ASPHALT.

AN OCCURRENCE OF ASPHALTITE IN NORTHEASTERN NEVADA.

By Robert Anderson.

INTRODUCTION.

In November, 1908, the writer visited an asphaltite prospect that has been opened in Eureka County, northeastern Nevada, about 15 miles south of Palisade. It is situated in the Pinon Range, up a canyon about 4 miles east of the Maples ranch, which is in the valley of Pine Creek on the Eureka and Palisade Railway. The occurrence of asphaltite here is interesting from the fact that heretofore no asphaltic substance has been recorded from that State.

THE ASPHALTITE.

CHARACTER.

The asphaltite found here would be commercially known as "grahamite," but its characteristics show it to differ from the variety so known scientifically. A few tests revealed a close relationship to the variety from Indian Territory described by G. H. Eldridge[a] as impsonite. It has a bright pitchlike luster on fresh surfaces, a jet-black color, a crushed or somewhat layered structure, and irregular or very imperfectly conchoidal fracture. It is very brittle, but when pure is compact and homogeneous. Its powder is black, and it leaves a light-black streak with a faint brownish tinge. At first sight a fragment of it might be mistaken for a piece of hard coal, but its light weight reveals a marked distinction at once, the specific gravity being roughly estimated at somewhat less than 2. When held in a flame it decrepitates slightly at first, softens and swells up in incip-

[a] The asphalt and bituminous rock deposits of the United States: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 1, 1901, pp. 265 et seq.

ient fusion, and burns, continuing to burn a short time after removal from the flame, and then forms a light coke. In boiling water it is not affected, but it softens and cokes when heated in a close tube. It is insoluble in turpentine. These qualities show it to be different from albertite and to be most like impsonite.

OCCURRENCE.

The asphaltite occurs as a filling in fractures within steeply dipping Carboniferous strata. These rocks consist of alternating sharply defined beds of sandy shale, calcareous shale, and sandstone, mostly well indurated, with important zones of hard, coarse conglomerate. They strike in general S. 75° E. and dip 50° to 60° on the average, though in places in this region they have been thrown into a nearly vertical position. They are referred to the Carboniferous on the basis of specimens of *Productus* found in beds supposedly of the same series a little over 2 miles east-southeast from the Maples ranch house. An indeterminate plant impression was found in the sandstone at the asphaltite prospect.

The asphaltite deposits can not be traced at the surface, but the prospect openings from which several tons of the material have been taken afford exposures for a short way. The principal deposit follows a zone of fracturing in the sandstone and shale beds. This vein has been traced about 100 yards beyond the main opening by small pits excavated at the surface, and appears to strike about N. 60° E. and to stand nearly vertical. The asphaltite occurs in lenses, stringers, and sheets along a fractured zone about a yard wide, mingled with and impregnating the fissured rock. Every gradation may be seen, from the pure material which occurs in wedge-shaped masses to sand and clay impregnated and cemented by the asphaltite. The thickest lens of the solid pure material exposed in the cuttings is about 18 inches thick. Though asphaltic material is continuous along the vein, the filling is irregular. It looks as if it had been intruded as a liquid into every crevice of a splintery fracture and had there hardened.

The country rock on either side of the vein is impregnated for a little way, especially along bedding planes. At the prospect an opening has been made at a distance of 40 feet along the strike of the beds from the main vein, exposing a zone about 4 feet thick of softer, somewhat clayey, and crushed beds between hard strata of shale. This zone is impregnated with the asphaltite and contains fairly regular layers of it several inches thick following the bedding.

It is probable that the asphaltite of this region has wide extent. Stringers of it are reported to have been found about half a mile up the canyon in a general easterly direction from the prospect, possibly along the extension of the zone already described; on Trout Creek about 3 miles to the north; and on Willow Creek about 7 miles to the south.

CONCLUSIONS AS TO THE POSSIBLE OCCURRENCE OF OIL.

There is little doubt that the strata in this region at one time contained considerable petroleum. Owing, however, to the disturbed condition of the beds, their great age, the long lapse of time since the disturbances took place, and the consequent opportunities for the escape of the petroleum content, it is likely that almost if not quite all of such oil has escaped or become altered in the derived form of asphalt. Further investigation should be made before such a conclusion should be considered as applying to any area except the immediate vicinity of the asphalt prospect mentioned. Strata of probable Paleozoic age elsewhere in this portion of Nevada are reported to be petroliferous, and it is not impossible that careful study might reveal areas in which the conditions are more favorable than in the one here discussed.

