MINERAL DEPOSITS OF THE BULLARD MINERAL DISTRICT, HARCUVAR MOUNTAINS, YAVAPAI COUNTY, ARIZONA

by

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19 page text.

INTRODUCTION

The Bullard mineral district is one of approximately 15 mineral districts in west-central Arizona and southeastern California that are related to large-displacement, regionally low-angle normal faults known as detachment faults (Spencer and Welty, 1986; Roddy and others, 1988). Detachment faulting occurred during regional mid-Tertiary extension in the Basin and Range province and was associated with formation of extensional basins and elevated geothermal gradients (Spencer and Reynolds, 1989a). Mineral deposits related to detachment faults formed within this tectonic setting and were the result of hydrothermal ascent of basin brines along detachment faults (Wilkins and others, 1986). One of these districts includes the Copperstone mine, which has yielded several hundred thousand ounces of gold (Spencer and others, 1988).

This article briefly describes the mineral deposits of the Bullard district and summarizes gold-assay data from numerous surface samples and from two drilling programs. Geologic similarities between the Bullard district and Copperstone deposit suggest that significant gold deposits could be present in the subsurface in the Bullard district.

GEOLOGIC SETTING

The Harcuvar metamorphic core complex of west-central Arizona (Rehrig and Reynolds, 1980) includes the Bullard mineral district (Fig. 1). Metamorphic core complexes typically consist of two rock assemblages separated by a detachment fault that has accommodated tens of kilometers of normal displacement. Rocks below detachment faults include commonly mylonitic plutonic and metamorphic rocks, and those above the faults generally include Tertiary volcanic and sedimentary rocks and the basement that they were deposited on. Rocks below detachment faults, referred to as "lower-plate rocks", are typically greenish due to chlorite-epidote alteration near the detachment fault. Rocks above detachment faults, referred to as "upper-plate rocks", are commonly reddish due to the near-surface, oxidizing conditions they experienced before and during detachment faulting.

The Buckskin-Rawhide-Bullard detachment fault separates upper- and lower-plate rocks in the Harcuvar metamorphic core complex (Reynolds and Spencer, 1985; Spencer and Reynolds, 1989b). This detachment fault has a regionally subhorizontal, undulating form and dips to the northeast beneath Date Creek basin. The corrugated form of the fault is reflected by the topography of the ranges. Resistant lower plate rocks form northeast-trending, antiformal ridges that underlie the highest parts of the ranges. The Harcuvar Mountains are a large antiformal corrugation of the detachment fault. Upper-plate rocks are exposed along the flanks of the Harcuvar Mountains and are separated from the lower-plate rocks by the outward-dipping detachment fault.

GEOLOGY OF THE BULLARD MINERAL DISTRICT

The Bullard fault in the Bullard mineral district is an exposed segment of the regional detachment fault associated with the Harcuvar metamorphic core complex (Reynolds and Spencer, 1985; Figs. 1, 2). Within the Bullard mineral district, the Bullard fault dips moderately to the southeast and has a fairly linear trace. To the northeast, the fault decreases in dip as it curves abruptly around the eastern end of the Harcuvar Mountains (Reynolds and Spencer, 1984). Top-to-the-northeast displacement on the detachment fault system, parallel to the crest of the range, indicates that movement on the Bullard fault in the Bullard district was primarily horizontal, with upper-plate rocks to the southeast moving northeast relative to lower-plate rocks to the northwest.

Upper-plate rocks in the district consist primarily in Miocene mafic- to intermediate-composition volcanic rocks and locally interbedded sandstone. These rocks rest on a sequence of Miocene conglomerate, sedimentary breccia, and tuff. The entire sequence dips steeply to the south, is broken by a few small faults, and strikes westward into the Bullard fault (Figs. 2, 3, 4; Table 1; Reynolds and Spencer, 1984, 1985).

MINERALIZATION AND ALTERATION

The Bullard mineral district, as defined by Keith and others (1983), includes two areas of mineralization: The Bullard Peak area, and the Nellie Meda mine area 7 to 8 miles to the east of the Bullard Peak area. These two areas are here separated into two mineral districts because the genesis of the deposits in each area appears to have been different and the deposits are not apparently related. The revised Bullard district includes the mineral deposits of the Bullard Peak area, and the Nellie Meda district (new district) includes the Nellie Meda mine area.

Total recorded production from the Bullard district consists of 614,000 pounds of copper, 3300 ounces of gold, and 5900 ounces of silver. Over 90% of this production was from the Bullard mine, and occurred between 1933 and 1956. Production from the Nellie Meda district consists primarily of precious metals (approximately 10 pounds of copper, 330 ounces of gold, and 60 ounces of silver). The ratio of Au + Ag to Cu production from the two districts is much different, and supports separation the two areas into two mineral districts.

Roddy and others (1988) studied the mineral deposits and alteration of the Bullard mineral district and of the strike ridge of tilted tuffs east of the Bullard district. Their study revealed that the mafic volcanic flows that host most of the mineral deposits in the Bullard district are highly altered by regional K- (potassium) metasomatism. K-metasomatism converted these rocks into a holocrystalline mixture of K-feldspar, hematite, calcite, quartz, and epidote. Primary plagioclase is replaced by K-feldspar except near mineral deposits where secondary K-feldspar is itself replaced by chlorite and calcite. Metasomatized mafic flows contain 8 to 10 weight percent K_2O and less than 0.4 weight percent Na_2O (Roddy and others, 1988). The ratio of K_2O to Na_2O is thus greater than 20, which is an indication of potassium metasomatism (Brooks, 1988). K-metasomatism also strongly affected the rhyolitic tuffs exposed east of the Bullard district.

Mineral deposits in the Bullard district consist of veins and fracture fillings along shear zones. The Bullard mine deposit is within a vein up to two meters thick within steeply dipping mafic volcanic rocks. Similar deposits of smaller size are scattered across the Bullard district. Common ore minerals include chrysocolla and brochantite with less abundant malachite and chalcopyrite. Native gold is associated with iron oxides. Gangue minerals include abundant earthy and specular hematite, pyrite, quartz, and calcite with minor barite and fluorite (Roddy and others, 1988). Analysis of fluid inclusions in quartz and calcite indicates that mineralizing solutions were brines with 13 to 17 weight-percent equivalent NaCl. Fluid-inclusion homogenization temperatures varied from 230 to 310 °C, which indicate minimum temperatures for mineralizing fluids (Roddy and others, 1988). Oxygen-isotope analyses support the interpretation that the mineralizing fluids were basin brines.

