THE MANGANESE ORE BODY
AT THE
THREE KIDS MINE,
CLARK COUNTY, NEVADA

A THESIS

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By

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ABSTRACT

The Three Kids manganese deposit lies within the lake and playa sediments belonging to the Muddy Creek formation of Pliocene (?) age. The manganiferous zone can be divided into three distinct sections: the lowermost is a series of thin manganese oxide beds separated by layers of tuff; the middle section is a thick massive manganese oxide bed; the upper section is composed of manganese oxide fragments in a tuffaceous sediment. The main manganese mineral is pyrolusite with smaller amounts of hollandite and cryptomelane. The mineral celadonite occurs extensively throughout the mining area; its origin is problematical.

The origin of the manganese is difficult to ascertain as the deposit exhibits both hydrothermal and sedimentary characteristics.

INTRODUCTION

SCOPE OF THE PAPER

The author was employed at the Three Kids mine of 2 years as Junior Mine Engineer. During this time an acute interest was developed concerning this deposit. A search of the literature revealed several papers concerned with the mine, but none could conclusively show the source of the manganese, nor was the mineralogy of the deposit accurately determined. Some authors advocated a sedimentary origin while others a hydrothermal; most lumped the various manganese oxides present into a catch-all term "wad".

X-ray diffraction methods were used by the author to determine what manganese oxide minerals were present in the "wad" ore. Thin section and polished section work coupled with field work revealed some additional information which seems to unravel the sedimentary-hydrothermal enigma.

ACKNOWLEDGEMENTS

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LOCATION, CLIMATE, VEGETATION AND TOPOGRAPHY

The Three Kids district is located 15 miles southeast of Las Vegas and 6 miles northeast of Henderson, on Highway 41, in Clark County, Nevada. (Fig. 1)

The principal workings of the Three Kids mine are slightly less than 2,000 feet above sea level and are situated at the upper edge of the sloping plain along the northwest foot of the River Mountains.

In the district the climate is characteristic of the arid Southwest. In mid-summer temperatures of 110° F or greater are common. Rainfall in the area is scant and uncertain, usually less than 5 inches per year. Most of the rain falls during "cloudbursts" that commonly occur in the months of July and August. In winter some snow usually falls at the higher altitudes; it is very rare in the valleys.

The vegetation in the Three Kids district and adjacent areas is very sparse. Creosote is the most common shrub with mesquites occasionally growing in intermittent stream courses.

Some clumps of "sand grass" grow in bunches on the slopes of alluvial fans.

The topography at the mining site is gentle, being situated on the upper edge of a broad alluvial fan. The adjacent River Mountains are steep and rugged with a difference in elevation of over 1,000 feet between the highest peak and the valley floor.

HISTORY OF MINING

According to Jones and Pardee (1919) the Three Kids deposit was discovered in the fall of 1917, and by the summer of 1918 it had produced about 12,000 tons of ore, which contained approximately 40 percent manganese. All of this ore was taken from an open pit near the western edge of the property (Three Kids pit). Several thousand tons in addition were produced in 1919 and 1920.

Only a few hundred tons of ore were produced during the period 1920-40, until the M. A. Hanna Co. and the Western Minerals Exploration Co. each took over a portion of the property.

In the fall of 1940 these owners granted permission to the United States Bureau of Mines to drill, trench, and sample their properties in order to determine the total quantity of ore. The U. S. Bureau of Mines (Hunt, McKelvey, and Wiese, 1942) estimated the reserves of the property as being

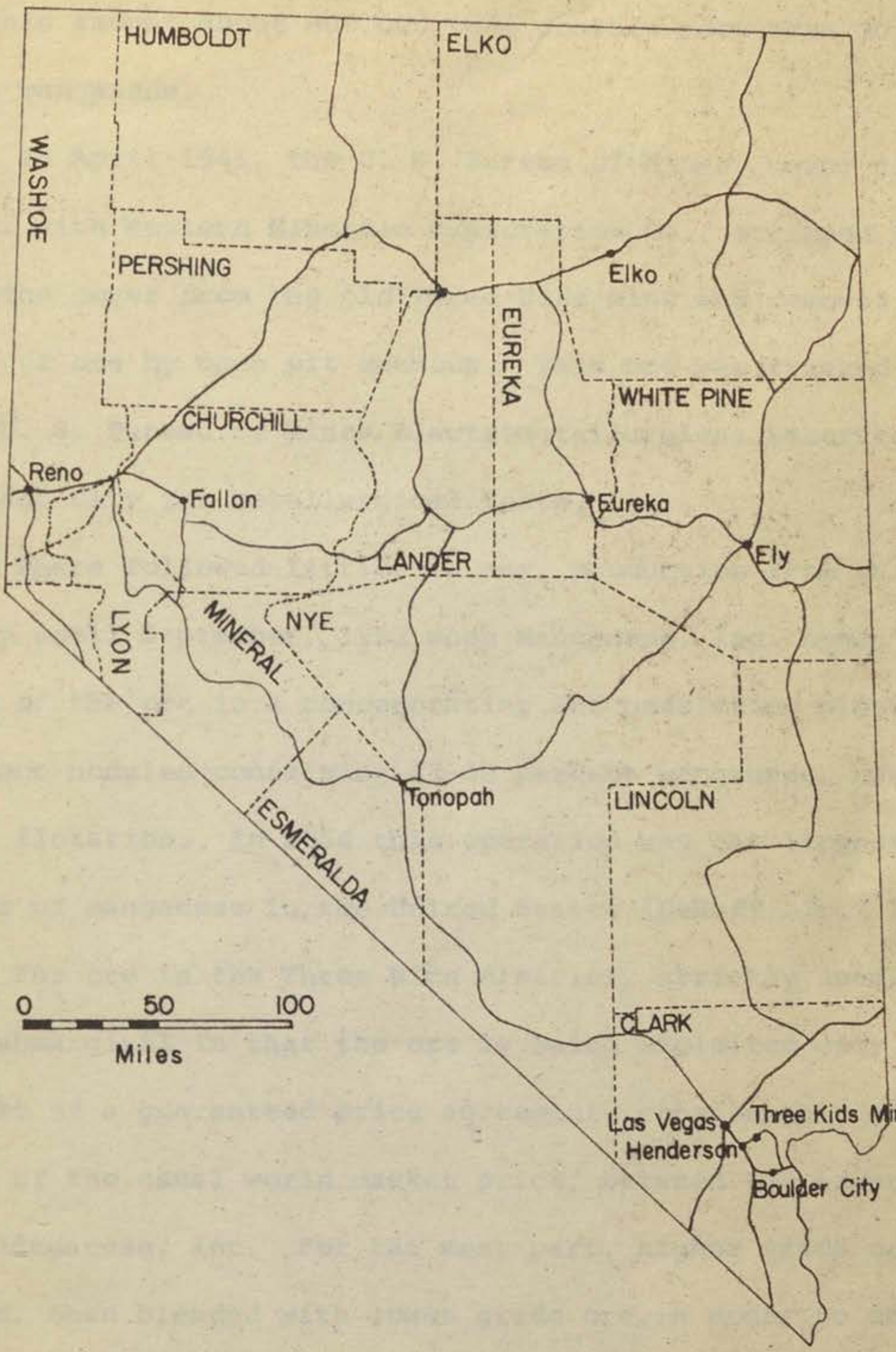

Figure 1

INDEX MAP SHOWING LOCATION OF THREE KIDS MINE

5,500,000 short tons of ore averaging 10 percent manganese. Of this amount about 800,000 tons contain more than 20 percent manganese.

In April 1941, the U. S. Bureau of Mines, under contract with Western Minerals Exploration Co., stripped the surface cover from the old Three Kids mine and removed 3,650 tons of ore by open pit methods. This ore was trucked to the U. S. Bureau of Mines Electrometallurgical Laboratory at Boulder City for metallurgical tests.

There followed little, if any, production from this property until September, 1952 when Manganese, Inc. began treatment of the ore in a concentrating and nodulizing plant to produce nodules containing 47-48 percent manganese, using soap flotation. In 1954 this operation was the largest producer of manganese in the United States (DeHuff, Jr., 1956).

The ore in the Three Kids district, strictly speaking, is submarginal in that the ore is being exploited only as a result of a guaranteed price agreement, considerably above that of the usual world market price, between the government and Manganese, Inc. For the most part, higher grade ore is mined, then blended with lower grade ore in order to obtain a desired mill feed containing around 18 percent manganese. The property to date has yielded several million tons of manganese oxide averaging between 15 and 20 percent manganese.

Since the stoppage of the manganese stock piling program (1959), Manganese, Inc., has ceased mining operations.

GENERAL GEOLOGY

STRATIGRAPHY

The general geology of the district has been described by Hale (1918), Jones and Pardee (1919), Hewett and Webber (1931), and Hunt, McKelvey, and Wiese (1942). As pointed out by them, the manganese deposit is in sedimentary rocks, which overlie a thick series of volcanic rocks. Both the sedimentary and the volcanic rocks have been tilted and faulted. The sedimentary rocks are part of the Muddy Creek formation (Longwell, 1928), which is an extensive lake and playa deposit of Pliocene (?) age in southern Nevada. The volcanic rocks are assumed by Longwell to be of Miocene age. The following section given by Hunt, McKelvey and Wiese (1942) illustrates the sequence and character of the rocks in the district.

Pliocene (?) Muddy Creek formation:

Gypsum, red beds; gypsum, red and gray clay, tuff, sandy shale, sandstone; gypsum beds are massive but contain thin contorted interbeds of clay and silt; thickness varies due to unconformity at the top. Maximum thickness..1,000'

Manganiferous beds; associated with tuff in the lower portion and with clay and some sand in the upper portion. In beds and finely disseminated fragments or blebs............0-75'

Basal conglomerate; andesitic (?) lava, flow breccia, and interbedded conglomerate containing pebbles, cobbles, and boulders derived from underlying volcanic rocks; some boulders are a foot in diameter, but pebbles predominate and are usually less than 2 inches in diameter; boulders are generally isolated in a reddish-brown laminated matrix. Thickness varies because of basal overlap.........0-500'

Angular Unconformity.

Miocene (?) Volcanics:

Latite flow; chocolate color, glassy matrix; feldspar is uniformly sodic plagioclase; hornblende common. Thickness varies due to unconformity at top...........................0-300'

Latite breccia and flow breccia; light colored. Andesitic breccia and vesicular flows. Maximum thickness.......................300-400'

Latite; reddish-brown; rounded blades of sodic plagioclase, sporadic biotite, reddish glassy matrix....................................500'

Pliocene (?) Muddy Creek Formation

According to Longwell (1928, 1949), the Muddy Creek formation is a lake and playa deposit which is probably Pliocene in age. About 1,000 feet of the formation is exposed in the district, (Hunt, McKelvey, and Wiese, 1942).

The formation was deposited in a basin produced by earlier deformation. The graben in which the Three Kids pit is located (see Plate I), according to Hunt, McKelvey, and Wiese (1942), came into existence before Muddy Creek time and was an elongate topographic depression that connected with the more open part of the basin to the North. The formation was evidently deposited upon a rough surface produced by the erosion of faulted and tilted blocks of the underlying lavas, for it extends unconformably across different members of the lava series, and in places the strata at the base of the Muddy Creek formation are cut off by overlap against the old erosion surface.

The portion of the Muddy Creek formation present in the Three Kids district can be divided into three units. The uppermost is composed of massive gypsum beds, red and gray clay beds and a small amount of tuff, arenaceous clay and sandstone. The middle unit is the manganiferous zone. The manganese-bearing beds are conformably overlain by the gypsum and clay unit. It is composed of manganese oxide-bearing tuffs in thin bands and massive beds in the lower portion and tuffaceous clays and sands containing fragments of manganese oxide in the upper portion of the unit. Beds of pure tuff and thin seams of tuffaceous clay and sand separate the manganese-bearing tuffs in the lower portion of this zone, giving it a "bacon rind" appearance (see Fig. 2). The maximum thickness of the manganiferous zone is 75 feet.

The lowermost unit of the Muddy Creek formation exposed in the district is a basal conglomerate which lies conformably below the manganiferous zone. This bed contains boulders of volcanic rocks in a reddish-brown, fine grained or gritty matrix, which is so abundant in most places that the boulders are often widely separated. The conglomerate is well-bedded and even thin layers persist for hundreds of feet. Interbedded with the conglomerate are lava flows and flow breccias, apparently andesitic in composition. This unit varies in thickness from approximately 25 feet in the Three Kids area to nearly 250 feet in the western part of the district. Numerous exposures of the unconformity at the base of the conglomerate indicate that this variation in thickness is due largely to basal overlap (Hunt, McKelvey, and Wiese, 1942).

Fig. 2 - Showing "bacon rind" appearance of beds in lower portion of the manganiferous zone. Massive manganese oxide beds have been stripped off. East end of A pit.

Miocene (?) Volcanic Rocks

The age of the pre-Muddy Creek volcanic rocks in the Three Kids district has not been accurately determined, but they are tentatively assigned to the Miocene because they resemble the other middle Tertiary eruptives in the Southwest and are overlain by late Tertiary sedimentary deposits (Hunt, McKelvey, and Wiese, 1942).

Hewett (1931) made a study of the upper 1,200 feet of this sequence in the Three Kids district. He found that the lowermost flow is a reddish-brown latite about 500 feet thick. The rock contains rounded blades of feldspar and sporadic biotite in a matrix of reddish glass. In thin section the feldspars were determined to be sodic plagioclase, the biotite largely altered to ferric oxide, and the glass matrix contains myriads of plagioclase crystals 0.01 to 0.02 milimeters long. The rock contains 5 to 10 percent of corroded angular fragments of a similar but finer-grained rock.

Overlying the reddish latite flow is a group of light-colored latite breccias and flow breccias, andesitic breccias, and vesicular flows. The group ranges in thickness from 300 to 400 feet.

Of the three groups the uppermost flows exhibit the most uniform features throughout the district. They are entirely latitic in composition and have a matrix composed of vitreous glass. The feldspar present is uniformly sodic plagioclase. A little fresh biotite and moderate amounts of quartz are present. This group is 200 feet thick (Hewett, 1931).

STRUCTURE

The Three Kids manganese district is on the northwest slope of the uplifted volcanic rocks composing the River Mountains. The manganiferous beds, together with the other units belonging to the Muddy Creek formation, dip in general northwestward from the River Mountains. Dip varies from nearly horizontal to 45 degrees. Block faulting occurs throughout the area with practically all the faults being normal and having a strike that is northward or northwestward with the downthrow on most of these to the east. The general structure of the area is illustrated by the map and cross sections (Plates I and II).

In the eastern part of the district is the Three Kids graben, which has been dropped between the Extension and Lowney faults (see Fig. 3). The Lowney fault strikes northwestward and dips 45 degrees to the northeast. The Extension fault also strikes northwestward, but dips to the southeast. Some consider that there has been substantial right lateral movement along the Lowney fault and attribute the presence of the manganiferous beds in the Hydro pit to displacement from the beds in "A" pit. There is no evidence to support this; in fact, the persistent white tuff bed found near the bottom of the manganiferous zone in the "A", "B", and Three Kids pits is absent in the Hydro pit. Manganese occurs along the Lowney fault; its presence is attributed to drag, as several small faults parallel to the Lowney "step" the beds upward along it (see Fig. 14, dashed lines show parallel faults).

Fig. 3 - Looking east into the Three Kids graben.

Many smaller faults, which for the most part strike northward and dip either eastward or westward, occur between the Extension and Lowney faults. These faults are normal and divide the Muddy Creek formation into blocks. The Annex fault (see Fig. 4) is the only major fault in the area on which the amount of movement was measured; the stratigraphic throw is approximately 125 feet.

