ART. XIV.—*On the Emery Mine of Chester, Hampden County, Mass., with remarks on the nature of Emery, and its associate minerals*; by J. LAWRENCE SMITH, Pres't Louisville Gas Co.

CONSIDERABLE interest is attached to the recent developments of an extensive deposit of emery in Chester, Hampden county, Mass., by Prof. C. T. Jackson; and my name has been associated in various ways with it, without my having had any thing directly to do with it. Sundry communications have also been received by me from various parties. These communications are best answered by the facts embraced in this article, some portions of which it has always been my intention to publish without reference to the special interest of any one in the matter.

Prior to 1846, emery was simply known as a mineral, coming to us from a few remote localities, and was used in the arts without our having any knowledge of its true geological position or its mineralogical relations. About that period, circumstances favored my commencing those geological and mineralogical discoveries in relation to emery, that were afterwards embodied in two papers, presented to the Academy of Sciences of Paris, in 1850, in which the subject was thoroughly discussed, and I might say almost exhausted. The light in which those discoveries were considered will be seen by the conclusions of the report of the committee of the Academy, consisting of Messrs. Dufrenoy, Elie de Beaumont, and Cordier, viz:

"It results from the review just given of the labors of Dr. Smith, that he has made known—

1st. The precise nature of the geology of emery in Asia Minor and the Grecian Archipelago;"

2d. "That he has described the properties of the principal minerals associated with it, and the manner in which they occur,

especially diaspore and emerylite; this last mineral forms, by the identity of its composition in the different formations that the author had occasion to study, a mica constituting a new species, and one well determined;"

3d. "Finally, that he has given a means for determining the qualities of emery, and consequently their commercial value; this process, eminently practical, offers, besides, an interest in a scientific point of view, inasmuch as it permits of determining the difference in the tenacity of minerals of equal hardness.

"These researches of geology, mineralogy, and of analytical chemistry, constitute a work of the highest interest, both as a whole, as well as from the new facts they promise to science. Your committee consequently propose to thank Dr. Smith for having communicated them to the Academy, and in consideration of the importance of the work, to order the insertion of his paper in the *Recueil des Mémoires des Savants étrangers*."

At that time I had discovered six new localities of emery in Asia Minor, and the Grecian Archipelago. Those localities were far removed from each other, and furnished so many different places for the study of emery and its associate minerals in addition to the old locality of Naxos; and consequently many points of general interest were brought out, besides others connected with the line of study. Those who may feel interested in the subject will find the investigation and results there arrived at in this Journal, vols. x and xi, 1850 and 1851; they embrace the geology, mineralogy, chemical composition, manner of mining, commercial considerations, associate minerals, &c.

The study of the associate minerals I considered of great importance, as they would be guides in future explorations in other parts of the world; and even prior to completing the researches on the subject I wrote to Professor Silliman and asked him to examine the American corundum localities for these minerals, one of them in particular, which he immediately did. With the corundum from the locality in Chester county, Penn., and Buncombe county, N. C., he "soon found the mineral indicated," and communicated the same to this Journal, Nov. 1849, pp. 379 and 383.

Nothing further came to my notice in relation to emery until I received from Prof. C. T. Jackson a letter dated Oct. 9th, 1864, containing what follows:

"You discovered emerylite or margarite in Asia Minor as an associate mineral with emery. On the 22d of October last, 1863, I discovered, while surveying an iron mine in Chester, Mass., some beautiful veins of the margarite, from half inch to two inches wide, and of a fine delicate rose color, or light pink. The nature of this mineral I did not discover until my return to Boston, but at first supposed it was lepidolite; on analysis it proved

to be margarite, and from that I ventured to predict the occurrence of emery, but no attention was paid to this prediction by the owners of the mine, who were more intent on the iron ore. A few weeks since, I saw Dr. Lucas, one of the owners, resident in Chester, and called him into my office, and explained to him the great value of emery, and told him how to detect it, and he promised to make the search I required, and took exact directions from me."

"The next day after his return to Chester, he found the emery, a big vein nearly six feet wide, which had been mistaken by him for iron ore, it being very magnetic. I write you this, to show you the importance of your discovery of the emerylite or margarite (for this appears to be identical), as an associate of emery, and also as an interesting case of deduction from scientific memoirs."

Accompanying the letter he sent me a paper giving me a summary of a communication he had made to the Boston Society of Natural History on the subject, concluding by remarking that "had not the occurrence of emerylite and chloritoid called his attention to the probable existence of emery at this locality, it would have been overlooked to this day, and no one knows how much longer. The fact was mentioned as an example of the real uses of supposed useless minerals; and the Doctor took occasion to express his obligations to Dr. Smith, of Louisville, for his valuable contributions to our knowledge of the associate emery minerals of the Grecian Archipelago and Asia Minor."

