THE RAWLINS, SHIRLEY, AND SEMINOE IRON-ORE DEPOSITS, CARBON COUNTY, WYOMING

By T. S. Lovering

INTRODUCTION AND ACKNOWLEDGMENTS

For many years iron ore has been known to exist in central Wyoming. As early as 1870 the paint-rock deposits near Rawlins were opened, and in the early eighties only the isolation of the Seminoe deposits prevented their exploitation. Although the deposits have been known for nearly 60 years the available information about them is extremely meager, and owing to the demand for a detailed report on this region a survey of the Seminoe iron-ore deposits, the Rawlins paint-rock ores, and the Shirley iron-bearing veins was made by the writer in June, 1926.

The Union Pacific Railroad Co. and the Colorado Fuel & Iron Co. courteously permitted the writer to examine their private reports on the iron districts described in this paper. The help extended by the officials of both companies is deeply appreciated, and this opportunity is taken to thank Messrs. J. M. Shively, the land commissioner of the Union Pacific Railroad Co., and L. B. Weed, the superintendent of mines of the Colorado Fuel & Iron Co., for their courtesy and aid. The field work was greatly expedited through the efforts of the Rawlins Chamber of Commerce, and the writer is glad to acknowledge the assistance rendered by the members of this organization. The hospitality of Mr. Matt Brantley and his first-hand knowledge of the development of the Seminoe region were of great value.

GEOGRAPHY

LOCATION AND ACCESSIBILITY

The three iron-ore deposits described in this report are in the northern half of Carbon County, Wyo. (See fig. 27.) The Rawlins " paint-rock " ores are 1½ miles north of Rawlins. The Seminoe iron-ore deposits are halfway between Rawlins and Casper and are more readily accessible from Rawlins. The Shirley iron-bearing veins are 25 miles due north of Hanna and may be reached from either Hanna or Medicine Bow.

The Rawlins-Casper highway is an excellent automobile road, well graded, and graveled most of its length. The "paint-rock" ores north of Rawlins can be reached easily over this highway and are by far the most accessible of the deposits described in this report. The best route to the Seminoe Mountains in 1926 was over the Casper highway to a point 16 miles north of Rawlins, thence by a branch road across the flats to the oil camp called G. P. 16, about 35 miles from Rawlins. This road is kept in fair condition, as it is used for most of the freighting to the near-by oil camps. The Seminoe iron deposit is only 3½ to 4 miles in an air line east of the G. P. 16 camp,

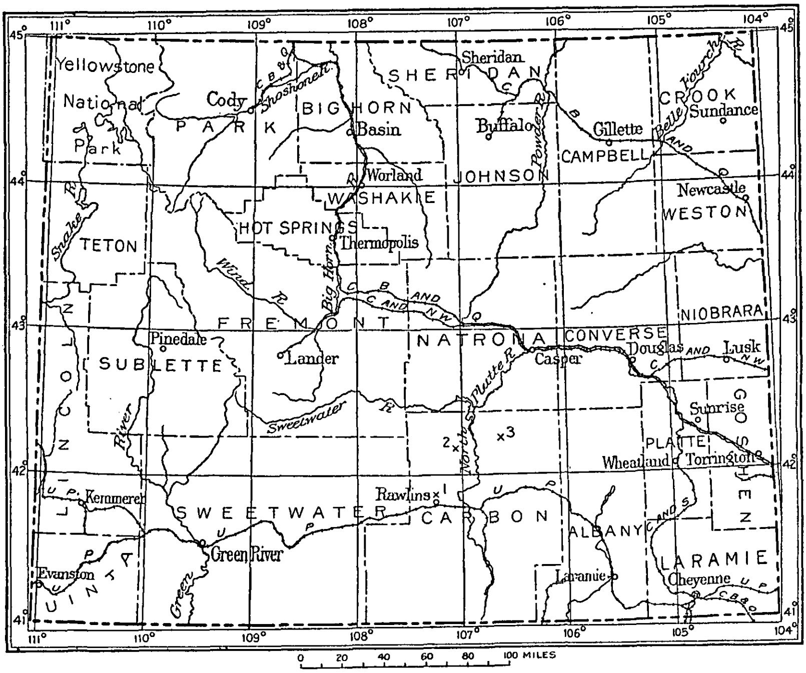


FIGURE 27.—Index map of Wyoming, showing the location of the Rawlins (1), Seminoe (2), and Shirley (3) iron-ore deposits

but the shortest practicable route from the camp necessitates traveling 9 miles over very rough roads.

A graded dirt road leads from both Medicine Bow and Hanna to a point within 2 miles of the Shirley iron-bearing veins, which are 6 miles west-northwest of the Shirley post office.

TOPOGRAPHY

The eastern Rocky Mountains of Colorado are made up of great north-south ranges, and two of these—the Medicine Bow Mountains and the Park Range or Sierra Madre—continue into Wyoming. About 75 miles north of the Colorado line, however, the axes of the

Rocky Mountain ranges swing toward the northwest, and throughout central and west-central Wyoming these mountains trend west-northwest. Near the Yellowstone National Park the ranges resume the northward course, followed by the mountains that border the plains in Colorado and southern Wyoming.

The North Platte River rises in Colorado and flows northward into Wyoming between the Medicine Bow Mountains on the east and the Sierra Madre on the west. It continues this course across the east-west ranges between Rawlins and Casper to the vicinity of Casper, where it turns east around the west end of the Laramie Mountains. The largest tributary that enters the North Platte south of Casper is the Sweetwater River. This stream rises in the west-central part of Wyoming south of Wind River Peak and flows east to the North Platte River between the Rattlesnake Range on the north and the Green River Mountains, the Ferris Mountains, and the Seminoe Mountains on the south. The North Platte a few miles south of its junction with the Sweetwater and just above the Pathfinder Reservoir, has cut a great gorge through the eastward continuation of these southern ranges and separates the Seminoe Mountains from the Freezeout Mountains. In these two ranges, respectively, lie the Seminoe iron deposits and the Shirley iron-bearing veins.

Few perennial streams persist far beyond the mountains in this semiarid region, and in the plains surrounding the ranges playas and alkaline lakes are common. Fortunately springs are found in a few localities and furnish much of the water used for livestock.

The principal topographic expression in the plains is caused by the hard sandstone of the Mesaverde formation cropping out in pronounced ridges. Meade Ridge and the Table, Haystack, and Rattlesnake Hills are thus formed and connect the north end of the Medicine Bow Range with the Seminoe Mountains. This series of hills marks the western edge of the Laramie Plains and shuts off the high plains on the west from the North Platte River. The region stretching northeastward from Rawlins to the Ferris Mountains and Table Hills has no outward drainage and forms a high interior basin. This basin has an average altitude of a little more than 6,500 feet, ranging from a minimum of 6,420 feet at Boundary Lake to more than 7,000 feet in the vicinity of the major uplifts. The Ferris Mountains, 30 miles due north of Rawlins, are notably conspicuous, some of the highest peaks of the range rising well above 10,000 feet. A few miles southeast of the Ferris Mountains the Seminoe Mountains rise slightly above 9,000 feet. The Freezeout Mountains, east of the Seminoe Mountains, also attain altitudes of a little more than 9,000 feet. Within these mountains erosion has uncovered the ancient pre-Cambrian complex, and the irregular pattern of the ridges and peaks is typical of the dissection of granite in high country. Bordering the granite areas, the " rim rocks " and hogbacks of sharply upturned sediments give distinctively linear features to the topography. In the basin south of these mountains sharp ridges and escarpments mark the outcrop of the hard Cretaceous sandstones, and saline lakes and ponds, shining white areas of alkali, and wide stretches of nearly level somber-colored land mark extensive areas of Cretaceous shales. Throughout most of the central and northern parts of the basin, however, the chief features of the landscape owe their origin to the wind-blown sand derived from the extensive outcrops of soft Tertiary sandstones on the high plains farther west. The great areas covered by bare drifting sand, large sand dunes, and sand ridges miles in length testify to the aridity of the climate.

VEGETATION

In the mountains sufficient rain falls to support a moderate growth of timber, although much of the wood has been removed by the ranchers. Along the perennial streams dense thickets of aspen are common and supply material for fence posts and firewood. In the arid basins, however, the chief growth consists of sagebrush. Grass is found near the few springs, and in relatively wet years the growth in certain sections is sufficient to support fairly large bands of sheep or cattle.

GENERAL GEOLOGY

STRATIGRAPHY

Pre-Cambrian schists, gneisses, granites, and dioritic intrusives are found in the areas in south-central Wyoming where very old rocks are exposed in the high parts of the major uplifts. In the adjacent basins Paleozoic, Mesozoic, Tertiary, and Quaternary deposits overlie the ancient floor formed by these rocks. The pre-Cambrian formations, the Cambrian quartzite, and the Carboniferous limestone are the only deposits of especial interest in a study of the iron ores and are described in detail beyond.

A generalized section of the region is given below, taken largely from Fath and Moulton's report on the Lost Soldier-Ferris district[1] but supplemented to some extent by additional information from recent work in the Bell Springs district.[2]

[1] Fath, A. E., and Moulton, G. F., Oil and gas fields of the Lost Soldier-Ferris district, Wyo.: U. S. Geol. Survey Bull. 756, pp. 10–11, 1924.

[2] Dobbin, C. E., Hoots, H. W., and Dane, C. H., Geology and oil and gas possibilities of the Bell Springs district, Carbon County, Wyo.: U. S. Geol. Survey Bull. 796, pp. 174–175, 1928.

Generalized section of the rocks in central Wyoming

Age	Group	Formation	Thickness (feet)	General character
Quaternary.		Alluvium and wind-blown sand.		The alluvium consists principally of worked-over material from the surrounding formations. The wind-blown sand is probably derived from the Tertiary formations that crop out west of the district.
(?)		(?)	(?)	Yellowish-brown and white massive and thin-bedded sandstones interbedded with brown, gray, and black shales.
Cretaceous.	Montana.	Lewis shale.	680	Principally dark-gray, thinly laminated shale containing several beds of yellowish-brown sandstone from 1 to 20 feet thick. Marine fauna. The thickness given was measured in T. 25 N., R. 89 W.
		Mesaverde formation.	200–2,200	Generally characterized by the three divisions described below. Varies greatly in thickness, from 1,700–2,200 feet where believed to be normally developed down to 200 feet or less (probably a local condition). Nonmarine and marine fauna. 1. Thick sandstone beds interbedded with equally thick series of alternating thin beds of sandstone and shale. A white sandstone about 100 feet thick (Teapot sandstone member) generally lies at or within a few hundred feet of the top. Coal bearing locally. Forms ridges and escarpments. 2. A thick mass of dark-gray to brown shale, sandy shale, and light-gray to yellowish and reddish-brown sandstone with a few layers of brown limy sandstone. Presents in places a striking banded appearance. Forms a surface of low relief. 3. Thick sandstone beds interbedded with equally thick series of alternating thin beds of sandstone and shale. Forms ridges and escarpments. In this report the lowermost thick white sandstone is considered the base of the formation.
		Steele shale.	4,000–4,750	Mainly dark-colored soft shale with thin zones of sandy shale and sandstone. The upper part is relatively more sandy and is transitional into the overlying Mesaverde formation. At about 1,500 feet below the top (in some localities the formation is considered to be subnormally developed, and the interval where measured is only 960 feet) is a 50-foot sandstone bed that appears to be persistent throughout a large area. Marine fauna with some brackish-water forms in upper part.
	Colorado.	Niobrara shale. Carlile shale.	1,425–1,600	Top marked by a series of very thin beds of hard, comparatively resistant yellow limestone, which shows a wavy lamination on weathered surfaces, interbedded with soft argillaceous sandstone and shale. The main body of the mass is composed of dark-gray thin-bedded shale. Marine fauna.
		Frontier formation.	263–705	Uniformly characterized at its top by two to five beds of comparatively resistant light-colored sandstone and interbedded shale, below which is several hundred feet of soft shale. The sandstones dip steeply and form striking walls a few hundred feet high.

