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Item #41

GEOLOGICAL AND GEOCHEMICAL RELATIONSHIPS AT THE GETCHELL MINE AND VICINITY, HUMBOLDT COUNTY, NEVADA

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Introduction

The Getchell gold mine, located in eastern Humboldt County, Nevada (Figure 1), was a producer of gold bullion intermittently between 1938 and 1967. This occurrence is one of several disseminated-type gold deposits in the western United States, including Carlin, Cortez, Gold Acres, Jerrett Canyon, Mercury, and numerous smaller deposits (Roberts and others, 1971). The geological and geochemical characteristics of these deposits are similar; high gold to silver ratio, associated arsenic and mercury, carbonaceous limy host rocks, associated intrusive igneous rocks, and extensive silica replacement.

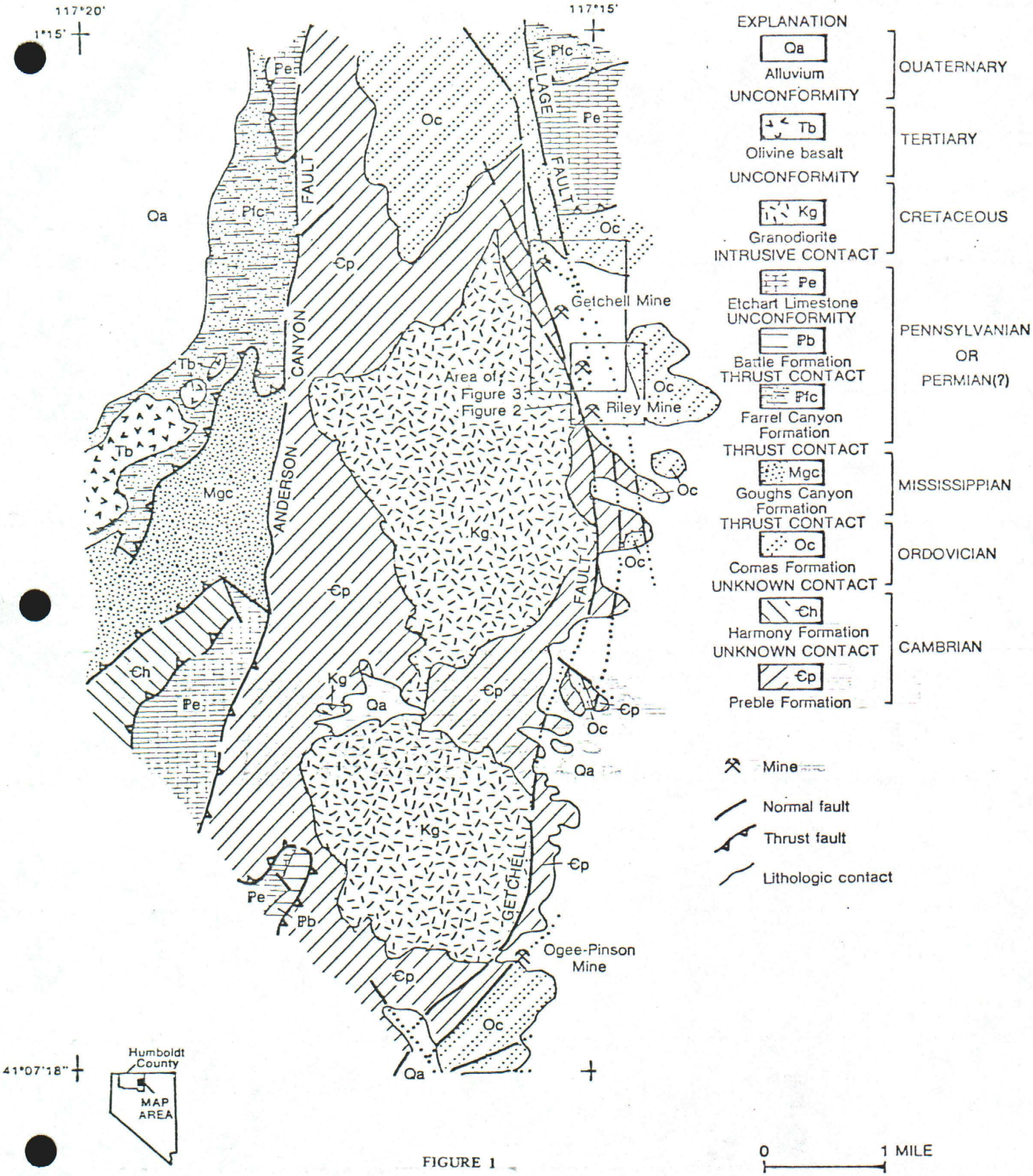
The purposes of this report are to describe the geologic relationships at the Getchell mine and their effects on the localization of gold mineralization, and to present data concerning the geochemical characteristics of the ore bodies and the consequent ramifications for exploration.

GENERAL GEOLOGIC SETTING

The Getchell mine is located in the Potosi mining district on the eastern flank of the Osgood Mountains, about 70 km northeast of Winnemucca, Nevada (Figure 1). Initial geologic mapping in a portion of the Osgood Mountains was done by Hobbs (1948), followed by a study of the entire Osgood Mountains 15-minute quadrangle by Hotz and Willden (1964).

Studies of the mineral deposits of the Potosi mining district include Hobbs and Clabaugh (1946), Joralemon (1949, 1951, 1975), Cavender (1963), Hsu and Galli (1973), Silberman and others (1974), Taylor (1974), Berger (1975), Berger and others (1975), Berger (1976), and Taylor and O'Neil (1977).

In the vicinity of the Getchell mine (Figure 2 and 3), lower Paleozoic sedimentary rocks are intruded by a granodiorite stock of Cretaceous age (Silberman and McKee, 1971). The oldest rocks are Middle and Upper Cambrian carbonaceous shale and thin-bedded limestone, in part intercalated, called the Preble Formation (Hotz and Willden, 1964). The shale beds are commonly phyllitic, and appear light-greenish in the near surface weathered zone. The Preble Formation is unconformably overlain by a sequence of intercalated dolomitic limestone and chert, shale, siltstone, and mafic volcanic rocks belonging to the Comus Formation of Early and Middle Ordovician age. The mafic volcanic rocks are in part intrusive into the intercalated dolomitic limestone and chert, although vesicular textures, pillow-like structures, and interbedded shale indicate that they are mainly submarine flows. All of these lower Paleozoic rocks are isoclinally folded, with the fold axes overturned to the west (Erickson and Marsh, 1974). This style of folding is not seen in younger rocks. North of the mine area, Etchart Limestone and chert, shale and quartzite of the Farrel Canyon Formation are imbricately thrust over the older Paleozoic rocks. The Etchart Limestone is similar to the Highway and Antler