GRAHAMITE DEPOSITS OF SOUTHEASTERN OKLAHOMA.

By Joseph A. Taff.

LOCATION AND OCCURRENCE.

The grahamite deposits of Oklahoma occur in two distinct geologic and structural provinces, the Ouachita Mountains, in the southeastern part of the State, where the mineral has been found at a number of localities, and the plains region, between the Arbuckle and Wichita mountains, where it occurs in a single district. (See fig. 23.) In the Ouachita region the grahamite occurs in greatly folded rocks, but the rocks that contain similar deposits in the plains lie almost flat.

The grahamite is found filling fissures in the form of veins or dikes that cut across or extend with the bedding of the rocks. In the Ouachita Mountains it occurs in both Ordovician and Carboniferous rocks; in the plains region it is found in late Carboniferous or probably "Permo-Carboniferous" strata.

During the geologic surveys of the Ouachita region of Indian Territory, now southeastern Oklahoma, in 1897, grahamite veins were discovered in McGee Valley, T. 1 N., R. 14 E. More extensive deposits were located later the same season in Impson Valley on Tenmile Creek, T. 1 S., R. 15 E. The veins in Impson Valley had been considered beds of coal for a number of years, and the lands including them were taken up under coal leases. Little had been done in the way of development, however, beyond prospecting on one of the thicker veins. A deposit of bitumen nearly related to grahamite was located on the south slope of Black Fork Mountain, about 3 miles east of Page, on the Kansas City Southern Railway. This deposit occurs as a vein similar to those in Impson Valley. In 1906 grahamite deposits were noted at certain prospects in McGee Creek valley, T. 1 S., R. 14 E., where a small amount of development work had been done. Recently a deposit of grahamite in a vein of considerable thickness has been located in Jackfork Valley, about 10 miles west of Tuskahoma, where active development is now

