Effects of Abandoned Mine Wastes on Streamwater in New York and Vermont

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Abstract:

Mine wastes present the potential for severe environmental hazards. Quantification and investigation of dissolved constituents resulting from mine wastes are essential to the understanding and mitigation of these hazards. This project quantifies the downstream effects of abandoned mine wastes by measuring pH, conductivity, and metal concentrations upstream, on-site, and downstream of three abandoned mines in New York and Vermont. These mines, chosen for their varied geology and localities, were the Belvidere asbestos mine (Eden Mills, VT.), the MacIntyre titanium dioxide mine (Tahawus, NY.), and the Ely copper mine (Vershire, VT). Samples were analyzed using an inductively coupled plasma optical emission spectrometer (ICPOES) to determine metal contents and concentrations.

The metals found in the samples were congruent with the metal content of the bedrock and ore rocks of the mines. High levels of soluble metals such as calcium and sodium were measured in all samples. Insoluble metals were not found except at the Ely copper mine. The drainage of the mine had elevated levels of Al, Ca, Cu, Fe, K, Mg, Na and Zn. The drainage was the most acidic water measured, with a pH of 4.4.

The data suggest that the metals in the samples are the result of the weathering of bedrock. This weathering seemed to be accelerated and augmented by the low pH at the Ely Mine.

Introduction:

Drainage from mine wastes can contribute significantly to water contamination(Griggs, 1983). Mine wastes are capable of raising metal levels in local water sources as well as contributing to the acidification of both surficial and groundwater sources(Griggs, 1983). This acidification further exacerbates the leaching of metals and other contaminants from waste piles(Griggs, 1983).

Three mines were studied by taking water samples upstream and downstream as well as from pit lakes or drainages. At two mines there are large pit lakes that sit in direct contact with tailings. At Ely Copper Mine there is a drainage that drains directly into the upstream/downstream source after running through tailings. These mines had been abandoned and the waste piles left untouched.

History and Bedrock Geology:

The Belvidere Asbestos mine, Eden Mills, VT (Figures 1 and 2), was mined from 1960 to 1993 when the carcinogenic nature of asbestos depressed the market and made mining economically unfeasible (Gale, 2003). At the height of its production the mine produced 3500 tons of ore daily (Gale, 2003). The bedrock at this location represents a sequence of ultramafic rocks including serpentine ($Mg_6Si_4O_{10}(OH)_8$), amphibolite ($Fe_7Si_8O_{22}(OH)_2$), and muscovite ($Kal_2(AlSi_3O_{10})(OH)_2$) schist (Gale, 2003). The Belvidere mine drains directly into the Dark Branch River. The Dark Branch, in turn, flows into the Gihon River in Eden, VT. The upstream sample came from a small seep at the summit of Belvidere mountain.

The Ely copper mine of Vershire, VT. (Figures 1 and 3) was mined from 1821 to 1950 (Howard, 1969). At the height of production, the Ely mine produced 3,186,175 pounds of copper in 1880 (Howard, 1969). the Ely mine and the nearby Elizabeth and Pike Hill mines occur at the contact between the Gile Mountain Formation (weakly calcareous mica ($Kal_2(AlSi_3O_{10})(OH)_2$) schist containing beds of amphibolite ($Fe_7Si_8O_{22}(OH)_2$) and the Standing Pond formation (fine-grained acicular amphibolite ($Fe_7Si_8O_{22}(OH)_2$)) (Howard, 1969). The Ely mine drains into Schoolhouse Brook,

The MacIntyre titanium dioxide mine in Tahawus, NY. (Figures 1 and 4) was mined from 1941 to 1982 (Chilson, 2003). The area was previously mined for iron ore. The land was bought in 1907 by the Tahawus Iron Ore Company, it was then purchased by National Lead Industries in 1941 (Chilson, 2003) who then mined it for the next forty-one years. The bedrock of the mine is ilmenite ($FeTiO_3$) with magnetite (Fe_3O_4) inclusions. These ore bodies are found within the country rock of olivine ($(Mg,Fe)_2[SiO_4]$) metagabbro. The upstream and downstream samples were collected from the Opalescent River. The pit lake sample was collected from the northern pit lake (Figure 3).

Methods:

The mines were selected by their varied geology and locations. Topographic maps were used to determine the best sampling sites (Figures 2, 3, and 4). An upstream site was selected to represent water unaffected by mine drainage. A pit lake/drainage sample was taken to represent water in direct contact with tailings. A downstream sample was taken just below the mine to quantify the off-site effects of the mine. The samples were collected in 14-mL sample tubes after being filtered through a glass-fibre prefilter (0.2

micron). These were treated with nitric acid and refrigerated. Larger samples were collected and used to measure pH (using a mini-Lab pH meter) and conductivity (using a Sper Scientific conductivity meter) onsite.

