BIOGEOCHEMISTRY
Discovery Using Metal Concentrations in Plants

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Winters Creek, Jerritt Canyon District

Fig 1. Location map of Winters Creek, Jerritt Canyon District, Independence Mountains, Northern Nevada.

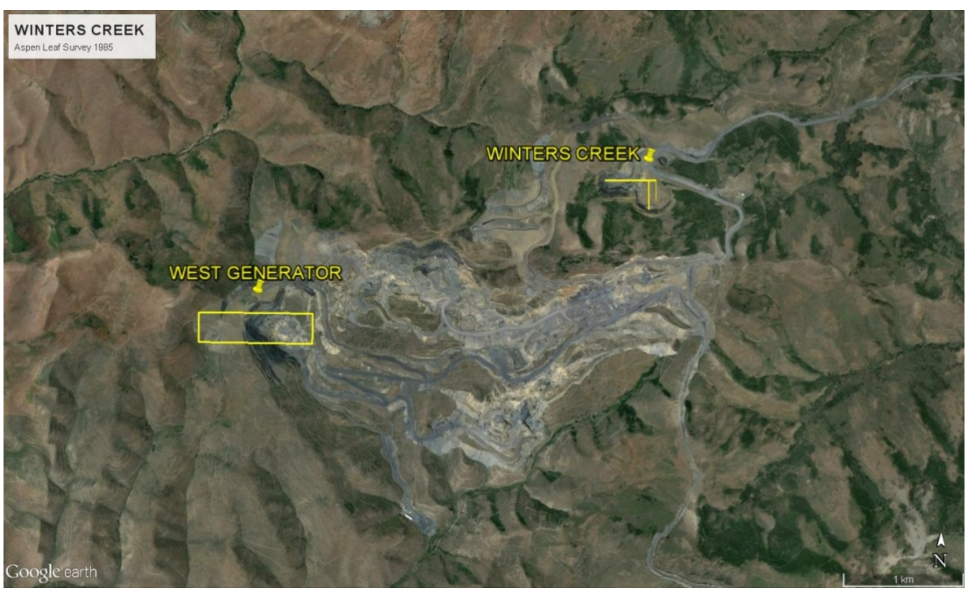


Fig 2. Location map of Winters Creek & West Generator deposits, Jerritt Canyon District.

Introduction

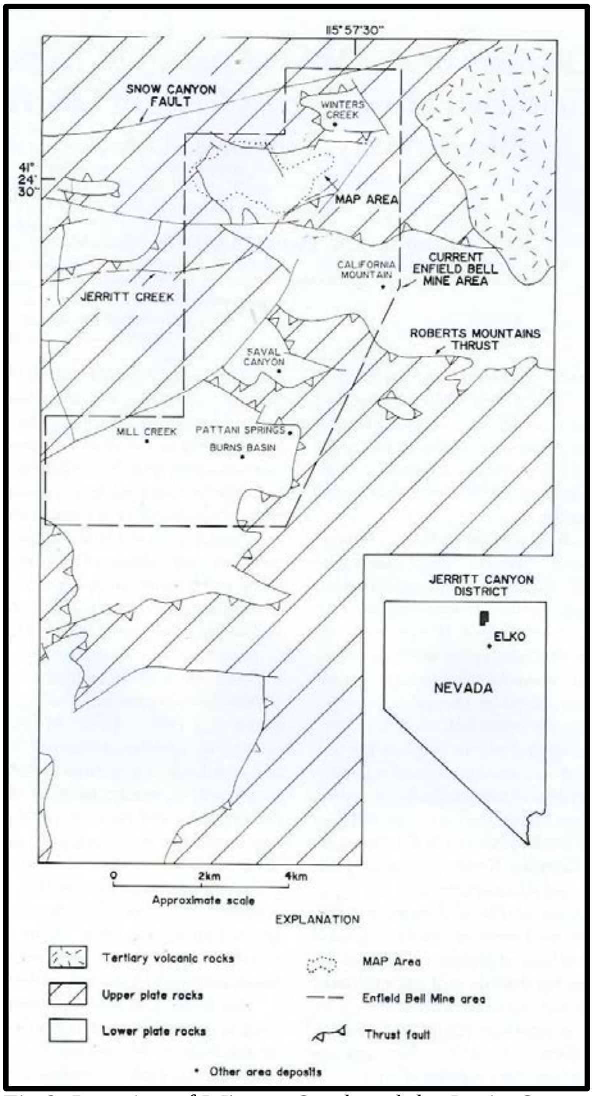


Fig 3. Location of Winters Creek and the Jerritt Canyon District on a generalized geology map.

Ore discovery in the Jerritt Canyon district was a 70/30 joint venture between Freeport McMoRan Gold Company and FMC Gold Inc. In the early 1970’s FMC began reconnaissance exploration in the district looking for antimony. Anomalous gold and pathfinder anomalies in soil were drilled in 1973 at the “Alchem” target on the North Fork of Jerritt Creek. The hole encountered “interesting” grade yet uneconomic tonnage in lower portions of the Roberts Mountain Formation. After three more years of mapping and soil sampling, Freeport (now operator), discovered the Marlboro Canyon orebody (with credit to Robert B. Hawkins). Operations as the E.B. Bell Mine began in the fall of 1976.

Exploration at Winters Creek began in 1978, with mapping and sampling of soil and surface rocks along the mine haul road at Deadman’s Curve (Figs 6 & 7) using 50 ppb-Au (considered then to be the most reliable and economical assay available for gold). That work resulted in three jasperoid drill targets, one of which delineated a small economic resource (86,200 mT @ 3.1 g/T).

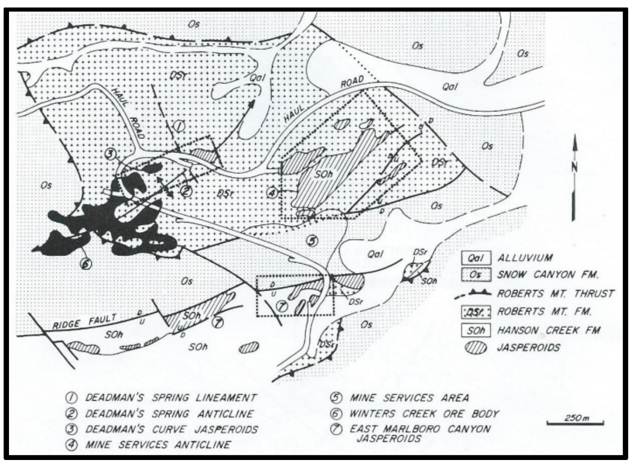
Further sampling along the haul road proved to be difficult and very misleading due to contamination from ore haul spillage, in addition to limited outcrop exposures from overlying glacial till, thick soils, dense aspen groves and boggy conditions from numerous springs. Only successful drilling by the end of 1984 accounted for a 10-fold (725,500 mT @ 3.9 g/T) increase in estimated resources.

