THE ENVIRONMENTAL AND SOCIAL HISTORY OF THE O'DONNELL ROAST YARD AND TOWNSITE NEAR SUDBURY ONTARIO

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Abstract

The Environmental and Social History of the O'Donnell Roast Yard and Townsite near Sudbury Ontario

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This thesis examines the historical and social aspects of the townsite of O'Donnell which supplied the workforce for the Canadian Copper Company's giant open roast yard nearby. It considers the impact of the roast yard on the human and environmental health of the surrounding area during the 14 years it operated 1916-30. In order to better assess the magnitude of the environmental impact of the roast yard during its operation the thesis also assesses the extent of environmental pollution, 68 years after its closure. The soil concentrations of metals are still phytotoxic and indicate that environmental contamination at the time of O'Donnell's operation must have been extreme, with workers and residents exposed to high atmospheric levels of sulphur and toxic heavy metals. Despite these extreme conditions, former O'Donnell residents enjoyed their life and had strong social bonds which were more important than the adverse environmental conditions. The Canadian Copper Company was aware of the negative environmental consequences of the roasting process, yet it wasn't until O'Donnell became uneconomic that it was closed.

Acknowledgements

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This thesis relied heavily on interviews from former O'Donnell residents and others in the Sudbury region. Tom Davies, the former Regional Municipality Chair was invaluable in locating former O'Donnell residents. A special thank-you to the former residents who spent many hours sharing their memories of O'Donnell with me: Eva Macdonald, Maude O'Malley, Bob Bryson, Loretta McPhail, Lawrence Lalonde, Evelyn Germa, and Camile Lafrombois. Bob Bryson, Loretta McPhail and Maude O'Malley who supplied historical O'Donnell photographs. Tom Peters provided a wealth of historical information about Inco and the Sudbury region in general. Carman Fielding Sr. helped locate former O'Donnell residents. Bill McKinnen showed me the historical townsite of O'Donnell. Bill McIlveen took me to the eleven historical roasting sites. And Jim Fortin, curator of the Andersen Farm museum shared information about the school and working conditions at O'Donnell. All of which contributed significantly to this thesis.

A great group of friends helped with the completion of this thesis as well. Roxanne Miles, Eric Sager, Shaun Watmough and Claire Wilson provided expertise in the field and lab with soil, plant and tree ring collection and analyses. Dave Woodfine helped with the historical picture reproductions. And Richard Hughes who completed the ICP analyses. Big thanks to the football pub, dart, dog walking and general support crew of which I haven't already mentioned.

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List of Figures

List of Tables

List of Plates

Table of Contents

1.0 Introduction:

1.1. General purpose and rationale

Research into the environmental history of a region allows one to look at the changing relationships people have with their environment, as well as how the environment itself has changed. Humans are a part of their environment, and our perceptions of that environment are themselves to a large extent an extension of our ideas and attitudes about ourselves, the world, and our place within it. Particularly in the past, people lived in contaminated environments often unaware of the extent of contamination and with attitudes quite different to those of the late 20th century. It is worthwhile to examine our past in order to better understand why certain decisions were made and in turn document and learn from the resulting impact of these decisions upon the surrounding environment and people. It is useful to combine cultural and ecological investigations when trying to understand our relationship with nature in order to better determine the extent of the physical impact our actions have on the surrounding environment.

The mining industry has had a particularly dramatic and long lasting impact on its surrounding environment, and leaves a marked, often persistent ecological foot print. The length and severity of environmental impacts are important considerations when assessing damage to ecosystems, and subsequently, their ability to recover once the environmental stress is alleviated. Mining in the Sudbury region has dramatically affected its social, economic, and environmental status for more than one hundred years. Over this time period, mining has changed in its industrial attitudes, values and reactions to environmental questions. In the words of D.A. Smith, 1987,

> Mining cannot claim environmental sainthood for its actions over the past two centuries, but neither should it be smeared as a covetous, black-hearted, greedy sinner. The story is not that simple. We can learn much about ourselves from what took place in former years. Those actions should not be judged by standards other than those current at the time; it is not fair or historically accurate to evaluate 1820 or 1882 or 1914 solely by today's aspirations and values.

The O'Donnell roast bed was the largest operation to roast ore in the Sudbury region. The sulphur smoke emitted during this first step in nickel-copper smelting killed all vegetation for miles and exposed workers and nearby residents to a "choking" breathing environment. The O'Donnell roast yard closed in 1929 and its associated townsite was also abandoned shortly afterwards. Aspects of the residual environmental impact after this closure began to be recorded in 1977 by Hogan *et al.* However, little has been recorded about the company town of O'Donnell that housed the workers of the roast bed, nor the ongoing environmental consequences to the area following the abandonment of the roast yard and the closure of the O'Donnell townsite. This lack of information became a reason for the development of this thesis.

This thesis represents a dual approach using both social/historical and scientific methods of investigation. The O'Donnell roast bed (15 km west of Sudbury) operated from 1916 to 1929 with its associated townsite located 1.6 km directly downwind. Historical records, such as archives and oral histories, have been combined with a physical investigation of environmental changes of the area surrounding the O'Donnell roast yard since its closure in 1929, in an attempt to document the social, cultural and environmental impact of this historical roasting site.

In this thesis I shall use a variety of approaches to document the events leading up to the establishment of O'Donnell, the conditions under which it operated and finally the extent of the residual toxicity as well as the extent of recovery of the area surrounding the roasting site at the time of this thesis, i.e., 68 years after its closure.

The objectives of the thesis include my intent:

1. To document the reasons (driven by the nickel industry) for the establishment of this isolated roast yard (O'Donnell) in 1916.

2. To document living conditions (environmental and cultural impacts) during the time of the O'Donnell roast bed's operation.

3. To document the ecosystem recovery and to determine if environmental toxicity exists at the O'Donnell site, and in the surrounding area, 68 years after it's closure. (Residual effects on the environment and its recovery)

This thesis has been set up in the form of five chapters. This first introductory chapter describes the approach and methodology taken in writing the thesis. Following this, I describe the development of mining companies in the Sudbury region which reflects the monopoly INCO had on the nickel industry not only in Sudbury, but in all of Canada. I then address the importance of nickel production during World War I, which had a direct impact at the local level at O'Donnell through both social and environmental consequences. Finally in this chapter the general roasting process is described, necessary to understand the potential exposure of workers, townspeople, and the environment to pollutants.

The second chapter documents the circumstances that led to the establishment of and the particular location of the O'Donnell roast yard in 1916. Also within this second chapter, other historical roasting sites in the Sudbury area are identified, in addition to a brief description of the environmental impact of these roasting processes. Attitudes towards the roasting process in general, from the local, provincial and federal level are presented, along with a brief account of the mining companies' response to these attitudes.

Chapter three focuses on the roasting process specifically at the O'Donnell roast bed. In addition to describing the site itself, chapter three portrays the living conditions at the time of O'Donnell's operation, with respect to both human and environmental health, drawing primarily upon oral interviews with former O'Donnell residents. To determine who the workers were and where they came from, employee cards from the INCO archives were used to give a snap shot of the O'Donnell workforce during its operation. Also reflected in this chapter are the strong bonds established within the O'Donnell community, despite harsh working and living conditions.

Chapter four describes the present day ecological assessment of the historical O'Donnell roasting site. This type of assessment can be used to both reconstruct historical levels of pollution at the time of O'Donnell's operation, as well as predict what types of vegetation may be able to tolerate low pH and high heavy metal content in order to re-vegetate such heavily contaminated areas.

