ART. XXXV.—*On the occurrence of Grahamite in the Huasteca, Mexico, and Notice of the Geology of that Region;* by JAMES P. KIMBALL, Lehigh University, Bethlehem, Pa.

THE descriptions of the albertite deposit of Hillsborough, New Brunswick, by Professor C. H. Hitchcock,* and of the grahamite deposit of the Ritchie Mine in West Virginia by Mr. W. M. Fontaine,† as well as by Mr. Henry Wurz,‡ show these deposits to widely differ from any known, or even possible, occurrence of mineral coal, from the nature of which albertite and grahamite have been shown by Wetherill, Wurz, and others, likewise to differ essentially. Both varieties occur in the state of Vera Cruz, Mexico, under such circumstances as to exhibit well the nature and proximate origin of such deposits.

A closer comparison of the two varieties, by means of a more extensive series of analyses than has yet been published, is required to fix the exact relationship between them. As distinguished by physical properties, they seem to pass into each other by insensible gradations, especially in the Ritchie deposit, and in such of the Mexican deposits as I have seen. Such analyses as are at hand, of specimens from one and the same deposit, indicate inconstant ratios in each variety—evidently depending on the degree of oxidation. This variableness shows that neither variety is a true mineral species, any more than other native hydrocarbon compounds, like petroleum, asphaltum, or mineral coals. The following observations serve to confirm the received theory of the nature and origin of albertite and grahamite, and to demonstrate that these bodies are essentially mineralized or fossilized asphaltums, derived from asphaltic petroleum, pittasphalt or maltha, by the loss of hydrogen and the addition of oxygen. In the degree of this alteration albertite seems to occupy a place between asphaltum and grahamite—the two varieties, however, constituting a single mineral type. The degree of oxidation of such compounds does not always correspond to the amount of retained or fixed oxygen—a large proportion of the increment of oxygen forming volatile compounds along with carbon and hydrogen, especially in the more advanced changes which result in their conversion to such anthracitic bodies, low in oxygen, as are often found in cavities of the rock in the older formations.

Numerous springs of asphaltic maltha, forming in places superficial deposits of solid asphaltum, occur on the eastern slope of the Cordilleras of Mexico, or rather, in the littoral zone

* This Journal, xxxix, 1865, 26–7.

† Ibid., vi, III, 1873, 409. ‡ Ibid., xlii, II, 1866, 420.

toward their base. A small lake fed by a spring of bitumen is reported to occur as far north as Galveston Bay in Texas within the Tertiary area.* More or less extensive sources of the same substance are common throughout the large area watered by the numerous streams discharging into the Tampico and Tuspan rivers, at whose mouths are the gulf ports of Tampico and Tuspan. A considerable quantity of chapapote, as it is called, is brought down by these streams, washed out to sea, and finally left upon the beach by the action of the waves. After such a thorough exposure to the elements, it loses its pitchy consistency, and becomes brittle and lustrous like jet. It has then a conchoidal fracture. In this condition it is sometimes gathered, and, though not extensively known, is highly esteemed as an article of export.

The northwestern portion of the state of Vera Cruz is known as the Huasteca, which may be described as the area south of the Panuco River, embracing the territory to the north of the plateau of Anahuac, watered by the three forks of the principal affluent of the Panuco—the Rio San Juan de Mexico—namely, the Capadero, the Amajaque and the Moctezuma. This section has received no attention from scientific travelers. In 1825, Burkhart, traveling from Tampico to Real del Monte, via Tantoyuca, passed along the upper Capadero. This river he mistook, however, under the name of the Rio Garzes, and supposed it to have an easterly, instead of a northerly, course, and to empty into the Laguna de Tamiagua. Saussure's map of the plateau of Anahuac represents this portion of Mexico with some approach to its geography, if not to its topography.†

Last April I made the journey from Tampico to Tempoal on the Capadero, crossing the Topila at Tanseme, and returned to the same port by way of Trinidad and Panuco. The topographical features of the country, which thus came under my observation, are not unlike what I have described to be the character of the eastern slope of the Cordilleras farther north as observed in Chihuahua.‡

The same succession of longitudinal valleys separated by parallel ridges is here seen, together with the same gradual acclivity toward the summit of the Sierra Madre, which in this latitude is about Zacatecas. The valleys, though broad, are, unlike the champlain valleys of Chihuahua, comparatively rugged, owing to the uneven erosion of the sedimentary rocks, which is caused by intrusions of trachyte. Their configuration is largely due to the successive changes of the beds of streams,

