BIOGEOCHEMISTRY

Discovery Using Metal Concentrations in Plants

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Bald Mountain, White Pine County, Nevada

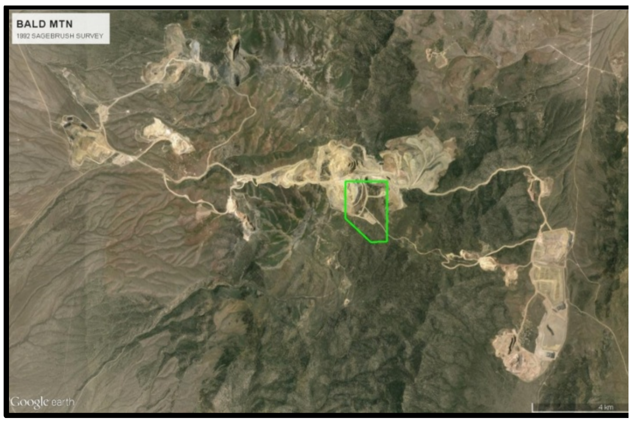
Fig 1. Location map of Bald Mountain, White Pine County Nevada, relative to other gold mines in Northern Nevada.

Introduction

Placer Dome U.S., Inc. began mining operations for gold in the Bald Mountain Mining district in 1983. The ores are known for high concentrations of arsenic and antimony with elevated concentrations of bismuth, copper, molybdenum, tin, mercury, tellurium, and thallium. Base metal character (Bi, Mo, Te, Sn) is attributable to the influence of intrusives, evidenced by Late Jurassic porphyry dikes and other magmatic rocks. Several types of mineral deposits have been mined in the district since 1916: 1) W-Mo-Zn skarn deposits, 2) porphyry-related vein and disseminated Au-Ag deposits in intrusive igneous rocks, 3) Au-Ag replacement and fissure-hosted deposits in limestone (dolomite) and shale, and 4) placer gold deposits. The chemical character of the sedimentary hosted gold deposits are considered to be “Carlin-type”, with generally elevated concentrations of As, Sb, Hg, Tl, +/-Ag.

In March, 1992 Placer Dome contracted MEG to collect and prepare sagebrush samples from Sage Flats. At the time of the survey, the area was relatively undisturbed. A total of 228 samples were collected through a cover of snow ranging up to three feet thick. Since the crown material comprises the preferred tissue, sample tissue was available at almost every grid station.

In February, 2003, the data was revisited and a new interpretation was prepared for Placer Dome. This presentation summarizes the 2003 report, with additional information about the district (GSN Symposium Proceedings, 1996 and 2010), and with imagery from Google Earth. Current mine development (revealed in the imagery) shows an open pit now covering the northwest quarter of the original biogeochemical survey area. This is an anomalous area of biogeochemical gold and pathfinders. Yet much larger anomalies lie farther to the east of the growing mine pit. The Sage Flats biogeochemical survey area and the Sage Flats Extension deposit are separated by the Dynasty Fault, which is steeply dipping (70^{o}) to the east-southeast and presumably with an offset of several hundred feet, putting ore deeper than economically recoverable at this time. Mining is currently constrained by depth and metallurgy, since the deeper ore is sulfide.



Figs 2 &3. The 1992 biogeochemical survey area located within the Bald Mountain District (left) showing current (2016) mine development, and the same area dated August, 1994 (right).

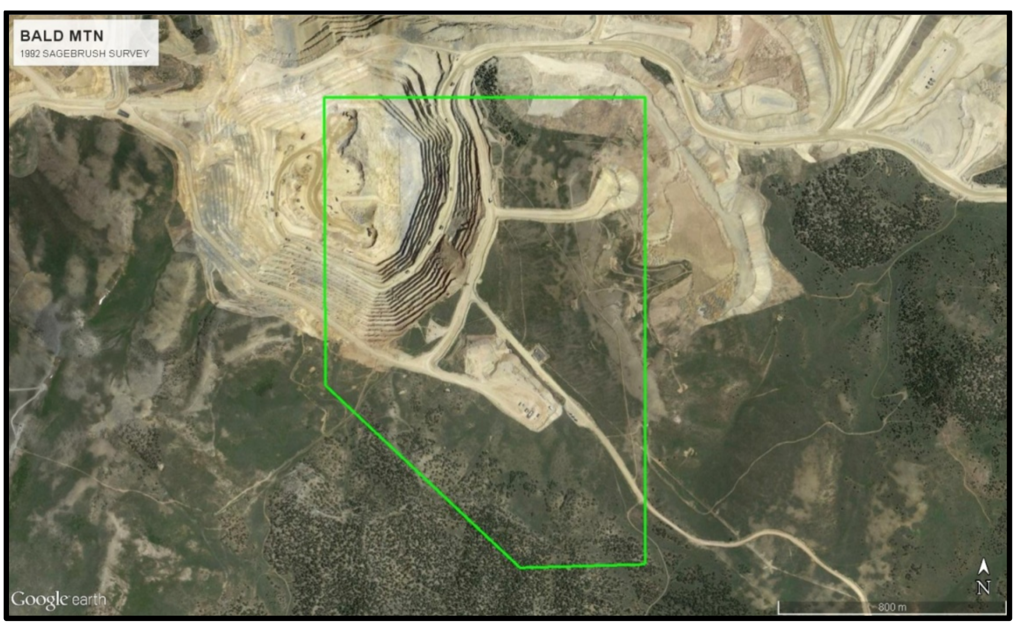


Fig 4. The 1992 biogeochemical survey area superimposed on a 2016 satellite true color image, showing current mine development covering the northwest corner, and which is an area of anomalous biogeochemistry.

Geology

A conformable Paleozoic stratum composed of limestone, dolomite, shale, quartzite and siltstone is exposed in the Bald Mountain area. These have been intruded by a Late Jurassic quartz monzonite stock and northwest-trending quartz monzonite porphyry dikes. The dike swarm is about 6.5 km by 16 km which has produced a mineralized area of 60 km^2.

Gold orebodies include fault-controlled ore shoots and disseminated stock work ores of both Paleozoic sedimentary and Late Jurassic intrusive rocks. Mineralization is associated with steeply dipping structures and dikes, and controlled by low-angle and bedding-plane faults, favorable horizons and lithologic contacts within Cambro-Ordovician limestones and shales.

Most of the productive Bald Mountain District ore deposits fall within the N45-50W Bida Trend, which include “hybrid” (not Carlin-type) deposits, with ore in Devonian-Mississippian rocks and Jurassic intrusive rocks.

