Manganese Deposits of Southeastern Utah

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MANGANESE DEPOSITS OF UTAH, PART 2

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A report on manganese resources in the Little Grand district and areas to the east, west, and south

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By A. A. Baker, D. C. Duncan, and C. B. Hunt

ABSTRACT

Small deposits of manganese oxide are widely distributed in southeastern Utah. The manganese occurs mainly in well-exposed, stratified deposits, but some of it occurs in veins along faults and fractures, and at places accumulations of residual or detrital ore have been mined. Most of the stratified deposits are in the Upper Jurassic Morrison and Summerville formations, but there are similar deposits in the Upper Triassic Chinle formation, in the Upper Jurassic Carmel formation, and in lime-cemented gravel of Tertiary or Recent age. The manganese oxide deposits in the Morrison and Chinle formations consist mainly of small nodules and veinlets in shale or occur as cementing material in sandstone and conglomerate. The deposits in the Summerville formation consist of manganese oxide in thin blanket veins and nodules in limestone and thin blanket veins, nodules, veinlets, and cementing material in sandstone. The ore minerals are dominantly pyrolusite, with some psilomelane and manganite. The manganese content of the ore ranges from 4 percent or less to more than 40 percent. Abundant silica in the form of sand grains, chert, jasper, or chalcedony is present in some deposits, and abundant calcium carbonate is associated with much of the ore. Iron oxide and small amounts of barite are present in nearly all deposits, and locally there are veinlets of celestite and small crystals of gypsum.

Intermittent mining over a period of about 40 years has resulted in the production of about 12,000 tons of ore. This ore has been obtained from shallow open pits along the outcrops of blanket veins, from residual or detrital material screened from the soil, or from shallow workings on fissure veins. Residual or detrital fragments of manganese oxide were the source of a substantial part of the ore that has been mined, but the main accumulations of ore of that type have been depleted. The fissure-vein deposits are small, and the richer parts of the known ore bodies have been removed; the limited information that is available indicates that such deposits probably are present only near the surface and therefore are not considered to be a source for large tonnages of ore. The principal remaining sources of manganese oxide are the blanket veins in the Summerville formation and the nodular ore in the Morrison and Chinle formations. The richer and more accessible parts of the blanket veins in the Summerville formation have been mined, but it is estimated that as much as 15,000 tons

of ore containing more than 30 percent manganese could be obtained by hand sorting of material from open-cut workings along the outcrops of widely scattered small deposits. The reserves of lower-grade oxide ore in scattered deposits of various types are estimated to aggregate nearly 500,000 tons, of which about 350,000 tons contains less than 10 percent manganese.

INTRODUCTION

PURPOSE OF THE REPORT

In connection with investigations of strategic and critical minerals the Geological Survey undertook in 1940 to examine the manganese deposits in southeastern Utah. Small, widely scattered deposits of manganese oxide have been known in the region and have been mined intermittently for 40 years or more; however, they have yielded only a small production of manganese oxide ore, and a systematic study of the deposits was needed to determine the possibilities of larger production. A comprehensive inventory of the manganese resources in the region was obtained, but no evidence was found to indicate the presence of large reserves of either commercial-grade or low-grade ore.

PREVIOUS INVESTIGATIONS

Two reconnaissance investigations of the manganese deposits have been made: one by Harder (1910, pp. 145–147), who visited part of the Little Grand district in 1908, and another by Pardee (1921, pp. 179–206), who reexamined the district in 1918 in connection with the development of manganese resources during World War I. The systematic geological surveys that have been made in the region do not consider the deposits themselves, but they provide essential basic data and were of great assistance to the present writers. Geologic and structure maps were available for most of the area, and considerable information regarding the lithologic variation of the formations and the geological history of the region was obtained from the reports of Baker (1933 and 1946 [1947]), Dane (1935), McKnight (1940), Gilluly (1929), Hunt (in preparation), and Gregory and Moore (1931).

FIELD WORK AND ACKNOWLEDGMENTS

Field work in connection with this report was conducted during July and August 1940 with the assistance of A. M. Hanson. Individual manganese deposits were located on the maps contained in previous reports or on aerial photographs, and large-scale plane-table surveys were made of the deposits in some areas. In addition to studying the outcrops of favorable formations, the writers questioned

many local inhabitants, who, as a group, are thoroughly familiar with the distribution even of very small deposits. Throughout the field work special attention was given to the relationship of the deposits to various elements of the regional geology, such as the physiography, structure, or paleogeography of the rocks containing the manganese oxide.

The collaboration and guidance of S. G. Lasky during the early part of the field work and during the preparation of the report was extremely helpful. Charles Milton made many of the chemical and mineralogical determinations, and Charles H. Johnson, of the U. S. Bureau of Mines, cooperated in part of the field work and collected numerous samples of ore for analysis. Officials of the Ironton plant of the Columbia Steel Co., at Provo, Utah, provided access to helpful information contained in the files of the company; the writers are especially indebted to S. G. Sargis for his cordial cooperation. A great many residents of the region freely gave their time as guides and supplied information that expedited the search for little-known deposits.

HISTORY OF MINING AND PRODUCTION

The early history of the mining of manganese ore in southeastern Utah has been described by Pardee (1921, pp. 179–180). He states:

> Manganese ore was first mined in Utah in 1901. In that year deposits in the Little Grand district, southeast of Green River, were exploited by the Colorado Fuel & Iron Co., which shipped a quantity of the ore to furnaces at Pueblo and Chicago for use in making steel. At times thereafter a little ore was produced, but mining was unprofitable, and for several years after 1906 the district was idle. In 1915 rising prices caused by the war stimulated the district to renewed activity. Ore production was resumed and continued with few interruptions until the market declined shortly after the signing of the armistice in November 1918. * * *
>
> The total amount of manganese ore produced in Utah from 1901 to 1918, inclusive, was about 16,000 tons. Of this somewhat less than 4,000 tons, presumably all of which came from the Little Grand district, was produced during the period 1901 to 1906. * * * In the years 1915 to 1918, inclusive, three-fourths of the 12,000 tons produced in Utah came from the Little Grand district.

After the cessation of mining in 1918, the Little Grand and other manganese districts in southeastern Utah remained idle until 1939, when the outbreak of World War II brought about an increasing need for domestic sources of manganese. In 1939–40, small-scale development work was done on many of the deposits, mostly to determine the quality and quantity of manganese available. At several deposits a few tons of ore were mined and placed in stockpiles, but as of August 1940 shipments of ore had consisted mainly and perhaps entirely of samples taken to determine the suitability of the ore for metallurgical purposes.

DISTRIBUTION OF THE DEPOSITS

The distribution of the manganese deposits in southeastern Utah is shown on figure 3. Most of the deposits are within a fairly small area, known as the Little Grand district (loc. 1), located a few miles southeast of the town of Green River. Other widely separated deposits are distributed in a belt extending eastward and southeastward beyond Moab and in the Green River Desert (loc. 11) west and southwest of the Little Grand district, near Castledale (loc. 12) and Emery (locs. 13 and 14), on Boulder Mountain (loc. 15), in the northern part of the Waterpocket Fold (loc. 16), and near Kanab (loc. 17).

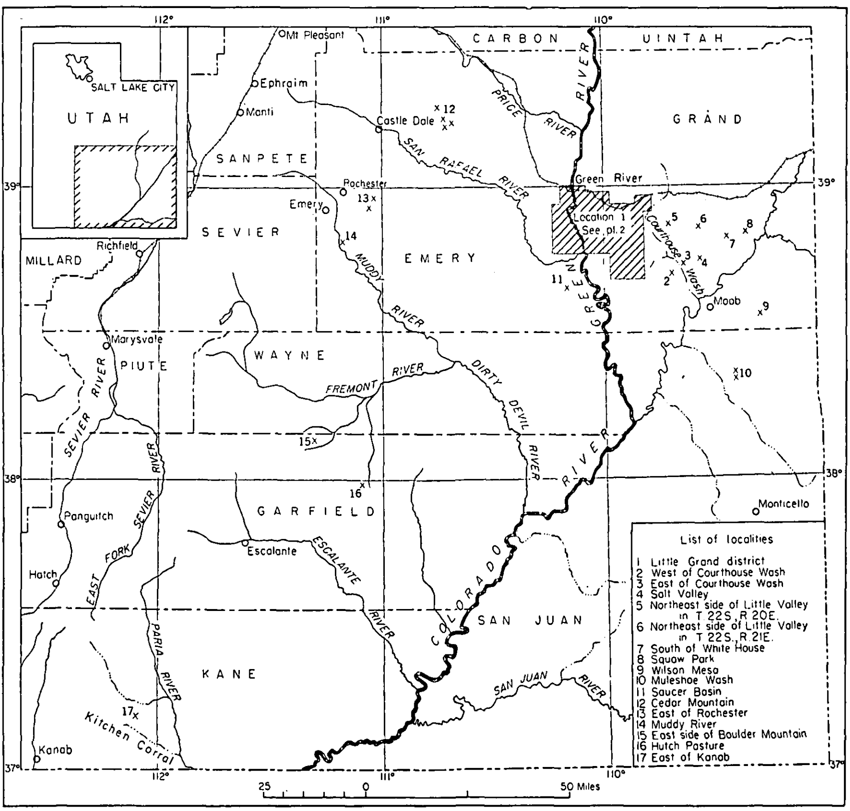

FIGURE 3.—Index map of southeastern Utah showing location of the manganese deposits.

The following list gives a summary description of the deposits.

Manganese deposits of southeastern Utah

Locality	*Character of deposit*
Little Grand district (loc. 1, fig. 3):	
Desert Rock claim (loc. 1, pl. 2).	Fissure vein in Morrison formation.
Black Bird claim (loc. 2, pl. 2).	Nodular ore in shale and impregnations in sandstone; in Morrison formation.
Salt Wash (locs. 3, 4, and 5, pl. 2).	Nodules and lenses of manganese oxide in sandstone and limestone; in Summerville formation. Some detrital ore on surface.
Dry Lake Wash (loc. 6, pl. 2).	Nodules and lenses of oxide in sandstone, limestone, and shale; in Summerville formation.
Vicinity of Colorado Fuel & Iron Co. mine (loc. 7, pl. 2).	Nodules, lenses, and impregnations in limestone and nodules in underlying sandstone; in Summerville formation. Detrital ore on surface.
Northeast of head of White Wash (loc. 8, pl. 2).	Lenses in limestone and sandstone and nodules and veinlets in sandstone; in Summerville formation.
Duma Point (loc. 9, pl. 2).	Lenses and nodules in limestone and sandstone; in Summerville formation.
Southeast of Duma Point (locs. 10–21, pl. 2).	Lenses, nodules, and veinlets in sandstone, limestone, and shale; in Summerville formation.
West of Courthouse Wash (loc. 2, fig. 3).	Fissure vein along fault where shale of Morrison formation is faulted against sandstone of Kayenta formation.
East of Courthouse Wash (loc. 3, fig. 3).	Impregnation and partial replacement of sandstone; in Morrison formation.
Salt Valley (loc. 4, fig. 3.	Nodules and veinlets in shale and impregnations in sandstone; in Morrison formation.
Northeast side of Little Valley in T. 22 S., R. 20 E. (loc. 5, fig. 3).	Nodules in shale and impregnations in sandstone and conglomerate; in Morrison formation.
Northeast side of Little Valley, in T. 22 S., R. 21 E. (loc. 6, fig. 3).	Nodules and veins in shale; in Morrison formation.
South of White House (loc. 7, fig. 3).	Partial replacement and impregnation of a sandstone bed; in Summerville formation.
Squaw Park (loc. 8, fig. 3).	Replacement of a limestone bed; in Summerville formation.
Wilson Mesa (loc. 9, fig. 3).	Impregnation in sandstone; in Morrison formation.
Muleshoe Wash (loc. 10, fig. 3).	Lenses and impregnations in limestone of Carmel formation and veins in Navajo sandstone.

Locality	*Character of deposit*
Saucer Basin (loc. 11, fig. 3).	Disseminated manganese oxide in caliche.
Cedar Mountain (loc. 12, fig. 3).	Nodules and lenses in shale and limestone and fissure fillings and impregnation in conglomeratic sandstone; in Morrison formation.
East of Rochester (loc. 13, fig. 3).	Nodules, veinlets, and sooty impregnation in shale and impregnations in conglomerate and chert; in Morrison formation.
Muddy River (loc. 14, fig. 3).	Nodules in shale and impregnations in shale and conglomerate; in Morrison formation.
East side of Boulder Mountain (loc. 15, fig. 3).	Nodules, lenses, and impregnations in sandstone; in Carmel formation.
Hutch Pasture (loc. 16, fig. 3).	Veinlets and partial replacement of Navajo sandstone.
East of Kanab (loc. 17, fig. 3).	Nodules and veinlets in shale and limestone of Chinle formation.

GENERAL GEOLOGY OF THE DEPOSITS

Most of the manganese deposits in southeastern Utah are stratified and occur as oxides in two formations, the Morrison and Summerville formations of Jurassic age. They are blanket deposits associated with thin beds of limestone, or they consist of nodules in clay beds; elsewhere the manganese occurs as veins and as detrital deposits.

Although several of the deposits are associated with minor structural features, in general there is little or no relationship between the distribution of the deposits and the regional structure or physiography.

STRATIGRAPHIC RELATIONS

Probably the most striking feature of the manganese deposits in southeastern Utah is their concentration at two reasonably definite stratigraphic positions several hundred feet apart. About half of them are in the Morrison formation, 200 to 300 ft below its top; these occur at widely separated localities in a belt extending for more than 150 miles along the outcrop of the formation. Most of the other deposits are in the Summerville formation, distributed through a thickness of 100 ft or more along 50 miles of outcrop. No deposits are known in the zone, 300 ft or so thick, that separates the two zones of ore deposits, and only one important deposit is known outside the two formations—the Kitchen Corral deposit in the Triassic Chinle formation at Kanab.

The stratigraphic relations of the manganese deposits are illustrated in the accompanying columnar section of the Mesozoic formations in the region.

Generalized columnar section of Mesozoic formations in southeastern Utah

Age	Formation	Character	Thickness (feet)	Manganese deposits
Tertiary or Quaternary.				At Saucer Basin caliche resting upon Entrada sandstone contains very minor amounts of manganese oxide.
Upper Cretaceous.	Mesaverde	Coal-bearing sandstone and shale.	700-1,350	No deposits known.
	Mancos	Dark-gray marine shale	3,400-4,400	Do.
	Dakota	Conglomerate and sandstone.	0-180	Do.
Upper Jurassic.	Morrison	Interbedded conglomeratic sandstone and variegated shale and some limestone and gypsum; terrestrial.	480-850	Contains nodular ore in shale and manganese-impregnated sandstone 200-300 ft below top of formation at Black Bird claim, locality east of Courthouse Wash, two localities northeast of Little Valley, Wilson Mesa, Cedar Mountain, locality east of Rochester, and Muddy River.
	Summerville	Thin-bedded red silty sandstone and some interbedded gray to brown sandstone, limestone, chert, and gypsum.	0-260	Contains numerous deposits at several stratigraphic positions in Little Grand district and two small deposits at Squaw Park and locality south of White House.
	Curtis	Gray marine sandstone	0-175	No deposits known.
	Entrada	Cross-bedded red to buff and gray sandstone; terrestrial.	25-1,000	Do.
	Carmel	Interbedded red to gray siltstone, shale, sandstone, gypsum, and limestone; marine.	100-500	Contains very minor deposits of manganese oxide at Muleshoe Wash and on east side of Boulder Mountain.
Jurassic (?)	Navajo	Cross-bedded gray to buff sandstone; terrestrial.	100-2,000	Contains very minor vein deposits of manganese oxide at Muleshoe Wash and Hutch Pasture.
	Kayenta	Irregularly bedded gray to red sandstone, conglomeratic sandstone, and shale; terrestrial.	40-290	No deposits known.
	Wingate	Cross-bedded buff to red sandstone; terrestrial.	300-400	Do.
Upper Triassic.	Chinle	Interbedded variegated shale, buff to red sandstone, and conglomerate; terrestrial.	140-980	Contains manganese oxide near base of formation east of Kanab.
	Shinarump	Gray conglomeratic sandstone.	0-210	No deposits known.
Lower Triassic.	Moenkopi	Thin-bedded red shale, siltstone, and sandstone and some interbedded marine limestone.	0-850	Do.
Permian and older.				Do.

The formations that contain the manganese oxide were deposited under different conditions, for the Morrison and Chinle formations are of continental origin, whereas the Summerville formation is marine and probably was deposited near shore in quiet water.

Practically all the blanket deposits are associated with thin beds or local lenses of gray to pinkish-lavender limestone which weathers greenish brown. Limestone comprises only a very small part of the Morrison, Summerville, or Chinle formations, yet with few exceptions the manganese deposits are found only in the limestone beds or immediately below them. In general the limestone beds, though lenticular, are more extensive than the manganese deposits.

Nodules of manganese oxide are found in the Morrison and Chinle formations in thick massive clay beds. Unlike the blanket deposits associated with the beds of limestone, these nodular deposits do not appear to have an orderly relation to the host rock. Volcanic ash has been observed in the Morrison and Chinle at several places in the Colorado Plateau, and it is probable that the massive clay beds contain much altered volcanic material, although the writers obtained no definite proof of its presence. Other clay beds that are similar to those containing the nodular manganese oxide are widespread in the Morrison and Chinle but contain no known deposits of manganese.

STRUCTURAL RELATIONS

There seems to be very little relationship between the distribution of the deposits and the general structure of the rocks. Although in general the rocks of southeastern Utah are nearly flat lying (Baker, 1935, pp. 1472–1507), they are flexed into numerous folds with small structural relief; a few major folds have a structural relief of several thousand feet. Normal faults, in part forming fault zones that are continuous for tens of miles, are common and have a general northwesterly trend. Most of the manganese deposits are in the relatively flat lying strata, and their localization appears to be independent of the structural features.

The deposits in the Little Grand district and in the area to the southeast are in a belt paralleling the outcrop of the Morrison and Summerville formations and roughly coinciding with a fault zone that extends from Moab to a point west of the Green River. The manganese oxide, however, is neither restricted to nor enriched along the fault zone, because it occurs in the nonfaulted rocks for several miles on either side of the zone. Moreover, the only deposits of manganese oxide in fissures along the faults (loc. 1, pl. 2, and loc. 2, fig. 3) occur in places where one wall of the fissure is approximately the same part of the Morrison formation that elsewhere contains the stratified deposits. Only at one locality, the Black Bird claim, does the manganese oxide seem related to faulting. Not only is this deposit elongate parallel and close to one of the very few faults transverse to the main fault zone, but a very small deposit a mile south of the claim also coincides with a fault of the transverse zone, although neither manganese oxide nor transverse faults occur again for several miles in any direction.

Several deposits are associated with minor structural features. Within the Snow and Kitchen Corral deposits, for example, manganese oxide is concentrated in vertical zones, but at other places manganese oxide in a group of beds is cut off abruptly at joint planes. However, these relationships between the local structural features and the occurrence of the manganese oxide are no more than would be expected in deposits that have been subject to ground-water action.

PHYSIOGRAPHIC RELATIONS

The deposits do not seem to bear an orderly relation to the physiography of the region, although Pardee (1921, pp. 191–192) thought that they were mostly located on spurs. This is true for the deposits he examined, but it is not true for the region as a whole. A deposit may be found in the face of a steep cliff, on the surface of a broad flat, at the point of a spur, or at the head of a cove. Size and grade do not appear to have been conditioned by the maturity of the surface at the deposit.

At two localities (locs. 3 and 17, fig. 3) the manganiferous beds are involved in landslide blocks, and the beds in these blocks—as well as in the parent cliffs—contain manganese oxide. The landslides are very old features of the topography; at Kitchen Corral Canyon, for example, the cliffs have retreated many hundreds of feet since the slides occurred. Evidently the manganese in these deposits antedates the present cycle of erosion.

FORM AND SIZE

There are three types of manganese deposits in southeastern Utah: (1) stratified deposits associated with a single bed or group of beds; (2) vein fillings and impregnations of the country rock along faults or fractures; and (3) detrital ore.

STRATIFIED DEPOSITS

By far the greatest number of deposits are stratified, and they contain essentially all the reserves of manganese in the region. The ore is in the form of nodules and blanket deposits consisting of fairly high grade ore partly replacing beds of limestone and lime-cemented sandstone, disseminated ore partly replacing beds of limestone or lime-cemented sandstone and conglomerate, and small nodules of manganese oxide in shale.

The blanket deposits are lens-shaped masses of hard manganese oxide approximately concordant with the bedding. At some places these occur singly; elsewhere they are clustered in discontinuous, overlapping lenses. Most of the lenses are only a few inches thick; they seldom exceed a foot. The largest are a few hundred feet long. Parts of blanket deposits commonly contain more than 50 percent manganese, but because they are thin, much waste has to be removed to recover the manganese oxides. However, the manganese oxides are easily separated from the barren rock.

At some localities the limestone and lime-cemented sandstone beds with which the blanket deposits are associated also contain nodules and veinlets of hard manganese oxide. At many places the nodules are an inch or more in diameter; the veinlets are rarely as much as a quarter of an inch wide. Generally the nodules and veinlets are irregularly distributed through a zone a foot or two thick. The nodules, commonly containing more than 50 percent manganese, are easily separated from the enclosing rock, but the nodular beds as a whole rarely contain as much as 10 percent manganese.

Limestone, lime-cemented sandstone, and conglomerate at many places have been impregnated with manganese oxide. The manganiferous beds may be several feet thick and many hundreds of feet long, but the manganese content rarely is as high as 5 percent and, moreover, part of the manganese oxide occurs as sooty pyrolusite that could not easily be recovered from the rock.

Shale beds that contain nodules of manganese oxide commonly are several feet thick and many hundreds of feet long. In these beds the manganese oxide occurs in the form of tiny nodules of hard oxide and as irregular masses and soft, sooty, finely disseminated manganese oxide. At a few places these manganiferous beds average as much as 10 percent manganese, but the soft, sooty manganese oxide is difficult to recover. A sample from this type of deposit was collected at the Black Bird claim (loc. 2, pl. 2) and analyzed by the U. S. Bureau of Mines. The sample was divided into three parts, A representing the lowest third (3½-ft section) of the bed, B the middle third, and C the top third. Each sample was split in two; half was analyzed as received to show the manganese content of a head sample of the bed, and the other half was hand-picked into three fractions—nodules, barren shale fragments, and fines. The results of the various analyses are given in the accompanying table.

At one locality, near Saucer Basin (loc. 11, fig. 3), a small quantity of manganese oxide is finely disseminated in the caliche cement of a gravel bed, but in southeastern Utah this type of deposit probably is not a commercially important source of manganese.

VEIN DEPOSITS

Vein deposits of manganese oxide are rare in southeastern Utah. They consist of podlike bodies of fairly high grade ore, usually less than 3 ft wide, irregularly distributed along faults for distances of 100 ft or less to half a mile. The vertical extent of the veins can be observed only at the deposits in Muleshoe Wash, but it is doubtful

Analysis of sample from the Black Bird claim

[Sample obtained and analyzed by U. S. Bureau of Mines]

	Mn	Fe	Insoluble	S	P	CaO	Zn	Distribution percent of total	
								Weight	Mn
Heads:									
A	9.18	1.19	68.63	-------	-------	-------	-------	-------	-------
B	16.9	.85	53.75	-------	-------	-------	-------	-------	-------
C	4.32	1.65	67.58	-------	-------	-------	-------	-------	-------
Average	10.13	1.23	63.24	-------	-------	-------	-------	-------	-------
Nodules:									
A	32.0	0.75	18.16	0.30	0.002	1.80	<0.01	26.7	88.4
B	40.8	.63	18.55	.21	.006	6.30	<.01	33.7	80.2
C	46.4	1.11	18.04	.24	.003	.52	<.01	7.3	77.2
Average	39.7	0.83	18.25	0.25	0.004	2.87	<0.01	22.8	81.9
Fines:									
A	1.95	1.35	74.96	-------	-------	-------	-------	55.0	11.1
B	6.8	.92	69.91	-------	-------	-------	-------	48.8	19.3
C	1.14	1.88	70.46	-------	-------	-------	-------	82.9	21.5
Average	3.30	1.38	71.78	-------	-------	-------	-------	62.2	17.3
Shale:									
A	0.27	1.31	83.80	-------	-------	-------	-------	18.3	0.5
B	.6	.83	85.63	-------	-------	-------	-------	17.5	.6
C	.54	1.78	75.16	-------	-------	-------	-------	9.8	1.2
Average	0.47	1.31	81.53	-------	-------	-------	-------	15.2	0.8

that any of the veins extend below the surface to depths greater than a few tens of feet. Commonly the country rock adjacent to the veins also contains small amounts of manganese oxide. Several of the vein deposits along faults are adjacent to those beds in the Morrison formation that elsewhere contain the stratified deposits.

DETRITAL DEPOSITS

The detrital ore, which is mainly confined to the Little Grand district, consists of fragments of ore freed from the country rock by erosion and concentrated on the ground surface or in the soil. Such deposits include detrital fragments that collect on the slopes below the ledges of blanket deposits and residual fragments that have accumulated on bench surfaces. These detrital deposits supplied much of the manganese that was produced during former periods of mining activity, and little additional ore of this type remains.

MINERALOGY

The manganese minerals observed by the writers in southeastern Utah are all oxides, although the manganese carbonates rhodochrosite and manganocalcite have been reported (Pardee, 1921, pp. 190, 203) from one locality. In order of abundance, the oxide minerals definitely recognized are pyrolusite, psilomelane, and manganite. A

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soft, earthy, brownish-black mineral that constitutes an important part of the ore in some deposits may be wad.

Pyrolusite.—Pyrolusite (MnO_2) is steel gray to black and finely to coarsely crystalline in its most common form, but it occurs also in a brownish-black, earthy form. Practically all the crystalline ore is pyrolusite, and this variety of the ore occurs in all the deposits in the Summerville formation, in fissure veins, in the hard nodules in shale of the Morrison and Chinle formations, and as a replacement of limestone, sandstone, and conglomerate. The sooty or earthy variety occurs principally in the Morrison and Chinle formations as coatings on harder nodules of pyrolusite or nodules of limestone and as veinlets and irregularly shaped nodular masses in shale.

Psilomelane-type minerals.—Psilomelane-type minerals (formula variable) are a minor constituent of some deposits. Commonly they are intimately intermixed with pyrolusite. Some of the nodules in the shale of the Chinle formation at the Kitchen Corral deposit east of Kanab contain considerable psilomelane intimately intermixed with microcrystalline pyrolusite. Other limonite-rich nodules from the same deposit contain thin shells and veinlets of psilomelane.

Manganite.—Manganite [$MnO(OH)$] is present in very small quantities. It occurs as small, isolated acicular crystals, sparsely distributed through masses of pyrolusite, and has been identified in polished specimens of ore from deposits in the Summerville and Morrison formations.

Gangue minerals.—The principal nonmanganiferous minerals associated with the manganese deposits are quartz, chert, jasper, chalcedony, calcite, gypsum, feldspar, barite, celestite, limonite, and hematite. Rounded to angular grains of quartz, chert, and feldspar are present in much of the ore and in some deposits constitute a large percentage of the ore body. Many of the grains are etched and are partly replaced by manganese oxides. Beds and nodules of chert or jasper are conspicuous at the manganese deposits in the Summerville and Morrison formations. Calcium carbonate occurs abundantly as limestone, as cement in sandstone and conglomerate, and as crystals and veinlets of calcite. One of the beds of gypsum in the Summerville formation locally contains manganese oxide, and small crystals of gypsum are common in the manganese deposits. Most of the deposits have small crystals of barite scattered through them. Coarsely crystalline celestite in thin blanket veins and small nodules is associated with the manganese oxide in the Summerville formation at a few localities north of Salt Wash. The iron oxides limonite and hematite are widely distributed with the manganese oxide, occurring along joints, disseminated in sandstone, in nodules in shale, or as a film coating grains of quartz or other mineral or rock fragments.

All these gangue minerals, however, have a wide distribution in southeastern Utah and are not at all restricted to the manganiferous localities.

ORIGIN

The origin of the manganese oxide deposits in southeastern Utah is obscure, but the manganese may have been deposited with the enclosing sediments and later reworked by supergene processes.

