

BIOGEOCHEMISTRY

Discovery Using Metal Concentrations in Plants

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Mule Canyon Mine

Introduction

Mule Canyon was discovered in October, 1986 by Gold Fields Mining Corporation. As part of the exploration campaign, biogeochemical samples were collected after stream sediment and rock chip sampling had identified the headwaters of Mule Canyon as the source of anomalous gold and silver concentrations. Seventy-two sagebrush samples were collected from a 3600 x 1000 foot grid in August, 1986 and were sent to Neutron Activation Services (Ann Arbor, MI) on August 23, 1986 for INA (neutron activation) analysis. Sampling was done by Darryl Killian and Andy Schumacher, under the direction of Ray Irwin.

Though biogeochemical results were reported from NAS in September, 1986 (pre-dating discovery) the data were not used to guide further exploration activity, since the rush was on to successfully drill economic mineralization and make a valid discovery. In fact, the data were not interpreted until June, 1987, nine months later.

Unlike the history at Twin Creeks, discovery at Mule Canyon was not the result of effective use of biogeochemistry. However, it is an excellent example of the method, had it been an active part of the exploration campaign.

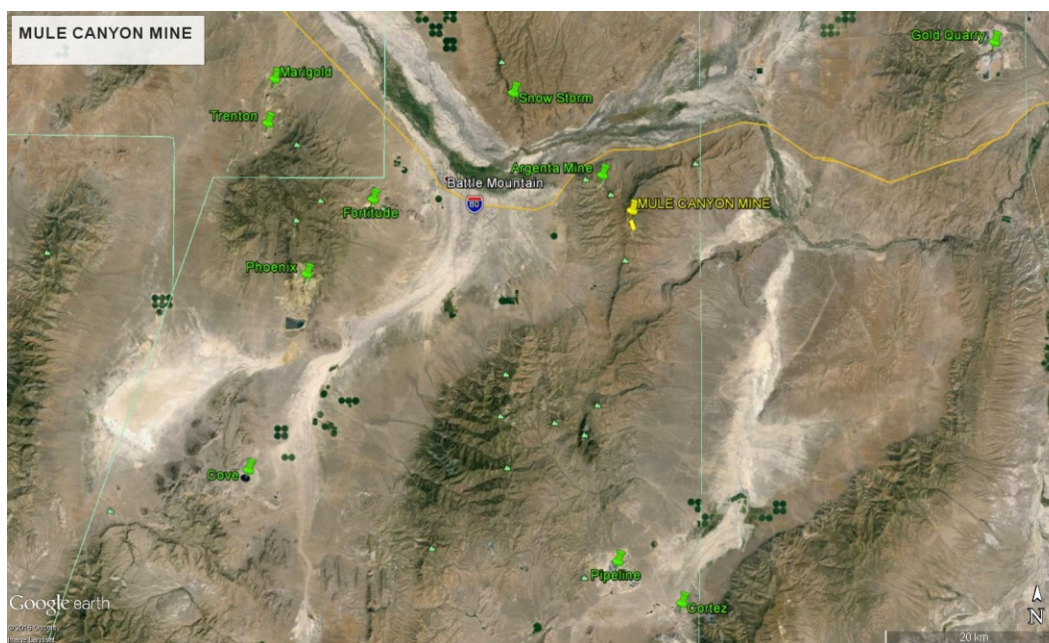


Fig 1. Location map of the Mule Canyon Mine, showing active gold mines within the Battle Mountain – Eureka Trend (including Pipeline, Cortez, Phoenix, Marigold, Cove).

Discovery History

Andy Schumacher is credited with the discovery of ore at Mule Canyon while working for Gold Fields Mining Corporation (GFMC) in October, 1986. He was familiar with the area where he had previously conducted stream sediment and rock chip surveys for Mapco. As a result, Mapco found the Elder Creek gold deposit (60K ounces of gold), and located uneconomic mineralization in Slaven Canyon. GFMC recognized Andy's valuable experience, hired him from Mapco, and expanded his exploration work into both sediment and volcanic terrains. GFMC kept him in the Northern Shoshone Range, known for the Northern Nevada Rift and several associated gold occurrences (Buckhorn, Rock Creek, Fire Creek, and others).