The 14-mL samples were analyzed using an inductively coupled plasma optical emission spectrometer (ICPOES). The ICPOES was calibrated using a mixed metals solution and rinsed thoroughly with nitric acid between samples (Figures 5, 6, and 7).

Data:

Belvidere and MacIntyre mines had pH's ranging from 7.7 to 9 (Table 1). The pit lake of Belvidere is more basic than the upstream and downstream sample. Ely had lower pHs with the drainage measuring 4.4, an average of 2 units lower than the upstream and downstream samples. The pH of the downstream sample is .5 lower than the upstream sample.

The conductivities of the MacIntyre and Belvidere mines show downstream values significantly higher than the upstream values. The pit lake values were above detection limits. Ely mine showed much higher conductivity than the other mines, again with the drainage conductivity above detection limits.

The Belvidere mine upstream sample (Figure 2, Table 2) , contained high levels of calcium (2.2 ppm) and sodium (6.93 ppm). The pit lake sample showed comparable concentrations of calcium (3.68 ppm) and sodium (2.07 ppm) and higher levels of magnesium (34.36 ppm).

The Ely mine upstream sample (Figure 3, Table 2) had elevated levels of calcium (22.70 ppm), magnesium (0.97 ppm), and sodium (4.39 ppm). The drainage sample had a wide range of metals present, including aluminum (5.90 ppm), calcium (15.83 ppm), copper (2.42 ppm), iron (4.45 ppm), potassium (2.63 ppm), magnesium (4.70 ppm), and sodium (4.69 ppm). The downstream sample has calcium (20.46 ppm), potassium (1.20 ppm), magnesium (1.29 ppm), and sodium (4.58 ppm) present.

The metal concentrations of the MacIntyre mine pit lake samples (Figure 4, Table 2) show elevated levels of calcium (79.87 ppm), magnesium (31.78 ppm), sodium (43.00 ppm), and potassium (1.76 ppm). The downstream samples showed lower levels of calcium (6.92 ppm), magnesium (0.32 ppm), and sodium (6.90 ppm) than the pit lake samples.

Discussion:

The data from Belvidere shows high levels of sodium and calcium in all three samples. These are both water soluble minerals and are commonly found in surface waters . The high magnesium levels in the pit lake sample could be explained by the occurrence of amphibolite and serpentine, both magnesium bearing rocks. The multiple fracture networks in the mine itself, through which percolation was observed, allow for large surface areas of amphibolite to be exposed. The slightly elevated level of sodium in the downstream sample may be due to the proximity of Dark Brook to the road. This location would make the brook susceptible to road salt runoff, contributing to the sodium content of the water. Road salt can remain in soils and groundwater, slowly leaching into surface waters. (Runge, 2001.) Overall, the downstream sample contained higher levels of the major metals than in the upstream sample.

The samples at the MacIntyre mine contained the same water soluble metals found at Belvidere. The high magnesium levels could be a result of weathering of the surrounding olivine metagabbro. There are no salted roads around the mine so the sodium must be from the weathering of feldspars within the country rock. The calcium may be weathering from local marble lenses or glacial sediments.

The Ely Copper mine is an area with previously documented and data-supported claims of highly acid drainage. There were higher levels of insoluble metals than at the other two mines. The distribution of these metals between the samples was different from the other mines, with the majority of metals found in the direct drainage from the mine tailings. The drainage represented the most acidic of the samples and was therefore able to remove the aluminum, copper, iron, potassium, magnesium and manganese from the tailings.

Conclusion:

The data collected in this study show that metals can be leached from mine tailings and transferred into local surface waters, especially in areas with acidic drainages. The acidity at the Ely Copper Mine allowed for the weathering and leaching of metals insoluble in water. The metals in the MacIntyre and Belvidere samples can be related to the weathering of bedrock and mine wastes. The sodium levels at the Ely upstream and downstream sample sites and at the downstream Belvidere sample site could be affected by road salt use. These mines are indeed impacting local waters, both in the addition of dissolved constituents and in the modification of pH.

Location:	Sample Site:	pH:	Conductivity(μS):
Belvidere	Upstream	7.7	39.2
Belvidere	Pit Lake	9	ADL
Belvidere	Downstream	7.7	81.6
Ely	Upstream	6.7	119.2
Ely	Drainage	4.4	ADL
Ely	Downstream	6.2	118.8
MacIntyre	Upstream	9	20.8
MacIntyre	Pit Lake	8	ADL
MacIntyre	Downstream	8	64.1

Table 1: pH and Conductivity Data: Table showing pH and conductivity at each sample site. The conductivity data for the drainage and pit lakes is above detection limits (ADL) for the conductivity meter used.

