Geochemical Exploration Near the Getchell Mine Humboldt County, Nevada

GEOLOGICAL SURVEY BULLETIN 1198-A

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By R. L. ERICKSON, A. P. MARRANZINO, UTEANA ODA, *and* W. W. JANES

CONTRIBUTIONS TO GEOCHEMICAL PROSPECTING FOR MINERALS

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By R. L. ERICKSON, A. P. MARRANZINO, UTEANA ODA, and W. W. JANES

ABSTRACT

Geochemical work at the Getchell mine, Nevada, and vicinity has demonstrated that arsenic-tungsten-mercury anomalies occur in rocks and soils over the arsenic-gold deposits. The highest metal contents are found in oxidized iron-rich material along fractures and bedding planes in barren bedrock, lesser values in caliche coatings on exposed bedrock, and lowest but still anomalous values in soil.

Several areas of anomalous arsenic-tungsten-mercury concentrations were found in or near the Getchell fault zone, mostly south of the principal Getchell mine workings. Some of these anomalies appear to be worthy of exploration for concealed gold deposits.

Lead-zinc-silver anomalies were detected in jasperoid along the Village fault in the northern part of the Getchell mine area.

INTRODUCTION AND ACKNOWLEDGMENTS

Geochemical investigations by the U.S. Geological Survey were begun at the Getchell gold mine in 1961 to study the arsenic-gold association and to test the idea that determination of arsenic in soils and rocks at the surface would aid in the search for additional concealed gold ore.

The Getchell gold deposit is on the northeast flank of the Osgood Mountains in Humboldt County, Nev., and is accessible from U.S. Highway 40 by 14 miles of black top and about 10 miles of gravel road. It has produced about $17 million in gold from open-pit and underground operations, and during World War II it became the largest gold producer in Nevada. Most of the known oxidized ore was mined by 1945. A considerable amount of sulfide ore remains. Operation of the Getchell mine was taken over by Goldfield Mines, Inc., in 1961, and they have carried on an intensive metallurgical research program on the treatment of the sulfide ore.

The writers are indebted to Mr. W. H. Hisle, general manager of the Getchell mine, and his staff, and to Mr. H. N. Witt, consulting geologist for the Getchell mine, for their help and support during this study. Base maps and mine and assay maps were provided for our use, trenches were bulldozed to bedrock where requested, and the physical facilities of the camp were made available.

GEOLOGIC SETTING

The geology of the north-central part of the Osgood Mountains has been described by Hobbs and Clabaugh (1946); the occurrence of gold at the Getchell mine has been described by Joralemon (1951); and the geology of the Osgood Mountains 15-minute quadrangle has been mapped by Hotz and Willden (1961). The Getchell mine is near the northeast border of this quadrangle.

The north-central part of the Osgood Mountains consists of complexly folded and thrust-faulted Paleozoic sedimentary rocks intruded by a Cretaceous granodiorite mass. This mass is about 6 miles long and has an hourglass-shaped outcrop pattern that ranges in width from less than 1,000 feet (fig. 1) to about 2½ miles. The shape of the intrusive mass is not known, but the contact is nearly vertical on the western side and dips 40°–60° E. on the eastern side. Several small satellite bodies of granodiorite crop out north and east of the main mass. Hotz and Willden (1961) described the granodiorite as an equigranular medium-grained light-gray intrusive rock composed of the following minerals in order of decreasing abundance: plagioclase, quartz, orthoclase, biotite and hornblende. There are several iron-stained altered areas that show different intensities of sericitization, chloritization, pyritization, and silicification. Some of the more intense areas of alteration contain anomalous amounts of copper (up to 1,000 ppm) and molybdenum (up to 200 ppm).

The intruded sedimentary rocks along the east side of the range are chiefly greenish-gray to yellowish-gray phyllitic shale, argillite, and shaly hornfels and interbedded bluish-gray limestone of the Preble Formation of Cambrian age. Along the contact with granodiorite, some of the limestones are altered to tactite zones that contain tungsten and molybdenum mineralization. The Comus Formation (interbedded limestone, dolomite, shale, and argillite) of Ordovician age and limestone of Pennsylvanian and Permian age are exposed in a few places north and south of the Getchell mine. They are mapped in fault contact with each other and with the Preble Formation (Hotz and Willden, 1961).

The Getchell fault zone that extends along the eastern front of the Osgood Mountains is the dominant structural feature of the Getchell mine area, and it contains most of the gold ore bodies. In

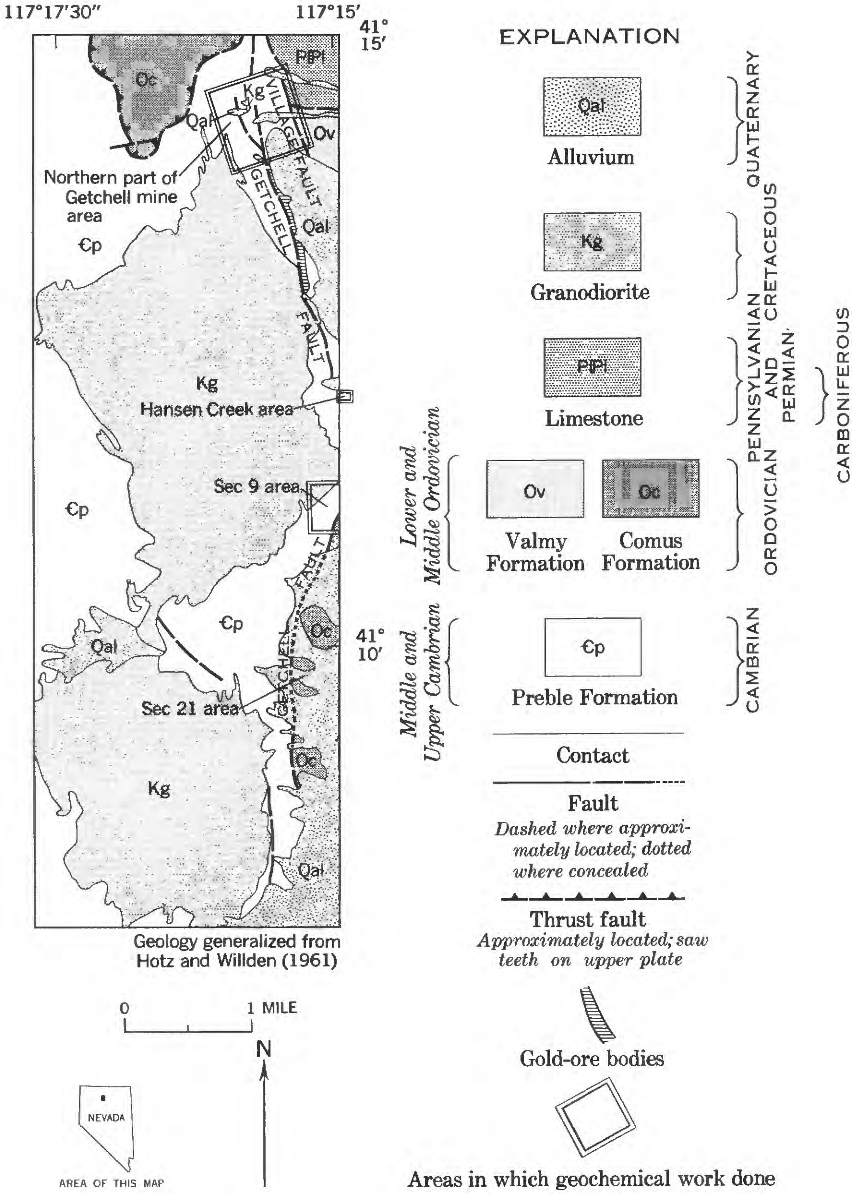

FIGURE 1.—Index map of central part of Osgood Mountains, Humboldt County, Nev., showing generalized geology and location of geochemical work.

this area the fault movement is mostly in black fine-grained carbonaceous beds of the Preble Formation; the footwall is usually hard massive limestone, and the hanging wall is argillite and shaly argillite.

The dip of the fault is from near vertical to about 60° E. and in some places appears to parallel the bedding.

Well-defined horizontal mullion structure exposed in the central pit at the Getchell mine indicates some rift movement along the fault. Joralemon (1951) reported that eastward projections of the granodiorite into the Preble shale in the south pit have been displaced to the north by rift movement.

Farther east the Village fault makes an acute angle with the Getchell fault and brings Pennsylvanian and Permian limestone in fault contact with the Cambrian Preble Formation.

GEOCHEMICAL EXPLORATION

The opportunity to carry out this geochemical exploration investigation was brought to our attention by William J. Newman, former general manager of the Getchell mine. In the spring of 1960 Mr. Newman became interested in finding out if the determination of arsenic in soil could be used as a geochemical prospecting tool to find additional oxide gold-arsenic ore at the Getchell mine. The authors agreed to determine the arsenic content of a suite of 15 soil samples collected by members of Mr. Newman's staff over barren bedrock and known oxide gold ore. The results of this preliminary work showed an excellent correlation of high arsenic contents at the surface with known gold mineralization in the subsurface (fig. 2). Because of these encouraging results, geochemical investigations by the U.S. Geological Survey were begun at the Getchell gold mine in 1961.

Most of the samples were prepared and were analyzed for 33 elements in the field in the truck-mounted spectrographic laboratory; arsenic was determined chemically in the field; mercury was determined in the Denver laboratory by L. E. Patten using the method of Ward (1958).