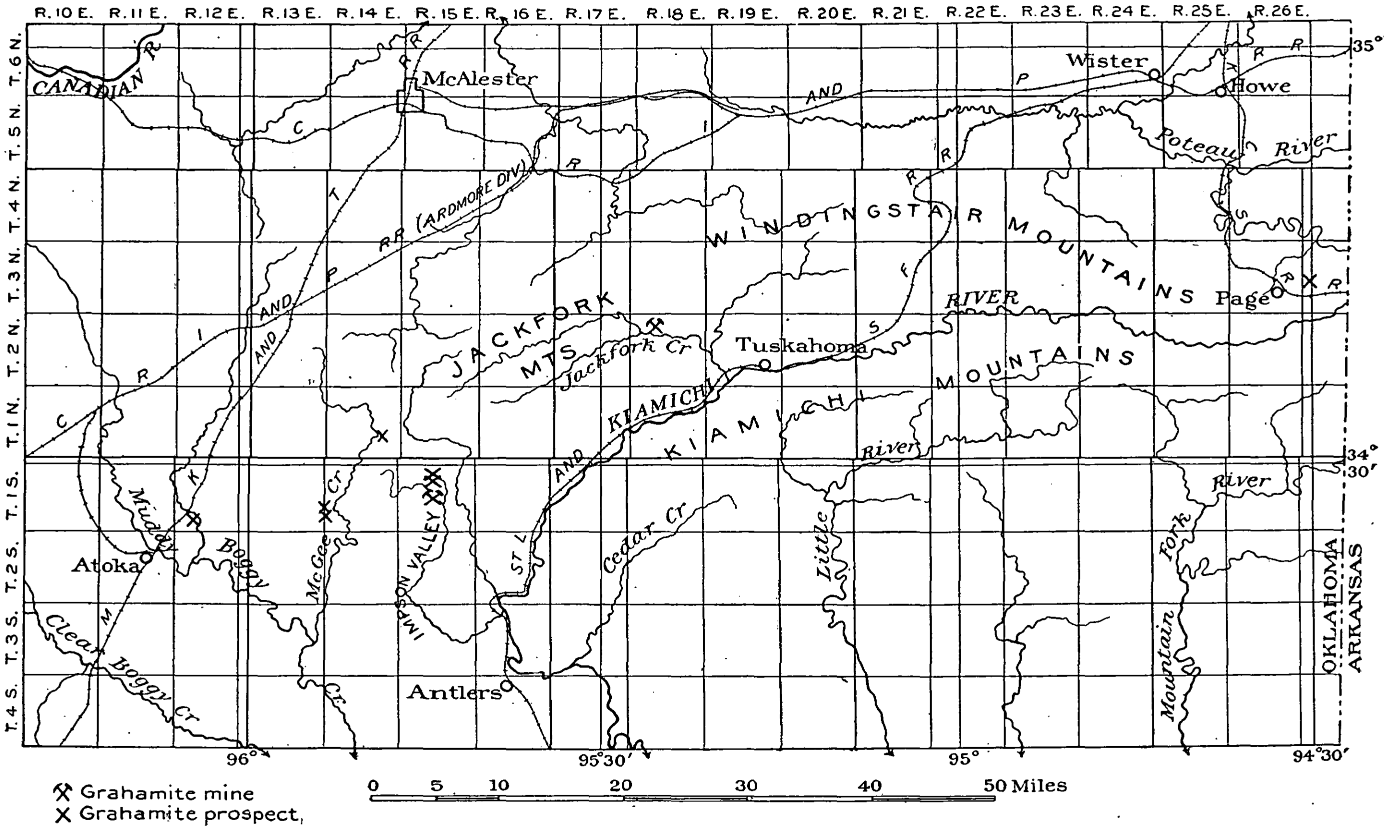

FIGURE 23.—Map of southeastern Oklahoma, showing location of grahamite deposits.

going on. The deposits thus far named occur in rocks of Carboniferous age. In 1906 or 1907 a vein of grahamite was discovered in Ordovician rocks on Boggy Creek, about 6 miles northeast of Atoka, T. 1 S., R. 12 E. Grahamite or a nearly related bitumen was discovered in 1902 about 6 miles northwest of Loco, or 12 miles east-northeast of Duncan. This deposit is in the rolling plain between the Arbuckle and Wichita mountains, and occurs in undisturbed late Carboniferous rocks.

PHYSICAL FEATURES OF THE REGION.

The Ouachita Mountain region, in which the grahamite deposits occur, consists of groups or ranges of rugged sandstone hills and mountains. These groups of mountains are separated from one another by wide and almost flat valleys. The principal mountain groups are as follows: (1) Winding Stair Mountain, which, in its easterly extension, near the Oklahoma-Arkansas line, is known as Rich Mountain. A high member of the same mountain group a little north of Rich Mountain and separated from it by a narrow valley is known as Black Fork Mountain. (2) Kiamichi Mountain, which extends from the Arkansas line westward, south of Kiamichi River. (3) The Jackfork Mountains, composed of a couple of high, rugged ridges about 15 miles in length that lie near the sources of Jackfork Creek and between the west ends of Winding Stair and Kiamichi mountains. Winding Stair Mountain is succeeded on the north and Kiamichi Mountain on the south by successively lower ridges of a similar kind until the Arkansas and Canadian valleys are reached on the north and that of Red River on the south. The high ridges composing these mountains in Oklahoma rise gradually from elevations of about 1,000 feet above sea near the Missouri, Kansas and Texas Railway on the west to about 2,900 feet near the state line on the east. Kiamichi River flows southwestward and southward from Tuskahoma in a deep gorge or boxlike canyon through Kiamichi Mountain. There is no gap or pass in this mountain farther east, but to the west it is cut by the deep, narrow gorges of Buck and McGee creeks. Winding Stair Mountain has a single high gap where the St. Louis and San Francisco Railroad crosses it, and a similar depression southwest of Page separates Winding Stair Mountain from Rich Mountain.

A broad, flat valley lies between Winding Stair and Kiamichi mountains. In the region of Talihina, 10 miles northeast of Tuskahoma, it is broken by a group of chert and novaculite hills known locally as the Potato Hills. The south ridge of the Jackfork group of mountains stands in the course of this broad valley and separates it into two parts that are occupied by the south and north forks of Jackfork Creek. This valley affords a means of easy access to the region, extending through the Ouachita Mountains from the source of Kiamichi River at the Arkansas-Oklahoma state line westward to Atoka.

All the grahamite deposits except that on Black Fork Mountain, near Page, are contiguous to or in the main valley leading through the central part of the mountain region. The Impson Valley deposits in T. 1 S., R. 15 E., are more accessible to the lower Kiamichi Valley, and shipments of grahamite from these deposits are made from Kosoma, on the St. Louis and San Francisco Railroad, about 8 miles north of Antlers. Grahamite from the mines in Jackfork Valley, T. 2 N., R. 18 E., is hauled to Tuskahoma and there shipped by rail. The deposits in McGee Creek valley are more accessible to the Missouri, Kansas and Texas Railway at Stringtown or Atoka, from which flat valleys extend to the mines.