Analyses of the limestone with which the blanket veins are associated show a manganese content ranging from 0.02 to 0.48 percent, probably in the form of a carbonate. Limestone specimens heated in an oxidizing flame become spotted grayish black. Such small quantities of manganese in the limestone beds probably are not the main source of the deposits, for the quantity of limestone is small and, moreover, the limestone beds are compact at the outcrop and show no sign of leaching. At a few localities pink limy sandstone contains tonguelike brownish-black areas along joints, as if manganese carbonate were being altered to manganese oxide. A test of the soluble carbonate matrix of these beds showed only 1.3 percent manganese as compared with the 25.9 percent manganese in brownish-black material. The individual deposits of manganese oxide are small, and so far as they have been developed, they do not reveal a continuity or alinement that would suggest deposition along channels of ground-water circulation.

Clay beds in the Morrison and Chinle formations locally contain abundant nodules of manganese oxide, but the clay at these deposits seems to be identical with the barren clay in other parts of the formations. Samples of the barren clay contain less than 0.001 percent manganese; hence these clay beds give no evidence of having been the source of the manganese. The theory that the manganese was deposited with the enclosing sediments therefore is an assumption, for no source beds can be indicated.

Moreover, even if the manganese were originally deposited with the enclosing strata, the fact that many of the deposits are veins, in part lying along fault planes, clearly indicates that the present form and location of those deposits were determined after the strata were deposited and after they had been broken by the faults and joints. Because most of the deposits are not dependent on the faulting, it must be assumed that the vein deposits reflect comparatively minor supergene changes. Presumably most of the supergene changes to which the deposits have been subjected occurred prior to the present erosion cycle, because at several places mature erosion surfaces contain concentrates of the nodules in detrital deposits. At other places, where a clay bed contains nodular ore, the same bed in old landslide blocks contains nodules of manganese oxide in about the same quantity:

Pardee (1921, pp. 191–192) believed that the manganese had been deposited as finely disseminated carbonate with the sediments and that the manganese oxide had been concentrated at the outcrop during erosion of the rocks. He was impressed by the fact that many of the deposits, especially those near Green River, are at spurs, and he inferred that retarded erosion at the spurs had permitted greater concentration of manganese oxide. Recent mapping, however, indicates that although several of the deposits (locs. 7 and 9, pl. 2; loc. 13, fig. 3), including two of the best, are at spurs, most of the deposits bear no orderly relation to the topography (pl. 3).

Possibly the nodules of manganese oxide in shale were originally deposited in that form with the shale, like some that are forming in certain present-day fresh-water lakes (Kindle, 1932, pp. 496–504; 1936, pp. 755–760). The rest of the manganese may have been deposited, presumably as carbonate, and finely mixed with the beds of limestone or the limy matrix of sandstone beds. Such bedded deposits of carbonate have been described as existing in many localities (Hewett, 1932, pp. 569–573), but their presence in southeastern Utah has not been demonstrated.

Residual deposits may be formed from any of the other types. This type of deposit, as described by Pardee (Pardee, 1921, p. 183), is due to residual concentration of the hard, heavy manganese oxide fragments by removal of the lighter fragments of sand and rock.

RESERVES

Few of the deposits have been developed sufficiently to delimit the ore with accuracy. Furthermore, error is invited in assuming that the grade of the ore at the outcrop, where samples had to be taken, will be maintained back from the outcrop. With these uncertainties in mind, it is estimated that the deposits in southeastern Utah aggregate about half a million tons of manganese ore containing 4 to 50 percent manganese. Of this total, only about 15,000 tons would contain more than 30 percent manganese, and very little ore would contain more than 40 percent manganese. Material of this grade occurs only in small deposits scattered over a large area, principally in the Little Grand district, and is recoverable from shallow open pits and by hand sorting of the ore. Ore containing 10 to 30 percent manganese is estimated to aggregate somewhat more than 100,000 tons. It consists of thin blanket veins, small lenses, and nodules and impregnations in limestone and sandstone from which the ore probably could be recovered only by mining the containing rocks, crushing them, and concentrating the ore. About 350,000 tons of ore contains 10 percent manganese or less. About half that tonnage consists of nodules of fairly high grade oxide in shale that could be easily concentrated although considerable earthy oxide might be lost in the process; the other half is generally lower in grade and consists largely of sandstone containing disseminated ore that would be difficult to concentrate.

The manganese occurs in widely scattered deposits, none of which are sufficiently large to justify installation of elaborate mining and milling equipment. Only the small tonnage of relatively high grade ore which is recoverable by portable equipment and hand labor is likely to be worked at the present time.

LITTLE GRAND DISTRICT

GEOGRAPHY

The Little Grand district (fig. 3, loc. 1) contains a considerable number of small manganese deposits. Plate 2, a geological map of the district, shows the distribution of the deposits.

The northern part of the Little Grand district is a broad plain, between 4,000 and 4,900 ft in altitude, which is underlain by shale. Southward the plain is broken by small canyons and southward-facing cliffs and ledges as much as 500 ft high. The cliffs are considerably dissected and follow a sinuous course around innumerable reentrants and promontories; in places buttes, mesas, and spires have been isolated from them. In general, the manganese deposits are distributed along these cliffs.

The climate is arid. For mining or milling operations water would have to be brought from the Green River. A few springs supply small quantities of potable water. Vegetation is sparse and consists mainly of low-growing, desert-type plants. A few cottonwood and willow trees grow along the Green River and some of the larger tributary streams, and scattered juniper trees are found in the uplands.

The district is thinly populated. Three ranches along the Green River and a cattle ranch near Dubinky Spring furnish a livelihood for a few people. The town of Green River has a population of several hundred, and there is a small settlement at Floy.

The manganese deposits are 3 to 15 miles south of the main line of the Denver & Rio Grande Western Railroad and paved United States Highway No. 50, which parallels the railroad. Several unimproved roads lead south from the main highway to the manganese deposits, but the condition and even the location of these roads vary from season to season and from year to year. The roads that were used in 1940 are shown on plate 2. Road construction would not be difficult, but at present the broad shale flats and numerous washes that must be crossed make these access roads nearly impassable in wet weather.

PRODUCTION AND MINING CONDITIONS

Early production of manganese in the Little Grand district had been described by Pardee (1921, pp. 183–184), as follows:

> The first manganese mining in Utah was done in the Little Grand district in 1901 by the Colorado Fuel and Iron Company, which developed the deposits now known as the C. F. & I. mine. In that year and in 1903, 1904, and 1906, a total of somewhat less than 4,000 tons of ore was produced. * * * A second period of mining activity began in 1915 and lasted until late in 1918. During this period several deposits were exploited in addition to the C. F. & I. mine, which, however, continued to be the chief producer. In May 1918, three operators—the Green River Mining Company, the Needles Mining Company, and J. B. Fonder—were together producing ore at an average rate of about 500 tons a month. The total reported production of this later period is 8,000 tons.

From 1918 to 1940 no shipments are known to have been made from the district.

A large part of the manganese produced in the Little Grand district has been recovered by screening residual nodules or fragments of ore from the soil. At several places the richer ore in thin beds or blanket veins has been mined in small areas by stripping the overburden with a plow and scraper, or even with hand tools. At the Desert Rock claim (pl. 2, loc. 1) a nearly vertical vein has been mined by adits and a shaft. The ore mined from these deposits has been hand-picked. The low-grade manganese ore at the Black Bird claim (pl. 2, loc. 2), consisting of nodules of manganese oxide in shale, had not been mined in 1940 but could probably be recovered either by underground-mining methods or by stripping the overburden. The hard nodules of manganese oxide could be readily separated from the shale, but complex treatment might be required to recover the associated soft oxides.

GEOLOGY

STRATIGRAPHY

The formations that crop out in the Little Grand district are of Jurassic(?), Upper Jurassic, and Upper Cretaceous age and have an aggregate thickness of about 3,000 ft. Plate 2 shows the distribution of the Summerville and Morrison formations, which contain the manganese deposits; the accompanying generalized section gives all the rocks exposed in the district.

Formations exposed in the Little Grand district

Age	Formation	Thickness (feet)	Description
Upper Cretaceous.	Mancos shale	1,400	Slate-gray shale containing some thin sandy zones, such as the Ferron sandstone member, 440–500 ft above base; forms broad flats and badlands; low relief.
Upper Cretaceous.	Dakota sandstone	0–25	Discontinuous lenses of light- to dark-brown conglomeratic sandstone and some interbedded gray and black shale.
Upper Jurassic	Morrison formation.	590–850	Interbedded sandstone, conglomerate, variegated shale, and siltstone. Salt Wash sandstone member forming lower part of formation consists of thick, irregularly bedded, white to buff, fine-grained to gritty, ledge-forming sandstone interbedded with variegated mudstone and siltstone and has gypsum or limestone at base in western part of district. Upper part of formation consists principally of thin-bedded variegated mudstone and some interbedded, ledge-forming conglomeratic sandstone and quartzite, especially near top, and occasional thin beds of limestone and cherty limestone. Manganese oxide occurs as nodules in shale and as impregnations in sandstone in upper part of formation at Black Bird claim.
Upper Jurassic	Summerville formation.	96–180	Thin, regularly bedded, slope-forming reddish shale and mudstone, silty sandstone, and some resistant thin beds of gray to brown sandstone and gray to lavender-brown cherty limestone. In western part of district Summerville contains many thin beds of gypsum; toward east, intertongued with Entrada sandstone. Summerville is principal manganese-bearing formation of district. Manganese oxide occurs as lenses, nodules, and impregnations in limestone and sandstone beds and as veins and small irregular masses in sandstone mainly at or near the top of the formation.
Upper Jurassic	Curtis formation	0–130	Similar to Summerville formation except for preponderance of greenish-gray rather than reddish color. Recognized only in western part of district; forms slopes or benches.
Upper Jurassic	Entrada sandstone.	325–400	Light reddish-brown, largely fine-grained sandstone; in part evenly bedded, in part cross-bedded. Cross-bedded pink to white sandstone, the Moab tongue, present in eastern part of area; 56 ft thick east of Tenmile Wash but separated from main body of Entrada sandstone (270 ft thick) below by a tongue of red beds (72 ft thick) of Summerville formation; toward west Moab tongue wedges out a short distance west of Tenmile Wash. Main part of Entrada forms steep cliffs or rounded buttes; Moab tongue forms vertical cliffs.
Upper Jurassic	Carmel formation	125	Irregularly bedded, pink to reddish-brown silty sandstone and gray to red mudstone containing some fragments and nodules of chert; forms benches and cliffs below Entrada sandstone.
Jurassic (?)	Navajo sandstone	300	Cross-bedded, medium- to fine-grained gray to buff sandstone; forms rounded cliffs.

SUMMERVILLE FORMATION

The outcrop of the Summerville formation forms a prominent escarpment along the north and west walls of Dry Lake Wash and from there extends southeastward across the district to the southwestern part of T. 24 S., R. 19 E. A general northward dip carries the Summerville formation below the surface in that direction, but north of the main escarpment faults bring the formation to the surface in a narrow belt about 7½ miles long in the cliffs on the north side of Salt Wash and, farther north, in the cliffs of a small area in the valley of the Green River in the southeastern part of T. 21 S., R. 16 E. These escarpments are capped by the sandstone ledges at the base of the Morrison formation.

In the eastern part of the district the escarpment formed by the Summerville formation rises above cliffs of Entrada sandstone, but westward the Entrada is less resistant and is overlain by the easily eroded Curtis formation. In this part of the district the Summerville escarpment overlooks a broad plain.

The Summerville formation consists of reddish or chocolate-brown shale and mudstone; occasional thin beds of purplish-brown or lavender shale; chocolate-brown and red sandy mudstone and muddy sandstone; reddish soft sandstone; and gray, purplish, or reddish sandstone, commonly somewhat calcareous. In the upper part of the formation are thin lenses of gray to brown and purplish limestone. At places the Summerville contains irregular masses of varicolored chert, generally gray, yellow, black, or red. In the western part of the district, especially west of the Colorado Fuel & Iron Co. mine, the upper part of the formation contains considerable gypsum, generally in beds an inch or less thick. Thin, regular bedding is characteristic of the formation, but some of the sandstone beds are as much as 4 ft thick.

Manganese oxide is found principally in the lenses of limestone in the upper part of the formation. It occurs also as blebs, mostly less than an inch in diameter, in sandstone and as crosscutting veinlets in mudstone, shale, and sandstone. The deposits are widespread in the formation, but at most localities they are restricted to one or two zones and the greater part of the formation is barren.

The thickness of the Summerville formation varies considerably. On the west bank of the Green River, in sec. 34, T. 21 S., R. 16 E., it is 118 ft thick; northwest of the mouth of the San Rafael River, in sec. 20, T. 23 S., R. 16 E., it is 96 ft thick; at Dellenbaugh Butte on the east bank of the Green River, in sec. 12, T. 23 S., R. 16 E., it is 180 ft thick; a mile east of the Colorado Fuel & Iron Co. mine it is 152 ft thick; and 2½ miles southeast of the mine it is 127 ft thick. On Tenmile Wash the thickness of the Summerville is 72 ft below the Moab tongue of the Entrada sandstone, and 48 ft above it, making a total of 120 ft. In the western part of the district the Summerville is gradational into the underlying Curtis formation, and eastward the greenish-gray sandstone of the Curtis grades into red shaly beds that are inseparable from the Summerville. East of the Colorado Fuel & Iron Co. mine the Curtis is not recognized and the Summerville rests upon the Entrada sandstone.

On the west side of Tenmile Wash a thin bed of gray sandstone in the upper part of the Summerville formation marks the west edge of the Moab tongue of the Entrada sandstone. Eastward this tongue thickens and the part of the Summerville that underlies it wedges out.

At many places in southeastern Utah the Summerville formation is overlain unconformably by the Morrison formation; locally there is a slight angular discordance between the two. In the Little Grand district, however, the contact is gradational and cannot be selected with certainty. Near the Green River a thick bed of gypsum has been mapped as the basal bed of the Morrison formation. Farther east the gypsum is absent and the contact is tentatively placed a few feet above the manganiferous limestone. At this contact typical red beds of the Summerville are overlain by gray and lavender shale and mudstone, thin beds of sandstone, and some blue-gray limestone, and these in turn are overlain by the Salt Wash sandstone member of the Morrison.

The Summerville formation is of Upper Jurassic age. It contains no fossils, but both the underlying Curtis formation and the overlying Morrison formation contain fossils of Upper Jurassic age at several localities in southeastern Utah. The sediments of the Summerville formation are shallow-water deposits that apparently accumulated at the margin of the Jurassic sea.

MORRISON FORMATION

The Morrison formation is the surface rock in a large part of the Little Grand district. Resistant sandstone beds in the lower part of the formation crop out at the top of the escarpments formed by the Summerville formation and form terraced dip slopes for distances of 1 to 4 miles north of the escarpments. Thick beds of mudstone in the upper part of the formation form badlands and steep slopes capped by ledges of resistant sandstone and conglomerate. These areas have a rough topography broken by cliffs, canyons, mesas, and steep-sided badland hills.

The Morrison consists principally of interbedded sandstone, shale, and mudstone. The lower part of the formation, which contains more sandstone than the upper part, is referred to as the Salt Wash sandstone member. In much of the western part of the district the basal bed of this member is a massive white gypsum as much as 30 ft thick which forms a ledge at the top of the escarpment formed by the Summerville formation. At other places the basal bed is a light-gray cherty limestone less than 5 ft thick. East of the Colorado Fuel & Iron Co. mine the basal unit of the Salt Wash sandstone member of the Morrison consists of 35 ft of gray to variegated shale and mudstone containing many thin beds of sandstone and some nodular limestone. These are overlain by highly lenticular sandstone beds 30 ft or more thick, interbedded with shale and mudstone. The sandstone is light greenish gray to brown, fine- to coarse-grained, locally conglomeratic, and cross-bedded. The shale and mudstone interbedded with the sandstone are variegated in shades of gray, green, purple, brown, and red, are in part sandy, and locally contain calcareous nodules or nodular limestone beds. The top of the Salt Wash member is arbitrarily placed at the top of the uppermost prominent bed of sandstone underlying the main body of variegated mudstone in the upper part of the formation; because of the lenticularity and discontinuity of the sandstone beds the top of the member is not everywhere at the same stratigraphic position. On the west side of the Green River, in the southwestern part of T. 21 S., R. 16 E., the Salt Wash sandstone member is 185 ft thick; north of Tenmile Wash it is 330 ft thick.

Above the Salt Wash sandstone member the Morrison consists principally of variegated mudstone and some ledges of sandstone and conglomerate, a very few thin beds of limestone, and—locally—nodules of manganese oxide. The variegated mudstone at most places is thin-bedded; it contains numerous isolated highly polished pebbles 3 in. or more in diameter.

Some thin beds of sandstone are interbedded with the mudstone, and near the top of the formation the sandstone beds may be 75 ft thick. This sandstone is medium- to coarse-grained, locally conglomeratic, dominantly gray or buff, highly lenticular, and cross-bedded. Some of the sandstone beds are soft and friable; others have a siliceous cement and are very hard.

The total thickness of the Morrison is 590 ft west of Green River, in the southwestern part of T. 21 S., R. 16 E., and about 850 ft north of Tenmile Wash.

The Morrison formation is unconformably overlain by rocks of Cretaceous age. At some places the gray Mancos shale rests directly upon the Morrison formation, but at others the lenticular Dakota sandstone, which consists of gray to light-brown conglomeratic sandstone, lies between the Mancos and the Morrison.

The Morrison is of continental origin and at many localities in southeastern Utah contains fossil bones that indicate an Upper Jurassic age.

STRUCTURE

The rocks of the Little Grand district have been arched into a low, northward-plunging anticlinal nose whose axis trends southeastward from the town of Green River to the southeast corner of T. 23 S., R. 17 E. The average dip of the rocks is 2°–4°. Numerous normal faults have displacements ranging from a few feet to hundreds of feet. The Little Grand fault, located along the north edge of the drainage basin of Little Grand Wash, crosses the Green River about 3½ miles south of the town of Green River and continues northwestward beyond the limits of the district. Near the river the strike of the fault is approximately east, but eastward the strike changes to a northeasterly direction and westward it changes to a northwesterly direction. The maximum displacement on the fault is about 950 ft down toward the south. Near the river the displacement is along two essentially parallel faults that are 400 ft or less apart; about 700 ft of the total displacement occurs along the southern fault. The manganese deposit at the Desert Rock claim in sec. 31, T. 21 S., R. 17 E., is on a small subsidiary of the Little Grand fault.

About a mile east of the mouth of Little Grand Wash two branch faults on the downthrown side of the Little Grand fault trend about S. 30° E. and bound a shallow graben block. The maximum displacement is about 100 ft on the east fault and about 50 ft on the west fault. Toward the southeast the east fault splits into several small faults which cross the manganese deposit at the Black Bird claim near the southeast corner of sec. 12, T. 22 S., R. 16 E. Small faults in secs. 19 and 30, T. 22 S., R. 17 E., apparently are not connected with graben faults, but they have a similar trend and represent a continuation of the fault zone.

The zone of faults that follows the valley of Salt Wash fairly closely and separates the manganese deposits in the main escarpment from those in the cliffs north of Salt Wash is part of a fault zone that has been traced for about 60 miles from a point west of the Green River southeastward across the Colorado River at Moab. McKnight (1941, pp. 120–122) has divided the fault zone into three major units, which are, from east to west, the Moab fault, the Tenmile graben, and the Salt Wash graben.

Only the northwest end of the Moab fault is in the Little Grand district. This fault enters the district near the southeast corner of sec. 32, T. 23 S., R. 19 E., and trends N. 35° W. Toward the northwest the trend changes to about N. 70° W. and the Moab fault becomes the south fault bounding the dropped block of the Tenmile graben. The Moab fault is a normal fault along which the north side has been dropped relative to the south side. The displacement is 400 to 600 ft, and the dip of the fault plane is about 60° N. The Morrison formation on the south is faulted against the lower part of the Mancos shale on the north.

The Tenmile graben trends about N. 75° W. and extends about 7 miles westward from the east line of T. 23 S., R. 18 E. It is entirely within the Little Grand district. The graben faults converge westward, so that the east end of the graben is about 3,500 ft wide but the west end is only about 500 ft wide. The north fault has a maximum displacement of about 800 ft; it splits into smaller faults both east and west of the point of maximum displacement. The south fault has a maximum displacement of about 700 ft, but it connects southeastward with the larger Moab fault. Near Tenmile Wash a branch fault with opposite displacement trends eastward parallel to the general trend of the graben. The net effect of the displacement along the graben faults is uplift of the rocks north of the graben relative to the rocks south of the graben, thus reversing the direction of displacement caused by the Moab fault. Near the middle of the graben, where the displacement is greatest, Mancos shale in the graben is faulted against rocks of the Morrison formation to the north and south.

The Salt Wash graben is en echelon with the Tenmile graben; the eastern part of the Salt Wash graben is about three-quarters of a mile south of the western part of the Tenmile graben. The Salt Wash graben is about 14 miles long and lies within the Little Grand district. It extends about 4 miles west of the Green River and crosses the river about 7 miles south of the town of Green River. It trends about N. 70° W. and has an average width of about 2,500 ft. The maximum displacement is about 1,000 ft on the north fault and about 800 ft on the south fault. Near its east end the north fault splits into several small faults, and westward there is a slight northward offset of the graben caused by echelon faults along both the north and south sides of the graben. The rocks north of the graben are raised relative to those in the south; the maximum net displacement is about 300 ft. The surface rocks in most of the graben are Mancos shale, abutting on the north against rocks as old as Entrada sandstone and abutting on the south principally against the Morrison formation.

MANGANESE DEPOSITS

The manganese deposits in the Little Grand district can be divided into three groups: (1) those associated with the Little Grand fault in the northwestern part of the district; (2) those located in the cliffs north of Salt Wash; and (3) those located in the escarpment farther south. The individual deposits in each group are described in order from west to east.

DESERT ROCK CLAIM

The Desert Rock claim (loc. 1, pl. 2) is in the SE¼ sec. 31, T. 21 S., R. 17 E., about 5 miles southeast of the bridge across the Green River at the town of Green River. A rough road that turns south from U. S. Highway 50 just east of the bridge leads to the deposit. Some manganese ore has been mined from this deposit, but the amount is not known. Pardee (1921, p. 205) mentions a reported shipment of a carload of ore in 1917 from the Mongol claim, which is the claim now known as the Desert Rock. Work was not in progress in the summer of 1940, but some development work had recently been done and some ore may have been shipped.

The prospect is along a subsidiary fault 200 ft north of the Little Grand fault. It is located at the head of a small tributary of Little

Grand Wash and is near the base of an irregular, southward-facing escarpment 100 ft or more high. The rocks exposed are slope-forming, variegated shale or mudstone capped by a ledge of sandstone that forms cliffs at the top of the escarpment; these rocks are approximately 250 ft below the top of the Morrison formation. They dip 2°–3° NE. except in a drag zone along the main fault where they dip south.

The main fault in the vicinity of the mine has a displacement of about 800 ft, dropping Mancos shale on the south against beds of the Morrison formation on the north. The subsidiary fault at the mine strikes N. 85° W. and dips about 60° N. The fault surfaces are slickensided and grooved. Displacement along the fault is probably small, as the rocks in both the hanging wall and the footwall are variegated shale of the Morrison formation.

Two entries have been made into the deposit. An older adit, which is reached by an open trench 30 ft long, is 6 to 18 ft high and follows the fault eastward for 75 ft. High-grade manganese oxide ore exposed at the face of this adit occupies the fault fracture and encloses some crushed country rock. The vein is 18 in. wide at the face of the adit. Pardee (1921, p. 205) reported the vein to range in thickness from 6 in. to 3 ft. Judging from the width between the slickensided fault faces along the adit, it is possible that the vein had a maximum thickness of as much as 4 ft. Pardee also stated that a waste-filled shaft at one end of the open-cut was reported to have followed the vein to a depth of 40 ft and that the thickness did not decrease to this depth. The present adit floor is approximately level with the floor of the open-cut approach, and the extent of former excavation below this level is not known.

A second, more recent adit about 50 ft west of the older adit is reached by an open trench 30 ft long that trends N. 40° E. An adit with the same trend continues for 28 ft beyond the fault into the hanging wall, and a branch adit near the mouth of the entry extends eastward for 40 ft along the fault. The vein of manganese oxide, as exposed in this adit in 1940, has a maximum thickness of about 6 in. and pinches out in places. In the hanging wall the variegated shale contains abundant small nodules of manganese oxide in a zone about 5 ft thick and a few thin short lenses parallel to the bedding of limestone containing manganese oxide. It was estimated that locally the manganese oxide nodules may constitute as much as 15 percent of the rock.

At the surface the rocks are poorly exposed. West of the mine no nodular ore was observed in the shale, but small fragments of ore found at several places indicate that the rocks are manganese bearing for a considerable distance. It seems likely, however, that the manganese minerals occur in small, discontinuous veinlets rather than in a single vein. A crosscutting vein 800 ft from the mine is about 1 in. thick and 25 ft long. Eastward from the mine manganese oxide exposed discontinuously at the surface for a distance of 750 ft along the fault has been explored by several shallow pits. Although veins of the oxide ore a few inches to 2 ft thick, dipping 40°–50° N., are exposed at several places, the ore probably is in discontinuous lenses along the fault zone. At other places, where exposures are poor, the oxide ore appears to be interbedded with shale in a zone up to 3 ft thick.

The nodular manganese ore observed in the western adit is, so far as known, limited to a small area cut by that adit, but manganese oxide may be relatively widely disseminated through the shale and may have been the source from which the vein matter was derived by circulating ground water. It seems significant that the rocks adjoining the vein are in approximately the same part of the Morrison formation that contains manganese deposits in other parts of the region.

From the development work that has been done and the outcrops of the ore it is evident that the principal ore deposits of the Desert Rock claim consist of a series of discontinuous pods along one or more faults. The extent of ore in depth is conjectural, but it seems probable that the deposits are near-surface features and that they do not extend downward along the faults for more than a few tens of feet below the present surface. Without further development work it would be unsafe to assume that more than a few hundred tons of ore could be recovered from this claim.

The ore consists chiefly of pyrolusite filling veins and replacing crushed sandstone and shale. Unreplaced fragments of the country rock are embedded in the manganese oxide. Small crystals of barite are present in the ore. The ore shipped in 1917 is said to have averaged 47 percent manganese and 15 percent silica.

BLACK BIRD CLAIM

The Black Bird claim of C. R. Hanks and others is located in sec. 12, T. 22 S., R. 16 E., and sec. 7, T. 22 S., R. 17 E., in the valley of a tributary of Little Grand Wash (loc. 2, pl. 2). A rough road that branches southward from the highway just east of the bridge across the Green River leads to the claim; southeast of the central part of sec. 1, T. 22 S., R. 16 E., the road in part follows the bed of the tributary to Little Grand Wash and would require considerable maintenance to provide a satisfactory haulageway. The distance by road from the town of Green River is approximately 10 miles. As of September 1940, no manganese ore had been shipped from the claim and only shallow pits had been dug to explore the deposit.

The deposit occurs principally in the stream bed and on the east wall of a narrow, steep-sided gorge 50 to 75 ft deep. The walls of the gorge are mainly shale, with ledges of massive sandstone forming the rims. Figure 4 is a sketch map of the claim.