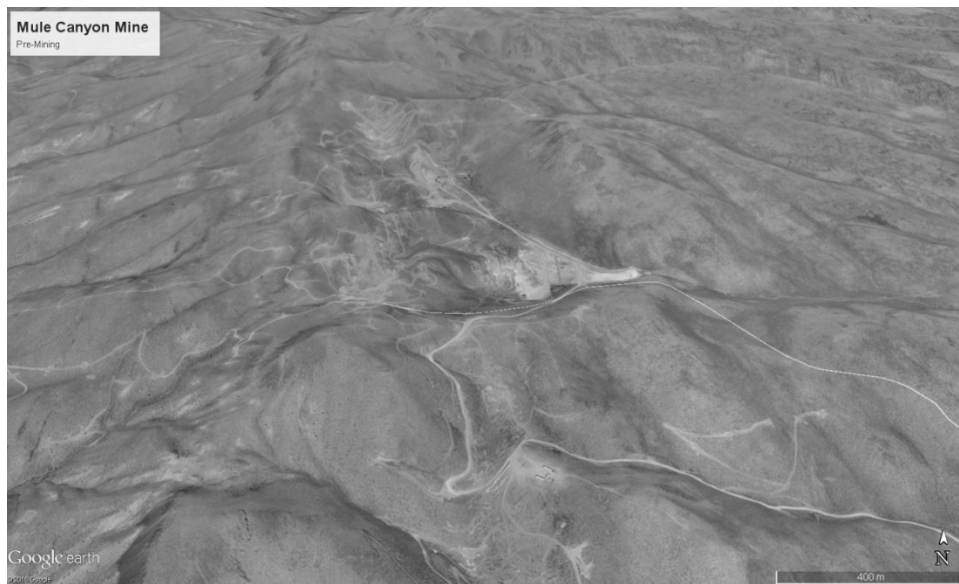


Fig 2. Pre-mining view of the Mule Canyon Mine.

Reconnaissance sample results were reported in late July 1986, from which an anomalous gold value in stream sediment from the Mule Canyon area reported 20 ppb Au. In addition, a volcanic float sample, containing quartz veins, collected from the same location, assayed 3400 ppb gold. By the end of August, 1986, significant soil and float alteration had been located at the headwaters of the drainage in an area measuring 100 x 200 feet. Fourteen rock samples from the area returned 7 values over 0.10 oz/T gold, with one over 1.0 oz/T gold + 20 oz/T silver. All had elevated arsenic, antimony, and mercury.

The discovery hole was drilled in October, 1986. It was a vertical hole collared on a small silicified knob in the Main Gold Zone. To a depth of 135 feet, the average gold concentration was 0.721 oz/T.

Four separate yet discontinuous areas of economic mineralization were initially discovered: Main, East, Ashcroft, and the North Gold Zones. A short time later, an aerial reconnaissance of the area resulted in the discovery of an altered area that developed into the discovery of the South Gold Zone.