According to Hunt, McKelvey, and Wiese (1942) the faulting and tilting in the area began before the deposition of the Muddy Creek formation and was repeated intermittently after the deposition of the part of the formation that is exposed in the district.

Fig. 4 - Looking southwest into "B" pit and "A" pit. Annex Fault in center dipping to the east.

THE MANGANIFEROUS ZONE

The manganiferous zone (see Fig. 5) lies stratigraphically between a conglomerate on the bottom and clay and gypsum beds on the top. It occupies a consistent stratigraphic horizon, but varies in thickness from a few feet in the Extension area to as much as 45 to 60 feet in the "A", "B", and Hydro pits area. The average thickness of the zone is approximately 35 feet. Several manganese oxide minerals are present; pyrolusite (MnO_2), hollandite ($BaMn_8O_{16}$), cryptomelane (KMn_8O_{16}), and perhaps a small amount of coronadite ($PbMn_8O_{16}$). These minerals are intimately mixed with pink and white tuffs and tuffaceous sediments. The tuffs in this zone occur not only with the manganese but as pure beds up to 11 feet thick.

There are three distinct types of manganese oxide beds occurring within this zone: (1) the lowermost, a series of thin manganese oxide bands, which are silicified in part, (2) a middle massive manganese oxide bed, and (3) an upper bed composed of angular fragments of manganese oxide in a tuffaceous sediment.

Manganese Oxide Bands ("Bacon Rind Zone")

These layers, when present, are always found at the bottom of the manganiferous zone. They occur in the Three Kids, "A", and "B" pit areas, but are absent in the Hydro

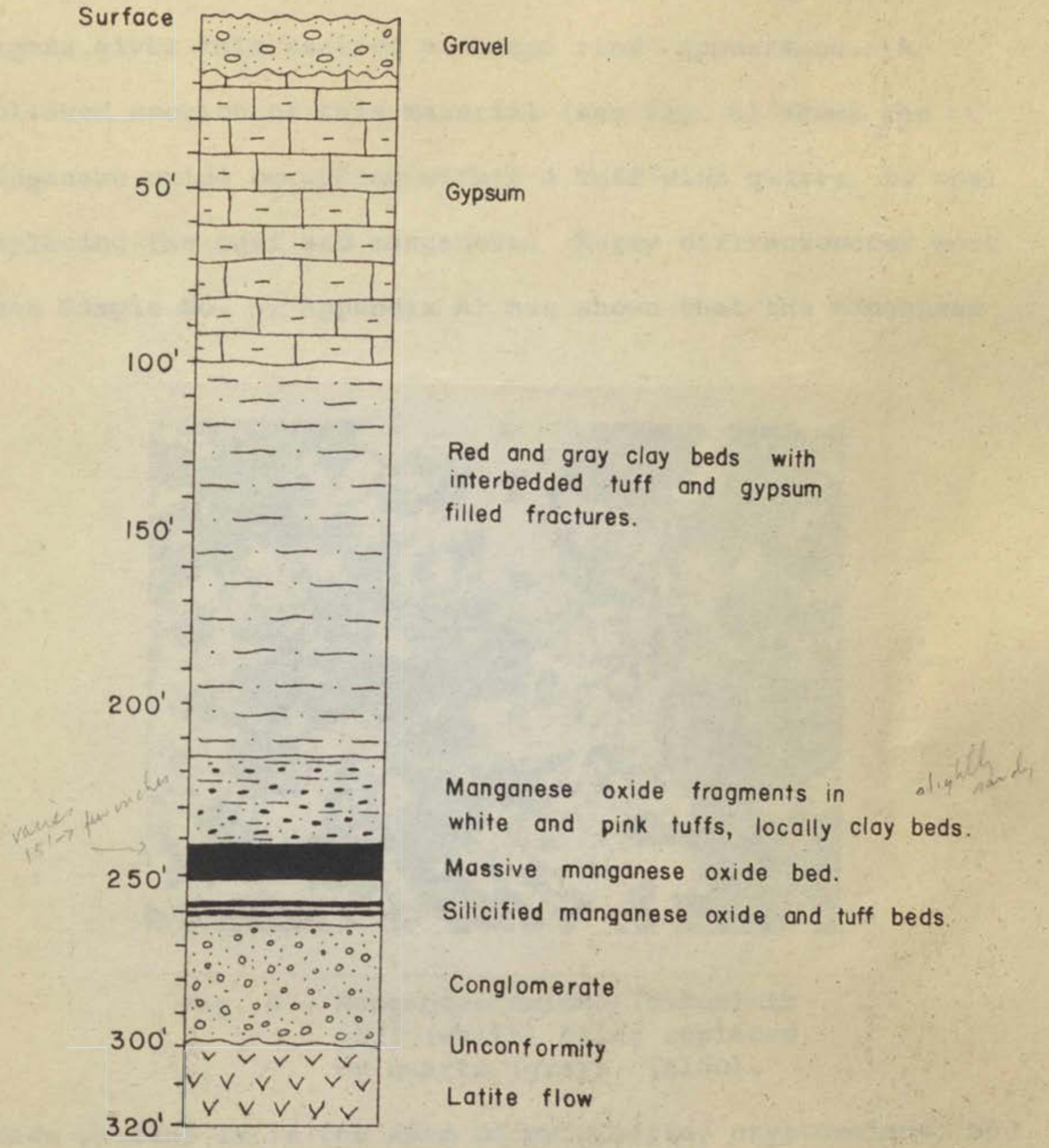

Fig. 5 - Typical section showing occurrence of manganiferous zone. Diamond drill hole V-4, "A" Pit.

pit. Each are composed of hard (silicified) and soft layers, no more than a foot thick, separated by a few inches of tuff. The alternating black (manganese oxide) and white (tuff) layers gives this section a "bacon rind" appearance. A polished section of this material (see Fig. 6) shows the manganese oxide occurring within a tuff with quartz or opal replacing the tuff and manganese. X-ray diffractometer work (see Sample No. 5, Appendix A) has shown that the manganese oxide present is in the form of pyrolusite, cryptomelane, and possibly coronadite. There is also abundant quartz in the sample. It seems probable that the quartz or opal present is secondary and was introduced into portions of this bed by

Fig. 6 - Manganese oxides (black) in
tuff (white) being replaced
by quartz (gray), (X100).

circulating ground water. Assays of manganese from this series of bands show values as high as 20% Mn.

A persistent bed of white vitric tuff about 11 feet thick, and containing no manganese, separates this section of thin bands from a thicker, more massive manganese oxide bed.

Massive Manganese Oxide Bed

This bed is found in all of the pits and in the workings and outcrops in the Extension area. It varies in thickness from a few inches in the Extension area to 15 or more feet in the Three Kids, "A", "B", and Hyrdo pits area. It is characterized by its relative softness, sooty black nature, and high manganese content. The host rock for the manganese

Fig. 7 - Thin section of manganese oxide (black) surrounding fragments of quartz, plagioclase, and tuff, (X30).

is a tuff or tuffaceous sediment. In thin section (see Fig. 7) the manganese oxides form an opaque background for such minerals as; quartz, gypsum, celestite, biotite, plagioclase, augite, hematite, and glass shards.

Polished sections (see Fig. 8) show the manganese oxides to be cryptocrystalline and possessing colloform texture.

Fig. 8 - Polished section of manganese oxide showing colloform texture, (X100).

X-ray diffractometer determinations (see Samples 1-9, pp. 56 - 76) indicate that the manganese oxides are pyrolusite, cryptomelane, and hollandite. Coronadite does not seem to be present in this bed. Pyrolusite is always present and is usually the dominant oxide. Cryptomelane occurs in samples from Hydro pit, the Three Kids pit, and from the Extension area. Cryptomelane is the dominant oxide in some of the samples from "A" and "B" pits. Hollandite occurs in all of the "A" pit samples and one each from the Three Kids pit, "B" pit, and the Extension area; it is absent in the Hydro pit samples. The above mentioned distribution of the manganese oxides shows that there is some variation within this massive manganese oxide bed.

Assays of this material show as high as 40% Mn in the Three Kids pit, but the over-all average of the bed is closer to 20-25% Mn.

Manganese Oxide Fragments Bed

This bed occurs throughout the area and varies from a few feet in thickness in the Extension area to as much as 40 feet in the "A" and "B" pits area. The host rock for the manganese oxide fragment is usually a pink or white tuffaceous sediment; however, thin beds of clay, identified as montmorillonite by x-ray methods, occur within this bed. The tuff beds, in general, are more sandy than the underlying tuffs associated with the massive oxide and "bacon rind" beds. The manganese oxide fragments in this bed are angular and from 1/4 to 1/2 inch in diameter, though some are as much as 2 inches in diameter.

This bed is probably an erosional product, which is indicated by the change in lithology of the host tuff to a more sandy sediment, the presence of clay seams, and the manganese oxides occurring as isolated fragments rather than a continuous bed. The depth of the intermittent lake in which the tuffs and manganese oxides of the massive and "bacon rind" beds were deposited probably fluctuated and was shallow enough at one period to allow the upper portion of the already deposited massive oxide bed to be eroded. This erosion probably took place through wave action along the lake edge and provided material for the fragmental manganese oxide bed.

Fractures thinly coated with manganese oxide occur throughout this bed, which implies that at least a certain amount of the manganese deposited in this blebby bed has been removed by ground water, transported down fractures and redeposited in the massive manganese oxide bed below.

Savage (1936) states "....since the manganese oxides are relatively insoluble in water, transportation is accomplished by suspension. Any secondary enrichment of manganese oxide beds probably takes place as ground water removing the oxide from one area and carrying it in suspension to another."

It may be reasonable to assume then, that a portion of the high manganese content of the massive manganese oxide bed is due to supergene enrichment.

CHARACTER OF THE MANGANESE ORE

Pardee and Jones (1919) report the following analysis of manganese ore from the Three Kids pit.

(Smith, Emory & Co., Los Angeles, Calif., Analysts)

MnO_2	56.04	MgO	1.41
MnO	7.08	CuO	0.49
Fe_2O_3	1.68	ZnO	none
Al_2O_3	1.85	P_2O_5	0.07
SiO_2	13.73	SO_3	0.43
PbO	2.07	As_2O_3	0.06
BaO	0.02	$K_2O + Na_2O$	3.82
CaO	trace	H_2O	11.25

Hewett (1931) considers most of these constituents common in a wad (mixture of manganese oxides) ore, but the percentages of lead and copper are uncommonly high, whereas those of barium are low (later analyses show higher Ba content, see pp. 24, 25). Most of the remaining constituents Hewett considers to be ingredients of the tuff portion of the ore.

Engel (1954) reports two analyses of samples taken at the property (see pp. 24 and 25). Exact locations are not given, but sample No. 14184 is from the massive manganese bed, while sample No. 14185 is from the overlying bed containing the manganese oxide fragments. The determinations, made by the Keldon Research Laboratory, are semi-quantitative spectrochemical analyses.

As can be seen from the analyses there is a relatively high lead and copper content, which Hewett (1931)

Manganese Ore Sample No. 14184

	Manganese, Inc.	Keldon Research	Pomeroy & Associates
Mn	25.10%	3-30%	27.30%
MnO			7.30%
MnO_2			34.32
Fe		0.5-5	
Fe_2O_3	3.32		2.44
Al		0.1-1	
Al_2O_3	5.93		5.40
Cr		0.005-0.05	none
Ni		0.005-0.05	none
Co		undetected	trace
Ti		0.05-0.5	trace
Mo		0.05-0.5	trace
Cu	0.023	0.03-0.3	trace
Pb	1.22	0.03-0.3	0.84
PbO			0.90
Zn	0.027	0.01-0.1	0.10
Sb		undetected	trace
Ca	trace	0.3-3	
CaO			1.80
Ba		undetected	
BaO	2.33		2.18
Sr		0.03-0.3	
SrO	0.55		0.50
Mg		0.01-1	
MgO	trace		2.63
K		0.3-3	
K_2O			1.15
Na		0.5-5	
Na_2O			0.61
Li		undetected	none
Si		10-100	
SiO_2	30.56		30.10
P	0.015	undetected	none
B		0.001-0.01	trace
CO_2			1.22
SO_4	0.59		
SO_3	0.49	0.12	0.11
H_2O (110°C)			2.40
Ignition loss (300° C)			5.80

Excess Oxygen with FeO and MnO - 6.56% TOTAL 98.96%

Note: In addition to the elements listed above, the following were searched for in all analyses and were found to be absent: Ag, Bi, Cd, Hg, As, and Sn.

Manganese Ore Sample No. 14185

	Manganese, Inc.	Keldon Research	Pomeroy & Associates
Mn	15.76%	3 - 30%	19.05%
MnO			4.10
MnO_2			25.13
Fe		0.5-5	
Fe_2O_3	1.56		1.67
Al		0.1-1	
Al_2O_3	5.80		6.30
Cr		0.005-0.5	none
Ni		0.005-0.05	trace
Co		undetected	trace
Ti		0.05-0.5	trace
Mo		0.05-0.5	trace
Cu	0.019	0.03-0.3	trace
Pb	0.77	0.03-0.3	1.09
PbO			1.17
Zn	0.028	0.01-0.1	trace
Sb		undetected	trace
Ca		1-10	
CaO	trace		2.90
Ba		undetected	
BaO	2.28		0.17
Sr		1-10	
SrO	4.35		8.60
Mg		0.1-1	
MgO	0.12		2.70
K		0.3-3	
K_2O			0.60
Na		0.5-5	
Na_2O			0.38
Li		undetected	none
Si		10-100	
SiO_2	29.83		30.70
P	0.011	undetected	none
B		0.001-0.01	trace
CO_2			1.30
SO_4	6.23		
SO_3	5.19	7.13	7.23
H_2O (110° C)			1.60
Ignition loss (300° C)			4.00
			TOTAL 98.55%

Excess oxygen with FeO and MnO - 4.80%

believes indicates a hot springs origin for the deposit. Also appearing in the analyses are small amounts of Cr, Ni, Co, Ti, Zn, and Mo, all of which were previously unreported as occurring in the ore, and may tend to support Hewett's hypothesis for a hot springs origin. Several authors, Mason (1954), Edwards (1954), Bastin (1950), and Lindgren (1932), have reported that manganese oxides, which have existed in the colloid state, commonly carry small amounts of Cr, Ni, Co, Ti, Zn, and Mo.

Sample No. 14185 shows a higher CaO content than sample No. 14184 (2.90 vs 1.80), a higher SrO content (8.60 vs 0.50), and a higher SO_4 content (6.23 vs 0.59). The CaO, SrO, and SO_4 probably represent for the most part gypsum and celestite. Gypsum beds overlie most of the area and the many fractures occurring in the ore zone offer excellent channels for gypsum taken into solution by water, at or near the surface, and then redeposited in these fractures. As seen in the various pits, the gypsum veinlets (up to three inches thick) are more prevalent near the surface. Gypsum commonly occurs in the bed containing the manganese oxide fragments, giving a characteristic high SO_4 content to this bed in chemical analyses. The celestite probably occurs along with the gypsum. X-ray diffractometer patterns of samples from the Hydro pit and the "A" pit show strong lines for celestite and gypsum which are absent in the patterns for the Three Kids pit, "B" pit, and Extension area samples. This may be explained by the absence of the gypsum cap rock (containing celestite) in these areas (see Plate 2). Hewett (1959) says that celestite is a common constituent of manganese oxide deposits in the Southwest.

The lead present in the samples may be due in part to coronadite ($PbMn_8O_{16}$), but more so to cerrussite ($PbCO_3$). X-ray patterns show coronadite may possibly be present only in the "bacon rind" portion of the manganiferous zone, but assays show (see Fig. 9) that lead is abundant in the beds containing the manganese oxide fragments and the massive manganese oxide. In this case the lead is probably entirely in the form of cerussite. Hewett (1931) has shown that cerussite does occur in the ore. The author has not been able to definitely show the presence of cerrusite, but it seems that this is the only logical occurrence for the lead.