STRATIGRAPHY OF ROCKS CONTAINING GRAHAMITE.

The rocks of the region in which the grahamite deposits are found consist of three general classes—shales, sandstones, and cherts or cherty novaculite. There are various gradations from one to the other of these classes of rock. The section of the formations in the Ouachita Mountains, in descending order, is as follows:

CARBONIFEROUS ROCKS.

1. Atoka formation, 3,000 to 6,000 feet thick; composed of numerous beds of sandstone and shale. The sandstone is most abundant in the middle and lower parts. In the central part of Winding Stair Mountain the sandstones in this formation attain a thickness of several thousand feet. Exact measurements of the thickness can not be obtained because of the excessive disturbances to which the rocks have been subjected.

2. Caney shale, 800$\pm$ feet thick; composed of black and blue shales with bowlders of limestone, chert, quartzite, etc.

3. Jackfork sandstone, 5,000 feet thick; composed of thick beds of gray and brown sandstone with little shale; contains grahamite in Black Fork Mountain.

4. Standley shale, 5,000 feet thick; composed of blue, black, and greenish shales and friable drab sandstone. Contains grahamite veins in Jackfork, McGee Creek, and Impson valleys.

The Carboniferous rocks occupy all of the region except the areas mentioned below as containing Ordovician, Silurian, and Devonian rocks.

DEVONIAN AND SILURIAN ROCKS.

Small areas of Silurian and Devonian cherts and black shales occur in the northwestern part of T. 2 N., R. 15 E., and in the corresponding part of T. 3 N., R. 17 E. Chert of probable Devonian age crops out near the northeast corner of T. 1 N., R. 13 E., and in the northeastern part of T. 4 N., R. 21 E.

ORDOVICIAN ROCKS.

5. Talihina chert, 1,200± feet thick; composed of light-colored novaculitic chert at the top, greenish shales in the central part, and bluish-black bituminous chert and shale in the lower part. The greenish shale in the center part of the formation contains the grahamite deposits north of Atoka.

6. Stringtown shale, 600± feet exposed, consisting of black and blue shales. The lower part of the formation is concealed.

The Ordovician rocks of the region crop out in the Potato Hills, which are about 50 square miles in extent and lie between Winding Stair and Kiamichi mountains, opposite Tuskahoma, and in a single ridge at the extreme west end of the Ouachita Mountain region just west of the Missouri, Kansas and Texas Railway.

STRUCTURE.

The rocks of the Ouachita region have been crumpled into many folds, to which are due the arrangement and the location of the principal mountains and valleys. In addition to the folding, the rocks have been fractured and in places faulted. In certain localities some of the fractures have opened as fissures and have received deposits of bitumen that are now classed as "grahamite." The grahamite-bearing fissures in south-central Oklahoma cut horizontal rocks and cross beds of shale and sandstone which in the vicinity are impregnated with bitumen.

DESCRIPTION OF DEPOSITS BY LOCALITIES.

IMPSON VALLEY.

The first discovery of grahamite deposits in paying quantity in Oklahoma (then Indian Territory) was made in 1897, on a branch of Tenmile Creek, in the west side of Impson Valley, near the south side of sec. 21, T. 1 S., R. 15 E. In the following year the lands, including the deposits of grahamite, were taken under an asphalt lease and operations were begun on a vein 20 to 25 feet thick. Samples of the mineral were collected in 1898 from the workings at a depth of 30 feet. These samples were analyzed and tested by William C. Day, and the tests revealed certain properties closely related to those of albertite. The results of these tests were published in a paper by the writer.[a] The following comparative data, derived from statements

[a] Taff, J. A., An albertite-like asphalt in the Choctaw Nation, Indian Territory: Am. Jour. Sci., 4th ser., vol. 8, 1899, pp. 219–224.

in Dana's manual pertaining to albertite from Nova Scotia and from the results of the tests by Doctor Day, are submitted to show the relations of the two substances:

Physical properties and composition of Nova Scotia albertite and Impson Valley grahamite.

