GS-12 Natural revegetation of Gunnar minesite, Manitoba (NTS 52L14)

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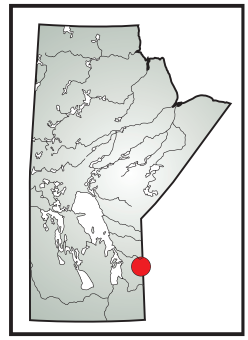

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Summary

The mine tailings deposited during operation of the Gunnar gold mine have remained largely nonvegetated since the mine was closed 67 years ago. For this study, the natural spruce/larch forest that has developed in the southwest portion of the tailings was examined. Vegetation sampled along transects showed a consistent pattern of succession from horsetail (*Equisetum* spp.) to willows (*Salix* spp.), birch (*Betula* spp.) and balsam poplar (*Populus balsamifera*) and then larch (*Larix laricina*) to black spruce (*Picea mariana*). Estimates of the ability of roots to grow into the tailings, using a penetrometer, showed a marked decrease in the force needed to penetrate the tailings as vegetation developed. While a number of heavy metals, including Cr (111 ±10 ppm), Cu (194 ±33 ppm), Mn (1185 ±47 ppm), V (162 ±35 ppm) and Zn (212 ±23 pm), were present at high concentrations in the tailings, they have not accumulated in the plant tissues tested or the surface organic layer. The metal concentrations in conifer needles were 218 ±179 ppm Mn and 38 ±27 ppm Zn whereas all other analyzed metals were below 5 ppm.

Introduction

The Gunnar gold mine (50°51.37'N, 95°15.31'W), situated within the Archean Rice Lake greenstone belt in southeast Manitoba, was in operation from 1936 to 1942 (Slivitzky, 1996). The minesite contains approximately 11 ha of tailings and since the time that the mine closed, natural revegetation on the tailings has been limited. On the north and west side of the tailings pond, vegetation from the surrounding forest has invaded less than 10 m onto the tailings. On the southwest side of the pond, vegetation has developed following in what appears to be a regular pattern of colonization (Figure GS-12-1).

The total vegetation zone varies from 60 to 80 m in width, while the remaining nonvegetated area of tailings covers approximately 360 by 120 m. Previous work (Renault et al., 2006, 2007) has shown that the chemical and physical properties of the tailings may have prevented or limited plant growth on the tailings. These properties could include high bulk density, low levels of nutrients (nitrogen), low organic matter content and elevated concentrations of potentially harmful elements (Slivitzky, 1996). Research in 2008 showed that the tree species (larch and black spruce) have been invading the tailings along the south and west ends of the pond at a rate of approximately 1.75 m/a (Markham et al., 2008). Positive correlations exist between tree growth increments and both the total spring precipitation and the mean daily temperature during the growing season. The organic matter depth was less than 60 mm throughout the first 30 m of the vegetation and averaged 91 mm between 30 and 60 m. The pH of the tailings was consistently near a value

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Figure GS-12-1: *Gunnar mine tailings, Manitoba; south side covered with vegetation and north side with very limited vegetation.*

of 7.5, and both the pH and the conductivity of the tailings were lower for the revegetated regions of the tailings deposit.

Objectives of the study

The purpose of this study is to examine changes associated with the natural revegetation that has occurred on the Gunnar mine tailings site. First results of the study are summarized in Markham et al. (2008). The current report presents a quantitative assessment of vegetation cover, along with the results from chemical analyses of tailings, organic matter and tree tissue samples collected along the established transects. These results will help to determine how soil fertility on this site is shifting and what changes can be expected in soil development as remediated areas become naturalized. This will provide insight into the changes that need to be made in order to enhance the revegetation process at this, and potentially other similar mine tailings sites.

Analytical methods

On June 24, 2008, four transects were sampled along the southwest side of the tailings pond running into the natural vegetation (Markham et al., 2008). Transects were set up by selecting points approximately every 30 m along the edge of the vegetation (the horsetail zone) and along perpendicular lines directed towards the pond edge. In every 10 m segment of the transect line, a spruce and a larch tree were selected at random, if present. Following removal of the organic matter layer, tailings cores were collected to a depth of 20 ±5 cm and air dried. In September, 2008, shoot tips (20 cm long) of each selected tree were collected and freeze dried. Tailings, organic matter and plant tissues (stems and needles) were analyzed by instrumental neutron activation analysis (INAA) and inductively coupled plasma–mass spectrometry (ICP-MS) by Activation Laboratories Ltd. to determine metal and nutrient content. In July and August, 2009, vegetation was assessed along the previous transects and five additional transects. A visual estimate of the cover of each species was made in m^2 plots along each transect. Given the often waterlogged nature of the tailings, bulk density estimates were prone to error since known soil volumes could not easily be extracted. As such, a penetrometer was used as a proxy for bulk density and as a measure of the potential for roots to grow into the tailings.

