A COMPARISON OF PRE-DEVELOPMENT AND PRESENT MOLYBDENUM CONCENTRATIONS IN VEGETATION ON THE ENDAKO MINE SITE AND IMPLICATIONS TO UNGULATE HEALTH

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ABSTRACT

Biogeochemical data collected at Endako Mine between 1950 and 1965, demonstrated that vegetation containing very high molybdenum concentrations was present over the orebody before mine development. Work conducted by the Geological Survey of Canada shows that a large molybdenum anomaly exists in the Endako Mine area, and vegetation with elevated molybdenum concentrations was present in areas surrounding the site before development. Since there is no evidence of unhealthy ungulates before mine development, it is assumed that the elevated molybdenum concentrations were not harmful to wildlife.

The present risk of consuming vegetation growing in reclaimed areas of the mine site to moose and deer was assessed by comparing concentrations of molybdenum in vegetation growing on tailings and waste rock dumps with samples collected in 1964. The concentrations in reclaimed areas are lower than those measured over the orebody, and indicate that vegetation on reclaimed sites is not more harmful to wildlife than that sampled before mine development. This is supported by two studies conducted at the mine which demonstrate that moose and deer are not showing signs of molybdenosis.

INTRODUCTION

Endako Mine of Thompson Creek Mining Ltd. and Nissho Iwai Moly Resources Inc. is located in central British Columbia and has been in operation since 1965, except for a temporary shutdown between 1982 and 1986. The mine has a 30,000 tonne per day capacity to mine and process molybdenum oxide and disulphide, and is estimated to have enough ore to keep the mine in operation until 2010. The end land use objective for Endako Mine is to provide habitat for wildlife, including moose and deer.

An environmental assessment conducted at Endako Mine in 1990, showed that aquatic plants accumulate the highest levels of molybdenum, up to 753 mg/kg, while mean levels of indigenous terrestrial vegetation range from 3.2 to 79 mg/kg. Legumes and grasses growing on the tailings and waste rock dumps average 145 mg/kg and 52 mg/kg of molybdenum respectively. The copper to molybdenum ratios for vegetation both on and off the mine site are well below 2:1, and sulfur concentrations are conducive to thiomolybdate production (Mathieu, 1995). Although the literature suggests these conditions would lead to molybdenosis in cattle, the implications to wild ungulates is uncertain. A study of molybdenum toxicity in female mule deer concluded that deer are at least ten times more tolerant to high molybdenum levels in their diet than domestic ruminants (Nagy *et al.* 1975). The difference in tolerance can be explained by the toxic properties of the different thiomolybdate compounds. Dithiomolybdate is less toxic than tetrathiomolybdate produced in cattle and was found to be the predominant form in deer (Mason *et al.* 1984).

Without more knowledge of the tolerance levels of wild ungulates to molybdenum, the risk of consuming vegetation growing at the mine to the health of wild ungulates is of concern. One method Endako Mine used to assess this risk was to compare present levels of molybdenum in vegetation growing on mine wastes to concentrations measured before mine development.