Generalized section of the rocks in central Wyoming—Continued

Age	Group	Formation	Thickness (feet)	General character
Cretaceous.	Colorado.	Mowry shale.	200-300	Hard fissile dark-gray shale, which weathers light colored; contains abundant fish scales. The formation is resistant in comparison with the overlying shale. Marine fauna.
		Thermopolis shale.	50-135	Soft dark-gray shale.
		Cloverly formation.	75-180	Characterized by a hard, resistant, light-colored conglomerate or quartzitic sandstone bed, 25 to 75 feet thick, at its base. In places this is overlain by 100 to 150 feet of shale, followed by a hard quartzitic sandstone about 28 to 35 feet thick.
Cretaceous (?).		Morrison formation.	400-700	Interbedded varicolored shale, yellow to light-gray soft sandstone, and a few thin beds of fossiliferous limestone. The shale and sandstone in the upper part (chiefly Morrison) vary greatly in character and composition from place to place. Except for the limestone beds, which are not everywhere exposed, these formations, for general purposes, can be described merely as the interval between the conglomerate at the base of the Cloverly formation above and the Triassic and Permian red beds below.
Jurassic.		Sundance formation.		
Triassic and Permian.		Red beds.	1,250±	Red sandstone, red sandy shale, and red shale, all rather soft, with one thin light-gray limestone near the middle, conspicuous by the contrast in color. At the base several thin beds of impure cherty gray limestone interbedded with deep-red shale and sandstone.
Pennsylvanian.		Tensleep sandstone.	150-300	Massive to thin-bedded and cross-bedded resistant sandstone, locally quartzitic.
		Amsden formation.	210-298	A series of limestone, sandstone, and shale; lower part notably red.
Mississippian.		Madison limestone.	165	Limestone; some layers sandy and in places of quartzitic character.
Cambrian.		(?)	450	Quartzite.
Pre-Cambrian.		Crystalline rocks and schists.		Granites, monzonite porphyry, diorite, greenstone schists, and ferruginous jaspers.

MAJOR STRUCTURAL FEATURES

In southern Wyoming, where the Rocky Mountains swing toward the northwest, the rocks have been folded into a few major arches and many subordinate domes and basins, which are strongly faulted in many places. The general structural features in Wyoming are shown on the geologic map of the State published by the United States Geological Survey in 1925. An uplift extends more than 100 miles west-northwestward through Carbon, Natrona, and Fremont Counties from Difficulty to Hailey, and midway of its length, near the Pathfinder Reservoir, is about 30 miles wide. For convenience it will be referred to in this report as the Pathfinder uplift. The southern flank of this uplift is one of the major structural elements of northern Carbon County. The Rawlins uplift, which extends 40 miles north of Rawlins, is the most conspicuous structural feature of the western border of Carbon County. Both of these uplifts have been greatly modified by faulting. The Seminoe fault is well defined in the south-central part of the Pathfinder uplift, and so is the Bell Springs fault in the Rawlins uplift. East of the Rawlins uplift and south of the Pathfinder uplift is the Hanna Basin. The Rawlins uplift has brought pre-Cambrian rocks to the surface. Its age, according to Fath and Moulton,[3] is pre-Wasatch, presumably early Tertiary, whereas the major uplift of the Ferris and Seminoe Mountains is considered to be post-Wasatch.

The Ferris, Seminoe, and Freezeout Mountains are part of the south side of the Pathfinder uplift, the axis of which trends about N. 55° W. The southwest border of this great arch has buckled and broken at many places. Overturned folds and overthrust faults commonly mark localities where the flanking sediments show pronounced divergence from the axial strike of the broad regional arch. This is well illustrated by the Seminoe fault, in which pre-Cambrian formations have been thrust southward over Paleozoic and Mesozoic sediments.

The Seminoe iron deposits are exposed near the southern toe of the overthrust fault block, and the details of the local structure will be considered in the section devoted to these deposits.

RAWLINS PAINT-ROCK DEPOSITS

LOCATION AND ACCESSIBILITY

The iron-ore deposits 1½ miles north of Rawlins were worked at one time for the pigment value of the hematite, and for this reason they are widely known as the "paint-rock" deposits. Nearly all the ore shipped came from the old workings in the cornering quarters of secs. 4, 5, 8, and 9, T. 21 N., R. 87 W., sixth principal meridian. This land is now owned by the Union Pacific Railroad Co. Some ore is said to have been shipped from the NE. ¼ SW. ¼ sec. 31, T. 22 N., R. 87 W. The principal workings are easily accessible by automobile from Rawlins; a few minutes' drive on the Casper highway brings one around the north side of a quartzite hill, where the old Lander road branches off to the west and leads directly across

[3] Fath, A. E., and Moulton, G. F., op. cit., pp. 30–31.

the principal developed ground. The roads to the ore deposits have only gentle grades; and if the deposits were again worked no difficulty should be experienced in running a spur track from Rawlins or taking the material out by truck.

HISTORY

The ore was first mined in 1870 because of its value as a metallurgical flux, and it was shipped in barrels to Salt Lake City, Omaha, and eastern points. A paint mill was erected in the seventies; the exact date was not ascertained. In the early eighties the hematite paint produced here was widely and favorably known for its durability and covering qualities. The " Rawlins Red," as the pigment was called, enjoyed the distinction of being selected to paint the then newly completed Brooklyn Bridge (1883). In 1886 the mill was dismantled. The deposits were worked intermittently until after 1900, but no ore is known to have been shipped in the last 20 years.

According to Ricketts[4] the total production from these deposits prior to 1890 was about 100,000 tons of ore, most of which was sold to smelters for flux. After the development of iron ore nearer the smelting centers the Rawlins ore was unable to pay a profit because of the long haul necessary to bring it into the market. The isolation of the deposits also prevented them from competing with eastern sources of mineral paint, and their situation will have to be carefully considered before any new attempt to work them for paint material is made.

GEOLOGY

STRATIGRAPHY

Pre-Cambrian granite and Paleozoic, Mesozoic, and Cenozoic sediments are present in the region near Rawlins, but the iron ore is confined to Cambrian and Mississippian beds. The Cambrian is dominantly quartzite and rests on pre-Cambrian granite. It is separated by a marked erosional unconformity from the overlying Madison limestone, of Mississippian age. The iron ore occurs near the contact of these two formations.

PRE-CAMBRIAN

The pre-Cambrian granite, exposed a mile west of the iron-ore deposits, is an unmetamorphosed, much jointed rock. No schist or gneiss was observed in the mass near the paint-rock deposits, and the exposure was not studied far to the north. The granite is a medium to coarse grained pinkish rock, containing abundant quartz

[4] Ricketts, L. D., Wyoming Territorial Geologist Ann. Rept. for 1890, pp. 60–62. See also U. S. Geol. Survey Mineral Resources for 1882, p. 147, 1883; idem for 1883–84, p. 285, 1885.

and microcline and various amounts of black biotite. No evidence of iron-bearing veins or pegmatite was seen in it.

The sedimentary contact of the overlying Cambrian quartzite with the granite clearly establishes the pre-Cambrian age of the granite. The lack of metamorphism in the granite indicates that it is probably younger than the iron formation of the Seminoe Mountains. It is similar in appearance to the granites found in both the Ferris and Seminoe Mountains and may be of the same age, but it is unsafe to correlate the granites on lithologic similarities, and no other evidence was found.

CAMBRIAN

The Cambrian rocks of this region are represented by a formation about 450 feet thick that is predominantly a pink to gray quartzite and subordinately sandstone and shale. The lower member is 395 feet thick and is made up chiefly of hard but somewhat porous pink quartzite, though locally it grades into a well-cemented sandstone. The base is conglomeratic and contains white quartz and pink granite pebbles, the largest 2 inches in diameter. Most of the lower part of the section is arkosic; in places the arkose becomes very coarse, and thin layers of conglomerate may appear well above the base.

The pink quartzite makes a handsome building stone and has been used for many buildings in Rawlins. At one time grindstones were made from the quartzite, and some of the old stones may be seen near the quarries.

Above the lower member the formation is made up chiefly of glauconitic sandy shale interbedded with thin layers of hard reddish-brown sandstone. This upper member varies greatly in thickness, reaching nearly 100 feet in some places, but in others it is entirely absent. Some siderite and limestone were found in the upper part of the bed, and locally hematite may be present. Although no fossils were found in the shaly beds, the presence of glauconite and the general lithology of the beds are characteristic of the upper Cambrian rocks in other parts of the State, and so these beds are provisionally included with the Cambrian.

CARBONIFEROUS

MADISON LIMESTONE

The Madison limestone, of Mississippian age, overlies the Cambrian formation unconformably. The basal member is a massive gray limestone, which shows many calcite stringers. On a weathered surface solution pits and deeply etched lines are conspicuous. Above the basal limestone the formation becomes very cherty and contains a few jaspery layers a foot or more in thickness. At many horizons the limestone is very reddish, and locally the beds are soft, sandy, and markedly ferruginous. This material is often mistaken for soft ore, although little of it contains as much as 5 per cent of metallic iron.

The thickness of the Madison limestone is said to be 165 feet at one place in the Rawlins Hills,[5] but near the paint-rock deposits diamond drilling shows the presence of a 4-foot bed of conglomerate 100 feet above the base. This bed is believed to be the base of the Amsden formation in this region, and thus the Madison limestone is believed to be only 100 feet thick near Rawlins.

AMSDEN FORMATION

The Amsden formation, probably all of Pennsylvanian age, overlies the Madison limestone in this region and throughout the Hanna Basin. It is said to be about 200 feet thick.[6] Above the 4-foot bed of conglomerate believed to mark its base is a thin bed of porous limestone; this is overlain by 15 feet of gray sandstone, which is iron stained at the top. Beds of ferruginous sandstone and iron-stained limestone alternate for the next 100 feet, and the remainder of the formation is made up of cherty gray and white limestone containing thin beds of purple limestone near the top of the section.

QUATERNARY

The wash from the near-by hills covers the Carboniferous formations a short distance north of the exposures of iron ore. Drilling indicates that the wash is about 75 feet thick 800 feet north of the old inclined shaft in the SE. 1/4 SE. 1/4 sec. 5. It is composed of sand and gravel. Some well-sorted material is found, but most of the wash is a mixture of pebbles and boulders of limestone, quartzite, and granite. In places the material is partly cemented, but most of it is still unconsolidated.