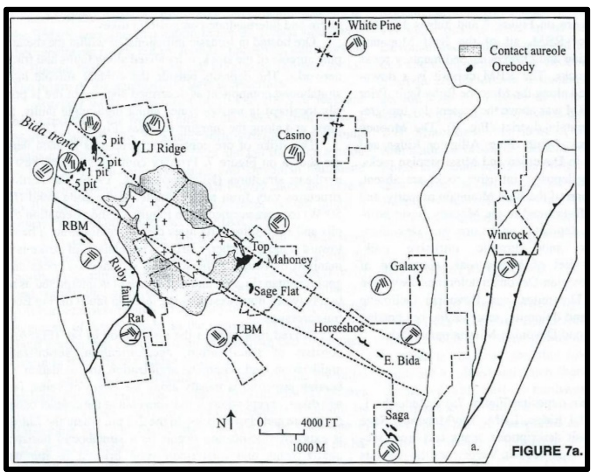
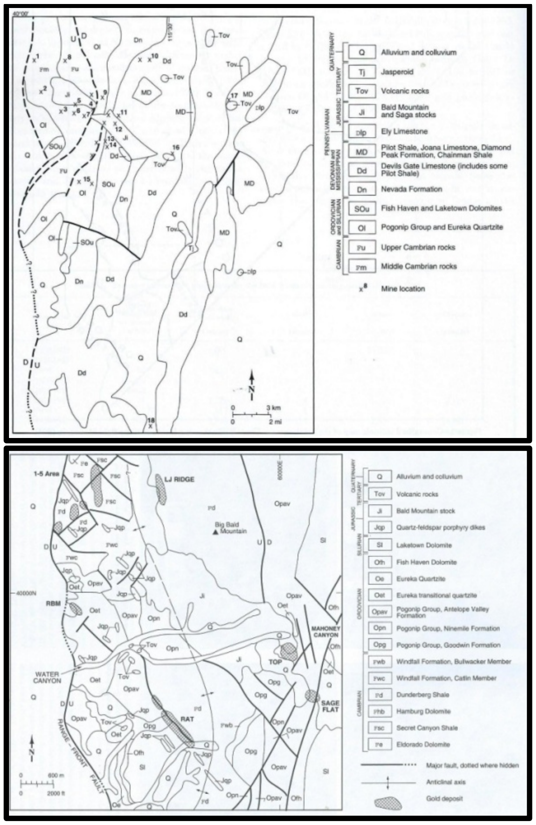
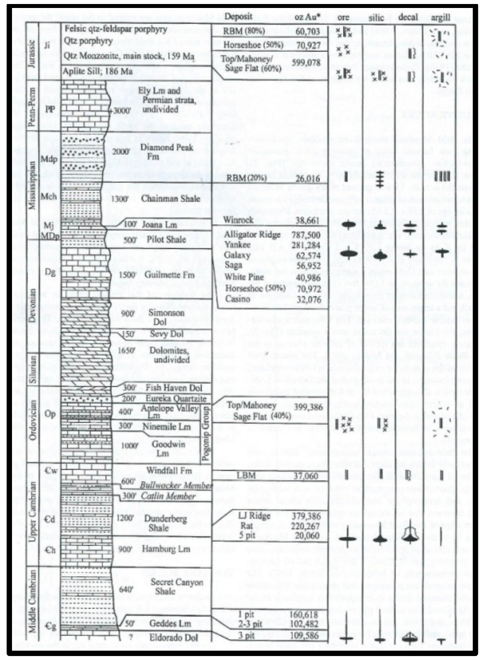


Fig 7b. The Bida Trend

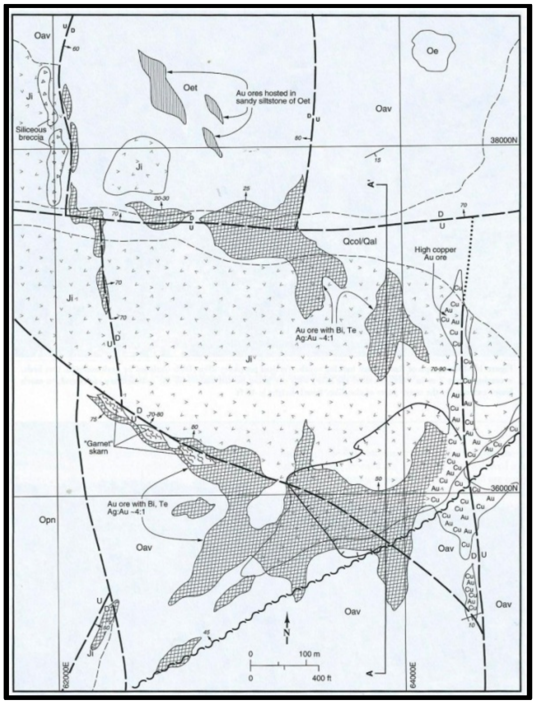
Sage Flats Extension mineralization is hosted by porphyry and rock of the Antelope Valley Formation, and is considered to be an extension of the Top deposit. The Sage Flats biogeochemical survey area and the Sage Flats Extension deposit are separated by the Dynasty Fault, which is steeply dipping (70^o) to the east-southeast and presumably with an offset of several hundred feet, putting ore deeper than economically recoverable under the current mine plan.

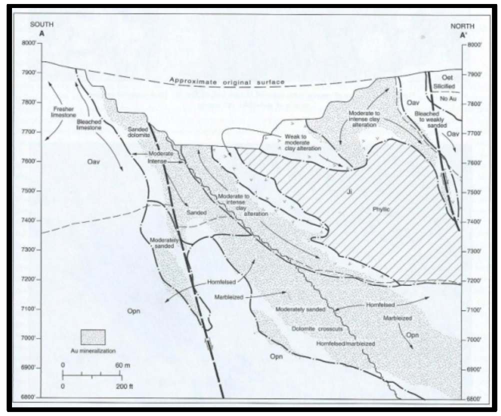
A geology map and section of the Top deposit (Figs.7 & 8) show features that should prevail under the alluvial cover at Sage Flats. Note in particular the association of mineralization and structure, and particularly the Au-Cu zone along the high angle, westerly dipping N-S structure. The Au-Cu zone at Top and the Au-Cu biogeochemical anomaly at Sage Flats are probably from similar rock and structure relationships.





Figs 5 & 6. Geology (left, Hitchborn, et al.,1996), and generalized stratigraphy (right, Nutt, et al., 2000) of the Bald Mountain – Alligator Ridge Districts. The Top deposit (9, and TOP) is comparable to the geology at Sage Flats. Ore at Sage Flats is 60% hosted by quartz monzonite (Ji) and 40% hosted by Antelope Valley Limestones of the Pogonip Group (Op).





Figs 7 & 8. Geology (left) and section (right) of the Top deposit showing ore and structure relationships that likely prevail under the alluvial cover at Sage Flats.

Ore Geochemistry

All gold ores have high concentrations of As and Sb (Carlin-type). Generally, gold ores that are spatially associated with intrusive rocks commonly have low Ag/Au ratios and elevated concentrations of Bi, Cu, Mo, Sn, Hg, Te, and Tl. The operative model involves the deposition of gold from a large, meterioric-water dominated hydrothermal convection system that was driven by deep intrusives of the Bald Mountain magmatic system.

Sage Flats ores are characterized by high concentraitons of Cu, Mo, Sn, Pb, Zn, Ag, Hg, Tl and Te, which suggests that mineralization was strongly influenced by magmatic fluids. Silver to gold ratios are less than 0.5 making Sage Flats ore more typical of “distal disseminated” type ores.