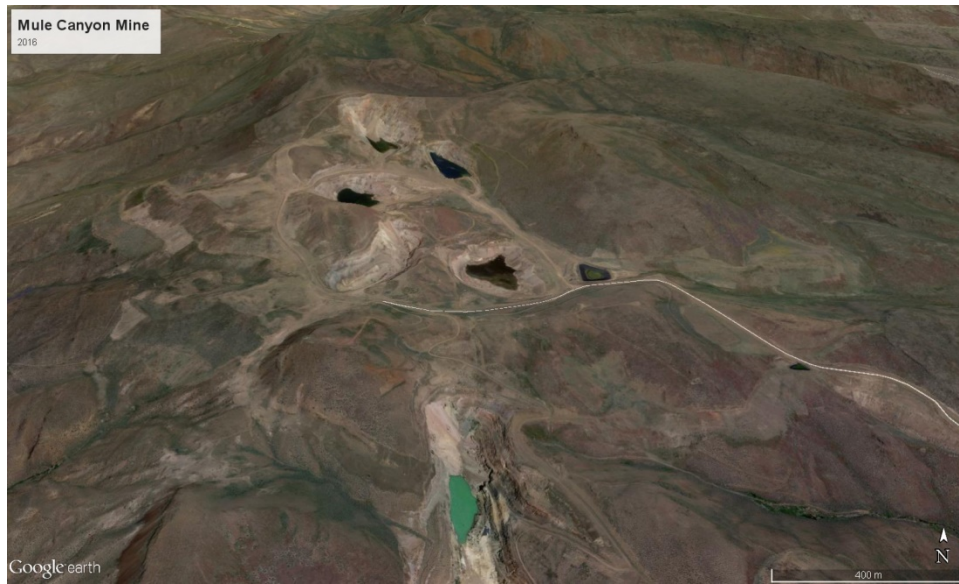


Fig 3. Current view (2015) of the Mule Canyon Mine, showing five economic deposits.

Biogeochemical Survey

Sagebrush samples (leaves and twigs) were shipped to Neutron Activation Services (NAS) on August 23, 1986. Sample preparation simply 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 hydrothermal gold systems. Results from this early survey included relatively high gold concentrations ranging from 1 – 8 ppb (median about 1.5). No concentrations of gold were less than 0.5 ppb, which is uncommon in Nevada. This indicates that the sagebrush may have been flowering, which elevates all metal concentrations, since flowers are known to have much higher concentrations than corresponding leaves or twigs. Elevated metal concentrations may also result from inorganic dust from mineral alteration of soil and rock. Since the samples were not washed prior to preparation and analysis, pollen and/or detritus may account for these generally elevated metal concentrations. Despite these issues, patterns in the data were independent of known surface metal influences. Rather, the biogeochemical patterns seemed to be more indicative of subsurface (blind) structure and blind mineralization.

As a test, a suite of 11 samples were resubmitted in March, 1987 after the samples had been washed at MEG (Carson City, NV). NAS reported generally lower INAA concentrations of Au, Ba, Br, Cr, Fe by a factor of about 2x. However, As values were 10x lower after washing. These results were validated by data from another lab that was developing a new ICP method at the time, where 30 grams of tissue were ashed, then digested in aqua regia followed by MIBK organic extraction.

Arsenic loads in pollen can be as much as 10x higher than corresponding leaf and twig, so it is suspected that indeed the plants were flowering at the time of collection. This did not, however, adversely interfere with a valid interpretation, which accurately identified major faults, offsets, and mineralization.



Fig 2. Pre-mining view of the Mule Canyon Mine, showing the pre-mining biogeochemical survey area (1986).



Fig 3. Current view (2015) of the Mule Canyon Mine, showing the pre-mining biogeochemical survey area (1986).