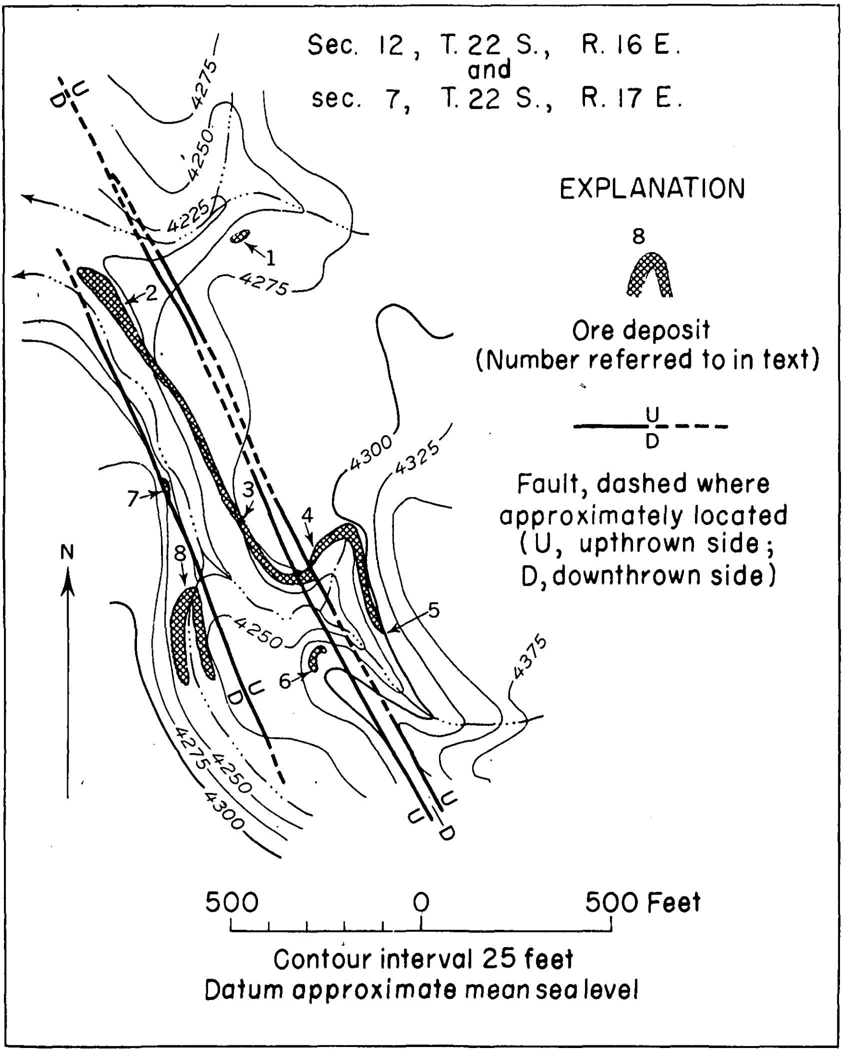

FIGURE 4.—Map of the manganese deposit on the Black Bird claim, in sec. 12, T. 22 S., R. 16 E., and sec. 7, T. 22 S., R. 17 E., Little Grand district, Utah.

The rocks at the claim belong to the Morrison formation and consist of gray to variegated shale, interbedded buff to gray massive sandstone, and a few thin beds of conglomerate, limy shale, and sandy limestone. The manganese oxide occurs as pyrolusite in nodules and lenses in shale and as an impregnation or replacement of the limy sandstone and sandy limestone. It is confined to one group of beds about 10 ft thick which are approximately 200 ft below the top of the Morrison. Exposures are moderately good. The rocks dip about 4° NE. and are broken by three small faults that strike N. 20°–30° W. The two parallel faults east of the main outcrop belt of the manganiferous beds bound a graben 40 ft wide. At the south end of the deposit (near loc. 4, fig. 4) the displacement is 8 ft on the west fault and 16 ft on the east fault, so that the net displacement of the two faults is 8 ft toward the west. These graben faults appear to join near the north end of the deposit, and farther north a single fault has a displacement of 75 ft or more. A third fault, which is west of the main outcrop belt of the manganiferous beds, follows the course of the stream bed fairly closely and drops the manganiferous beds about 40 ft toward the west.

At the north end of the deposit the base of the manganiferous beds is only 2 ft above the level of the creek. The basal bad uncovered by a shallow pit is a ledge of lime-cemented sandstone 10 in. thick that is dominantly black, but the black color fingers out into pink limy sandstone. A thin section shows that the manganese oxide in the black portions of the rock occurs principally as cement between the sand grains and apparently has replaced the lime cement (fig. 5).

The extent of this ledge northward beneath the cover of younger rocks is unknown, but southward it thins about 3 in. in a distance of

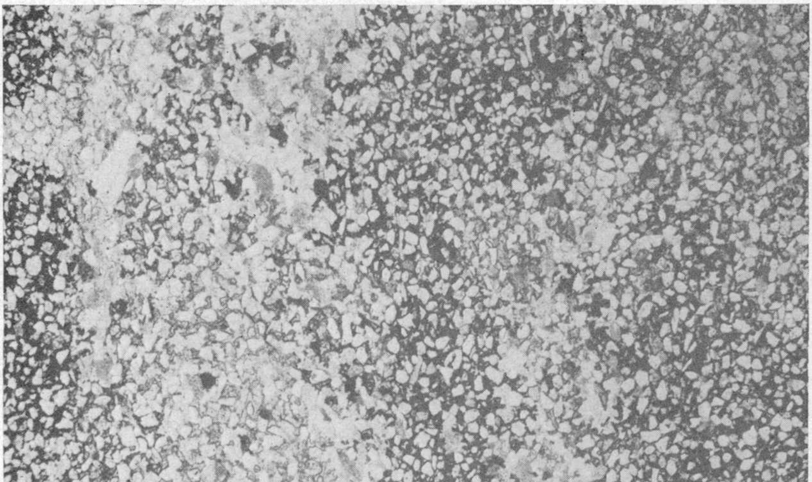

FIGURE 5.—Thin section of fine-grained manganiferous sandstone from the Black Bird deposit in the Morrison formation, Little Grand district, Utah.

100 ft. At the extreme north end of the outcrop the shale overlying the basal manganiferous ledge is barren of manganese. The strata that contain the manganese deposits are exposed east of the graben faults at the north end of the outcrop, but the strata are barren except at locality 1 (fig. 4), where a few nodules of manganese oxide were found in float. A trench at locality 2 exposes the following section of the manganiferous zone:

Section measured at Black Bird claim (loc. 2, fig. 4)

Sandstone, at top of section.	Ft	in.
1. Gray shale	5	0
2. Gray to red shale; contains nodules of manganese oxide, considered to be chiefly pyrolusite, ranging from size of a pinhead up to 2 in. but mostly less than half an inch in diameter; also contains thin lenticular beds of limy sandstone impregnated with manganese oxide like the underlying bed	8	10
3. Pink to black sandstone with lime cement partly replaced by manganese oxide		6
Base of section.		

A sample chipped from units 2 and 3 contains 3.9 percent Mn.

Southward from locality 2 the manganiferous beds gradually rise higher above the stream bed and crop out discontinuously through the veneer of weathered shale and sandstone debris on the slope. In places manganese oxide occurs in a thin, brown-weathering, pinkish limestone, partly as nodules and partly as a replacement of the limestone. At locality 3 nodules of manganese oxide occur in gray and red shale 8 ft 10 in. thick. They are most abundant in the upper part of the shale. An analysis of a chip sample of the upper 4 ft 2 in. of the shale showed a manganese content of 6.1 percent. It was estimated that the percentage of manganese in the lower 4 ft 8 in. locality 4 contains 10.1 percent manganese (see p. 73).

Southward from locality 3 the thickness of the manganiferous rocks increases slightly, and at locality 4, east of the graben, nodules of pyrolusite are abundant in most of the shale through a thickness of 10½ ft. A bed 5 in. thick of hard, pink and black, limy sandstone containing some manganese oxide is present near the middle of the manganiferous beds. A chip sample of the manganiferous zone at locality 4 contains 10.1 percent manganese (see p. 73).

East of locality 4 the shale contains abundant nodules of manganese oxide as far as the head of the gulch, but farther south the manganese content decreases and beyond locality 5 the shale is essentially barren.

A small part of the original deposit, separated by erosion from the main deposit, crops out in an area about 50 ft in diameter at locality 6.

At locality 7 on the west side of the main creek a shallow pit has exposed a bed of limy sandstone 1 ft thick containing manganese oxide. It is similar to the sandstone at the base of the section at locality 2. No manganese ore was observed in the associated shale. The beds cannot be traced along the side of the gulch, but the deposit is at about the same level as the deposit on the opposite wall of the gulch and appears to be a remnant of it. West of the westernmost fault manganiferous rocks crop out only in a small area near stream level south of locality 8. A pit in the bed of the wash near locality 8 has exposed the upper 4 ft of a limy sandstone bed which is in part strongly impregnated with manganese oxide. The manganese content of this bed was not determined by analysis, but it appears to be somewhat higher than that of similar ledges of manganiferous limy sandstone elsewhere on the claim. South of locality 8 this bed of sandstone contains manganese oxide along both sides of the creek for a distance of about 200 ft, beyond which the rocks are barren. No information is available concerning the northward extent of the manganese ore on the west side of the western fault. West of locality 2 these beds would be about 50 ft below the stream bed.

It is estimated that the manganiferous rock in the part of the deposit east of the gulch has an average manganese content of 7 or 8 percent. The area in which this ore is inferred to be present has a maximum width of about 300 ft and extends from the head of the gulch east of locality 4 to the north end of the deposit near locality 2. Within this area the thickness of the overburden of shale and sandstone probably does not exceed 25 ft except for the narrow belt in the graben block where it is 8 to 16 ft thicker. Little manganese ore is available except as nodules in shale. The nodules contain as much as 45 percent manganese, but the concentration of the nodules varies. In the richer parts of the deposit the nodules constitute 20 to 25 percent, by weight, of the rock. The nodules contain an average of less than 1.0 percent iron, about 0.2 percent sulfur, about 0.1 percent P_2O_5, and a trace of zinc.

A few thousand tons of manganiferous rock is probably present in the vicinity of locality 8, mostly west of the outcrop. Much of this tonnage probably lies too deep for recovery by strip mining. The estimate necessarily assumes a limited extent of ore of the type contained in the ledge that crops out at locality 8; nodular ore in shale is not present at the outcrop of the manganiferous beds west of the fault. The grade of this ore is not known, but the average manganese content is probably less than 20 percent.

Nodules of manganese oxide occur at approximately the same stratigraphic position as the Black Bird deposit at three localities along the fault zone about half a mile south of the Black Bird deposit. These deposits occupy only a few square feet of area adjacent to faults.

SALT WASH GROUP OF DEPOSITS

The manganese deposits in the valley of Salt Wash are in the cliffs that form the north side of the valley, ½ to 1 mile north of the wash, in the southern part of T. 22 S., R. 17 E., and the northeast corner of T. 23 S., R. 17 E. (locs. 3, 4, and 5, pl. 2). The road that turns south from the highway at Floy crosses Salt Wash near the eastern deposits, and branch roads to the deposits could readily be constructed. A rough road extending southward from the Black Bird claim provides direct access from the town of Green River to the western deposits of the group.

At several localities ore has been mined from small pits along the outcrop; Pardee (1921, pp. 203–204) states that there was some production in 1916–18. In 1940 no mining was in progress, but there had been recent efforts to screen and collect detrital ore from the slopes below the deposits. A few tons of ore had been gathered into small piles, but as far as is known no shipments were made.

The cliffs rise above Salt Wash in a series of steps to a height of about 200 ft near the eastern deposits and about 400 ft near the western deposits. The eastern deposits are about 100 ft above the bed of Salt Wash, but the deposits toward the west are somewhat higher. The manganese occurs principally in resistant strata that crop out on the rims of prominent dissected benches.

The lowest prominent sandstone of the Salt Wash sandstone member of the Morrison formation forms the rim of the main escarpment. The basal beds of the Salt Wash sandstone member above the manganese deposits in the eastern half of the cliffs are varicolored thin-bedded shale, sandstone, and sandy limestone, but a massive bed of gypsum is present at the base of the member westward from the northern part of sec. 33, T. 22 S., R. 17 E. The underlying Summerville formation, which contains the manganese deposits, consists of thin-bedded, reddish-brown silty sandstone and siltstone with occasional beds of limestone and some irregular masses of varicolored chert. The Summerville formation is about 75 ft thick in the NE¼ sec. 33, T. 22 S., R. 17 E. Manganese occurs in different parts of the formation. The deposits in the eastern half of the cliffs are principally in sandy limestone 16 to 20 ft below the top of the formation, but the sandstone and siltstone for as much as 30 ft below the limestone contain nodules and veinlets of manganese oxide. In the westernmost group of deposits the manganese is present as nodules and veinlets in a zone, locally as much as 24 ft thick, beginning 5 ft above the base of the formation.

The Summerville formation dips 3°–5° N. except locally where the dip steepens along faults. Small faults are associated with the Salt Wash group of manganese deposits at two localities. At the west end of the Tenmile graben one of the ore bodies is offset about 20 ft by the southern fault of the graben. Another small fault striking about N. 30° W. and dipping 45° SW. displaces the manganiferous rocks about 30 ft in the western group of deposits.

The western deposits (loc. 3, pl. 2) included in the Big Blanket claims crop out in an embayment in the cliffs in the northern part of sec. 30, T. 22 S., R. 17 E. The deposits are discontinuous and irregularly distributed in an area of about a quarter of a square mile. At the north, between the forks of the wash, manganese oxides are present along the outcrop for about 1,500 ft. The manganese occurs in sandy limestone and sandstone 25 ft above the base of the Summerville formation and just below a fairly persistent zone of brown, black, and red chert. The manganiferous zone is 2 ft thick, and the manganese oxides are in scattered nodules and thin lenses estimated to have an average aggregate thickness of about half an inch. On the east side of the wash some manganese oxide float occurs at the same stratigraphic position east of the fault, but the quantity of manganese in the rocks is believed to be small. West of the fault manganese oxides occur along the base of a cliff for about 2,000 ft and extend nearly to the sharp bend in the cliffs at the east side of the embayment. At the northernmost exposures of the deposit nodules of manganese oxide are scattered through 2 ft of red sandstone. Five hundred feet to the south nodules, veinlets, and lenses of the oxide are scattered through red sandstone and shale 24 ft thick, but the manganese oxide probably constitutes less than 5 percent of the rock. The thick zone of manganiferous rock extends only about 600 ft, although the upper part of the zone containing scattered nodules extends southward nearly to the sharp bend in the cliff. The lower part of the manganiferous zone contains a small amount of manganese in a bed of chert in a pink limestone which crops out at the base of the main cliff just east of the reentrant. The quantity of manganese in this group of deposits is small, and probably little of it is recoverable.

Eastward along the cliffs for about 1½ miles the rocks are practically barren of manganese. At a few places in the lower part of the Summerville formation nodules occur sparsely in sandstone and other traces of manganese oxide are present in irregular masses of varicolored chert a few feet in diameter.

Still farther east along the cliffs, between the northeastern part of sec. 32 and the north-central part of sec. 33, T. 22 S., R. 17 E., a small amount of manganese oxide occurs sporadically in light-brown to black chert or pink limy sandstone underlying a massive bed of gypsum that is probably in the upper part of the Summerville formation but may be part of the basal gypsum bed of the Morrison formation. A very few nodules of manganese oxide are present in the red sandstone underlying the cherty bed. At the eastern margin of the gypsum bed, in the north-central part of sec. 33, the basal part contains small nodules and minute veinlets of manganese oxide, and at one place 5 ft of manganiferous gypsum has been explored by a shallow pit.

The most important group of deposits along the north side of Salt Wash extends along the cliffs for 1½ miles from the north-central part of sec. 33 to the southeastern part of sec. 34, T. 22 S., R. 17 E. (loc. 4, pl. 2). Ore has been mined from several small open-cuts. The principal workings are in the eastern and extreme western parts of the deposits. The ore has been obtained from a pink to gray, light-brown-weathering, sandy limestone as much as 6 ft thick containing manganese oxide in lenses parallel to the bedding. Most of the lenses are 1 to 6 in. thick and vary from ovate bodies a few inches long to thin lenses 100 ft or more in length. At some places the limestone bed contains two or more lenses of manganese oxide, and at other places the limestone is barren. In the western half of these deposits the limestone contains little manganese oxide except at the extreme west end, where there has been some mining. Locally, at the west end of the deposits, nodules and veins of chert and celestite similar in shape and size to the bodies of manganese oxide found elsewhere are present in the limestone, and celestite veins 1 to 2 in. thick are parallel to the bedding in the sandstone underlying the limestone. Nearly everywhere along the outcrop the sandstone below the manganiferous limestone contains small nodules and, in places, veinlets of manganese oxide to a depth of as much as 30 ft. Most of the nodules contain considerable silica. It is estimated that the nodules nowhere constitute as much as 5 percent of the rock, and they are not considered recoverable. Detrital deposits of nodules and fragments of manganese oxide derived from erosion of the sandstone and the overlying limestone have accumulated on the slopes below the deposits and probably contributed some of the ore shipped from this locality. Prior to the field work there had been attempts to recover more of this detrital ore by hand picking and screening, but the quantity of detrital ore on the slopes in 1940 was very small. The thickest blanket-vein deposits exposed in the limestone have been mined, and in general mining has been carried on where the overburden was thinnest. A small tonnage of ore might be recovered by open-cut methods. By hand picking, it might be possible to obtain ore containing 25 to 40 percent manganese.

At the east end of the Salt Wash group of deposits manganese ore is present in an area about 1,000 ft in diameter located in the NE¼ sec. 2, T. 23 S., R. 17 E. (loc. 5, pl. 2). A small amount of ore has been obtained from open-cuts in these deposits in former years. The manganese occurs discontinuously along the outcrop as ovate bodies or thin blanket veins in a bed of sandy limestone and limy sandstone

2 to 3 ft thick and about 16 ft below the top of the Summerville formation. The ore pockets are elongate parallel to the bedding and range in thickness from a fraction of an inch to as much as 4 in. They consist of small, nearly circular bodies or thin sheets tens of feet in length. At places the limy bed is barren of manganese, but at other places the pockets of ore are closely spaced. Locally, cavities in the limestone 2 in. high and 1½ ft long, elongate parallel to the bedding, are lined with powdery to crystalline manganese oxide. These cavities have about the same size and shape as many of the ore pockets and may have resulted from the leaching of ore pockets. Below the limestone bed the red sandstone to a depth of as much as 13 ft locally contains scattered, irregularly shaped nodules and cross-cutting nodular veinlets of manganese oxide, but the concentration is too low for the sandstone to be a minable source of manganese. A few tons of ore containing 25 to 40 percent manganese could be obtained from the east end of the Salt Wash group of deposits.

The manganese in the Salt Wash group of deposits is chiefly in the form of pyrolusite. The ore in the limestone bed contains considerable unreplaced bedrock and possibly some secondary calcite. Most of the ore contains sand grains and can be expected to assay moderately high in silica.

DEPOSITS IN CANYON OF DRY LAKE WASH

Four small deposits of manganese oxide that crop out in the canyon walls of the south fork of Dry Lake Wash (loc. 6, pl. 2) are probably the deposits previously described by Pardee (1921, p. 205) as the Sunrise deposits. They are in sec. 24, T. 23 S., R. 15 E., and sec. 18, T. 23 S., R. 16 E., west of the Green River in Emery County, and about 13 miles south of the town of Green River. The deposits are in the lower part of the steep canyon walls of the narrow gorge, 100 to 150 ft deep, occupied by the south fork of Dry Lake Wash. A dirt road that connects with the Green River-Hanksville road about 3 miles south of Green River follows the rim around the head of the canyon and passes within a mile of the deposits. A few tons of ore have been mined from small shallow pits, and doubtless a small additional tonnage of ore has been recovered from the debris in the slopes below the deposits. No work was in progress at the deposits in 1940.

The rim of the canyon is formed by the lowest thick ledge of sandstone of the Morrison formation and is underlain by 20 ft of variegated shale and interbedded limestone considered to be the basal beds of the Morrison. The walls of the canyon are formed mainly by the thin-bedded reddish-brown sandstone and siltstone of the Summerville formation, which is 105 ft thick. At four places the manganese oxide, chiefly pyrolusite, occurs a few feet above the base of the Summerville. The underlying Curtis formation, consisting of brownish-gray shaly sandstone and some gray slaty sandstone, crops out in the lower part of the canyon walls below the eastern deposit. The strata dip less than 2° N.

At the northeasternmost deposit, located near the west line of sec. 18, T. 23 S., R. 16 E., on the southeast side of the canyon, the manganese oxide occurs in small, widely spaced nodules and as impregnations of thin lenses of sandy shale, sandstone, and sandy limestone which do not exceed an inch in thickness or a few inches in length. Manganese was observed 5 ft above the base of the Summerville formation, and it occurs irregularly through beds 13 ft thick. Most of the manganese oxide is in the lower 2 ft of the manganiferous zone, which can be traced along the outcrop for about 300 ft, but is nowhere sufficiently concentrated to be classed as ore. One shallow pit has been opened in the zone.

Half a mile to the southwest another small manganese deposit on the southeast side of the canyon is 1½ ft thick and the manganese oxide, in small nodules and thin lenses of impregnated and partly replaced shaly sandstone and sandy shale, is estimated to constitute about 10 percent of the zone. The deposit is on a spur 60 ft long and has a maximum width of only 30 ft.

A third deposit, located about an eighth of a mile farther upstream on the southeast side of the canyon, also consists of small lenses and nodules of manganese oxide in reddish-brown limy sandstone and sandy shale in a zone 3 ft thick. In the upper 6 in. of the zone the manganese-rich bodies are widely separated; in the lower 2½ ft they are estimated to compose about 40 percent of the rock but extend only 35 ft along the outcrop. Several tons of ore apparently have been shipped from a trench extending for the length of the outcrop. A small tonnage of siliceous ore remains and could be obtained from an open-cut, but the average manganese content is probably less than 20 percent.

The westernmost deposit, included in the Red Cloud claim of C. R. Hanks and J. G. Adams, of Green River, is about an eighth of a mile farther upstream and is located on the north side of the canyon near the canyon floor. As in the other deposits, the manganese oxide occurs in nodules and as impregnations of sandstone and sandy shale. The manganiferous beds are 6 ft thick and can be traced for about 200 ft along the north side of the creek, but on the south side of the creek, less than 200 ft distant, only traces of manganese oxide could be found. Some manganiferous rock has been removed from a shallow pit about 25 ft in diameter, but the rock remaining in place seems to be too low in grade to be ore. Small fragments of manganese oxide, weathered from the deposit and concentrated on the surface in an area about 75 ft in diameter, constitute a very small source of relatively high grade ore.

DEPOSITS NEAR COLORADO FUEL & IRON CO. MINE

The deposits near the Colorado Fuel & Iron Co. mine are west of White Wash along the main escarpment in the north-central part of T. 23 S., R. 17 E. (loc. 7, pl. 2). These deposits, irregularly distributed through about 2 sq mi, have supplied most of the ore produced in the Little Grand district. Pardee (1921, pp. 192–193) reports the early history of the deposits as follows:

> The deposits were located prior to 1901 and * * * worked * * * in that year and in 1903, 1904, and 1906. * * * Early in 1917 mining was begun * * * which continued * * * until some time in the second half of 1918. * * * During the later period of mining activity several thousand tons of manganese ore were produced * * *.

No work was in progress on these deposits in the summer of 1940, and apparently the only recent workings were a few trenches near the eastern limit of the deposits.

The road that branches south from the main highway at Floy provides access to the deposits; it leads to the main workings at the Colorado Fuel & Iron Co. mine, and branch roads extend to several other deposits nearby. The distance from Floy to the main workings is about 10 miles. The road has steep gradients at a few places but, except in very wet weather, is reasonably satisfactory for truck haulage.

A large part of the ore mined from these deposits was obtained by gathering loose fragments of residual ore from the surface and by screening fragments from the soil. However, ore was also obtained from manganese-rich ledges mined in shallow pits along the outcrop.

The main workings of the Colorado Fuel & Iron Co. mine are on a bench that has a maximum width of about a mile from its rim at the south to the base of the cliff at the north. Much of the bench is a plain sloping gently northward and interrupted by only a few shallow swales or low knobs. Toward the northwest the smooth surface gives way to badlands in the headwaters of Hogan Gulch. Toward the east the bench is absent except for remnants on two flat-topped spurs projecting southward from the cliffs, and only a narrow shelf along the cliffs connects the remnants of the bench. The south edge of the bench is the rim of an escarpment 100 ft or more high. North of the bench is a row of sandstone knobs that merge eastward into a cliff and form the southern margin of a dissected upland surface that slopes northward to the valley of Salt Wash; the cliffs rise as much as 100 ft above the level of the bench east of the Colorado Fuel & Iron Co. mine. The manganese deposits west of the head of Hogan Gulch are at the edge of this upland surface and are near the summit of southward-facing cliffs.

The rocks exposed near the Colorado Fuel & Iron Co. mine belong to the Summerville and Morrison formations. The Summerville consists principally of red sandstone, siltstone, and some shale containing nodular to lenticular masses of red, yellow, and black chert as much as 3 ft thick. A rather persistent bed of limestone, weathering brown to greenish brown, 10 to 24 ft below the top of the formation forms the broad bench and is the host rock for most of the manganese oxide in the deposits. The limestone is sandy, fine-grained, and gray, pink, or purplish red on fresh surfaces. The average thickness of this limestone is 2 to 3 ft, but at many places it is 1 ft or less in thickness and locally it is absent; east of the Colorado Fuel & Iron Co. mine it is as much as 6 ft thick. West of the head of Hogan Gulch, manganese oxide occurs also in 3 ft of red sandy shale and siltstone overlying the limestone, and traces of manganese oxide are present as veinlets and thin lenses in the uppermost sandy shale beds of the Summerville about 20 ft above the limestone. Generally, however, the limestone is the highest bed in the Summerville containing manganese.

One mile east of the Colorado Fuel & Iron Co. mine the Summerville formation is 152 ft thick and rests upon the Entrada sandstone. Toward the west, beneath the outer part of the main bench, interbedded brown, red, and gray sandstone, shaly sandstone, and sandy shale at the base of the Summerville are regarded as the easternmost recognizable beds of the Curtis formation, which grades eastward into the lower part of the Summerville. The upper limit of the Summerville is not clearly defined and was somewhat arbitrarily selected at the base of platy greenish-gray shaly sandstone and sandy shale 10 to 24 ft above the rather persistent manganiferous limestone in the Summerville.

The Colorado Fuel & Iron Co. mine is located approximately on the axis of a low northwestward-plunging anticlinal nose (McKnight, 1941, pl. 3). In the vicinity of the mine the average dip of the flanks is 3° or less, and the northward plunge of the axis is less than 1°.

Manganese ore occurs in this group of deposits chiefly as pyrolusite in the form of (1) residual nodules concentrated on the surface of the bench by selective erosion, (2) nodules, lenses, and thin blanket veins in the rather persistent limestone bed near the top of the Summerville formation, and (3) scattered nodules and veinlets in the sandstone underlying the limestone.

The residual ore on the main bench at the Colorado Fuel & Iron Co. mine, on the small bench half a mile to the east, and on a similar bench west of Hogan Gulch in the NW¼ sec. 16, T. 23 S., R. 17 E., was the source of much of the manganese ore obtained during former mining activities at these deposits. Twenty to one hundred pounds of residual ore to the square yard was recovered at that time (Pardee, 1921, p. 195). Although small fragments of manganese oxide remain on the surface of the benches it appears that the bulk of the residual ore has been removed and that the fragments remaining on the surface and in the soil cannot be considered an important source of manganese ore. The nodules and veinlets scattered through the sandstone underlying the persistent limestone likewise cannot be considered an important source of manganese ore as they constitute a very small percentage of the rock. The veinlets commonly contain nearly pure manganese oxide but are at most only a few inches wide and have a maximum observed length of less than 10 ft. The veinlets are in the rocks immediately underlying the limestone but are not abundant. Nodules of manganese oxide in the sandstone are generally less than 2 in. in diameter and are high in silica. They are most abundant immediately below the limestone but are present in decreasing abundance to a maximum observed depth of 30 ft below the limestone; at places the sandstone beneath the limestone appears to be barren of manganese, and where the limestone is absent the sandstone rarely contains nodules of the manganese oxide. Near the southern tip of the bench and in the head of Hogan Gulch manganese oxide occurs in small isolated deposits in red limy sandstone (fig. 6) and varicolored chert 40 to 50 ft below the main limestone bed. A few tons of ore have been removed from open pits on these deposits. No recoverable

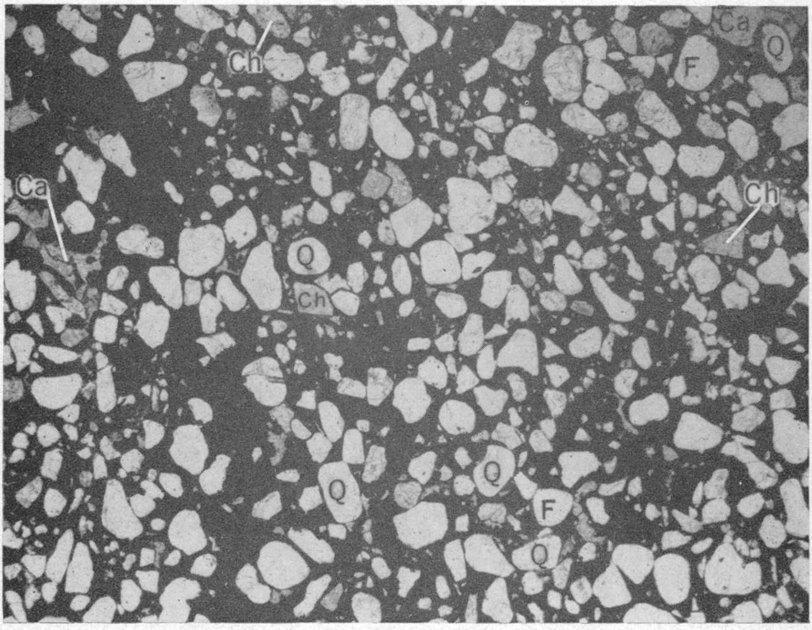

FIGURE 6.—Thin section of manganiferous sandstone from the Summerville formation, southeastern Utah. Black manganese oxide forms the cement between rounded to angular grains of quartz (Q), feldspar (F), and chert (Ch) and appears to have replaced the original lime cement (Ca), only remnants of which are preserved. ×22.

ore is considered to remain in any of them with the exception of one deposit in the head of Hogan Gulch which contains a few tons of ore similar in quality to the ore in the limestone bed.

