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The Reclamation of Sudbury: The Greening of a Moonscape

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INTRODUCTION

Approaching Sudbury from the east on Highway 40, the change in vegetation is surprisingly subtle. Subtle enough so that, it is not until you are within a few miles of the town limits that you ask the begging question, "What happened here"? It is this subtly that gives a clue as to how widespread the effects of human disturbance have been here. The barren landscape, blackened rock faces, lack of vegetation and endless sea of dead tree stumps make this place seem like a different planet. A moonscape. Indeed, it was these very features that prompted NASA to conduct its moon landing trials here. These very features that have earned Sudbury its international reputation as a highly polluted area; and these very features that have, more recently, led local residents and governments to initiate a massive reclamation effort.

SUDBURY: A HISTORY OF HUMAN DISTURBANCE

Sudbury is located about half way between Sault St. Marie and Montreal and about 200 miles north of Toronto in Ontario, Canada (46° 30'N 81° 00'W). It lies on the southern border of the Canadian Shield and in a landscape that the most recent glaciers scoured well, leaving exposed outcropings of bedrock and relatively shallow soils. It is located in a forest zone that is transitional between the boreal, coniferous forest to the north and the deciduous forest to the south. Though no presettlement vegetation surveys were conducted, the charred stumps of pine (*Pinus resinosa* and *P. strobis*) and cedar (*Thuja occidentalis*) suggest that the pre-settlement forest probably consisted of a mosaic of white (*P. strobis*)and red pine (*P. resinosa*) in the uplands and white cedar swamps in the lowlands. The upland forest may have also contained a mixture of northern hardwoods like sugar maple (*Acer saccharum*) and yellow birch (*Betula alleghaniensis*).

The combined impacts that the European settlers had, and continue to have, on the land in terms of logging, fire, and mining have led to the conditions alluded to above. Understanding these processes and how they have interacted is essential to understanding the environmental impacts and motivations for reclamation in the Sudbury area.

The Sudbury area was opened up for logging around 1872, and the large logs of pine and cedar were floated down rivers to Georgian Bay and Lake Huron. By the time the first settlers came, the forest was probably regenerating in birch and aspen. After the settlers came, logging was less selective and areas were clearcut. Perhaps the most serious environmental impact of this was the increase in fires from the massive amounts of slash left behind.

As early as 1856, surveyors detected the presence of copper and nickel in the Sudbury area. In 1885, a surveyor discovered the richest deposits of nickel ore in the world. One year later, mining of copper and nickel began in earnest and continues to this day . In these early days, the sulfur was removed from the copper-nickel ore in an "open roast yard", a mound of ore and wood that was kept burning for months before being loaded into a furnace. This process not only stripped the surrounding land of its timber for use as fuel wood, but also increased the frequency of fires. These roast yards, now long abandoned, are believed to have contributed significantly to the barren landscape that has characterized the Sudbury area because of their highly toxic soils. They have also been a source of native vegetation that has acquired variation in nickel and copper tolerance (Hogan et al. 1977).

While smelters have replaced open roast yards, they still have significant environmental impacts and have, rightfully so, received their share of blame for the denuded landscape. The effects of these smelters have been strikingly widespread: 40 square miles around Sudbury had been rendered completely barren of vegetation, 140 square miles around supported only shrub and herbaceous cover and vegetation had been in some way effected within a 1700 mile area (DeLestard, 1967). The extensive nature of pollution in the Sudbury region is due to the emission of sulfur dioxide, copper, and nickel pollutants into the atmosphere from the smelter stacks. While building the "superstacks" higher has decreased the intensity of pollution in the immediate Sudbury area, much more of the surrounding region has now become effected.

The emission of sulfur dioxide into the atmosphere has had three major effects on the surrounding ecosystems: 1) the direct "burning" of foliage and subsequent decrease in plant productivity and possible plant death and 2) acidification of the soil to pH of 2.0-4.5 (Winterhalder, 1983) and 3) consequent aluminum toxicity. There have been numerous studies documenting the effects of SO2 in the Sudbury region. Nieboer et al. (1972) showed that lichens decreased drastically as the smelters are approached and that only some crustose lichens were present in highly polluted areas. Gorham and Gordon (1960a and b, respectively) showed a similar decrease in diversity closer to the smelters for vascular plants and documented the effects of acid precipitation on aquatic systems in the Sudbury region.

In addition to SO2 pollution, the elevated levels of copper, nickel and aluminum have also decreased plant growth and retarded natural recolonization. The total levels of copper and nickel in the soil in this area often exceed 1000 ppm while available levels approach 100 ppm (Winterhalder, 1983). As with SO2 pollution, Winterhalder (1975) has shown that copper and nickel levels in the soil increase with the proximity of a smelter.

