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ON THE
MOLYBDATES AND VANADATES OF LEAD,
AND ON A
NEW MINERAL FROM LEADHILLS.

BY

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IN 1825*, Professor Wöhler published the analysis of a rare variety of pyromorphite from Leadhills, which he describes as an aggregation of very diminutive, orange-red hexagonal crystals, fixed on cerussite. The normal constituents of pyromorphite are mixed in them with small quantities of iron and arsenic. Professor Wöhler having ascertained the existence of vanadate of lead only five years later (1830), and the presence of partly

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* Poggendorff's Ann. vol. iv. p. 169.

chromium, partly vanadium in Russian specimens of pyromorphite having been stated, it may be supposed that the red pyromorphite from Leadhills owes its characteristic coloration to one of the two elements named before.

An examination of a great number of cabinet specimens from Leadhills gave no satisfactory result. I could not find any red pyromorphite, as described by Professor Wöhler, on the specimens at my disposal, and must consequently leave unproved the above-stated supposition concerning the colouring-substance of red pyromorphite. A cabinet specimen, dating from the years 1820–1825, gave me, however, the proof that the specimens of cerussite found at Leadhills during this period were not completely free from an admixture of molybdenum and vanadium. I succeeded in finding out a specimen of crystallized "vanadine-molybdate of lead" from Leadhills so strikingly different in crystallographical and chemical characters from its nearest allies, wulfenite and descloizite, that I am authorized to consider it as the type of a new species, for which I propose the name of "eosite," alluding to its saturated aurora-red colour.

§ 1. *Paragenetic relations of Eosite.*

The cabinet specimen on which I have found the crystals of eosite has been in possession of the Imperial Museum since 1828 ; it must therefore, as remarked above, date from the years between 1820 and 1825. Its matrix, abundantly beset with crystals of cerussite, is cellular, ochreous galena. The crystals of cerussite, about 3–8 millimetres in size, bear the aspect of plates, and are greenish yellow ; some of them completely fill up a deep cavity in the ochreous matrix, others are scattered on the surface of the specimen. This cerussite, as also some parts of the matrix, is in several points covered with small moss-like aggregations of delicate and minute acicular yellow crystals. If such a fascicular aggregation is detached, and the concentrically grouped acicular crystals taken away, their nucleus is found to be a very small red crystal fixed on cerussite. When examined with a powerful magnifying-lens, the specimen shows about twenty such minute red crystals more or less scattered over the surface of the cerussite, wrapped up, some of them entirely, others only by half, in the above-described fine yellow acicular crystals. As was subsequently proved by precise determination, the minute red octahedra are eosite, and the yellow acicular crystals are pyromorphite.

These last crystals, being only $\frac{1}{2}$–1 millimetre in length and about $\frac{1}{10}$ millimetre in thickness, could only be determined by the aid of the microscope.

They are yellow, pellucid or transparent, very brilliant, with light-yellow streaks. The microscope shows prismatic planes without any distinguishable terminal planes. As previously for my investigations on labradorite, I used for the measurement of the angles of the prismatic planes a vertical circle adapted above the horizontal table of the microscope, whose axis bears the object to be measured beneath the microscope's focus;

the crystal fixed to the axis being duly adjusted and centred, the proceedings go on as usual. Two acicular crystals, duly adjusted, gave as results:

0°,
60°,
120°,
180°,

from which the planes, including them, must be admitted to be those of a regular hexagonal prism.

Their colour, and even their streak, being light yellow, they may be either mimesite or pyromorphite on vanadate of lead. A drop of hydrochloric acid poured on such a crystal makes its tint vanish gradually without bringing to view a dark-brown nucleus (as is the case with vanadate of lead), and finally produces a pseudomorph of white chloride of lead. By heating on charcoal, a brown globule with facetted surfaces is produced; traces of lead are obtained; the smell of arsenic is very insignificant. Fusing with bisulphate of potash in a platinum spoon gives merely a portion of white saline substance. All these tests were indicative of pyromorphite without any admixture of vanadium; the quantities submitted to operation being, however, very minute, a definitive judgment is not to be pronounced.

§ 2. *Chemical Characters of Eosite.*

The crystals of this mineral are all below ½ millim. in size, and difficult to be freed from the acicular pyromorphite covering them. They are easily detached from the cerussite, on whose surface they are fixed. Their hardness lies between 3 and 4 (Mohs's scale). When compressed, they are crushed into small, irregular granules, showing slight traces of cleavage.