117°20'
41°15'
117°15'
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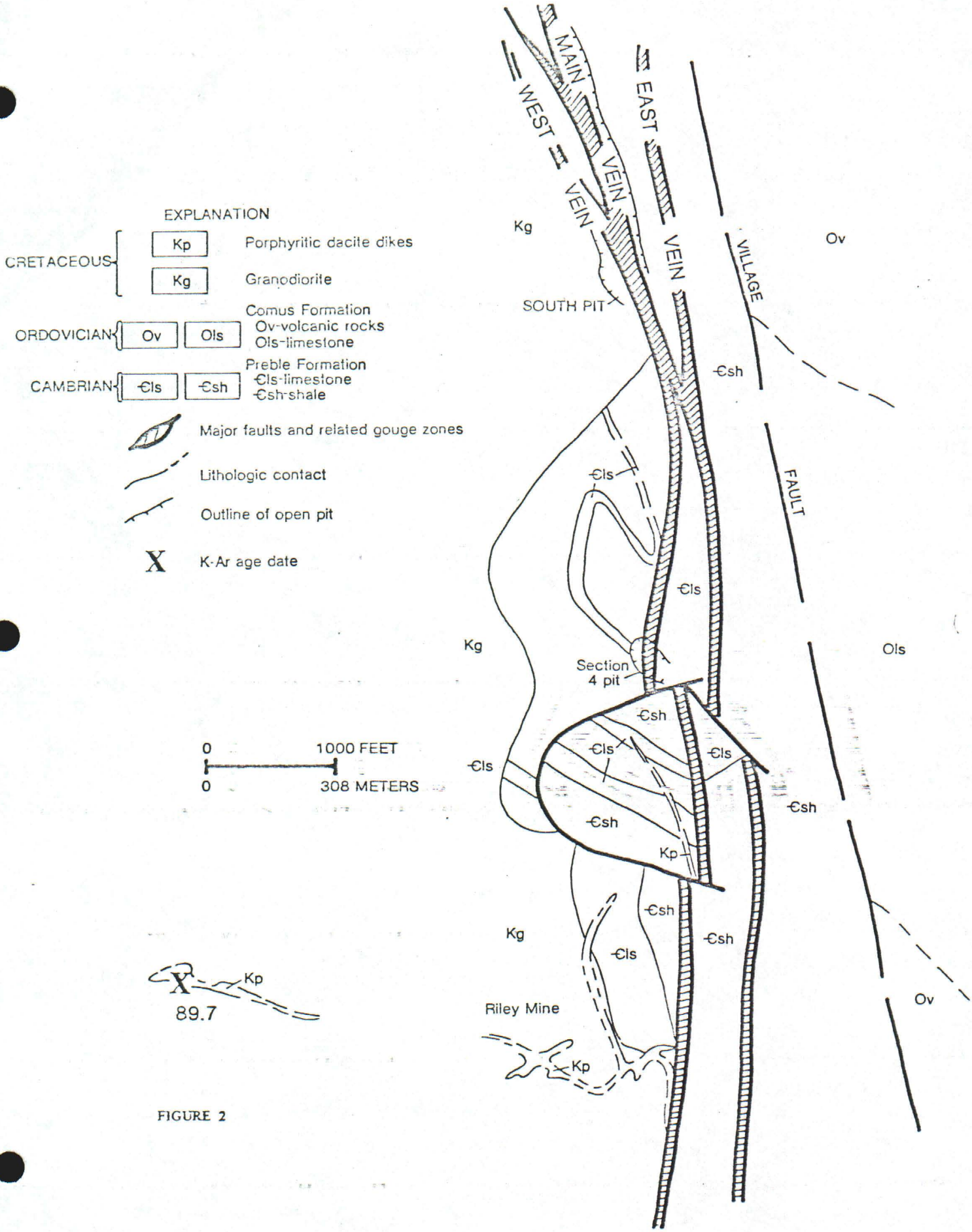
EXPLANATION
Qa
Alluvium
UNCONFORMITY
QUATERNARY
Tb
Olivine basalt
UNCONFORMITY
TERTIARY
Kg
Granodiorite
INTRUSIVE CONTACT
CRETACEOUS
Pe
Etchart Limestone
UNCONFORMITY
Pb
Battle Formation
THRUST CONTACT
Pfc
Farrel Canyon Formation
THRUST CONTACT
PENNSYLVANIAN OR PERMIAN(?)
Mgc
Goughs Canyon Formation
THRUST CONTACT
MISSISSIPPIAN
Oc
Comas Formation
UNKNOWN CONTACT
ORDOVICIAN
Ch
Harmony Formation
UNKNOWN CONTACT
Cp
Preble Formation
CAMBRIAN
Mine
Normal fault
Thrust fault
Lithologic contact
Qa
Pfc
Pe
Oc
Cp
Tb
Mgc
Kg
Ch
Pb
ANDERSON CANYON FAULT
VILLAGE FAULT
GETCHELL FAULT
Getchell Mine
Riley Mine
Ogee-Pinson Mine
Area of Figure 3
Figure 2
Humboldt County
MAP AREA
0
1 MILE
0
1.6 KILOMETER

FIGURE 1


EXPLANATION
CRETACEOUS
Kp
Porphyritic dacite dikes
Kg
Granodiorite
ORDOVICIAN
Ov
Ols
Comus Formation
Ov-volcanic rocks
Ols-limestone
CAMBRIAN
Ꞓls
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Preble Formation
Ꞓls-limestone
Ꞓsh-shale
Major faults and related gouge zones
Lithologic contact
Outline of open pit
K-Ar age date
0
1000 FEET
0
308 METERS
MAIN
WEST
VEIN
EAST
VEIN
VEIN
VILLAGE
FAULT
SOUTH PIT
Section
4 pit
Riley Mine
Kg
Ov
Ols
Ꞓsh
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Kp
89.7

FIGURE 2

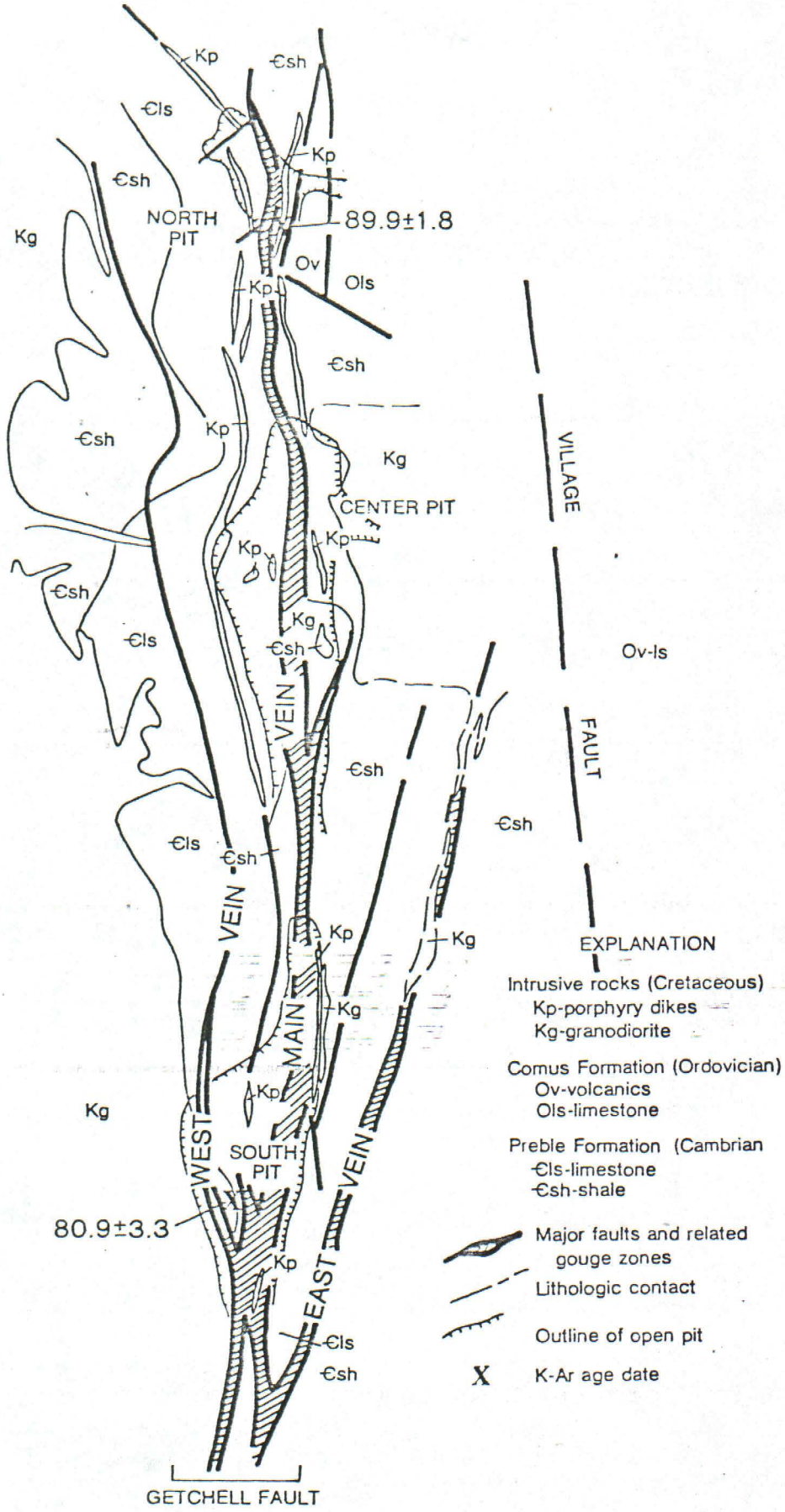

FIGURE 3. Geologic map of Getchell mine area. *Revised from Silberman, Berger, and Koski (1974, after Joralemon, 1951).*

Peak Formations found elsewhere in the region, and contains rocks of Middle to Late Pennsylvanian or Early Permian age (Hotz and Willden, 1964). The Farrel Canyon Formation of Pennsylvanian (?) to Permian age resembles the Havallah and Pumpernickel Formations found to the south and southeast of the Osgood Mountains.

The Cretaceous Osgood Mountains biotite granodiorite and related dike rocks intrude all of the Paleozoic rocks. The stock is an homogenous, coarse body of variable grain size. The dikes consist of both granodiorite and dacite porphyry. The stock is symmetrical, and appears to dip outward 45°-60° on both east and west flanks (Continental Oil Co., unpublished aeromagnetic data, 1973). There is a metamorphic aureole around with the intrusion with a mineral assemblage in shaly rocks consisting of cordierite-, biotite-, and andalusite-hornfels. Locally limy beds are recrystallized and calc-silicate minerals are developed.