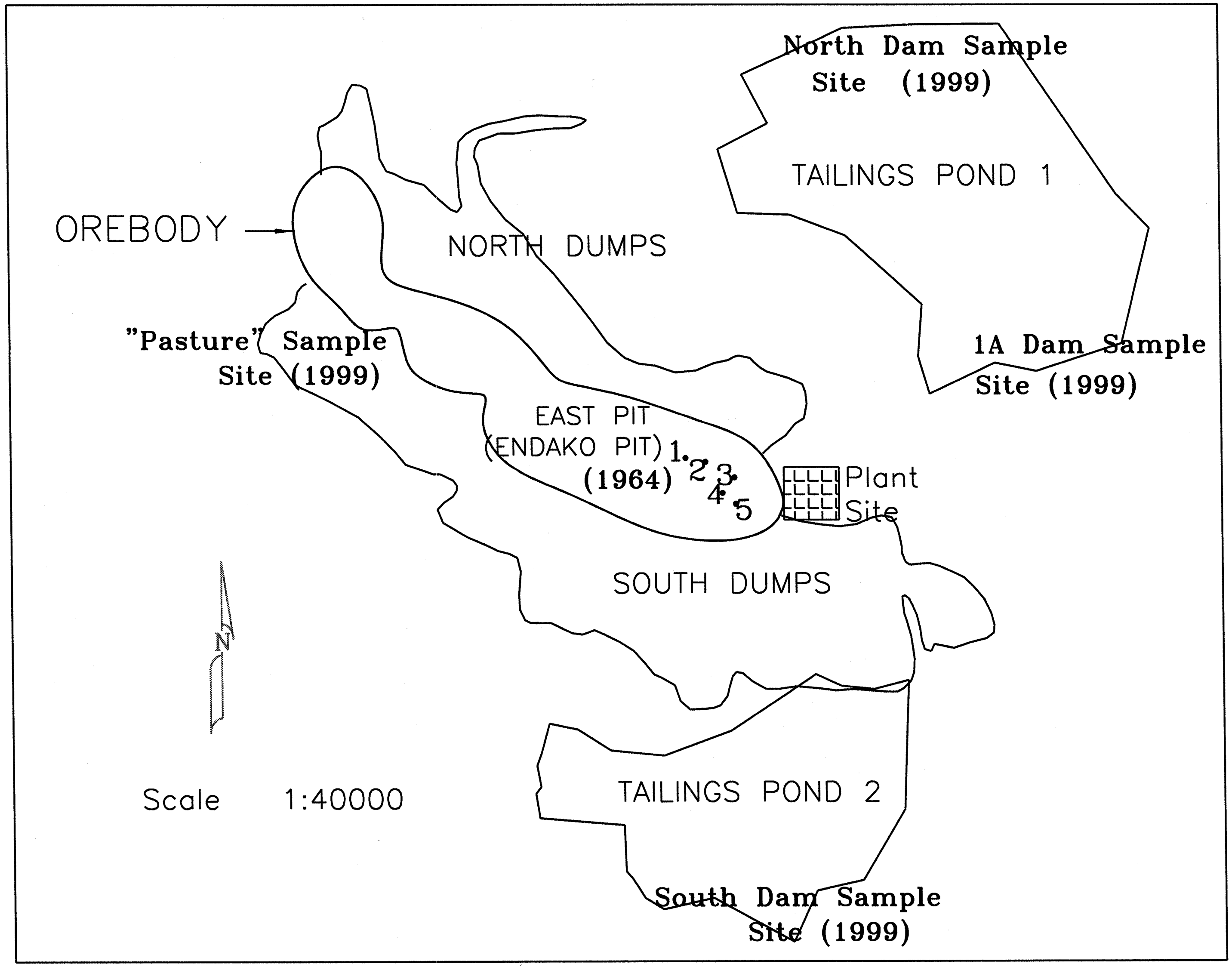
BACKGROUND

Pre-mine Molybdenum Concentrations in Vegetation

The sampling and analysis of vegetation for metal concentrations has been used successfully to identify mineral deposits beneath the soil. This procedure, known as biogeochemistry, was used by Harry Warren *et al.* in 1953 at various sites, including Endako Mine. Samples were taken from alpine fir growing over what is now the Endako Pit. Although results are limited, the investigators demonstrated that the needles and second year stems of the trees contained an average of 65 and 43 mg/kg of molybdenum respectively, and that these concentrations were 10 to 20 times higher than those in samples collected from a carefully selected control site (Warren, 1972).