The colour of the eosite is a saturated aurora-red, even deeper than that of chromate of lead, and approaching the tint of realgar; the red tint of the wulfenite from Ruskberg (Banat) is less intense, that of the Phenixville specimens has more of yellow in it; the tints of dechenite and descloizite vary between brownish carnation and greenish brown.

The powder resulting from the friction on a hard surface is brownish orange in eosite, somewhat darker than that from red chromate of lead.

Like the powder from chromate of lead, or from red wulfenite, that from eosite loses its colour and becomes white by contact with hydrochloric acid. This solution, diluted and spread over a glass plate, shows under the microscope the formation of chloride of lead in white acicular crystals. A minute splinter of eosite, when put on a glass plate and a drop of cold hydrochloric acid poured on it, undergoes, within a quarter of an hour, a partial solution along its margins, pseudomorphizing into white chloride of lead, the interior still remaining partly unaltered. The solution in hydrochloric acid is slightly tinted with yellow; chromate of lead and vanadinite are more easily dissolved, and the tints of their solutions are more intense. Wulfenite, even when used in fragments ten times larger, loses its colour and becomes white in far shorter time.

If a splinter of eosite is dissolved in a drop of slightly heated hydrochloric acid, the solution spread on a glass plate, some alcohol added to it, and the whole again heated to dryness*, a bluish deposit, somewhat verging into greenish grey, is obtained. With respect to the quantity of eosite experimented upon, and to the extent of the deposit, its tint may be considered as of medium intensity; it is bordered on its margin by a delicate green, somewhat acicular precipitate. Fragments of yellow wulfenite, vanadinite, or red chromate of lead, of equal size and treated in the same way, give different deposits on the glass plate,—wulfenite a deep blue one (on account of the formation of molybdate of molybdenum), vanadinite a yellowish or bluish-green one, and crocoïte a feeble yellowish-green one†. The crystals of eosite being of scarce occurrence and of diminutive size, only few experiments could be made concerning the action of the blowpipe on them.

Eosite, when heated in a glass tube, assumes a darker tint without decrepitating, and, when cooled, takes again its original colour. A splinter of this mineral, mixed with three times its volume of bisulphate of potash and fused on platinum-foil, gives under a glowing heat a transparent, nearly colourless saline mass with a very slight light-yellow tint. During its cooling, this mass becomes for a moment reddish brown, and, after complete cooling, assumes a light orange-brown tint.

Comparative experiments made with chromate, vanadate, and molybdate of lead, as also with binary mixtures of the powders of these three substances, proved the colour of the eosite salt to approach very nearly the tint of the saline mass obtained by fusing a mixture of two to three parts of molybdate of lead and one part of vanadate of lead with bisulphate of potash.

The substance obtained by fusing eosite with bisulphate of potash, brought into contact with water in a platinum spoon, gives a solution which, some tin-foil being added to it and the whole being brought to ebullition‡, assumes a faint greenish-blue tint. A second experiment gave the same result, and proved the solution to give, when further evaporated, a yellowish-brown residuum—possibly caused by the presence of

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* It must be remarked that all these experiments have been made under the microscope, or, at least, under a powerful magnifying-lens, so that it was impossible to separate the chloride of lead from the solution containing molybdenum.

† As M. Czudnowicz has stated (Poggendorff's Ann. vol. cxx. p. 17), the action of alcohol on the hydrochloric solution of vanadium gives rise to precipitates tinted between blue or brown, according to the degree of oxidation. I also obtained at first, by mixing with alcohol a solution of vanadate of lead, precipitates changing from yellowish green into brown, according to the degree of heat. The exact and constant temperature for the evaporation of alcohol was, however, soon ascertained by a series of experiments.

‡ The splinters of eosite submitted to chemical action being scarcely $\frac{1}{5}$ millim. in size, the chloride of lead could not be isolated.

vanadium. Wulfenite, treated in the same way, gave a deep blue tint, vanadinite a light yellowish-green, and chromate of lead a light yellowish grey of the saline solution heated in contact with tin-foil.

It would be desirable to ascertain experimentally the presence of other metals besides lead, were not the scarcity of the material an obstacle to any further experiments besides those of absolute necessity.