The manganese ore in the nodules, lenses, and thin blanket veins in the limestone bed near the top of the Summerville formation was mined at open-cuts along the outcrop during earlier periods of mining activity and was the source of a substantial part of the production. Old workings are numerous along the north side of Hogan Gulch in the southern part of sec. 9, west of Hogan Gulch in the NE¼ sec. 17, on the southern tip of the bench in the SW¼ sec. 16, on the edge of the main bench in the east-central part of sec. 16, and on the edge of the small bench half a mile east of the main bench and near the head of White Wash in the SW¼ sec. 11. The unmined parts of these deposits in limestone include essentially all the manganese ore that could be obtained by additional mining activity. The manganese content of the limestone bed underlying the main bench has evidently been tested by numerous prospect pits which are now partly filled; judging from the excavated material, the bed contains only small quantities of manganese oxide. The distribution of the manganese oxide in the limestone is extremely irregular. At places the limestone is barren or essentially barren of manganese oxide, and at other places the entire bed is blackened with oxide. In general the ore is confined to the lower part of the limestone. It occurs in part as irregularly shaped nodules of nearly pure manganese oxide as much as 18 in. in diameter; as discontinuous overlapping lenses of oxide, a fraction of an inch to several inches thick and as much as 100 ft or more in length, grading laterally and vertically into limestone; and in part as speckled ore consisting of innumerable small masses of oxide in limestone or innumerable small masses of unreplaced limestone in oxide (fig. 7), all with gradational boundaries and distributed more or less uniformly through the limestone. The average thickness of the more manganiferous portions of the limestone is 1½ to 2 ft, but only about 5 in. of this thickness could be considered ore. High-grade ore in the nodules and lenses contains 40 to 50 percent manganese, but little ore of that grade could be recovered without beneficiation. Most of the ore contains considerable unreplaced limestone, coarsely crystalline calcite, and some barite.

The deposits have been mined where the blanket veins were thickest and where the overburden along the outcrop was thinnest. Further mining will in general involve thinner veins and greater overburden. Within an average width of about 50 ft from the outcrop and under an overburden of 20 ft or less, parts of the blanket veins 3 in. to 1 ft or more thick probably contain several thousand tons of manganese ore. Probably not more than one-quarter of the ore as recovered would contain over 30 percent manganese, and the remainder would

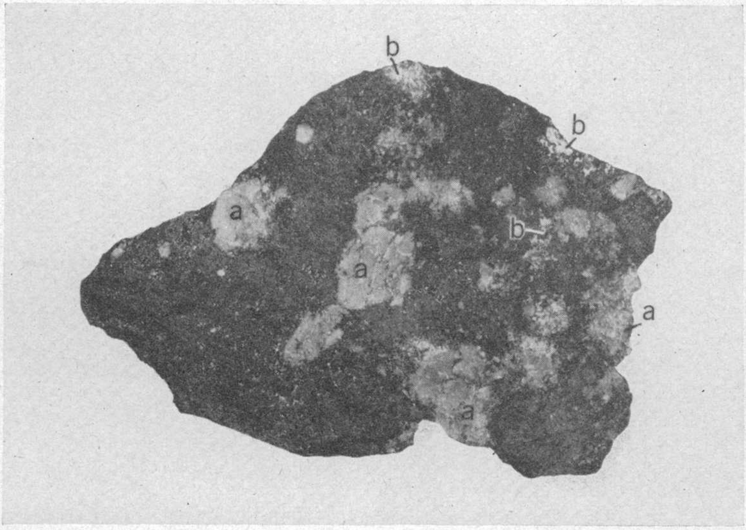

FIGURE 7.—Manganese ore from a blanket vein in the Summerville formation east of the Colorado Fuel & Iron Co. workings, Little Grand district, Utah. Dark-gray to black pyrolusite contains inclusions of unreplaced pink limestone (a) and crystals of barite (b). Natural size.

contain 15 to 30 percent manganese. A much larger tonnage of manganiferous rock containing 15 percent or less manganese is present in thin blanket veins that are not likely to be a source of recoverable manganese.

DEPOSITS NORTHEAST OF HEAD OF WHITE WASH

Between the southern part of sec. 11 and the southeast corner of sec. 14, T. 23 S., R. 17 E., for a distance of more than a mile along the outcrop, the rocks are essentially barren of manganese oxide. Farther southeast, for a distance of about a mile in secs. 13, 14, and 24, T. 23 S., R. 17 E., numerous small deposits are irregularly distributed along the cliffs northeast of the head of White Wash (loc. 8, pl. 2). The sketch map (fig. 8) shows the erratic distribution of the many small manganese deposits in this group.

Narrow strip pits along the outcrop are reported (Pardee, 1921, pp. 198–199) to have yielded several carloads of ore prior to May 1918. The deposits are reached by a rough road, sandy in part, that branches from the Floy road on the south bank of Salt Wash.

The cliffs in this vicinity are formed by the Summerville formation and, like the cliffs farther west, rise 150 to 200 ft to the rim of the upland surface that lies to the north.

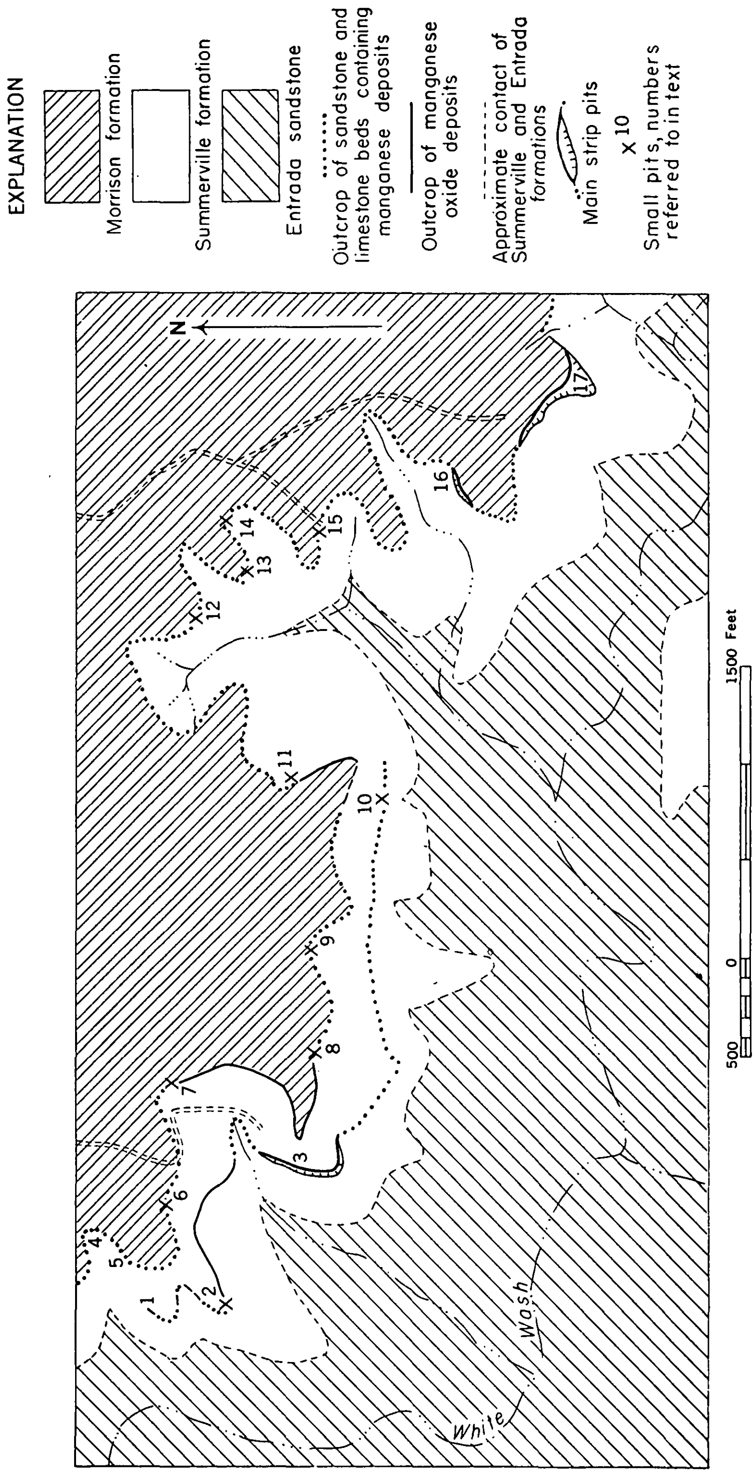

FIGURE 8.—Sketch map showing the distribution of manganese deposits along the cliffs northeast of the head of White Wash in secs. 13, 14, and 24, T. 23 S., R. 17 E., Little Grand district, Utah.

A section of the Summerville formation follows:

Section of Summerville formation measured in southwestern part of sec. 13, T. 23 S., R. 17 E. (loc. 3, fig. 8)

	Ft	in.
Morrison formation: Variegated shale with interbedded thin beds of gray limy sandstone and brownish limestone at base	20±	0
Summerville formation:		
1. Interbedded red sandstone, red shale, and pink sandy limestone containing scattered nodules and veinlets of manganese oxide; grades laterally into pink sandy limestone 6 to 12 ft thick; forms benches	5	0
2. Nodular-weathering, brownish-red, thin, evenly bedded, silty sandstone containing occasional nodules and veins of manganese oxide	70	0
3. Pink sandy limestone	1	0
4. Red sandy shale, locally absent		6
5. Manganese oxide and some red sandy shale, discontinuous		3±
6. Black shale, manganiferous		2
7. Red shaly sandstone		3
8. Black manganiferous sandstone, locally rich in manganese oxide; forms rim of bench		10
9. Thin-bedded red sandstone and siltstone	55	0
Approximate total, Summerville formation	133	0
Entrada sandstone.		

The manganese deposits are near the axis of a low, northwestward-plunging anticlinal nose, and the rocks have an average dip of about 2° NE.

This group of manganese oxide deposits is entirely in the Summerville formation, principally in the bench-forming limestone and sandstone at the top of the formation (units 1 and 2) and in a bench-forming sandstone near the middle of the formation (units 5–8). One of the two main deposits in this group and the largest deposit in the sandstone near the middle of the formation is that at locality 3 (fig. 8), where the ledge crops out around the point of a small promontory projecting from the cliffs. The manganese deposit here can be traced for about 600 ft along the outcrop. A narrow open pit has been dug along the outcrop, and some ore has been recovered. The thickness of the ore-bearing beds ranges from a maximum of 1½ ft on the west side of the spur to a fraction of an inch at the ends of the deposit. The main ledge, which contains the bulk of the manganese oxide, is 10 in. thick on the west side of the spur but is only about 5 in. thick on the point of the spur. Analysis of a chip sample of the 1½ ft of manganiferous beds at the thickest part of the deposit showed a manganese content of 15.4 percent. A sample of the main ledge forming the lower 10 in. of the manganiferous beds, collected only a few feet from the other sample, contained 41.9 percent manganese. Microscopic examination of specimens of the richer ore from the ledge in the lower part of the zone showed that the manganese oxide is pyrolusite which has replaced the cement and—to a lesser extent—the quartz, feldspar, and chert grains in the sandstone (fig. 9). Considerable iron oxide is intricately intergrown with the pyrolusite. By removing an overburden as much as 20 ft thick, a few thousand tons of ore containing 30 percent manganese possibly could be recovered from this deposit.

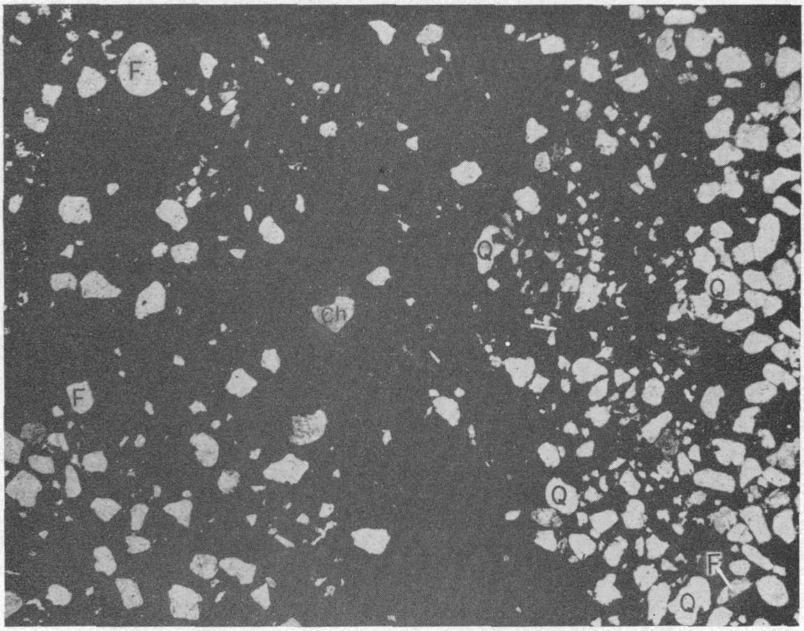

FIGURE 9.—Thin section of manganese ore from a deposit in the Summerville formation north of the head of White Wash, Little Grand district, Utah. Finely crystalline manganese oxide (black) replaces sandstone. Remaining sand grains consist of quartz (*Q*), feldspar (*F*), and chert (*Ch*). ×22.

Northwest of this deposit manganese oxide occurs sporadically in the same or approximately the same strata as far as locality 1 (fig. 8), but the aggregate average thickness of the lenses and nodules is 3 in. or less and none of these deposits is believed to contain recoverable ore. A small prospect pit has been dug at locality 2, where the average thickness of the ore is about 2 in. Farther northwest, beyond the area included in figure 8 but in the eastern part of sec. 14, similar small deposits at approximately the same stratigraphic position occur at two localities.

East of locality 3 and below locality 10 manganese oxide partly replaces sandstone for a distance of 160 ft along the outcrop. The sandstone is 45 ft above the base of the Summerville formation. The manganese oxide is in discontinuous overlapping lenses in zones approximately 2 ft apart but with an aggregate thickness of only about 3 in. This deposit has been explored by small trenches along the outcrop.

The other main deposit in this group is at locality 17 (fig. 8), and it is in the manganiferous limestone at the top of the Summerville. The deposit crops out at the edge of a bench that forms a small promontory projecting southward from the cliffs. An open-cut about 600 ft long and 10 to 50 ft wide follows the edge of the bench and exposes the blanket vein. The maximum thickness of the blanket vein is about 15 in., and the average thickness is about 6 in. The ore varies in quality from nearly pure pyrolusite to sparsely disseminated manganese oxide in pink, coarsely crystalline limestone. An analysis of ore from this deposit, which was said to represent a 30-ton sample, showed 51.3 percent manganese, 4.2 percent silica, and 0.3 percent iron (Pardee, 1921, p. 198). A small amount of barite is associated with the manganese. For a distance of 100 ft or more from the old workings the overburden does not exceed 10 ft. Probably the deposit extends for 100 ft or more under cover; on that assumption it contains possibly a few thousand tons of 40-percent ore.

East of locality 17 the limestone bed is essentially barren of manganese oxide for about a mile, but toward the northwest the limestone and the sandstone immediately underlying it contain small deposits of manganese oxide sporadically distributed across the area shown in figure 8. Between localities 16 and 17 the limestone bed contains very little manganese oxide. At locality 16 a blanket vein in the limestone, exposed in an open pit 200 ft long and 20 ft wide, is similar in thickness and quality to the deposit at locality 17. Little manganese oxide is present north of locality 16 as far as locality 15, where an open-cut 75 ft long and a maximum of 20 ft wide has yielded ore from a blanket vein 3 in. thick in red sandstone. At localities 13 and 14 the upper 6 ft of sandstone in the Summerville formation contains scattered nodules, lenses, and veinlets of manganese oxide estimated to compose less than 10 percent of the volume of the rock for a distance of about 20 ft along the outcrop. At locality 12, six ft of sandstone 4 to 10 ft below the thin, sandy, brown-weathering limestone at the top of the formation has been prospected by an open-cut 50 ft long; the sandstone contains lenses and nodules of manganese oxide estimated to comprise as much as 25 percent of the volume of the rock, and some of the nodules consist of nearly pure pyrolusite.

Between localities 10 and 11 manganese oxide occurs in sandstone 15 ft below the limestone at the top of the formation, but the sandstone contains significant amounts of ore only at locality 11, where open pits have been dug and lenses and nodules of oxide in 6 ft of sandstone are estimated to comprise about 10 percent of the rock for a distance of 50 ft. At locality 9 a small amount of manganese oxide occurs as lenses and as impregnations in sandstone about 5 ft below the base of the brown-weathering pink limestone at the top of the formation for about 75 ft along the outcrop, but this deposit probably contains no recoverable ore. At locality 7 an open-cut 75 to 100 ft long exposes irregularly shaped nodules, thin lenses, and veins of high-grade manganese oxide in the limestone at the top of the formation and in the immediately underlying sandstone. Between localities 7 and 8 a few scattered nodules and lenses of oxide occur at this stratigraphic position. West of locality 7 and extending to locality 6 the upper 8 ft of the sandstone underlying the uppermost limestone bed contains a few nodules of manganese oxide, but the nodules comprise only 1 or 2 percent of the rock and are not considered to be recoverable ore. At localities 5 and 6 nodules and lenses of manganese oxide are scattered through 8 to 10 ft of sandstone at the top of the Summerville formation and have been prospected at both localities, but practically none of the manganese is considered to be recoverable.

Locally, in this group of deposits, scattered nodules of manganese oxide were observed through a 30-ft thickness of sandstone at the top of the Summerville formation. Also, veins containing nearly pure manganese oxide as much as 30 ft long and 6 in. thick cut the same series of sandstone beds at several localities. At places the veins are associated with clusters of nodules and branching veinlets in the sandstone. The deposit at locality 4 is in a crosscutting fissure vein 30 ft long and about 6 in. wide. The northernmost deposit in sec. 14, T. 23 S., R. 17 E. (pl. 2), is in a fissure vein about 4 ft long and 6 in. wide.

Possibly several thousand tons of ore containing upwards of 30 percent manganese could be obtained from this group of deposits.

For about a mile south of the deposits the rocks exposed in the cliffs do not contain deposits of manganese oxide.

DEPOSITS AT DUMA POINT

Another group of small deposits is on a prominent spur of the cliffs known as Duma Point, in secs. 24, 25, and 26, T. 23 S., R. 17 E., and in secs. 29 and 30, T. 23 S., R. 18 E. (loc. 9, pl. 2). No mining was in progress in August 1940. Ore containing about 50 percent manganese has been shipped from some of the claims (Pardee, 1921, pp. 199–200), but production figures are not available. This ore was mined principally from a few short adits and from open-cuts along the outcrop that involved the removal of 10 ft or less of overburden. Duma Point can be reached by a road that branches from the Floy road 4 miles south of Floy; the distance from Floy to the deposits is about 13 miles, of which the last 9 miles is rough and unimproved.

Duma Point is a prominent southwestward-projecting spur of an escarpment similar to the one at the Colorado Fuel & Iron Co. mine.

At Duma Point, however, there are two prominent lower benches in addition to the bench forming the summit of the spur. The manganese deposits occur in the Summerville formation, which forms the escarpment. The basal beds of the Morrison formation cap the northeastern part of the upper bench, and the Entrada sandstone forms the dissected lowland at the foot of the escarpment. The deposits are northeast of the axis of the same low, northwestward-plunging anticlinal nose that extends through the Colorado Fuel & Iron Co. mine, and the rocks dip about 3° N. and NE.

Duma Point, about 2 miles long, is deeply dissected, and the intricate outcrop provides an unusual opportunity to study, not only the extent of individual deposits, but also their areal distribution (pl. 3). The map shows about 60 deposits but does not attempt to show innumerable minor concentrations of manganese oxide, mostly in the form of small nodules, widely scattered through the sandstone.

These manganese deposits occur at several stratigraphic positions in the Summerville formation, which here is 125 to 130 ft thick, but most of them are at two particular stratigraphic positions. The upper group of deposits, about 18 ft below the top of the formation, is in a thin sandy limestone and in the immediately underlying sandstone along the rim of a bench. This group of deposits is approximately at the same stratigraphic position as the main deposits at the Colorado Fuel & Iron Co. mine and elsewhere in the district. The second group is associated with a thin sandstone that is 58 ft below the upper bench and forms the rim of the main bench that is prominently developed nearly everywhere around Duma Point. This group of deposits occurs, not only in the ledge-forming sandstone of the main bench, but also in underlying and overlying silty sandstone a few feet thick. Scattered nodules of manganese oxide are common in silty sandstone in the upper part of the formation. Manganese oxide is less abundant in the beds below the main bench, but a few deposits are in a sandstone forming the rim of a lower bench locally prominent at the southwest extremity of Duma Point and 30 ft above the base of the Summerville. A few deposits are present, also, at other stratigraphic positions in the part of the formation below the main bench.

The individual deposits, located with reference to the locality numbers shown on plate 3, are described in sequence around Duma Point.

Locality 1.—A small amount of manganese oxide impregnates and replaces red sandstone for about 20 ft along the outcrop and about 18 ft below the top of the Summerville formation at the edge of the upper bench. The deposit has been developed by a small open pit. North of locality 1 the cliffs are barren of manganese oxide for about a mile.

Locality 2.—On the point of a small spur red-brown limy sandstone 8 ft thick at approximately the same horizon as at locality 1 forms the rim of the upper bench and contains veinlets of manganese oxide half an inch to 2 inches wide, as well as small nodules and disseminated manganese oxide. The manganese oxide is estimated to comprise less than 5 percent of the rock. An open-cut at this locality reveals a lens that may contain slightly more manganese.

About 30 ft below the upper bench on the west side of the spur at locality 2 a prospect pit exposes a group of small veins and nodules of manganese oxide in sandstone. The deposit has a known vertical extent of only about 3 ft, and the manganese oxide is abundant for a width of only 2 ft.

Locality 3.—At the edge of the upper bench a prospect pit about 20 ft long exposes a lens of manganese oxide 4 in. thick. Three to five feet below the lens the sandstone contains irregularly distributed nodules of manganese oxide for a distance of about 50 ft along the outcrop.

Locality 4.—In the head of the reentrant between localities 3 and 4 the manganiferous beds contain only a few nodules of manganese oxide, but at locality 4 the oxide occurs in thin blanket veins as much as 3 in. thick and 10 ft long. For about 50 ft along the outcrop sandstone is impregnated with manganese oxide. A short adit has been driven near the north end of the deposit.

On the ridge spur north of locality 4 are four similar small deposits at the same stratigraphic position, but none of these has a linear extent along the outcrop greater than 50 ft and the lenses of manganese oxide are only an inch or two thick.

Locality 5.—For about 150 ft along the outcrop at the edge of the upper bench thin lenses and nodules of manganese oxide comprise an estimated 5 percent of a 4-ft thickness of limy red sandstone.

Locality 6.—At the edge of the upper bench nodules and lenses of manganese oxide have an average aggregate thickness of 1 to 2 in. in 4 ft of red sandstone and extend for 300 ft along the outcrop.

Locality 7.—Around the head of the reentrant between localities 6 and 7 the rocks are essentially barren of manganese oxide. At the point of the cliff at the edge of the upper bench (loc. 7) manganese oxide occurs as veins in red sandstone in a crosscutting mass 8 ft in diameter and about 15 ft long vertically; the rock is estimated to contain less than 20 percent manganese.

Locality 8.—From locality 7 to locality 8 the manganiferous zone at the edge of the upper bench contains only a few nodules and a few thin lenses of manganese oxide. At locality 8 the nodules and lenses of manganese oxide are slightly more abundant for about 100 ft on both sides of the end of the spur, but they do not constitute recoverable ore.

Localities 9 and 10.—The sandstone forming the main bench, 58 ft below the manganiferous beds at the edge of the upper bench and about 53 ft above the base of the Summerville formation, includes several small masses of sandstone that contains scattered nodules or that is impregnated with manganese oxide.

Locality 11.—The rocks at the edge of the upper bench are essentially barren of manganese oxide for about half a mile between localities 8 and 11. At locality 11 a deposit of manganese oxide has been mined in a shallow open-cut extending for 200 ft along the outcrop. The deposit is in sandy limestone, and the manganese oxide occurs as a lens about 6 in. thick. The manganese oxide is intergrown with crystals of calcite, and the ore on the dump ranges from nearly pure manganese oxide to nearly pure calcite. The overburden does not exceed 20 ft for several hundred feet back from the edge of the bench. The ore consists of fine pyrolusite and a little barite. A carload of ore from this deposit and probably from neighboring deposits to the south as well is reported to have contained about 50 percent manganese, 0.336 percent iron, 0.851 percent copper, and 0.382 percent sulfur (Pardee, 1921, p. 200).

Locality 12.—The limestone and sandstone of the manganiferous zone at the edge of the upper bench are mostly barren between localities 11 and 12 but contain a very few nodules or groups of nodules of manganese oxide. Around the head of a small gully at locality 12 thin lenses of the oxide occur in the limestone and the upper 1 to 2 ft of the underlying sandstone. Most of the ore has apparently been removed in several small shallow open pits. The ore was about 2½ in. thick and contained abundant calcite.

Locality 13.—The limestone bed about 5 in. thick is barren of manganese oxide along the outcrop from locality 12 to locality 13. At locality 13, in an open pit 40 ft long, limy sandstone contains some scattered nodules of manganese oxide. On two spurs west of locality 13 the limestone bed 6 in. thick contains lenticular bodies of manganese oxide having an average thickness of about 1 in. in very small areas.

Locality 14.—At the southwest tip of the upper bench a manganese deposit has been mined in an open-cut over 300 ft long and 10 to 50 ft wide. Unmined ore consists of only 1 in. of relatively pure manganese oxide in a layer of manganiferous limestone about 6 in. thick. It is doubtful that additional ore is recoverable from this deposit.

Localities 15 and 16.—Manganese oxide occurs in red sandstone 24 ft above the main bench and 34 ft below the upper bench at localities 15 and 16. The sandstone is manganiferous along the outcrop for about 100 ft at locality 15 and 50 ft at locality 16. The deposit at locality 16 has been developed by a shallow open pit 50 ft long.

The manganese oxide occurs as nodules, lenses, and impregnations estimated to comprise about 10 percent of the thickness of a bed of sandstone 2 ft thick.

Locality 17.—On the west side of Duma Point a bed of red sandstone, about 12 ft above the main bench and about 45 ft below the upper bench, is manganiferous for about 500 ft along the outcrop. Three to six feet of the sandstone contains about 3 percent manganese in the form of nodules, lenses, and impregnations of manganese oxide.

Locality 18.—The deposit at locality 18 is in the sandstone that forms the main bench 58 ft below the upper bench. The sandstone is manganiferous for about 300 ft along the outcrop, and the manganese oxide occurs as impregnations of the sandstone and as small nodules and thin lenses of relatively pure oxide replacing the sandstone. The sandstone bed is 1 ft thick and is estimated to contain 10 percent manganese.

Localities 19 and 20.—Between localities 19 and 20 the sandstone forming the main bench is irregularly manganiferous through a thickness of 3 ft for about 1,500 ft along the outcrop. It contains a few lenses of manganese oxide as much as 6 in. thick in addition to nodules and impregnations, but the average content of manganese probably is only 5 percent or less.

