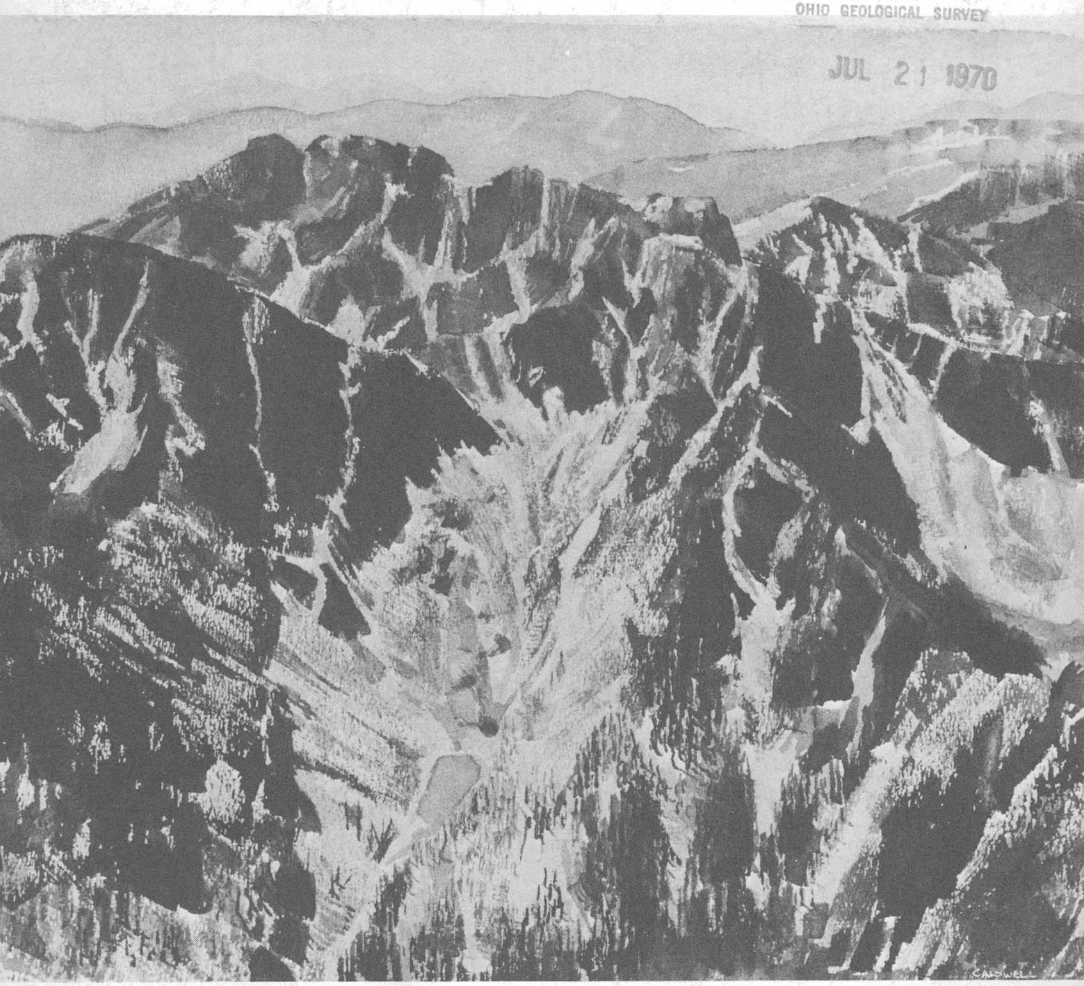
STUDIES RELATED TO WILDERNESS
PRIMITIVE AREAS



JACK CREEK BASIN, MADISON COUNTY, MONTANA

GEOLOGICAL SURVEY BULLETIN 1319-B

Mineral Resources of the Jack Creek Basin, Madison County, Montana

By GEORGE E. BECRAFT *and* THOR H. KIILSGAARD, U.S. GEOLOGICAL SURVEY,
and by RONALD M. VAN NOY, U.S. BUREAU OF MINES

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An evaluation of the mineral potential of the area

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PRIMITIVE AREAS

STUDIES RELATED TO WILDERNESS

Pursuant to the Wilderness Act (Public Law 88–577, Sept. 3, 1964) and the Conference Report on Senate bill 4, 88th Congress, the U.S. Geological Survey and the U.S. Bureau of Mines are making mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe' when the act was passed were incorporated into the National Wilderness Preservation System. Areas classed as "primitive" were not included in the Wilderness System, but the act provided that each primitive area should be studied for its suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. This bulletin reports the results of a mineral survey in the Jack Creek basin, Madison County, Mont. The basin is being considered for possible inclusion with the Spanish Peaks primitive area as part of the proposed Spanish Peaks Wilderness.

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

MINERAL RESOURCES OF THE JACK CREEK BASIN, MADISON COUNTY, MONTANA

By GEORGE E. BECRAFT and THOR H. KIILSGAARD, U.S. GEOLOGICAL SURVEY
and
by RONALD M. VAN NOY, U.S. BUREAU OF MINES

SUMMARY

The Jack Creek basin is along the west flank of the Madison Range and comprises about 36,000 acres. Most of the bedrock in the basin is sandstone and shale of Cretaceous age. Along the south side of the basin, these rocks have been intruded by a series of thick andesite and dacite prophyry sills. The north side of the basin consists of crystalline Precambrian rocks that have been raised by large vertical movement along the steep Spanish Peaks fault. Upturned strata of limestone and quartzite of Paleozoic age form the crest of the range-front ridge to the west. Glacial deposits derived chiefly from mountain peaks to the north and south cover much of the basin floor.

Traces of copper and other metals are distributed sporadically along the Spanish Peaks fault, and prospect pits have been dug at several of these exposures. No commercial-grade material has been mined from these workings, however, and none is known to occur in the basin. Samples of stream sediments and rocks from the basin are low in metal content. Phosphate rock crops out, but the phosphatic beds are too thin to be mined at a profit at the present time. Abundant reserves of more accessible phosphate rocks occur elsewhere in the West. Although coal has been reported, none was found either during the present investigation or by prospectors who have worked previously in the basin. Oil or gas might be present in the basin, but results from dry holes drilled in the vicinity to date indicate that the potential of the basin is poor. Limestone in the basin is too far from marketing areas to be exploited at a profit.

Nearly all the odd-numbered sections in the basin are owned by the Northern Pacific Railway Co. Several privately owned ranches are in the lower part of the basin.

INTRODUCTION

Jack Creek basin is in the Beaverhead National Forest, Madison County, southwestern Montana, near the northern end of the Madison Range. It adjoins the southwest margin of the Spanish Peaks primitive area (fig. 1) and contains about 36,000 acres. The basin is bordered on three sides by high ridges: on the north by a broad glaciated ridge formed by crystalline rocks; on the west by a nearly straight, relatively narrow ridge formed by upturned sedimentary rocks; and on the south by an irregular ridge formed by intrusive igneous rocks. The eastern margin of the basin is a relatively low, broad divide formed on sedimentary rocks between the Gallatin River and Madison River drainages. The entire Jack Creek basin is dominated by two majestic mountains along the southern margin—Lone Mountain and Fan Mountain. Most of the basin is drained by Jack Creek, which flows westward through a sharp canyon cut in the upturned Paleozoic and Precambrian rocks and into the broad Madison Valley east of Ennis. A small area of the northern part of the basin is drained westward by Jordan Creek.