Warren returned to Endako in 1964 to complete a more extensive biogeochemical investigation and to determine whether the information gathered could be used to delineate mineral deposits. The only portion of that data that has been found is from samples of first year leaves and needles of alpine fir *Abies lasiocarpa*, white and Engleman spruce *Picea glauca* and *Picea engelmanni*, sitka alder *Alnus sinuata*, various species of willow *Salix sp.*, fireweed *Epilobium angustifolium*, and paint brush *Castilleja sp.*, collected in August 1964. The samples came from five undisturbed sites located within the "East Pit" (Figure 1). Samples from a number of plants at each site were composited.

Figure 1: Location of 1964 and 1999 Sampling Sites in Relation to Orebody and Present Mine Disturbance



Samples were ashed and analysed for total molybdenum. These results are presented in Table 1 below.

Table 1: Molybdenum Concentrations of the Ash of Vegetation Samples - 1964 (mg/kg)

	Site 1	Site 2	Site 3	Site 4	Site 5
Fir	260	1700	2900	310	
Spruce		1800			
Paint brush					4600
Fireweed	17,700	7,700	12,000	9,600	
Alder				9,000	5400
Willow	9600	1200	6100		

Source: Warren et al. (1964)

The biogeochemical work conducted at Endako was later reviewed by Kovalevsky (Kovalevsky, 1987) who made the following comments. "The history of biogeochemical prospecting and research at the large Endako molybdenum deposit in Canada is a classical example, illustrating the high effectiveness of biogeochemical exploration for molybdenum ore…………………… The maximum molybdenum concentration in the ash of non-barrier biosamples (vegetation) reached 2% (20,000 ppm) for a molybdenum content of 0.1-1.0% in the ore………The deposit was delineated by an isoconcentration contour of 25 ppm molybdenum at a background of 1 ppm using the needles of subalpine fir…………… Concentrations of 500 - 1500 ppm in the ash (of vegetation samples) correspond to the zone of intense molybdenum mineralization below a mean thickness of 3 - 5 m of overburden."

It can be concluded that elevated molybdenum levels in vegetation were present before the development of Endako Mine. Samples included alder and willow, which are moose browse species, and so provide information on the pre-mine exposure of moose to molybdenum. Unfortunately, the data for the samples referred to above as containing 2% molybdenum has not been found, but nonetheless indicates that molybdenum levels greater than those measured in the 1964 samples were present before mine development. Based on the above statements regarding the influence of mineralization on molybdenum concentrations, it is probable that an area containing vegetation with molybdenum levels as high as, and higher than, those seen in 1964 extended beyond the five sampling sites and at least included the orebody outlined in Figure 1.

A soil map (Figure 2) assembled in 1972 by the mine geologist shows that pre-mine molybdenum concentrations were significantly elevated above the regional background level of 2 mg/kg, particularly in those areas close to the mineralization. Some soils directly over the mineralization contained more than 81 mg/kg of molybdenum. Although the highest values are directly over the orebody, the soil anomaly and a train of anomalous concentrations was shown to extend 5 km eastward. Isolated anomalous pockets were also shown to exist 1.5 to 5 km north and northeast of the orebody (Kimura, 1972).

This demonstrates that soil containing elevated molybdenum concentrations was present outside of the mine disturbance and is at least partially responsible for the high levels of molybdenum in vegetation growing east of the mine. The Geological Survey of Canada (GSC) visited the Endako Mine area in 1996 and measured 3530 mg/kg of molybdenum in ashed alder leaf samples 1 km east of the mine, 1500 mg/kg at 2 km, 374 mg/kg at 4 km and 212 mg/kg at 6 km (unpublished data). By comparison, regional background levels for alder is less than 20 mg/kg. Since the prevailing winds are from the west, airborne contamination is probably responsible for a portion of the molybdenum present in the vegetation.