STRUCTURE

Rawlins is near the south end of a great anticline that stretches 40 miles north to the Ferris Mountains. Erosion has gone deepest along the crest of this anticline, and a few miles northwest of Rawlins all the overlying beds have been stripped from the pre-Cambrian granite core. On the east side of the uplift the Paleozoic beds that surround the granite dip 10°–35° E., and on the west side they dip west at steep angles. At the south end of the uplift the fold swings eastward and merges with the series of anticlines that mark the southern boundary of the Hanna Basin. Although the north-south anticline

[5] Fath, A. E., and Moulton, G. F., op. cit., p. 12.

[6] Idem, p. 13.

is still the dominant structural feature near Rawlins, minor folds striking east are present on the eastern flank of the large arch. The paint-rock deposits occur on the north side of one of these minor folds, and here the beds dip 25° N.

A fault striking N. 10° W. limits the exposure of the ferruginous beds about a mile west of the Casper highway. This fault is the only one noted in the region that has the downthrown side on the east. A few miles to the southwest and west, where the Bell Springs fault zone is present, much of the ground is badly faulted, but east of the fault first mentioned the beds are not disturbed.

THE PAINT-ROCK BEDS

The hematite mined near Rawlins came chiefly from beds above the Cambrian quartzite and below the cherty limestones of the Madison, or in other words from the lower part of the Madison limestone and the upper shaly layers of the Cambrian formation. The ore did not come from a single deposit but was taken from a number of shallow openings scattered over half a square mile. The ore bodies were very irregular in outline and cross section, and their thickness ranged from 2 to 30 feet. The best information obtained indicates that the largest ore body was followed nearly 200 feet down the dip of the beds by an inclined shaft, from which rooms were turned to the east and west. Most of the ore bodies were smaller. The distribution of the old workings indicates that a distinct zone trending northeast contains more hematite than can be found on either side, but many individual ore bodies show greater persistence along the strike than down the dip.

CHARACTER AND OCCURRENCE

Most of the ore is a soft powdery hematite of low density. There are also some streaks of hard blue hematite, some oolitic and pisolitic ore—the so-called "grape ore"—and locally stalactitic varieties. Siliceous hematite nodules are said to occur in the country rock.[7] The oolitic ores are lenticular masses, few of them more than 2 feet thick, and are interbedded with shale, sandstone, and quartzite, suggesting primary concentration. H. V. Winchell[8] mentions a 2-foot bed of hematite (63 per cent Fe) underlying quartzite in the bottom of a test pit in sec. 8. Some hard blue hematite occurs at the base of the Madison limestone and grades into the surrounding shale. This ore was probably formed earlier than the soft hematite. The soft powdery hematite is believed to be secondary. In many places the ore bodies in the Madison limestone have nearly vertical walls,

[7] Boyle, A. C., private report to the Union Pacific R. R. Co.

[8] Private report to the Union Pacific R. R. Co.

indicating that the soft ore was introduced into an open channel in the limestone. Other features, such as the form and distribution of the ore chambers, also indicate that the soft powdery hematite found in the Madison limestone filled old solution chambers developed by underground drainage. Smooth but irregular channels have been left in the limestone by the removal of the ore, and there is no evidence of gradation from ore to limestone in the small masses of soft ore that remain, but some siderite and glauconitic limestone on a dump show evidence of alteration to hematite.

The density of the ore as mined ranged between 3.5 and 5.0, averaging a little more than 4.0. The moisture content was usually about 2 per cent.

Analyses of ore from Rawlins paint-rock deposits

	Fe	SiO_2	P	S	CaO	CO_2
1	64.94	3.16	0.013	0.011	1.46	2.84
2	47.5	30.10	.016			
	55.2	17.73	.015			
	50.9	25.36	.015			
	52.3	6.95	.037			
3	62.25		.016			
4	62.25		.013			
5	63.05		.037			
6	64.75		.010			
7	67.05		.013			
8	66.40		.014			
9	66.85		.006			
10	61.10		.004			
11	66.35		.004			
12	64.94	3.16	.013	.011	1.46	2.84

1. Average of 9 carloads of ore, according to H. B. Jennings, formerly county clerk of Carbon County, at Rawlins.
2. Samples taken by Q. L. Brewer in 1927 from an old ore face. Analyzed by chemist of Colorado Fuel & Iron Co.
3-12. Samples taken by H. V. Winchell in 1899 and analyzed by Dickman & Mackenzie, Chicago, Ill.:
3. 14 feet of ore on north side of pit sunk in floor of large room of ore.
4. 6 feet of ore above sample 3.
5. 4 feet of ore in 20-foot layer north of shaft.
6. 6 feet of ore from 20-foot layer in stope northwest of shaft.
7. 6 feet of ore in stope east of incline shaft, 40 feet from surface.
8. 4 feet of ore from south stope east of shaft.
9. 4 feet of ore from bottom of shaft.
10. 2 feet of ore under limy quartzite in west prospect.
11. Grape ore under limy quartzite in west prospect.
12. Average sample of ore (same as No. 1).

ORIGIN

The basal Cambrian sandstone throughout the Ferris Mountains is highly ferruginous, and it is probable that the iron in these sediments was derived from Archean iron deposits similar to the iron-bearing Seminoe formation. Indeed, the weathering and erosion of pre-Cambrian iron deposits during the Paleozoic era probably supplied more than the normal amount of iron to many of the sediments of this system. Iron was deposited in the Cambrian sea as glauconite, siderite, and oolitic hematite, although some of the siderite was probably derived later from the glauconite. The unconformity at the base of the Madison limestone represents a long period of active erosion during which the iron contained in the basal Cambrian sandstone and shale would have been concentrated along stream channels and later reworked into iron-bearing lenses at the base of the Madison limestone.

When the ferruginous Paleozoic beds were raised above sea level, in post-Carboniferous time, the siderite and, to a less extent, the glauconite oxidized and hydrated into limonite. At this time the ground water was probably developing underground drainage systems in the readily soluble Madison limestone, and the iron minerals, largely in the form of limonite and hematite, were carried into the underground passages and caves, partly in solution and partly as fine ore débris. In the accessible parts of the largest paint-rock workings there is evidence of this type of cavity filling and of roof collapse and further infiltration of iron oxides. It is possible that much of the soft powdery hematite now found is dehydrated limonite.

The origin of the deposits is worthy of consideration by those interested in the development of the ores, for an understanding of the subject is essential to intelligent prospecting.

FUTURE POSSIBILITIES

The future development of the Rawlins paint-rock ore depends on the amount and character of ore in the ground, the cost of finding it, and the costs of mining and shipping. According to Winchell the quality of the ore mined was very good. The tonnage now in sight is so small that the resumption of mining is not justified unless additional ore is shown to exist. Nothing was seen in the geology to preclude the possibility of more ore being present, and therefore prospecting the vicinity of the former mines seems to be warranted. It is unlikely that any single large ore body will ever be uncovered near Rawlins, but probably a number of small deposits are present in the vicinity of the old paint-rock mines and in the region showing iron-stained rocks a few miles to the northwest.

A series of diamond-drill holes were made by the Union Pacific Railroad Co. to prospect the country rock beneath the wash north of the old workings. The results indicated that workable ore did not extend more than 200 feet north of the inclined shaft in the SW. ¼ sec. 5. However, as the trend of the ore bodies in the paint-rock deposits is about N. 50° E., the absence of ore on the north does not indicate that ore will not be found toward the northeast.

PROSPECTING

The cost of finding new bodies of ore by sinking shafts is apt to be too high to be justified, because of the spotty occurrence of the deposits. For the same reason diamond drilling would probably be unwarranted. Geophysical methods seem to offer the greatest likelihood of obtaining trustworthy information without expending too great a sum for exploration, but reliable conclusions would depend on the interpretation of the geophysical data in the light of a knowledge of the origin of the ores. A reconnaissance with a magnetometer could be followed by torsion-balance readings where the magnetometer indicated the possibility of finding ore. In making such a reconnaissance the most efficient plan would seem to be to make two traverses about 300 feet apart roughly parallel to the outcrop of the Cambrian beds. Promising areas found on these traverses should be considered as probably representing parts of old subsurface drainage channels or remnants of an ancient surface drainage system largely obliterated by an advancing sea. Two points would suffice to indicate the general direction of any channel, and detailed work with the torsion balance could then be carried on to determine the extent of the deposit; this should be supplemented by diamond drilling if necessary. The work could be done in two or three weeks at an outlay of a few thousand dollars.

The cost of mining deposits near the surface would be small, but the depth to the ore horizon increases about 30 feet in 100 feet toward the north, and this increase in depth might largely increase the cost of working deposits far from the outcrop, particularly if they proved to be discontinuous. It would also limit the area in which examination by the magnetometer and torsion balance would be effective.

SHIRLEY IRON-BEARING VEINS

The Shirley iron-oxide veins are about 25 miles due north of Hanna, in sec. 18, T. 26 N., R. 81 W. They lie at an altitude of about 8,000 feet in the east end of the Freezeout Mountains. The road from Medicine Bow to Casper through Shirley passes within a few miles of the deposits, and it is possible to drive over a branch road to a point only 2 miles from them. The land is moderately rough, timber is fairly plentiful, and the water supply is ample for stock raising and irrigation. The location of Shirley and the granite mass in which the iron-bearing veins are found is shown on the geologic map of Wyoming published by the United States Geological Survey.

GEOLOGY

Pre-Cambrian granite is widely exposed in this region and is the country rock of the iron-bearing deposits. It is a medium to coarse grained biotite granite and has a decidedly pink color. Practically no schist inclusions were seen, but some irregular masses of diorite may have been either intrusives or inclusions. The granite is cut by dikes and irregular masses of aplite, aplitic syenite, and pegmatite and by veins of pegmatitic quartz. The dimensions of these bodies differ greatly; some are 20 feet wide and more than half a mile long, and others are only a few inches wide and 5 or 6 feet long. Many of the quartz veins carry small quantities of hematite as rosettes or knots of bladed crystals apparently contemporaneous with the quartz. The most noteworthy occurrences of hematite are in pegmatite veins and in disseminated deposits in a syenite adjacent to one of the pegmatites.

In the E. ½ sec. 18 two dikelike masses of quartz, feldspar, and hematite occur. The eastern dike strikes nearly north, and the western dike strikes from north to N. 30° E. In a brief visit only one of the deposits was studied, but the other dike is said to be very similar to the one examined. This deposit strikes N. 5° E. and is about 10 feet wide for much of its length, although in many places it grades into large irregular bordering masses of pegmatitic quartz and feldspar. It is well exposed for more than half a mile along its strike, and through most of this distance a strong central seam of hematite-bearing quartz can be traced. The country rock is largely granite, but small masses of diorite and syenite also border the pegmatite.

IRON ORE

Mode of occurrence.—The best iron ore was found in the dike adjacent to a body of microcline syenite. The syenite was strongly impregnated with hematite for more than 100 feet from the pegmatite, and some of the near-by granite was similarly enriched. A sample of the hematitic syenite was found to contain 19.70 per cent of iron. The presence of secondary silica and the abundance of hematite crystals in the syenite make it resemble a biotite granite, for which it has been mistaken. In this locality the pegmatite dike is about 15 feet wide and consists essentially of hematite, orthoclase, fine-grained black quartz, and medium-grained white quartz. Orthoclase is most abundant at the borders of the pegmatite; black quartz intergrown with the feldspar is common at the edge of the dike and is increasingly abundant toward the center. These two minerals are cut by many veinlets of white quartz and hematite—in places they appear to have been brecciated and then injected by quartz or hematite or both. The hematite is best developed near the center of the dike, where it forms a seam of massive blue ore 1 to 2 feet wide. This seam is nearly free from silica, but veinlets of white quartz cross it here and there.