Fluid-inclusion characteristics, mineralogy, and structural setting indicate that the Bullard district is a member of a group of detachment-fault related mineral districts in west-central Arizona. This group of districts all formed during Miocene detachment faulting and associated ascent of basin brines along active detachment faults (Wilkins and Heidrick, 1982; Wilkins and others, 1986; Spencer and Welty, 1986, 1989). Mineralization in the Bullard district overprinted regional K-metasomatism, but the two events are probably related. Both occurred during detachment faulting and metals that were deposited during mineralization were possibly liberated from rocks by K-metasomatism (Roddy and others, 1988).

Gold deposits

Gold exploration in the Bullard district in the 1980's by eight different companies has outlined several areas containing elevated concentrations of gold (Figs. 3, 5). These areas have been extensively sampled and some have been drilled. Results of gold assays of surface samples are summarized in figure 6. Results of gold assays of drill samples are summarized in tables 2, 3, and 4, and drill holes are located in figures 7, 8, and 9.

In the North Hill area east of Bullard Peak, a north-trending, steeply dipping mineralized shear zone is discontinuously exposed for more than 2000 feet along strike, and several other smaller mineralized shear zones are present in the area (Figs. 3, 7). Thirty-one surface samples from mineralized shear zones and small quartz stockworks were assayed during an exploration program by Cominco American Resources, Inc. (Fig. 6; Telford, 1990). Twenty-two of the samples contained an average gold concentration of 0.226 ounces per ton. One sample from a stockwork contained 0.812 ounces per ton. Over 12,000 feet of reverse-circulation drilling by Cominco in the North Hill area revealed several subsurface gold anomalies (Table 2). The northern part of the north-trending mineralized shear zone was penetrated by five inclined drill holes (B-14 through B-18). Assays from these drill holes indicate that anomalous gold concentrations along the shear zone extend downward for at least 200 feet (Fig. 8, Table 2).

Numerous mineralized shear zones of various orientations are present south and west of Bullard Peak (Figs. 3, 5). Assays of surface and subsurface samples from the John Moore area indicate that gold in anomalous concentrations is restricted to shear zones and is not generally disseminated in host rocks (Figs. 6, 9; Table 3). Smaller and fewer gold anomalies have been recognized in the nearby Stage House, Unity, and Accident Hill areas (Figs. 3, 5, 6, 9; Tables 3, 4).

The Bullard detachment fault is exposed in two areas north and west of Bullard Peak. Thirty-two gold assays from surface samples of lower- and upper-plate rocks adjacent to the fault in the Unity North area were all less than the approximately 0.006 ounce-per-ton assay detection limit. Anomalous gold was detected in both lower- and upper-plate samples from the Broken Ladder area (Figs. 5, 9; Table 4). Assays of samples from four drill holes in the Broken Ladder area indicate that anomalous gold (0.006 to 0.010 ounces per ton) is largely restricted to lower-plate rocks (Fig. 5, Table 4).

CONCLUSION

The mineralogic and structural similarities between the Bullard and Copperstone districts suggest that potential exists for a major gold deposit in the area of the Bullard district. Gold mineralization at Copperstone occurred within Tertiary sedimentary breccias that were highly porous and permeable at the time of mineralization. Virtually identical breccias are present north and northeast of Bullard Peak, but have not been drilled. Although these breccias are not obviously mineralized in outcrop, similarity to host rocks at Copperstone suggests that significant gold mineralization could have affected these rocks. If significant gold is present, it is probably in the subsurface and may be directly above the contact with the Bullard detachment fault (Fig. 4).

Geologic mapping and gold assays indicate that the Bullard district is fairly typical of mineral districts related to detachment faults in nearby areas. The presence of several areas of anomalous gold, distributed over much of the district, indicates that mineralizing fluids were gold bearing and affected a large area. These features, past production, and the presence of untested targets for gold exploration (the sedimentary breccias) suggest that the Bullard district will continue to be the target of gold exploration.

ACKNOWLEDGMENTS

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FIGURE CAPTIONS

Figure 1. Location map of the Bullard mineral district, which is at the center of the area labeled "Figure 2".

Figure 2. Simplified geologic map of the southeastern Harcuvar Mountains and Bullard mineral district.

Figure 3. Geologic map of the Bullard Peak area showing major mineralized areas. Geology from Reynolds and Spencer (1984). See Table 1 for map legend.

Figure 4. Cross section of the Bullard Peak area. See figure 3 for location.

Figure 5. Geologic map of the area west of Bullard Peak showing major mineralized areas. Geology from Reynolds and Spencer (1984). See Table 1 for map legend.

Figure 6. Histograms of gold assays from surface samples. Analyses are from reports by eight different companies and were done by both fire assay and atomic absorption methods. See figures 3 and 5 for areas represented.

Figure 7. Map of the North Hill mineralized area showing mineralized shear zones and drill hole locations. Drill-hole locations from Telford (1990). Drill-hole sample assays are given in table 2.

Figure 8. (A) Map of vein system and drill hole and mine locations in the northwestern part of the North Hill mineralized area. (B) Cross sections through vein in areas of drill holes.

Figure 9. Drill-hole locations from the western part of the Bullard mineral district. Drill-hole sample assays are given in tables 3 and 4. Data from Freeport (1987) and Telford (1990).

TABLE CAPTIONS

Table 1. Map units and map symbols in figures 3, 4, and 5.

Table 2. Cominco drill-hole data from the North Hill mineralized area. See figure 7 for locations of drill holes. Data from Telford (1990).

Table 3. Cominco drill-hole data from the John Moore and Stage House mineralized areas. See figure 9 for locations of drill holes. Data from Telford (1990).

Table 4. Drill-hole data from the Broken Ladder, Accident Hill, and Unity mineralized areas. See figure 9 for locations of drill holes. Data from Freeport (1987).