Biogeochemical Interpretation

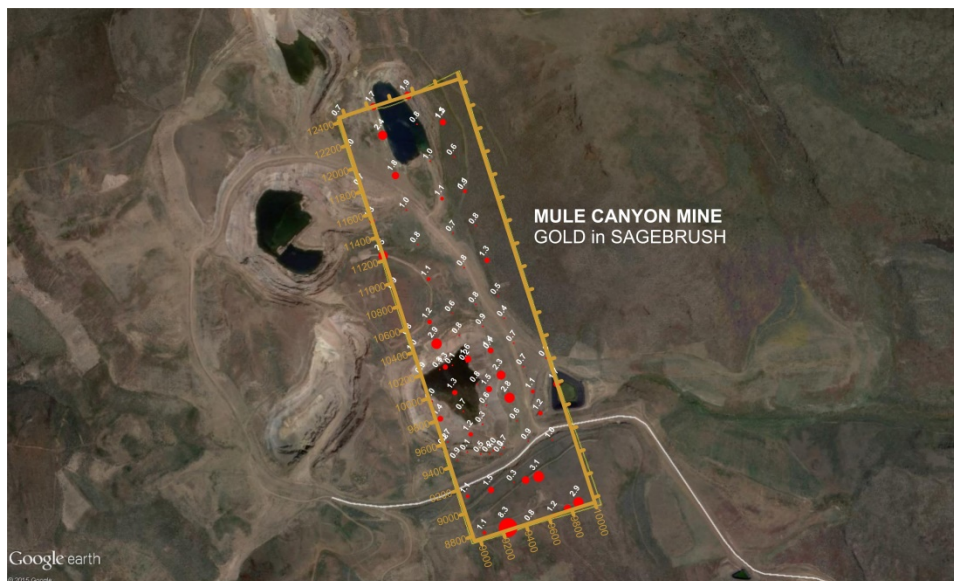


Fig 4. Current view (2015) of the Mule Canyon Mine, showing gold concentration in sagebrush from the pre-mining biogeochemical survey (1986).

The author was asked to interpret Mule Canyon biogeochemical data nine months after the original survey data was first available (September, 1986). As a footnote, the mining group of GFMC was active with biogeochemical survey work in 1984 at Chimney Creek (now Twin Creeks) and at Mesquite (California). Roland Riddler, Ken Lovstrom, and Warren Rehn, under direction from Don Kohls may have been responsible for these very early biogeochemical surveys. The exploration group of GFMC started there biogeochemical work about a six months later.

The most effective pathfinders available for interpretation from the 1986 survey were Au, As, Sb, Ba, Br, Fe, U, and Zn. Biogeochemical metal concentrations are the result of mineral-ground water interaction. The depth at which this interaction zone is most active will determine the depth to which the method is able to locate mineralization. Current Google Earth images of Mule Canyon reveal that the water table is relatively shallow, since the pits are filled with water. At the time of the 1986 survey, a spring at the headwaters of Mule Canyon was noted on USGS maps.

Structures are identified biogeochemically by linear patterns in the data, which result from mineralized ground water that migrates to the surface into shallow root zones. Iron, barium, bromine and uranium responded well to structures, and collectively identified predominant northwest structures that are dissected by northeast sets. The northwest structures were interpreted to comprise a dip-slip component that placed ore deeper to the west, yet there appeared to be a regional dip that suggested deeper ore should lie to the southeast. Drilling later proved that mineralized structures dip to the west.

Areas of gold, arsenic and antimony anomalies more effectively relate to hydrothermal gold mineralization. These relationships are apparent on the Google Earth images where Au, As, and Sb anomalies cluster over and near mine pits.

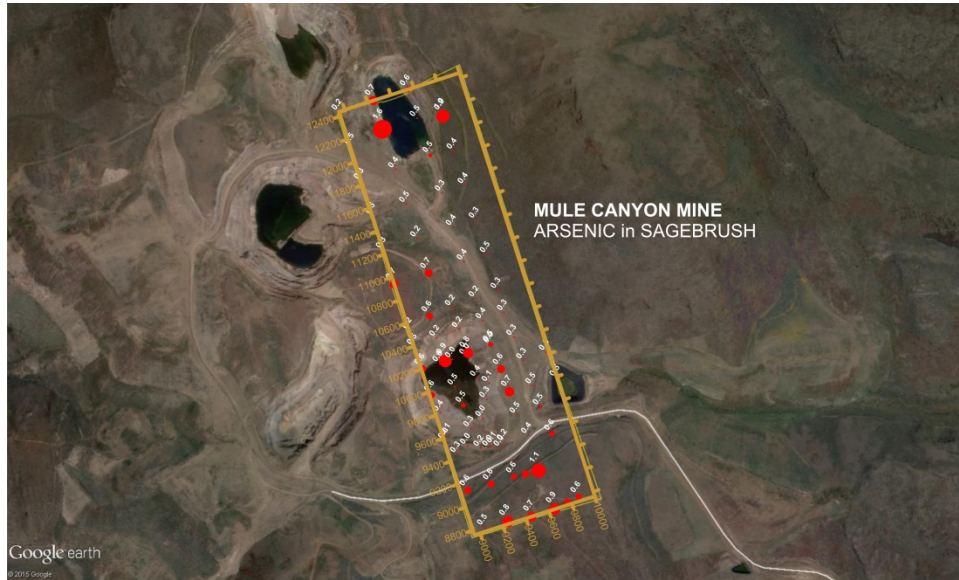


Fig 5. Current view (2015) of the Mule Canyon Mine, showing arsenic concentration in sagebrush from the pre-mining biogeochemical survey (1986).