Considering the whole of the experiments above described, the way in which eosite is acted upon by heating in a glass tube, by hydrochloric acid, alcohol, and bisulphate of potash, proves this mineral to be essentially a vanado-molybdate of lead; possibly with an excess of molybdenum, as it may be supposed from the colorations caused by chemical action, the presence of an undoubtedly minute quantity of chromium being concealed by the chemical action of the prevalent constituents*.

The investigations here detailed having ascertained the presence of lead, molybdenum, and vanadic acid in eosite, it is still to be proved that the chemical actions of vanadate and molybdate of lead are essentially different from those manifested by eosite, and that consequently this mineral is to be identified neither with the red varieties of wulfenite actually known, nor with the crystals of dechenite, vanadinite, or descloizite.

§ 3. *Chemical Properties of the Chromo-Wulfenites.*

The late Professor H. Rose (Poggendorff's Ann. vol. xlvi. p. 639) is known to have investigated the red varieties of wulfenite from Rézbánya (Banat) and Siberia, and to have ascertained the presence of chromium in them. I have before me cabinet specimens from Rézbánya, Ruskberg (Banat), and Phenixville, which I shall comprehend here under the general denomination of "chromo-wulfenites." The specimens from Rézbánya being rather yellowish than pure red, I must confine my investigations to those from Ruskberg and Phenixville.

The matrix of the Ruskberg pyromorphite is cellular quartz† and galena. A good number of rather bright, deep-red octahedral crystals of wulfenite, 1–2 millims. in size, are fixed at the surface of the pyromorphite.

The crystals of Phenixville are notably larger (2–4 millims.), and concreted into a crust on the surface of the matrix (quartz and pyromorphite). Although apparently of even surface, these crystals show merely a peculiar wax-like brightness.

The red of eosite is deeper than that of crocoïte; it is somewhat more intense than that of the Ruskberg chromo-wulfenite, and less mixed with yellow than in the Phenixville specimens. The streak is browner in

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* The existence of vanadium, as accidentally entering into the composition of the *genuine* wulfenites, was ascertained by Prof. Wöhler on the occasion of his experiments concerning the production of molybdic acid by the treatment of wulfenites (see Liebig and Kopp, Ann. d. Chem. und Pharm. vol. cii. p. 383).

† Ruskberg lies in Austrian Banat, next to the threefold frontier between Banat, Transylvania, and Wallachia.

eosite than in chromate of lead. The streaks of the Ruskberg crystals and of those from Berezowsk are quite identical; the powder of the Phenixville crystals is light orange, verging into sulphur-yellow.

The Ruskberg and Phenixville chromo-wulfenites, treated with hydrochloric acid in the way above described, both leave a deep-blue precipitate with a yellowish-green margin. Fused with bisulphate of potash in a platinum spoon, they both give a saline compound, becoming very faintly yellowish green after cooling. In the beginning of fusion a brownish-purple tint appeared, especially on the Phenixville crystals. This circumstance, not remarked in eosite or vanadate of lead, confirms the fact ascertained by Prof. Rose, of chromium being a prevailing component of the red wulfenites of the Banat, with which, according to my observations, I rank also the yellowish-red wulfenites from Phenixville. According to Mr. Smith, these last contain vanadium; however, the specimen before me, when fused with bisulphate of potash, would certainly have manifested the presence of this metal had it been a prevailing constituent, as chromium really is. At all events, the red wulfenites may possibly contain a certain proportion of vanadium, as may be expected with regard to nearly all wulfenites in consequence of Prof. Wöhler's statements.

§ 4. *Chemical properties of the Vanadates of Lead (Dechenite, Descloizite, and Vanadinite).*

Eosite, as containing vanadic acid, stands next to the just-mentioned vanadates of lead. Dechenite was first found in 1851 by M. Krantz, near Schlettenbach; and M. Bergemann, neglecting a notable proportion of zinc[*] contained in this mineral, has stated for it the chemical formula VO_3PbO. Vanadinite, first found at Kappel (Carinthia), received its specific name by the late Prof. Zippe, and is, according to M. Tschermak, $PbOVO_3$. Descloizite was stated by Mr. Damour (1854) to correspond to the formula $2PbO, VO_3$. I have, as early as 1861[†], expressed the opinion that these three species, concordant in a great number of properties, may be considered as being specifically identical. M. Czudnowicz (*l. c.*), in his paper on vanadinite, has offered several arguments against the vanadium supposed to enter into the composition of these minerals, so near related to each other that they must be submitted altogether to comparative investigation. The Peruvian descloizite is of so rare occurrence, that I

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[*] See Czudnowicz in Poggend. Ann. vol. cxx.

