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TESTS

FOR

GOLD AND SILVER IN SHALES FROM WESTERN KANSAS

BY

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TESTS FOR GOLD AND SILVER IN SHALES FROM WESTERN KANSAS.

By WALDEMAR LINDGREN.

INTRODUCTION.

The assertion that certain clay shales of western Kansas contain gold and silver dates back about seven years. In 1895 a company of men, among them a certain H. H. Artz, sunk a shaft near Smoky Hill River, in Trego County, prospecting for zinc. It is stated that some indications of this metal were found, but of more importance was the announcement that the soft clay shales encountered contained a notable percentage of gold. It soon became known that the same clay shales extended through a large part of Ellis County and were especially well exposed in the bluffs along Smoky Hill River in the southern part of that county. A great number of assays of these shales were made by different persons, and a large percentage of the samples was said to contain gold and silver. The asserted amounts vary considerably. Dr. J. T. Lovewell, of Topeka, in a paper read before the Kansas Academy of Science,[a] stated that he had made many hundreds of assays and supposed that the clay had average values of $2 to $3 per ton in gold and silver, the latter metal always accompanying the gold. One series of 100 assays gave an average of more than $10 per ton. Dr. Ernst Fahrig, of Philadelphia,[b] obtained from actual mill runs in an experimental plant an average of $2.80 per ton. One of these runs yielded 2.6 ounces silver and $1.36 gold per ton, and another of them gave an aggregate value of $6.75 per ton. The Kansas Pioneer Gold Shale Company, advertising their stock in the principal papers of St. Louis, Chicago, and New York, state the value as $8 to $10 per ton, and compute the wealth contained in one acre of shales to be $5,250,000. Others, among them Prof. E. Haworth, of the Kansas State University, have denied that the shales contain gold in notable quantities.[c]

The statements of tenor obtained by assays are usually accompanied by the explanation that the values are extremely irregular, different assays from the same carefully mixed pulp giving widely differing results.

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[a] Topeka Semiweekly Capital, January 3, 1902.

[b] Kansas Daily Capital, Topeka, May 3, 1902.

[c] Kansas Semiweekly Capital, Topeka, June 6, 1902. Mineral Resources of Kansas for 1898, Lawrence, Kans., 1899.

It was not long before mills were erected to extract the values from the clay shale. In 1900 a company was formed and erected a mill on Smoky Hill River, 14 miles west-southwest of Hays. Some kind of a chloridizing process was to be used, but no run was ever made, the superintendent and owner of the process, W. F. Miller, absenting himself unexpectedly before actual work had begun. In 1901 a smaller experimental mill was built near the works just mentioned by Mr. A. G. Gage, who used a variation of the cyanide process, and claimed to have extracted some gold during a series of short runs. In the spring of 1902 the Kansas Pioneer Gold Shale Company built a mill using the same process and supposed to handle 100 tons per day. This mill, which is located 11 miles southwest of Hays, on Smoky Hill River, had just started crushing and leaching in May, 1902. Finally, during the same month, a company called the Fahrig Mining and Milling Company was organized in Topeka for the purpose of constructing and operating a 100-ton mill on Smoky Hill River. The Fahrig process consists in treating the ore with a salt of unrevealed composition and in precipitating the gold and silver by electrolytic methods.

FIELD WORK.

The investigation of the Kansas shale deposits was undertaken by the United States Geological Survey in May, 1902. The actual work in the field occupied eight days, from May 12 to May 20, and was carried on from Hays as a base.

LOCATION.

Although attention was first drawn to the shales in question through prospecting work in Trego County, all the later developments have taken place in Ellis County, adjoining Trego County on the east. Ellis is one of the west-central counties of Kansas. Its county seat, Hays, is located on the line of the Union Pacific Railroad, 272 miles west of Kansas City. Although near the western limit of the "rain belt," the county produces much wheat and supports a numerous and well-to-do farming population.

TOPOGRAPHIC FEATURES AND DRAINAGE.