The imbricate thrust faults juxtaposing the early and late Paleozoic formations have been interpreted by Erickson and Marsh (1974) in the Edna Mountain area south of the Osgood Mountains as representing two distinct episodes of deformation--Late Pennsylvanian to Early Permian and Late Permian to Early Triassic (Sonoma orogeny). The Getchell fault zone, an anastomosing system of high-angle, dip-slip faults, cuts the thrust faults along the eastern margin of the Osgood Mountains and the zone is a clearly younger feature. Hobbs (1948) and Joralemon (1951) felt that the Getchell fault system postdated the granodiorite stock, and that the earliest sense of movement on the fault was lateral based on presumed mullion structures and horizontal slickensides. Berger and Taylor (1974) re-evaluated the field evidence and concluded that the displacement has been predominantly vertical, and that the fault system controlled the emplacement of the granodiorite stock and related dikes. The fault system has been active to the present as evidenced by the displacement of Quaternary(?) alluvium in the mine area.

MINERALIZATION IN THE OSGOOD MOUNTAINS

Mining activity in the Osgood Mountains has been described by Hotz and Willden (1964). For completeness, a brief summary of the types of deposits other than disseminated gold and the geochemical characteristics of some is presented here.

Barite

Barite is a widespread gangue mineral in many of the hydrothermal mineral deposits in the Osgood Mountains. In addition, barite commonly occurs as rosettes in carbonate beds of the Ordovician Comus and Cambrian Preble Formations, and massive, bedded barite deposits are known in sec. 12, T. 37 N., R. 41 E., sec. 32, T. 38 N., R. 42 E., and sec. 30, T. 39 N., R. 42 E. Silver-bearing quartz veins cross-cut the bedded barite, but otherwise there is no hydrothermal sulfide mineralization accompanying the barite.

Tungsten

Copper

Tin

Metasomatic skarn deposits occur in carbonate host rocks around the periphery of the Osgood Mountains granodiorite. A number of the skarns have been mined for tungsten, with the most active periods being 1942-1945 and 1951-1957. Copper is a minor accessory element in most of the deposits, and molybdenum is a significant co-product of the Moly tungsten mine (figure 2). Tin is present in garnet-pyroxene skarn as an accessory trace element.

Disseminated sulfides occur in the granodiorite stock in two places, one within each of the exposed lobes. Hotz and Willden (1964) referred to the zone in the central part of the northern lobe west of the Riky mine as the Section 5 pit (sec. 5, T. 38 N., R. 42 E.), and at this locality tungsten occurs with quartz in a matrix of quartz sericite and pyrite. The second zone is located at the north end of the southern lobe (secs. 19, 20, T. 38 N., R. 42 E.) and was described by Neuerburg (1966) as consisting of "thin seams of iron sulfides along subparallel irregular fractures." Molybdenum and tin occur in trace amounts in these altered zones.

Molybdenum
Tin

Silver
Gold

Small silver-bearing quartz veins occur at numerous localities throughout the range. The veins are fault controlled, and are also common in the broken noses of plunging antiformal structures. Lead and zinc are associated with the silver, and secondary oxides of these elements are common in outcrop. Gold is present in amounts subordinate to the silver.

Manganese

Minor manganese sulfide and oxide prospects occur at several localities in the range. Most are in chert of the Farrel Canyon Formation as coatings along fractures and as a matrix cementing breccia fragments.

GEOLOGY AT THE GETCHELL MINE

The geology of the Getchell mine area is shown on Figure 3. The alluvium and dump materials have been omitted to better illustrate the geologic relationships.

The Getchell fault system generally consists of two persistent gouge zones referred to locally as the "footwall strand" (Joralemon, 1951) and the "hangingwall strand" (Berger and Taylor, 1974). However, a single fault is not consistently present in either position for the entire length of the range (Figure 1). In the mine area, the Getchell fault exclusive of the Village fault has been simplified into three main strands that are of importance in the localization of the mineralization. These are the West, Main, and East veins (Figure 2 and 3). Ancillary faults do contain gold mineralization, although this mineralization is of limited economic importance.

At the mine, the Getchell fault system consists of a series of anastomosing, east-dipping, normal faults. The dip of the faults varies from about 30° to 60°, with the eastern strand generally dipping more steeply than the western strands. In spite of a thick gouge zone along the Main vein of the Getchell fault (Figure 3), the greatest vertical displacement appears to have taken place to the east along the Village fault, although the absolute displacement is unknown. This interpretation is based on the stratigraphic continuity of the Preble Formation limestone across the Main vein of the fault system in the Getchell mine workings and on drill data south of the workings and along the Village fault (unpublished data, Continental Oil Co.).

Host rock is ls. of Preble fm.

Limestone of the Preble Formation is the most important host rock for gold mineralization in the mine area. Arenaceous limestone beds (1-2" thick) are intercalated with equally thick carbonaceous shale beds. The shales are in part limy, particularly in the North Pit area. Thick shale units lie both stratigraphically above and below the predominantly limestone portion of the formation. Against the intrusion the shales are metamorphosed to cordierite-

andalusite hornfels. Biotite hornfels appears along some faults and biotite schist appears along others. Berger and Taylor (1974) interpreted these biotite-rich areas as faults ancestral to the present day Getchell system. The shale and limestone beds strike northerly and dip 30°-50° to the east. Outside the zone of contact metamorphism Pre-Cretaceous regional metamorphism has converted the Preble shales into phyllitic rocks.

The main mass of the granodiorite stock is located along the west side of the mine area (Figure 3). It forms the footwall of the West vein of the Getchell fault system in the South pit. Another large mass is located in the hangingwall of the Main vein to the east of the Center pit. Hotz and Willden (1964) suggested that the latter mass was offset approximately 0.7 miles laterally from the main stock. However, an intricate set of offshoot granodiorite dikes along the East vein and to the north of the body along the Main vein imply that the body was emplaced along the faults and is not an offset portion of the main stock. Three- to ten-foot wide granodiorite and dacite porphyry dikes also were emplaced along the Main vein. All of the intrusive dikes are of Cretaceous age (Silberman and McKee, 1971; Silberman and others, 1974).

Ash beds younger than mineralization

Several sequences of Tertiary and Quaternary alluvial deposits cover most of the eastern portion of the mine area. These deposits have been unaffected by hydrothermal activity. A rhyolitic ash is incorporated in the oldest alluvium exposed in the North, Center, and South pit areas. The ash units are found in the alluvium in the east wall of all of the open pits and about two miles north of the mine along the Village fault. The largest exposure of ash is adjacent to the North pit entrance ramp. Joralemon (1951, 1975) felt the ash adjacent to the North pit was genetically related to the gold mineralization. However, eroded fragments of mineralized rock occur in alluvium beneath the ash beds, and portions of the ore zones are truncated by alluvium-filled channels which contain the ash beds.

GEOLOGIC RELATIONS OF THE GOLD MINERALIZATION

Gold was discovered at Getchell in 1934. Opencut and undergound production of primarily oxide ore commenced in 1938 and continued to 1950. The gold was extracted using the cyanide process. Sulfide ores, mined from three open pits, were primarily treated during a later stage of mining (1962-1967) using a fluid-bed roast to oxidize the ores prior to cyanidation. The bullion production record for both periods of mining is given in Table 1.

The gold ore deposits are low temperature (Nash, 1972) replacements of limestone along the Getchell fault zone with the faults serving as conduits for the ore solutions. Typical of many epithermal deposits, the ore bodies form irregular pods of erratic grade (Figure 4). Mining widths averaged 12 meters (Joralemon, 1951), although zones as much as 61 meters wide were mined. Deep explorations shows that the mineralization persists at least 1 kilometer down-dip on the Getchell fault system and also occurs along the parallel Village fault (Berger, 1976). Although the major strands of the Getchell fault appear to converge down-dip, the complex pattern of mineralization remains consistent to considerable depths, and there is still more than one persistent mineralized structure at the deepest levels investigated.