[†] See Schrauf, in Poggend. Ann. vol. cxvi. I must here remark expressly, in order to avoid misunderstandings, that in the course of this paper I have purposely quoted the formulæ of preceding authors with the (older) symbols used by *them* to express vanadic acid. I do not intend to discuss the results of former analyses, because Professor Roscoe, in the course of his ingenious researches concerning vanadium, has expressly (see Proceedings of Royal Society, vol. xvi. p. 226) said, "It is the author's intention to investigate the composition of the vanadates at a future time."

could not detach any particle of the small group of crystals at my disposal for the purpose of chemical investigation, being thus obliged to confine it to two varieties of vanadinite from Kappel, and to a specimen of dechenite. On two specimens of vanadinite from Kappel, vanadinite appears in the form of crystals intimately connected into a crust, the single crystals not exceeding the size of $\frac{1}{2}$–$\frac{2}{3}$ millim. On one specimen (variety A), the greater number of the larger crystals is of a dark greenish-brown colour (fluorescence-colour?), and without translucidity; the smaller ones are reddish brown and translucid; the streak is brownish orange. This variety agrees, in all its external characters, with the specimen of Peruvian descloizite now before me; the crystals of it are reddish to greenish brown, translucid, and their streak is brownish orange*.

The crystals of the second specimen (variety B) form a thin crust over limestone; they are $\frac{1}{2}$–1 millim. in size, rather translucid, of lighter carnation tint, and less bright than those of variety A. The crystals of variety A show a vivid metallic brightness, while the light carnation ones of variety B scarcely offer a faint vitreous brightness, very easily altered by contact with moist air; even the moisture contained in the breath is sufficient to produce a superficial decomposition of the crystals of variety B. Their brightness is immediately tarnished, and in a few minutes very diminutive greyish-white globules cover, like Mucedineæ, the surface of the crystal. Some time after, these globules assume a slight yellowish colour, but spread no further over the specimen if it is kept in dry air. The supposition of this alteration being caused by the presence of arsenic is contradicted by the results of subsequent investigation; proving arsenic, if it exists at all, to exist in such diminutive proportion that visible marks of its presence could not be obtained by heating the mineral on charcoal or in a glass tube†. Notwithstanding the differences detailed above the actions of hydrochloric acid, of alcohol, and of bisulphate of potash give evidence of the notable difference between eosite, descloizite, and vanadinite, and of the nearly absolute identity of the two varieties of vanadinite from Kappel.

Small splinters of both these varieties, moistened with hydrochloric acid on a glass plate, become yellowish grey on their margins, the internal portion assuming a dark reddish-brown tint. Under the protracted action of the acid this nucleus becomes darker and lessens in size, till at last it disappears, leaving a portion of uniformly greyish-white substance. The nucleus of the carnation variety B shows a somewhat lighter tint at first; this difference, however, vanishes more and more under the lengthened action of acid; alcohol added to the cold solution of both varieties causes the separation of a yellowish-green gelatinous substance,

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* See Schrauf "On the identity of vanadinite and descloizite" in Poggend. Ann. vol. cxvi. (1861).

† Several experiments intended for ascertaining directly the chemical character of these efflorescences remained without any satisfactory result.

which, being heated to evaporation, leaves on the glass plate a precipitate of fine green colour.

These alterations are common to both varieties, as also those produced by fusion with bisulphate of potash. The saline substance thus obtained is yellow during fusion; it becomes reddish during cooling, and deep reddish orange after complete refrigeration. This last coloration may exceed two or three times in intensity the coloration obtained by treating eosite with bisulphate of potash.

These experiments, merely tried with some few minute fragments, although any thing but decisive, are sufficient for ascertaining the difference between eosite and the vanadates of lead.

As the dark variety (A) resembles Peruvian eosite, the light variety (B) bears some resemblance to the dechenite from Schlettenbach.

This dechenite is likewise of carnation colour, somewhat fainter on the surface than on the recent fracture. The cabinet specimen before me shows isolated crusts, transversely concreted, with globular external surface, offering a blackberry-like aspect. A fracture shows these crusts to be concentric agglomerations of minute crystals (1 millim. in size), externally exhibiting only one or two of their planes. Isolated margins may be found by careful inquiry, but I could not succeed in obtaining any measurable angle. The crystalline crust includes a number of spheroidal cavities (similar to those of pisolite), around which the aggregations of crystallized dechenite are concentrically disposed. Greenish pyromorphite appears on the inferior surface of the specimen in question.