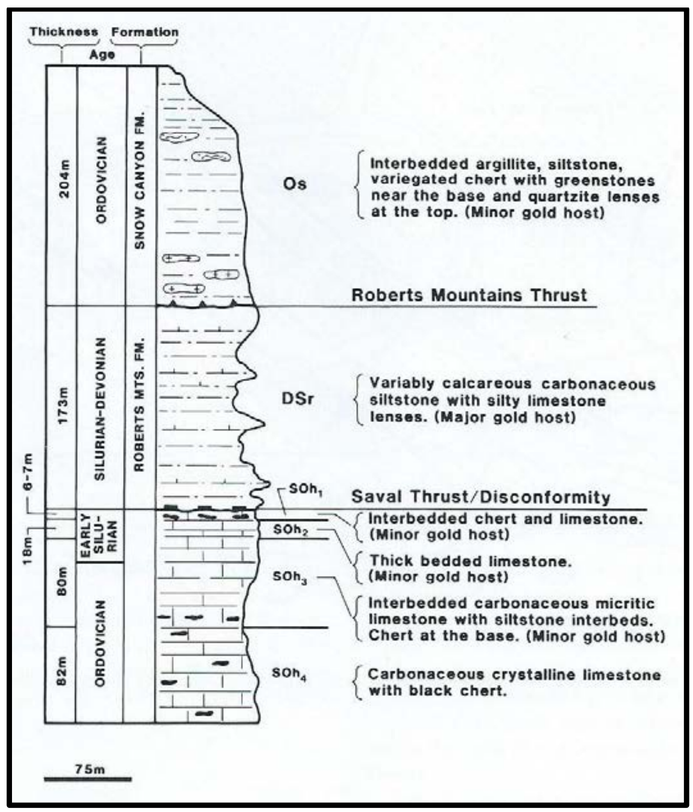
Cross section interpretations indicated that gold mineralization was located in the lower Roberts Mountain Formation along flanks of a N70E-trending, doubly plunging anticline, with a southeast limb that dips more steeply than the northwest limb (Figs 4 and 6 & 7). The Deadman’s Spring Anticline is cut by high angle reverse faults that strike parallel to the fold axis, and much later northwest-striking normal fault sets.

In 1985, a research program was initiated at Winters Creek and several other project areas with the objective of testing the efficacy of various geochemical methods, including multi-element soil geochemistry, soil gas geochemistry, geomicrobiology (Bacillus cereus), sagebrush and aspen biogeochemistry, in addition to IP and resistivity geophysics (Weideman, et al.). These were early “proof of concept” tests, with intent to determine which plant tissues and plant species were useful for the detection of blind mineralization. A mercury soil gas collector survey was also undertaken. The contents of this presentation report the results of these geochemical survey data. Hopefully the reader will appreciate that this work was done after discovery, but well before mining of the Winters Creek deposit. The reader should also reflect on how biogeochemistry and soil gas geochemistry might add to the efficiency of discovering the next Jerritt Canyon.

Geology

The Jerritt Canyon District is in the Independence Range of north-central Elko County, Nevada, and lies at a regional stuctural crossroads, the most important of which is the Midas Trough, home to the Twin Creeks Mine and the Midas Mine. The Bell Mine is located in the northern quarter of the Jerritt Canyon Window in Sections 33,34, and 35 of Township 41N, Range 53E (Fig. 3). The geology and ore of Jerritt Canyon is considered to be “Carlin-type” (Radtke, et al.). Siliceous rocks of the western facies were thrust over carbonate rocks of the eastern facies along the Roberts Mountains thrust fault in the late Devonian period as the Antler Orogeny culminated.



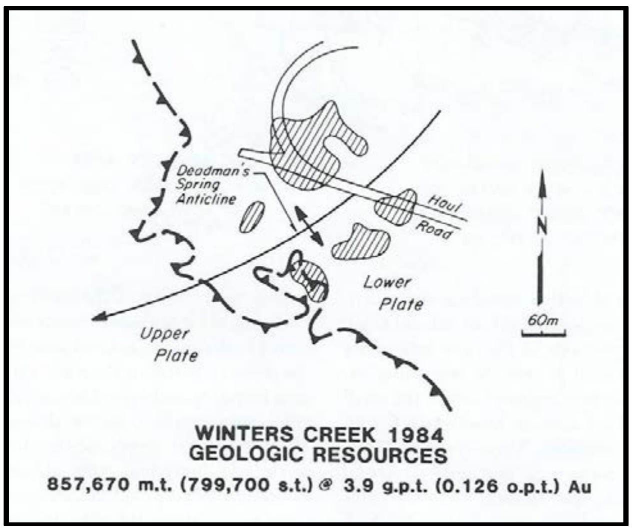


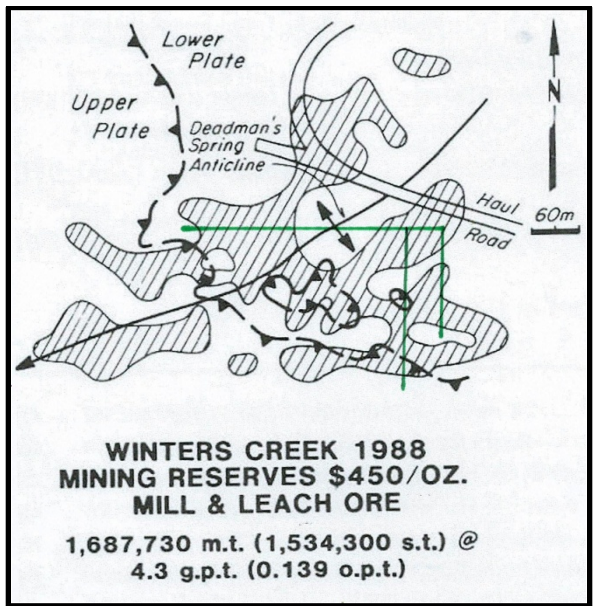
Figs 4 & 5. Local geology and generalized stratigraphy of the Winters Creek Mine area. Ore is indicated by solid black polygons on both the geology map and generalized stratigraphic column.

Locally, the lithologies (Snow Canyon Formation, Os) of the upper plate Valmy sequence consist of intermediate to mafic volcanic flows, argillite, silttone, chert, minor limestone, and quartzites (Churkin and Kay). The lower plate rocks consist of siltstones, carbonates, and quartzites. Geological relations suggest that gold mineralization occurred before or during Basin and Range magmatism and block faulting approximately 10 ma (Hofstra, et al.). Gold was deposited along east-west and northeast striking high-angle and low-angle faults, and along northwest-trending high-angle faults, and especially at intersections of these structural features.

Hanson Creek Formation (SOh) is the primary gold host in the Jerritt Canyon District. It is composed of reactive carbonates characterized as banded, interbedded carbonaceous and shaly limestones, to massive, cherty, bioclastic limestones and dolomites, to fine grained, banded, grey-black carbonaceous limestone. Bounding these productive units are massive limestone units that have been hydrothermally altered to jasperoid.

The basal 60 m of the Roberts Mountain Formation (DSr) is generally a minor gold host in the Jerritt Canyon District, yet the principal host at Winters Creek. It is composed of reactive carbonaceous carbonates, calcareous siltstones, and dolomites. Carbonaceous matter is contains sygenetic and diagenetic pyrite, some of which is gold bearing. Exposures of DSr dominate all other ore-bearing host rocks at Jerritt.





Figs 6 & 7. Resource development at Winters Creek in 1984 compared to 1988 after several successful drilling campaigns but with little guidance from geochemistry and geophysics.

Ore Description

The Winters Creek ore body in plan view is somewhat horseshoe shaped around the axis of the Deadman's Spring Anticline. Mineralization approaches to within 5 meters of the surface and plunges both northwest and southeast to depths of about 175 meters. The thickness of the ore body is variable, but averages about 10-20 meters. Ore is 78% refractory, composed of variable amounts of graphite and sulfides.

Hydrothermal minerals that are associated with gold include realgar, orpiment, arsenopyrite, and cinnabar. Therefore, arsenic and mercury concentrations in plant tissue should be directly related to ore at Winters Creek. Stibnite (Sb), barite (Ba), and quartz occur with jasperoid alteration and are believed to have formed during the later stages of mineralization.

Fig 4. Biogeochemical and mercury soil gas (GASic) survey lines (1985) at Winters Creek, superimposed onto the current mine workings. Survey line locations are approximate.