	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr
ADK Up	BDL	0.046	BDL	0.148	BDL	2.195	BDL	BDL	BDL
ADK Pit Lake	BDL	0.656	BDL	0.094	BDL	79.872	BDL	BDL	BDL
ADK Down	-0.004	0.039	BDL	0.162	BDL	6.922	BDL	BDL	BDL
BEL Up	BDL	0.045	BDL	0.211	BDL	3.812	BDL	BDL	BDL
BEL Pit Lake	BDL	BDL	BDL	0.129	BDL	3.679	BDL	BDL	BDL
BEL Down	-0.003	BDL	BDL	0.253	BDL	5.128	BDL	BDL	BDL
ELY Up	BDL	0.155	BDL	0.231	BDL	22.702	BDL	BDL	BDL
ELY Drain	BDL	5.9	BDL	0.145	BDL	15.827	BDL	0.048	BDL
ELY Down	BDL	0.172	BDL	0.262	BDL	20.457	BDL	BDL	BDL

	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb
ADK Up	BDL	0.004	0.211	0.062	BDL	BDL	6.927	BDL	BDL
ADK Pit Lake	BDL	BDL	1.755	31.78	BDL	BDL	43.003	BDL	BDL
ADK Down	BDL	0.011	0.321	1.781	BDL	BDL	6.896	BDL	BDL
BEL Up	BDL	0.028	0.083	2.587	BDL	BDL	2.2	BDL	BDL
BEL Pit Lake	BDL	BDL	0.303	34.364	BDL	BDL	2.073	BDL	BDL
BEL Down	BDL	0.029	0.315	4.782	0.009	BDL	5.285	BDL	BDL
ELY Up	BDL	BDL	1.185	0.97	-0.001	BDL	4.392	BDL	BDL
ELY Drain	2.416	4.445	2.63	4.696	0.434	BDL	4.692	BDL	BDL
ELY Down	BDL	BDL	1.203	1.29	0.028	BDL	4.582	BDL	BDL

	Sb	Se	Sn	Sr	Ti	V	Zn
ADK Up	BDL	BDL	BDL	0.011	BDL	BDL	BDL
ADK Pit Lake	BDL	BDL	BDL	0.414	BDL	BDL	0.049
ADK Down	BDL	BDL	BDL	0.032	BDL	BDL	0.027
BEL Up	BDL	BDL	BDL	0.003	BDL	BDL	0.054
BEL Pit Lake	BDL	BDL	BDL	0.004	BDL	BDL	BDL
BEL Down	BDL	BDL	BDL	0.021	BDL	BDL	0.032
ELY Up	BDL	BDL	BDL	0.109	BDL	BDL	0.044
ELY Drain	BDL	BDL	BDL	0.05	BDL	BDL	0.583
ELY Down	BDL	BDL	BDL	0.097	BDL	BDL	0.09

Table 2: Metal Contents of Water Samples: Table showing metal concentrations in parts per million of water samples taken at mine sites. The Belvidere Asbestos Mine is referred to as BEL, Ely Copper Mine as ELY, and MacIntyre Titanium Mine as ADK. BDL indicates that the metal concentrations were below detection limits.