The barium and potassium recorded in the analyses are for the most part contained in the manganese minerals hollandite ($BaMn_8O_{16}$) and cryptomelane (KMn_8O_{16}). Barite ($BaSO_4$) was not found in any of the thin sections or diffractometer patterns.

The moisture content of the manganese oxide ore is usually quite high, around 15%, but samples containing 20%

moisture or more are not uncommon. After standing in stock piles for several months the moisture content drops to 5% or less, which indicates the manganese ore is quite porous. Ground water has undoubtedly leached out material and occupied the vacated openings.

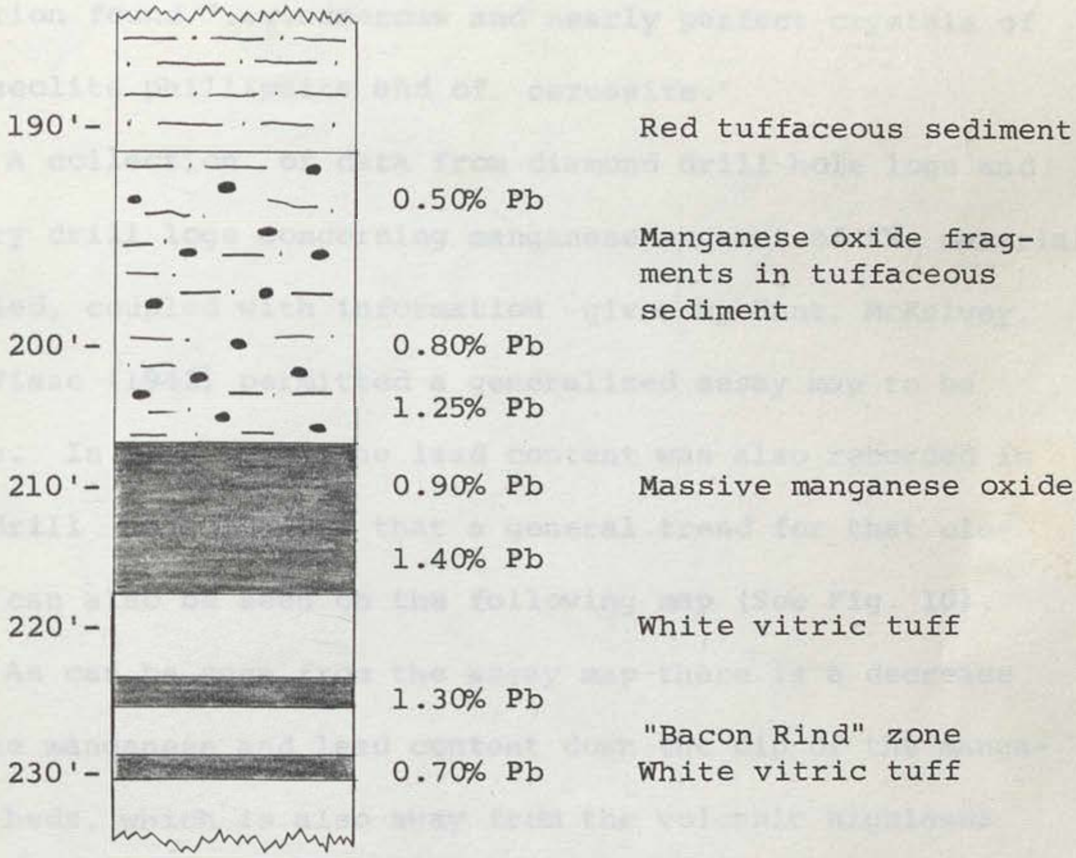

Fig. 9 - Portion of diamond drill hole log showing manganiferous zone with lead content. Hole V - 16, "A" pit.

The remaining constituents of the manganese ore analyses most likely are represented by the minerals plagioclase, biotite, hematite, and the host rocks, tuff and clay.

The manganese in most of the area is readily and completely soluble in sulphurous acid. Several samples were treated with the acid and the residual material was mounted on slides. Microscopic examination revealed the presence of abundant grains of volcanic glass, plagioclase, quartz, biotite, and celestite. Hewett (1931) also performed a similar treatment on ore samples and found not only the above minerals, but in addition found "....numerous and nearly perfect crystals of the zeolite phillipsite and of cerussite."

A collection of data from diamond drill hole logs and rotary drill logs concerning manganese content of the material drilled, coupled with information given by Hunt, McKelvey, and Wiese (1942) permitted a generalized assay map to be drawn. In many cases the lead content was also recorded in the drill hole logs so that a general trend for that element can also be seen on the following map (See Fig. 10).

As can be seen from the assay map there is a decrease in the manganese and lead content down the dip of the manganese beds, which is also away from the volcanic highlands of the River Mountains. Hewett (1959) also notes a similar decrease in the barium content, from 4% to 0.25%. These changes, coupled with a decrease in thickness down dip of the manganiferous zone, seem to indicate that the volcanic highlands are in some way connected with the source of the manganese.

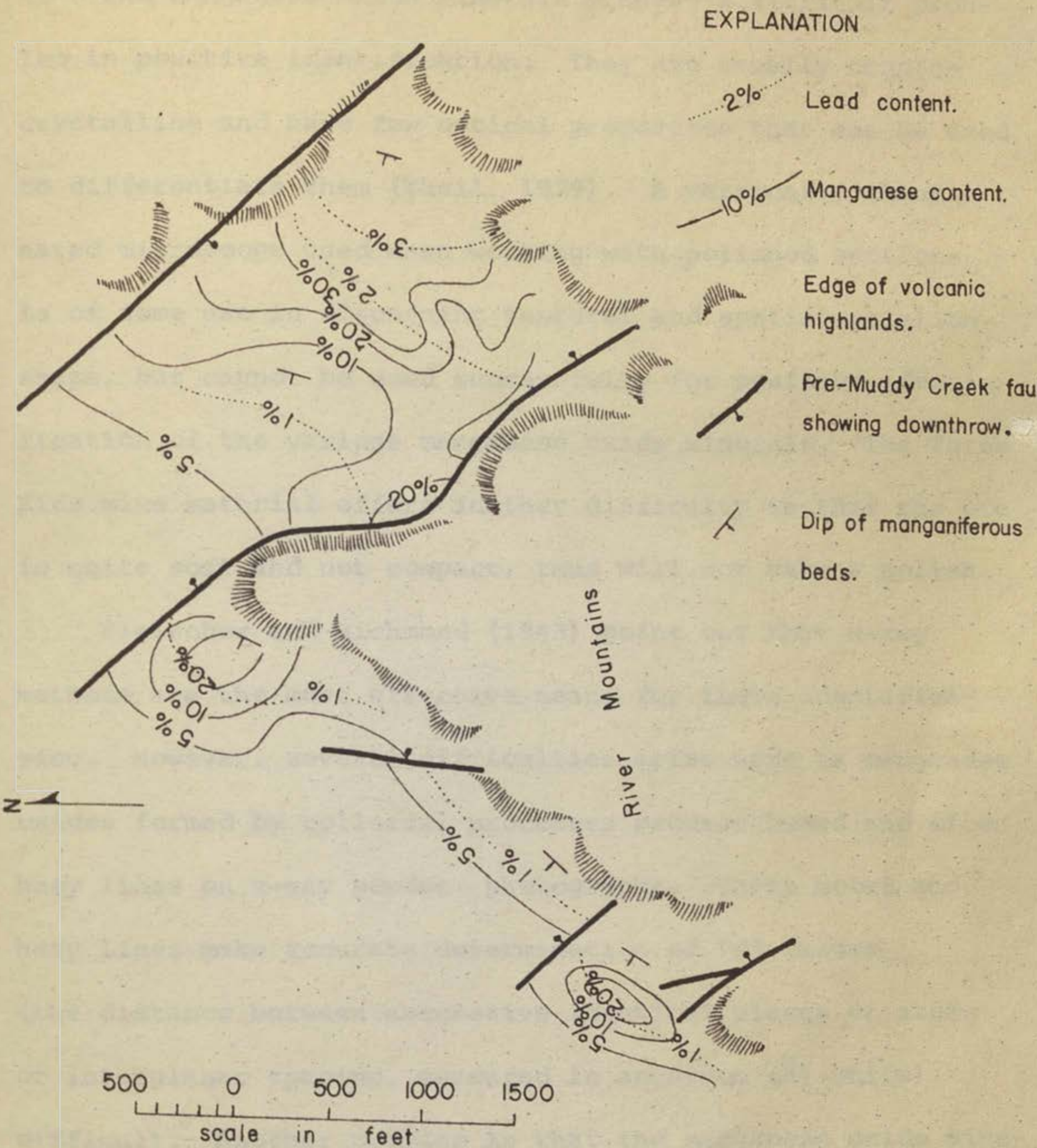

Fig. 10 - Generalized assay map showing decrease of manganese and lead content downdip and away from the volcanic highlands. In part after Hunt, McKelvey, and Wiese (1942).

MANGANESE OXIDE MINERALS AND THEIR IDENTIFICATION

The manganese oxide minerals present a difficult problem in positive identification. They are usually cryptocrystalline and have few optical properties that can be used to differentiate them (Theil, 1929). A vertically illuminated microscope used when working with polished sections is of some use in discerning textural and spatial relationships, but cannot be used successfully for positive identification of the various manganese oxide minerals. The Three Kids mine material offers further difficulty in that the ore is quite soft and not compact, thus will not take a polish.

Fleischer and Richmond (1943) point out that x-ray methods are the most effective means for their identification. However, several difficulties arise here as manganese oxides formed by colloidal processes produce broad and often hazy lines on x-ray powder photographs. These broad and hazy lines make accurate determination of "d" values (the distance between successive identical planes of atoms or interplanar spacing, measured in angstrom (Å) units) difficult. Another problem is that the manganese oxide minerals pyrolusite, cryptomelane, hollandite and coronadite have "d" values which are either equal or are so nearly equal as to make accurate determination impossible when the lines are broad and hazy (see Fig. 11).

Powder photographs of manganese minerals are best obtained with an x-ray unit having an iron target tube (Azaroff and Buerger, 1958), as this tube does not absorb or scatter x-rays when manganese is present in the sample. Unfortunately, an iron target x-ray tube is not available at the University of Nevada and the mineral identification had to be carried out with copper and cobalt target tubes. When manganese is present in a sample and either the copper or cobalt tube is used the x-rays are badly absorbed and scattered. This prevented good results with powder photographs. Fair results, however, were obtained when the x-ray diffractometer was used.

All x-ray powder photographs were obtained with a North American Phillips x-ray unit using cobalt K-alpha (1.7902Å) radiation, and operating under a potential of 40 kilovolts and 7 milliamperes. Exposure time for large camera films (114 mm) was 8 hours. Diffractometer patterns were obtained using copper K-alpha (1.5418Å) radiation at a potential of 35 kilovolts and 15 milliamperes, with a scale factor of 8, a multiplier of 1, a time constant of 4, slits of 4 degrees and 0.006 inches, and a nickel filter. The diffractometer patterns were run from 10 to 70 degrees (2θ).

The samples for the diffractometer were prepared by grinding a few grams of the material to about 200 mesh and

d (Å)	Pyrolusite	Cryptomelane	Hollandite	Coronadite
6.92	-	20 *	-	-
6.80	-	-	20	-
4.95	-	-	10	-
4.91	-	20	-	-
3.48	-	-	70	-
3.47	-	10	-	60
3.11	100	60	-	-
3.10	-	-	100	100
2.46	-	10	-	-
2.40	50	100	-	40
2.38	-	-	40	-
2.21	4	20	-	40
2.16	-	20	-	20
2.14	-	-	40	-
2.12	12	-	-	-
2.00	-	-	-	10
1.98	4	-	-	-
1.96	-	-	-	10
1.95	-	-	10	-
1.93	-	-	10	-
1.92	-	-	-	-
1.84	-	60	-	20
1.83	-	-	30	-
1.75	-	-	10	-
1.74	-	-	-	10
1.69	-	-	10	10
1.64	-	20	50	20
1.62	50	20	50	-
1.56	12	-	-	-
1.54	-	60	-	50
1.53	-	-	80	-
1.44	8	-	-	-
1.43	-	20	10	10
1.42	-	-	10	-
1.40	-	-	10	10
1.39	4	-	-	-
1.37	-	-	-	20
1.36	-	-	60	20
1.35	-	60	60	-
1.30	16	20	10	10

* relative intensity of the line, where 100 is the strongest.

Fig. 11 - Comparison of "d" values between Pyrolusite, Cryptomelane, Hollandite and Coronadite. Values obtained from A.S.T.M. Index Card.

mixing a little flour in with the sample (1 part flour to 3 parts sample was found to be best) to act as a binding agent.

Interpretation of X-ray Data

Nine samples were chosen from the various pits at the Three Kids mine and submitted to x-ray examination. The samples contained a mixture of the manganese oxide minerals pyrolusite, cryptomelane and hollandite, and the gangue minerals quartz, celestite and gypsum. In interpreting the x-ray data, pyrolusite was considered to be the prominant manganese oxide present when the highest "d" value for pyrolusite (3.11) was more intense than the highest "d" value for cryptomelane (2.40) or hollandite (3.10). In several samples the 2.40 line was stronger than the 3.11 or 3.10 lines, in which case cryptomelane was considered to be the most abundant manganese oxide present in the sample.

Hewett (1959) says "....from two samples taken in the better oxides the ore minerals are cryptomelane-hollandite, with minor amounts of pyrolusite." Hewett apparently took his two samples from the Three Kids pit area where this higher cryptomelane-hollandite to pyrolusite relationship seems to hold true.

Huttl (1955) and Gates (1957) report the presence of coronadite in the ore. The author was unable to definitely prove its presence, but corresponded with both J. B. Huttl and E. G. Gates in an attempt to find out how they made their determination of coronadite. Huttl (1959) was unable to shed any light on the problem, but Gates (1959) said his information came from an unpublished report by Rene Engel (1954) and that the presence of coronadite was made more from inference (the presence of lead in the ore) than from actual evidence. It is doubtful then that coronadite is present in the ore zone.

Colloform Texture and Manganese Oxide Formulae

The manganese oxide minerals at the Three Kids mine exhibit colloform texture (see Fig. 8). The term colloform, implying colloid or gel-texture, is used to describe the texture of minerals that occur in a series of concentric, curved or scalloped layers, in which the curvature is always convex toward the younger or free surface. A free surface, if present, is reniform, botryoidal, mammillary, or even stalactitic (Bastin, 1950). These curved surfaces, according to Boydell (1925), are manifestations of surface tension effects in a viscous material and are indicative of colloidal origin. Colloidal processes can play a role in the formation of both supergene and hypogene minerals with a resultant colloform texture (Edwards, 1954).

Colloidal processes play an important role in the formation of the manganese oxide minerals pyrolusite, cryptomelane, hollandite, and coronadite, according to Ramdohr (1955), Edwards (1954), Bastin (1950), Lindgren (1932), Fleischer and Richmond (1943), and Boydell (1925). The manganese oxide gels have a high capacity to adsorb appreciable quantities of K, Ba, Ca, B, Ti, Co, Ni, Cu, Zn, Pb, and W (Rankama and Sahama, 1950). These adsorbed elements give rise, on crystallization of the gel, to distinctive manganese minerals such as, cryptomelane (KMn_8O_{16}), hollandite ($BaMn_8O_{16}$), and coronadite ($PbMn_8O_{16}$). These elements are not adsorbed in definite stoichiometric proportions, but exist within the crystal structure of the mineral in varying amounts. Mathieson and Wadsley (1950) show that the potassium in cryptomelane is not fixed and could be variable over a wide range without modification of the structure. This variation also holds true for the barium found in hollandite and the lead in coronadite. It can be seen then that it is impossible to assign a definite formula to these exotic cation-bearing quadra-positive manganese oxides.