As the dike was followed away from this high-grade ore, hematite appeared along the sides of the pegmatite in vertical layers 2 or 3 inches thick and at the same time diminished to negligible amounts in the center. Some hematite could nearly always be found associated with the central quartz seam, but where the dike widened out into coarse-grained irregular masses of pegmatitic quartz and feldspar the mass as a whole was nearly barren of iron. These barren zones occur in many places and some are several hundred feet long.

Petrographic features.—Under the microscope the black quartz was seen to consist of fine-grained quartz and finely disseminated hematite. The hematite occurred throughout the individual grains of quartz but also showed a distinct tendency to form small seams along the interfaces of many of the crystals. This characteristic is interpreted to mean that much of this hematite was contemporaneous with the quartz but that some iron was still being precipitated after the silica had crystallized.

The white quartz of the pegmatite crosses the black quartz in veinlets and is almost free from hematite. Recrystallization of the rock has taken place and indicates that the white quartz is very early and can not possibly be late supergene silica.

The syenite consists of nearly equal parts of microcline and orthoclase. The hematite in the syenite is in the form of medium-grained bladed crystals. Albite, chlorite, apatite, and siderite are present in the pegmatite in very small quantities, and some albite and apatite were observed in the syenite. Chlorite and scattered grains of carbonate are associated with veinlets of hematite. The feldspar in both pegmatite and syenite appeared fresh, and no evidence of alteration by either hot or cold water was seen.

Origin.—Both the laboratory and the field evidence indicate that the hematite was formed at the pegmatite stage of the consolidation of a granite and should be considered a high-temperature deposit of the class to which the term "vein dike" may justifiably be applied. The intrusion of the pegmatite, which carried hematite disseminated through its quartz, was closely followed by fracturing and the deposition of additional magmatic material of the same general character but somewhat richer in iron. This later vein stuff was fluid enough to penetrate the surrounding rocks for some distance from the dike. The deposition was principally in the nature of fissure filling on a minute scale, although some microcline is partly replaced by hematite.

Future possibilities.—The inaccessibility of the deposits precludes their development at the present time. Even if transportation should be provided near by, it is unlikely that any large tonnage could be developed. The pockety appearance of the deposits along the strike indicates a pockety occurrence underground. A dike could be mined only through a shaft, and this would be costly. The reported occurrence of gold in these deposits is not supported by assays of the ore made for the writer by W. C. Burlingame, of Denver, Colo. Only a trace of gold was found in any of the samples tested.

SEMINOE IRON-ORE DEPOSITS

LOCATION AND ACCESSIBILITY

The Seminoe iron-ore deposits are best displayed in sec. 12, T. 25 N., R. 86 W., but ore is exposed also in secs. 1 and 13, T. 25 N., R. 86 W., and secs. 7 and 18, T. 25 N., R. 85 W. The deposits are about 27 miles in a direct line north-northeast of Rawlins, which is the supply center for this region. Rawlins is a division town on the main line of the Union Pacific Railroad and has a population of about 4,000. A very fair dirt road turns off from the Casper highway 16 miles north of Rawlins and trends north and east for 20 miles to the General Petroleum Co.'s oil camp, locally known as the "G. P. 16." The camp is only a few miles west of the iron deposits, but the roads to them are rough and hilly; the road leading through the Fieldhouse Cut is about 9 miles long and was in an extremely poor state of repair in 1926, and the road past Brantley's ranch and Deweese Creek is nearly twice as long and contains some very steep grades. However, the ore could be placed within 40 miles of Rawlins, the nearest shipping point, by building a few miles of road east of camp "G. P. 16." The deposits lie at an altitude of 7,500 to 8,000 feet, and a gentle grade to the oil camp could be easily found.

HISTORY

The Seminoe district is said to have been first prospected in the early eighties and is mentioned by the Territorial geologist of Wyoming in the reports for 1886 and 1890. No authentic record of any production can be found, although residents of the district state that in the nineties some ore was hauled to Rawlins and shipped.

Two or three short tunnels have been driven into the hills at various places; there are several scattered shallow pits, and one shaft is said to have been sunk 100 feet but is now badly caved. No systematic effort has been made to determine the quantity of ore in any given body.

TOPOGRAPHY AND DRAINAGE

The geologic structure of the region has in a large measure determined the topography. The Seminoe thrust fault, described on page 228, has brought hard pre-Cambrian metamorphic rocks up over soft Cretaceous sediments and is sharply outlined in part by a prominent ridge of quartzite that extends southeastward from the Ferris Mountains to Bradley Peak, 7 miles distant. (See pl. 46.) Immediately south of Bradley Peak (pl. 47) the pre-Cambrian rocks consist of relatively soft hematite and schist, and erosion has etched this into many small basins and mounds strongly colored by red iron oxide. East of Bradley Peak a depression marks the presence of a downthrown block of Cretaceous and Paleozoic beds, but farther east, beyond this depression, the Seminoe Mountains trace the uplifted pre-Cambrian rocks uninterruptedly to the great North Platte River Canyon. Behind the front of this eastern part of the Seminoe Mountains the rugged highland reaches altitudes of slightly more than 9,000 feet. In the downthrown block east of Bradley Peak the outcrop of the pre-Cambrian rocks has been shifted to the north, forming a ridge that divides the drainage of the fault valley between streams flowing in opposite directions. Deweese Creek flows northwest from the divide, and an unnamed stream flows southeast to the North Platte River. In the hummocky ground south of Bradley Peak the drainage is not well developed, and there are a few small swamps. Several springs occur in this region and probably mark hidden faults.

GEOLOGY

STRATIGRAPHY

EARLY GREENSTONE SCHISTS

The oldest pre-Cambrian rocks in the Seminoe Mountains are a series of complexly folded and faulted greenstone schists. Chlorite-hornblende schist and clinozoisite-hornblende schist are both abundant, and gradations from one to the other are common. In the field it is usually impossible to distinguish the two types, as the light-green clinozoisite imparts the same color and general appearance to the rock as the chlorite. Interbedded with these schists are small masses of light-gray sericite schist, dark-green hornblende schist, and grayish-green quartz-hornblende schist. All these rocks have an even-grained schistose texture and rarely show any metacrysts. Conglomerates are lacking. No evidence of ellipsoidal parting ("pillow structure"), vesicles, flow structure, or other macroscopic indications of extrusive rocks was found. Under the microscope some medium feldspar (andesine) could be seen in nearly all these rocks, and much if not all of the clinozoisite was derived from it. This fact strongly suggests that the clinozoisite-hornblende schists were formed from igneous rocks of intermediate composition and that the more basic schists probably represent basic igneous rocks. The thin beds of sericite schist and quartz-hornblende schist are probably metamorphosed sediments, and their presence as interbedded layers suggests surface conditions for the associated igneous rocks. Thus the available evidence indicates that the earliest rocks exposed in the Seminoe district are in large part ancient andesitic lavas and to a less extent sediments and basalts.

SEMINOE FORMATION (IRON BEARING)

A banded jaspery iron-bearing quartzite, here named the Seminoe formation, lies unconformably on the formations described above and is infolded with them in highly contorted layers. Greenstone schists are a common associate of the banded jasper that characterizes many pre-Cambrian iron deposits, and one who has studied such districts as the Vermilion in Minnesota or the Michipicoten in Ontario will feel a pleasure akin to that of recognizing an old friend in a distant land when he first sees the jasper and greenstone complex of the Seminoe region.

Throughout most of the Seminoe area the quartzite is underlain by the andesitic greenstones, but in some places south of Bradley Peak it lies upon a dark-green hornblende schist. The greatest thickness that can be ascribed to this formation with certainty is about 300 feet. When examined in detail its banding is usually found to be crenulated or slightly wrinkled, whether the formation is horizontal or vertical. Its attitude is extremely varied; in some localities it has been infolded with schists in complexly contorted folds, and in other areas its dip is less than 15°. It is represented throughout the schist region but makes up only a small percentage of the rocks exposed. It usually occurs in well-defined belts, although it is markedly discontinuous in outcrop along both dip and strike. The jasper overlies different schists in different places but is parallel to them and has suffered the same degree of metamorphism. From the facts just stated it seems probable that the iron formation consists of many discontinuous masses formed on the erosion surface of an ancient lava field. From the degree of metamorphism that it has suffered and its relation to the other pre-Cambrian formations, as well as its similarity to the Archean iron formations of northern Minnesota, the iron-bearing Seminoe formation is regarded as probably of Archean age. Its siliceous nature makes the formation extremely resistant to erosion, and it usually weathers in relief, standing out above the surrounding schists in knobs and ridges.

Lithology.—The Seminoe formation is extremely variable in detail, but its lithology is sufficiently distinctive to make it easily recognized wherever it is found. Its thickness is known to range from a few feet to a little over 300 feet, but in many places the beds are so highly contorted that its thickness can not be measured or estimated with any close approach to accuracy.

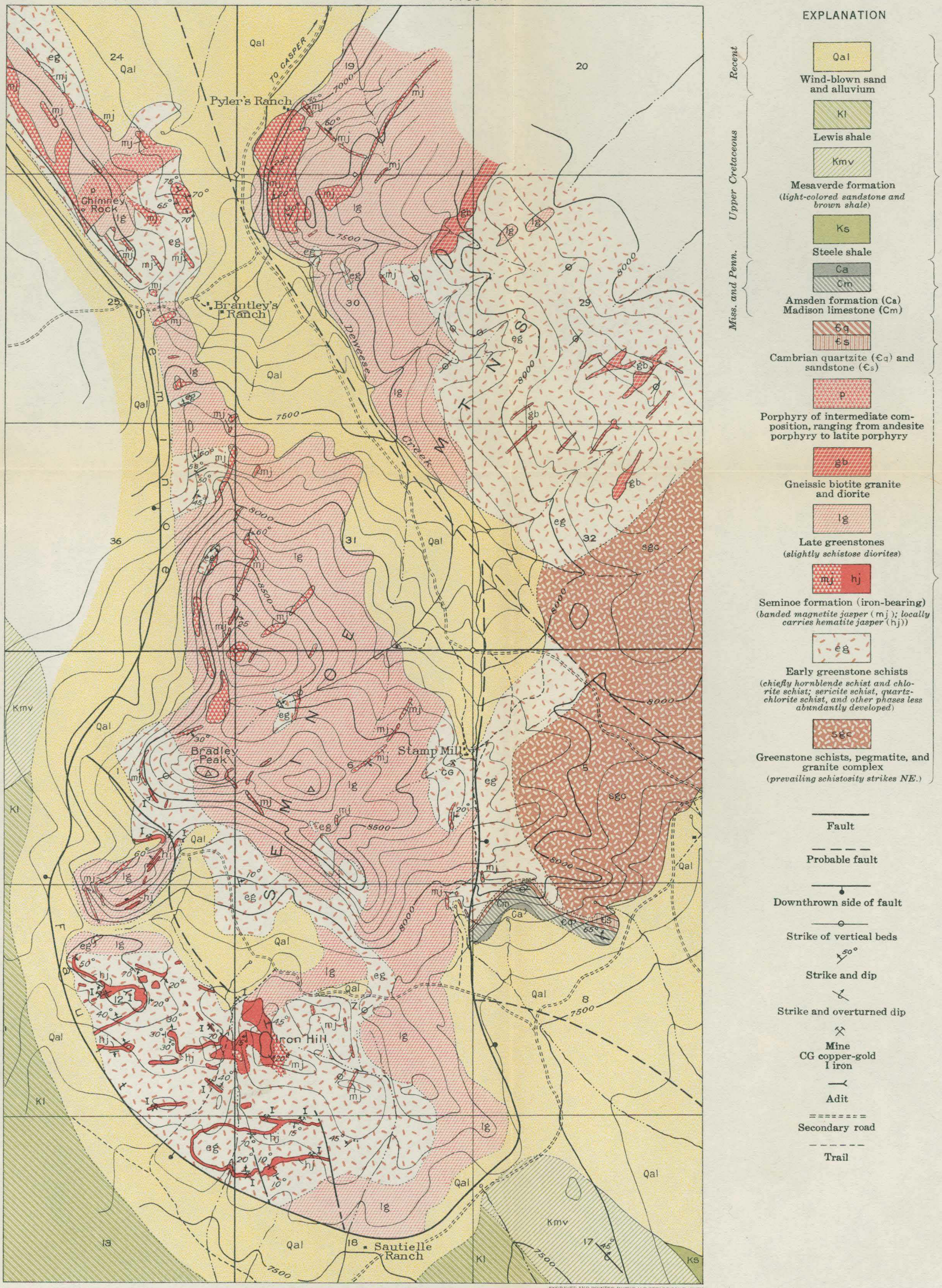
Wherever the formation is well developed it shows clearly a definite change in composition from a strongly ferruginous jasper at the base through a highly siliceous layer in the middle to a layer rich in hypersthene near the top. The thinner phases are as a rule lithologically similar to the base of the thicker parts of the formation.

