SUMMARY REPORT ON THE BIGHORN BASIN

Prepared for

The Wyoming State Planning Board

by

S. H. Knight,
State Geologist

1940

SUMMARY REPORT ON THE BIGHORN BASIN

LOCATION AND AREA

The Bighorn Basin is located in Bighorn, Park, Washakie, and Hot Springs counties, northwestern Wyoming, and comprises an area of about 8,500 square miles. It is bounded on the west by the Beartooth, Absaroka, and Shoshone mountains, on the south by the Owl Creek and Bighorn mountains, and on the east by the Bighorn mountains.

RELIEF

The area, for the most part, is a broad structural basin bounded on the west, south, and east by mountain ranges and open to the north into Montana. The valley floor is characterized by irregular ridges, buttes, badland slopes, and gravel terraces. The badlands are most prominent east of the Bighorn River in the southeastern part of the basin. Stream valleys in the district are broad and relatively deep.

The average altitude of the valley floor is about 5,000 feet above sea level. The lowest altitude, about 3,600 feet, is in Bighorn Canyon at the Montana line; the highest altitude, 12,496 feet, is that of the Washakie Needles, peaks in the Shoshone mountains.

The Beartooth and Absaroka mountains form the western border of the Bighorn Basin from Montana southward to the Shoshone River. They have an average altitude of about 7,500 feet. From Shoshone River southward, the basin is bordered by the Shoshone mountains. This mountain range has the form of a deeply dissected plateau.

The Bridger and Owl Creek mountains form the southern margin of the Bighorn Basin. Their average altitude is about 8,000 feet. The north flank of the range is characterized by long, gentle slopes; the south flank by short, steep slopes. Near the middle of the range the northward flowing Bighorn River has cut a gorge with a maximum depth of 2,250 feet.

The western flanks of the Bighorn mountains form the eastern margin of the Bighorn Basin. The range trends northwestward and has an average altitude of about 8,000 feet. Some peaks have an elevation of over 10,000 feet. A number of minor folds along the base of the mountains form topographic ridges.

DRAINAGE

Bighorn River enters the area near Thermopolis, flows northward across the basin and enters Bighorn Canyon near the Montana boundary. It is the principal stream in the district. Shoshone River, the main tributary of Bighorn River, enters the area near Cody and flows eastward across the northern part of the basin to the junction with Bighorn River about ten miles south of the Wyoming-Montana boundary. Greybull River rises in the Shoshone mountains and flows northeastward across the central part of the basin to the confluence with Bighorn River. The headwaters of Greybull River are fed by melting snow during the summer. Consequently, the stream has a proportionately large volume.

Other important tributaries of the Bighorn River in the basin are Gooseberry, Meeyero, and Owl creeks from the west, and No Wood and Shell creeks from the east.

Clark Fork, which is not a tributary of the Bighorn River, rises in the Absaroka mountains to the west and flows across the extreme northwestern part of the area. It carries much water, especially during the summer months.

STRATIGRAPHY

pre-Cambrian Rocks

The core of the mountain ranges surrounding the Bighorn Basin is a pre-Cambrian complex of igneous and metamorphic rocks with granite predominating, which has been elevated several thousand feet above its original position. Extensive exposures of the pre-Cambrian rocks occur in the Bighorn, Owl Creek and Beartooth mountains.

Granite is the predominate rock type of the pre-Cambrian complex. The granites of the Bighorn mountains are of two types: a coarse-grained red variety, and a fine-grained gray variety. The red granite, which contains abundant pink feldspar, predominates. Dikes of diabase and peridotite cut the granites. The dikes are from two to twenty-five feet in width and normally trend at right angles or diagonally to the major axis of the fold. The dikes are harder than the country rock and stand above the softer granites into which they were intruded. The diabase and peridotite decompose into a reddish-brown soil which contrasts markedly with the lighter color of the granites. These dikes are most prominent in the vicinity of Bald mountain and on Porcupine and South Beaver creeks.

The granites exposed on the north flank of the Owl Creek mountains are essentially like those of the Bighorn mountains.

Granite exposed in Shoshone Canyon between Rattlesnake and Cedar mountains is gneissoid in places. It has a well-developed system of joints and is cut by dikes and sills of quartz-bearing diabase.

Cambrian System

General relations.- The oldest sedimentary formations cropping out in the area are composed of a succession of sandstones, shales, limestones, and conglomerates of middle and upper Cambrian age. The Depass formation is of middle Cambrian age; the Boysen is upper Cambrian. The Cambrian rocks have a total thickness of 700 to 1,500 feet. The section described below was measured in the Owl Creek mountains.

Depass formation.--The Depass formation is divided into two members, the basal Flathead sandstone member and the overlying Gros Ventre shale member.

The Flathead member consists chiefly of tan, gray, and green sandstones interbedded with thin drab-green and gray micaceous shales, and a basal sandstone containing quartz pebbles. The Flathead member is 280 feet thick.

The Gros Ventre member consists, for the most part, of dull-green, maroon, gray, and purple shales and intercalated green sandstones; thin limestones and beds of intraformational conglomerate appear in the upper part. The Gros Ventre member of the Depass formation is 300 feet thick.

Boysen formation.--The Boysen formation has three members: the Maurice, The Snowy Range, and the Grove Creek.

