

THE GREENING OF SUDBURY

BY

K. WINTERHALDER



**INSTITUTE ON LAKE SUPERIOR GEOLOGY
43rd ANNUAL MEETING, MAY 6 - 11, 1997
SUDBURY, ONTARIO**

Field Trip Guidebook, Volume 43, Part 7

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May 10, 1997

Leader:

Prof. Keith Winterhalder
Department of Biology
Laurentian University

Institute on Lake Superior Geology

Sudbury, 1997

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One hundred years of logging, fire, acidification by sulphur dioxide, particulate metal deposition, enhanced frost action and erosion have created 10,000 hectares of barren land and 36,000 hectares of stunted, open birch woodland around the Sudbury copper and nickel smelters. It was found that the steep, stony barren slopes, which have been acidified and contaminated with copper, nickel and aluminum, can be detoxified by the manual application of pulverized dolomitic limestone. Revegetation began on an operational scale in 1978, and approximately 3,500 hectares of surface soil have been detoxified by manual application of limestone, and revegetated using a grass/legume seed mixture. Rapid invasion by birch, poplar and willow seedlings occurred spontaneously, and the resulting woody deciduous cover has been enriched by the planting of more than 2.5 million tree seedlings, the majority of them native pines. Understory species in blocks of their own soil are being introduced at an experimental level, to facilitate and accelerate the establishment of an appropriate herb and shrub stratum, microflora and microfauna. Unique features of this program include its community-based format, the predominantly manual approach employed, and the use of a minimal amelioration approach that relies heavily on spontaneous colonization by native species and other natural dynamic processes.

In addition to the degraded natural landscape, deposits of materials that are discarded after the ore is separated by milling flotation, known as tailings, cover more than 2,000 hectares. Experimental revegetation began on the Inco Ltd. tailings in the 1950s in response to a dust problem, and has reached the point at which all non-active tailings areas are in various stages of revegetation. The revegetation process includes liming and fertilizing, seeding with a grass-legume mixture, use of a cereal rye nurse crop, and ultimately planting of trees, many of which are grown underground at the 4600' level.

Stop # 1 - McKim Street Transmission Tower, 3.5 km northeast of the Copper Cliff smelter

This previously barren area was grassed in 1981 by the Regional Land Reclamation Program, and planted with red and jack pine in 1983. Also planted in this area were smaller numbers of white spruce, white ash, sugar maple, silver maple, white cedar and red oak. As you walk up the hill, you will also see volunteer trembling and large-tooth aspen, white birch and pin cherry. From the top, you will see the city of Sudbury to the

east and south-east, 20 hectares of grassed barrens to the west, and an untreated area across the railway tracks to the north that has been colonized by a metal tolerant strain of dwarf or bog birch (*Betula pumila* var. *glandulifera*).

Stop # 2 - Barren site east of Clarabelle, 2 km northeast of the Copper Cliff smelter.

On the way to this site, we shall see a slag disposal area, and the process of grinding slag for construction of railway beds (coarse slag) and driveways (fine slag mixed with sand, known as "Drypack").

You will see a mosaic of land that is totally barren, and in the early stages of revegetation, including bare rock outcrops, soil pockets and stony slopes, with large white pine stumps indicating the original vegetation. The rare, coppiced and stunted individuals of red maple and red oak, which pre-date denudation, arise from large stools, and are often surrounded by a litter of earlier, much larger stems. The soil is highly acidic, with a pH between 3.5 and 4.5, and plant-available copper, nickel and aluminum can each exceed 100 ppm. Some of this land has been aerially limed, fertilized and seeded by Inco Ltd. in 1990 and 1991, and is grass-covered.

The sole colonizer of the untreated land is *Deschampsia caespitosa* (tufted hairgrass), which has been shown by Cox & Hutchinson (New Phytologist 84: 631-647:1980) to have evolved multiple-metal tolerance. A few individuals of *Agrostis scabra* (tickle grass), also a metal-tolerant ecotype (Archambault & Winterhalder, Canadian Journal of Botany 73:766-775), have also begun to colonize.