Localities 21, 22, and 23.—At the southwest tip of Duma Point a limy sandstone bed forms a ledge and bench 30 ft above the base of the Summerville formation and about 20 ft below the top of the main bench. Manganese oxide occurs as lenses, nodules, and impregnations in the top of this sandstone for 250 ft along the outcrop at locality 22, where some prospecting has been done, and in a small area at the tip of a spur at locality 21. At locality 23 the ledge is manganiferous for 75 ft along the outcrop and contains about 5 percent manganese in about 3 ft of sandstone.

Localities 24 and 25.—The sandstone of the main bench on the east side of Duma Point is 3 to 4 ft thick between localities 24 and 25 and contains lenses and nodules of manganese oxide averaging perhaps 5 percent manganese.

Locality 26.—The deposit at locality 26 is at the same stratigraphic position as the deposit at locality 17—that is, 40 to 45 ft below the upper bench. Nodules of manganese oxide as much as 4 in. in diameter are present in 3 to 4 ft of soft, thin-bedded sandstone. At the most favorable places the manganese content of the sandstone does not exceed 5 percent, and the average grade must be considerably less.

Locality 27.—East of the southwest tip of the upper bench on Duma Point the sandstone and limestone at the edge of the bench contain only a few nodules of manganese oxide for several hundred feet. At locality 27 a bed of limy sandstone 8 in. thick contains lenses and nodules of manganese oxide estimated to comprise about 25 percent of the bed. This bed is manganiferous only on a small spur in an area less than 100 ft in diameter; the outcrop of the bed on each side of the deposit is essentially barren.

Locality 28.—East of locality 27 the rocks at the edge of the upper bench consist of limy sandstone that grades eastward to sandy limestone, and for about 400 ft they contain only a few nodules of manganese oxide and some associated nodules of iron oxide. At locality 28 an open pit, 200 ft long and about 30 ft wide, at the edge of the upper bench, reveals manganese oxide in an upper bed 6 in. thick and a lower bed 9 in. thick. These beds are separated by red sandy shale 9 in. thick. Chip samples from the beds of manganese oxide were obtained and analyzed by the Bureau of Mines. The upper bed contains 31.5 percent manganese and 0.28 percent iron; the lower bed contains 23.5 percent manganese and 0.58 percent iron. Examination of specimens of the ore under the microscope shows that it consists of finely crystalline pyrolusite intergrown with embayed crystals of calcite, small masses of iron oxide, and numerous iron-coated grains of quartz and feldspar (fig. 10).

Fifty feet east of the open pit a trench 10 ft long extends at right angles to the outcrop. At this trench red sandstone contains a few nodules of manganese oxide.

Locality 29.—For a distance of about 50 ft along the outcrop the sandstone bed forming the main bench contains, at the top, a thickness of about 3 in. of manganese oxide which has replaced and impregnated the sandstone.

Locality 30.—The surface of a small spur of the main bench has been worked by extensive open-cuts. The manganese oxide occurs in a sandstone lens 5 in. thick, about half of which is manganese oxide.

Locality 31.—At locality 31 manganese oxide has been mined from a series of open-cuts for about 300 ft along the outcrop. The manganese oxide occurs in nodules in a sandstone bed about 3 ft below the rim of the main bench. This bed, about 5 in. thick, contains about 25 percent manganese.

Locality 32.—Six feet of shale, sandstone, and sandy limestone, about 25 ft above the base of the Summerville formation and about 25 ft below the main bench, locally contains considerable iron oxide and manganese oxide. A trench 60 ft long has been dug in the deposit. The oxides are irregularly and finely disseminated through the shale and occur also as nodules in the shale. Thin lenses of limestone are partly replaced by iron and manganese oxides. The group of strata is estimated to contain perhaps 15 percent manganese oxide for 100 ft along the outcrop.

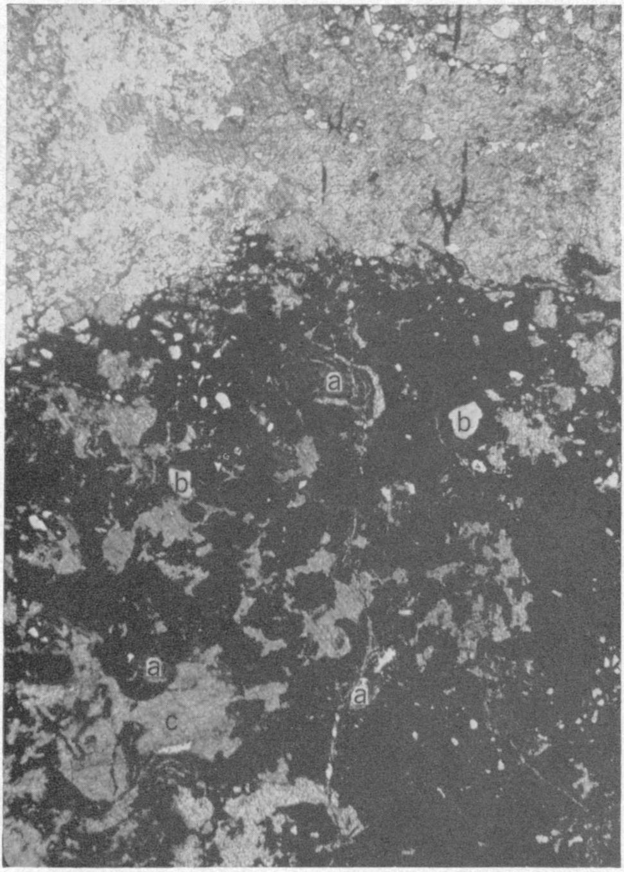

FIGURE 10.—Thin section of manganese ore from a blanket vein in the Summerville formation at Duma Point, Utah. The light area at the top of the photograph is unaltered limestone containing numerous grains of quartz and feldspar. Finely crystalline pyrolusite (black) encloses small laminar masses of iron oxide (a), numerous sand grains (b), and embayed remnants of large crystals of calcite (c). ×22.

Locality 33.—The sandstone bed forming the main bench is only 6 in. thick but locally contains abundant nodules of manganese oxide as much as 4 in. in diameter.

Locality 34.—Thin nodules and lenses of manganese oxide in silty sandstone about 20 ft below the rim of the upper bench are irregularly distributed along the outcrop for 200 ft.

Localities 35 and 36.—The sandstone forming the main bench and the overlying 5- to 8-ft thickness of silty and limy sandstone contain irregularly distributed lenses and nodules of manganese oxide. Beds 2 ft thick may contain about 10 percent manganese. Some small pits have been opened on the richer parts of the deposit.

Locality 37.—The deposit at locality 37 is at the edge of the upper bench, and the manganese oxide occurs as small nodules and in veinlets extending through 10 ft of silty sandstone just below the rim of the bench. A thin lens of ore at the top of the manganiferous zone was mined in a small open-cut on the east side of the spur. On the west side of the spur a thin vein of manganese oxide extends downward from the top of the zone through 20 ft or more of silty sandstone.

Locality 38.—At locality 38 silty sandstone 8 ft above the main bench contains thin lenses and nodules of manganese oxide in an area about 50 ft in diameter on the point of a spur. Thirty feet below the main bench on the point of this spur nodules of manganese oxide are scattered through 6 ft of silty sandstone at approximately the same horizon as the deposit at locality 32.

Locality 39.—For a distance of about 100 ft along the outcrop at locality 39 the pink sandy limestone 15 in. thick forming the rim of the upper bench contains flattened nodules of manganese oxide 1 to 2 in. thick and 5 to 12 in. long. At places these nodules comprise nearly half the bed, which, as a whole, contains perhaps 5 percent manganese. Ore has been mined from this bed in two small open-cuts.

Locality 40.—Between localities 39 and 40 the pink limestone at the edge of the upper bench and the silty sandstone forming the upper few feet of the cliffs beneath the limestone contain only scattered thin lenses and nodules of manganese oxide.

Locality 41.—At locality 41 red sandstone of the Summerville formation, 25 to 30 ft below the base of the Morrison formation and about 10 ft below the sandy limestone bed that forms the main bench, contains lenticular pods and nodules of relatively high grade manganese oxide. The masses of oxide are as much as 4 in. thick and several feet long. They are distributed through 3 to 5 ft of sandstone for about 60 ft along the outcrop. They are estimated to comprise about 10 percent of the thickness of the rock. The bodies of oxide have been mined in an adit 15 ft long and 7 ft wide. The oxide is finely to coarsely crystalline and consists principally of pyrolusite and a small amount of manganite. The gangue includes quartz grains, barite, and iron oxide (fig. 11).

Locality 42.—The deposit at locality 42 is similar in quality and stratigraphic position to that at locality 41, but it extends for only 40 ft along the outcrop. Ore has been mined from open trenches and a shallow prospect pit.

Locality 43.—At locality 43 is another deposit like those at localities 41 and 42. It extends for 140 ft along the outcrop and has been mined from an open trench 80 ft long and from an adit 10 ft long.

Locality 44.—A deposit similar to those at localities 41, 42, and 43 but lower in grade has been mined at locality 44 in a 75-ft open trench.

Locality 45.—At locality 45 nodules of manganese oxide are scattered through about 5 ft of sandstone 15 ft below the main bench, but the manganese content is probably considerably less than 5 percent.

FIGURE 11.—Polished section of manganese ore from a deposit in sandstone of the Summerville formation at Duma Point, Utah. Cavernous, coarsely crystalline pyrolusite (P), with considerable barite (B) and some limonite (L), is associated with finely crystalline pyrolusite enclosing unreplaced sand grains (Q). ×40.

East of locality 45 a few deposits of manganese ore in the Summerville formation are distributed irregularly along the south side of Duma Point for 1¼ miles, extending to the northwestern part of sec. 29, T. 23 S., R. 18 E., as shown on plate 2. Most of the deposits occur in the upper 30 ft of the Summerville formation, but two deposits immediately overlie the main bench and one deposit is about 15 ft below the main bench. The individual deposits extend only 50 to 100 ft along the outcrop, except for the deposit near the top of the Summerville in the NW¼ sec. 29, T. 23 S., R. 18 E., which is 200 ft long. Nodules of manganese oxide in these deposits are estimated to comprise 5 to 15 percent of a thickness of 2 to 3 ft of rock. At the northernmost deposit in the NE¼ sec. 30, T. 23 S., R. 18 E., high-grade manganese oxide forms a lens 1 ft thick and 50 to 75 ft in diameter near the top of the Summerville. This deposit has been developed by two short adits, but little ore has been removed.

Possibly as much as 1,500 to 2,000 tons of ore containing 30 to 50 percent manganese could be recovered by open-pit mining at Duma Point, but a large amount of barren rock would be handled in the process of separating the relatively rich oxide in nodules, veinlets, and thin lenses from the sandstone and limestone host rock. In addition, an overburden as much as 10 ft thick would have to be moved. However, the manganiferous beds in the upper bench are overlain by 20 ft or less of overburden in a large area near the southwest tip of the bench, and a considerable additional tonnage of ore may be present in this area.

Manganese is present also in low-grade ores containing 5 to 15 percent manganese. A large volume of rock containing such percentages of manganese is believed to be present on Duma Point, principally in the deposits in the main bench indicated by locality numbers 18, 19, 20, 24, and 25 and in the deposit about 12 ft above the main bench indicated by locality numbers 17 and 26. The belief is based upon the assumption that the rocks contain approximately the same amount of manganese under cover between the outcrops on the two sides of Duma Point as they do at the outcrops. The maximum overburden at these places is about 60 ft.

DEPOSITS IN T. 23 S., R. 18 E.

Two small deposits of manganese oxide are present in the Summerville formation west of Tenmile Wash near the southwest corner of sec. 29, T. 23 S., R. 18 E. (loc. 10, pl. 2). Both deposits are about 26 ft below the base of the lowest ledge of gray massive sandstone in the Salt Wash sandstone member of the Morrison formation and about 18 ft below the top of a brown- to tan-weathering sandy limestone considered to mark the top of the Summerville formation. The outcrops of the manganiferous beds are partly concealed by wind-blown sand. The manganese oxide, estimated to comprise about 50 percent of the rock, occurs as nodules, lenses, and some veinlets in silty sandstone and as impregnations of the sandstone. The northern deposit is 3 ft thick and 10 ft long. The southern deposit, also about 3 ft thick, is about 30 ft long; sandstone 3 ft thick and a few feet higher in the section contains scattered nodules and veinlets of manganese oxide for 50 ft along the outcrop. Small open-cuts have been made at these deposits.

About three-quarters of a mile toward the south, in the SE¼ sec. 32, is a small deposit of manganese oxide in the cliffs on the west side of a narrow ridge (loc. 11, pl. 2). The ore is in the Summerville formation 18 ft below the top and occurs in a blanket vein 30 ft long and 2 to 6 in. thick. The ore is estimated to contain 30 percent or more manganese.

Two small deposits (loc. 12, pl. 2) in the NE¼ sec. 27, T. 23 S., R. 18 E., about half a mile northwest of Tenmile Wash, are accessible by road from the Moab road to the east. The deposits are in the Summerville formation about 20 ft below the top. Manganese oxide has partly replaced mottled pink and black limestone. Lenses and nodules of manganese oxide occur in pink limestone and in red sandstone underlying the limestone. The lenses and nodules in the limestone are as much as 1 ft thick in an open-cut 20 ft long and 15 ft wide at the southern deposit; the manganiferous beds on both sides of the open-cut are covered by rock debris and wind-blown sand. At the northern deposit the manganiferous limestone and sandstone, 2 to 3 ft thick, are exposed for 200 ft, but in places the rocks contain practically no manganese. The ore is fine-grained and consists mostly of pyrolusite, some psilomelane, and associated barite, calcite, and iron oxide.

The deposits in the northern part of sec. 35, T. 23 S., R. 18 E., are in the lower part of the Summerville formation, 26 to 36 ft below the Moab tongue of the Entrada sandstone and about 120 ft below the stratigraphic position of the deposits between this vicinity and Duma Point. At the easternmost deposit (loc. 13, fig. 2) manganese oxide has partly replaced 1 to 2 ft of sandstone in an area about 50 ft in diameter on the crest of a small hill. Ore has been mined from shallow open-cuts. Nodules of oxide less than 1 in. in diameter are abundant in red silty sandstone 2 to 3 ft thick below the main manganiferous bed. In the main cliffs 200 ft south of the deposit, manganese oxide at the same stratigraphic position is about 2 in. thick for 100 ft along the outcrop. About a third of a mile toward the northwest, on the summits of two low hills (loc. 14, pl. 2), manganese oxide at the same stratigraphic position occurs in red sandstone and lenses of limestone about 1 ft thick. The manganese content is estimated to be about 5 percent. Along the cliffs for about 1,500 ft southwest of this deposit, the sandstone and limestone at the same stratigraphic position are manganiferous, and the manganese oxide occurs as small nodules and thin lenses in the sandstone and limestone and as small black spots mottling the surface of partly replaced limestone. The manganiferous zone is 2 in. to 1½ ft thick and contains only small amounts of high-grade ore.

DEPOSITS IN T. 24 S., R. 18 E.

Small deposits of manganese oxide in the northern part of T. 24 S., R. 18 E., are mainly in the steep slopes formed by the upper part of the Summerville formation above the cliff of the Moab tongue of the Entrada sandstone. From the NW¼ sec. 2 to the east-central part of sec. 3 (loc. 15, pl. 2), the manganese oxide is 40 ft above the Moab tongue and has partly replaced sandstone 2 ft thick. The manganiferous zone is debris-covered and poorly exposed, but discontinuous exposures and float indicate that the deposit extends more or less unbrokenly for about 2,000 ft southward along the cliffs. Beneath the Moab tongue of the Entrada sandstone, in the east-central part of sec. 3, scattered nodules of manganese oxide occur in sandy limestone at the same stratigraphic position at which the small deposits 1½ miles to the north are located.

In the NW¼ sec. 12, T. 24 S., R. 18 E. (loc. 16, pl. 2), a small deposit of manganese oxide occurs in the cliffs in the upper part of the Summerville formation 26 ft above the Moab tongue of the Entrada sandstone. The oxide partly replaces sandstone as much as 1½ ft thick for 10 ft along the outcrop, but the ore bed is estimated to contain less than 10 percent manganese. Another small deposit in the NW¼ sec. 13 (loc. 17, pl. 2), at the same stratigraphic position, is indicated by float on the debris-covered slope for a distance of 50 ft. Some of the float fragments 3 to 4 in. in diameter were estimated to contain 30 to 40 percent manganese, but the deposit probably contains very little high-grade ore.

DEPOSITS AT THE NEEDLES

A group of deposits in the southeastern part of T. 24 S., R. 18 E., is located near the picturesque rock forms known as the Needles. Some ore was produced from these deposits in 1918, but production figures are not available. The deposits are near a graded dirt road that branches from Highway 160; the distance from the deposits to the railroad at Crescent is 27 miles, about half of which is paved highway and the other half graded dirt road. The deposits occur along the main Summerville escarpment, which is less abrupt at this locality than it is farther west. The main part of the Entrada sandstone crops out at the foot of the escarpment, and the thick ledges of gray sandstone in the lower part of the Salt Wash sandstone member of the Morrison formation form the rim. The Summerville formation, which crops out in the escarpment, is divided into two parts by the Moab tongue of the Entrada sandstone. The upper part of the Summerville, in which the manganese deposits occur, forms a steep slope and is 85 ft thick; the lower part is 72 ft thick. The buff to pink, cross-bedded, medium-grained, ledge-forming sandstone of the Moab tongue of the Entrada is 45 ft thick. The rocks have an average dip of about 2° N.

Manganese oxide occurs in the Summerville formation 10 to 35 ft above the top of the Moab tongue of the Entrada sandstone and is present more or less continuously along the outcrop for about

1½ miles, but at only a few localities is the oxide abundant. At the westernmost deposits, in the SE¼ sec. 23, T. 24 S., R. 18 E. (loc. 18, pl. 2), the manganese oxide crops out as a blanket vein in red sandstone in the steep slope 35 ft above the Moab. The blanket vein, 75 ft long, is about 1 ft thick for a distance of 30 ft and is thinner toward the ends. The ore in the main part of the vein, estimated to contain 40 to 50 percent manganese, could be recovered to a width of about 20 ft by an open-cut involving the removal of 10 ft or less of overburden. Oxides occur at the same horizon for about 600 ft toward the southwest, but not in important quantities.

The deposits located mainly in the SW¼ sec. 24 T. 24 S., R. 18 E. (loc. 19, pl. 2), formerly were known as the Gustavus claim (Pardee, 1921, pp. 202–203). They occur in the steep slope formed by the upper part of the Summerville formation 10 to 25 ft above the top of the Moab tongue of the Entrada sandstone. The manganese oxide occurs in sandstone and sandy shale as irregular blanket veins that thicken and thin, finger out into the host rock, and cut obliquely across the bedding of the host rock. The veins extend for about 250 ft along the outcrop and locally have an aggregate thickness of as much as 3 ft in 12 ft of rock. They have been explored by several open-cuts as much as 90 ft long and 10 to 50 ft wide. The ore consists of pyrolusite and manganite with some barite and calcite and some unreplaced sandstone. Pardee reported some light-pink, coarsely crystalline rhodochrosite, but none was observed at the present outcrops or pit faces. He also reported that the hand-sorted ore as shipped contained 40 percent or more manganese.

A deposit at locality 20 (pl. 2), about a quarter of a mile east of the deposit at locality 19, occupies an area about 175 ft in diameter. The ore is 20 ft above the top of the Moab tongue of the Entrada sandstone and crops out in a gentle slope formed by the upper part of the Summerville formation. Several pits, the largest of which is 100 ft long and 30 ft wide, are in the ore zone and expose blanket veins 2 in. to 1 ft thick. At one pit 75 ft long and 15 ft wide a blanket vein of high-grade oxide ore 1 ft thick was separated from a lower blanket vein of high-grade ore 8 in. thick by 3 ft of sandstone containing some manganese oxide. The ore-bearing beds are overlain by not more than 20 ft of cover for about 500 ft from the outcrop, but the lenticular blanket veins may not extend throughout that area. East of the prospected area the ore-bearing beds are covered by dune sand, and west of the area the rocks contain only scattered nodules of manganese oxide.

For a distance of nearly a mile east of locality 20 manganese oxide occurs sporadically as float, but exposures are poor for most of the distance. At locality 21 (pl. 2) the oxide is in nodules in red shale and standstone 3 ft thick about 20 ft above the top of the Moab tongue of the Entrada sandstone. The deposits are on the summits of two low knolls in areas approximately 50 and 80 ft in diameter. Some cuts have been opened at these deposits.

In the part of the Little Grand district southeast of Duma Point some high-grade manganese ore could be recovered, mainly from the deposits near the Needles. The quality of the ore from these deposits is indicated by the following statement from Pardee (1921, p. 203):

> A large number of samples of mixed ore from the localities described, reported by the Needles Mining Co., average a little more than 45 percent of manganese. Several carry from 59 to 86 percent of manganese dioxide, 6 to 9 percent of silica, about 0.35 percent of iron, 0.033 percent of phosphorus, and 0.20 percent of copper.

AREA EAST OF LITTLE GRAND DISTRICT

DEPOSIT WEST OF COURTHOUSE WASH

A manganese deposit west of Courthouse Wash, located in the NE¼ sec. 28, T. 24 S., R., 20 E. (loc. 2, fig. 3), is about three-quarters of a mile west of U. S. Highway 160. It is reached from the highway by a steep but passable dugway. The distance along the paved highway from the deposit to the railroad at Crescent is 19 miles. Old workings at the deposit consist of an open trench about 100 ft long and three shallow pits. Production figures are not available, but a small amount of high-grade ore probably has been produced from this deposit. No work was in progress in August 1940, but a few tons of ore were piled near the workings.

The deposit is situated on a bench at the base of a steep northeastward-facing escarpment. A fault trending N. 25° W. and dipping about 70° NE. at the foot of the escarpment has a displacement of about 1,500 ft down to the northeast. Variegated shale, probably about 200 ft below the top of the Morrison formation, crops out northeast of the fault, and sandstone of the Kayenta formation crops out southwest of the fault. In the vicinity of the fault shale of the Morrison formation dips steeply toward the northeast, but 150 to 200 ft away the dip is only 1° or 2° NW.; the Kayenta formation dips about 4° NW.

Manganese oxide, chiefly pyrolusite, associated with brown and white calcite, occurs in lenticular pods in the clay gouge along the fault. The pods exposed in the gouge have a maximum thickness of 10 in. and a length of several feet, but some of the fragments of mined ore at the workings are 1½ ft in diameter. The open trench, which follows the fault for about 100 ft and is 5 to 10 ft deep and about 3 ft wide, provides poor exposures of the ore bodies, but the lenses of manganese oxide probably average about 4 in. in thickness. A pit 6 ft deep at the north end of the trench exposes only thin lenses of manganese oxide in the fault gouge. No manganese ore was observed along the poor exposures of the fault zone for several miles northwest of the trench, and only scattered float was observed for a distance of a few hundred feet southeast of the trench. A few nodules of manganese oxide occur in shale of the Morrison formation adjacent to the vein deposits, but the shale is barren of manganese oxide 20 to 30 ft from the fault, as exposed in pits northwest of the trench.

The chief manganese mineral is pyrolusite, which is both coarsely crystalline and finely granular. The ore varies in quality from almost pure pyrolusite to mixed calcite and pyrolusite containing perhaps 25 percent manganese. A small amount of barite also is present. This deposit is similar to that at the Desert Rock claim.

DEPOSIT EAST OF COURTHOUSE WASH

A manganese deposit east of Courthouse Wash, in the SW¼ sec. 14 and the SE¼ sec. 15, T. 24 S., R. 20 E. (loc. 3, fig. 3), is about 18 miles by U. S. Highway 160 south of the railroad at Crescent and about three-quarters of a mile east of the highway. Automobiles can be driven to the foot of the slope below the deposit, and little road work would be necessary to make trucking possible.

The deposit is 100 to 150 ft above the base of a steep northeastward-facing slope and about 60 ft below the flat summit of the ridge. The manganese occurs in sandstone that is interbedded with shale and is about 200 ft below the top of the Morrison formation. The dip of the rocks is about 3° SW.

The sandstone is irregularly impregnated and partly replaced by manganese oxide for about 1,500 ft along the outcrop. Locally the greater part of the sandstone, in places as much as 8 ft thick and extending for 50 ft along the outcrop, is impregnated with manganese oxide, but elsewhere the sandstone contains only traces of the oxide. The enriched parts of the sandstone end abruptly at bedding planes and joints. Some manganese occurs below the main outcrop in small landslide blocks of the sandstone.

The manganese occurs chiefly as finely crystalline pyrolusite in the cement in the sandstone. The pyrolusite locally fills all the pore space between unetched or only slightly etched rounded grains of quartz, chert, and feldspar and in part replaces the calcium carbonate cement of the sandstone (fig. 12). Some limonite is present as cement and coatings of sand grains and as tiny veinlets in the sandstone.

The deposit contains several thousand tons of rock averaging about 5 percent manganese.

DEPOSIT IN SALT VALLEY

Manganese oxides are exposed in the bluffs on the northeast side of Salt Valley in the south-central part of sec. 3, T. 24 S., R. 21 E. (loc. 4, fig. 3). The locality is 25 miles by road from the railroad at Thompsons; the road is the one, mostly unimproved, that traverses Salt Valley. A cribbed shaft 32 ft deep and several small pits have been dug. One or two tons of manganese ore were piled near the shaft in August 1940.

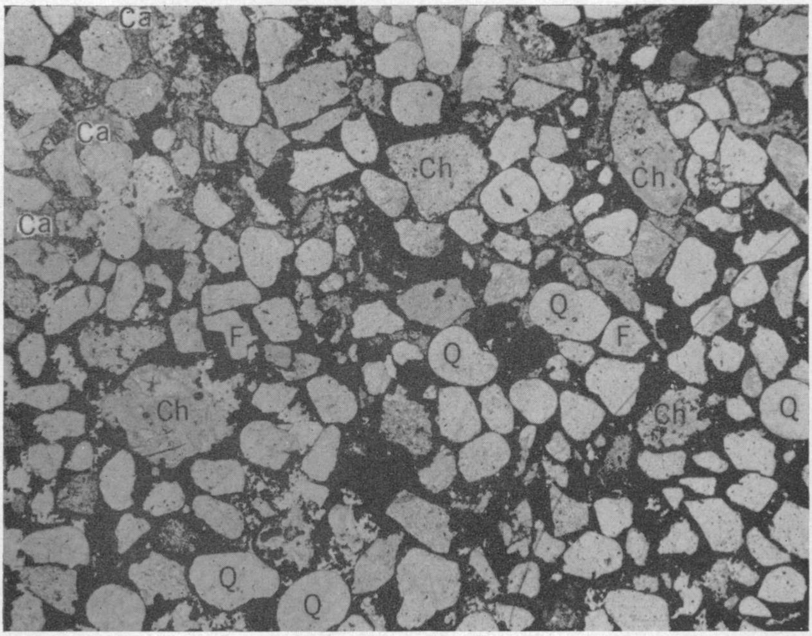

FIGURE 12.—Thin section of manganiferous sandstone from a deposit in the Morrison formation east of Courthouse Wash, Utah. Sand grains consisting of quartz (Q), feldspar (F), and chert (Ch) are cemented by calcite (Ca); the cement and, to a lesser extent, the sand grains are partly replaced by manganese oxide (black). ×22.

The manganese oxide occurs in variegated shale and interbedded sandstone in the upper part of the Morrison formation where the shale is sheared and contorted along a fault that drops Mancos shale on the southwest against the Morrison formation. The dip of the rocks ranges from 35° SW. to vertical. The geology in the vicinity of the deposit has been described by Dane (1935).

Oxides of manganese occur as nodules and veinlets in the shale, as coatings on sand grains, and as a replacement of some of the cement of the sandstone. Most of the manganese is in irregular small patches of the Morrison formation within about 100 ft of the fault and extending for a distance of about 1,000 ft parallel to the fault. These patches of manganiferous rock do not appear to be more than 50 ft long and 5 ft thick. Much of the shale and sandstone is barren. Samples of ore from the shaft were reported by W. G. Morrison to contain 36 to 42 percent manganese.

The manganese oxides are predominantly pyrolusite with some psilomelane. Much iron oxide is present.