Biogeochemical Survey

Aspen (Populus tremuloides) are the dominant plant species with secondary sagebrush (Artemisia tridentata) in the Winters Creek area. The soils are water-saturated from numerous springs, which make it an ideal location for aspen. Groves of aspen were dense at the time of collection. Conversely, very few sagebrush were available for sampling, and the few that were sampled were for comparison purposes only. Both leaves and twigs of aspen were collected and treated separately at MEG Labs (Carson City, NV). Sample spacing was 100 feet on one E-W line, and two N-S lines that were approximately 200 feet apart. Splits of each tissue (leaf or twig) were washed and the washed and unwashed data were compared.

Geochemical analysis was reported by X-Ray Assay Laboratories, Toronto, Canada, (XRAL) on October 3, 1985. Analytical preparation involves pelletizing 8 grams of dry plant tissue. Instrumental neutron activation analysis (INAA) reports concentrations of As, Au, Ba, Br, Cr, Fe, Mo, Sb, U, W, and Zn, which are useful for mapping structures and defining zonation related to the gold system.

XRAL also reported Ag, Cu, Pb , and Zn concentrations after digesting 30 grams of ashed sample in aqua regia. Mercury was reported after wet digestion in aqua regia (without ashing). Analysis was done by either atomic absorption (AAS) or plasma spectrophotometry (DCP). These biogeochemical data were later compared to results from the mercury soil gas collector (GASic) survey.

Results

Washing proved to be important for the removal of mineralized dust. At the time of the survey, reverse circulation exploratory drilling was ongoing, and in 1985 RC drilling was done dry. Consequently, dust was a hygienic and environmental hazard, as well as a hazard for reliable geochemical survey work. Air-borne dust (inorganic and organic) in windy arid environments is still a geochemical problem. Drilling is now done with water circulation to sequester fugitive dust. Nevertheless, human sources (road traffic, excavation, industrial activity, mine activity, etc.) and natural sources (plant pollen, aeolian dust, etc.) will always create an opportunity for contamination, so washing continues to be part of the sample preparation procedure.

Particularly at Winters Creek, the proximity of the Mine Haul Road created an adverse condition where even after thorough washing, contamination from road dust and haulage dust was apparent. Twigs have a smooth bark, and dust was easily removed from twig surfaces. This was apparent since metal concentrations were 10x lower compared to unwashed twigs.

Leaves were not so easily washed. Washed leaves had metal concentrations that were only half the unwashed concentrations. Also, ash weights of washed leaves (about 5%) were just fractionally less than unwashed leaves (about 6%), suggesting that a lot of dust remained after washing. Consequently, data from washed aspen twigs are more reliable than washed leaf data, and this is apparent from the more concise and less erratic patterns in the washed twig data.

Since pattern rather than high concentration is a better guide to ore, the more stable washed twig data are preferred for interpretation when metal concentrations are sufficiently above analytical detection limits. In this survey, some metal concentrations in aspen twigs were at or below detection; consequently some of the leaf data were used for interpretation.

The reader must appreciate that in 1985 standard analytical methods for biogeochemistry had not yet been thoroughly developed, resulting in unstable and unreliable data. Traditional instrumental methods for soils and rocks did not work well for plant tissue. For instance, data from Winters Creek suffered from highly variable detection limits, where some sample concentrations were reported at levels of 0.0X ppm, while others were reported <1.0 ppm (apparently the detection limit for that particular sample).

The mercury soil gas method did not suffer these analytical problems. The results show a concise anomaly pattern over deep ore of the southeast limb of the anticline (Fig 16). It is now appreciated that volatile mercury is released where oxidizing ground water and microbial activity interact with mineralization, releasing plumes of molecular mercury to the surface through structural pathways including low-angle and high-angle structures, with joints and fractures providing pathways in the hanging wall. Note that depending on the depth to the interaction zone, survey data may show higher biogeochemical metal concentrations over deep ore, and lower concentrations over shallow ore. This is not intuitive.

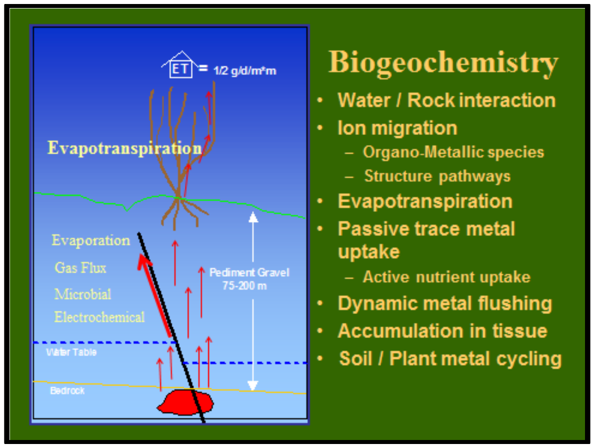


Fig 5. Diagrammatic explanation of ion mobility from deeply sourced mineralization.

It would have been more elegant if the mercury in aspen leaves had not been contaminated by dust from the haul road and drilling, and a comparison to mercury soil gas could be made. But, the patterns are only vaguely similar. It would have been equally elegant if the mercury in aspen twigs could have been compared to soil gas results, but biogeochemical analytical detection at 5 ppb was not sufficiently low. So, mercury soil gas stands alone as the only reliable mercury data from this study.

Biogeochemical Interpretation

Interpretation of the biogeochemical gold pattern (Figs 6 & 7) relied heavily on supporting pathfinder data. The best pathfinders were arsenic (Figs 8 & 9), antimony (Figs 10 & 11), bromine (Figs 12 & 13), and mercury from buried "GASic" collectors (Fig 16). Biogeochemical mercury (Figs 14-15) in the leaves and twigs of aspen may have proven to be an effective pathfinder, but the data were corrupted by dust contamination from the haul road, and local drilling.

Jasperoids have a relatively restrictive mineralogy including stibnite, variscite, wavellite, apatite, (calcium and aluminum phosphates), and fluorite (Daly, et al.). Bromine and fluorine are mobile halogens and useful pathfinders to many if not most hydrothermal ore deposits. Bromine patterns at Winters Creek mimic the As, Hg, and Sb patterns over the mine pit, and appear to indicate deep ore, presumably associated with jasperoid alteration.

Other metals that appear to be related to gold mineralization (with relationship to deeper sulfide ore) are molybdenum (Figs 17 & 18), copper (Figs 19 & 20), lead (Figs 21 & 22), and zinc (Figs 25 & 26). Ore mineralogy includes sphalerite, pyrite, realgar, orpiment, cinnabar, arsenopyrite, and graphite.

Analytical detection for uranium (Figs 23 & 24) was high relative to plant tissue concentrations, yet interesting patterns related to structure and gold mineralization are apparent.

Barium (Figs 27 & 28) stands alone, displaying a pattern that is perhaps related to mineralized jasperoid and / or more oxidized ore, and / or unmapped upper plate Snow Canyon Formation that has been overthrust onto the host rocks of the lower plate Roberts Mountain Formation.

Gold concentrations in aspen leaves from Winters Creek reached highs of 5-13ppb, with broad zones of 6-9 ppb (Fig 6). These concentrations may be due to dust contamination. On the other hand, twig concentrations range from 0.5 – 2.9 ppb with broad zones of >1 ppb. It was not appreciated at the time of this survey that concentrations above 0.5 ppb represent the upper 60^{th} percentile of all biogeochemical gold concentrations commonly encountered in the Great Basin. Those in the range 1-3 ppb are in the upper 80^{th} percentile. Based only on absolute concentrations of gold from presumably uncontaminated twig data, the values at Winters Creek are a strong indication of significant mineralization.

Conclusions

The challenge for biogeochemistry (and mercury soil gas geochemistry) at Winters Creek was to detect blind ore through thick glacial deposits, thick soils, dense aspen groves and boggy conditions in a terrain that offered little to no outcrop.