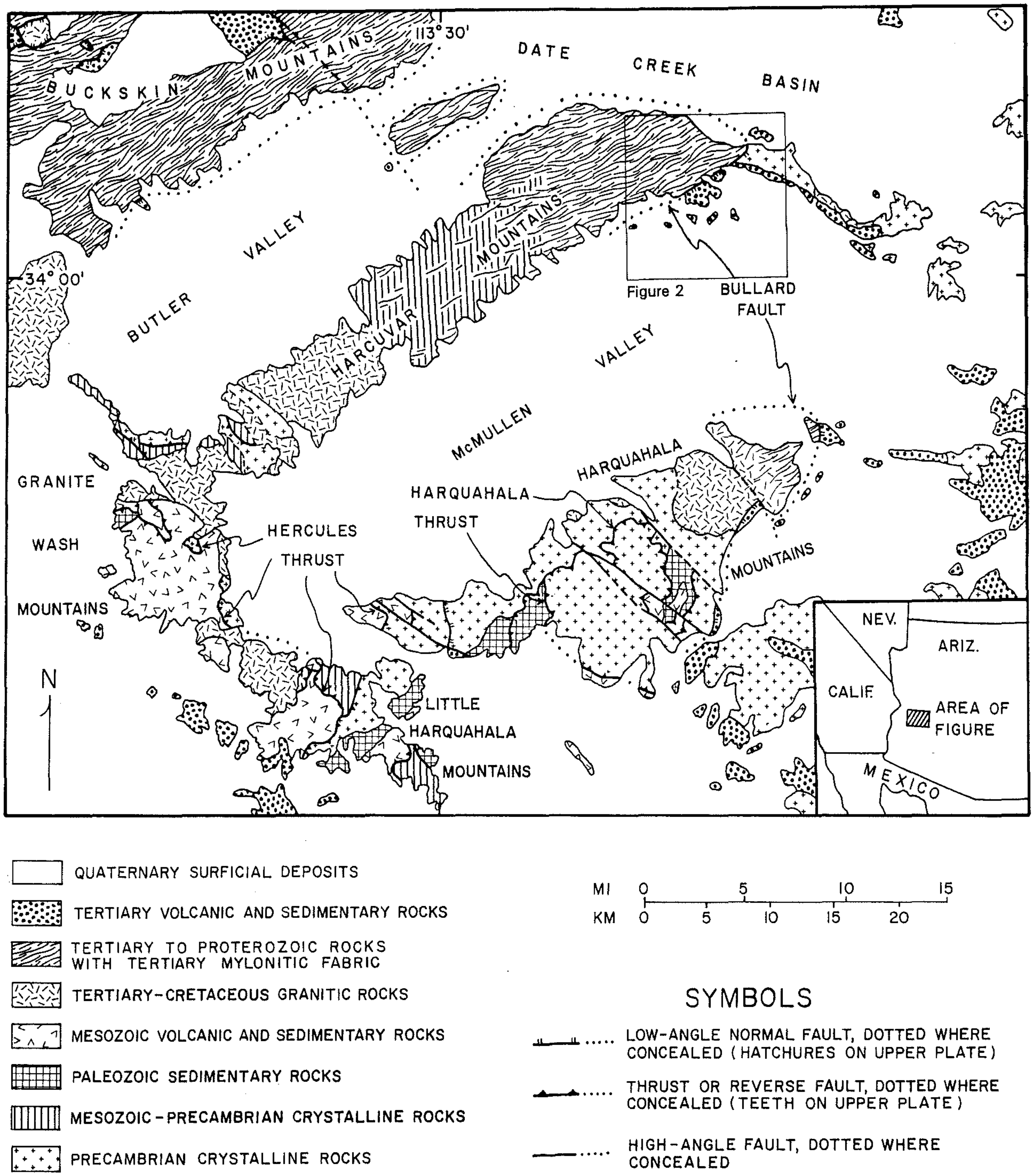
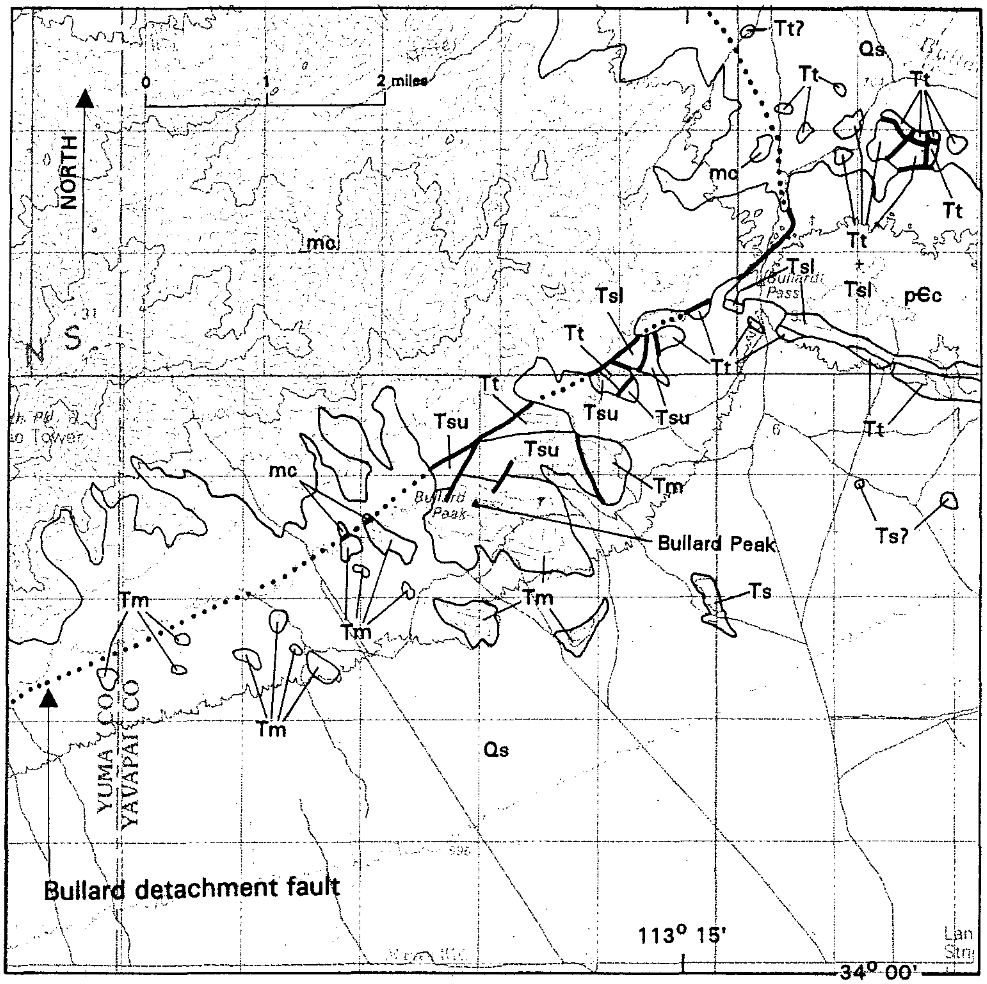

