A Morphological and Geochemical Comparison of a Partially Reclaimed Open Mine Pit to a Similar But Undisturbed Site, Cooke City, Montana

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INTRODUCTION

This study is a comparison of an area that has been strip mined for gold and copper during the early and middle parts of this century, and then partially reclaimed within the past 2 years; and a nearby area that is quite similar but was never mined. The study area is approximately 4km north of Cooke City, Montana at 45° 4' N latitude and 109° 57' W longitude, and ranges in elevation from approximately 2860m to 3100m (Figure 1). The mined area is on the northeastern side of Fisher Mountain, and is known as the Como Pit. The unmined study area is located on the northern face of nearby Scotch Bonnet Mountain. The Como Pit lies at the head of Fisher Creek, which forms the headwaters of the Clarks Fork of the Yellowstone River, while the Scotch Bonnet site drains into Daisy Creek, which forms the headwaters of the Stillwater River (Figure 2).

The study area is a high alpine zone, and is covered by many meters of snow for much of the year. It is located approximately 5km to the east of the northeastern corner of Yellowstone National Park, 3km west of the Absaroka-Beartooth Wilderness Area, and about 6.5km north of the North Absaroka Wilderness Area. It is located on a combination of private mining claims and public lands primarily falling under the jurisdiction of the Gallatin National Forest. The area is known as the New World Mining District and has a long and colorful history of mining for many precious metals. The area is heavily used by off road vehicles in the summer and snomobilers in the winter, and is an access point for backpackers and horsepackers into the nearby wilderness areas. It harbors a great number of pikas, marmots, assorted raptors, deer, moose, and mountain goats, and is considered prime grizzly habitat. The Fisher Creek valley is also the site of the proposed Crown Butte gold mine, operated by Crown Butte, Inc., of Billings, Montana.

GOALS AND METHODS

The main goal of this study is to compare the geomorphology and geochemistry of an area that was surface mined for gold and copper and partially reclaimed, to an area that has not been mined, and is essentially undisturbed. Through this comparison, I hope to determine more specifically what sorts of effects mining can have on ecological communities. The comparison includes two major areas of study, subdivided as follows:

I.) Erosion

A.) General observation of the types of erosion features generated on a disturbed erosion surface

B.) Gully transects, measured at every 15m of elevation change, using a 50m tape and a tape measure to measure gully widths and depths

C.) Approximate calculations of sediment loss, based on gully transects and the fact that all gullies on the disturbed site were generated within the past year (the Como Pit was recontoured last year; therefore, all gullies were generated since that event)

II.) Geochemistry

A.) Water--I collected 29 surface water samples. Of these, 18 samples were taken at various elevations and locations from the Como Pit site and the drainages below it; 11 samples were collected at various elevations from the Scotch Bonnet site and the drainage below it as well. Each of the water samples was analyzed for:

1.) pH, both field and lab measured

2.) Field measurements of Conductivity, Temperature, Total Dissoloved Solids, and Dissolved Oxygen

3.) Atomic Absorption Spectometry (AAS) for metals; specifically, for iron, copper, zinc, and possibly arsenic and lead

4.) Ion Chromatography (IC) for anions, especially sulfate and chlorides

B.) Soil--I collected 67 soil samples from 21 soil pits, ranging in depth from approximately 10cm to over 1.5m deep. Of the 21 pits, 8 were located in or near the Como Pit site, while 13 were located in the Scotch Bonnet site. Observations of differences and the thicknesses of the soil horizons were recorded, and samples were then taken of each horizon for the following analyses:

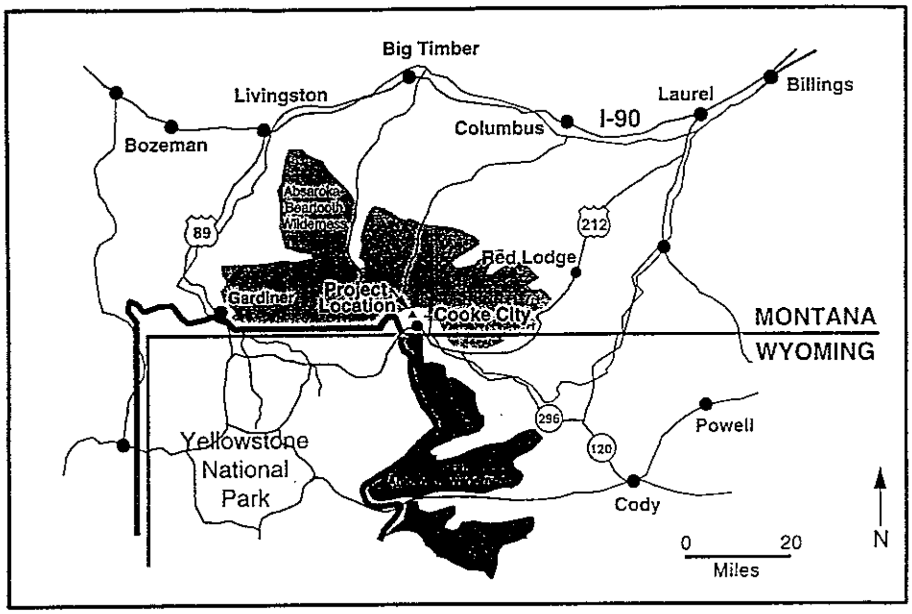

Figure 1--Project Location Map
(from Crown Butte Mines, Inc., information folder)