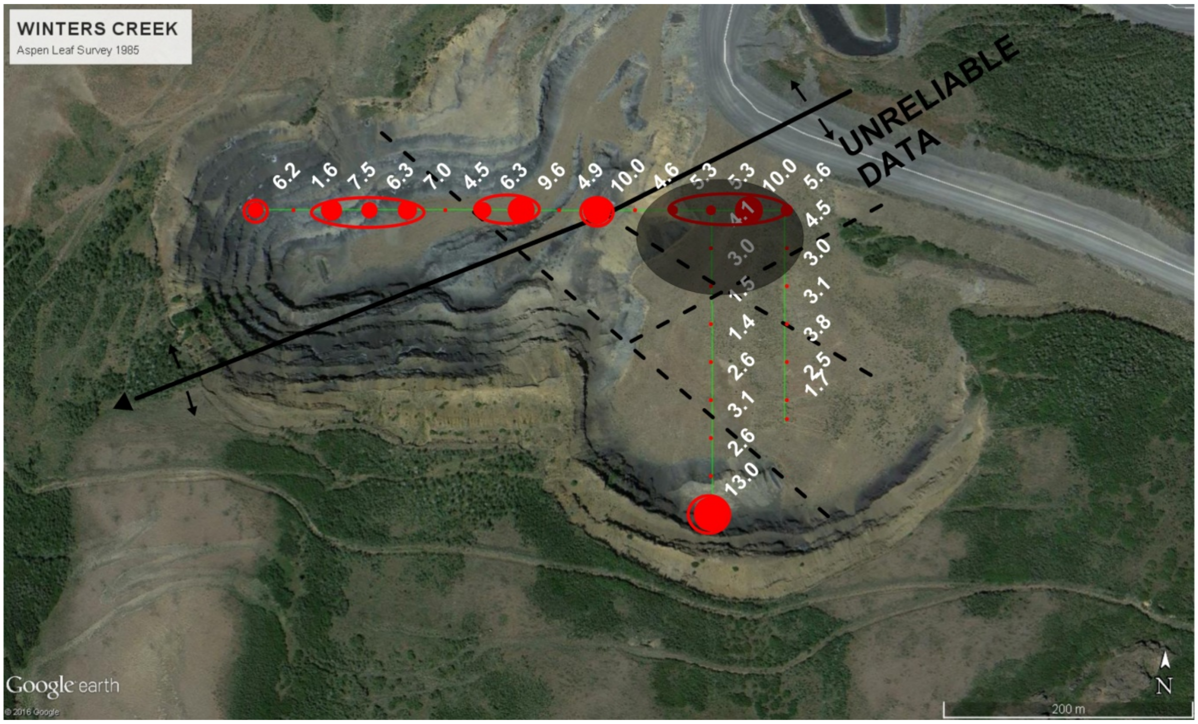
The project was complicated by proximity to the mine haul road. Dust and spillage created a contamination issue that adversely affected aspen leaf tissue, but fortunately did not affect twig tissue. The haul road issue was so severe that it also foiled the use of more conventional soil and rock chip sampling that had been tried previously. Additionally, biogeochemical analytical issues presented unstable data due to floating detection limits that prevented the use of some twig assay data. Nevertheless, by disregarding the most egregious contamination issues (near the haul road), and data affected by dusting from previous drilling, patterns emerge that seem to be a reflection of deeply sourced mineralization.

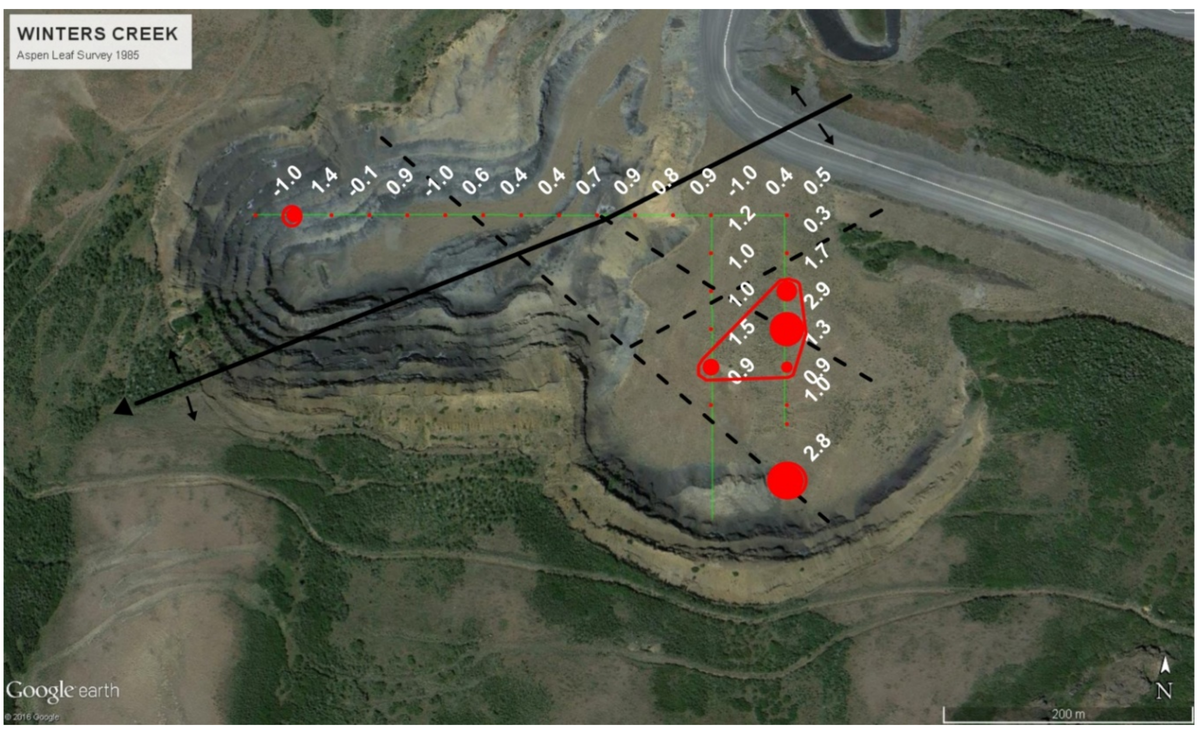
The most reliable gold and pathfinder patterns appear on the two N-S lines. These patterns are 200-600 feet from the haul road, and their consistency makes them believable. Survey notes at the time state there was active drilling on the E-W line, but not on the N-S lines.

The resulting patterns (collectively) on the N-S lines suggest a footprint of sulfide ore at depths approaching 175 meters. Base metals (Cu, Pb, Zn, Mo) indicate a zone of sulfide mineralization that lies south (and presumably deeper) than gold mineralization, which might be partially oxidized (as suggested by its spatial relationship to anomalous barium). Plumes of more mobile metals (As, Hg, Sb, also sulfides in ore, and Br) are also spatially related to the base metal footprint and gold anomaly. Mobile pathfinders (including gold) are good indicators of deep ore because they find vertical pathways (joints, fractures, etc.) to the aspen rhizosphere.