Previous work conducted by the GSC in the mid 1990's shows that a large molybdenum anomaly exists in the Endako Mine region (Figure 3). The metal concentrations in ash of lodgepole pine bark samples were used to assist in bedrock mapping for mineral exploration. The accompanying map depicts the molybdenum anomaly associated with Endako Mine. The background concentration for lodgepole pine bark is typically 2 mg/kg molybdenum. Concentrations between 600 and 700 mg/kg were measured at distances greater than 10 km west of the mine site, indicating the anomaly extends up-wind and up-stream from the mine so can not be explained entirely by airborne contamination or mine drainage. The size of the anomaly is approximately 3000 km^2 and has been described as "the largest biogeochemical molybdenum anomaly of any reported from around the world, and of any metal it is second only in size to the Wollaston biogeochemical uranium anomaly in Saskatchewan".

Vegetation with naturally elevated molybdenum concentrations exists outside the mine disturbance and, in all likelihood, was present prior to development. Since there has been no evidence of unhealthy moose or deer previous to mine development, it is assumed that the elevated molybdenum levels both on and off the mine site did not cause molybdenosis in wild ungulates.

Figure 2: Map of Pre-Mine Soil Molybdenum Concentrations in Relation to the Orebody and 1964 Sample Sites

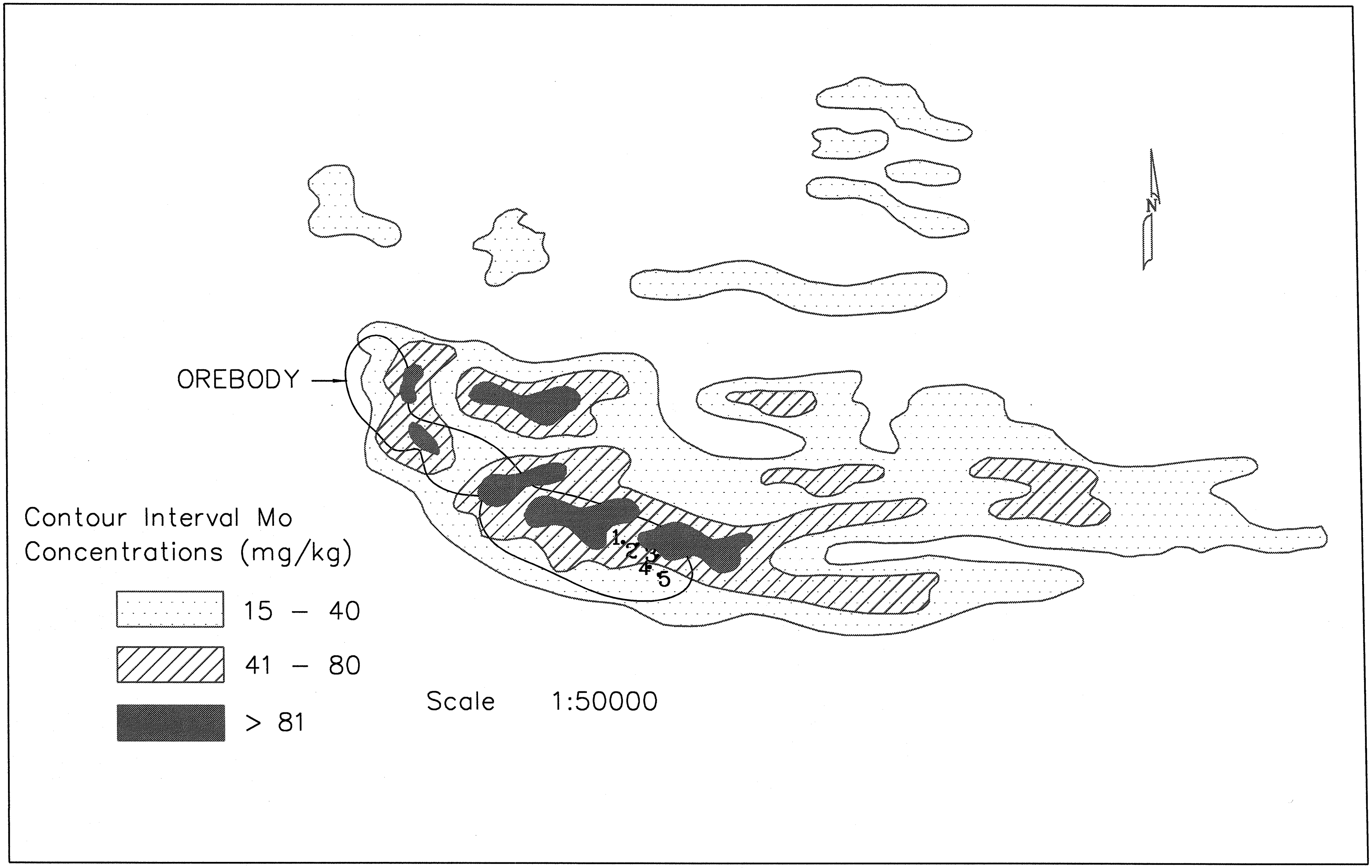
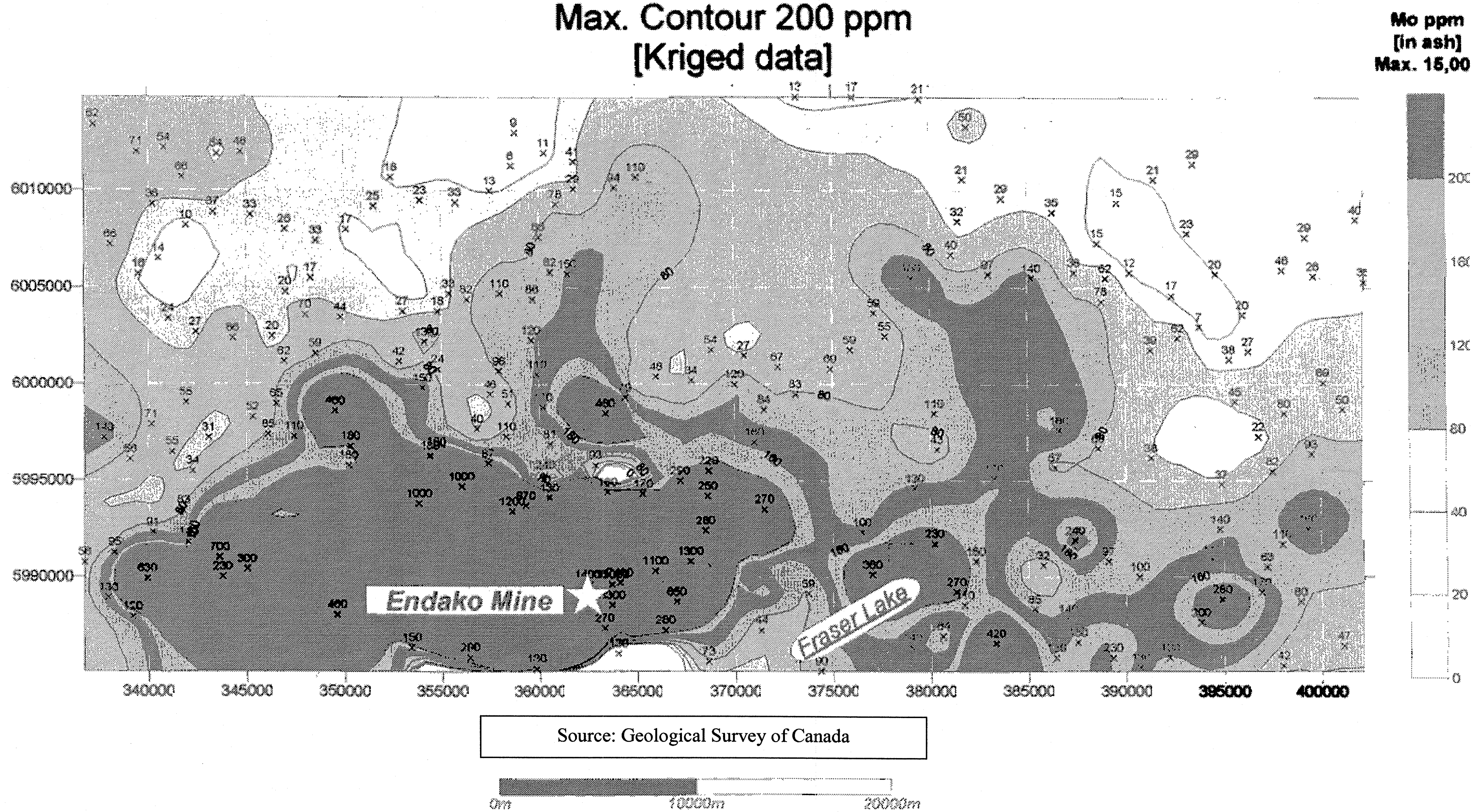