The Maurice is the basal member of the Boysen formation. The lower part of the Maurice consists of interbedded green shales, thin limestones, and intraformational conglomerate. The upper part of this member is largely massive thick-and thin-bedded limestones, with intraformational conglomerate and thin green shale partings. The total thickness of the Maurice member is about 180 feet.

The Snowy Range member, which overlies the Maurice member, is a succession of interbedded greenish shales and shaly and thick-bedded limestones.

The Grove Creek member is the youngest Cambrian unit present in the area, and consists of green and maroon sandy shale, impure limestone, and edgewise conglomerate. Dikelocephalus occurs in this member, which has a thickness of 40 feet.

Ordovician System

General relations.-- The Ordovician rocks, like the underlying Cambrian formations are exposed along the flanks of the Bighorn and Owl Creek mountains and in the Shoshone Canyon. The Ordovician Bighorn dolomite forms conspicuous escarpments, which stand above the less resistant Cambrian formations.

Bighorn dolomite.--The Bighorn dolomite has a total thickness of about 300 feet. A yellow to tan sandstone, designated as the Lander sandstone member, occurs at the base of the Bighorn. It ranges from 15 to 25 feet in thickness. The Lander sandstone member is overlaid by 200 feet of massive dolomite. The massive dolomite is in turn overlain with 75 to 100 feet of white platy dense dolomite.

Devonian System

General relations.-- Devonian rocks are present in the Shoshone Canyon area, and rocks of possible Devonian age are present near Kane. The Devonian rocks thin progressively to the east. At most places, unless diagnostic fossils are present, it is difficult to distinguish the Devonian rocks from the underlying rocks of Ordovician age.

Jefferson dolomite.--The Jefferson is a dark grey dolomite similar in lithology to that of the underlying Bighorn dolomite. The section measured at Shoshone Canyon consists of 75 feet of limestone overlain by 295 feet of massive dolomite; the section measured at Kane consists of 110 feet of limestone.

Threeforks shale.--The Threeforks at Shoshone Canyon has a massive limestone about 50 feet thick at the base. This is overlain by 65 feet of interbedded shales, limestones, and sandstones. At Kane the Threeforks is composed entirely of green shale, which is 25 feet in thickness.

Mississippian System

General relations.--Rocks of Mississippian age constitute the greater part of the high anticlinal front range of the Bighorn and Owl Creek mountains. In the northwestern part of the area the Madison formation is exposed in Shoshone Canyon and high on the flanks of Rattlesnake, Black, and Heart mountains. In the northeastern part of the basin, from near the mouth of Shell Creek northward to Lovell, there are a number of anticlines. The most prominent of these are Sheep and Little Sheep mountains. In canyons cut through these mountains, and along the crests the Madison limestone is exposed. The Madison is also present along the west flank of the Bighorn mountains from Trapper Creek to the upper end of Bighorn Canyon.

Madison limestone.--The Madison is a gray massive limestone ranging in thickness from 600 to 1,000 feet. In Shoshone Canyon the Madison consists of a lower massive dark-grey member containing thin-bedded layers, and an upper

upper member which is lighter gray and somewhat softer. These members can also be recognized in the Bighorn and Owl Creek mountains.

Mississippian--Pennsylvanian Systems

General relations.--The Amsden formation overlies the Madison limestone and, like the underlying formation, is present in the Absaroka, Bighorn, and Owl Creek mountains. The lower part of the Amsden formation is of Mississippian age; the upper part is Pennsylvanian in age.

Amsden formation.--The Amsden formation is a succession of red sandy shale and sandstone, with layers of limestone and chert. The thickness is from 150 to 200 feet. The red sandy shale is best developed in the lower part of the formation.

Pennsylvanian System

General relations.--The Tensleep sandstone, of Pennsylvanian age, occurs in the Absaroka, Bighorn, and Owl Creek mountains. It is also exposed in the Sheep mountain uplift and in the anticline southeast of Hyattville.

Tensleep sandstone.-- The Tensleep is a gray massive cross-bedded sandstone containing thin layers of limestone. In the Bighorn mountains it is only 30 feet thick; however it thickens markedly to the south and west. Its maximum thickness in the area is 230 feet.

Permian System

General relations.-- The Embar formation overlies the Tensleep sandstone, and is exposed on the northern flanks of the Owl Creek mountains and on the flanks of Rattlesnake and Cedar mountains.

Embar formation.-- The Embar formation is a succession of gray limestone and interbedded gray and red sandy shale and gypsum. On the east side of the basin the limestone is very thin. The Embar ranges from 250 to 480 feet thick.

Permian and Triassic Systems

General relations.--The Chugwater formation, a Permo-Triassic unit, occurs in extensive outcrops, especially along the eastern side of the basin. Along the western side of the basin the outcrops are generally narrow, but the Chugwater is present on both sides of Rattlesnake and Cedar mountains and along the base of the Beartooth and Absaroka ranges. In the southern part of the area the Chugwater redbeds occur extensively in the central part of the Thermopolis anticline and also between Ember and Anchor.

Chugwater formation.--The Chugwater formation is composed largely of red sandy shale but includes also red sandstone, gypsum, and limestone. The thickness of the formation ranges from 700 to 1,100 feet.

Jurassic System

General relations.--The Jurassic system is represented by the Sundance and Morrison formations, which occur as narrow outcrops flanking the base of the uplifts on the east, west, and south sides of the basin at the Absaroka, Bighorn, and Owl Creek mountain regions.