Altitudes in the basin range from about 5,600 feet, where Jack Creek cuts through the western ridge, to 11,166 feet on Lone Mountain. A good graveled road extends from Ennis to the Forest Service camp-

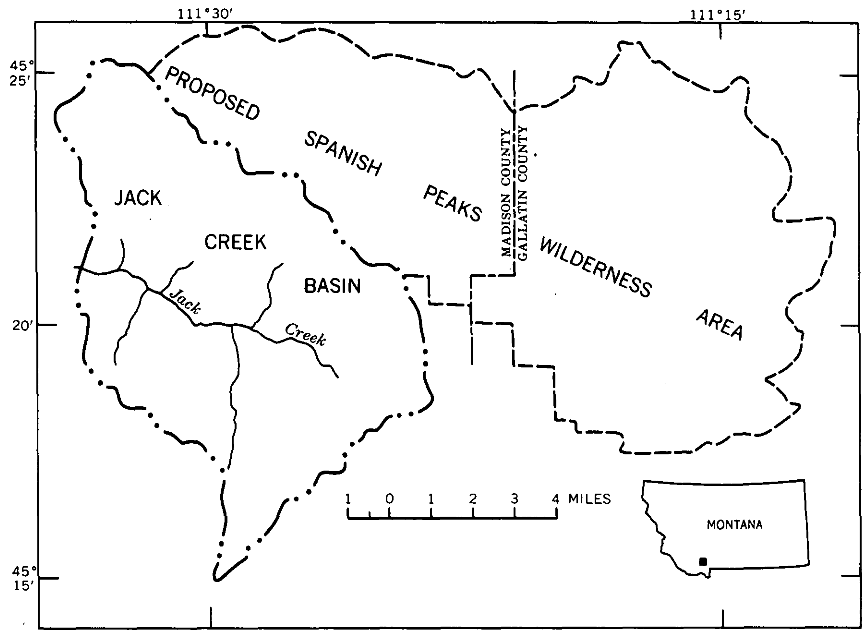

FIGURE 1.—Index map showing the Jack Creek basin and the proposed Spanish Peaks Wilderness.

ground along Jack Creek, in the northwest part of sec. 6, T. 6 S., R. 2 E., in the lower part of the basin. Several dirt roads extend from the road along Jack Creek to western parts of the basin, and well-marked trails cross other parts of the basin.

We are indebted to Roger W. Swanson for his description of the geology of the Jack Creek basin (written commun., 1968) and for his geologic map (Swanson, 1950). Without his work, we would have been unable to evaluate the mineral potential without spending many months in the field interpreting the complex geology of the basin. We also wish to acknowledge cooperation received from officials of the Northern Pacific Railway Co. as well as information from local citizens.

PURPOSE AND SCOPE

This survey of the mineral resources of the Jack Creek basin was made at the request of the U.S. Forest Service to provide information on lands being considered for inclusion in the proposed Spanish Peaks Wilderness. The survey was made during July and August 1968 by the U.S. Geological Survey and U.S. Bureau of Mines. Fieldwork included the checking of the geologic map prepared by Swanson (1950). This map, which was made on a planimetric base, subsequently was modified and transposed to a topographic base and is presented in this report as plate 1. The map is, of necessity, generalized from the original version. Traverses made on foot over the area enabled close checks to be made on rock outcrops, which were carefully scrutinized for evidence of mineral deposits. Rocks that appeared to be altered in any way were collected for analysis. Rocks along faulted and sheared zones also were collected for analysis, as were unaltered rocks that were considered to be typically representative of the area. Stream-sediment samples were collected from all major streams in the basin and from most of the minor tributaries. The use of a helicopter during the field study greatly increased the speed of the work, permitted access to high areas that are difficult to reach on foot, and enabled near-treetop-level scrutiny to be made of the entire basin.

Courthouse records were examined for information on mining claims, and the surface of the basin was carefully searched for prospect workings. Published and unpublished geologic reports on the basin and on nearby areas were studied for mineral-deposit data. Several local citizens, who had been familiar with the basin for decades, kindly supplied information on the area.

GEOLOGY

Most of the bedrock of the Jack Creek basin is relatively soft standstone and shale of Cretaceous age. Crystalline Precambrian rocks on the north have been raised by large vertical movement along the steep Spanish Peaks fault. Limestone and quartzite of Paleozoic age form the crest of the range-front ridge in the upturned strata on the west, and intrusive igneous rocks of intermediate composition form the ridge on the south. Glacial deposits derived chiefly from the mountain peaks on the north and south sides cover much of the basin floor, but only the thickest deposits that completely conceal the bedrock geology are shown on plate 1. The following description of the Paleozoic and younger rocks of the basin is based almost entirely on a report by Roger W. Swanson (written commun., 1968). The description of the Precambrian rocks is from Becraft and others (1966).

PRECAMBRIAN ROCKS

The Precambrian metamorphic rocks are a complex mixture of many varieties of rock. They were not mapped in detail, and only a brief discussion of these rocks is given. Reid (1957, 1963), in two reports on the geology of the Tobacco Root Mountains, and McThenia (1960), in a report on the area north of Ennis, have described the petrography of similar Precambrian rocks in considerable detail.

The major rock type in the Jack Creek basin area is granitic gneiss which ranges from light gray to nearly black, depending upon the amount of biotite and amphibole in the rock. It is generally very strikingly foliated; alternate light and dark layers produce a banding that is obvious for considerable distances from the outcrops. In some places, however, particularly where no layers rich in dark minerals are present, the foliation is not as obvious but can be seen on close observation. The granitic gneiss consists principally of quartz, plagioclase, potassium feldspar, biotite, hornblende, and in places, muscovite.

Schists of many different compositions are also common in the area; some of the more common types are amphibole-biotite-quartz, muscovite-biotite-quartz, garnet-biotite-quartz, amphibole-feldspar, and muscovite-biotite-feldspar.

Amphibolite, a dark-green rock consisting of hornblende, plagioclase, quartz, and locally garnet, is present but is not as common as in the Spanish Peaks primitive area to the northeast. It occurs as irregular masses, lenses, dikes, and in sill-like bodies.

Small pegmatite masses occur throughout the area. They are commonly discontinuous dikes and sills ranging in thickness from a few inches to a few feet. The mineralogy of the pegmatites is simple. They consist largely of quartz and potassium feldspar, but they contain some plagioclase, biotite, hornblende and minor amounts of muscovite, magnetite, and tourmaline. Some of the potassium feldspar is microcline and much is perthitic.

PALEOZOIC ROCKS

Paleozoic rocks are exposed on the west and north sides of Jack Creek basin. The rocks in both areas are extensively faulted and are in fault contact with the Precambrian rocks, but elsewhere in the Madison Range the Paleozoic rocks overlie similar Precambrian rocks with a sharp unconformity. The old weathering zone beneath the unconformity is locally 30 to 40 feet thick. Most of the Paleozoic Systems are represented in this area, but the total thickness of Paleozoic strata is only about 4,000 feet. These strata are generally shallow-water facies typical of the platform or continental-shelf environment of sedimentation. The formations of Paleozoic age exposed in Jack Creek basin are listed in table 1, which gives their age and approximate thicknesses.

TABLE 1.—*Ages and approximate thicknesses of Paleozoic formations exposed in Jack Creek basin*

Formation	Age	Approximate maximum thickness (feet)
Phosphoria Formation	Permian	45
Shedhorn Sandstone	do	80
Park City Formation	do	80
Quadrant Formation	Pennsylvanian	260
Amsden Formation	Late Mississippian and Early Pennsylvanian.	200
Sacajawea Formation of Branson (1936).	Mississippian	120
Mission Canyon Limestone	Early and Late Mississippian	750
Lodgepole Limestone	Early Mississippian	850
Three Forks Formation	Late Devonian and Early Mississippian.	110
Jefferson Dolomite	Devonian	530
Bighorn Dolomite	Middle and Late Ordovician	90
Red Lion Formation	Late Cambrian	100
Pilgrim Limestone	do	60
Park Shale	Middle Cambrian	200
Meagher Limestone	do	380
Wolsey Shale	do	220
Flathead Sandstone	do	100

Because rocks of Permian age contain minable phosphate desposits elsewhere in the northern Rocky Mountains, those in the Jack Creek basin area are described in detail. The following descriptions are by Roger W. Swanson (written commun., 1968).