As can be seen from Fig. 12 Hewett lists the mineral hollandite as being hypogene in origin. If hollandite is hypogene then it seems reasonable to assume that cryptomelane and coronadite are also hypogene, as Byström and Byström (1950 and 1951) and Gruner (1943) show that these three minerals form an isostructural series. The reverse reasoning might also be employed; if cryptomelane is supergene then hollandite and coronadite should also be supergene. Unfortunately, the literature concerned with the origin of these minerals is in a lamentable state and it is impossible at this time to definitely say that the members of this isostructural series are either supergene or hypogene.

Mineral	Authority	Hypogene	Supergene
Pyrolusite	Hewett, 1956		x
Hollandite	Hewett, 1956	x	x(?)
Cryptomelane	Hewett, 1956		x
Coronadite	Dana, 1944	x(?)	
Celestite	Bateman, 1952		x
Cerussite	Bateman, 1952		x
Phillipsite	Lindgren, 1932	x	

Fig. 12 - Modes of formation of some of the minerals occurring in the manganiferous zone.

The Occurrence of Celadonite

The mineral celadonite, a heptaphyllite mica, occurs throughout the Three Kids mine and because of its widespread occurrence deserves special mention.

Celadonite is found along the major faults (Lowney, Extension, Annex, and Hydro faults), in the ore zone, the conglomerate underlying the ore zone, and in the fractures of an intercalated andesite with the conglomerate.

Along the faults it is intermixed with fault gouge and usually shows a slickensided surface. It varies in thickness from mere stains to 6 inches, though locally it can be a foot or more.

The celadonite occurs in the ore zone as stringers an inch or so in thickness. It is confined to the lowermost portion of the ore and along the contact between the manganiferous beds and the underlying tuff. Along this ore-tuff contact the celadonite forms stringers ranging from paper-thin veinlets to three-or four-inch seams.

Its occurrence in the conglomerate underlying the ore zone is marked by a rather wide-spread staining of the matrix material of the conglomerate and by forming halos around some of the volcanic fragments. These halos, as seen in thin section study, are not formed by the alteration of any minerals contained in the volcanic fragments.

In the andesite intercalated with this conglomerate the celadonite occurs in fractures up to 1/2 inch thick.

Under the microscope (see Fig. 13) the celadonite appears as clouds or smears of green; even under high magnification individual crystals cannot be seen. This apparent lack of crystallinity is attributed to its being composed of colloidal-sized particles (Hendricks and Ross, 1941). In none of the samples examined can the celadonite be seen forming directly as an alteration product of any mineral; it does alter in part to limonite. It fills microscopic cracks and small voids within the manganese oxides which indicates that its occurrence there is as fracture filling rather than replacement.

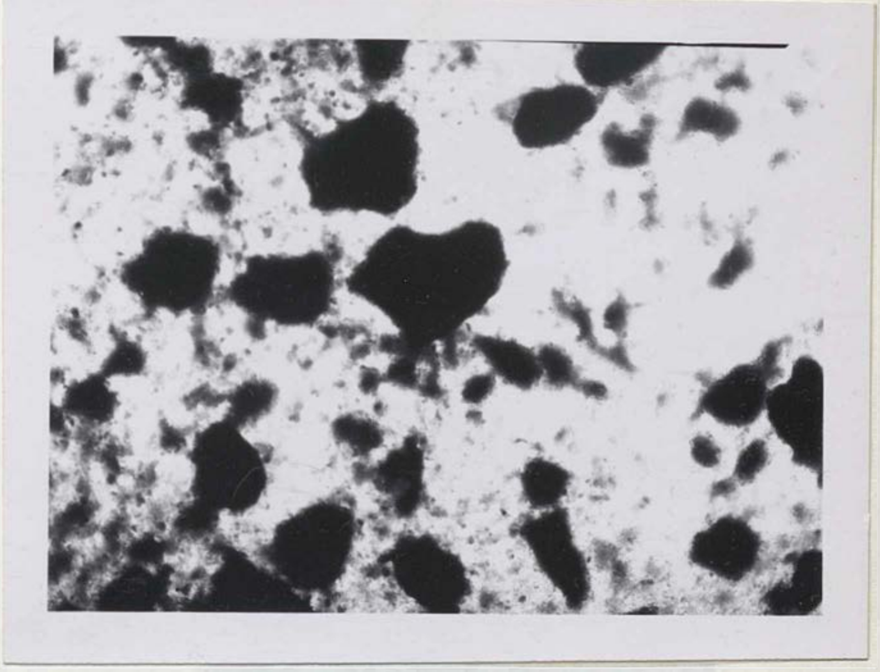

Fig. 13 - Grain mount showing celadonite "clouds" (gray) forming around quartz grains (black).

From an exposure in the west corner of "A" pit (see Fig. 14) the celadonite can be seen occurring along the Lowney fault from a point near the surface (below the clay and gypsum beds) to a point in the manganiferous zone where it is in contact with the fault. From this point the celadonite stringers turn and follow a course away from the fault and extend into the manganiferous zone for some 50 feet from the fault until the celadonite eventually disappears. This particular exposure suggests that the celadonite is a weathering product carried downward along the fault by circulating ground water and deposited in its present location. However, the occurrence of celadonite in this exposure may be due to drag along the Lowney fault. The formation of the celadonite

Fig. 14 - Dotted lines show occurrence of celadonite down along Lowney fault and into manganiferous zone. "A" pit.

must have occurred prior to the deposition of the clay and gypsum beds overlying the manganiferous zone, as no celadonite is present in either, even along faults, and it must have been deposited after the manganese oxides were formed, in that the manganese oxide serves as a host mineral for the celadonite on occasion.

The celadonite was identified by means of an x-ray powder photograph (see Fig. 15). It has a marked similarity to the mineral glauconite, both in physical appearance and chemical formula. Hendricks and Ross (1941) give the representative formulae for celadonite and glauconite as being identical, $(K, Ca_{\frac{1}{2}}, Na)_{.84}\ (Al_{.34}Fe^{3}_{.76}Fe^{2}_{.24}Mg_{.76})$ $(Si_{3.89}Al_{.11})\ O_{10}(OH)_{2}$.

Little is known concerning the origin of celadonite. Clarke (1924) suggests that it is an alteration product of augite and perhaps of olivine, and says:

> If celadonite and glauconite are (essentially) the same ferri potassic silicate, differing only in their impurities, it may be seen that the several modes of its formation are not absolutely different at all. The final reaction is probably the same, namely; the absorption of potassium and soluble silica by colloidal ferric hydroxide.

Hendricks and Ross (1941) show that a supply of ferrous iron (necessitating a reducing environment), magnesium, and potassium, is a controlling condition for the formation of celadonite. They also believe that celadonite derives its essential magnesium, iron and silica from the alteration of olivine. They point out as an example the occurrence of olivine in a basalt near Reno, Nevada, directly altering to

Line	d (Å)	d (ideal)	Est. Int.
1	10.05	10.0	s
-	-	4.99	w
2	4.53	4.52	s
3	4.38	4.32	m
4	3.62	3.65	s
5	3.35	3.31	s
6	3.08	3.08	s
7	2.91	2.89	m
8	2.69	2.67	m
9	2.57	2.57	vs
-	-	2.48	w
10	2.40	2.39	s
11	2.25	2.25	m
12	2.23	2.20	m
13	2.15	2.14	m
14	2.00	1.99	m
15	1.96	1.95	m
16	1.82	1.82	w
17	1.71	1.71	w
18	1.65	1.65	m
-	-	1.59	m
19	1.52	1.51	s
-	-	1.34	m
-	-	1.30	m
-	-	1.28	w
-	-	1.25	m

note: w - weak line, m - moderate line, s - strong line, vs - very strong line.

Fig. 15 - X-ray Powder Photograph Pattern of Sample No. M18-73. Cobalt K-alpha radiation, Fe filter, 40 kilovolts, 7 milliamps, 8 hour exposure. The ideal "d" values were obtained from A.S.T.M. Index card No. 2-1011 and indicate the mineral is celadonite.

celadonite.

If Twenhofel's (1939) suggestion, that celadonite and glauconite are the same, is valid then Galliher's (1935) work on glauconite forming from the alteration of biotite in Monterey Bay, California, would indicate that biotite could also be a source for celadonite.

The close association of celadonite with the faults in the district suggests that it could be a product of hydrothermal solutions working their way up along the faults late in the epoch of mineralization and attacking certain minerals, probably biotite since it is abundant in the volcanics on the footwall side of the fault and contains the essential constituents for the formation of celadonite. Schwartz (1959) says that biotite is normally one of the first minerals to be attacked by hydrothermal solutions.

The following photomicrograph (Fig. 16) shows the relationship of the celadonite to the manganese oxides and the host rock tuff. The tuff and the manganese oxide both serve as a host for the celadonite, as is shown by its forming thin coatings around manganese oxide nuclei and occurring in fractures within the tuff. The celadonite appears to have followed the same channels that the manganese did, but at a later time in the epoch of mineralization.

In the company of E. F. Lawrence of the Nevada Bureau of Mines the author visited several other manganese oxide mines in north central Nevada, with the hope of finding other deposits similar to the Three Kids deposit. It was interesting to note that celadonite occurred in several of the deposits visited that were obviously hydrothermal in origin.

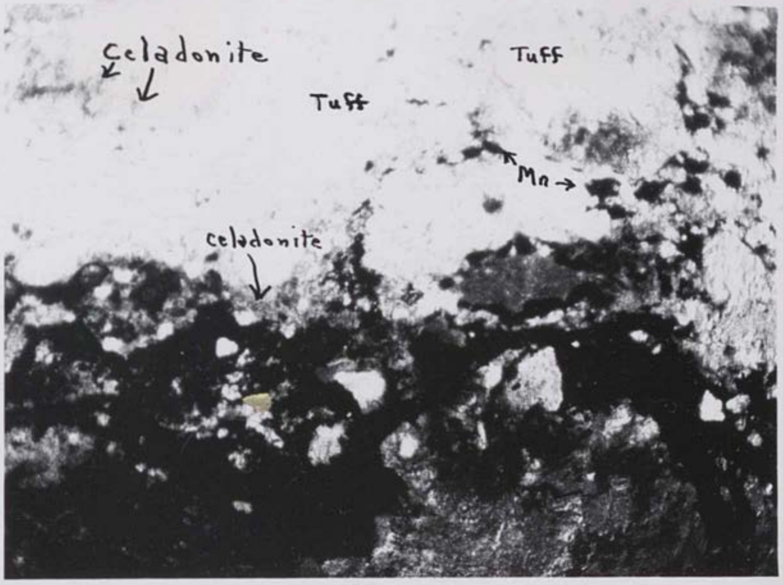

Fig. 16 - Showing relationship of celadonite (gray) to manganese oxide (black) and tuff (white). See text.

Origin of the Manganese

The first paper concerned with the origin of the ore at the Three Kids mine was one by F. A. Hale, Jr. (1918). It was his opinion that "....the manganese oxide ores are of sedimentary origin." Concerning the original source of the manganese, Hale thought that the "gabbro intrusives" in the area contained enough manganese that through weathering a residual deposit of manganese silicate and carbonate was formed, which was subsequently altered to the oxide form.

In regard to Hale's ideas several misconceptions are present. There are no gabbro intrusives in the area, in fact there are no intrusives of any kind. The igneous rocks that are present are for the most part latites, which, according to Clarke (1924), usually contain less than 0.1% MnO. The volcanic material exposed in the River Mountains show no evidence that any leaching has taken place, which would not be the case if the manganese contained therein had been removed to form the Three Kids deposit.

If, as Hale supposed, the deposit was originally composed of manganese silicate and carbonate it would seem likely that some trace of rhodonite or rhodochrosite would be present. However, this is not the case. No trace of these minerals has been found nor any indication that they were ever present.

It also seems quite unlikely that the deposit could have been formed by the erosion of some manganese-bearing rock, due to the fact that the main manganiferous bed is relatively pure, containing up to 40% Mn (pure pyrolusite contains 63% Mn). This high manganese content would not be true if a residual deposit, as other material eroded along with the manganese would tend to dilute the manganese content of the deposited bed.

Mason (1952) reports that "Vernadsky introduced the term <u>clarke</u>, defining it as the average percentage of an element in the earth's crust. In discussing dispersion and concentration of the elements, he introduced a further term, the <u>clarke of concentration</u>, which is a factor showing the concentration of an element within a particular deposit or even a particular mineral. Thus, if the clarke of manganese is 0.1, the clarke of concentration of manganese in pyrolusite is 632." The clarke of concentration of manganese in a deposit containing 35% Mn would be 350, showing that from such a small content a considerable amount of concentration must occur in order for the deposit to commercial.

Jones and Pardee (1919) made an investigation of the deposit which they thought was formed by the replacement of tuff, sand and clay beds by manganese. They felt that there was little doubt that manganese-bearing solutions were introduced along the main fissures (probably Lowney and Extension faults) and replaced the adjacent beds.

The close association of the manganiferous beds and faults gives some weight to this idea, however, there is no direct evidence that manganese-bearing solutions were introduced along the faults. Postmineral movement along the major faults has apparently destroyed any evidence (if ever present) that these structures were used by mineralizing solutions.

It is difficult to determine whether the manganese has replaced the tuff, but certain criteria are present which, according to Fairbanks (1928), Bastin (1950) and Edwards (1954) could indicate replacement: (1) inclusions or cores of tuff surrounded by envelopes of manganese oxide, (2) embayments of manganese oxide into tuff, (3) manganese oxide crosscutting tuff, (4) in general, the contact between tuff particles and manganese oxide is jagged.

It is likely, however, that the above criteria for replacement could be explained by circulating ground water moving the manganese oxide in suspension into these replacement-like positions.

Hewett and Weber (1931) made a study of the deposit, and these authors proposed a sedimentary origin for the manganese using the following criteria to support their theory:

1. In their broader relations, tabular bodies of manganese oxides are found in persistent zone about 100 feet above the base of a series of volcanic tuffs and gypsum beds.

2. The thin partings of tuffaceous material between the layers of manganese oxide are known to persist at least 100 feet in several places without great change in thickness, even though the surfaces of contact are not precisely sharp and definite. In their larger dimensions the layers of both oxides and partings are lenticular. These features are consistent with the idea that the beds accumulated in intermittent playas under arid conditions.

3. The most abundant oxide of manganese is brown earthy wad. Wad has been noted widely in residual deposits as well as in stratified material of recent origin, but does not seem to be recorded as a product of hypogene replacement.

4. The variations from the hardness and coherence characteristic of the normal earthy oxide seem to depend upon cementation by opal and chalcedony or by neotocite, all probably of recent supergene origin under the arid conditions prevailing in this region.

5. In thin sections of distinctly bedded materials no evidence of replacement of tuffaceous material or silicate minerals by manganese oxide has been noted. In the few places where small masses of wad of irregular shape appear to replace tuffs, it seems more probable that they have been formed recently by waters of surface origin.

Hewett and Weber (1931) further state that the original source of the manganese was probably from hot springs, due to relatively large quantities of lead and copper and the zeolite phillipsite in the ore.

Hunt, McKelvey, and Wiese (1942) state that in general Hewett's conclusions have been sustained by their own mapping and that the manganiferous beds are now known to extend, essentially at one stratigraphic horizon, far beyond the limits of the Three Kids district.

Further work by the United States Geological Survey led McKelvey, Wiese, and Johnson (1949) to believe that the close regional association of the manganese with "pillow basalts" suggested the possibility that the manganese was contained in solutions that accompanied the eruptions or was leached from the subaqueous flows.

