BIOGEOCHEMISTRY
Discovery Using Metal Concentrations in Plants

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Presented at the annual meeting of the Society of Economic Geologists, 2003.
Additional information added January 20, 2016.

Twin Creeks Mine

The Twin Creeks deposit is hosted by black calcareous shales, siltstones, cherts, and basaltic hydroclastic tuffs of Early Ordovician age Comus Formation. Igneous rocks include sills and lava flows of basalts of tholeiitic-to-alkalic composition, and at least one sill of ultramafic composition. The rocks have been hydrothermally altered, including decalcification, silicification, dolomitization, and minor sericitization. The ore contains very high concentrations of As (avg. 5600 ppm, max 38.5 wt%), Sb (avg. 763, max 2.2 wt%), Hg (avg. 25 ppm, max 0.1 wt%, and a high Au/Ag ratio (>10:1). The deposit occurs within a north-south trending belt of gold mineralization that is at least 5.6 Km long and 300-450 m wide. It appears to be localized by a major, deep-seated structural zone ("suture"), and by favorable calcareous lithologies within a major north-west trending overturned anticline. The deposit is concealed under coalescing alluvial material consisting of three lithologic units. The lower unit is thin and discontinuous, composed of gravel containing chert, siltstone, shale and altered basalt. The middle unit is the most voluminous and composed of limestone gravel. The upper unit is fluvially reworked, wind-blown loess up to 7 m thick. Total overburden thickness is 12-200 m over the mine area. (Bloomstein, 1991).

Fig 22a. Pre-mining view of Twin Creek (1985).

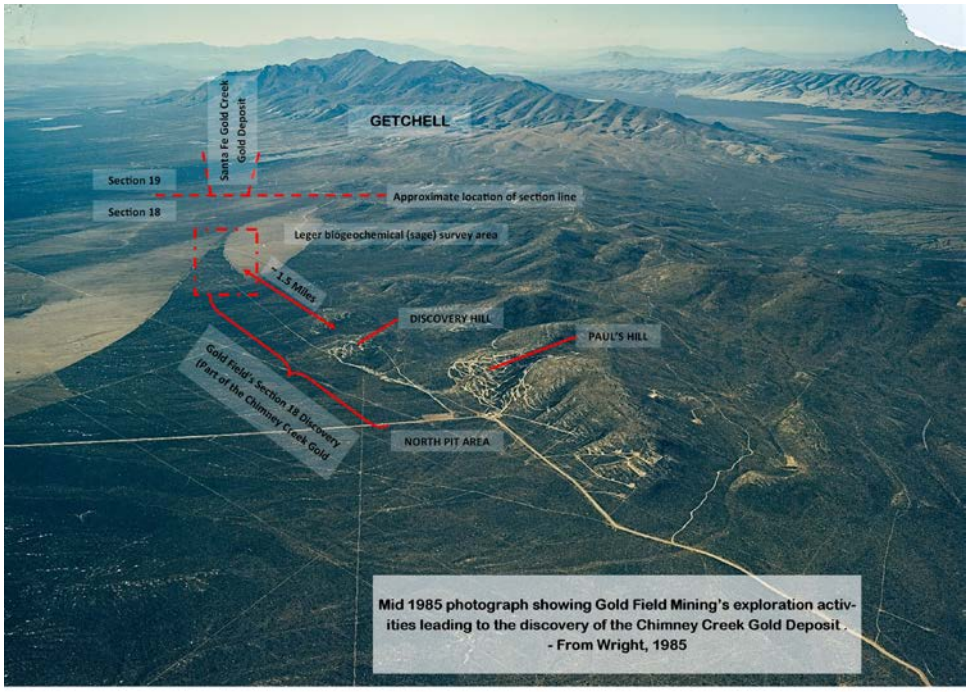

Fig 22b. Pre-mining view of Twin Creeks (1985), showing discovery location and biogeochemical survey area, relative to other landmarks (pers comm. A. Leger)