Overlying the quartzitic sandstone of the Quadrant Formation at Shell Creek canyon 6 miles south of Jack Creek is 79 feet of variably sandy to cherty light-to yellowish-gray thick-bedded to massive dolomite or dolomitic limestone that is assigned to the Park City Formation. The lower 48 feet is lacking in phosphate and is believed to represent the Grandeur Member. The upper 31 feet contains pellets, fossil fragments, and spicule-canal fillings of apatite and is assigned to the Franson Member. A cherty sandstone bed at the base of the Franson contains fairly abundant apatite and also spicular chert pebbles and seems to represent the Meade Peak Tongue of the Phosphoria Formation. The top contact is fairly sharp.

At Shell Creek canyon, 125 feet of strata composed mostly of quartzitic sandstone and sandy chert in the lower and upper parts and dark phosphatic shale and chert in the central part are identified as the lower and upper members of the Shedhorn Sandstone and the Retort Phosphatic Shale and Tosi Chert Tongues of the Phosphoria Formation. The basal contact is marked by a color change from medium and light gray to darker brownish gray that is visible in the cliffs from several miles away in the Madison Valley, and by abundant pebbles and sand of spicular chert, carbonate rock, quartzite, and phosphorite in a dolomitic matrix. The soft 17-foot-thick Retort Phosphatic Shale forms a bench between high and persistent cliffs, with the 16-foot-thick lower Shedhorn at the top of the lower cliff and the 28-foot-thick Tosi Chert and 65-foot-thick upper Shedhorn quartzite and cherty sandstone in the upper cliff. All these rocks and dark and the phosphatic shale and chert are very dark. The section at Jack Creek canyon is similar but the basal part is not exposed, the phosphatic shale is much thinner, and the upper Shedhorn is less cherty. The geologic structure there is very complex and several faults cross the section in the cliffs where measured.

MESOZOIC ROCKS

Rocks of Mesozoic age are exposed on the slopes of the ridge forming the western margin of the basin, across the central part of the basin, and on the broad divide forming the eastern margin of the basin.

The oldest Mesozoic rocks in the basin are limestone, sandstone, and shale, about 100 feet thick, of the Dinwoody Formation of Triassic age. This is overlain by the Ellis Formation of Middle and Late Jurassic age. The Ellis is impure limestone, shale, and glauconitic sandstone and is about 250 feet thick. This formation is at the top of the dominantly marine part of the stratigraphic section. The Morrison Formation of Late Jurassic age, composed mostly of soft, variegated, fine-grained, impure sandstone, shale, and some limestone, overlies the Ellis Formation. It is poorly exposed in Jack Creek basin but a short distance to the south appears to be about 300 feet thick. It is overlain by the Kootenai Formation of Early Cretaceous age. The Kootenai Formation consists of about 500 feet of standstone, siltstone, shale, and limestone beds that are of nonmarine origin. A series of alternating gray to black shale and sandstone layers, apparently unconformably overlying the Kootenai Formation, are included in the Colorado Group of Cretaceous age. In Jack Creek basin about 1,000 to 1,500 feet of these strata are preserved; the uncertainty in thickness is due to poor exposure, complex geologic structure, and igneous intrusion.

Coal was reportedly mined from strata of Late Cretaceous age south of Jack Creek basin (Swanson, 1950). Because of this and because of unconfirmed reports that several coal prospects had been located in

Jack Creek basin, the rocks of Late Cretaceous age were examined carefully in many places in the basin. No layers of coal were found, but layers of black carbonaceous shale occur in several places in the Upper Cretaceous rocks. Samples were collected from three localities and were analyzed by the Bureau of Mines Coal Research Center, Pittsburgh, Pa. Results of these analyses are given in table 4.

At the end of the Cretaceous Period the rocks of the entire region were folded and faulted during part of the Laramide orogeny. In this part of the region, large blocks of the crystalline crust were uplifted and tilted along large faults, and the overlying sedimentary rocks were compressed into sharply asymmetric folds. The Precambrian rocks at the western edge of Jack Creek basin were part of such a large uplifted block, and the steeply dipping strata in that area were dragged upward and broken by faults accompanying that uplift. Somewhat later, but during the same orogeny, the large block of crystalline rocks underlying most of the Spanish Peaks primitive area was uplifted along the Spanish Peaks fault, and the sedimentary rocks south of the fault were dragged upward.

MESOZOIC OR CENOZOIC ROCKS

At about the same time as the uplift on the Spanish Peaks fault, a thick series of andesite and dacite porphyry sills was injected into the Cretaceous sediments in the synclinal heart of the Madison Range. There were three main centers of injection, from which the magma spread outward between the strata as sheets ranging from only a few feet to 200 feet or more in thickness. The sills are thickest near the centers of intrusion, and thus domal, laccolithic structures were formed. The resultant stratiform sequence of alternating sedimentary and igneous rocks forms a pattern of igneous rocks that suggests broad Christmas trees in cross section. Two of these centers are on the south side of Jack Creek basin, Lone Mountain on the east and Fan Mountain on the West (fig. 2). The rock is mostly light to medium gray, although some dark-gray sills that weather dark brownish gray are present but generally not as part of the main mass. Phenocrysts of feldspar are mostly less than 4 millimeters across, and those of quartz, biotite, and hornblend are generally smaller. The magma was low enough in temperature so that the invaded rocks were only slightly altered and were baked to a hornfels in only narrow zones. Quartz veins and other evidence of mineralization are almost totally absent.

A sill near the Spanish Peaks fault appears to be cut by a smaller fault; this would indicate intrusion before formation of that small fault. In the range-front band of strata north of Jack Creek, several andesite sills occur in the Cambrian rocks, and at Jack Creek one or

FIGURE 2.—Fan Mountain, from the west.

two occur in the Lower Cretaceous rocks. These sills were later faulted during the final stage of tectonism, when the range-front strata were overturned and were locally thrust faulted.

CENOZOIC ROCKS

During the Tertiary erosion cycle, the rocks of Jack Creek basin were eroded almost to their present landforms (fig. 3). Late in this stage of erosion, thick basin sediments accumulated in the Madison Valley to the west, and some similar gravels accumulated on the surface of low relief that had formed in Jack Creek basin. Subsequent erosion has deepened Jack Creek and its tributaries, and remnants of these gravels now cap low ridges in the basin.

During the Pleistocene Epoch, extensive glaciation on the higher peaks of the Madison Range created many cirques on the flanks of the peaks and U-shaped valleys below these cirques. The glaciers on the north side of Lone Mountain left extensive gravels on the south side of Jack Creek basin, and some on Fan Mountain contributed lesser amounts.

FIGURE 3.—Upper part of Jack Creek basin, showing Ulerys Lakes in foreground and rugged ridge that marks the southern boundary of Spanish Peaks primitive area in the background.

On the north side of the basin, glacial gravels were left near the base of the ridge by small glaciers in valleys that cut into the south side of that ridge, particularly near Hammond Creek. Other deposits occur farther east where there are no valleys cut into the south side of the ridge. These deposits probably were left by ice overflowing from the glacier in Spanish Lakes cirque basin on the north side of the ridge. That glacier traveled parallel to the ridgecrest for more than a mile before turning north, and in much of that distance its valley floor is only 400–600 feet below the ridgecrest. The ice that overflowed across this ridgecrest avalanched down the south side of the ridge into Jack Creek basin, and the burden of rock debris it carried formed an unusual type of glacial deposits. These avalanche-ice deposits contain boulders several feet in diameter and form a peculiar hummocky terrain that is without much pattern.

MINERAL RESOURCES

The Jack Creek basin has been prospected for mineral deposits, but no commercial-grade material has been mined from the basin or is known to occur in it. According to Swanson (1950), coal has been mined near the head of Mill Creek, south of the basin. Much placer gold has been mined from the gravels of Alder Gulch, near Virginia City, about 20 miles west of the basin. Veins in the Tobacco Root Mountains, northwest of the basin, are known to contain gold, silver, copper, lead, zinc, and tungsten.