Sundance formation.--The Sundance formation is moderately uniform in thickness throughout the area, but contains many stratigraphic variations. It is marine in origin and consists of shales, sandstones, and limestones. The shales and sandstones are greenish-grey in color, and the shales predominate. It is from 250 to 500 feet thick.

Morrison formation.--The Morrison formation is composed of soft sandy shales and clays alternating with layers of massive sandstones, all of freshwater origin. The prevailing color is pale green with shades of red, maroon, and purple, and in the upper part of the formation the clays are very dark. The thickness varies from 130 to 380 feet.

Cretaceous System

General relations.--The Cretaceous rocks of the Bighorn Basin consist of a succession of shales and sandstones 6,000 feet or more in thickness. Some of the formations are coal bearing. The Cretaceous units, from oldest to youngest, are: the Cloverly formation, the Colorado group, which includes the Thermopolis and Mowry shales, the Frontier formation, and the lower part of the Cody shale; the Montana group, which consists of the upper part of the Cody shale, the Mesaverde and Meeteetse formations; and the Lance formation at the top of the succession.

The area of Cloverly outcrop in the basin is about equivalent to that of the underlying Morrison formation. The Colorado group is exposed in a wide area in the northeastern part of the basin, and from Shell creek southward its outcrop is from 4 to 6 miles wide. It is exposed in a wide area on both sides of Rattlesnake mountain, but farther north, along the base of the Absaroka and Beartooth ranges, the beds dip steeply and the outcrop is narrow. Small exposures occur along the axes of anticlines east of Sage creek, at intervals along the base of the Shoshone mountains from Fourbear to the Antler ranch, on the divide between Rawhide creek and Greybull River north of Pitchfork ranch, and on Wood River and Gooseberry creek near Sunshine post office. In the Owl Creek Mountain Region it occupies an area 3 to 6 miles wide, extending along the base of the mountains from a point west of Embar to the middle of Range 92. South of Cottonwood creek 5 or 6 square miles of the Colorado group is exposed in an anticline.

The Montana group is exposed in an area near Sage and Dry creeks, and as a narrow band along the west side of Sheep mountain. East of Basin the Montana group is exposed in a broad, shallow syncline. These rocks occupy considerable area on the head of No Water and Kirby creeks, and between Owl and Cottonwood creeks. Between Sunshine post office and Cedar mountain it occupies an area 4 to 10 miles wide at the base of the Shoshone Range.

Geologic maps of the area do not show the Lance formation as a unit. Further field work is necessary before detailed information as to its distribution is available.

Cloverly formation.-- The Cloverly consists of two beds of massive buff sandstone separated by gray or variegated shale. The upper sandstone is known as the Greybull sandstone member. The thickness of the Cloverly is from 110 to 300 feet.

Thermopolis shale.-- The Thermopolis shale, which overlies the Cloverly formation, consists of 400 to 800 feet of gray to black shale with one persistent sandstone. This sandstone is known as the Muddy sand by drillers.

Mowry shale.--The Mowry is a hard grey shale containing fish scales and lenses of gravel-bearing sandstone. It ranges from 160 to 375 feet thick.

Frontier formation.--On the west side of the Bighorn Basin the Frontier is composed of seven or more beds of gray and buff sandstone with grey and brown shale and bentonite; on the east side, of two to six or more beds of sandstone. The thickness is from about 500 to 650 feet.

Cody shale.--The Cody is a thick succession of gray, green, and black shale, with calcareous concretions at the base merging with buff sandstone at the top. There are no persistent marker beds. The Cody is 1,900 to 3,400 feet thick.

Mesaverde formation.--The Mesaverde is an alternating succession of buff and white sandstones and grey and brown shales. It contains lenticular beds of coal near the base. The thickness is from 1,120 to 1,400 feet.

Meeteetse formation.--The Meeteetse consists of soft grey and brown shale; grey and buff sandstone and lenticular beds of coal. The thickness is highly variable, ranging from 250 to 1,400 feet.

Lance formation.--The Lance is a succession of buff and drab sandstones alternating with drab and green shales. It contains no red shale or coal beds, and is from 840 to 1,800 feet thick.

Tertiary System

General relations.--The Tertiary formations have a more extensive outcrop than any other formation in the district, occupying a broad area in the central part of the basin, which narrows rapidly to the northwest. They extend entirely around the base of Heart mountain, occupy the low divide between Bighorn and Clark Fork basins, and give rise to a number of prominent peaks along the base of the Beartooth mountains from Clark Fork to the Montana line. They continue from Greybull south to beyond Bighorn River in the region of the Honeycombs.

Fort Union formation.--The Fort Union overlies the Lance unconformably. It consists of 2,000 to 5,600 feet of buff and white gritty sandstone, with drab, red, and green clay. It contains lenses of gravel and lenticular beds of coal.

Wasatch formation.--The Wasatch formation overlies the Fort Union formation unconformably. Part of the Wasatch has been removed by erosion, but a thickness of 1,300 feet has been measured at some localities. For the most part, it is a red and drab clay containing buff and white sandstone with gravel lenses. It forms many areas of badlands around the border of the basin.

Volcanic rock.--In the southwestern part of the area the older formations are covered by an overlap of volcanic rock thought to be of late Tertiary age. The thickness of the volcanics, which are andesite tuffs and flows, is variable.