GETCHELL ORE BODY

Gold deposits in carbonaceous beds of the Preble Formation in the Getchell fault zone have been mined since 1937. Joralemon (1951, p. 270) reported that "The gold ore bodies are sheet-like masses * * * They extend at least 7,000 feet horizontally and 800 feet down the dip and vary in width from a few feet to more than 200, averaging about 40 feet wide." The highest gold contents are closely associated with soft black carbonaceous material (called gumbo by Joralemon) and abundant arsenic sulfide (realgar and orpiment). Other metalliferous minerals recognized by Joralemon include arsenopyrite, stibnite, ilsemannite, and cinnabar. Gangue minerals are quartz, calcite, and minor barite, gypsum, fluorite, and chabazite. Joralemon noted that

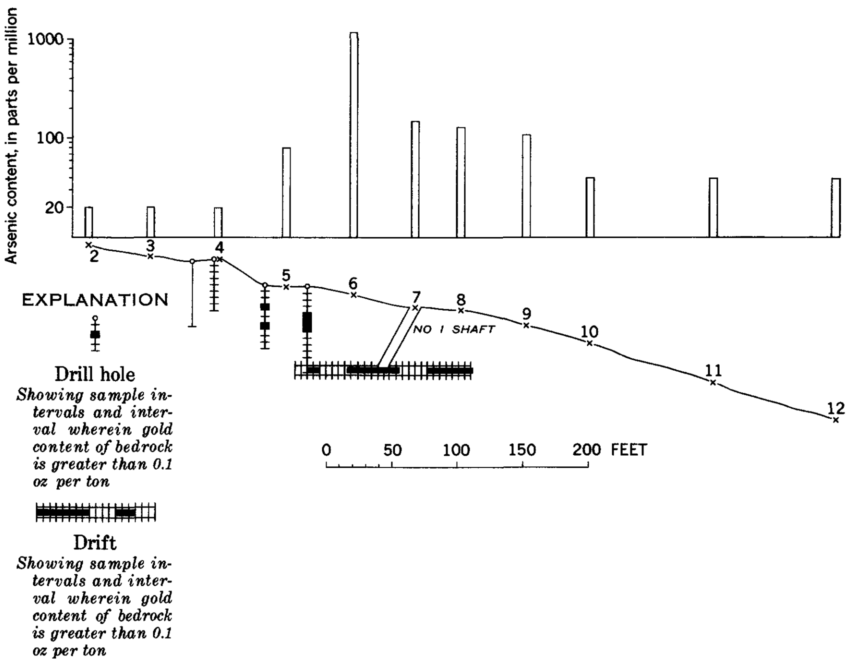

Figure 2.—Bar graph and cross section showing arsenic content of soil samples (numbered) collected over gold mineralization in bedrock. Sample 6 also contained 30 ppm mercury. Cross section and gold assays from map prepared for Getchell Mine, Inc., by W. J. Newman.

realgar occurs throughout the commercial ore bodies in amounts ranging from 1 to 10 percent and shows such a consistent relation to gold that the presence of realgar is usually a strong indication of high gold contents.

In order to determine the kind and abundance of other elements that might be useful as indicator metals in geochemical prospecting, composite samples of the ore zone in the north, central, and south workings were obtained from W. H. Hisle, general manager of the Getchell mine. Analyses (table 1) of four splits of each sample show:

1. Arsenic is the most abundant metal.
2. Arsenic, tungsten, and mercury are the only metals that are consistently present in anomalous concentrations in all composite gold ore samples. Arsenic and tungsten show fairly uniform concentrations from the north workings to the south pit; mercury appears to increase to the south.
3. Molybdenum, antimony, and silver occur in anomalous concentrations only in the south pit. Thus these metals probably would have only limited usefulness as an indicator of gold ore.

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4. Although the differences in selenium content are small, several repeat analyses indicate that selenium also is slightly more abundant in the south pit.
5. Lead, zinc, and copper are not present in the arsenic-gold ore in significant amounts.
6. Iron, magnesium, titanium, manganese, barium, and zirconium are somewhat more abundant in the south pit.

NORTH WORKINGS

Red-brown to yellow-brown iron-rich material in fractures and along bedding planes was collected by the writers on a traverse beginning near the portal of the 100-foot-level adit in the north workings and progressing toward the ore crosscut in the mineralized zone approximately 335 feet from the portal (fig. 3). The traverse extended about 120 feet beyond the ore crosscut into the limestone footwall. Unfortunately, the adit crosses the mineralized zone where the black carbonaceous host rock has feathered out to thin beds and partings in the footwall limestone, and gold mineralization is very weak. The footwall limestone is dark gray, vuggy, and laced with white quartz veinlets that mostly are parallel to bedding. The vugs are lined with

TABLE 1.—*Analyses of composite gold*

[Semiquantitative spectrographic analysis by Uteana Oda; chemical analyses for arsenic by W. W. Janes, I. C. Frost; silver determined by fire assay

Location	Field No.	Semiquantitative spectrographic analyses									
		Percent			Parts per million						
		Ca	Fe	Mg	Ti	Mn	Ag	B	Ba	Be	Co
North workings—100-foot level	GMN-5	1.5	0.5	0.07	700	15	<1	100	500	<1	<10
	10	1.5	.5	.05	700	15	<1	100	500	<1	<10
	15	1.5	.5	.05	500	10	1	100	300	<1	<10
	20	1.5	.5	.07	500	10	1	100	200	<1	<10
Central pit—surface trenches	GMC-5-10	1	1.5	.2	2000	100	1	100	500	1	10
	15	1	1.5	.2	1500	100	1	100	500	1	10
	35	.7	1.5	2	2000	70	1	100	500	1	10
	40	1	1.5	.2	1500	100	1	100	500	1	10
Central pit—rotary drill cuttings	GMC-5-5	.7	1.5	.1	300	30	1	100	500	1	10
	20	1	1 5	.15	1500	70	1	100	500	1	10
	25	.7	1.5	.15	1500	70	1	100	500	1	10
	30	.7	1.5	.15	1500	70	1	100	500	1	10
South pit—surface trenches	GMS-5-2	.7	1.5	.2	2000	100	10	100	1000	1	<10
	4	.7	1	.15	2000	100	7	100	1000	1	<10
	8	.5	1.5	.2	2000	50	7	100	1000	1	<10
	11	1	1.5	.15	2000	100	5	100	1000	1	<10
South pit—rotary cuttings	GMS-5-3	2	2	.3	2000	200	5	100	1000	1	15
	6	2	2	.3	2000	200	5	100	1000	1	15
	9	1.5	1.5	.2	1500	200	5	100	700	1	10
	12	2	1.5	.2	1500	200	2	100	700	1	10

[1] Value (oz. per ton) reported by Getchell mine.

red-stained quartz crystals. The hanging-wall beds from portal to ore crosscut are chiefly soft altered contorted and brecciated shale with interbedded hard argillite ribs. This sequence of disturbed rocks probably is the Getchell fault zone.

Figure 3 shows the relative abundance of several elements in each sample taken from stations along the traverse. Arsenic is anomalously high (>500 ppm) throughout the traverse and increases to greater than 1 percent in the thin black carbonaceous partings in the mineralized zone. Tungsten and mercury show marked increase in the mineralized zone, and their highest concentration correlates well with the arsenic peak. Zinc, lead, molybdenum, and silver show very small increase in concentration in the mineralized zone and are most abundant in the footwall limestone 100 feet from the arsenic-gold mineralization. Copper is most abundant in red-brown material filling fractures in an altered igneous dike rock. The small peaks in zinc, lead, and molybdenum contents near the portal of the adit probably reflect very weak base-metal mineralization in the Getchell fault zone. These samples show that there is an order of magnitude increase in barium content from about 100 ppm in the unmineralized rock to more than 1,000 ppm across the mineralized zone. Strontium,

ore samples, Getchell mine, Nevada

mercury by L. E. Patten, selenium by H. L. Neiman; total carbon determined by induction furnace by method by D. L. Skinner and I. C. Frost]

Semiquantitative spectrographic analyses—Continued										Chemical analyses				Fire assay analyses	
Parts per million—Continued										Percent		Parts per million		Ounces per ton	
Cr	Cu	Mo	Ni	Sb	Sr	V	W	Y	Zr	As	C	Hg	Se	Ag	Au[1]
50	50	<2	15	<50	70	100	100	10	20	>3.2	2.39	40	6	0.06	0.26
20	30	<2	10	<50	50	70	100	10	20						
50	50	<2	10	<50	70	100	50	10	20						
50	30	<2	10	<50	70	70	50	10	20						
50	70	5	15	<50	70	100	100	10	100	>3.2	.64	60	4	.05	.258
30	70	5	20	<50	70	70	70	10	100						
50	70	2	20	<50	70	100	50	10	150						
30	70	2	15	<50	70	70	50	10	70						
20	70	5	20	<50	20	70	100	10	50	2.4	.56	60	4	.06	.22
30	70	7	20	<50	70	70	150	10	70						
30	70	7	20	<50	70	70	150	10	70						
30	70	7	30	<50	70	70	200	10	70						
50	50	50	15	700	100	100	100	10	100	>3.2	.53	140	10	.13	.295
30	70	100	15	700	70	100	100	10	200						
30	50	100	15	1000	70	100	150	10	100						
70	50	100	15	700	100	100	150	10	100						
70	150	200	30	500	100	100	150	10	100	2.0	1.26	180	7	.12	.26
50	70	200	30	700	50	100	150	10	100						
50	70	150	30	300	50	100	100	10	100						
30	70	200	20	300	50	100	70	10	70						

NOTE.—Bi <10, La <50, Pb <10, Sc <10, Sn <10, Zn <200 in all samples.

