tourmaline and the quartz, when taken out, leave large openings in the laminæ, and have greatly disturbed the structure of the mica around them.

The crystals of tourmaline thus formed in the mica, have almost always the faces of the flattened hexagonal prism parallel to the laminæ of the mica. I have found, however, a few cases in which the flat summit of the hexagonal prism is parallel to the laminæ. The crystallisations of quartz have also the axis of the prism, or its hexagonal faces parallel to the laminæ.

The other crystals of tourmaline which I have discovered in mica have a very different character: They have been formed subsequently to the crystallisation of the mica, and exist only between its laminæ. I have not been able to discover any cavities in mica containing fluids or gases, but I have found thousands from which the fluids and gases have escaped,—the one crystallising into hexagonal plates of tourmaline, and the other separating the laminæ, or running between them, and carrying along with it minute portions of crystallisable matter.

The hexagonal crystals thus formed have their faces perpendicular to the axis of double refraction, which is the axis of the prism; and what is peculiarly interesting, the fluid from which they were formed has insinuated itself between several of the laminæ, and the different plates of tourmaline which they formed have, of course, the sides of the hexagon incoincident. Sometimes these crystals extend to different distances from the centre of the original cavity, and are occasionally formed round it in a circular group. See Plate XV., Fig. 1.

The centre of the cavity from which these crystals have been projected is occupied by a spherical group of granular or capillary crystals, which is generally very *opaque*, though such groups sometimes exhibit, in particular spots, double refraction, and a speck of light is occasionally seen through the centre of the group. In some cases I have observed these very thin hexagonal plates without this opaque centre; and they have probably been formed by a portion of the fluid projected to a distance between faces of easy cleavage. The black spherical group already mentioned has its outward surface bristled with points, which are the extremities of the crystals radiating from its centre; and in one fine specimen to be farther described, it is surrounded with a ring of less opacity than the nucleus, and analogous to what is common in circular crystals. See Fig. 1.

The thin plates thus formed between the laminæ, whether hexagonal or prismatic, are always of a faint *brownish yellow*, which at an increased thickness becomes *green;* and so exceedingly thin are these plates, especially those farthest from the nucleus, that with a power of 400, it is often very difficult to see their terminal lines.

In order to convey an idea of these phenomena, I have given a drawing in Fig. 1 of a very interesting one, where the prismatic crystal nearest the black central group is a bright *green* in all azimuths with polarised light, surrounded with three or four larger prismatic yellowish plates, growing fainter both in tint and outline as they recede. In some cases the crystals are brown, and in others beautifully dichroitic, being *bright green* and *pink* in the different azimuths of polarised light.

As considerable forces must have been in operation during the production of these phenomena, we may expect to see the effects of them upon the surrounding mica. We accordingly observe the polarisation produced by pressure round almost all of these crystalline groups. Rents and other marks of violence are distinctly seen in the mica, and cracks or luminous streaks often occur in the tourmaline plates themselves. I have observed, too, in portions of the mica where I cannot find any cavities or crystals, distinct luminous sectors of polarised light, which could only be produced by a force emanating from their centre. This force may have been that of gas discharged from some neighbouring cavity, and driven by change of temperature to some other part of the mica plate; and in the following remarkable phenomenon we may perhaps find some evidence in favour of this opinion.

Plates of mica contain many beautiful systems of Newton's rings, occupying a circular space where the laminæ have been separated by some cause or other, and where, of course, there must be either air or some gaseous body. The colours of the first order are at the circumference of the circular space where the laminæ are in optical contact, and the higher orders of colour extend towards, and often to the centre of the space. Now it is a curious fact, that wherever there is a cavity which has projected its *fluid* and probably *gaseous* contents, *it is situated in the circumference of one of these circular spaces.* When two cavities have been near each other, the circular spaces unite and lose their form, and when the cavities have been more numerous, the circular spaces unite into very irregular shapes. That these circular hollows or spaces between the laminæ have been produced by something which has issued from the cavity to which they are so constantly related, cannot admit of a doubt. That it has not been a fluid is evident, and therefore it must have been a gas, which is either there still, or has escaped through some minute openings between the laminæ, where optical contact has been restored.*