Quaternary System

General relations.--The Quaternary deposits are confined mainly to the northern part of the basin, where they occur as gravel terraces capping the high divides and bordering the larger streams. Deposits of three different periods are recognized, early and late terrace gravels and alluvium.

Early terrace gravels.--Early terrace gravels cap the high plateaus between the larger streams in the central portion of the basin. They are composed of alternating layers of gravel, sand, and silt and have a total thickness of 30 to 40 feet.

Later terrace gravels.--Later terrace gravels border all the larger streams and some of the smaller streams. They are prominent in the northern part of the basin. The most extensive of these deposits lie along the northern side of the Shoshone River from Garland to Eaglenest.

Alluvium.--The alluvium is from a few to 50 feet in thickness and occurs as valley and flood-plain deposits along streams.

MINERAL RESOURCES

Bentonite

Most of the Bentonite in the Bighorn Basin occurs on the east and south sides. In sections 30 and 31, T. 58 N., R. 95 W., in the extreme northeast portion of the area, bentonite seams were noted as follows: Thermopolis shale, total thickness 960 feet, contained 15 seams of bentonite ranging in thickness from 0.5 foot to 2.5 feet. The total thickness of the bentonite seams in the Thermopolis is 16.3 feet. In the Mowry shale, which has a total thickness of 95 feet, two 2.5 feet layers of bentonite occurred. The Frontier formation, 820 feet thick, contained five seams of bentonite. The individual seams vary from 0.3 foot to 2.0 feet thick.

The beds on the southern and eastern margins of the Bighorn Basin are involved in a number of sharp anticlines and synclines. The lower formations of the Upper Cretaceous series crop out in the steep flanks of the folds, and the outcrops of bentonite seams are, in most cases, narrow. In the few areas of low dips the bentonite beds dip under cliffs fromed by the Frontier sandstones.

The largest bentonite outcrop in the Bighorn Basin is located 18 miles northwest of Greybull and one-half mile east of the oiled road between

Greybull and Lovell. The outcrop is approximately a mile long and 50 feet wide. The bentonite seam dips 31 degrees to the west. The hard altered shale bed forming the floor under the bentonite seam stands out in a number of smaller flatirons on the dip slope of the hogback. The sediments above the bentonite, and part of the bentonite, have been removed by erosion, so that the thickness of the seam ranges from a knife edge at the top of the flatirons to a full thickness of four feet at the base.

Coal

Southwest Side of the Bighorn Basin

General relations.--Coal fields form an irregular zone 6 to 15 miles wide at the base of the Shoshone-Rattlesnake mountain range, extending from a point two miles north of Clark Fork of the Yellowstone River 110 miles southeastward to Bighorn River near Kirby. They constitute an area of about 1,300 square miles. Coal beds which have sufficient thickness and extent to be of local interest are distributed throughout the fields, but deposits of commercial importance lie mainly in the southern part of the basin.

Colorado group.-- A few thin beds of coal, with a maximum thickness of eight inches, interbedded with massive sandstone, occur in the lower part of the Colorado group. No beds of coal in the Colorado group are thick enough to be worked.

Mesaverde formation.--In comparison with coal beds in younger formations, those of the Mesaverde are well exposed. The coal beds occur in thin zones of shale and sandstone between thick beds of massive sandstone. The coal beds commonly dip from 10° to 50°.

Although a few thin beds of coal are found locally in the upper part of the Mesaverde, the beds more than 14 inches thick and those which have been mined occur near the base of the formation. Generally there are from three to seven beds containing more than 14 inches of coal in a zone 160 to 220 feet thick that overlies the basal sandstone. This is the common condition in Spring Creek, Little Buffalo, and Grass Creek basins. In the northern part of Oregon Basin, in the Gooseberry Creek Valley, and in Cottonwood Creek Valley, however, there are two coal-bearing zones, separated by a massive sandstone.

Here and there exposed rock sections indicate lack of persistence of coal and sandstone beds, but both the coal seams and adjacent sandstone beds may generally be traced with considerable assurance along outcrops for distances of three to six miles.

Meeteetse formation.--The coal beds in the Meeteetse formation are poorly exposed and therefore not as well known as those in the Mesaverde. Although individual beds may be satisfactorily correlated for distances of 3 or 4 miles in some parts of the region, commonly exposures are so isolated that no accurate correlation may be made. Most of the good outcrops trend from S. 40° E. to due east. Practically no outcrops having a strike in the northeast quadrant can be correlated with others near by, so that nothing is known concerning the changes that take place in the beds in that general direction.

Fort Union formation.--Beds of coal in the Fort Union are lenticular and sporadically distributed over a large area. They are confined to the basal 600 feet in the group of outcrops near the mountains and in the region of unconformity between the Fort Union and Lance formations. The areal distribution of the thickest beds or thickest parts of beds coincides approximately with that of beds of overlying conglomerate; the converse relation is not apparent, for there are extensive beds of conglomerate not overlain by coal beds.

Southeast Side of the Bighorn Basin

General relations.--The coal-bearing rocks crop out in a belt 6 to 12 miles wide, extending southeastward from the lower course of No Wood creek along Sand and Cottonwood creeks to the east side of the "Honeycombs," then turning west across No Water creek to Bighorn River. The field contains about

600 square miles. It is limited on the west and northwest by badlands and on the east and southwest by the dissected plains adjacent to No Wood and Kirby Creeks.