The region is drained by Smoky Hill River, which has its headwaters in eastern Colorado and flows through the southern part of Trego and Ellis counties almost due east to its junction with the Saline River. In Ellis County Saline River flows parallel to and 25 miles north of Smoky Hill River. Big Creek traverses Ellis County diagonally, flowing southeasterly to its junction with Smoky Hill River. As may be expected of a stream heading in an arid country, Smoky Hill River sometimes runs dry. After heavy rains it rises rapidly and is often unfordable.

The general relief is that of a rolling, gently undulating country, through which the rivers have cut well-defined though not very deep trenches. The elevation at Hays is 2,000 feet. Along Smoky Hill River south of Hays elevations range from 1,900 to 2,000 feet. Smooth, grassy hills rise between Big Creek and Smoky Hill River to 2,200 and 2,300 feet, and to somewhat less elevation between Big Creek and the Saline. East of Hays still more gentle outlines prevail, the divide rising little more than 100 feet above the main streams. The highest elevations, 2,400 feet, are in the rough hills south of Smoky Hill River, about 20 miles west-southwest of Hays.

Smoky Hill River flows in a sandy bed rarely more than a few hundred feet in width. The gentle curves of the stream are marked by steep bluffs, 20 to 80 feet high, on the convex side and moderate slopes on the opposite, concave, side. These bluffs are due to the lateral cutting of the banks by the river.

This part of Kansas is mapped by the United States Geological Survey on a scale of 2 miles to the inch and with a contour interval of 20 feet; the Hays and Ellis quadrangles embrace all points referred to in this paper.

GEOLOGICAL FEATURES.

The geology of this part of Kansas is described in a general way in Volume II of the Report of the University Geological Survey of Kansas. The rocks exposed are sedimentary and of Cretaceous age, excepting the sands and gravels along the river, which, of course, are of much later (Pleistocene) age. The two great divisions of the Cretaceous, the Benton and the Niobrara, cover the whole area. The beds of shale and lime lie nearly horizontal but have a slight northeasterly dip.

CRETACEOUS ROCKS.

Beginning from the top, that part of the Cretaceous column with which we are here concerned is subdivided as follows:[a]

Section of Cretaceous rocks in western Kansas.

			Feet.
Niobrara group		Smoky Hill chalk	300
		Fort Hays limestone	50
		Septaria horizon.	
Benton group	Upper	Blue Hill shale	100
		Ostrea shales	150
		Fencepost limestone	1
	Lower	Inoceramus horizon	5
		Flagstone	10
		Lincoln marble	15
		Bituminous shale	30
		Total	661

[a] The divisions here used follow the description by Prof. E. Haworth, Geol. Surv. Kansas, Vol. II, pp. 215-221.

Niobrara group.—The upper member of this group, the Smoky Hill chalk, does not cover notable areas in Ellis County. The Fort Hays limestone, on the contrary, is exposed on the hills south of Hays and also to some extent on the ridge north of that town. The thickness is not over 50 feet. The rock is a yellowish limestone, easily dressed and locally used as building stone. It appears again south of Smoky Hill River, capping the shale in the roughly eroded area 20 miles west-southwest of Hays.

Just below the Fort Hays limestone is a well-marked horizon, in which the shales contain large calcareous concretions (septaria), often large and containing abundant veins and crystallized masses of calcite of different colors ranging from white to dark brown.

Benton group.—A great thickness (250 feet) of shales underlies the Fort Hays limestone. The upper 100 feet are called the Blue Hill shales and are fissile light-gray to dark-gray shales without fossils and containing only small amounts of pyrite and organic matter. These are exposed in the hills west and northeast of Hays. They also outcrop below the same limestone on the south side of Smoky Hill River, 18 miles west-southwest of Hays, and extend far up into the adjoining Trego County along the river. Samples 3, 18, and 19 are from this horizon. The shales forming the bed rock at Hays probably belong in the lower part of this division. Several deep wells sunk 4 and 5 miles east and east-northeast of Hays penetrated nothing but shales to a depth of 200 to 360 feet.