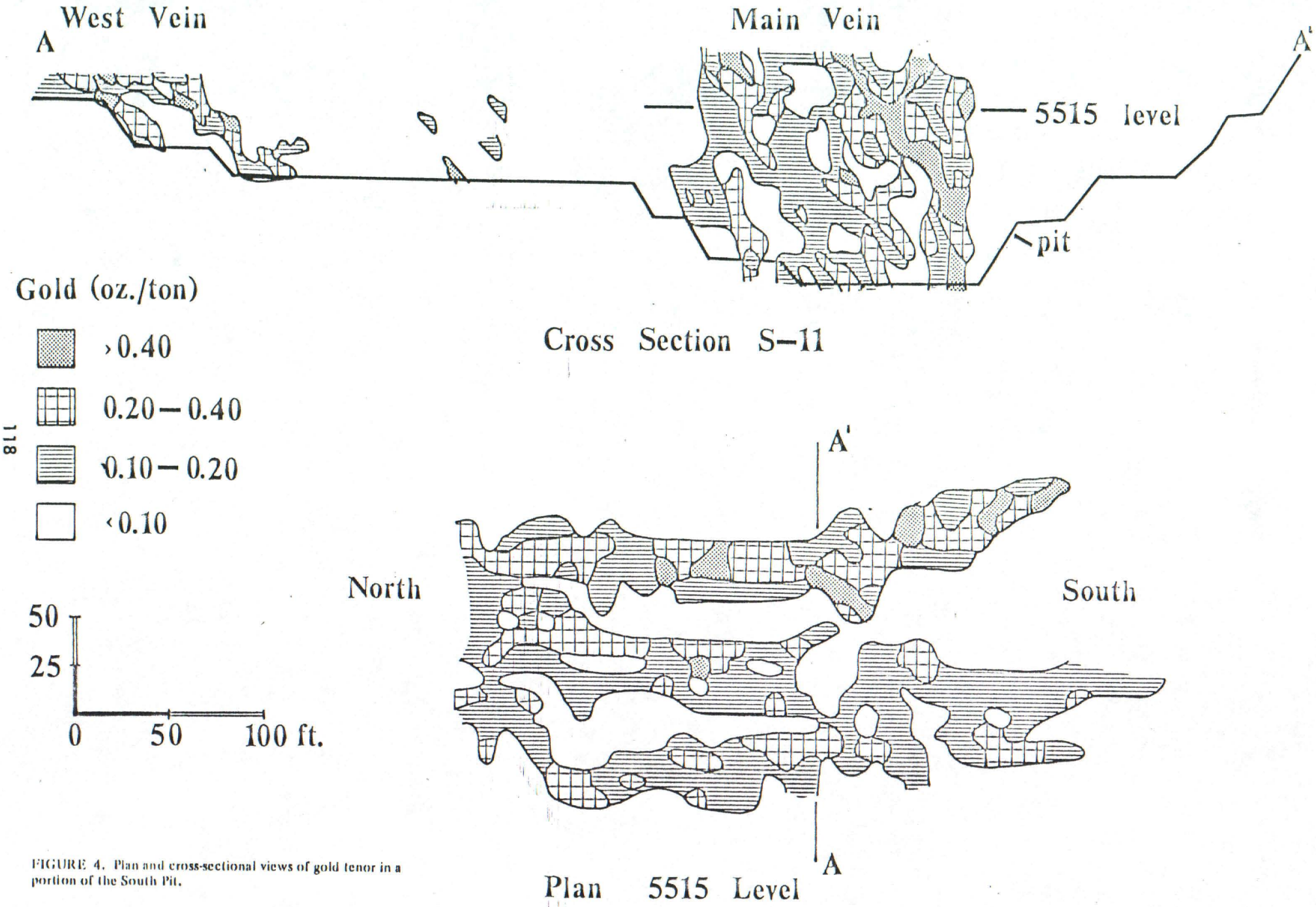

FIGURE 4. Plan and cross-sectional views of gold tenor in a portion of the South Pit.

TABLE 1. Gold production at the Getchell mine*
1938-1950

Year	Ounces	Value
1938	24,818	$ 868,632
1939	49,135	1,719,740
1940	63,385	2,218,467
1941	59,515	2,083,033
1942	49,168	1,720,868
1943	34,949	1,223,232
1944	35,536	1,243,760
1945	9,925	347,375
1946-47	No Production	
1948	10,754	376,390
1949	18,758	656,530
1950	32,090	1,123,150
TOTAL	388,033	$13,581,177

1962-1967

	Tons	Ounces/Ton
North Pit	804,130	0.33
Center Pit	396,100	0.25
South Pit	879,400	0.23
Section 4	33,400	0.23
	2,113,030	0.271

*Data compiled as shown from annual reports of Getchell Mine, Incorporated.

Alteration and Ore Mineralogy

Hydrothermal alteration consists chiefly of decarbonatization accompanied by silicification of the limestone beds. Some portions of the limestone have been completely altered to fine, granular quartz. Secondary quartz is also present in all other rock types in the mineralized zone. Where relict bedding is preserved, the quartz is very fine grained, and the grains are elongated parallel to the bedding. Where silicification is more intense, the quartz is fine to medium grained, and grew obliquely to the bedding. All of the secondary quartz grains display an irregular outline in contrast to the equant, mosaic texture found in the unmineralized metamorphosed rocks. Polished section examination has shown some native gold to be jacketed by and along the margins of quartz grains (Joralemon, 1949). Amorphous and/or cryptocrystalline masses of silica referred to as "jasperoid" have only been found in oxidized portions of the mineralized zones and are probably supergene in origin.

jasperoid "supergene"

Some of the silicified zones are surrounded by pods of carbonaceous material. The carbon has probably been in part remobilized from limestone and shale by the hydrothermal solutions, and is a mixture of amorphous carbon, organic carbon complexes (B. R. Berger, unpublished data), and graphite (Botinelly and others, 1973). The most carbonaceous zones occur where shale made up a significant proportion of the host rock. Where the bedding has been preserved, the carbonaceous material forms thin laminae paralleling quartz layers. The carbon often surrounds the quartz, but is not, in general, adjacent to subhedral pyrite grains which form elongate clots parallel to the bedding. The pyrite is intergrown with larger quartz grains and commonly contains blebs or rims of arsenopyrite. Joralemon (1949, 1951) found some visible gold in association with pyrite, arsenopyrite, and carbonaceous material. Where silicification is more intense, the carbonaceous material forms irregular, intergranular mattes surrounding quartz grains. However, the sulfides again tend to be enclosed by elongate quartz grains and not carbonaceous material, implying that there is a closer relationship of gold to quartz and sulfide than to carbonaceous material (Wells and others, 1969). Depending on the original host rock mineralogy, other alteration products include sericite, clay, and chlorite. Cordierite, andalusite, and biotite are altered to sericite and/or chlorite. Feldspar is argillized and/or sericitized. X-ray data from an altered granodiorite mass in the South pit indicate that the clay is primarily kaolinite.

Realgar and orpiment are late-stage products of the hydrothermal activity. They are generally interstitial to other ore and gangue minerals along veins, fractures, or bedding planes. In rocks with considerable carbonaceous material, realgar and orpiment are surrounded by dense mattes of late-stage remobilized carbon.

The igneous dikes and portions of the main stock are altered. Plagioclase is altered to sericite and kaolinite; biotite is altered to sericite, chlorite, and pyrite. Stockwork quartz veins cut the igneous bodies, and these veins are cut by calcite-dolomite veins in the South pit. Realgar occurs along the stockwork veins and around the boundaries of altered feldspar grains. Much of the groundmass of the porphyritic intrusions is altered to quartz and clay. Joralemon (1949) suggested that the alteration of the igneous dikes may be deuteric. The only deuteric alteration noted during the present study consisted of partial sericitization of biotite in dikes crosscutting tactite in the Riley mine to the south of the Getchell mine (Figure 2). Intense argillic alteration and pervasive quartz and sericite along dike boundaries are found only in dikes located in areas having gold mineralization. Away from the ore bodies or within the granodiorite, dikes are fresh; even a short distance from the Getchell fault they do not show alteration of any sort.

Hg
Sb
Cu
Zn

Minor ore minerals include cinnabar, stibnite, and occasional chalcopyrite and sphalerite. In addition to quartz and calcite, gangue minerals include marcasite, magnetite, barite, fluorite, and chabazite. Stibnite is most common in the South pit ore body and along the East vein. Fluorite occurs in the North pit ore body as do the rare minerals getchellite ($Sb_3As_2S_3$) and galkhaite $(Hg,Cu,Tl,Zn)(As,Sb)S_2$ (Botinelly and others, 1973).

gangue
SiO_2
$CaCO_3$
Fe_3O_4
$BaSO_4$
CaF_2
FeS_2

Stratigraphic and Structural Ore Controls

The Getchell and Village faults are the primary loci of mineralization. Alteration and metallizations string out along minor structures into the hangingwall or footwall only a few meters. The hydrothermal solutions mineralized all rock types in the mine area, although economic mineralization for the most part appears to be restricted to the limestone and limy portions of the shale of the Preble Formation.