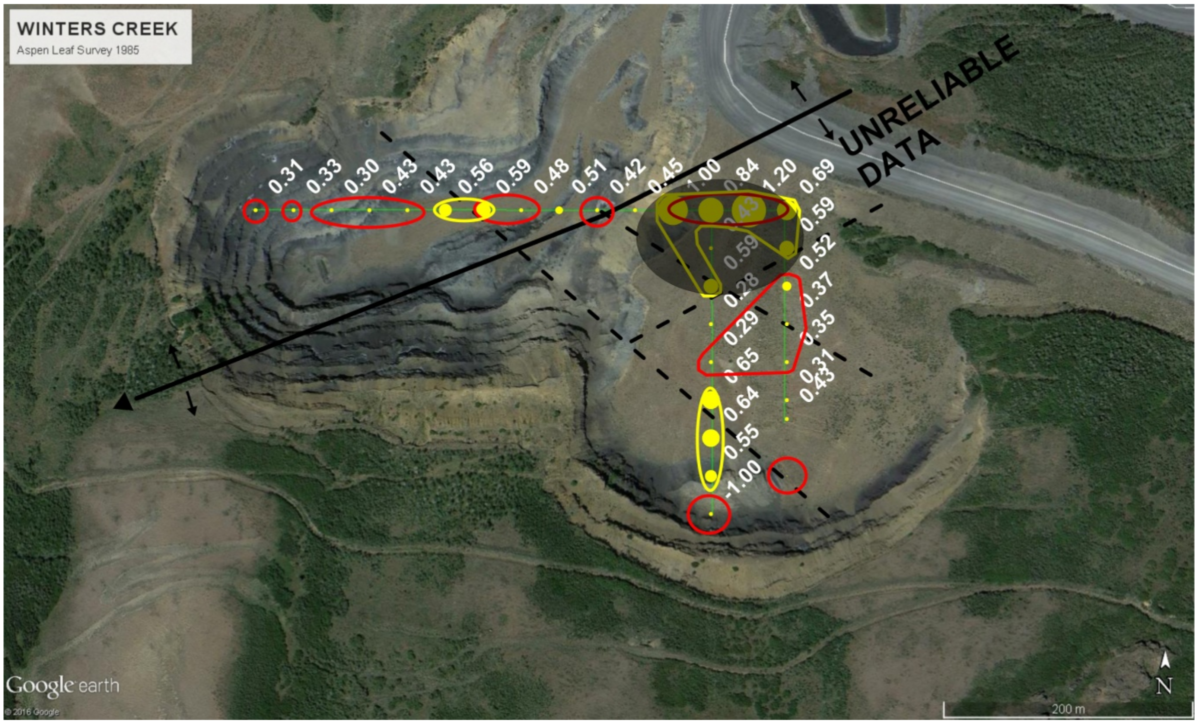
Mercury soil gas is a very reliable pathfinder to Winters Creek ore. The anomalous pattern is not affected by dust contamination and spillage near the haul road, nor dust from drilling.

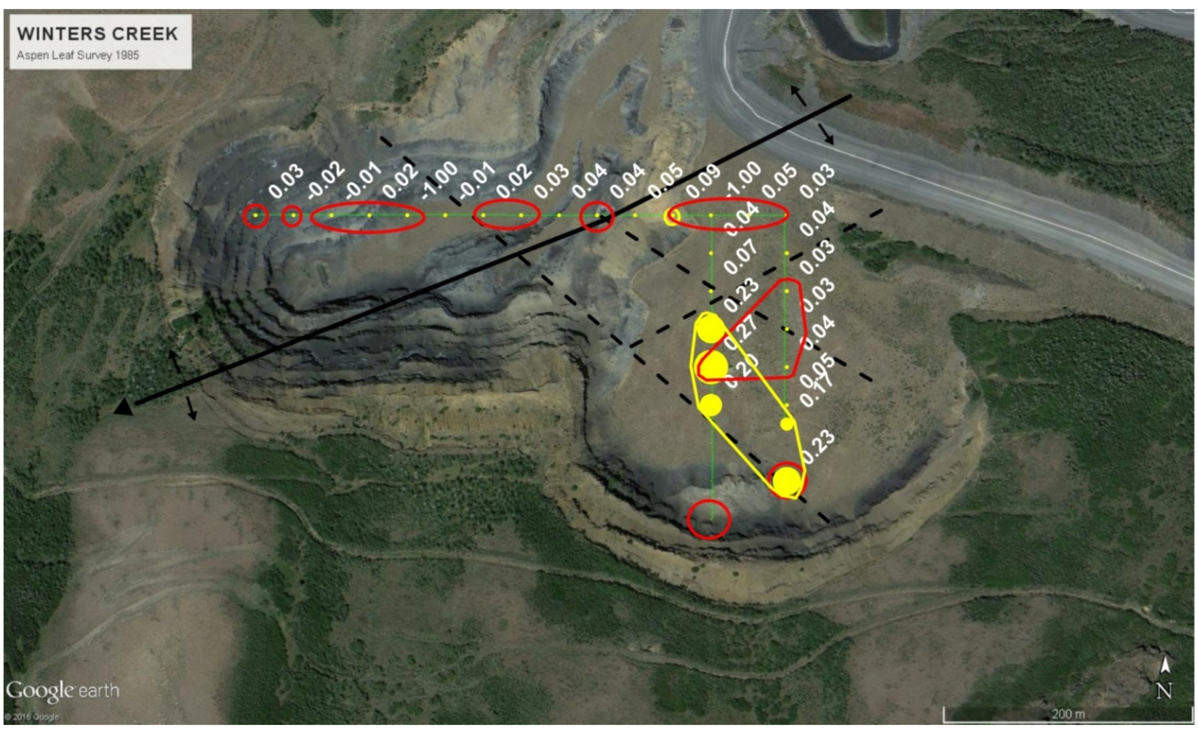
Barium stands alone, displaying a pattern that is perhaps related to mineralized jasperoid and / or unmapped upper plate Snow Canyon Formation. The barium pattern may also be associated with oxidized ore.