	Albertite.	Grahamite.
Physical properties.		
Specific gravity	1.097	1.175
Color	Jet black.	Jet black.
Softens in boiling water	A little.	Does not.
In candle flame	(a)	(b)
Soluble in alcohol	Trace.	Trace.
Soluble in ether ..... per cent..	4	5.34
Soluble in turpentine ..... do....	30	(c)
Composition.		
Carbon (Weatherill) ..... per cent..	86.04	86.57
Hydrogen (Weatherill) ..... do....	8.96	7.26
Nitrogen:		
(Weatherill) ..... do....	2.93	....
(Day) ..... do....	1.84	1.48
Sulphur:		
(Weatherill) ..... do....	Trace.	....
(Day) ..... do....	0.17	1.38
Oxygen (Weatherill) ..... do....	1.97	2.00
Ash (Weatherill) ..... do....	0.10	1.31

[a] Shows incipient fusion.
[b] Shows incipient fusion; takes fire and burns a short time after removal of flame.
[c] Almost insoluble.

The only important difference in the two materials as shown by these tests is in their solubility in turpentine. Accordingly, Doctor Day concluded that the material resembles the albertite from Nova Scotia more than other asphaltic bodies which had thus far been investigated.

There are some further distinctions in the physical properties of albertite and the solid bitumen of Oklahoma. Albertite usually has a bright luster, is massive or compact, and has smooth fractures. The absence of these features in the Oklahoma material, however, may be due in part at least to the fact that it has suffered crushing since it was solidified. Albertite and the Oklahoma bitumen are also very distinct from one another in degree of solubility in carbon disulphide and naphtha. The bitumen in albertite is soluble only to a small extent in carbon disulphide, but the Impson Valley material is almost completely so. In this and many other respects the Oklahoma solid bitumen corresponds most closely with grahamite from the type locality in Richie County, W. Va., as has been worked out by Richardson.[a] A proximate analysis of the Impson Valley grahamite will be found on page 296.

The solid bitumen of Oklahoma that has been mined commercially is classed in the trade as grahamite, and it is probably true that all

[a] Richardson, Clifford, Modern asphalt pavement, New York, John Wiley & Sons, 1908.

the deposits, with the possible exception of that in Black Fork Mountain, fall within this class, though it is known that variations in composition are shown by solid bitumen occurring in separate localities in the same region, and even in a single mine from the surface downward if considerable depth has been attained. Such changes are regarded to have been brought about by the loss of the more volatile substances. On the assumption that all the bitumen has the same source, differences in the character of the rocks adjoining the vein, variations in the structure of the rocks, and differences in the time at which the deposits were introduced into the fissures would tend to produce variations in composition.

The rocks in which the grahamite occurs in Impson Valley are near the top of the Standley shale. The formation has been strongly folded upward and thrust over slightly toward the west. The strata have been fractured and probably faulted along a belt parallel with the axis of the fold and near the west side of the valley. The beds of shale and sandstone contiguous to the veins have suffered crushing and shearing to such an extent that they are retained in the walls of the mines with great difficulty after the grahamite has been extracted. Strong pressure has been exerted on the rocks since the bitumen became solid, thereby causing it to be fractured and intimately jointed. The grahamite veins are lenticular and variable in form, both laterally and vertically. The strike of the veins has a general north-south direction, parallel with the general trend of the rocks, but not necessarily parallel with the individual beds. The pitch of the veins is steep toward the east, in the direction of the dips of the rocks, but usually at a greater angle. These veins have been exploited more or less continuously since 1898.

JACKFORK VALLEY.

An important discovery of grahamite was made recently in the broad, flat valley of Jackfork Creek, near the center of the east side of sec. 9, T. 2 N., R. 18 E., on a low swell produced by the outcrops of certain friable sandstone and sandy shale beds that occur in the central part of the Standley shale. The operators claim to have located the grahamite vein by prospecting three-fourths of a mile west and one-fourth mile east of the mine. The rocks at the place of discovery dip 37° S. and the vein, which is 19 feet thick at the surface, lies between even beds of sandy shales. At a depth of 140 feet in the main entry of the mine the vein turns downward, cutting the rock beds irregularly at a slope varying between 45° and 50°. Entries driven east and west from the main slope encounter rock masses that have fallen from the hanging wall when the bitumen was in a plastic or viscous state. In accordance with the general rule of grahamite or other solid-bitumen veins, the fissure which has been filled here is variable, both in lateral extent and in width, but its size has been determined only so far as exploitation has been carried. The vein varies also in structure. The central part, separated more or less irregularly by distinctions of structure from the grahamite above and below, is intimately jointed and affords an uneven granular surface closely resembling that of the Impson Valley grahamite. The product of this part of the vein, on account of the surface character, has a dull luster, though the luster of individual small facets is bright. The zone of the vein next to the foot wall has a columnar or pencillate structure, with a flatly conchoidal fracture developed perpendicular to the wall rock. The upper zone, in contact with the hanging wall, has a more distinctly conchoidal fracture and a more pronounced columnar structure than the lower zone. The same kind of structure also characterizes the material surrounding the larger rock masses that have fallen into the grahamite vein. Besides being more distinctly conchoidal in fracture than the zone of the vein in contact with the foot wall, this material has also a brighter luster. The upper and lower parts of the vein are brittle, like the other grahamite of the region. In contrast with the central part, the fracture and luster of the upper and lower parts of the vein resemble more closely those of albertite.