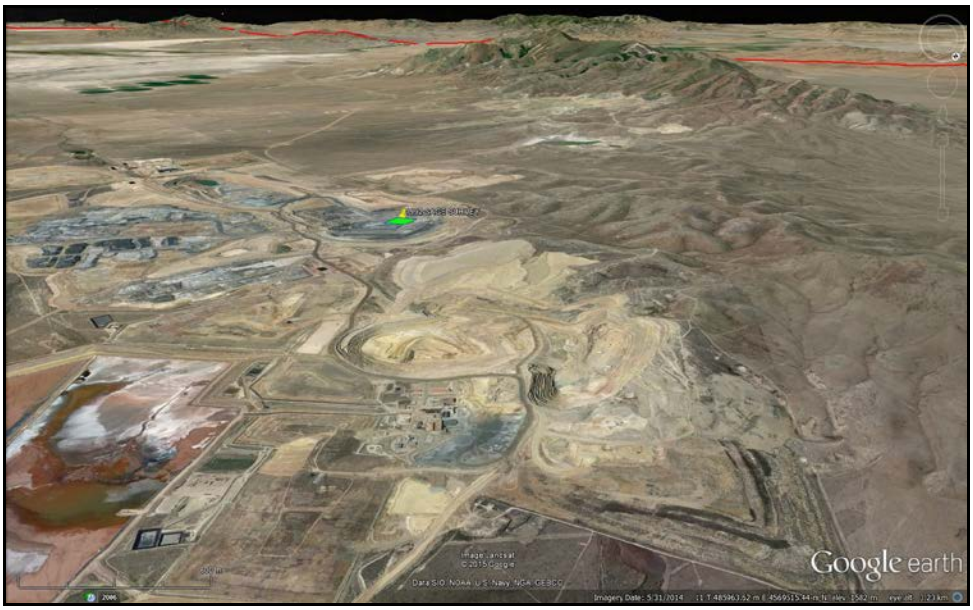

Fig 22c. Location of biogeochemical survey (green) relative to GE image (2015), showing Twin Creeks mine development.