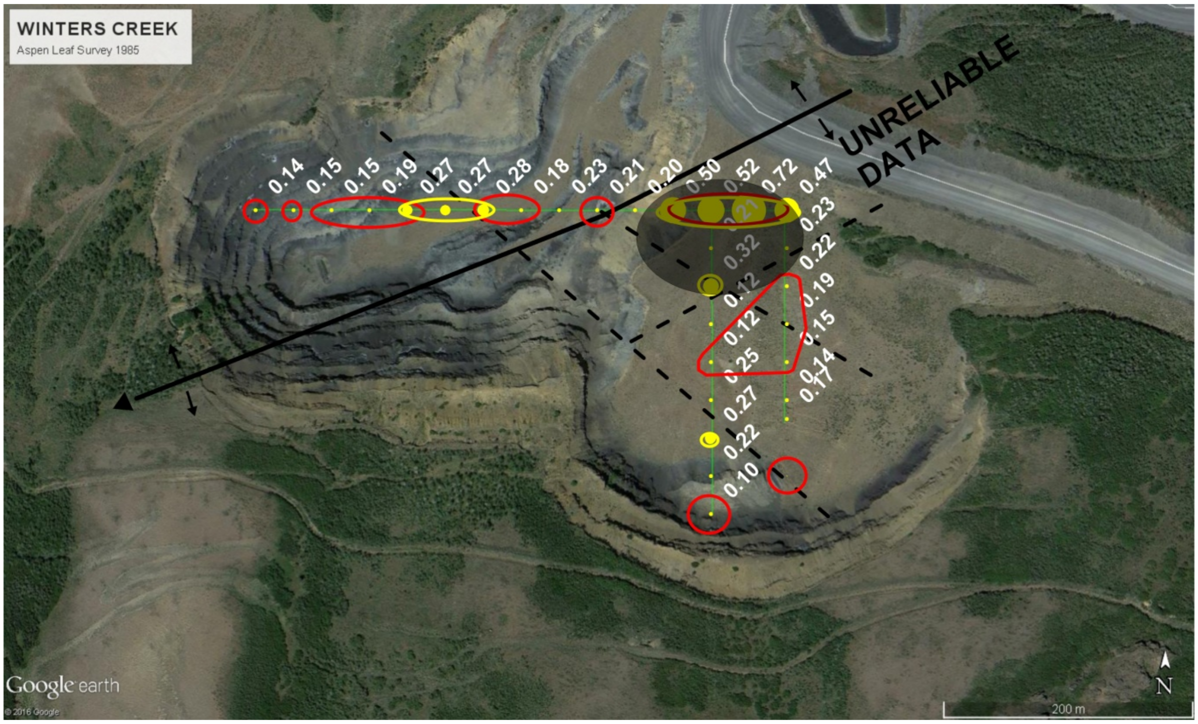


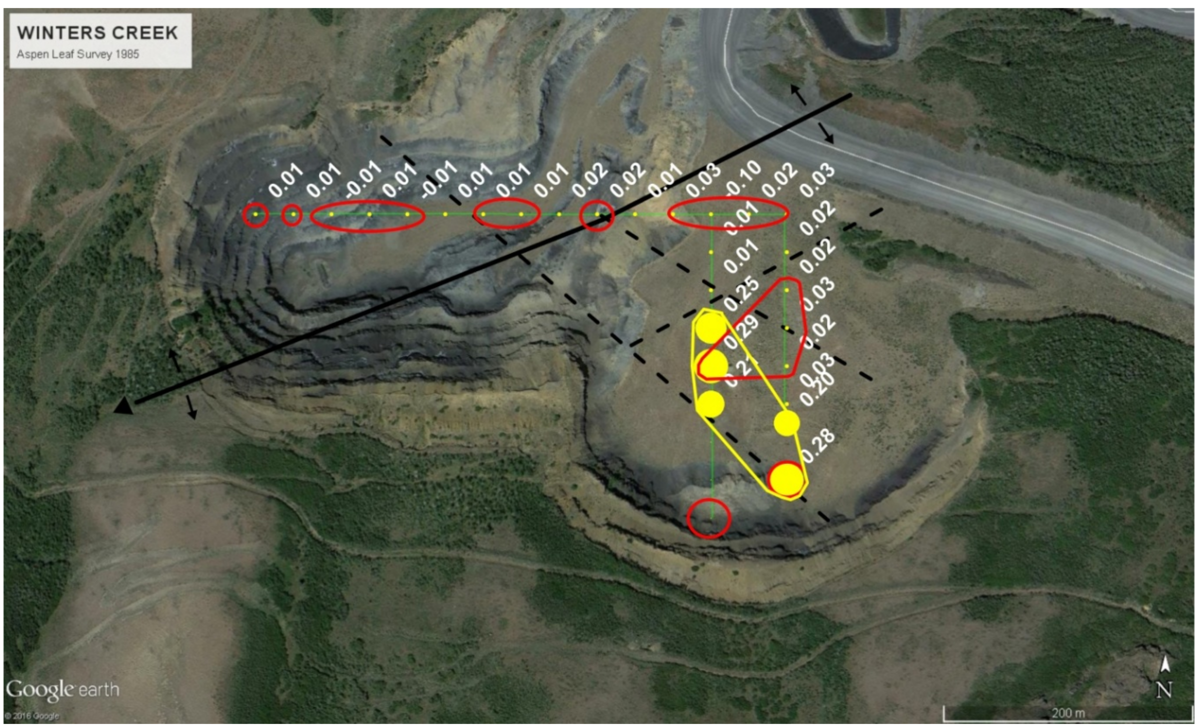
Figs 6 & 7. Gold concentrations (ppb) in leaves (top) and twigs (bottom). Leaf concentrations of gold are generally higher, but in this study, dust contamination from the haul road may be seriously compromised the integrity of these data. Anomalies on the E-W line cannot be fully trusted. However, anomalies on the N-S lines form a concise pattern that seems to relate to ore.



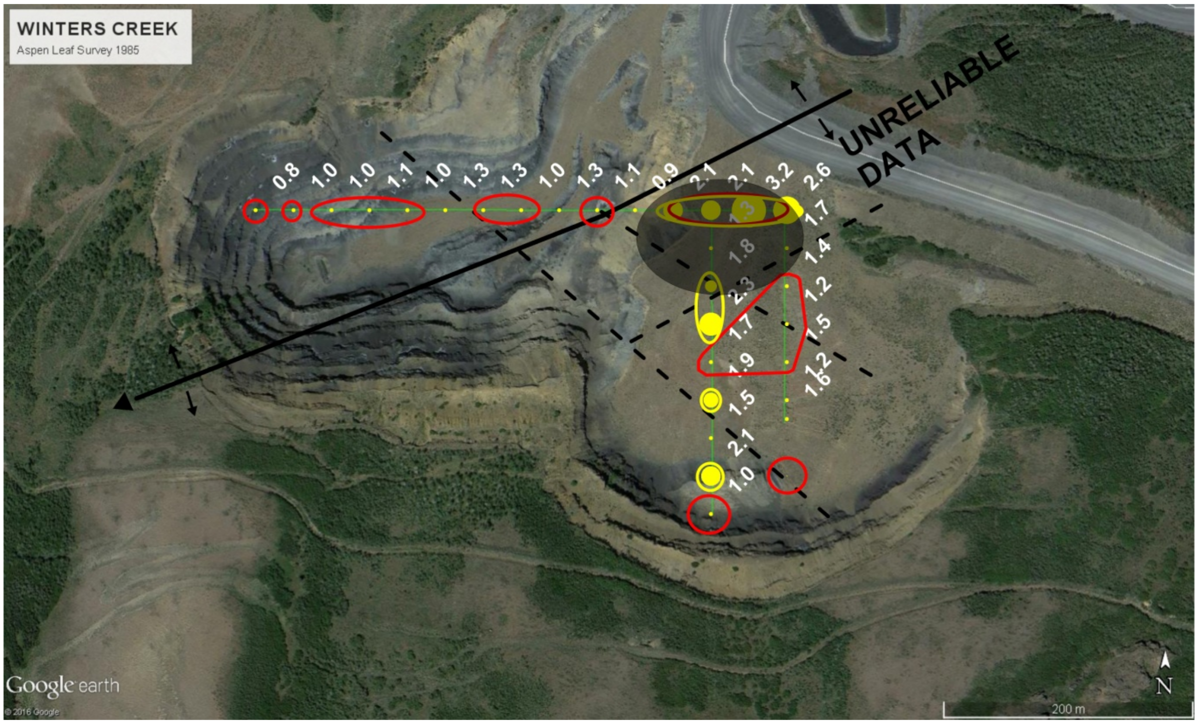


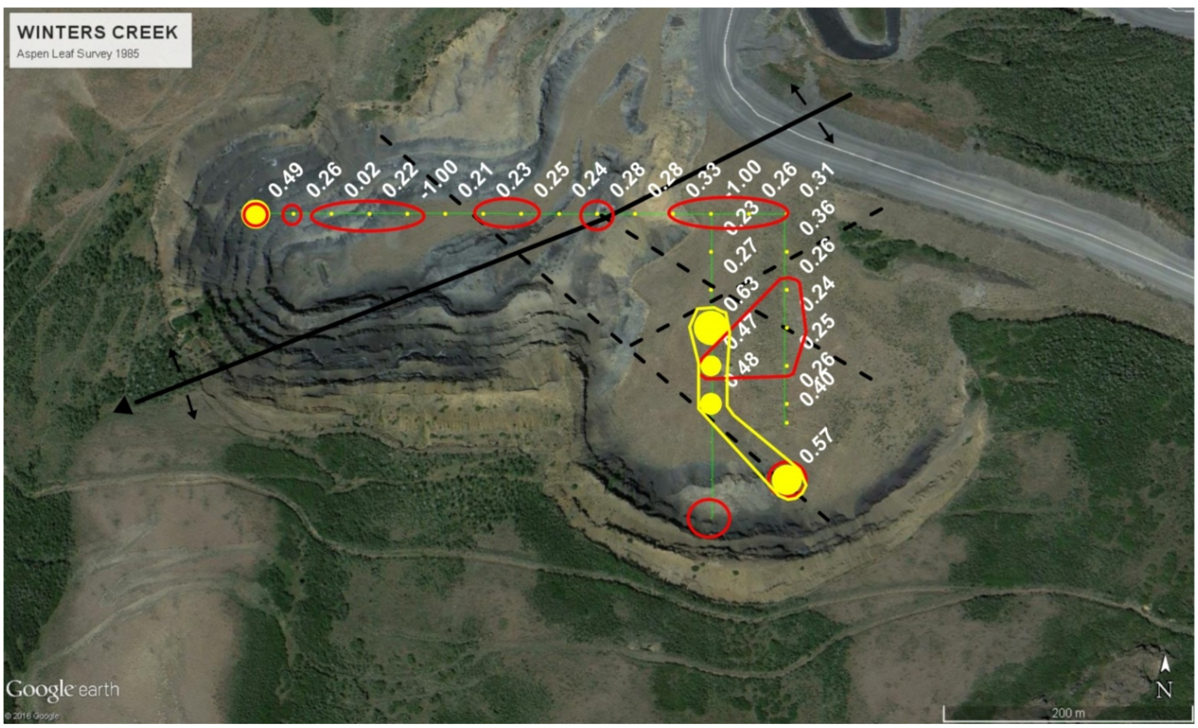
Figs 8 & 9. Arsenic concentrations (ppm) in leaves (top) and twigs (bottom). Arsenic anomalies appear to halo gold anomalies (red) where the data are reliable (away from the haul road).