Like the variety B of vanadinite, this specimen is very easily affected by moisture. Even when a sheet of paper is held before the mouth, the moisture of the breath is sufficient to produce globular yellowish-grey efflorescences. The streak is orange, verging into reddish brown.

The action of hydrochloric acid and bisulphate of potash is nearly the same with that exercised on vanadinite, as already detailed.

A splinter moistened with hydrochloric acid shows a yellow margin and a darker nucleus, in which the vanadium is concentrated. The colour of this nucleus, instead of being very intensely brownish red, is of a rather darker brown than the unaltered mineral. The action of the acid, manifested by the progressive darkening and lessening of the nucleus, is, however, less prompt and less evident than when vanadinite is acted upon, and resembles rather the alterations undergone by eosite. The difference lies, however, in the yellowish coloration of the solution around the crystal lying on the glass plate. Alcohol gives rise to the secretion of a gelatinous yellowish-green liquid, which, evaporated by heat, assumes a fine green or bluish-green tint, nearly identical to the tint assumed by vanadinite under the same circumstances.

Dechenite, melted with bisulphate of potash, gives a deep brownish-yellow substance, reddening by cooling, and finally becoming of a deep orange. This salt, heated in a platinum spoon with tin-foil, gives a faintly greyish-green solution.

The analogy between the vanadate of lead from Schlettenbach (dechenite) and the vanadate from Windisch-Kappel (vanadinite) goes still beyond their chemical characters. I submitted both these minerals to the action of the blowpipe, in order to find out, independently of my comparative studies concerning eosite, the cause of the prompt decomposition of the cabinet specimens from both these localities.

A splinter of dechenite from Schlettenbach, heated in a glass tube, emits, previously to its melting, a greenish-white vapour, not condensing into water drops nor into any other deposit upon the cooler portions of the tube. The presence of arsenic is manifested neither by its characteristic smell nor by any specular sublimate. The mineral takes a darker tint when heated, and assumes again its original tint by cooling. It melts in the glass tube, without previous decrepitation, into a brownish-yellow substance. Heated on charcoal, dechenite melts easily, and with ebullition, into a hollow dark steel-brown globule, giving at the same time a slight orange aureola and a whitish slag, including metallic granules. Fusing with soda gives rise to a yellowish slag, including granules of metallic lead, and to graphitic vanadium imbedded in the charcoal. The slag imbibed with cobalt-solution and heated to redness, assumes a dirty greenish tint and is surrounded by a greenish-yellow aureola, thus betraying the presence of a rather notable quantity of zinc, not mentioned in M. Bergemann's account of his analysis of dechenite.

Among the vanadinites from Kappel, only the carnation variety B seems to contain a notable proportion of zinc. Its tint darkens transitorily during heating, it emits a faint vapour (of water) when heated in a glass tube, without manifesting the presence of arsenic, and melts on charcoal into a dark greyish-brown, steel-bright globule, proving hollow when the flame of the blowpipe touches it. A notable aureola of oxidated lead appears, together with a small quantity of a dark slag, including globules of lead and graphitic vanadium, and assuming a green tint in contact with nitrate of cobalt.

The darker variety A exhibits the same phenomena when heated in the glass tube or by the blowpipe-flame, only the remaining slag is dark coloured, and only in one case among repeated experiments could I perceive on it some faint traces of green coloration. Possibly this variety may contain but a small proportion of zinc, as M. Damour has found only 2½ per cent. of this metal in the Peruvian descloizite.

The results of the before-detailed investigations, leaving out of account at present the subsequent crystallographical facts, may be resumed as follows :—Of both the varieties of vanadinite from Kappel, the darker one (A) contains but a small proportion of zinc, and may be assimilated to the Peruvian descloizite; the lighter one (B) is far richer in this metal, and may be identified with the dechenite from Schlettenbach. Eosite differs from both these minerals as to its chemical characters.

§ 5. *Crystallographical form of Eosite.*

Nearly all the eosite crystals attached to the surface of the cabinet specimen are octahedra, three-fourths of which are completely developed, only one of them showing one angle truncated by the basal plane c (0 0 1). The planes, instead of being completely even, are somewhat bent and scaly; however minute the planes p (1 1 1) and c (0 0 1) are, the intense metallic brightness of the crystals admits a precise determination of the angles.