The strike and dip of the bedding in the Preble Formation are subparallel to the Getchell fault; as a result the replacement ore bodies in plan view are thin and sheet-like zones along the fault. Isoclinal folding of the sedimentary rocks also controls the mineralization: (1) the folds have duplicated the relatively thin limestone member of the Preble Formation resulting in a thicker mineralized zone transected by the fault zone; and (2) increased permeability in the crushed noses of the folds allowed the mineralization to follow the plunge, increasing ore length. However, the folds do not carry the mineralization away from the main fault zone more than a few meters. Depending on the position of the limy rocks relative to the fault the mineralization can occur either against the footwall or adjacent to the hanging wall.

The geometry of the ore bodies is shown in Figure 4. Both cross sectional and plan views are shown from the South pit (Berger, 1975). The higher grade bodies form scattered pods and narrow, continuous shoots down the dip of the vein. Although in the interior of the veins ore grade generally decreases gradually away from high-grade bodies, locally it decreases abruptly. The high-grade bodies commonly persist to the margin of the vein, where grade drops off abruptly.

Joralemon (1975) reported that for ore grades exceeding 0.10 ounces per ton the ore bodies apex within 9 to 15 meters of the present-day land surface, reflecting current topographic highs and lows and implying a very young age for the deposit. Berger and others (1975) found that for the minimum grade of 0.10 ounces per ton gold, the relation between the top of the north ore body and the surface prior to mining is as shown in Figure 5. Small pods of ore and altered rocks cropped out or were exposed in shallow trenches along ancillary faults in the footwall of the North pit ore body (Witt, 1936b). Where the Center Pit is now located, silicified gold-bearing ledges up to 45 m high and 24 m thick were traceable for over 900 m to the south (Witt, 1936a) to the South Pit (Figure 3). Mine reports indicate that an ore width of over 31 m was covered directly by 1 to 6 m of unaltered, unmineralized alluvium in the South Pit area (unpublished data, Getchell Mine, Inc., 1934). Five hundred meters south of the South pit over 15 m width of ore cropped out, and gold ore crops out at the Riley tungsten mine, 2 km south of Getchell. The mineralization is pervasive along parts of the Getchell fault, and what constitutes ore is wholly dependent upon the economics of mining and recovery. As a result, the geometry of ore pods can vary depending on the chosen cutoff grade, and no age can be inferred from the ore geometries.

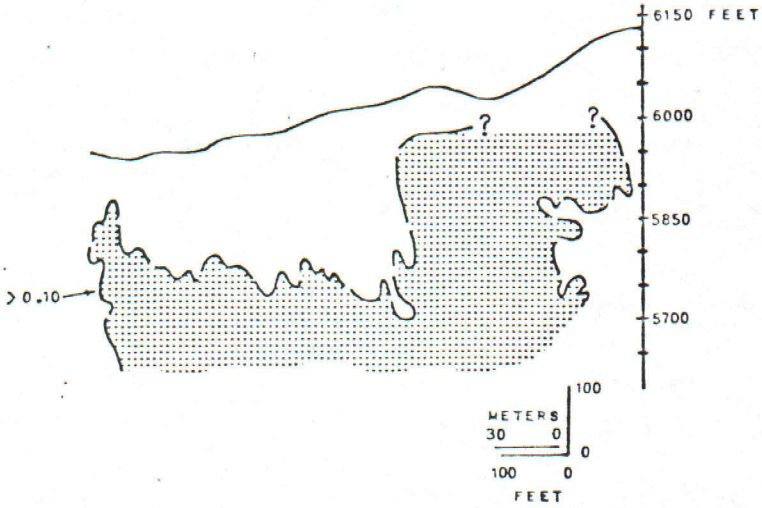

FIGURE 5. Longitudinal, vertical projection of ore apex (greater than 0.10 oz/ton) North Pit orebody, Getchell mine. *Taken from Getchell mine cross sections N19–N36.*

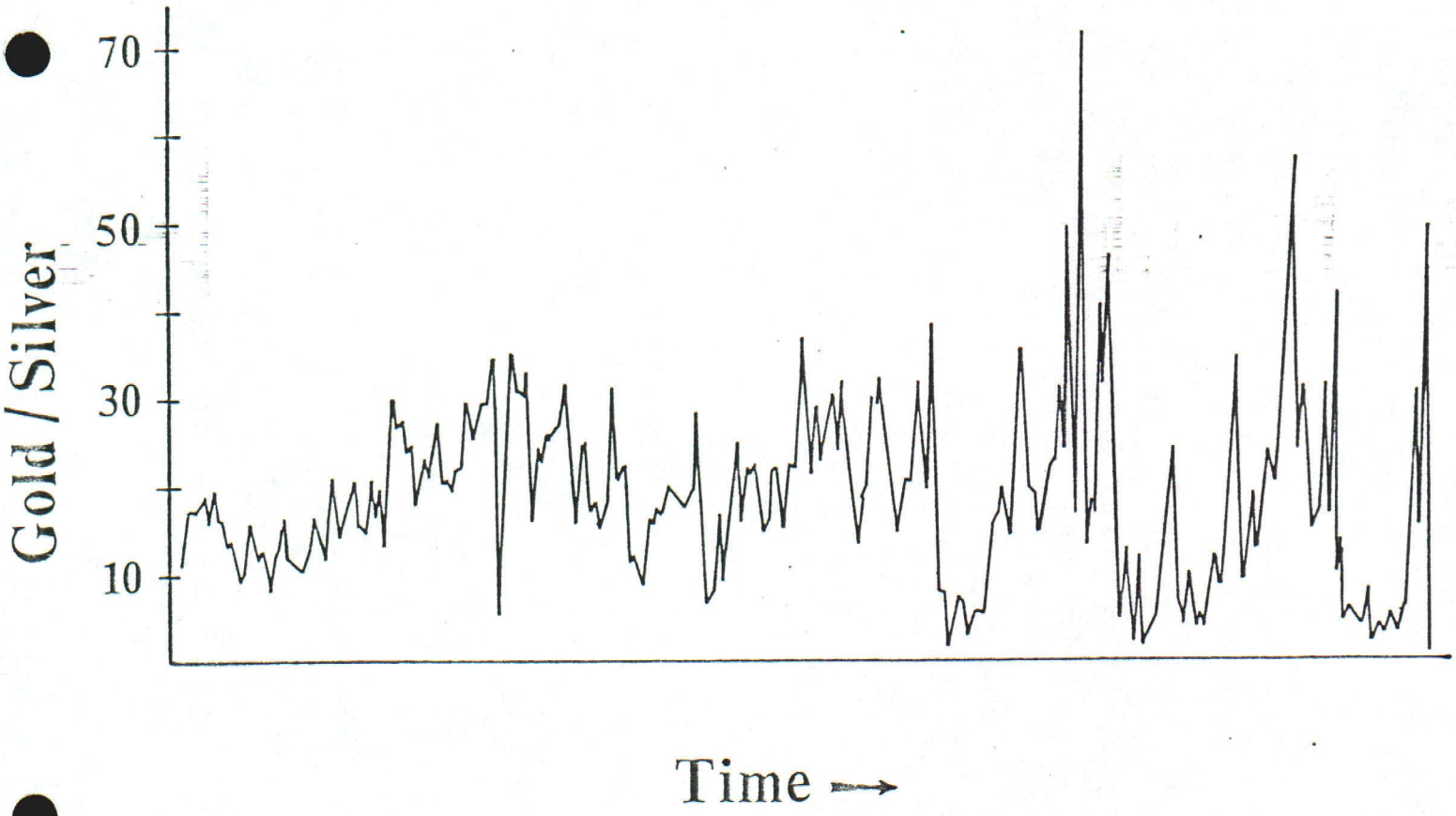

FIGURE 6. Gold to silver rations for bullion produced at Getchell for the period 1938-1945. *Unpublished data, Getchell Mine, Inc.*

GEOCHEMICAL NATURE OF THE MINERALIZATION

Gold occurs in the native state as micrometer- to submicrometer sized particles. Unpublished electron microprobe data (A. Radtke, personal commun.) show the gold to occur in association with carbonaceous material, within sulfide minerals, and as particles within and between quartz and clay grains. The average grade of the exploited Getchell ore bodies was about 9 to 10 ppm (Table 1). The subeconomic mineralization ranges from 0.02 ppm to 3 ppm gold. Silver is generally less than 1 ppm in the ore zones, but ranges from 0.2 ppm to 16 ppm in samples taken for this study. The gold to silver ratio in bullion for the period 1938 to 1945 is shown in Figure 6. Presuming that the mining progressed to greater depths with time, there is no discernible systematic trend to increased gold/silver ratios with depth in the oxidized parts of the ore bodies which made up the bulk of the ores mined. Cycles of progressively higher ratios followed by progressively lower ratios possibly reflect the somewhat irregular grade distributions shown in Figure 4, and the poor gold-silver correlations shown in Table 4 also corroborates this interpretation.