These statements are sufficient to show how far my geological observations served as a guide to Prof. C. T. Jackson, in his deductions with reference to the existence of emery in Chester, and with what diligence Dr. H. S. Lucas followed up the latter's directions, resulting in the valuable development of emery.

I have since visited the locality, having done so in the month of March last. The geological character and position of the rocks was not as well made out by me as might have been done in a more favorable season; but as my observations accord, as far as they go, with those of Dr. Jackson and Prof. Shepard, I prefer inserting their observations, rather than my own, in describing the geology of the emery locality.

"The mine is situated nearly in the center of the Green Mountain chain as it traverses the western border of the state, at a point not far from half way between the Connecticut and Hudson rivers. It is included in the metamorphic series of rocks, here consisting of vast breadths of gneiss and mica-slate, with considerable interpolations of talcose slate and serpentine. The general direction of the stratification is N. 20° E. and S. 20° W., the relation to the horizon varying from vertical, to a dip of from 75° to 80°, sometimes east, sometimes west.

"The immediate vicinity of the mine presents a succession of lengthened rocky swells with rather precipitous sides, having summits between 750 and 1000 feet above the level of the principal streams by which the hills are traversed. The longer axis of the elevations generally coincides with the directions of the strata.

"The emery vein traverses in an unbroken line the crests of two of these adjoining mountains, and scarcely deviates as a whole from the magnetic meridian. Each mountain is estimated to have a length of two miles, thus giving four miles extent to the metalliferous stratum, for such it may be truly called, consisting as it does so largely of the metals iron and aluminum. The Westfield river, here a small stream about four rods in width, flows directly across the northern end of the vein, dividing it into two equal portions. The height of each mountain is estimated at 750 feet.

"The emery vein, whose average width may be taken at four feet, is situated near the junction of the great gneiss formation constituting the western flank of the mountains with the mica-slate forming the eastern slope. To speak more exactly, however, it lies just within the gneiss, having throughout a layer of this rock of from four to ten feet in thickness for its eastern wall. Nor does the mica slate advance quite up to this outside layer of the gneiss; but in place thereof, an extensive intrusion of talcose slate occurs, having an average thickness of twenty feet on the south mountain, and widening out at the north mountain to a breadth of nearly 200 feet as it reaches the terminus of the vein, in the bed of the Westfield river.

"The gneiss, more especially in the vicinity of the vein, is a very peculiar rock. It abounds in thick seams of a coarse-grained, very black and shining hornblende; and where this is not found, it is much veined and penetrated by epidote. The stratification is much contorted also; and when the surface of the formation happens to be weathered or water-worn, its bassetting edges strikingly resemble in color some of the serpentine marbles. It is also noticeable that in it quartz is everywhere singularly deficient. Traces of a white calcareous spar (calcite) are now and then visible upon the joints of the gneiss, with occasional specks of yellow copper, together with malachite stains; but no corundum, emery, or magnetite particles have thus far been detected as constituents of the gneiss. It is quite otherwise, however, with the talcy rock exterior to the wall of gneiss; for that formation in all its different varieties of talcose slate, soapstone, chloritic aggregates (with included seam of indianite), talcy dolomite, &c., which together constitute the stratum separating the gneiss from the mica slate, contain here and there disseminated grains of either emery, corundum, or magnetite; but,

like the gneiss again, are strikingly free from quartz or uncombined silica in any of its forms. Indeed this generally abundant substance is altogether wanting, not only in the emery-vein but in the talcose formations constituting its eastern boundary.

"It makes its appearance, however, in abundance in the mica slate as soon as the talcose rocks are passed—showing itself not only as the usual constituent of the slate, but in more or less continuous seams, from a few inches thick up to above six inches, and sometimes a foot, in width. Where the seams are thin and discontinuous, the included masses thin out at each end before disappearing, the sharp edges being curved in opposite directions, so as to form frequent white patches upon the surface of the rocks in the shape of the letter S."

Mineralogical Character and Composition of the Chester Emery.

It resembles more nearly that from Gumuchdagh (near Ephesus,) than any other that I know of. It is of a fine grain, and dark blue bordering on black, not unlike certain varieties of magnetic iron ore; with it there are frequently found pieces of corundum of some size. The interior of the mass is free from micaceous specks, such as are found in the emery of Naxos. Its powder examined under the microscope shows the distinct existence of more than one mineral, which are often so inseparably connected that the smallest fragments contain them together. The two predominating are *corundum* and *magnetic oxyd of iron*.

