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MINERAL RESOURCES OF UPPER MISSOURI RIVER BASIN, MONT.

Fort Peck Reservoir to Morony Dam

By C. R. Hubbard, R. N. Roby, W. C. Henkes, and P. Biggs

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

1964

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MINERAL RESOURCES OF UPPER MISSOURI RIVER BASIN, MONT.

Fort Peck Reservoir to Morony Dam

by

C. R. Hubbard,[1] R. N. Roby,[2] W. C. Henkes,[3] and P. Biggs[4]

ABSTRACT

The Bureau of Mines investigated the mineral resources of the Upper Missouri River Basin as a part of a comprehensive water and related land resources study by six Bureaus of the Department of the Interior, coordinated by the Department's Missouri River Basin Field Committee.

The mineral resource study covers an area of about 18,000 square miles within the Great Plains physiographic province of central Montana. Exposed formations in the plains are chiefly flat-lying Cretaceous sediments. Plutonic rocks crop out in the central parts of the mountain uplifts, with steeply tilted Paleozoic sediments exposed around the margins.

Oil and gas have been produced from several fields in the study area; total value exceeds $45 million. Coal-bearing formations of Upper Jurassic and Cretaceous age cover approximately 45 percent of the study area. Total production of coal since 1880 has been between 40 and 50 million tons, exceeding $75 million in value. Total metal production has been about $52.5 million. Industrial mineral production from 1925 through 1960, is valued at $24 million.

INTRODUCTION

A preliminary analysis of the natural resources complex of the Missouri River between Fort Peck Reservoir and Morony Dam was authorized on October 27, 1961, by the Secretary of the Interior, and a draft report prepared by

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Work on manuscript completed November 1963.

six Interior Bureaus and the Interior Missouri Basin Field Committee staff was completed on November 15, 1962.

A section of the report draft on mineral resources was prepared by the Bureau of Mines and included as an appendix in a joint report by the U.S. Army Corps of Engineers and Department of Interior.[5] The appendix, with minor revisions, is reproduced here.

The location, extent, past production, and importance of the mineral resources in the Basin Study Area are reported as a background for discussion of the future potential. Much of the factual data has been compiled from publications of the Geological Survey, the Montana Bureau of Mines and Geology, published and unpublished data of the Bureau of Mines, and various miscellaneous reports. Reconnaissance field work was done in late 1961 and early 1962, consisting of investigations of active mining operations (including coal mines) and producing oil and gas fields. Mineral exposures along the Missouri River and in the "breaks" area were examined by means of a float trip down the river from the Virgelle Ferry near Fort Benton to the Robinson Bridge near the upper end of the Fort Peck Reservoir.

ACKNOWLEDGMENT

The assistance of A. J. Kauffman, Jr.[6] and the Area VII Mineral Resources Office staff, Bureau of Mines, Albany, Oreg., is acknowledged in supplying statistical data on mineral industries and mineral production in the study area.

MINERAL RESOURCES AND THEIR UTILIZATION

Physical Features

The Upper Missouri Basin Study Area, a part of the Northern Great Plains physiographic province, is characterized by a nearly level to gently rolling, almost treeless plateau. The otherwise monotonous terrain is interrupted by several isolated mountain groups which rise abruptly 2,000 to 4,000 feet above the plains and by the principal rivers which have entrenched themselves 200 to 800 feet below the surface of the plateau. The river canyons are steep sided with erosional features similar to badlands topography, commonly referred to as the "river breaks."

The elevation of the plateau surface ranges from 2,700 to 3,300 feet above sea level, the Missouri River flows at about 2,500 feet, and the mountain range from 4,500 to 8,000 feet above sea level.

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[5] U.S. Army Corps of Engineers and U.S. Department of the Interior. Joint Report on Water and Related Land Resources Development for Missouri River, Fort Peck Reservoir to Vicinity of Fort Benton, Montana, v. 3, Appendix 4, Mineral Resources, June 1963, 68 pp.

[6] Supervisory physical scientist, Area VII Mineral Resources Office, Bureau of Mines, Albany, Oreg.

The Missouri River flows in a generally eastward direction across the central part of the study area, making a great bend between Fort Benton and Arrow Creek. The principal tributaries are the Marias, Teton, and Judith Rivers.

Railway transportation facilities are provided by the main line and branches of the Great Northern Railway and the Chicago, Milwaukee, St. Paul, and Pacific Railroad. Railroads and highways are shown on the map, figure 1.

General Geology

The generalized surface geology of the Missouri Basin Study Area is shown in figure 2.

The exposed rocks in the plains area are chiefly Cretaceous sediments. The older sediments of Lower Cretaceous age are exposed generally in the western part of the study area, with Colorado formation predominating. Upper Cretaceous beds, largely Bearpaw Shale formation, are exposed in the eastern part of the study area. Except locally, and near the mountain uplifts, the sedimentary beds are largely undisturbed with very gentle regional dips.

The mountain ranges were generally formed by intrusive and, in a few instances, extrusive igneous activity. Sedimentary rocks around intrusive margins have been tilted to steep angles. In most cases, later erosion has exposed the plutonic rocks near the center of the uplift and exposed older sediments around the margin.

Metal deposits are directly related in origin to the intrusive masses, although deposition may have occurred on the contact or within the surrounding sediments or metasediments. It follows, therefore, that the metal deposits are found in the several mountainous regions. Some of the older sediments such as the Madison group of Mississippian age contain limestone beds of commercial grade and thickness; these are covered by the younger sediments in the plains area, but are exposed around the margins of the uplifts.

The study area is one in which the stratigraphic sequence varies so much that one typical representative section is difficult to develop. The following generalized stratigraphic chart lists formations which may be encountered in one or more localities but not necessarily throughout the area. Formations producing oil or gas in Montana are so indicated and, consequently, are of potential interest in the area studied. A generalized stratigraphic chart of the study area is shown in table 1. The oil and gas producing formations are noted.

On the Sweetgrass arch, the oil and gas producing formations are the Madison, Ellis Group, Cut Bank, and Sunburst. Present interest is in the deeper possibilities. In north-central Montana, gas is produced from the Eagle Sandstone (Cretaceous) and oil from the Sawtooth (Jurassic); the discovery of oil in Devonian limestones and dolomites (Nisku) in northeastern Montana will undoubtedly stimulate interest in these formations in the study area. To the south, the principal source of oil has been the First and Second Cat Creek sands in the Cat Creek field; however, nearby fields have produced from the Big Snowy Group (Heath, Otter, and Kibbey), Swift, and Morrison.

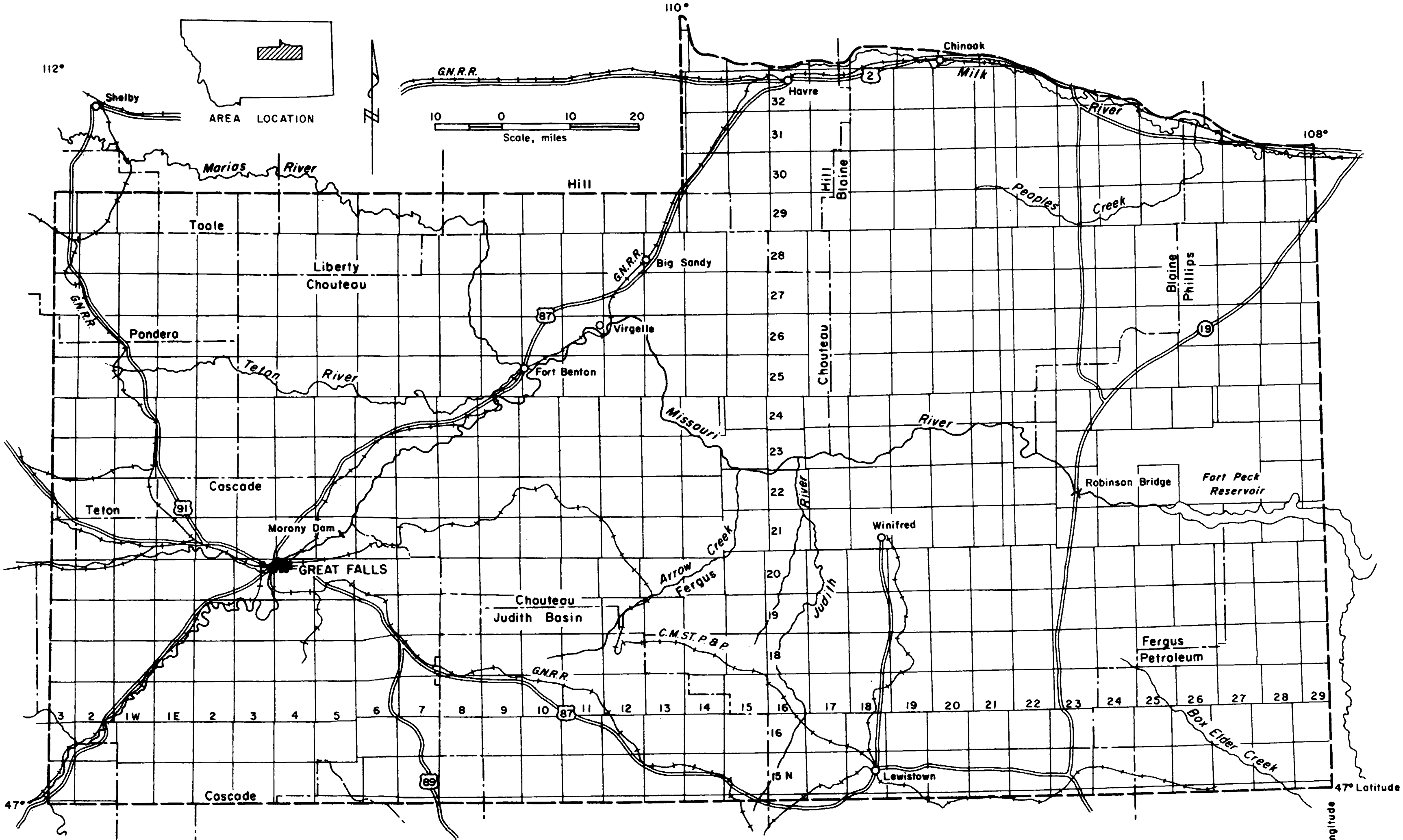


FIGURE 1. - Location Map, Missouri Basin Study Area.

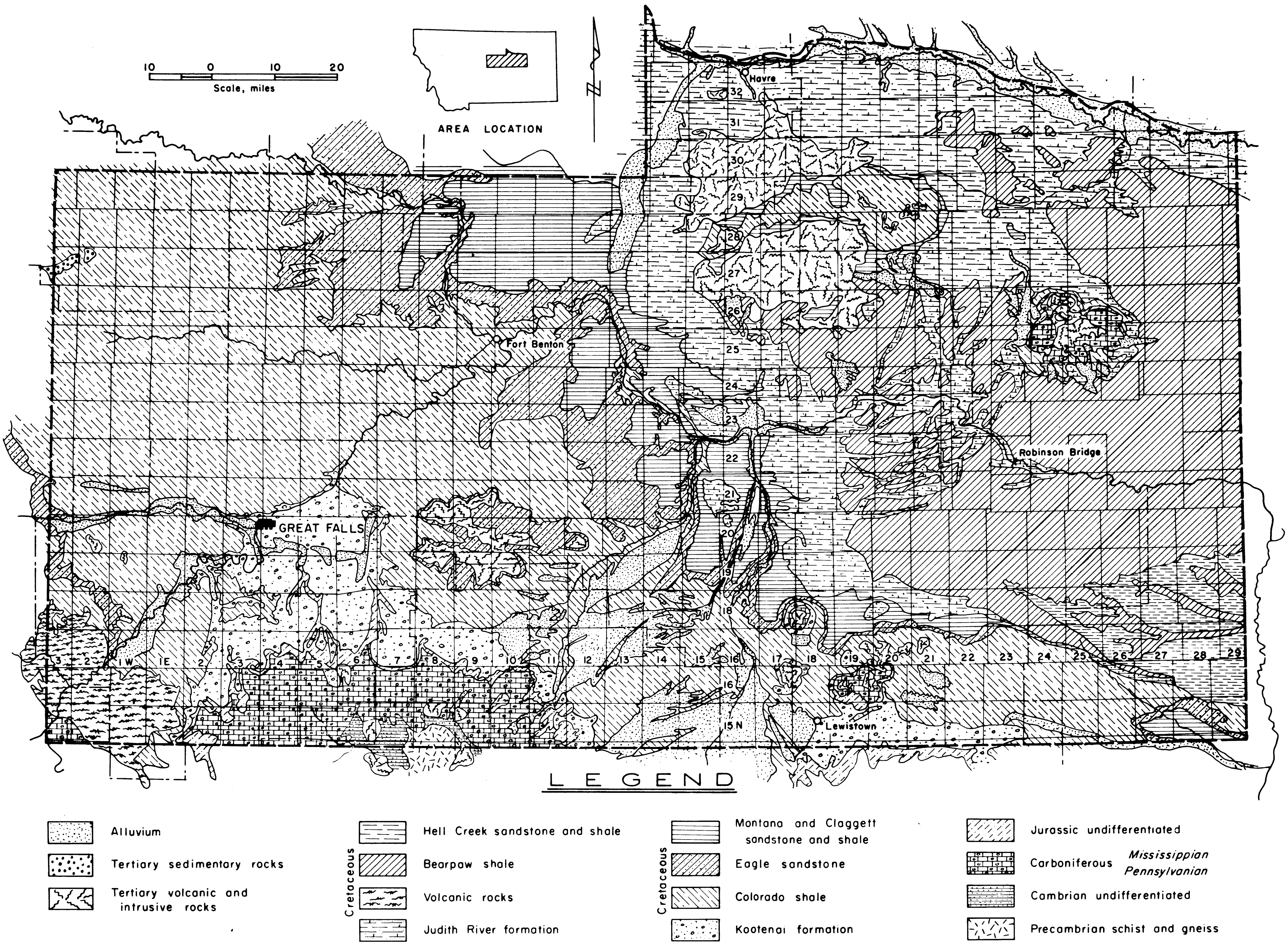


FIGURE 2. - Geologic Map, Missouri Basin Study Area. (Modified from U.S.G.S. Geologic Map of Montana.)

TABLE 1. - Generalized stratigraphic chart[1]

System	Series	Formation	Thickness, feet	General description
Quarternary	Pleistocene	Glacial drift	(Varies)	
Cretaceous	Upper	Montana group (includes Eagle sandstone)[2]	950-1,300	Gray, marine shale, and sandstone.
		Colorado group (1st Cat Creek[2] at base).	1,200-1,700	Gray, marine shale, sandy in lower part.
	Lower	Kootenai (2nd Cat Creek and Sunburst)[2]	250- 300	Variegated shales with coarse sands.
Jurassic	Upper	Morrison[2]		Green-gray to yellow shale and sandstone.
		Swift[2]	180- 620	Gray sandstone, shaly.
		Rierdon		Gray, marine shale.
	Middle	Sawtooth[2]	-	Sandstone and limestone, shaly.
Triassic	-	(Absent)	-	-
Permian	-	(Absent)	-	-
Pennsylvanian	-	Amsden	-	Reddish shale and sandstone.
Mississippian	-	Big Snowy group[2] Charles[2] [3] Mission Canyon[2] [3] Lodgepole[3]	1,120-2,760	Limestone; dolomite; anhydrite; red, green, black shale; thin sand lenses.
Devonian	Upper	Three Forks Duperow[2] Birdbear ("Nisku")[2] Beaverhill Lake	95-1,180	Shales, limestones, and dolomites.
	Middle	Elk Point	-	-
Silurian	-	(Absent)	-	-
Ordovician	-	Big Horn-Red River[2]	50-125	Dolomite and limestone.
Cambrian	-	Undifferentiated	0-1,121	Mainly black shale and limestone.
Precambrian	-	Undifferentiated	-	Igneous and metamorphics.

[1] Adopted from data in Billings Geol. Soc., 4th Annual Field Conf., 1953, and 9th Annual Field Conf., 1958.

[2] Formations productive of oil and gas.

[3] The Charles, Mission Canyon, and Lodgepole are included in the Madison group, a term declining in use in Montana and North Dakota because of a more specific breakdown in nomenclature.

The southern part of the study area lies almost entirely within the southeastward-plunging syncline (Blood Creek syncline) which is bounded on the south by the Big Snowy anticlinorium, on the west by the Little Belt Mountains-Sweetgrass arch uplift, and on the north by the Bearpaw-Little Rocky Mountain uplift. The northern part includes the Bearpaws and Little Rocky Mountains and the southwest flank of the Coburg syncline.

These general structural features are further modified and complicated by local variations. In a wide peripheral zone around the south side of the Bearpaw Mountains is a series of shallow thrust faults; these have caused some wildcat drilling in a search for fault traps, but no commercial production has resulted.