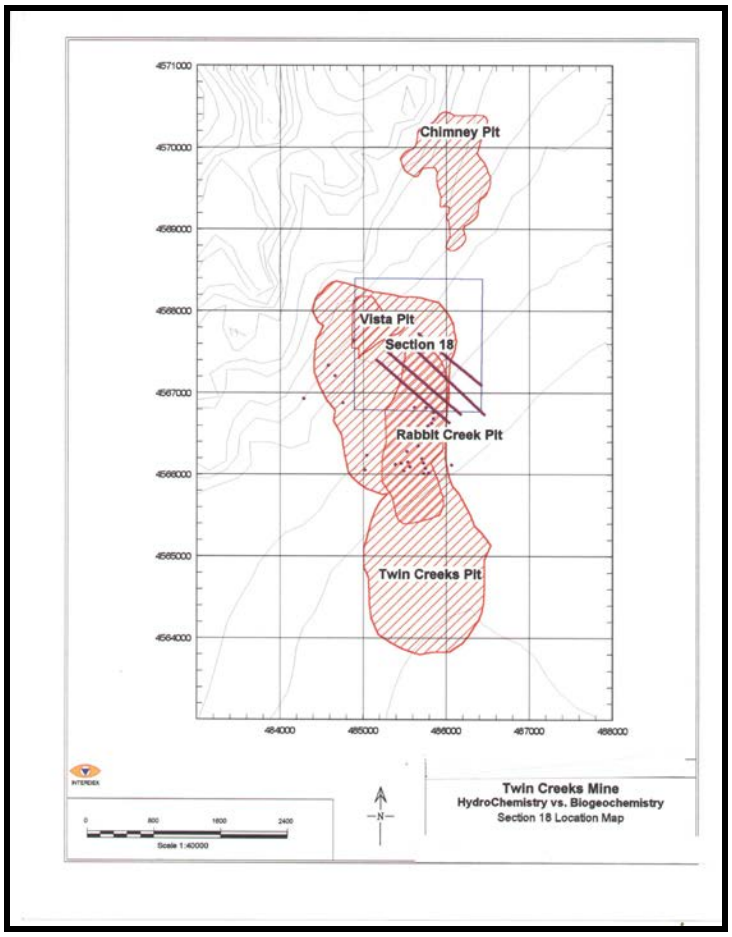

Figure 22. Location map of the 1985 sagebrush survey (four lines) relative to ore deposits of the Twin Creeks Mine. Small dots are the locations of monitor wells.

While Gold Fields Mining Corporation was developing the Chimney Creek deposit and exploring the mineral potential around the recently discovered Vista deposit in Section 18, one of their geologists, Aldo Gambardella, did a sagebrush survey of that Section in 1984. Once the results were in, there was immediate concern about influences from the Getchell Plume (an area of arsenic contamination down wind (northeast) from the Getchell roaster) that is visible in Landsat imagery. Despite significant overprinting from the plume, an anomaly was recognized and drilled, which led to the discovery of the South deposit. In May of 1986, Santa Fe Pacific Mining geologists began exploration in the area, and in July, exploratory drilling began south of Section 18 (Bloomstein, 1991). The South deposit is now part of the Twin Creeks open pit mine which is the consolidation of the Vista, South, and Rabbit Creek deposits, the latter having been developed by Santa Fe Pacific Mining, Inc., prior to Newmont ownership. This history supports the notion that biogeochemistry was directly involved in the discovery of a world class gold deposit.