Phosphate rock underlies Jack Creek basin, but beds of acceptable grade are too thin to be mined by underground methods under present economic conditions. The steep dip of the phosphatic beds makes strip mining unfeasible. Various parts of the basin have been prospected for coal, but none has been found. Areas along the Spanish Peaks fault also have been prospected for various metals, but minable quantities of these metals have not been found. Rocks of the basin are not known to contain oil shale. Rocks beneath the basin could contain oil or gas, although none has been found in nearby parts of Montana. Limestone crops out along the western side of the area, but it is too far from markets to be of minable value.

SAMPLING AND ANALYTICAL TECHNIQUES

The objective of the sampling and analytical techniques used in the Jack Creek basin study was to obtain maximum information on possible mineral deposits in the area consistent with rapid coverage of the area. This objective was met principally by sampling and analyzing sediments from streams. Stream sediments are derived from eroding masses of rocks; thus, the metal content of a sediment sample reflects the metal content of the eroded material. Anomalous samples may be identified quickly and the anomalies may be traced upstream to the source. Sediment samples were collected from all major streams in the basin and from most of the smaller tributaries. The sample sites and sample numbers are shown on plate 2, and the analytical results are shown in table 2. Each sample consisted of a couple of handfuls of the finest grained part of the sediment, preferably clay or silt. The sample was dried and sieved. The plus 80-mesh part of the sample was discarded and the finer grained material was analyzed spectrographically for a variety of elements, as may be noted in table 2. Analytical results from the sediment samples generally indicate metal contents that are normal for rocks of the types that occur in the Jack Creek basin.

Analytical results of the rock samples also are given in table 2. Like the sediment samples, the rock samples also are low in metallic content. The sample results are further described in the section on lode deposits.

MINING CLAIMS AND PROSPECTS

Courthouse records at Virginia City, Madison County, Mont., show that at least three groups of unpatented claims were located in the Jack Creek basin. These consist of four coal claims totaling 360 acres and 35 lode claims. No placer or patented mining claims are within the basin. The claims were recorded during the period 1888 to 1906; most were filed in 1890 and 1891. Several of the claims were probably relocations.

There is no recorded mineral production from the Jack Creek area. The only prospect workings observed were on the lode and coal claims. All the work appeared to have been done many years ago. No evidence of recent prospecting activity was seen.

Nearly all the odd-numbered sections in the study area are owned by the Northern Pacific Railway Co. Several privately owned ranches are in the lower part of Jack Creek basin.

ECONOMIC APPRAISAL

PHOSPHATE ROCK

The Phosphoria Formation underlies the Jack Creek basin. It crops out along the western border of the basin along the overturned limb of a broad syncline. It also crops out sporadically along the northern side of the basin, south of the Spanish Peaks fault (pl. 1). Depth to the formation would vary depending upon location in the basin and on topography, but in the central part of the basin the depth probably would be more than 2,000 feet. Phosphate rock of the formation is in the Retort Phosphatic Shale Member, which is 17 feet thick in Shell Canyon about 3 miles southwest of Jack Creek basin, but which thins to the north. Much of the area in which the formation crops out along the western edge of the basin has been withdrawn for phosphate classification and the phosphate rights have been retained in Federal ownership. The withdrawn land forms a strip that extends roughly 1 mile to the north and 2½ miles south of Jack Creek and includes parts of secs. 25, 26, 35, and 36, T. 5 S., R. 1 E., and parts of secs. 1, 2, 11, 12, and 13, T. 6 S., R. 1 E. In the vicinity of the basin, phosphate rock is confined to a few thin beds of the Retort Member. The data in table 3 on samples and measured sections of phosphate rock of the basin and nearby areas are from Cressman and Swanson (1964, p. 384–408), Swanson (1950, p. 5–11), and Condit, Finch, and Pardee (1928, p. 183).

TABLE 2.—*Analyses of samples*

Semiquantitative spectrographic analyses

Sample	Location T. R. S.	Cu (2)	Pb (10)	Mo (2)	Co (10)	Ni (2)	Cr (5)	Be (1)	V (5)	Nb (10)	Zr (10)	La (20)	Sc (5)
						(ppm)							
						Rock samples							
1	5-2-19	10	50	10	N	N	50	1.5	20	10	150	150	5
2a	5-2-19	30	15	N	30	100	50	3	300	N	150	N	30
2b	5-2-19	300	N	N	50	150	300	N	500	N	70	N	50
3	5-1-13	150	10	N	70	70	30	N	500	N	200	N	70
4	5-1-23	70	100	N	N	5	N	N	50	N	50	N	5
5a	6-2-24	7	L	N	10	10	5	1	30	N	150	50	N
5b	6-2-24	5	15	N	N	15	20	1	70	10	300	30	5
5c	6-2-24	15	10	N	5	30	20	1	70	15	300	20	5
5d	6-2-24	10	20	N	5	20	70	3	70	15	200	N	10
5e	6-2-24	L	N	N	N	5	30	L	70	L	200	100	N
11a	6-2-14	20	30	N	30	100	200	1	200	10	200	70	20
11b	6-2-14	15	50	N	15	70	70	1	150	10	200	70	15
13b	6-2-14	15	L	N	5	10	5	N	70	N	100	20	5
13c	6-2-14	10	20	N	N	10	5	5	50	20	150	20	7
16b	6-2-11	10	20	N	7	15	70	1	70	L	100	30	10
18	6-2-11	20	100	N	10	30	50	1	100	10	100	100	10
23	6-2-5	10	70	N	15	50	100	1	100	L	150	70	10
24 1/	5-1-24	20	10	N	N	5	20	N	70	10	300	50	5
26	5-1-24	L	15	N	N	5	10	N	50	L	30	20	N
28	5-1-24	7	L	N	5	15	15	N	30	N	20	N	N
30	5-1-24	5	L	N	N	L	20	L	100	15	700	70	5
31	5-1-24	15	20	N	5	L	N	N	20	L	50	N	L
39 1/	5-1-23	7	10	N	N	5	10	N	100	N	100	N	5
41	7-2-4	15	20	N	15	50	100	1.5	300	15	200	50	15
42	6-2-33	50	70	N	20	70	150	1	200	10	150	100	20
133	6-2-6	30	70	N	20	100	100	2	150	20	200	70	20
136	5-2-34	7	N	N	N	5	5	N	10	N	5	N	N
140	5-2-32	7	10	N	N	5	15	1	70	10	150	N	L
142	6-2-5	10	100	N	15	30	70	1	150	10	200	100	10
143	6-2-5	10	100	N	10	30	30	1.5	70	10	200	100	7
150	6-1-14	10	L	N	N	10	20	1	70	N	200	20	5
151	6-1-11	7	N	N	N	5	20	N	50	N	20	20	N
152	6-1-14	20	10	N	N	7	30	1.5	150	20	500	N	15
153	6-1-14	15	20	N	5	10	100	2	150	20	500	50	15
155	6-1-1	L	N	N	N	N	15	N	50	N	20	N	N
159	6-2-6	20	30	N	10	30	100	1.5	150	15	150	30	15
						Samples from prospect workings and from faulted areas							
58 2/	6-2-1	150	10	10	20	300	1,500	L	300	10	150	N	20
60 3/	6-2-1	200	10	N	50	70	20	L	700	10	300	20	50
109	6-3-7	10	50	N	5	10	20	3	70	20	200	30	5
134	5-2-34	20	30	N	5	20	50	L	70	10	150	50	5
135	5-2-34	7	30	N	N	5	N	1.5	N	N	N	N	N
139	5-2-34	30	30	N	20	100	300	1	200	L	100	N	30

1/ Analyses show 0.5 ppm Ag.
2/ Sample contained 300 ppm Zn and 5,000 ppm As.
3/ Sample contained 200 ppm Zn.