Several specimens were submitted to chemical examination from those most largely impregnated with magnetic oxyd of iron to those that appeared to contain least. They all consisted essentially of alumina and oxyd of iron; but I invariably found a little titanio acid and silica, and most commonly a minute quantity of magnesia. No. 1 was an inferior specimen; No. 2, the better quality of rock; No. 3, the emery rock crushed and prepared for market in the form of emery; No. 4, the same, and called emery crystals.

	1.	2.	3.	4.
Alumina,	44.01	50.02	51.92	74.22
Magnetic oxyd of iron,	50.21	44.11	42.25	19.31
Silica,	3.13	3.25	5.46	5.48

I examined a specimen of No. 2: grain fine, and treated repeatedly with hydrochloric acid and water over a water-bath: a great deal of oxyd of iron and a little alumina were dissolved; the residue on analysis proved to be nearly pure corundum, giving,

Alumina,	-	-	-	-	-	84.02
Magnetic oxyd of iron,	-	-	-	-	-	9.63
Silica, ¹	-	-	-	-	-	4.81

¹ No attempt was made to estimate the water.

All the chemical and physical examinations made go to show that the emery of Chester is, like all other emeries, a mixture of corundum and oxyd of iron; a fact that will be reverted to again a little farther on.

Prof. Jackson analyzed two specimens, after digesting them with nitro-muriatic acid, and has given as the composition,

Alumina, - - - - -	¹ 60.40	² 39.05
Protoxyd of iron, - - - - -	39.60	40.95

and then goes on to state, "from which it would appear that protoxyd of iron is an essential chemical ingredient in emery, and not an accidental admixture." Dr. J. Lawrence Smith's experiments lead to the same result, but he considers the oxyd of iron to be an irregular mixture with the alumina and not a regular chemical constituent. In either case, I think emery ought to rank as a separate species, and not as a granular variety of corundum, from which it differs so in physical characters."

I would here remark that Dr. Jackson's conclusion would be correct in the first state of the case, were the iron an essential chemical ingredient; but in the latter, it would be erroneous, and introduce inextricable confusion into the science of mineralogy by admitting mere mechanical mixture as a specific distinction.

Prof. C. U. Shepard writing on the same point says, "His conclusions (Dr. Jackson's) would obviously be acquiesced in were it not for the strong resemblance in striæ and cleavage between the emery and common corundum, making it impossible for us to separate the substances crystallographically from one another. Nothing like a perfect crystal of emery has yet been found at the mine; but it is quite remarkable that the mineral is here generally coarsely massive, or in large separate individuals often of the size of kernels of Indian corn, whose cleavages are perfect, and which present on their planes the delicate striæ so characteristic of corundum from the Carnatic." Yet Prof. Shepard is for making emery a new mineral species and calling it *Emerite*, with the formula FeAl .

If the views of Profs. Jackson and Shepard are to be taken as correct, the question as to the mineralogical position of emery is easily settled without resorting to any new mineral species. It is simply a massive iron-spinel (hercynite) with the anomaly of having a hardness equal to corundum.

		Emeries,	
		Jackson.	Shepard.
Alumina, - -	(Iron spinel. 58.75	60.49	} AlFe
Protoxyd iron, -	41.25	39.60	

I would say, at this point, that if the mineral of Chester is to be regarded as an aluminite of iron, the rock called emery

¹ An examination of my analyses in 1850, which it is supposed are the ones referred to here, most certainly do not sustain the conclusion.—J. L. S.

coming from Naxos and other well known localities is not that compound, and that if one is emery the other is not. But as I do not take their view of the matter, I consider the Chester mineral as true an emery as that of Naxos.

As there seems to be some mistake and incorrect quotation in regard to my analyses of emery and corundum, I reproduce the tabular statement of the analyses, and effective hardness, referring the reader to the original paper for a correct view of what is understood by the effective hardness.