There are some specimens of mica in which the crystals of tourmaline are large and opaque, and exhibit phenomena which I believe have not been recognised in any other mineral. The most interesting specimen of this kind I owe to Professor Fleming, who pointed out to me one of the peculiarities which it contains. This specimen is accurately represented, of the natural size, in Fig. 2. The largest of the five crystals is 0·28 of an inch broad, and the smallest 0·08 of an inch. Their thickness cannot greatly exceed the thousandth of an inch, and yet it is with difficulty that the strongest sun-light can be seen through them. The form of the smallest is a perfect hexagon, and in the rest the same form is more or less distinct. In the oval crystal there are numerous holes, and in all of them there are numbers of rectilineal cracks parallel to the sides of the hexagon, and some of them so narrow that light can scarcely pass through them. When we look at the sun through one of these crystals, a curious optical phenomenon is seen, a luminous hexagonal surface, composed of lines of light, parallel to the

* A fluid even may have thus escaped, and the circular hollow remained as before. In support of this opinion, see *Edinburgh Transactions*, vol. x., p. 11; but especially vol. xvi., p. 13; or *Phil. Mag.*, vol. xxxi., p. 101, August 1847.

sides of the hexagon, and six beautiful radiations, like those of the Asterial Sapphire, perpendicular to the sides of the hexagon.

The existence of these rectilineal fissures is an important fact in crystallography. It proves that the crystals were in a soft state after they had attained their present form; and that, in the process of induration, the fissures were produced by the shrinking of the tourmaline, in the same manner as similar fissures are produced during the induration of clay. In the mica which surrounds some of the crystals, there is the appearance of considerable disturbance; but I can find no trace of any cavity from which the tourmaline may have been ejected in a fluid state. The faces of these crystals are not everywhere in optical contact with the mica, and it is very probable that they could be removed without any adhering mica, as I have occasionally found crystals of tourmaline that were moveable between the laminæ.

In the same specimen which contains these tourmalines, and in others, I have found, what I believe has never before been observed, the woolly filaments of the *Penicillum glaucum* of LINK, with its sporules scattered about between the laminæ, and sometimes beautifully moniliform, as in the *Penicillum glaucum* obtained from milk by M. TURPIN.*

2. *On the Distribution of Titanium in Mica.*

In examining a remarkable specimen of mica from Irkutsk, in Siberia, I found *titanium* between the laminæ in various forms, sometimes in amorphous plates, sometimes in a powdery state adhering to the mica, and most frequently in beautiful dendritic forms, of various degrees of thickness. At a thickness of about the hundredth of an inch, the titanium, in all these forms is opaque; but at less thicknesses, it has a brownish transparency, becoming almost perfectly transparent at thicknesses which do not seem to exceed the 2000th part of an inch. In Fig. 3 I have given a drawing of an opaque group executed for me with minute accuracy by my celebrated friend Mr HAIDINGER of Vienna, during his residence in Edinburgh. The transparent groups are much more beautiful than the opaque ones, the crystalline ramifications having the most diversified forms, resembling often regular organisations.

When the *mica* is removed from above the titanium, so that only an exceedingly thin film of it is left, the reflected light is extremely brilliant, and consists of the most splendid colours. These colours, which have always the form of the titanium, are those which are produced by the thin film of mica which covers the titanium, and are not produced, as has been supposed, by a vacuity in the mica.

In some specimens of mica from Bengal, the imbedded titanium is spread out

* See *Comptes Rendus*, tom. v., p. 822, 1837, Dec. 11.

in a very irregular manner from a nucleus, sometimes having the form of a thin film; sometimes of oriental characters; and sometimes it is disseminated in grains so extremely minute, that the flame of a candle seen through it is surrounded with a halo of five or six perfectly-formed coloured rings.

3. *Distribution of Quartz in Mica.*

In mica from various localities, I have found large crystallisations of quartz, the quartz replacing the mica. I have never even once met with a regular crystal of quartz; and what is curious, all the crystalline masses of it which I have examined have their axis of double refraction in the plane of the laminæ of mica. In some very large specimens of Bengal mica given to me by Mr SWINTON, I have found layers of quartz, several inches in area, and about the 200th of an inch thick. The two surfaces of the plates are exceedingly inequal and corrugated, owing to the circumstances under which they were formed, but they possessed regular double refraction, and gave the colours of polarised light.