Throughout most of the region the iron oxide in the formation occurs chiefly in the form of magnetite. South of Bradley Peak hematite is present in place of the magnetite to a marked degree, and in part of this region little or no magnetite can be found. Here the hematite is a late mineral and is largely an oxidation product of the earlier magnetite. The following vertical section, measured about 3 miles north-northeast of Bradley Peak, is typical of the magnetite-bearing formation and represents the greater part of the iron-bearing beds exposed in the Seminoe Mountains. At this locality the formation dips 25° N. A siliceous asbestos vein 3 inches wide was observed cutting the formation.

Section of iron-bearing Seminoe formation on east bank of Deweese Creek a quarter of a mile south of Pyler's ranch in the SW. ¼ sec. 19, T. 26 N., R. 85 W.

	Feet
Seminoe formation:	
Light-brown siliceous thinly laminated layers, consisting largely of small fibrous needles arranged perpendicular to the banding	25
Fine-grained banded gray jasper; yellowish-brown layers are moderately abundant at the base and greatly predominate at the top; carries small amount of magnetite	100
Dark-green amphibolite schist interlayered with quartz-chlorite schist	25
Fine-grained gray jasper or quartzite sparsely banded with black magnetite and light-brown layers; brown color caused by fibrous needles in the jasper	25
Dominantly gray jaspery quartzite thickly banded with black magnetite. The layers are slightly crumpled at irregular intervals along the bedding planes. Here and there thin veins of magnetite and quartz cross the banding. The formation weathers yellowish brown on joint surfaces. The magnetite bands range in width from 0.05 to 0.25 inch and become less abundant higher in the section	100
	275
Schistose andesitic greenstone (a hornblende chlorite schist), exposed down to stream bed	100

The gray color of the quartz is caused by finely disseminated magnetite grains, which are so small as to be best described as dust.



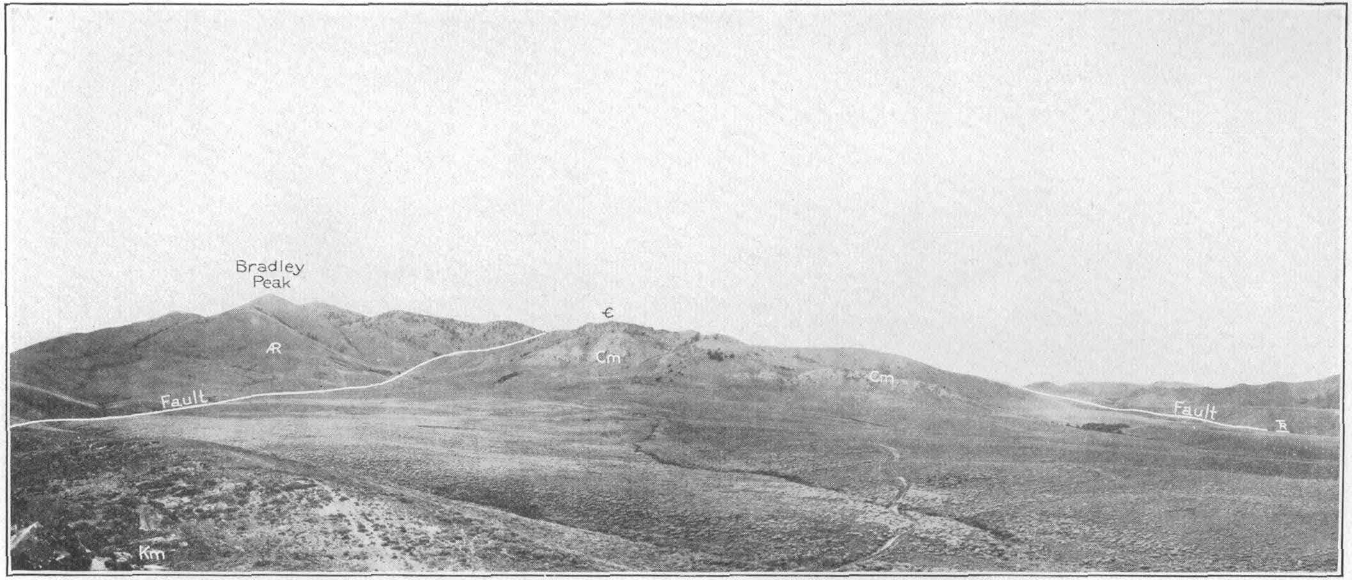
TOPOGRAPHIC AND GEOLOGIC MAP OF THE BRADLEY PEAK AREA, SEMINOE MOUNTAINS, CARBON COUNTY, WYOMING

0 1 Mile

Contour interval 100 feet

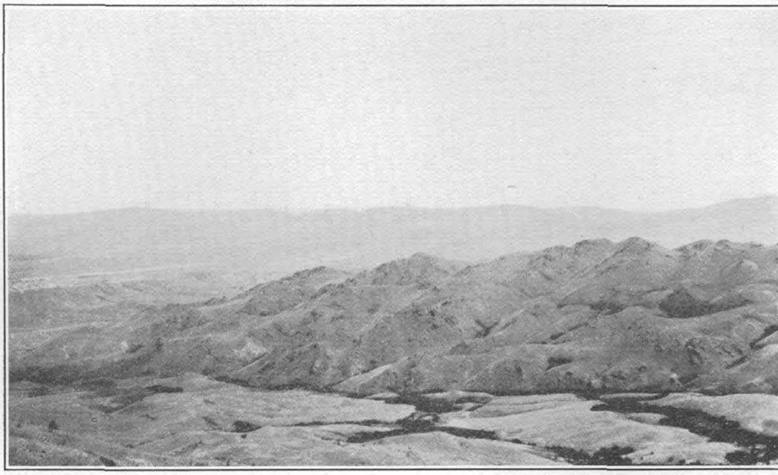
1929

Geology by T. S. Lovering

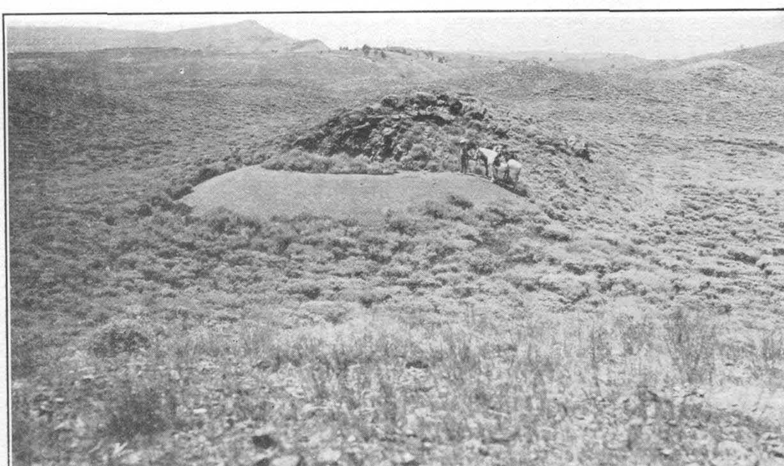


PANORAMA OF BRADLEY PEAK FROM THE SOUTH

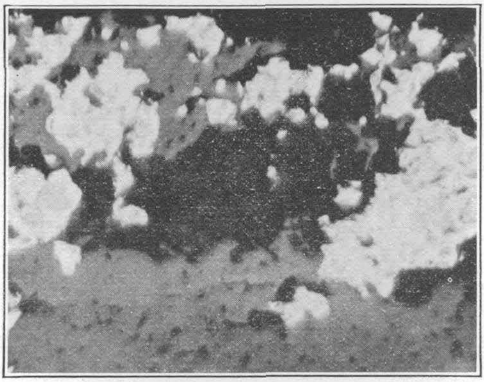
Downthrown block of Paleozoic and Mesozoic sediments in foreground. AR, Pre-Cambrian (probably Archean); Є, Cambrian quartzite; Cm, Mississippian limestone; Ћ, red beds; Km, Mesaverde sandstone.



A. DEWEESE CREEK FROM NORTH SPUR OF BRADLEY PEAK, SHOWING THE EFFECT OF THE NORTHWEST-SOUTHEAST FAULT IN DETERMINING THE STREAM COURSE

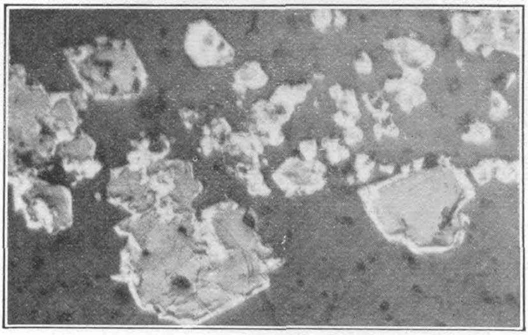


B. TEST PIT IN HARD ORE ONE-THIRD OF A MILE WEST OF IRON HILL, WYO.



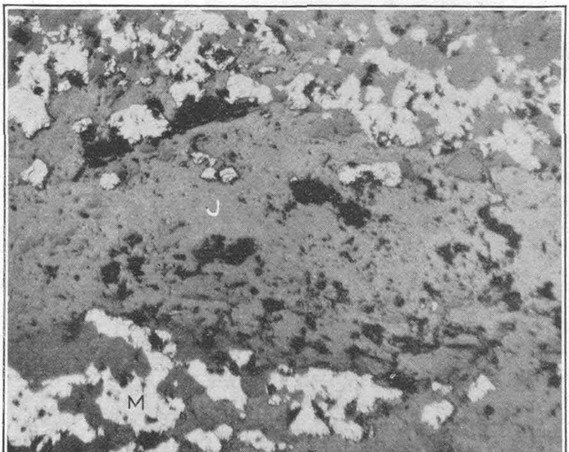
A. HEMATITE JASPER SHOWING DARK-COLORED MAGNETITE ALMOST COMPLETELY REPLACED BY LIGHTER-COLORED HEMATITE

Enlarged 160 diameters.