No.	Locality.	Effective hardness Sapphiro 100.	Specific gravity.	Composition.				
				Water.	Alumina.	Magnetic oxyd of iron.	Lime.	Silica.
EMERY.								
1	Kulah,	57	4.28	1.90	68.50	32.25	0.92	1.61
2	Samos,	56	3.98	2.10	70.10	22.21	0.62	4.00
3	Nicaria,	56	3.75	2.53	71.06	20.32	1.40	4.12
4	Kulah,	53	4.02	2.36	68.00	30.12	0.50	2.36
5	Naxos,	46	3.75	4.73	58.53	24.10	0.86	3.10
6	Nicaria,	46	3.74	3.10	75.12	12.06	0.72	6.88
7	Naxos,	44	3.87	5.47	69.46	19.08	2.81	2.41
8	Ephesus,	42	4.31	5.62	60.10	33.20	0.48	1.80
9	Kulah,	40	3.89	2.00	61.05	27.15	1.30	9.63
CORUNDUM.								
1	Sapphire of India,	100	4.06	....	97.51	1.89	....	0.80
2	Ruby " "	90	....	....	97.32	1.09	....	1.21
3	Corundum, Nicaria,	77	3.88	1.60	92.39	1.67	1.12	2.05
4	" Asia M.,	65	3.92	0.68	87.52	7.50	0.82	2.01
5	" Asia,	60	3.60	1.68	86.62	8.21	0.70	3.85
6	" India,	53	3.80	2.86	93.12	0.91	1.02	0.96
7	" Asia,	57	3.80	3.74	87.32	3.12	1.00	2.61
8	" India,	55	3.91	3.10	84.53	7.06	1.20	4.00
EMERY.								
1	Chester, Mass.,	33	....	....	44.01	50.21	....	3.13
2	" "	40	....	....	50.02	44.11	....	3.25
3	" "	39	....	....	51.92	42.25	....	5.46
4	" "	45	....	....	74.22	19.31	....	5.48
5	" " .....	..	....	....	84.02	9.63	....	4.81

By the above it will be seen that the magnetic oxyd of iron in the emery of Naxos, Ephesus, &c., varies from 13 to 33 per cent, the water from 1.9 to 5.0 per cent, the silica from 1.6 to 9.6 per cent. All of these ingredients form minerals apart from the corundum, which is represented by the principal portion of alumina. Some of the alumina found in the analysis is associated with the above ingredients to form associate minerals which have been fully studied. This last will serve to explain why it is that emeries having the same amount of alumina may have different degrees of effective hardness. Thus: Nos. 9 and 4, both Kula emeries, containing about the same amount of alumina, have effective hardness in the proportion of 40 to 53; but it will be seen that No. 9 contains 9.6 per cent of silica, which doubt-

less appropriates a portion of the alumina, thus reducing the alumina attributable to corundum; so that, were it possible to ascertain the exact amount of corundum present in 9 and 4, it would doubtless be in proportion to their effective hardness. So again, if we compare Nos. 8 and 1, the effective hardness will be found in the proportion of 42 to 57, while their amounts of alumina vary only as 60 to 63; but if we regard the amount of water in the two it is as 5.6 to 1.9, much of this water coming from diaspore that is intimately mixed with the corundum; and in several specimens I possess, the two minerals shade into each other so completely, that it is impossible to tell where one begins and the other ends. The above facts were all well examined when my first memoirs appeared on this subject, which accounts for the following remark then made:

"Those emeries which contain the least water, everything else alike, are the hardest, as instanced by that from Kulah, notwithstanding the quantity of iron it contains. The silica existing in emery is most often in combination with alumina, or the oxyd of iron, or both; for this reason we must not always regard the quantity of alumina as an indication of the quantity of corundum in emery."

In concluding this part of the subject I would state that while I do not consider my opinions infallible in this matter, still all my experience and research, gathered from such varied sources, point to the conclusion that emery is a mixture of several minerals, principally corundum and magnetic oxyd of iron, the former being the effective agent in the mechanical abrasion to which it is applied; the oxyd of iron is not to be considered as an unimportant ingredient, it serving by its presence to destroy to some extent the harsh cutting action of the corundum.

Minerals associated with the emery of Chester.

Corundum.—This mineral, as might naturally be expected, is found with the emery, sufficiently distinct and separate to be at once recognized, sometimes in thin seams, massive in its character, but more commonly in flattened crystals of small dimensions.

Diaspore.—Very excellent and beautiful specimens of this hydrate of alumina have been found at this emery locality; it is often in distinct and separate prismatic or bladed crystals, quite colorless and transparent.

Emeryllite or Margarite.—Some of the finest specimens of this mineral that are known have been found at this locality. It will be seen by referring to my former papers on emery, that I first discovered this mineral associated with emery; its composition showed it to differ from any other then known mineral. I compared it subsequently with margarite, which had been discovered before, and suspected the identity of the two minerals;

but as the analysis made out and accepted as the composition of margarite did not accord with that of emerylite, I undertook to reexamine margarite, when I found that its composition had been erroneously determined, and that it was, in fact, the same mineral with emerylite, which last name has had to yield to the priority of date of the other.