Finally, chapter five is the concluding chapter which focuses on the motives and pressures placed upon decision makers at the time of O'Donnell's operation. Steps that can lead to a change in behaviour include varying levels of awareness, information, knowledge, and attitude. An awareness is usually achieved by asking a new question. This question often leads to an investigation and the subsequent gathering of information. However, at this stage, you can have bits of information, but without the knowledge of interacting processes, it may not lead to a change in attitude. Once there is a strong working knowledge of previously unknown consequences, this can lead to a change in attitude which in turn can lead to a change in behaviour. Ecological awareness, information and knowledge, can be used to inform decision making processes in particular with respect to polluting industries. Decisions that have economic, human and environmental health consequences often depend on the awareness, quantity of information, the level of knowledge, and prevailing attitude. However, the "value" placed on each consequence often overrides the awareness, knowledge model as is shown in the concluding chapter five.

1.2. Methods/Sources

Historical documents from the Ontario Bureau of Mines Reports, and the Royal Commission on Nickel, provincial archives, INCO archives, newspaper articles, local histories and personal interviews have provided the information regarding the foundation of mining and smelting in the Sudbury region. These sources have been used to document the environmental and cultural conditions under which the O'Donnell roast bed operated. Present day environmental conditions at the site, coupled with this historical information provide a picture of the historical, environmental, and cultural impact of O'Donnell during its years of operation (1916-1929).

INCO Archives:

All INCO employee cards are filed according to the date the employees **left** employment. Information from boxes of cards containing the years 1914 to 1931, which covered the time of O'Donnell's operation was recorded. Any employee continuing to work for INCO beyond 1931 (after the closure of O'Donnell) were **not** included in these employee cards. All INCO employees were filed together, independent of location of employment. There were a total of 75 boxes. Every fifth box (total of 17 boxes) was sampled and information from O'Donnell employees only, was collected for a total sample number of 506 workers. Therefore the numbers presented should be approximately a one fifth representation of the actual total. Information about other employees working at O'Donnell during its operation was obtained through housing records for O'Donnell, indicating where each O'Donnell resident lived and for how long. These cards were filled out by the employer, rather than the employee and therefore the information included would reflect the attitudes of the time keeper who entered the information. The information on these cards in no way reflects a complete picture of the O'Donnell work force, but it does provide limited detail about who worked at O'Donnell, where they came from, how long they stayed and why their employer felt they left. Each card consisted of the employee's name, the dates of employment, their date of birth, their nationality, next of kin information, their rate of pay, record of previous employment, and the reason for leaving employment with INCO. For an example of these cards, please see appendix A. A town map for O'Donnell, containing decommissioning details was also obtained at the INCO archives.

Provincial archives:

At the Provincial archives in Toronto I located details of court cases launched against both the CCC and their successors the International Nickel Company (INCO). These claims were for sulphur damage to crops by farmers in the Sudbury region. A Sulphur fumes arbitrator was appointed in 1921 and his reports provided detailed information about the sulphur claims and subsequent awards during the time of O'Donnell's operation. The Sulphur fumes arbitrator reports were a valuable source of information regarding the response of the local residents to the noxious sulphur fumes produced by the ore roasting and smelting operations, and how these complaints were then addressed by both the company and government at that time.

Oral Interviews:

Tom Davies (now sadly deceased), the former Region Municipality Chair, played a critical role in my research of the O'Donnell roast bed, by locating people for me to interview, providing me with pictures and taking time from his busy schedule to show me the old roasting site. The oldest former O'Donnell resident, Eva Macdonald (nee Lalonde) was located with the help of Tom Davies (Plate 1). Bob Bryson was interviewed in 1979 for an article in the INCO triangle magazine and I simply found him in the Sudbury phone book. The other former O'Donnell residents were subsequently found through these two former residents.

Detailed oral interviews were done with a total of seven former O'Donnell residents. Interviewing techniques described by Yow, 1994 were used to conduct in-depth interviews with Eva Macdonald (nee Lalonde) born 1902, Bob Bryson born 1914, Maude O'Malley (nee Denomee), born 1913 , Loretta McPhail (nee Hamilton), born 1912, Lawrence Lalonde born 1913, a former O'Donnell resident who wishes to remain anonymous, born 1913, Evelyn Fox (nee Germa), born 1913, and Camile Lafrombois born 1917. Interviews have been most frequent with Eva Macdonald, Bob Bryson and Maude O'Malley, composing more than 15 hours of taping. In September 1997, I arranged a meeting of five of these former O'Donnell residents which was hosted by Maude O'Malley, on Oct. 7th, 1997. This afternoon consisted of a very lively interaction, as some of these childhood friends had not seen each other in 25 years (Plate 2).

The son of a former O'Donnell resident, Bill Mckinnen was located with the help of Jim Fortin, curator of the Andersen Farm museum of Lively, ON. Bill's grandparents, his mother, and some of his aunts all lived at O'Donnell. Bill is a retired geography teacher who took his classes out to the old town site of O'Donnell. It was Bill who kindly showed me the location of the townsite of O'Donnell. The old town site was dismantled in 1930, to a few remnant house foundations and is now well vegetated and is therefore very difficult to find, unless you know exactly where to look. There is no sign of it from the road leading into the roast yard. Jim Fortin, has also been a great source of information with regards to the O'Donnell roast bed and town site.

Interviews have been conducted with Dr. Tom Peters, a former INCO employee who is presently an agricultural consultant for the mining industry. Dr. Peters was in charge of the agricultural section for INCO for 20 years in the 1960's - 1980's and his knowledge of this sector of INCO and its history is extensive.

Interviews with Sudbury Regional Municipality Chairman Tom Davies were very informative. Mr. Davies was a former Mayor of Creighton which was the small mining

Plate 1. Eva Macdonald (nee Lalonde) and Sheena Symington Sager, 1995. Eva Macdonald is a former O'Donnell resident, born 1902.

Plate 2. Left to right: Loretta McPhail (nee Hamilton), Evelyn Fox (nee Germa), Bob Bryson, Maude O'Malley (nee Denomee), and Lawrence Lalonde are all former O'Donnell residents. Meeting at Maude O'Malley's house, Oct. 1997.


2

community closest to O'Donnell. Other former Creighton residents that were interviewed include Mr. Tomassini (located through my cousin Doris Currie, Tom Shannon and Jim Nicholls (both located through Tom Davies).

Three open interviews have also been conducted with Carman Fielding Sr.(1913), also of the Sudbury area, again, located through Tom Davies. Camile Lafrombois who was introduced to me by Carman Fielding Sr., lived at O'Donnell when his father had the contract for collecting wood to fuel the roasting process and was also interviewed. These oral histories are inevitably subjective. As stated by Yow, 1994:

> Its subjectivity is at once inescapable and crucial to an understanding of the meanings we give our past and present. This is the great task of qualitative research and specifically oral history interviews: to reveal the meaning of lived experience. The in-depth interview offers the benefit of seeing in its full complexity the world of another.

These oral histories of former O'Donnell residents are used to give the reader an idea of the memories former O'Donnell residents have of life as a child in the early part of this century at the O'Donnell roast bed. An oral historian Alessandro Portelli, as cited by Yow 1994 "reminded us that "untrue" statements are psychologically "true" and that errors in fact may be more revealing than factually accurate accounts". This is particularly relevant when investigating O'Donnell workers and residents perceptions towards and relationship with natural environment surrounding them during the roast bed operation.