Figure 3

MOLYBDENUM - Pine Bark
Endako
Max. Contour 200 ppm
[Kriged data]



Source: Geological Survey of Canada

Present Molybdenum Concentrations in Vegetation

Between July 21 and August 12 1999, samples of first year leaves and needles were collected from alpine fir, spruce (white and Engleman), sitka alder, willow (various species), fireweed and paint brush. These samples were taken from sites on the tailings ponds (Saddle Dam, North Dam, 1A Dam) and a waste rock dump (The Pasture) illustrated in Figure 1.

The samples were sent to a lab for analysis of total molybdenum for both ashed and dried vegetation, so each sample received an ashed molybdenum concentration and a dry weight concentration. This not only allowed a direct comparison with the 1964 samples, but allowed a relationship between the ashed and dry weight concentrations to be determined for each species. If strong relationships existed between the ashed and dry weights, they could be applied to the 1964 ash concentrations to convert them to dry weight concentrations. Dry weight concentrations are preferred for two reasons. The vegetation data collected since 1964 is in dry weight concentrations, and the literature uses dry weight concentrations when referring to toxic and non-toxic concentrations of molybdenum.

RESULT AND DISCUSSION

Table 2 below contains the ranges of molybdenum concentrations for the 1964 and 1999 data.

Table 2: A Comparison of Molybdenum Concentrations Between 1999 and 1964 Ashed Samples, by Species

	1964 (mg/kg Mo)	1999 (mg/kg Mo)	1999 Means (mg/kg Mo)
Fir	260 - 2900	199 – 666	404
Spruce	1800	161- 507	289
Paint Brush	4600	655 – 2750	1265
Fireweed	7,700 – 17,000	565- 4930	2105
Alder	5400 - 9000	1370 – 4090	2642
Willow	1200- 9600	393 – 2100	786

All samples taken of spruce, paint brush, fireweed and alder in 1999 had lower molybdenum concentrations than samples taken in 1964. The concentrations in fir and willow in 1999 are well below the maximum values for 1964. All means for the 1999 data are well below the 1964 concentrations except for fir.

Linear regression and correlation analyses were conducted on the ash and dry weight data from the 1999 samples, and with the exception of spruce, yielded very good coefficients of correlation. The coefficient for spruce was only 0.65, while the other species had coefficients greater than 0.900. White spruce and Engleman spruce were sampled together and may have differences which yield different ash vs dry weight relationships, resulting in a poor correlation. With the exception of spruce, dry weights were calculated for the 1964 data using the equations developed from the linear regression analysis. A comparison of the calculated 1964 dry weight molybdenum concentrations with the measured 1999 dry weight concentrations is displayed in Table 3.