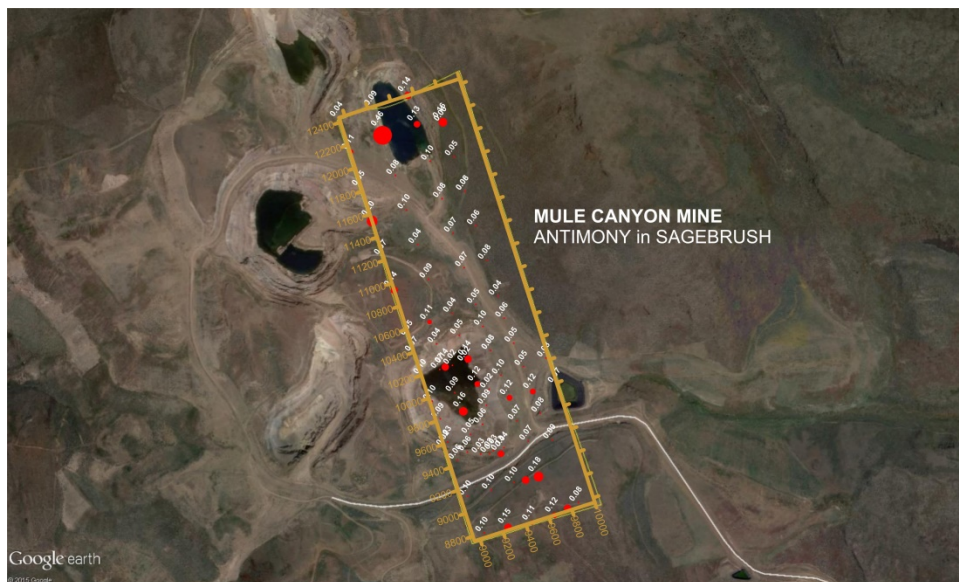


Fig 6. Current view (2015) of the Mule Canyon Mine, showing antimony concentration in sagebrush from the pre-mining biogeochemical survey (1986).

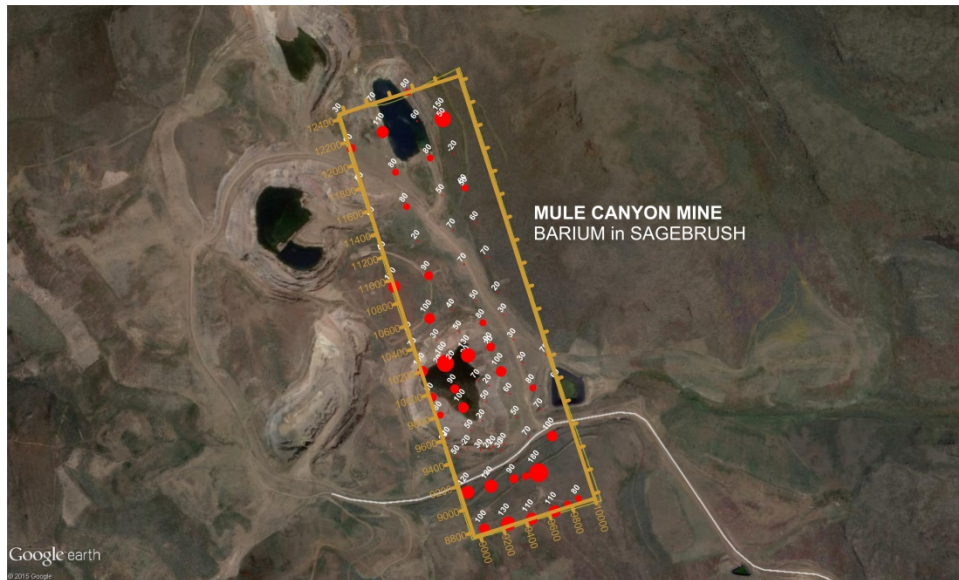


Fig 7. Current view (2015) of the Mule Canyon Mine, showing barium concentration in sagebrush from the pre-mining biogeochemical survey (1986).