[Samples were analyzed by six-step semiquantitative spectographic analyses. The analytical data are reported in ppm's (parts per million) except where shown in percent. They are reported to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, which represent approximate midpoints of group data on a geometric scale. The assigned groups for the series will include the quantitative value about 30 percent of the time. The data should not be quoted without stating these limitations. The sensitivity limit of detection for each element listed in the table is shown in parentheses below the element symbol at the head of the column. The symbol N indicates the element was looked for but was not found; L indicates that an undetermined quantity of the element is present but is below *from the Jack Creek basin*

Semiquantitative spectrographic analyses

	(ppm)					(percent)				
Sample	Y (5)	Ba (20)	B (10)	Sr (50)	Mn (20)	Fe (.05)	Ti (.002)	Ca (.05)	Mg (.02)	Sample description
					Rock samples					
1	15	1,500	N	300	200	1.5	.15	1	.30	Gneiss.
2a	30	300	L	150	1,000	7	.30	3	2	Mafic gneiss.
2b	30	200	L	100	1,500	10	.70	10	5	Do.
3	50	200	L	150	2,000	10	.70	10	7	Mafic dike.
4	N	100	10	700	3,000	1	.07	20	1	Gray limestone.
5a	10	300	30	N	500	.50	.10	.20	.15	Sandstone.
5b	20	700	50	N	1,000	3	.20	7	2	Fissle shale.
5c	20	300	50	N	1,000	2	.30	.50	.50	Massive shale.
5d	10	300	30	N	500	3	.20	.20	.50	Andesite.
5e	30	700	50	1,000	200	.10	.10	.05	.07	Conglomerate.
11a	20	1,500	10	1,000	1,000	7	.50	3	3	Dacite.
11b	15	1,500	L	1,000	700	5	.50	3	2	Do.
13b	15	700	10	100	700	.70	.15	3	.3	Sandstone.
13c	30	500	50	N	300	1.50	.20	.50	.5	Black shale.
16b	15	700	30	150	300	3	.15	5	1.50	Carbonaceous shale.
18	N	1,500	10	1,000	500	3	.30	1	1.50	Andesite.
23	10	1,500	L	1,000	700	3	.30	3	1.50	Porphoritic andesite.
24	30	500	10	2,000	300	5	.20	1	.05	Altered rock.
26	15	10	10	500	700	2	.10	20	5	Limestone.
28	10	1,000	10	700	200	1.5	.05	20	1	Limestone.
30	30	300	70	200	100	.50	.30	.05	.07	Sandstone.
31	50	300	N	2,000	5,000	7	.05	20	7	Limestone.
39	20	1,000	10	700	5,000	2	.10	20	7	Do.
41	30	700	150	N	700	5	.50	1	1.50	Carbonaceous shale.
42	20	2,000	10	1,500	700	7	.50	2	3	Porphoritic andesite.
133	50	300	100	150	1,500	7	.50	.50	.50	Carbonaceous shale.
136	N	500	15	N	70	.20	.07	.20	.03	Chert.
140	20	200	30	N	300	1	.20	5	1	Sandstone.
142	10	2,000	10	1,000	700	7	.30	1	1	Andesite.
143	10	2,000	10	700	700	3	.30	.5	.10	Rhyolite.
150	20	200	30	N	500	1.5	.20	7	1	Sandstone.
151	10	200	30	200	50	.1	.15	.07	.05	Do.
152	30	300	70	N	50	1	.50	.10	.15	Shale.
153	50	1,000	70	100	150	1	.50	.20	.20	Do.
155	N	N	N	700	300	.10	.02	20	1	Limestone.
159	20	300	70	150	300	1.50	.70	.15	.70	Carbonaceous shale.
					Samples from prospect workings and from faulted areas					
58	50	1,000	10	500	200	20	.50	5.0	.15	Fault breccia.
60	50	500	N	300	1,500	20	1	7	2	Sandstone.
109	30	300	50	N	200	3	.20	.20	.50	Carbonaceous shale.
134	50	300	10	200	500	2	.30	.70	.70	Gossan frags., old pit.
135	N	300	10	100	200	.10	.01	.30	.05	Float, near pit.
139	30	500	30	100	1,000	3	.50	10	1	Dump, old adit.

the level of detection; G means the quantity of the element is greater than 10 percent or is greater than the value shown in parentheses. The following elements, the detection limits of which are shown in parentheses, were looked for but were not detected except as shown in footnotes: Au (10), Ag (.5), Zn (200), Cd (20), Bi (10), As (200), Sb (100), Sn (10), and W (50). No analyses were made for Pd, Pt, Te, and U. In the "Location" column the number under T identifies the township, the number under R identifies the range, and the number under S, the section. Thus T. 5 S., R. 2 E., sec. 28 is shown as 5–2–28. Analysts: K. C. Watts, E. L. Mosier, and D. J. Grimes]

TABLE 2.—*Analyses of samples*

Semiquantitative spectrographic analyses

Sample	Location T. R. S.	Cu (2)	Pb (10)	Mo (2)	Co (10)	Ni (2)	Cr (5)	Be (1)	V (5)	Nb (10)	Zr (10)	La (20)	Sc (5)
						(ppm)							
					Stream sediment samples								
6	6-2-13	7	15	N	15	30	100	1	70	15	500	50	15
7	6-2-13	20	20	N	15	50	200	1	100	10	150	50	15
8	6-2-13	10	20	N	20	70	500	1.5	70	20	200	50	15
9	6-2-13	10	30	L	10	50	100	1	70	10	150	50	10
10	6-2-14	10	20	10	5	50	150	1.50	100	15	150	50	10
12	6-2-14	30	30	N	10	100	500	1.50	100	10	100	50	10
13a	6-2-14	20	30	10	5	30	150	1.50	70	15	150	50	10
14	6-2-14	10	30	10	20	70	500	1	70	20	200	30	15
15	6-2-11	15	15	N	5	30	100	1	50	15	150	50	7
17	6-2-11	10	10	20	7	20	100	1	100	15	300	50	15
19	6-2-10	10	15	N	10	50	200	1	70	10	300	50	15
20	6-2-9	10	10	N	7	50	100	1.5	70	10	150	30	10
21	6-2-9	10	15	N	10	50	200	1	70	10	150	20	15
22	6-2-4	15	15	N	7	50	200	1.5	100	10	150	50	10
25a	5-1-24	30	20	N	20	50	150	1.50	70	30	500	70	20
25b	5-1-24	30	30	N	20	70	200	1	100	30	500	7	30
27	5-1-24	20	20	N	20	70	200	1	100	20	300	50	30
29	5-1-24	70	20	N	15	70	200	1	100	10	150	100	20
32a	5-1-24	10	30	N	10	50	150	1.50	70	15	300	70	20
32b	5-1-24	15	30	N	10	30	150	1	100	20	200	50	20
33	5-1-24	20	20	N	15	60	150	1.50	70	20	500	70	20
34	5-1-24	30	30	N	20	70	150	1	100	10	300	150	20
35	5-1-25	7	30	L	20	70	300	1	70	10	200	50	20
36	5-1-25	5	30	N	10	30	150	1.5	70	30	700	50	10
37	5-1-25	10	20	N	7	50	150	1.5	70	10	700	70	15
38	5-1-36	10	30	L	7	30	150	1	100	15	300	50	10
43	6-2-33	30	30	L	5	30	150	1	150	15	150	50	15
44	6-2-33	L	20	N	L	10	70	1.50	70	10	150	30	5
45	6-2-28	15	30	N	L	20	100	1	70	10	100	50	5
46	6-2-28	20	30	N	7	20	150	1	100	15	200	30	10
47	6-2-21	7	20	N	5	20	100	1.5	100	10	200	50	10
48	6-2-21	10	20	N	5	20	100	1.50	70	10	200	30	7
49	6-2-21	30	30	N	L	15	100	1	70	10	100	30	7
50	6-2-21	10	20	N	20	100	500	1	100	10	70	50	20
51	6-2-21	15	15	15	15	100	500	1	100	10	150	50	20
52	6-2-16	7	15	N	10	100	500	1	70	10	100	50	20
53	6-2-9	20	20	5	5	50	200	1.5	100	15	300	50	10
54	6-2-9	10	30	N	7	30	150	1.5	150	15	200	50	15
55	6-2-1	20	10	N	10	50	200	1.5	100	L	200	50	15
57	6-2-1	50	20	N	20	100	200	1	150	10	200	20	20
59	6-2-1	50	20	N	15	100	500	1	100	10	200	20	30
61	5-2-35	150	L	L	50	200	1,000	L	70	10	30	20	20
62	5-2-35	20	20	5	15	100	500	1	100	10	150	30	10
63	5-2-34	20	20	L	10	30	150	1	100	10	300	30	15
64	5-2-34	20	20	L	15	70	300	1	100	15	200	30	15
101	5-2-18	20	50	N	15	50	100	1	100	L	70	50	20
102	5-2-18	20	30	N	10	70	200	1.5	70	15	200	50	15
103	5-1-13	20	50	N	15	50	150	1	100	15	200	70	15
104	5-1-13	10	30	N	15	30	100	2	70	15	1,000	50	20
105	5-1-14	10	50	N	15	50	150	1	100	15	200	70	20
106	5-1-14	10	30	N	15	50	150	1	100	20	300	50	20
107	5-1-14	15	20	N	20	50	200	1	150	L	100	20	20
108	6-3-7	15	20	N	L	20	70	1	70	L	100	50	10
110	6-3-7	20	30	N	7	30	70	1	50	15	100	70	10
111	6-3-6	10	30	N	L	20	70	1.5	100	10	70	50	15
112	6-2-12	15	30	N	15	30	100	1.5	100	20	1,000	50	15
113	6-2-12	5	10	N	N	L	15	L	30	N	30	L	L
114	6-2-12	15	20	L	L	20	100	2	100	15	300	70	10
115	6-2-12	15	20	L	5	20	100	1	100	15	300	50	10
116	6-2-12	10	15	N	L	20	70	1	70	10	200	50	10