DEPOSITS IN LITTLE VALLEY

A deposit of low-grade manganese ore 7 miles due south of Thompsons is located in the eastern part of sec. 28 and the western part of sec. 29, T. 22 S., R. 20 E. (loc. 5, fig. 3). It is accessible from the railroad at Thompsons or Crescent by dirt road. The distance from the deposit to Thompsons by road is 13 miles; the distance to Crescent is 10½ miles. Five and one-half miles of either distance is dirt road; the remainder is surfaced. No work was in progress in August 1940, but several small open-cuts and shallow pits had been dug, probably within the preceding year. Possibly a few tons of ore had been shipped.

The deposit is on the steep bare slope on the northeast side of Little Valley, which is 1½ miles or more northeast of and roughly parallel to Salt Valley. In the vicinity of the deposit the ridge northeast of the valley is about 220 ft high at its south end and about 100 ft high at the north. The deposit is 40 to 50 ft below the top of the ridge.

8he manganiferous rocks are 200 ft below the top of the Morrison formation. Gray and red shale with thin beds of gray sandstone, some conglomerate, and a persistent bed of brown-weathering pink limestone near the top are exposed on the northeast side of the valley. These beds are overlain by thick, massive, gray to buff conglomeratic sandstone. In the vicinity of the deposit the rocks dip about 10° NE.

The deposit extends for 1,400 ft along the valley wall, as shown in figure 13. The manganese oxide is chiefly, if not entirely, pyrolusite and occurs as nodules in shale, as impregnations and partial replacement of sandstone and conglomerate, as dendritic growths in sandstone and sandy limestone, and as thin films on fracture surfaces. Most of the manganese is in interbedded shale and sandstone 14 to 26 ft below the top of the manganiferous beds, but some occurs through as much as 60 ft of rocks. The stratigraphic distribution of the manganese oxide in the northwestern part of the deposit at locality 2 (fig. 13) is shown by the following section:

Section of manganiferous beds measured at Little Valley (locality 2, fig. 15)

	Ft	in.
1. Brown-weathering, gray to pink limestone; forms ledge about 20 ft below top of ridge	2	0
2. Pinkish-gray shale; slight stains of manganese oxide	14	0
3. Gray shale with lenses and nodules of manganese oxide and streaks of sand impregnated with manganese oxide; analysis of chip sample showed manganese content of 3.0 percent	1	5
4. Gray shale slightly stained with manganese oxide	1	10
5. Gray shale with nodules of manganese oxide; analysis of chip sample showed manganese content of 14.5 percent	1	0
6. Gray shale slightly stained with manganese oxide	6	0
7. Gray sandstone, fine-grained; locally forms ledge 1½ ft thick; contains sooty manganese oxide; analysis of chip sample showed manganese content of 3.0 percent		9
8. Pink shale slightly stained with manganese oxide		10
9. Pink sandstone, fine-grained; contains nodules and impregnations of manganese oxide; analysis of chip sample showed manganese content of 1.8 percent		7
10. Pink shale	1	10
11. Pink sandstone, fine- to medium-grained, impregnated with manganese oxide		2
12. Red and gray shale, locally stained with manganese oxide and with a few lenses of shale 2 to 3 in. thick containing nodules, veinlets, and impregnations of manganese oxide	22	0
13. Red sandstone, fine-grained, locally impregnated with manganese oxide		5
14. Red and gray shale	2	8
15. Gray sandstone, fine-grained, impregnated with manganese oxide		6
16. Red shale	2	9
17. Light-gray limy sandstone slightly stained by manganese oxide	1	0
Total	59	9

The manganese oxide below unit 9 of the section was observed only in the northwestern part of the deposit and is found only in very thin beds. As shown by the section, the upper part of the manganiferous zone at locality 2 (fig. 13) contains considerable quantities of manganese in beds having an aggregate thickness of only 3 ft 9 in. out of a total rock thickness of 12 ft 5 in. A bed 1 ft thick contains 14.5 percent manganese, and another, consisting of 2 ft 9 in. of manganiferous rock, contains 3 percent manganese or less. At locality 1 the manganiferous beds are only slightly stained by manganese oxide, and about 200 ft farther northwest no manganese oxide was observed. At locality 3 a shallow pit has been dug on a sandstone ledge equivalent to unit 7 of the section. The sandstone ledge, containing 5.7 percent manganese, is 2 ft 5 in. thick and is overlain by 20 ft of gray

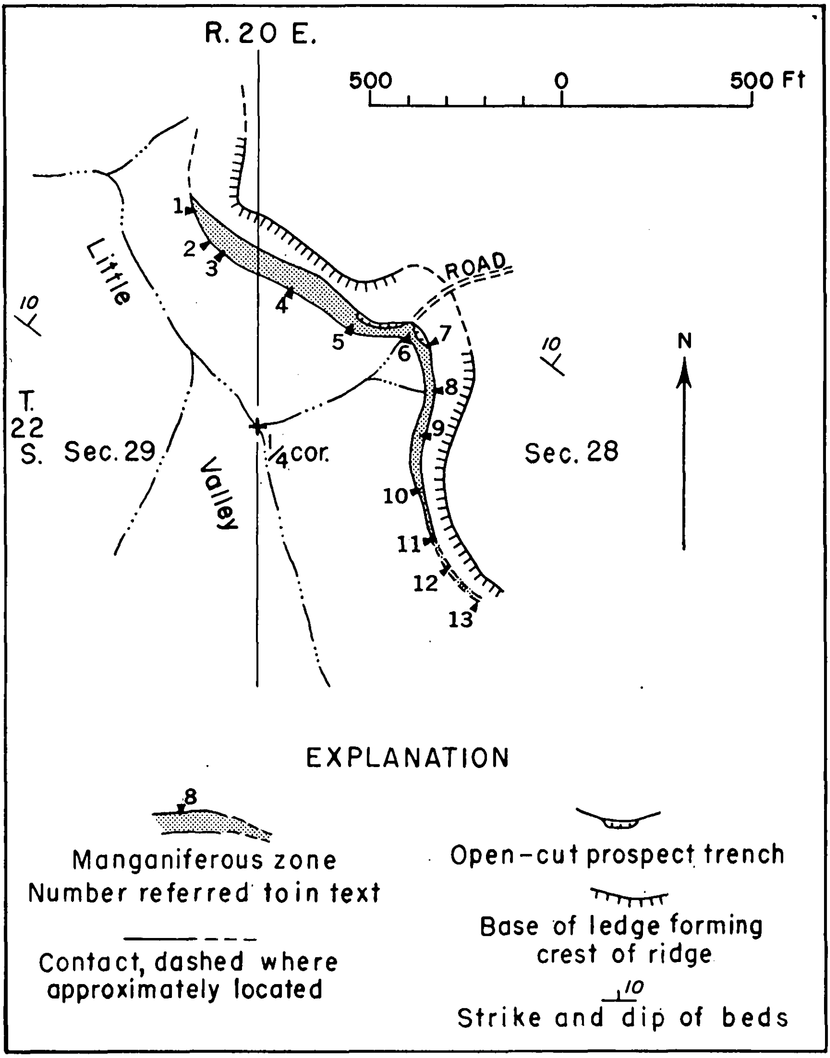

FIGURE 13.—Map of the manganese deposit on the northeast side of Little Valley in T. 22 S., R. 20 E., Utah.

to pink shale; the lower 3 ft and upper 12 ft are barren, whereas the intervening 5 ft of shale contains hard, sooty manganese oxide. At the top is a ledge-forming, brown-weathering limestone (unit 1 of the section) about 10 ft thick. A chip sample of the manganiferous part of the shale contains 5.0 percent manganese.

The manganiferous rocks at locality 4 are 7 ft thick and consist mainly of shale and sandy shale containing nodules and impregnations of manganese oxide. However, the grade is estimated to be slightly lower (less than 5.0 percent manganese) than that of the shale at locality 3. Pinkish-gray shale 10½ ft thick and essentially barren of manganese oxide overlies the manganese-bearing shale and is in turn overlain successively by soft manganiferous sandstone 1½ ft thick, gray shale 7½ ft thick which is barren of manganese oxide, and the brown-weathering limestone equivalent to unit 1 of the section. The manganiferous sandstone bed in the upper part of the shale 7½ ft below the limestone is practically barren of manganese about 100 ft northwest of locality 4.

Locality 5 is at the west end of a trench 150 ft long and 8 to 10 ft wide cut in the sandstone and shale 8 to 10 ft thick immediately underlying the limestone bed at the top of the manganiferous zone. About 7 ft of shale between the sandstone ledge and the brown-weathering limestone contains numerous irregularly shaped, ovate, or rounded masses of limy sandstone as much as several feet in diameter, which together with the underlying ledge are sparsely impregnated with manganese oxide. A representative specimen from the basal ledge of manganiferous limy sandstone contained 6.5 percent manganese, 0.05 percent sulfur, and 0.10 percent P_2O_5. At locality 5 the top of the lower manganiferous shale and sandstone is 10 ft below the basal ledge in the open-cut and is 4 ft thick. The content of manganese is similar to that of equivalent beds to the northwest.

Between localities 6 and 7 is another open-cut, 60 ft long and 5 to 10 ft wide, that exposes manganiferous beds of about the same quality and stratigraphic position as those exposed at locality 5. At locality 6 the manganiferous shale is 2½ ft thick.

At locality 8, gray shale 1 ft 2 in. thick contains nodules of manganese oxide. This shale is 20 ft below the base of the limestone that marks the top of the zone. Manganiferous sandstone, similar to that exposed in the open-cuts at localities 5 and 6, is interbedded with shale in the 10 ft of beds underlying the limestone.

At locality 9, pinkish-gray shale 4 ft thick underlies the limestone at the top of the manganiferous zone and contains interbedded limy sandstone sparsely impregnated with manganese oxide. A sandstone bed 1 ft 7 in. thick and 17 ft below the limestone also contains nodules of manganese oxide. This manganiferous sandstone bed wedges out toward the south at locality 10, beyond which the shale contains no visible manganese oxide. A 3½-ft sandstone bed at locality 11 is 8 ft below the limestone at the top of the manganiferous zone and is slightly impregnated with manganese oxide. Locality 12 is 50 ft from the south end of a conglomerattic lens 250 ft long, 1 ft thick, and 15 ft below the limestone at the top of the zone; the conglomerate is slightly stained with manganese oxide. At locality 13, at the south end of the deposit, the sandy limestone at the top of the zone is slightly stained with manganese oxide.

Analyses of seven samples of ore from this deposit indicate that the ore is low in grade. One sample of a bed of shale a foot thick, containing relatively abundant nodules of manganese oxide, contained 14.5 percent manganese. None of the other samples contained more than 6.5 percent manganese, and the manganese content of some was as low as 1.8 percent. The average manganese content of the ore probably does not exceed 5 percent. Iron oxide is abundant, but the quantity was not determined. A trace of zinc was found in two samples. The content of sulfur ranges from 0.05 to 0.48 percent; that of P_2O_5, from 0.05 to 0.20 percent. The manganese oxide occurring as nodules in shale probably could be easily concentrated, but much of the oxide is finely disseminated in sandstone and would be difficult to recover.

If it is assumed that the grade of the ore remains fairly constant for a distance of 75 ft from the outcrop, the deposit contains tens of thousands of tons of ore containing approximately 5 percent manganese beneath 50 ft or less of overburden.

Another deposit of manganese ore in Little Valley (loc. 6, fig. 3) is located in T. 22 S., R. 21 E. (unsurveyed), and is near the E¼ cor. sec. 33 (projected). The deposit is near the base of a steep slope at the head of a reentrant in the cliffs on the north side of the valley. Practically no prospecting has been done at the deposit.

The rocks exposed in the vicinity are principally slope-forming variegated shale overlain by bench-forming sandstone in the upper part of the Morrison formation. The manganese deposit occurs in the shale 240 ft below the top of the formation. The rocks have a northerly dip of 2°.

Manganese oxides in nodules and veins are irregularly distributed through 6 ft of variegated shale for 200 ft along the outcrop. The shale contains pockets, relatively rich in manganese oxide, that are as much as 1 ft thick and 5 or 6 ft long parallel to the bedding. Groups of nodules in zones as much as 1 ft wide appear to be associated with vertical joints. A thin, brown-weathering, evenly bedded to nodular limestone immediately overlying the manganiferous shale is locally impregnated with a small amount of manganese oxide. Although nearly pure oxide occurs in very small pockets, the ore bodies are so thin and discontinuous that the deposit is not considered to contain recoverable manganese.

DEPOSIT SOUTH OF WHITE HOUSE

A small manganese deposit in the SW¼ sec. 11, T. 23 S., R. 22 E., is 8 miles due south of the station of White House on the Denver & Rio Grande Western Railroad (loc. 7, fig. 3). A road south from White House leads to a small reservoir 1½ miles northwest of the deposit, which is on the north bank of the south fork of the stream dammed at the reservoir.

Manganese oxide partly replaces and impregnates a blocky-weathering bed of gray to red, medium-grained sandstone that forms the rim of a shallow gorge. The sandstone bed is 1½ to 3 ft thick and is in the Summerville formation 17 ft above the base of the formation and 15 ft below the base of a zone of large chert nodules. The manganiferous sandstone is stained black with desert varnish. Manganese oxide partly fills the pores of the sandstone and locally is present in sufficient quantity to impart a metallic luster to freshly broken surfaces of the rock. The manganese oxide is most abundant in thin sheets parallel to the bedding in the upper 6 to 8 in. of the sandstone. Rock containing sufficient manganese oxide to have a metallic luster extends continuously for 300 ft along the outcrop. The same bed of sandstone 500 ft to the southeast also contains manganese oxide in lenses 1 ft long and 1 to 2 in. thick, and a bed of brown-weathering sandy limestone 6 in. to 1 ft thick 4 ft above the sandstone contains scattered small nodules of manganese oxide.

The low grade of the ore and the small size of the deposit probably will preclude recovery of the manganese. The thin sheets parallel to the bedding contain nearly pure manganese oxide, but it is doubtful that ore containing more than 20 percent manganese could be mined. Moreover, the silica content would be very high. It is not likely that there are more than a few hundred tons of ore in the deposit.

DEPOSIT AT SQUAW PARK

A deposit of manganese oxide on the north side of Squaw Park is located in the southern part of the SE¼ sec. 4, T. 23 S., R. 23 E. (loc. 8, fig. 3). A road that branches from the Cisco-Dewey road just south of the crossing of Sagers Wash and about half a mile west of the Colorado River follows Owl Wash, a tributary of Sagers Wash, and leads to a vanadium mine half a mile northeast of the manganese deposit; the road could be extended from this mine with little difficulty and at small expense. The distance by road from the deposit to Cisco, on the main line of the Denver & Rio Grande Western Railroad, is about 15 miles, of which 1½ miles is along Highway 50 and is paved, 7½ miles is on the Cisco-Dewey graded dirt road across shale flats, and 6 miles is on a rough, rocky road that in part follows the bed of Owl Wash. No mining had been done at the deposit through the summer of 1940.

The deposit is in the Summerville formation, which dips 4° NE. The manganese oxide occurs as a stratified deposit or blanket vein 35 ft above the base of the formation and caps the tip of a spur of the southward-facing cliffs which form the north boundary of Squaw Park. The ore is approximately 1 ft thick and occupies an elliptical area with a long diameter of 120 ft and a short diameter of 100 ft. It is overlain by only a few inches of sand and sandy shale. The ore is somewhat vuggy, hard, crystalline pyrolusite containing much calcium carbonate. The edge of the bed at the outcrop is dominantly manganese oxide except on the east side of the deposit, where, for a distance of 40 ft, a large part of the ore bed consists of fine-grained, pink, somewhat sandy limestone and contains an aggregate thickness of as little as 4 in. of manganese oxide. The presence in the deposit of other, similar areas of lean ore could be determined by means of shallow pits. North of the main deposit, along the east side of the spur, no manganese oxide was observed. On the west side of the spur manganese oxide occurs sporadically for 1,000 ft as impregnations in limestone and as nodules in shale. None of these bodies of mineralized rock are more than a few feet long, and they are not believed to contain recoverable ore. No traces of manganese oxide were observed farther north and west along the cliffs for a distance of about 2 miles.

A chip sample of the ore-bearing bed, obtained on the south side of the deposit and analyzed by the Bureau of Mines, showed a manganese content of 31.7 percent and an iron content of 0.17 percent. Parts of the bed appear to contain a higher percentage of manganese; as reported by Bert Turner, one of the owners, an analysis of a sample of the ore showed 48 percent manganese. A sample of the pink limestone from the east side of the deposit was analyzed and found to contain only 0.02 percent manganese.

If it is assumed that no areas of lean ore exist other than the one noted on the east side, the deposit contains several hundred tons of ore containing 30 percent or more manganese.

PROSPECT ON WILSON MESA

A manganese prospect on Wilson Mesa east of the town of Moab is located in the SE¼ sec. 18, T. 26 S., R. 24 E. (loc. 9, fig. 3). The prospect is on the Robinson ranch and is about three-quarters of a mile east of the graded dirt road on Wilson Mesa. The distance by road from the deposit to the railroad at Crescent by way of Moab is about 55 miles; the distance to the railroad at Cisco by way of Castle Valley and Dewey is about 45 miles. The shorter route is dirt road practically all the way, whereas the longer route is paved for about three-quarters of the distance. No work was in progress at the deposit in 1940, and the only development work that had been done consisted of an adit reported to be 40 ft long but caved 20 ft from the portal. No ore is known to have been shipped from the deposit.

The deposit is near the base of a steep wooded slope rising toward the east above Wilson Mesa. The manganese occurs as oxide in a sandstone bed believed to be near the top of the Salt Wash sandstone member of the Morrison formation. The Salt Wash member includes at least one sandstone ledge above the manganese-bearing sandstone bed. The beds in the vicinity of the deposit have a slight westward dip.

The exposures are very poor, and the workings are not adequate to provide much information about the nature and extent of the ore body. The manganese is in the form of the oxide pyrolusite, which impregnates a coarse-grained siliceous sandstone. Most of the oxide occurs as cement between the sand grains, but some small bundles of acicular crystals appear to fill cavities or to replace the sandstone. Irregularly shaped parts of the sandstone contain no manganese oxide and are light-colored. At places as much as 90 percent of areas 2 ft square is impregnated with the oxide and is black, but a much smaller part of the average rock on the dump appears to be impregnated with the oxide. No manganese oxide was found in the float at the position of the manganiferous sandstone north or south of the adit except for a single boulder of sandstone impregnated with manganese oxide about 50 ft north of the adit. However, manganese oxide in float is found as much as 30 ft above the adit. The deposit thus appears to be small in extent, both horizontally and vertically. The average manganese content of the sandstone in the adit is estimated to be about 10 percent, and judging from available information only a few hundred tons of ore of that grade is contained in the deposit.

DEPOSITS ON MULESHOE WASH

A group of small deposits of manganese oxide is located southeast of Moab on a tributary of Muleshoe Wash in secs. 19 and 30, T. 28 S., R. 23 E. (loc. 10, fig. 3). Highway 160 passes within half a mile east of the deposits, and the distance along the paved highway from the deposits to the railroad at Crescent is 53 miles. The deposits occur in the walls of small canyons and on the benches bordering the canyon rims. Shallow pits or trenches have been dug at several of the deposits, but apparently little or no ore has been shipped.

A limestone bed, 3 to 5 ft thick in places, rims the canyon and forms the flat intercanyon areas. The limestone, which contains some of the manganese deposits, rests upon the Navajo sandstone and is overlain by red shale, siltstone, and sandstone of the Carmel formation; it is assumed that the limestone is the basal bed of the Carmel formation. The underlying cross-bedded, buff to gray Navajo sandstone is the host rock of other manganese deposits in the group.

The rocks dip about 3° NE. Numerous joints and small faults strike N. 50° W., and some of the manganese deposits occur in the fracture zones.

The manganese deposits may be separated into a southern and a northern group. The southern group, in the NW¼ sec. 30, T. 28 S., R. 23 E., is associated with the limestone at the contact between the

Navajo sandstone and the Carmel formation. The northern group, in the NW$\frac{1}{4}$ sec. 19 of the same township, is composed of vein deposits along joints and fractures in the upper part of the Navajo sandstone. The southern group includes four deposits within an area about 700 ft in diameter. The largest deposit is about 800 ft southwest of the N$\frac{1}{4}$ corner sec. 30. It is partly covered by sand, but along the north and east edges of a bench it is practically continuous for 550 ft. The manganese oxide occurs in a blanket vein, 1 to 3 in. thick at most places but locally as much as 10 in. thick. The ore is very porous or spongy; it consists of fine-grained masses and slender rods of manganese oxide and contains much calcium carbonate. The character of the ore suggests a surficial deposit formed at the outcrop by evaporation of manganese-bearing solutions. Similar ore 500 ft to the south, at the south end of the bench, has a maximum thickness of 6 in. and can be traced for only 50 ft along the outcrop, although toward the east the ore-bearing beds are covered by wind-blown sand. Across a small canyon to the west of the latter deposit porous pink limestone 3 ft thick on the east rim of a bench contains a little manganese oxide in a zone 6 in. thick for 10 ft along the outcrop; on the west rim of the same bench, jointed gray limestone 5 ft thick is slightly impregnated with manganese oxide in an area about 10 ft in diameter.

The northern group of deposits, in the NW$\frac{1}{4}$ sec. 19, includes three deposits along parallel fracture zones in the Navajo sandstone. The southernmost zone is discontinuous but can be traced from the vicinity of the highway northwestward across a fork of Muleshoe Wash to a point about 700 ft south of the northwest corner of sec. 19, a total distance of about half a mile. Southeast of the canyon the sandstone is impregnated with abundant iron oxide along the fracture zone for a width of 150 ft. A trench 3 ft wide, 25 ft long, and 4 ft deep had been dug along the southwest side of the fracture zone. As exposed in the trench, the manganese oxide occurs between angular fragments of sandstone (fig. 14) and in a few thin veinlets in sandstone. Numerous veinlets of iron oxide also are present in the sandstone. The surficial character of the mineralization is demonstrated in the canyon, where the floor and lower walls are not mineralized along the fractures in the sandstone. Northwest of the canyon manganese and iron oxides, occurring as thin veinlets and as impregnations in the sandstone, are distributed sporadically for more than 1,000 ft. A trench 50 ft long, 3 ft wide, and 10 ft deep reveals a variable quantity of manganese oxide (pyrolusite) and much associated iron and calcium carbonate. At one place in the deeper part of the trench the vein is 2 ft thick and consists of about equal proportions of manganese oxide and sandstone, but 10 ft away only thin stringers of manganese oxide are associated with abundant iron oxide in sandstone.

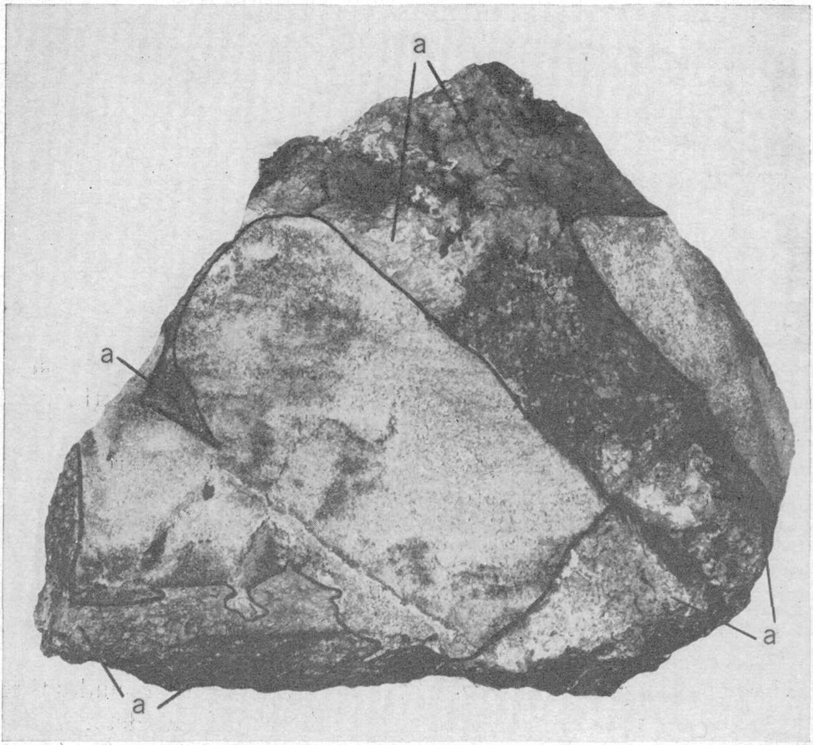

FIGURE 14.—Manganese ore from a vein deposit in Muleshoe Wash, southeast of Moab, Utah. Manganese oxide (a), chiefly pyrolusite, with numerous vugs and stalactitic growths (top of specimen), fills spaces between large angular fragments of Navajo sandstone. Natural size.

Five hundred fifty feet to the north along the tributary of Muleshoe Wash is another fracture zone in the Navajo sandstone that also contains manganese oxide and abundant iron oxide. The mineralized fracture zone is 10 ft wide and contains several veins about a quarter of an inch wide containing mixtures of iron and manganese oxides. The sandstone adjoining the fractures is impregnated with the oxides in zones as much as 8 in. wide. The mineralized zone extends only 70 ft west of the canyon rim. The fractures are not mineralized in the bed of the canyon and are only slightly mineralized on the east side of the canyon.

One hundred thirty feet farther north is a fault in the Navajo sandstone having a displacement of about 4 ft down on the north. A fracture zone 30 ft wide associated with the fault contains some iron and manganese oxides for a distance of 120 ft west of the canyon rim, principally as impregnations of the sandstone. In the canyon wall, a zone 3 ft wide along the fault contains several veins of pyrolusite as much as 2 in. thick, and the oxide impregnates the sandstone. About a third of the width of the zone is estimated to consist of manganiferous material, but the mineralization extends only 30 ft down the canyon wall; below, unaltered sandstone is exposed in the walls and floor of the canyon. Across the canyon to the southeast, about 250 ft away, the fracture zone in the upper part of the canyon wall contains abundant iron oxide, and at the rim of the canyon the sandstone contains veins of iron oxide as much as 2 in. thick and veins of manganese oxide a quarter of an inch or less thick. Irregular fragments as much as 6 in. in diameter consisting of spongy pyrolusite are on the surface near the pit.

These deposits probably are very small, because the thin veins of manganese oxide are irregularly distributed along the fracture zones and the apparent vertical extent is only 30 ft.

AREA WEST AND SOUTH OF LITTLE GRAND DISTRICT

DEPOSIT NEAR SAUCER BASIN

The deposit of manganese oxide near Saucer Basin (loc. 11, fig. 3) was not visited by the writers; this description is based on observations by L. G. Henbest, of the Geological Survey, made in 1930 in connection with the regional geological mapping of the Green River Desert-Cataract Canyon region.

The deposit is located south of Saucer Basin in T. 25 S., R. 16 E., and is 1.8 miles due south of the S¼ cor. sec. 32, T. 24 S., R. 16 E. It is about a mile west of the road from the town of Green River to the Robber's Roost Ranch.

Disseminated manganese oxide occurs in an area of 10 to 15 acres in the caliche cement of gravel on the crest of a low ridge. The cemented gravel, 4 or 5 ft thick, rests on Entrada sandstone and locally is overlain by a thin mantle of wind-brown sand which in places forms small dunes. The manganese content was not determined.

DEPOSITS ON CEDAR MOUNTAIN

Four manganese deposits are known on Cedar Mountain, in T. 18 S., Rs. 10 and 11 E. (fig. 15). They are 12 to 17 miles southeast of Huntington in Emery County (loc. 12, fig. 3) and are reached by a dirt road that branches from the main highway a mile south of Huntington. All the deposits have been prospected, but no commercial shipments of ore have been made.