4. *Distribution of Titanium in Amethyst.*

While examining, many years ago, along with the late MARQUIS of NORTHAMPTON, several bags of amethyst which had been imported into Scotland from the Brazils, we were surprised to observe a number of fine pyramidal crystals, which seemed to have a powdery matter distributed through their mass. Upon more narrowly examining these crystals, I found that this dust formed an inner pyramid, all the faces of which were parallel to the faces of the pyramid of amethyst. When two parallel faces were ground upon the pyramid, and perpendicular to its axis, the particles of dust were seen by the microscope to consist each of several spicular crystals of titanium, crossing one another at angles of 60° and 30°, and forming distinct groups. In one crystal there were two interior pyramids composed of these groups; and it will be seen, from the explanation which I shall presently give of this phenomenon, that there may be any number of such pyramids.

As the crystals of amethyst are supposed to have been produced by the gradual enlargement of a small crystal placed in an amethystine solution, we have only to assume that a solution containing titanium has been introduced into the amethystine solution at different times during the growth of the crystal. The small crystals of titanium will deposit themselves on each of the surfaces of the pyramid; and when the whole of the introduced titanium has been thus deposited, the enlargement of the amethyst will go on, leaving a pyramid of titanium crystals in its interior. If a second solution of titanium is introduced, a second pyramid of its particles will be formed in the same manner; and this process may be repeated any number of times.

If we now suppose that the amethystine solution is exhausted, just when the titanium solution has deposited all its crystals, the completed crystal of amethyst will have its outer surfaces covered with spicular crystals of titanium, or the pyramid of titanium groups will be on the very outside of the pyramid of amethyst. I had the good fortune to find such a crystal, in which the coat containing the titanium is laid like varnish on all the faces of the pyramid, but only on the upper end of three of them; the lower end of these three faces having lain on the solution protected from the deposition of the titanium. This crystal is, I believe, unique, and possesses the great interest of exhibiting the very process by which it was formed.

The two phenomena which I have just described are shewn in Figs. 4 and 5.

5. *Distribution of Titanium in Brazil Topaz.*

In examining a great number of very imperfect crystals of Brazil topaz, I found many which contained crystals of titanium of a brilliant scarlet colour, with a tinge of yellow. These crystals were perfectly transparent, and occurred in *seven* different forms.

1. In flat amorphous plates, which were highly transparent.
2. In hexagonal plates, lying in different planes.
3. In transparent lines running in different directions, and, though continuous, lying in different planes.
4. In lines running inwards from the margin of the specimen, and terminating in small flat plates. See Fig. 6.
5. In the most remarkable symmetrical forms like sceptres or maces, resembling some of those symmetrical cavities which I had previously found in the white topazes of New Holland.* See Fig. 7.
6. In some specimens the plates of titanium are actually bent, as in Fig. 8.
7. In little groups of transparent circular plates of a scarlet colour, and having concentric rings.

When light is reflected from the separating faces of the titanium and topaz, it is almost completely polarised; and at greater angles than that of maximum polarisation, colours of singular brilliancy cross the reflected images. These colours are doubtless connected with the fact, that at some of these faces there are *three* images of a luminous object seen by reflexion, one of the two outer ones being polarised oppositely to one of the double middle images, as in the case of the multiplication of images in composite crystals of calcareous spar.†

6. *On the Crystals and Cavities in Garnet.*

In the greater number of the crystals of garnet which I have had occasion to examine, I have found many crystals and cavities, and much amorphous matter. In

* See *Edinburgh Transactions*, 1826, vol. x., Plate XX.
† See *Phil. Trans.*, 1815, Plate XV., Fig. 2.

one specimen, in particular, the included crystals form a larger mass than the garnet, which is merely a cement for holding them together. These crystals have various crystalline forms, while some are amorphous, though regularly crystallised in their interior. All these crystals are doubly refracting, and give the colours of polarised light from their small size.

In another specimen, many of the crystals, in the form of hexagons and rhombic plates, are opaque, and exhibit by polarised light the remarkable phenomenon, which I had never before seen, of having luminous edges, so that when the rest of the crystal and all the field of view is dark, we observe hexagons and rhombs, and other geometrical figures, depicted in lines of red light. It is not easy to ascertain the cause of this singular appearance, because we cannot see the form of the crystals where the light exists; but I have no doubt that the luminous lines consist of light depolarised by reflexion from the sides of the hexagonal and rhombic plates, because the illuminating pencil is much larger than the crystals, and the crystals much smaller than the pupil of the eye, so that light must be reflected from the prismatic faces of the hexagons and rhombic plates, if they have sufficiently broad faces, and that light so reflected must enter the pupil of the eye.