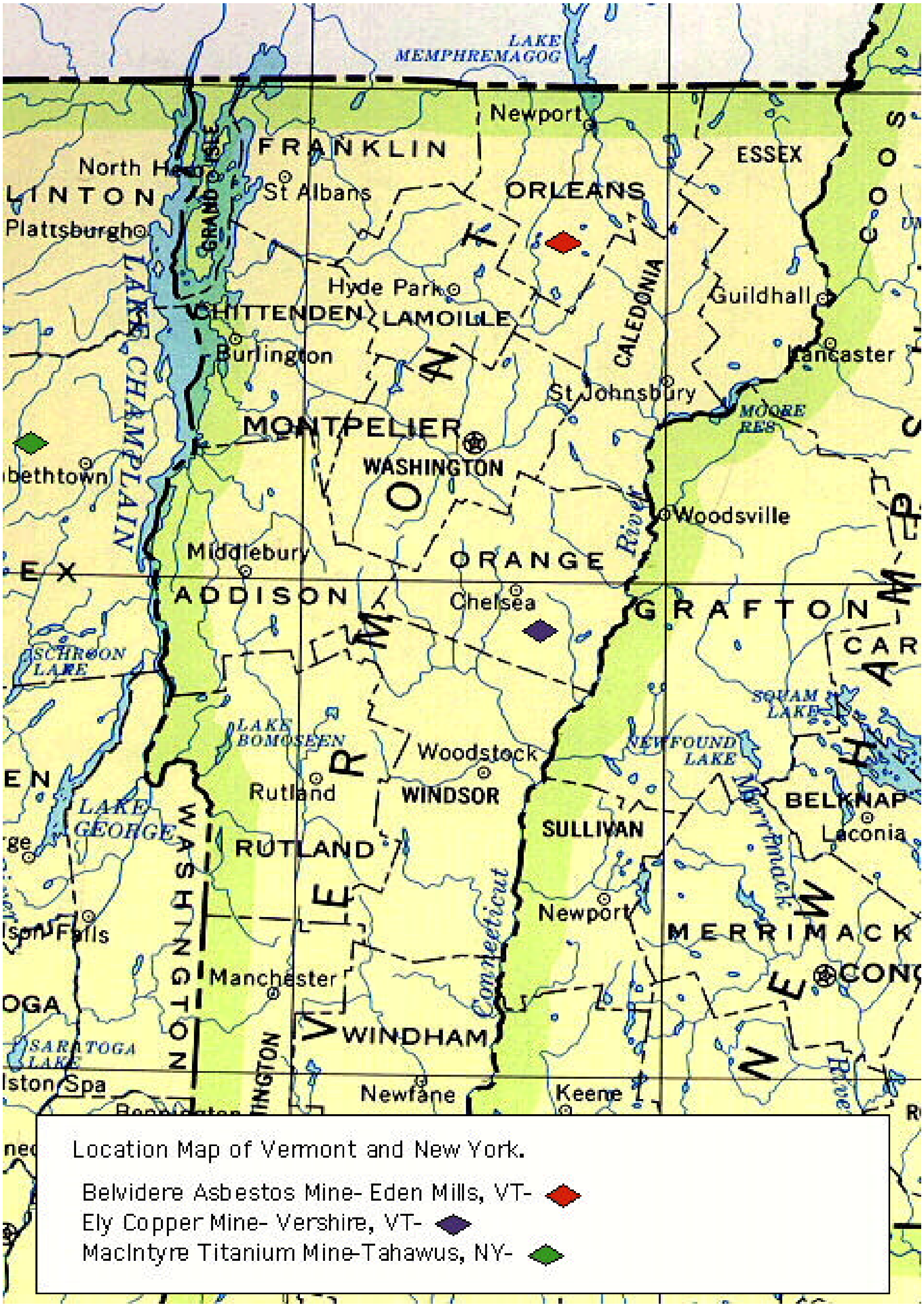

Figure 1: Location map with mines marked.

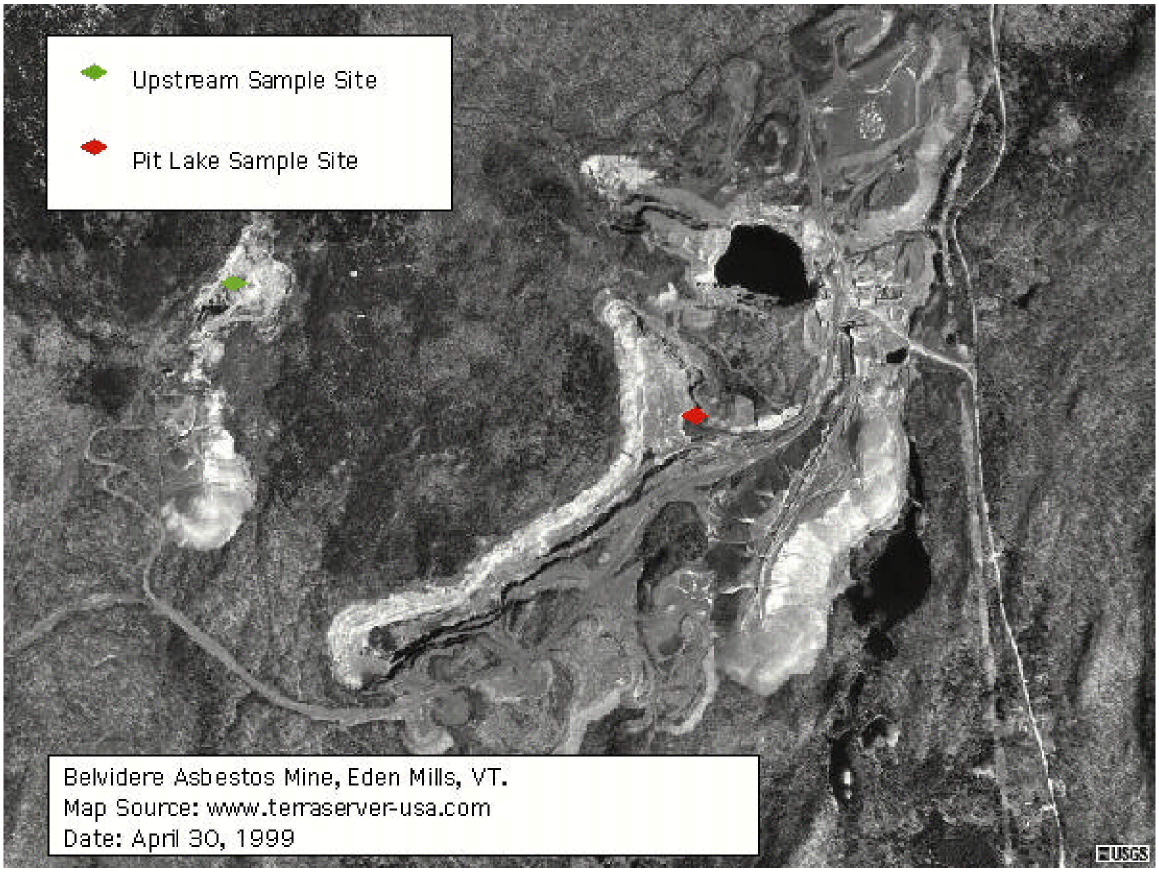

Figure 2: Aerial photo of Belvidere Asbestos Mine, sample sites marked.