BUCKSKIN MOUNTAINS
113°30'
DATE CREEK BASIN
34°00'
BUTLER VALLEY
HARCUVAR MOUNTAINS
Figure 2
BULLARD FAULT
McMULLEN VALLEY
GRANITE WASH MOUNTAINS
HERCULES THRUST
HARQUAHALA THRUST
HARQUAHALA MOUNTAINS
LITTLE HARQUAHALA MOUNTAINS
N
NEV.
ARIZ.
CALIF.
AREA OF FIGURE
MEXICO
QUATERNARY SURFICIAL DEPOSITS
TERTIARY VOLCANIC AND SEDIMENTARY ROCKS
TERTIARY TO PROTEROZOIC ROCKS WITH TERTIARY MYLONITIC FABRIC
TERTIARY-CRETACEOUS GRANITIC ROCKS
MESOZOIC VOLCANIC AND SEDIMENTARY ROCKS
PALEOZOIC SEDIMENTARY ROCKS
MESOZOIC-PRECAMBRIAN CRYSTALLINE ROCKS
PRECAMBRIAN CRYSTALLINE ROCKS
MI 0 5 10 15
KM 0 5 10 15 20
SYMBOLS
LOW-ANGLE NORMAL FAULT, DOTTED WHERE CONCEALED (HATCHURES ON UPPER PLATE)
THRUST OR REVERSE FAULT, DOTTED WHERE CONCEALED (TEETH ON UPPER PLATE)
HIGH-ANGLE FAULT, DOTTED WHERE CONCEALED

Figure 1



Qs	Surficial deposits (Quaternary)
Tm	Mafic volcanic rocks (Miocene)
Tsu	Sandstone, conglomerate, and sedimentary breccia (Miocene)
Tt	Tuff (Oligocene to Miocene)
Tsl	Sandstone and conglomerate (Oligocene to Miocene)
XYc	Crystalline rocks, undivided (early to middle Proterozoic)
mc	Mylonitic crystalline rocks, undivided (early Proterozoic to Tertiary protolith with Tertiary mylonitic fabric)