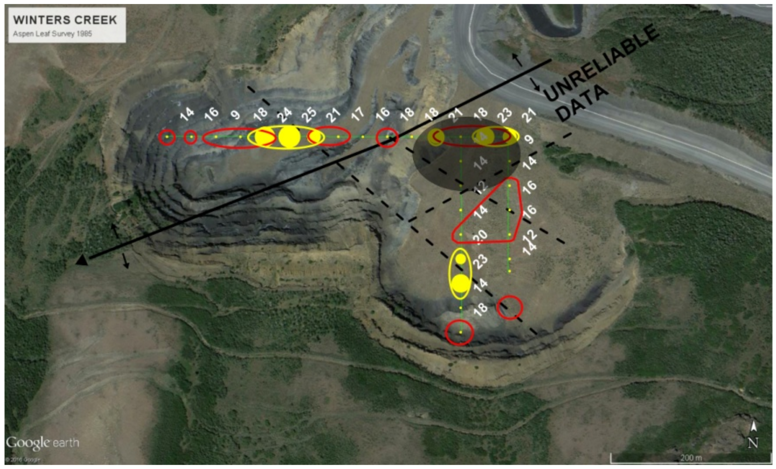


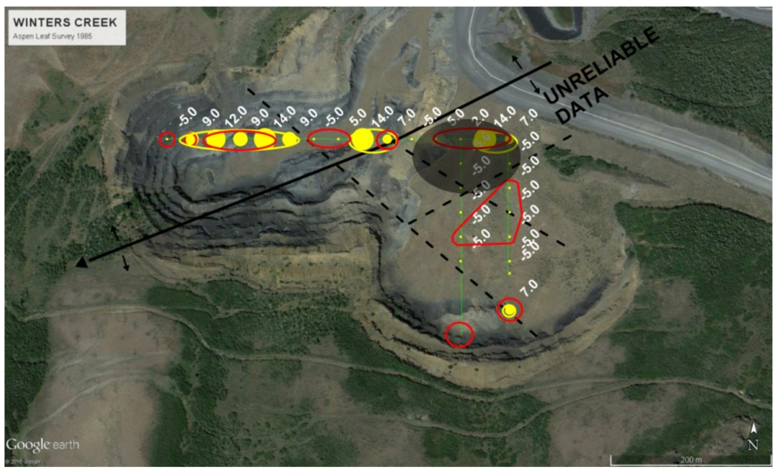
Figs 10 & 11. Antimony concentrations (ppm) in leaves (top) and twigs (bottom). Antimony anomalies appear to halo gold anomalies (red) where the data are reliable (away from the haul road). Stibnite mineralization is late in ore genesis at Jerritt and likely identifies jasperoid occurrences.

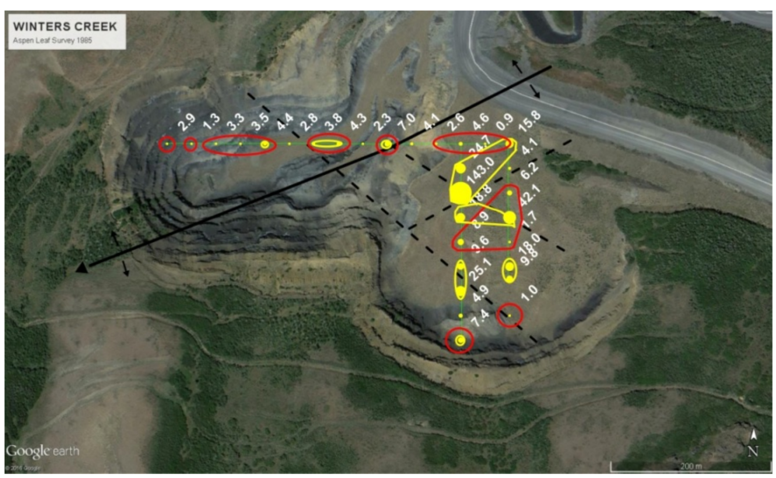




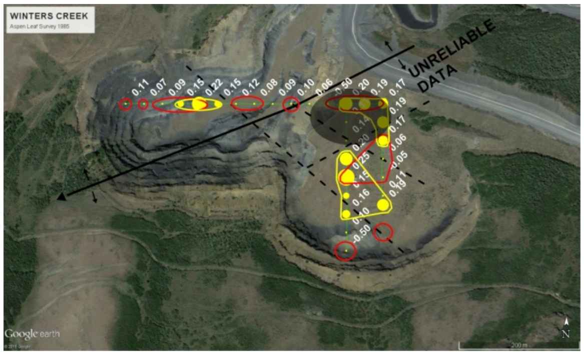
Figs 12 & 13. Bromine concentrations (ppm) in leaves (top) and twigs (bottom). Bromine anomalies appear to halo gold anomalies (red) where the data are reliable (away from the haul road). Br is highly mobile and a good pathfinder to deep ore.

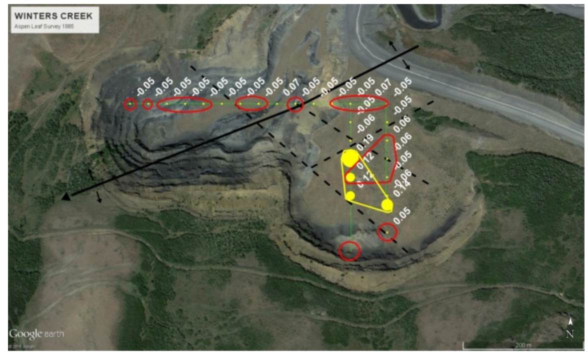




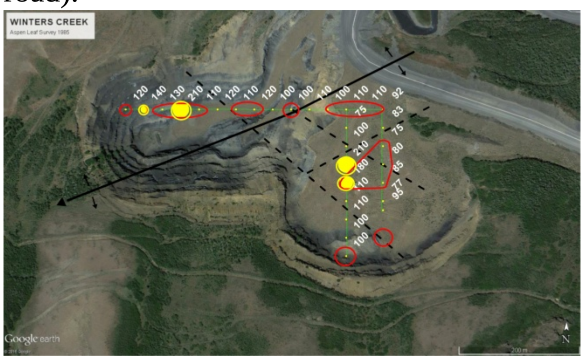


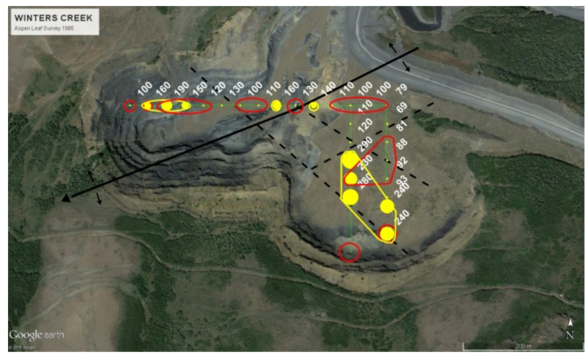
Figs 14-16. Mercury concentrations (ppb) in leaves (top) and twigs (middle). Mercury anomalies appear to halo gold anomalies (red) where the data are reliable (away from the haul road, see "Results" discussion). GASic mercury vapor from buried collectors (bottom) is considered to be a reliable indicator of buried ore.