I have analyzed the margarite from Chester and find its composition as follows:

Silica,	-	-	-	-	32.21
Alumina, -	-	-	-	-	48.87
Lime,	-	-	-	-	10.02
Oxyd of iron,	-	-	-	-	2.50
Manganese,	-	-	-	-	.20
Magnesia,	-	-	-	-	.32
Soda and little potash,	-	-	-	-	1.91
Lithia,	-	-	-	-	.32
Water,	-	-	-	-	4.61

There is a little titanio acid with the oxyd of iron that I did not estimate.

Chlorite.—This mineral as found with the emery is the so-called *corundophilite* of Shepard; on examination it proves to be, both chemically and physically, a chlorite of the variety ripidolite.

Biotite.—In examining a specimen of dark green micaceous mineral which I took to be chlorite (the corundophilite of Shepard) and from its purity expected to get a very accurate idea of its composition, but in the very commencement of the examination it was discovered to be well characterized *biotite*.

This mineral occurs on the surface of a white rock that Prof. Shepard calls indianite, but which I have not had time to examine. It is in small thin micaceous crystals perpendicular to the surface of the indianite; in the mass, it is of a dark green color, so dark that at a little distance it looks like lamellar plum-bago. A careful analysis gave the following composition:

Silica,	-	-	-	-	39.08
Alumina,	-	-	-	-	15.38
Magnesia,	-	-	-	-	23.58
Peroxyd of iron,	-	-	-	-	7.12
Manganese,	-	-	-	-	.31
Potash,	-	-	-	-	7.50
Soda, -	-	-	-	-	2.63
Water,	-	-	-	-	2.24
Fluorine,	-	-	-	-	.76
					<hr/> 98.60

This corresponds with the composition of the biotite from Monroe county, New York, as made out by Prof. Brush and myself in our reexamination of American minerals several years ago.

Corundophilite proved to be a chlorite.—About the time I published my memoirs on emery in 1850 and 1851, Prof. Shepard made the announcement of a new mineral (this Journal, 1851, xii, 211), stating that it "occurs with corundum near Asheville, in Buncombe Co., N. C., in imperfect stellate groups, and also spreading out in laminæ between layers of corundum; color leek-green, etc." An analysis of it afforded silica 34.76, protox. iron 31.25, alumina 8.55, water 5.47, making a loss of nearly 20 per cent, a portion of which he attributes to alkalis; neither lime nor magnesia were detected. He operated on 140 milligrams; this mineral was considered a new one, and Prof. Shepard called it corundophilite. Supposing that I had observed the same mineral in certain specimens of emery and emerylite from Chester, Mass., I enclosed a fragment of the specimen to Prof. S. to ascertain if this was the mineral he called *corundophilite*; he returned the specimen, announcing that it was. I then analyzed the same and found it to be, both chemically and physically, a chlorite, identical no doubt with the chlorite I found associated with the emery of Asia Minor; both the Asia Minor and Chester varieties occur in compact mass, composed of an agglomeration of small crystalline plates—identical with the chlorites of Mont des Sept Lacs and of St. Christophe, and the ripidolites of Rauris and St. Gothard. In the following analysis I do not pretend to furnish that of the pure mineral, as from the thinness of the layers in the specimens at my disposal it cannot be separated in that state of purity I am in the habit of seeking for in all minerals that I examine:

Silica,	-	-	-	-	-	25.06
Alumina, -	-	-	-	-	-	30.70
Protoxyd of iron,	-	-	-	-	-	16.50
Magnesia,	-	-	-	-	-	16.41
Water,	-	-	-	-	-	10.62
						<hr/> 99.29

The optical characters were not examined, there being no means at hand.

I may remark that the alumina and magnesia were separated by resolution and reprecipitation three times.

Tourmaline.—This mineral is also found with the emery of Chester in the same manner as with the emery of Naxos.

Titaniferous iron (ilmenite).—This is found principally in flattened crystals in the margarite.

Oxyd of titanium (brookite or rutile).—With the diaspore we found some beautiful flattened hair-brown crystals; the specimen in my possession does not furnish the face of the crystals so as to enable me to make out what form of titanium oxyd it is. Prof. Shepard thinks he has sufficient evidence to pronounce it to be brookite.

Magnetic oxyd of iron.—This ore of iron is found in great abundance associated with the emery, and is worked for the manufacture of iron; it contains a little oxyd of titanium.

The above, as well as some other associated minerals of less importance, justify the concluding remarks of my paper on emery fifteen years ago, viz: "I do not risk much in saying that the hydrate of alumina or diaspora, as well as the silicate or emerylite, chlorite or tourmaline, and the minerals of iron, as magnetic, titaniferous iron, &c., will be found almost everywhere with the emery and corundum."