XV. Memoir on Bardiglione or Sulphate of Lime, containing a Sketch of a Theory of the true Nature of Plaster, as well as of its Properties; in order to determine the differences that exist between it and Bardiglione.

By The Count de Bournon, F.R.S. &c.

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[Translated from the original French Manuscript.]

This substance is a combination of lime and sulphuric acid, in the proportion, according to Vauquelin, of 0.40 lime and 0.60 sulphuric acid. It has obtained various names: being called Chaux Sulphatée Anhydre by Hauy, Chaux Sulfatine by Brongniart, Anhydrite and Würfelspath by Werner, Muriacite by Poda and Klaproth, Pierre de Vulpino by Fleuriau de Bellevue, and Marmo bardiglio di Bergamo by the Italian statuaries. The name sulphate of lime has hitherto been applied to gypsum; but as it is now well known that the simple combination of lime and sulphuric acid produces bardiglione, while water is essential to the composition of the former, that expression is inapplicable, and might be supplied by that of Hydro-sulphate of lime.

Essential specific Characters.

A. Crystallographic.

Primitive Crystal. A rectangular tetrahedral prism with square bases, which, from every indication, do not belong to the cube, but
the height of which it has hitherto been impossible to determine, fig. 1.

**Integrand Molecule.** The tetrahedral prism very distinctly exhibits natural joints, parallel to the diagonals of its bases; the integrand molecule is therefore a right trihedral prism, having for its terminal face a right angled isosceles triangle, fig. 2: the height of the integrand molecule as well as that of the primitive crystal, which is composed of four of these molecules, fig. 3,* is yet undetermined.

**Fracture.** Even and shining in the direction of the cleavage; but having commonly more lustre, and often a pearly aspect, on those sides of the prism on which the cleavage is most easily obtained. In every other direction it is uneven and granular; but this latter fracture is rarely observed, from the facility with which the fracture takes place in the direction of the natural joints.

**B. Physical.**

**Specific Gravity.** In very pure and transparent crystals from the salt-works of Hall in the Tyrol, I found it to be 29.57, which agrees perfectly with that stated by the Abbé Haüy.

**Hardness.** It scratches carbonate of lime with great facility; but is scratched, though with some difficulty, by fluate of lime.

**Refraction.** Double in a high degree according to the Abbé

*As my conclusions with respect to the primitive crystal and integrand molecule of bardiglione do not agree with what the Abbé Haüy has said concerning them in his *Tableau Comparatif*, &c. I have inserted, after the details relating to the several varieties of this substance, the reasons that have compelled me to dissent from the opinion of that celebrated mineralogist, for whom I have the greatest esteem, and from whom I never differ but with extreme regret.*
Haüy. I have however been able to perceive only a simple refraction in this substance.

C. Chemical.

Action of Acids. None, when the bardiglione is pure.

Action of Heat. A moderate degree of heat renders such of its varieties as are indeterminate of a dull white colour; but has no such effect on those that are crystallized; yet when the crystalline variety of the salt-works of Bex, enclosed in a mass of compact bardiglione mixed with gypsum and sea-salt, is exposed to heat, it gives both to its crystal and to their fragments a whitish tint, frequently accompanied with a pearly lustre.

When the heat of the blowpipe is applied to the thin edges of this substance, it appeared to me to act in the same manner as it does on gypsum: the bardiglione passing, without any ebullition, into a very friable white enamel. The resistance of this substance to fusion, when tried on large pieces, added to the friability of the enamel, is no doubt the reason why several mineralogists have said it was infusable by the blowpipe; but if its action be applied, as I have mentioned, to the thin edges, their blistered appearance instantly demonstrates its fusibility.

Analysis. In the first analysis of bardiglione, Klaproth found 15 parts of sea-salt, 27 of gypsum, and 58 of sand; but the specimen analysed by him must certainly have been very impure. Vauquelin, after having freed it from the sea-salt, which is foreign to its composition, found it to consist of 40 parts of lime and 60 of sulphuric acid.
Colour. Bardiglione is most frequently colourless; but it is sometimes of a pale violet-red; such is the crystalline variety of Hall, as well as that of Sweden, and that of the lead mine of Pesai near Mont Blanc. It is of a deep grey at the salt-works of Bex, and of a bluish tint at Vulpino, which has occasioned some mineralogists to confound it with the bluish variety of sulphate of strontian.

Electricity. The transparent violet-coloured bardiglione of Hall is pretty strongly electrical by friction. That of the salt-works of Bex is likewise electrical, but in a less degree. I could not find this property in any of the other varieties of this substance: even in that of Hall the intensity of the electricity varies considerably; for in some pieces it is very weak, and is excited with difficulty.

Phosphorescence. This character, like the preceding, varies very considerably. Some of its varieties, as that of the salt-works of Hall, give a slight and bluish phosphorescent light. In others, as that of Sweden, which I have already noticed in the 77th number of the Journal des Mines, and which I have said is mixed with actinote, yellow copper, and magnetic iron ore (fer oxidulé), the phosphorescent light is of a yellow colour inclining to orange. In some of the varieties of this substance, which come from Vulpino, this light is of a very deep orange yellow, and with the brightness of a burning coal. Several other varieties, among which is that belonging to the salt-rock of Arbonne near Mont Blanc, as well as that of a deep grey with a somewhat reddish tint of the salt-works of Bex, are totally destitute of this character.
**Table of Bardiglione and its Varieties.**

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<th>Variety</th>
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<tr>
<td>Lamellar . . With large laminæ . .</td>
<td>Lying in the same direction. Very thin, and placed one upon another, so as to form separate and distinct aggregations.</td>
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<tr>
<td>Compact.</td>
<td>Mixed with quartz (pierre de vulpino). Including small globules of the same substance.</td>
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<td>Epigène of Hañy.</td>
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Bardiglione of a determinate Figure.