Figure 2

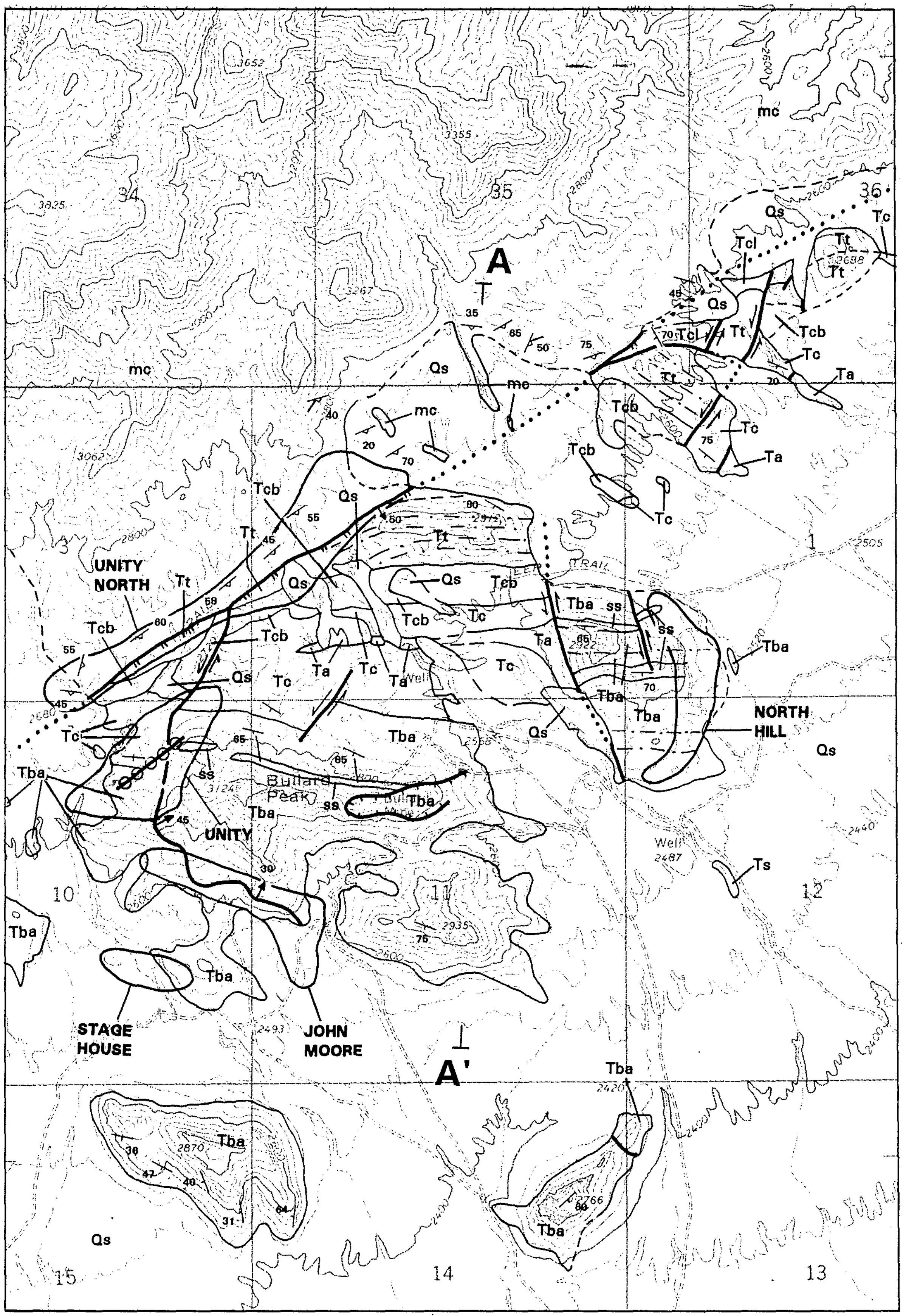

A
A'
UNITY NORTH
UNITY
STAGE HOUSE
JOHN MOORE
NORTH HILL
Bullard Peak
TRAIL
mc
Qs
Tcl
Tt
Tc
Tcb
Ta
Tba
ss
Ts
34
35
36
1
10
11
12
15
14
13

Figure 3

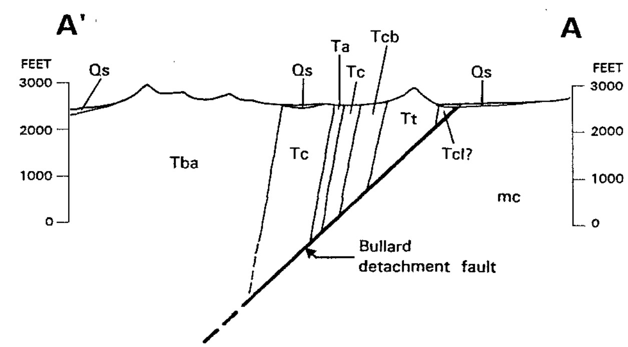

A'
A
FEET
3000
2000
1000
0
FEET
3000
2000
1000
0
Qs
Qs
Qs
Ta
Tc
Tcb
Tt
Tcl?
Tba
Tc
mc
Bullard
detachment fault