This field contains coal beds of workable thickness in four separate districts--near the head of Cottonwood Creek, on Bud Kimball Draw, along No Water Creek, and north of Kirby Creek near Bighorn River.

Occurrence of coal.-- The occurrence of coal in the southeastern portion of the basin is similar to that of the southwestern part, with minor stratigraphic changes.

The following summary is quoted from "Analyses of Wyoming Coals", U. S. Bureau of Mines Technical Paper 484, Washington, 1931.

> Big Horn Basin.--The coal in the Big Horn Basin region is of sub-bituminous rank and is found in the Mesaverde, Meeteetse, Lance, and Fort Union formations, of Upper Cretaceous and Eocene age. Two beds of low-rank bituminous coal, each about 3 feet thick, occur in the Eagle sandstone near the Montana boundary, and a thin bed occurs in the Cloverly formation on the eastern rim of the basin.
>
> Beds of coal are present throughout the Mesaverde in the basin, but the most valuable beds are usually in a zone 120 to 340 feet thick that overlies the basal massive sandstone. These coals range in thickness from a few inches to about 15 feet and are very lenticular. The coals of the Meeteetse, Lance, and Fort Union formations are thin, impure, and nonpersistent; however, those of Fort Union age may be fairly numerous.
>
> The Gebo field is the only important coal-mining center in the Big Horn Basin at present. At Gebo the Gebo bed, lying near the base of the Mesaverde formation, ranges from 8 to 12 feet in thickness and dips 20° to 33° northeast. The Big Horn seam, which is mined at Crosby, ranges from 4 to 14 feet in thickness and dips about 15° northeast. The coal from this field is of excellent quality and compares favorably with the best sub-bituminous coal in the Rocky Mountain region.

A representative analysis of the sub-bituminous coal from the Big Horn Basin follows*:

Moisture	16.5
Volatile matter	32.9
Fixed carbon	45.8
Ash	4.8
Sulphur	.6
Heat value	10.750

*"The Coal Fields of the United STAtes" by Marius R. Campbell, U.S.G.S., Prof. Paper 100-A, p.33, Washington, 1917.

Gypsum

Gypsum in the Bighorn Basin occurs at two horizons, the upper at or near the top of the Chugwater formation and the other in the upper part of the Ember formation. Only the upper bed, however, is of economic importance at Sheep Mountain and in the vicinity of Thermopolis. The beds of gypsum vary in thickness and number from place to place in both the Chugwater and Ember formations. The beds are from a few inches to 54 feet thick. The thickest gypsum bed occurs two miles northwest to Tensleep in the Chugwater formation.

The greater part of the gypsum is white, but in many places it has a slightly pinkish or flesh tint caused by particles of red clay. The color varies from pure white to reddish or dark, according to the amount and kind of impurities. Analyses show the gypsum to be of good quality and to contain little calcite.

Mineral Waters

Cody Hot Springs.--About three miles west of Cody, in the bed of Shoshone River, there are a number of warm mineral springs. The water issues from crevices in Ember limestone immediately underlying the Chugwater redbeds, which dip eastward at an angle of about 15 degrees. These beds are overlain by a deposit of Quaternary gravel 25 to 30 feet thick, capped by about 20 feet of travertine. The warmest spring has a temperature of 98°. Associated with the springs are vents or crevices in the rock, from which large volumes of hydrogen-sulphide gas escape.

Hot springs occur at different levels in Shoshone Canyon, at its upper and lower end, far above the present level of the river. There are a number of extinct geyser or hot-spring cones.

Thermopolis Hot Springs.--At Thermopolis, in the southeastern part of the basin, there is a hot mineral spring. This spring is so well known that no detailed description is included.

Metaliferous Deposits

Considerable effort has been put forth in attempts to develop metaliferous deposits in the mountains adjacent to the Bighorn Basin. To date these efforts have not been successful. Hewett* reports that prior to 1912--

> "between 12,000 and 15,000 linear feet of tunnels have been opened, of which approximately 500 feet represents three cross-cut tunnels in the Kirwin district."

Kirwin is situated near the headwaters of the north fork of Wood River, a tributary to Greybull River, about 38 miles southwest of Meeteetse. The value of the ores in this district is reported to lie mainly in gold content, and only rarely in silver. Hewett reports (1912) that

> "The only ores that have thus far been produced are of medium or high grade, but in quantities too small to warrant costly equipment or operation on a large scale.* * * From what is to be seen in the district it seems unlikely that there will be developed masses of low-grade ore large enough to warrant the installation of elaborate milling plants. Mining, however, is full of uncertainties and it would be unsafe on a basis of a brief examination to predict that none of the Kirwin deposits will ever prove to be important."

This office has not made any study or investigation of the Kirwin district, consequently we are not in a position to report upon it. Further explorations may lead to the development of profitable metaliferous deposits in the mountains surrounding the Bighorn Basin. However investigations to date have not been encouraging.

---

*Hewett, D. F., The Ore Deposits of Kirwin, Wyoming, Bulletin No 540, U.S. Geological Survey, Washington, 1913.

OIL AND GAS

Oil and gas are produced in the Big Horn Basin from rocks of Cretaceous, Permian, Pennsylvania and Mississippian age. Cretaceous production is found in the Frontier sands (Torchlight, Peay, etc); in the Muddy sand in the Thermopolis shale; and in sands in the cloverly formation (Greybull, etc.). The higher Cretaceous units have been unproductive, with the exception of some gas found in the Mesaverde sandstones in one field.