Residual Environmental Impact:

The scientific methods used to assess the present environmental impact of the 1916-1929 roast yard operations are given separately in chapter three.

1.3. Discovery of Copper Nickel ore in the Sudbury region

The activities of the mining industry have determined the economic, social and environmental conditions of the Sudbury region (Table 1). Mineral deposits in the area were first discovered in 1856 by government geologist A.P Salter who recorded a magnetic disturbance in his compass while traveling throughout Snider Township (Royal Ontario Nickel Commission [RONC], 1917; Wallace and Thomson, 1993). The economic consequences of this discovery were not realized at this time, but in 1883 the area's copper mining potential was again uncovered by a member of the crew laying track for the Canadian Pacific Railway, when blacksmith Tom Flannagan noticed a mineralization in the rocks alongside a cutting (Wallace, 1993; Gunn, 1995). Early prospectors in this area such as Thomas Frood, Rinaldo McConnell, F.C. Crean, J.H. Metcalf, W.B. McAllister and

Table 1. A chronology of important events (taking place before 1930) influencing the Sudbury region as given by Conroy and Kramer, in Gunn 1995 (modified).

Event	TIME (years since 1998)
Formation/accretion of earth	4,600,000,000
Oldest known rocks of the Canadian Shield	3,920,000,000
Origin of life	3,400,000,000
Formation of Sudbury Basin	1,850,000,000
Beginning of mountain building period causing deformation of Sudbury Basin	1,800,000,000
End of mountain building period	1,630,000,000
Evolution of modern humans	1,000,000
End of last glaciation and formation of glacial deposits	10,000
Ojibways, Hurons, and Ottawas settle in the area	from 10,000
Evidence of first settlement Sheguindah	from 7,000
First European explorer (Champlain) (1615)	383
Chemical and physical properties of nickel recognized	253
Richter produced the first pure nickel (1806)	192
Hudson Bay Trading Post established west of Sudbury Basin (1824)	174
First geological reconnaissance of the north shore of Lake Huron (Logan) (1849)	149
First mapping of mineralization in Sudbury area (1856)	142
First use of nickel in token money coinage (with 75%Cu,25%Ni composition)	139
Discovery of mineralization at Sudbury during construction of transcontinental railway (1883)	115
First purchase of mining lands by Murray (1884)	114
First uses of corrosion resistant nickel steel (1885)	113
First smelting of Sudbury ores by open roast heap (1888)	110
Thomas Edison stops exploring just short of discovering Falconbridge deposit (1901)	97
First geological map of Sudbury Basin (1905)	93
Ontario Royal Commission on Nickel (1915)	83
Austentite structure for stainless steel determined by Guillet (1915)	83
First ore roasted at the O'Donnell Roast yard (1916)	82
Damages by Sulphur Fumes Arbitration Act proclaimed (1921)	77
Founding of The International Nickel of Canada Ltd. (INCO) (1928)	70
Formation of Falconbridge Nickel Mines Ltd. (1928)	70
Open roast heap practice abandoned at the O'Donnell Roast Yard (1930)	68

(Conroy and Kramer, 1995, modified)

James Stobie, would locate the copper deposits, unaware of their nickel content, then buy the land for a minimal fee (i.e., one dollar per acre) and sell it to companies who had the resources to develop a mine, because unlike gold and silver, copper could not be mined profitably by individuals (INCO, 1932; Goltz, 1986).

1.4. Historical background of those mining companies successful in the Sudbury region

The Canadian Copper Company (CCC) was among the first, and most successful, of these companies to develop in the Sudbury area (Royal Ontario Nickel Commission [RONC], 1917). In 1885 Samuel J. Ritchie and his group purchased Frood Mine from Thomas Frood at a price reputed to be $30,000, and formed the Canadian Copper Company (INCO, 1932). The CCC was incorporated in January, 1886 under Ohio state laws by Samuel J. Ritchie of Cleveland, Ohio (Bray, 1984). Once the CCC mined the ore, it was sent to the Orford Copper Company (OCC) in New Jersey to be refined. The OCC contracted to buy 100,000 tons of ore from the CCC, and the first shipment of ore was received by OCC in autumn of 1886. At this point it was discovered that the method of smelting then used produced a pale metal that no copper fabricator would accept. Detailed analysis showed that this was a result of the ore's 2.5% nickel content (INCO, 1932). At this time nickel was worth $1 a pound, which was a large amount at this time, so new uses for the metal were investigated. In France, chrome-steel projectiles; and ferro-nickel and nickel-steel were being produced, which led to British investigations, the result of which was James Riley's now famous 1889 paper on "Alloys of Nickel and Steel" (INCO, 1932). As a result of these findings, in 1891 the U.S. Congress decided to purchase nickel to be used in making armour plate. The U.S. Navy Department approached the Orford Copper Company to fill their order. Subsequently, Colonel R.M. Thompson of the Orford Copper Company discovered the Orford Process, which later became the cornerstone of the nickel industry. This simple process involved melting normal matte with nitric cake, a by-product of nitric acid manufacture which resulted in almost pure nickel settling to the bottom with the top portion "containing copper, iron, some nickel and a large amount of sodium" (INCO, 1932).

As Thompson perfected his refining method, another smelting method called the Mond process was accidentally discovered by Dr. Ludwig Mond. "Dr. Mond and Dr. Karl Langer were experimenting with the decomposition of carbon monoxide gas by passing the gas through nickel in a heated combustion tube" (INCO 1939). The escaping gas was led into a Bunsen flame and then passed through another heated glass tube to collect the deposit. Analysis showed that this deposit that, at first thought to be arsenic, was in fact nickel. "From a purely scientific point of view, this was an important discovery; for at that time no one conceived the possibility of volatilizing a heavy metal at practically ordinary temperature and of later recovering it in solid form without having first reduced the metal to a molten state" (INCO, 1932). This process was simple but difficulties were encountered with the handling of "so dangerous a gas" (the carbon monoxide), so the Mond company sent ore to Clydach, Wales for refining.

The growth and development of INCO included the following:

> In April 1902, a number of companies from United States, Canada, and Great Britain, who were vitally interested in the production of nickel, merged to form the International Nickel Company (INCO), with headquarters in New York City. Established as a holding company, INCO united the CCC, the Orford Copper Company, and the Anglo-American Iron Ore Company with a number of other companies, among which were American Nickel Works, Nickel Corporation Ltd., Vermilion Mining Company of Ontario and Societe Miniere Caledonienne. The CCC operated as a subsidiary of INCO until 1919, and Copper Cliff, which was the Canadian headquarters of the holding company, continued to be the centre from which all CCC operations in the Sudbury area were directed (Goltz, 1989).
>
> In 1918, the International Nickel Company of Canada Limited, consolidated the Canadian mining and smelting interest of the parent International Nickel Company with the refining component at the Toronto headquarters...In 1919, INCO dissolved the CCC, (and) converted its assets to the International Nickel Company of Canada Ltd. (Goltz, 1989).

Mond Nickel Company later united with The International Nickel Company of Canada (INCO). The historical development of these, and some other mining companies working in the Sudbury area is shown in Figure 1.