From several years experience at the Three Kids mine, which included close examination of open pits, cuts, underground workings, and drill hole logs, the author was unable to recognize any pillow basalts as occurring in the area. There are basalt capped peaks several miles from the mining area, but none presumably close enough to be connected with the origin of the manganese.

White (1955), following a similar trend of thought as McKelvey, Wiese and Johnson (1949), suggested that a likely source of the manganese was the underlying volcanic rocks of intermediate and basic composition. White believed that ".....near-neutral circulating waters containing free CO_2 derived from the volcanic rocks or from a deeper source could leach manganese as soluble bicarbonate. The waters were probably warm or hot and rose along faults near the borders of the basins. The waters emerged into alkaline lake waters or migrated out from fissures into recently deposited lake sediments, and the manganese was precipitated".

The following evidence could suggest a possible hydrothermal origin for the manganese:

(1) The presence within the manganese ore of relatively large amounts of lead and copper, with smaller amounts of Cr, Ti, Mo, Zn, and Sb.

(2) The presence of the zeolite phillipsite within the manganese ore.

(3) The close association of the manganese-bearing beds with faults.

(4) Manganese oxide possibly replacing tuff.

(5) A possible hydrothermal mineral celadonite intimately associated with the manganese oxide.

(6) The presence of hollandite, which according to Hewett (1956), is a hypogene mineral.

(7) The formation of the manganese oxide deposit at the close of a period of volcanic activity.

However, the following evidence seems to disprove a hydrothermal origin for the manganese:

(1) The lack of concrete evidence showing manganese oxide replacing the material in which it occurs.

(2) The lack of any typical alteration products in the manganese-bearing beds.

(3) The lack of hydrothermal minerals.

(4) No evidence showing that the manganese actually came up along the faults in the area.

(5) No evidence showing that hot springs activity ever took place in the area.

CONCLUSIONS

It seems apparent that the manganese was not derived by being leached from the volcanic rocks of the River Mountains nor through the erosion of some rock containing manganese and a residual deposit formed. If the manganese did not replace the material it occurs in, and since the upper portion of the manganiferous zone (manganese oxide fragment bed) is obviously sedimentary, and the lower portion (massive manganese oxide bed) is considered by some authors to be hydrothermal, the origin of the deposit is not readily apparent. The author proposes the following in an attempt to explain the hydrothermal-sedimentary enigma:

(1) The manganese was introduced into the area via the main faults by hydrothermal solutions.

(2) The manganese was probably in the bicarbonate form.

(3) The manganese bicarbonate-charged solutions migrated directly into the lake which was present at that time.

(4) Upon reaching the lake environment, the manganese bicarbonate molecule ~~split up~~ hydrolysed and the unstable manganous hydroxide formed.

(5) With oxygen available, the unstable manganous hydroxide oxidized and precipitated as partly dehydrated manganic hydrate, which would readily oxidize to manganese dioxide. The preceding is illustrated by Savage (1936), ".... when a slightly alkaline solution containing manganese bicarbonate....meets with the oxidizing conditions such as exist in the surficial layers of bodies of water, the following takes place:

$$2Mn(HCO_3)_2 + 4H_2O \longrightarrow 2\,Mn(OH)_2 + 4H_2O + 4CO_2$$

$$2Mn(OH)_2 + 4H_2O + O \longrightarrow 2MnO{\cdot}OH + 5H_2O$$

$$2MnO{\cdot}OH + 5H_2O + O \longrightarrow 2MnO_2 + 6H_2O\text{.......''}$$

(6) The presence of colloform texture indicates that the manganese existed as a colloid, probably while in the manganic hydrate state. While in this colloid state it adsorbed such cations as Ba, K, Cu, Cr, Ni, Co, Ti, and Mo.

(7) As the solutions progressed further out into the lake and away from the source faults, which bordered the basin of deposition, the amount of manganese present began to lessen, as well as Ba, Pb, and K.

(8) While the manganese was being deposited, the lake was also receiving smaller amounts of tuffaceous sediments.

(9) At some time after the manganese oxides became indurated the upper portion of the bed became eroded, probably through wave action along the edge of the lake, and the manganese oxide fragments bed was formed.

(10) A series of clays and silts was then deposited over the manganiferous zone. In the last stages of the lake's existence a layer of gypsum was formed.

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APPENDIX A

X-RAY DATA

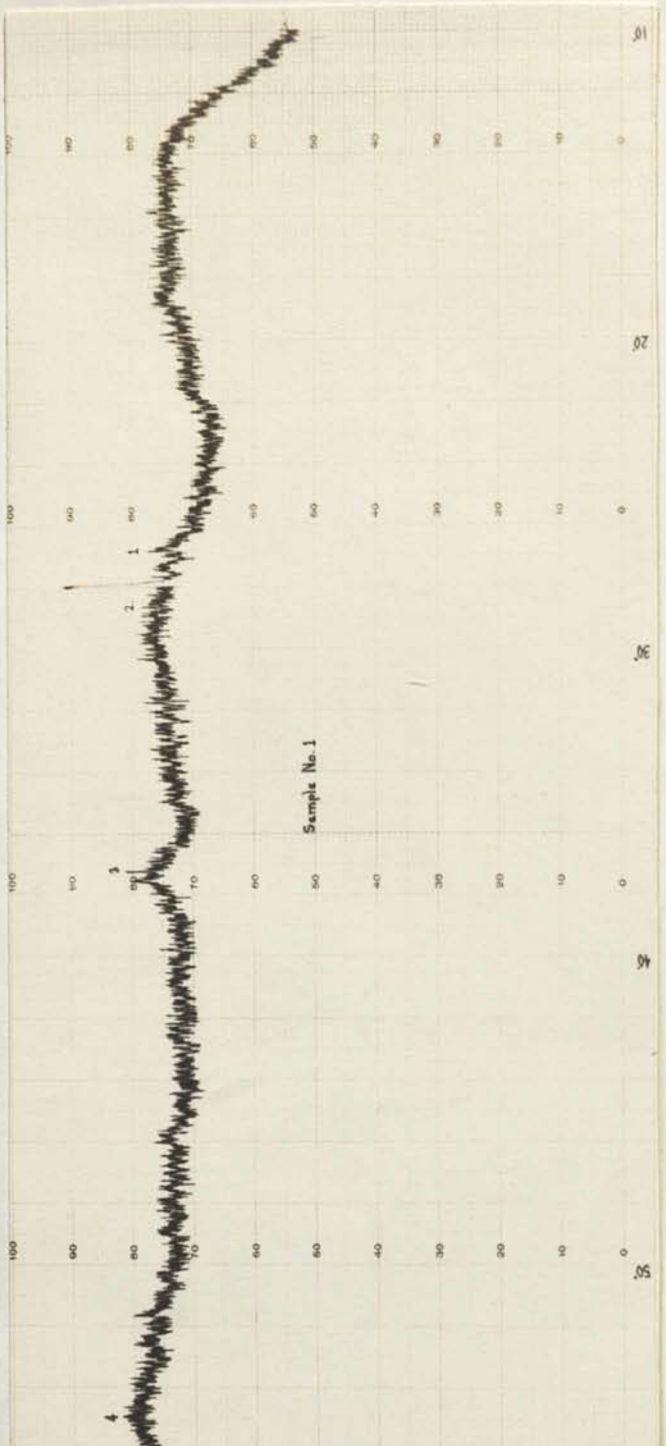

Fig. 17 Diffractometer Pattern of Sample No. 1 (Hydro Pit)

Diffractometer Pattern of Sample No. 1 (Hydro Pit)

CuKα 35KV 15MA 8-1-4 4^{o} .006 Ni filter 1 inch = 2^{o}

Minerals Present: Cryptomelane, Pyrolusite, Celestite, quartz

Line	d (Å)	Est. Int.	Mineral
1	3.33	w	quartz
2	3.11	w	cryptomelane, pyrolusite
3	2.40	m	cryptomelane, pyrolusite
4	1.67	w	celestite
5	1.61	w	cryptomelane, pyrolusite
6	1.56	w	pyrolusite, quartz
7	1.42	w	pyrolusite

note: w - weak line, m - moderate line.

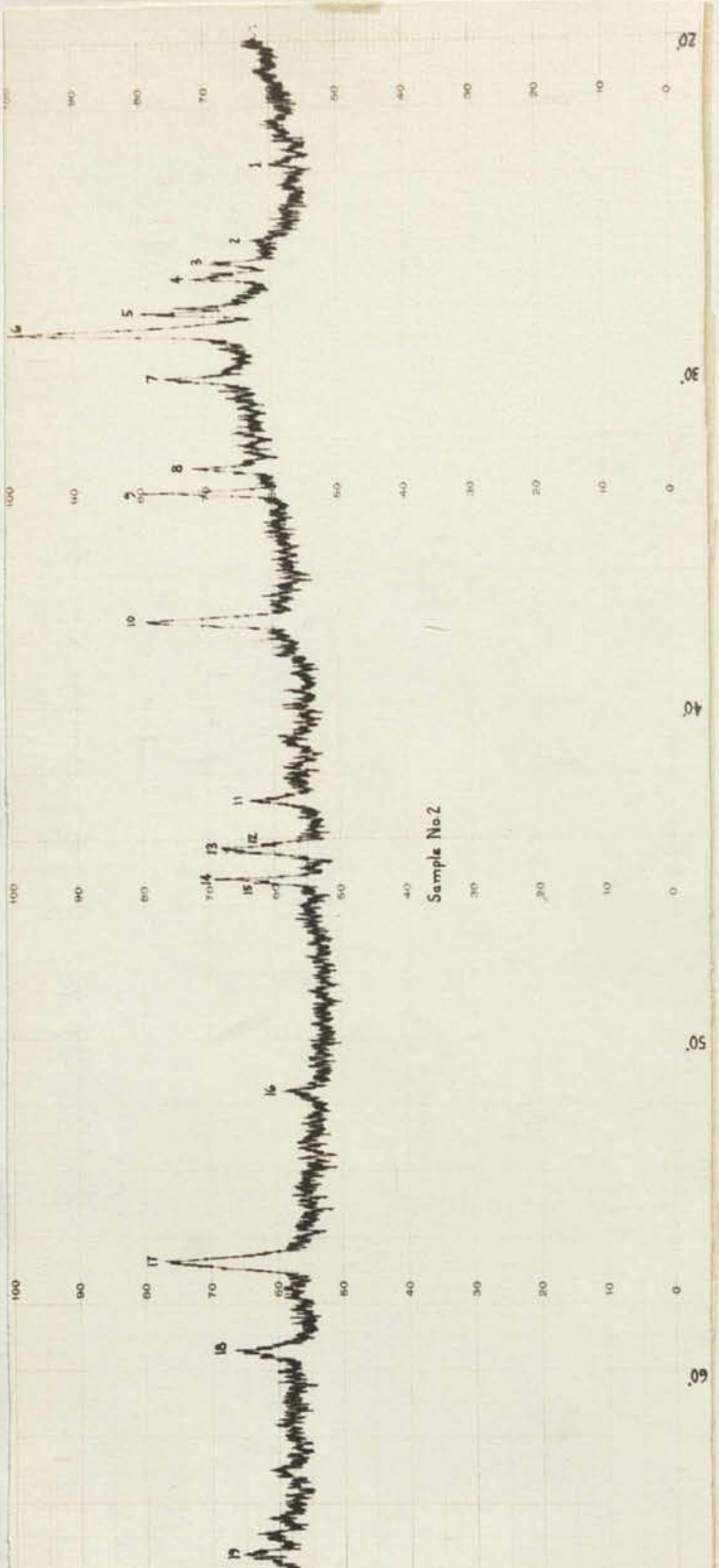

Fig.18 Diffractometer Pattern of Sample No.2 (Hydro Pit)

Diffractometer Pattern of Sample No. 2 (Hydro Pit)

CuKα 35KV 15MA 8-1-4 4° .006 Ni filter 1 inch = 2°

Minerals Present: Pyrolusite, celestite, quartz, gypsum (?).

Line	d (Å)	Est. Int.	Mineral
1	3.76	w	celestite
2	3.43	w	quartz
3	3.34	m	quartz
4	3.28	m	celestite
5	3.17	s	celestite, gypsum
6	3.11	vs	pyrolusite
7	2.97	s	celestite
8	2.73	m	celestite
9	2.67	s	celestite, gypsum
10	2.40	vs	pyrolusite
11	2.11	m	pyrolusite
12	2.05	m	celestite
13	2.04	s	celestite
14	2.01	m	celestite
15	2.00	s	celestite
16	1.77	m	pyrolusite
17	1.62	vs	pyrolusite
18	1.55	s	pyrolusite, quartz
19	1.42	m	pyrolusite
20	1.38	s	quartz

note: w - weak line, m - moderate line, s - strong line, vs - very strong line.

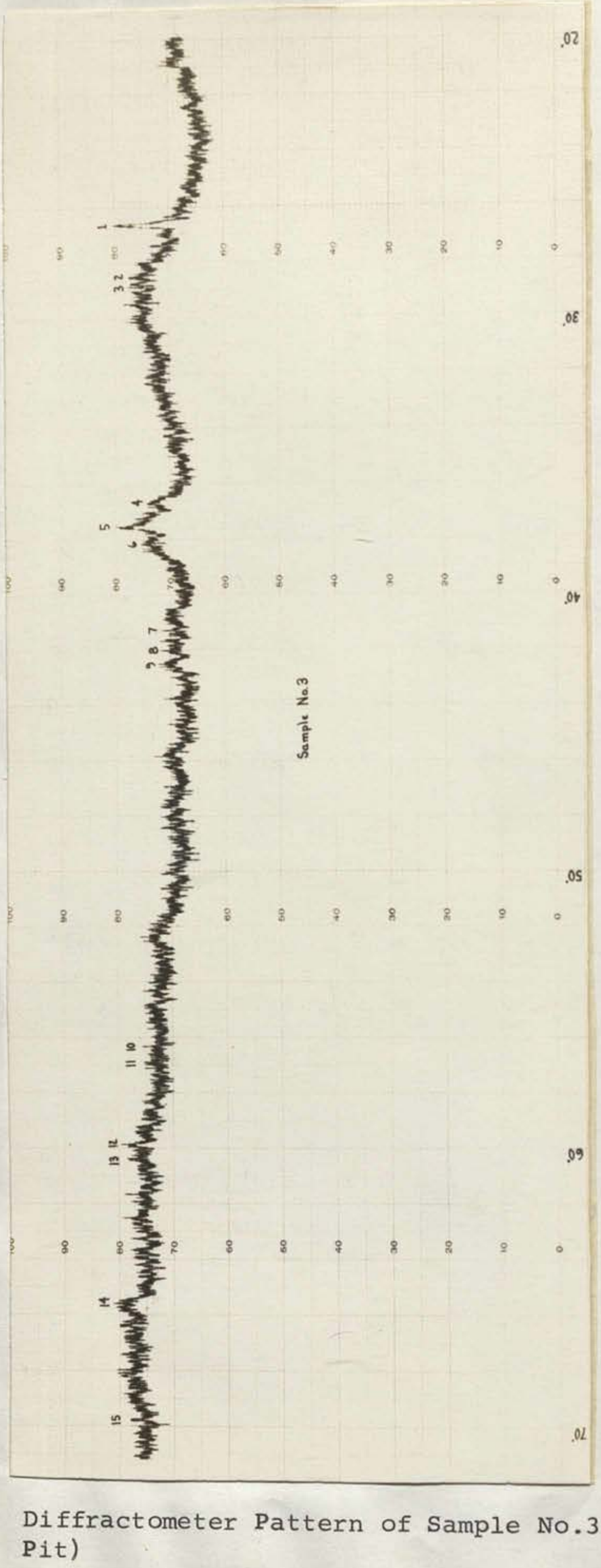

Fig.19 Diffractometer Pattern of Sample No.3 (Three Kids Pit)

Diffractometer Pattern for Sample No. 3 (Three Kids Pit)

CuKα 35KV 15MA 8-1-4 4° .006 Ni filter 1 inch = 2°

Minerals Present: Cryptomelane, Hollandite, Pyrolusite.