As we leave the area, a site opposite a school building will be pointed out. This is where the manual technique was tried out at the "semi-operational" level in 1975 by elementary school pupils, on one acre of land beside their school. It was the success of this trial that encouraged the Regional Municipality of Sudbury to apply for job-creation funds to establish its ongoing land reclamation program.

Stop # 3 - Inco Ltd. tailings, Copper Cliff.

Your guide will be Bob Stanzel of Inco's Environmental Control Department. It is my hope that you will be shown the spigotting process,

stages in vegetation establishment, and the end product at the "C-D" area, which shows the results of revegetation initiated over 30 year ago, including the originally seeded grasses and legumes, some spontaneous colonizers, and planted pines.

You will also see attempts to diversify the pine plantations by introducing plots or plugs of plant and their native soil from undisturbed forest.

Stop # 4 - South shore of Kelly Lake, 4 km south of the Copper Cliff smelter.

Our walk begins in an area that was limed, fertilized and seeded in 1982, and planted with red and jack pine in 1984. The grasses are a mixture of metal-tolerant tufted hairgrass and tickle grass with seeded species. The seeded legumes Alsike clover and birdsfoot trefoil are also present. Colonists include white birch, trembling aspen, balsam poplar, fireweed, pearly everlasting, yarrow and hawkweed, as well as acid-tolerant sheep sorrel. Relict red maple and red oak are common. We eventually emerge into an untreated area. Note that here, at a greater distance from the smelter than Site 2, there is an almost complete cover of metal-tolerant tufted hairgrass, with occasional relict red maple and red oak. Some white pines were also planted in this area in 1984, and one of them has survived and grown on the untreated soil, but exhibits necrotic needle tips.

You can see the north shore of the lake, with a clear line marking the point at which liming stopped.

We return by way of a south-facing slope, facing away from the smelter, on which there is a relict community of large red oaks.

Stop # 5 - South of southeast bypass, north of Richard Lake, approximately midway between the Copper Cliff and Coniston smelters.

We shall walk through a typical semi-barren ("birch transition") community, with birch, red maple and red oak, some of which may have lost some stems to the combined effects of drought and gypsy moth defoliation. The larger red pines are native here, but some planting of tree seedlings (pine and spruce) has also occurred. It is not necessary to lime the soil before planting trees in the semi-barren zone. The understory consist of tufted hair grass and two species of blueberry, with mosses

(*Pohlia* and *Polytrichum*) and lichens, and Labrador tea in damp sites. Returning by way of the gully, where the soil is deeper, Labrador tea is more common, and the fire-tolerant clubmoss known as ground cedar can be seen.

Stop # 6 - north of Highway 17E, 4 km northwest of the Coniston smelter.

We shall begin by walking up the overgrown dirt road that was constructed by the land reclamation crew in 1979 for the transportation of ground limestone. In 1979, the area to the west of the road, partly sheltered from the Coniston fumes, supported birch transition woodland, but the area to the east of the road was barren except for a few scattered relict birches and maples. The upper section of the road crosses the revegetated area obliquely on its way to the top of the hill. Young birches predominate, with occasional relict white birch, red maple and red oak. Larger shrubs include beaked hazel and willows, with the N-fixing shrub sweet fern and blueberries in the understory with hair moss (*Polytrichum*). At some points along the trail we shall still see some of the originally seeded species such as birdsfoot trefoil, Alsike clover and tall fescue. Note the small experimental plantation of European larch. The main native herbaceous colonists are pearly everlasting, rough and Canada goldenrod, fireweed and yarrow, accompanied by weedy non-native species such as the yellow and orange hawkweed. Woody colonists include pin cherry and staghorn sumac. Native woody plants such as bush honeysuckle and trailing arbutus have been seen here, but we may not encounter them. Near the treated/untreated junction is a healthy red pine that has become rooted in untreated soil. This is probably because the active physical weathering of rock in this microsite has created a rooting environment that is not metal-toxic.