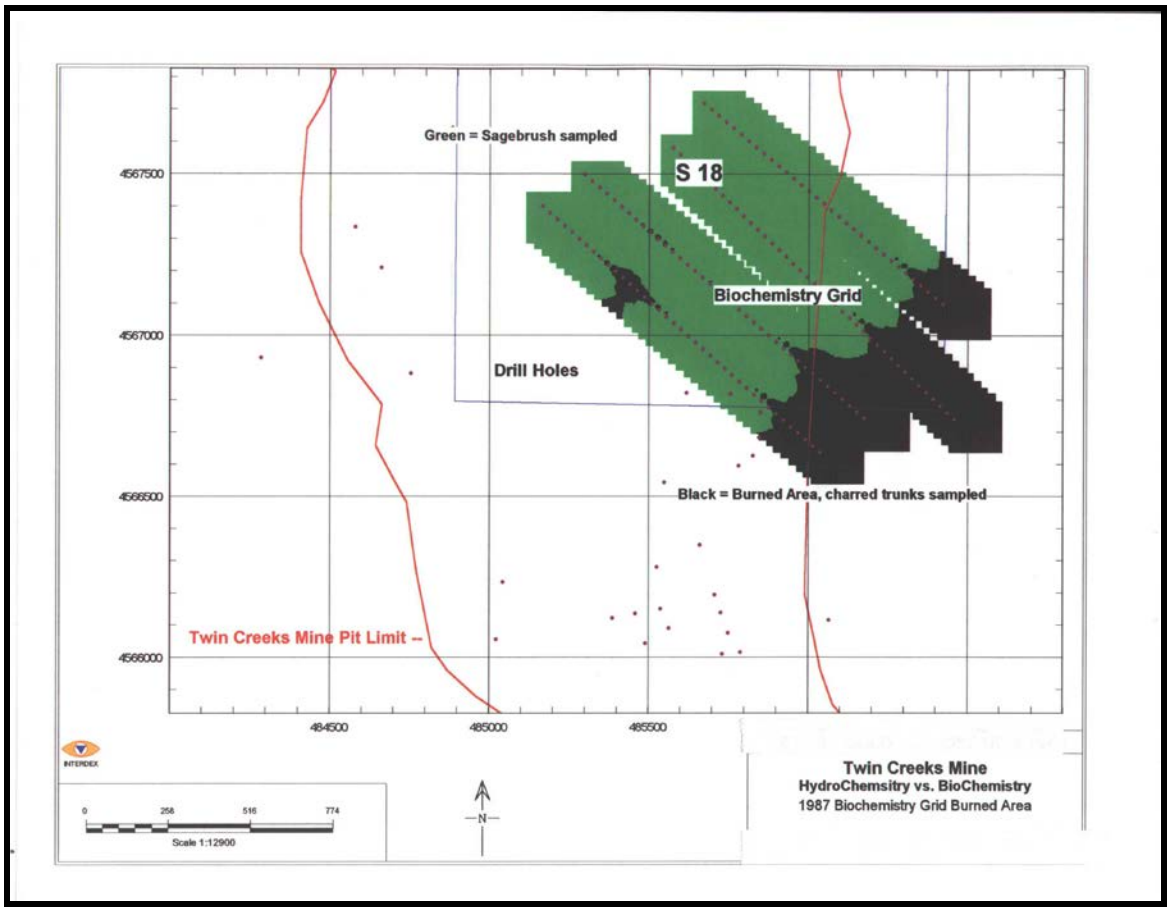

Figure 23. Location map of the 1985 biogeochemical survey (enlarged), showing the areas of living and burned sagebrush. Small dots are the locations of monitor wells. Red line is the pit margin (ca. 1998).

In 1985, Gold Fields Exploration geologists re-executed part of A. Gambardella's original survey to determine if the results could be repeated. In the meantime, a range fire had burned part of the area. Four lines over the South deposit were sampled on 30 m centers. Leaves and twigs were sampled where sagebrush had not been damaged by fire, and charred stumps were sampled elsewhere. The samples were macerated and ashed at 450^0C and analyzed by AR/GF/AAS and ICP, yet reported on a dry weight basis. Figure 22 shows the location of the 1985 survey relative to the various deposits that now comprise the Twin Creeks Pit, and Figure 23 shows the areas of living and charred sagebrush. Small dots on these maps identify monitor well locations, which provide an opportunity to discuss the relationships of ground water chemistry to trace metal accumulations in sagebrush (discussed below).