1.5. Importance of Nickel for World War I

In the words of the Royal Ontario Nickel Commission 1917: "Nickel was a necessity in modern warfare; it was needed for armour-plate, for rifle-barrels, for heavy ordnance, bullet coverings, cartridge cases, automobile parts and the whole catalogue of military and naval equipment". Careless (1953), noted that "Canada came to control over 90% of the world's nickel production" and that close to one third of the shells fired by British forces in France during WW1 had come from Canada in 1917. This huge war-time demand in nickel resulted in an increase of nickel production and in turn increased the

Figure 1. The historical development of mining companies in the Sudbury area.

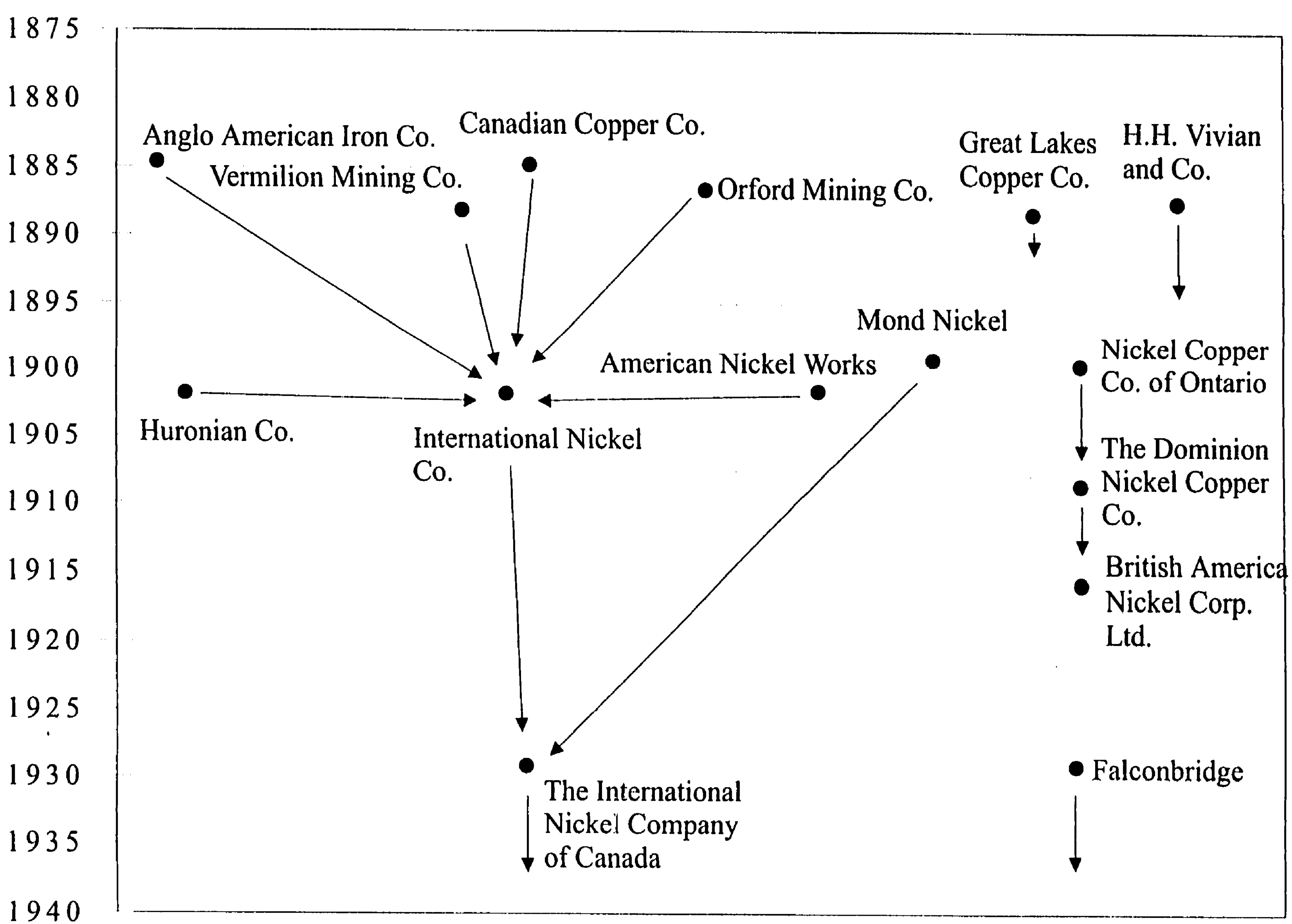


Figure 1. Historical development of mining companies in the Sudbury area.

quantity of ore roasted at the companies only roast yard, O'Donnell. Canada played other important "home-front" roles in WW1. "Since the war was cutting off or destroying much of Europe's farming production, Canada's wide farmlands became immensely important in feeding the western Allies" (Careless, 1953). Wheat, flour, meat, cattle and lumber exports escalated. "Since Germany blocked the way to Baltic forest lands, the need for Canadian wood pulp also rose, because the Swedish supply was not available" (Careless, 1953).

1.6. Description of the roasting process

Open heap roasting of the ore was done as a first step in the metallurgical process. This involved laying a wood (usually dead pine) foundation of at least half a metre thick, heaping raw ore on top of it in a number of separate heaps, and igniting the wood which would in turn light the sulphur within the ore, thus roasting it (Plates 3,4). This roasting was done in order to reduce the high sulphur content (by "burning" it off as sulphur dioxide) in the ores of the Sudbury region, the product being a more concentrated nickel-copper matte. The sulphur content was reduced from approximately 23% to 10 or 12%. After lighting the roast heap, the wood would burn out within 60 hours, leaving the ore in vigorous combustion. The roast beds would be left to burn from one to seven months at a time, depending on both the size of the roast bed, and the sulphur content of the ore. During the roasting process, drafts were used to regulate the heat in order to prevent fusion and subsequent smelting of the ore (RONC, 1917). This roasting process released a huge amount of sulphur dioxide and significant particulate heavy metals, severely contaminating and damaging the surrounding environment. The chemical process involved in roasting is described in an Ontario Bureau of Mines report as the following:

> When the ore, a mixture of iron, nickel, copper and sulphur with silica and rock matter, is roasted in the open air a large portion of sulphur burns to sulphur dioxide and passes off into the atmosphere; the iron having lost most of its sulphur supplies the vacancy with oxygen from the air, forming oxides, while that portion of the sulphur which it still retains is combined as iron sulphates (Ontario Bureau of Mines, 1899).

Plate 3. O'Donnell Roastbed construction showing mechanization, after 1919. Note wood piled in background at left of picture. This over head bridge would move up and down the tracks depositing ore. Picture INCO archives.