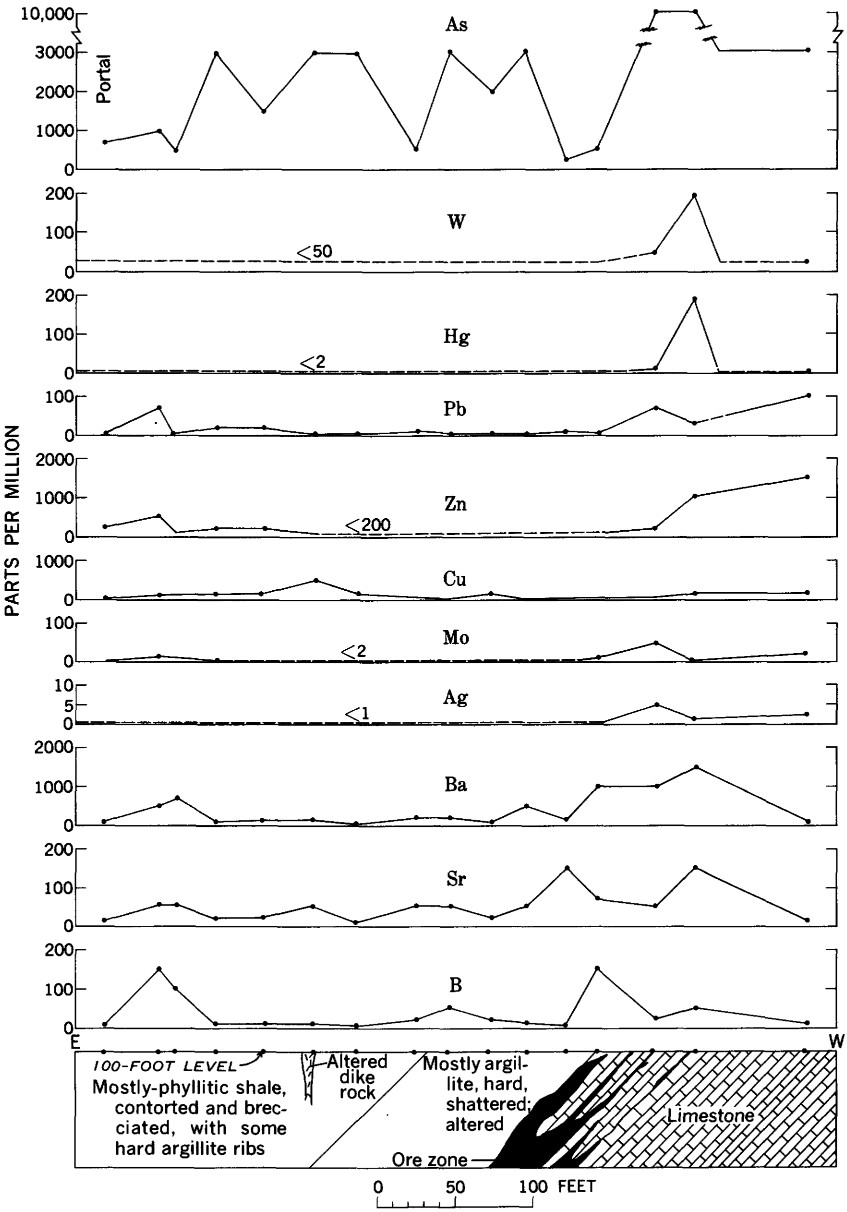

FIGURE 3.—Geochemical profile of 100-foot-level adit, north workings, Getchell mine, Nevada.

much less abundant than barium, generally increases in content from 20 to 150 ppm, but shows the high peaks at the concentrations along the footwall and hanging wall of the mineralized zone. Boron content is highest at the hanging-wall edge and near the portal of the adit, where it correlates well with the small zinc-lead-molybdenum peak.

Figure 3 clearly indicates that arsenic, tungsten, and mercury show the greatest amount of enrichment and are the most abundant metals in the zone of gold mineralization. Arsenic and mercury are enriched 100-fold; tungsten is enriched 10-fold. These analyses also suggest that the high arsenic content (500–3,000 ppm) in samples from the hanging wall may be a primary leakage halo from the arsenic-gold deposit downdip from the mineralized zone. Mercury and tungsten were not detected in the hanging wall probably because their concentrations in the halo-forming fluids had been low and were depleted rapidly as these fluids moved up fractures and bedding planes away from the main centers of metal deposition. Thus, the results of these analyses suggest that a coincidence of arsenic, mercury, and tungsten anomalies is a good indicator of the proximity of a gold deposit. Arsenic anomalies without accompanying mercury and tungsten anomalies may indicate only weak mineralization, or the arsenic anomalies may be at such a distance from a significant subsurface gold deposit that the mercury and tungsten in the halo-forming fluids had been depleted along the way.

Several surface traverses by the writers were made normal to the strike projection of the known zone of arsenic-gold mineralized rock in the north workings (pl. 1, southwestern part). In this area the strike of the favorable black carbonaceous shale host rock angles away to the northwest from the north-trending Getchell fault zone. Where possible, fracture-coating material or caliche in bedrock was sampled; soil was the only material available at some of the sample localities. Soil samples were collected from a depth of about 12 to 18 inches to minimize possible contamination by arsenic- and mercury-bearing fumes and dust from the Getchell mill.

Three arsenic anomalies were detected. The strongest anomaly occurs across the updip projection to the surface of the gold ore body exposed in the 100-foot level. Gold ore was found to within a few feet of the surface in this area.

The highest arsenic concentration (>1,600 ppm) is in the one sample of yellow-brown to red-brown iron-rich fracture-filling material directly over the ore body; lesser concentrations are in caliche, and lowest but still anomalous concentrations (75 ppm) are in residual soils. High concentrations of tungsten (2,000 ppm), antimony (300 ppm), and mercury (15 ppm) also were detected in the iron-rich fracture-filling material. Caliche at this locality contained lesser but still anomalous concentrations of tungsten and mercury (70 ppm tungsten and about 5 ppm mercury). Tungsten was not detected in the soil (<20 ppm), but a trace of mercury occurs in soil directly over the ore body.

Copper, lead, zinc, molybdenum, and silver did not show any significant increase in these samples.

Open-pit mining operations in 1962 showed that the outline of the surface geochemical anomaly mapped prior to open-pit mining conformed to the outline of the underground arsenic-gold ore body. This is another illustration of the association of arsenic, mercury, and tungsten anomalies with the Getchell mine gold deposits.

The second anomaly is in iron-rich fracture-filling material west of the known ore body, probably in the hanging-wall beds (pl. 1). The arsenic contents of samples taken from this anomaly are not as high as those of samples taken over the known gold deposit, and tungsten and mercury were not detected.

Many of the soil samples to the south and footwall side of the known ore body contain about 75 ppm arsenic, and two samples showed traces of mercury (the third anomaly). Bedrock is not exposed in this area, and the significance of these apparent anomalies in soil is not known. However, the management of the Getchell mine reported that thin streaks of commercially unminable gold ore, occurring as offshoots from the main ore body, have been found underground in the footwall in this area.

AREA NORTH OF GETCHELL MINE

Two east-west soil traverses across the northward projection of the Getchell fault zone and a northwest split of the Getchell fault were made north of the known ore body (Pl. 1).

Trenches were cut to bedrock with a bulldozer in most of the areas where the soil showed arsenic concentrations of 75 ppm or more. Rocks and fracture-filling material were analyzed from each trench. Although anomalous arsenic contents were found in some samples from all trenches, mercury and tungsten were not detected, and the

TABLE 2.—*Semiquantitative spectrographic and chemical analyses of rocks and*

[Semiquantitative spectrographic analyses by Uteana Oda; chemical

Field No.	Description	Percent			Parts per million			
		Ca	Fe	Mg	Ti	Mn	Ag	As
GM-205	Jasperoid, yellow-green	0.5	3.0	0.1	150	200	5	20
205-A	Jasperoid, red-brown	.3	5	.07	100	200	2	150
206	Jasperoid breccia	1.5	.7	.1	700	1,000	<1	30
211	Fracture-filling yellow-green material in coarse saccharoidal limestone.	.7	2	.07	100	50	<1	60
211-A	Jasperoid, dark-brown	.15	3	.015	15	70	15	200
198-B	Altered rock, yellow-brown to red-brown, soft.	1	5	.1	5,000	1,500	<1	2,000
198-D	Altered rock, igneous(?), laced with brilliant green clayey mineral.	10	5	.2	10,000	700	<1	20
198-E	do	3	3	.7	>10,000	300	<1	15

NOTE.—Bi<10, Ga<10, Sb<50, Sc<10, in all samples.

concentration of arsenic in these samples is much lower than the concentration in samples taken over known gold ore bodies. Copper (as much as 1,000 ppm) and bismuth (as much as 150 ppm) were detected in thin jasperoid stringers in the two westernmost trenches cut by the northwest branch of the Getchell fault. Zinc-lead-silver anomalies containing smaller but still anomalous concentrations of arsenic (table 2 and pl. 1) were found in jasperoid in Permian and Pennsylvanian limestone beds on the east side of the Village fault about 800 feet east of the Getchell fault zone. A high concentration of arsenic was found in soil on the west side of the fault (pl. 1), but this area has not been trenched to bedrock.