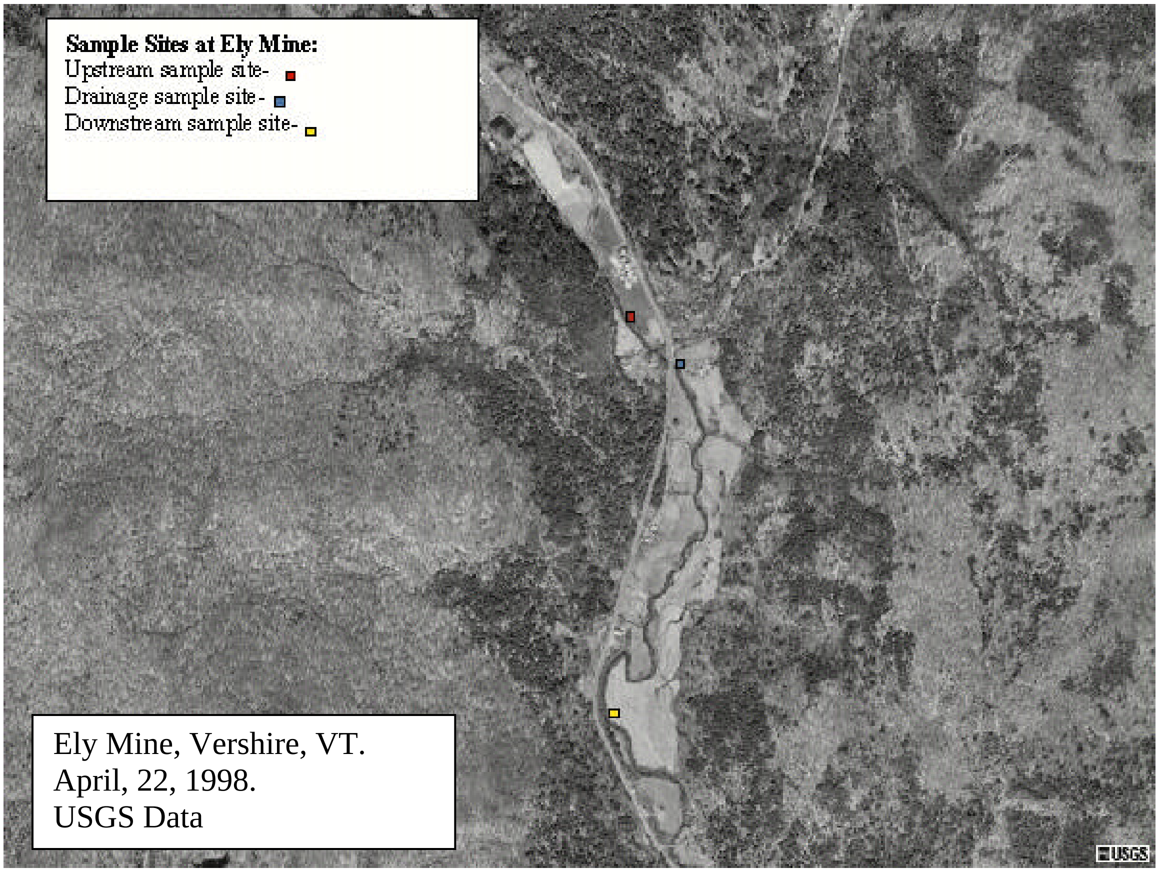

Figure 3: Aerial photo of Ely Copper Mine, sample sites marked.