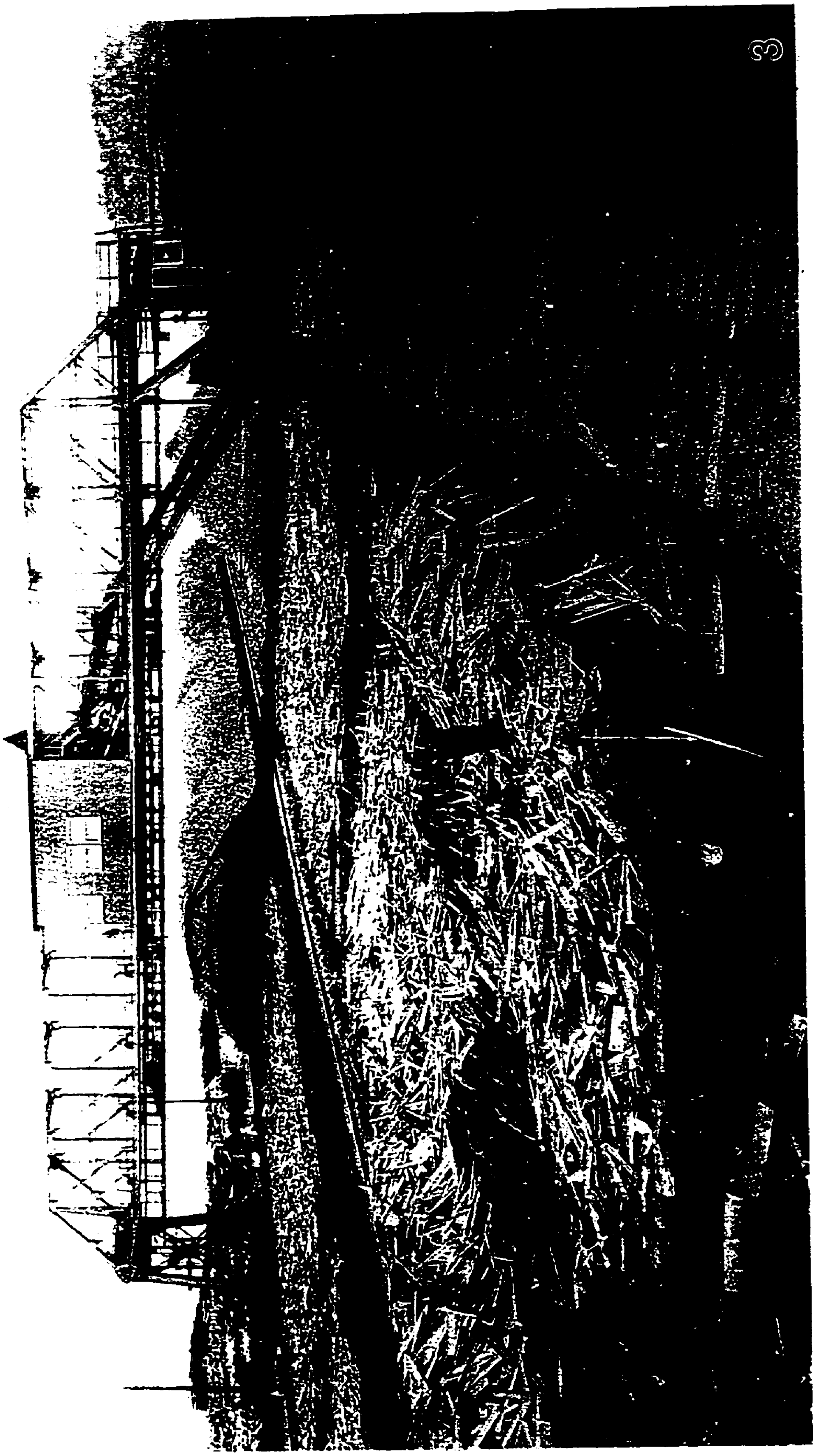


Plate 4. The O'Donnell Roastbed firing. Smoke emitted contained sulphur dioxide and particulate heavy metals. Picture INCO archives.

This change in chemical composition is shown below in Figure 2. The pie chart on the left represents the chemical composition of raw ore and the pie chart on the right, is that of roasted ore (Ontario Bureau of Mines, 1899).

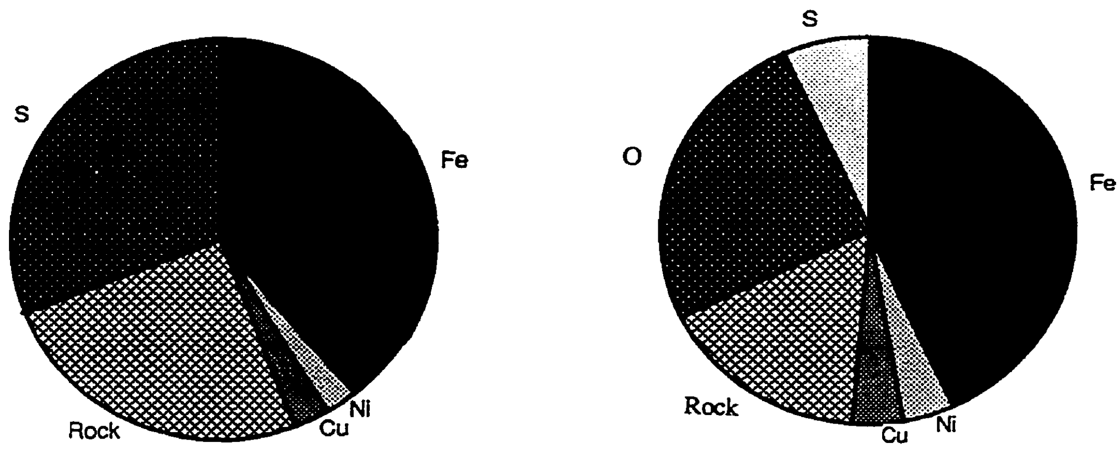


Figure 2. Chemical composition of raw and roasted Sudbury ore

The SO_2 driven off was very acidic and when it combined with moisture, it created sulphuric acid, which acidified the soil and corroded metal.

The first of at least eleven roast yards in the Sudbury area was established at Copper Cliff in 1888. The O'Donnell roast bed was the largest in the Sudbury region and it operated from 1916 to 1929. The yard contained four parallel railroad tracks, consisting of one main track and three service tracks. Two service tracks were used for green ore and ran along the outside of the roasting heaps (50 metres apart) and the roast ore track ran between the heaps, equidistant from the two outer tracks. In 1916, the O'Donnell roast yard roasted more than 250, 000 tons of ore at one time, with a single heap containing approximately 2, 500 tons of ore, with dimensions of 17m x 29m, and 2.3m high (RONC, 1917). The roast yard was 2.3 km long, consisting of more than 100 heaps, and was located approximately 16 km west of Sudbury ON, 5 km west of Highway 144, towards Chelmsford, close to Lively ON. The townsite for the workers was located 1.6 km east (downwind) of the roast yard (Figure 3).

Figure 3. Map locating the O'Donnell roastbed, townsite and scientific sampling sites.