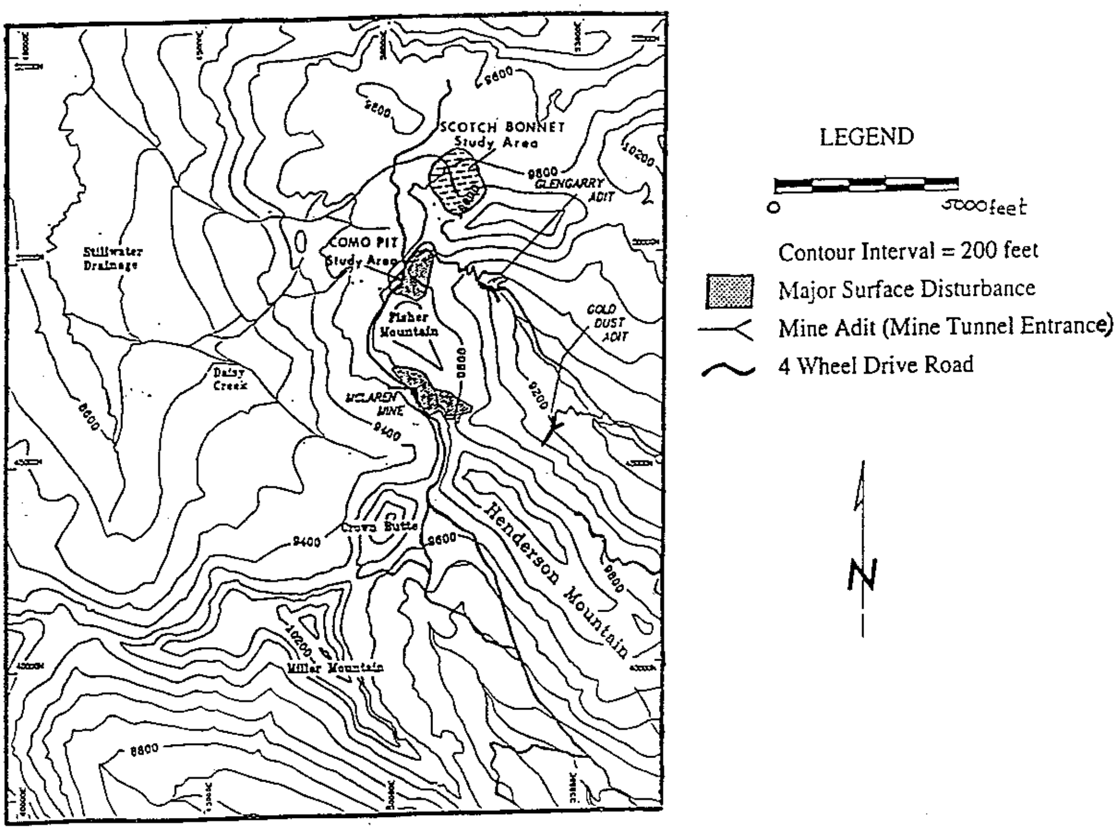

Figure 2--Study Area Location Map
(modified from map in Crown Butte Mines, Inc., Application for a Hard Rock Operating Permit, Vol. 4)

1.) pH, measured in a 1:1 solution with distilled water and allowing the solution to stabilize for approximately 10 minutes
2.) Loss on Ignition (LOI) for percent organics, using a muffle furnace at 600°C for 6 hours to burn off the organic portion of each sample
3.) AAS for the same metals as in the water analysis, using an acid extraction technique to generate the solution required for analysis
4.) IC for the same anions as in the water analysis

OBSERVATIONS AND DISCUSSION

Preliminary results show quite a wide range in the amount of difference between the two sites. Even though the Como Pit had been stripped of all soil and heavily disturbed and compacted by mining operations, many of the major impacts that I expected were not nearly as profound as I would have at first believed, while others were as bad or worse than expected. It appears that some aspects of small scale surface mining have an impact that lasts long after the disturbance has ceased, while the effects of other impacts decline rapidly, and return to near normal levels within the span of a human lifetime.

Erosion studies showed a profound difference between the two sites. The undisturbed Scotch Bonnet site showed virtually no rill or gully formation, with most of the overland flow not creating channels until it reached a central stream channel. Even on an area that had virtually no vegetation, and was probably covered by snow in most years, there was very little gullying, and the gullying that was present seemed to be concentrated near an old mining prospect pit.

The Como Pit, however, was heavily gullied. Even though it had been recontoured less than a year before, and therefore had no gullies or other erosion channels at that time, at the time of the study the area was deeply scarred by erosion features ranging from sheet wash concentration zones, evidenced by flow indicators in areas of very fine sediment, to major gully channels more than 1.5m deep and 3m wide. The loosening of substrate definitely encouraged channel incision and sediment transport on a large scale on all slope angles and on all slope aspects. Though I observed some degree of fining on the shallower slopes (indicating less entrainment strength of the flow), gullying was still present, particularly below areas that had been zones of gullying higher on the slope. Even undisturbed areas near the pit were affected by the massive amounts of sediment transport. On the steeper slopes, walled "flumes" of sediment developed below gully networks on grassy areas. In other vegetated areas with lower slopes, the high sediment loads (probably in combination with altered geochemistry) produced areas of meandering wash zones devoid of vegetation.

Preliminary geochemical results are definitely not as clearly defined, however. While some indicators showed a strong difference between the sites, many others were virtually identical at both sites (See Figure 3 for all data references that follow).

The pH of the water samples from the Como Pit were quite low, generally ranging from 4.0 to 4.5, while those taken from Scotch Bonnet tended to fall between 6.0 to 6.5. In addition, a number of samples taken in a series from one channel show the effects of the pit disturbance quite dramatically. A notable example is the Snowmelt gully system (designated MCS-elevation). This channel began just below the snowfield on the northern side of the pit, and therefore much of the water in it was obviously snowmelt. It began at 2980m with a pH of near 7.6. However, 30m of elevation lower, where runoff from the pit had started to enter the system, the pH was below 4.6, and remained in the low 4 range throughout the remainder of the field area. This example, and other similar results, seems to indicate a strong correlation between a lowering of pH and the pit disturbance.

AAS for copper also supports this. Levels of copper in the water samples from Scotch Bonnet tend to be in the 0.1 to 0.2mg/L range, while those from the Como Pit are significantly higher, with quite a wide variety of values dependent upon location. The Snowmelt gully again offers a good example, as it shows the same trend with copper that it did with pH--above the Pit, levels of copper are very low (0.07mg/L); while once runoff from the Pit enters the system, copper levels jump substantially, going above 1.0mg/L at 2920m.