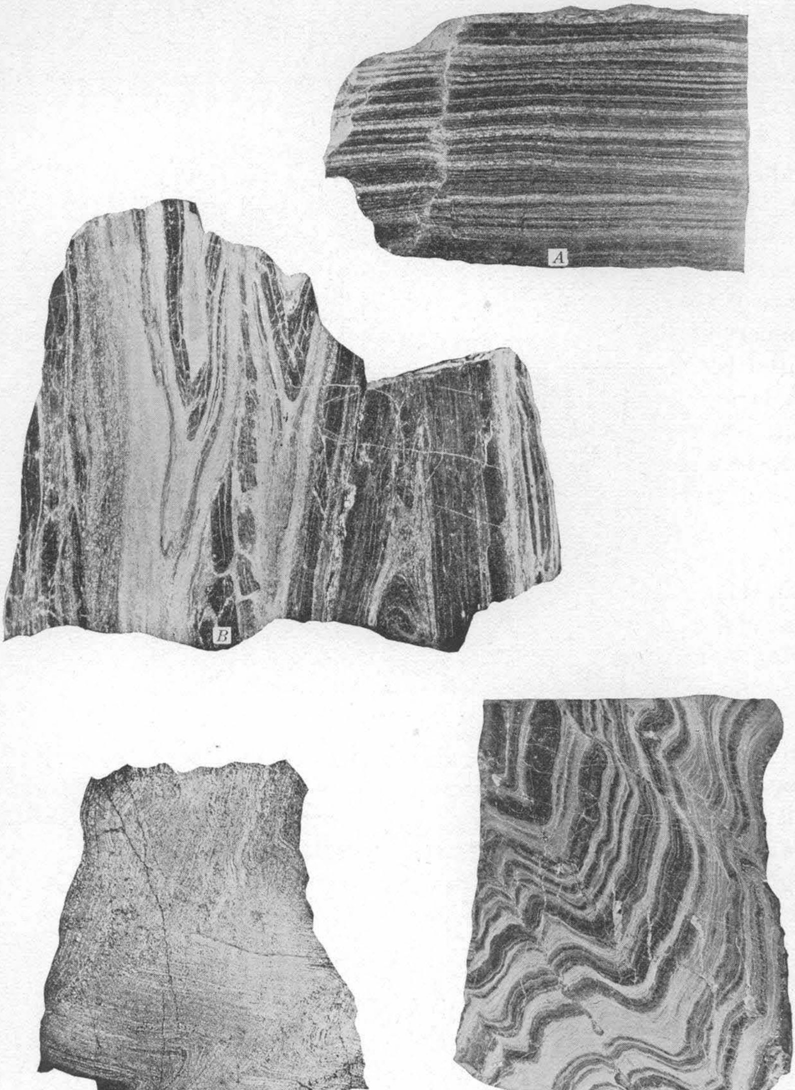
B. MAGNETITE-HEMATITE JASPER SHOWING BEGINNING OF REPLACEMENT OF DARK-COLORED MAGNETITE BY LIGHTER-COLORED HEMATITE

Enlarged 160 diameters.



C. MAGNETITE BAND IN SPECIMEN SHOWN IN PLATE 50, *A*

J, Jasper; M, magnetite. Enlarged 100 diameters.



TYPICAL SPECIMENS OF MAGNETITE JASPER AND HEMATITE JASPER

A. Magnetite jasper. *B*. Lean magnetite-hematite jasper. *C*. Hematite jasper. *D*. Hard hematite. All specimens natural size. (For analyses of specimens see p. 232.)

The brown bands in the jasper are colored by a limonitic alteration of small needles of pargasite and hypersthene. Most of the quartz is very fine grained, the crystals between the magnetite bands generally ranging from 0.005 to 0.030 millimeter in diameter. The quartz associated with the magnetite is much coarser than that between the iron oxide layers, and the grains may be 0.10 millimeter across.

The magnetite bands contain much more admixed quartz than would be suspected from examining a hand specimen. (See pl. 49, *C*.) The magnetite crystals are small, most of them ranging between 0.01 and 0.1 millimeter in diameter. The lower part of the formation has an iron content of 35 per cent in many places, but, as the rock is very fine grained, it would be unsuitable for the present commercial processes of beneficiation, as has been determined for similar beds in the Soudan formation in Minnesota.[9]

A large-scale and determined effort to concentrate iron from magnetite-bearing rock was made on the eastern Mesabi iron range of Minnesota, at Babbitt, from 1922 to 1924. In that region a large mass of intrusive igneous rock (the Duluth gabbro) has baked and recrystallized the iron-bearing formation with an attendant development of amphibole, magnetite, and quartz.[10]

The changes in the composition and texture of the rocks have made them resistant to weathering, and thus local alteration to hematite has not taken place, and the iron is nearly all present as magnetite. The material mined contained from 25 to 30 per cent of iron, and from it a concentrate was produced carrying 63 to 65 per cent of iron and 0.025 per cent of phosphorus.[11] Two difficulties were encountered in the effort to treat the ore—the intimately mixed minerals were so fine that it was hard to get a satisfactory metallurgical separation of the magnetite from the gangue, and the exceptional toughness and hardness of the rock involved a high cost for mining and grinding. Much of the magnetite was medium-grained material, the grains running coarser than 0.254 millimeter (0.01 inch) in diameter. Some of it was decidedly coarse grained and some was fine grained, the crystals running about 0.0508 millimeter (0.002 inch).[12] About 80 to 86 per cent of the total magnetite was recovered from the ore as a sintered concentrate of Bessemer grade. At the time of

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[9] Gruner, J. W., The Soudan formation and a new suggestion as to the origin of the Vermilion iron ores: Econ. Geology, vol. 21, p. 630, 1926.

[10] Grout, F. F., and Broderick, T. M., The magnetite deposits of the eastern Mesabi range, Minnesota: Minnesota Geol. Survey Bull. 17, 1919.

[11] Parsons, A. B., Operations of the Mesabi Iron Co.: Eng. and Min. Jour.-Press, vol. 117, pp. 157–164, 202–210, 1924.

[12] Schwartz, G. M., New ore of the east Mesabi range: Eng. and Min. Jour.-Press, vol. 116, pp. 409–412, 1923.

maximum production about 1,000 tons of ore a day was treated, but in spite of the large scale of the operations, the premium commanded by the concentrate, and the additional revenue derived from the sale of low-grade cobbings for crushed stone the enterprise was not a commercial success.

The magnetite jaspers of the Seminoe district are finer grained, occur in a tougher and harder rock, and are more remote from markets for concentrates and tailings than the eastern Mesabi ores, and the value of iron ore will have to be correspondingly higher before these rocks can be regarded as of possible commercial importance.

Small needles of amphibole and pyroxene (pargasite and hypersthene) are usually associated with the magnetite, and many of the quartz bands carry these minerals in varying amounts. Most of the needles are more or less altered to limonite; some are only thinly coated with it, and some have been completely changed over to the hydrous iron oxide. The dense texture and fresh appearance of the rock and the uniformity of the alteration throughout the formation suggests that the hydration resulted from some agency other than weathering. A small percentage of the altered needles will give a decided brownish color to the quartz bands, and the rusty tinge of most outcrops is in large part caused by the presence of limonite-stained amphibole or pyroxene and to a less degree by recent weathering.

A very little iron carbonate is present; it is later than much of the magnetite and quartz. A few small veins of magnetite, quartz, hypersthene, and siderite cross the banded structure of the rock.

A small quantity of hematite occurs in some of the jaspers remote from the ore deposits, but these occurrences are rare. This hematite appears to be contemporaneous with the associated magnetite. The red banded jasper near Chimney Rock owes its color to the small flakes of hematite present. By far the greatest part of the hematite in the formation is restricted to the vicinity of the iron-ore deposits south of Bradley Peak, and as the ore is of later origin than the formation it will be described in the section on the ore deposits.

Origin.—The iron-bearing Seminoe formation has none of the characteristics of an igneous rock. It completely lacks igneous texture, and its high silica content is not in harmony with an igneous origin, nor does it give any evidence of replacement of an igneous rock. On the other hand, the composition and appearance of the formation, together with the negative evidence cited above, warrant the assumption that the Seminoe formation is of sedimentary origin, and the very fine-grained jasper, which makes up most of the formation, suggests that it is probably a chemical sediment.

The Seminoe formation is very similar to some of the oldest iron-bearing formations of the Lake Superior region. In its broad features it bears a striking resemblance to the iron-bearing Soudan formation in the Vermilion district of northern Minnesota, where a great series of greenstones are complexly infolded with a banded ferruginous jasper. Locally the jasper is replaced by hematite to such an extent that workable ore bodies are formed.

Nearly everyone who has studied the Soudan formation has concluded that it is sedimentary. Leith and Van Hise suggest that it was laid down as a siliceous iron carbonate, or that the iron-bearing sediments may have been originally deposited substantially as banded chert and iron oxide of the jasper type, or else that the iron and silica may have been precipitated from hot solutions coming directly from the magma into the sea.[13]

The Michipicoten district lies in a region of strongly folded pre-Cambrian rocks that are dominantly of volcanic origin but include an iron-bearing sedimentary formation. This formation consists of an upper banded silica (jasper), an intermediate pyritic siderite, and a lower ferruginous carbonate. Collins and his associates[14] believe that the banded silica was probably deposited by water flowing over the tuff while it was a land surface and that all these deposits were formed by water rising from igneous sources.

The extremely fine-grained silica and interlayered fine-grained iron oxide that make up most of the iron-bearing Seminoe formation are readily explained if the formation represents metamorphosed hot-spring deposits. The spotty distribution and great variation in thickness of the iron formation are in complete accord with the theory that the beds were formed by hot springs, and their diversity in composition is paralleled in the sinter deposits of the Yellowstone National Park to-day. The analysis of the deposit of a spring in the Norris Geyser Basin[15] indicates that both silica and iron can be carried in hot-spring waters and deposited contemporaneously.

Analysis of deposit from spring No. 75, Norris Geyser Basin, Yellowstone National Park

SiO_2	54.36	Na_2O	1.30
Al_2O_3	5.90	K_2O	1.21
Fe_2O_3	25.48	Li_2O	.00
MnO	.33	H_2O	9.60
MgO	.17	As_2O_5	.28
CaO	1.86		

[13] Van Hise, C. R., and Leith, C. K., Geology of the Lake Superior region: U. S. Geol. Survey Mon. 52, pp. 126, 514, 1911.

[14] Collins, W. H., Quirke, T. T., and Thompson, Ellis, The Michipicoten iron ranges: Canada Geol. Survey Mem. 147, 1926.

[15] Clarke, F. W., The data of geochemistry, 5th ed.; U. S. Geol. Survey Bull. 770, p. 209, 1924.

The composition of this hot-spring deposit is probably very close to that of much of the lower member of the Seminoe formation. (See pl. 49, *C*.) It is significant that the Seminoe deposits carry most of their iron at the base and become more siliceous and less ferruginous toward the top—a relation noted by Hague[16] in the hot-spring deposits of the Yellowstone National Park.