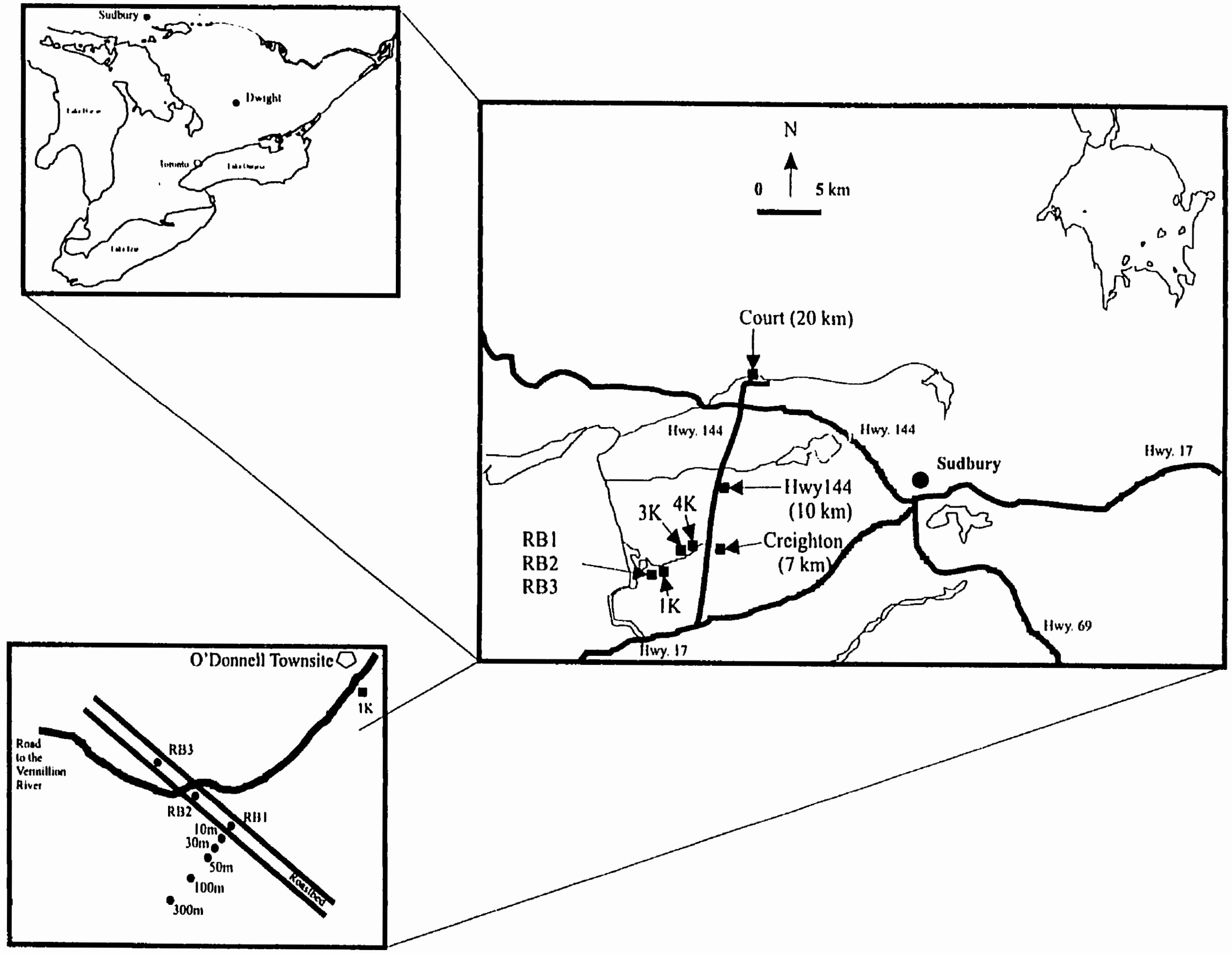


Figure 3. Map showing the location of the O'Donnell roast bed and townsite along with permanent sampling plots.

2.0 Reasons for the establishment of the O'Donnell Roast bed

The sulphur-rich ores of the Sudbury basin were roasted in open heaps to reduce the sulphur content before it was sent to the smelter in Copper Cliff for further processing. Laroche et al (1979) have located 11 of these roasting sites in the Sudbury region.

2.1 Historical roasting sites of the Sudbury region

Table 2. Roasting locations of the Sudbury region.

Number *	Name	Years of operation	Status
6	Copper Cliff #1	1888-1905	Covered by slag pile
7	Copper Cliff #1	1899-1903	Residential and park area
8	Copper Cliff #3	1901-1916	Covered by railroad yard
4	O'Donnell	1916-1929	Intact, with road crossing it
5	Gertrude Mine	1901-1903	Disturbed
10	Blezard Mine	1889-1895	Crossed by water line, partially intact
1	Chicago Mine	1891/94-1894	Intact
2	Victoria #1	1901	Decommissioned by INCO (covered and seeded)
3	Victoria #2	1902-1913	Decommissioned by INCO (covered and seeded)
11	Coniston	1913-1918	Intact, some erosion
9	Murray Mine	1890-1894	Destroyed by more recent mining activity

* Numbers correspond to roast yard locations indicated on map (Figure 4).

(Laroche et al, 1979, modified)

2.2 Environmental impact of the roasting process

Prior to 1916, three small roast beds had operated in the town of Copper Cliff. The toxic acidic fumes released by the roast beds caused many farmers and local residents to complain about the sulphur smoke damaging their crops and gardens. The situation at Copper Cliff was described in a Ontario Bureau of Mines report:

Figure 4. Locations of historical roastyards in the Sudbury area. Reproduced from: Laroche *et al*, 1979.