Figure 4

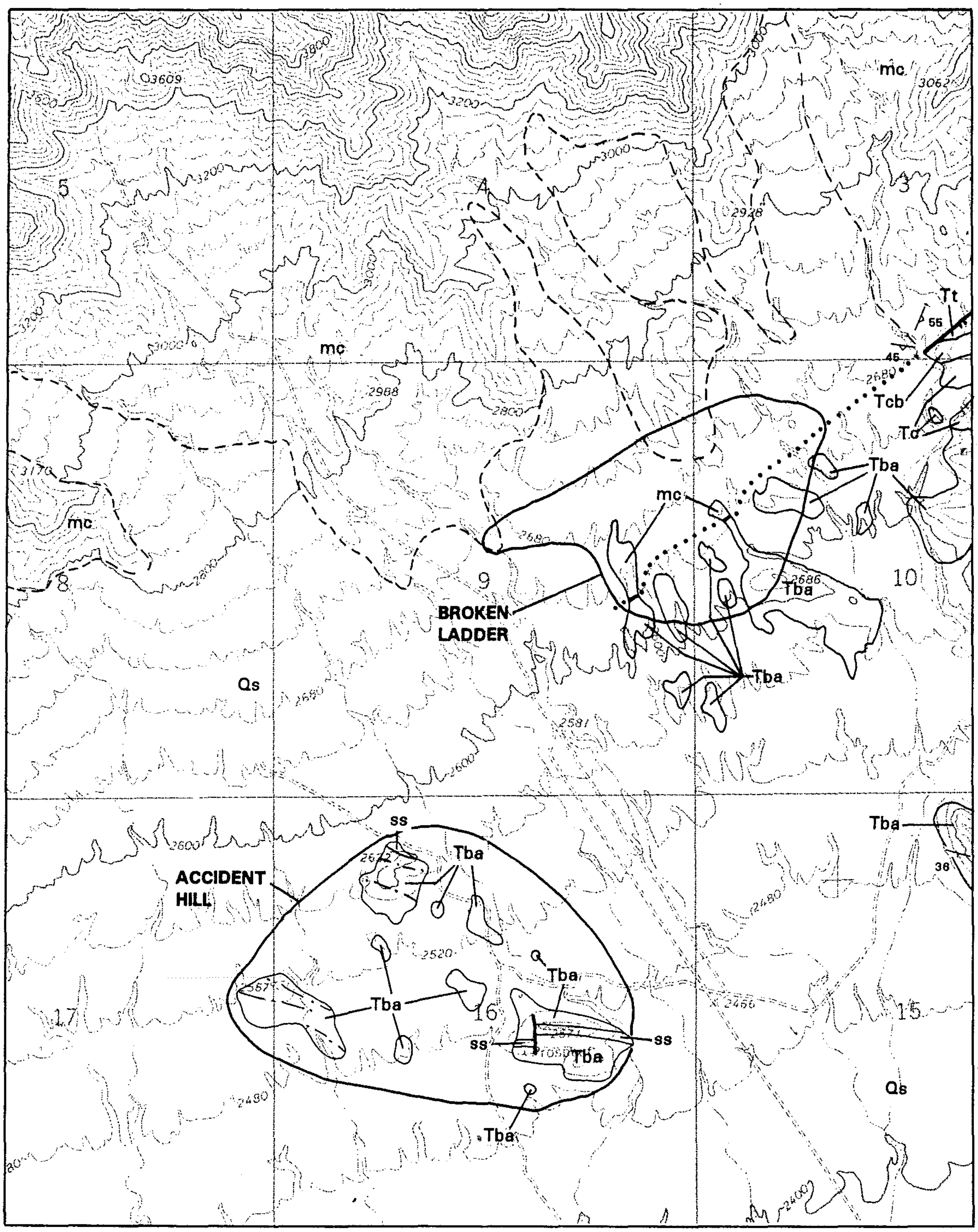
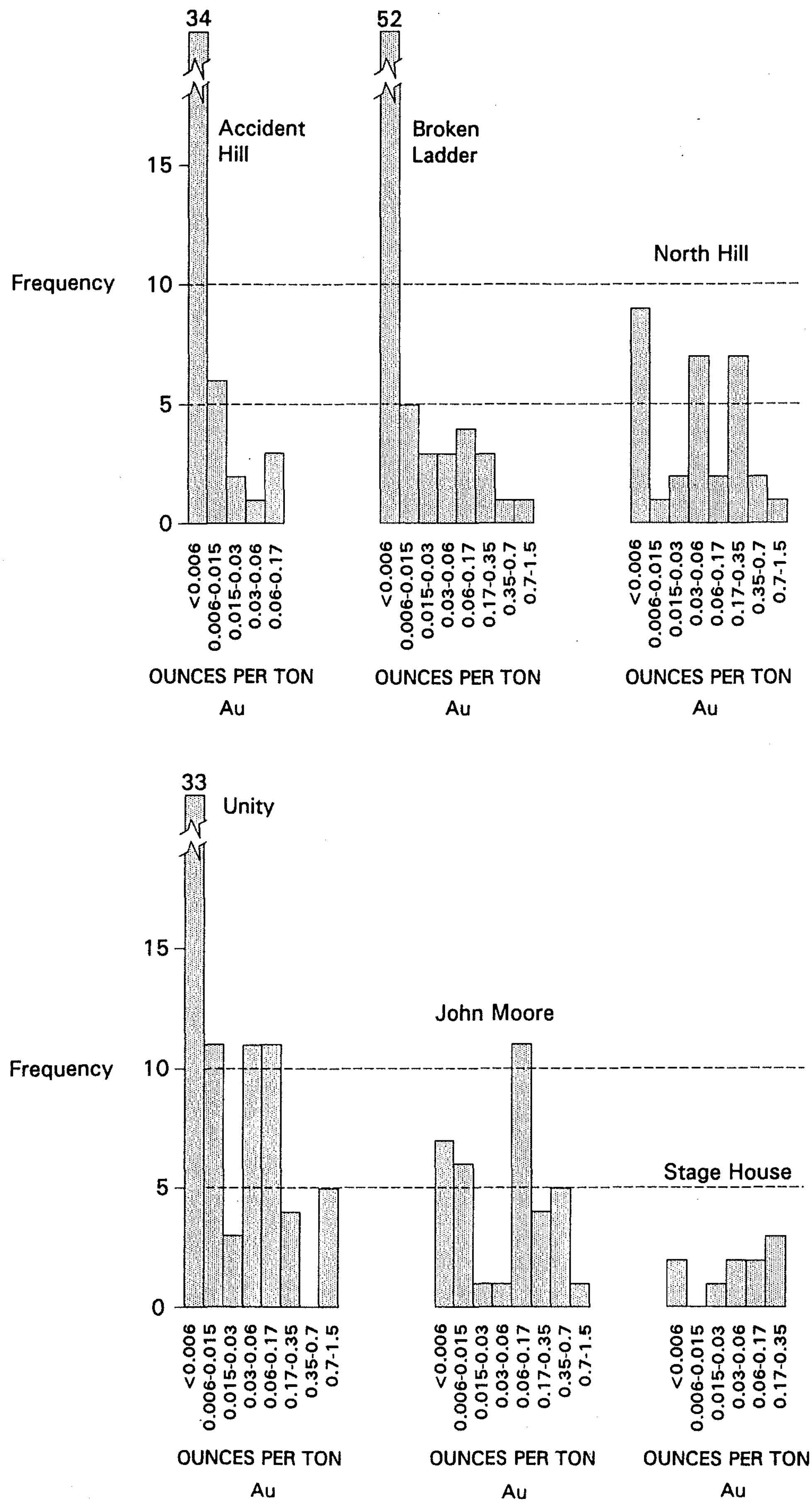
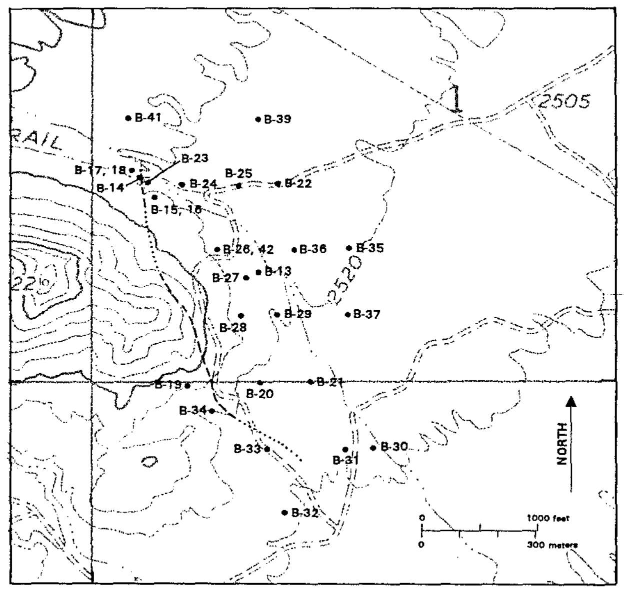

mc
3609
3062
5
3
4
2928
Tt
55
46
Tcb
Tc
mc
2988
Tba
3170
mc
mc
BROKEN
LADDER
9
10
8
2686
Tba
Tba
Qs
2581
Tba
ss
Tba
36
ACCIDENT
HILL
2520
Tba
Tba
17
16
15
ss
ss
Tba
Qs
Tba

Figure 5

Figure 6


34
52
Accident Hill
Broken Ladder
North Hill
Frequency
15
10
5
0
<0.006
0.006-0.015
0.015-0.03
0.03-0.06
0.06-0.17
0.17-0.35
0.35-0.7
0.7-1.5
OUNCES PER TON
Au
33
Unity
John Moore
Stage House



B-41 Drill hole
Mineralized shear zone, (dotted where concealed)