McGEE CREEK.

Two thin veins of grahamite, one 4 inches and another nearly a foot in thickness, were discovered in 1897 on the west side of the McGee Creek valley, in the SW. ¼ sec. 23, T. 1 N., R. 14 E. These veins are vertical and cut folded and crumpled green shales of the Standley. The strike of the veins is almost north and south, but the general trend of the rocks is east and west. The grahamite is friable and lustrous. Angular fragments of shale are mingled with the vein material as if crushing had occurred since the vein material had been introduced and become solidified. The deposits here have not been prospected sufficiently to prove their volume, but are of possible economic importance.

Two locations were made on a vein of grahamite in the valley of a tributary to McGee Creek late in 1905 or early in 1906—one in the northwest corner of sec. 30, T. 1 S., R. 14 E., and the other one-fourth mile farther south. At the former a shaft was sunk to a depth of 75 feet, according to report; but in 1906, when the locality was visited, it was almost filled with water and the vein could not be inspected. It is said to have been 4 feet thick in the shaft, from which several carloads of grahamite have been extracted. The vein at the second locality shows a thickness of 2 feet 6 inches and fills a fissure that extends in a north-south direction and dips 66° E., approximately with the bedding of the rocks.

These deposits occur in the Standley shale. The rocks, however, are but meagerly exposed in the vicinity. They have been crumpled and folded near these deposits. As stated above, the rocks at the southern prospect dip eastward, but 500 feet farther south the strata strike east and west and the rocks dip very steeply toward the south. A zone of faulting, in which the rocks to the south are thrust upon those to the north, has been traced eastward across McGee Creek and thence northeastward for a number of miles.

Specimens of grahamite float were collected from the shoals of McGee Creek in sec. 32, T. 1 S., R. 14 E., 2 miles south of the fault zone, an occurrence which suggests the presence of grahamite in the bed of McGee Creek not far upstream.

BLACK FORK MOUNTAIN.

Black Fork Mountain is composed of the Jackfork sandstone, a thick formation of many beds of sandstone interbedded with some layers of shale. The sandstone of Black Fork Mountain is tilted steeply toward the south. The structure of the mountain is that of a closed fold that has been overturned toward the north, or else of a monocline that is bounded on the south by a thrust fault of great displacement. The sandstone has been sheared and faulted at certain places in the south side of the mountain. An illustration of this condition may be seen in a quarry prospect near the base of the mountain southwest of the grahamite deposit, massive bituminous sandstones having been sheared and moved laterally on the fault plane. At the location of the grahamite deposit, also, the rocks are fissured and sheared.

The grahamite vein fills a fault fissure that bears in an irregular southwest course, cuts across the strata, and pitches steeply toward the southeast. The strike of the country rock is generally east and west. Faulting has developed also since the introduction of the bitumen into the fissure. At the northeast end of the main exposure the bitumen is abruptly terminated at a fault, where it abuts against thin beds of sandstone. This fault bears almost due south, the eastward extension of the fissure being displaced in a direction that is not determinable. Another fault 50 feet west of the first crosses the vein in a southerly direction. At this fault the strike of the vein changes from S. 45° W. to nearly S. 20° W. and so continues to the prospect. At the south end of the exposure a short prospect entry has been driven into the vein across sandstone beds that dip 60° S. 10° E. The vein at this point cuts across the strata with a pitch of 50°. At the outcrop it is 10 feet thick. A complete exposure of the vein was not revealed in the drift, but it is reported that 4 feet could be seen. These observations on the structure indicate a variable and highly disturbed vein deposit whose extent and volume under cover can be determined only by exploitation.