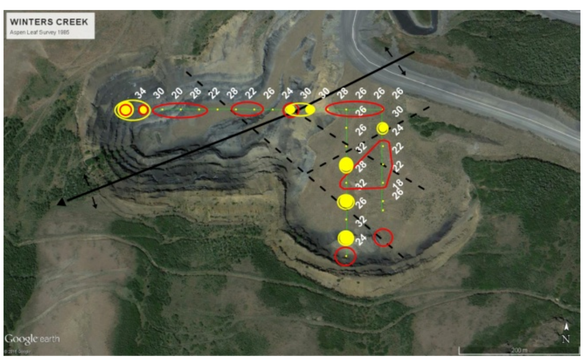


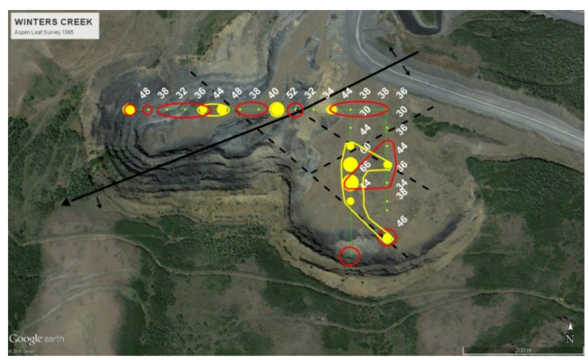
Figs 17 & 18. Molybdenum concentrations (ppm) in leaves (left) and twigs (right). Mo anomalies appear to halo gold anomalies (red) where the data are reliable (away from the haul road).



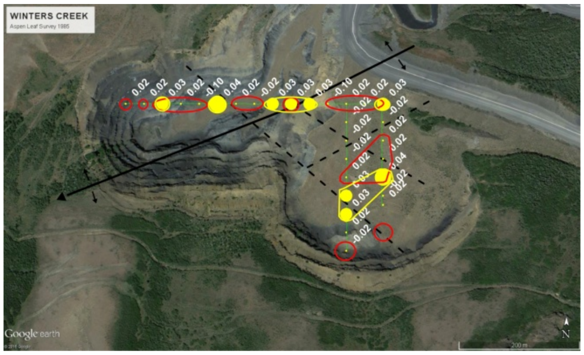


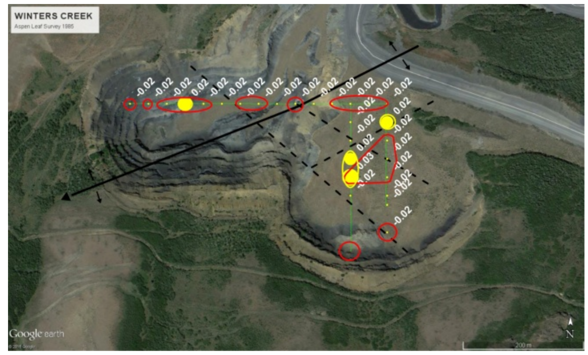
Figs 19 & 20. Copper concentrations (ppm) in leaves (left) and twigs (right). Cu anomalies appear to halo gold anomalies (red) where the data are reliable (away from the haul road).



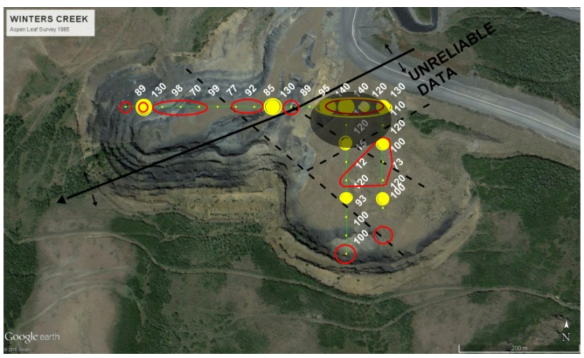


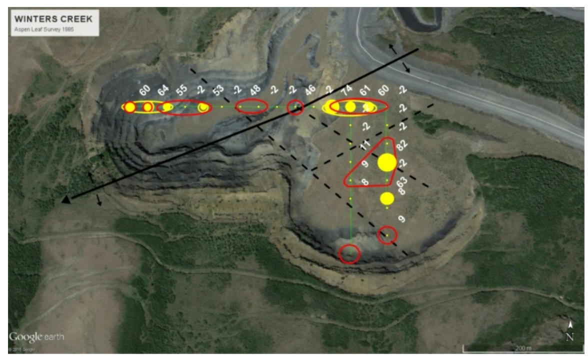
Figs 21 & 22. Lead concentrations (ppm) in leaves (left) and twigs (right). Cu anomalies appear to halo gold anomalies (red) where the data are reliable (away from the haul road).



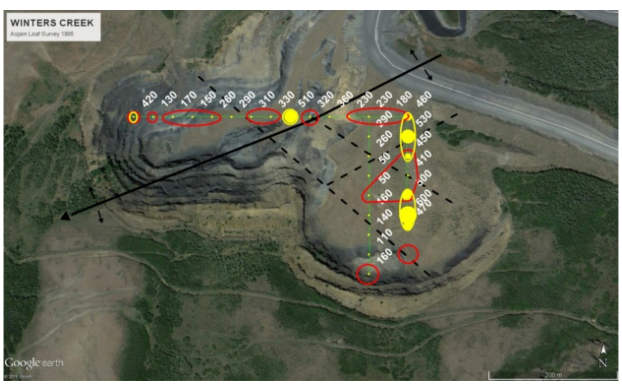


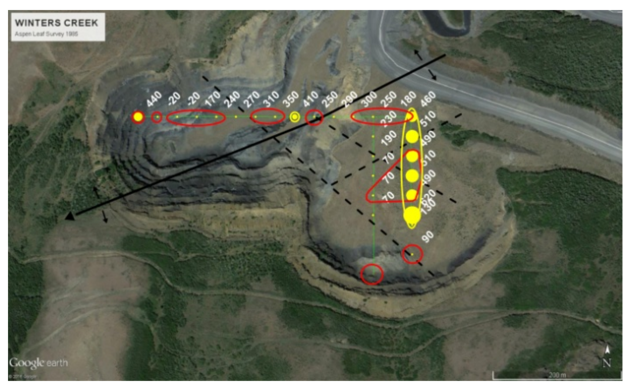
Figs 23 & 24. Uranium concentrations (ppm) in leaves (left) and twigs (right). U anomalies appear to halo gold anomalies (red) where the data are reliable (away from the haul road).





Figs 25 & 26. Zinc concentrations (ppm) in leaves (left) and twigs (right). U anomalies appear to halo gold anomalies (red) where the data are reliable (away from the haul road).





Figs 27 & 28. Barium concentrations (ppm) in leaves (left) and twigs (right). Ba anomalies appear to not be influenced by contamination from the haul road. Possibly the barium pattern is an indication of oxidized ore and jasperoid. Note that Ba concentrations in twig tissue are generally higher than in leaf tissue, suggesting different biochemical compartmentalization than other metals.

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