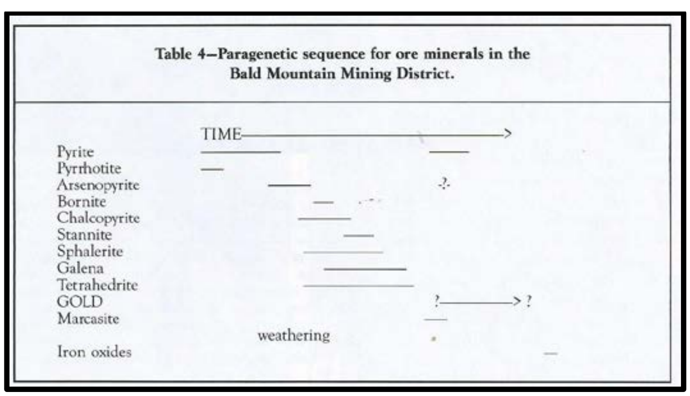


Fig 9. Paragenesis of ore in the Bald Mountain District.

Host	Deposit	Au	Ag	As	Sb	Hg	Tl	Cu	Pb	Zn	Mo	Bi	Te	Sn	Hole	Feet
Ji	RBM						no	data								
	Top/Mahoney/ Sage Flat	1.40	0.92	646	78	1.97	3.29	100	40	67	40	138	1.4	9.5	RT-92	0-560
Mch/Mdp	RBM						no	data								
Mch/Mj	Winrock						no	data								
MDp/Dg	Alligator Ridge	4.10	<0.2	1,135	48	9.0	6.3	26	15	267	25	<1	<0.02	<20	VVD-8	720-820
	Yankee	0.97	2.90	329	64	3.0	2.0	13	5	23	5	<1	<0.02	<20	YX-1	430-510
	Galaxy	1.67	0.16	938	152	28.8	10.2	27	27	92	15	<1	<0.02	<20	GXR-229	290-340
	Saga	0.92	<0.2	298	101	3.3	4.7	45	24	96	31	<1	<0.02	<20	SGR-222	160-240
	White Pine						no	data								
	Horseshoe	0.44	<0.2	379	127	20.7	31.4	20	20	88	13	<1	<0.02	<20	EBQ-045	270-330
	Casino	1.37	0.3	618	180	<32	<49	21	29	37	8	<1	<0.02	<20	CR-157	50-80
Op	Mahoney	4.68	5.21	914	699	na	na	712	67	121	54	79	3.5	na	MCR-22	160-270
	Sage Flat	2.37	1.21	940	559	na	na	593	24	146	115	238	3.7	na	RSC-11	480-630
	Top, east side	1.91	26.67	943	700	27.8	10.3	316	27	134	36	56	0.7	17	BDR-88	330-400
Op/Cw	Top, skarn	4.18	0.23	1,332	161	8.8	40	42	6	55	45	215	0.8	23	RT-41	250-290
	LBM	1.69	0.7	631	88	6.5	2.6	37	31	465	1.9	<1	<0.5	<20	85L-7	80-110
Cd/Ch	LJ Ridge	7.80	0.8	1,696	1,343	<0.1	<0.1	28	102	125	4.8	<1	<0.1	<20	LJR-052	340-380
	Rat (discordant)	1.96	0.5	2,013	71	na	na	67	12	36	3.8	8.2	0.1	na	RR-397	160-180
	Rat (concordant)	3.47	1.2	297	67	na	na	85	15	43	4.0	1.7	0.1	na	RR-379	280-310
	5 pit						no	data								
Cg	1 pit	2.28	1.11	6,237	5,236	<0.1	0.8	39	46	395	1.3	1.0	<0.5	<1	R1-71	230-390
	2-3 pit	3.65	3.66	2,346	9,066	<0.1	<0.5	38	23	659	4.8	0.18	<0.5	0.39	R3-100	230-340
	3 pit	8.95	14.6	18,480	4,408	0.37	<0.5	120	299	2,662	8.3	0.87	<0.5	2.4	R3-77	230-330

Fig 10. Ore geochemistry at several deposits of the Bald Mountain – Alligator Ridge Districts. Sage Flat chemistry is shown for the Qtz Monzonite host (Ji) and Antelope Valley Limestone host (Op). Ji host rocks contribute 60% of the ore, while the Op hosts contribute 40% of the ore at Sage Flat (Nutt, et al.)

Biogeochemical Survey

Two subspecies of sagebrush were collected: Artemisia tridentata and A. arbruscula. Sample spacing was 200 feet on lines that were 400 feet apart. A total of 228 samples were collected through a cover of snow ranging up to three feet thick. Since the crown material comprises the preferred tissue, sample tissue was available at almost every grid station.

It has been found that within the genus Artemisia, the accumulation of trace metal is very similar, if not identical. Therefore, data were not statistically normalized prior to interpretation. Samples consisted of leaves and twigs (together). Sample preparation was done at MEG Labs (Carson City, NV), which included washing, drying, maceration (-2 mm) and pelletization (15g) for instrumental neutron activation analysis (INAA) at Activation Laboratories Ltd. (Ancaster, Ontario, Canada), which reported 35 elements, including key pathfinders (As, Au, Ba, Br, Sb, and Zn), rare earth elements, alkaline and alkaline earths, and trans-uranium metals. Unfortunately, several key base metal pathfinders are not within INAA capability (Bi, Te, Tl) and are not available for interpretation.

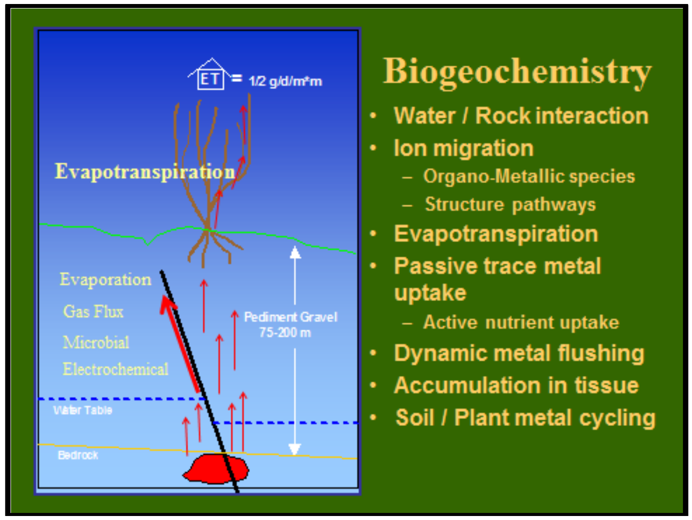


Fig 11. Generalized schematic describing ion mobility from deeply sourced mineralization and the influences of evapotranspiration, microbial activity, oxidizing ground water, barometric pumping, etc. Two pathways prevail: up major structures where large metal concentrations in plant tissue are commonly found, and weaker levels of metal concentration in plant tissue from aqueous ions in the joints, fractures, and fissures in the hanging wall.

Results

The biogeochemical data infer that significant mineralization (ore?) exists under thin alluvial cover at Sage Flats. The major trend of this mineralization is to the southeast from the Sage Flats Extension mine across the Dynasty Fault.

