NATURAL RE-VEGETATION OF ARSENIC-BEARING ALKALINE TAILINGS AT COBALT, ONTARIO[1]

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Abstract: Mining and milling of silver and arsenic-rich carbonate veins have resulted in the deposition of tailings in many lake basins and other depressions of the Cobalt area. In some places where the tailings are exposed and salt crusts form in the summer, no vegetation has been able to grow 60 years after mill operations ceased, even when seeding was attempted. The largest tailings deposit, at the north end of Crosswise Lake, received effluent from five mills over a 60 year period (1908 to 1970) and covered the Farr Creek valley floor over a length exceeding two km. Construction of a water level control dam at the north end of the valley created a wetland that grades southward into drier exposed tailings.

Vegetation surveys conducted by Carleton University Environmental Science students at Cobalt since 2004 included uncontaminated forest, meadow, and wetland, as well as tailings sites at Cobalt. Soil pH ranges from slightly acidic (mean of 6.14) at forested sites to alkaline in tailings (mean of 8.04). The high tailings pH is due to the abundance of crushed calcite and dolomite vein material. On the Crosswise Lake tailings, only 8 plant species were found that were not observed in the other ecosystems and only 2 of these were abundant (*Juncus balticus* and *Equisetum pratense*). They dominate the exposed tailings and aid in the prevention of tailings erosion and in moisture retention. Within the Crosswise Lake wetland, *Typha latifolia* and *Eupatorium maculatum* dominate and form a thick growth. Major limiting factors for plant growth on the tailings include availability of moisture and nutrients, and to some extent toxicity of the tailings.

Key Words: *Juncus balticus, Equisetum pratense, Typha latifolia, Eupatorium maculatum,* wetland, diversity

Introduction

The Cobalt mining camp in north-eastern Ontario developed as a result of the discovery in 1903 of silver-arsenide mineralization hosted within carbonate veins (calcite and dolomite) that included a complex mineralogy containing metals such as cobalt, nickel, iron, bismuth, and antimony (Petruk et al. 1971). Mining of high-grade ore began in 1904, peaked in 1911 and continued non-stop into the early 1930s; afterwards it continued intermittently until the late 1980s, with ore grades decreasing as technology improved and the highest-grade ore veins were exhausted. Mill operations began in 1907, processing over 850,000 kg of silver in 1911 alone, and recovering thousands of kilograms of cobalt, nickel and copper in addition to the silver and some arsenic during the 20th century. Mill effluent (tailings), containing unrecovered metals, arsenic, silicates and carbonates, was deposited by gravity flow into nearby lake basins and other local depressions.

Tailings deposits derived from mining at Cobalt are alkaline due to the large content of carbonate minerals and the lack of significant sulfide minerals in the ore. The lack of acid mine drainage in the

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camp has led to the perception that there are no environmental issues in Cobalt. However, many of the exposed tailings sites have remained vegetation free even years after the cessation of mining and milling activity. For example, the tailings from the low-grade mill of the Nipissing Mining Company, although small in area, were barren of any vegetation 60 years following abandonment of the mill. In summer, the Nipissing tailings would form dry salt crusts on the surface that were enriched in metals and highly toxic (Dumaresq 1993, Percival et al. 2004). Attempts to artificially seed these tailings failed and finally they had to be covered with uncontaminated soil and then seeded.

The largest tailings deposit in the Cobalt camp is located at the north end of Crosswise Lake (Figure 1), where five mills deposited tailings into the lake and adjacent lowland from 1908 to 1970. Tailings were also added to the lowland from mills operating upstream in the Mill Creek and Sasaginaga Creek watersheds that drain the main mining area of the Cobalt camp. Tailings can be found covering the floor of the entire present lake (over 2 km long) in addition to infilling completely the northern 800 m of the original lake and 1.7 km of downstream valley. The water level of Crosswise Lake is regulated by a low concrete and gravel spillway across which water discharges to form Farr Creek, a small stream averaging 2 to 3 m in width and 1.5 to 2 m depth. Mill (and Sasaginaga) Creek flows into Farr Creek about 150 m below the spillway.