Erickson and others (1964) suggest that the trace element suite found at the Getchell deposit is similar to that found at the Carlin gold mine (Hausen, 1967; Radtke and others, 1972) and other disseminated gold deposits (Ferguson, 1924; Gilluly, 1932; Wells and others, 1969). Arsenic, mercury, and antimony are most closely associated with gold mineralization. Erickson and others (1964) also suggested that tungsten may be anomalous in the Getchell ore, though any genetic relationship is obscured by the proximity of tungsten-bearing tactites to the main productive gold zones.

As, Hg Sb.

The average trace element content of the Getchell gold deposit based on 50 samples collected for this study is shown in Table 2. The most notably enriched elements are arsenic, antimony, and mercury. The low concentration of copper, zinc, and lead is conspicuous and characteristic of the disseminated gold deposits along the Getchell fault. There appear to be trace element variations between the north, center, and south ore zones (Table 3) although the population of 50 samples evenly divided for each pit is not large enough to statistically validate the differences shown. Nevertheless the geological relationships in the pits provide corroborative evidence to the geochemical variations shown. Silver, molybdenum, and tungsten are highest in the South pit (Figure 3) where the most pre-gold calc-silicate is in evidence. Disseminated molybdenite can be found in the granodiorite stock adjacent to tungsten-bearing skarn along the West Vein, and granodiorite dikes in the east wall of the pit are spatially associated with the alteration of some of the Preble Formation limestone to a garnet-pyroxene skarn. The average mercury abundance increases from about 15 ppm in the North pit to over 80 ppm in the South pit. The highest mercury values occur as cinnabar in association with antimony. The footwall of the Center pit is siliceous hornfels, which may explain the generally lower concentrations of copper, lead, and zinc in the central ore zone. However, the concentrations of these base metals are uniformly low and the differences between the pits minor.

TABLE 2a. Average trace element content of the Getchell gold deposit.

Element	Average abundance(%)	Element	Average abundance(%)
Arsenic	0.285	Nickel	≤0.0018
Boron	0.0052	Lead	0.0018
Barium	0.019	Antimony	≤0.0935
Cobalt	≤0.0009	Strontium	≤0.0186
Chromium	0.0031	Titanium	0.103
Copper	0.0047	Vanadium	0.034
Gallium	≤0.0016	Tungsten	0.0016
Lanthanum	0.0028	Yttrium	≤0.0015
Manganese	0.0113	Zinc	0.0050
Molybdenum	0.001		

TABLE 2b. Abundance of arsenic, mercury, and antimony in ore and unmineralized host rock.

[Numbers in parantheses show the sample population size]

Element	Ore	Background
Arsenic	0.285% (181)	0.0003% (74)
Mercury	0.0022% (181)	0.000007% (50)
Antimony	0.0325% (36)	0.0007%(40)

TABLE 3. Trace element variations in parts per million between mining areas at the Getchell mine.

[All samples other than Oxide Zone represent primary sulfide ore]

Location	Ag	Cu	Pb	Zn	Mo	As	W	Hg
North Pit	2.3	84	27	99	22	2,800	26	15
Center Pit	1.9	69	14	69	13	2,800	19	30
South Pit	7.4	44	42	98	208	2,800	33	88
Oxidized Ores	--	169	59	--	18	900	--	14

The results of a correlation analysis of selected elements in ores are shown in Table 4. The ore samples were collected from all of the mining areas including the Section 4 pit south of the South pit and north of the Riley mine (T. 38 N., R. 42 E.). The relatively higher correlations between gold and molybdenum and gold and tungsten are interesting in light of the trace-element chemistry of disseminated molybdenite and scheelite-bearing skarn mineralization in the area. These correlations suggest that the gold, molybdenum and tungsten were deposited in response to different geochemical parameters than the arsenic, mercury, antimony, and thallium. Arsenic, mercury, antimony, and thallium are closely related, with thallium also showing a dependent relationship with molybdenum. The fluorine content is linearly independent of all of the elements except arsenic. The lack of correlations between gold, arsenic, mercury, and antimony with copper, lead, and zinc underscore the deficiency of base metals as a characteristic of the disseminated gold ore bodies.

TABLE 4. Table of correlation coefficients for selected elements in ores from the Getchell mine.

		Number of Qualified Pairs										
CORRELATION COEFFICIENT	Au	Ag	As	Hg	Sb	W	Tl	F	Mo	Cu	Pb	Zn
Au		78	67	77	44	81	42	37	57	56	48	49
Ag	.11		66	77	44	78	43	34	59	60	51	52
As	.13	.20		72	37	69	40	30	46	46	44	46
Hg	.20	.29	.73		36	82	40	30	57	57	56	58
Sb	.004	.60	.91	.69		37	37	38	15	16	9	8
W	.24	.09	.33	.27	.37		47	37	59	58	50	52
Tl	.14	.33	.71	.73	.72	.38		37	17	17	8	10
F	-.10	-.05	.50	.13	-.04	-.07	-.04		7	7	0	0
Mo	.50	.32	.08	.03	-.20	.38	.75	-.26		66	58	59
Cu	-.10	.19	-.03	-.05	-.13	-.008	-.35	-.15	.05		58	59
Pb	-.02	.48	-.01	-.08	.14	-.08	-.21		.05	.13		58
Zn	-.10	.09	-.03	-.11	-.26	.13	.41		.21	.38	.55	

There is no strong evidence, however, for mechanical or chemical supergene leaching and enrichment of gold at the base of the oxidized zone. Some depletion of arsenic and mercury has taken place in the oxidized, mineralized zones (Table 3) but no enriched areas are recognizable. The abundances for arsenic and mercury from selected samples are given in Table 5. Therefore, observed arsenic and mercury dispersion halos are primarily hypogene features, a fact which is useful in applying these data to exploration.

TABLE 5. Representative arsenic and mercury data from oxidized ores.

[Data from Erickson and others (1964)]

Sample No.	Arsenic	Mercury	Sample No.	Arsenic	Mercury
252	700	3	216-G	500	9
250	30	<2	216-H	300	6
212	3,000	3	216-J	1,000	5
214-C	1,000	10	216-K	700	9
245	2,000	2	216-R	40	8
246	1,000	8	216-S	1,000	30
251	500	<2	216-T	500	14

Major element redistribution accompanying hydrothermal alteration is illustrated in Table 6. In the limestone calcium, carbon dioxide, and magnesium were removed and silica, aluminum and iron were added. There was a loss in the granodiorite of silica, ferrous iron, and sodium. Since there was a decrease of bulk density during alteration, there was probably a significant loss of aluminum. Titanium, phosphorus, and manganese were essentially unchanged. There was an increase in ferric iron, magnesium, calcium, potassium, water, and carbon dioxide.

Trace element halos around the ore bodies are not extensive except where the rock is strongly fractured. Erickson and others (1964) demonstrated that calcite and quartz veinlets and limonite-coated fractures away from the pervasive hydrothermal alteration represent leakage halos and may contain pathfinder elements leading to buried mineralization. The present study has found that arsenic and mercury have moved along fractures for several hundreds of meters laterally and vertically from the ore zones. Within the pervasively altered zones and in fractured rock away from the main faulting, arsenic and mercury anomalies are scarcely broader than the areas with detectable concentrations of gold (more than 0.02 ppm).

TABLE 6. Whole rock analyses of altered and unaltered rock types in the Getchell mine area.