Line	d (Å)	Est. Int.	Mineral
1	3.34	s	quartz
2	3.11	w	cryptomelane, pyrolusite
3	3.10	w	hollandite
4	2.42	w	pyrolusite
5	2.40	m	cryptomelane, pyrolusite
6	2.38	w	hollandite, cryptomelane
7	2.19	w	hollandite, cryptomelane
8	2.14	w	hollandite, cryptomelane
9	2.11	w	pyrolusite
10	1.64	w	hollandite
11	1.62	w	pyrolusite, hollandite, cryptomelane
12	1.55	w	pyrolusite
13	1.53	w	hollandite, cryptomelane
14	1.43	w	hollandite
15	1.35	w	hollandite, cryptomelane

note: w - weak line, m - moderate line, s - strong line.

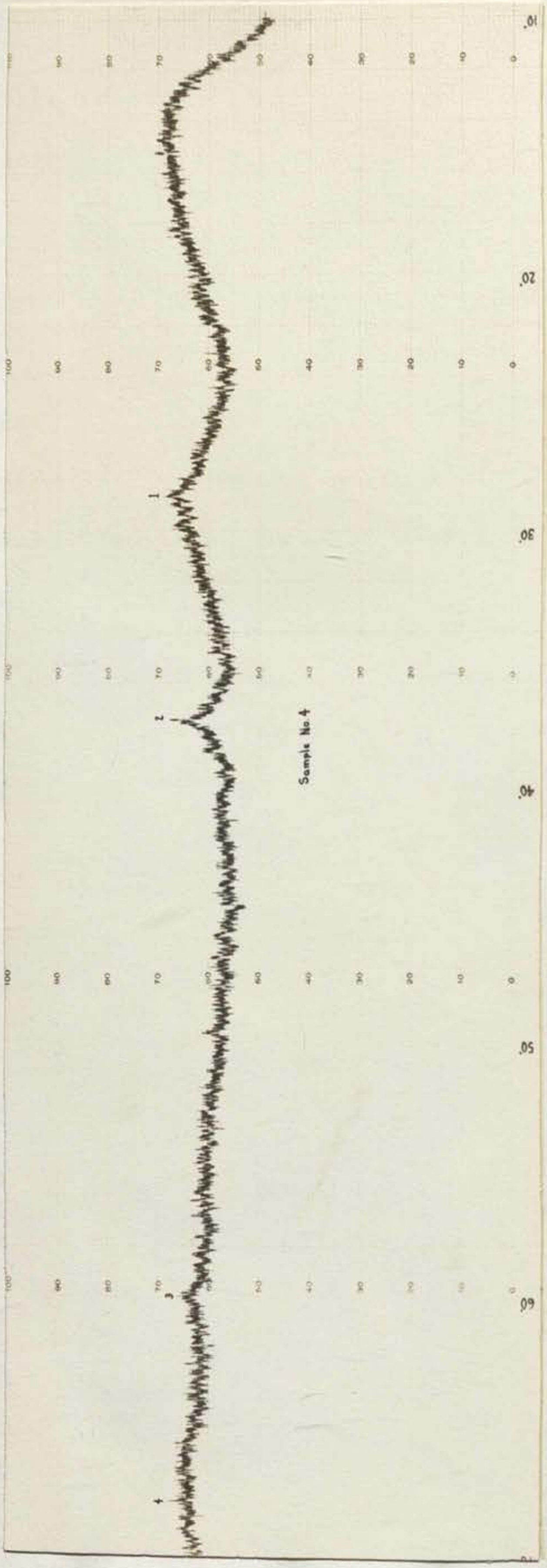

Fig.20 Diffractometer Pattern of Sample No. 4 ("B" Pit)

Diffractometer Pattern for Sample No. 4 ("B" Pit)

CuK α 35KV 15MA 8-1-4 4° .006 Ni filter 1 inch = 2°

Minerals Present: Pyrolusite, Cryptomelane.

Line	d (Å)	Est. Int.	Mineral
1	3.11	w	cryptomelane, pyrolusite
2	2.40	m	cryptomelane, pyrolusite
3	1.54	w	pyrolusite, cryptomelane
4	1.38	w	pyrolusite

note: w - weak line, m - moderate line.

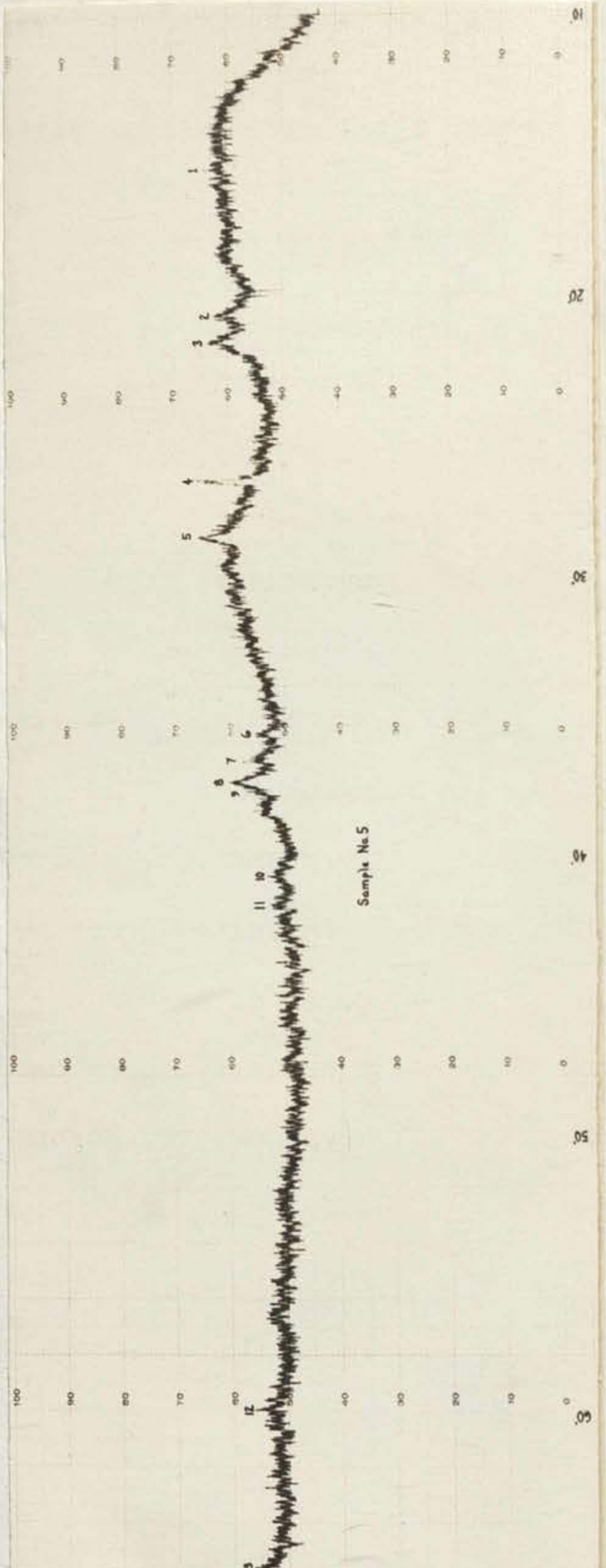

Fig. 21 Diffractometer Pattern of Sample No. 5 ("B" Pit)

Diffractometer Pattern for Sample No. 5 ("B" Pit Siliceous ore)

CuKα 35KV 15MA 8-1-4 4° .006 Ni filter 1 inch = 2°

Minerals Present: Pyrolusite, Cryptomelane, Coronadite, quartz.

Line	d (Å)	Est. Int.	Mineral
1	5.72	w	cryptomelane
2	4.26	m	quartz
3	4.10	m	pyrolusite
4	3.35	vs	quartz
5	3.11	vs	pyrolusite, cryptomelane, coronadite (?)
6	2.52	w	pyrolusite
7	2.45	w	cryptomelane, quartz
8	2.40	vs	pyrolusite, cryptomelane, coronadite (?)
9	2.38	w	coronadite (?)
10	2.21	w	pyrolusite, cryptomelane, coronadite (?)
11	2.16	w	cryptomelane, coronadite (?)
12	1.54	w	pyrolusite, quartz, coronadite (?)
13	1.42	w	pyrolusite, cryptomelane, coronadite (?)

note: w - weak line, m - moderate line, s - strong line, vs - very strong line.

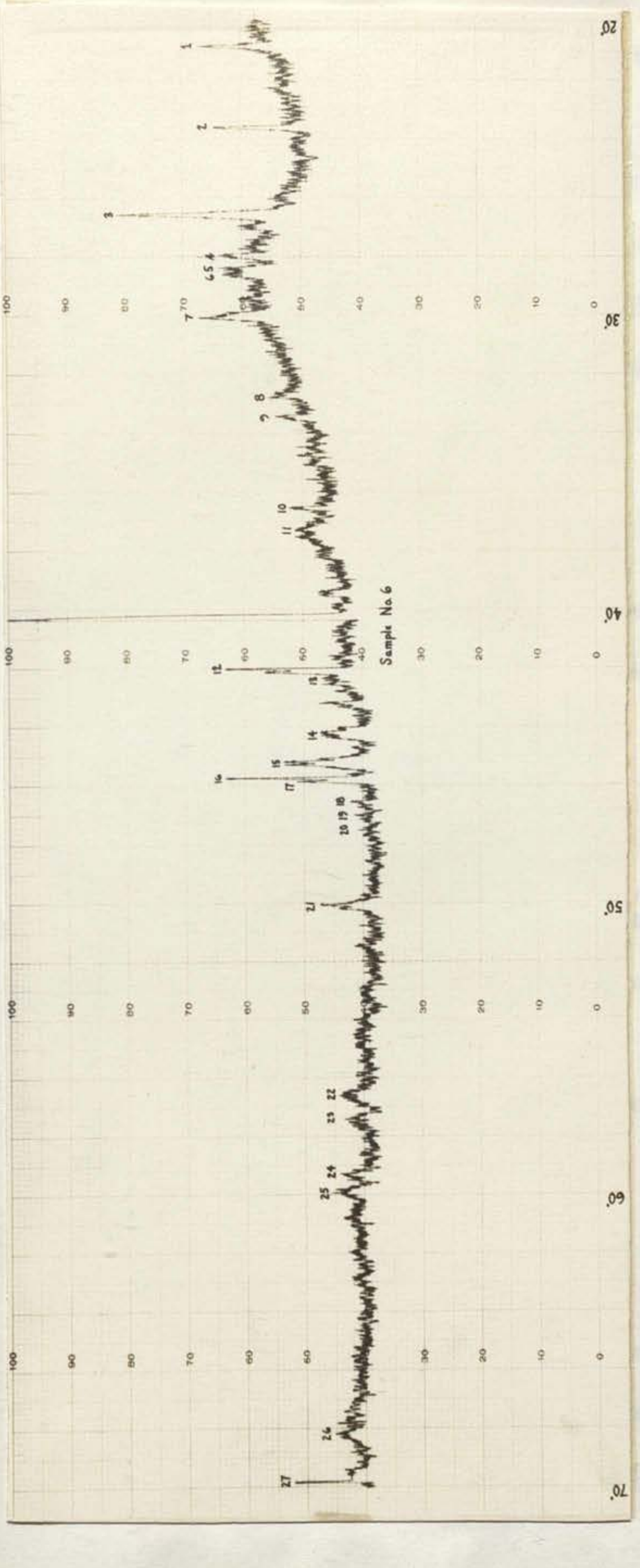

Fig.22 Diffractometer Pattern of Sample No. 6 ("A" Pit)

Diffractometer Pattern of Sample No. 6 ("A" Pit)

CuKα 35KV 15MA 8-1-4 4° .006 Ni filter 1 inch = 2°

Minerals Present: Pyrolusite, Cryptomelane, Hollandite, celestite, quartz, gypsum.

Line	d (Å)	Est. Int.	Mineral
1	4.26	s	quartz, gypsum
2	3.76	s	celestite
3	3.35	s	quartz
4	3.19	m	celestite
5	3.11	m	pyrolusite, cryptomelane
6	3.10	m	hollandite
7	2.97	s	celestite
8	2.73	m	celestite
9	2.68	m	gypsum
10	2.45	m	cryptomelane
11	2.40	m	pyrolusite, cryptomelane
12	2.14	s	celestite
13	2.12	w	pyrolusite
14	2.05	m	celestite
15	2.00	s	celestite
16	1.99	s	celestite
17	1.97	m	pyrolusite
18	1.95	w	hollandite
19	1.93	w	hollandite

Sample No. 6 continued.

Line	d (Å)	Est. Int.	Mineral
20	1.91	w	hollandite
21	1.82	m	cryptomelane
22	1.63	m	cryptomelane
23	1.62	m	pyrolusite
24	1.56	m	pyrolusite
25	1.54	m	cryptomelane, hollandite
26	1.36	w	hollandite
27	1.35	s	pyrolusite, cryptomelane, hollandite

note: w - weak line, m - moderate line, s - strong line, vs - very strong line.

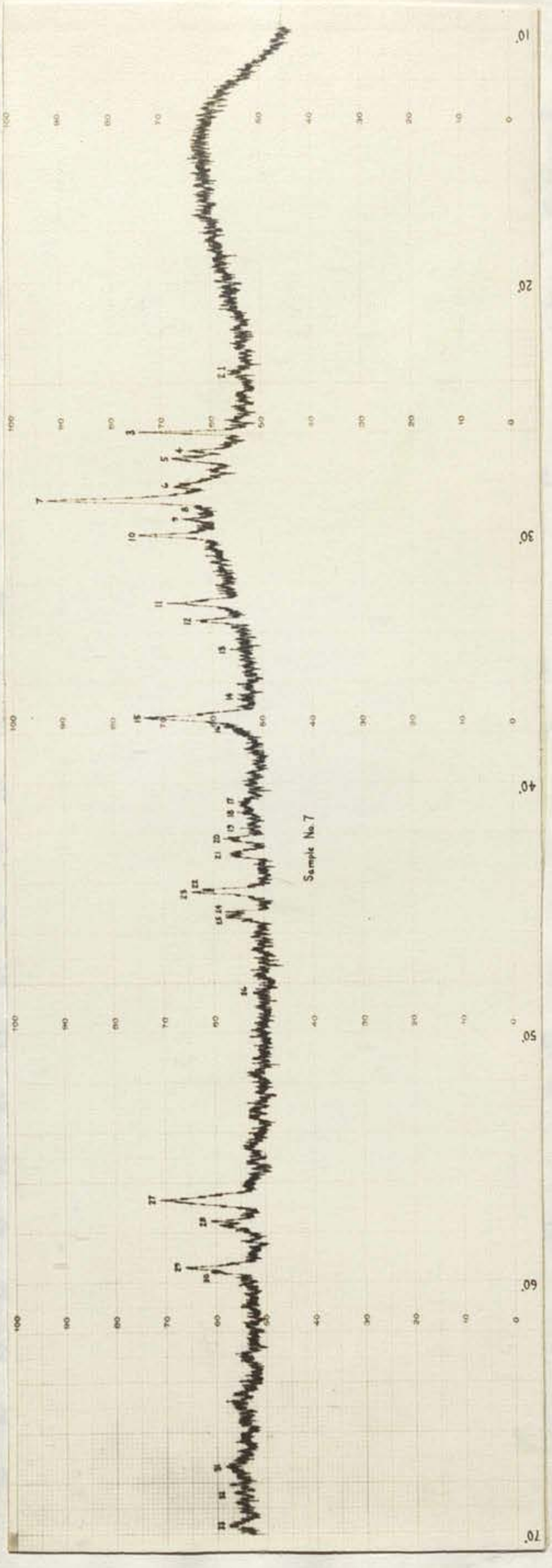

Fig.23 Diffractometer Pattern of Sample No. 7 ("A" Pit)

Diffractometer Pattern of Sample No. 7 ("A" Pit)

CuKα 35KV 15MA 4° .006 Ni filter 1 inch = 2°

Minerals present: Pyrolusite, Hollandite, Cryptomelane, quartz, celestite, gypsum.