The lower division, called the Ostrea shales, is 150 feet thick and covers a large area, especially along Smoky Hill River, from some point in Trego County down to a point south or a little southeasterly of Hays. It is a dark-gray calcareous shale, containing a little pyrite, finely divided and also sometimes in concretions. It also contains an abundance of fossil shells, largely of *Ostrea congesta;* sharks' teeth are also often found. Narrow bands of light-gray or yellowish-gray limestone part the shale at intervals of from 5 to 20 feet. Almost the only good exposures are found along the river banks, on either side, according to the curves of the river. Here the bluffs are from 20 to 60 feet high, and if the rock is not fresh on the surface it takes but little work to obtain unaltered material. Near the top of the bluffs the shales are whitish and decomposed and usually covered with Pleistocene sands.

The shales are almost black when somewhat moist, but have a dark-gray color when dry. They generally appear mottled by minute whitish specks in a darker predominating mass. The weathered outcrops are soft and disintegrate into a clayey soil, breaking up into small flat fragments. When fresh the shale is quite compact, though breaking easily into large flat fragments 2 to 4 inches thick. While the upper Blue Hill shales are poor in calcite, the Ostrea shales effervesce readily with acids. When washed in a miner's pan, the heavy residue consists of calcite grains, a few fragments of quartz, and some scant, well-rounded granules of black iron ores; besides there is always a little extremely fine-grained pyrite. No colors of gold could be detected. Samples 1, 2, and 4 to 14 (see pages 10–12) are from the Ostrea shales.

The Lower Benton group contains much more limestone than the upper division. It consists of about 70 feet of alternating shales and limestone, as indicated in the above table. It is exposed in the eastern part of Ellis County, though the identification of its various members is not easy during a rapid traverse of the country. The 50-foot bluffs of shale covered by limestone, on the north bank of Smoky Hill River, 3 miles west of Pfeifer and also at Falkenstein's farm on the south bank, about the same distance from the town mentioned, are believed to belong in this horizon. Samples 15, 16, and 17 are from this horizon. The Ostrea shales on Smoky Hill River at a point 14 miles west-southwest of Hays are 250 feet below the Fort Hays limestone, and must consequently be near the bottom of the Upper Benton. The vertical distance from here to the Dakota sandstones below can hardly be more than 100 feet.

PLEISTOCENE ROCKS.

To this most recent time division belong the sands and fine gravels along the bottoms of Smoky Hill River and also covering the low shale bluffs which follow the stream. The material of this terrane is chiefly quartzose and the grains are remarkably well rounded. By washing the material in a miner's pan a heavy residue of black sand, probably both magnetite and ilmenite, is obtained. These grains also are extremely well rounded. Besides, the sand contains abundant grains of garnet and some epidote; fragments of topaz are also said to occur. A number of pans of this sand was washed near Copeland's road crossing, and in one a very minute color of gold was obtained.

SAMPLING AND ASSAYING.

SAMPLING.

The principal gold-bearing stratum is supposed to be the Benton group, including the Ostrea shales and the Blue Hill shales. It is stated that these rocks over practically the whole of the areas in which they occur contain more or less gold and silver, though the metals may be rather irregularly distributed. Samples showing value are claimed to have been obtained in Trego County along Smoky Hill River as far westward as the Benton shales extend, all along Smoky Hill River in Ellis County, and also in Rush County, adjoining on the south.

It is claimed that values have also been found in samples collected near Hays; for instance, in the shales underlying the Fort Hays limestone 4 miles west of the town, and also in samples collected along Saline River, along which Fort Benton shales are also said to outcrop. All the mills, however, are located on Smoky Hill River southwest of Hays, and from this vicinity have also been taken the by far largest number of assayed samples.

In order to arrive at a reliable conclusion regarding the contents of these shales in precious metals, the samples described below were carefully taken. The method used included, first, the clearing of a convenient exposure to a required depth so as to obtain fresh material. Along the river bluffs the shales are very little altered and fresh rock is comparatively easily found. The required thickness of shale being exposed (usually amounting to from 2 to 4 feet), a sample of from 20 to 30 pounds was broken down on a square of canvas; this material was then reduced to pieces about the size of a walnut, or smaller, and the whole amount was quartered down twice to a weight of from 3 to 5 pounds. It was then put into quart jars and the same securely sealed. The following samples were taken:

Samples collected for assay.