Emerging at the top of the hill, where liming stopped, we see that birch is actively colonizing this site, which has been relatively unaffected by smelter fallout since closure in 1972. In the last 20 years, the average soil pH in this area has risen from around 3.5 to around 4.5. You will also see relict coppiced birch, and red maple undergoing regressive dieback. The metal-tolerant grass is tickle grass. This hilltop may be too isolated from the moist valley to have been colonized by metal-tolerant tufted hairgrass. Also common are the moss *Pohlia*, and blueberry bushes which may be relicts. Note the signs of frost activity visible in the soil.

Looking across the highway, you will see an area that was limed but not seeded. We know that this use of limestone as a "trigger factor" is an effective method of regreening, but the Regional authorities like the

bright green grass in the spring. In 1979, the revegetation crew ran out of seed, providing a useful demonstration site.

On the way down, we shall see a small experimental plantation of white pine. White pine, once the dominant tree species in this area, is extremely SO₂-sensitive, but can survive again under current atmospheric conditions.

En route to Stop #7:

On the left hand side of the bus, just prior to the Coniston turnoff, you will see 1 acre of sloping land that was treated by elementary school students in 1975.

Stop #7 - just east of Coniston smelter

After passing a small industrial complex, you will see untreated barren land on your right. As we drive onto the net slag-surfaced area, you will see a good transition between two-year and three-year-old grassing. We shall take a walk on the grassed area so that you can see the colonization process, mostly by poplar and willow seedlings. The second-year area seems to have more woody colonization, probably due to the right combination of weather, wind etc. when the seeds were shed. Much of the limed ground has been colonized by the moss *Funaria hygrometrica*. Note how grass grows better at the soil-rock interface. Pine seedlings have already been planted here.

Stop # 8 - north of Highway 17E, 1.5 km northeast of the Coniston smelter.

This area was treated in 1978, and the seed mixture contained no legumes. Nevertheless, trefoil and clover have colonized from a nearby Inco seeded site. Red and white pine were planted here in 1983. We shall examine an experiment in which typical understory species have been transplanted in blocks of their own soil (the so-called "nucleation" approach). Especially successful were the woody ground cover bearberry and the nitrogen-fixing shrub soapberry (or buffalo berry). Note that many other species were introduced with the woody plants, wild strawberry and starry false Solomon's seal being especially conspicuous. The later normally favours limestone soils, and its success here is probably the result of the limestone treatment used. Some tree species, such as balsam fir and white spruce, have also been accidentally introduced in the soil blocks.

Stop # 9 - Coniston Hydro road, 2 km east of the Coniston smelter.

From this vantage point, it is possible to see land treated in 1978, 1981, 1987, 1993 and 1994, respectively, as well as untreated land and land aerially-limed by Inco in 1995 and 1996 in the distance. Note that the untreated land closer to the smelter is still barren, while that to the east is undergoing rapid colonization by white birch. Plantings of pines, black locust and red oak can also be seen here. Some of the red and jack pine seen here was propagated underground by Inco.

If we drive further down the Hydro road, we can get a close-up view of barren terrain, with birches beginning to colonize.

Stop (or drive-by) # 10 - north and south of Highway 17E, 3.5 km east of the Coniston smelter.

Following grassing in 1978, container and bare-root stock of red and Jack pine were planted here, plantation-style, in 1979. Later planting in this area were in a more informal, natural-looking style. If we stop at this site, we shall have the opportunity to look at another understory transplanting trial using soil blocks.

Stop # 11 - Coniston-Garson road, 4 km north of the Coniston smelter.

Prior to initiation of manual liming of hillsides, this sandy valley bottom was limed, fertilized and seeded with Canada bluegrass in 1974. Some areas showed rapid, diverse colonization, while others remained bare. The latter areas were probably short of organic matter and phosphorus (see experimental plot). The nitrogen-fixing shrub called sweet fern is spreading rapidly. Interesting herbaceous species now found at this site include rattlesnake ferns, ladies' tresses orchids and a small blue early violet (*Viola adunca*).

The red and Jack pine plantations at this site were established following grassing in 1976, using paper-pot container stock. Seedlings planted in neighbouring ungrassed areas showed almost total mortality.

En route to Stop # 12 - north of Garson

Here you will see extensive tracts of blueberries, with scattered pines. Tree planting here has been kept to the minimum, to conserve the blueberry stands.