The surface of Cedar Mountain slopes gently northwestward and is essentially a dip slope on the top of a bed of massive gray conglomeratic sandstone which is dissected by several canyons with steep walls. All the deposits are in the sandstone or in immediately overlying shale and limestone within a stratigraphic interval of 20 ft. The conglomeratic sandstone is in the Morrison formation and

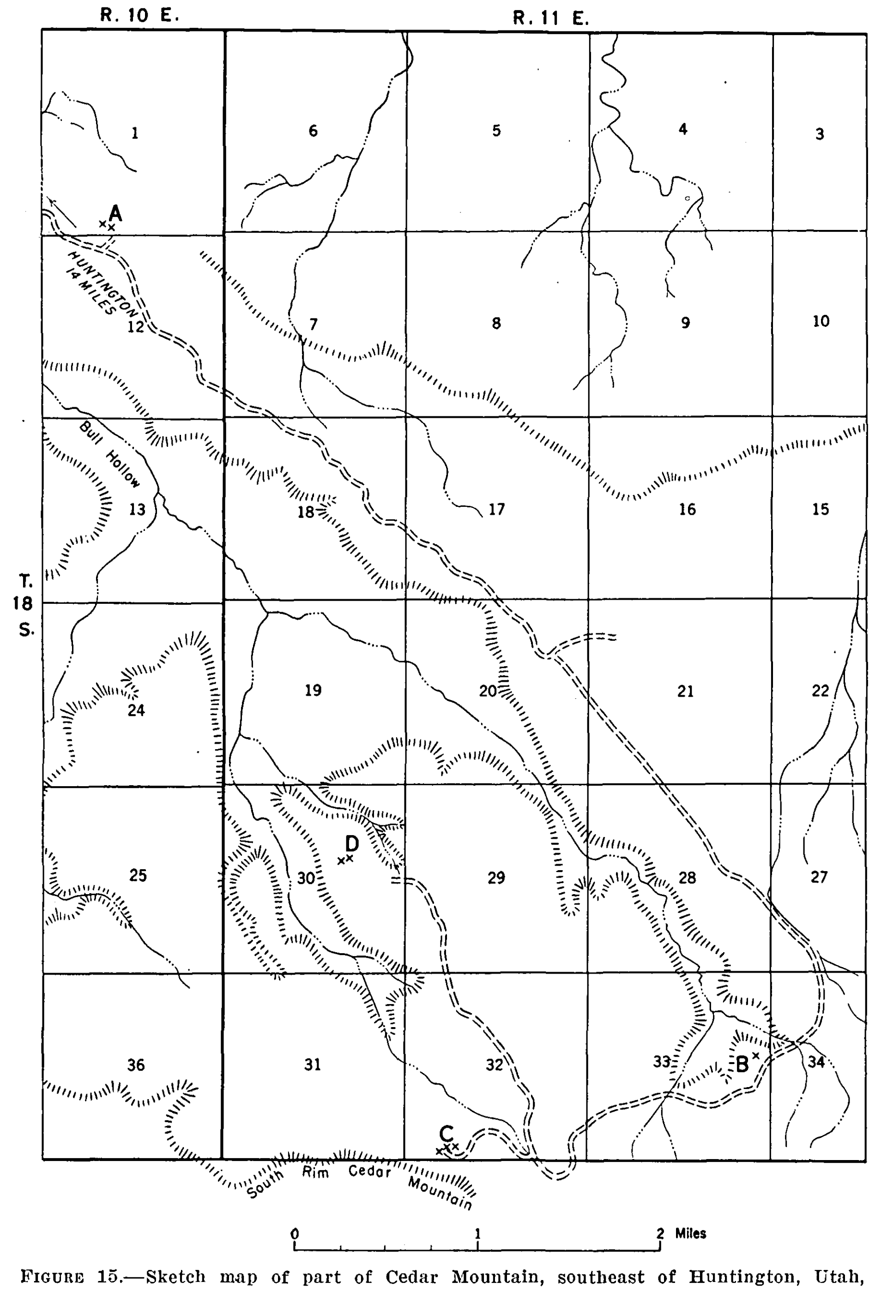

FIGURE 15.—Sketch map of part of Cedar Mountain, southeast of Huntington, Utah, showing the location of the manganese deposits.

about 200 ft below the top of the formation. In general the rocks dip about 2° NW.

Locality A.—At locality A (fig. 15), in the SW¼ sec. 1, T. 18 S.,

R. 10 E., about 700 ft west of the S¼ corner, manganiferous beds are exposed on the steep south and east slopes of a flat-topped ridge about 30 ft high which is bounded by a gulch on the south and by a shallow valley on the east. For 200 ft along the south side of the ridge manganese oxide (pyrolusite) occurs as nodules in shale and shaly limestone, but 100 ft across the gulch to the south these beds contain only a very few nodules of manganese oxide. A prospect pit 80 ft from the east end of the deposit exposes the following section:

Section measured on Cedar Mountain (loc. A, fig. 15)

	Ft	*in.*
Top of ridge.		
1. Gray to pink limestone, shaly in part; contains a very few small nodules of manganese oxide	15	0
2. Gray to pink limestone interbedded with gray shale; contains small manganese nodules in upper 3 ft	5	0
3. Gray sandy shale containing scattered small chert pebbles and abundant small nodules of manganese oxide	2	3
4. Gray shale	5	0
5. Gray, massive, conglomeratic sandstone containing chert pebbles as much as several inches in diameter; top of sandstone forms surface of much of Cedar Mountain.		

A chip sample of the manganiferous shale of unit 3 of the section contains 4.4 percent Mn, 0.1 percent S, and 0.4 percent P_2O_5. No zinc was found. The 3-ft zone of manganiferous shale and limestone in unit 2 is of comparable grade. In a second prospect pit, 130 ft to the west, unit 3 is 2 ft 5 in. thick and contains fewer but larger nodules of manganese oxide than in the other prospect pit; the manganese content probably is about the same or slightly less. One nodule of manganese oxide observed in this pit is 4 in. thick and 2 ft long. Shale and limestone 5 ft thick overlying the nodule-bearing shale are equivalent to unit 2 in the section cited; they contain only an occasional nodule of manganese oxide. West of the prospect pit no manganese was found in fairly good outcrops for a distance of 500 ft, except at one place where there is a trace at the approximate position of unit 2 of the section.

For 150 ft along the east side of the ridge, manganese oxide occurs as float. The manganese oxide occurs as nodules in interbedded limestone and shale, 7 ft thick, equivalent to unit 2 and the basal part of unit 1 of the section. The ore is probably no higher in grade than that sampled on the south side of the ridge. Strata equivalent to the manganese-bearing beds are well exposed for 1,000 ft north, 1,000 ft south, and 500 ft east of the deposit, but they contain only an occasional nodule of manganese oxide.

Assuming that the manganiferous strata are continuous between the outcrops on the east and south sides of the ridge, the deposit may contain several thousand tons of ore having an average manganese content of about 4 percent.

Locality B.—The manganese deposit at locality B (fig. 15), in the NE¼ sec. 33, T. 18 S., R. 11 E., about 450 ft northwest of the E¼ corner, is on a flat bench at the head of the canyon of Bull Hollow. Several shallow pits have been dug, most of them along a belt about 200 ft long on a narrow zone highly stained with iron oxide. On the northwest side of this zone is gray conglomeratic sandstone; southeast of the zone is gray fine-grained limestone overlain by sandy and shaly gray limestone containing scattered small pebbles. The limy beds southeast of the zone dip southeast and are of the type found stratigraphically above the conglomerate. The iron-stained zone and the aberrant dip of the limy beds suggest the presence of a small fault, downdropped on the southeast side and trending about N. 40° E., but no displacement could be detected in good exposures 400 ft northeast of the trenches.

No manganese oxide was seen in the trenches, but a small amount of fine-grained pyrolusite and psilomelane was found on the dumps. G. A. Johnson, of Huntington, one of the persons interested in the Cedar Mountain deposits, reported that manganese oxide was found along an open crack in the rocks. Some fragments found on the dump indicate that the manganese oxide also impregnates the conglomerate and partly replaces some of the limestone.

Only a very small amount of manganese oxide can be expected at the locality, and this small amount will contain much iron oxide, sand, and limestone.

Locality C.—A third deposit of manganese oxide (loc. C, fig. 15) is located near the south rim of Cedar Mountain in the SW¼ sec. 32, T. 18 S., R. 11 E. Three shallow prospect pits have been dug in the deposit on three distinct mineralized bodies of rock which are separated by barren rock.

One pit has been dug in the conglomerate capping Cedar Mountain. No ore shows in the pit, but a ton or less of hard, fine-grained oxide ore is piled nearby. Most of the waste rock is conglomerate stained with iron and manganese oxide. The writers infer that the ore came from a fissure in the conglomerate.

Two pits about 300 ft to the west are in gray limestone 16 to 20 ft above the top of the conglomerate. Some gray shale is interbedded with the limestone. Manganese oxide occurs as nodules and as veinlets crosscutting the shale and limestone. The nodules remaining in the pits are less than a foot in diameter, but G. A. Johnson reports that some that were removed were 2 to 3 ft in diameter. He reports, also, that several tons of ore obtained from such nodules have been shipped for testing. The ore contains much brown calcite and some coarsely crystalline barite. Not more than a few hundred pounds of ore could be expected from these prospect pits, but no doubt other small pods of ore could be found in the vicinity.

Locality D.—The fourth deposit on Cedar Mountain is in the NE¼ sec. 30, T. 18 S., R. 11 E., on the nearly flat surface between two canyons tributary to Bull Hollow.

The deposit is an essentially flat-lying blanket vein that partly replaces a thin bed of limestone overlying massive conglomeratic sandstone equivalent to unit 5 in the section at locality A. The limestone bed is overlain by 6 ft of gray shale that is at the stratigraphic position of the nodule-bearing shale at locality A but here appears to be barren of manganese. All the observed manganese oxide is within a triangular area about 500 ft long and increasing in width to a maximum of 120 ft at the southwest edge of the deposit. Toward the north and west the deposit is limited by the outcrop of the limestone bed, but toward the south the manganiferous limestone grades into barren limestone.

Several prospect pits, a few inches to a foot or two deep, have exposed the ore, which consists of hard, fine-grained manganese oxide. The manganese oxide ranges in thickness from a fraction of an inch to a foot; it occurs as irregularly shaped bodies separated by limestone containing little or no manganese. At places the oxide terminates abruptly at joints in the limestone; at other places the limestone contains two or more thin lenses of oxide in different stratigraphic positions within the bed.

The ore in the deposit is readily recoverable by stripping. The average manganese content would certainly be less than 25 percent, but a few hundred tons of higher-grade ore could probably be recovered by careful sorting.

DEPOSITS EAST OF ROCHESTER

Two manganese deposits east of Rochester are located in the NW¼ sec. 32, T. 21 S., R. 8 E., and near the center of sec. 6, T. 22 S., R. 8 E. (loc. 13, fig. 3). A graded dirt road that branches from the main highway at Rochester passes between the deposits. The deposit in sec. 32 is 1 mile north of the road; the deposit in sec. 6 is half a mile south of the road. The distance from Rochester to the deposits is approximately 7 miles. Several small pits have been dug in the northern deposit, but no work has been done at the southern one.

Both deposits are in the Morrison formation about 300 ft below the top of the formation. They are located in the upper part of a steep slope 150 to 200 ft high that is part of a prominent eastward-facing escarpment. The rocks that crop out in the slope are principally variegated shale containing some interbedded, brown-weathering gray limestone, thin lenses of conglomerate and sandstone, and irregularly shaped masses of chert. The rocks dip about 5° NW.

At the northern deposit the manganese ore occurs along the steep slopes of an eastward-projecting spur of an escarpment and can be traced along the outcrop for a distance of over 2,000 ft. The rocks are most abundantly manganiferous for a distance of about 900 ft along the south side of the spur, where the manganiferous zone is 50 ft thick. The manganiferous rocks are gray, lavender, or red shale containing small chert pebbles and interbedded with some sandstone and conglomerate. Overlying this is 10 ft of gray, brown-weathering, cherty, sandy limestone, the base of which is about 35 ft below the edge of a broad bench at the top of the spur.

The manganese oxide occurs as nodules and as crystalline or sooty impregnations irregularly distributed through the shale, principally in its lower part. At places the shale contains no visible manganese oxide; at other places nodules of the oxide are very few, although distributed through the entire thickness of the shale. Locally as much as 8 ft of shale contains abundant nodules estimated to constitute 15 to 20 percent of the rock, but these relatively rich beds occur at different stratigraphic positions and form lenticular bodies 150 ft or less in length. On the south side of the spur, along the east half of the outcrop, the base of the manganiferous zone consists of 5 to 25 ft of shale and some interbedded sandstone and conglomerate. This shale is silicified and forms a ledge. In it there is locally abundant manganese oxide in the form of nodules, veinlets, and impregnations in the shale. The cement in the conglomerate locally is replaced by manganese oxide. These manganiferous beds at places are 12 ft thick, but at other places the rocks are barren of manganese. Tabular masses of black, red, and yellow manganiferous chert are intercalated with the shale and in places oriented diagonally to the bedding. Around the point of the spur and along its north side the manganese is confined to this basal ledge of the manganiferous zone. Hard nodules of manganese oxide are scattered through silicified shale 5 ft thick; manganese oxide also impregnates a band of chert that overlies the shale. This chert has an average thickness of about 3 in. but is absent at places and elsewhere is as much as 3 ft thick. The average manganese content of the silicified shale and the associated chert along this part of the outcrop is estimated at about 2 percent.

It seems reasonable to infer that several thousand tons of ore containing 5 to 10 percent of manganese could be obtained from the deposits along the south side of the spur.

At the deposit south of the Rochester road, in sec. 6, T. 22 S., R. 18 E., manganese oxide was observed at two places 700 ft apart. At the southern locality the manganese oxide occurs for a distance of about 100 ft. Here two beds of manganiferous black chert, separated by pink pebbly shale 1½ ft thick, contain nodules of manganese oxide estimated to constitute 10 percent of the rock. The total thickness of the manganiferous beds is 2½ ft. They are 35 ft below the base of a brown-weathering, cherty, sandy limestone that is at about the same stratigraphic position as the limestone overlying the manganiferous beds in section 32 of the township to the north. Toward the north, for a distance of about 400 ft, the rocks contain no visible manganese minerals. At the point of the spur where the outcrop swings westward into the valley followed by the Rochester road, pink to gray shale 5 ft thick is irregularly impregnated with pyrolusite and contains large, irregularly shaped nodular masses of the oxide. The manganese content probably is about 10 to 15 percent. Overlying this is barren gray shale 2½ ft thick, but the next higher unit, a pebbly pink shale, contains a few percent of manganese in the form of nodules. These beds are manganiferous for only 100 ft westward along the north side of the spur. Southward along the east side of the spur and 100 ft from the point, gray, pebbly, and partly indurated shale 14 ft thick contains a few nodules of manganese oxide. At the point of the spur this deposit probably contains a few tons of ore averaging a few to several percent of manganese.

SNOW DEPOSIT ON MUDDY RIVER

The manganese deposit known as the Snow deposit is located on the northeast bank of the Muddy River near the center of sec. 19, T. 23 S., R. 7 E. (loc. 14, fig. 3). Several tunnels and pits have been dug in the deposit, but so far as is known no commercial shipments of ore have been made.

The deposit is 10 miles east of Emery and is reached by a rough, unimproved road that follows the valleys of Muddy River and one of its tributaries. The distance by improved roads from Emery to the Richfield branch of the Denver & Rio Grande Western Railroad at Salina, Utah, is 49 miles, and the distance to the main line of the same railroad at Price, Utah, is 57 miles.

Surface features at the deposit are shown diagrammatically on figure 16. The manganese ore is exposed along the northeast side of the valley near the base of a steep slope that rises from the edge of a narrow alluvial flat bordering the stream. The southeastern part of the deposit is about 50 ft below the crest of a narrow ridge, but the

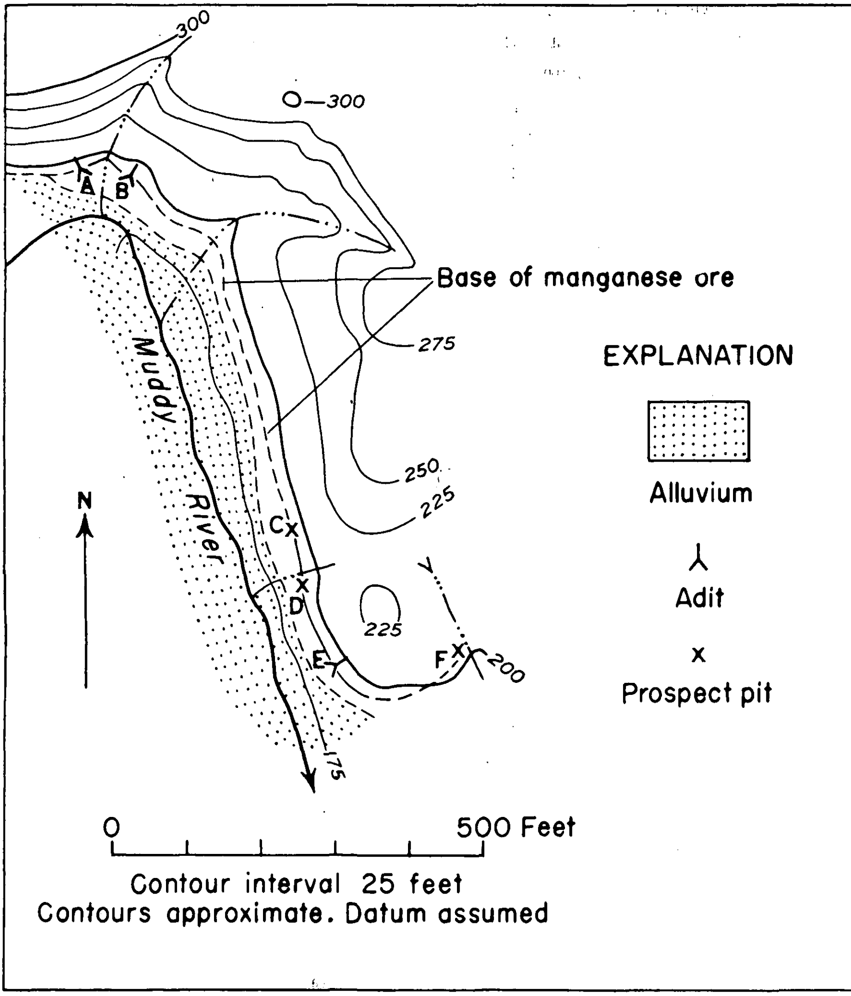

FIGURE 16.—Sketch map of the Snow manganese deposit on Muddy River, east of Emery, Utah.

ridge crest rises northward and near the northwest end of the deposit the ore zone is about 115 ft below the edge of a broad bench.

The rocks at the deposit are in the Morrison formation and consist of interbedded variegated shale and buff to gray conglomeratic sandstone containing thin beds of gray to brown limestone. The manganiferous zone is about 285 ft below the top of the formation. The strata dip about 3° W.

Manganese oxide is present in the rocks discontinuously for about 900 ft along the outcrop. At the north, or upstream, end the manganese-bearing rocks are concealed by the alluvium in the valley bottom. At the southern, or downstream, end the deposit grades into barren shale.

As shown on figure 16 there are short adits at localities A, B, and E and prospect pits at localities C, D, and F.

At locality A an open trench 27 ft long leads to an adit 5 ft long. The trench and adit are in a gray shale that contains occasional pebbles of chert and quartzite but appears to be practically barren of manganese.

At locality B an open trench 21 ft long leads to an adit 15 ft long. A section of the manganiferous zone at this locality follows:

Section measured at Muddy River (loc. B, fig. 16)

	Feet
Top of section.	
Brown sandy limestone containing nodular reddish-brown and yellowish-brown chert, stained by dendrites of manganese oxide. Dark irregular streaks through limestone also may be manganese oxide. Limestone is shattered, and dikes of clay as much as a foot wide cut across bedding	7
Gray shale containing occasional pebbles of quartzite and chert less than an inch in diameter; some red staining around pebbles; manganese dendrites on fracture surfaces	8
Gray sandy shale containing occasional pebbles of quartzite and chert less than an inch in diameter; contains nodules of pyrolusite and some psilomelane mostly less than half an inch in diameter; in places manganese oxide present as earthy pyrolusite	5
Gray shale on floor of adit; contains no visible manganese oxide.	

Along the trench and near the mouth of the adit the pebbly shale bed 5 ft thick contains abundant nodules of manganese oxide. A sample of this bed, cut from the floor to the roof of the adit, was shown by analysis to contain 14.7 percent manganese, most of which is in the form of nodules which could easily be separated from the shale. About 7 ft from the mouth of the adit a thin zone of gougelike clay dips 75° SW. The clay contains some nodules of manganese oxide and in places is stained dark. Farther into the adit, beyond the gougelike zone, the shale contains fewer nodules, and near the face of the adit there are only a very few scattered nodules. In the trench leading to the adit numerous joints trend about N. 70° W. Nodules in the shale are concentrated along vertical zones.

Westward to locality A these beds are concealed by talus. Southeastward from locality B the nodular shale can be traced along the outcrop for about 40 ft, beyond which it is covered by slope wash and talus to locality C.

The prospect pit at locality C is 13 ft wide, 12 ft long, and 13 ft high at the face. The following section was measured at the face and above it to the top of the brown limestone that appears to be the upper limit of the manganiferous rocks at this deposit.

Section measured at Muddy River (loc. C, fig. 16)

	Feet
Top of section.	
Brown sandy limestone containing nodules and lenses of brown, red, and yellow chert	5
Concealed by talus; probably all gray shale	9½
Top of prospect pit.	
Surface wash	3
Gray sandy shale containing abundant small pebbles of quartzite and chert; contains only a trace of manganese oxide in form of small nodules; some dendrites on joint planes	5
Conglomerate containing pebbles of chert and quartzite; trace of manganese oxide	2
Gray sandy shale containing abundant small pebbles of chert and quartzite; contains a few nodules of manganese oxide one-quarter to one-half inch in diameter; dendrites along joint planes; some patches of shale stained dark	3

At locality D, less than 100 ft south of locality C, is another prospect pit measuring 25 ft along the outcrop and 9 ft in height at the face. The lowest rocks exposed are 5 ft of gray sandy shale containing scattered nodules and irregular patches of manganese oxide. An analysis of a sample of this shale showed 7.9 percent manganese. Overlying it is 4 ft of conglomerate that extends to the top of the face in the prospect pit; above the pit is another 3 ft of conglomerate. The conglomerate contains chert and quartzite pebbles in a sandy matrix in part replaced by manganese oxide, mostly in the form of pyrolusite but including some psilomelane and manganite. Gray sandy shale 9½ ft thick overlying the conglomerate contains only a few stains of manganese oxide. Two feet of brown sandy limestone overlies this shale and contains chert in thin bands parallel to the bedding.

Between localities D and E nodules of manganese oxide are present in the soil. At locality E a trench 22 ft long leads to the mouth of an adit which extends 50 ft into the hillside. The trench and adit are in a gray sandy shale and shaly sandstone containing lenses of conglomerate. The sandy shale and shaly sandstone contain nodules and earthy patches of pyrolusite, and the matrix of the conglomerate has been partly replaced by pyrolusite and some manganite (fig. 17). Analysis of a composite of six samples from the floor to the roof of the adit through 6 ft of strata, taken at regular intervals, showed a manganese content of 12.7 percent. Above the portal of the adit the shale is cut by a vein of chalcedony 4 in. thick containing some crystalline manganese oxide. Gray sandy shale 14 ft thick containing veinlets and lenses of black and brown chalcedony and stains of man-

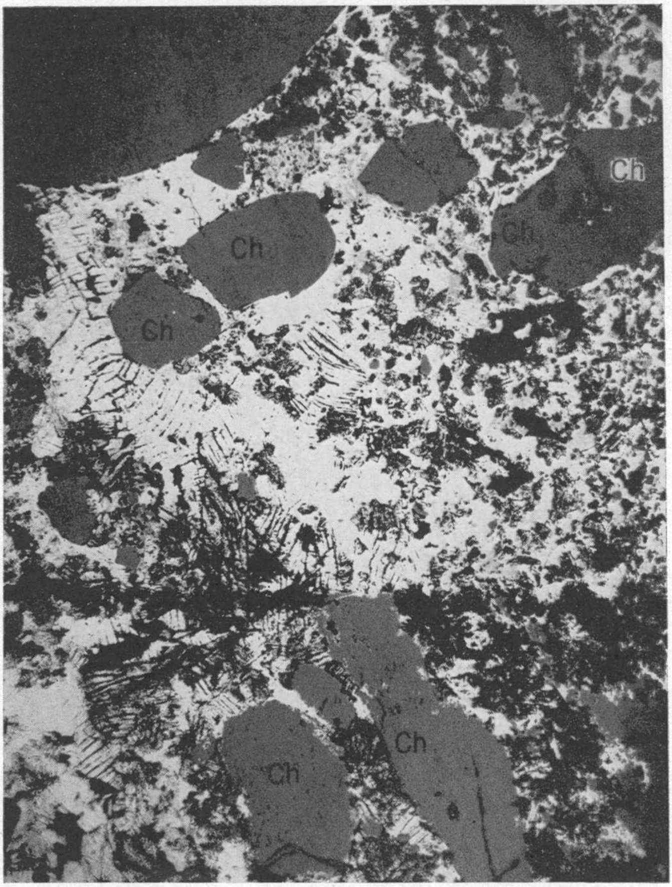

FIGURE 17.—Polished section of manganese ore from the Snow deposit in the Morrison formation on Muddy River, east of Emery, Utah. Manganese oxide, chiefly pyrolusite, forms the cement between embayed chert pebbles (Ch) and scattered sand grains. ×40.

ganese oxide extends from the roof of the adit to the base of an overlying brown sandy limestone 8 ft thick.

Eastward from locality E around the south end of the ridge traces of manganese oxide are present in the soil and in several shallow pits. At locality F a prospect trench 19 ft long and 5 ft high at the face exposes gray shale 2 ft thick containing a few nodules of manganese oxide. This shale is overlain by 1 ft of conglomerate containing a trace of manganese oxide in the matrix. The upper part of the face of the pit and the surface of the hillside for 14 ft above the top of the conglomerate are covered by surface wash. The brown sandy limestone at the top of the manganiferous zone is 6 ft thick and crops out at the top of the concealed interval.

About 100 ft toward the east, across a small gulch, the brown limestone at the top of the manganiferous zone is absent, and no trace of manganese oxide was observed at the stratigraphic position of this deposit.

Several thousand tons of ore containing 7 to 15 percent of manganese is present in the vicinity of localities B, D, and E. A considerable part of this manganese is in the form of soft, sooty pyrolusite and might be difficult to recover.

DEPOSIT ON BOULDER MOUNTAIN

A deposit of manganese ore on the east side of Boulder Mountain is located on the cliffs at the head of Pleasant Creek in northern Garfield County (loc. 15, fig. 3). The deposit is about 6 miles south of the town of Grover and is three-quarters of a mile east of the graded Grover-Boulder road. A branch road could easily be built to the top of the cliffs about 75 ft above the deposit. No manganese ore has been mined from the deposit.

The deposit is on the south side of a small spur projecting eastward from the line of cliffs. The manganese ore occurs in nearly flat lying, massive, buff to pink, limy, medium-grained sandstone in the lower part of the Carmel formation about 35 ft above the top of the Navajo sandstone. The beds of the Carmel formation underlying the manganiferous sandstone consist of thin-bedded sandstone and sandy shale containing chert nodules. Light-gray platy limestone, about 25 ft thick, overlies the manganiferous sandstone.

Manganese oxide occurs along the outcrop for a distance of 100 ft and through a maximum thickness of 9 ft of sandstone. The manganese occurs as pyrolusite in more or less cylindrical, pipelike masses as much as 2 in. in diameter around central cavities or tubes (fig. 18) and in irregular lenses as much as 1½ ft thick and 5 or 6 ft long. The manganese oxide impregnates the sandstone by replacing the cement and, to a lesser extent, the sand grains. All the ore contains abundant unreplaced grains of quartz sand. Considerable iron oxide is associated with the manganese oxide. It is most abundant near the margins of the manganiferous rock. The sandstone is well exposed on the north side of the small spur but is barren. In the vicinity are several prominent northward-trending joints, but manganese oxide does not occur along them. A few tons of highly siliceous ore containing 10 to 15 percent manganese could be obtained from this deposit.

DEPOSIT AT HUTCH PASTURE

A small deposit of manganese ore is located near the middle of sec. 36, T. 32 S., R. 7 E., along the canyon draining the southern part of

Hutch Pasture in the northern part of the Waterpocket Fold (loc. 16, fig. 3). Manganese oxide associated with more abundant iron oxide occurs near the middle of the Navajo sandstone in crosscutting veinlets one-eighth inch wide and in small, irregularly ovate bodies of the sandstone coating the sand grains and partly replacing the cement in the sandstone. This deposit does not contain recoverable ore.