Gold anomalies (Fig. 13) surround the Dynasty Fault zone, which trace into the 2002 mine Sage Flats Extension mine workings. Several prominent clusters of >1 ppb Au concentration occur east of the Fault, with the largest of these (3200 ft x 600 ft) lying subparallel to the Fault at a distance of 2000 feet to the east. This large anomaly also contains one value of 32.7 ppb Au (95%ile of all commonly encountered gold concentrations in Nevada). Gold and associated pathfinder patterns indicate this large anomaly is not related to the Dynasty Fault and may have association with high angle, west dipping fault or mineralized dike. It may also be a W-Mo-Au skarn.

Halos of As (Fig. 14) and Sb (Fig. 16) are co-spatial with or adjacent to Au anomalies. In some locals, Sb displays a “rabbit-ears” pattern, which is usually an indication of deep mineralization. Arsenic to gold spatial relationships east of the Dynasty Fault indicate up-dip leakage is to the east.

Barium (Fig. 18) is strongly enriched in sagebrush tissue in the northeast corner of the survey grid, accompanied by low concentrations of Au and variable concentrations of As and Sb. This might be an isolated zone of jasperoid alteration.

The bromine plot (Fig. 15) is very intriguing. Bromine is a volatile element that relates to hydrothermal salts that are often part of the chemistry of fluid inclusions. As a pathfinder, it often relates to very deep ore where it displays “rabbit ears” patterns on the hanging wall side of mineralized faults. In this survey, the Br pattern is controlled by dominant NW structures. The area surrounding the Dynasty Fault is very strongly enriched in Br, showing a consistent halo near the 2002 mine workings. In the middle of the survey area, Br displays a “rabbit ears” pattern, which lies adjacent to the largest Au anomalies and concentrations. This Au-Br association suggests that leakage from deep mineralization is up-dip to the east. Because of the very strong NW-trending Au-Br-As-Sb association, there is a high likelihood that deep drilling in Sage Flats along this trend could be successful. It should be noted that the Br pattern also indicates the area is structurally complex, including several E-W, and NW-SE offsets (Fig. 12).

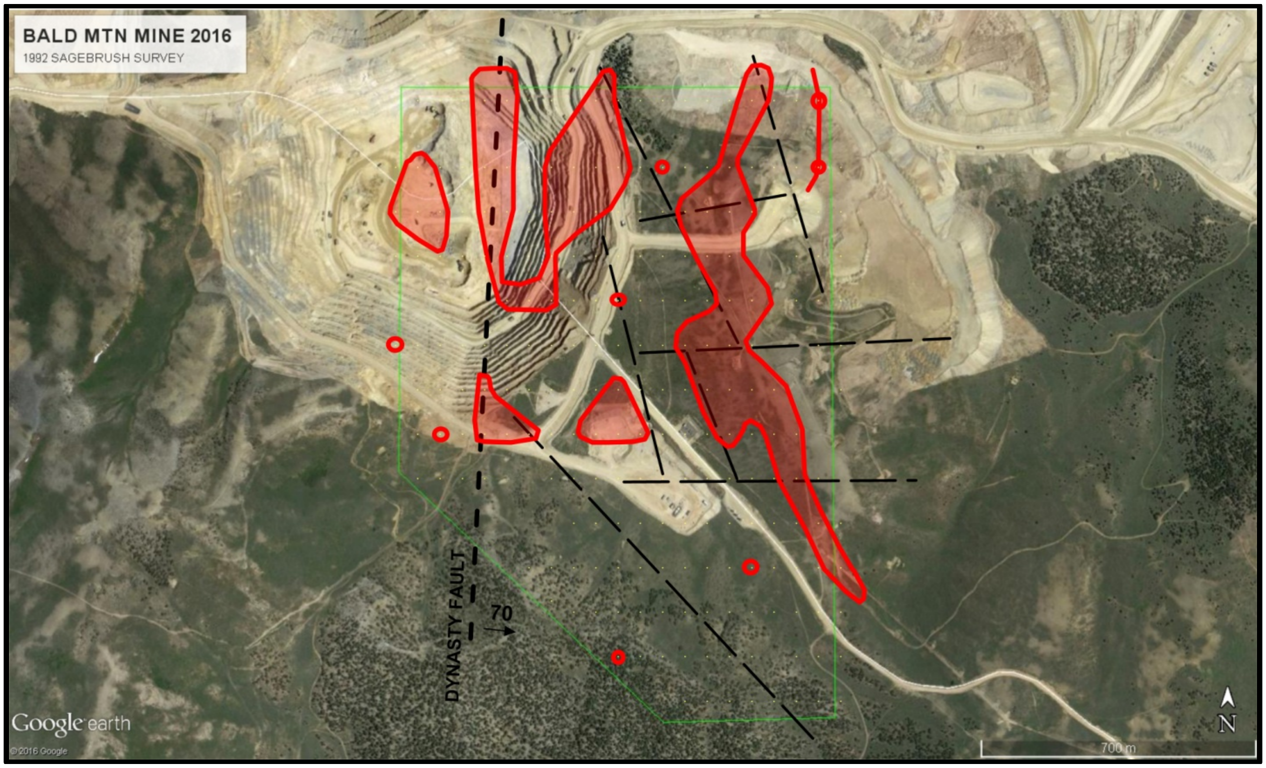


Fig 12. Structural interpretation based on composite biogeochemical data, showing offsets and boundaries.

Zones of weak selenium (Fig. 17) enrichment might be related to areas of deep silver mineralization, while zones of coincident W-Mo enrichment may be related to skarn alteration (Figs. 20 & 21). Zinc may be related to post-mineral faults (Fig. 19).

Conclusions

The 1992 biogeochemical survey at Sage Flats is strongly indicative of subsurface gold mineralization. Several areas of anomalous (>1 ppb) gold, including one value of 32.7 ppb (which is in the 95%ile of all biogeochemical anomalies from sagebrush in the Great Basin) are evidence of this mineralization. The largest anomaly is 3200 ft x 600 ft which is a footprint the size of the other deposits that have been and are currently being mined.

It does not appear from current satellite images of the area that the large remaining anomaly has been tested for ore potential. This seems to be a virgin deposit waiting patiently to be discovered.