Line	d (Å)	Est. Int.	Mineral
1	3.78	w	gypsum
2	3.76	w	celestite
3	3.43	s	quartz, celestite, hollandite
4	3.33	m	quartz
5	3.29	m	celestite
6	3.16	m	gypsum, celestite
7	3.11	vs	pyrolusite, cryptomelane
8	3.07	w	hollandite
9	3.03	m	gypsum
10	2.96	s	celestite
11	2.72	s	celestite
12	2.67	m	gypsum, celestite
13	2.58	w	celestite
14	2.46	w	hollandite
15	2.40	vs	pyrolusite, cryptomelane
16	2.38	m	hollandite
17	2.21	w	cryptomelane
18	2.19	w	pyrolusite, hollandite
19	2.16	w	cryptomelane

Sample No. 7 continued.

Line	d (Å)	Est. Int.	Mineral
20	2.14	m	quartz, celestite, cryptomelane
21	2.11	m	pyrolusite
22	2.05	s	celestite
23	2.04	s	celestite
24	2.00	m	celestite
25	1.995	m	celestite, quartz
26	1.83	w	cryptomelane
27	1.62	vs	pyrolusite, cryptomelane
28	1.61	s	hollandite
29	1.55	s	pyrolusite, cryptomelane, quartz
30	1.53	m	hollandite
31	1.38	w	quartz
32	1.36	w	hollandite
33	1.35	w	pyrolusite, cryptomelane

note: w - weak line, m - moderate line, s - strong line, vs - very strong line.

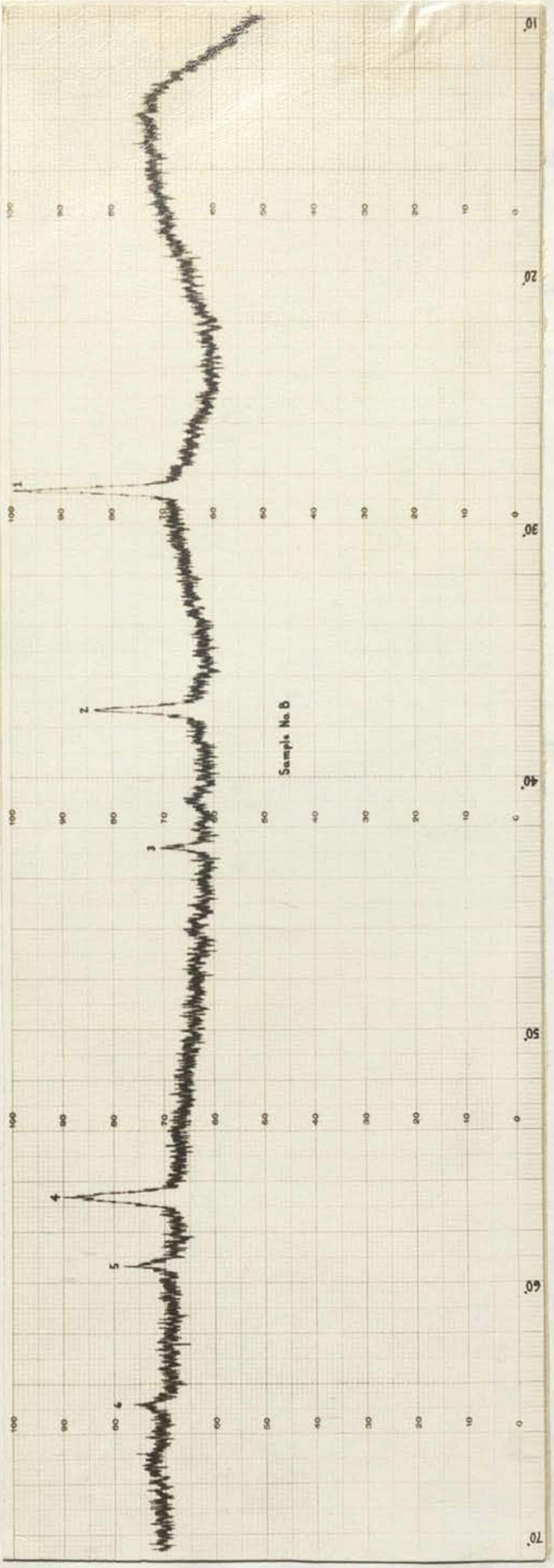

Fig.24 Diffractometer Pattern of Sample No. 8 (Extension Area)

Diffractometer Pattern for Sample No. 8 (Extension Area)

CuK α 35KV 15MA 4° .006 Ni filter 1 inch = 2°

Minerals Present: pyrolusite

Line	d (Å)	Est. Int.	Mineral
1	3.11	vs	pyrolusite
2	2.40	s	pyrolusite
3	2.11	m	pyrolusite
4	1.62	s	pyrolusite
5	1.55	m	pyrolusite
6	1.43	m	pyrolusite

note: w - weak line, m - moderate line, s - strong line, vs - very strong line.

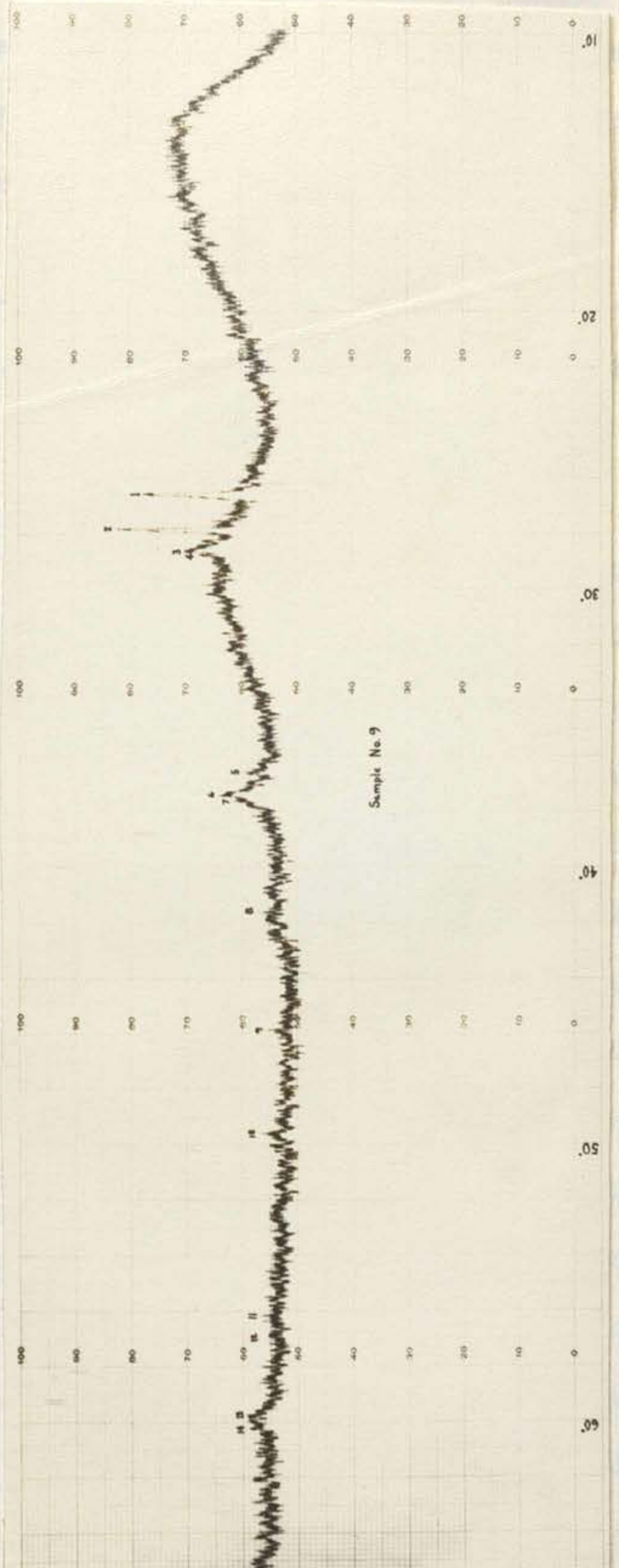

Fig. 25 Diffractometer Pattern of Sample No.9 (Extension Area)

Diffractometer Pattern of Sample No. 9 (Extension Area)

CuK 35KV 15MA 4° .006 Ni filter 1 inch = 2°

Minerals Present: Pyrolusite, cryptomelane, hollandite, quartz.

Line	d (A)	Est. Int.	Mineral
1	3.35	s	quartz
2	3.20	s	?
3	3.11	m	pyrolusite, cryptomelane
4	3.10	w	hollandite
5	2.46	w	hollandite, cryptomelane
6	2.40	m	pyrolusite, cryptomelane
7	2.39	m	hollandite
8	2.18	w	hollandite
9	1.97	w	pyrolusite
10	1.84	w	hollandite, cryptomelane
11	1.64	w	hollandite, cryptomelane
12	1.61	w	pyrolusite
13	1.55	w	pyrolusite, cryptomelane
14	1.53	w	hollandite
15	1.43	w	cryptomelane
16	1.38	m	pyrolusite
17	1.36	m	hollandite, cryptomelane
18	1.34	w	hollandite

note: w - weak line, m - moderate line, s - strong line

APPENDIX B

DRILL HOLE DATA

Note: The author logged and sampled holes V-4, V-5, V-6, V-7, V-8, V-9, V-10, V-11, V-12, V-13, V-14, V-15, and V-16. The other holes recorded here were logged by the U. S. Bureau of Mines in 1942 and the cores were not available.

Drill Hole #1199 ("A" Pit)

N 1500 W 736 Elev. 1934

Depth	% Mn	Material Drilled
0'-5'		
5'-10'		
10'-15'		
15'-20'		
20'-25'		
25'-30'		
30'-35'		Clay and silt
35'-40'		
40'-45'		
45'-50'		
50'-55'		
55'-60'		
60'-65'		
65'-70'		
70'-75'		
75'-80'		
80'-85'		
85'-90'		
90'-95'		
95'-100'	7.3	
100'-105'	13.0	
105'-110'	10.5	
110'-115'	1.2	Silt
115'-120'	1.3	
120'-125'	0.9	Lava

Note: Lowney fault intersected at 112' depth.

Drill Hole #V-4 ("A" Pit)

N 1475 W 515 Elev. 1908

Depth	%Mn	$\%SO_4$	%Pb	Description
0'-215'	---	---	---	Red clay and gyp. stringers.
215'-220'	9.28	5.00	---	Mn Blebs & bands in red tuff sed. 2" opal @ 237.5'.
220'-225'	7.38	6.27	---	
225'-230'	10.71	7.88	---	
230'-236.5'	10.00	0.79	---	
236.5'-241'	17.97	0.34	---	
241'-247'	24.87	0.37	1.45	Massive and finely divided Mn in white tuff.
247'-253'	10.71	0.34	0.80	" " " "
253'-257'	---	---	---	Barren white tuff.
257'-261.5'	4.52	0.43	---	Banded Mn in red tuff sed.
261.5'-298.5'	---	---	---	Conglomerate.
298.5'-303'	---	---	---	Lowney fault zone, very fine, hard, white clay.
303'-320.5'	---	---	---	Fractured volcanics.

Note: At 263' cgl. stained for a few inches with celandonite ore in stringers 1/2" to 1" across. No celadonite at contact. From 253'-254' tuff considerably stained with celadonite before going into massive Mn.

Drill Hole #V-5 ("A" Pit)

N 1476 W 435 Elev. 1903

Depth	%Mn	$\%SO_4$	%Pb	Description
0-3'	---	---	---	Gravel.
3'-35'	---	---	---	Gypsum.
35'-203'	---	---	---	Red and blue clays.
203'-208'	6.33	2.96	---	Mn blebs in red tuff sed.
208'-213'	2.39	5.38	---	" " " " " "
213'-218.5'	9.80	6.33	---	" " " " " "
218.5'-221'	---	---	---	Barren red clay.
221'-225.5'	15.30	8.55	0.60	Mn blebs in red tuff sed.
225.5'-232'	3.47	11.87	---	" " " " " "
232'-238.5'	9.08	14.91	0.40	" " " " " "
238.5'-240.5'	---	---	---	Barren pink clay.
240.5'-245'	9.92	9.98	---	Mn blebs in pink tuff sed.
245'-251'	14.10	0.40	---	Finely divided Mn in
251'-255-	9.32	0.36	---	tuffaceous sediment.
4" opal @247'; 3"@ 248.5'				
255'-266'	---	---	---	Barren white tuff.
266'-274.5'	20.08	0.34	1.40	Massive Mn, tuff inclusions.
6" opal @ 266'; 4@ @ 267'				
274.5'-282'	5.62	0.32	---	Mn bands in tuffaceous ss.
6" silica @ 281'.				
282'-290'	---	---	---	Green tuffaceous sediment.
290'-296'	---	---	---	Conglomerate.

Tuff stained for 2.5 feet with celadonite below ore @ 282'.

Drill Hole #V-7 ("A" Pit)

N 1482 W 278 Elev. 1924

Depth	%Mn	$\%SO_4$	Description
0'-18'	---	---	Gravel.
18'-220'	---	---	Gypsum and red clays.
220'-225'	12.22	11.25	Mn blebs in red tuffaceous sediment.
225'-230'	10.30	0.23	" " " " " "
230'-235'	5.63	0.21	" " " " " "
235'-239'	11.86	0.19	" " " " " "
239'-245'	---	---	Barren white tuff.
245'-254'	3.95	0.15	Mn bands in red & white tuff sed.
254'-260.5'	8.15	0.10	" " " " " " "
6" opal @ 245'; 8" @ 254'; 3" @ 259.5'.			
260.5'-269'	---	---	Conglomerate.

Note: At 260.5' there is a 1-inch stringer of Mn with 1/8-inch celadonite on top and 6"-8" below contact. 6" of barren tuff above ore; 1/4" celadonite, then 6" massive Mn joins in to blebs.

Drill Hole #V-6 ("A" Pit)

N 1475 W 357 Elev. 1911

Depth	%Mn	$\%SO_4$	Description
0'-11'	---	---	Gravel.
11'-210'	---	---	Gypsum and red clays
210'-215'	10.90	6.62	Mn blebs in red tuffaceous sed.
215'-220'	14.38	7.80	
220'-225'	13.42	12.35	
225'-230'	9.46	16.71	" " " " " "
230'-235'	13.66	1.04	
235'-240'	18.33	0.26	
240'-247'	17.01	0.37	" " " " " "
247'-255'	---	---	Barren white tuff.
255'-258'	11.02	0.21	Mn blebs in red and white tuff sed.
4" opal @ 256.5'.			
258'-275'	---	---	Barren pink tuffaceous sediment.
275'-278'	5.52	0.32	Banded Mn in pink tuff sed.
12" opal @ 276'			
278'-285'	---	---	Conglomerate.

Note: Tuff stained with celadonite for 1-1/2" below ore-tuff contact @ 278'.