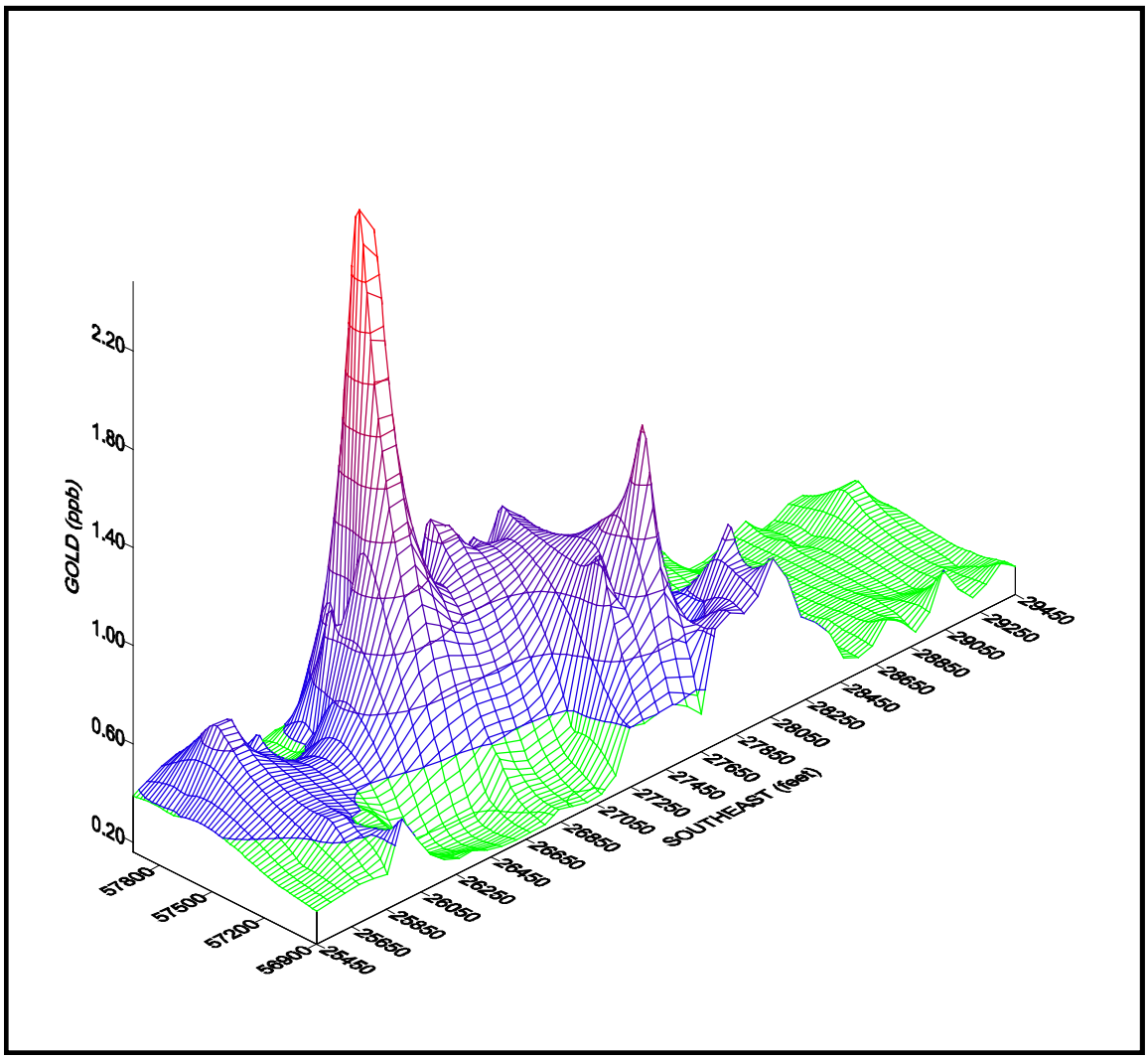

Figure 24. Gold concentrations in live and burned sagebrush over the South deposit, Twin Creeks Mine.

Fortunately, the South deposit lies almost entirely under the areas where live sagebrush material was sampled, eliminating the complication of having to deal with two sample media while determining an anomalous pattern. Gold is it's best pathfinder here, and Figure 24 shows a coherent signal to the underlying deposit. Anomalous Au concentrations in living sagebrush range from 0.5 ppb to greater than 2.5 ppb. The Sb pattern (Figure 25) is a cluster of sharp spikes over the deposit, reaching above 600 ppb, yet relatively incoherent and obviously affected by the burn. Other elements (Ag, Ga, Mo, Pb, Zn) were not particularly diagnostic, since many of these showed preferential enrichment in either the live, or the burned, sagebrush.