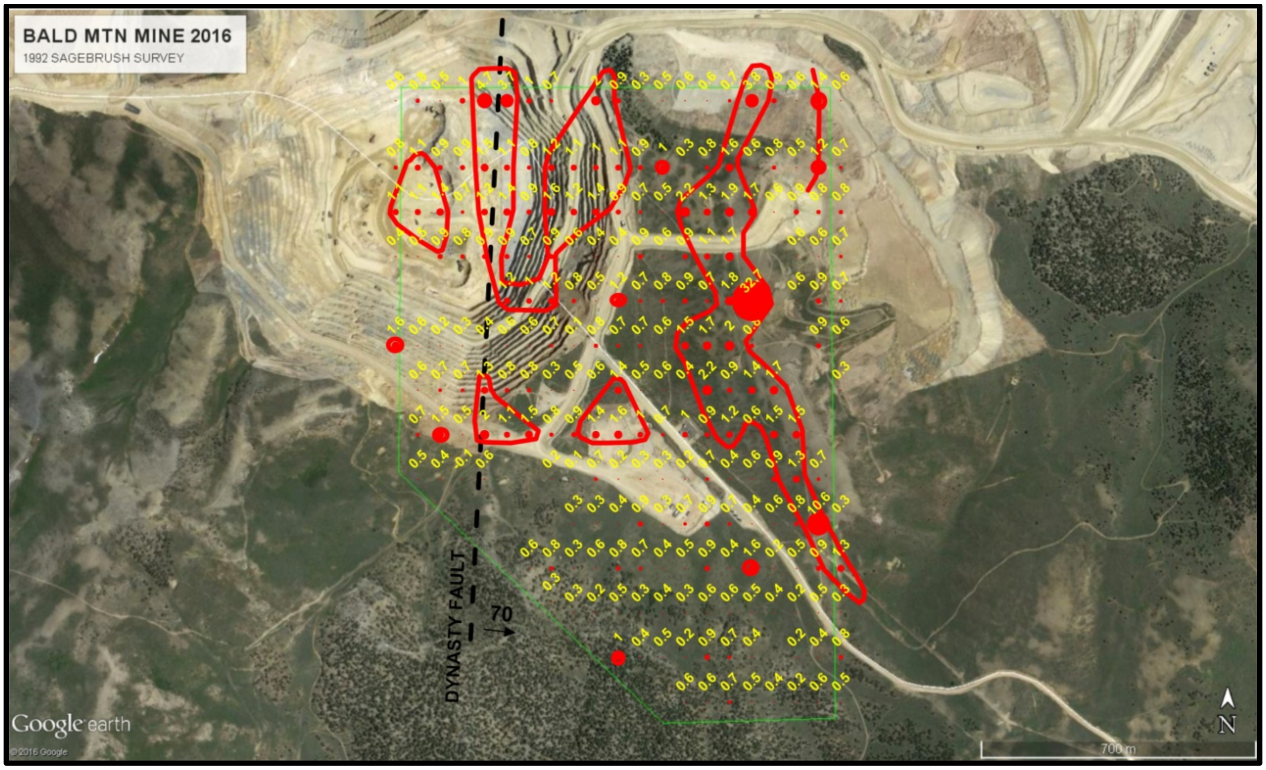


Fig 13. Gold in sagebrush leaves and twigs.

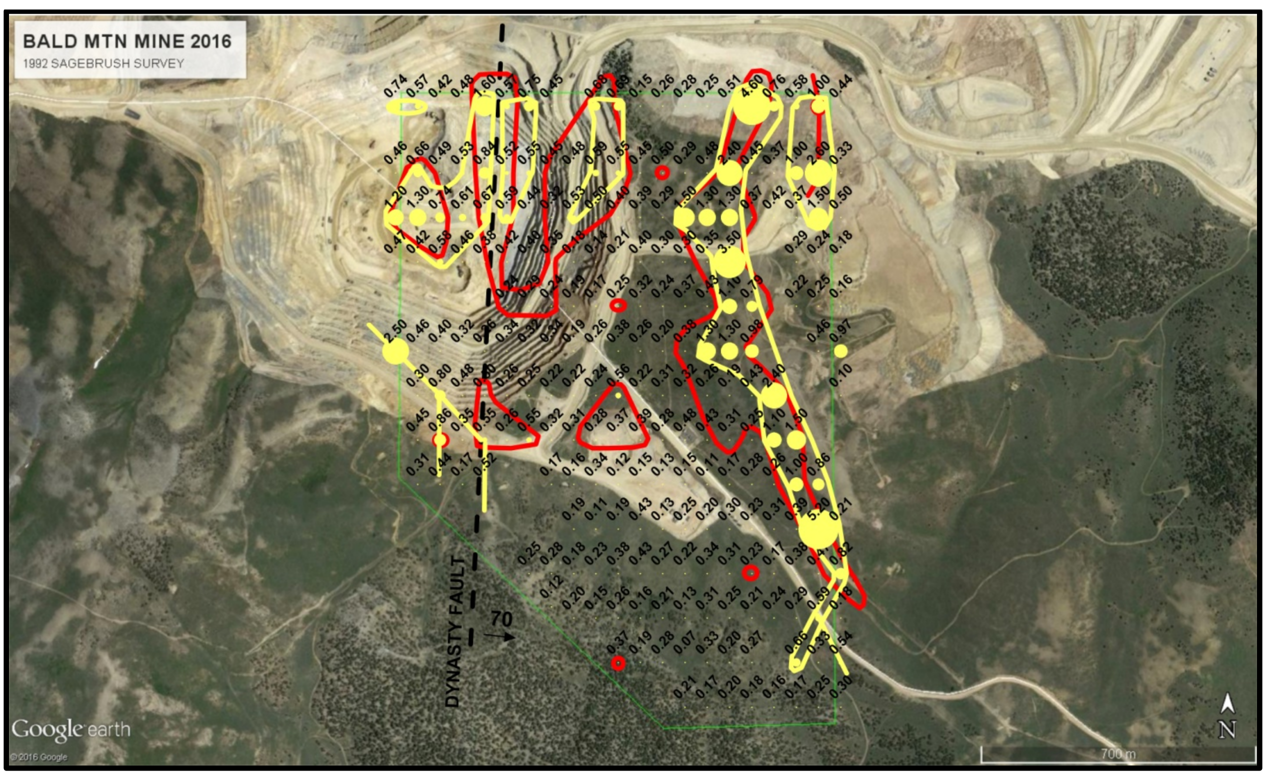


Fig 14. Arsenic in sagebrush leaves and twigs.