In addition to the vast areas of land effected by the smelters, the emission of slag and mine tailings has impacted smaller areas. In 1984, the area occupied by slag was 400 acres and slag was still being produced at a rate of 4,000 tons per day. The area occupied by mine tailings was 3,000 acres while the rate of deposition was 8 million tons per year (Winterhalder, 1984). Since the area effected by SO2 and heavy metals, however, is much more extensive, the restoration efforts have primarily been focused there.

One of the most significant effects of the unvegetated landscape has been soil erosion. Soil erosion began with logging and fires in the late 1800's and intensified as frequent fires burned the herbaceous and shrub plant cover. The complete lack of vegetation brought about by the mining activities caused soil erosion to take place virtually unchecked for many years (Winterhalder, 1984). By the time the restoration efforts began in the 1970's, most of the fine soil particles had eroded away, stripping the soil of much of its valuable microflora and fauna. Since the parent material is unsorted, dense, coarse glacial till, however, some of the rocks and gravel remained and held in place some fine material. This formed much of the soil base for the restoration efforts.

To sum up the soil site conditions in the Sudbury region, erosion has removed a significant portion of the topsoil and has left the remaining soil deficient in phosphorus, nitrogen, and possibly calcium, magnesium and manganese. The pH ranges from 2.0-4.5 which results in aluminum toxicity. Areas close to the smelters (± 15 mile radius) are contaminated with high concentrations of copper and nickel. It has be suggested that if these areas are alleviated from the heavy metal contamination, nitrogen and phosphorus would then become the limiting factors.

THE RECLAMATION EFFORT: A NEW BEGINNING?

GOALS

Given the seemingly insurmountable barriers to the reclamation of this land, it is not surprising that it was nearly 100 years before a concerted restoration effort took place. The early reclamation efforts, however small and (in many cases) unsuccessful give valuable clues to the goals behind such efforts. One of the first efforts was undertaken by the nearby town of Copper Cliff in 1947. The residents of Copper Cliff were apparently "plagued" by a persistent, continuous dust problem from unstable mine tailings (Winterhalder, 1984). By 1960, after years of research, a grass-legume mixture was established on the tailings. There are also reports of Sudburians in 1953 "rooting out the great pine stumps that disfigure the landscape" (LeBourdias, 1953). Finally, in 1957, trees were planted directly into untreated soil in the hopes of establishing a "green approach" to the town of Sudbury (Winterhalder, 1984). After a few years of trial and error research, trees were planted into holes in which loamy soil was placed and have since become established.

The goals behind these historical efforts at reclamation are perhaps different than the goals of most reclamation projects. Grasses and legumes were planted to stop the dust problem. Trees were planted to bring color to the landscape. Though I have found no record or these projects outlining specific goals, the efforts suggests that the main motivation was not a desire in ecological harmony or desire to save native plant communities, but pure and simple necessity. People are greatly effected by the place in which they live. For many that were raised in the Sudbury region and have always known it as "barren" place, they must also have known that it could be better. And if it were better, that they would be better for it as well. This situation clearly illustrates the vital link between ecosystem health and human health.

The specific goals of these historic and the current projects, therefore, are of utmost importance. They not only shape the actions which will be taken, but also provide a measuring stick to assess success. For reclamation efforts as large as this, the "goals" are very diverse. Since, as we will see, they involve the entire community, they may be different things to different people. To citizens, the goals may be as simple as having a green landscape to enjoy, free from dust or other health concerns. Recreationists may want woods to hike or bike in. Students may just want a summer job. Business people may want a more pleasant landscape that attracts tourists. Given the complexity of these "goals", the assessment of "success" on the community level must likewise be just as complex.

THE "SCIENCE" OF RECLAMATION

The numerous scinetists that have been a part of the current restoration project have stated goals that differ from the goals of the community listed above. Their overridding goal, obtaining viable functioning ecosystems, is divided into three parts. First is restoring the chemical balance of the systems. This includes decreasing toxic compounds in the soil, increasing nutrients and organic matter and raising the pH in the soil and water. The second part is restoring the biological integrity of the systems. The main focus of this goal is re-establishing the plant cover on the barren landscape. The third goal is to restore the species diversity of the area. This includes encouraging the less common plant and animal species to colonize the area (Bradshaw, 1995). Given these goals, the overall measure of success is "the degree to which ecosystems are created that have satisfactory structure and function" (Bradshaw, 1995).