	1	2	3	4	5	6	7	8	9	10
SiO_2	67.6	68.4	65.9	44.0	5.8	2.4	53.1	83.4	76.4	59.0
Al_2O_3	16.8	16.8	16.8	16.8	.80	.34	26.4	4.2	5.1	10.4
Fe_2O_3	1.3	1.6	1.5	2.3	.43	.10	3.0	1.70	.11	1.30
FeO	1.6	1.4	2.0	.96	.01	.02	5.3	2.60	1.20	1.90
MgO	1.0	1.2	1.4	2.4	.26	.42	1.7	.13	.21	.83
CaO	4.0	4.0	4.3	10.4	52.7	54.9	.19	.92	1.10	1.60
Na_2O	3.5	3.5	3.6	.06	.07	.06	1.0	.01	.01	.05
K_2O	2.8	2.8	2.8	7.8	.12	.02	3.9	1.10	1.30	2.60
TiO_2	.42	.40	.53	.62	.04	.02	.87	.23	.35	.38
P_2O_5	.22	.22	.19	.27	.09	.10	.14	.25	.70	.09
MnO	.10	.09	.07	.10	--	.01	.11	.30	.077	.097
CO_2	.05	.05	--	10.1	40.1	42.6	.05	--	--	--
H_2O^+	--	--		3.3	.01	.02	5.1	.80	1.50	1.20
H_2O^-	--	--						2.30	9.80	19.0
F(%)								.12	.15	.13
Au (ppm)	--	--		7.8				9.3	.08	6.2
As (%)	--	--		.50				.39	3.6	14.5
Hg (ppm)	--	--		19.5				101.8	110.6	112.5
Sb (%)	--	--		.001				.005	.068	.17
Tl (ppm)	--	--		--				80	50	69

1, 2 Granodiorite--unaltered, Hotz and Willden (1964)
3 Granodiorite--unaltered, Silberman and others (1974)
4 Granodiorite--altered, Silberman and others (1974)
5, 6 Preble Formation--limestone, Hotz and Willden (1964)
7 Preble Formation--phyllite, Hotz and Willden (1964)
8, 9, 10 Preble Formation--altered limestone, this study

The variation of total sulfur and total carbon (carbonate and organic) with gold, arsenic, and mercury contents in ores is shown in Table 7. There is no apparent correlation between the gold tenor and the sulfur or carbon contents, suggesting that gold was introduced at a different stage in the alteration-metallization paragenesis. An increase occurred in sulfur introduced as pyrite in the sedimentary rocks during hydrothermal activity. The hydrothermal solutions apparently removed virtually all the carbonate from intensely altered limestone (see CO_2 analyses for altered and unaltered limestone, Table 4). Assuming that these solutions were just as effective in removing carbonate from other rock types as well, the carbon analyses shown for altered rock in Table 7, which are total carbon determinations, represent mainly carbonaceous material rather than carbonate.

TABLE 7. Sulfur and carbon data for selected ore and host-rock samples showing correlation between sulfur, carbon, gold, arsenic, and mercury.

		Gold oz/ton	Arsenic ppm	Mercury ppm	% Sulfur	% Carbon
SOUTH PIT	Carbonaceous (oxidized)	0.023	700	100.9	0.10	0.90
	Carbonaceous	0.006	640	72.6	0.74	1.17
	Carbonaceous	0.05	0.16%	45.8	0.89	1.42
	Carbonaceous	0.029	0.84%	641.8	1.28	0.97
	Carbonaceous	0.006	2.1%	67.9	2.46	1.10
	Siliceous	0.006	380	69.0	1.27	0.46
	Siliceous, arsenical	0.131	12.8%	248.9	6.7	0.23
	Siliceous, arsenical	0.015	5.7%	400.1	6.9	0.34
CENTER PIT	Argillic, arsenical	0.175	6.4%	93.9	4.5	0.20
	Argillic, arsenical	0.090	7.8%	89.3	7.7	0.51
NORTH PIT	Carbonaceous	0.114	0.28%	57.6	1.12	2.29
	Carbonaceous, arsenical	0.073	4.8%	467.8	2.88	1.72
	Carbonaceous limestone (unmineralized)	----	0.012%	0.505	0.44	10.9
	Limestone (unmineralized)	----	0.007	0.82	0.18	7.13
	Carbonaceous shale (unmineralized)	----	0.0480	0.86	0.16	3.55

AGE AND ORIGIN OF THE MINERALIZATION

Age Relationships

Controversy has surrounded discussions concerning the ages of the various disseminated gold deposits. Associations of mineralization with Basin-Range faults and Tertiary volcanic rocks have led several workers to assume a late Tertiary to Quaternary age for all of the disseminated gold occurrences (Joralemon, 1951; Hotz and Willden, 1964; Hardie, 1966). At most of the occurrences, geologic relationships are obscure, allowing only maximum age estimates.

Silberman and others (1974) and Berger and others (1975) interpreted the age of the Getchell deposit to be Cretaceous based on both field and laboratory evidence. Alteration assemblages associated with gold mineralization yielded K-Ar ages of 80 to 96 m.y., and the mineralization is consistently associated with intrusive dikes of the same age. Granodiorite and/or porphyry dikes of similar or equivalent composition occur in all of the mineralized areas along the Getchell fault trend including the Hansen Creek (3 km south of Getchell), Summer Camp Creek (5 km south), Ogee-Pinson mine (10 km south), and Preble prospect (32 km south). A discordant Cretaceous age obtained using K-Ar was found for sericite from a granodiorite dike in the Preble deposit (M. L. Silberman, personal commun.). Oxidation of the dike rocks inhibits using radiometric age dating techniques on most samples. Further investigations of the age relationships are currently being done by B. R. Berger and R. P. Ashley of the U.S. Geological Survey. Fission track studies on apatite from the granodiorite stock in the South Pit indicate a major thermal event during the Miocene. The significance and precision of this event need to be assessed before a better understanding of the relationship of the age to the gold mineralization can be reached.

Character of the Hydrothermal Solutions

Discussion of the geochemistry of the ore-forming solutions is tenuous due to the lack of detailed laboratory studies relevant to the Getchell deposit. The ore mineral suite (Au-As-Hg-Sb) and alteration assemblage (quartz-clay-K-mica) suggest one possible interpretation that the mineralization took place from near-neutral to slightly alkaline, low salinity solutions (Tunell, 1964; Barnes and Czamanske, 1967; Seward, 1973; Learned and others, 1974). Fluid inclusion studies by Nash (1972) suggest that the temperature of formation may have been as high as 200°C, and the salinity of the fluid about 6% (NaCl equivalent by weight). The character of the products of alteration and metallization, taken together with properties of the fluid, suggest that the ore constituents may have been transported as sulfide complexes in solutions of low ionic strength (F. W. Dickson, personal commun.). Fluids having these properties are found in presently active hot springs systems. Joralemon (1951) noted the similarities between present-day hot springs systems and the alteration and mineralization at Getchell. Hausen and Kerr (1967) suggested a similar origin for the Carlin deposit and the stable isotope data of Rye and others (1974) are consistent with a thermal spring origin for the Cortez deposit.

EXPLORATION GUIDES

The Getchell gold deposits contain many of the characteristics that typify the Carlin-type disseminated gold occurrences. They are as follows:

(1) Moderate to low temperature hydrothermal replacement-type deposits;
(2) They are best developed in thin-bedded, carbonaceous, sandy carbonate rocks;
(3) Intrusive igenous rocks of intermediate granitic composition are present as dikes or sills;
(4) Gold predominates over silver in abundance, and the gold is associated with arsenic, mercury, and antimony and to a lesser extent with thallium, fluorine, tungsten, and molybdenum; and
(5) High-angle faults serve as conduits for the ore-forming solutions.

These characteristics are the best exploration guidelines. The geochemical studies at Getchell suggest several other relationships that may be useful in regional exploration programs.

There is a consistent trace-element suite through all of the skarn, stockwork sulfide, and disseminated gold deposits in and around the Osgood Mountains stock. This is the suite Mo-W$\pm$Sn. This fact of occurrence suggests that irrespective of the relative ages of the various types of deposits, the same trace-element suite is being produced by hydrothermal activity, implying that the crustal source of magmas is the same through time or the crust is uniform in composition, giving rise to a consistent trace-element suite through time. This is particularly exemplified if one considers the disseminated gold mineralization to be much younger (e.g., Miocene) than the skarn formation which has been interpreted to be Cretaceous by Silberman and others (1974). An analogous magma to-hydrothermal situation has been inferred by the present author from studies by Shawe (1977) in the Round Mountain, Nevada, 7 1/2-minute quadrangle, where the trace-element suite of Mo-Sn-W is associated with four separate episodes of igenous activity spanning the time interval from approximately 90 m.y. to at least 26 m.y. B.P. Additionally, Joralemon (1978) documents a Carlin-type gold deposit in the area; the fact of this occurrence again underlines the possible importance of the Mo-Sn-W trace-element suite as an exploration guide.

The whole-rock chemistry of the Osgood Mountains stock may provide some clues as to the types of igneous rocks that may be related to the disseminated gold deposits. Neuerburg (1966) found the stock to be higher than normal granitic rocks in its gold content, and showed that the gold content was highest near the eastern contacts with the sedimentary rocks. Berger (1979) reported that the trace-element suite Mo-Sn-W is found associated with leucocratic batholithic rocks in southwestern Montana that have low K_2O/Na_2O ratios and low calcium contents. The data in Table 6 show the Osgood Mountains stock to also be somewhat sodium-rich relative to potassium, further suggesting that the whole-rock chemistry may provide clues to the species of metals associated with specific igneous complexes.