Highly altered soft rock, probably of igneous origin and intermediate composition, laced with seams of a brilliant green claylike mineral, is exposed in the shallow trench that crosses the projection of the Village fault to the south. One sample of yellow-brown to red-brown soft altered material near the middle of the trench contains 2,000 ppm arsenic, 70 ppm tungsten, and 15 ppm beryllium (table 2, GM–198–B); mercury was not detected.

Additional trenches to bedrock should be cut across the Village fault in several places to investigate the apparent transition from arsenic-gold deposition in the upthrown Cambrian Preble block on the west and lead, zinc, and silver mineralization in the Permian and Pennsylvanian limestone in the downthrown block to the east.

HANSEN CREEK AREA

Strong arsenic, tungsten, and mercury anomalies were discovered in bedrock on a geochemical traverse made along the roadcut that makes the first bench above the portal of the Hansen Creek tunnel about 300 feet south of the tunnel and 900 feet north of the Riley

fracture-filling material in traverses across the Village fault, Getchell mine, Nevada

analyses for arsenic by A. P. Marranzino and W. W. Janes]

Parts per million—Continued														
B	Ba	Be	Co	Cr	Cu	Mo	Ni	Pb	Sr	V	Y	Zn	Zr	W
10	500	<1	<10	20	30	<2	20	50	<20	15	<10	500	30	<50
15	500	<1	<10	<10	100	5	50	200	<20	70	<10	1,000	20	<50
10	700	<1	<10	50	70	<2	5	700	20	70	15	500	700	<50
10	700	1	15	<10	70	<2	10	70	<20	30	<10	1,000	10	<50
<10	100	<1	<10	<10	200	2	<5	2,000	<20	20	<10	7,000	10	<50
50	700	15	20	<10	70	10	50	10	100	150	15	<200	150	70
<10	500	1	10	<10	100	2	10	<10	200	100	50	<200	150	<50
20	7,000	2	15	10	150	<2	10	<10	200	150	20	<200	200	<50

extension shaft. Semiquantitative spectrographic and chemical analyses (table 3) show that the highest metal contents are in thin orange-brown oxidized streaks in black shale, lesser concentrations are in black shale, and the carbonate rocks are barren.

A block diagram (fig. 4) shows the inferred relation of gold mineralization in the Hansen Creek tunnel to arsenic, tungsten, and mercury contents of surface samples collected on the geochemical traverse. The location of the intersection of the Hansen Creek tunnel with the limestone beds was derived by projecting the strike and dip of the limestone exposed on the geochemical traverse to the line of cross section. This interpretation suggests that the limestone forms the footwall of the low-grade gold mineralization found by the personnel of the Getchell Mine, Inc., in the Hansen Creek tunnel. Southward extension of this low-grade gold zone along the footwall side of the limestone may be indicated by the high arsenic, tungsten, and mercury contents of surface samples at localities GM–251 and GM–252. The high metal contents detected at GM–214–B and GM–214–C, farther to the east, and at GM–212, collected underground about 50 feet in from the portal of the tunnel, also may be correlative.

The strongest surface anomalies occur on the west side of the limestone beds near the footwall of the Getchell fault zone, which contains most of the known arsenic-gold ore bodies to the north. If these anomalies are leakage halos caused by updip migration of metals, the shale and argillite on the hanging-wall side of the lime-

TABLE 3.—*Semiquantitative spectrographic and chemical analyses of*

[Semiquantitative spectrographic analyses by Uteana Oda; chemical analyses:

Field No.	Description	Percent			Parts per million				
		Ca	Fe	Mg	Ti	Mn	Ag	As	B
GM-212-A	Shale, blue-black	0.1	0.5	0.2	5,000	10	1	60	300
214-A	do	.2	1.5	.2	1,500	20	2	700	100
214-B	do	.15	1	.15	2,000	50	2	80	100
252	Shale, blue-black, stained orange-brown.	.2	2	.2	1,500	30	2	700	500
253	do	1	3	.3	1,500	100	<1	500	100
214	Shale, blue-black, calcareous	10	1.5	.15	1,000	50	<1	30	50
248	Shale, blue-black, dolomitic	15	2	5	1,000	1,500	2	40	20
250	Limestone, soft, sanded, stained yellow-brown.	>20	.5	.15	200	500	<1	30	10
249	Caliche in fracture in limestone.	15	1	1	300	300	<1	40	10
247	Dike rock, altered, pale orange-brown.	.7	1.5	.3	2,000	100	1	250	30
212	Iron-rich material in fractures and along bedding planes in shale.	.3	5	.1	700	30	<1	3,000	20
214-C	do	.2	3	.05	300	30	1	1,000	50
245	do	.7	3	.2	1,500	1,500	2	2,000	1,000
246	do	.2	7	.1	700	70	1	1,000	50
251	do	.3	3	.2	1,000	200	<1	500	200

NOTE.—Bi <10, Ga <10, Sb <50, Sn <10 in all samples.

stone beds in the subsurface should be even more favorable for the discovery of additional gold mineralization than the rocks on the footwall side. If the geologic interpretations shown on the block diagrams are reasonably accurate, the Hansen Creek tunnel should be extended westward toward the footwall of the Getchell fault zone to intersect the northward projection of the surface anomalies on the hanging-wall side of the limestone beds.

SECTION 9 AREA

Anomalously high amounts of arsenic, tungsten, mercury, lead, antimony, and zinc were detected in irregular masses and thin stringers of jasperoid in argillite and shale in or near the Getchell fault zone in sec. 9, T. 38 N., R. 42 E., about 2 miles south of the south pit of the Getchell mine (pl. 2). Weak gold mineralization in this area was discovered previously in a shallow 60-foot-long inclined shaft by the staff of the Getchell mine.

The bedrock in this area was mapped by Hotz and Willden (1961) as the Comus Formation of Ordovician age downfaulted against the Preble Formation of Cambrian age along the Getchell fault zone. Unfortunately, most of the bedrock in the area of economic interest is concealed by a thin soil cover, and stratigraphic contacts and the location of the Getchell fault can only be inferred. The geologic interpretations shown on the geologic map are inferred from the few exposures of resistant ribs of brecciated and sheared jasperoid that protrude above the soil cover and the limited amount of bedrock

rocks and iron-rich material, Hansen Creek area, Getchell mine, Nevada

mercury by L. E. Patten, arsenic by W. W. Janes and A. P. Marranzino]

Parts per million—Continued															
Ba	Be	Co	Cr	Cu	Hg	Mo	Ni	Pb	Sc	Sr	V	W	Y	Zn	Zr
700	<1	<10	100	10	15	2	7	20	<10	70	500	<50	20	<200	300
700	1	<10	70	70	3	10	20	70	<10	100	500	50	20	<200	150
1,000	1	<10	70	15	3	7	10	10	10	150	200	<50	20	<200	150
500	1	<10	70	70	3	7	30	15	10	100	300	50	20	200	150
1,000	1	10	30	50	<2	5	30	20	15	100	100	150	20	200	70
1,000	1	10	70	100	<2	2	70	50	10	300	200	<50	150	200	70
1,000	1	10	30	70	<2	<2	150	15	10	200	200	<50	20	1,000	100
700	<1	<10	15	10	<2	<2	20	<10	<10	300	70	<50	<10	<200	10
700	1	<10	30	20	<2	<2	50	<10	<10	300	100	<50	<10	700	20
1,000	1	<10	10	20	<2	15	20	<10	<10	150	100	<50	10	<200	70
1,000	<1	<10	70	100	3	10	100	50	<10	20	300	50	20	1,000	50
200	<1	<10	20	50	10	7	30	30	<10	<20	150	100	10	300	20
5,000	5	<10	50	70	2	2	100	<10	15	200	200	150	70	1,000	100
300	10	20	70	200	8	10	200	70	<10	50	500	100	50	2,000	50
2,000	2	15	30	100	<2	5	50	50	10	50	150	100	50	200	100

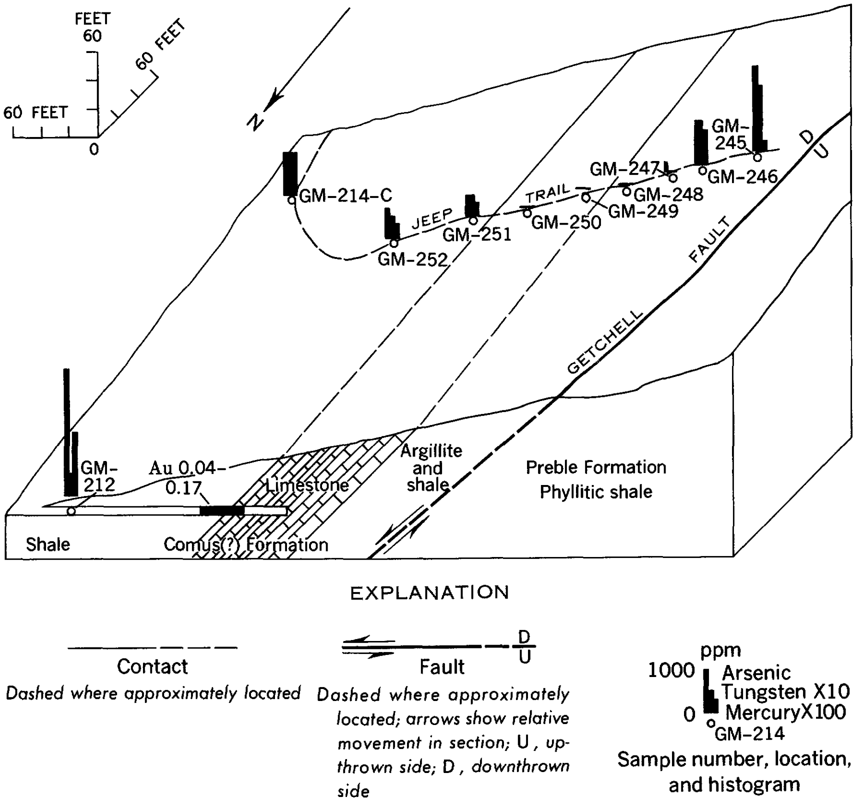

FIGURE 4.—Block diagram showing inferred relation of gold mineralization in Hansen Creek tunnel to arsenic, tungsten, mercury content of surface samples. Subsurface intersection of limestone beds and Hansen Creek tunnel inferred from projection of surface exposure of limestone on geochemical traverse to line of cross section.

exposed in shallow bulldozer cuts made during earlier exploration work by the Getchell mine staff. The rocks exposed in the cuts are probably part of the Comus Formation and consist of altered gray limestone with thin chert bands and argillite and shaly argillite containing the mineralized jasperoid. The pattern of the jasperoid masses (pl. 2) in the southern part of the mapped area suggests the presence of a southeast-trending shear that splits off from the main Getchell fault almost at right angles to the regional (northerly) strike of the rocks. However, the attitude of the beds in and near the sheared zone cannot be measured with any confidence.