The physical properties of the bitumen deposit in Black Fork Mountain resemble those of the grahamite of Impson Valley and of the central part of the vein in Jackfork Valley. It is thoroughly black, is friable, and has a hackly fracture. The luster on the whole is not brilliant, but individually the small faces of the planes of fracture show a bright luster. A peculiar feature of the physical properties of certain parts of the vein is a banded structure, in which the planes of fracture in one band are parallel with one another but lie at divergent angles to similar sets of fractures in adjoining bands. The bitumen deposit of Black Fork Mountain has been metamorphosed to a greater degree than any other that has been tested in this region. A greater percentage of the more volatile part has been removed. On application of a particle of the bitumen to a candle flame it decrepitates, but does not fuse or become ignited like the Impson Valley or Jackfork Valley material. A comparison of the proximate analyses, given on page 296, shows that the percentage of carbon in the Black Fork Mountain product is much higher than that in the Impson Valley grahamite and is probably so high as to place it in a class of bitumens or so-called asphaltites other than that of grahamite. This fact will be determined, however, by tests of solubility and of chemical characteristics that have not yet been made at the Geological Survey or elsewhere so far as known to the writer. The high percentage of fixed carbon suggests that the material will be found practically insoluble by the media used in testing soluble bitumens.

FOURCHE MOUNTAIN, ARKANSAS.

Deposits of solid bitumen were located at the west end of Fourche Mountain, in Arkansas, about 12 miles east of the Black Fork Mountain locality. The place is about 1 mile east of Eagle Gap, which separates Black Fork Mountain from Fourche Mountain, and 2 miles east of Harris, on the Kansas City Southern Railway.

The deposits occur in a shear zone of shale and sandstone and are in the form of veinlets separated by crushed and slickensided shale. The bitumen product itself shows the effects of crushing forces, being sheared and slickensided. It resembles the solid bitumen of Black Fork Mountain, except that it is probably more friable. The proximate analysis below shows that it is more highly metamorphosed than the Black Fork Mountain product. The prospect from which the samples were taken, however, was shallow and without doubt the material had been affected by weathering agencies. The Fourche

Mountain deposit is of no apparent economic value, in view of the structural conditions and the quality of the material.

The subjoined table affords a means of comparing the Fourche Mountain, Impson Valley, and Black Fork Mountain bitumens.

Proximate analyses of bitumens from Impson Valley and Black Fork Mountain, Oklahoma, and Fourche Mountain, Arkansas.

	Impson Valley, grahamite.	Black Fork Mountain, solid bitumen.	Fourche Mountain, solid bitumen.
Moisture	0.25	0.09	2.51
Volatile bitumen	43.33	23.06	17.78
Fixed carbon	55.97	75.90	79.15
Ash	1.45	.95	.56
Sulphur	1.47	1.69	1.38

BOGGY CREEK.

A vein of grahamite has been found in the valley of North Boggy Creek about 6 miles northeast of Atoka. The vein occurs in greenish clay shales of Ordovician age. These rocks are tilted steeply toward the east and the grahamite fills the fissure that extends between the beds, according to the report of a workman who was in charge of the property when the place was visited. A slope had been driven on the vein with the dip of the strata. The mine was not in operation and the slope was filled with water. The vein could not be inspected, but a quantity of the grahamite was stored ready for shipment. The thickness of the vein was reported to vary from a fraction of an inch to a few feet; the exact dimensions were not ascertained.

The physical properties of this bitumen are essentially the same as those of the Impson Valley grahamite. The material is black, has a bright luster, is brittle, and presents an irregular fracture. It takes fire and swells in a candle flame and continues to burn with a short flame for a moment after the candle is removed.

LOCO.

A grahamite deposit northwest of Loco is in sec. 6, T. 2 S., R. 4 W. So far as known it is found in a single vein that bears in a southwesterly course across the south half of the section. The country rocks consist of rather soft sandstone and shale that lie in a flat position. The grahamite vein cuts almost vertically across them. At a depth of 40 feet the vein cuts massive coarse bituminous sandstone, which crops out along the neighboring valley. Similar asphaltic sandstones occur in a large area in the vicinity of Loco.

Four shafts have been sunk on the vein, two in the southwest and two in the southeast quarter of sec. 6. The most easterly of the shafts was sunk to a depth of 96 feet, and the grahamite was mined by drifts run laterally on the edge of the beds. The mines were not in operation when the locality was visited, and they could not be entered on account of water. The keeper stated that the vein had an average thickness of 2 feet 6 inches and varied from an extreme of 10 feet 6 inches to a thin film. A reported output of 100 carloads of grahamite had been removed from the vein. It is said also that the vein had been traced by prospecting for a distance of half a mile. In this locality, as well as in others where the deposits occur in faulted rock, the thickness and extent of the vein can be determined only so far as exploitation has gone.