The crystalline state is that in which this substance most commonly occurs; but its forms are seldom determinate. The finest crystals, and the greatest variety, have been found in the mine of rock-salt at Hall in the Tyrol; which is also the place where it has been most commonly observed of a determinate crystalline figure. The crystals occur there in groups, either colourless, or of a pale red slightly inclining to violet. They are commonly pretty large, frequently flattened, and often of very little thickness. They intersect each other in different directions, and very often several are joined together so as to have the appearance of a single crystal; but in these cases their lines of separation are readily perceivable; and, as they adhere together but slightly, they are easily separated. Sea-salt is frequently found disseminated through these crystals; and in this case, the same salt very often also shews itself externally in small distinct masses, which are easily known by their inferior lustre and hardness. When the Abbé Poda first noticed these substances, it was the variety of Hall that came under his observation. The sea-salt, of which there are frequently considerable masses in it, led him to consider it as a mixture of this salt with gypsum. Its rectangular figure also contributed to this error, which made him give it the name of Muriacite.

In 1802, when Mr. Chenevix analysed this variety of bardiglione from Hall, at my request, the person employed in pulverizing it found some small needles of antimony included in the interior of one of the crystals, most of them adhering to small groups of crystals of quartz; and to prevent all dispute about it, he preserved a fragment of the crystal, to which one of these needles still adhered. This fact,
which I mentioned at the time in the brief account I gave of this substance in the *Journal des Mines*, No. 77, is very singular, when we consider the local circumstances of the bardiglione in which it occurred.

There is another variety of this substance in determinate crystals, often of considerable bulk, and imbedded in a mass of compact bardiglione of a reddish-brown colour, penetrated with gypsum and sea-salt. In this mass different cavities are perceivable, in which the gypsum, likewise coloured red, is in small crystals; and some of these also include sea-salt, perfectly pure, and of a red colour. The crystals of bardiglione which are scattered through this mass, while they remain adhering to it, appear themselves reddish, on account of their transparency; but, when they are detached, their colour is a deep grey. This variety comes from the salt-works of Bex, and is that which I have already mentioned as having its colour destroyed by heat.

*Bardiglione of indeterminate Crystallization.*

1. *Approaching to a determinate form.* Among the crystals of this substance there are several in very thin rectangular laminae, which grow thinner by imperceptible degrees towards the two narrow sides of the prism, and this thinning, which varies considerably, is subject to no law.

At other times, as the edges of the primitive tetrahedral prism, according to the observations hitherto made, may be subjected to six different retrogradations with regard to the placing of the crystalline laminae, the crystals having undergone these six retrogradations in succession, without the crystallization having perceptibly rested at any of them, the faces have assumed a curvilinear figure through-
out a more or less considerable portion of their extent. This variety, as well as the preceding, is frequently observed among the crystals of bardiglione from Hall.

2. Fibrous. I have a small specimen of bardiglione from Hall, in which the crystals, which are very thin, extremely brittle, and nearly colourless, intersect each other in very different directions. In one of the parts of the specimen, this substance exhibits itself in divergent fasciculi, the fibres of which are of unequal lengths, and have a glistening lustre, which gives them an appearance that has considerable resemblance to that of the satiny coralliform arragonite. M. Mohs, in his catalogue of the splendid mineralogical collection of M. Von der Null of Vienna, mentions another variety of fibrous bardiglione, which he says came from Ischel in Upper Austria, and is of a colour intermediate between brick-red and blood-red.

3. Globular. To this variety I believe should be referred the globules of different sizes, from that of a poppy seed to that of a large pea, or still larger, which are met with in a rock of compact bardiglione mixed with sea-salt, known by the name of the Salt Rock of Arbonne, and situated at a very considerable height, being a very little distance from the region of perpetual snow near St. Maurice, in the vicinity of Mont Blanc. These globules are distinguishable from the compact bardiglione in which they are included, not only by their figure, but by their brown colour, that of the mass being grey, or reddish. Their substance is mixed in like manner with sea-salt. They are much more fusible before the blowpipe.

**Lamellar Bardiglione.**

1. *With large laminae, lying in the same direction.* Such is the tex-
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ture of one of the varieties of this substance, of which I have never seen but two specimens; one in the collection of the late Mr. Greville, the other in my own. The bardiglione of these two fragments is of a light violet colour: it is intermixed with a great deal of actinote of a pale green colour, and of asbestos; as well as with a great number of small particles of yellow copper ore, of pyrites, and of magnetic iron ore, \( \textit{fer oxdulé} \) which makes them act strongly on the magnetic needle. I have said, in No. 77 of the \textit{Journal des Mines}, that I presumed, from the nature of the substances accompanying it, that this bardiglione came from Sweden or Norway. The specimen I have, was given to me about two years ago, with a positive assurance that it came from Sweden; but I could not gain any more particular information respecting the place.

M. Mohs, in the same catalogue, mentions two specimens of bardiglione of a similar texture, and of a smalt blue colour, one from Carinthia, the other from Swabia. This variety appears also in the violet bardiglione from the lead-mine of Pesai near Mont Blanc.

2. \textit{With large laminae, very thin, and placed one upon another, so as to form separate and distinct aggregations.} This variety, which is of a very beautiful white slightly inclining to blue, comes from Vulpino, a few leagues from Bergamo in Italy. Its laminae are very thin, and placed one upon another, so as to form little separate aggregations, crossing each other in different directions, and giving the whole mass sometimes a lamellar, sometimes a fibrous appearance, according as the eye is directed toward the flat sides of the laminae, or their edges. This variety, which belongs to one of those of the stone known by the name of Marmo Bardiglio di Bergamo, takes a very fine polish, and has often a little admixture of quartz.

3. \textit{With small laminae, in an uniform direction.} This variety differs from that with large laminae, only in regard to their size. I have a
specimen of it that exhibits an interesting fact. Its surface shews the union of an immense number of small rectangular prisms, all, or nearly all, having their planes in a parallel direction; but a very great number of them are very distinct in all the extent of their square surface. This texture appears to have been occasioned by a very slight alteration. The matrix of this bardiglione is an indeterminate massive quartz, to which there adheres a fragment of foliated micaceous rock, mingled with galena and some iron pyrites. It came from the lead-mine of Pesai, near Mont Blanc.