To achieve these goals, in 1969 a joint program between the Ontario Department of Lands & Forests and the Laurentian University Biology Department was initiated and known as the Sudbury Environmental Enhancement Programme (SEEP). SEEP conducted a large amount of research aimed at reclaiming the denuded landscape. After planting several thousand trees (bare root and container stock) into unamended soil and, at most sites, watching them die, they focused much of their efforts on the efficacy of soil amendments. Evidence from previous reclamation efforts concluded that the best way to ensure plant recolonizaton was to import soil. Due to the vast areas that required reclamation, however, this technique was limited to key locations like parks (Lautenbach, 1986). Amendments such as lime, fertilizer and mulches were therefore studied in the field and greenhouses to better understand the complex factors limiting plant growth. One of the most important findings was that the primary limiting factor at most sites was pH combined with elevated copper and nickel levels (Hutchinson and Whitby, 1974). Another, perhaps more important finding was that liming increases germination and growth of plants on these soils. This is probably related to the fact that liming also has a significant effect on the microflora and fauna: stimulating the growth and reproduction of Aztobacter, Rhizobium and arbuscular mycorrhizal fungi (Blundon, 1976 in Winterhalder, 1984). Later experiments also showed that after a few years, secondary limiting factors such as phosphorus and nitrogen become significant (Winterhalder, 1984).

Aside from research, SEEP was also in charge of organizing the reclamation efforts. The tasks that they outlined were:

1. site improvement (removal of dead trees and branches from barren and semi-barren areas);
2. soil sampling and pH analysis;
3. greening (liming and fertilizing of semi-barren sites to improve growth and encourage the spread of existing vegetation);
4. grassing (liming, fertilizing and seeding of barren sites);
5. native seed collection, concentrating on species that have been shown to be valuable for reclamation in the area;
6. transplanting of species that have been shown to be relatively tolerant on semi-barren sites, thereby forming a nucleus from which the plants can spread;
7. experimental in situ composting of various local waste materials.

While large areas were cleared of "unsightly" tree stumps, the bulk of the time and money went into tasks 3 and 4. In the large, relatively flat areas (including tailings), these amendments and seed could all be reincorporated using traditional agricultural machinery. Much of the effected area, however, was either too steep or too rocky to use this machinery. The majority of these areas was therefore done by hand. Lime was applied first at rate of about 5 tons/acre. Fertilizer high in P, usually 6-24-24, was then applied at a rate of about 350 pounds/acre. Lastly, seeding was conducted with cyclone seeders at a rate of 25-40 pounds/acre. The seed mix included the following species: Canada blue grass (*Poa compressa*), Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*), red top (*Agrostis gigantea*), creeping red fescue (*Festuca rubra*), alsike clover (*Trifolium hybridum*), and birdsfoot trefoil (*Lotus corniculata*) (Lautenbach, 1986).

In addition, some reforestation projects were added on to the tasks. This began as planting hardwoods and conifers that were native or hardy to the region. In high visibility areas, trees like sugar maple and red oak were introduced to provide color to the landscape. In both the grassing and reforestation efforts, much emphasis has been placed on planting at densities and in spacings that will allow for natural recolonization of native plants into the established turf. Winterhalder (1984) reports that following establishment of the cover species, recruitment by native herbaceous and woody plants is rapid.

THE SOCIAL ASPECTS OF RESTORATION

Coinciding with the start of these massive reclamation efforts, the summer of 1978 found many student summer workers unemployed due to cutbacks in the local mining industry. With funds from local and regional governments, 175 students under the auspices of the Young Canada Works Programme, were hired that summer to carry out much of the labor intensive work described above. For at least 10 years after that, student workers were hired to carry out those and other reclamation tasks during the summer. In addition, in the early 1980s as local industry continued their cutbacks, the municipality of Sudbury began hiring unemployed individuals and welfare recipients to undertake similar tasks. During this period there were many programs giving wage supplements to individual with unemployment insurance and further helping those without. These programs had the effect of strengthening the local economy, the individual, the reclamation effort and decreasing the growing welfare cases. The net result was that 3,600 acres of barren land was reclaimed, 230,000 trees were planted and 1,740 short term jobs were created (Lautenbach, 1986). This would bring the total area covered by reclamation projects to about 10 square miles as of 1986 (Lautenbach, 1986).

CRITIQUE AND ASSESSMENT OF SUCCESS

Were the reclamation efforts in the Sudbury region a success? Would a strict scientific assessment of success be narrow in scope given the history of this project and the amount of community involvement? As mentioned above, the goals of this reclamation effort are complex, and so must be the assessment of success. One point that may help clarify this situation is that, despite what a few scientists may think, this was primarily not an ecological restoration. First and foremost, this was a social restoration. The goal for most people was "an aesthetic one" (Bradshaw, 1995). The environment in the Sudbury region is so intertwined with the social, economic, and physical health of the community that this seemed to be the major driving factor in the restoration efforts.