Figure 7

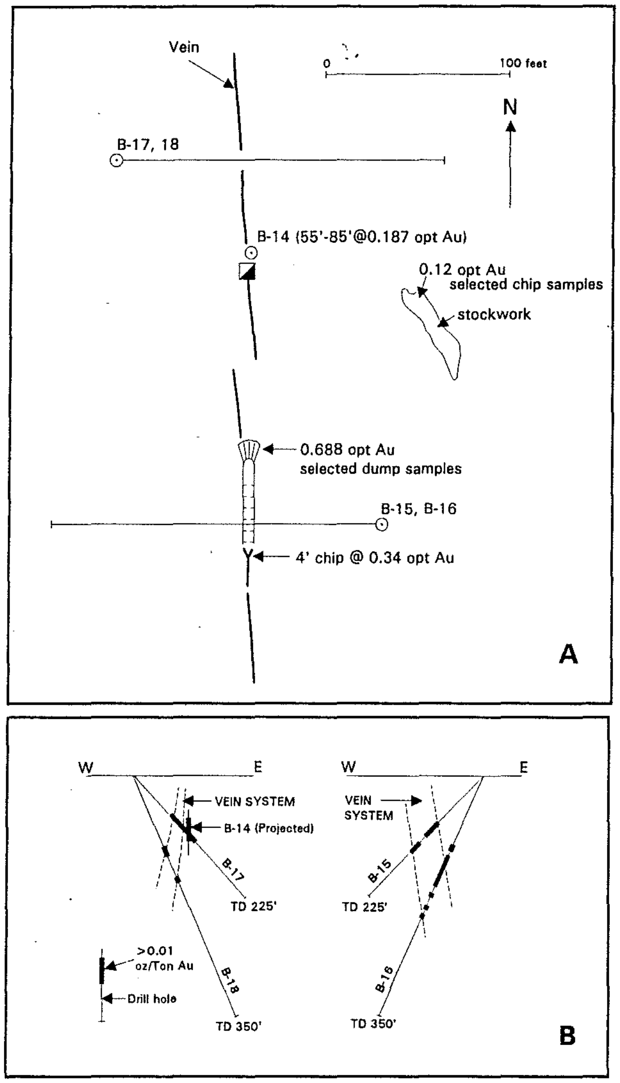

Vein
0
100 feet
N
B-17, 18
B-14 (55'-85'@0.187 opt Au)
0.12 opt Au
selected chip samples
stockwork
0.688 opt Au
selected dump samples
B-15, B-16
4' chip @ 0.34 opt Au
A
W
E
VEIN SYSTEM
B-14 (Projected)
B-17
TD 225'
>0.01
oz/Ton Au
Drill hole
B-18
TD 350'
W
E
VEIN
SYSTEM
B-15
TD 225'
B-16
TD 350'
B

Figure 8

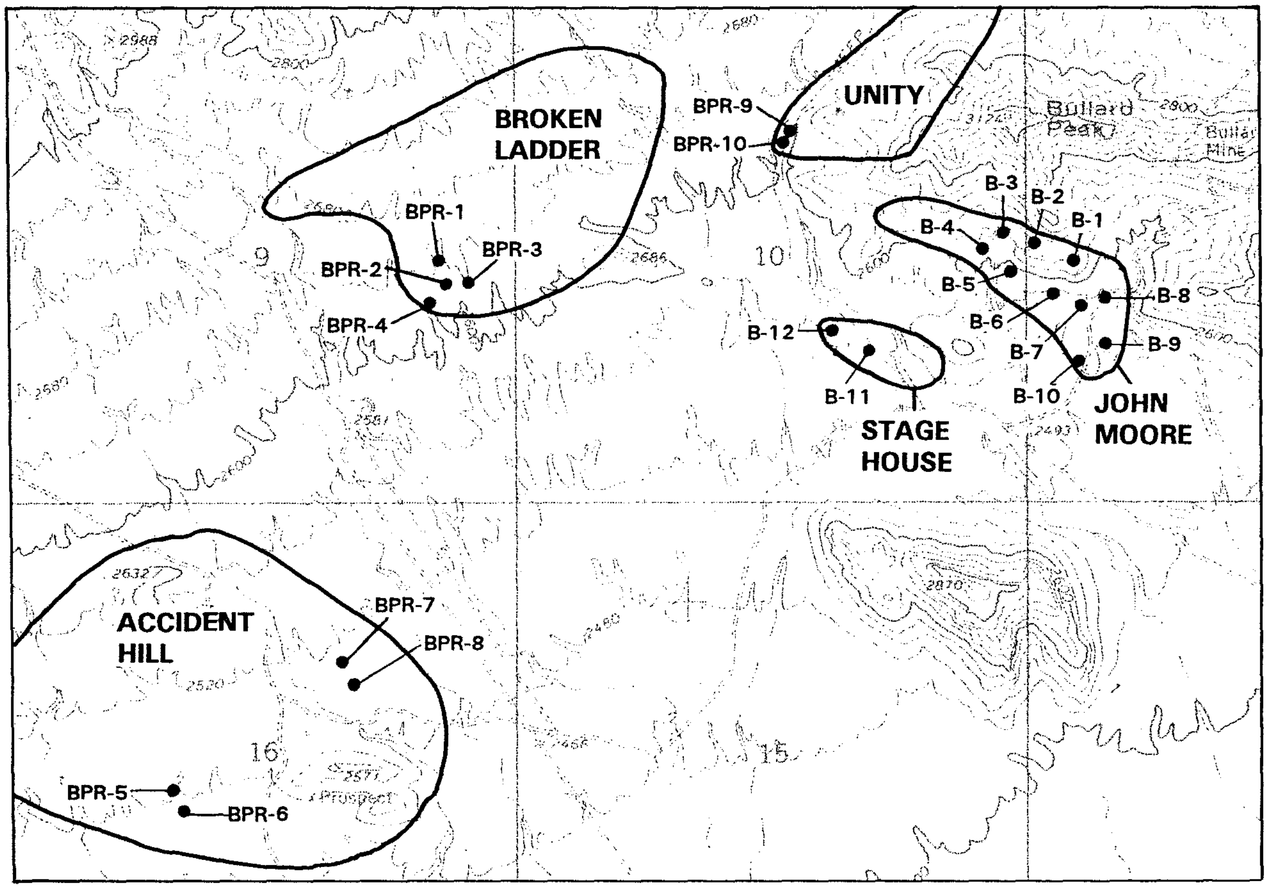
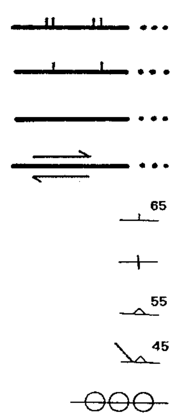