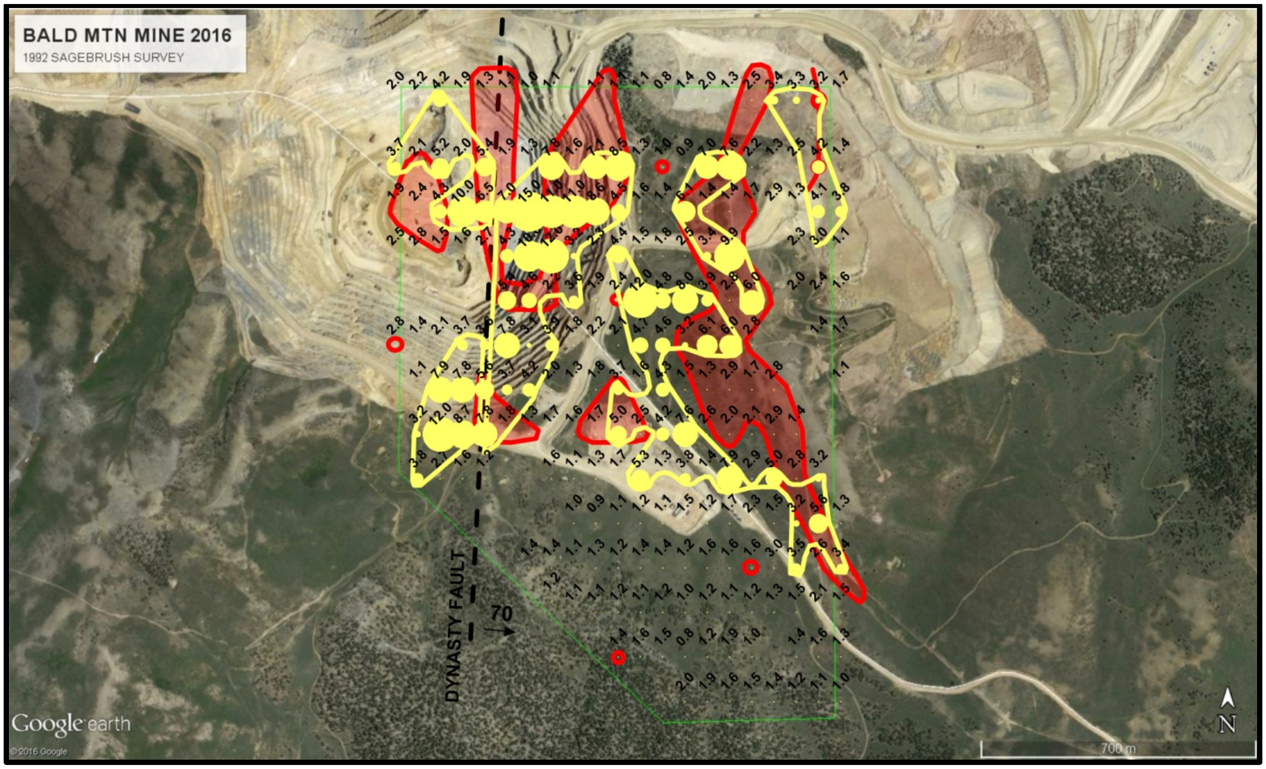


Fig 15. Bromine in sagebrush leaves and twigs.

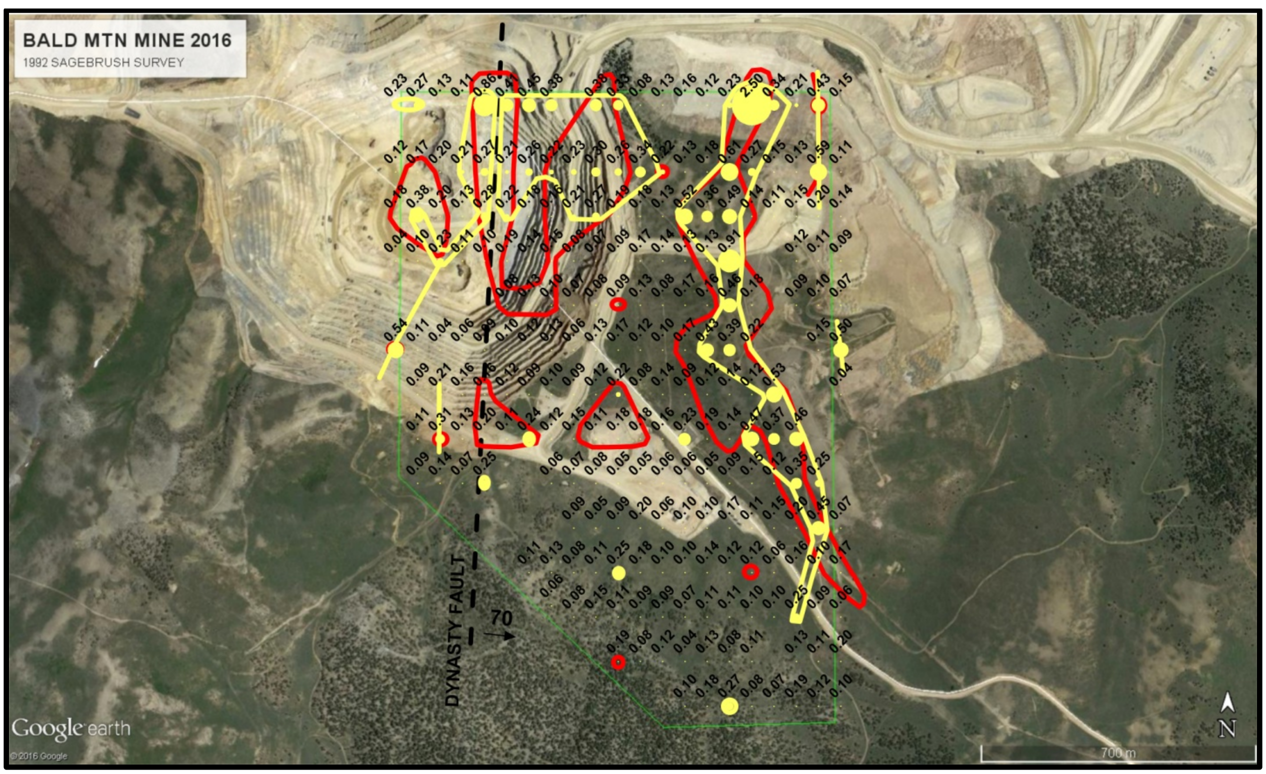


Fig 16. Antimony in sagebrush leaves and twigs.