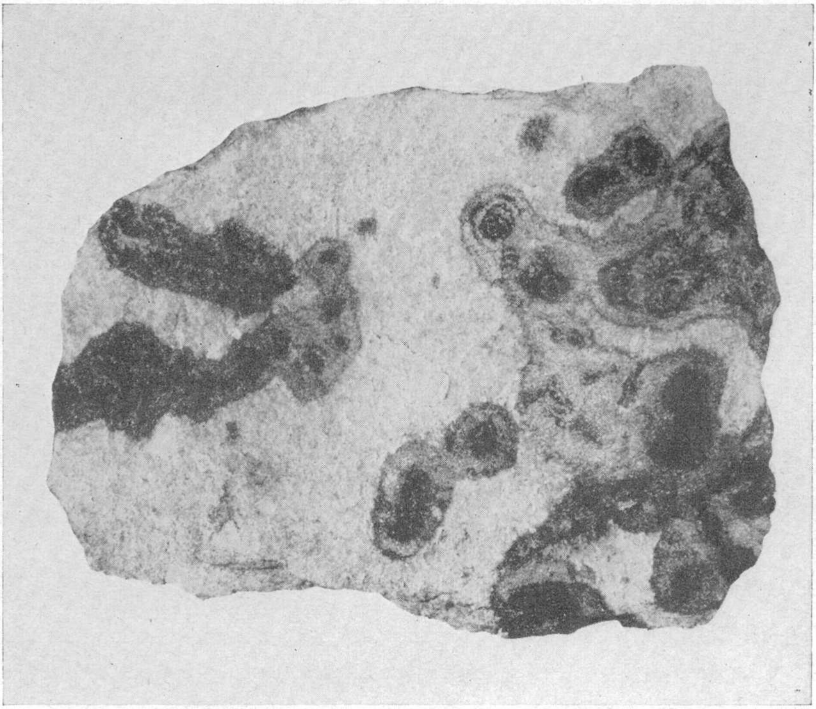

FIGURE 18.—Manganiferous sandstone from the Carmel formation, Boulder Mountain, northern Garfield County, Utah. The lime cement of the sandstone is replaced by manganese oxide in cylindrical masses around central cavities or tubes. Natural size.

DEPOSIT EAST OF KANAB

A manganese deposit east of Kanab is located in Kitchen Corral Canyon in the southern part of sec. 2, T. 42 S., R. 3 W., in southern Kane County (loc. 17, fig. 3). Considerable prospecting had been done at the deposit prior to August 1940, but so far as known, little or no ore has been shipped from it.

The Kanab-Paria graded dirt road extends eastward from Kanab and passes a few miles south of the deposit. The distance from the deposit to Kanab is 34 miles.

The deposit is in the side slopes of a small gulch tributary to Kitchen Corral Canyon and is 10 to 40 ft above the bed of the gulch. North of the deposit the ground rises irregularly to an eastward-trending cliff whose summit, half a mile away, is 700 ft above the deposit. Kitchen Corral Canyon is usually dry; no water has been developed in the immediate vicinity of the deposit.

The manganese ore occurs in the lower part of the Chinle formation about 100 ft above its base. The beds containing the manganese ore are principally gray and grayish-lavender shale, irregularly mottled with greenish gray. The shale may contain some volcanic material, as bentonitic clays are present in the Chinle formation at many places (Allen, 1930, pp. 283–288) and are probably more widespread in the variegated clays of the formation than has generally been recognized. Nodules of gray limestone with an average diameter of about 2 in. are common in the shale. Analysis of samples of the limestone nodules indicates a manganese content of 0.5 percent. A bed of fine-grained, brown-weathering, gray to pink limestone containing some manganese oxide and some small crystals and veinlets of secondary calcite is interbedded with the shale and immediately overlies the manganiferous shale. It forms a ledge and is the rim rock of a prominent bench on the west side of the gulch. The rocks at the deposit dip about 1½° SW. No faults having a large displacement were observed, but slickensided surfaces are common in the manganiferous shale and numerous joints occur in the overlying limestone.

A ridge about 700 ft south of the manganese deposit trends transverse to Kitchen Corral Canyon and has been trenched by the stream. It consists mainly of huge landslide blocks and slabs of sandstone from the beds that form the cliffs north of the deposit.

The shale at the deposit is manganiferous through a thickness of as much as 17 ft and for an outcrop distance of about 1,000 ft (fig. 19); some manganese oxide is present, also, in the basal part of the overlying limestone. The manganese occurs principally as pyrolusite with some psilomelane. The oxides are distributed through the shale and the limestone as nodules 3 in. or more in diameter, as vein fillings, and as fine particles disseminated through the host rock. Some of the oxide nodules are hard and finely crystalline and have a nearly smooth to very rough outer surface (figs. 20 and 21). Other nodules are small, irregularly shaped, and more or less interconnected masses of earthy oxide with wedgelike apophyses fingering into the shale (fig. 22). Sooty oxide impregnates the shale, coats nodules of the hard oxide and nodules of limestone, and coats joint faces.

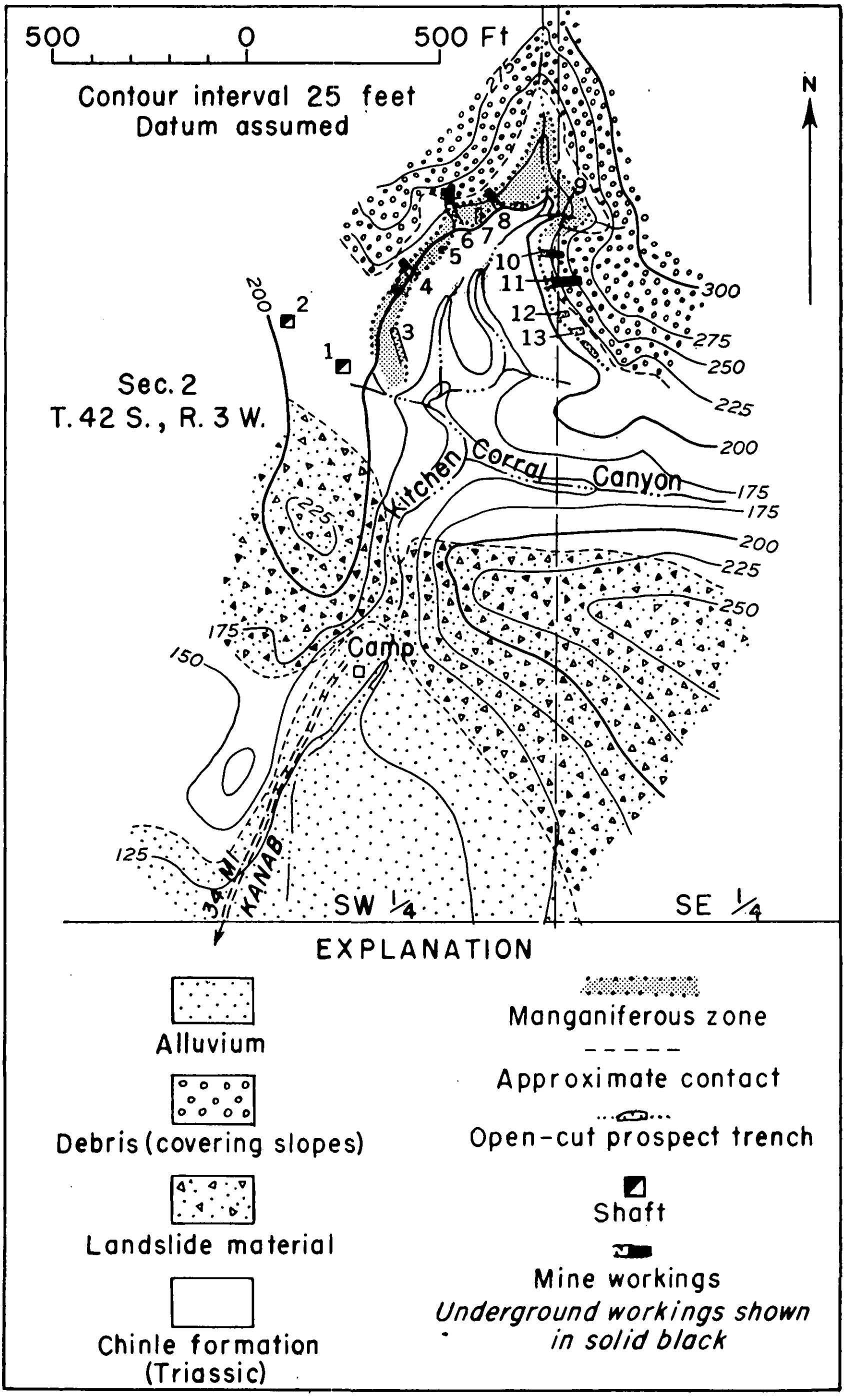

FIGURE 19.—Map of the manganese deposit in Kitchen Corral Canyon, in sec. 2, T. 42 S., R. 3 W., east of Kanab, Utah.

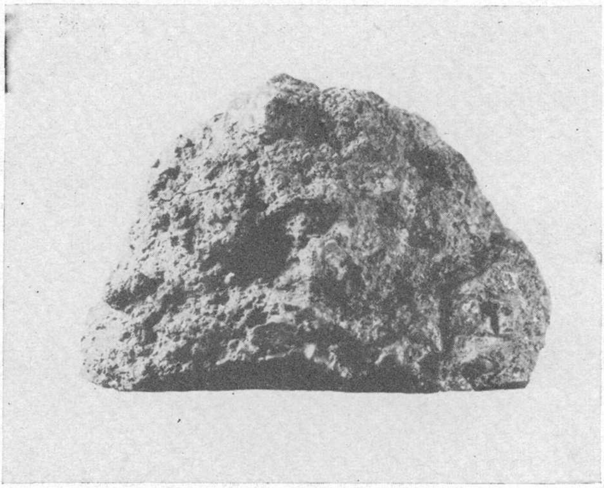

FIGURE 20.—Exterior surface of part of a hard nodule of pyrolusite from the manganese deposit east of Kanab, Utah. Natural size.

FIGURE 21.—Polished surface of the same nodule shown in figure 20. Finely crystalline pyrolusite contains iron oxide (dark gray) in masses of various sizes and shapes. $\times 45$.

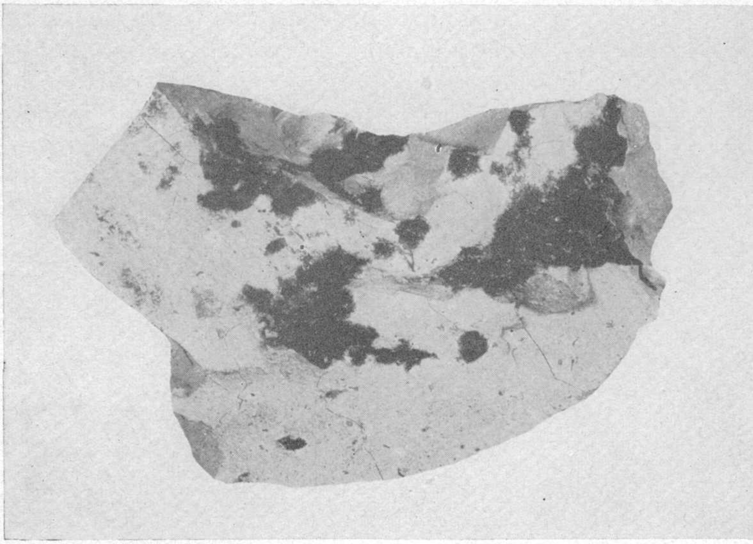

FIGURE 22.—Manganese ore from shale of the Chinle formation in the deposit east of Kanab, Utah. Soft, earthy manganese oxide (black) apparently has locally replaced the shale (gray). Natural size.

Hand-picked fragments of the hard nodules of manganese oxide from locality 4 (fig. 19) were analyzed by Charles Milton in the Chemistry Laboratory of the Geological Survey with the following results. Column A indicates the analysis as made; in column B it is recalculated, soluble to 100 percent.

	A	B
Insoluble:		
SiO_2 (7.35), $BaSO_4$ (0.64), R_2O_3 (1.99)	9.98	
Soluble:		
SiO_2	.15	0.18
BaO	1.46	1.62
Na_2O	.22	.24
K_2O	.85	.94
CaO	.47	.52
MgO	.09	.10
Fe_2O_3	1.32	1.47
Al_2O_3	.40	.44
CaO, PbO	.10	.11
H_2O	6.20	7.01
MnO	68.10	19.32
O	11.33	-----
MnO_2	-----	68.05
	100.67	100.0

A few brown, iron-rich nodules in the deposit (fig. 23) are several inches in diameter and have a rough botryoidal exterior. Many of them have a core of white clay containing veinlets of barite, calcite, and manganese oxide. Some of the nodules are principally iron oxide containing little manganese oxide; others consist of pyrolusite containing little iron oxide. A partial analysis of a nodule containing little manganese oxide but containing thin shells and irregular radial

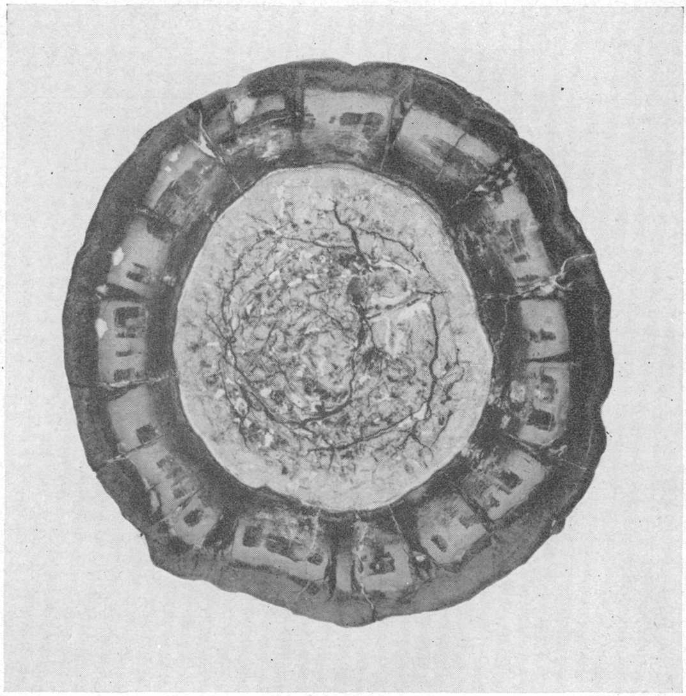

FIGURE 23.—Section of an iron oxide-chalcedony nodule from the manganese deposit in the Chinle formation east of Kanab, Utah. The clay core is crossed by numerous veinlets of pyrolusite (black) and contains some barite (white). The shell consists of finely to coarsely interlaminated limonite and chalcedony crossed by radial veinlets of calcite. The light band consists mainly of limonite with rectangular patches of chalcedony. The outermost thin layer of the shell locally contains laminae of manganese oxide. Natural size.

veinlets of barite and carbonate showed 0.40 percent MnO, 69.82 percent Fe_2O_3, 0.03 percent P_2O_5, 4.09 percent $BaSo_4$, and 0.42 percent BaO. Other iron-rich nodules show regular banding of limonite alternating with chalcedony or a carbonate, presumably calcite. The limonite bands are bordered with a thin coating of black manganese oxide which in places fills the space between limonite bands. Chalcedony lines openings and fills cracks in some nodules.

The character and occurrence of the manganese is described in greater detail in the following descriptions of individual workings. The localities are those shown on figure 19.

Locality 1.—A shaft 9 ft square and 11 ft deep located on the flat bench west of the gulch starts in the top of the limestone overlying the manganiferous shale. The shaft was dug to a depth sufficient to explore only the upper half of the manganiferous shale. Apparently little manganese was found. The material on the dump consists of black, sooty coatings on the surfaces of a few limestone nodules and sooty manganese oxide in the shale.

Locality 2.—A second shaft west of the gulch has its collar 7 ft below the top of the limestone and is 18 ft deep. It explored the full thickness of the manganiferous shale; shale on the dump contains a few small patches or stains of sooty manganese oxide and a few nodules of hard crystalline oxide.

Locality 3.—An open-cut about 100 ft long exposes 6 ft of the lower part of the manganiferous shale. The only manganese oxide observed in this cut is near the north end where a few veinlets a fraction of an inch thick and films of sooty manganese oxide crosscut the shale.

The absence of appreciable quantities of manganese in the workings at localities 1, 2, and 3 definitely limits the southward extent of the deposit along the west side of the gulch. Strata equivalent to the manganiferous shale are well exposed in a large area south and west of these workings, but only an occasional nodule of manganese oxide could be found in it.

Locality 4.—A trench 40 ft long and an adit 20 ft long at locality 4 trend N. 45° W. The following section was measured in the workings and in the slope above the mouth of the adit.

Section measured at Kitchen Corral Canyon (loc. 4, fig. 19)

Top.	*Ft*	*in.*
Limestone, fine-grained, gray; weathers brown	3	0
Shale, gray, containing limestone nodules slightly impregnated with manganese oxide. Shale contains masses of earthy or sooty pyrolusite as much as 3 in. in diameter, but manganese content of shale is low	8	0
Shale, purple, with irregularly shaped white spots as much as half an inch in diameter; limestone nodules in upper part coated and slightly impregnated with manganese oxide. Nodules of hard manganese oxide in shale irregularly shaped, with average diameter of about one-third inch. Concentration of manganese oxide greatest along trench; in adit this unit practically barren of manganese	6	0
Shale, finely mottled purple and white; contains some hard nodules of manganese oxide, but oxide occurs principally in earthy, irregularly shaped nodular masses as much as 7 in. in diameter elongate across bedding and containing some shale	2	8
Floor of trench.		

A chip sample of 10 ft of the lower part of the manganiferous shale from the wall of the trench was analyzed by the Bureau of Mines with the following results:

	Mn	Fe	Insoluble	S	P	CaO	Zn
Head sample	8.6	2.13	61.04				
Nodules, hand-sorted	37.4	3.91	23.80	0.18	0.038	2.65	<0.01
Fines, hand-sorted	5.4	1.86	66.02				
Shale, hand-sorted	.8	2.15	70.52				

The distribution percent, by total weight and by total manganese content, of the various fractions was:

	Total weight	*Total Mn*
Heads	100	100
Nodules	13.8	59.1
Fines	62.3	38.7
Shale	23.9	2.2

Another chip sample, taken by S. G. Lasky, of the Geological Survey, was cut horizontally along 15 ft of the north wall of the trench. The percentage of manganese contained and the distribution percent by manganese content were found by the Geological Survey to be:

	Percent Mn contained	*Distribution percent of total Mn*
Heads (calculated)	4.4	100
Nodules (8 percent of sample)	36.3	65.6
Remainder (92 percent of sample)	1.7	34.4

Locality 5.—An open-pit at locality 5 trends N. 70° W., is 20 ft long and 6 ft wide and exposes 11 ft of purplish shale. No manganese oxide was visible in the shale except some earthy manganese oxide in a surface layer 18 in. thick along the edges of the pit. Gray calcareous shale in the slope above the pit is slightly stained by manganese.

Locality 6.—The largest workings in the deposit are at locality 6. An open trench leading to the portal of an adit trends N. 35° W. and is 75 ft long. The adit continues with the same trend for 10 ft and then trends N. 15° E. for 55 ft to the face. A crosscut 30 ft long, trending N. 50° W., branches from the main adit 20 ft from the face. Timbers have been removed from the workings, and large masses of shale have caved from the roof, especially near the mouth of the crosscut.

The section of rocks exposed at locality 6 is as follows:

Section measured at Kitchen Corral Canyon (loc. 6, fig. 19)

	Feet
Top.	
Limestone, gray, fine-grained, brown-weathering, containing very thin veinlets of manganese oxide	5
Shale, gray; contains lenses of earthy manganese oxide parallel to bedding and abundant nodules of manganese oxide in lower 8 in	4
Shale, purple; scattered irregularly shaped white spots; nodules of gray limestone partly replaced by manganese oxide; nodules of hard, earthy manganese oxide as much as 1 in. in diameter; shale is abundantly slickensided, and slickensides curve around and polish some hard nodules of oxide	8
Floor of trench.	

The manganese oxide is irregularly distributed through the shale. Commonly nodules are concentrated through several feet of beds, but the concentration ends abruptly against a vertical or steeply dipping plane, on the other side of which the rock is essentially barren of manganese oxide. In the trench near the mouth of the adit a vertical vein of hard manganese oxide 6 in. wide cuts across 3 ft of strata. Near the face of the adit the average grade of the ore appears to be lower than that of the ore near the portal and along the trench.

Two chip samples of the ore were obtained and analyzed by the Bureau of Mines. A sample of 5 ft of shale from the southwest wall of the open trench, about 20 ft from the outer end, contained 18.2 percent manganese, 2.3 percent iron, and 42.10 percent insoluble residue. A sample of 5 ft of shale from the west wall of the adit just north of the crosscut contained 9.5 percent manganese, 2.4 percent iron, and 57.7 percent insoluble residue, but the shale for a thickness of 3 ft above the section sampled is practically barren of manganese oxide. A sample obtained by S. G. Lasky and analyzed by the Geological Survey was cut from a thickness of 14 ft of shale at locality 6. The sample contained 6.9 percent manganese, and the nodular ore in 10.6 percent of the sample contained 37.6 percent manganese as contrasted with 3.2 percent manganese in the residual 89.4 percent of the sample.

Locality 7.—The following rocks are exposed in an open-cut at locality 7:

Section measured at Kitchen Corral Canyon (loc. 7, fig. 19)

	Feet
Top.	
Brown-weathering, fine-grained, gray limestone	7
Light-gray, limy shale; lenses and nodules of soft earthy manganese oxide and a few nodules of hard oxide	5
Purplish shale; irregular patches of bleached shale; a few nodules of gray limestone	10
Floor of pit.	

The occurrence of manganese oxide in the purplish shale is similar to the occurrence of manganese at locality 6, and the quality of the ore seems to be about the same.

Locality 8.—An open-cut and an adit at locality 8 trend N. 35° W. The open-cut approach to the adit is 5 ft wide and 20 ft long, and the adit is about 30 ft long. Along the walls of the adit beds of light-gray, gritty clay dip 10° NW., and the adit slopes in accordance with the dip of the beds. The surface rocks do not reflect this anomalous dip, which may be due to cross bedding. The following section was measured at the face in the adit.

Section measured at Kitchen Corral Canyon (loc. 8, fig. 19)

	Ft	*in.*
Purple shale, barren of manganese oxide except for tiny nodules along crosscutting veins	3	2
Purple shale, with abundant nodules and irregular earthy patches of manganese oxide		5
Light-gray gritty clay; lenses of manganese oxide; at places clay is nearly barren of manganese oxide, and at other places oxide comprises nearly half of unit		4
Purple shale, barren of manganese oxide		8
Light-gray, gritty clay; abundant lenses of hard to earthy manganese oxide elongate parallel to bedding and comprising about one-fourth of bed		6
Floor of adit.		

The concentration of manganese oxide is extremely variable in these beds as exposed in the walls of the adit and the trench.

Six feet from the face earthy manganese has irregularly impregnated the top unit of purple shale. Ten feet from the face the upper light-gray, gritty clay contains the same type of earthy manganese oxide as the upper shale unit on the west wall of the adit, but on the opposite wall the gritty bed and the lower half of the overlying shale are barren. In the walls of the outer 20 ft of the adit and the open-cut approach, each of the rock units locally is barren of manganese oxide. The rocks are crosscut by a few vertical veins of manganese oxide a fraction of an inch wide.

Two chip samples from this locality were obtained and analyzed by the Bureau of Mines. A composite sample of vertical cuts 5 ft long from the floor to the roof of the adit 3 ft from the face contained 9.4 percent manganese, 3.2 percent iron, and 61.2 percent insoluble residue. A second sample from a vertical cut 5 ft long from the surface to the base of the manganiferous shale (about 1½ ft above the floor of the trench) was obtained about 15 ft from the outer end of the trench. It contained 7.2 percent manganese, 2.2 percent iron, and 65.2 percent insoluble residue. A vertical chip sample collected by S. G. Lasky from 7½ ft of beds at this locality was analyzed by the Geological Survey and found to contain 6.3 percent manganese; 8.3

percent of this sample was separated by washing and found to contain 42.2 percent manganese, whereas the remaining 91.7 percent of the sample contained only 3.1 percent manganese.

Fifty feet east of locality 8 two shallow pits show only traces of manganese oxide, although a few nodules of manganese oxide were observed in the float. The manganiferous beds are exposed toward the east and can be followed around the closure in the gulch. They are considered to be essentially barren of manganese, as they contain only an occasional nodule of the oxide.

Locality 9.—Manganese oxide in the shale in the bluff on the south side of the gulch at locality 9 has been explored by a shallow pit. Purple shale, 8½ ft thick, contains a few hard nodules of manganese oxide, most of which are about a quarter of an inch in diameter. There also are many small, irregularly shaped patches of earthy oxide. A thin bed of gray limestone overlying the shale contains thin veinlets of manganese oxide. Gray shale overlying the limestone is 8 ft thick and extends to the base of the main limestone bed overlying the manganiferous shale. The shale contains scattered nodules of gray limestone slightly veined by manganese oxide, but the shale itself contains no visible manganese oxide.

Locality 10.—An open trench and an adit at locality 10 trend S. 85° E. The open-cut is 25 ft long, and the adit, which is caved, has an estimated length of 30 ft. Purple shale, small patches of which are bleached gray, is 8 ft thick. Manganese oxide occurs in the shale in a few hard nodules, but principally in small earthy patches. A small open pit about 25 ft to the north and another pit about the same distance to the south of locality 10 expose 4 ft of slightly manganiferous shale equivalent to the lower part of the shale exposed in the adit.

Locality 11.—At locality 11 an adit 60 ft long and an open trench, 42 ft long, that leads to it trend N. 80° E. About 11 ft of shale was explored by the workings. The upper 6 ft of the shale has the purple color typical of the shale in this vicinity and contains nodules of both the hard and the soft manganese oxide fairly uniformly distributed.

A sample cut vertically through 4 ft of shale at the face of the adit was obtained and analyzed by the Bureau of Mines. One portion of the sample was analyzed as a head sample, and the other was hand-sorted into nodules, waste shale, and fines. The results of the analyses of the different portions are as follows:

	Mn	Fe	Insoluble	S	P	CaO	Zn
Heads	6.8	1.85	66.3	------	------	------	------
Nodules	30.3	1.54	33.9	0.14	0.03	0.51	<0.01
Fines	3.6	1.73	69.2	------	------	------	------
Shale	1.2	2.31	69.9	------	------	------	------

The distribution percent, by total weight and by total manganese content, of the various portions was:

	Total weight	Total Mn
Heads	100	100
Nodules	15.6	65.6
Fines	60.0	30.3
Shale	24.5	4.1

Locality 12.—An open-pit at locality 12 is 25 ft long and 3 ft wide and trends N. 60° E. Six feet of purple shale exposed in the pit beneath the surface mantle of sandstone debris contains hard and soft nodules of manganese oxide. A sample of 5 ft of the shale was obtained and analyzed by the Bureau of Mines. The sample contained 16.6 percent manganese, 1.72 percent iron, and 50.20 percent insoluble residue.

Locality 13.—The open-cut at locality 13 is 28 ft long and trends N. 50° E. Manganiferous purple shale 11 ft thick is exposed in the open-cut. The upper 5 ft of the shale contains hard nodules of manganese oxide and nodules of gray limestone slightly veined with the oxide. The lower 6 ft of the shale here appears to contain more nodules of hard oxide than on the east side of the gulch, but the total manganese content is estimated to be about the same.

Fifteen feet southeast of locality 13 is the end of a trench that extends for 60 ft along the outcrop. It reveals the upper part of the manganiferous shale as exposed at locality 13, but little manganese oxide is visible. A few nodules of the oxide occur as float on the slope above the pit.

On the point of the spur 150 ft southeast of locality 13 gray and purple shale equivalent to the manganiferous shale is well exposed, but no manganese oxide was observed in it. Similar exposures of the shale for a quarter of a mile or more farther east also are barren of manganese. The limestone bed at the top of the manganiferous zone is absent on this point, and the greenish-gray limy shale between the manganiferous purple shale and the limestone is absent to the east.

The mineralization at the deposit in Kitchen Corral Canyon is essentially restricted to two small areas on opposite sides of the gulch. Possibly the two areas represent parts of a single ovate area from which most of the manganiferous shale has been removed during erosion of the intervening gulch. The content of manganese oxide has a rather wide range, as shown by the analyses, but within the limits of the mineralized area the shale appears to be barren of the oxide only at locality 5. The quality of the ore varies widely; the average manganese content probably is less than 10 percent.

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