* Taylor, Statistics of Coal, p. 498.
† Coup d'œil sur l'hydrologie du Mexique, Geneva, 1862.
‡ This Journal, xlviii, 1869, p. 385.

caused by the gradual elevation, or periodic oscillations of level, of the Cordilleras during the Tertiary period and afterwards, and which phenomena, as I have elsewhere noted, are likewise strongly marked in northern Mexico.*

The area over which my route lay, is occupied by argillaceous sandstone, calcareous in places, whose foldings seem, generally speaking, to correspond with the present configuration of the surface, the whole of which, however, has been subjected to a very powerful erosion. One of the most remarkable evidences, both of the gradual character of the elevation of the Cordilleras in the lower latitudes, and of the fluvial character of their erosion, is to be seen in a widespread alluvium, composed of coarse gravel and heavy rolling stone in the valley of the Capadero, observed many miles away from the present channel of the river, wherever its heavy covering of fine silt-like alluvium has been washed away. Through these two superficial deposits successively the river has cut its present channel deep into a formation of soft shale beneath, locally known as *t-petate*, which overspreads the whole valley of the Capadero.

The shale is highly fossiliferous in places. Imperfectly indurated and weathering excessively, it causes the fossils to crumble. They include *Cardium*, *Arca*, *Ostrea*, *Corbula*, *Pecten*, *Caryatis*, *Serpula*, and a discoid, coiled and chambered rhizopod. With the exception of the last, all are too imperfectly preserved to admit of specific determination. Common to both the Cretaceous and Tertiary as these genera are, such specimens as I was able to extract fail to distinguish between these two periods. In a private report, written without access to my collection, the shales were referred to the Cretaceous upon the grounds of the apparent facies of these specimens. They prove however, upon examination, to be wanting in characteristic types, and too uncertain of specific identification to rest any conclusion of the kind upon them, especially as the stratigraphical relations of the shales themselves indicate, as I shall presently show, an unbroken and immediate sequence with alluvial Quaternary deposits. Arguing from the latter circumstance, it will be seen that they are more logically referred to the Tertiary. These shales are important as the seat of the grahamite deposits in the vicinity of Tempoal, and probably throughout the much larger region of the Huasteca, including, at least, the middle portion of the Capadero basin, or so much of it as lies between the Huejutla Mountains on the west and the Alacranes hills on the east. The region thus defined corresponds to the so-called "Coal-field of the Huasteca," the coal, however, as I judge from

* This Journal, xlviii, 1869, p. 381.

such specimens as I have seen, really being grahamite and other less thoroughly altered asphalts.*

Judging from a number of specimens of these outcrops from farther up the Capadero than the district visited by me, as well as from such facts as I could gather by inquiry, it seems most probable that the shales of Tempoal and of the Cristo Mine, which came under my observation at these and other points in the banks of the Capadero, extend, at least, some 60 miles farther up the river, as far as Chalma, so as to include the so-called coal deposits at the base of the Cochiscuatitlan hills mentioned by Antonio del Castillo, viz., Purisima, Providencia and Virginia. A specimen of grahamite, now in my possession, from Huautla, 50 to 60 miles still farther up the river, suggests a still greater extension of the same shales, found to be the seat of grahamite at Tempoal and elsewhere.

Except in the banks of the river, and the beds of branching arroyos, the grahamite-bearing shales nowhere come to the surface in the Capadero basin, within the range of my observation, although not far below the level of the valley-plain, or lower terrace of the river. Together with grahamite, they are reported, and may be readily believed, to outcrop in the Huejutla Mountains, as at the Venados, where a deposit of the former was described by the messenger sent thither for specimens, to be upward of two feet in thickness.

The shales are immediately covered by the above mentioned deposit of coarse rounded rubble, generally more or less cemented by selenite so as to form a conglomerate from 3 to 6 feet thick, and containing shells of *Paludina*. This is immediately overlaid by the heavy deposit of fine alluvium, the least thickness of which, as seen in the river banks, is some 60 feet. It overspreads the whole valley in the vicinity of Tempoal, as well as of the Aguacates, some 12 miles farther up the river.