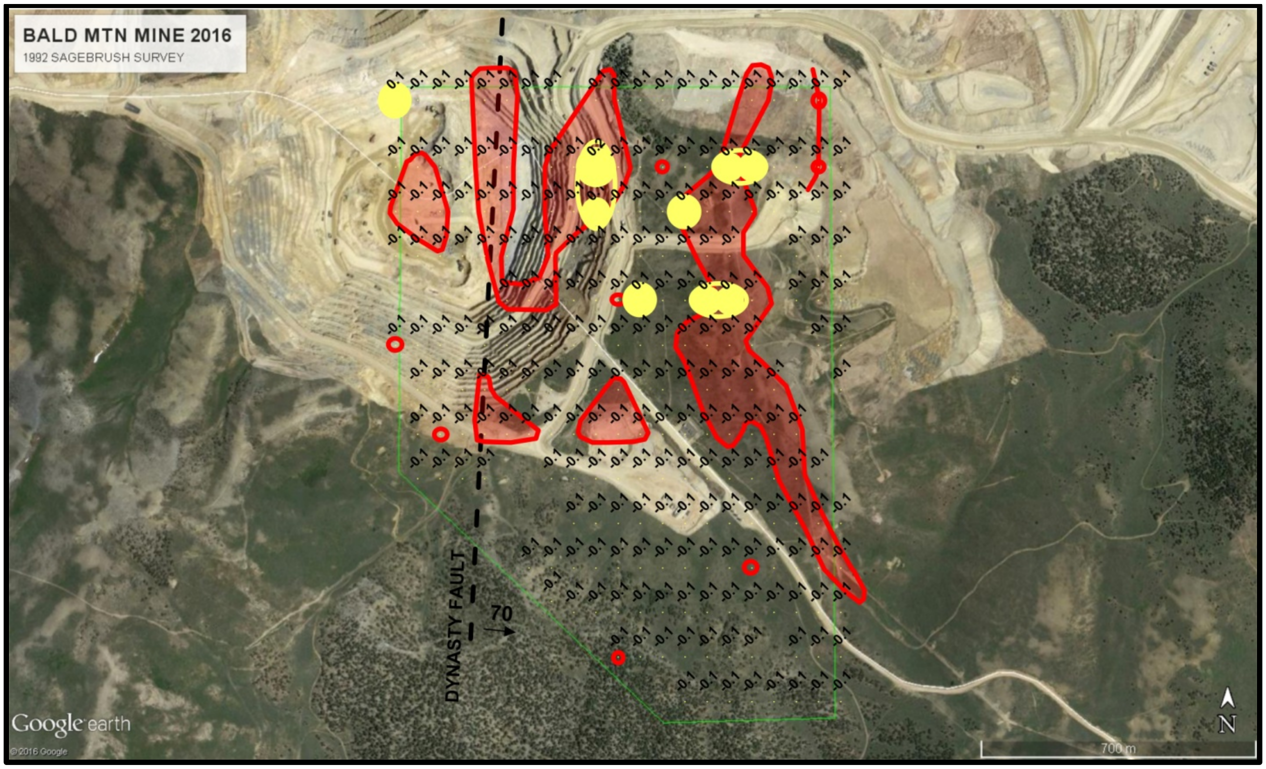


Fig 17. Selenium in sagebrush leaves and twigs.

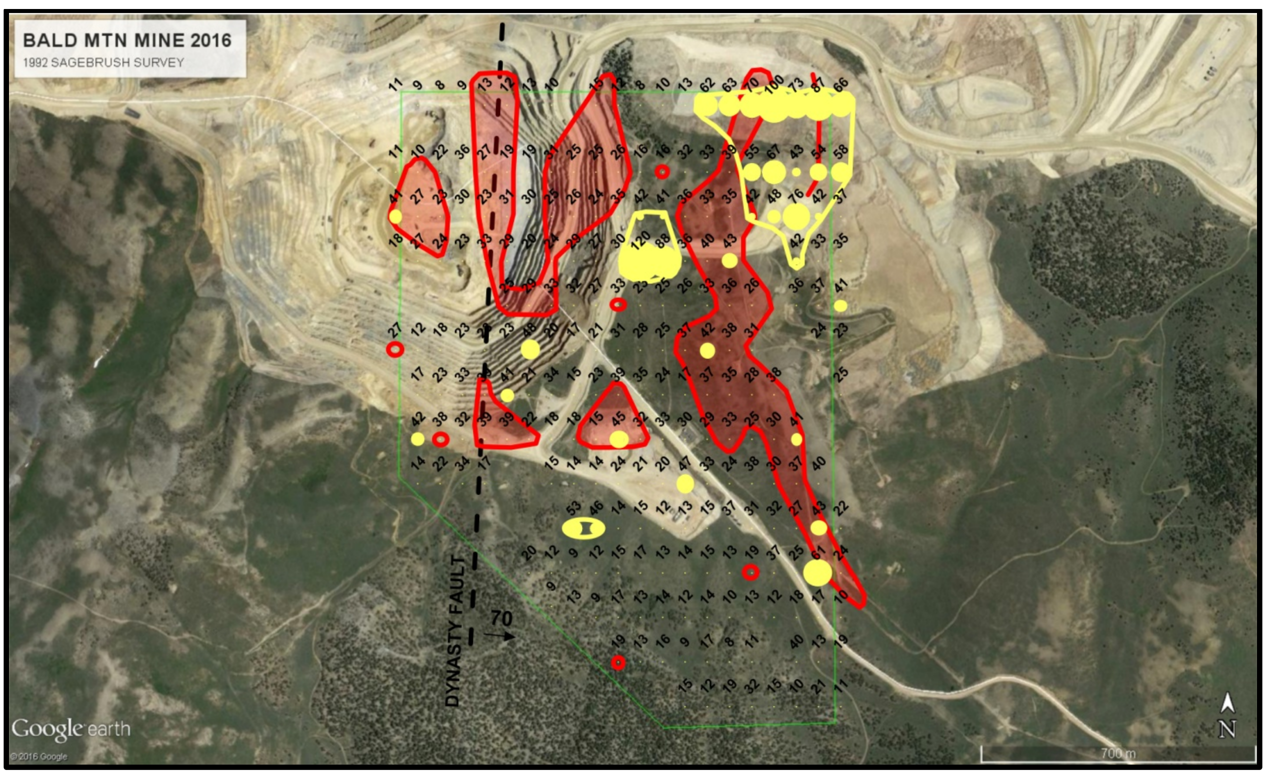


Fig 18. Barium in sagebrush leaves and twigs.

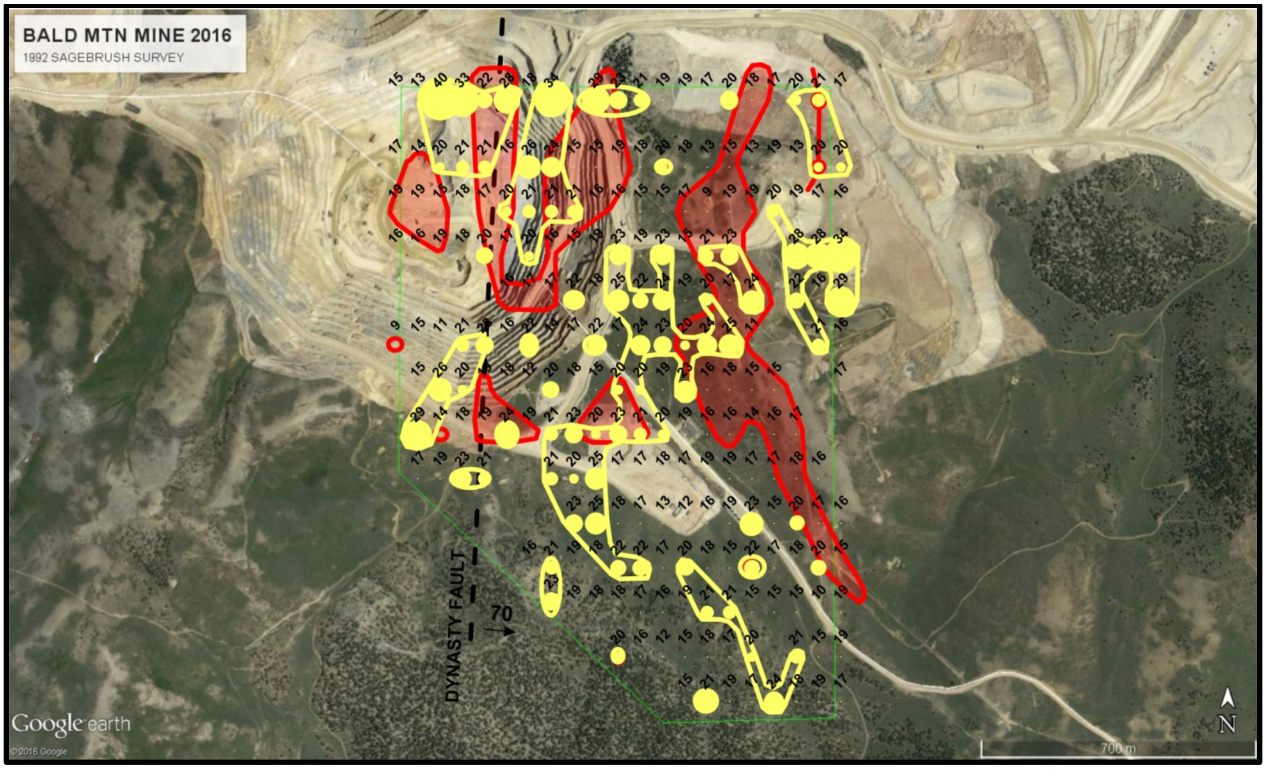


Fig 19. Zinc in sagebrush leaves and twigs.