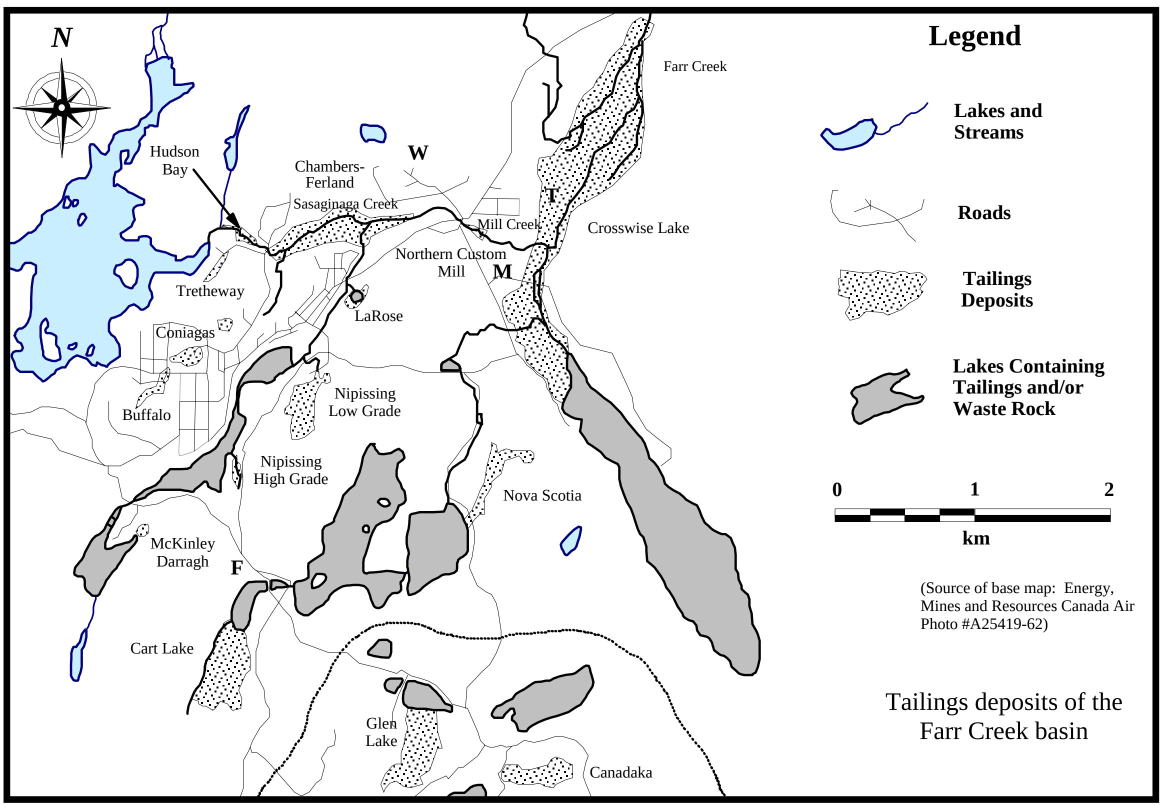

Figure 1: Distribution of tailings in the Cobalt area and the four vegetation study sites: (F) forest, (M) meadow, (T) tailings, (W) wetland (modified from Dumaresq, 1993).

Construction of a water level control dam on Farr Creek at the north end of the tailings deposit caused flooding of the northern half of the tailings in the lowland, creating a vegetated wetland that grades southward into drier exposed tailings. The central part of the wetland contains essentially cattails (*Typha latifolia*) cut by several channels maintained by an active beaver colony. Kelly (2006) found that the cattails in the wetland are enriched in metals obtained either directly from the tailings beneath or by removal of dissolved metals in the water. The drier tailings to the south of the wetland are less than 1.0 m above the level of Farr Creek and form an open meadow-type environment that is also naturally vegetated and dominated by Juncus balticus.

Studies of rehabilitation of sites contaminated with acid-mine tailings have shown that some plants can help reduce heavy metal concentrations (Das and Maiti 2007). *Typha latifolia* is known to take up and sequester a variety of heavy metals, including Cu, Ni, Zn, Fe, in root, rhizome and shoot tissue (Taylor and Crowder 1983). In a study of degraded soil at a mine site in Portugal, *Juncus* conglomerates were found to sequester arsenic (Freitas et al. 2004).

The purpose of this study was to investigate the types of vegetation that are able to grow on the alkaline Crosswise Lake tailings since they would be potentially suitable for remediation of similar tailings deposits in the region.

Study Sites

The Crosswise Lake tailings were chosen for investigation because of their relative success at natural re-vegetation. As previously noted, the tailings located in the lowland between the concrete spillway and the control dam represent an area that grades from wetland to meadow, with varying vegetation types and varying moisture conditions. The tailings are bordered by higher terrain that is primarily forested, although a small open field exists adjacent to the tailings at the south end.

To determine how unique the vegetation is to the tailings environment, three non-tailings (uncontaminated) sites, representing wetland, open meadow (field) and forest environments, were also examined (Figure 1). All three of these additional sites contain unconsolidated glacial silt/sand till as the soil, rather than tailings.

The wetland site is located in a small valley tributary to Sasaginaga Creek and contains small areas of standing water that are transitional to low-lying open meadow. The meadow site was a forested area cleared of trees during mining operations adjacent to Crosswise Lake and is near the spillway at the southern end of the tailings. The forest site, adjacent to the Little Silver Vein, contains an upland mixed forest with undergrowth that is typical of the Cobalt area.