Past the airport turnoff, on the Falconbridge road, you will see extensive grassing and pine planting carried out by Falconbridge Ltd. in collaboration with the Region.

Stop (rolling stop?) # 12 - south of Falconbridge

Here we shall see very early revegetation work carried out by Tom Lloyd of Falconbridge Ltd. Carolina poplars were planted in large pits filled with black loam, in plantation fashion. This is a very different approach from what we would take today.

Stop (rolling stop?) # 13 - Falconbridge community

We shall drive past Centennial Park, which is a park built on Falconbridge's first tailings deposit. We shall also view Falconbridge's "conservation area", a barren peatland that has been restored to a cattail marsh by flooding it with alkaline mine waste water and sewage sludge. This is currently being encroached upon by granulated slag, and negotiations are underway between the Environmental and Smelter officials to find an alternative dumping site.

En route, re-entering Sudbury by the Kingsway

As we enter Sudbury, you will notice that the semi-barren woodland has a grassy understory. Only occasionally are woodland sites grassed in this way.

PARTIAL CHECK LIST OF VASCULAR PLANT SPECIES
FOUND ON BARREN AND REVEGETATED SITES

CB	COLONIZING SPECIES (BARRENS)
CR	COLONIZING SPECIES (REVEGETATED)
P	PLANTED (NURSERY STOCK)
R	RELICT SPECIES
S	SEEDED SPECIES
SC	SUSPECTED SEED CONTAMINANT
T	TRANSPLANTED SPECIES
*	PART OF "WILDFLOWER" MIXTURE

Mosses and lichens

<i>Ceratodon purpureus</i>	CR
<i>Funaria hygrometrica</i>	CR
<i>Pohlia nutans</i>	CB, CR
<i>Polytrichum commune</i>	CB
<i>Cladonia cf. deformis</i>	CB
<i>Stereocaulon cf. paschale</i>	CB

Ferns and fern-allies

<i>Botrychium multifidum</i>	CR
<i>Dennstaedtia punctiloba</i>	R
<i>Equisetum arvense</i>	CB
<i>Ophioglossum vulgatum</i>	CR

Conifers

Cedar, eastern white	<i>Thuja occidentalis</i>	p
Larch, European	<i>Larix decidua</i>	P
Larch, Japanese	<i>Larix leptolepis</i>	P
Pine, Jack	<i>Pinus banksiana</i>	P
Pine, Mugo	<i>Pinus mugho</i>	P
Pine, red	<i>Pinus resinosa</i>	P
Pine, white	<i>Pinus strobus</i>	P
Spruce, black	<i>Picea mariana</i>	P
Spruce, white	<i>Picea glauca</i>	P

Grasses

Bluegrass, Canada
Bluegrass, Kentucky
Fescue, creeping red
Fescue, tall
Hairgrass, wavy
Hairgrass, tufted
Orchard grass
Quack grass
Redtop
Tickle grass
Timothy

Poa compressa S
Poa pratensis S
Festuca rubra S
Festuca arundinacea S
Deschampsia flexuosa R
Deschampsia caespitosa CB, CR
Dactylis glomerata CR (SC?)
Agropyron repens CR
Agrostis gigantea S, CR
Agrostis scabra CB, CR
Phleum pratense S

Other Monocotyledons

False Solomon's-seal, starry
Lady's tresses, nodding
Lady's tresses, slender
Sedge
Sedge
Sedge, wool

Smilacina stellata AT
Spiranthes cernua CR (moist sand)
Spiranthes gracilis CR (moist sand)
Carex houghtoniana CR
Juncus brevicaudatus CB(wet)
Scirpus cyperinus CB (wet)

Herbaceous Dicotyledons

Alfalfa
Alsike clover
Alyssum, yellow
Bindweed
Black-eyed Susan
Bristly sarsaparilla
Cornflower
Cow vetch
Dame's rocket
Devil's paintbrush
Fireweed
Flax
Foxglove
Grass-leaved goldenrod
Grass-leaved stitchwort
Hawk's beard
Heal-all
Horseweed
Iceland poppy
Moth mullein