The angles ascertained by measurement are:

Crystal I. $\{p\,(1\,1\,1)\}$.	Crystal II. $\{p\,(1\,1\,1)\}$.	Crystal III. $\{c\,(0\,0\,1)\,;\ p\,(1\,1\,1)\}$.
$p:\bar{p}=\ 53°\ 30'$	$p:{}'p=\ 77°\ 30'$	$c:p=\ 63°\ 20'$
$p:{}'\bar{p}=102°\ 50'$	${}'p:\bar{p}=102°\ 10'$	$c:{}'p=\ 62°\ 30'$
${}'p:\bar{p}=103°$	$p:p'=\ 77°\ 50'$	$c:p'=\ 62°\ 50'$
$p:{}'p=\ 77°\ 50'$		${}'p:\bar{p}=103°\ 25'$
		$p:\bar{p}=\ 53°\ 50'$
		$p:p'=\ 77°\ 30'$
		$p:{}'\bar{p}=102°$

The means of these results are:—

$$c:p=(0\,0\,1)(1\,1\,1)=65°\ 50'$$
$$p:{}'p=(1\,1\,1)(\bar{1}\,1\,1)=77°\ 50',$$

and consequently

$$(1\,1\,1):(1\,0\,1)=38°\ 55'$$
$$(1\,1\,1):(1\,1\,0)=27°\ 10'$$
$$(1\,1\,1):(1\,0\,0)=51°\ \ 5'$$
$$(1\,0\,0):(1\,1\,0)=45°\ \ 5'.$$

The preceding data lead to the parametrical proportion

$$a:b:c=1{\cdot}003:1:1{\cdot}375,$$

not very far different from a pyramidal axial proportion. The last-quoted prismatic angle differs also only by 5′ from the pyramidal principal prism. Notwithstanding the prisms with an angle of 90° 10′ being proper to several prismatic minerals, the slight difference obtained in the present case may be ascribed to an error of observation, owing to the exiguity and the curved surface of the planes, and eosite may be safely ranked among the pyramidal system, with the axial proportion

$$a:a:c=1:1:1{\cdot}3758,\quad cp=62°\ 50'.$$

This parametrical proportion of eosite, together with its chemical characters, proves its near relation to wulfenite and descloizite. Eosite unites the crystallographical system and the lateral angles of wulfenite with the pyramidal angle of descloizite[*],

Eosite having	62° 50′,	descloizite	63° 35′,	and wulfenite	65° 47′.
,,	51° 5′,	,,	57° 35′,	,,	49° 50′.
,,	51° 5′,	,,	44° 9′,	,,	49° 50′.

The proportion of the principal axis of eosite to the same axis of wulfenite is

$$\frac{1{\cdot}375}{1{\cdot}574}=\frac{7{\cdot}0085}{8{\cdot}0000}.$$

The pyramid of eosite could therefore be considered as a representative of the pyramid 778 of wulfenite, and the crystals of eosite to be merely a new form of the crystallographical form of the last-named mineral. Setting aside the chemical differences, a number of crystallographical characters may be alleged against the identity of these two minerals. All the crystals of eosite carefully examined by me show only one dominant pyramid, without any secondary pyramidal plane. The difference between the angles of the pyramids of eosite and wulfenite amounts to only 3°. It would have been too slight for admitting, with any degree of probability, that the secondary pyramid (778), having grown out into a principal plane, has completely superseded the original principal pyramid, had not an alteration in the chemical constitution of the substance been attended by an altered arrangement of the atoms entering into the composition of the crystalline molecule.

§ 6. *Crystallographical forms of Descloizite and Vanadinite.*

The similarity of the pyramidal angles of eosite and Peruvian descloizite (the second one, as stated by M. Des Cloizeaux) led me at first to suppose the existence of similar forms among the crystals of the carnation variety B of vanadite or of dechenite.

The crystalline agglomerations of dechenite are so confused that it was

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[*] I alluded, a number of years ago, to the necessity of beginning any crystallogenetic theory with distributing the molecules of the elements constituting a combination according to the three directions of space, which thus is differentiated in the required way. In the case here in question the subsequently acceding substance (vanadium) seems to have assumed its direction according to the principal axis, the molecules of wulfenite having kept meanwhile their original direction along the secondary axis; and this supposition could, indeed, account for the successive transition of form from wulfenite into descloizite. However, such investigations could lead to any real, not merely apparent, success only under condition of not being confined to the parameter of the crystals, but also founded on the molecular values of the constituting elements.