Petroleum and Natural Gas

General

The Upper Missouri Basin Study Area has produced significant amounts of oil and gas, although the source has been some distance from the actual river channel. Natural gas was found in commercial quantities near Havre in 1914 and was used there in 1915. Oil production started at Cat Creek in 1920. The locations of the oil and gas fields, pipelines, and refineries are shown in figure 3. A major portion of the oil produced in the study area has come from the Cat Creek field. Total oil produced to the end of 1961 amounted to 25,597,838 barrels valued at $43,462,172 (4).[7] According to the data of the Geological Survey, natural gas production to the end of 1961 amounted to 32,184 million cubic feet with an estimated value of $3,218,000 at $0.10 per thousand cubic feet. Individual reports are given for the fields and areas where appreciable shows of gas have been encountered.

The only active refinery at Great Falls started operation in 1922. Oddly enough, in 1924 about 40 percent of the gasoline produced at the plant was marketed outside Montana. A small plant operated in the Bannatyne field until 1935. Outside the study area, a plant was built at Miles City in 1923 to process crude oil from the Cat Creek field. Records showing the amount of oil refined, or duration of operation, are not available.

The first pipeline in the area was a gasline built in 1915 to Havre from the Havre field. Major gas-transmission lines now border the area on the north and west. The first oil pipeline was the 16-mile line from the Cat Creek field to the town of Winnett, built in 1922. The Powder River pipeline from Billings to Cat Creek was completed in 1955. The Glacier oil pipeline from the Cut Bank area to Byron, Wyo., was completed in 1961. The Cat Creek field has been connected to this pipeline. It is the major oil outlet for the area. The 5-inch pipeline from Cut Bank to Great Falls was built in 1946. The Pondera field is connected to this line at Conrad, Mont.

[7] Underlined numbers in parentheses refer to the list of references at the end of this report.

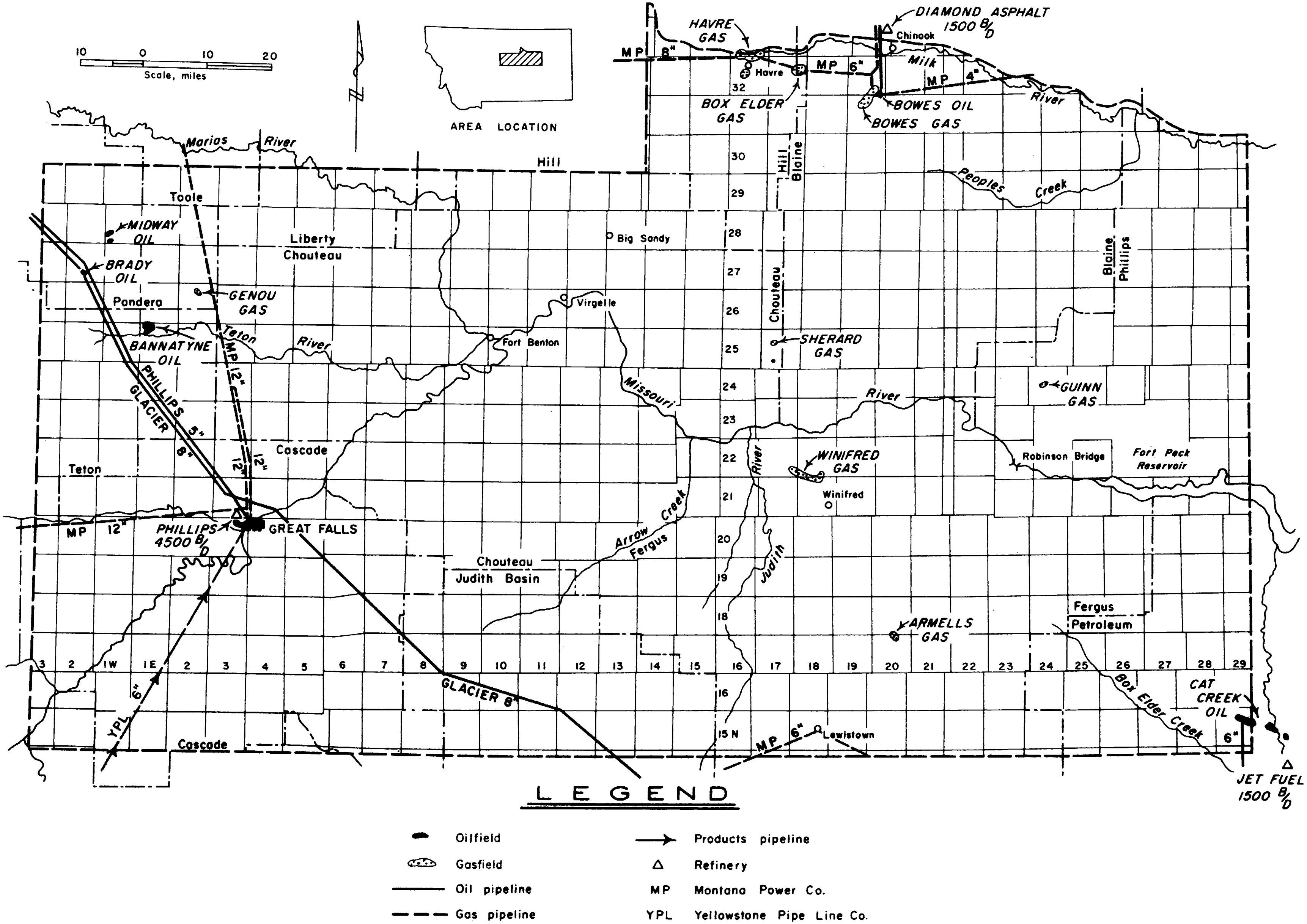


FIGURE 3. - Oilfields and Gasfields, Missouri Basin Study Area.

Oilfields and Gasfields

Armells Structure

The Armells gasfield is a small anticline on the north flank of the Judith Mountains in Tps 17 and 18 N, R 20 E, Fergus County, Mont. (fig. 3). A well drilled in 1922 and 1923 reported gas flowing at the rate of 2,500,000 cubic feet per day from Kootenai (Cretaceous) sandstones at a depth of 1,252 feet. A second well also reported a large flow of gas from the Second Cat Creek sand at a pressure of 420 psi.

Analysis of the gas showed 56.0 percent nitrogen, 0.5 percent carbon dioxide, 42.3 percent methane, 0.4 percent ethane, and 0.6 percent helium. Heating value was 436 Btu per cubic foot.

Nine wells have been drilled on the structure, of which two were gas wells, two had gas shows, and the rest were dry. The field has not produced commercially and as of December 1961 two wells are still reported as shut in.

The deepest well in the field was drilled in 1930 to a depth of 3,569 feet in the Madison formation (Mississippian); fluid recovery from the Madison is not reported.

Bannatyne Field

The Bannatyne field is the southernmost producer on the Sweetgrass arch, and is located in Tps 25 and 26 N, R 1 E, Teton County, Mont. (fig. 3). Surface elevations range from 3,270 feet to 3,470 feet above sea level; the surface formation is Colorado shale (Upper Cretaceous) largely covered by glacial debris. The Bannatyne structure is a simple anticlinal trap with about 150 feet of structural closure.

The field was discovered in 1927 when the Genou No. 1 Speer, NW¼NW¼ sec 8, T 25 N, R 1 E, was drilled to 1,580 feet and completed on July 21 for 30 barrels of oil a day from the Swift formation (Jurassic). Within 3 years after its discovery, 41 wells had been drilled in the field, 28 wells were reported to have produced oil at rates of 3 to 100 barrels of oil a day, and half of these were considered commercial. Completion usually involved shooting the wells with nitroglycerin (7).

A small refinery was built to treat the oil produced in the field. It operated until 1935. From discovery until 1936, the Bannatyne field produced 55,245 barrels of black, asphalt-base oil (6). The field was inactive from 1936 until 1955, when drilling was renewed. Some of the new wells were drilled to the Madison formation (Mississippian) where production was obtained from the upper part of the formation. Oil from the Madison is almost identical with that from the Swift.

The deepest horizon tested in the field is the Devonian. The horizon was cut in a well known as Carney No. 1 Speer, NW¼NW¼SE¼ sec 5, T 25 N, R 1 E. It was drilled to 3,115 feet. Tops of formations were reached at the following depths in feet: Sunburst, 1,310; Madison, 1,505; and Devonian, 2,430.

The Swift sandstone, from which the original production was obtained, is hard and tight with much interlaminated shale. It has a gross thickness of about 80 feet and a net pay thickness of 30 feet. Average porosity is 14.5 percent, and average permeability is 7 millidarcies. The oil column is approximately 100 feet, and the oil-water contact is about 1,940 feet above sea level (2). Oil from the Swift is brownish black, 26.3° API gravity, and contains 2.2 percent sulfur. Specific gravity is 0.897, and viscosity is 100 Saybolt Seconds at 100° F. Water produced from the Swift is slightly brackish, with 7,407 parts per million (ppm) of solids and a high percentage of sodium chloride.

The Madison horizon in the Bannatyne field is a fractured and vuggy dolomite with a gross thickness of 10 feet and a pay thickness of 5 feet. Average porosity is 10 to 20 percent, and average permeability is 2 to 25 millidarcies. The oil column is about 25 feet, and the oil-water content is about 1,935 feet above sea level. Water produced from the Madison has 2,425 ppm solids. It has high sodium bicarbonate content with some hydrogen sulfide present. Both the Swift and Madison oil reservoirs have an active water drive.

Oil from the field is trucked to Conrad where it enters the pipeline to the Phillips refinery at Great Falls.

As of December 31, 1961, the field has 12 producing oil wells, 1 gas well, and 62 abandoned wells. Gas production is negligible, and apparently is used only in the field. Annual production figures are shown in table 2.

TABLE 2. - Oil production, (in thousands of barrels), Bannatyne Field, Teton County, Mont.

Year	Production	Year	Production
1928	5.0	1955	0.8
1929	1.2	1956	0.4
1930	15.2	1957	6.0
1931	3.4	1958	7.5
1932	6.1	1959	28.7
1933	11.1	1960	15.6
1934	11.1	1961	17.9
1935	2.1	Total	132.1
1936-1954	([1])		

[1] From 1936 through 1954 there was no production.

Source: Montana Oil and Gas Conservation Commission. Annual Review for 1960, v. 5.

Production in December 1961 was 1,124 barrels, and the average price during 1961 was $1.79 a barrel. Cumulative value of the oil produced is $209,995 (4).

Bowes Gasfield

The Bowes gasfield is in Blaine County, Mont., in secs. 3, 9, and 10, T 31 N, R 19 E, and secs 26, 27, 34, and 35, T 32 N, R 19 E (fig. 3). The gas accumulation is in the Cretaceous Eagle sandstone which forms a stratigraphic trap on the west flank of the Bowes Dome.

Gas was discovered in October 1926 when a well in the NE¼NE¼Ne¼ sec 9, T 31 N, R 19 E, tested 40,000 cubic feet of gas. Although this well was plugged, the show of gas stimulated additional drilling which established commercial production by the end of 1926.

Analysis of the gas is as follows: Methane, 93.2 percent; carbon dioxide, 2.7 percent; and nitrogen, 4.1 percent.

The Eagle gas sand is a white to light-brown, fine-grained, lignitic, massive sandstone which varies in thickness from 250 feet to less than 1 foot. Initial production in the field ranged from 7 million to 30 million cubic feet of gas a day; initial pressures ranged from 250 to 300 psi. The reservoir does not have a water drive.

In 1926, pipelines were laid from the field to the towns of Havre and Chinook. The sugar refinery at Chinook was an important consumer.

At the end of 1961, 23 gas wells were producing in the field. Production in December 1961 was 115,883,000 cubic feet (4). Gas production by years is given in table 3.

TABLE 3. - Gas production (millions of cubic feet) Bowes Gasfield, Blaine County, Mont.

Year	Production	Year	Production
1926	89.5	1944	505.5
1927	285.3	1945	640.3
1928	465.1	1946	726.8
1929	612.1	1947	854.1
1930	620.1	1948	903.0
1931	522.9	1949	1,140.8
1932	456.5	1950	1,336.5
1933	361.2	1951	1,325.6
1934	433.4	1952	615.3
1935	480.9	1953	720.4
1936	431.9	1954	735.0
1937	578.8	1955	864.9
1938	526.2	1956	716.8
1939	628.4	1957	835.3
1940	623.2	1958	886.1
1941	577.2	1959	897.0
1942	477.4	1960	1,432.4
1943	453.7	Total	23,759.6

Source: Geological Survey records, Great Falls, Mont.

Bowes Oilfield

The Bowes oilfield is situated in Tps 31 and 32 N, R 19 E, Blaine County, Mont. (fig. 3). The oilfield lies immediately east of the gasfield and produces from the Jurassic Sawtooth formation whereas the gas is produced from the Cretaceous Eagle formation.

The Bowes field Sawtooth unit totals 7,751.64 acres (5,280 acres are considered productive) and, as of December 31, 1961, had 82 producing wells and 5 water-injection wells. The structure is essentially a quaquaversal anticline with 120 feet of closure. The deepest well in the field, located in NE¼SW¼NW¼ sec 1, T 31 N, R 19 E, logged the following depths, in feet, to formation tops: Eagle, 612; Colorado shale, 967; Bow Island, 2,341; Kootenai, 2,627; Ellis, 3,008; Sawtooth pay, 3,343; Madison, 3,516; Devonian, 4,160; and total depth, 5,081. Large quantities of water were recovered from the Upper Madison and the Devonian. The producing formation is a light-gray to buff, sandy, oolitic, and dolomitic limestone having an average pay thickness of 27 feet, average porosity of 11.7 percent, and permeability ranging from 0.1 to 264 millidarcies. The formation is generally uniform across the structure except on the north side where some lenticularity of the beds exists. Interstitial water averages 31 percent, and has a salinity of 6,187 ppm (7). During early unit production, the solution gas-oil ratio was low, amounting to only 20 cubic feet of gas per barrel. This caused the operator to estimate the ultimate primary recovery at 7,187,000 barrels, or only 5.5 percent of the estimated oil in place (5).

The crude oil is black, asphalt-base, 19.2° API gravity oil with a pour point of 5° F, sulfur content of 3.75 percent, and viscosity of 460 Saybolt Seconds at 100° F. The original reservoir pressure, at 132° F, was 1,664 psi (5).

The oilfield was discovered in August 1949, when the Northern Ordnance, Guertzgen No. 1, SW¼NW¼NE¼ sec 2, T 31 N, R 19 E, was completed in the Sawtooth formation, pumping 200 barrels of oil a day. Average peak production was reached in 1953 at a level of 3,000 barrels of oil a day. Production at the end of 1961 totaled 5,876,533 barrels, and the cumulative value was $7,296,205 (3). In December 1961 production was 16,022 barrels. Average price during 1961 was $1.61 per barrel. Estimated remaining primary reserves are 1,264,000 barrels (4). The crude oil is shipped by pipeline to the Diamond Asphalt Co. refinery at Chinook, Mont.

A pilot waterflood project aimed at a secondary recovery program for the whole field is underway. The project covers a 20-acre tract centering around the southwest corner of sec 36, T 32 N, R 19 E,; it is based on a 5-spot pattern with the outer wells being used for injection. Water for the flood will come from the Cat Creek sands or from the Madison Limestone; injection rate is anticipated at 125 to 250 barrels of water a day for each well. It is anticipated that approximately 7 million barrels of oil will be obtained by waterflood in addition to that recovered by primary means (5).

Oil production for the field since its discovery is presented in table 4.

TABLE 4. - Oil production (in thousands of barrels), Bowes Oilfield, Blaine County, Mont.

Year	Production	Year	Production
1949..............	1.7	1956..............	338.6
1950..............	61.3	1957..............	306.0
1951..............	427.5	1958..............	277.3
1952..............	1,025.3	1959..............	332.9
1953..............	1,094.8	1960..............	279.9
1954..............	980.4	1961..............	240.9
1955..............	510.1	Total...........	5,876.7

Source: Montana Oil and Gas Conservation Commission. Annual Review 1960, v. 5 (3).

Box Elder Field

The Box Elder gasfield is located in secs 13, 14, and 24, T 32 N, R 17 E, Hill and Blaine Counties, Mont. (fig. 3). The Judith River formation is exposed on the surface at an elevation of 2,800 feet. The structure is elongated faulted anticline.

The field was discovered in June 1931 with the completion of a well in NW¼NW¼NE¼ sec 14, T 32 N, R 17 E. Initial production test was 7,250,000 cubic feet of gas per day with a reservoir pressure of 430 psi. Production was from the Eagle sandstone of Upper Cretaceous age. The deepest well in the field was drilled in the C SE¼SE¼ sec. 14, and reported the following depths to formation tops, in feet: Claggett, 810; Eagle, 1,295; Bow Island, 2,967; Kootenai, 3,305; Ellis, 3,532; Sawtooth, 3,890; Madison, 4,111; and total depth, 4,212.

The gas from the Box Elder field was put in the Bowes-Havre gasline and marketed in Havre. Analysis of the gas shows the following: Methane, 93.7 percent; ethane, 1.7 percent; nitrogen, 0.1 percent; and 0.04 percent helium. Heating value was 980 Btu per cubic foot.

In 1959, the Box Elder field was converted to gas storage use by Montana Power Co. At the end of 1961, the field had eight active gas wells. The three wells used for gas input were: State No. 1-C, SW¼SW¼ sec 13, Conroy No. 1, NW¼NW¼NW¼ sec 24; and Morphey No. 1, SE¼SE¼ sec 14.