4. With small lamina intersecting each other in different directions. The bardiglione of Vulpino frequently presents us with this variety, which sometimes has a very deep bluish colour, and is frequently mixed with a few particles of quartz. We are indebted to M. Fleuriau de Bellevue for a knowledge of the different varieties of the bardiglione at Vulpino. It was he who found that this substance, which takes a very fine polish, and is employed by the statuaries of Bergamo and Milan for making slabs, chimney-pieces, &c. differed essentially both from carbonate of lime and gypsum. The first analysis of this substance having shewn it to contain sulphate of lime and quartz, the latter in the proportion of 0.8, it was called quartziferous sulphate of lime; till a second analysis by Vauquelin ascertained its real nature. The interposition of quartz, and the interruption of contiguity occasioned by this interposition, diminishes its specific gravity, which was found to be 28.78 by the Abbé Haüy, who some time after discovered that it belonged to the bardiglione. The quartz interposed in this substance may sometimes be perceived by a good lens.

Sometimes too this variety of bardiglione, and more particularly the following, in the granular state, includes particles of carbonate of lime, but always in very small quantity.
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I have seen specimens of bardiglione, in small bluish laminae, including pretty considerable masses of sulphur; but I was unable to learn whence they were obtained.

Granular Bardiglione.

This variety has considerable resemblance in its texture and external aspect to the granular magnesian carbonate of lime; but in its lustre it approaches nearest to the lamellar variety of that substance.

Stalactiform Bardiglione.

This variety presents itself in a mamillary, and frequently contorted form, resembling the convolutions of the intestines, whence it was called Pierre de Tripe, by which name alone it was known for some time. Its texture is compact, approaching more or less to lamellar.

This variety of bardiglione appears hitherto to have come exclusively from the salt-mines of Wieliczka, though it is also said to have been met with in those near Bochnia, in Poland. It was at first very improperly considered as a sulphate of barytes, which very probably may have been the cause of a variety of the latter substance, which sometimes approaches to a stalactical figure, having been confounded with it; hence it has been said by some mineralogists to have been found also in Saxony, and in Derbyshire, from which places I have never seen any thing that could be referred to it.

According to Klaproth this substance is mixed with a small proportion of sea-salt; his analysis gives 42 parts of lime, 56.5 of sulphuric acid, and 0.25 of sea-salt, leaving a loss of 1.25.
Compact Bardiglione.

This variety is less compact in its texture than compact carbonate of lime, or compact feldspar: its substance, at least in all the specimens which I have hitherto had an opportunity of observing, being more or less mixed with small particles of lamellar bardiglione. Hence its fracture is very rough and irregular; but we can always distinguish in it those little prominent and somewhat detached splinters, which are characteristic of minerals having a compact structure. This variety has generally a slight semitransparency at its edges.

1. Mixed with quartz. This variety of the compact bardiglione occurs with the lamellar variety at Vulpino; the quartz which it contains is sometimes visible with a good lens.

2. Mixed with sea-salt. The salt-rock of Arbonne belongs to this variety. Hitherto this rock has been considered as a gypsum mixed with sea-salt; but all the specimens I have yet seen, and which have been sent to me by my friend Gillet de Laumont, belong no doubt to the species bardiglione. This variety includes also in its substance very brilliant small laminae of bardiglione, and its fracture is more irregular than that of the pure compact variety.

The salt-rock of Arbonne presents two varieties of this substance; one of a dirty grey, and the other a little reddish. The latter of these varieties is somewhat closer and finer grained than the other, and it is also less loaded with sea-salt. Very small dodecahedral crystals with pentagonal faces of iron pyrites, are disseminated through its substance. Small globules of compact bardiglione, very easily separable from the substance inclosing them, are likewise included in it. These little globules are destitute of the brilliant laminae observable in the surrounding mass, are of a brown colour,
and appeared to me larger and more numerous in the grey compact
variety, than in the reddish. I observed similar globules in one of
the varieties of bardiglione, consisting of small blue laminae, from
Vulpino.

When pieces of the rock of Arbonne have been boiled a certain
time in water, to free them from the sea-salt they contain, they be­
come porous, but very irregularly so; and thus shew, that the sea­
salt is distributed unequally, and chiefly in small masses.

Bardiglione Epigène of Hauy.

M. l'Abbé Haüy, in his Tableau Comparatif, gives the name of
epigène, agreeably to its Greek etymology, to every transition of one
mineral to another.

The mention which he makes of this variety of bardiglione, from
which alone I am acquainted with it, is in consequence of a specimen
presented to him by M. Cordier, in which one part of the substance is
in the state of lamellar bardiglione, while the other is in that of com­
 pact gypsum. To the gypsum of this specimen M. Haüy gives the
name of bardiglione epigène, because, in his opinion, its formation has
taken place from an action exerted on the lamellar bardiglione itself,
subsequent to its production; which action, from what he says
p. 141, was effected by the introduction of water into its interior:
whence, he adds, the substance of the bardiglione has lost part of its
hardness, and its texture has become looser. He further states, that
according to an observation communicated to him by M. Hassenfratz,
there are at Pesai, whence this specimen came, galleries carried
through the bardiglione, the outward part of which, being penetrated
by moisture, has experienced a considerable enlargement.
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Such a transition of one substance into another essentially different, not by decomposition and the consequent loss of one of the component parts of the substance; not by another kind of decomposition, in which the loss of one of the component parts of the substance is spontaneously replaced by another, thus giving rise to a new compound; but by the introduction of a new principle, by the combination of new constituent molecules with those of which the integrant molecules of a substance are previously composed; would be so highly interesting, and lead to consequences so new, so remote from every thing presented to us in the mineral kingdom, and at the same time so important to the science of geology, that it requires to be examined with the most scrupulous attention. Accordingly I shall reserve the further consideration of this subject for the observations which will conclude this memoir.

Observations on the Primitive Crystal, and Integrant Molecule of Bardiglione.