No.	Locality.	Character of material.
1	South side of Smoky Hill River, 3½ miles east of the line dividing Ellis and Trego counties. Small quarry located behind Miller's mill, 20 feet above the river. Exposure 25 feet high. This sample represents the average of 3 feet from floor of quarry up to the lower band of limestone.	Black shale containing some pyrite and divided by two narrow bands of gray limestone.
2	Same as No. 1. This sample represents 3 feet of shale between the two layers of limestone. Above the upper limestone band the shales appear decomposed by surface action.	Dark-gray shale with fossils and some concretions of pyrite.
3	South side of Smoky Hill River, 3½ miles northeast of the southwest corner of Ellis County, and about 2½ miles south of Miller's mill. The horizon is in the Blue Hill shales just below the Fort Hays limestone. The elevation is about 2,250 feet. This sample represents an average thickness of 2 feet.	Thinly laminated gray clay shale with no fossils and but little organic matter.
4	Mouth of gulch emptying into Smoky Hill River from the south, 3¼ miles west of the Ellis-Trego county line. This locality is about 200 feet west of Gage's experimental mill. The bluff is here 30 feet high and consists of dark-gray shale divided by two narrow partings of gray lime. The sample represents 3 feet of shales 2 feet above the bed of the gulch.	Dark-gray Ostrea shale with fossils and a little pyrite.

Samples collected for assay—Continued.

No.	Locality.	Character of material.
5	Same as No. 4, 500 feet east of Gage's experimental mill. From small pit in shales at the river level, which showed indication of having been recently blasted. Material for experimental work in Topeka was reported to have been taken from this locality. The exposure showed 6 feet of shale covered by 10 inches of gray lime; above this 6 feet of shale. The sample covered 3 feet of the lower shale.	Fossiliferous Ostrea shales of dark-gray color containing a little pyrite.
6	Same as Nos. 4 and 5, 650 feet east of Gage's experimental mill at base of 30-foot bluff, the upper part more or less decomposed. This sample is an average of 2 feet close to river level.	Dark-gray fossiliferous shale with a little pyrite.
7	Same as No. 6. Average of 3 feet, from 5 to 8 feet above river level.	Dark-gray fossiliferous shale with a little pyrite.
8	South bank of Smoky Hill River, 11 miles southwest of Hays and 1 mile west of Copeland's crossing, in quarry from which material was being extracted for reduction in the Pioneer Company's new mill. The place is less than 100 feet distant from the mill. The bluff is here approximately 30 feet high, the upper 6 feet consisting of well-washed Pleistocene sand. Below this 4 to 6 feet of decomposed shale, below which the quarry has exposed fresh material. The sample is an average of the shale from 8 up to 10 feet above the river.	Dark-gray clay shale, fossiliferous and containing a little pyrite.
9	Same as No. 8. The sample is an average of 2 feet, from 10 to 12 feet above the river level.	Dark-gray fossiliferous shale containing a little pyrite.
10	About 150 feet east of the Pioneer Company's mill. The bluff is here 18 feet high and consists of shale with two or three narrow bands of harder limestone. The sample represents an average of 3 feet, from 5 to 8 feet above the river.	Dark-gray fossiliferous shale.
11	South bank of Smoky Hill River, one-fourth mile west of the Pioneer Company's mill. Twenty-five-foot bank of shale covered by 6 feet of sand and gravel. The sample was taken from blasted cut 2 feet above river level, from shale averaging 2 feet in thickness.	Dark-gray fossiliferous shale with a little iron pyrites.

Samples collected for assay—Continued.