Table 3: A Comparison of Dry Weight Molybdenum Concentrations Between 1999 and 1964 Samples, by Species

	1964 (mg/kg Mo)	1999 (mg/kg Mo)	1999 Means (mg/kg Mo)
Fir	50 - 541	5 - 15	9
Paint Brush	757	127 - 467	228
Fireweed	622 - 1411	44 – 423	180
Alder	257 - 428	70 – 218	105
Willow	78 - 618	24 – 146	103

Vegetation growing on the tailings and waste rock dumps have lower molybdenum levels than that which was growing over the orebody. This is not unexpected since these are waste materials and contain less molybdenum than the ore. This suggests that the vegetation growing on the tailings and waste rock dumps is not more harmful to wild ungulates than that growing over the orebody.

Two studies conducted at Endako Mine have demonstrated the absence of molybdenosis in the moose and deer populations. A comprehensive wildlife survey was conducted in 1989 and 1990 (Mathieu, 1995). The survey consisted of intensive ground and aerial surveys identifying 20 species of mammals, 55 species of birds, and three species of amphibians within the general mine site area.

Moose was the most widespread mammal species. The minimum density of moose was estimated at 0.51 moose/km^2, which is comparable or higher than moose densities in the surrounding region (Provincial Management Unit 6-4 (D. Hatler, pers. comm.)). Moose observed during the survey probably included both year-round residents and seasonal migrants.

Large numbers of mule deer were also observed during each of the ground and aerial surveys. In the summer months, the mule deer were observed across the entire mine site region, but in the winter months, the deer concentrated almost exclusively in the south end of the region on the dry slopes facing Francois Lake where they feed on various herbaceous and woody forage species.

Between 1990 and 1992, Endako Mine initiated a monitoring study of molybdenum and copper concentrations in moose and deer hair to assess the mineral status of animals in the mine area in relation to animals from other parts of the province (Mathieu, 1995). Hair samples from moose and deer harvested by hunters up to 200 km away were analysed for total copper and molybdenum. Data was analysed according to distance from the mine.

Molybdenum and copper concentrations were not significantly different between deer harvested less than 10 km from the mine and those more than 10 km from the mine. No correlation could be found between molybdenum and copper concentrations suggesting that copper metabolism was not affected by molybdenum concentrations. This was demonstrated in one deer harvested 3 km from the mine which had a molybdenum concentration 40 times higher than all other deer samples. It also had the second highest level of copper. If thiomolybdate production was interfering with copper metabolism, one would expect this animal to have the lowest copper concentration.

Molybdenum concentrations in moose harvested within 10 km of the mine were significantly higher than animals harvested more than 10 km away. The fact that moose near the mine had much higher molybdenum concentrations than deer suggests that moose are exposed to higher molybdenum levels through ingestion of riparian and aquatic vegetation. Copper concentations did not differ significantly with distance from the mine and no correlation could be found between copper and molybdenum concentrations in moose. Again, if thiomolybdate production was interfering with copper metabolism, one would expect the moose harvested within 10 km of the mine to have significantly lower copper levels. None of the animals harvested displayed the symptoms of molybdenosis, such as deformed antlers or overgrown hooves.

Today, sitings of moose and mule deer in and around the mine site are a daily occurrence. Moose especially are seen browsing on woody vegetation established on the tailings and waste rock dumps. Tailings operators can identify residential moose which are seen each year with calves.

There have been no physical signs of molybdenosis in any of the animals observed on the mine site, and hunters who harvest deer and moose in the area have not reported any abnormalities. The wild ungulates do not appear to be affected by the vegetation in and around the mine.

This may be a result of a higher tolerance of ungulates to molybdenum as suggested by Nagy and Mason, or perhaps this is a result of adaptation. Studies have shown that the pre-mine molybdenum concentrations in vegetation were a result of mineralization. The map of the molybdenum anomaly suggests that at least part of the anomaly can not be attributed to mine contamination and is therefore a natural occurrence. It can be concluded that elevated vegetation levels were a result of geology and would have developed over time. This may have allowed the moose and deer to adapt to increasing molybdenum concentrations.

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