These ideas of mine, and the calculations of crystalline forms from the molecular values of the elements founded on them, have been thoroughly discussed in several of my publications.

See Schrauf, Physikalische Studien (Vienna, 1867), c. xvi. p. 240; Lehrbuch der Mineralogie, vol. ii. Krystall-Physik (Vienna, 1868), c. xi. p. 160; Pogg. Ann. 1867, vol. cxxx. p. 33.

impossible to detach any complete crystal out of them. Here and there isolated lateral angles, some of them offering an angle of about 90°, are distinguishable.

As to the form of crystals, the variety B of vanadinite from Kappel bears some resemblance with these aggregations of dechenite. Some few solid angles of the variety B could be detached and their angles measured. The results thus obtained are:—

Crystal I.	Crystal II.	Crystal III.
$p : p' = 90°$	$p : \overline{p} = 52°$	$p : {}'p = 64\frac{1}{2}°$
		$p : p' = 91°$
		${}'p : p' = 127°.$

These angles are perfectly concordant with those obtained by my former measurements (see Poggendorff's Ann. vol. cxvi.), as well as with those at present taken on the crystals of the dark variety A from Kappel. These last gave:

For crystal I.	For crystal II.	For crystal III. (with the planes p and m).
$p : {}'p = 65°$	$p : {}'p = 64° \; 50'$	$p : p' = 91° \; 30'$
$p : p' = 92°$	${}'p : {}'p' = 90°$	${}'p : {}'p' = 90° \; 50'$
${}'p : p' = 128°$	${}'p' : p' = 63° \; 30'$	$p : \overline{p} = 53° \; 30'$
	$p' : p = 90°$	$\overline{p} : {}'\overline{p} = 65° \; 0'$
	$\overline{{}'p}' : {}'p = 116° \; 10'$	$m : m' = 116° \; 30'$
	$\overline{{}'p} : {}'p = 53°$	$p : m = 32° \; 50'$
	$p : {}'p' = 127°$	

All these numbers are in perfect concordance with those ascertained by M. Des Cloizeaux on the Peruvian descloizite; these are:—

$$m \, m' = 116° \; 25'$$
$$m \, b\tfrac{1}{2} = 147° \; 45'$$
$$b\tfrac{1}{2} \, b\tfrac{1}{2} = 127° \; 10'$$
$$b\tfrac{1}{2} \, (m) \, b\tfrac{1}{2} = 115° \; 15'$$
$$b\tfrac{1}{2} \, (e\tfrac{3}{2}) \, b\tfrac{1}{2} = 88° \; 18'.$$

These results prove thus the absolute identity of the forms of Peruvian descloizite with those of both varieties of vanadinite from Kappel, probably also with those of dechenite, all of them discrepant from the characteristic forms of eosite. These investigations throw likewise some light on the indices of the planes observed on descloizite.

M. Des Cloizeaux has observed the three planes m $b\frac{1}{2}$ and $e\frac{3}{2}$, whose indices are, (1 1 0), (1 1 1), and (2 0 3). M. Des Cloizeaux expressly states that he could not find out from these data any isomorphism between this form and that of any other lead salt. I can, however, in no way explain how so eminent a mineralogist came to omit comparing the parameter of anglesite with that of descloizite, as he did with the parameter of cerussite.

Such a comparison proves immediately the isomorphism of both these minerals, the angles of anglesite being:

$$\begin{aligned} nn' &= 115^\circ\ 6' \\ ay &= 56^\circ\ 51' \\ by &= 45^\circ\ 3' \\ cy &= 63^\circ\ 19', \end{aligned}$$

and those of descloizite:

$$\begin{aligned} mm' &= 116^\circ\ 25' \\ \frac{b\frac{1}{2}\,b\frac{1}{2}}{2} &= 57^\circ\ 35' \\ &= 44^\circ\ 9' \\ &= 63^\circ\ 35' \end{aligned}$$

M. Des Cloizeaux's symbols must consequently be admitted as equivalent[*] to

$$\begin{aligned} m' &= n\ (0\ 2\ 1) \\ b\tfrac{1}{2} &= y\ (2\ 2\ 1) \\ e\tfrac{3}{2} &= e\ (3\ 0\ 1). \end{aligned}$$

These notations and symbols I intend to adopt in future. This disposition equalizes the terminal angles of eosite with those of descloizite,—$[cy]$ of descloizite being nearly equivalent to $[cp]$ of eosite.