No.	Locality.	Character of material.
12	North bank of Smoky Hill River, 10½ miles southwest of Hays and 300 feet east of Copeland's road crossing. The shale bluff is 30 feet high and contains four smaller bands of dark-gray lime. The sample was taken 4 feet across just above the river.	Dark-gray fossiliferous shale.
13	North bank of Smoky Hill River, 800 feet west of Copeland's road crossing. Shaft 40 feet deep, 15 feet above the river. Filled with water. The sample was carefully picked from east side of dump.	Dark-gray fossiliferous shale.
14	Same as No. 13. Sample picked from west side of dump.	Dark-gray fossiliferous shale.
15	Fifteen miles south-southeast of Hays, in Rush County, 3½ miles west-southwest of the town of Pfeifer. South side of Smoky Hill River, 1 mile south of sharp bend; Baskel's farm on Shelter Creek; bluff opposite house on west side of creek, consisting of 35 feet of thin-bedded shale capped by 12 feet of yellowish limestone.	Dark-gray clay shale with some fossils.
16	Fourteen miles south-southeast of Hays, in Rush County, near boundary line of Ellis, 4 miles west-southwest of Pfeifer. South side of Smoky Hill River at Falkenstein's farm. Bluff 15 feet high from river level of shale with several indistinct limy layers.	Nodules of partly decomposed iron pyrites in shale.
17	Same as No. 16. Average of 2 feet of shale about 8 feet above river level.	Dark-gray shale without much carbonaceous substance.
18	Four and one-half miles west-northwest of Hays and one-fourth mile south of railroad, on farm of J. C. West. Bluff of 50 feet of Blue Hill shale without lime partings, overlain by 20 feet of Fort Hays limestone. Average of 2½ feet near top of shale, 6 feet below limestone.	Dark-gray clay shale without fossils, and with little carbonaceous material.
19	Same as No. 18. Average of 3 feet of shale at foot of bluff.	Dark-gray clay shale.

PREPARATION OF SAMPLES FOR ASSAYING.

The 19 samples described above were sent to Washington, D. C., and further examined. The shale in each lot was crushed, carefully mixed, and quartered down until the last half of the sample amounted to one-half to three-fourths pound. This quantity was finally ground and sieved through an 80-mesh screen. From this ground material the assays were made.

METHODS OF ASSAY.

The fire assay, as well known, consists in smelting in crucible or scorifier with litharge or lead. The lead absorbs the gold and silver contained in the ore, and this gold and silver remains behind when the lead is driven off by a process of oxidation. For small and moderate amounts of the precious metals this is the most accurate method known, and in skillful hands always gives reliable results. The claim that "the fire assay will not bring out the values" is well known and reiterated to weariness, especially in districts where higher values are desired than nature put in the ores. True enough, the fire assay, like any other analytical operation, requires intelligent care and suitable ingredients. Where there are large amounts of copper, zinc, tellurium, and similar elements in the ore, this assay needs particular attention in order to prevent losses. As in every other quantitative analytical process, there are sources of error in the fire assay. A very small quantity of gold and silver may be lost in the slag in the first smelting. This is generally inappreciable. But in cupelling the lead button there is always a certain loss of silver by absorption by the cupel, much less by volatilization. This loss may amount to several per cent in case of very poor ores and small silver beads, but is then generally practically negligible. The loss of gold during cupellation is ordinarily very much smaller than that of silver, and practically nil. One often hears assertions that the proper values are not brought out by this assay because of the extremely fine distribution of the gold. This is absurd, because the chemical reaction, i. e., the absorption of gold and silver by the lead, takes place practically independent of the mechanical state of the precious metals. If anything, a fine division would be more favorable to their absorption by the lead. In the same category may be put the assertion that the gold in these shales is carried away in the fumes from the crucible.

When one considers that the very minute particles in a low-grade but paying ore, even after fine crushing, are likely to be securely locked up in grains of quartz or other refractory material, it becomes clear that the extraction of gold by chlorine, bromine, or potassium cyanide, which have little effect on these inclosing shells, must be less effective than a fusion. In a fusion with proper fluxes these shells are completely disintegrated, and the molten lead dissolves the precious metal almost entirely. The fire assay is, in fact, used in all cyanide and chlorination works to test ores and tailings.

This statement regarding the wet process also holds good for analytical work. Only in case the ores contain large quantities of gold or silver do the wet methods offer any advantage over fusion and cupellation. Electrolytic quantitative tests of gold and silver are known, but rarely used,[a] offering no advantage over other assays and requiring as much preliminary work in the elimination of other metals as do wet tests by precipitation of the gold by hydrogen sulphide, zinc, oxalic acid, or other means.