Production from discovery to conversion to gas storage is shown in table 5.

TABLE 5. - Gas production (millions of cubic feet), Box Elder Field, Hill and Blaine Counties, Mont.

Year	Production	Year	Production
1932...............	151.2	1946...............	462.9
1933...............	208.4	1947...............	522.4
1934...............	412.2	1948...............	346.3
1935...............	451.3	1949...............	139.7
1936...............	460.6	1950...............	122.0
1937...............	250.2	1951...............	138.2
1938...............	276.7	1952...............	276.6
1939...............	311.7	1953...............	148.1
1940...............	308.4	1954...............	169.1
1941...............	479.4	1955...............	89.7
1942...............	484.1	1956...............	77.5
1943...............	482.4	1957...............	23.1
1944...............	455.8	1958...............	19.6
1945...............	395.9	Total............	7,663.5

Source: Geological Survey records, Great Falls, Mont.

Brady-Midway Field

The small Brady and Midway oilfields are combined for production statistical purposes by the Montana Oil and Gas Conservation Commission. The Midway field was originally carried as the "Conrad-Midway" field. Because of this change in nomenclature, some confusion and ambiguity exists in the annual production figures. Surface formations in both pools are shales of the Colorado group (Upper Cretaceous age) and both pools produce from the Sunburst sand member of the Kootenai formation (Lower Cretaceous age). The Brady pool is in secs 21 and 27, T 27 N, R 2 W, and the Midway pool is in secs 19 and 20, T 28 N, R 1 W, Pondera County, Mont.

Midway pool was discovered in 1942 when the R. C. Tarrant No. 1-Woods, C, NE¼NW¼ sec 32, T 28 N, R 1 W, produced oil from the Sunburst sand at about 1,740 feet. The test was drilled to 3,695 feet in formations of Devonian age and plugged back for completion in the Sunburst; initial production was estimated at from 5 to 20 barrels of oil a day. Oil stain was found in the top of the Madison, but a heavy flow of water was recovered on testing.

The Brady pool was discovered the following year (1943) when the Texas Co. No. 1 Schlepp, SE¼SE¼SE¼ sec 21, T 27 N, R 2 W, was completed for 11 barrels of oil a day in the interval 1,470-1,482 feet (Sunburst). The well was drilled to 1,725 feet in the Madison formation (Mississippian) which contained sulfur water, and then plugged back to the Sunburst.

A recent well drilled on the south edge of the field, in the SW¼SE¼ sec 27, T 27 N, R 2 W, reported formation depths, in feet, as follows: Colorado, 276; Kootenai, 1,118; Sunburst, 1,442; Morrison, 1,479; Swift, 1,602; Rierdon, 1,742; Sun River, 1,754; and Mission Canyon, 1,818.

Analysis of the oil from the Brady pool showed a greenish-black 34.0° API gravity oil with 1.77 percent sulfur, a specific gravity of 0.855, a pour point below 5° F., and a viscosity of 55 Saybolt Seconds at 100° F. As of December 31, 1961, the Brady pool had four producing oil wells, plus one suspended; the Midway pool had two oil wells, plus one suspended.

Production for the combined Brady and Midway pools is shown in table 6.

TABLE 6. - Combined oil production (in thousands of barrels), Brady-Midway Field, Pondera County, Mont.

Year	Production	Year	Production
1943...............	1.0	1953...............	0.5
1944...............	1.0	1954...............	2.5
1945...............	-	1955...............	1.9
1946...............	1.0	1956...............	0.7
1947...............	0.9	1957...............	-
1948...............	1.0	1958...............	0.8
1949...............	0.9	1959...............	-
1950...............	0.7	1960...............	-
1951...............	0.2	1961...............	0.2
1952...............	0.3	Total..........	13.6

Source: Montana Oil and Gas Conservation Commission. Montana Oil and Gas Statistical Bull., 1961 (4).

The State of Montana quotes an average price for Brady-Midway crude oil during 1961 as $2.51 a barrel; the cumulative value of the oil produced from these pools was $32,011 (4) to the end of 1961.

Cat Creek Field

The Cat Creek field is actually a group of three main fields occupying separate closures along the 60-mile-long Cat Creek anticline. The overall structure lies in Tps 14 and 15 N, Rs 29, 30, and 31 E, Petroleum and Garfield Counties, Mont. (fig. 3). The Geological Survey defines the three main structures as West dome lying in secs 9, 10, 11, 12, 13, and 14, T 15 N, R 29 E; Mosby dome in secs 16, 17, 20, 21, 22, 23, 26, and 27, T 15 N, R 30 E; and East dome in sec 1, T 14 N, R 30 E, and sec 6, T 14 N, R 31 E.

The anticline is long, fairly narrow, and trends northwest-southeast. The structure is asymmetric with steep dips of 60° to 75° on the north flank and 2° to 3° on the south. There are eight or more local highs having structural closure of up to 600 feet. Some of these local highs are cut by small normal faults having displacements as much as 150 feet; this faulting appears to have had a definite influence on the accumulation of oil because the highs, with numerous faults, are oil productive, and those without faults are barren. A theory for this relationship between faulting and oil trapping is that the producing sands are prolific artesian aquifers, and the faulting may have prevented the flushing of oil from the faulted highs (1).

Oil was discovered in February 1920 when the Frantz Corp. drilled a well in SW¼SE¼NW¼ sec 21, T 15 N, R 30 E, on Mosby dome, and completed it for 10 barrels of oil a day from the Second Cat Creek sand; the First Cat Creek sand was water bearing. This well reached a total depth of 998 feet.

The same operator drilled another well in May 1920 on West dome in NE¼SE¼NE¼ sec 14, T 15 N, R 29 E. This well found oil in the First Cat Creek sand and initially flowed 50° API gravity oil at the rate of 250 barrels of oil a day; by August, however, the rate of flow had increased to 2,500 barrels of oil a day.

Development drilling continued on both West dome and Mosby dome, spurred, in part, by the discovery of oil in the Second Cat Creek sand on West dome. This discovery, in the SW¼NW¼ sec 10, T 15 N, R 29 E, was completed in June 1922, flowing about 1,000 bar~els the first day. Most production came from the First Cat Creek sand on West dome, and this continues true to the present time. Shortly after the field was discovered a pipeline was built to the railroad at Winnett, 16 miles southwest. At first, oil was shipped to the refinery at Greybull, Wyo., but two small refineries were soon built at Lewistown for processing this crude oil. Also, a small refinery was built about 1923 at Miles City, which operated a few years on crude oil from the Cat Creek field.

In 1945 oil was discovered in a sandstone of the Jurassic Morrison formation (Brindley sand); this discovery was on Mosby dome in sec 21, T 15 N, R 30 E. A new campaign of drilling followed this discovery, with many of the old wells being successfully deepened. Oil was found in a second Morrison sand and also in a sand in the Swift formation.

Although the major production in the Cat Creek fields has been from the First and Second Cat Creek sands, there has been production from the Morrison and Swift (Ellis) formations and from a stray sand in the Mowry formation.

The productive zone in the First Cat Creek sand occurs at a datum between 1,500 and 1,630 feet above sea level. The average thickness of this sandstone is 40 feet, porosity ranges from 10 to 26 percent, and permeability from 10 to 150 millidarcies (5). The oil from the First and Second Cat Creek sands are commingled, and an analysis shows the following general characteristics: Specific gravity, 0.786; API gravity, 48.5°; pour point, below 5° F.; sulfur, 0.33 percent; viscosity at 100° F., below 32 Saybolt Seconds; color, greenish black.

The productive zone in the Second Cat Creek sand occurs at a datum between 1,350 and 1,460 feet above sea level. The thickness of the sand ranges from 10 to 60 feet; the porosity, from 0 to 20 percent; and permeability, from 0 to 393 millidarcies (5).

The Morrison (Brindley) sand ranges in thickness from 0 to 60 feet; the porosity ranges from 0 to 31 percent; and the permeability from 0 to 553 millidarcies (5). The oil has an API gravity of 50.8°, a specific gravity of 0.776, a pour point below 5° F., a sulfur content of 0.26 percent, a viscosity at 100° F. of less than 32 Saybolt Seconds, and a greenish-black color.

Thickness of the Swift (Ellis) sand ranges from 25 to 50 feet; porosity from 11 to 25 percent; and permeability from 12 to 162 millidarcies (5). The oil has the following general characteristics: API gravity, 50.6°; specific gravity, 0.777; pour point, below 5° F.; sulfur, 0.24 percent; viscosity at 100° F., below 32 Saybolt Seconds; nitrogen, 0.003 percent; and a greenish-black color.

The waters produced in the Cat Creek fields are compatible or when mixed do not form an insoluble compound. It is turned into local streams where it is used for irrigation and for stock water. It contains only 1,000 to 3,500 parts per million of salts.

The deepest well in the Cat Creek field was drilled in the NW¼SE¼NW¼ sec 21, T 15 N, R 30 E, on Mosby dome. It was drilled to 5,705 feet, total depth, approximately 700 feet into the Cambrian; no production was found below the Swift (Ellis).

A typical well, in SE¼NE¼ sec 9, T 15 N, R 29 E, shows the following formation depths, in feet: Mosby, 350; First Cat Creek, 1,080; Second Cat Creek, 1,400; Third Cat Creek, 1,525; Morrison, 1,710; Ellis, 1,869. Deeper horizons occur at approximately the following depths: Big Snowy group, 2,275; Madison, 4,050; and Cambrian, 5,100.

The West dome of Cat Creek field has been unitized with a total of 1,240 acres. There are two participating areas for the First and Second Cat Creek sands which total 787.50 acres. Plans are now underway to waterflood these two sands, using water from the Third Cat Creek sand. The initial cost of the waterflood project is estimated at $485,600; it is expected that this will about double the oil recovery from the field and extend the life of the field about 10 years. The planned water injection rate is 7,000 barrels of water a day at 600 psi pressure (5).

As of the end of 1961, the fields along the Cat Creek anticline had 116 producing oil wells, 45 shut-in oil wells, and 10 water-injection wells.

Annual oil production figures from the Cat Creek fields is tabulated in table 7.

In 1961, the average price for crude oil in the field was $2.63 a barrel, and the cumulative value of the production has been $35,923,960 (4).

TABLE 7. - Oil production (in thousands of barrels), Cat Creek Fields, Petroleum and Garfield Counties, Mont.

Year	Production	Year	Production
1920	236.8	1941	171.5
1921	1,350.5	1942	137.6
1922	2,201.9	1943	118.9
1923	2,080.8	1944	114.8
1924	1,529.2	1945	130.7
1925	1,234.5	1946	483.7
1926	1,003.2	1947	586.3
1927	775.7	1948	510.3
1928	610.7	1949	460.0
1929	487.6	1950	398.3
1930	414.8	1951	324.9
1931	356.9	1952	270.8
1932	312.1	1953	208.6
1933	262.3	1954	200.5
1934	236.0	1955	173.6
1935	292.8	1956	164.0
1936	254.2	1957	164.8
1937	223.6	1958	171.2
1938	211.9	1959	150.8
1939	195.7	1960	180.8
1940	181.7	Total	19,575.0

Source: Montana Oil and Gas Conservation Commission. Montana Oil and Gas Statistics, Statement for 1961.

Genou Field

Genou field is the name given to a one-well gas area in sec 4, T 26 N, R 2 E, Pondera County, Mont. (fig. 3). The well was drilled in the SE¼SE¼SE¼ sec 4, T 26 N, R 2 E, to a total depth of 2,140 feet and completed March 6, 1950, as a "small gas well." The only formation tops reported were at the following depths: Kootenai, 1,400 feet; Sunburst, 1,845 feet; and Madison, 1,980 feet. At a plugged back depth of 1,300 feet the gas-producing zone is in the lower Colorado Shale (Upper Cretaceous), probably in a thin stray sand.

There has been no commercial production from the well, and it is being reported as a shut-in gas well.

Guinn Dome

The Guinn dome is a small anticline on the south flank of the Little Rocky Mountains in Phillips County, Mont. Like the Little Rocky Mountains, it is believed to be of igneous origin.

The dome lies in T 24 N, R 24 E, and the surface formations are the Judith River and Claggett (both of Upper Cretaceous age). In 1931, gas was discovered in the Eagle sand (Cretaceous) at depths of 500 to 670 feet. An open flow test by the Geological Survey on July 22, 1931, gaged gas at a rate of 2,034,000 cubic feet per day with a shut-in pressure of 190 psi. Analysis of the gas showed the following: Carbon dioxide, 0.1 percent; oxygen, 0.0 percent; methane, 58.8 percent; ethane, 2.3 percent; and nitrogen, 38.8 percent; and helium, 0.06 percent. The heating value of the gas was 633 Btu per cubic foot.

Deepest test on the structure was drilled in 1923 and 1924 to total depth of 2,035 feet with the top of the Madison (Mississippian) at 2,015 feet; hot water flowed from the Madison at an estimated rate of 40,000 barrels a day.

Gas has never been commercially produced from the field, and two of the six wells drilled on the structure were reported as shut in at the end of 1961.

Havre Field

The Havre field is a virtually abandoned gasfield in Tps 32 and 33 N, R 16 E, Hill County, Mont. (fig. 3). It is a small, nearly east-west trending faulted anticline in surface beds of Judith River formation (Upper Cretaceous).

The field was discovered in 1914, and gas was piped to the town of Havre where it was marketed for about 10 years. The initial potential ranged from 1 million to 15 million cubic feet of gas a day. Production was from the Eagle sand (Cretaceous) at depths of from 950 to 1,140 feet. Reservoir pressure was reported to be between 400 and 540 psi. Analysis of the gas shows the following: Methane, 94.8 percent; carbon dioxide, 0.2 percent; and nitrogen, 5.0 percent. A check of the gas for helium, made in 1918, showed 0.27 percent. Heating value was 897 Btu per cubic foot. Much water was encountered both above and below the producing sand. It is reported that improper completion of certain wells permitted water to enter the gas sand, and this eventually forced abandonment of the field (6, p. 75).

During the life of the field, 27 gas wells were drilled, 4 wells are now shut in, and the remainder have been abandoned. There is no record of these tests below the Eagle sand.

Available data showing the production figures are given in table 8.

TABLE 8. - Gas production (millions of cubic feet), Havre Field, Hill County, Mont.

Year	Production	Year	Production
1916	51.9	1926	32.7
1917	168.9	1927	([1])
1918	136.0	1946	15.9
1919	71.5	1947	-
1920	27.0	1948	23.1
1921	39.7	1949	9.9
1922	40.6	1950	1.7
1923	43.2	1951	1960 Unknown
1924	31.6	1961	4.8
1925	32.9	Total	731.4

[1] From 1927 through 1945 there was no production.
Source: Geological Survey records, Great Falls, Mont.

Sherard Structure

The small Sherard anticline lies in sec 17, T 25 N, R 17 E, Chouteau County, Mont. It is in the area of shallow peripheral thrust faulting southwest of the Bearpaw Mountains.

Gas was discovered in 1922 when the Huebschwerten No. 1, NE¼NE¼NE¼ sec 17, T 25 N, R 17 E, flowed gas at rates of 3 million and 20 million cubic feet per day from depths of 1,050 and 1,750 feet, respectively; the lower horizon has been identified as Eagle Sandstone (Upper Cretaceous).

An analysis of the gas showed the following composition and characteristics: Methane, 94.9 percent; carbon dioxide 0.2 percent; oxygen, 0.2 percent; nitrogen, 4.7 percent; specific gravity, 0.576; and heating value, 980 Btu per cubic foot (6).

No commercial gas has been produced; one well, however, is still reported (December 1961) as shut in.

Winifred Field

The Winifred structure is a small northwest-trending fold approximately 6 miles south of the Missouri River in Tps 21 and 22 N, Rs 17 and 18 E, Fergus County, Mont. (fig. 3). It is near the outermost limits of the peripheral thrust faulting surrounding the Bearpaw Mountains. Surface elevation is approximately 3,400 to 3,500 feet. Surface formations are Judith River and Claggett shale (Upper Cretaceous).

Little information is available on the field. It appears that the first well on the structure was drilled in 1934 in the SW¼SW¼SW¼ sec 24, T 21 N, R 17 E; this well is also apparently the deepest test in the field, having reached a total depth of 3,305 feet in the Kootenai. It reported a show of oil and gas.

Altogether, 11 wells have been drilled in the area; three reported gas shows in the Eagle formation at depths ranging from 450 to 1,000 feet, no gages have been reported. No gas has been commercially produced. At the end of 1961, five wells were reported shut in.

An analysis made in 1941 of the gas from Winifred shows the following components: Methane, 90.74 percent; ethane, 1.71 percent; nitrogen, 7.43 percent; hydrogen sulfide, 0.07 percent. The specific gravity was 0.591 and the gross heating value is 941 Btu per cubic foot.

Production Facilities

Oil and Gas Pipelines

To prevent confusion in the terminology in this report, the definition of production facilities as used herein means pipelines and refineries. It is assumed that all wells in the area capable of producing oil or gas have the required surface or wellhead facilities necessary for the production of oil or gas.