Berger (1976) and Brooks and Berger (1978) investigated two approaches to exploration in the Getchell area. The presence of potassium-rich alteration phases and thallium in the ores suggested that radiometric surveys may be of some value in exploration. Figure 7 shows the results of an aeroradiometric survey over the Getchell mine area. A trend clearly outlines the fault zone,

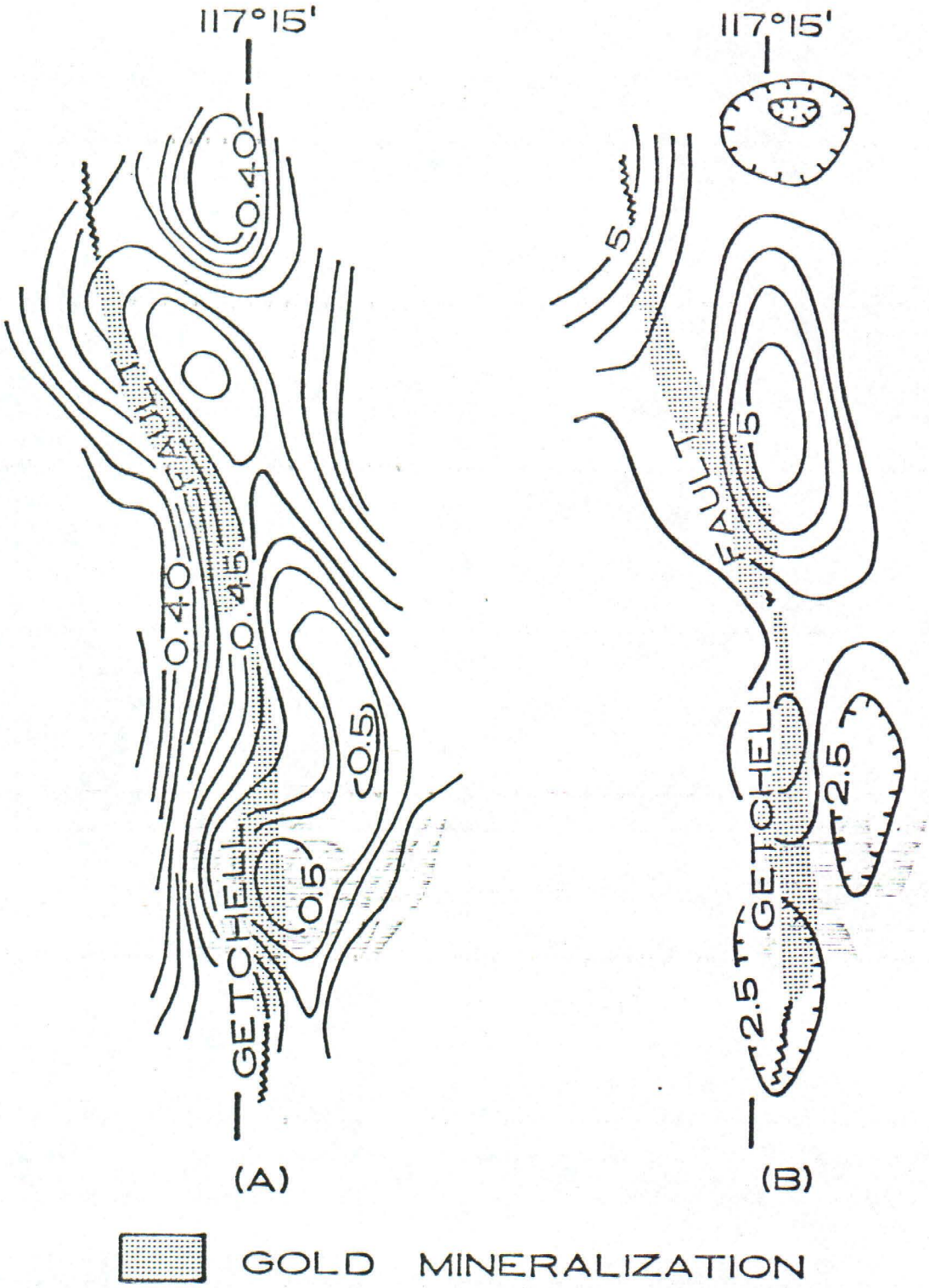

FIGURE 7. Bi^{214}/K^{40} ratios (A) and Tl^{208} radiation (B) over gold mineralization at the Getchell mine. *Data from Berger (1976).*

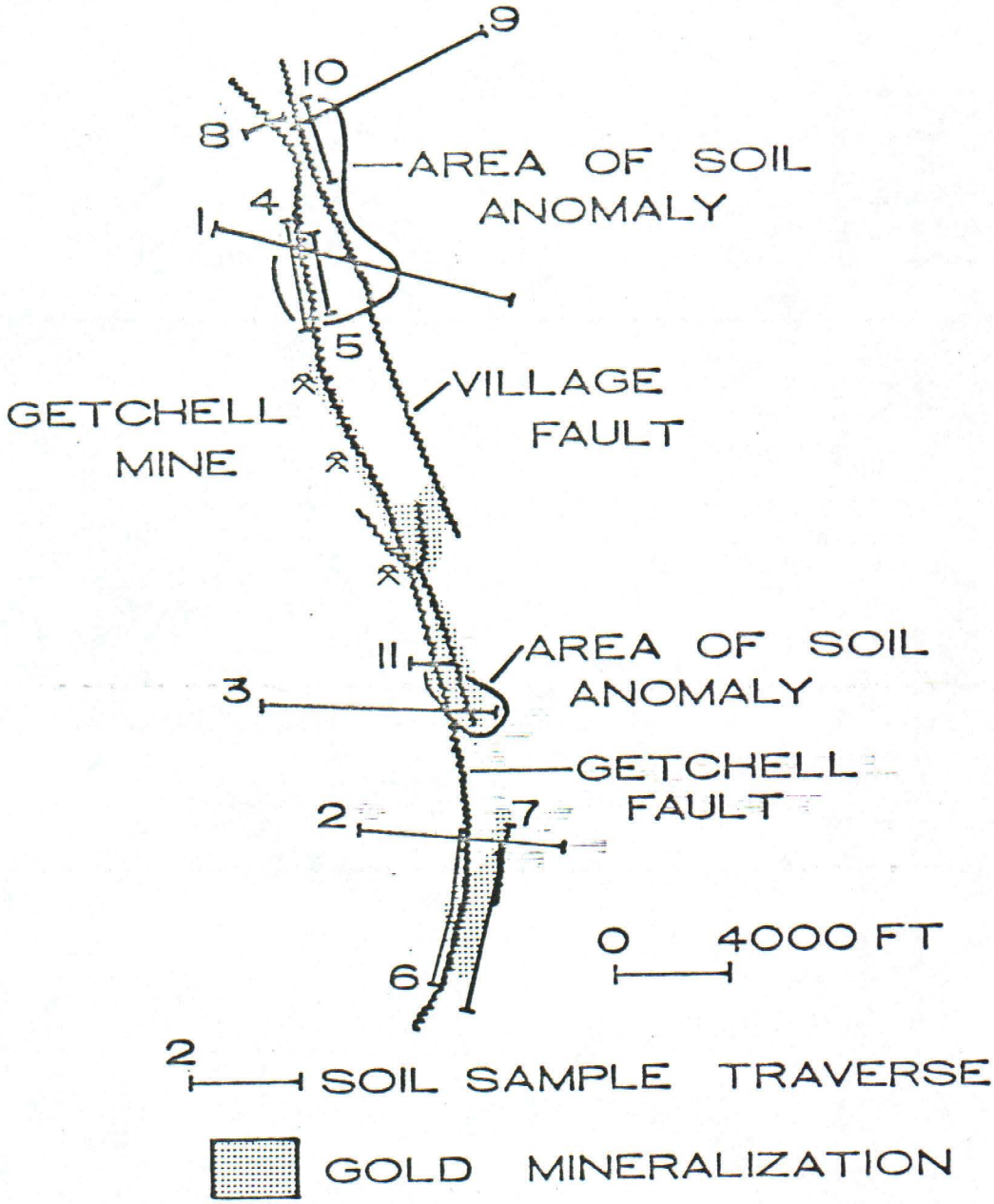

FIGURE 8. Relationship of anomalous concentrations of arsenic in soil to gold mineralization at the Getchell mine. *Data from Brooks and Berger (1978).*

but the locations of ore grade mineralization are not detected. Figure 8 shows a summary of the findings of Brooks and Berger (1978) wherein they found that arsenic and mercury in soils may be anomalous in the vicinity of gold mineralization, but the soil type plays a stronger role in arsenic and mercury entrapment than the presence or absence of arsenic and mercury in mineralized rock beneath the soil. Thus high-organic soils can lead to partial or displaced anomalies.

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