The Jurassic rocks which have been prolific producers of gas and oil elsewhere in the State are unproductive in the Big Horn Basin and have yielded only slight shows of oil.

The Permian Embar beds, the Tensleep sandstone, of Pennsylvanian age, and especially the Mississippian Madison lime have been prolific producers.

Older Paleozoic rocks, of Devonian and Ordovician age, are potential oil producers, but little is known as to their possibilities.

Cretaceous oil is of the best quality, is of pariffin base and of high gravity. The Paleozoic oil is of naphthene base and is of lower gravity.

Oil Fields

Park County.- Important fields in Park County are as follows:

Name	Year of Discovery	1939 Production	Total Production
Badger Basin	1931	91,120 bbls.	483,201 bbls.
Elk Basin	1915	204,483	10,971,926
Frannie	1928	534,565	3,219,077
Oregon Basin	1927	1,006,756	11,649,327
Shoshone	1929	10,063	23,596

During 1939, 3 oil wells, 3 gas wells, and one unproductive well were drilled in the county and at the end of the year two uncompleted wells were being drilled.

Big Horn County.- Important fields in Big Horn County are as follows:

Name	Year of Discovery	1939 Production	Total Production
Byron	1906	543,109	3,851,596
Garland	1930 (deep pay)	851,820	2,873,062
Greybull	1907	0	346,730
Torchlight	1915	0	270,279

During 1939 there were 3 oil wells, 1 gas well, and three failures in Big Horn County. Four wells were uncomplete at the end of the year.

Hot Springs County.- The Important oil fields in Hot Springs County are as follows:

Name	Year of Discovery	1939 Production	Total Production
Black Mountain	1925	0	235,654
Grass Creek	1914	814,989	27,809,454
Hamilton	1913	188,433	5,056,079
Warm Springs	1917	45,093	341,530
Waugh	1935	Abandoned	210,069

During 1939 1 oil well was completed and 3 wells were uncompleted at the end of the year.

Washakie County.- The only important oil field in Washakie County is Hidden Dome, with production as follows:

Hidden Dome	1933	25,908	282,335

There were no completions in the county during 1939, but one well was drilling at the end of the year.

Gas Fields

The only important gas field in the Big Horn Basin other than fields which also produce oil is the Little Buffalo Basin field, in Park County. During 1939 3 wells were completed for a total output of 46,500,000 cu. ft. of gas per day, initial. The Golden Eagle dome, in Hot Springs County, which produced gas from the Mesaverde sands, high in the Cretaceous section, has been abandoned.

Summary

Of the fields above enumerated, only the following showed an increase in production in 1939 over 1938:

Field	Year of greatest production
Badger Basin	1939
Elk Basin	1917
Garland	1939
Grass Creek	1918
Torchlight	1919

It is pertinent to point out that the only oil field of any importance discovered since 1930 is the Badger Basin field. This is the deepest producing field in the state and wells are drilled to the Frontier sands at a depth of around 8,700 feet.

Most of the older fields reached their peak production prior to 1930. Since that time deeper drilling has opened up new reserves in the older rocks.

The 15 important fields listed above have produced a total of 67,623,915 barrels of oil and seem certainly to have passed their peak production. In addition, essentially every promising structure in the Basin has been tested by a well.

New reserves may be opend up through (1) the discovery of oil in deep sands in old fields, (2) deep tests on domes which proved unproductive in higher sands, and (3) the discovery through geophysical methods of domes toward the center of the Basin which are obscured by younger deposits.

SULPHUR

Cody deposits. These deposits are located three miles west of Cody along the base of Cedar Mountain, on the south side of Shoshone River in Secs. 3 and 10, T. 52 N., R. 102 W. According to Woodruff* the sulphur occurs native in small yellow crystals and streaks in the irregular beds in limestone and travertine associated with fine white crystalline aggregates. In enriched pockets the sulphur reaches from 30 to 50 percent of the rock. Laterally a deposit may be rich at one point and barren 10 feet away. Woodruff concluded that "it seems improbable that rich pockets of sulphur will be found far below the surface." A sulphur mining and milling plant was built in 1906, and during the first year of operation 850 tons of sulphur were produced from 2,833 tons of ore. These operations apparently did not prove successful as the property was idle in 1908.

Thermopolis deposits. This deposit is located 3½ miles northwest of Thermopolis in Sec. 21, T. 43 N., R. 95 W. The deposits were described by Woodruff* as follows:

> Location and extent.--The sulphur deposits are located 3½ miles northwest of Thermopolis, Wyo., on the gentle northeast slope of a small eroded anticline adjacent to the valley of Owl Creek, in sec. 21, T. 43 N., R. 95 W. A large number of drill holesput down in this area by the Wyoming Sulphur Company have found the deposits of sulphur in a zone about one-eighth of a mile in width and one-fourth of a mile in length, along the base of the anticline. * * *It is believed that the sulphur-bearing zône extends for a considerable distance * * *beyond the limits of proved ground. One condition that is considered to point to the presence of sulphur within the area outlined above is the occurrence of deposits of travertine upon beds of altered limestone. This association of travertine and limestone seems to be necessary to the deposition of sulphur. * * *

The minable sulphur deposits occur in the altered Embar limestone

---

*Woodruff, E. G., "Sulphur Deposits at Cody", U. S. Geological Survey Bulletin No. 340, p. 451-454, Washington, 1908.