The accuracy of the fire assay varies, of course, with the quantity and character of the material, the purity of the reagents, and the skill of the assayer. Dr. W. F. Hillebrand, operating on Leadville rocks, gives 0.005 ounce per ton as the limit of accuracy for silver assays when 4 assay tons of material are used and extremely careful and painstaking work is done.[b] Using 2 assay tons in ordinary work, one ought to easily determine quantities of 0.05 ounce of silver ton, and 0.005 ounce, or 10 cents, per ton of gold.

RESULTS OF ASSAYS.

The nineteen samples were first assayed by myself in the laboratory of the Survey. The general proportions of the charge were as follows: One A. T.[c] shale, 2 A. T. litharge (contents of silver, 0.005 ounce per ton), 2 A. T. soda, one-half A. T. borax. A layer of litharge was spread over the mixed charge and a layer of salt above this. Samples 1 to 8, inclusive, were assayed with a charge of 2 A. T. shale, and the rest of the fluxes were in the proportion given above. For the remaining numbers 1 A. T. was used. Samples 1, 3, 17, 18, and 19 were assayed without addition of nitrate of soda, and in case the lead button was too large it was scorified down to suitable size. In the remainder of the samples which contained much carbon, niter was added in varying proportions to obtain a convenient button.

For the purpose of collecting the gold, in case no silver was present in the shale, 1.5 to 3 mg. of chemically pure silver was added to each assay, excepting Nos. 1 and 2. This was recovered, minus the minute losses chiefly caused by the absorption of the cupels. No gold was found in any of the samples, though in some of them minute black specks remained after parting the silver buttons. Some of these disappeared on ignition, while others remained, but upon examination with the lens failed to show the luster and color of gold.

The same samples were then assayed in the laboratory of the Survey, by Dr. E. T. Allen, who reports as follows:

I have examined nineteen samples of shale from western Kansas, collected by Mr. Lindgren, and find no gold in any of them.

The samples were assayed in the crucible with about 1 part soda and 2 parts of litharge to 1 part of the ore, and, since most of the shales contained considerable carbonate of calcium, from one-half to 2 parts of borax and some powdered glass were added to make the fusion thinly fluid. Niter was put in to oxidize the excess of carbonaceous matter in all but Nos. 15, 18, and 19. Two A. T. of each sample

[a] A. Classen, Ausgewaehlte Methoden der analytischen Chemie, Braunschweig, 1901, pp. 3, 245, and 254.

[b] Mon. U. S. Geol. Survey, Vol. XII, p. 595.

[c] A.T. = Assay ton = 29.166 grams.

were taken except Nos. 7, 8, 10, and 12, where only one A. T. was used. Two or 3 mg. of gold-free silver were added to each crucible charge to collect the gold in case the quantity of silver in the shale should prove insufficient. This silver was recovered after cupellation, minus a very small and nearly constant loss, which is always caused by absorption by the cupels, volatilization, etc. When the beads were parted the majority dissolved without residue. In several there remained one or two extremely minute, unweighable black specks. These either disappeared on ignition or else failed to develop the color and luster of gold, though they were examined carefully with a good lens.

In the previous work the added silver might easily have masked the presence of small fractions of an ounce of that metal per ton in the shale. Consequently, a third series of assays of the same samples was undertaken jointly by Dr. E. T. Allen and myself, in order to ascertain whether small quantities of silver were present. The laboratory and all utensils employed were kept scrupulously clean, and we do not believe that there was any possibility of the introduction of gold or silver into the samples except from the litharge. The latter was assayed in duplicate, using 10 A. T. in each charge, with the following result:

Assay of litharge.

Number.	Silver.	Gold.
	Ounce per ton.	
1	0.005	Distinct trace in 10 A. T.
2	0.005	Doubtful trace in 10 A. T.

The particles remaining after parting were carefully examined by a microscope of high power.

The charges for the assays were in the main similar to those indicated above. Two A. T. shale were used in all of the assays except in 11, 15, 16, 17, 18, and 19, in which 1 A. T. was taken. The assay of No. 3 failed and no more material was available. About 1½ parts of litharge to 1 part of shale were used. The cupellation was undertaken with particular care to guard as much as possible against losses from absorption and volatilization. In the cases where weighable buttons were obtained the quantity of silver due to the litharge was subtracted, and the figures given in the following table thus indicate the true amount of silver contained in the shale.