The grahamite in the Loco vicinity has physical characteristics very similar to those of the deposits in Impson, Jackfork, and Boggy valleys. It is black, brittle, lustrous, and friable. In a candle flame it fuses readily, swelling to several times its former size, and it continues to burn for a moment after the candle is removed.

RÉSUMÉ.

The grahamite deposits of southeastern Oklahoma occur as veins filling fissures in sandstone and shale, which lie in various positions from horizontal beds to those that are highly folded or tilted. The rocks that contain the grahamite occur in Ordovician and at several positions in Carboniferous sections. The bitumen deposits are known to vary in composition in three localities and probably vary from one to another of all the localities so far discovered. This variation is evidently due to differences in the degree of metamorphism, the progressive change brought about by the loss of the more volatile hydrocarbon. It is apparently not due to the age of the rocks in which the deposits occur. In a comparison of physical tests the grahamite in Ordovician shales near Atoka seems to be more nearly related to the Loco deposit in late Carboniferous rocks than to any other in the region. The deposits containing the highest percentages of fixed carbon occur in Black Fork Mountain, Oklahoma, and in Fourche Mountain, Arkansas, where they are either associated with sandstone or occur in closely folded and extensively fractured strata. In such relations the more volatile substances of the bitumen veins would escape with greater facility than where the material is in contact with shales and in association with less intense disturbance of the strata. The grahamite veins, like any other vein deposits, have been found to be variable in extent. They may be expected to vary in thickness in any direction or to terminate abruptly, for they occur in a region of faulted strata where both faulting and folding have progressed since the introduction of bitumen into the fissures. Thus far the only deposits that have warranted extended development and that are being worked at the present time are those in Impson and Jackfork valleys.

SURVEY PUBLICATIONS ON ASPHALT.

The following list comprises the more important papers relative to asphalt published by the United States Geological Survey or by members of its staff. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.:

BOUTWELL, J. M. Oil and asphalt prospects in Salt Lake basin, Utah. In Bulletin No. 260, pp. 468–479. 1905. 40c.

DAY, W. C. The coal and pitch coal of the Newport mine, Oregon. In Nineteenth Ann. Rept., pt. 3, pp. 370–376. 1899. $2.25.

ELDRIDGE, G. H. The uintaite (gilsonite) deposits of Utah. In Seventeenth Ann. Rept., pt. 1, pp. 909–949. 1896.

——— The asphalt and bituminous rock deposits of the United States. In Twenty-second Ann. Rept., pt. 1, pp. 209–452. 1901.

——— Origin and distribution of asphalt and bituminous-rock deposits in the United States. In Bulletin No. 213, pp. 296–305. 1903. 25c.

HAYES, C. W. Asphalt deposits of Pike County, Ark. In Bulletin No. 213, pp. 353–355. 1903. 25c.

HILGARD, E. W. The asphaltum deposits of California. In Mineral Resources U. S. for 1883–84, pp. 938–948. 1885. 60c.

HOVEY, E. O. Asphaltum and bituminous rock. In Mineral Resources U. S. for 1903, pp. 745–754. 1904. Idem for 1904, pp. 789–799. 1905.

RICHARDSON, C. Asphaltum. In Mineral Resources U. S. for 1893, pp. 626–669. 1894. 50c.

SMITH, C. D. (See Taff, J. A., and Smith, C. D.)

TAFF, J. A. Albertite-like asphalt in the Choctaw Nation, Indian Territory. Am. Jour. Sci., 4th ser., vol. 8, pp. 219–224. 1899.

——— Description of the unleased segregated asphalt lands in the Chickasaw Nation, Indian Territory. U. S. Dept. Interior, Circular No. 6. 14 pp. 1904.

——— Asphalt and bituminous rock. In Mineral Resources U. S. for 1906, pp. 1131–1137. 1907. 50c.

——— Asphalt and bituminous rock. In Mineral Resources U. S. for 1907, pt. 2, pp. 723–730. 1908.

TAFF, J. A., and SMITH, C. D. Ozokerite deposits in Utah. In Bulletin No. 285, pp. 369–372. 1906. 60c.

VAUGHAN, T. W. The asphalt deposits of western Texas. In Eighteenth Ann. Rept., pt. 5, pp. 930–935. 1897.