A second fault to the east of and subparallel to the Getchell fault, which separates rock units within the Comus Formation, is inferred from the strike of the banded carbonate beds on the hill near the east edge of the map and from one narrow exposure in a bulldozer cut.

The isolated jasperoid masses in the northern half of the mapped area may occupy tension shears in the belt of deformed rock between the two faults.

Two west-east geochemical traverses across the belt of disturbed rocks were made in 1961 by sampling altered rocks, yellow-brown to red-brown iron-rich fracture-filling and coating material, jasperoid, and caliche in the bulldozer cuts. The metal concentrations obtained in this close-spaced sampling are projected to lines *A–A′* and *B–B′* and are shown as profiles (figs. 5 and 6). The planetable map was made, and the isolated outcrop patches of jasperoid were sampled (numbered localities on map) and analyzed (table 5) in 1962.

Two principal anomalous areas were detected—both in interbedded soft black shaly argillite and hard argillite ribs that had been hydrothermally altered, leached, and silicified. The silicified areas are brecciated, and brecciation appears to postdate silicification. Strong iron-oxide staining in shades of yellow, orange, and brown is characteristic of the jasperoid in the southern and most intense metal anomaly. Jasperoid in the northern and less intense anomaly occurs chiefly as white quartz veining in hard dark-gray to black argillite.

The strongest and most extensive areas of coincident arsenic-tungsten-mercury mineralization are in the jasperoid and adjacent shaly argillite west of the shaft on the *A–A′* traverse and in the jasperoid outcrop about 200 feet north of the west end of the *A–A′* traverse (fig. 5). High concentrations of arsenic (2,000 ppm) were also found coincident with moderate concentrations of tungsten (150 ppm) and mercury (6 ppm) in a narrow jasperoid band in limestone at the east end of the *A–A′* traverse, but this anomaly appears to be of very limited extent.

A very restricted and distinctively different type of metal anomaly (lead, antimony, zinc, mercury, silver) occurs in thin jasperoid ribbons in a narrow zone (15 ft wide) in soft blue-black-weathering shaly argillite near the east end of the *A–A′* traverse.

High concentrations of barium and strontium are associated with both types of metal anomalies, but the peaks are not coincident. The metals are concentrated in jasperoid, whereas barium and strontium are concentrated in adjacent wallrock.

Semiquantitative spectrographic and chemical analyses of the samples taken along the *A–A′* profile (table 4) show a wide range in metal content which is attributable, in part, to the wide range in composition of the material sampled: relatively unaltered argillite and shaly argillite, altered rocks, caliche, jasperoid, and red-brown to orange-brown iron-rich material along bedding planes and fractures. Following are some observations made from the analytical data:

1. Arsenic occurs in anomalous amounts in all types of samples but is concentrated chiefly (as much as 2,000 ppm) in the red to dark-

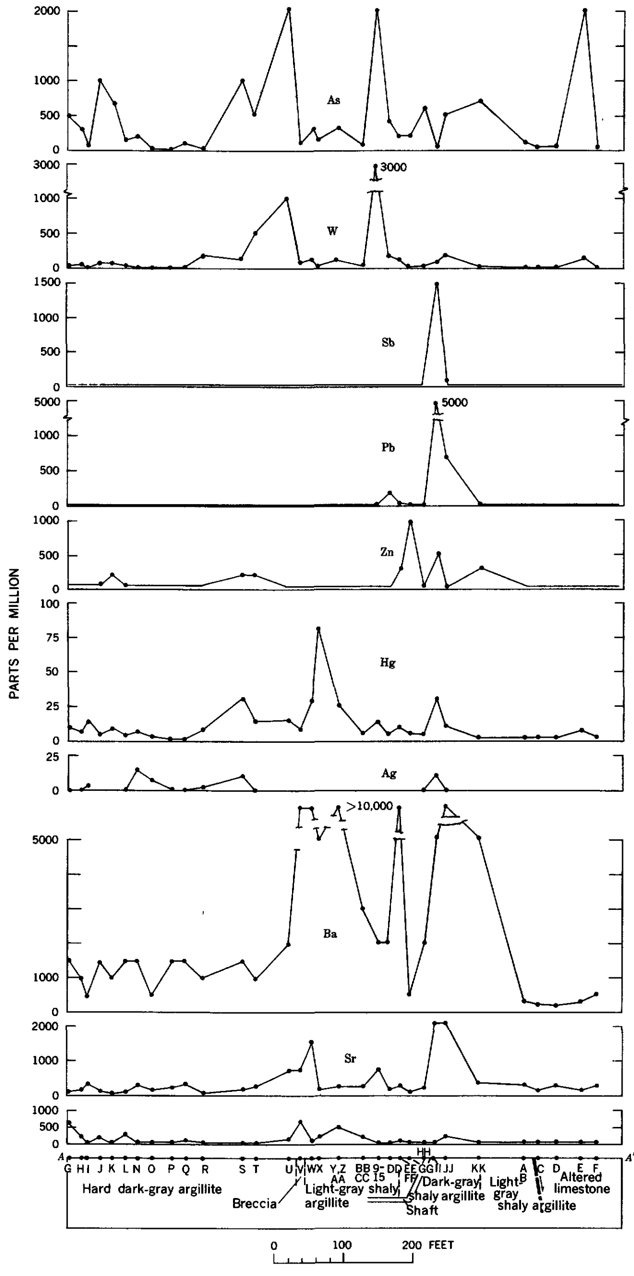

FIGURE 5.—Geochemical profile, *A–A'* traverse, sec. 9, T. 38 N., R. 42 E., Humboldt County, Nev. Beds are steeply dipping, but actual attitude of beds is not known. Lowermost graph is for boron.

brown iron-rich material in jasperoid. The lowest arsenic content is in caliche.

2. Tungsten was detected in all types of samples except caliche and is highest in the iron-rich material (3,000 ppm) and jasperoid (200 ppm).
3. Mercury was detected in all types of samples and is highest in the altered bluish-black shaly argillite (80 ppm).
4. Silver is most consistently present and occurs in greatest amounts in caliche (15 ppm). It is interesting to note that the two samples in the jasperoid group that contain 10 ppm silver also have an appreciable calcium content. The writers have found small amounts of silver in caliche over known ore bodies in other mining districts in the Basin and Range province and are encouraged by the possibility of using silver analyses of caliche as a geochemical prospecting tool. The manner of occurrence of silver in caliche is unknown.
5. Titanium, boron, and chromium are most abundant in the least altered rocks.
6. Small amounts of beryllium (5 to 10 ppm) occur near the east end of the traverse.
7. Copper content is highest in a single sample (GM–216–Z) in the middle of the traverse, but it is most consistently present in association with molybdenum in more than background amounts in the altered rocks at the west end of the traverse.

Small amounts of gold ranging from a trace to 0.16 ounces per ton were found by the staff of the Getchell Mine, Inc., in 5-foot channel samples on the walls of the shallow inclined shaft and crosscut. Although the structural attitude of the jasperoid masses and the bedrock is not known, the shaft and crosscut probably did not test the most intense parts of the surface arsenic-tungsten-mercury anomalies.

The anomaly at locality 7 (pl. 2 and table 5)—chiefly zinc, copper arsenic—is weak and confined to thin iron-rich streaks in altered argillite. The anomaly at locality 8, from which a single sample has been collected (fig. 6 and table 5), is of particular interest because the exposed argillite rib appears unaltered, but the suite of metals (arsenic, zinc, copper, tungsten, antimony) found in the iron-oxide films on the bedding planes is impressive. The covered area between localities 8 and 9 (pl. 2) may conceal more intense metal anomalies in an eastward extension, along the postulated shear zone, of the large anomalous area to the west.