In this specimen and in others there are many spherical cavities, surrounded with sectors of polarised light, and also several amorphous masses of matter, round which there is also polarised light, indicating, as all the phenomena of the crystals do, that the matter of the garnet must have been in a soft state, and compressed by some force emanating from these cavities.

In another specimen of garnet, a large fissure in its interior is occupied with granular matter, which must have issued either from a burst cavity containing a fluid or a gas, or both; but what is very interesting, and what I have never observed in any other mineral, the matter has, in several places, formed circular crystals of singular beauty, some being very simple, and others very composite.

St Leonard's College, St Andrews,
December 11, 1852.

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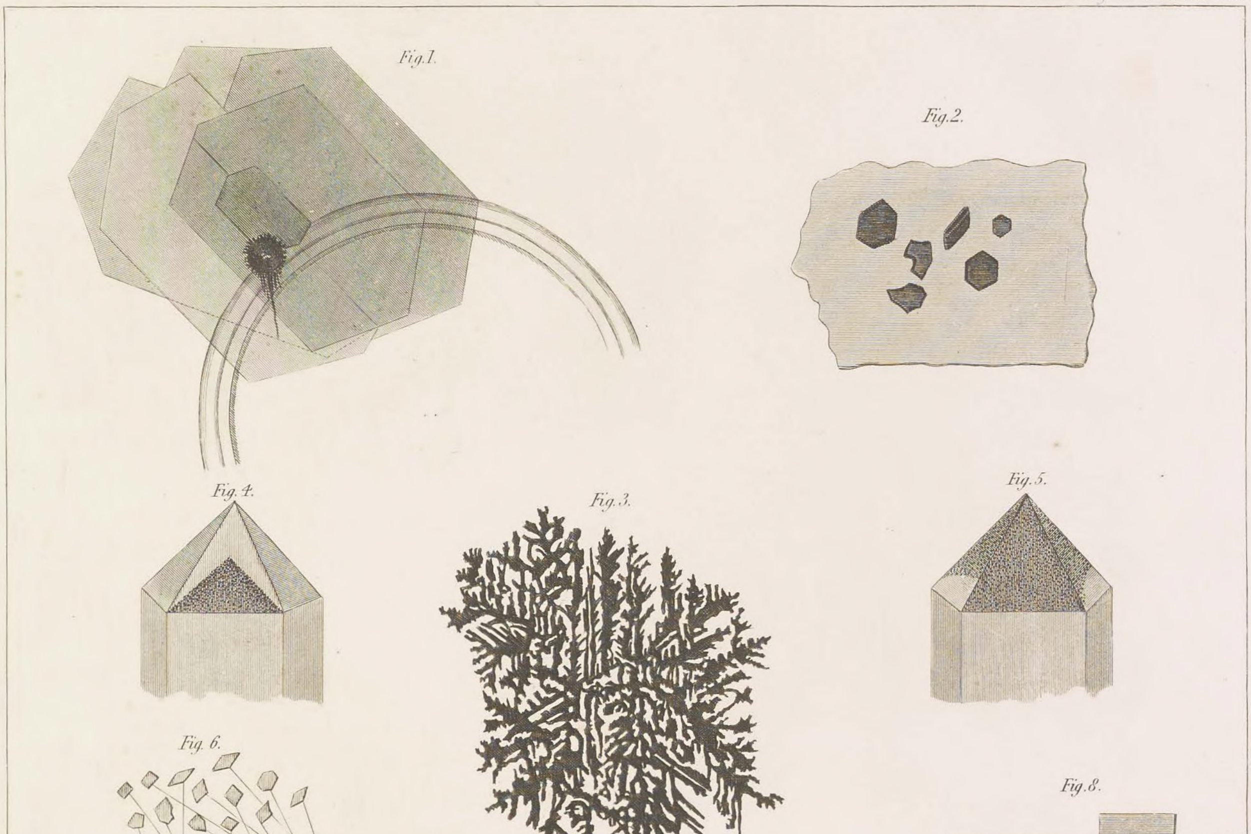

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