In the vicinity of Tempoal, where alone my examinations have been special, the top of the shales is generally brought by undulations above low water mark—that is, above the level of the river in the dry season. Near the village, it rises some 30 feet above this level; at the Parajes, two miles below, some 25 feet; at the Aguacates, 12 miles above, some 60 feet; while at the Cristo Mine, it is near the water's edge, though rising directly on either side. We have as yet no data bearing on the thickness of the shale, as its edges are everywhere concealed—if not by overlying alluviums—by a detritus resulting from its own weathering, as it slacks at once on exposure to the air.

* Some attention of late, in the City of Mexico and elsewhere, has been turned to this region upon the strength of rather venturesome computations of the extent and value of the alleged coal deposits, based upon unexplored outcrops of what is assumed to be beds of bituminous coal. (*Compania Explotadora de Criaderos de Carbon de Piedra.* Mexico, 1876. A report by Antonio del Castillo.)

At Tempoal, at the Cristo Mine, and at the Aguacates—three out of five points where I have observed exposures of the shales in the banks of the Capadero, grahamite is found in greater or less quantity. Like many similar Tertiary sediments, the shales are in places quite gypsiferous.

Remnants of these Tertiary shales are to be seen in the banks of the Panuco at Puebla Vieja, near the mouth of that river. The same formation seems to answer to Burkhart's description of the formation occupying the Garzes, (Capadero) valley as high up as Chapula, and even still higher, as far as a little south of Pinolco, with occasional protrusions of the lower sandstone series—including beds of limestone, as between Huautla and Tlacolula, and again, south of Zagualtipan.*

According to this traveler, the clay shale of the valley about Chapula apparently overlies unconformably the limestone, which he believed to be the upper member of the sandstone series, forming the heights all the way from the coast, except where covered by trachyte. The mesa tops of the mountains just west of Chapula are of the latter volcanic rock, which likewise seems to form the summits along the whole range to the north. Approaching the volcanic plateau of Anahuac, the whole body of sedimentary rocks—together with overlying trachyte, was observed by Burkhart to decline to the south and to pass beneath the diorite and basalt of the table-land, which was geognostically mapped by Gerolt and Berghes in 1827.†

Mention is made by Sr. Castillo of the discovery of an "hexagonal" sigillarid as well as nummulitic forms in the so-called coal-bearing rocks of the Huasteca. The sandstone series, in whose depressions the Tertiary grahamite shales have been preserved from a sweeping denudation, has furnished a few fossils at Tampico, where it has been quarried. I succeeded, however, in finding none but fragmentary gasteropods, though perfect specimens of the same are said to be preserved in private collections there, which it has not been my privilege to see. So doubtful is the existence of true coal in the Huasteca, that the alleged discovery of palæozoic fossils, as claimed in Mexico by way of confirmatory evidence, as I infer, of the carboniferous age of the sandstone series—requires the support of other facts. It is proper to remark that in the interior of the country, the rock surfaces are absolutely unbroken, while covered with a tropical forest; hence the present impracticability of a successful search for fossils in this part of Mexico.

Burkhart also identified in the banks of the "Rio Grande" (Amajaque) the same formation of clay shale observed by him

* Aufenthalt und Reisen in Mexico in den Jahren 1825 bis 1834. Stuttgart, 1836. I, p. 53.

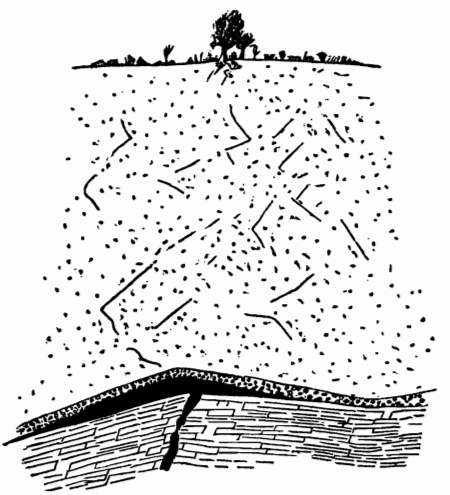
† Carta Geognostica de los principales Distritos Minerales del Estado de Mexico, 1827.

between Chapula and Pinolco in the Capadero basin, and thence inferred the geological identity of these neighboring basins.

I now proceed to describe the deposit of grahamite known as the Cristo mine.*

The original outcrop of the deposit appeared at the base of the west bank of the Capadero, on the Cristo Ranch, near the edge of the river at low water, and below the surface of the water during the rainy season. It appears to have been long observed, and to have been regarded by some persons as a deposit of bituminous coal, and by others as chapapote, but to have remained unexplored—perhaps through some discovery of its ill adaptation to the ordinary purposes of either fuels or asphalts. In 1873, the deposit was denounced as a coal-mining property.