In my enumeration of the specific characters of bardiglione, I have said that its form was a rectangular tetrahedral prism with a square base, fig. 1; in which the absence of additional faces, either at the edges or angles of the terminal faces, had not hitherto permitted me to determine the height. I added, that this prism was divisible in a direction parallel to its two diagonals, as pointed out in fig. 4, which shows at the same time, that each of the primitive rectangular tetrahedral prisms is composed of four right trihedral prisms, the bases of which are right angled isosceles triangles, fig. 3. The height of these trihedral prisms remains equally unascertained, and they constitute the integrant molecule of this substance, fig. 2.
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When I, thus determined the primitive crystal and integrant molecule of bardiglione, the Tableau Comparatif des Résultats de la Crystallographie et de l'Analyse Chimique of M. l'Abbé Haïy had not appeared. This work informs me, that its learned author had also determined the form of the primitive crystal, as well as of its integrant molecule; and at the same time I perceive, with infinite regret, that, as he was not more fortunate than myself with respect to the height of these two molecules, the other dimensions he assigned them differ from those to which I had been led by my study of this substance. According to this distinguished mineralogist, the base of the rectangular tetrahedral prism is not a square, but a rectangle, the sides of which are to each other as 16 to 13.4 (fig. 5); the prism is divisible in a direction parallel to its diagonals by planes, the intersection of which forms angles of 100° 6' and 79° 54' (fig. 6). Thus it would be divisible into rectangular rhomboidal prisms, the bases of which would be rhombs of 100° 6' and 79° 54'. But these prisms, it appears to me, cannot in any way be considered as the integrant molecules of the tetrahedral prism with rectangular bases, considered as the primitive one; for this prism being also divisible in a direction parallel to each of its sides, as shown at fig. 7, this second division would separate each of the prisms with rhomboidal bases of 100° 6' and 79° 54' into four rectangular trihedral prisms, of which two opposite ones would have for their base an isosceles triangle of 100° 6', and the other two an isosceles triangle also of 79° 54', fig. 5. Thus these molecules would be of two different forms, and consequently could no more be considered as the integrant molecules of the substance, than those with rhomboidal bases of 100° 6' and 79° 54'.

On the other hand, this substance presents a very particular and interesting fact, likely to mislead, with respect to the primitive
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crystal, and which probably deceived the Abbé Hauy. On looking at the crystals of this substance, through their terminal faces opposite to the light, lines are observed in the interior of several, perfectly distinct, and in the direction of the two diagonals of these terminal faces. The intersection of these lines, instead of taking place perpendicularly, so as to be at right angles, and thus forming squares, as in figs. 3 and 4, appears to be made obliquely, fig. 5, so as to form rhombs, as shown at fig. 6. If, in order to find the measure of the angles of these rhombs, different angles be placed on them till their sides apparently coincide, an angle of 100°, or nearly so, appears to agree very well with the obtuse angles, so that the rhombs have apparently 100° and 80° for the measures of their angles. But then if a natural, or an artificial fracture, the latter of which is very difficult, be made according to the natural diagonal joints of the primitive crystal of this substance, the plane produced should make with the adjacent planes of the prism on one side an angle of 140° 3', and on the other an angle of 129° 57'; which never is the case, for these two angles are always very exactly 135°, being what the same section must produce on the supposition of the sides of the terminal faces being equal. Yet if we compare the direction of this face, with the lines traced in the interior of the crystal, according to the natural joints, it appears to be perfectly parallel with that of these lines.

Such are the reasons which determined me to consider the base of its primitive rectangular tetrahedral prism as a square: yet, as I have observed above, there is in this substance, on account of the difference between the appearance of the angles formed by the meeting of the interior lines, indicating the natural joints; and the correspondent ones formed by the planes parallel to these joints, something very peculiar, which would seem owing to some illusion dependent on refraction, for which I cannot account.
The only crystals of this substance in which I have found perfectly determinate forms, except the primitive prisms and its fragments, have occurred to me in the bardiglione from Hall, in specimens that included groups of these crystals. Most of them, though having secondary faces, are so united together, commonly in a direction parallel to their planes, that, till they were broken, and their planes thus exposed, they appeared absolutely to compose but one crystal, as is also the case in the laumonite. Owing to this their additional faces are most frequently destitute of that lustre, which commonly belongs to the crystals, and are even in general striated. The fractures made in the direction of the diagonals, which are difficult to obtain, are likewise usually striated, thus exposing to view the edges of the laminae placed on the planes of the prism, especially on those which have a pearly lustre.

I have represented at fig. 23, that which was already given at fig. 14, but of which, in the crystal that has furnished me with the variety I possess, as well as all those I have inserted in the plate annexed to this work, one part alone is in a state of perfect preservation. I placed this crystal so, that I could show the natural interior joints, as they are perceived in looking through its terminal faces. The lines that indicate these joints are very conspicuous in it. The two planes 1 and 3 are equally devoid of all lustre and striated, and both of them appear parallel to the interior joints. That marked 1, which I consider as belonging to a fracture, and which might have been produced by a retrogradation by a single row along the edges of the prism with square bases, makes with the faces of the primitive crystal adjacent to it an angle of 135°. That marked 3 appears to answer to r fig. 24, pl. II. of the Abbé Haüy's Tableau Comparatif; but instead of making with the primitive planes an angle of 129° 56', as mentioned by that celebrated author, that
which it does form has constantly appeared to me to be at least one degree smaller. I conceive it to be the product of the retrogradation by five rows in breadth and four laminae in height on the edges of the prism with square bases. The angle it forms with the primitive planes would consequently be $128^\circ 40'$. I place this crystal here anew, under the aspect proper to it, because it appeared to me better adapted than any other, to set in its true light the opinion of the Abbé Hauy, as well as my own; and may more easily enable the reader to decide between the two. Whichever may be adopted, the crystals represented will remain the same; the calculation alone will require to be rectified, as I have myself done in the second table of the modifications of the primitive crystal, annexed to this memoir.

General Observations on Bardiglione.

From what has been said, in the preceding description of the varieties of bardiglione, of the different circumstances in which they present themselves, and of their localities, this substance appears not to be confined to secondary strata, but also to occur in some veins in primitive rocks. Such is the bardiglione that has been said to be found in the vein of lead-ore at Pesai near Mont Blanc, as well as that accompanied with actinote from Sweden. But hitherto it has been met with much more frequently in the newer rock formations, particularly those that include large deposits of sea-salt. Of this kind is the bardiglione which is found in the salt-works of Bex, in the salt-mines at Hall, in those of Wieliczka, and in the salt-rock of Arbonne: as well as that of Carinthia, Upper Austria, and Swabia. Are these the only places in which this substance accompanies rock-salt? and in the great repositories of this mineral, at Voltiera in Navarre, Almen-
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Granilla in la Mancha, and elsewhere in Spain, at Northwich in Cheshire, in the salt-works of Altamonte in Calabria, &c. may not much of the accompanying gypsum, as it has been hitherto considered, be rather in the state of bardiglione? It appears besides, that under certain circumstances bardiglione forms particular deposits, such as that at Vulpino, at a little distance from Bergamo in Italy, which has long been employed by the statuaries of that city, and of Milan: but we are still in want of information respecting its exact position, as well as the nature of the accompanying rocks.