Of six samples marked "repeated" in the table duplicate assays were made. In the duplicates the niter method was avoided and a charge was made as follows: One A. T. ore, 3 A. T. litharge, 2 A. T. soda, one-half A. T. borax. Nos. 14 and 16 were roasted and some argol was added to the charge.

The parting was effected in small glazed porcelain capsules and with very exceptional care. The residue after parting and annealing was examined by a petrographic microscope. In No. 5 we obtained from 2 A. T. two flakes of gold weighing together 0.01 mg., equaling 0.005 ounce per ton, or a value of 10 cents per ton. In No. 13 several very minute, unweighable flakes of gold were discovered by using high magnifying powers; they could not be recognized by an ordinary lens.

In nearly all of the samples after parting and ignition almost microscopic, unweighable black specks were found. It was determined to subject these to more detailed examination. Under high magnifying power these specks appeared as angular, irregular masses having a dark-gray or black color and submetallic to metallic luster. A few of them were loose aggregates of the same substance with occasional glints of silvery or yellowish luster, which might possibly arise from included particles of gold. The appearance under the microscope is that of graphite. Besides this substance only a few particles of oxide of iron were noted in the residue. A number of the black specks collected were then subjected to the following chemical tests: First, evaporated with aqua regia to dryness, the specks were still visible and seemed unattacked. We next tried burning in a stream of oxygen. The operation was difficult on account of the minute size of the particles, but in two separate trials the specks disappeared upon being treated in a current of that gas. In conclusion, we assert that these dark particles are neither gold nor platinum, though we suspect that in many cases they have been reported as traces of gold. We believe it most probable that these particles are graphitic carbon, contained in the silver. It will probably be objected that carbon could not without change pass through the oxidizing operation of cupellation. Be this as it may, the quantity of carbon obtained was certainly extremely small, and it is a known fact that silver has a decided tendency to unite with carbon under some conditions, as shown by Gmelin-Kraut.[a]

Content of gold and silver in samples of shale.

Number.	Silver.[b]	Gold.	Total value.
	Ounce per ton.	*Ounce per ton.*	*Per ton.*
1	None.	None.	----------
2	0.007	None.	$0.004
4	None.	None.	----------
5	0.017	0.005	.110
6	0.007	None.	.004
7	0.022	None.	.013
8	0.037	None.	.022
9	0.097	None.	.060

[a] Handbuch der Chemie, Vol. III, pt 2.

[b] Although the quantities of silver have been given to the third decimal, as calculated from the weights of the beads, it must be understood that quantities below 0.01 or 0.02 ounce per ton are very doubtful under these conditions.

Content of gold and silver in samples of shale—Continued.

Number.	Silver.	Gold.	Total value.
	Ounce per ton.	*Ounce per ton.*	*Per ton.*
10	Probably none.	None.	
10	None.	None.	
11	0.045	None.	$0.027
11	0.030	None.	.018
12	Probably none.	None.	
12	0.030	None.	.018
13	0.087	Microscopic trace.	.052
13	None.	None.	
14	0.072	None.	.043
14	None.	None.	
15	0.085	None.	.051
16	0.037	None.	.022
16	None.	None.	
17	0.095	None.	.057
18	Probably none.	None.	
19	Probably none.	None.	

For further confirmation the samples of most importance—that is, those from the banks of Smoky Hill River, in the vicinity of the mills—were sent to Mr. George E. Roberts, the Director of the Mint, who kindly had them assayed. Nos. 1, 2, 4, 5, 6, 7, and 8 were assayed by Mr. W. F. Bowen, assayer of the mint bureau, and Nos. 9, 10, 11, 12, 13, 14, and 16 were assayed by Mr. Jacob B. Eckfeldt, assayer of the mint in Philadelphia.

Mr. Bowen states that he used 1 A. T. ore to 1 A. T. litharge with necessary fluxes, and that a little niter was added. His results are as follows:

Assays of samples by W. F. Bowen.