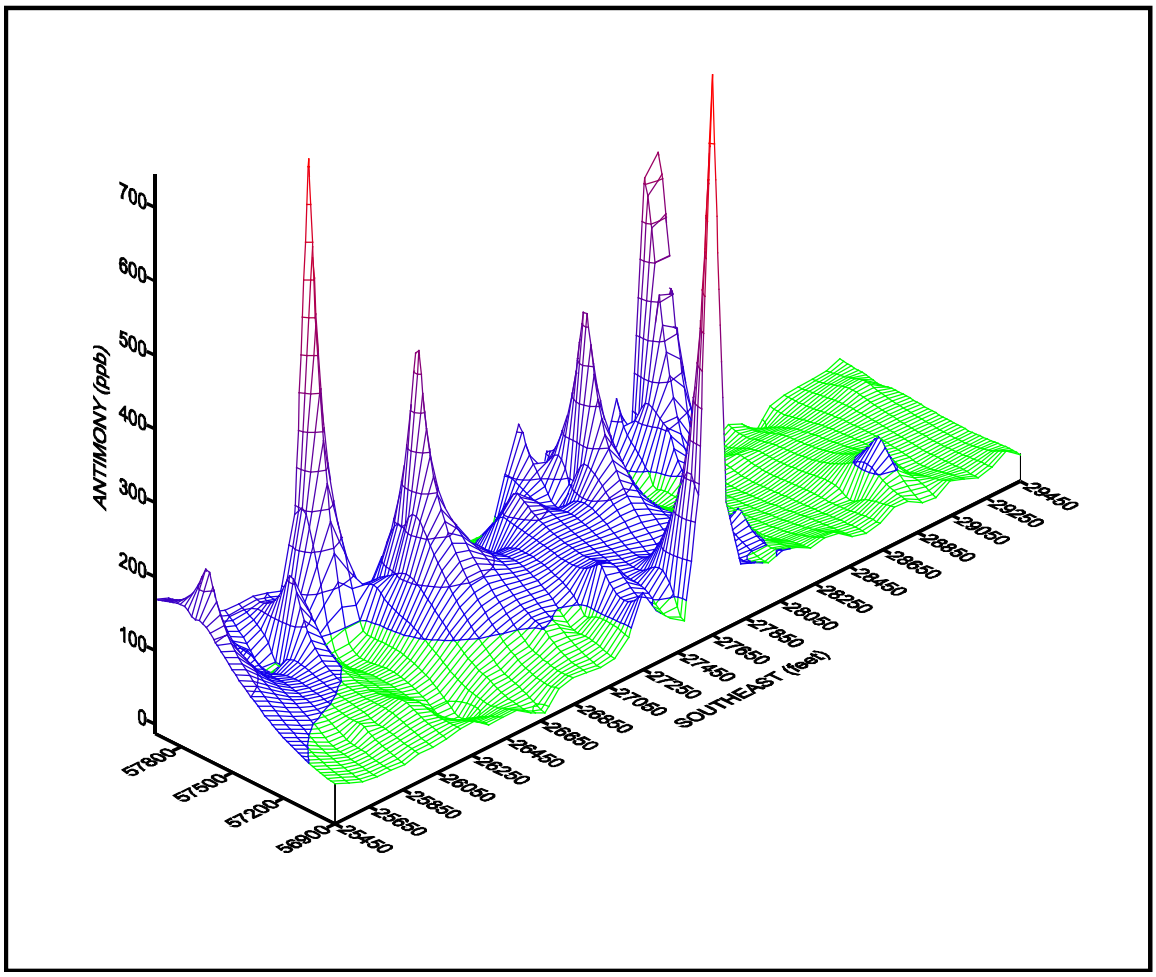

Figure 25. Antimony concentrations in live and burned sagebrush over the South deposit, Twin Creeks Mine.

There is a strong link between ground water chemistry and trace metal loads in shrubs as the result of water / rock interaction and the migration of ions to the surface, strongly influenced by evapotranspiration. Very recent work has focused on these relationships, and the Twin Creeks data provides some insight. Figure 26 is a plot of Au in sagebrush combined with Au hydrochemistry data from the monitor well field. The two data sets had to be normalized to their respective means to make one figure. The results are fairly convincing. The close relationship of Au in ground water to Au in sagebrush is demonstrated by the anomalous wells immediately southwest of the biogeochemical grid. Four wells display anomalous concentrations that continue the mineralized trend another 300 m to the south. Gold concentrations in sagebrush range from 0.2-3.8 ppb, with a mean of 0.4. Well water concentrations range from 0.001-0.82 ppb, with a mean of 0.007.