This substance must still be considered a new object of observation for the geologist. I am strongly persuaded, that it will be to him what the magnesian carbonate of lime has proved, since Mr. Tennant turned his attention towards it, and shewed, that it exists in deposits of considerable extent, where its presence had not been before suspected.

I have postponed to this part of my paper the grounds of my opinion as to the essential difference between bardiglione and gypsum, the detail of which will oblige me to take a view of the calcination of gypsum, and of the different phenomena it exhibits.

By calcination, gypsum is known to undergo no other alteration than the loss of the water that formed part of its substance. The residue of this process, properly called plaster, contains nothing but lime and sulphuric acid in the same proportions as in bardiglione. These two substances might therefore be ranked together, but we shall presently see that there is a wide difference between them. In this state of calcination, when we would make use of it, we mix it with water, by tempering and beating them together. A certain quantity of the water is absorbed, and after the evaporation of the superabundant part of this liquid, which is promoted in some degree by the caloric evolved in the operation, the mixture acquires solidity;
still however retaining a slighter cohesion between its particles than existed between those of the gypsum previous to its calcination, and without receiving any degree of transparency. In the transition of Plaster to this state of solidity, the gypsum has hitherto been said to resume its water of crystallization; but what is this water of crystallization? what idea ought this expression to convey to the mind?

If, in order to settle my opinion on the subject, I consult those who have written on chemistry, or on mineralogy, the majority conceive, that this water is that which a large quantity of salts and earthy substances retain when they crystallize; and that this water is necessary, in these cases, to the crystallization of the substances, but constitutes no part of their essence. But how can the water, absorbed by the plaster, which is evidently very different from water of crystallization, be necessary to the process? What part does the water in crystallized gypsum act in the crystallization of it? a satisfactory answer to these two questions, is, I conceive, requisite in all the cases in which they occur.

Some of these authors think, that, in several instances, the water enters into their composition as an essential ingredient; and upon this subject I refer to a passage in the first volume of the Mineralogy of M. Brongniart, page 96; as also to a very judicious doubt expressed by the Abbé Haüy, in his Mineralogy, vol. IV. p. 351. I confess, that I had long ago adopted this opinion. But is all the water, that may be included in these mineral substances, to be so considered? Certainly not. In many of them the water is foreign to their substance, and has entered merely in consequence of the attraction (to which I have given the name of attraction by approximation) more or less powerful, exerted upon it by their integrant molecules; in this case it is only imbibed and interposed between
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them, but does not affect, in any degree, the essence of the substance containing it; this is water of crystallization in the true sense of that term. But it happens not unfrequently that water enters as an essential part or principle into the formation of their integrant molecule, in which case it is not water of crystallization but water of composition, and ought so to be denominated. It is obvious, that the one does not necessarily exclude the other, for they are totally unconnected with each other. It is obvious too, that we cannot consider the water, which a substance may contain, as making one of its component principles, unless there be solid reasons for such a conclusion. For instance, in the case in question, the combination of lime with sulphuric acid gives rise to rectangular tetrahedral prismatic molecules with square or rectangular bases; while water, uniting with the same principles, combined in the same proportion, gives rise to molecules in right tetrahedral prisms, with rhomboidal bases, having angles of 113° 4' and 66° 56'; it is very evident, that this water, by its union, has totally changed the form of the integrant molecule, which it could only do by combining with it. This fact will be rendered still more evident by what follows.

Calcined gypsum then, from what has been shewn, must have lost its water of composition. This loss must be owing to the molecules of water having a much greater affinity for caloric in motion, or heat, than it has for the other component molecules of gypsum.

If the gypsum had lost in calcination only its water of crystallization, or, what comes to the same thing, that which was regularly interposed between its molecules, there would remain a simple combination of lime and sulphuric acid, in the proportion of 32 parts of lime and 46 of acid in every 78 parts, or 40 of lime and 60 of acid in 100; a combination precisely the same with that which consti-
tutes bardiglione. Plaster, which is the result of the calcination of gypsum, would then be bardiglione, which is far from being true. The distinctive property of gypsum, when changed to the state of plaster, is rapidly to absorb water, and, by that absorption, to acquire consistency, and even a certain degree of hardness. Bardiglione, neither before nor after calcination, has any action whatever on water; and if reduced to powder before it is mixed with it, its particles still retain their state of division.

It is certain, therefore, that bardiglione and plaster, though composed of the same principles, lime and sulphuric acid, and in the same proportions, are two substances of different natures. And as this difference cannot arise from the nature of the principles entering into combination, or from the manner in which they are proportioned to each other, it must necessarily arise from the mode of arrangement of the constituent molecules which form the integrant molecules. Directing our view to this point, we shall see that gypsum, in its transition to the state of plaster, having been deprived only of its water of composition without the combination of sulphuric acid with the lime having been destroyed, each of the integrant molecules, which compose the mass of plaster, should be considered as a right trihedral prism, having scalene triangles for its base, perfectly similar to the integrant molecules of gypsum, and exactly the half of its primitive crystal; but having void spaces, within the solid, similar in shape to the molecule or molecules of water removed, the figure of which is yet unknown to us. Thus the component particles of lime and sulphuric acid are not in immediate contact in the integrant molecules of plaster, except in parts of their surface; while in bardiglione, on the contrary, these same component molecules are in that state of approximation which is adapted to their complete solidity.
Hence we can readily explain the cause why plaster, when in contact with water, absorbs this liquid, and acquires solidity; while bardiglione, in similar circumstances, undergoes no change. From what has been said of the effect of calcination on the integrant molecules of gypsum, it appears that the moment when plaster is brought into contact with water, the molecules of the fluid are attracted into the vacuities of similar shape with themselves by the compound attraction of the bare surfaces of the constituent molecules of lime and sulphuric acid, and are fixed there anew. The plaster then returns in reality to the state of gypsum; and this change takes place more perfectly, when the same water that has completed anew the imperfect integrant molecules of gypsum, affords by its temporary superabundance a vehicle, by the intervention of which, the new formed molecules are enabled to approach each other afresh, and crystallize. The gypsum however neither recovers the form, the hardness, nor the transparency which previously belonged to it: the crystallization just mentioned cannot be otherwise than greatly confused, on account of the considerable motion that must exist at the moment in which the process takes place, on the one hand, from the absorption of the water in the transition of the integrant molecules from the state of plaster to that of gypsum; and on the other, from the evaporation of that liquid, which is occasioned by the disengagement of caloric, expelled by the return of the molecules of water of which it had occupied the place, added to that set free by the water of combination, at the moment of its passage from the liquid to the solid state. The superabundance of the water, beyond what is necessary for the regeneration of the molecules of the gypsum, is indicated by the volume of that absorbed by the plaster. It is well known, that the volume of this is at least equal to that of the plaster, which is itself of more considerable bulk than the
gypsum from which it was produced. It is known too, that the moment the water is absorbed by the plaster, there is always a disengagement of heat, though much less than that produced in the absorption of the same liquid by quicklime.