from the Jack Creek basin—Continued

Semiquantitative spectrographic analyses

Sample	(ppm) Y (5)	Ba (20)	B (10)	Sr (50)	Mn (20)	(percent) Fe (.05)	Ti (.002)	Ca (.05)	Mg (.02)
				Stream sediment samples					
6	30	700	10	700	1,000	2	.20	5	.70
7	20	700	L	700	3,000	3	.50	5	2
8	20	500	10	500	700	2	.20	3	2
9	20	1,000	10	700	2,000	1.50	.15	1	.70
10	30	700	15	200	700	2	.30	1	1
12	20	700	10	500	500	2	.30	1.50	2
13a	30	700	15	500	700	2	.20	2	1
14	20	1,000	20	500	500	1	.30	1.50	2
15	20	500	10	200	500	1.50	.20	1.50	.70
17	20	500	10	200	500	1.50	.20	1	.70
19	30	700	10	500	500	1.50	.30	2	1
20	20	500	10	300	500	1.50	.15	1	.70
21	20	700	10	500	700	1.50	.20	2	1.50
22	20	700	10	500	500	1.50	.20	2	.70
25a	70	500	L	200	700	2	.50	2	1.50
25b	70	500	10	200	700	3	.70	5	2
27	70	700	10	200	1,000	3	.70	2	2
29	50	500	15	150	1,000	2	.30	3	3
32a	50	500	15	200	1,000	2	.50	5	1.50
32b	30	500	10	300	700	2	.50	1.50	1
33	50	500	20	200	1,000	2	.50	2	1
34	50	700	10	200	1,000	3	.70	2	1.50
35	50	500	10	200	700	3	.50	2	1.50
36	50	500	20	200	700	3	.50	1.50	1
37	50	700	10	200	500	2	.50	1.50	1
38	20	700	20	300	500	2	.30	1	.70
43	30	500	20	150	500	2	.50	.70	.70
44	30	500	10	200	200	1.50	.20	7	1.50
45	20	700	10	200	500	1.50	.20	1	.70
46	20	700	50	200	700	2	.30	.70	.70
47	20	500	20	200	1,000	1	.20	2	.50
48	20	700	10	200	500	1.50	.30	5	.70
49	20	500	10	300	500	1	.20	1.50	.70
50	20	700	10	700	700	2	.20	5	2
51	20	1,000	L	700	500	2	.50	5	2
52	15	700	10	500	700	2	.20	5	3
53	20	700	15	500	500	1.50	.20	1.50	1
54	20	500	20	200	500	1.50	.20	.70	.50
55	30	500	15	200	700	1.50	.20	5	2
57	30	500	15	200	700	3	.50	3	2
59	20	300	10	300	1,000	3	.30	5	3
61	20	500	10	200	1,000	5	.50	5	5
62	30	700	10	300	700	2	.30	1.50	1.50
63	30	700	20	300	500	2	.30	.70	.50
64	50	500	10	300	700	2	.50	3	1
101	20	500	L	200	700	2	.30	1.50	1
102	50	500	10	500	700	2	.20	2	1
103	50	500	L	200	500	2	.30	2	1
104	50	500	10	200	700	2	.50	5	1
105	70	500	10	200	700	2	.50	2	1
106	50	500	10	200	700	2	.50	3	1
107	30	300	10	200	1,000	3	.30	5	1.50
108	20	300	10	200	300	1	.15	.7	.30
110	30	700	10	300	500	1.50	.15	1	.50
111	50	500	20	200	200	1.5	.30	.70	.70
112	50	700	L	150	1,000	3	.70	2	.70
113	L	100	L	L	100	.07	.05	.50	.20
114	50	700	30	200	300	1.50	.20	.70	.50
11[illegible]	50	500	15	200	500	1.50	.20	.70	.50
116	50	500	20	200	300	1.50	.20	1	.70

TABLE 2.—*Analyses of samples*

Semiquantitative spectrographic analyses

Sample	Location T. R. S.	Cu (2)	Pb (10)	Mo (2)	Co (10)	Ni (2)	Cr (5)	Be (1)	V (5)	Nb (10)	Zr (10)	La (20)	Sc (5)
		(ppm)											
						Stream sediment samples--Continued							
117	6-2-12	10	20	L	7	50	150	1	100	10	200	70	15
118	6-2-11	20	20	N	7	50	150	1	150	10	200	30	20
119	6-2-2	10	20	N	7	50	150	1	100	10	150	50	20
120	6-2-2	10	20	N	10	50	150	1	100	10	200	50	15
121	6-2-3	20	20	N	7	50	150	1	100	15	200	30	15
122	6-2-3	30	20	N	20	70	300	1	100	10	100	30	15
123	6-2-3	10	20	N	10	50	150	1	100	15	300	20	15
124	5-2-33	10	30	N	10	70	500	1	100	10	150	30	15
125	5-2-32	10	20	N	10	50	200	1	70	15	200	30	10
126	5-2-32	10	30	N	5	30	150	1.5	70	15	300	50	10
128	6-2-7	7	30	N	5	20	70	1.5	100	15	200	30	10
129	6-1-13	15	30	15	L	30	70	1.5	150	10	100	30	10
130	6-1-12	10	30	N	L	15	70	1	70	10	150	20	7
131	6-1-12	10	30	N	5	20	100	1.5	100	15	200	70	10
132	6-1-12	15	20	N	5	20	100	1	100	L	100	50	7
137	5-2-34	10	30	L	7	50	100	1	50	10	150	50	7
138	5-2-34	20	30	L	15	100	300	1	100	15	200	30	20
141	6-2-6	10	30	L	7	50	500	1.5	150	15	700	50	15
144	5-2-29	20	30	L	15	50	200	2	100	20	500	50	20
146	5-1-30	30	20	L	20	100	300	1.5	100	15	300	70	30
148	5-1-19	10	30	5	10	50	200	1	100	10	300	50	20
149	5-1-30	7	30	N	7	30	200	1.5	100	15	1,000	50	20
156	6-1-1	20	20	10	L	20	70	1.5	70	10	200	30	7
157	6-2-6	15	20	N	L	20	70	1.5	70	20	500	70	10
161	5-2-27	20	20	N	20	70	300	1.5	70	20	300	50	20
162	5-2-28	10	30	N	15	50	200	1	50	15	200	70	15
						Soil samples							
127	6-2-8	7	10	N	N	5	10	L	20	L	L	L	L
145	5-2-29	20	15	N	10	30	200	1	100	10	200	50	15
147	5-2-30	15	20	N	7	50	150	1	100	15	150	50	10
154	6-1-2	10	30	N	L	15	100	1.5	70	10	300	20	7
160	5-2-34	20	30	N	5	30	70	1.5	70	15	200	30	10
						Panned sample							
158	6-2-6	7	10	N	20	100	1,000	1	100	20	700	70	50