*Woodruff, E. G., "Sulphur Deposits near Thermopolis, Wyo.", U. S. Geol. Survey Bulletin No. 380, pp. 373-380, Washington, 1909.

which lies immediately below the travertine and through which the sulphur-bearing waters passed in their course to the surface. The sulphur seems to be present in very irregular deposits or pockets about the sites of extinct springs, where the sulphur-bearing waters came into contact with the limestone. * * * There is no uniformity in the shape, size, or arrangement of these ore-bearing pockets. * * *

Native sulphur in this district occurs in two forms--in small yellow crystals filling veins or cavities in the rocks, and in a massive form where the original structure of the limestone is retained, but where the clacium carbonate is replaced by the sulphur. * * * Laterally a deposit may be rich at one point and barren 10 feet away. The sulphur ores thus vary from a low percentage associated with barren rock to small masses of almost pure mineral, but as the deposits follow no general laws all of the area where geologic conditions are favorable must be tested to locate the sulphur beds. * * *

Mining, smelting, and marketing. The Wyoming Sulphur Company, of Thermopolis, Wyo., the only company operating in the area at the present time, began development in the fall of 1908. Mining is carried on in open-pit quarries, in which promising places are located, small drill holes are put down to prove the ground, the surface rock is removed from favorable sites, and the rock and ore are extracted by drilling and blasting. The rock is then broken to convenient size and sorted by hand, and all ore estimated to contain sufficient sulphur for treatment is hauled by wagon to the reduction works, one-fourth of a mile distant. At the smelter the ore is placed in bins, from which it is discharged into small steel cars with perforated sides, each holding about 2 tons. A string of three cars is then run into a large cylindrical retort, the door closed, and steam admitted at 60 pounds pressure for two hours. The sulphur is melted and flows to the bottom of the retort, from which it escapes through a trap, into bins, where it is allowed to cool. When the sulphur has been melted the cars containing the gangue are removed from the retort, other cars are admitted, and the process is repeated. This process is not considered highly efficient, as only about two-thirds of the sulphur which the rock contains is melted out; the remainder is lost in the refuse. After the sulphur is cooled, it is crushed in an 8-inch Blake crusher and pulverized to an impalpable powder in a rotary grinder. It is then sacked and taken to Crosby, 8 miles distant, for shipment to various points in Wyoming and adjoining states.

Production. The plant now installed has a capacity of 20 tons a day, but has not yet been operated to the full capacity. According to a statement of the superintendent of the company on December 15, 1908, the plant had produced up to the time 200 tons of sulphur and was then yielding 10 tons a day. The demand for ground sulphur is reported to be fairly good at $35 a ton at destination.

Sunlight Basin deposits. The following excerpts are from Hewett's report as given in Mineral Resources of the United States, Part VI, 1911.*

> Location.--The sulphur deposits described are located in the upper part of Sunlight Basin, Park County, Wyo., about 32 miles in a direct line northwest of Cody and 14 miles east of the east boundary of Yellowstone National Park. There is a fair wagon road from Cody, from which the distance is 52 miles, but the deposits are inaccessible owing to a steep hill, the ascent over which amounts to about 2,000 feet in 2 miles.
>
> Deposits.--The sulphur deposits occur in seven isolated groups, six of which lie in a belt about 3½ miles long, which crosses the valley of Sunlight Creek. The other deposit is situated on Little Sunlight Creek, about 4 miles northeast. Prospecting has been limited to digging numerous shallow trenches and pits, none of which has penetrated more than 12 feet below the surface.
>
> The six groups lie in an approximately straight line and each is located on the slope of a ridge, practically adjacent to a ravine. The sulphur deposits are irregularly distributed in areas of the bleached igneous rocks, and are devoid of vegetation and in contrast to the well-wooded slopes surrounding them. The positions of the groups of sulphur deposits are determined by a broad zone of intricate fracturing on a small scale.
>
> Sulphur occurs in two forms--cementing surface debris and incrusting irregular open fractures in the lava. The first mode of occurrence is more widespread superficially than the second, but exploration has shown that the sulphur-bearing debris is merely a mantle covering small areas in which sulphur is found in the second form. The sulphur occurs as a clear lemon-yellow incrustation, the surface of which is covered with numerous minute crystals.
>
> The debris is of local origin and has been set free by weathering and washed to the lower slopes. It is almost certainly not more than 15 feet thick at any place. Sulphur fills the interstitial spaces of the debris in varying degree, impregnating the mantle very irregularly. The largest area in which sulphur is found in this condition is slightly in excess of 2 acres, but most of the deposits are less than half an acre in extent.
>
> Though no analyses have been made, inspection indicates that those portions of the debris nearest the present surface are richest, the maximum content of sulphur being about 60 per cent. The debris lying on bedrock generally contains much less sulphur, the amount varying with the thickness of the entire cover of the debris, but as a rule not exceeding 10 per cent.
>
> Small pieces of wood associated with the deposit are impregnated with sulphur, but there is no evidence of replacement of wood fiber by sulphur.

---

*Hewett, D. F., "Sulphur Deposits of the Sunlight Basin, Wyoming", Bull. U. S. Geological Survey, No. 530, 1912.

The odor of hydrogen sulphide was detected near every deposit and carbon dioxide has apparently accumulated in the bottom of most of the pits and trenches.