As the integrant molecules of gypsum, in their regeneration from plaster, can only crystallize, as has been said, in a very irregular and confused manner, the space occupied by the whole mass, after this reproduction, must be in proportion to this irregularity. Accordingly it is found that plaster acquires a very evident increase of bulk, a circumstance that is often very detrimental in the purposes for which it is employed; and this increase is greater, in proportion to the purity of the gypsum from which it was made. The swelling allows part of the water, superfluous to the regeneration of the gypsum, to remain interposed in the plaster, till the caloric of the ambient air has in its turn absorbed it, during the process of drying. In this state, the plaster must be considered as perforated with little vacuities interspersed throughout its substance; and in consequence of this texture, when it afterward comes again into contact with water, or even with air loaded with humidity, these vacuities exert a capillary attraction, and imbibe the water afresh; and plaster of this sort can be used only in places that are dry, and sheltered from all accidental dampness.

Gypsum mixed with carbonate of lime affords a better plaster than such as contains none; that is to say, it acquires in time greater solidity and hardness, because, while by calcination it loses only its water of composition, the carbonate of lime loses its carbonic acid, and passes to the state of quicklime, which, in course of time regaining its carbonic acid, returns to its former state by a process of real crystallization. This reproduction of the carbonate of lime, occasioning it to occupy a more considerable space, compresses the particles of the plaster, which it has been shewn had a very loose texture; and this
joined to the hardness of the carbonate of lime itself, must impart to the plaster that additional solidity, which, in such cases, it obtains by age.

When, on the contrary, the gypsum includes either quartz, sand, or clay, as these substances undergo no change by calcination, they produce an additional want of contiguity between the molecules regenerated from the plaster; and in so far diminish their mutual cohesion, and consequently the compactness of the mass.

I have deferred to this part of my memoir some further observations respecting the bardiglione, placed among the varieties of this substance under the name of Epigène, on the authority of the Abbé Haüy, who has established that variety from a specimen in his collection, one part of which is in the state of lamellar bardiglione, while the other is in that of compact gypsum; and, from the sense in which he uses the word Epigène, he considers the part of the specimen, which is in the state of compact gypsum, as having been originally lamellar bardiglione similar to the other part; and as having undergone this change in consequence of the intervention of water, which has introduced itself into the interior of the substance, and which, in his opinion, has rendered its texture more loose, and diminished its hardness.

From this explanation of the transition of lamellar bardiglione to compact gypsum by the mere absorption of water, it would seem as if this learned mineralogist supposed gypsum to differ from bardiglione only by the interposition of a certain quantity of water; or, if the expression "introduced into its interior," implies the combination of this fluid, it would necessarily follow, that bardiglione, like plaster, must pass to the state of gypsum on the addition of water, which we have seen is by no means the case. As to the opinion of the transition of bardiglione into gypsum by the mere interposition of water in its substance, the difference of figure between the
integrand molecules of these substances is alone sufficient to prevent our assenting to it; and it certainly cannot be that of the Abbé Haii y. But does a real transition take place in this case, according to the sense in which he uses the term *Epigène*?

As an example of what he means to express by this word, he quotes the transition of sulphuret of iron, or pyrites, to the state of hepatic iron, which is a reddish-brown oxide of that metal, more or less compact in some parts, and frequently cellular in others. He quotes also the transition of phosphate of lead in hexahedral prisms to sulphuret of lead, or galena.

In the first of these examples we can easily understand the nature of the operation which takes place, and which consists in the actual decomposition of the pyrites by the loss of the sulphur that was combined with the iron: a decomposition probably produced by the slow oxygenation of the pyrites, by which the sulphur is changed into sulphuric acid, and is disengaged, leaving the iron in the state of a brown oxide.

The second of these examples, which offers more difficulty, may however also be conceived, though without our being able clearly to trace what was the primary or direct cause of the change. It appears, with respect to this transition, that the decomposition, while it deprived the phosphate of lead of the phosphoric acid, probably by the intervention of sulphuric acid, occasioned at the same time the de-oxydation of the lead as well as of the sulphuric acid, which then combined in the state of sulphur with the lead, and produced galena, which is so moulded into the space occupied by the phosphate of lead, that it has completely retained its external form.

In these two natural operations, so interesting and at the same time so remarkable, the change which occasions the decomposition and transformation of the substance begins at the surface, without in the
least affecting its figure or dimensions. It then proceeds gradually, till the decomposition and regeneration are complete. Specimens of pyrites are found, in which only the surface to a very slight depth is in the state of hepatic iron, as well as prisms of phosphate of lead, which are precisely in the same circumstances. We find also crystals of these two substances, in which, though the centre has participated in the same decomposition and regeneration, particles of greater or less bulk, that are nowise altered, remain interspersed here and there in the regenerated substance. In phosphate of lead, which has passed into the state of galena, we frequently observe one or more laminae, of different degrees of thickness, parallel to the planes that form the exterior surface of the hexahedral prism, which have still retained their primitive form. In the interior of these prisms the galena is in a state of confused crystallization with small laminae, frequently lying in different directions, so that the fracture, which is irregular and granular, and has no resemblance to what we should expect in sulphate of lead or phosphate of lead, exhibits nothing but shining laminae of galena without any determinate direction. Frequently too we observe that in the two transitions of which I have been speaking, when they are completed, there are several small cavities, in which the decomposed substance has not been replaced.