The first pipeline in the area was the gasline from the Havre field to the town of Havre, which was built and placed in operation in 1915. The first oil pipeline was the one from Cat Creek field to the town of Winnett. The line was 16 miles long and connected with the railroad at Winnett. It was built in 1922.

Major gas pipelines (fig. 3) were built to most of Montana's cities during the 1930's. All of the present oil pipelines were built after World War II. In fact, northern Montana crude could not be moved out of the state by pipeline until late in 1960.

Several pipelines cross the western and northern parts of the study area. In the north, Montana Power Co. has facilities connecting the gasfields of Bowes, Havre, and Box Elder with some of the towns in northern Montana. These facilities include (within the study area) 24 miles of 8-inch pipeline, 19 miles of 6-inch, and 22 miles of 4-inch line. From the Sweetgrass arch to Great Falls, Montana Power Co. also has a 12-inch diameter pipeline of which 79 miles are within the study area. Montana Power Co. has a 12-inch branch line serving Great Falls from its 20-inch-gas pipeline from Cut Bank to Anaconda; 34 miles of this lies within the area. A 6-inch pipeline provides gas to the town of Lewistown.

The Phillips Pipe Line Co. 5-inch oil pipeline from Cut Bank serves the Phillips refinery at Great Falls; 59 miles of this line are within the study area; 130 miles of the Glacier Pipe Line Co. 8-inch line from Cut Bank to Byron, Wyo., crosses the area of study. Although the actual pipelines are outside the area, it should be mentioned that the Cat Creek field is connected with both the Powder River pipeline to Billings and the Glacier pipeline to Byron, Wyo. Yellowstone Pipe Line Co., has a 6-inch finished-product line from Helena to Great Falls; 41 miles lies within the study area.

<u>Refineries</u>

The Phillips Petroleum Co. refinery at Great Falls, built in 1922, is the only active refinery in the study area. By August 1924 it had a throughput of 3,000 barrels of crude oil a day. The method of refining was the simple distillation or "skimming" process. In 1924 about 40 percent of the gasoline produced at the plant was exported from Montana. Ownership of the plant changed in 1932, and the throughput was lowered to 2,500 barrels of crude oil daily. In 1933, the plant throughput was further reduced to 1,000 barrels a day. The plant ownership changed in 1947 and again in 1949. Cracking facilities were installed in 1946. Since 1949 the plant has been modernized and now uses most of the processes found in the larger eastern refineries. The Oil and Gas Journal of March 19, 1962, lists the refinery as having a calendar day capacity of 4,500 barrels of crude oil.

Following the discovery of the Bannatyne field in 1927, a small topping plant was built in the field and used until 1935 to process the oil produced.

Two small refineries located just outside of the study area are the Diamond Asphalt Co. plant in Chinook (T 33 N, R 19 E), which processes the heavy black, asphalt-base crude oil from the Bowes field, and the Jet Fuel Co. refinery at Mosby (T 14 N, R 30 E). Both plants have a rated capacity of 1,500 barrels of crude oil daily.

Potential of Present and Future Oil and Gas Production

Engineering calculations of recoverable oil and gas remaining in the fields of the Basin Study Area are not feasible. Technological advances in secondary or tertiary recovery of oil and possible secondary recovery of gas would upset any current estimates. However, records of the Montana Oil and Gas Commission public hearings and comparisons with similar fields give reasonable estimates of future production.

Primary production of oil from the fields is about completed and secondary recovery projects are being started. An expected remaining 25 million barrels of both primary and secondary oil will be recovered from the existing fields. This estimate is based on current ratio of cost to sale price of oil and reported remaining oil content of the sands. Any increase in the sale price of crude oil would encourage the production of additional oil, while a decrease in the sale price would tend to have the opposite effect. Assuming an average price of $2.15 a barrel for this anticipated oil production, the gross value would be $53,750,000.

Estimation of future gas production from existing fields in the study area is in the nature of a guess based upon experience. There is no obvious reason why the Bowes field should not produce for at least 3 more years and possibly 6. Thus, we can expect gas production ranging from 3 to 6 billion cubic feet. Based on an estimated value of $0.15 per thousand cubic feet, such gas would be worth from $450,000 to $900,000.

The ultimate oil and gas potential of the study area cannot be adequately evaluated on the basis of drilling accomplished to the present time. The discovery of oil, particularly in stratigraphic-type traps, is closely related to the concentration of drilling and the resultant concentration of geologic data within a given area. In some areas of the mid-Continent oil region the well density may average as high as one or two wells for each square mile. The study area totals roughly 18,000 square miles; within which approximately 188 wells have been drilled to the Madison formation to give a well density of 1 well for each 96 square miles; of these, 42 were drilled to formation deeper than the Madison for a well density of 1 well for each 430 square miles.

The already complex problem of finding oil in this area is further complicated because considerable igneous activity has occurred here. One well, for example, (in T 29 N, R 18 E) while drilling 4,925 feet to the Cambrian encountered seven igneous sills. Numerous unconformities in the area effectively mask the underlying formations; the igneous activity, shallow thrust faulting, and burned coal beds offer great obstacles to the efficient use of the seismograph in mapping the deeper beds.

In 1962, petroleum exploration in Montana was directed toward (1) the Devonian and older Paleozoic rocks in the northeastern part of the State (which became of interest because of the discoveries at Tule Creek and Dwyer fields); (2) the Tyler sand southeast of the area (the Sumatra area); and (3) the pre-Mississippian formations on the Sweetgrass arch northwest of the area. In the future, this activity may move into the Basin Study Area as oil companies exhaust more favorable possibilities elsewhere.

The petroleum prospects of the area may be summed up with the statement that although they are not completely condemned, they are not very favorable.

Economic Feasibility of Development

Operations in the oil and gas fields in the area have ranged from marginal to highly profitable. It obviously has not been economically feasible to develop the gas shows at Armells, Winifred, Guinn, Genou, and Sherard; the probable reasons are distance from market, small structures, low heating value, and small gas flow. The future potential of the areas just mentioned is dependent on an increased demand for gas in western and north-central Montana. At present, there is ample gas available from existing fields in Montana and Alberta, Canada, which may retard the development of new gasfields in the study area.

Any plans for a park area should recognize the possibility of oil or gas in commercial quantities being found on either side of the Missouri River. Provision should be made for the building of future pipelines across the river. In a relatively treeless area such as the study area, the traces of the pipeline would be virtually unnoticeable after 1 or 2 years.

Coal

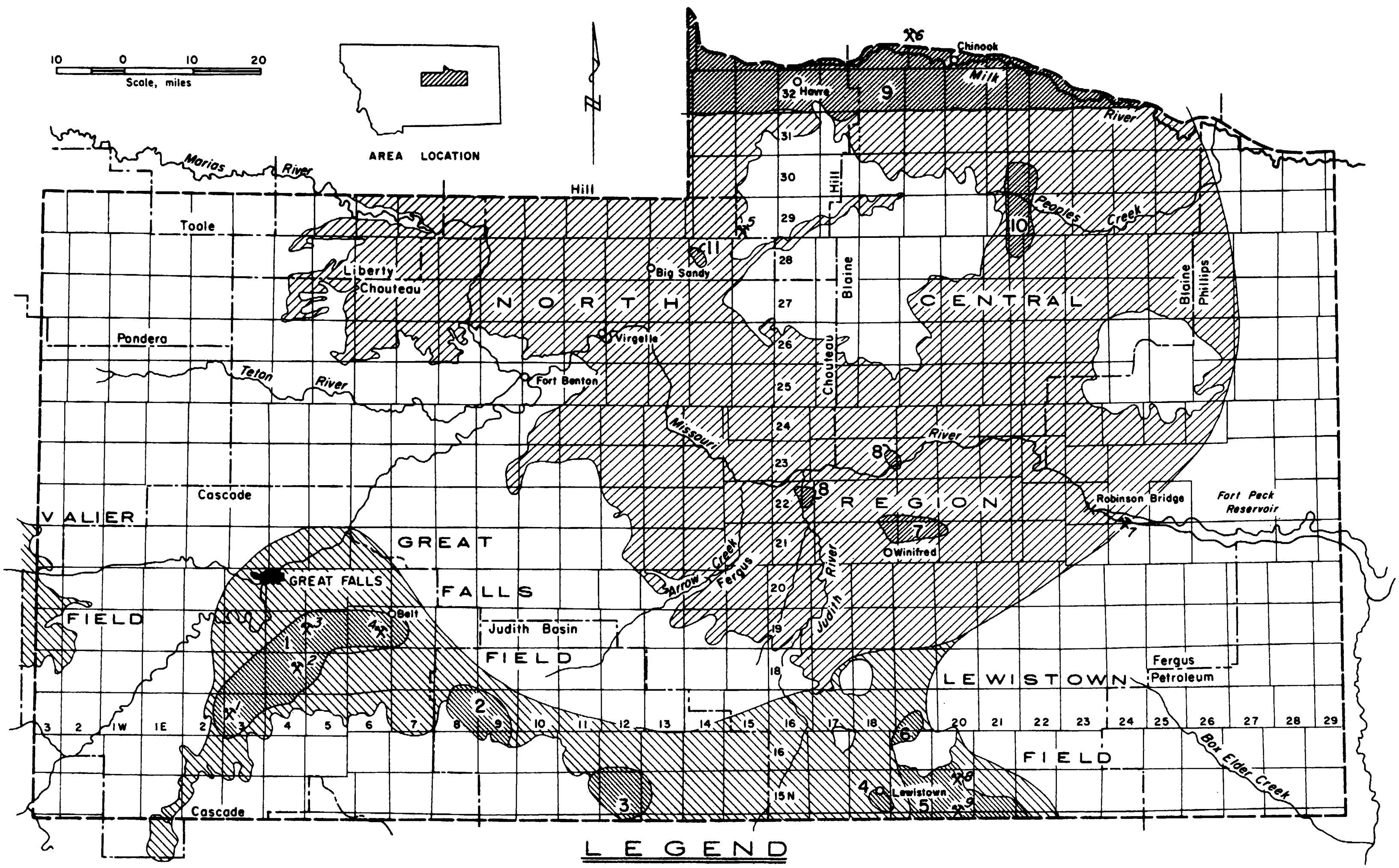
General

The coal fields in the Upper Missouri Basin Study Area comprise that part of the North-central field south of the Milk River, the Great Falls field, the northern part of the Lewistown field, and the Cascade County portion of the Valier field as shown on the map (fig. 4). The coal-bearing formations are of Cretaceous and Upper Jurassic age; the coal is bituminous and subbituminous in rank. No lignite beds of economic significance occur in the study area.

Great Falls Field (19, 26)

The Great Falls coalfield lies principally in Cascade County with a southeastward extension into Judith Basin and Fergus Counties, merging into the Lewistown field on the east (fig. 4).

The total area of the Great Falls field exceeds 1,000 square miles; however, the workable coalbeds are found in only three areas: (1) Sand Coulee basin (2) Otter Creek and, (3) Sage Creek districts.



LEGEND

GREAT FALLS FIELD	LEWISTOWN FIELD	NORTH CENTRAL REGION	RECENTLY PRODUCTIVE MINES		SYMBOLS
1 Sand Coulee Basin	4 Spring Creek District	7 Winifred District	1 Loveland	6 Milk River	Bituminous
2 Otter Creek District	5 McDonald Creek District	8 Judith River District	2 Canyon	7 Russell	Subbituminous
3 Sage Creek District	6 Warm Springs District	9 Milk River District	3 Surmi	8 Swanson	Mine
		10 Cleveland District	4 East Belt	9 Tuss	
		11 Big Sandy District	5 Rocky Boy		

FIGURE 4. - Coalfields, Missouri Basin Study Area. (Modified from U.S.G.S. Coal Investigations Map C2.)

The coal is of Upper Jurassic age. Coal beds are overlain by 1 or 2 feet of shale, followed by 60 feet of massive gray sandstone. Regional dip is about 5° northward except in a narrow belt at the base of the Little Belt Mountains where dips increase to 10° or 15°.

The coalbeds vary widely in thickness, comprising one, two, or sometimes three benches separated by bone or shale partings. Workable beds range from 4.5 to 15 feet thick.

Virtually all the coal produced in the Great Falls field has come from Cascade County. Yearly production is shown in table 9. The output from Judith Basin and Fergus Counties has been small and intermittent. Yearly output in Cascade County exceeded a million tons in 1896, 1897, 1900, 1907, 1917, and 1918, but has declined to a few thousand tons in recent years. Total production has been close to 36 million tons of bituminous coal valued at more than $75 million.

TABLE 9. - Coal production, Cascade, Blaine, and Hill Counties, Mont. (exclusive of mines producing less than 1,000 tons)

Year	Production, short tons	Average value per ton	Total value
GREAT FALLS FIELD			
Cascade County:			
(1880-1950)	(35,901,180)		
1951	18,105	$5.41	$97,900
1952	3,242	6.31	20,500
1953	1,738	5.89	10,200
1954	7,186	5.04	36,200
1955	2,348	6.17	14,500
1956	3,198	6.16	19,700
1957	2,098	6.34	13,300
1958	1,816	6.77	12,300
1959	1,922	6.40	12,300
1960	1,850	6.50	[1] 12,000
Total	43,500	-	248,900
NORTH-CENTRAL FIELDS			
Blaine County:			
1951	10,275	6.32	64,900
1952	8,472	6.39	54,100
1953	6,540	6.42	42,000
1954	6,750	7.00	[1] 47,300
1955	7,030	7.90	55,500
1956	5,830	7.83	45,600
1957	5,228	7.85	40,900
1958	4,343	7.85	34,100
1959	4,650	8.09	37,600
1960	3,967	8.01	31,800
Total	63,085	-	453,800

[1] Estimated.

TABLE 9. - Coal production, Cascade, Blaine, and Hill Counties, Mont. (exclusive of mines producing less than 1,000 tons)--Con.

Year	Production, short tons	Average value per ton	Total value
NORTH-CENTRAL FIELDS			
Hill County:			
1951	-	-	-
1952	-	-	-
1953	-	-	-
1954	-	-	-
1955	1,350	$9.00	$12,200
1956	1,230	10.00	12,300
1957	1,118	10.00	11,200
1958	-	-	-
1959	1,200	10.00	[1] 12,000
1960	-	-	-
Total	4,898	-	47,700

[1] Estimated.

Source: Bureau of Mines. Minerals Yearbook, 1951-60.

Sand Coulee Basin

This basin, a few miles south of Great Falls, is about 32 miles long, extending from near the confluence of Hound Creek and Smith River northeastward to the town of Belt, Cascade County (fig. 4). It covers about 231 square miles. General usage has subdivided the Sand Coulee basin into the Smith River (Hound Creek), Sand Coulee, and Belt districts.

Belt was one of the earliest coal-producing districts in the State; coal mining started at the town of Belt in 1876. The Sand Coulee basin bas been the largest producer in the Great Falls field, with maximum output occurring from about the early 1900's to about the end of World War I.

Most of the coal produced in the Great Falls field was used by the transcontinental railroads that pass through the State and by Montana's nonferrous metal smelters. A small quantity of coal from a 5- to 7-inch seam in the Anaconda coal mine at Belt was used for coke. The Anaconda Co. operated coking ovens at Belt for a short time, but the practice was abandoned because of the difficulty and expense of separating the coking coal from the noncoking coal. The mine has been closed for several years.

Virtually all coal in the Belt district has been mined by underground methods, generally room and pillar. The coal ranks as bituminous high volatile; it does not slake appreciably in air and ships well. Pyrite nodules and lenses are common, and the ash content is medium to high. The beds range from 4.5 to 7 feet thick in three benches with partings of bone or other impurities. Usually the full thickness of the bed has been mined.

The coalbed in the Sand Coulee district is 8 to 14 feet thick, consisting of four benches. Only the lower two benches, totaling 7 to 10 feet thick, have been mined.

The Smith River district coalbeds also consist of four benches, but the total bed thickness is 5 to 12 feet and only 5 to 6 feet has been mined.

During the early period of greatest productivity, the Anaconda mine at Belt, the Cottowwood mine at Stockett, the Nelson and Gerber mines near Sand Coulee, and the Carville mine near Smith River were the principal producers. They are no longer active. During the last 10 years the East Belt, Canyon, Latham, Surmi, and Loveland mines in the Sand Coulee basin have been intermittently active (18). Table 10 lists the mines with reported coal analyses. Table 11 lists the recently active mines.

Otter Creek District (14, 19, 22)

The Otter Creek coal district covers about 37 square miles along Otter Creek in T 16 N, R 9 E, T 17 N, Rs 8 and 9 E, Judith Basin County (fig. 4).

Output from this district did not exceed a few thousand tons, produced by "wagon mines" for local use.

The coal occurs as only one bed about 4 feet thick. Sampling was recorded in two mines, the Nollar and the Meredith; the sample analyses are in table 10.

There are no active mines at present in the Otter Creek district.

Sage Creek District (14, 19, 22)

The Sage Creek coal district is at the eastern end of the Great Falls field near the town of Windham, principally in T 15 N, R 12 E, Judith Basin County (fig. 4).