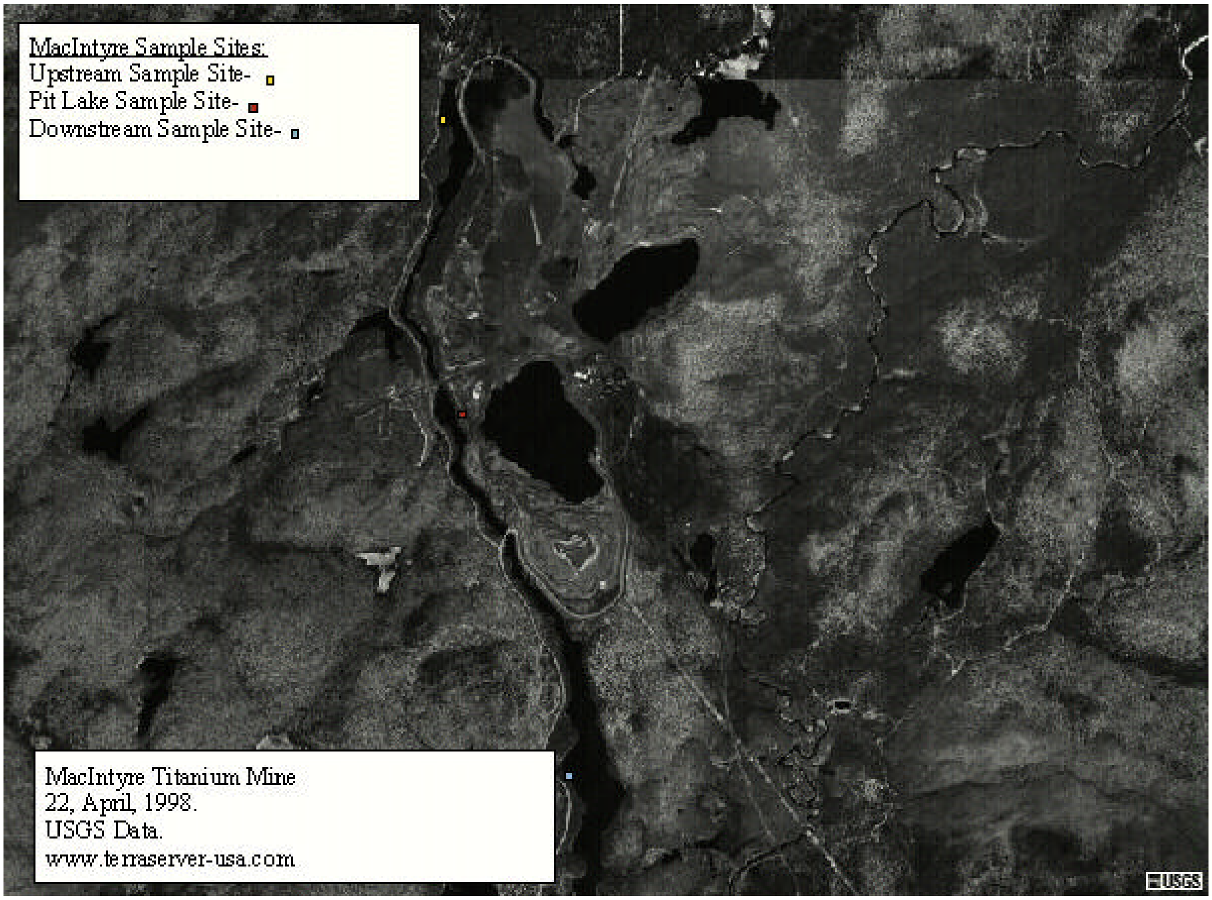

Figure 4: MacIntyre Titanium Mine, sample sites marked.