In the second mode of occurrence * * * the sulphur occurs as a clear yellow incrustation upon the walls of open fractures in the lava and as an impregnation in the partly or wholly decomposed rock near these fractures. The incrustation varies from a small fraction of an inch to 3 inches in thickness and is practically pure sulphur, but the impregnated rock does not generally contain more than 10 per cent of sulphur and would probably average considerably less when considered in large masses.

At several places there are roughly conical mounds, the largest being 20 feet in diameter and 5 feet high, composed of angular fragments of andesite heavily incrusted with sulphur. The rock surrounding these mounds contains only a trace of sulphur. The accumulation of sulphur is greatest at the center of the mounds, whence hydrogen sulphide and carbon dioxide issue freely and where sulphur is probably forming at the present time. The size of these mounds indicates the small areal extent of this second mode of occurrence of sulphur when compared with the overlying mantle of sulphur-bearing debris.

Genesis.--It is believed that the sulphur deposits have formed from the decomposition of hydrogen sulphide rising through irregular fractures in the lava flows. This decomposition probably took place according to the well-known reaction $2H_2S\ O_2\ 2H_2O\ 2S$. The amount of sulphur deposited in the bed rock lava is small, owing apparently to the inability of the relatively dry gases to replace or dissolve siliceous rocks. * * * The high-grade sulphur-incrusted debris on the surface is due apparently to the exceptional conditions favoring the aeration and oxidation of the gases. It is thought that each deposit of this character covers one or more vents from which the sulphur-bearing gases are escaping.

Alum and gypsum are present and are thought to be due to the reaction between the sulphuric acid formed by the complete oxidation of the hydrogen sulphide with the bases of the igneous rocks.

The deposits are thought to be of relatively recent origin, probably being wholly postglacial. In one of the mounds the dead root of a cedar tree, similar to those growing near by, penetrates the fractured sulphur-bearing rock in such a manner as to make it certain that the tree once grew there. It is believed that here the sulphur is of very recent origin.

Production.--No sulphur has been produced from these deposits and it is extremely improbable that they will be sources of production until the transportation facilities of the region are greatly improved.

The amount of sulphur existing in the surface debris is capable of easy demonstration, but it is not thought to be great compared with that in workable deposits of sulphur in general. The maximum content os ul of sulphur in material of this class can not exceed 50 per cent in large amounts of material, as it is governed by the pore space of loosely-packed slide rock, which seldom exceeds 40 per cent. The amount of sulphur existing below this superficial cover is undoubtedly very much less, owing both to the relatively poorer chance for oxidation of the sulphurous gases and to the small amount of open space available for the deposition of sulphur. The occurrence of sulphur is distinctly superficial and it is not thought that the deposit will become important.

Park County deposits.--The following description is excerpts from Hewett's* report as given in Mineral Resources of the United States. Part II, 1912.

The deposits of sulphur in Park County, Wyo., are 12 miles south of those in Sunlight Basin, described in this report for 1911. They lie at an elevation of 6,500 feet along Sweetwater Creek, about 2 miles north of its junction with the North Fork of Shoshone River, near which is located the summer settlement of Wapiti, about 32 miles west of Cody on the road to the Yellowstone Park.

The deposits are in a narrow belt about 1,400 feet long, joining Sweetwater Creek on the east. The area within which sulphur has been found does not exceed 20 acres. The largest deposit occurs in the strip of debris formed by the merging of alluvial fans from two dry gulches, composed of talus washed from adjacent slopes. Several smaller deposits lie along the slope of the ridge to the east of the stream. The sulphur occurs as bands of crystalline aggregates which fill the interstices between the rock fragments. A comparison of sections dug in the trenches shows that the sulphur-bearing material occurs as one or more lenticular beds essentially parallel to the present surface, but practically covered with debris free from sulphur.

In another deposit 1,200 feet farther north the sulphur occurs in two distinct associations: (1) cementing the debris of a small alluvial fan near the stream and (2) in the form of a crust coating the walls of small crevices in bedrock, the greater part of the sulphur occurring in the first form mentioned. No prospecting has been done here.

In addition to the deposits noted, the rock at the surface of the ridge east of Sweetwater Creek up to an elevation of 6,800 feet has been locally bleached and décomposed. Where the bleaching has been most intense sulphur occurs as thin crusts or in the form of minute crystals. Four such occurrences were observed, no one of which covered an area greater than 50 feet square.

The sulphur deposits, though smaller, are essentially similar to those occurring in the upper portion of Sunlight Basin. They have apparently been derived from the decomposition of hydrogen sulphide contained in gases issuing from crevices in the igneous rocks. The debris through which the gases pass, being highly porous, offers

---

*Hewett, D. F. "Sulphur Deposits in Park County, Wyo." Bull. U.S. Geol. Survey, No. 540, Part I, 1914.

better conditions for the aeration and oxidation of hydrogen sulphide than do the massive rocks, which are believed to contain little, if any, sulphur additional to that contained in the open crevices. The thickness of the debris above water level is probably as much as 25 feet in places, and a considerable portion of this may be found to be sulphur bearing, but it is very doubtful whether any sulphur will be found below water level, as, from the theory of origin postulated, oxidation of the hydrogen sulphide and deposition of sulphur could not go on in this zone. It appears probable that the sulphur-bearing gases are of deep-seated or of igneous origin.