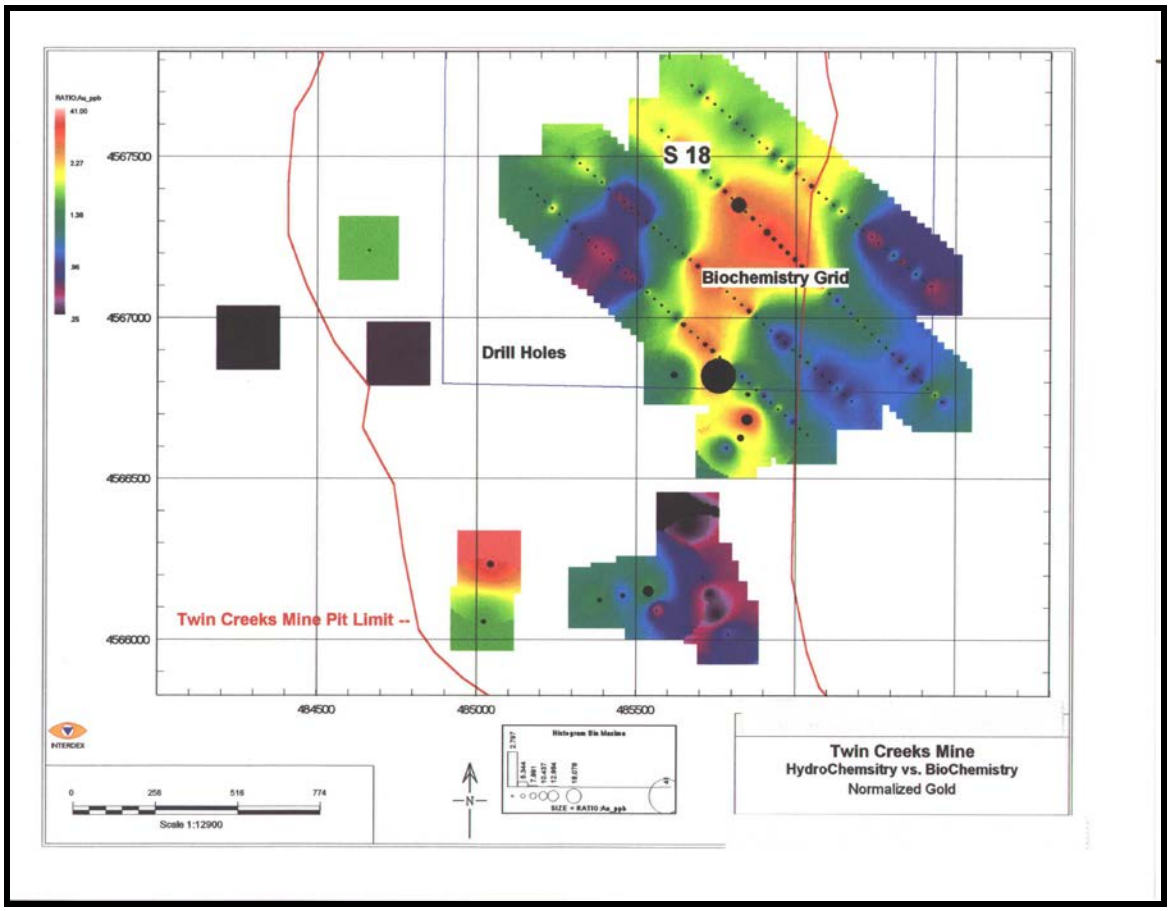

Figure 26. Gold concentrations in sagebrush (normalized) compared to gold concentrations in monitor well water (normalized) from the 1985 biogeochemical survey on Section 18 at the Twin Creeks Mine, Humboldt County, Nevada.

The biogeochemical As pattern is consistent with the gold pattern, but extends much farther into the monitor well field (Figure 27). The differences between As loads in live and burned sagebrush are less apparent, allowing several more structural patterns to appear. The distribution histogram suggests the As population is unimodal. Arsenic concentrations in sagebrush range from 350-1530 ppb, with a mean of 710 ppb. Well water concentrations range from 10-1100 ppb As with a mean of 280 ppb. It is interesting to note that the magnitude of these concentrations is similar for As in both sagebrush and ground water.