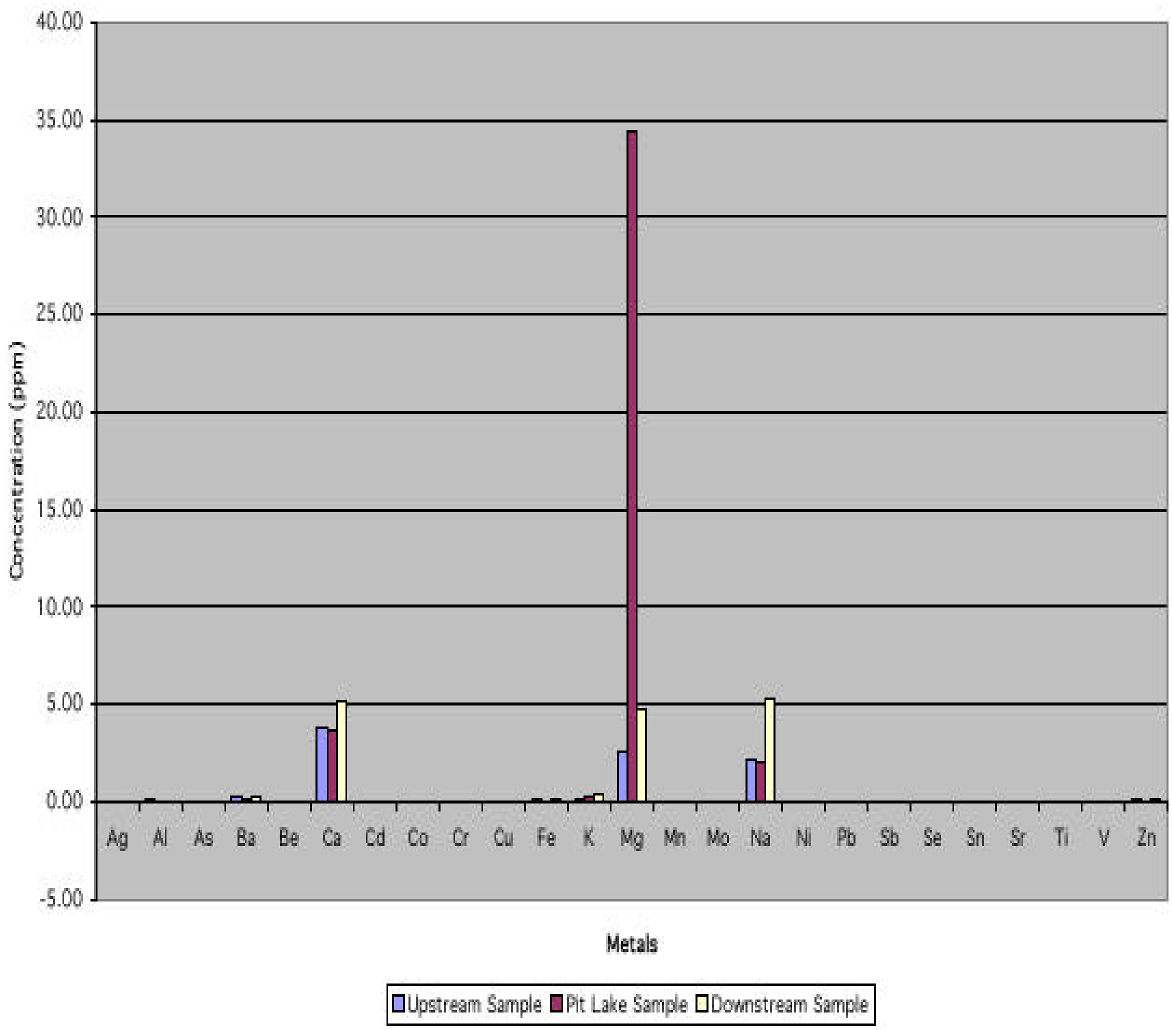

Figure 5: Metal concentration chart for Belvidere Asbestos Mine, Eden Mills, VT.