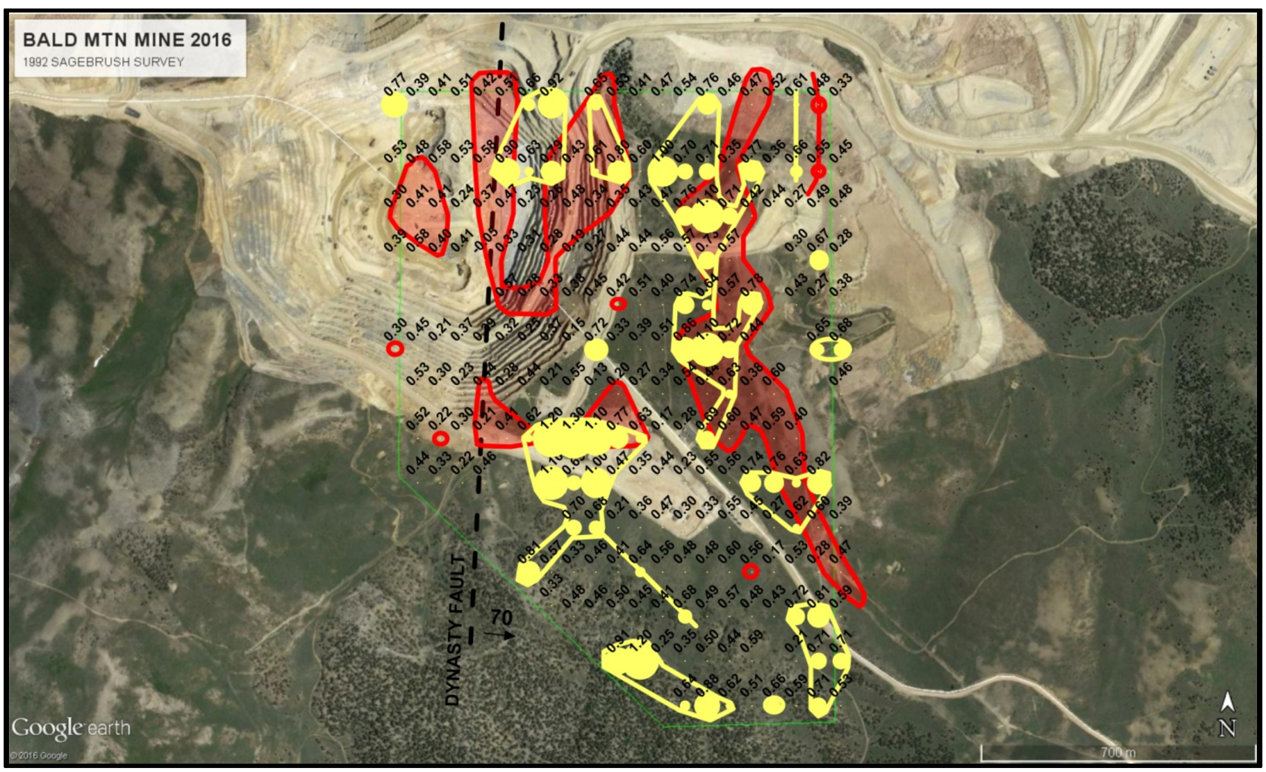


Fig 20. Molybdenum in sagebrush leaves and twigs.

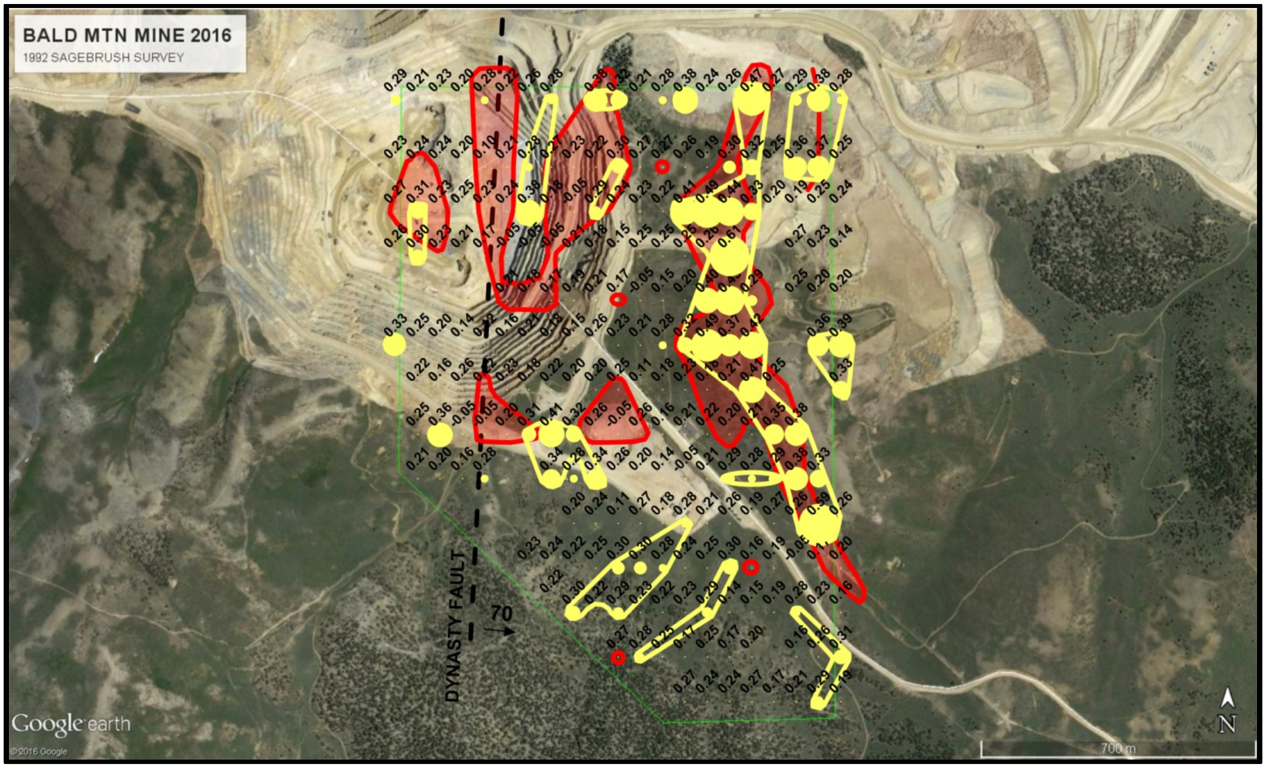


Fig 21. Tungsten in sagebrush leaves and twigs.

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