Results and discussions

The concentration of elements in the revegetated tailings is generally lower than in the nonvegetated tailings (Table GS-12-1). Half of the elements show a significant decrease in concentration in the organic layer with increased distance along the transects (Table GS-12-2). This could be attributed to the fact that the depth of the organic layer increases along the transects and thus contamination by tailings decreases. The plant species do not appear to have concentrated any elements in their tissues; although relatively high levels of Ti and V were found in stem samples (Table GS-12-1). A correlation matrix of elemental concentration in the tailings, the organic matter layer and in leaf tissue samples indicates that metal concentrations generally correlate within tailings samples collected along the transects. Both Ni and Zn show positive correlation with all other metals. However, Cu and

Table GS-12-1: Element contents of tailings, organic layer and plant tissues along vegetation transects, Gunnar minesite, Manitoba. Values are means ± standard deviations. Values marked with an * vary over the length of the transect. BDL: below detection limit.

Element	Tailings	Organic layer	Plant tissues	
			Stems	Needles
As (ppm)	15 ±4*	14 ±10	0.56 ±0.16	0.71 ±0.47
Au (ppb)	157 ±76*	252 ±110	1.69 ±1.13	0.42 ±0.48
Ca (%)	7.9 ±0.2	4.0 ±0.5	0.49 ±0.14	0.59 ±0.34
Cr (ppm)	111 ±10	56 ±39*	2.3 ±0.7	0.04 ±0.01
Cu (ppm)	194 ±33	151 ±77	5.0 ±3.4	4.49 ±4.37
Fe (%)	6.1 ±0.4	3.2 ±2.0*	0.013 ±0.005	0.006 ±0.003
Mg (%)	2.1 ±0.2	1.05 ±0.76*	0.065 ±0.020	0.097 ±0.29
Mn (ppm)	1185 ±47	1160 ±532	220 ±172	218 ±179
Mo (ppm)	BDL	3.25 ±4.45	0.21 ±0.13*	0.43 ±0.43
Ni (ppm)	76 ±6	54 ±24*	1.01 ±0.29	0.64 ±0.51
Ti (ppm)	3050 ±919	439 ±279*	414 ±155	2.25 ±0.50
V (ppm)	162 ±35	74 ±49*	70 ±22	0.52 ±0.23
Zn (ppm)	212 ±23	200 ±94*	40.4 ±20.5	38.2 ±26.9
Ash (%)	N/A	43 ±20	2.3 ±0.4	4.5 ±1.0

Table GS-12-2: Correlation coefficients of element concentration with distance along transects (and ash content of the organic layer), Gunnar minesite, Manitoba. Only significant correlations are shown. NS: nonsignificant.

Element	Tailings	Organic layer	Plant tissues	
			Stems	Needles
As	–0.45	NS (NS)	NS	NS
Au	–0.52	NS (NS)	NS	NS
Ca	NS	NS (NS)	NS	0.7
Cr	NS	–0.67 (0.95)	NS	NS
Cu	NS	NS (NS)	NS	NS
Fe	NS	–0.67 (0.92)	NS	NS
Mg	NS	–0.69 (0.69)	NS	NS
Mo	NS	NS	–0.69	NS
Ni	NS	–0.64 (0.79)	NS	NS
Rb	NS	NS	0.67	NS
Ti	NS	–0.73 (0.98)	NS	NS
V	NS	–0.67 (0.97)	NS	NS
Zn	NS	–0.78 (0.89)	NS	NS
Ash	N/A	–0.77	NS	NS

Au are negatively correlated with Cr, Fe, Mg, Mn, Ti and V concentrations. The correlation matrix shows that samples in the organic layer either have high levels of several elements or none. However, there seems to be little correlation between element concentrations in tailings and the organic layer. Additionally, the concentrations of elements in plant tissues do not generally correlate with concentrations in the tailings. Only Au shows a significant decrease from 260 to 110 ppb in the tailings over a distance of 50 m along the transect.

A total of 46 plant species have been observed along the transects. While most are typical of the surrounding boreal forest, some species, such as white clover (*Melilotus alba*), Canada thistle (*Cirsium arvense*) and sow thistle (*Sonchus arvense*), are not native to the surrounding forest communities but are invasive species indicative of highly disturbed sites. The gradient in vegetation from the tailings outward to the forest stands appears to be consistent (Figure GS-12-2). A dense cover of horsetails dominates the first few metres of the vegetation zone (Figure GS-12-3). Further along each transect the cover of horsetails gradually decreases with the advent of shrubs (willow and birch), balsam poplar and larch. The black spruce cover gradually increases outward from the horsetail zone and becomes the dominant species at about 35 m. Balsam fir was recorded at the far end of each transect, marking the edge of the surrounding boreal forest. The penetrometer readings dropped exponentially with increased distance from the nonvegetated zone of the tailings

Figure GS-12-2: *Development of vegetation on the tailings pond at the Gunnar minesite, Manitoba.*

(Figure GS-12-3), suggesting that roots can more easily grow into the tailings as vegetation cover develops.