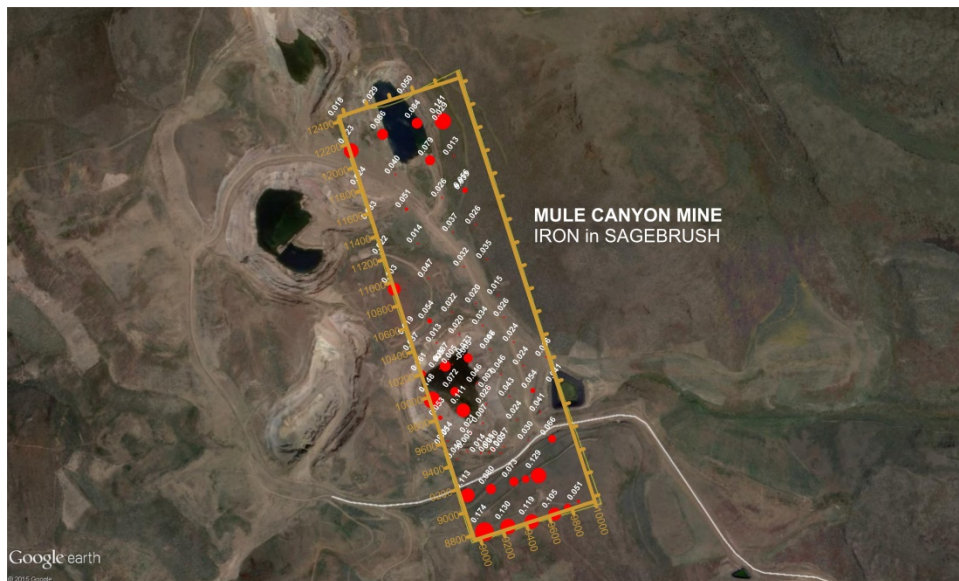


Fig 8. Current view (2015) of the Mule Canyon Mine, showing iron concentration in sagebrush from the pre-mining biogeochemical survey (1986).

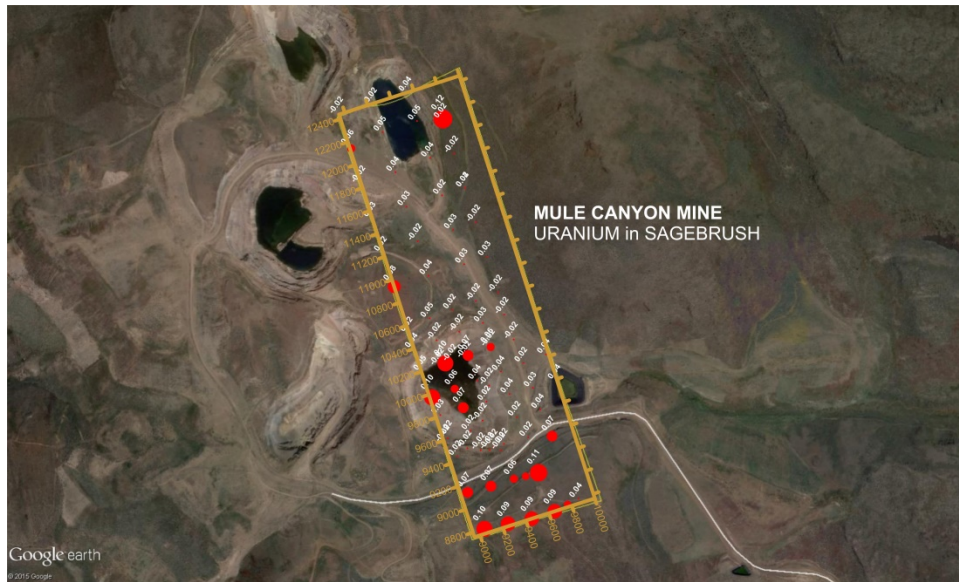


Fig 9. Current view (2015) of the Mule Canyon Mine, showing uranium concentration in sagebrush from the pre-mining biogeochemical survey (1986).