Drill Hole #V-16 ("A" Pit)

N 1524 W 586 Elev. 1911

Depth	%Mn	$\%SO_4$	%Pb	Description
0'-10'	---	---	---	Gravel.
10'-192.5'	---	---	---	Red clay and gyp. stringers.
192.5'-197.5'	23.38	14.35	0.50	Massive high grade Mn.
197.5'-202.5'	25.21	5.08	0.80	" " " "
202.5'-207.5'	18.97	1.24	1.25	" " " "
207.5'-212'	16.16	0.29	0.90	Mn bands in red
212'-217'	21.18	0.46	1.40	tuffaceous sediment.
217'-222'	8.94	0.26	0.50	4" opal @ 214'; 4" @ 222'.
222'-226'	22.03	0.24	1.30	
226'-229'	8.81	0.27	0.70	
229'-231'	---	---	---	Green and white tuff.
231'-241.5'	---	---	---	Green and white tuff sed.
241.5'-242.5'	---	---	---	Lowney fault gouge.
242.5'-251'	---	---	---	Volcanics (andesite?).

Note: "Green tuff" is tuff stained with celadonite.

Drill Hole #1082 ("A" Pit)

N 1500 E 200 Elev. 1931

Depth	%Mn	Classification of Material
0'-5'	30.6	
5'-10'	36.4	
10'-15'	33.3	Tuffaceous silt and sandstone.
15'-20'	19.3	
20'-25'	5.2	
25'-30'	25.6	
30'-35'	10.6	
35'-40'	6.8	
40'-45'	3.5	
45'-50'	2.3	Sandstone and conglomerate.
50'-55'	14.4	(sub ore)
55'-60'	11.9	
60'-65'	3.7	
65'-70'	1.1	
70'-75'	1.9	
75'-80'	2.6	Cgl. and lava.
80'-85'	0.9	
85'-87'	0.8	

Note: Much overburden removed before this hole was drilled.

Drill Hole #1151 ("A" Pit)

N 1500 E 100 Elev. 1927

Depth	% Mn	Classification of Material
5'	26.8	
10'	21.6	
15'	24.4	
20'	33.2	Tuffaceous silt and sandstone.
25'	29.0	
30'	36.5	
35'	31.8	
40'	30.4	
45'	31.6	
50'	23.3	
55'	4.3	
60'	4.9	
65'	6.6	Conglomerate
70'	1.0	
75'	0.5	
80'	0.9	Lava (?)

Note: Much overburden removed before hole drilled.

Drill Hole #1152 ("A" Pit)

N 1500 E 150 Elev. 1929

Depth	%Mn	Classification of Material
5'	34.5	
10'	35.5	
15'	39.3	Tuffaceous silt and sandstone.
20'	38.0	
25'	34.7	
30'	35.0	
35'	14.8	
40'	3.4	
45'	11.8	Conglomerate.
50'	7.4	

Note: Much overburden removed before hole drilled.

Drill Hole #1153 ("A" Pit)

N 1500 E 50 Elev. 1922

Depth	%Mn	Classification of Material
5'	30.9	
10'	30.3	
15'	32.3	
20'	34.3	
25'	34.7	Tuffaceous silt and sandstone.
30'	39.9	
35'	33.7	
40'	27.5	
45'	35.5	
50'	32.1	
55'	29.4	
60'	26.9	
65'	14.4	
70'	3.7	
75'	1.3	
80'	9.4	
85'	6.9	
90'	1.3	
95'	1.7	Sandstone and conglomerate.
100'	3.2	
105'	2.3	
110'	2.7	
115'	2.3	
120'	0.8	
125'	1.0	Lava (?)

Note: Much overburden removed before hole drilled.

Drill Hole #1188 ("A" Pit)

N 1500 0-0 E-W Elev. 1890

Depth	%Mn	Classification of Material
0'-5'	3.0	Silt (sub ore)
5'-10'	8.7	
10'-15'	12.7	
15'-20'	7.4	
20'-25'	13.4	
25'-30'	12.7	Tuffaceous silt and sandstone
30'-35'	11.5	
35'-40'	15.2	
40'-45'	16.6	
45'-50'	13.7	
50'-55'	14.4	
55'-60'	13.5	
60'-65'	1.9	
65'-70'	1.8	Conglomerate
70'-75'	0.8	

Note: Much overburden removed before hole drilled.

Drill Hole #1108 ("B" Pit)

N 1500 E 424 Elev. 1874

Depth	%Mn	Material Drilled
0'-5'	25.9	
5'-10'	29.8	Tuffaceous silt and sandstone
10'-15'	31.3	
15'-20'	30.7	
20'-25'	11.7	
25'-30'	9.8	
30'-35'	1.6	Conglomerate
35'-40'	5.0	
40'-45'	4.8	
45'-50'	1.1	
50'-55'	0.3	Lava (?)

Drill Hole #1114 ("B" Pit)

N 1500 E 450 Elev. 1874

Depth	%Mn	Material Drilled
0'-5'	24.2	Tuffaceous silt and sandstone
5'-10'	13.4	
10'-15'	4.0	
15'-20'	1.5	
20'-25'	0.4	Conglomerate
25'-30'	1.7	
30'-35'	1.6	
35'-40'	0.5	
40'-45'	0.1	Lava (?)

Note: Much overburden removed before these holes were drilled.

Drill Hole #1119 ("B" Pit)

N 1500 E 380 Elev. 1875

Depth	%Mn	Material Drilled
0'-5'	32.5	
5'-10'	34.8	
10'-15'	35.6	
15'-20'	36.3	
20'-25'	27.6	
25'-30'	28.2	Tuffaceous silt and sandstone
30'-35'	32.8	
35'-40'	31.5	
40'-45'	31.9	
45'-50'	24.8	
50'-55'	9.7	
55'-60'	10.3	
60'-65'	2.4	
65'-70'	1.0	
70'-75'	7.9	Conglomerate
75'-80'	1.3	
80'-85'	1.1	Lava (?)

Note: Much overburden removed before hole drilled.

Drill Hole #V-8 (Las Vegas Extension)

N 288   W 3500   Elev. 1834

Depth	%Mn	$\%SO_4$	Description
0'-6'	---	---	Gravel.
6'-135'	---	---	Red and yellow clays with gypsum stringers.
135'-140'	14.02	1.09	Mn blebs in red tuffaceous sed.
140'-144'	19.17	0.31	" " " " " "
144'-147'	8.51	1.60	
147'-153'	13.54	5.26	
153'-158'	10.06	3.27	
158'-163'	9.22	3.73	" " " " " "
163'-168'	7.19	1.11	
168'-173'	3.00	0.16	
173'-177'	2.28	0.24	" " " " " "
177'-181'	---	---	Barren red tuff sediment.
181'-188'	7.79	0.96	Mn blebs in red tuff sed.
188'-198'	---	---	Barren red tuff sediment.
198'-202'	17.37	0.30	Mn blebs in red tuff sediment.
6" opal @ 199'; and 6"			opal @ 201'.
202'-210'	---	---	Barren red, pink, and green tuff sediments.
210'-217'	---	---	Barren white tuff.
217'-222'	14.14	0.28	Mn blebs and bands in red tuffaceous sediment.
222'-223'	---	---	Green tuff sediment
223'-227'	---	---	Barren white tuff.
227'-253'	---	---	Conglomerate.

Drill Hole #V-9 (Las Vegas Extension)

N 366 W 3496 Elev. 1821

Depth	%Mn	$\%SO_4$	Description
0'-175'	---	---	Red & yellow clays with gyp. stringers.
175'-180.5'	5.71	5.08	Mn blebs in red tuff sed.
180.5'-181.5'	---	---	Barren white tuff.
181.5'-186'	4.05	5.53	Mn blebs in red tuff sediment.
186'-191'	5.36	4.65	" " " " "
191'-196'	6.66	3.16	" " " " "
196'-202'	11.54	1.31	" " " " "
202'-214.5'	---	---	Barren red tuff sediments.
214.5'-219'	11.31	0.20	Mn blebs in red tuff sediments.
219'-229'	---	---	Red, white, and green tuffs.
229'-233.5'	7.62	0.18	Mn blebs & bands in red & white tuff sediments.
233.5'-239'	---	---	Barren white tuff.
239'-241.5'	---	---	Conglomerate.

239' Contact between white tuff (top) and cgl. (bottom) contains no celadonite. At 233.5' contact between ore (top) and tuff with 3" of celadonite at contact. Massive Mn for 4" then into blebby Mn to 229'. No celadonite at upper contact, grades into pure tuff again.

219' In second Mn bed celadonite stains--then Mn massive for 3" then blebby for 1 foot grades into pure tuff then celadonite for 3" then massive Mn for 6" then bleb, to 214.5'. Slight amount of celadonite at contact of Mn and tuff at 202'. Massive Mn for 1 foot blebby to 185.5'. One foot of white tuff (no celadonite present), then blebby Mn to 175'.

Drill Hole #V-10 (Las Vegas Extension)

N 318 W 3557 Elev. 1834

Depth	%Mn	%SO_4	Description
0'-217.5'	---	---	Red & yellow clays with gyp. stringers.
217.5'-226'	6.42	2.61	Mn blebs red tuff sed.
226'-238.5'	---	---	Barren red tuff sed.
238.5'-241.5'	20.48	0.26	Mn blebs in red tuff sed.
241.5'-251'	---	---	Barren pink, grey, & green tuff sediment.
251'-257.5'	8.83	0.18	Mn blebs in red tuffaceous sediment.
257.5'-263'	---	---	Green & white tuff.
263'-275'	---	---	Conglomerate.

Note: At 268'-269' depth vesicular volcanic. Could be either large boulder in conglomerate or thin flow. Similar occurrence in Hole V-8 at a depth of 243'-244'; however, this did not show up in Hole V-15. The contact at 263' between white tuff (top) and conglomerate apparently is an old erosion surface. The "green tuff" contains several layers (6" thick) of celadonite apparently concordent to bedding. At 257.5' the contact between the lowermost Mn bed and the tuff is marked with a 4" layer of celadonite, as is the upper contact at 251'. The ore is about 1' thick on bottom (massive black) which becomes blebby toward the top. (Erosion of original Mn bed to form this?) At the top of the ore the tuff contains a few thin stringers of celadonite. At 241' more celadonite in bands (in several zones 3" thick). Mn above contact is massive for about 8" then is blebby above. No celadonite present at upper part of Mn bed. Thin stringer celadonite at 235'. In third Mn bed at 226' there is thin stringer (1/8 in.) of celadonite along contact. Ore is massive for 1 foot then blebby rest of way.

Drill Hole #V-11 (Las Vegas Extension)

N 235 W 3618 Elev. 1834

Depth	%Mn	$\%SO_4$	Description
0'-50'	---	---	No core - tuff seds.
50'-55'	5.32	0.18	Mn blebs in red tuffaceous seds.
55'-60'	13.67	0.17	" " " " " "
60'-63'	---	---	Barren pink & gray tuff.
63'-67'	---	---	Conglomerate.
67'-82.5'	---	---	Barren pink & gray tuff.
82.5'-90'	7.32	0.28	Mn blebs in red tuff seds. 6" opal @ 82.5'.
90'-102'	---	---	Barren pink & green tuffaceous seds.
102'-104.5'	---	---	Conglomerate.
104.5'-107'	---	---	Pink tuffaceous sediment.
107'-110'	7.20	0.19	Mn bands in red tuffaceous sediment.
110'-121'	---	---	Pink & gray tuff sed.
121'-126.5'	---	---	Conglomerate.
126.5'-130.5'	---	---	Pink and gray tuff sed.
130.5'-134	10.56	0.27	Mn bands in pink & gray tuff, sediment.
134'-163'	---	---	Conglomerate.

Note: Bottom "conglomerate" contains large angular fragments of underlying volcanic. Traces of celadonite present in fractures, etc. At 134' depth celadonite present in fractures and joints in "conglomerate" below Mn bands. Mn in lower zone (130'-134') in bands parallel to bedding. Celadonite not noted in this zone.

Drill Hole #V-13 (Las Vegas Extension)

N 91 W 3098 Elev. 1898 (in open ground)

Depth		Description
0'-6'	No Manganese	Gravel
6'-10'		No core.
10'-45'		"Conglomerate" with inclusion of vesicular lava flow.
45'-50'		Vesicular lava flow. Joints, fractures and pores filled with green mineral.

Note: This hole was drilled near the center of a magnetic high. This high probably due to volcanics. No traces of manganese anywhere in hole. Contact between underlying vesicular lava flow and overlying "conglomerate" is an erosion surface. Quite uneven. "Conglomerate" above contains angular and sub-angular fragments of underlying volcanic. Celadonite in fractures of volcanic stop at contact between volcanic and "conglomerate". Do not extend into "conglomerate".

Drill Hole #V-12 (Las Vegas Extension)

N 71 W 2915 Elev. 1899 (in open ground)

Depth		Description
0'-10'	No Manganese	Gravel.
10'-50'		Light gray volcanic, possibly latite.

Note: This hole was drilled in the center of a magnetic low. No traces of Mn anywhere in hole.

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Drill Hole #V-14 (Las Vegas Extension)

N 450 W 3503 Elev. 1813

Depth	%Mn	$\%SO_4$	%Pb	Description
0'-185'	---	---	---	Yellow & red clay with gyp. stringers.
185'-190'	8.52	3.69	0.50	Mn blebs in red tuffaceous sediment.
190'-195'	3.96	3.19	0.45	" " " " "
195'-203.5'	5.04	3.50	0.40	" " " " "
203.5'-210'	---	---	---	Pink & white tuff. sed.
210'-216.5'	8.88	3.32	0.40	Mn blebs in red tuff sediment.
216.5'-223.5'	16.68	0.84	1.15	" " " " " "
223.5'-227'	---	---	---	Red & green tuff clay.
227'-233'	15.60	0.30	0.75	Mn blebs in brown and red tuff. sed.
233'-239'	9.24	0.25	0.55	" " " " "
239'-240'	---	---	---	Green tuff. clay.
240'-250'	---	---	---	Green & white tuff.
250'-254'	---	---	---	Red tuff sediment.
254'-265'	---	---	---	Conglomerate.

Note: At 253.5' stringer of celadonite in conglomerate. Cgl. is similar to that in other holes. Contact between red tuff (cgl.) and white tuff at 248' with celadonite (about 1/2 inch) along this contact. At 239' contact of ore and tuff. Celadonite about 1 foot thick here. 6-8" of massive ore then into blebs. Green mineral from 235.5'-227'. Massive Mn for 3 ft. then blebby. In upper Mn bed no massive manganese, only blebs and no celadonite.

Drill Hole #V-15 (Las Vegas Extension)

N 350 W 3600 Elev. 1827

Depth	%Mn	%SO_4	Description
0'-285'	---	---	Red & yellow clays with gyp. stringers.
285'-289.5'	---	---	Red tuffaceous sediment, traces of Mn.
289.5'-295'	2.69	0.24	Mn blebs in red tuffaceous sed.
295'-299'	2.82	0.21	" " " " " "
299'-303'	10.65	0.14	" " " " " "
303'-309'	---	---	Barren red & white tuff.
309'-325'	---	---	Conglomerate - volcanics.

Note: At 287' there is a change in lithology, from a coarse pink sand to a finer grained pinkish clay. Celadonite occurs along contact. There are a few isolated blebs of Mn at around 289', in the "ore zone". The Mn occurs as small isolated blebs (sedimentary?) and in stringers cutting the bedding at right angles (transportation of Mn downward by suspension). Fragments of Mn are about 1/4" diam. and smaller; also fine disseminations in zones a fraction to an inch thick, paralleling the bedding. Host rock is pink sandy material. Some blebs are elongated, with long axis parallel to bedding. This zone is only a few feet thick. Grades into gougy fine-grained pink tuff which after a few feet comes in contact with a white tuff. Celadonite occurs along contact, and along a few fractures above. White tuff about 4' thick. Contact at bottom with pink tuff braccia; contains angular fragments of vesicular volcanic rock. Celadonite quite pronounced along contact. This rock type has been referred to as "conglomerate" in work previously done in the area. Contains celadonite. In the last foot of core volcanics (latite?) begin to appear. Contact between "conglomerate" ill-defined.