Only one coalbed occurs in this district. It has a total thickness ranging from 6 to 18 feet. The minable coal is about 4.5 feet thick, separated by two bony partings. The Hughes and the Seman mines were sampled (table 10). The Sage Creek district is nonproductive at present.

Lewistown Field (17, 19)

Only the northern portion of the Lewistown coalfield lies within the Basin Study Area. The field extends northward from Lewistown, Mont., merging with the North-central field to the north, and extends southwestward to merge with the Great Falls field on the west (fig. 4). The present investigation covers the workable coalbeds in the Warm Spring Creek, McDonald Creek, and Spring Creek districts in Fergus County.

TABLE 10. - Coal mines with sampling record, Upper Missouri Basin Study Area, Montana

County and mine	Sec	T	R	District	Formation	Rank	Date sampled	Bed thickness		Sample thickness		Dried coal			
								Ft	In	Ft	In	Volatile, percent	Fixed carbon, percent	Ash, percent	Btu/lb
							GREAT FALLS COALFIELD								
Cascade County:															
Richardson........	36	19N	6E	Belt	Kootenai	[1] B	1906	4	10.5	3	10.5	27.4	52.4	20.2	11,280
Hill..............	36	19N	6E	do.	do.	B	1906	5	0	3	2	25.7	57.8	16.5	10,990
Millard...........	26	19N	6E	do.	do.	B	1906	5	10.5	5	4	32.0	48.4	19.6	-
Anaconda..........	26	19N	6E	do.	do.	B	1906	5	10	4	10	27.4	53.1	19.5	10,890
Orr...............	23	19N	6E	do.	do.	B	1906	6	2	4	1	22.7	47.1	30.2	8,690
Bickett...........	32	18N	4E	Smith River	do.	B	1906	7	9	7	1	28.5	48.5	23.0	10,550
Patterson.........	20	17N	3E	do.	do.	B	1906	4	10	4	7	28.8	55.5	15.7	12,990
Carville..........	24	17N	2E	do.	do.	B	1906	5	6	5	0	28.8	50.2	21.0	10,970
Deep Creek........	18	17N	3E	do.	do.	B	1927	5	10	4	6	34.8	52.5	12.7	12,180
Geiber............	23	19N	4E	Sand Coulee	do.	B	1906	9	4	8	10.5	29.5	55.6	14.9	11,900
Cottonwood........	26	19N	4E	do.	do.	B	1906	11	5	7	4	30.3	54.7	15.0	11,870
Judith Basin County:															
Nollar............	29	17N	9E	Judith Basin	Otter Creek	B	1906	4	0	4	0	28.2	55.2	16.6	11,100
Meredeth..........	3	17N	9E	do.	do.	B	1906	4	10	3	7	27.6	50.4	22.0	-
Hughes............	19	15N	12E	do.	Sage Creek	B	1906	6	1	4	8	27.6	49.1	23.3	9,870
Seman.............	20	15N	12E	do.	do.	B	1906	5	11	4	7	32.6	50.6	16.8	11,260
							LEWISTOWN COALFIELD								
Fergus County:															
Mace..............	32	17N	19E	Warm Spring Creek	Kootenai	B	1907	4	4	3	7	28.2	55.8	16.0	12,060
Nevin.............	7	16N	19E	do.	do.	B	1907	3	4	2	6	30.7	45.8	23.5	10,110
Brew Parson.......	32	16N	19E	do.	do.	B	1907	6	2	5	8	30.6	49.7	19.7	10,750
Sherman...........	33	16N	20E	McDonald Creek	do.	B	1907	3	9	3	3	32.1	58.8	9.1	11,320
Shipley...........	33	16N	20E	do.	do.	B	1907	2	0	1	7	28.4	59.9	11.7	11,730
Cliffe............	3	15N	20E	do.	do.	B	1907	2	10	2	9	28.9	60.9	10.2	12,510
Gold Reef.........	9	15N	20E	do.	do.	B	1907	3	0	2	10	32.6	58.5	8.9	12,840
Flaherty..........	18	15N	20E	do.	do.	B	1907	-	-	3	10	31.8	46.8	21.4	10,550
Peiper............	6	14N	20E	do.	do.	B	1927	3	10	2	10	31.0	59.6	9.4	12,020
Tuss..............	19	15N	20E	do.	do.	B	1927	4	0	3	7	37.5	54.1	8.4	12,940
Spring Creek......	26	15N	18E	Spring Creek	do.	B	1907	4	10	3	0	34.3	56.8	9.8	12,540
Sharp.............	13	15N	19E	do.	do.	B	1907	3	6	2	9	32.4	58.5	9.1	12,720
Hamilton..........	24	15N	19E	do.	do.	B	1907	5	5	4	4	33.9	55.9	10.2	12,490
Black Diamond.....	25	15N	19E	do.	do.	B	1907	4	4	4	4	31.9	56.4	11.7	12,150
Calderwood........	31	22N	19E	Winifred	Judith River	[2] Sub	1914	4	6	2	1	35.9	48.8	15.3	10,980
Hahn..............	7	21N	20E	do.	Eagle	Sub	1921	4	5	3	8	36.7	52.3	11.0	11,170
Tuss..............	11	21N	18E	do.	do.	Sub	1921	5	9	3	1	40.4	43.4	16.2	10,520

NORTH-CENTRAL COALFIELDS

Blaine County:															
Ruby Gulch........	21	21N	23E	-	Judith River	Sub	1921	4	6	3	0	33.9	46.0	20.1	9,810
John McClellan....	13	23N	18E	-	do.	Sub	1922	5	9	4	2	36.3	50.6	13.1	10,950
Joe Shellenberger.	33	23N	22E	-	do.	Sub	1922	4	9	3	11	41.9	47.1	11.0	10,900
Landusky No. 2....	21	23N	22E	-	do.	Sub	1924	3	0	3	0	34.9	44.1	21.0	10,040
Hill County:															
Cook..............	25	30N	20E	Cleveland	do	Sub	1912	3	6.5	3	1	38.8	49.7	11.5	11,250
Alcott............	29	33N	16E	Milk River	do.	Sub	1908	5	2	3	2	35.0	51.4	13.6	10,770
Havre.............	31	33N	16E	do.	do.	Sub	1908	5	9	2	6	30.5	56.2	13.3	10,530
Kinney............	26	33N	15E	do.	do.	Sub	1908	3	6	2	6	38.0	48.3	13.7	10,660
Electric..........	29	32N	16E	do.	do.	Sub	1908	4	8	3	6	38.0	44.8	17.2	10,240
Brown.............	21	32N	17E	do.	do.	Sub	1908	5	4	4	11	33.4	43.7	22.9	9,250
Barrott's.........	29	33N	15E	do.	do.	Sub	1908	4	0	3	3	37.3	45.3	17.4	10,000
Staton's..........	4	31N	17E	do.	do.	Sub	1908	5	9.5	4	11.5	37.7	52.8	9.5	11,070
Clack.............	5	31N	17E	do.	do.	Sub	1908	5	2	4	2	37.6	52.6	9.8	11,140
Milk River........	7	33N	19E	Milk River	do.	Sub	1927	5	11	5	3	38.6	51.9	9.5	11,510
Kerr..............	30	32N	20E	do.	do.	Sub	1908	3	4	2	11	36.2	49.4	14.4	-
Roder.............	5	31N	19E	do.	do.	Sub	1908	4	7	3	2	34.6	52.7	12.7	11,150
Raeder............	5	31N	19E	do.	do.	Sub	1926	11	5	6	4	36.4	50.5	13.1	11,100
Government........	1	31N	23E	do.	do.	Sub	1921	9	0	2	6	38.1	47.2	14.7	9,950
McDaniels.........	9	33N	22E	do.	do.	Sub	1908	2	6	2	1	57.3	25.7	17.0	9,880
Choteau County:															
Machton...........	18	28N	14E	Big Sandy	Ft. Union	Sub	1912	7	6	6	1	41.7	46.1	12.2	11,060
Nygard............		28N	14E	do.	do.	Sub	1927	3	10	3	10	38.8	53.9	7.3	11,850
Mack..............	18	28N	14E	do.	do.	Sub	1908	6	10	4	6	40.6	51.9	7.5	11,670
Van Buskirk.......	20	25N	16E	do.	Judith River	Sub	1922	14	10	8	0	38.4	43.0	18.6	10,260
Deda..............	6	24N	13E	do.	Eagle	Sub	1914	2	6	2	4	35.8	50.4	13.8	11,140
Lehfehlt..........	23	24N	15E	do.	do.	Sub	1922	6	0	3	0	37.1	42.7	20.2	9,960

VALIER COALFIELD

Cascade County:															
Rimmer............	19	19N	2W	Valier	Kootenai	B	1921	3	10	2	7	33.1	43.8	23.1	10,810

[1] Bituminous.
[2] Subbituminous.

Source: Bureau of Mines Technical Paper 529 (14).

TABLE 11. - Recently active coal mines, Upper Missouri Basin Study Area, Montana

County and mine	Sec	T	R	District	Formation	Rank	Bed thickness		Sample thickness		Dried coal			
							Ft	In	Ft	In	Volatile, percent	Fixed carbon, percent	Ash, percent	Btu/lb
LEWISTOWN COALFIELD														
Fergus County:														
Swanson.......	10	15N	20E	McDonald Creek	Kootenai	[1] B	2	2	-	-	-	-	-	-
Tuss..........	34	15N	20E	do.	do.	B	4	4	-	-	-	-	-	-
NORTH-CENTRAL COALFIELDS														
Blaine County:														
Milk River....	7	33N	19E	Milk River	Judith River	[2] Sub	8	0	7	6	27.5	40.9	7.2	11,650
Rocky Boy.....	31	29N	15E	do.	do.	Sub	4	6	-	-	35.2	46.3	18.5	10,970
Russell.......	33	22N	24E	do.	do.	Sub	4	0	-	-	-	-	-	-
Capplette.....		29N	15E	-	do.	Sub	-	-	-	-	-	-	-	-
GREAT FALLS COALFIELD														
Cascade County:														
East Belt.....	23	19N	6E	Sand Coulee	Kootenai	B	7	0	-	-	-	-	-	-
Canyon........	14	18N	4E	do.	do.	B	5	6	-	-	-	-	-	-
Loveland......	19	17N	3E	do.	do.	B	5	8	-	-	-	-	-	-
Surmi.........	18	19N	5E	do.	do.	B								
Latham........	25	19N	4E	do.	do.	B	6	0	-	-	-	-	-	-

[1] Bituminous.
[2] Subbituminous.

All workable coal is at the same stratigraphic horizon as in the Great Falls field. The areas are limited in extent. Between workable coal areas the coal-bearing horizon contains a carbonaceous shale. The coal is bituminous and subbituminous, and breaks into cubical or rectangular form providing lump coal well suited for domestic use. Pyrite is common in nodules and small lenses.

All mining in the Lewistown field has been underground. Beds are relatively thin but dips are moderate, and the coal is generally of good quality.

Production has been intermittent and probably does not exceed several hundred thousand tons. Where annual coal production from a county is small, or output is from one or two mines, the production is combined with one or more other counties of similar output in official Bureau of Mines records (16). Thus, there is no accurate record available from Fergus County. Current production is about 1,000 tons a year.

Warm Springs District (19)

The Warm Springs district is in the embayment of the Judith Mountains, drained by Warm Springs Creek (fig. 4). The best part of the coal is in an area of about 3 square miles, and does not extend north of Warm Springs Creek. Samples were recorded from the Mace and the Nevin mines (table 10). No operations are currently active.

McDonald Creek District (17, 19)

The most productive district of the Lewistown field is the McDonald Creek district. At one time, in the early 1900's, there were at least 17 mines operating in the district. It covers an area of about 126 square miles on the headwaters of McDonald Creek, south of the town of Giltedge, and 10 to 12 miles east of Lewistown (fig. 4). Most of the coal was used locally; some was used by the Montana Railroad. Mines in the district are listed where sampling has been recorded (table 10). Two small producers (Swanson and Tuss mines) are currently active when a local market is available (table 11).

Spring Creek District (17, 19)

The Spring Creek district is also known as the Lewistown district, as it is in the Spring Creek drainage just south of Lewistown (fig. 4). The Spring Creek mine, 2 miles south of Lewistown, was the largest single producer in the Lewistown Field. Sampling and analyses are recorded in table 10. The district is now inactive.

North-Central Region (19)

The part of the north-central coal region included in this study is in Fergus, Blaine, Phillips, Chouteau, and Hill Counties south of the Milk River (fig. 4).

The total area considered to be underlain by coal-bearing formation exceeds 5,000 square miles; however, known workable coalbeds cover much smaller, widely scattered areas. The extent and thickness of the coalbeds are difficult to determine because glacial drift over much of the area obscures possible outcrops.

Coalbeds occur in the Eagle and Judith River formations of Upper Cretaceous age. Locally, as in the Big Sandy mine, a down-faulted section has preserved a coal-bearing horizon in the Fort Union formation of Tertiary age. The coal is generally subbituminous; however, high volatile bituminous has been found locally.

Production has come principally from the Milk River district along both sides of the Milk River in Hill and Blaine Counties. The Milk River mine, near Chinook, has been the chief producer during the past decade. Production figures are given in table 9 for Blaine and Hill Counties.

Blaine County output has ranged from 4,000 to 10,000 tons per year over the past 10 years and has exceeded Cascade County production in all but 2 years.

Winifred District (19)

The Winifred district is a few miles north of the town of Winifred in Fergus County (fig. 4). Subbituminous coal occurs in beds 4 to 7 feet thick.

Two mines (Hahn and Tuss) produced on a small scale in the 1920's. Their locations and sample analyses are given in table 10. There is no current production from the Winifred district.

Judith River District

The Judith River district comprises an area near the confluence of the Judith and the Missouri Rivers and another small area about 12 miles downstream from the mouth of the Judith River as shown on figure 4. The coal is in the Judith River formation with beds 2 to 6 feet in thickness.

The John McClellan mine was a small producer in this district during the 1920's. Its location and a sample analysis is given in table 10. The Joe Shellenberger, Ruby Gulch, and Russell mines are all near the Missouri River, several miles farther downstream. The Russell has been a small producer within the last decade and is listed in table 11.

Cleveland District (12, 19)

The Cleveland district is east of the Bearpaw Mountains and on the western boundary of the Fort Belknap Indian Reservation, Blaine County (fig. 4).

Coalbeds are found only in the upper part of the Judith River formation; it is of subbituminous rank. Only the Cook mine has a recorded sample for the district. Sample data and analysis is given in table 10. There are no currently producing mines in the district.

Milk River District (19, 24, 25)

The Milk River district comprises a belt of workable coalbeds on both sides of the Milk River extending from near Harlem on the east to beyond Havre on the west, a distance of about 60 miles. The belt is about 20 miles wide, covering about 1,200 square miles in Blaine and Hill Counties.

Structure in this area is complex. Numerous faults and folds have caused vertical and lateral offsets of the coalbeds and, in places, tilted the beds at high angles.

Workable subbituminous coal, occurring in the Judith River formation, ranges from 3 to 8 feet thick.

The Milk River is by far the most productive district in the North-central field. It is subdivided into four areas according to proximity to the main towns, Havre, Chinook, Harlem, and Big Sandy.

The Havre area surrounds the town of Havre, Mont. In the early 1900's it was highly productive, with at least two large mines.

The Chinook area is in the vicinity of the town of Chinook immediately east of the Havre area. It was also a productive district in the early days and is currently producing a small tonnage at one mine. Mines which have been sampled and recorded are listed in table 10. The only active mine, the Milk River, is listed in table 11.

The Harlem area is east of the Chinook and in the vicinity of the town of Harlem. Minable coal is 2 to 3 feet thick; production has been small. Table 10 shows the mines with a recorded sample. There is no present production.

Big Sandy District (13)

The Big Sandy district is on the west side of the Bearpaw Mountains, in the vicinity of the town of Big Sandy. A down-faulted block has preserved a section of Tertiary Fort Union formation containing workable coalbeds. The Mackton, Nygard, Rocky Boy, and the Mack mines are in the Fort Union formation.

The Rocky Boy mine on the Rocky Boy Indian Reservation is currently operating to serve local agency and private demand. Its location and sample analysis are shown in table 11.

Several mines are scattered south of Big Sandy. The Van Buskirk mine is in sec 20, T 25 N, R 16 E, about 35 miles southeast of Big Sandy. It is in the Judith River formation, and the coalbed is 14.8 feet thick. The Deda mine is in sec 6, T 24 N, R 13 E, about 16 miles southeast of Virgelle. It is in the Eagle formation; the coal measures 2.5 feet thick. The Lehfehlt mine is in sec 23, T 24 N, R 15 E, 2 miles northeast of Iliad. It is in the Eagle formation with about a 6-foot-thick bed. These mines are listed in table 10.

Valier Field

The southeastern corner of the Valier coalfield extends into the western side of the Basin Study Area.

About 50 square miles in Tps 19 and 20 N, Rs 2 and 3 W, Cascade County, are reported to be underlain by coal-bearing formation. Minable coal is about 3 feet thick; the coal ranks as bituminous. Table 10 lists the sample and an analysis from the only mine (Rimmer) sampled in the area.