In the two examples quoted, though a perfectly exact explanation of the means employed by nature is very difficult, yet we can con-

* In such prisms of phosphate of lead as have passed entirely into the state of galena, we also very frequently observe concentric hexagonal laminae, the sides of which are parallel to the faces of the prism, and which sometimes even leave intervals between them. This observation alone would lead me to doubt, whether this substance actually has for its primitive crystal a pyramidal dodecahedron with triangular faces, as has been supposed. If to this we add the indications of natural joints parallel to the bases of the hexahedral prism of phosphate of lead, which I have often observed, I am strongly inclined to believe, that this prism is itself the form of the primitive crystal.
ceive the process; and finding on an examination of the native products, all the proofs necessary to substantiate it, we accede to the demonstration. But in the transition of bardiglione, now in question, there is no decomposition indicated, no loss of any principle, no replacing of one principle by another; it is simply the fortuitous introduction of a new principle, which, as far as it appears, has but an extremely weak affinity for the molecule of the substance, which however it must divide into its constituent molecules, since it has to form with them integrant molecules of a different figure belonging to a new compound. Of this we can form no idea; and as nature, when consulted respecting the facts, offers no foundation, on which we can in reality establish the existence of such a transition, we cannot adopt it. If this transition were admitted, it would put an end to all constancy in the nature of mineral substances. The moment they were in contact with any principle whatever, whether this principle could pass as easily as water, or through its intervention be received into their substance, changes would take place, and the large assemblages of matter would be in a continual state of transformation.

In the mountains of La Grande Chartreuse I have observed a calcareous stone including cylindrical nodules, three or four inches or more in length, one half of which was in the state of brownish-red oxide of iron, while the other was compact black oxide of manganese; and I have seen specimens of this stone, containing a great number of such nodules crossing them from one side to the other. I have a cylindrical Entrochus about eight lines in diameter, and which, before I had occasion to break it, was two inches and a half long; the exact half of it, supposing it to be cut in the direction of its axis throughout its whole length, is a grey lamellar carbonate of lime, while the other half is a deep violet granular fluate of lime; this Entrochus came from Derbyshire. Those fine speci-
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mens from Dumbarton are well known, in which analcime and prehnite are so conjoined, that it is generally impossible to say where one terminates and the other commences; but it would be endless to adduce all the examples of this kind, with which I am acquainted, and in which assuredly no transition can be suspected. Why should not the specimen of bardiglione, mentioned by the Abbé Haüy, be classed with these?

Remarks respecting the term Bardiglione.

I have applied to this substance the above denomination, which recalls that already appropriated to one of its varieties by the Italians, and which of itself has no other signification; conformably to my opinion, that every species, to whatever branch of natural history it belongs, should have a peculiar name allotted to it; a name that, from its nature, ought to be invariable, like the species it is intended to designate; while explanatory phrases, which are a natural exhibition of the state of the science at the time they are formed, must necessarily follow its course, and change with it. It is true the name of Anhydrite has already been given to this substance: but the intention of this name is to express the absence of water in its composition; and as on this account it may agree with a very great number of other mineral substances, which are in the same situation, it becomes therefore a general term, and not a proper name. This will always be the case, while authors endeavour to give mineral substances a significant name; it being sometimes taken from a quality supposed to be perceived for the first time, but soon after shewing itself to be too general to designate one substance in particular; and being at other times founded on a quality merely peculiar to the individual, or accidental and of which a great number
of the individuals that compose the species are afterwards found to be destitute.

Thus for instance M. Cordier, in a paper in which he has described with great perspicuity and accuracy a substance of a violet-blue colour, which is met with either at Cape de Gat in Spain, among volcanic products, or near Nijar, also in Spain, in a granitic rock, gives this substance the name of *Dichroite*, a word of Greek etymology implying *double colour*, because its crystals present a very deep blue when viewed in a direction parallel to their axis, while they appear of a brownish-yellow, when viewed in a direction perpendicular to this axis. But mica exhibits precisely the same phenomenon of refraction. I have a variety from Somma in very fine short hexahedral prisms, which, if viewed perpendicularly to their axis, are of a green, more or less deep in proportion to their thickness; but when viewed parallel to that axis, through their sides, are of a very deep reddish-orange yellow. A specimen in my collection, likewise from Somma, and perhaps unique for the beauty of the very bright, slightly greenish-yellow topazes it includes, contains small crystals of mica, in incomplete acute hexahedral pyramids, very transparent, and having the lustre of the hardest stones; these have a slightly yellowish-red colour, refracted through the sides of the prisms, in consequence of which they are pretty constantly mistaken for very fine garnets. I have also some specimens of that quartz, which comes from Macedonia, and is known by the name of Leuco-sapphire, polished *en cabochon*, which, seen in one direction, are of a light bluish-grey, or nearly colourless, while in a direction perpendicular to the former, they have the fine blue of the deepest coloured sapphire. Dr. Wollaston, to whom mineralogy is daily under important obligations, has observed tourmalines likewise possessing the same property. If a person, who has never seen the *Dichroite*,
should seek for it, resting on the single circumstance of the double colour, indicated by its name, without regarding the peculiar tints, he might very easily be led into a mistake, as either of the substances which I have just mentioned would exhibit this character.

The name of Volite, which had been given to bardiglione by M. Tondi, beside having the same defect of being derived from a variable character, that of colour, had also the inconvenience of recalling to the mind other substances, the names of which bore a considerable resemblance to it. All these inconveniences, it appears to me, would be avoided, by choosing for mineral substances a proper name without any peculiar signification in itself, and which should have no other object but that of preventing one mineral from being confounded with another.
TABLE OF THE MODIFICATIONS OF THE PRIMITIVE CRYSTAL OF BARDIGLIONE.

**Primitive Crystal.** A rectangular tetrahedral prism, the terminal faces of which are squares, and the height of which is yet unknown.