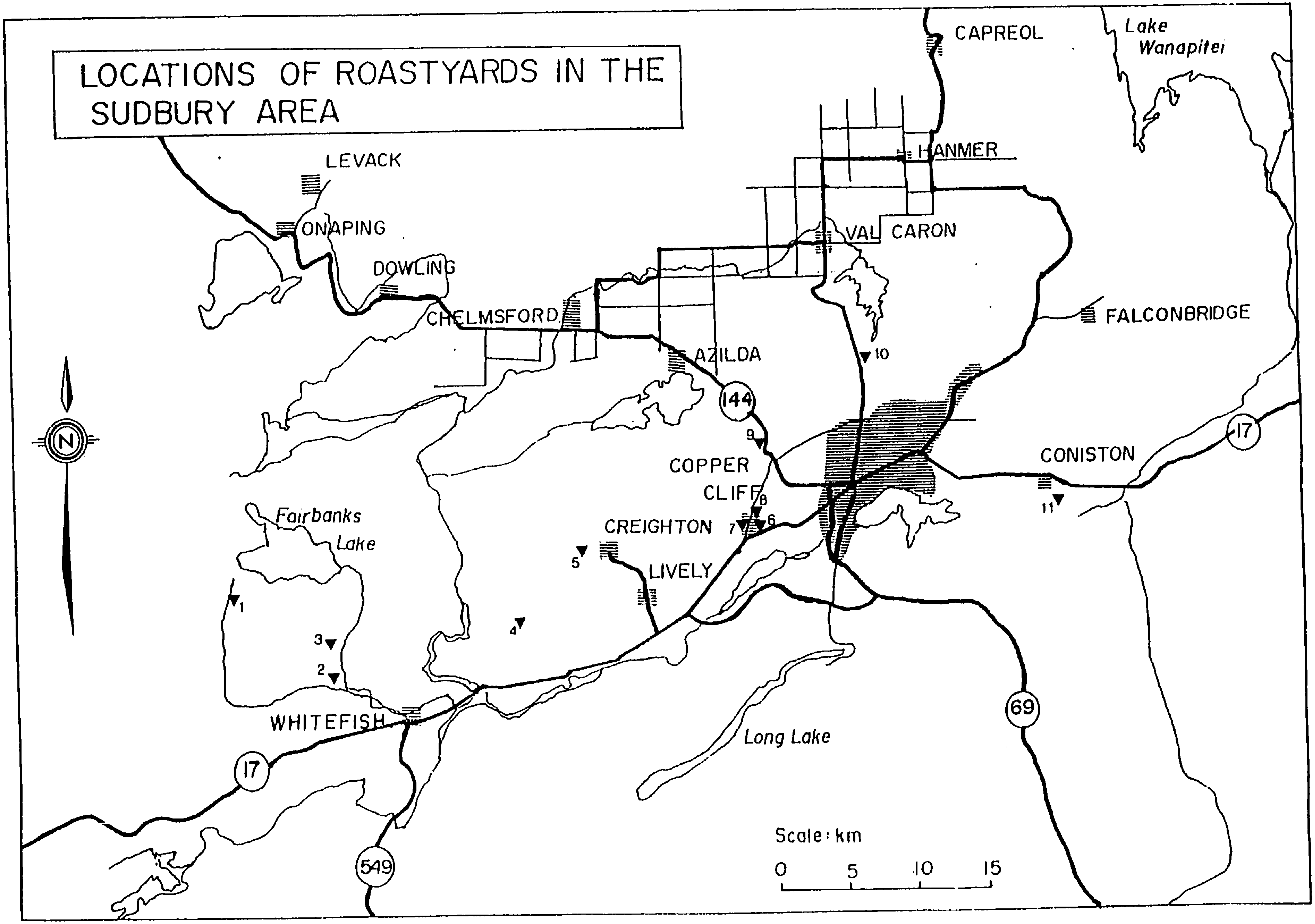

LOCATIONS OF ROASTYARDS IN THE SUDBURY AREA
CAPREOL
Lake Wanapitei
HANMER
LEVACK
ONAPING
VAL CARON
DOWLING
CHELMSFORD
FALCONBRIDGE
AZILDA
10
144
9
COPPER CLIFF
CONISTON
17
8
6
7
11
CREIGHTON
Fairbanks Lake
5
LIVELY
1
4
3
2
WHITEFISH
69
Long Lake
17
Scale: km
0 5 10 15
549
N

Figure 4.

> The destruction near the roast beds is complete, so that scarcely a green thing survives and the swampy flats have been turned into deserts with white or gray or brown stumps of the trees once growing there. The unpainted houses have taken on a curious brown tinge, and certain colors of the painted houses have suffered. Telegraph and fence wires are rapidly corroded and have to be frequently replaced. The fumes, being free from arsenic, seem to have no ill effect on men or animals, however, the numerous school children, for example, looking plump and rosy (Ontario Bureau of Mines Report, 1902). (Plate 5).

2.3 Local residents and farmers speak out against the roasting process

By 1905, opponents of the roasting process were becoming increasingly vocal. Under the Free Grants Act of 1906, the Ontario government opened up several new townships in the Sudbury district to farming. However, at the same time, nickel-copper production was increasing significantly, and as a result, within three years complaints by farmers of damage to their crops by sulphur emissions from the roast beds were so numerous that the local sheriff was called upon to act as an unofficial arbitrator. From 1909 to 1915 he settled claims, apparently to the general satisfaction of both the mining companies and farmers (Sudbury Star, July 18, 1917). A number of letters were published in the local newspapers, the Sudbury Journal and the Sudbury Star, written by frustrated citizens. One signed "a Sudbury citizen" wrote about a proposal made by City Council for a park, "Is that Park possible, if the Canadian Copper Company's sulphurous gas is always threatening its vegetation? ....Our Mayor and Council, must claim, for the citizen's interest, against the Copper Cliff roast bed process, and obtain its abolition" (Sudbury Journal, Sept. 11, 1915).

With the outbreak of World War I there was an increase in demand for nickel by the armaments industry which led to more ore being roasted than ever before and the public pressure to reduce the sulphur emissions was mounting. The Sudbury Star wrote, "1915 has been the worst year in the history of the districts for sulphur smoke, the immediate cause being the great increase in the production of the companies to meet the demand of the war, although unfavourable climatic conditions were also to some extent responsible" (Sudbury Star, October 30, 1915). With this increase in production, complaints escalated.

Plate 5. Landscape around Sudbury region during O'Donnell's operation (1916-1930). Courtesy of INCO.

In 1915, there were so many complaints from area farmers that the sheriff's office was unable to handle them all. As a way of coping with this number of complaints, the CCC formed a two-man committee, one of whom was a respected local farmer, Moses Gatchell to address complaints. However, this committee was short lived as the company believed that the awards were too generous. Therefore, in 1915 an "impartial" three man committee composed of one representative of the farmers, one of the company, and an independent third official was set up to settle claims (Bray, 1984). This new committee responded more to the liking of the company but was unacceptable to many farmers. Often the award was less than half the amount asked for by the farmer (Sudbury Star, June 2 and July 18, 1917). This lack of compensation led the farmers to drastic action. In the fall of 1915, lawsuits were launched in both the District Court of Sudbury and the Supreme Court of Ontario by dissatisfied farmers demanding not only increased compensation for their agricultural losses but also stop-work injunctions against Canadian Copper and Mond Nickel (Bray, 1984). The Supreme Court of Ontario selected six suits - four against Canadian Copper, and two against Mond Nickel - which collectively became a single test case on the issue of sulphur pollution (Wallace and Thomson, 1993). The trial began in March, 1916, and Justice J.J. Middleton passed his judgment 15 months later on May 31, 1917. Details of these court cases will be discussed later within this chapter.

A letter from a farmer demanded that the government put an end to the roasting process by saying "we farmers may not henceforth lose in one day the result of a whole year's labour" (Sudbury Journal, Sept. 11, 1915). Another farmer provided his description:

> Any man being on the road between Sudbury and Sudbury Junction, on the CNR on Monday August 23rd, could not help smelling the odour of dying vegetation, and on the following day the fields were a rusty dying colour, instead of living green. Is that not sufficient proof of the damage being done by sulphur smoke? (Sudbury Journal, Sept. 2, 1915).

2.4 Establishment of the Royal Ontario Nickel Commission, 1915

At the beginning of the first World War, INCO shipped its smelted ore to New Jersey for refinement. INCO was able to ignore the "requests" and pressure for it to refine it's nickel in Ontario, until World War I raised the issue of Sudbury nickel going to Germany, the enemy. In July 1916 a German cargo submarine, named the *Deutschland*. had, apparently without INCO's knowledge, transported Sudbury nickel from the U.S. to Germany. This scandal reflected badly on the Sudbury Board of Trade as well, as they were in full support of INCO. With INCO refining their nickel in the U.S., there was little control over the distribution of the refined product. This lack of control was the primary reason behind the establishment of the Royal Ontario Nickel Commission, to investigate the feasibility of refining in Ontario. The importance of the RONC was not in their conclusions, but in their existence as it was the first serious assessment of the mining industry (Main, 1955). INCO had a monopoly on nickel production in Sudbury, just as Sudbury had a monopoly on the world's nickel production.

Prior to the release of the Commission's report, INCO found that it could feasibly refine its ore in Ontario, and started construction of a refining plant in Port Colborne. The Royal Ontario Nickel Commission (RONC) Report and Appendix was published in 1917, also concluding that the Sudbury ores could be refined profitably in Ontario. In addition, the commission recommended that the method of open roasting be stopped. Detrimental aspects of roasting identified in this report include an estimation of just how much sulphur dioxide is released to the local area from roasting of ore, and "available" to cause damage to crops and vegetation:

> Assuming the ore to contain 25% of sulphur, and to be roasted on the heaps to 10%, every million tons of ore would yield at the roast heaps 150 000 tons of sulphur, i.e., 300,000 tons of sulphurous acid gas, which would be sufficient to produce 450,000 tons of ordinary strong sulphuric acid (RONC, 1917)

Smoke damage to crops:

> Large quantities of sulphur are expelled in the form of [sulphur dioxide] ($S0_2$) in roasting, smelting and refining the Sudbury nickel-copper ores. The larger proportion is driven off on the roast heaps under the worst possible conditions for agriculture, as the roast heaps are low-lying, and the gas, which is about two and one-fifth times as heavy as air, flows along the ground unless carried away by the wind (RONC, 1917).