Methods

Each of the sites was visited in early September of 2004, 2005 and 2006 as part of student exercises. Four transects were established at each site in 2004 and 2005, and five transects per site in 2006. For the tailings, each transect ran from the edge of Farr Creek to the edge of the tailings. Quadrat frames, measuring 1 x 1 m, were placed at five stations located every five metres along each transect and all of the plant species present within the quadrat were identified. Unknown species were sampled and identified later. Results for all stations along all transects at each site were tabulated for analysis. Soil pH was recorded at stations one, three and five of each transect.

Results and Discussion

The tailings site can be subdivided into two parts based on water conditions; wetland and stream (Farr Creek) margins where water covers the surface, and exposed tailings where the water table is below ground surface. The drier portion of the tailings was the only location where the vegetation cover was not complete and continuous; instead tailings sediment was visible in places at the surface between the plants. Within the tailings wetland, *Typha latifolia* and *Eupatorium maculatum* dominate and form a thick growth. Since each transect started at the stream margin and progressed inland, observations on vegetation were primarily confined to the drier exposed portions of the tailings.

Over the three years of observation, a total of 20 plant species have been identified on the tailings (Table 1). By comparison, 39 plant species were identified at the wetland site, while 45 species at

Table 1: Vegetation species identified on the Crosswise Lake tailings.

Common Name	Scientific Name	Other Sites Where Found
Aster, Bog	*Aster nemoralis*	wetland
Aster, Purple-stemmed	*Aster puniceus*	wetland, forest
Bluejoint, Canada	*Calamagrostis canadensis*	
Boneset	*Eupatorium perfoliatum*	wetland
British soldiers	*Cladonia cristatella*	
Bugleweed	*Lycopus amaericanus*	wetland
Bulrush, Hardstem	*Scirpus acutus*	
Cattail, Common	*Typha latifolia*	wetland
False pixie cup	*Cladonia chlorophaea*	
Goldenrod, Downy	*Solidago puberula*	wetland
Goldenrod, Swamp	*Solidago uliginosa*	wetland
Grass, Bluejoint	*Calamagrostis canadensis*	wetland
Grass, Tickle	*Agrostis scabra*	wetland, meadow
Horsetail, Field	*Equisetum arvense*	wetland
Horsetail, Meadow	*Equisetum pratense*	
Microbial mat	Cyanobacteria	
Joe Pye weed	*Eupatorium maculatum*	wetland
Rush, Baltic	*Juncus balticus*	
Sneezeweed	*Helenium autumnale*	meadow
Violet, Marsh Blue	*Viola cuculata*	

the meadow site and 62 species at the forest site were recorded. Some plant species are restricted to specific habitats, while others can be found in a variety of settings. Over 70% of identified species in meadow and forest locations were unique to their site (30 and 44 species, respectively). The wetland site had 59% of its species unique to the site and the tailings only had 40% (8 of 20) unique vegetation types. The lower values for the wetland and tailings sites are partly due to the presence of 9 species common to the two sites.

Although there is considerable overlap in the plant species between the wetland and tailings sites, the overlap with the other two sites is minimal. The tailings had one species in common with the forest site and two species in common with the meadow, even though the tailings are surrounded by forest and adjacent to a small open meadow in the vicinity of the tailings site. Of the eight plant species unique to the tailings, only two are abundant and dominate the site; *Juncus balticus* (Figure 2) and *Equisetum pratense*. Thin microbial mats (Cyanobacteria) were also found covering some of the exposed tailings throughout the site. These three tailings-unique species were also identified at tailings at Cart Lake and a low-lying wetter portion of the Nipissing low-grade tailings. *Eupatorium maculatum* and *Typha latifolia*, also found in the wetland site, were dominant in the wetter sections of the tailings, especially adjacent to the stream banks.

Figure 2: *Juncus balticus* growing on tailings (photo by K. Henein)

Low species richness on the tailings flats is related to the challenge of growing in a habitat low in moisture, organic material and nutrients, and high in toxic metals. However species able to establish here are having a positive impact. Cyanobacteria species are helping to prevent erosion and sedimentation as well as fixing nitrogen and adding organic material. *Juncus balticus* reproduces vegetatively, producing long rhizomes that create a network of plant cover that helps stabilize the substrate. *Equisetum pratense* naturalizes low, wet areas, takes up silicon, and also produces soil-stabilizing rhizomes.

Soil pH did not display a large variation among the four sites. It ranged from slightly acidic (mean of 6.14+/-0.79) at the forest site to alkaline in the tailings (mean of 8.04+/-0.07); the open meadow had a mean of 6.78 (+/-0.96) and the wetland mean was 7.95 (+/-0.08). The glacial tills in the Cobalt area contain carbonate material derived from Ordovician and Silurian limestones and dolostones exposed to the north (up ice) near New Liskeard that would produce near neutral to slightly alkaline pH values. The forest site was expected to have a slightly lower pH because of the presence of conifers.