TABLE 4.—*Semiquantitative spectrographic and chemical analyses*

[Semiquantitative spectrographic analyses by Uteana Oda; chemical analyses:

Field No.	Description	Percent			Parts per million					
		Ca	Fe	Mg	Ti	Mn	Ag	As	B	Ba
GM-216-F	Argillite, shaly, black	0.07	1.0	0.7	3,000	70	1	20	700	1,500
G	Yellow-brown material scraped from fractures in argillite.	.3	3	.07	300	50	<1	500	10	500
H	Argillite, altered, stained red-brown.	.15	2	.1	700	30	1	300	200	1,000
I	Caliche coating on argillite	15	.3	.2	200	30	3	50	20	500
J	Argillite, silicified, brecciated, stained red-brown.	.07	3	.07	700	20	2	1,000	200	1,500
K	Red-brown material scraped from fractures in argillite.	.7	3	.15	700	70	<1	700	50	1,000
L	Argillite, silicified, brecciated	.05	1.5	.15	2,000	20	<1	150	300	1,500
N	Caliche coating on argillite	15	.5	.15	150	30	15	200	30	1,500
O	do	7	.7	.2	700	200	7	40	30	500
P	do	10	.5	.2	500	100	<1	25	20	1,500
Q	Clay, brown, stiff	1.5	2	.7	3,000	300	<1	100	100	1,500
R	Breccia, vuggy, stained yellow	.1	2	.07	700	20	2	40	20	1,000
S	Jasperoid, iron-stained	3	3	.05	200	30	10	1,000	10	1,500
T	do	3	3	.07	700	50	1	500	50	1,000
U	do	.3	7	.05	500	30	<1	2,000	150	2,000
V	Argillite, shaly, brecciated, weathers soft, earthy blue-black.	1.5	3	.5	3,000	50	<1	100	700	10,000
W	Iron-rich yellow-brown soft altered material in gray sericitized(?) shaly argillite.	.1	3	.15	2,000	20	1	300	100	>10,000
X	Shale, silicified, brecciated, stained yellow.	.1	2	.2	2,000	10	<1	150	200	5,000
Y	Caliche coatings on shaly argillite.	10	.3	.15	200	30	1	40	20	5,000
Z	Argillite, shaly, altered, stained red-brown.	1.5	5	.5	3,000	50	<1	500	500	10,000
AA	Argillite, shaly, sericitized(?), gray.	.5	2	.7	5,000	300	<1	60	300	10,000
BB	Caliche	10	.3	.15	150	50	<1	75	10	2,000
CC	Argillite, shaly, sericitized(?), gray.	.15	2	.2	3,000	30	<1	40	200	3,000
GM-9-15	Iron-rich yellow-brown material scraped from brecciated jasperoid.	1	10	.15	700	100	<1	2,000	20	2,000
15-A	Jasperoid, brecciated	1.5	3	.02	70	10	<1	300	<10	500
GM-216-DD	Jasperoid	.3	2	.05	300	30	1	500	30	2,000
EE	Clay seams, orange-brown in shaly argillite.	.3	3	.15	700	30	<1	200	20	2,000
FF	Argillite, shaly, blue-black	.15	1.5	.2	3,000	20	<1	80	100	>10,000
GG	Clay seams, orange-brown in shaly argillite.	.7	5	.2	200	50	<1	200	30	500
HH	Argillite, shaly, weathers soft, blue-black.	.3	3	.07	500	30	<1	500	<10	2,000
II	Jasperoid, yellow	5	.5	.03	100	15	10	60	20	5,000
JJ	Jasperoid, orange-brown	5	3	.15	700	50	2	500	200	>10,000
KK	Jasperoid, yellow-green and orange.	2	1.5	.03	150	20	<1	700	20	5,000
GM-218-A	Clay, yellow-green in shaly argillite.	3	2	.2	200	150	<1	100	<10	300
B	Caliche coating on shaly argillite.	20	.5	.15	200	50	<1	75	10	300
C	Limestone, silicified in part	20	.2	.15	100	200	<1	40	<10	200
D	do	>20	.3	.3	100	300	<1	40	10	200
E	Jasperoid, stained red-brown	7	3	.07	150	500	2	2,000	<10	300
F	Limestone, pale yellow-gray, altered.	20	1	.3	300	200	<1	25	10	500

NOTE.—Bi>10 in all samples.

of rocks, A–A′ *traverse, sec. 9, Getchell mine district, Nevada*

mercury by L. E. Patten, arsenic by W. W. Janes and A. P. Marranzino]

Parts per million—Continued																
Be	Co	Cr	Cu	Hg	La	Mo	Ni	Pb	Sb	Sc	Sr	V	W	Y	Zn	Zr
1	<10	200	70	<2	50	7	30	50	<50	10	100	500	<50	10	<200	200
1	<10	100	100	9	200	20	30	20	<50	<10	100	150	50	<10	<200	50
1	<10	200	500	6	<50	20	50	10	<50	10	150	500	70	20	<200	150
<1	<10	20	30	12	<50	<2	5	10	<50	<10	300	70	<50	<10	<200	10
<1	<10	100	150	5	<50	50	10	50	<50	<10	100	200	100	10	<200	100
1	10	70	100	9	<50	15	70	<10	<50	<10	50	200	100	<10	200	70
<1	<10	150	100	5	<50	7	20	10	<50	10	100	300	70	<10	<200	150
<1	<10	30	30	6	<50	2	7	10	<50	<10	300	100	<50	10	<200	10
1	<10	30	20	3	<50	<2	10	<10	<50	<10	150	70	<50	<10	<200	50
<1	<10	30	15	<2	<50	<2	10	<10	<50	<10	200	50	<50	<10	<200	30
2	15	70	50	<2	<50	2	20	30	<50	10	300	100	<50	15	<200	150
<1	<10	15	15	8	<50	5	5	10	<50	<10	50	70	200	15	<200	70
<1	<10	10	30	30	<50	10	20	20	<50	<10	100	200	150	<10	200	30
<1	<10	30	20	14	<50	5	10	50	<50	<10	200	150	500	20	200	70
1	<10	150	50	15	150	7	20	10	<50	<10	700	150	1,000	<10	<200	30
2	<10	150	30	7	70	5	20	<10	<50	10	700	200	100	20	<200	200
1	<10	70	150	28	<50	10	10	10	<50	<10	1,500	200	150	<10	<200	150
2	<10	100	30	80	<50	7	5	<10	<50	15	100	100	50	10	<200	150
<1	<10	20	50	12	<50	<2	<10	<10	<50	<10	300	30	<50	<10	<200	150
1	<10	200	2,000	14	70	10	20	<10	<50	20	700	200	150	20	<200	200
2	<10	200	200	25	50	7	10	<10	<50	15	150	150	100	20	<200	300
<1	<10	20	15	3	<50	<2	5	<10	<50	<10	200	20	<50	<10	<200	20
1	<10	100	30	6	<50	5	5	<10	<50	15	150	100	50	10	<200	150
<1	15	50	70	13	<50	15	30	20	<50	<10	700	1,000	3,000	<10	<200	10
<1	<10	15	10	7	<50	5	<10	30	<50	<10	300	100	300	<10	<200	<10
1	<10	30	100	5	<50	7	30	200	<50	<10	100	150	200	10	300	100
1	<10	70	70	9	<50	2	20	50	<50	10	100	150	<50	10	300	20
<1	<10	70	30	5	<50	5	15	10	<50	10	200	150	150	<10	300	150
7	<10	10	70	6	<50	2	70	<10	<50	<10	20	200	<50	<10	1,000	20
10	10	10	50	5	<50	10	50	<10	<50	<10	150	150	50	30	<200	70
1	<10	10	30	30	<50	<2	10	5,000	1,500	<10	2,000	50	100	50	500	30
5	<10	70	100	10	<50	10	30	700	100	<10	2,000	500	200	50	<200	50
7	<10	<10	15	<2	<50	<2	15	30	<50	<10	300	50	50	10	300	15
2	15	10	500	<2	<50	<2	30	<10	<50	<10	30	70	<50	20	<200	20
1	10	20	50	<2	<50	<2	5	<10	<50	<10	200	70	<50	10	<200	10
<1	<10	10	7	<2	<50	<2	5	<10	<50	<10	50	30	<50	10	<200	10
<1	<10	10	15	<2	<50	<2	10	<10	<50	<10	150	30	<50	10	<200	10
<1	15	20	200	6	<50	2	30	<10	<50	10	50	200	150	10	<200	10
2	<10	30	100	<2	<50	<2	20	<10	<50	<10	150	70	<50	10	<200	10

TABLE 5.—*Semiquantitative spectrographic and chemical analyses*

[Semiquantitative spectrographic analyses by Uteana Oda; chemical analyses:

Locality No. on fig. 6	Description	Percent			Parts per million				
		Ca	Mg	Fe	Ti	Mn	Ag	As	B
1	Iron-rich red-brown material in jasperoid.	0.7	0.07	15.0	500	30	0.5	600	70
2	Jasperoid, dark-gray	.3	.05	3	1,000	10	.5	400	100
3	Jasperoid, yellow-gray	.3	.05	10	300	20	1	3,000	<10
4	Argillite, silicified; veined with white quartz.	.2	.02	.2	300	50	<.5	30	20
5	do	.5	.03	1	500	30	<.5	60	15
5-A	Iron-rich red-brown material from silicified argillite.	2	.1	10	3,000	70	<.5	400	20
6	do	1	.05	7	300	70	<.5	600	15
7-A	Argillite, black, shaly, calcareous	7	2	1.5	5,000	150	<.5	20	10
7-C	Argillite, black, shaly, silicified	.3	.1	.3	300	10	<.5	20	<10
7-D	Iron-rich orange-brown and yellow-green material as stringers in shaly argillite.	1.5	<.2	15	1,500	150	<.5	300	<10
8	Iron-rich orange-brown material as films on joints and fractures in argillite.	.7	.2	20	500	5,000	.5	1,600	30
9	do	1	.07	>20	300	200	<.5	400	10
9-A	Argillite, silicified	.2	.02	.2	200	10	<.5	60	10
11-D	Limestone, altered, containing earthy yellow-brown material.	15	.07	1.5	300	1,000	<.5	3,000	15
11-E	Iron- and manganese-rich material from altered limestone.	7	.2	20	700	>10,000	<.5	1,600	20
11-H	Iron-rich material from granodiorite	1	.3	10	1,500	5,000	.3	300	100
12	Iron- and manganese-rich material as films on shaly argillite.	1	1.5	3	3,000	>10,000	<.5	20	50
13	Iron-rich material as films on shaly argillite.	2	1	10	5,000	1,500	<.5	40	10
243	Gossan, orange-brown, porous, siliceous.	.3	.07	7	200	100	<.5	2,000	10

NOTE.—Bi<10, Sn<10, in all samples.