Production Facilities (14, 16)

Producing mines in the Upper Missouri Basin Study Area are small seasonal operations to supply a local demand for domestic fuel. They are the "wagon mine" type. Surface plants for washing, sizing, or even for efficient handling are nonexistent, or limited to a screen and loading bin.

Operating Mines (See Table 11.)

Swanson Mine. - This mine is presently operating in the Lewistown field, McDonald Creek district, about 13 miles east of Lewistown. It is in sec 10, T 15 N, R 20 E, Fergus County, on public domain. The lessee and operator is William S. Swanson, Sr. This is a one-man operation, using only hand labor for coal handling underground. The mine is opened by two level drifts, and the coal bed averages 26 inches in thickness. The mine supplies coal to the local market. There is no surface plant.

Tuss Mine. - The Tuss mine is also in the Lewistown field, McDonald Creek district. It is on public domain in sec 34, T 15 N, R 20 E, Fergus County, about 16 miles southeast of Lewistown. The mine is opened by three drifts and a vertical shaft. The coalbed averages 52 inches in thickness.

C. M. Tuss is the lessee and operator; two men are employed. Only hand labor is used for coal handling underground. The mine operates during the winter months to supply the local demand. There is no surface plant.

Milk River Mine. - The Milk River mine is in the Milk River coalfield, Chinook district. It is situated in sec 7, T 33 N, R 19 E, Blaine County, about 4.5 miles northwest of the town of Chinook. The owners and operators are L. W. and C. L. Sargent. Hand labor is used underground for coal handling. The tipple is equipped with a gravity screen and loading bins for stoker and lump coal.

The mine is opened by a rock slope. It has produced about 400,000 tons from a bed averaging 7.5 feet thick. The coal is sold at the tipple to local consumers.

Rocky Boy Mine. - This mine, northeast of the town of Big Sandy, is on the Rocky Boy Indian Reservation in sec 31, T 29 N, R 15 E, Hill County. The owners are the Chippewa-Cree Indians. The permittee and operator is Alfred Laursen. It is a one-man operation; all underground loading is hand labor.

The mine is opened by two rock slopes. The coalbed averages 54 inches in thickness. There is a gravity screen and loading bin at the tipple. Coal is sold to the Indian Agency and employees for heating.

East Belt Mine. - The East Belt mine is in the Belt district of the Sand Coulee basin of the Great Falls coalfield in sec 23, T 19 N, R 6 E, about 1 mile southeast of the town of Belt in Cascade County.

The operator is Samuel E. Williamson. Two men are normally employed underground.

The mine is opened by a level drift and a vertical shaft. The coalbed averages 84 inches in thickness and dips 4° northeasterly. The mine has no surface plant.

Canyon Mine. - The Canyon mine is in the Sand Coulee district of the Great Falls field in sec 14, T 18 N, R 4 E, about 10 miles south of the town of Sand Coulee, Cascade County.

The mine belongs to the Canyon Coal Co., Sand Coulee, Mont. Two men are employed in the operation. The mine generally operates from November to March to supply the local demand for fuel.

A level drift and a rock slope provide entry to the mine; the coalbed is 5 to 6 feet thick. There is no surface plant.

Loveland Mine. - The Loveland mine is in the Smith River district of the Great Falls coalfield. It is in sec 19, T 17 N, R 3 E, about 17 miles southeast of Cascade, Mont.

The mine belongs to Earl Loveland who operates it during the winter season to supply the local market for coal. Two men are employed underground. There is no surface plant.

A 300-foot tunnel provides entry to the mine. The coalbed averages 68 inches in thickness.

Potential of Present and Future Coal Production (11, 19)

Coal reserves are reported by counties in the Basin Study Area as estimated original coal reserves (table 12). "The measured and indicated reserves include coal for which information was available from outcrop, mine workings, and drill records. The continuity of the coal beneath the surface was limited to less than 2 miles from the outcrop and more than 50 percent is less than 1 mile. This limits the depth in practically all instances to less than 2,000 feet below the surface. Inferred reserves include, in general, the coal within the areas of outcrops, but at a distance of more than 2 miles from the outcrop (19)."

Of this estimate of original coal reserves, only Cascade County has any appreciable amount of coal removed by mining operations. Deducting the recorded production of about 36 million tons from the measured and indicated reserves of 390 million, leaves about 345 million tons of measured and indicated reserves in Cascade County.

TABLE 12. - Estimated original coal reserves in Missouri Basin Study Area, Montana

Coal rank and county	Measured and indicated reserves, millions of short tons				Inferred reserves, millions of short tons				Unclassified as to thickness	County total, million of short tons
	14-24 inches bed thickness	24-36 inches bed thickness	+36 inches bed thickness	Total	14-24 inches bed thickness	24-36 inches bed thickness	+36 inches bed thickness	Total		
Bituminous coal:										
Cascade..........	81.1	74.7	234.1	389.9	38.4	-	6.8	45.2	-	435.1
Judith Basin.....	65.7	45.7	44.2	155.5	54.9	29.1	3.8	87.8	-	243.3
Fergus...........	59.3	83.4	126.8	269.4	31.2	30.7	10.1	72.0	-	341.4
Total.........	206.1	203.8	405.1	814.8	124.5	59.8	20.7	205.0	-	1,019.8
Subbituminous coal:										
Fergus...........	1.5	-	-	1.5	0.1	-	-	0.1	-	1.5
Blaine...........	-	-	-	-	21.6	-	-	21.6	18.1	39.7
Hill.............	28.0	-	-	28.0	48.5	-	-	48.5	-	76.5
Phillips.........	-	-	-	-	3.5	-	-	3.5	-	3.5
Chouteau.........	0.9	0.6	-	1.5	-	-	-	-	-	1.5
Total.........	30.4	0.6	-	31.0	73.7	-	-	73.7	18.1	122.7
Grand total...	236.5	204.4	405.1	845.8	198.2	59.8	20.7	278.7	18.1	1,142.5

Source: Geological Survey. Coal Resources of Montana, Geol. Survey Circ. 53.

Coal is potentially the most valuable mineral resource within the Upper Missouri Basin Study Area. The reserves are relatively intact, only small areas have been depleted. The decline in production from more than a million tons per year to the present few thousand tons per year is due to the lack of demand caused by changing patterns of utilization.

Virtually all coal produced in the study area in the past has been mined by underground mining methods. No on-the-site study has been made of reserves amenable to strip mining within the boundaries of the study area. Furthermore, much of the North-central coalfield in Blaine and Hill Counties is covered by glacial material which effectively masks the coal formations which otherwise might be exposed.

Some areas probably exist where large tonnages of coal of both bituminous and subbituminous rank could be produced by low-cost strip-mining methods with modern equipment. Exploratory drilling will be needed to determine their location.

Underground mining costs could be reduced by mechanization. Cleaning methods could be devised to produce a useable product from some of the coal high in ash or other impurities (23). Improved exploration methods could be used to detect coal beneath a reasonably shallow cover of glacial material.

Economic Feasibility of Development (15)

Some reversal in the coal usage pattern has already occurred in several sections of the Nation where large demand for electric power has resulted in an increased rate of construction of steam-electric plants, many of which are coal fired.

Demand for electric energy in Montana is presently adequately supplied by hydroelectric power with help from four thermal plants, but foreseeable future requirements can be met only by thermal electric-power generation. In 1956 the Washington Water Power Co. examined the Loveland Mine in Cascade County as a possible source of coal for steam-electric generation. Modern steam-electric power plants are competitive in cost of electric energy produced with hydropower, provided fuel costs are reasonable.

Much research has been done on cost-saving methods in the field of coal production. Hydraulic mining and pipeline transport are among the newer methods studied. Better mining methods utilizing new and better machines, such as the continuous miner, the coal auger, the coal planer, and conveyor belt and shuttle car underground transport, could increase the production per man-hour and substantially reduce the cost of coal mining.

Improved methods of utilization and development of new uses for coal are under study, and some are in the pilot plant stage.

A new carbonization process, in pilot plant stage, at Kemmerer, Wyo. will convert a subbituminous coal into metallurgical-grade coke and also produce a byproduct gas which can be used to produce ammonia and methanol. Tests indicate the coke can be used in electric furnaces.

Coal-gasification research has shown that coal can be gasified in place, underground, with air or oxygen, to produce gas suitable for steam-electric power generation. This process is being used in the U.S.S.R. at present.

Hydrogenation is another process for converting coal into other products of value for an established market such as synthetic liquid fuel and chemical raw materials (15, p. 123).

Experiments are being conducted to make fertilizer from coal by treatment with nitric acid and ammonia. The product is called Hu-mi-sol and is reported to contain more than 60 weight-percent nitro-humic acid salt with 8 percent available nitrogen. A pilot plant is under construction in Japan (18).

The far-reaching development of power transmission systems has made it feasible to locate steam-electric generating plants at the site of the coal mine or adjacent to the mine, providing an adequate water supply is also available. Elsewhere, pipeline transport of coal has proved efficient in terms of competitive cost.

The economic feasibility of development of the coal resources in the Basin Study Area depends primarily on the overall basin development. Increase in population and new industries will create demand for more power which can be produced by coal-fired steam-electric power plants. Development of chemical and related industries based on coal for raw materials is a sound future prediction. A Montana iron and steel industry using Montana iron ore is probable in the future. It would provide another market for coal or coke.

Metals (42, 44, 45, 46, 59)

The metalliferous deposits are directly related to igneous intrusives; however, the deposits and the host rocks differ greatly in the various mountain groups. Some of the mountains contain no known metal deposits. The Little Rocky, Judith, Little Belt, and North and South Mocassin Mountains are dome-shaped uplifts formed by laccolithic intrusions and have accounted for all the mineral output. The Highwood and Bearpaw Mountains comprise large areas of extrusive volcanic rock and have no recorded metallic mineral production.

Nonferrous Metals (28, 29-33, 38, 40)

Mineral production, as published by the Bureau of Mines since 1924 and by the Geological Survey before that date, is reported on a county basis. Table 13 shows the nonferrous mineral output for the four producing counties in the Basin Study Area. The table indicates the small output during the last 10 years. The total nonferrous metal production has been about $52.5 million, of which gold accounts for about 48 percent, silver 29 percent, lead 15 percent, zinc 6 percent, and copper 2 percent.

TABLE 13. - Nonferrous metal production, Upper Missouri Basin Study Area, Montana
(In units of recovered metal and value)

Location and year	Ore sold or treated, tons	Gold		Silver		Copper		Lead		Zinc	
		Troy ounces	Value	Troy ounces	Value	Pounds	Value	Pounds	Value	Pounds	Value
Cascade County											
Little Belt Mountains:											
1889-1950..........	-	35,538	$987,085	15,815,000	$12,122,000	7,950,000	$1,115,000	67,176,000	$4,850,000	18,712,000	$1,848,000
1951...............	920	13	455	10,000	9,000	2,000	(2)	10,000	17,000	22,000	4,000
1952...............	2,149	14	490	18,000	16,000	-	-	94,000	15,000	76,000	13,000
1953-55[1]...........	-	-	-	16,000	14,000	-	-	32,000	5,000	28,000	3,000
1956-57[1]...........	-	6	210	43,000	39,000	-	-	114,000	17,000	122,000	15,000
1958-60[3]...........	-	-	-	-	-	-	-	-	-	-	-
Total..........		35,571	988,240	15,902,000	12,200,000	7,952,000	1,115,000	67,426,000	4,904,000	18,960,000	1,883,000
Fergus County											
Judith, North and South Moccasin Mountains:											
1886-1950..........	-	607,787	13,642,249	168,000	144,000	34,000	6,000	441,000	27,000	162,000	10,000
1951...............	350	-	-	(2)	(2)	14,000	3,000	-	-	-	-
1952...............	12	-	-	(2)	(2)	-	-	-	-	-	-
1953-54[1]...........	-	14	490	2,000	2,000	2,000	1,000	6,000	1,000	2,000	(2)
1955[3].............	-	-	-	-	-	-	-	-	-	-	-
1956-59[1]...........	-	201	7,035	1,000	1,000	-	-	40,000	5,000	12,000	1,000
1960[3].............	-	-	-	-	-	-	-	-	-	-	-
Total..........	-	608,002	13,649,774	171,000	147,000	50,000	10,000	487,000	33,000	176,000	11,000
Judith Basin County											
Little Belt Mountains:											
1921-50............	-	4,017	97,225	2,667,000	1,598,000	860,000	124,000	46,411,000	2,980,000	17,998,000	1,196,000
1951...............	209	6	210	4,000	3,000	2,000	(2)	108,000	19,000	36,000	7,000
1952...............	106	4	140	3,000	2,000	-	-	64,000	10,000	24,000	4,000
1953...............	80	1	35	1,000	1,000	-	-	32,000	4,000	10,000	1,000
1954...............	307	4	140	1,000	1,000	-	-	94,000	13,000	6,000	1,000
1955...............	64	-	-	(2)	(2)	-	-	10,000	1,000	-	-
1956-58[1]...........	254	7	245	2,000	2,000	1,000	1,000	62,000	9,000	10,000	1,000
1959[3].............	-	-	-	-	-	-	-	-	-	-	-
1960...............	30	-	-	(2)	(2)	-	-	10,000	1,000	2,000	(2)
Total..........	-	4,039	97,995	2,678,000	1,607,000	864,000	125,000	46,791,000	3,037,000	18,086,000	1,210,000
Phillips County											
(Little Rocky Mountains:											
1903-50............	-	406,015	10,340,922	1,577,000	1,036,000	(2)	(2)	12,000	1,000	5,000	1,000
1952[3].............	-	25	-	-	-	-	-	-	-	-	-
1952[3].............	-	-	-	-	-	-	-	-	-	-	-
1953-54[1]...........	-	-	525	1,000	1,000	-	-	-	-	-	-
1955...............	6	4	140	(2)	(2)	-	-	-	-	-	-
1956-60[1]...........	-	1,354	47,390	26,000	24,000	-	-	-	-	6,000	1,000
Total..........	-	407,398	10,388,977	1,584,000	1,061,000	(2)	(2)	12,000	1,000	11,000	2,000

[1] Production for more than 1 year grouped to avoid disclosing individual company confidential data.
[2] Value is less than $500.
[3] No nonferrous metal production reported.

Source: Geol. Survey, Mineral Resources of the United States, 1885-1923; Bureau of Mines, Mineral Resources of the United States, 1924-31; Bureau of Mines, Minerals Yearbook, 1932-60.

The principal nonferrous metal production in the study area has come from mines yielding gold-silver and silver-lead-zinc ores. The gold-silver mines are mainly in the Little Rocky, Judith, and North Moccasin Mountains, with minor mineralization in the South Moccasin Mountains. Those yielding silver-lead-zinc ore are in the Little Belt Mountains.

Gold-Silver Deposits

The gold-silver deposits generally occur in or near a contact zone between limestone and syenite-porphyry.

In Fergus County about 50 gold mines and prospects are known in the Judith and North and South Moccasin Mountains. Ten of these properties have reported most of the production (48). In the Little Rocky Mountains of Phillips County, about a dozen properties have reported production. The major production has come from about half of them (31, 32, 38, 40).

With a few exceptions, the gold ore produced was low grade; however, some of the ore bodies were relatively large for gold-silver deposits and recovery was by an inexpensive cyanidation process. Low-cost mining and treatment provided for several profitable operations before World War II and prior to War Production Board (WPB) Order L-208 in 1942. The cost of rehabilitating and reopening the mines, coupled with the unfavorable economic position of gold since the war, has discouraged any major attempts to reactivate the gold mines.

Silver-Lead-Zinc Deposits

The silver-lead-zinc deposits are principally in the northern part of the Little Belt Mountains in Cascade and Judith Basin Counties. By far the largest production has come from the Neihart district in Cascade County. Next in importance is the Barker district in Judith Basin County (49).

Although the Little Belt Mountains are similar in origin to several other mountain groups in the study area, the mineral deposits are quite different. The Neihart district lead-silver-zinc veins are in pre-Beltian gneisses and schists, which are thought to be altered igneous rocks.

With one major exception, the ore occurs as relatively small, steeply dipping ore shoots averaging 3 to 5 feet in thickness and ranging in length up to 600 feet. The exception is the Silver Dyke mine, with an ore body occurring as a large mineralized mass of brecciated porphyry.

More than 50 veins have contributed to the $21 million metal production from Cascade County, principally from the Neihart district (49).

Prospects are numerous along the north end of the Little Belt Mountains in Judith Basin County. However, the Block P mine, in the Barker district, has accounted for almost all of the $6 million production from this county (50).

Other mines in the Barker district are reported to have produced small tonnages.

Processing Plants

Great Falls Reduction Works (31, 32, 40). - The Great Falls Reduction Works, a major metallurgical complex, is situated on the north bank of the Missouri River at Black Eagle in the Great Falls area. It is owned and operated by The Anaconda Co. and employs about 2,000 people.

The original plant was built in 1891-93 by the Boston and Montana Consolidated Copper and Silver Co. for the concentration of Butte copper ore and for electrolytic copper refining. In 1910 the plant was acquired by The Anaconda Copper Co., later renamed The Anaconda Co.