<table>
<thead>
<tr>
<th>Number of modifications</th>
<th>Figure of the crystal</th>
<th>Angles of incidence between the new planes, and the sides of the primitive crystal.</th>
<th>Angles of incidence of the new planes with each other above those of the prism on which the cleavage is least easy.</th>
<th>Nature of the retrogradations.</th>
<th>On the sides of the prism, on which the cleavage is most easy.</th>
<th>On the others, considered as auxiliary.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td></td>
<td>On those on which the cleavage is most easy.</td>
<td>On the others.</td>
<td>Retrogradation by a single row.</td>
<td>Retrogradation by a single row.</td>
<td></td>
</tr>
<tr>
<td>2d</td>
<td></td>
<td>108°, 27' .. .. .. 161°, 33' .. .. 143°, 6' .. ..</td>
<td>Retrogradation by 1 row in breadth, and 8 laminae in height.</td>
<td>Retrogradation by 3 rows in breadth.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3d</td>
<td></td>
<td>116°, 34' .. .. .. 158°, 26' .. .. 126°, 52' .. ..</td>
<td>Retrogradation by 1 row in breadth, and 2 laminae in height.</td>
<td>Retrogradation by 2 rows in breadth.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th</td>
<td>Primitive crystal with planes of substitution on the edges.</td>
<td>126°, 40' .. .. .. 141°, 30' .. .. 102°, 40' .. ..</td>
<td>Retrogradation by 4 rows in breadth, and 5 laminae in height.</td>
<td>Retrogradation by 4 rows in breadth, and 4 laminae in height.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5th</td>
<td></td>
<td>141°, 30' .. .. .. 128°, 40' .. .. 77°, 20' .. ..</td>
<td>Retrogradation by 5 rows in breadth, and 4 laminae in height.</td>
<td>Retrogradation by 5 rows in breadth, and 4 laminae in height.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6th</td>
<td></td>
<td>161°, 33' .. .. .. 108°, 27' .. .. 36°, 54' .. ..</td>
<td>Retrogradation by 3 rows in breadth.</td>
<td>Retrogradation by 1 row in breadth, and 3 laminae in height.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. As all these modifications, except the first, undergo no retrogradation at the edges of the prism, but on one side, I have noticed this retrogradation only with regard to that side on which the cleavage is expressed, pointing out at the same time the auxiliary retrogradation on the other side.

This table, together with the plate, displays the singularity I have just mentioned; which is, that all the crystals of this substance undergo no decrement except on one of the two planes that form each edge of the prism. The fourth and fifth modifications may be considered as forming but one; and the same may be said of the second and sixth: but to render the details respecting the crystallization of this substance more methodical, I have considered each of the retrogradations with respect to those sides of the prism on which the cleavage is easiest. In this view, each of these modifications is perfectly distinct from the other; and while one takes place on these faces, the auxiliary retrogradation is produced on the adjacent faces, which are those on which the cleavage is least easy.
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TABLE OF THE MODIFICATIONS OF THE PRIMITIVE CRYSTAL OF BARDIGLIONE,
According to the determination of it by the Abbé Hauy.

**Primitive Crystal.** A rectangular tetrahedral prism, the terminal faces of which are rectangles, the sides of which are in the ratio of 16 to 13.4, and the height of which is unknown.

<table>
<thead>
<tr>
<th>Number of the modifications</th>
<th>Figure of the crystal</th>
<th>Angles of incidence between the new planes, and the sides of the primitive crystal.</th>
<th>Angle of incidence of the new planes with each other above those of the prism on which the cleavage is least easy.</th>
<th>Nature of the retrogradations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st.</td>
<td></td>
<td>On those on which the cleavage is most easy.</td>
<td>On the sides of the prism, on which the cleavage is most easy.</td>
<td>Retrogradation by 5 rows in breadth, and 6 laminae in height.</td>
</tr>
<tr>
<td>2d.</td>
<td></td>
<td>134°, 52'.</td>
<td>89°, 16'</td>
<td>Retrogradation by 6 rows in breadth, and 5 laminae in height.</td>
</tr>
<tr>
<td>3d.</td>
<td></td>
<td>10°, 50'.</td>
<td>142°, 30'</td>
<td>Retrogradation by 7 rows in breadth, and 9 laminae in height.</td>
</tr>
<tr>
<td>4th.</td>
<td></td>
<td>115°, 32'.</td>
<td>125°, 36'</td>
<td>Retrogradation by 5 rows in breadth, and 2 laminae in height.</td>
</tr>
<tr>
<td>5th.</td>
<td></td>
<td>128°, 31'.</td>
<td>102°, 55'</td>
<td>Retrogradation by 3 rows in breadth, and 2 laminae in height.</td>
</tr>
<tr>
<td>6th.</td>
<td></td>
<td>140°, 4'.</td>
<td>19°, 56'.</td>
<td>Retrogradation by a single row.</td>
</tr>
<tr>
<td>7th.</td>
<td></td>
<td>161°, 29'.</td>
<td>37°, 2'</td>
<td>Retrogradation by 5 rows in breadth, and 2 laminae in height.</td>
</tr>
</tbody>
</table>

Retrogradations along the edges of the primitive crystal.

As the determination of the primitive crystal of bardiglione offers some difficulties, with respect to which I have felt myself obliged to differ from the Abbé Hauy, whose decisions are of great weight in this science; and as it is very possible that I may be mistaken, I have given above, the calculations of the same modifications as in the preceding table, but on the supposition that the bases of the primitive prism of this substance are rectangular,
but not squares. From this table we perceive, that the angle of 129° 56', arising from the retrogradation by a single row, belongs to the incidence of the plane produced on the narrowest sides of the prism; while that of 128° 31', which is next to it in the preceding table, belongs, on the contrary, to that of the incidence on the broadest side. We also see that the plane of substitution that makes an angle of 135° with the two adjacent sides of the prism, and which would be the product of a retrogradation by a single row, on the supposition of the bases being a square, may likewise exist, or at least with a very trifling difference, on the supposition of the Abbé Haüy. The fracture alone, and particularly that which the crystals themselves exhibit (for I could never obtain one sufficiently regular by cleavage), as well as its striking parallelism with the interior indications of natural joints, and the angle of 135° constantly formed by these fractures, appear to me most in favour of my opinion.

I ought however to add, that the peculiarity exhibited by the crystals of this substance, of undergoing a retrogradation only on one side of the edges of the primitive prism, would seem to support the view taken of it by the Abbé Haüy; though much less so than if a retrogradation took place on each side, and the retrogradations were of a different kind. On the whole, I think there is a majority of circumstances in favour of the opinion which I have formed, but on this point the crystallographical reader will decide.
TABLE OF MODIFICATIONS OF THE PRIMITIVE CRYSTAL OF BARDIGLIONE.