The results indicate that the tailings are becoming more fertile as the vegetation cover develops. There is no clear evidence that the heavy metals present in the tailings are accumulating in the dominant tree species, although other species have not been tested to see if they are negatively affected by heavy metals in the tailings. The vegetation along the sample transects seems to be following a typical boreal forest successional pattern. Previous results (Markham et al., 2008) suggest that the growth of selected trees is strongly dependent on spring precipitation, and that it would take between 70 and 110 years for the site to be completely and naturally revegetated, assuming that the conditions of the nonvegetated tailings are similar to the vegetated area, and that environmental conditions remain favourable for plant growth.

Current and future research

Given the deep organic layer that has developed on the Gunnar mine tailings site, the total amount of stored carbon needs to be assessed. This will provide a benchmark for future site remediation studies planned for 2010/2011. Both field and laboratory studies on the nearby Central Manitoba mine tailings site have shown that organic amendments can improve plant growth and survival (Markham, 2005; Szczerski, 2007; Green et al., 2008). Consequently, research evaluating the beneficial effects of amendments (fertilizer, paper-mill sludge and wood chips) to improve plant growth is currently being conducted at the Gunnar minesite.

Economic considerations

Mining activities result in the loss of timber, biodiversity and ecosystem services (i.e, productivity, nutrient cycling and retention). The Gunnar mine tailings site has missed a full timber rotation since it was abandoned. Without remediation, the site will remain barren for another

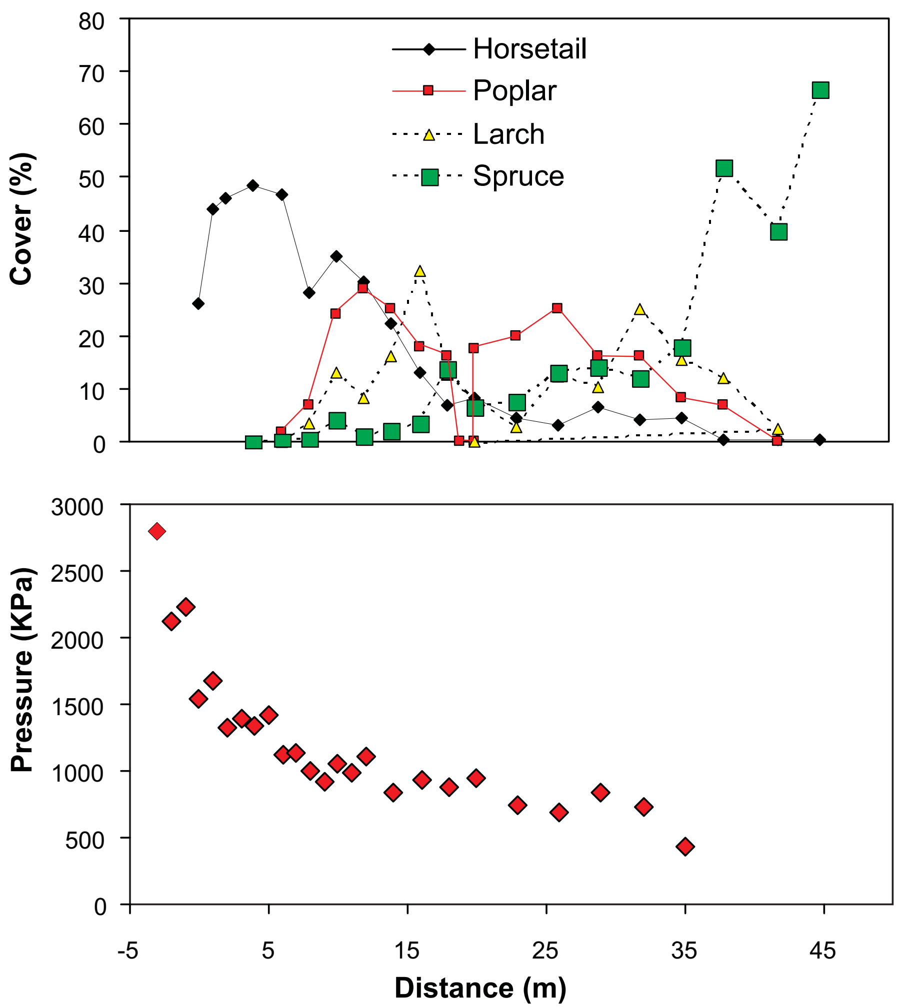

Figure GS-12-3: *Cover of dominant plant species (top) and penetrometer readings 30 cm into tailings (bottom) along sample transects from the nonvegetated portion of the tailings pond (corresponding to 0 m) toward the vegetated portion, Gunnar minesite, Manitoba.*

rotation. The site has also undergone a loss of carbon-holding capacity. Based on estimates for other coniferous stands (Yemshanov et al., 2005), a forest on the Gunnar mine tailings pond could have stored 57 tonnes of carbon per hectare in the form of wood. In addition, the large buildup of organic matter suggests that much more than the 200 tonnes of carbon per hectare, generally estimated to be stored in forest floors (van Kooten et al., 1999), can accumulate in the soil on this site. Based on a modest dollar value for carbon storage (e.g., $10/t) the ability of this site to hold in the order of 3000 tonnes of carbon represents a significant economic potential.

Acknowledgments

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