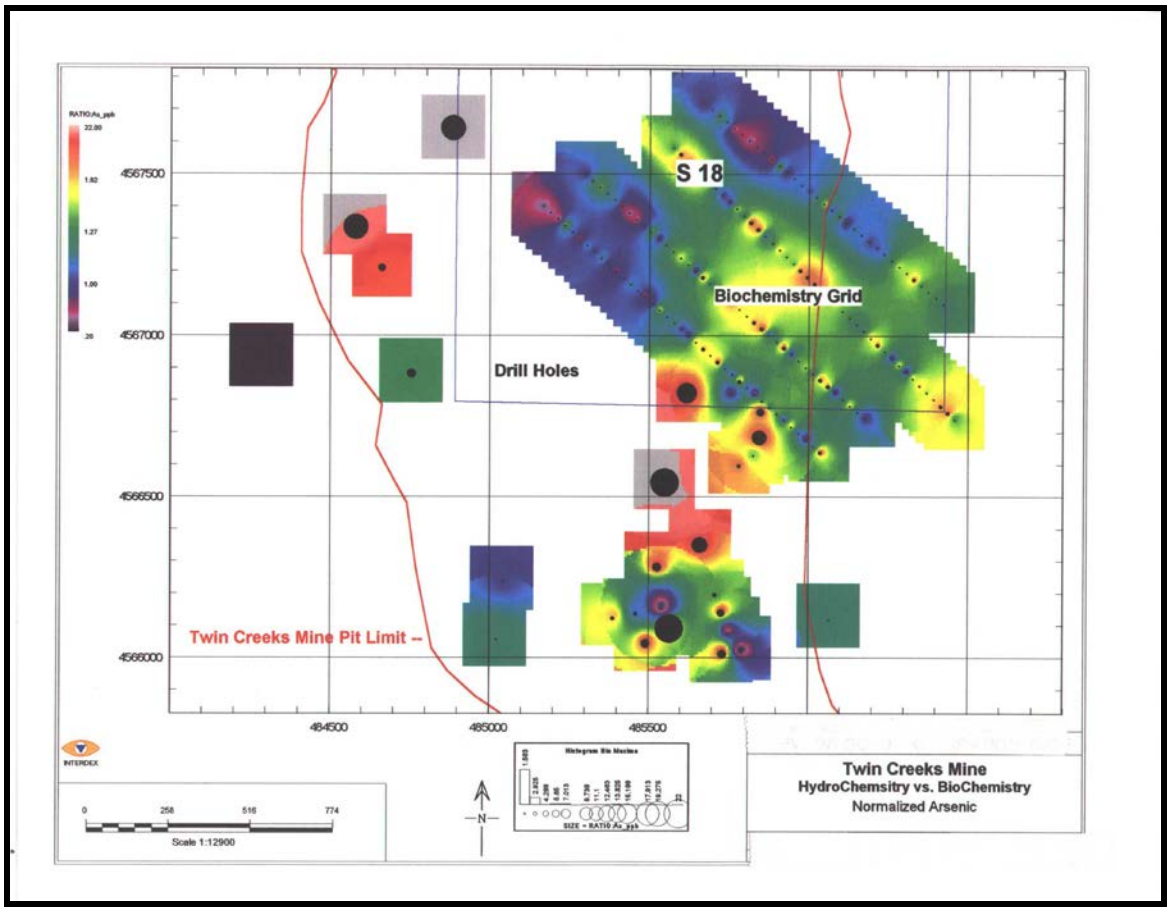

Figure 27. Arsenic concentrations in sagebrush (normalized) compared to arsenic concentrations in monitor well water (normalized) from the 1985 biogeochemical survey on Section 18 at the Twin Creeks Mine, Humboldt County, Nevada.