LATE GREENSTONE SCHISTS

A series of chlorite and hornblende schists overlie the iron-bearing Seminoe formation south of Bradley Peak. They have been closely folded and their thickness is difficult to estimate. The intrusion of large masses of diorite has further complicated their relations, and the stratigraphy was not worked out in detail. In general these schists are indistinguishable from the earlier ones described on page 220 and are probably Archean.

DIORITE

The second most widely exposed rock in the district is a massive but slightly schistose diorite. This diorite is included with the late greenstone schists in the mapping on Plate 46. It occurs in large crosscutting bodies and in small dikes cutting the formations described above. In some places it apparently forms sill-like masses parallel to the bedding of the iron formation. This intrusive is older than the pre-Cambrian granite near by but younger than the greenstone schists and the Seminoe formation. It is much less metamorphosed than these earlier rocks, and for this reason the writer believes it should be provisionally called Algonkian, although the evidence now at hand is admittedly meager and inadequate.

Most of the rock has been altered into a greenish aggregation of hornblende, clinozoisite, and oligoclase, which poorly preserve the original texture of the rock but do not show any tendency to parallelism. A schistose texture is entirely absent in most localities, in marked contrast to the formations previously considered. However, near the large granite mass that extends an unknown distance toward the east the diorite is locally converted into a schist.

GRANITE

A large granite mass forms the core of the Freezeout Mountains and extends into the Seminoe Mountains on the west. The contact with the invaded rocks is not sharp. Schist inclusions are rare in the central part of the granite mass but become increasingly abundant near its border, and in the near-by schist area granite, aplite, and pegmatite dikes are so intricately shot through the older rocks that it is almost impossible to define the limits of the granite. The

[16] Hague, Arnold, Origin of the thermal waters of the Yellowstone National Park: Geol. Soc. America Bull., vol. 22, p. 117, 1911.

rock is younger than the diorite described above and older than the Cambrian quartzite of the Ferris Mountains and is believed to be Algonkian. It is a pink medium to coarse grained biotite granite, usually somewhat gneissic in appearance. Both microcline and orthoclase are abundant, but very little plagioclase was found in it. The quartz runs through much of the rock in short, narrow stringers, giving the granite its gneissic texture. The biotite is not present in large amounts, and like the quartz it occurs commonly in small stringers and probably attained its present position during a period of diastrophism.

Pegmatites and aplites are common and differ from the granite chiefly in size of grain. No primary hematite was found in the pegmatite dikes, but as the nature of the near-by Shirley deposits was unknown until after the field work in the Seminoe Mountains was completed, little time was devoted to the study of the pegmatites, and it is possible that some of the dikes contain hematite as a primary mineral. A pegmatite that cuts the iron formation southwest of Bradley Peak, in sec. 12, is heavily stained with hematite, but as the oxide is confined to fracture planes it is clearly secondary.

LATE INTRUSIVE ROCKS

North of the region that was critically studied dikes and irregular intrusive masses of fresh-appearing dark-colored porphyry occur. A small mass of fine-grained biotite monzonite(?) porphyry cuts the iron formation and the schistose greenstone east of Chimney Rock, and a similar porphyry cuts gneissic granite about 2 miles to the northeast. Rock of this type forms a conspicuous knob about a mile north of Pyler's ranch on the road to Casper. It ranges in texture from a medium-grained granitoid rock to a fine-grained porphyry containing about 15 per cent of phenocrysts. Much of the material resembles typical diorite, but some phases appear to be closer to monzonite in composition. Little can be said of the age of these rocks. They are probably younger than the pre-Cambrian granite and may have been formed as late as the Tertiary period.

POST-CAMBRIAN SEDIMENTS

The Paleozoic and Mesozoic sediments that border the Seminoe Mountains are described in the table on pages 207–208, which gives information regarding their lithology, thickness, and sequence.

STRUCTURE

The essential structural features of Bradley Peak and the near-by region were worked out in the examination of the iron-ore deposits and are described below, but the Seminoe thrust fault extends far beyond the region of economic importance, and a sure interpretation of its history would necessitate the regional study of a broad area.

The Ferris Mountains trend slightly south of east, and throughout most of its course this uplift is bordered by nearly vertical Paleozoic sediments striking parallel with the mountain axis. Near its east end the upturned beds swing almost due east, and coincident with the change in strike the beds become overturned, dipping toward the mountains at lower and lower angles until they reach the Seminoe fault a short distance west of Sand Creek, where they disappear under a mass of overthrust pre-Cambrian rocks. A mile east of Sand Creek overturned red beds dip toward the mountains at an angle of only 9°, and in this region of maximum folding the strike of the beds swings sharply to the southeast. Unfortunately much of the structure near the Seminoe fault is hidden under a mass of wind-blown sand, but it is inferred that the space between the last outcrop of gently dipping Cretaceous beds of normal sequence and the first exposure of the completely overturned red beds near the fault is altogether inadequate to contain the sediments that should lie between the two outcrops. It is unlikely that folding alone would thin the beds so as to fit the space, and it is believed that the observed relations can be explained only by faulting. The plane of the fault probably dips toward the pre-Cambrian beds and comes to the surface in this area in one of the beds of the Colorado group. Southeast of Bradley Peak a similar narrowing of the distance between outcrops of the Steele shale and the red beds can be observed, and here also relations indicate thrust faulting on one of the formations of the Colorado group. This fault plane apparently passes beneath Bradley Peak and continues under the drifting sand on the northwest as the hidden fault first mentioned.

The Seminoe fault has a length of at least 15 miles. It is known to extend several miles through the pre-Cambrian northwest of the place where Sand Creek flows northward across the overturned red beds, and to the southeast and south the overthrust fault block of greenstones and jaspers forms a conspicuous ridge culminating in Bradley Peak, 7 miles away. The fault line swings to the east around the south flank of this peak and then turns sharply north along the east side and passes into the pre-Cambrian near the Seminoe Mining Co.'s stamp mill. The dip of the fault could not be observed, but thrust faults dip toward the upthrown side, mostly at angles of 30° to 40°, and thus it is probable that the Seminoe fault dips toward the pre-Cambrian at an angle of less than 45°. Bradley Peak is almost certainly underlain by Mesozoic sediments at no great depth. Southeast of the peak, in the N. ½ sec. 8, an eastward-trending ridge of nearly vertical Cambrian quartzite and Madison limestone swings toward the south at the Seminoe fault, and it seems probable that this bend was caused by the drag of the thrust fault as the pre-Cambrian rocks were pushed southward to their present position. (See pl. 47.)

Several faults of less extent occur farther east, but few of them were examined. Probably the largest of these is a strong fault that determines the northwesterly course of Deweese Creek from its source to the northward bend near Pyler's ranch. (See pl. 48, *A*.) This fault cuts only pre-Cambrian rocks in the valley of Deweese Creek, but southeast of the source of this stream, across a low divide, the fault has brought Cambrian quartzite and Madison limestone against the ancient granite mass that forms the core of the eastern Seminoe Mountains.

These sediments are overturned and dip northeast at high angles. East of this line of faulting the front of the Seminoe Mountains is marked by steeply tilted Paleozoic and Mesozoic formations, which strike nearly east and dip toward the plains.

There are probably several late minor faults in the pre-Cambrian area, but the early folding and mashing of the formations makes it difficult to recognize the later dislocations. It is probable that the south front of Bradley Peak is a fault scarp and that the springs and swamps along its base mark the hidden fault line, but the evidence is topographic, not geologic, and no certainty is felt as to the actual existence or trace of this fault.

NONFERROUS ORE DEPOSITS

Copper, gold, and arsenic occur near the Seminoe iron deposits and are apparently related genetically to the pre-Cambrian granite. In the Ferris Mountains about half a mile northeast of the head of Sand Creek several veins have been found. Low-grade gold-quartz veins, low-grade quartzose lead-zinc veins, and some veins 3 to 6 feet wide of nearly pure arsenopyrite occur in the schist just east of the large granite mass that makes the backbone of the Ferris Mountains. According to Mr. Matt Brantley, who was active in this district throughout the period when the deposits were being prospected, a lead-zinc vein was followed south by a drift through the granite until the upturned Paleozoic sediments were encountered. Here the previously well-defined vein ended abruptly. The cutting off of the vein by the sandstone that underlies the Madison limestone clearly indicates that the ores are of pre-Cambrian age and were probably deeply truncated before Cambrian time.

No ores are known to be present between this locality and Bradley Peak. On the east side of Bradley Peak many lenticular bodies of quartz and gold-bearing chalcopyrite occur. Near the surface the sulphides are oxidized and the gold is free milling. A stamp mill that is said to have been erected about 15 or 20 years ago ran for a few years on the oxidized ores and was shut down when this class of material was exhausted. High gold assays are said to have been obtained from the banded jasper of the iron formation, but the writer was unable to verify this statement, as the samples of the iron formation that he gathered carried only traces of gold, with one exception, which ran 0.01 ounce in gold to the ton. The gold is probably restricted to veins, and the iron formation as a whole does not carry appreciable amounts of it.

It is possible that the Bradley Peak veins were formerly in the mineralized district near the east end of the Ferris Mountains and were moved to their present position by the Bradley Peak thrust fault.

IRON-ORE DEPOSITS

Mode of occurrence.—The iron ore of the Seminoe district occurs at the surface in the upthrown pre-Cambrian rocks southwest of Bradley Peak. The differential weathering of the ores and the complexly folded jaspers and schists has resulted in a subdued hummocky topography (see pl. 46) that is characteristic of the ore-bearing locality. The ore is limited to parts of secs. 7 and 18, T. 25 N., R. 85 W., and secs. 1, 12, and 13, T. 25 N., R. 86 W., as shown on Plate 46.

The known ore is confined to the Seminoe formation. It is a low-phosphorus hematite and occurs chiefly in bodies that have replaced magnetite jasper with various degrees of completeness. East and north of the chief hematite areas only typical black-banded magnetite jasper occurs, but as this phase of the iron-bearing formation is followed toward the ore deposits a gradual change in its character can be noticed. On the eastern flank of Iron Hill, in the SW. ¼ sec. 7, T. 25 N., R. 85 W., the jasper is strongly magnetic, but less and less magnetism can be detected as one crosses the hill, and on the west side there is not enough magnetite present to deflect the needle of a compass. With the decrease in the proportion of magnetite that of hematite increases. As a consequence red bands appear and increase in the jasper, whereas black bands become less abundant and near the ore deposits are practically lacking. Within the ore district the lean parts of the iron formation consist chiefly of red and gray banded jasper with subordinate amounts of dark hematite in thin seams parallel to the banding. In places the hematite so strongly colors the rock that it has been mistaken for iron ore, although it may actually contain only 30 to 35 per cent of iron and more than 50 per cent of silica. In many places pegmatitic quartz cuts the iron formation near the high-grade ores or is intimately injected into the layers of the jasper along the bedding planes.