Zinc, arsenic, and copper are the most abundant metals in the anomaly in the northern part of the area, but the significance of this suite of metals in terms of possible concealed ore deposits is not known. The favorable arsenic-mercury-tungsten assemblage is present where the *B–B'* profile cuts the anomaly (fig. 6 and table 6), but the extent and concentration of the assemblage, particularly tungsten and mercury, are not as great as in the anomaly to the south.

A weak anomaly occurs in altered phyllitic shale of the Preble Formation at the west end of the *B–B'* traverse near the contact with granodiorite. Arsenic (as much as 700 ppm) and tungsten (70 ppm) were detected in orange-brown iron-rich material along bedding planes and fractures in the shale. About 200 feet north of the west end of the *B–B'* traverse, 1,600 ppm arsenic was found in earthy yellow-brown material in an altered limestone bed (loc. 11, pl. 2). Tungsten and mercury were not detected. The banded calcareous rocks along the central part of the traverse are impoverished in metals.

SECTION 21 AREA

The hanging wall of the Getchell fault zone is exposed about 1¼ miles south of the section 9 area in the NW¼ sec. 21 on the south

of rocks and iron-rich material, sec. 9, Getchell mine district, Nevada
mercury by L. E. Patten, arsenic by A. P. Marranzino and W. W. Janes]

Parts per million—Continued															
Ba	Be	Co	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Sr	V	W	Y	Zn	Zr
1,500	<1	<10	50	70	9	100	7	10	150	200	500	200	<10	<200	10
3,000	<1	<10	30	7	5	2	<5	<10	<50	500	200	300	<10	<200	50
1,000	<1	<10	30	15	26	5	5	10	<50	50	200	500	<10	<200	<10
5,000	<1	<10	10	10	<2	<2	<5	<10	<50	70	70	<50	10	<200	10
700	<1	<10	10	7	<2	7	15	<10	<50	50	200	<50	<10	<200	10
>10,000	<1	<10	50	300	<2	150	150	15	200	5,000	1,000	<50	<10	700	200
700	<1	<10	5	10	<2	10	70	<10	<50	50	200	<50	<10	700	10
5,000	<1	<10	150	70	<2	5	30	<10	<50	1,000	1,000	<50	50	<200	150
300	<1	<10	7	15	<2	<2	5	<10	<50	30	70	<50	<10	<200	30
2,000	5	20	70	300	2	20	300	20	<50	700	1,000	<50	70	2,000	50
700	5	100	15	300	<2	30	500	50	150	200	700	200	30	1,500	30
5,000	2	<10	100	150	14	50	20	30	<50	5,000	700	100	15	<200	10
1,500	<1	<10	7	10	<2	<2	<5	<10	<50	50	30	<50	<10	<200	<10
>10,000	<1	<10	5	3	2	<2	<5	<10	<50	1,000	<10	<50	10	<200	<10
>10,000	<1	10	10	15	<2	15	200	<10	<50	2,000	20	<50	30	200	<10
2,000	2	<10	<5	50	<2	5	7	15	<50	70	150	<50	20	200	30
1,500	<1	50	100	15	<2	7	50	10	<50	100	100	200	10	<200	70
500	2	70	50	70	<2	2	30	20	<50	200	150	<50	<10	<200	50
10,000	15	<10	20	500	<2	15	200	<10	<50	50	200	<50	30	3,000	70

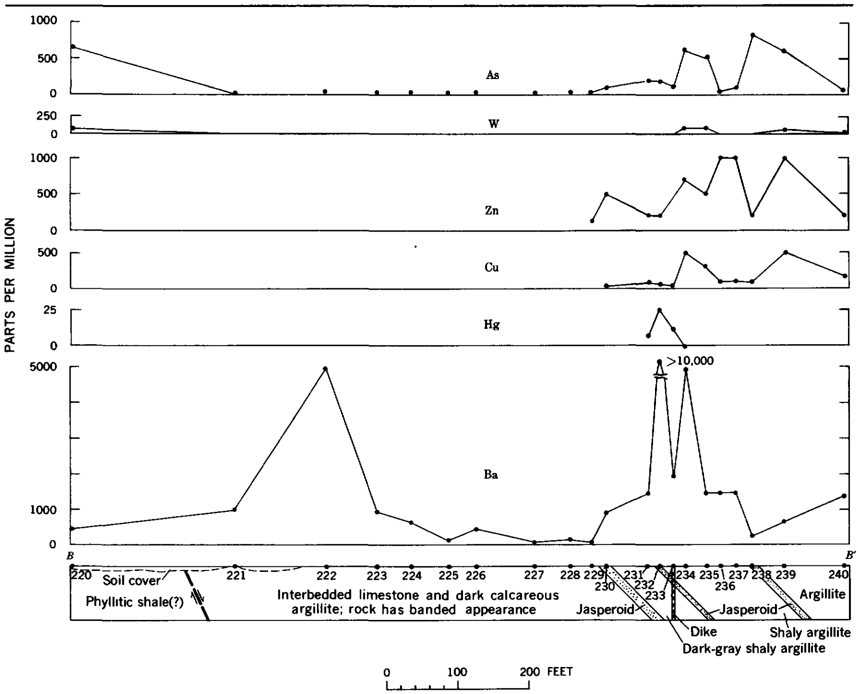

FIGURE 6.—Geochemical profile, *B-B'* traverse, sec. 9, T. 38 N., R. 42 E., Humboldt County, Nev.

TABLE 6.—*Semiquantitative spectrographic and chemical analyses*

[Semiquantitative spectrographic analyses by Uteana Oda; chemical analyses:

Field No.	Description	Percent			Parts per million				
		Ca	Fe	Mg	Ti	Mn	Ag	As	B
GM-220-A	Caliche coatings in orange-brown stained phyllitic shale.	15.0	0.7	0.2	500	150	<1	125	50
220-B	Iron-rich orange-brown material	1.5	7	.15	700	2,000	<1	700	200
220-C	Orange-brown fines sieved from shale	.5	3	.2	3,000	1,500	<1	500	300
221	Caliche, impure; sieved from weathered shale.	2	1	.2	700	200	<1	25	50
222-A	Hornfels, banded dark and light, calcareous and cherty.	10	2	3	3,000	200	<1	25	50
222-B	Caliche coatings on hornfels	15	.3	.3	100	20	<1	40	10
223	Hornfels, black; sieved fines	2	3	.7	2,000	700	<1	25	50
224	Caliche coatings on banded calcareous hornfels.	15	1	.3	700	150	<1	10	20
225	Caliche, pale-yellow	15	.7	.2	150	70	<1	10	10
226	Hornfels, banded, calcareous	15	1	.3	700	200	<1	10	30
227	Limestone, sanded, altered, yellow	>20	1.5	1	1,000	300	<1	30	20
228	do	>20	1	.2	500	700	<1	40	<10
229	do	15	.7	.2	300	300	<1	10	10
230	Hornfels, black, silicified	1.5	.7	.1	1,000	10	<1	80	100
231	Argillite, shaly, black, stained orange	.3	3	.2	2,000	50	1	160	100
232	Jasperoid, stained orange-brown	3	1	.05	700	10	<1	160	15
233	Dike rock, altered, chalky, quartz-bearing.	.7	.5	.1	2,000	30	<1	100	500
234-A	Argillite, shaly, bluish-black, sieved	5	.7	.1	1,500	15	1	150	150
234-B	Yellow-orange oxidized material in shaly argillite.	.3	3	.2	700	20	2	600	100
235	Clay, mixed yellow-green and dark-brown, soft.	.2	3	.15	300	100	<1	500	2,000
236	Clay, yellow-green; seams in hard black shaly argillite.	.2	2	.1	200	50	<1	30	10
237	Argillite, stained yellow-green and orange-brown.	2	3	1.5	300	300	<1	80	10
238	Jasperoid, stringer in argillite	.15	3	.03	150	20	<1	800	10
239	Argillite, shaly, stained orange-brown	2	5	.2	300	30	<1	600	50
240	Argillite, shaly, bluish-black	.3	1.5	.3	2,000	100	<1	30	200

NOTE.—La <50, Sb <50, Sn <10 in all samples.

side of Osgood Creek (fig. 1). The outcrop, mapped by Hotz and Willden (1961) as the Comus Formation, is composed of interbedded argillite, chert, and limestone. The western part of the outcrop, presumably the shattered hanging wall of the Getchell fault zone, contains vuggy leached dark jasperoid cut by randomly oriented white quartz veins.