The deposit consists of two continuous parts, the one occupying a nearly vertical fissure traversing the fossiliferous shales, and the other part conformably overlying these shales, which are slightly inclined. We have here the phenomena, first, of a deep-seated fissure transverse to the bedding of the formation, and filled out with grahamite; and, second, a nearly horizontal, and originally superficial, deposit of the same material overspreading the shale formation for a limited distance from the fissure. The latter occurrence is an overflow from the fissure, and, as it lies between the two formations, is to be referred to a period subsequent to the deposition of the shales, and before the conglomerate was spread upon them in the form of pebbly detritus. It thus happened when the shales formed the surface at this point, just as asphaltum is now commonly formed upon the surface, as a residuum from the evaporation and oxidation of liquid or pasty malthas, issuing from sluggish springs, or oozing from more extended sources, as from a certain stratum or rift in the rocks. Such phenomena, referable to the sandstone below, are to be seen beyond the boundaries of the shale formation in the neighborhood of the Cristo mine, and indeed are quite



* J. P. Kimball on a deposit of grahamite known as the Cristo Coal mine, with plate. 24 pp. 1876.

common in the surrounding portions of eastern Mexico, as already observed.

That portion of the overflow which originally appeared at the base of the river bank, has now been worked out, 210 tons having been quarried and shipped. So far as can now be ascertained, the overflow was altogether west of the fissure, which has a width, as far as developed, of 34 inches. The vein occupying the fissure has a columnar structure transverse to its sides, and shrinkage partings, or joints, parallel to its sides. It has thus far proved remarkably homogeneous in structure, and free from admixture of rock or clay. Its dip is 64° to the W. Near the point where it passes out of sight under the river bed, it is joined, at an acute angle, by a narrower and tapering vein of which the maximum width is 9 inches. According to those who have had charge of operations at the Cristo mine, the deposit, including both vein and overflow, was excavated within a dam to a depth of ten feet, and, at the same place, measured fifteen feet across. The vein proved of the same width as observed by me nearer the bank—that is, thirty-four inches. This point, now under water, was stated to be 120 feet from the base of the latter. Another small branch is partially seen on the opposite side.

The shape of the overflow is indicated as near as is now practicable, by the excavation outside of the bank and by the work underground. The latter consists of a timbered shaft, 72 feet deep, sunk from the top of the river bank or terrace, 196 feet from the edge. From the bottom two levels have been run out at right angles, one 19½ feet long toward the river (east), and the other 27½ feet long toward the north. These workings are in that portion of the deposit which for convenience I call the overflow. Its greatest thickness is developed in the east level, at the end of which it measures 6½ feet and dips 19½° S. W. At the end of the north level it has a thickness of but 15 inches, and a dip of 20° to the northeast. In the shaft the thickness of the deposit falls from 34 inches at the southeast corner, to 15½ inches at the opposite N. W. corner, to 20 inches at the S. E. corner, and to 15 inches at the N. E. corner. It therefore appears that the overflow of the vein has a limited spread underground, the same as it proved outside the bank at the water's edge. Its thickest portion is in the direction of the river, and continuous, I think, with the thickest part of the original outcrop; that is, the portion nearest the fissure, which was undoubtedly its source, and from which it sloped with the configuration of the surface at the time, and thinned away toward its edges. The fissure occupies the axis of a gentle anticlinal with a dip of 14° W. on the W. side, and of 4° E. on the opposite side. As the overflow conforms to the steeper dip,

it appears that the fissure must have been made at the time of the elevation of the shales, and soon afterwards filled with asphaltum, which continued to form after it had been filled. That no great period was required for this operation, is shown by the fact that the overlying conglomerate also conforms to the stratification of the shales as well as to the outline of the overflow of the grahamite, locally intervening.

The occurrence of such a fissure in shales so imperfectly hardened, and so easily weathered, affords another proof that the filling of the fissure immediately followed its formation, that is, after the emergence of the shales and before the deposition of the overlying alluvium. It is from this evidence of the direct sequence of terranes, and the relation thus established with subsequent alluviums that, in the failure of the evidence of their fossils, I refer to the Tertiary the grahamite-bearing shales of the Capadero basin. These are probably remnants of the littoral Tertiaries of eastern Mexico and Texas.*

The strike of the fissure is nearly north and south, directly across the river. No attempts have been made to trace it beyond the excavation near the water's edge, its character as a fissure not having been recognized previous to my visit. A length of about 300 feet upon it had at that time been developed.