The ore bodies fall into two divisions—the soft, nearly structureless red hematite associated with fractured and open ground and the hard dark-colored hematite, which preserves the contorted banding of the iron formation in great detail. Ore of the first class has been opened by tunnels and test pits in sec. 1, T. 25 N., R. 86 W., but unfortunately little information could be obtained from these workings, as the softness of the ore requires the use of timber to hold the ground, and most of the tunnels are caved. A rubble of hard ore in the soft earthy hematite and evidence of recent movement in the near-by rocks suggest that the ore of this type was formed along fissures in the hematite-jasper during the period since the pre-Cambrian mass was thrust over the Paleozoic and Mesozoic sediments. The ore of the second class is usually a hard, dense dark-colored hematite. The density of this ore varies considerably, however, and some of it is moderately open in texture, although the characteristic banding is present. Material of this type is well exposed in a test pit about one-third of a mile west of Iron Hill, shown in Plate 48, *B*. A piece of the hard ore is shown in Plate 50, *D*, and its analysis is given as No. 5 on page 232.

Petrographic features.—The high-grade ore ranges from dense blue hematite to porous bluish-red hematite. Although the hard ores faithfully preserve the crenulations and folding of a highly metamorphosed rock, the ore is not schistose and is evidently a replacement product. The texture of a specimen of high-grade ore is shown in Plate 50, *D*. Some of the soft hematite ore shows replacement texture, and some is apparently structureless. Although the high-grade ore does not contain any magnetite or jasper, the outlines of earlier magnetite crystals are preserved in some of the hematite and are readily distinguished under the microscope. The presence of many layers of very fine grained hematite probably indicates the replacement of jasper, and the bands of coarse-grained hematite are believed to represent bands formerly rich in magnetite. A few small veinlets and bleblike masses of quartz are present, but this silica is very different in character from pegmatitic quartz or that of the jasper and may be of recent supergene origin.

The high-grade ore is not sufficiently magnetic to affect the needle of a compass, but in specimens collected at greater and greater distances from the areas where the hard blue hematite crops out the magnetism of the jasper becomes more and more noteworthy. Thus the red-banded jaspers found on the west side of Iron Hill are not magnetic but grade through jasper containing black and red bands into strongly magnetic black-banded jaspers on the east side of the hill which are identical in appearance with those found many miles to the north. In these jaspers are many bands that consist chiefly of magnetite in crystals ranging from 0.01 to 0.07 millimeter in diameter; the black bands of silica owe their color to extremely minute grains of the magnetite. In the slightly magnetic red and black banded jasper from the top of Iron Hill both magnetite and hematite are present. The hematite occurs in thin rims at the edge of euhedral crystals of magnetite about 0.01 to 0.10 millimeter in diameter, and to a less extent it is found as minute veinlets in the interior of the grains chiefly along (111) cleavage planes, as illustrated in Plate 49, *B*. The black jasper bands in this group of specimens contain many small hematitic streaks, and the red oxide has apparently worked outward from submicroscopic fractures and replaced the magnetite dust and the ferromagnesian minerals of the typical magnetite jaspers. A small quantity of the thoroughly disseminated hematite dust is sufficient to color a band of jasper red.

In specimens selected on the basis of decreasing magnetism the most notable features revealed by the microscope are the progressive replacement of magnetite by hematite (pl. 49, *A*), the appearance of crosscutting veinlets of hematite, and an increasing replacement of the fine-grained jasper by very small laths of hematite. Specimens of lean ore, moderately siliceous ore, and high-grade ore are shown in Plate 50, and their analyses are given below.

Analyses of iron ore from Seminoe deposits

	1	2	3	4	5	6	7	8	9
Silica (SiO_2)	50.42	47.70	59.90	47.80	3.32	10.20	54.28	51.98	50.06
Ferrous oxide (FeO)	18.05	(a)							
Ferric oxide (Fe_2O_3)	26.29	(a)							
Metallic iron (Fe)	32.42	35.84	27.97	36.40	68.72	62.51	32.65	33.80	35.37
Lime (CaO)	2.24								
Sulphur (S)					(a)	.026			
Phosphorus (P)	.014				.015	.040			

[a] Not determined.

1. Magnetite jasper.
2. Magnetite jasper (pl. 50, *A*).
3. Lean magnetite-hematite jasper (pl. 50, *B*).
4. Hematite jasper (pl. 50, *C*).
5. Hard hematite from test pit one-third of a mile west of Iron Hill (pls. 48, *B*, and 50, *D*).
6. Hard hematite from same pit as 5.
7, 8, 9. Hematite jasper.

Analysts: Nos. 1, 2, 3, 5, 6, 7, 8, 9, E. P. Henderson, U. S. Geol. Survey; No. 4, W. E. Burlingame, Denver, Colo.

Structural relations.—The iron-ore deposits southwest of Bradley Peak are on the thin end of the great wedge of pre-Cambrian rocks that was thrust over the Cretaceous sediments. If the ores are confined to the Seminoe formation, which seems very probable, they can not continue through the fault plane, which presumably dips north at an angle of less than 45°. Thus the ores that crop out close to the fault line will probably be cut off at a shallow depth and those that crop out at some distance from the fault will probably continue much deeper before the fault plane is encountered. A few of the minor faults in the upthrown block seem to have shattered the iron-bearing formation sufficiently in some places to favor the leaching of silica and the formation of soft hematite ore bodies, and thus it is probable that some concentration has also occurred in favorable localities along the major thrust fault.

The iron-bearing formation is bent into sharp anticlines and synclines and many discontinuous, steeply dipping monoclines. Much of the close folding took place without appreciable fracturing of the formation, but tight folds in places show broken fragments of the jasper cemented by silica of the same general appearance as that which was broken. The structure of the formation apparently does not exercise any marked influence on the occurrence of ore. The best bodies of ore observed were in nearly vertical parts of the formation, and no indication of a large mass of ore could be seen in the trough of the syncline near the Saltiel ranch, just south of the center of sec. 18, T. 25 N., R. 85 W. The exposures were very poor here, and a soft hematite ore might be concealed under the red soil by which the formation was traced. However, the narrowness of the strip of ferruginous soil argues against the possibility of ore having been concentrated in this structural trough by descending meteoric waters.

Although the iron formation is exposed over a wide area on the north, it is everywhere a lean magnetic jasper, and no hematite deposits are known in the surrounding region. The deposits of hematite ore have been faulted to their present position by the Seminoe overthrust, and the bodies from which they have been broken are probably deeply buried, with little to indicate their location.

Origin.—Deposits of iron ore in the Lake Superior region of the same general character as those in the Seminoe region have been ascribed by most workers to weathering of the iron-bearing formation. Ground water, concentrated along pitching synclines in the iron-bearing formation, is thought to have leached silica from the ferruginous jaspers and left the insoluble iron oxides behind.[17] In the Seminoe iron district the best ore does not occur in the structural troughs, where it would be expected to be present if it were formed by meteoric waters, but is found in beds that show no indication of leaching by cold water and that are identical structurally with many unenriched jaspery parts of the formation. The hematite of the Seminoe hard ores is distinctly crystalline, and the largest crystals of hematite observed were in pegmatitic quartz.

Gruner [18] suggests that the ores of the Vermilion district have been formed by the action of hot ascending solutions. Hypogene solutions rich in iron and carbon dioxide but poor in silica are supposed to have leached out quartz and replaced it with hematite and carbon-

[17] Van Hise, C. R., and Leith, C. K., op. cit., pp. 142, 529.

[18] Gruner, J. W., The Soudan formation and a new suggestion as to the origin of the Vermilion iron ores: Econ. Geology, vol. 21, p. 644, 1926.

ates and to have oxidized the ferrous iron in the iron-bearing formation at the same time.

The Seminoe iron-ore deposits have been moved to their present position by the Seminoe thrust fault, and as there is no remnant left of the Paleozoic sediments that cap the pre-Cambrian rocks it is probable that the ore deposits represent ground that was far enough below the pre-Tertiary land surface to be uninfluenced by earlier weathering. The surrounding greenstones to-day weather much more readily than the jaspers, and the absence of ferruginous layers in these formations also suggests that some process other than leaching by meteoric waters must explain the origin of the ores. The existence of high temperature and the proximity of a large igneous mass after the close folding and development of schistosity are shown by the presence of pegmatites and injected beds. Coarse crystals of apparently contemporaneous hematite in the pegmatitic quartz indicate a genetic relation to the intrusive masses. Metasomatic replacement of magnetite and dense jasper by hematite took place in great part along tight fractures, many of them submicroscopic. Cold waters would encounter great difficulty in effecting the observed alteration along such channels, whereas magmatic emanations would be easily capable of working through these openings. The crystalline character of the hematite and the absence of limonite also support the theory that the ores are high-temperature deposits.

Because of the evidence above set forth and much for which there is not space here it is believed that the hard ores of the Seminoe district were formed by the replacement of ferruginous jaspers at high temperature, probably by emanations from an underlying body of granitic magma. This process also involved the alteration of the magnetite in the iron formation to hematite, probably through the influence of acids in the emanations or by the action of free oxygen. The fine-grained soft ores appear to have been formed by the action of ground waters along fissures.

Consideration of the origin of the ores suggests that shoots of the hard ores will more probably have the form of steeply dipping veins than that of blanket deposits. The continuity of the hard ores should not be greatly affected by the level of ground water, and for this reason they may be expected to persist to greater depths than the soft ores.

Future possibilities.—A small tonnage of high-grade low-phosphorus hematite ore is undoubtedly present in the Seminoe iron-bearing district. The maximum observed thickness of the hard Bessemer ore, measured across the banding, was about 20 feet. The length of this ore body is unknown, but could be easily ascertained by a series of transverse open cuts spaced at proper intervals along the strike of the bed. Only a few outcrops of the hard ore were observed, but as much of the bedrock is covered with soil it is possible that workable ore bodies are present and can be brought to light by intelligent trenching.

It would not seem advisable to use geophysical methods of prospecting in this region until after the ground had been thoroughly trenched. Because of the high magnetite content of the lean jaspers and the high conductivity of the magnetite there would be little use for instruments depending on magnetic susceptibility, induction, or conductivity. As seismic waves are distorted or reflected by fault planes, it is probable that the ground is too broken for the successful use of seismologic methods. The torsion balance would probably give the greatest satisfaction in an investigation of the deposits, but as only a few observations can be made in a day, the cost of obtaining information with it would probably be considerably higher than the cost of trenching.

If the origin of the deposits is as outlined above, there is, in the writer's opinion, a strong probability of the ore persisting in depth to the plane where it would be cut off by the Seminoe fault. There is nothing to indicate that the ore will stop where the water table is encountered, as it might if it were formed by descending meteoric waters.

Until exploratory work of some type has been done, it will be impossible to estimate the quantity of ore in the ground, but there is little indication of ore bodies large enough to warrant building a spur from the Union Pacific Railroad to the deposits—a distance of 35 miles. However, if railroad transportation should become available close by, very probably several ore bodies exist which might be profitably exploited.

Much of the hematite jasper is strongly colored and has been repeatedly mistaken for ore in the past. Most of it carries less than 35 per cent of iron and more than 50 per cent of silica. The illustrations of the typical banded jaspers given in Plate 50, together with their analyses on page 232 give an appreciation of the character of this type of material. There are large reserves of this phase of the iron formation, but it is unlikely that jaspery hematites of this grade will be worked for their iron content for a long period of years.

In conclusion the writer suggests that prospecting by means of trenches across the extension of the line of strike of the outcrop of high-grade ore, with a view of ascertaining the probable strike length of these ore bodies, would be the most practical way to determine whether the Seminoe district would warrant more intensive prospecting for iron ore—for example, by drilling or by driving tunnels and sinking shafts.