An electrolytic zinc plant and a copper rod, wire, and cable manufacturing plant were constructed in 1916-18.

The original copper refinery was enlarged in 1926, and again in 1957-59. It was undergoing a modernization program in 1961-62. The electrolytic zinc plant was enlarged in 1925, and again in 1942, and has had several improvements since 1942. The rod, wire, and cable plant was enlarged in 1925, and its operation was later transferred to The Anaconda Wire and Cable Co., a subsidiary of The Anaconda Co. A new mill was built in 1954-55, to manufacture aluminum rod, wire, and cable from the aluminum metal produced at the company plant at Columbia Falls, Mont.

The copper refinery treats copper anodes from the Anaconda smelter at Anaconds, Mont. The refinery operated at near its rated capacity of 24.5 million pounds of electrolytic copper a month during 1961 (31). Copper produced averages 99.955 percent pure.

The electrolytic zinc plant treats zinc concentrates from the Anaconda mill at Anaconda and from other sources in the Western States, Canada, Mexico, and South America. The refinery has a capacity of 27 million pounds of zinc a month which makes it probably the largest zinc refinery in the world. The zinc plant operated at from 50 to 75 percent of capacity during 1961 (31). Cadmium, a byproduct, was produced at the rate of approximately 100,000 pounds a month.

The Great Falls Reduction Works is one of the largest consumers of electric energy in Montana. Power is supplied by the Montana Power Co., chiefly from hydroelectric plants at Rainbow, Ryan, Morony, and Black Eagle Dams on the Missouri River in the vicinity of Great Falls. Natural gas, also supplied by Montana Power Co., is used as fuel in the metallurgical processes and for space heating.

An estimate of the electric energy consumption capability of the copper refinery based on a factor of 320 kwhr per ton of metal is 47.04 million kwhr a year; and of the zinc plant using a factor of 3,700 kwhr per ton of metal is 599.4 million kwhr a year. The energy consumption capability of the entire works, if operated at full capacity for a year, would probably be in the range of 650 to 675 million kwhr.

An estimate of the natural gas consumption capability of the copper refinery, assuming 100,000 Btu per cubic foot of natural gas and based on a factor of 5 million Btu per ton of metal, is 7.35 million cubic feet a year; that of the zinc plant, based on a factor of 2.5 million Btu per ton of metal is 4.05 million cubic feet of gas annually. The total gas consumption capability of the works operating at full capacity for a year is about 12 to 15 million cubic feet.

Concentration. - Many flotation and cyanide mills have operated in the region through the years, but most of them have been removed or have deteriorated into ruins.

Frequently when concentrating equipment is needed at a newly discovered deposit, the needed equipment at idle plants in nearby areas is purchased, moved, and set up at the new discovery. In this manner much concentrating equipment is used over and over.

Mining companies reporting concentrating equipment in 1960 are shown in table 14 (34).

TABLE 14. - Ore Concentrating Plants in Missouri Basin Study Area, Montana

County and property	Sec	T	R	Type of Mill	Daily capacity tons	Main commodity
Cascade County						
Lexington............	28	14N	8E	Flotation	125	Lead, silver, zinc.
Star.................	29,30	14N	8E	Flotation	50-75	Lead, silver, zinc.
Phillips County						
Hawkeye..............	7	25N	25E	Flotation	100	Gold.
Little Ben...........	15	25N	24E	Flotation	50	Gold.
Ruby Gulch...........	17	25N	25E	Cyanide	500	Gold.
Judith Basin County						
Yogo Sapphire Mines..	19,24	13N	11E	Washing plant	([1])	Sapphire.

[1] Capacity of washing plant, 100 cubic yards per day.

Source: Montana Bureau of Mines and Geology, Bull. 20, 1960 (34).

Potential of Deposits for Production and New Development

Since many of the gold-silver mines were closed during World War II by Government directive, it is evident that all the ore in the study area has not been mined and that some (probably low-grade) reserves remain to be exploited.

Likewise, in some areas such as the Neihart district in the Little Belt Mountains, mining has nearly exhausted the ore in the near surface enriched zones, but lower grade primary mineralization remains at deeper horizons (49).

Future production from these deep-seated deposits (presently submarginal) will depend on improved mining technology to provide a low-cost method of exploitation.

New ore discoveries are generally made on the margins or in close proximity to known mineralized districts. New and improved methods of prospecting and exploration should provide means for finding presently unknown or hidden ore bodies in the Missouri Basin Study Area.

Economic Feasibility of Development

The current low market price for most metals relative to the overall price index and to the present higher costs of production coupled with the generally low-grade nature of the deposits has discouraged continued output from active mines or the reopening of inactive ones in the study area. Production from gold-silver deposits has been especially retarded since WPB Order L-208, which in effect, closed all gold mining operations in October 1942 for the duration of World War II. During these years of idleness, the underground mines became inaccessible; surface facilities so deteriorated that large outlays of capital would be required to rehabilitate the properties. These capital outlays could not be justified in view of the reduced margin of profit in the period following the close of the war.

It is unlikely that metal mining in the study area will show any substantial gain under present conditions. However, if cost-price relations improve, due to higher metal prices or advances in technology of production, renewed interest and activity will be likely to follow. A prominent mining company, with widespread interests, optioned properties and conducted a substantial sampling program in the Little Rocky Mountain district after 1960.

Mining large tonnages at great depths requires large amounts of capital for equipment and development costs. Consolidation of groups of properties or mines under one company or management may make large-scale development programs economically feasible in some areas (57).

Ferrous Metals and Alloying Metals

Iron Ore

A number of small iron ore deposits are known within the Basin Study Area. With few exceptions they are of the contact metamorphic replacement type. The predominant iron mineral is magnetite with varying amounts of hematite and limonite. In some deposits iron pyrite is present in amounts that limit its use for steel. Table 15 lists the known iron ore deposits in the study area.

The Running Wolf deposit in Judith Basin County is the only one that has been exploited. The open-pit workings are on the eastern end of several iron ore lenses along a limestone-syenite porphyry contact that can be traced for about 6 miles on the north flank of the Little Belt Mountains.

TABLE 15. - Iron ore deposits in Missouri Basin Study Area, Montana

County and property or deposit	Sec	T	R	Description	Indicated metal content, percent	Production	Remarks
Fergus County							
West Armels Creek Bog Iron.	7,17,18	17N	20E	Limonite and manganese was deposited from solution as cementing material in fluvial deposits along banks of creek. Thickness as much as 20 feet.	-	None	
Iron King	19	17N	20E	Vein type deposit magnetite-hematite, some pyrite in altered syenite. Approx. 10 feet thick, depth 100 feet, length not known.	42-50 Fe 2- 5 S	None	
Independent No. 3 and No. 4	12	17N	19E	Madison limestone granite porphyry contact. Narrow lenses of magnetite-hematite.	50 Fe	None	
Cascade County							
Hurricane Tornado	13	15N	6E	Length up to 20 feet in width along limestone-granite porphyry contact. Limonite, hematite, magnetite, some gold, some sulfides indicated.	52-54 Fe	None	Old pits and adit.
Albright	13 18	15N 15N	6E 7E	Same as Hurricane.	52-54 Fe	None	Do.
Judith Basin County							
Running Wolf	2,4 7	14N 14N	10E 11E	Replacement deposits in Madison limestone along syenite porphyry contact; magnetite and hematite. Lenses of iron ore averaging 5 to 15 feet in thickness.	Average of two lenses: 58.75 Fe 0.109 S 0.02 P less than 0.01 TiO_2.	Estimate 100,000 tons through 1960.	Has been operated since 1956.

In 1943 the Bureau of Mines explored the eastern end of the deposit by surface trenching and diamond drilling (51). Two lenses of ore were partly delimited. The east lens was indicated to be 500 feet long with an average thickness of 5 feet. The west lens was 1,100 feet long with an average thickness of 15 feet.

In 1956 the Young-Montana Corp. of Hibbing, Minn., started open cut mining on the west lens. Since 1956 it is estimated that about 100,000 tons of 63 percent iron ore was shipped, principally to eastern markets.

The mining activity of the Young-Montana Corp. created interest that resulted in some new exploration work along the 6-mile Running Wolf contact. A few new discoveries were made, but no data are available as to the tonnage of ore developed. No new mining operations were reported as a result of the exploratory work.

Iron ore of the quality produced at the Young-Montana mine is known as lump or open hearth ore. This class of iron ore is added to the charge in open-hearth steel furnaces.

Molybdenum

Molybdenum occurs in the Neihart district in the Little Belt Mountains (fig. 5). The Big Ben mining claims, 2½ miles northeast of Neihart, were located in 1922. This property was examined by several large mining companies between 1930 and 1938.

Molybdenite, associated with pyrite and quartz, occurs in a stock work of quartz veinlets and mineralized fractures and as disseminations in silicified zones. The principal host rock is quartz porphyry and, to a lesser extent, diorite.

In 1943 the Bureau of Mines sampled the accessible underground workings and diamond-drilled four holes with a combined length of 1,385 feet. Ore reserves based on this work were estimated within the range of 3 million tons containing 0.23 percent MoS_2.

Several other occurrences of molybdenum are known in the Neihart district. The American Smelting and Refining Co. explored for molybdenum on Carpenter Creek northwest of the Big Ben deposit in 1958. Since 1959 American Metal Climax, Inc., has been working in the Big Ben area. Results of recent exploration work are not known.

Tungsten

Scattered tungsten mineralization is present in contact metamorphosed limestone at the Blue Dick property in secs 30 and 31, T 14 N, R 10 E, Judith Basin County. The tungsten content is not sufficient to be considered ore.

The Big Ben molybdenum ore contains approximately 0.01 percent tungsten trioxide (41).

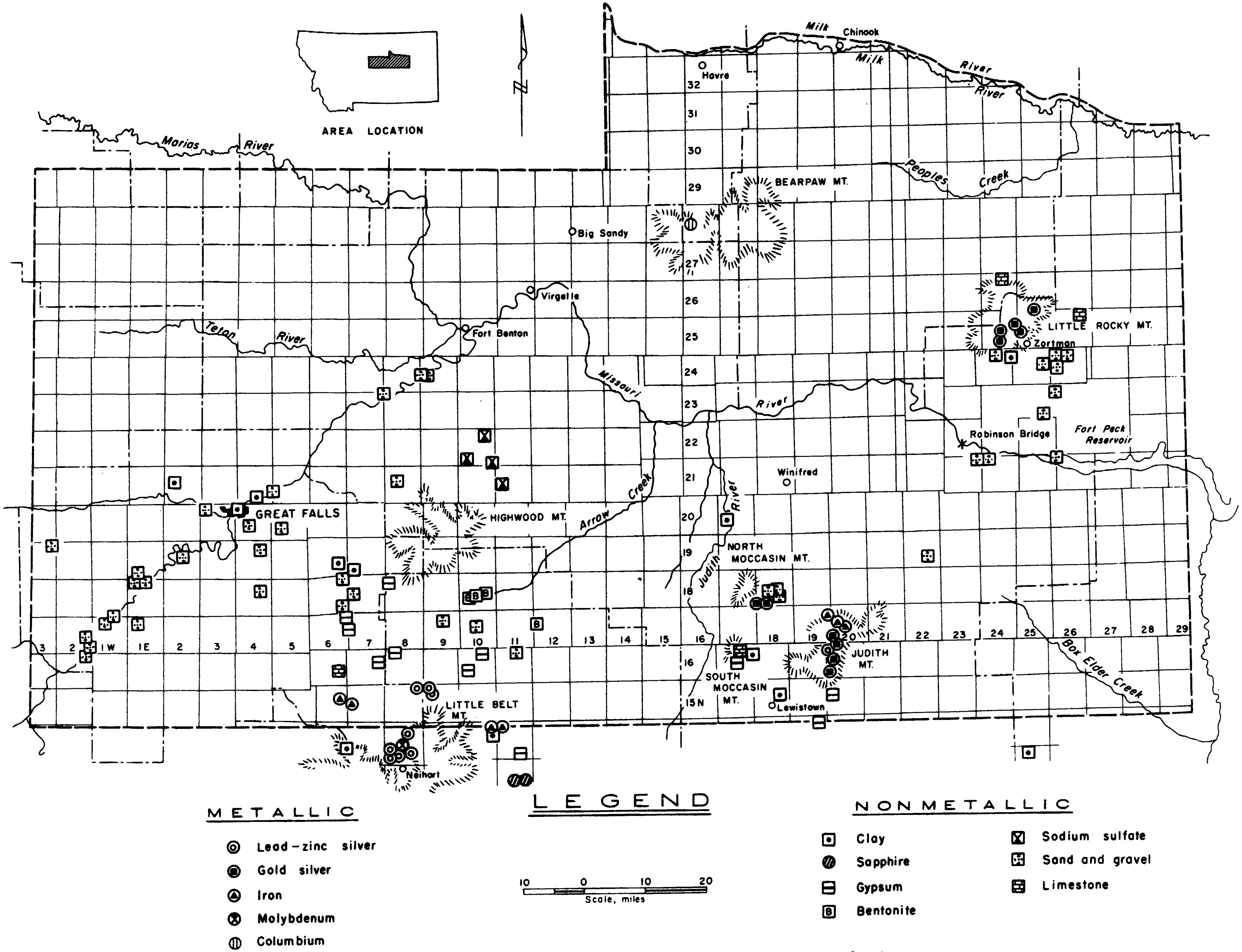


FIGURE 5. - Mineral Resources, Missouri Basin Study Area.

Columbium

No columbium has been produced in the area, but because the demand for the metal and for ferrocolumbium is expanding it should be mentioned. This is especially true in view of the presence of large areas in the region underlain by alkali-rich rocks. "The geologic association of columbium-tantalum-bearing minerals is principally with alkali igneous rocks, especially nepheline syenite, and granite. Carbonatites associated with alkali rocks and pegmatites associated with granites and syenites also contain columbium-tantalum minerals (27)."

Potassium-rich rocks are present in many of the mountain groups. Pecora describes silicate-carbonate-sulfide pegmatites in porphyritic potassic syenite on the Rocky Boy Indian Reservation in the western part of the Bearpaw Mountains in Hill County (44).

In 1957 the Texas Instruments Co., Inc. of Dallas, Texas, obtained a uranium prospecting permit from the Chippewa-Cree tribe on certain areas in sec 19, T 28 N, R 16 E, in the southeast corner of the reservation. Seven diamond-drill holes totaling 5,161 feet did not disclose uranium ore of commercial grade. However, the drilling, together with some underground drifting and crosscutting, indicated the possible presence of substantial amounts of a fine-grained, zircon-bearing, apatite-pyrochlore rock (fig. 5).

The pyrochlore, probably in the form of hatchettolite, contains uranium, columbium, and tantalum; however, it was found that the pyrochlore-bearing rock was not amenable to the standard methods of uranium extraction techniques. The Texas Instruments Co. concluded that the grade and available tonnage indicated were not sufficient to justify the large milling research program required to develop an economic method of extraction.

From the underground workings, two ore piles measuring 30 tons and 60 tons, respectively, were stockpiled on the dump. Grab samples from these ore piles were taken by a Bureau of Mines engineer and analyzed with the following results:

Sample:	Cb_2O_5, percent	Ta_2O_5, percent
Grab from 30-ton ore pile from drift.........	0.44	<0.05
Grab from 60-ton ore pile from crosscut......	0.17	<0.05

Potential of Deposits for Production and New Development

The iron ore deposits within the Missouri Basin Study Area are relatively small lenticular ore bodies of generally high-grade magnetite except for the bog iron on West Armells Creek. Individual ore bodies contain a few thousand to possibly a few hundred thousand tons of iron ore. As in the Running Wolf deposits, several lenses are sometimes closely spaced along a contact zone which may be followed for a mile or more.

Presently, the only iron ore consumed in Montana is used for cement manufacture at Trident, Mont. The nearest steel furnaces are several hundred miles distant at Provo, Utah; Pueblo, Colo.; Portland, Oreg.; and Seattle, Wash. About 100,000 tons of high-grade iron ore were shipped to eastern consumers for steelmaking, but the margin of profit is limited by the high freight cost.

The known iron-ore reserves in the study area are not large; however, coupled with the much larger deposits of lower grade iron-bearing material in nearby areas in Montana, sufficient tonnages are available for establishment of an iron and steel industry in central Montana. Several millions of tons of titaniferous magnetite iron ore are available in deposits in Teton, Pondera, and Glacier Counties within 100 miles shipping distance of Great Falls.

A steel plant at Great Falls would be well situated for low-cost electric power, natural gas, industrial water, labor, coal supply, and limestone. Population and industrial growth should eventually provide an adequate market for steel products within the market area of Great Falls.

The molybdenum deposit in the Neihart district, and possible columbium-tantalum deposits in the Bearpaw Mountains could contribute alloy metals for production of specialty steel products if a steel industry were established.

Economic Feasibility of Development

The development and mining of the iron ore deposits in the study area (except under special circumstances) is probably not economically feasible at present, because of the long haul to a market and the consequently high transportation cost coupled with a market price of only $12 to $14 for high-grade iron ore at point of delivery. Establishment of a steel industry in central Montana with possibly attendant demand for iron ore within 100 miles of the deposits conceivably might provide for profitable exploitation of iron ore deposits in the study area.