This isomorphism of anglesite ($PbOSO_3$) with descloizite ($2PbO,VO_3$ according to M. Damour) is only to be accounted for by granting to M. Damour's analysis less importance than its author's name allows to claim, and by admitting descloizite, vanadinite, and dechenite to be merely monovanadates. Thus another argument for separating these three minerals becomes untenable; the only distinctive character still remaining is the greater or lesser proportion of zinc contained in them.

§ 7. *Crystallographical form of the Chromo-Wulfenites.*

Prof. H. Rose, in his above-quoted investigation of the chromo-wulfenites, has given the measures of angles of the variety from Beresowsk, differing but slightly from the pyramidal angles generally admitted. I intend in the present paper to ascertain the angles of the chromo-wulfenites from Ruskberg and Phenixville, in order to state the changes arising from the accession of chromium to the constituting elements. The nature of the planes is, however, such that the measurements offer differences of nearly $\frac{1}{2}^\circ$, the averages from even a greater number of observations becoming thus rather objectionable.

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[*] Concerning the indices and forms of anglesite, see my 'Atlas der Crystalformen des Mineralreiches,' under the article "Anglesite." The isomorphism of descloizite and anglesite appears in the similarity of forms, as well as in the equality of angles, the vanadinite from Kappel resembling the anglesite from Siegen, as the Peruvian descloizite is similar to the anglesite from Wolfach. See Schrauf's 'Atlas der Crystalformen,' No. 2 (Vienna, 1870), tab. xi. fig. 1, and tab. xii. fig. 32.

The crystals of chromo-wulfenite from Ruskberg are 1–2 millimetres in size. Most of them are quadrilateral pyramids, formed by the planes *e* (1 0 1); in some of them the pyramid is truncated by the terminal plane *c* (0 0 1). The planes are convex. My measurements gave:—

For crystal I.	For crystal II.
$c\,e = 57° \, 30'$	$e\,\bar{e} = 65° \, 10'$
	$e\,e' = 73° \, 30'$.

I did not succeed in finding in the crystals from Phenixville the form alleged by Prof. Dana (Mineralogy, 1868). Those before me exhibit the pyramid *n*, common to all wulfenites, assuming a tabular shape by the development of the truncating terminal plane *c* (0 0 1). Their surface is opaque, rough, and curved, thus manifesting, as it were, the resistance opposed to regular development of the fundamental form, by the accession of heterogeneous substances. One of these crystals offered, besides the planes *c* (0 0 1) and *n* (1 1 1), two other planes, *m* (1 1 0) and *f* (3 2 0), the last of them in hemihedral development. I found on this last crystal:—

By measurement.	By calculation.
$n\,\bar{n} = 48° \, 30'$	$n\,\bar{n} = 48° \, 25'$
$n\,m = 24° \, 20'$	$n\,m = 24° \, 12\tfrac{1}{2}'$
$n\,f = 26° \, 50'$	$n\,f = 26° \, 35'$.

As the results of measurements show, this crystallographical revision of chromo-wulfenites afforded no data for ascertaining the action of chromium on the molybdate of lead; they, however, confirmed the fact that the characteristic forms of eosite are wanting in the red varieties of wulfenite.

§ 8. *Discussion of Results.*

As a perusal of the last paragraph, treating of the morphological properties, will prove, these properties run parallel to the chemical characters of the minerals here in question. The results obtained may be concisely enounced thus:—

The crystalline form of eosite differs from those of descloizite and wulfenite, having the terminal lateral angles of descloizite united with the crystallographical system of wulfenite.

Eosite is a vanado-molybdate of lead.

The red varieties of wulfenite have an admixture of chromium, but are not crystallographically different from the other varieties.

Descloizite is isomorphous with anglesite; thus the results of the analysis of descloizite seem to be questionable.

The dark variety of vanadinite (A) from Kappel is identical with Peruvian descloizite; the light variety (B) from the same locality is nearly identical in chemical characters with the dechenite of Schlettenbach and, as to the form of its crystals, with descloizite.

These appear to me to be the results of the present investigations: they are still incomplete as to the crystalline forms of dechenite; I would, however, congratulate myself if the hints given in their exposition could provoke further search for distinctly crystallized groups of dechenite.

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