Medicago officinalis CR
Trifolium hybridum S, CR
Alyssum saxatile * S
Polygonum cilinode CB, CR
Rudbeckia hirta * S, T, CR
Aralia hispida CR
Centaurea cyanus * S
Vicia cracca CR
Hesperis matronalis * S
Hieracium aurantiacum CR
Epilobium angustifolium CR
Linum perenne * S
Digitalis purpurea * S
Solidago graminifolia CR
Stellaria graminea CR
Crepis tectorum CR
Prunella vulgaris AT
Conyza canadensis CR
Papaver nudicaule * S
Verbascum blattaria CR *

Mullein
 Northern willow-herb
 Oxeye daisy
 Pearly everlasting
 Philadelphia fleabane
 Red clover
 Rock harlequin
 Rough cinquefoil
 Rough goldenrod
 Scentless mayweed
 Sheep sorrel
 Sulphur cinquefoil
 Tickseed
 White bedstraw
 White sweet-clover
 Wild strawberry
 Yarrow
 Yellow hawkweed

<i>Verbascum thapsus</i>	CR	
<i>Epilobium glandulosum</i>	CR	
<i>Chrysanthemum leucanthemum</i>		CR
<i>Anaphalis margaritacea</i>	CR	
<i>Erigeron philadelphicus</i>	CR	
<i>Trifolium pratense</i>	CR	
<i>Corydalis sempervirens</i>	CR	
<i>Potentilla norvegica</i>	CR	
<i>Solidago rugosa</i>	CR	
<i>Anthemis cotula</i>	SI	
<i>Rumex acetosella</i>	CR	
<i>Potentilla recta</i>	T, CR	
<i>Coreopsis lanceolata</i> *	S	
<i>Galium mollugo</i>	CR	
<i>Melilotus alba</i>	CR	
<i>Fragaria virginiana</i>	T, CR	
<i>Achillea millefolium</i>	CR, S	
<i>Hieracium florentinum</i>	CR	

Woody Dicotyledons

Balsam poplar
 Balsam willow
 Bearberry
 Black locust
 Choke cherry
 Common blueberry
 Downy-leaf blueberry
 Dwarf birch
 Large-toothed aspen
 Pin cherry
 Pussy willow
 Red elderberry
 Red maple
 Red Oak
 Silver maple
 Slender willow
 Soap or buffalo berry
 Sugar maple
 Sweet fern
 Trembling aspen
 White Ash
 White birch
 Witherod

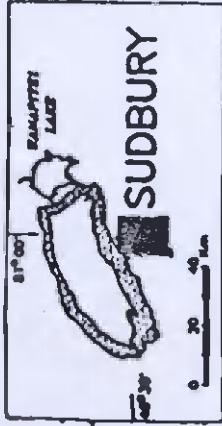
<i>Populus balsamifera</i>	R, CR
<i>Salix pyrifolia</i>	CR
<i>Arctostaphylos uva-ursi</i>	T
<i>Robinia pseudo-acacia</i>	P
<i>Prunus virginiana</i>	R, CR?
<i>Vaccinium angustifolium</i>	R, CR
<i>Vaccinium myrtilloides</i>	R
<i>Betula pumila</i>	CB, CR
<i>Populus grandidentata</i>	CR
<i>Prunus pensylvanica</i>	R, CR?
<i>Salix humilis</i>	CR
<i>Sambucus pubens</i>	CR.
<i>Acer rubrum</i>	R
<i>Quercus borealis</i>	R
<i>Acer saccharinum</i>	P
<i>Salix gracilis</i>	CR
<i>Shepherdia canadensis</i>	T
<i>Acer saccharum</i>	p
<i>Comptonia peregrina</i>	CR
<i>Populus tremuloides</i>	CR
<i>Fraxinus americana</i>	P
<i>Betula papyrifera</i>	R, CR
<i>Viburnum cassinoides</i>	R

Areas reclaimed/planted with trees

Tree plaques

(T1) - 1 millionth tree (Terry Fox Complex)

(T2) - 2 millionth tree (Nickel Centre Welcome Centre)



NICKEL CENTRE

SUDBURY

SUDBURY

GREENING MAP

0 1 km