Iron deposits of the contact replacement type are characteristically very irregular in outline and boundaries. Open-cut selective mining methods are virtually mandatory, and the small size of most ore bodies limits the size of power shovels and other equipment which can be profitably employed. Mining costs are substantially higher than those at larger and more consistent deposits, but are somewhat compensated for by the generally higher grade of the ore. Production rate is also limited to small or moderate tonnages because of the physical environment.

It is conveivable that the iron deposits in the Upper Missouri Basin Study Area would provide a small annual tonnage of high-grade iron ore to a market within about 100 miles of the deposits.

The Big Ben molybdenum deposit in the Neihart district is favorably situated for open-cut mining with a stripping ratio estimated to be about 1 to 5. Several prominent mining companies have explored the feasibility of development. Profitable exploitation might be possible with a strong demand and favorable market price for molybdenum.

New uses for columbium metal have more than doubled the rate of consumption within the last 5 years. If this increase in demand continues, it is likely that an increasing interest will be shown by industry and the government in possible columbium-tantalum deposits in the Bearpaw Mountains and elsewhere in the basin study area.

Nonmetallics

Nonmetallic mineral deposits occurring in the Upper Missouri Basin Study Area include sand and gravel, limestone, clay, gypsum, gem stones (sapphire), sodium sulfate, and building and ornamental stone.

The nonmetallic mineral production, exclusive of coal and petroleum, from 1925 through 1960 was $24,437,921 (31, 32).

Sand and Gravel

The study area is one of the major producers of sand and gravel in Montana. For a number of years Cascade County has ranked either first or second among Montana counties in production of sand and gravel. Table 16 lists the production of this commodity from 24 sand and gravel operations in the producing counties of the study area during recent years.

TABLE 16. - Sand and gravel production, Missouri Basin Study Area, Montana

County	Sand and gravel, tons			
	1957	1958	1959	1960
Cascade	552,000	446,000	550,000	492,000
Chouteau	-	13,000	-	-
Judith Basin, Phillips, and Petroleum[1]	74,000	40,000	156,000	124,000
Fergus	-	8,000	12,000	3,000
Total	626,000	507,000	718,000	619,000

[1] Production of more than one county grouped to avoid disclosing individual company confidential data.

Source: Bureau of Mines records, Albany, Oreg.

Sand and gravel produced in the area is used for subbase and surfacing material for highways and streets, aggregate for concrete, and for railroad ballast.

Sand and gravel deposits are shown in figure 5. The deposits include stream, alluvial fan, and terrace sediments of Recent and Pleistocene ages.

Sand and gravel is plentiful in the study area and usually can be supplied from a nearby source. For concrete aggregate, pit-run material usually is washed and graded into different size products. Much of the concrete aggregate used in public projects is supplied by private contractors who are required to meet rigid specifications on quality. Processing is done in both stationary and portable crushing and screening plants.

A typical example of a large-scale sand and gravel operation is the Oscar Martenson sand-gravel plant, 8 miles southwest of Cascade in Cascade County. It supplied large quantities of aggregate for airbase, city paving, and other construction in the Great Falls area and for several dams on the Missouri River. The deposit is an old channel of the Missouri River. Pit-run material approximates the desired composition of concrete aggregate, but generally contains excess coarse sand and a small percentage of soft altered material.

Gravel is mined by a dragline, washed to remove soft altered material, and then screened to required sizes. Water is pumped from a previously mined pit and, after being used for washing, is returned to a second pit for settling. About 1,800 gpm of water is used. The connected load for the plant is about 250 hp which is supplied by the Montana Power Co.

Most of the sand and gravel produced is shipped via the Great Northern Railway to Great Falls and vicinity. About 20 men usually are employed in the operation (60).

Limestone

Madison limestone of Mississippian age forms prominent and extensive outcrops in most of the mountainous areas of the region. Cambrian age Pilgrim and Meagher limestone beds are present in the Little Belt and Big Snowy Mountains.

Limestone for early day smelter use in Great Falls was mined at the Albright Quarry about 35 miles southeast of the city (47).

The Three Forks Portland Cement Co. manufactured portland cement at Hanover, Fergus County, from 1918 to 1932. Limestone for the operation was quarried from the Madison formation in secs 10 and 11, T 16 N, R 17 E. It has been estimated that about 500,000 tons of limestone was mined from the quarry (43).

Limestone was mined from a quarry in the N½ T 26 N, R 24 E, at the north edge of the Little Rocky Mountains. The limestone was used at the sugar mill while it operated at Chinook, Mont. (28).

Clay

Clay is classified by the Bureau of Mines for statistical purposes into six groups. They are kaolin, ball clay, fire clay, bentonite, fuller's earth, and miscellaneous clay (36). These classifications are based largely on the principal use to which the clay is put. Kaolin is used for filler and coater in the paper industry. The manufacture of pottery, stoneware, and tile are the major markets for ball clay. Refractories and heavy clay products are the major uses for fire clay. The principal uses of bentonite are for oil-well drilling mud and foundry sand. Fuller's earth is used principally as an absorbent for insecticides and fungicides. The manufacture of clay products such as building brick, sewer pipe, and draintile, and production of lightweight aggregate are the major uses for miscellaneous clay.

The Montana Bureau of Mines and Geology currently is sampling and testing clay deposits in the State. The results of these tests are published from time to time (55, 56). Table 17 lists clay samples tested from the Upper Missouri Basin Study Area.

Clay deposits in this area include kaolin, fire clay, bentonite, and miscellaneous clay.

Kaolin

A deposit of the kaolin mineral dickite occurs in the South Moccasin Mountains near Lewistown, Fergus County. The deposit was explored by the Bureau of Mines in 1943 as a possible source of alumina for aluminum production owing to its high percentage of available alumina, 32 to 37 percent (52). Although the indicated tonnage proved insufficient for an alumina operation, it could be considered of high quality for other purposes.

It is reported that clay of similar quality has been found in thin beds in the southern part of the Little Rocky Mountains, Phillips County.

Fire Clay

Fire clay has been mined for many years near Armington, Cascade County, by The Anaconda Co., for making refractory brick for the smelter at Anaconda, Mont. The tonnage mined is not reported, but probably does not exceed 2,000 tons per year.

The clay is mined from a bed about 4½ feet thick in the lower part of the Cretaceous Kootenai formation (39). The flat-lying bed crops out for several miles in the bluffs bordering Otter and Belt Creeks and their tributaries.

Bentonite

Bentonite occurs at numerous places in the Colorado shale formation. Apparently, most of it does not meet drilling-mud specifications.

An extensive deposit crops out in secs 20, 21, 22, and 23, T 18 N, R 10 E, Judith Basin County, about 4 miles east of Geyser (50). It has been exposed by bulldozer trenches at intervals over a distance of more than 1½ miles. The bed is nearly flat lying and ranges in thickness from 6 to 10 feet. It is covered overburden 2 to 20 feet thick. A small amount of the bentonite has been used locally for lining irrigation ditches and reservoirs.

Other deposits of bentonite have been mined in southern Phillips County. This bentonite has been used under the Agriculture Conservation Program for sealing stockwater and irrigation works. One-half the cost is refunded to the farmer or rancher by the Government.

TABLE 17. - Clay samples tested by Montana Bureau of Mines and Geology, Missouri Basin Study Area, Montana

Sample No.	County	Sec	T	R	P.C.E.	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	TiO_2	Possible use
24	Fergus	22	20N	17E	-	73.6	12.4	-	-	-	1.7	2.1	0.2	Not suitable.
25	do.	22	20N	17E	8-9	76.6	10.9	2.8	0.8	0.3	-	-	.2	Useable if blended.
63	Cascade	NE¼ 34	21N	4E		51.6	20.6	3.5	1.0	3.4	1.9	1.9	.4	Expanded lightweight aggregate.
64	do.	7	20N	4E		51.0	22.0	4.0	1.6	2.5	1.4	2.0	.4	Not suitable.
65	do.	SE¼ 20	21N	2E		52.8	22.3	4.8	2.2	2.6	1.4	2.2	.56	Expanded lightweight aggregate.
66	do.	SE¼ 20	21N	2E		58.7	19.3	4.2	4.2	2.7	1.7	2.0	.6	Not suitable.
67	do.	31	19N	7E	20	48.6	29.0	5.2	.4	.7	.7	1.0	.76	Fire brick stoneware.
68	do.	26	19N	6E	30	51.0	26.9	4.1	.4	.6	.5	1.2	.84	High-heat fire brick.
69	do.	26	19N	6E		4.3	1.0	.5	32.3	Nil	.4	Nil	Nil	Almost pure gypsum; not clay.
70	Judith Basin	12	14N	10E	33	44.7	30.4	.8	.6	Nil	.4	Nil	1.12	Excellent fire brick, whiteware.
71	Cascade	31	19N	7E	30	59.3	27.0	1.7	.3	.2	1.1	.8	.6	High-heat fire brick.
72	do.	24	14N	6E	20	53.9	28.2	3.0	1.0	.4	-	-	.7	Bonding clay.
73	Phillips	12	24N	24E	33	63.0	27.4	.7	.6	Nil	.4	.4	.2	Excellent fire brick, whiteware.
[1]74	Fergus	12	16N	17E	33+	45.4	39.1	.57	.35	.32	.43	.37	.26	Fire brick, porcelain whiteware.
[2]172	Petroleum	9	13N	25E	33	69.9	21.9	.9	.5	Nil	.4	Nil	Nil	
173	do.	9	13N	25E	33	69.0	23.8	.6	.2	Nil	.4	Nil	Nil	

[1] Samples 24 through 74 from Montana Bureau of Mines Inf. Circ. No. 23.
[2] Samples 172-173 from Montana Bureau of Mines Bull. 13.
Source: Montana Bureau of Mines and Geology Bull. 13, 1960; Inf. Circ. 23, 1948.

Miscellaneous Clay

"Miscellaneous clay" is a statistical designation used by the Bureau of Mines. It is sometimes referred to as common, brick, sewer pipe, or tile clay. Specifications for miscellaneous clay are less rigid than for other clays. A clay may be unsuitable for any other product, yet would produce satisfactory building brick.

The Lewistown Brick and Tile Co. has been manufacturing brick and tile at a plant near Lewistown since 1911.

Clay for the operation is mined from a thick bed of maroon-colored shaly clay interbedded with thin layers of shaly sandstone in the Kootenai Formation (48).

The Great Falls Brick Co. operated a brick plant in Great Falls until it was closed in 1956 (60). The claypit is 13 miles south of Great Falls.

Lightweight Aggregate

The Montana Bureau of Mines and Geology has done considerable work in Montana on expandable shale and clay for use as lightweight aggregate (53).

Lightweight aggregate is a low-priced commodity and, like sand and gravel, must be produced relatively close to a market.

The work by the Montana Bureau of Mines and Geology indicates that an expandable shale occurs in a bed in the Cretaceous Colorado group. It is quite extensive in the vicinity of Great Falls. This nearly flat-lying bed averages about 15 feet in thickness. Possibly 17 million tons of material could be mined by stripping an average of 30 feet of overburden within 3 to 5 miles of Great Falls.

Treasurlite Products, Inc., a branch of Treasure State Industries of Helena, Mont., recently built a lightweight aggregate plant at Great Falls. The firm is producing 200 to 250 cubic yards per day of calcined shale mined in the vicinity of Great Falls.

Gypsum

Gypsum occurs in numerous large deposits in the Basin Study Area. Table 18 gives information on a few deposits that are exposed or on which exploration work has been done. Favorable formations suggest the possibility of many more deposits (47, 61).

Near Lewistown, Mont., gypsum deposits are in the Ellis formation of Jurassic age. In Judith Basin and Cascade Counties, the deposits are in the Kibbey sandstone of Mississippian age.

Currently, the only two Montana gypsum operations are in Fergus County. The U.S. Gypsum Co. mines and processes gypsum at the Shoemaker mine at Heath, about 10 miles southeast of Lewistown.

TABLE 18. - Gypsum deposits, Missouri Basin Study Area, Montana

County	Sec	T	R	Thickness, feet	Remarks
Judith Basin	5	16N	8E	2	Deposit was mined and calcined from 1898-1900.
Do.	7	16N	8E	7	Small production in 1910.
Do.	3,10	16N	10E	15	No production. Outcrop length about 1 mile.
Do.	20,21	16N	10E	2-20	No production. Outcrop length 1,000 feet.
Do.	34	14N	11E	15	Two beds. One 15 feet thick. Extent not known.
Cascade	13,24	17N	6E	4- 6	Deposit was mined from 1908-1915.
Do.	1	17N	6E	?	Small production in 1910.
Fergus	1, 2 11,12	14N	19E	10-15	Owned and operated by U.S. Gypsum Co. 450-500 tons mined per day.
Do.	10,15 22,27	16N	17E	10-12	Owned by Ideal Portland Cement Co. Crude gypsum mined and shipped to cement plant.

The company mines 400 to 500 tons of gypsum per day from underground. It is calcined and marketed as ground gypsum or manufactured into wallboard and lath at the company plant at Heath. The operation has been continuous since 1928.

Near Hanover, about 10 miles northwest of Lewistown, the Ideal Cement Co. mines gypsum underground. The raw gypsum is shipped to company plants for cement manufacture.

The gypsum reserves in the area are very large. They can meet the current demand for gypsum and gypsum products for many years.

Gem Stones (Sapphire)

Sapphire was mined for several years prior to 1928 from two deposits west of Utica, Judith Basin County. The stones were recovered from the weathered, near surface material of a lamprophyre dike.

Various estimates place the total production of sapphire from the area at about 15 million carats, of which perhaps 15 weight-percent were gem quality. Most of the gem-quality stones were shipped to England for cutting. The lower quality stones were used for instrument bearings and abrasives.

Some interest has been shown in the deposits recently, but no production has been reported in recent years.

Sodium Sulfate

A number of intermittent lakes occur in Chouteau County in Shonkin Sag, a topographically low area that was once the course of the Missouri River. As a consequence of having little or no drainage, the salt content in the water and lake beds has accumulated so that they are a possible source of sodium sulfate.

Work of a preliminary nature has been done by the Montana Bureau of Mines and Geology to determine the sodium sulfate content (54).

The combined area of the four lakes is about 5 square miles. Results of the preliminary survey indicate that the reserves of sodium sulfate may be several million tons. Sample information is shown in table 19.

TABLE 19. - Sodium sulfate deposits, Missouri Basin Study Area, Montana

Lake	Sec	T	R	Description	Area, square miles	Indicated percent Na_2SO_4
White Lake (Teal)	2,3, 10,11	22N	10E	Surface covered with salt crust 1/16 to ½ inch thick over dry mud. 3 feet of wet mud sampled.	1.1	Water soluble portion of crystal crust, 67 percent. Dry mud, 3.9 percent 3 feet wet mud, 5.9 percent.
Lost Lake	29	22N	10E	Water was high when sampled; 2 feet of black mud above sand.	0.25	Water 11.8 percent. Wet crust 1 inch thick, 95.8 percent; 2 feet of black mud, 4.65 percent.
Big Lake	25,26 35,36	22N	10E	Little surface crust; 1 sample of 150-foot-wide beach above brine level. Sample of mud 2 feet thick.	2.0	2 feet of mud, 6.27 percent. Brine reported as 10 percent.
Kingsburt Lake (Mallard, Alkali Lake)	17,18 19,20	21N	11E	Similar to White and Big Lakes. 1 sample of 600-foot-wide beach above brine level. Sample of gray sandy clay 6 feet thick.	1.8	Sample of clay mud lost.

Source: Montana Bureau of Mines and Geology, Inf. Circ. 11, 1956.

Nepheline Syenite

Nepheline syenite is a feldspathoid-bearing rock that is used in the ceramic industry for the purpose of lowering the firing temperature for porcelain ware, glass, and porcelain enamels. The only production in the western hemisphere is at the Blue Mountain deposit in south-central Ontario.

Nepheline syenite occurs in the Bearpaw Mountains and in the Highwood Mountains. Some study would be needed to determine if it could be produced at a profit for a future ceramic industry.

Potential of Nonmetallic Deposits for Production and New Development

The nonmetallic mineral deposits known in the Missouri Basin Study Area, with the possible exception of sapphires and sodium sulfate, are sufficient to meet any foreseeable future demand. The current production rate from those deposits is controlled by market limitations and not by the ability of the deposits to produce.

Economic Feasibility of Development

Development of additional nonmetallic mineral deposits, or increase in the production rate from existing operations, depends upon the overall economic development of the Missouri Basin within the market radius of the commodities produced.

Sand and gravel will continue to be used locally, and will depend upon local industrial development and increase in population.

The gypsum and gypsum products produced in the area are marketed over a large part of the Northwest. Any consideration of new development in gypsum mining and processing should take into account the ability of the market to absorb additional production.

An important factor in the development of nonmetallic mineral deposits is the market limitation for the products. A nonmetallic mineral producer not only must develop his mineral deposit, but must also develop the market for the commodity and negotiate a price.

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