Number.	Silver.	Gold.	Total value.[a]
	Oz. per ton.	*Oz. per ton.*	*Per ton.*
1	0.30	Trace.	$0.18
2	0.20	Trace.	.12
4	None.	None.	
5	0.15	None.	.09
6	None.	None.	
7	0.30	0.05	1.18
8	0.15	Trace.	.09

[a] Column added by W. Lindgren.

At the writer's request Mr. Bowen repeated No. 7 on new material from the same original sample. This time he obtained 0.45 ounce silver and no gold; total value, 27 cents.

Mr. Eckfeldt states that he used 1 A. T. ore, 3 A. T. litharge, 2 A. T. soda, and ½ A. T. borax. No niter was added. His results are as follows:

Assays of samples by J. B. Eckfeldt.

No.	Silver.	Gold.	Total value.[a]
	Oz. per ton.	*Oz. per ton.*	*Per ton.*
9	0.3	0.01	$0.38
10	.35	Trace.	.21
11	Trace.	Trace.	----------
12	.5	.02	.70
13	.4	Trace.	.24
14	Trace.	Trace.	----------
16	.2	Trace.	.12

[a] Column added by W. Lindgren.

As statements were made that the shales examined contained considerable quantities of zinc (from 2 to 20 per cent), and certificates to this effect were shown me by local chemists, it was decided to test a few samples for zinc and also for copper. Samples 1, 5, and 8, respectively, from the quarry pits of Miller's, Gage's, and the Pioneer Company's mills were selected and examined by Dr. E. T. Allen, of the United States Geological Survey. These samples showed no trace of zinc or copper. The concretions in the shale just below the Fort Hays limestone (Septaria horizon) contain a brown carbonate of lime, which is frequently mistaken for zinc blende.[a]

SUMMARY AND CONCLUSIONS.

Nineteen samples of Benton shale were collected in Ellis and Rush counties, Kans., chiefly along Smoky Hill River. These samples were taken with great care, each representing the average of a certain thickness of beds, in order to ascertain whether these shales contain gold and silver and whether, if so, they may be considered as of economic value. The majority of the samples were collected in pits and quarries from which material had been extracted by other parties for the purposes of assays or treatment in gold mills. These samples were first assayed for gold by myself, then by Dr. E. T. Allen. No gold was found in any of the samples. The silver could not be determined with great accuracy, for some pure silver was added in order to collect any gold that might be present, but there was certainly not more than a small fraction of an ounce in any one of the samples.

[a] E. Haworth, Mineral Resources of Kansas for 1897.

The same samples, except No. 3, of which sufficient material did not remain, were then assayed jointly by Dr. Allen and myself. Twelve samples showed the presence of small amounts of silver up to 6 cents per ton in value, while in 6 no silver or only doubtful traces were found. No. 5 showed 10 cents of gold per ton, and No. 13 a trace of gold. No gold was found in the remaining 16 samples.

Samples 1, 2, 4, 5, 6, 7, and 8 were assayed by Mr. W. F. Bowen, acting assayer of the mint bureau. In five of these small values of silver were found, ranging up to 27 cents per ton. In two of the samples no silver was found. One of the samples (No. 7) gave $1 of gold per ton; this assay was repeated, and this time no gold was found. Traces of gold were found in three samples, and in three samples of the seven no gold was found.

Samples 9, 10, 11, 12, 13, 14, and 16 were then assayed by Mr. Jacob B. Eckfeldt, assayer of the mint in Philadelphia. In five of these silver was found, ranging up to 30 cents per ton, while two samples yielded only a trace. No. 12 gave 40 cents of gold per ton, and No. 9 gave 20 cents per ton, while traces of gold were found in the remaining five samples. In all, 77 assays were made of material taken from the 19 samples.

The results indicate that minute quantities of silver are often contained in these shales and that some samples show the presence of very small quantities of gold. The same samples do not always give the same results when repeated, which goes to confirm the statement on page 5, that the metals when present are somewhat unevenly distributed through the rock. None of the samples contain silver or gold in economically important quantities. While, of course, it is impossible to say what may be contained in those parts of the shale beds which have not been assayed, it is extremely improbable that this material will ever be of economic importance as a silver or gold ore.

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