The sandstone formation is the source of a number of deposits of chapapote or asphaltum. Numerous deposits are said to occur north of the Panuco River. One deposit, which I visited, is found on the Tanelul Ranch, occupying an elevated basin or cul-de-sac between two hills of the Alacranes range, here forming the boundary of the Capadero valley. The point is some $2\frac{1}{2}$ leagues east of the Cristo mine, and *directly in range with the course of the Cristo fissure as far as traced.* The chapapote has accumulated from the evaporation of liquid maltha, which now issues in the form of a sluggish spring with a number of orifices. Here may be witnessed the same process by which the above described overflow of the Cristo mine was originally formed. The source of the chapapote spring is the sandstone above mentioned, on which rest the grahamite-bearing shales of the valley below. It thus appears that the uplifted portions of the underlying sandstone are at present the source of chapapote springs depositing that mineral substance upon the surface. Ancient, and perhaps more copious, springs of the same kind issued from the depressed portions of this formation, and forced their liquid maltha into the fissures and lesser interstices of the overlying shale, which, as I have already stated, is remarkably cleavable and imperfectly indurated. The tendency of such a body of shale or shaly clay, exceedingly fine in texture, to form

* Archiv de la Commission Sc. du Mexique, ii, p. 124.

shrinkage and cleavage partings is well known. Hence this formation, from its nature otherwise impervious, became the permanent receptacle of maltha or asphaltic petroleum, issuing from the sandstone below; and probably the more freely under a hydrostatic pressure, in which water played a part, and the action of which is strikingly suggested by the configuration here observed of a stratigraphical basin bordered by elevated plateaus. The inspissation of maltha or pittasphalt, and even petroleum, to grahamite and other mineral bitumens, by the loss of hydrogen and the addition of oxygen, is a well known occurrence which may be artificially illustrated in the laboratory.* While asphaltum is observed to be the product of the immediate evaporation and oxidation of maltha at or near the surface, a slower and continued oxidation beneath the surface —in fissures, cavities and interstices of the rocks—has produced grahamite, albertite and other less hydrogenous hydrocarbons of the same type.

The smaller exhibitions of grahamite in the shale of the river banks, at Tempoal and the Aguacates, are of the same general nature as the deposit of the Cristo mine. They occupy interstices between divisional planes of the formation, thus forming veinlets which often pass from between one kind of partings to another. Hence even the larger of these deposits or pockets are very capricious in position, while the smaller ones merely reticulate the rock. They seem to have no connection or channels. The question is thus suggested, whether this formation, in places densely filled with organic remains, has not, in part at least, been the primary source of the hydrocarbons which it contains, as well as those of the underlying sandstone, from which, since its emergence, it has been for the most part denuded. This theoretical question must remain open until the relations of the numerous deposits of chapapote in eastern Mexico to the rocks from which they spring, shall be observed and compared. The above small and scattered deposits of grahamite have no economic value—although fine hand specimens can be taken from any of them.

Unlike the New Brunswick variety, which is compact in structure, conchoidal in fracture, and of a resinous and brilliant luster, the Ritchie and Cristo varieties, which are very similar, are of rather granular consistency. They possess a very distinct cleavage, a jointed structure, as well as columnar partings in the deposits, somewhat irregular, on account of the varying conditions of these deposits themselves. The Cristo mineral is more uniformly lustrous than that from Ritchie County, and of a greater coherence, though none the less distinctly cleaved and jointed.

* W. P. Jenny, Am. Chem., v, p. 10.

Both varieties are found at the Aguacates in veinlets. Some of these are filled with a conchoidal variety, like that from the Albert mine, while others consist of the same columnar and sub-conchoidal material as that from the Cristo mine. The conchoidal fracture in both differs simply as to degree, varying with the degree of brittleness.

A few barrels of the mineral from the Cristo mine having been sent last autumn to Glasgow, an analysis and technical examination of the sample were made by Mr. William Wallace, of that city.

ANALYSIS OF CRISTO-GRAHAMITE.

Specific gravity		1·156.	
Volatile matter	Illuminating gas	61·32	62·14
	Sulphur	·46	
	Water	·36	
Coke	Fixed Carbon	31·63	37·86
	Sulphur	·37	
	Ash	5·86	
			100·00

ANALYSIS OF COKE.

Carbon	83·56
Sulphur	·98
Ash	15·48
	100·00