Semiquantitative spectrographic analyses (table 7) of jasperoid and orange-brown iron-rich oxidized material in leached vugs in the jasperoid show that the Getchell fault zone is mineralized in this area. Arsenic and zinc are the most abundant metals, and mercury (2 ppm) was detected in the vug-filling material. The alluvium-covered area immediately west of the outcrop and through which the footwall of the Getchell fault zone is projected should be prospected.

DISCUSSION

Geochemical work at the Getchell mine and vicinity has demonstrated that arsenic-tungsten-mercury anomalies occur over the gold *of rocks,* B–B′ *traverse, sec. 9, Getchell mine district, Nevada*

mercury by L. E. Patten, arsenic by W. W. Janes and A. P. Marranzino]

Parts per million—Continued																
Ba	Be	Bi	Co	Cr	Cu	Hg	Mo	Ni	Pb	Sc	Sr	V	W	Y	Zn	Zr
300	<1	<10	<10	30	5	<2	<2	5	<10	<10	200	50	<50	<10	<200	10
300	1	<10	10	20	15	<2	15	30	50	<10	50	150	<50	20	<200	10
500	3	<10	20	150	30	<2	<2	30	<10	10	100	100	70	10	<200	100
1,000	2	<10	<10	20	20	<2	<2	20	<10	<10	50	30	<50	10	200	100
5,000	1	<10	10	70	30	<2	<2	15	10	20	700	100	<50	20	<200	150
500	<1	<10	<10	20	10	<2	<2	5	<10	<10	500	15	<50	<10	<200	10
1,000	3	<10	10	30	70	<2	<2	50	10	<10	150	50	<50	20	<200	150
700	1	<10	<10	20	20	<2	<2	10	<10	<10	300	50	<50	10	<200	20
200	<1	<10	<10	10	7	<2	<2	5	<10	<10	300	30	<50	15	<200	10
500	2	<10	<10	20	20	<2	<2	15	10	<10	300	50	<50	10	<200	70
150	1	<10	<10	50	15	<2	<2	10	<10	<10	700	70	<50	20	<200	70
200	<1	15	<10	20	10	<2	2	5	<10	<10	100	30	<50	10	<200	20
150	1	10	<10	20	7	<2	<2	5	<10	<10	200	30	<50	<10	<200	20
1,000	<1	<10	<10	70	30	<2	<2	15	10	10	100	500	<50	15	500	150
1,500	1	<10	<10	100	70	4	5	30	30	<10	300	300	<50	20	200	20
>10,000	<1	<10	<10	30	50	23	<2	20	10	<10	300	300	<50	20	200	20
2,000	1	<10	<10	10	10	8	<2	<5	10	<10	150	70	<50	<10	<200	150
5,000	2	<10	10	100	100	<2	<2	50	20	10	300	300	<50	15	700	200
1,500	2	<10	10	70	500	<2	5	150	70	10	100	1,000	70	20	700	150
1,500	7	<10	<10	<10	300	<2	10	100	30	<10	50	150	70	10	500	30
1,500	<1	<10	<10	<10	70	<2	<2	50	15	<10	<20	70	<50	<10	1,000	20
1,500	5	<10	10	10	100	<2	10	70	<10	<10	50	150	<50	20	1,000	20
300	2	<10	<10	10	70	<2	15	30	70	<10	20	70	<50	10	200	50
700	2	<10	20	50	500	<2	10	150	30	<10	150	300	50	50	1,000	30
1,500	2	<10	10	70	150	<2	2	100	20	10	100	300	<50	30	200	150

TABLE 7.—*Semiquantitative spectrographic analyses of rocks from NW¼ sec. 21, T. 38 N., R. 42 E., Humboldt County, Nev.*

[Uteana Oda, analyst: in parts per million, except Ca, Fe, Mg in percent]

Element	Jasperoid	Material in vugs in jasperoid	Element	Jasperoid	Material in vugs in jasperoid
Ca	3	5	Cu	30	200
Fe	10	10	Mo	50	30
Mg	.02	.1	Ni	70	200
Ti	150	1,000	Pb	<10	10
Mn	10	100	Sr	500	1,000
Ag	2	<.5	V	300	7,000
As	3,000	5,000	Y	<10	20
B	<10	20	Zn	1,000	2,000
Ba	5,000	5,000	Zr	<10	20
Be	<1	2	Hg [1]	-------------	2
Cr	10	30			

[1] Hg determined by J. B. McHugh by chemical method.

deposits and that these anomalies are not broad halos but are restricted to the mineralized area. The highest metal values are found in oxidized iron-rich material along fractures and bedding planes in barren bedrock, lesser values in caliche coatings on exposed bedrock, and lowest, but still anomalous, values in soils.

Arsenic and tungsten are strongly oxyphile and tend to form oxides or hydrated oxides and remain in the zone of oxidized rocks. During oxidation of a sulfide deposit (low pH, high Eh) and attendant formation of ferric minerals, arsenic and tungsten probably are adsorbed by ferric hydroxide precipitates as anion complexes (AsO_3^{-3} and WO_4^{-2}). Ferric hydroxide precipitates commonly form positively charged colloids at low pH which would attract negatively charged particles or ions (Hem and Skougstad, 1960). Krauskopf (1955, p. 425) pointed out

> the fact that iron oxide in most sedimentary environments forms a positive colloid while manganese oxide forms a negative colloid has been used to explain the supposed greater concentration of anion-forming elements (As, Se, probably Cr and V) with the former and of cation-forming elements with the latter; but available data are insufficient to establish such a distinction beyond question. The fact that Fe^{+3} forms an insoluble * * * arsenate has been used by * * * Fedorov as an alternative explanation for the concentrations of these elements with iron oxide sediments.

Whether arsenic and tungsten are adsorbed by precipitating iron hydroxide or form ferric arsenates and tungstates, it is clear that the strong concentration of arsenic and probably tungsten in the yellow-brown and red-brown iron-rich oxidized materials in bedrock over the gold deposits is to be expected.

The amount of arsenic that will remain in the oxidized zone probably is controlled, in part, by the amount of iron available to form ferric arsenates or arsenic-adsorbing ferric hydroxide. In the gold deposits at the Getchell mine arsenic is more abundant than iron in the unoxidized ore. Thus there would not be sufficient iron to fix all of the available arsenic in the oxidized zone. The iron deficiency would account for the fact that the concentration of arsenic in the oxidized zone is not as high as its concentration in the unoxidized ore.

As the oxidizing water becomes depleted in iron content and more alkaline through comingling with surface water and (or) contact with carbonate rocks, excess arsenic probably remains in solution as negatively charged anionic species. The Eh-pH diagram for arsenic given by Delahay, Pourbaix, and Van Rysselberghe (1951) suggests that arsenic may remain in solution, as progressively more dissociated, negatively charged arsenate complexes ($H_2AsO_4^{-1}$, $HAsO_4^{-2}$) through a wide pH range without appreciable change in Eh. Thus it is reasonable that caliche formed from evaporation of oxygenated alkaline waters on bedrock surfaces or in soil over the arsenic-gold deposits should contain small but still anomalous amounts of arsenic (as much as 250 ppm).

The small but anomalous amounts of arsenic in soil over concealed gold deposits may be due to upward diffusion of arsenic by surface and ground waters or by diffusion of arsine gas from arsenic concentrations in the bedrock.

Tungsten, unlike arsenic, appears to have a higher concentration in the oxidized zone than in the unoxidized ore. A possible explanation is that the original concentration of tungsten in the ore (100 to 200 ppm) is much less than the concentration of arsenic (several percent). Thus only a small amount of iron hydroxide would be required to concentrate tungsten through residual enrichment in the oxidized zone. Tungsten was not detected in soil at the limit of spectrographic sensitivity (<50 ppm).

Mercury, strongly sulfophile, is present in greatest amounts (as much as 200 ppm) in the unoxidized ore and decreases by one or two orders of magnitude (2 to 20 ppm) in the oxidized zone. Mercury is usually more abundant in the iron-rich oxidized material than in caliche and soil over the gold deposits. The nature of the mercury-bearing material in the oxidized zone is not known; it may be present as an oxide, halide, sulfate, or adsorbed on oxidate materials. Mercury in soil, in trace but anomalous amounts, is probably present as native mercury that has diffused as vapor into the soil from the underlying bedrock.

Rankama and Sahama (1950, p. 716–717) stated that "The volatility of mercury facilitates its migration, and in this respect mercury differs from all other metals. Mercury may migrate either in the native state or as the soluble mercuric chloride, $HgCl_2$. In the presence of oxidizing agents cinnabar is oxidized to sulfate."

Hawkes and Williston (1962, p. 30) believe that mercury migrates in vapor form and that the "vapor is recondensed as liquid mercury on the surface of minerals or is precipitated as weakly bonded complexes or compounds of various kinds." They pointed out the promise of the detection of mercury vapor halos "as an ore guide in desert areas where the bedrock is blanketed by hundreds of feet of dry sand, gravel, lake sediments, or volcanics."

The consistent occurrence of small amounts of tungsten (as much as 3,000 ppm) in and over the gold ore suggests some genetic relationship between tungsten-molybdenum mineralization in the tactite zone along the granodiorite contact and the arsenic-gold mineralization in the Getchell fault zone. This possibility is further supported by the occurrence of arsenic (as much as 2,000 ppm) in the few analyzed samples of oxidized iron-rich material from the tactite zone. Lead-antimony-arsenic-silver-mercury anomalies have been discovered at several localities along the east front of the Osgood Mountains, particularly near the northern and southern extremities of the range. The various types of metal deposits probably are genetically related to each other and to the granodiorite intrusive mass and formed as successive and overlapping stages of one period of complex mineralization.

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