from the Jack Creek basin—Continued

Semiquantitative spectrographic analyses

	(ppm)					(percent)			
Sample	Y (5)	Ba (20)	B (10)	Sr (50)	Mn (20)	Fe (.05)	Ti (.002)	Ca (.05)	Mg (.02)
					Stream sediment samples--Continued				
117	50	500	20	300	500	1.50	.20	1	1
118	50	700	30	200	500	2	.70	2	1
119	70	500	20	300	1,000	2	.50	2	1
120	50	700	20	200	2,000	2	.50	2	.70
121	50	500	15	200	500	2	.20	1	.70
122	20	700	20	500	500	2	.20	1.50	2
123	30	700	15	300	500	2	.30	1	.70
124	30	1,000	10	300	700	2	.30	3	1.50
125	30	500	10	200	500	2	.20	1.50	1.50
126	50	500	10	200	500	1.5	.20	2	1
128	30	700	20	300	500	1.50	.20	.70	.70
129	20	500	20	150	300	1.50	.15	.70	.70
130	20	1,000	10	300	500	1	.15	1.50	.70
131	50	700	15	300	500	1.50	.30	.70	.50
132	15	700	20	300	500	1.50	.15	1	.50
137	50	500	10	200	700	1.50	.20	1	.50
138	30	500	10	300	700	2	.30	5	2
141	50	700	50	300	500	2	.50	1	1
144	70	700	10	200	700	2	.70	2	1
146	100	500	10	200	1,000	3	.50	3	1
148	70	700	10	300	700	3	.50	3	2
149	70	500	20	300	500	2	.70	2	1
156	20	500	20	200	500	1	.15	.70	.50
157	20	700	20	300	500	1	.20	1	.50
161	100	500	15	200	700	2	.50	5	1
162	70	700	10	200	700	2	.50	5	1
					Soil samples				
127	L	100	L	L	200	.50	.02	.70	.20
145	30	700	20	500	1,000	2	.30	.70	.50
147	50	200	30	300	500	1.50	.30	2	.70
154	15	500	10	300	1,000	1	.15	5	1
160	30	500	50	700	500	1	.20	.70	.30
					Panned sample				
158	50	500	20	300	1,000	3	.70	7	3

TABLE 3.—*Thicknesses and analyses of beds of phosphate rock in Jack Creek basin and vicinity*

Sampling site	Location	Strike	Dip	Thickness (feet)	P_2O_5 (percent)
Shell Canyon (Lot 1214)	SE¼NE¼ sec. 33, T. 6 S., R. 1 E.	N. 5° W.	10° to 15° SW.	0.75	23.6
				.50	32.4
				1.50	32.5
Aspen Valley (Lot 1215)	SE¼SE¼ sec 11, T. 6 S., R. 1 E.	N. 45° E.	55° NW.	1.60	31.0
				.30	26.9
Jack Creek Canyon (Lot 1218.	SE¼NE¼ sec. 35, T. 5 S., R. 1 E.	N. 60° E.	45° NW.	1.15	28.8
West Fork, Gallatin River	Sec. 8, T. 6 S., R. 3 E			1.16	32.2
Do	NW¼SE¼ sec. 32, T. 6 W., R. 4 E.	N. 35° W.	45° to 50° SW.	.45	22.2
				.70	26.2

Phosphate rock is graded on the basis of P_2O_5 content. Three grades of phosphate rock are recognized: acid grade, containing more than 31 percent P_2O_5; furnace grade, containing 24 to 31 percent P_2O_5; and benefication grade, containing 18 to 24 percent P_2O_5. As noted in table 3, thin beds of all three grades of phosphate rock occur in or near the basin. In evaluating the phosphate resources of Montana, Popoff and Service (1965) note that economic underground mining of acid-grade phosphate rock has been limited to beds 3 feet or more thick in the Garrison district, about 120 miles northwest of the Jack Creek area. They also used a thickness of 4 feet as minable minimum for furnace- and beneficiation-grade phosphate. The steep dips of phosphatic beds in the basin make strip mining unfeasible.

Throughout the western phosphate field are large reserves of phosphate rock in beds of greater thickness that are more accessible and easier to mine than those in the Jack Creek area. Although the demands for phosphate products are expected to increase continually, the thinness of the beds, the structure and topography of the area, and the transportation costs would make it unprofitable to mine phosphate rock in the Jack Creek area in the foreseeable future.

COAL

According to Peale (1896), coal was found in the Laramie Formation in the Jack Creek basin. During the period 1883 to 1889, coal claims totaling 280 acres were filed in the basin, and an additional 80 acres were added in 1895. In 1910 and 1911, the coal lands were withdrawn for coal classification under the authority of Coal Land Withdrawal No. 1 and No. 8. Part of the withdrawn lands were restored from withdrawal in 1911, but most of the basin east of R. 1 E. continues to be withdrawn and the coal rights have been retained in Federal ownership.

Swanson (1950, p. 11) notes that anthracite coal has been mined near the head of Mill Creek, which is about 6 miles south of Jack

Creek basin. Local citizens at Ennis reported that coal had been prospected for in the basin, but there is no evidence of coal having been produced.

We did not find coal of any rank during the course of our field studies. Black shale with minor carbonaceous coatings along bedding planes crops out at many places in the Colorado Group, but the shale is not combustible. The black shale has been prospected for coal at several localities. A short caved adit is located near the confluence of Hammond and Jack Creeks, in the N½ sec. 6, T. 6 S., R. 2 E., and small surface excavations were seen in the NW¼ sec. 36, T. 5 S., R. 1 E.; N½ sec. 1, T. 6 S., R. 1 E.; W½ sec. 31, T. 5 S., R. 2 E.; and W½ sec. 7, T. 6 S., R. 3 E.

Two samples of shale, a composite sample from the caved adit near the confluence of Hammond and Jack Creeks and the other from a shallow pit in the N½ sec. 1, T. 6 S., R. 1 E., were analyzed by the Bureau of Mines Coal Research Center, Pittsburgh, Pa. The data in table 4 show that the shales are too low in volatile matter and fixed carbon to be of value as coal.

TABLE 4.—*Coal analyses of black shale, Jack Creek basin*

[Data in percent. British thermal units too low to be determined. Analyses by U.S. Bureau of Mines Coal Research Center, Pittsburgh, Pa.]

Type analyses	Composite sample RV-3, 4, 5 [1]		Sample RV-14A [2]	
	As received	Moisture free	As received	Moisture free
Proximate				
Moisture	1. 4	----------	3. 5	----------
Volatile matter	7. 8	7. 9	8. 5	8. 8
Fixed carbon	. 9	1. 0	. 1	. 2
Ash	89. 9	91. 1	87. 9	91. 0
Total	100. 0	100. 0	100. 0	100. 0
Ultimate				
Hydrogen	0. 9	0. 7	0. 9	0. 5
Carbon	1. 7	1. 7	3. 2	3. 4
Nitrogen	. 1	. 1	. 1	. 2
Oxygen	7. 4	6. 4	7. 8	4. 7
Sulphur	. 0	. 0	. 1	2
Ash	89. 9	91. 1	87. 9	91. 0
Total	100. 0	100. 0	100. 0	100. 0

[1] NW¼ sec. 6, T. 6 S., R. 2 E.
[2] N½ sec. 1, T. 6 S., R. 1 E.

OIL SHALE

No oil shale is known in the Jack Creek basin; nevertheless, two samples of black shale of the Colorado Group were collected and analyzed for oil content (pl. 2, samples 159 and 16). Analytical results are given in table 5. Both samples were taken at the surface, where much of the oil content in the shale could have been oxidized and could have escaped from the rocks. The complete absence of oil, however, as shown in table 5, indicates the rock cannot be considered as oil shale.