On this level, the restoration of Sudbury seems to be quite a success. The town of Sudbury, on its web site, claims to have a new "greener" image. Thousands of jobs were created to help ease the economic burden of mining cutbacks. Pictures of much greener landscapes fill the literature. I do not have information on new industry attracted to the area, but I would not be surprised if it has increased since the greening of the landscape. In some ways the true test of success is in the opinions of the Sudburians, "Does the landscape look better?" or "Is this a better place to live?". From what I have read I believe that most Sudburians would answer "Yes" to both of these questions. They also realize that they have not reached an end point: "...as Sudbury residents [we know] we still have a difficult job ahead of us...." (Gunn et al. 1995).

The scientific assessment of success of this restoration is also a vital element in the overall appraisal of the project. As claims to success, scientists list species of naturally recolonized native plants on their reclamation areas. The percentage of grasses has, over time, tended to decrease and the percentage of woody species has tended to increase (Lautenbach, 1986). The number of insects, birds and some mammals has increased in some reclaimed areas (ibid.). There have been specific programs to restore high profile animal species like the peregrine falcon and the aurora trout. All of these facts point to small successes of the restoration. Most of these successes are mild indicators of increasing structure and function of the ecosystems. However, I think that many scientists would agree that they are not finished with this project. Thousands of acres remain barren. Hundreds of square miles remain heavily contaminated. The only places that were really reclaimed were the high profile areas, highway corridors, and neighborhoods so that only 30% of the barren land received remedial treatment (Gunn et al. 1995). It may be centuries before the ecosystems that were treated are back to normally functioning states : toxic metals concentrations are still high, the soil structure is still lacking, there is very little biological diversity, insects populations reach epidemic proportions because of lack of biological control etc. (Gunn et al., 1995). Claiming success at this point is akin to praising the construction of a house when only the foundation has been laid.

In addition to an assessment of success, it is important to view the restorations efforts as a whole and learn what lessons we can from the restoration process. As an outsider I have the disadvantage of not knowing all the details that would be useful in this critique, but I also have the advantage of having an unbiased, unattached perspective. The first thing that strikes me about these restoration efforts is that, given the scale, only the bare minimum can be done. Such large areas need reclaiming that no area gets the attention that it really needs. The limited techniques of applying lime, fertilizer and seed seem appropriate as long as it is understood that their purpose is not restoration, but revegetation. In this case, revegetation is merely the precursor to real restoration. Once something can grow there, then it may be possible for native plants to colonize the area and natural ecosystem functions to begin again. The main strategy for native plant establishment into the area has been a hope for natural recolonization. This has proved efficient in some areas. While it may work well on the periphery, areas more internal may be devoid of all species save those with wind dispersed seeds. This technique also limits the rate at which the ecosystem will recover. Given this, I was somewhat surprised that no native seeds were used in the majority of the restorations.

I was also surprised at what few soil amendments were added to the revegetation sites. The soils were lacking in so many things (nutrients, soil structure, biologic activity, organic matter) that amendments of thin layers of topsoil or organic matter may have accelerated the restoration process exponentially. In addition, I have not seen any work done on monitoring the nutrient cycling rates and processes taking place in the revegetated areas. Since this is one of the fundamental factors regulating an ecosystem, such studies may prove invaluable.

Some of these above efforts were probably not undertaken because of financial constraints. In some ways, I saw a priority system take place here that did not have ecological restoration on the top of the list. For example, I feel that the time spent on removing dead stumps and branches from thousands of acres of land was, in ecological terms, time and money wasted. It makes little sense to spend money to remove these stumps and then add expensive commercial fertilizer. In addition to adding nutrients to the soil, they could also act as shade, erosion prevention and creation of microhabitat for plant and animal establishment. I also feel that spending time and money on the recovery of single, high profile species (peregrine falcon, aurora trout etc.) is more social restoration that ecological restoration. Such actions are undertaken not to increase ecosystem structure or function but as center points around which the public can rally and the scientists can gain valuable community support.

Not withstanding these critiques, I was very impressed overall with the reclamation efforts undertaken. The scale of this project and the degree to which the community has benefited and contributed to the reclamation efforts are truly remarkable. Given the extent of the problem, though, there much work left to be done, the fruits of which may not fully be seen for hundreds of years. Perhaps the region around Sudbury will stand as a lesson of the catastrophic consequences of unchecked resource exploitation that we humans are capable of. As Gunn, editor of the book Restoration and Recovery of an Industrial Region, so aptly quoted at the closing of his book:

It takes a clever person to fix a problem It takes a wise person to avoid one. -Einstein

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