BROKEN
LADDER
UNITY
Bullard
Peak
BPR-1
BPR-2
BPR-3
BPR-4
BPR-9
BPR-10
B-1
B-2
B-3
B-4
B-5
B-6
B-7
B-8
B-9
B-10
B-11
B-12
STAGE
HOUSE
JOHN
MOORE
ACCIDENT
HILL
BPR-7
BPR-8
BPR-5
BPR-6
9
10
15
16
Prospect

Figure 9

Qa	Surficial deposits (Quaternary)
Ts	Sandstone, siltstone, and conglomerate (lower Miocene)
Tba	Intermediate to mafic composition volcanic rocks (lower Miocene)
ss	Sandstone within map unit Tba (lower Miocene)
Ta	Andesite interbedded or intruded into map unit Tc (lower Miocene to upper Oligocene)
Tc	Upper conglomerate (lower Miocene to upper Oligocene)
Tcb	Conglomerate and sedimentary breccia (lower Miocene to upper Oligocene)
Tt	Tuff (lower Miocene to upper Oligocene)
Tcl	Conglomerate and conglomeratic sandstone (lower Miocene to upper Oligocene)
mc	Mylonitic crystalline rocks (early Proterozoic to Tertiary protolith with Tertiary mylonitic fabric)



Bullard detachment fault, double ticks on hanging wall block

Low-angle normal fault, single ticks on hanging wall block

Moderate to high-angle fault

Strike-slip fault

Attitude of bedding

Strike of vertical bedding

Attitude of mylonitic foliation

Attitude of mylonitic foliation and trend of lineation

Quartz vein

Table 1

TABLE 2

COMINCO DRILL-HOLE DATA, NORTH HILL AREA

DRILL HOLE	TOTAL DEPTH (feet)	INCLINATION (degrees)	AZIMUTH (degrees)	DRILL INTERCEPTS (feet)	Au (opt)
B-13	200	90	---	---	<0.001
B-14	95	90	---	55-85	0.187 av
B-15	225	45	270	85-110	0.197 av
				125-140	0.029 av
B-16	350	65	270	100-105	0.038
				115-130	0.052 av
				130-160	0.018 av
				170-175	0.015
				190-195	0.049
				200-205	0.247
B-17	225	45	090	75-100	0.078 av
				100-120	0.023 av
B-18	350	65	090	105-115	0.051 av
				150-155	0.012
B-19	735	60	090	30-35	0.003
				65-70	0.003
				165-205	0.001-0.032 (0.013 av)
				215-250	0.001-0.021 (0.005 av)
				545-550	0.024
				575-590	0.003-0.019 (0.013 av)
B-20	550	60	270	130-155	0.009-0.024 (0.016 av)
B-21	600	60	270	45-55	0.002
				165-170	0.003
				175-185	0.008
				510-515	0.010
				535-540	0.025
				575-580	0.002
B-22	500	60	090	---	<0.001
B-23	750	60	090	15-35	0.070-0.300 (0.123 av)
				220-225	0.021
B-24	400	90	---	---	<0.001
B-25	400	60	090	---	<0.001
B-26	400	60	090	---	<0.001
B-27	400	60	090	---	<0.001
B-28	400	60	090	---	<0.001
B-29	400	60	090	45-50	0.008
				60-100	0.0001-0.009 (0.004 av)
				130-135	0.003
				205-210	0.004
				215-220	0.002
B-30	400	60	090	---	<0.001
B-31	400	60	270	---	<0.001
B-32	400	60	090	300-305	0.005
B-33	500	60	090	105-110	0.031
B-34	420	60	090	55-60	0.045
				350-355	0.012
B-35	400	60	090	5-10	0.002
B-36	400	60	090	---	<0.001
B-37	400	60	090	85-110	0.001-0.080 (0.033 av)
				120-125	0.019
				300-305	0.090
B-39	420	60	090	10-15	0.016
				45-90	0.003-0.020 (0.011 av)
				105-110	0.008
				135-185	0.001-0.030 (0.010 av)
B-41	400	60	090	335-350	0.001-0.004
B-42	800	90	---	---	<0.001

TABLE 3

COMINCO DRILL-HOLE DATA, JOHN MOORE AND STAGE HOUSE AREAS

DRILL HOLE	TOTAL DEPTH (feet)	DRILL INTERCEPTS (feet)	Au (ppb)	Au (opt)
John Moore area				
B-1	300	255-260	42	0.0012
B-2	300	65-70	280	0.0081
B-3	250	40-45	6965	0.202
		45-50	585	0.017
B-4	250	---	≤14	≤0.00041
B-5	250	---	≤8	≤0.00023
B-6	250	---	≤6	≤0.00017
B-7	250	---	≤15	≤0.00044
B-8	155	30-35	250	0.0073
		35-60	79	0.0023
B-9	250	135-140	256	0.0074
B-10	250	35-40	290	0.0084
Stage House area				
B-11	250	45-50	775	0.022
B-12	250	---	≤9	≤0.00026

TABLE 4

FREEPORT MCMORAN DRILL-HOLE DATA, BROKEN LADDER, ACCIDENT HILL, AND UNITY AREAS

DRILL HOLE	TOTAL DEPTH (feet)	INCLINATION (degrees)	AZIMUTH (degrees)	DRILL INTERCEPTS (feet)	Au (opt)
Broken Ladder area					
BPR-1	300	60	345	0-15	0.0057
				65-70	0.009
				150-155	0.007
BPR-2	305	60	355	50-55	0.009
				60-65	0.007
				75-85	0.0055
				90-95	0.008
				105-120	0.0087
BPR-3	305	60	340	140-145	0.007
BPR-4	400	60	345	20-25	0.006
Accident hill area					
BPR-5	200	60	335	---	<0.005
BPR-6	300	60	330	---	<0.005
BPR-7	200	60	320	---	<0.005
BPR-8	385	90	---	---	<0.005
Unity area					
BPR-9	300	60	045	---	<0.005
BPR-10	305	60	010	45-50	0.089