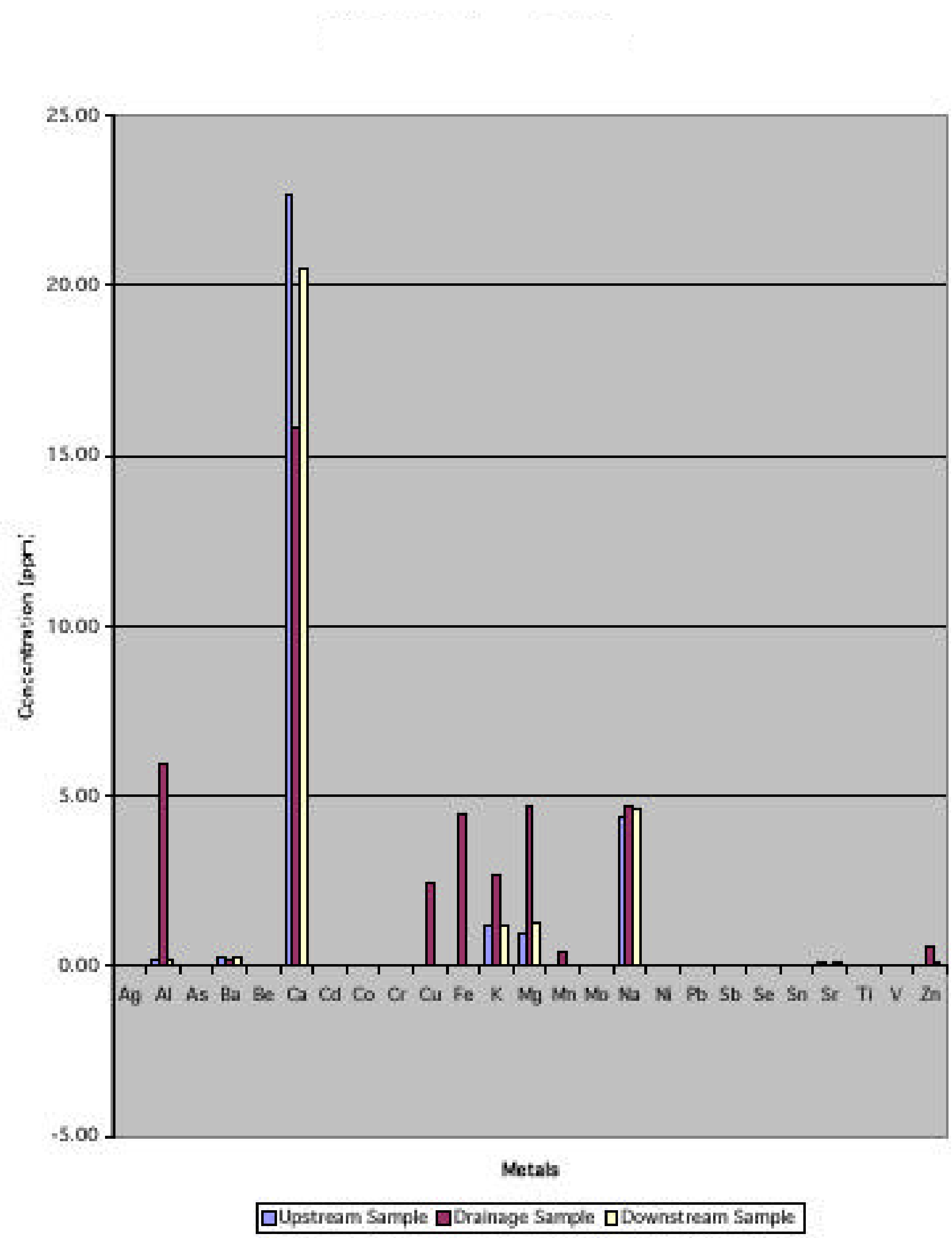

Figure 6: Metal concentration chart for the Ely Copper Mine site, Vershire, VT.

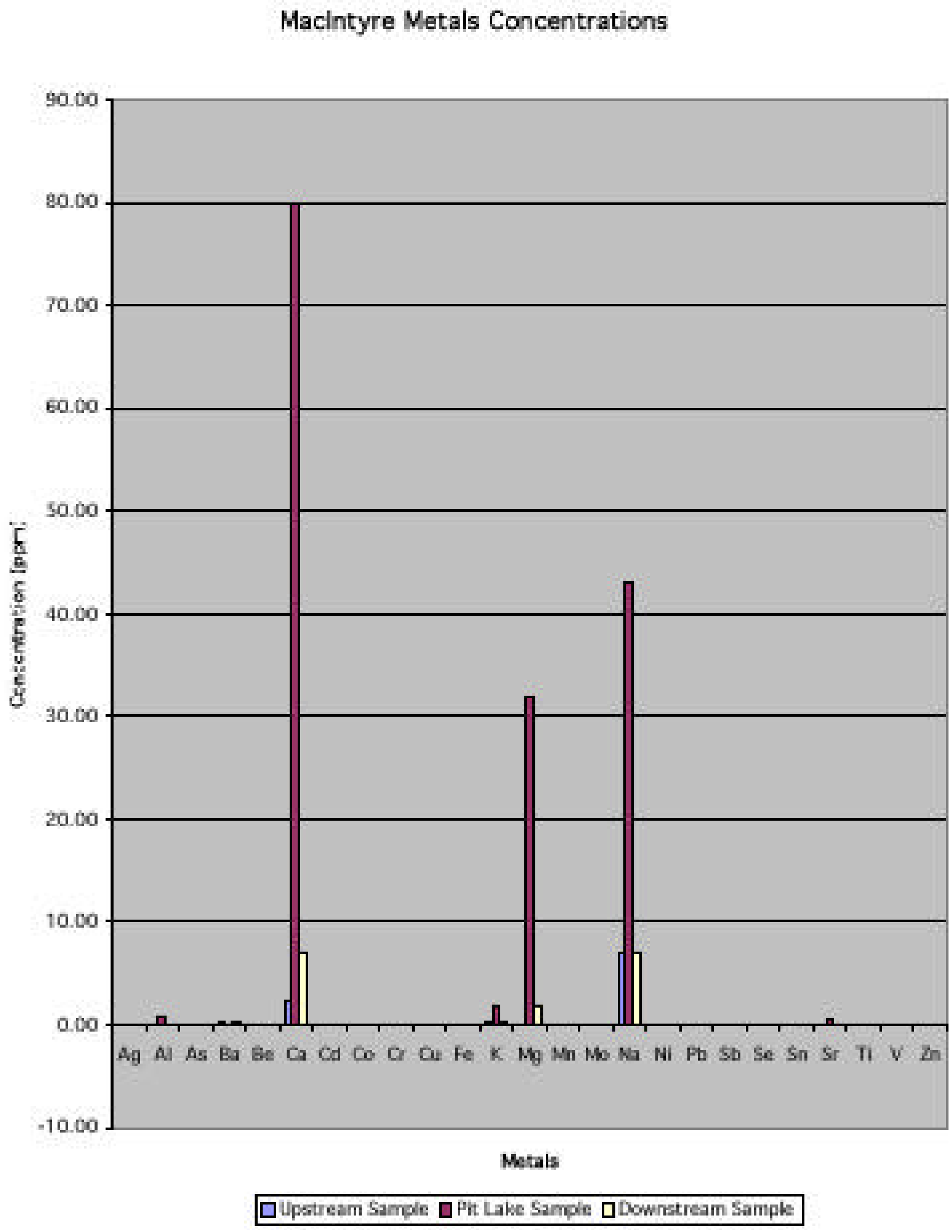

Figure 7: Metal concentration chart for MacIntyre Titanium Mine, Tahawus, NY.

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Personal Communication with Dr. Jack Drake, University of Vermont.