TABLE 5.—*Oil-shale assays of shale samples from Jack Creek basin*

[Assays by modified Fisher retort method, E. J. Fennelly and J. M. Gardner, U.S. Geological Survey]

Sample	Yield of product						
	Weight percent				Gallons per ton		Loss on ignition (percent)
	Oil	Water	Gas plus loss	Spent shale	Oil	Water	
159	None	2.4	1.2	96.4	None	5.6	7.46
16	None	1.4	1.4	97.2	None	3.2	7.45

Farther southwest in Montana, oil shale is present in the Retort Phosphatic Shale and in the Meade Peak Phosphatic Shale Members of the Phosphoria Formation, but the oil content (in gallons per ton) of these rocks decreases eastward and northward (A. F. Bateman, Jr., written commun., 1969). Rocks of the Phosphoria Formation in Jack Creek basin and vicinity are not considered valuable as oil shale.

OIL AND GAS

No oil or gas has been produced from the Jack Creek basin or from nearby parts of southwestern Montana. Elsewhere in Montana, oil and gas have been produced from some of the same sedimentary rock formations that underlie the basin. Data on test wells that have been put down for oil and gas at distances ranging from about 4 to 25 miles south and southeast of the basin are shown in table 6 (A. E. Bateman, Jr., written commun., 1969).

TABLE 6.—*Tests on oil and gas in southwestern Montana*

Location of hole	Depth of hole (feet)	Remarks
Sec. 3, T. 3 S., R. 4 E	795	No shows.
Sec. 9, T. 3 S., R. 4 E	1,302	Do.
Sec. 26, T. 7 S., R. 2 E	2,302	Do.
Sec. 11, T. 10 S., R. 3 E	2,138	Do.
Sec. 16, T. 13 S., R. 5 E	402	Do.
Sec. 21, T. 13 S., R. 5 E	1,138	Do.
Sec. 21, T. 13 S., R. 5 E	352	Do.
Sec. 22, T. 13 S., R. 5 E	1,390	Do.
Sec. 34, T. 13 S., R. 5 E	115	Do.

Oil and gas could occur in rocks underlying the Jack Creek basin, but the failure to find oil or gas in similar rocks in nearby areas, the widespread occurrence of intrusive igneous rocks in the basin, and its relatively small size make the basin an unattractive site for petroleum exploration.

LODE PROSPECTS

Several prospect workings have been dug along the Spanish Peaks fault in the search for mineral deposits. These workings are chiefly sloughed prospect pits; most of them are about 5 to 10 feet across and 2 to 5 feet deep. A short caved adit also was seen in the vicinity. Most of the workings probably were dug for copper, as copper-stained rocks have been found at different localities along the fault (Becraft and others, 1966, p. B14).

Prospect workings were reported near the head of Mill Creek, in sec. 24, T. 5 S., R. 1 E., but we did not find them. Rock samples 24, 26, 28, and 30, taken in that section along the Spanish Peaks fault, did not contain unusual amounts of metals, nor did sediment samples taken downstream from the fault. (See pl. 2 and table 2.) Two prospect pits were found in the southern part of sec. 19, T. 5 S., R. 2 E., near the Spanish Peaks fault, and both were in the upper parts of tributaries of Mill Creek. A sample of selected rocks (RV–10, table 7) from the easternmost of the pits did not reveal any appreciable metal values. Sediment samples 148 and 149 (see table 2), taken downstream from the pits, also did not contain unusual metal values. No concentrations of ore minerals worthy of prospecting are indicated in the headwaters area of Mill Creek by our analytical findings.

In the northern part of sec. 34, T. 5 S., R. 2 E., on the ridge between East Hammond Creek and Wickiup Creek and alongside the trail leading to the Spanish Peaks primitive area are two prospect pits. The eastern pit is the more conspicuous and is about 6 feet in diameter and 2 feet deep. The pit is east of a prominent outcrop of phosphatic chert of the Phosphoria Formation and slightly northeast of the Spanish Peaks fault. It is in a soil-covered area, where no bedrock is exposed but where there is Precambrian gneissic talus from the ridge to the northeast and also sparse iron-stained fragments of quartz, some of which are brecciated. Minor amount of pyrite are visible on freshly broken surfaces of the iron-stained quartz. Some weathered surfaces of the quartz show faint green copper stains. A selected sample of the dump material, sample 134, did not contain unusual metal values, nor did sample 135, taken of float fragments of quartz collected a few feet west of the pit. Samples RV–1 and RV–2 (table 7), taken from the two prospect pits, also did not contain unusual amounts of metal.

TABLE 7.—*Analyses of samples from three lode prospects, Jack Creek basin*

Element	RV-1	RV-2	RV-10
	SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES		
	Ppm		
Cu	50	50	100
Pb	100	--------	200
Mo	<15	<15	--------
Co	<30	<30	<30
Ni	20	40	20
Cr	50	50	30
Be	--------	--------	<20
V	10	10	100
Zr	50	50	100
	Percent		
Fe	>3.50	>3.50	>3.50
Ba	.20	--------	.10
Mn	.14	.14	.14
Ti	.60	.60	.10
Mg	.50	3.00	>3.00
	FIRE ASSAY (Ounces per ton)		
Au	0.03	Tr	Tr
Ag	Tr	Tr	Nil

About 1,100 feet south of the prospect pit on the ridge, and about 400 feet lower, is an adit that was driven N. 78° W. in buff, iron-stained dolomite. The adit is partly caved at the portal but appears to have been driven about 30 feet, following an iron-stained fracture that is as much as 1 foot wide. A sample of stained dump material, sample 139, did not contain unusual quantities of metals. Sediment sample 64, taken downstream from the prospected area, also did not contain anomalous quantities of metal.

Farther southeast along the Spanish Peaks fault, sediment sample 61, taken from a tributary of Wickiup Creek at the point where the fault crosses the creek, contained 150 ppm (parts per million) copper, which is well above the average of other sediment samples in the area. The sample also contained more cobalt, nickel, and chromium than other sediment samples from the area. The copper content could be considered anomalous with respect to the copper in other sediment samples from the Jack Creek basin in general but not in respect to other samples taken along the Spanish Peaks fault. The sporadic nature of mineralized occurrences along the fault is emphasized by sediment samples 62 and 63, both of which were taken from streams that cross the fault in nearby areas but which do not contain unusual amounts of copper.

Brecciated and iron-stained limestone and sandstone occur at sample site 58, the easternmost site sampled along the Spanish Peaks fault. Some of the brecciated rock is silicified. Sample 58 contained 150 ppm copper, 300 ppm zinc, and 5,000 ppm arsenic. About half a mile to the northwest, along the fault, sample 60 was collected from intensely brecciated Cretaceous sandstone. This sample contained 200 ppm copper and 200 ppm zinc. The two samples also show the sporadic nature of copper along the fault, although at no place were enough copper minerals seen to warrant exploration. The spotty nature of copper mineralization along the fault is further emphasized by the negligible copper content of sediment sample 55, taken from a stream that drains across the fault midway between sample sites 58 and 60.

Samples 10, 13a, 14, 17, 51, 129, and 156, taken farther south in the basin, contain more than normal amounts of molybdenum. Samples 10, 13a, 14, and 17 are from the upper part of Jack Creek; sample 51 is from the South Fork of Jack Creek; sample 129 is from the upper part of Aspen Creek; and sample 156 is from a southern tributary to Jack Creek. The molybdenum content in all of these samples is rather low and is not believed to be indicative of deposits of commercial value. No evidence was seen in any of the rocks upstream from the sampled sites that was indicative of concentrations of molybdenum minerals.

LIMESTONE

Limestone occurs in Paleozoic rocks along the western side of the basin (pl. 1). Limestone is an important industrial material but has low value and must be close to marketing areas to be minable at a profit. The limestone deposits in the study area would be very difficult to exploit because Montana has vast limestone reserves that are more accessible and closer to rail and marketing areas.

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