Within the tailings area, the least vegetated portions were also the driest and at the highest elevation above stream level, although large parts of the tailings immediately adjacent to Crosswise Lake are also barren of vegetation. At the low-grade Nipissing mill tailings, only a small relatively wet section in the south-eastern corner was capable of vegetation growth; the remainder as noted earlier was dry and infertile. Both the forest and meadow sites are relatively well drained, but the soils are capable of retaining sufficient moisture to support the growth of abundant vegetation. In contrast, the tailings are primarily sand-size material that drains rapidly and does not retain moisture. Therefore, the presence or absence of moisture and the ability of the soil to retain moisture appear to be limiting factors for re-vegetation of the tailings.

Nutrient availability is also important for plant growth. Sasaginaga Creek, which flows into Farr Creek and the Crosswise Lake tailings via Mill Creek, has long been the outlet for sewage from the Town of Cobalt. Recently, the town constructed a wetland for sewage treatment within the valley through which Sasaginaga Creek flows and water quality in the streams has improved visibly. Nevertheless, the sewage wetland still provides nutrients to the water that flows through the Crosswise Lake tailings. The availability of these nutrients to areas beyond the stream channel and downstream wetland is unknown.

Another factor that needs to be considered is the toxicity of the tailings; not all tailings are alike in this regard. Some of the older tailings, such as the Nipissing tailings, contain higher concentrations of metals and arsenic than many of the newer tailings that resulted from processing lower-grade ore (Percival et al. 2004). Even after 60 years of leaching by precipitation, metal concentrations remained quite high in the drier near-surface tailings and may have been sufficiently toxic to inhibit germination of the seeds sown during initial attempts to re-vegetate. In these circumstances, an uncontaminated soil cover may be necessary. For other more recent tailings, such as at Cart Lake, re-vegetation attempts in experimental plots were successful, so toxicity does not appear to be a critical factor there. However, the upper tailings are quite dry and nutrient-poor. This may explain the lack of natural re-vegetation and the need to add a soil cover prior to reseeding. The Crosswise Lake tailings are also relatively young with lower metal concentrations, since mill activity only ended in 1970. The combination of lower toxicity and an adequate supply of moisture and nutrients appear to have contributed to the success of natural re-vegetation of these tailings.

Conclusions

The tailings deposited downstream of Crosswise Lake have been partially flooded by a water level control dam to create conditions that vary from wetland to open meadow. These tailings have been naturally revegetated with a number of plant species unique to the tailings environment and by some species that occur in other local wetland areas. On the drier exposed tailings only two species were abundant, *Juncus balticus* and *Equisetum pratense*, and the overall diversity of plants on the tailings was much lower than any of the three other environments measured. Major limiting factors for plant growth on the tailings include availability of moisture and nutrients, and to some extent the toxicity of the tailings.

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Literature Cited

Das, M. and Maiti, S.K. 2007. Metal accumulation in 5 native plants growing on abandoned Cu-tailings ponds. Applied Ecology and Environmental Research, 5(1), p. 27-35.

Dumaresq, C.G. 1993. The occurrence of arsenic and heavy metal contamination from natural and anthropogenic sources in the Cobalt area of Ontario. M.Sc. thesis, Department of Earth Sciences, Carleton University, Ottawa.

Freitas, H., Prasad, M.N.V. and Pratas, J. 2004. Plant community tolerant to trace elements growing on the degraded soils of Sao Domingos mine in the south east of Portugal: environmental implications. Environment International, 30, p. 65-72.

Gregory, J.T. and Crowder, A.A. 1983. Uptake and accumulation of heavy metals by Typha latifolia in wetlands in the Sudbury, Ontario region. Can. J. Bot., 61, p. 63-73.

Kelly, J. 2006. Biogeochemical characterization of a wetland impacted by alkaline mine tailings located in North Cobalt, Ontario. M.Sc. thesis, Department of Earth Sciences, Carleton University, Ottawa.

Percival, J.B., Kwong, Y.T.J., Dumaresq, C.G. and Michel, F.A. 2004. Transport and attenuation of arsenic, cobalt, nickel in an alkaline environment, Cobalt, Ontario. Geological Survey of Canada, Open File 1680.

Petruk, W., Jambor, J. and Boyle, R.W. 1971. History of the Cobalt and Gowganda area. in: the Silver-Arsenide Deposits of the Cobalt-Gowganda Region, Ontario (Berry, L.G., ed.), The Canadian Mineralogist, 11(1), p. 1-7.