Water analysis of iron and zinc shows much less difference between the sites, however. Levels of both metals are quite low (<0.15mg/L) at nearly all sample locations for both sites. The only significant jump occurs just outside the Glengarry Mine adit entrance at 2840m (samples MC Glen, MCF+Glen, MCF+G+H+S). This gated adit entrance had a significant flow out of it even during drier periods of the project when other gully systems dried up. The water that was flowing out of this abandoned mine shaft had iron levels nearly 20 times higher and zinc levels 3 times higher than any other location. Levels of both metals begin to fall very rapidly upon reaching the surface, however (within 15m), suggesting the possibility that iron and zinc tend to precipitate from solution rapidly upon exposure to air. It is also interesting to note the extremely low pH levels at the same location (<3.0), suggesting that pH levels may also have some correlation with the iron and zinc levels.

It is interesting to note the degree of change that the mining has caused in the Como Pit. Comparing it to the undisturbed Scotch Bonnet site visually, the lack of vegetation and the differences in the erosion patterns are readily apparent, and it would seem likely, therefore, that further analysis would lead to many other differences becoming apparent. This is true to some extent--pH levels are much lower at the Como Pit, and the amount of copper in suspension is significantly higher as well. However, the amount of iron and zinc is quite similar at both sites, with the notable exception of the entrance to the Glengarry Adit. Further study will enable a greater degree of comparison, allowing a more accurate description of the effects of surface mining on a high alpine zone such as this one.

BIBLIOGRAPHY

American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 16th edition, 1985.

Application for a Hard Rock Operating Permit and Proposed Plan of Operations--New World Project, Volumes 1, 2, 4, and 6, Submitted by Crown Butte Mines, Inc. to the Montana Department of State Lands and the USDA Forest Service, 1994.

Horowitz, Arthur J., A Primer on Trace Metal Sediment Chemistry, USGS Water Supply Paper 2277.

Sample	pH	mg/L Cu	mg/L Fe	run 2 Fe	mg/L Zn
MCS-9,25	4.158	0.45	0.08		0.04
MCS-9,30	4.06	0.86	0.12		0.08
MCS-9,40	4.22	0.96	0.08		0.07
MCS-9,50	4.09	1.04	0.1		0.05
MCS-9,60	4.579	0.84	0.06		0.04
MCS-9,70	7.621	0.07	0.05		0.02
MCF+G+H+S	2.94	1.7	peg-dilute1:10	1.28	0.32
MC Glen	2.895	1.98/1.99	peg-dilute1:10	1.9	0.37
C Adit	7.2	0.08	0.08		0.04
MCF+Glen	2.881	1.87	peg-dilute1:10	1.69	0.34
MCH-9,25	4.288	0.28	1.23		0.13
MCH-9,30	3.239	0.28	1.4		0.13
MCH-9,40	3.12	0.27	1.66		0.14
MCF-9230	4.39	0.74	0.12		0.03
MCF-9,25	4.382	0.74/0.75	0.13		0.03
MCF-9,30	4.358	0.74	0.13		0.03
MCF-9,40	4.08	0.83	0.19		0.05
MCF-9,50	4.231	1.59	0.15		0.08
MS flat	6.078	0.14	0.16		0.01
MS 1	6.382	0.15	0.14		0.11
MS 2	6.975	0.16	0.15		0.04
MS 3	6.799	0.15	0.15		0.03
MS 4	6.388	0.17	1.2		0.01
MS 5	6.925	0.17	0.16		0.04
MS 6	6.76	0.18	0.17		0.07
MS 7	6.68	0.17	0.17		0.01
MS 8	5.364	0.18	0.16		0.02
MS 9	6.808	0.18	0.09		0.03
MS 10	6.33	0.17	0.14		0/0

Figure 3--Water Sample Data, showing lab measured pH as well as Cu, Fe, and Zn analysis from Atomic Absorption Spectometry