The loss of metals during the roasting process:

> In other words, any water draining from the roast heaps, will be highly charged with nickel salts, and to a lesser extent with copper salts. There is reason to think that the losses in this form (leaching), especially of nickel, are not negligible, and although the prevention of these losses alone might not justify the giving up of roasting in heaps, it is an important additional reason for abandoning roast heap practice" (RONC, 1917).

The motivating factor for roasting was to **cheaply** reduce the sulphur content of the ore prior to smelting. This is shown in the letter written by Mr. C.V. Careless, the manager at Coniston (Mond Nickel Company), quoted by the Royal Ontario Nickel Commission (1917).

> We have been running a month or two, experimentally, with no roasted ore...should we abandon heap-roasting altogether. We intend running for some months in this way while collecting full data for the final calculation as to the economy of the practice....As winter roasting eliminated all damage to neighbours from the roast yard, the question as to abandoning heap roasting altogether will be purely one of economy. My present feeling is that heap-roasting will be eliminated from our operations entirely within a year or two (RONC, 1917).

As mentioned earlier, during the growing season of 1915, farmers experienced severe damage to their crops. Reasons given for this damage included sulphur smoke damage, advocated by the farmers, while climatic conditions were more likely responsible, according to the mining companies. During the months of March and April 1916, seventy-two farmers from twelve neighbouring townships in the Sudbury area signed a petition, requesting the sympathy and support of the Sudbury Board of Trade. The farmers wanted the Board of Trade to speak out on their behalf against the mining companies. These farmers argued that their crops had been so badly affected that those farmers in the "smoke zone" had not been able to raise sufficient grain for seed to plant in the 1916 season, and if the sulphur smoke continued, farming in the Sudbury region would be seriously threatened (Sudbury Star, Mar 4, 1916).

2.5 Selection of the O'Donnell roasting site with provincial government support

With this increase in public pressure to abandon the roasting process, the response by the mining companies varied. For example, the Mond Nickel Company roasted only 30% of its ore using this method of heap roasting and switched to winter roasting only in 1916-17. The British America Nickel Corporation did not use the heap roasting method, and the CCC consolidated its roasting operation in a new, much larger roasting yard, in the township of Graham (O'Donnell) and continued year-round roasting for a further 13 years. The conflict between agricultural interests and the CCC resulted in the CCC paying farmers the huge amount of $137, 398 for smoke damages in the year ending March, 1916 (RONC, 1917). In order to avoid future conflict with the farming community, the "Canadian Copper Company petitioned the government to withdraw all unallocated Crown lands in the vicinity of the proposed roast beds from public sale, arguing that the area was largely unfit for agriculture and that mining must take precedence" (Ontario Dept. of the Environment 1915, as cited by Bray, 1984). In October 1915, land in Graham township was taken out of settlement by the provincial government on the grounds that the land was largely unsuitable for agriculture. This was done in an attempt to prevent further claims being launched against the CCC for smoke damages from those farming relatively close to the roast beds. These lands were set aside and the site for the O'Donnell Roast Bed was confirmed, four miles west of Creighton. It was hoped "this location would minimize as far as possible the damage and annoyance resulting from sulphur smoke in this district" (Sudbury Star, October 30, 1915). Named after a long-term employee, O'Donnell was laid out during the winter of 1915-1916, taking the place of the roast beds located at Copper Cliff (Peters, 1996; Laroche et al, 1979).

The provincial government was obviously supportive of the mining companies in the Sudbury region in that it basically "donated" public land to the company as a buffer against claims, but without compelling the companies to buy it, essentially, a gift from the crown. This restriction on additional development of agriculture in the Sudbury region prevented additional clashes between the farmers and the mining companies, but it did nothing to solve the complaints from existing land owners affected by the sulphur fumes.

In April, 1916, Mr. Clary, the farmers' representative, discussed this withdrawal by the provincial government of twelve townships from settlement, with the Sudbury Board of Trade. Mr. Clary characterized the plea that these lands were not fit for cultivation as "false, and a damnable lie". He argued that these lands were withdrawn from settlement in order "to allow the two big smelting companies to use the most primitive methods of treating ore and also the cheapest so as to increase their profits". Mr. Clary continued by saying that Germany, France and Belgium had devised ways of treating the ore, without injury to the agriculture community and he was convinced that the same could be done in the Sudbury region, "if the operating companies were made to spend the money". He argued that "the Public Health Act in Great Britain would not permit the kind of smelting that is done here". He continued with "nothing would be done as long as we fellows sit and grin and bear it, as long as we keep on spitting and coughing. These companies could be indicted tomorrow by the Attorney General for maintaining a public nuisance". He urged that situations in the United States should be learned from, in how such grievances between the smelting companies and the farmers had been settled amicably (Sudbury Star, March 4, 1916).

Finally, on April 14, 1916, the Sudbury board of Trade came forward with their resolutions. Of the 3 resolutions then adopted, one requested the appointment of a provincial commission to assess damage by sulphur smoke to crops in the region, the second petitioned the Hearst government to provide Sudbury farmers with much needed grain for the 1916 season, and the third was to "respectfully request" the mining companies to roast their ore during the winter months only (Sudbury Star, April 19, 1916). As quoted in the Sudbury Star, ""Very little discussion centred around a motion asking the operating nickel companies to roast all their ore in the winter months. It says: "That this Board of Trade respectfully request the mining companies to consider the roasting their ores between the months of October and April." The motion carried unanimously"" (Sudbury Star, April 19, 1916). The Ontario government responded quickly to these suggestions, agreeing both to appoint a special sulphur fumes investigator for 1916 and to assist farmers in purchasing seed grain for 1916 (Sudbury Star April 22, 1916).

Also, during the spring of 1916, in the Legislature, Sam Carter, of Wellington, stated that while he was in the Sudbury area, he had heard complaints of crop damage done by smelting, twenty miles from the source, and people were "likely to be moved off their property on which they had made improvements". He stated that the "Canadian Copper Company was getting too much of a strangle hold on that part of the province".

Again, farmers attributed damage to sulphur fumes, but the company valuators had reported that the grain was suffering from an epidemic of oat blight, rather than sulphur damage (Sudbury Star, April 12, 1916).

Reverend Father Cote, of Chelmsford parish, spokesperson for the farmers, emphasized the need to arrange amicable settlements, in light of previous offers being "ridiculous compensation" to many farmers. The CCC had already responded to the "pressure" by moving it's roasting activities to the "remote" O'Donnell site, but Father Cote did not expect any improvement in the "sulphur smoke situation" as a result of moving the roast beds to their new location (Sudbury Star, April, 19, 1916). As Father Cote predicted, complaints of sulphur damage to crops continued after the relocation of the roast beds from Copper Cliff to the "remote" site of O'Donnell. How these complaints were addressed in the provincial courts is discussed in the following section. There were many farms in the O'Donnell area at this time. According to Santala (1972) three townships surrounding the O'Donnell roast bed, namely Drury, Denison and Graham, had a substantial amount of farm land in operation in 1921 (9,608 acres). He also reports a population of these townships in 1911 of 2,121. By 1921 it had fallen to 1,038 and as of 1931 it decreased to 747 (Santala, 1972).

2.6 Court Cases launched against the Canadian Copper Company (later INCO)

It has been well known since the turn of the century that even "extremely minute quantities of sulphur dioxide are injurious" to vegetation (Haywood, 1907). The impact of SO_2 on plant life was the focus of much research and attention because of the economic ramifications to agricultural crops surrounding these resource extraction centres. This clash between mining and agriculture was by no means confined to the Sudbury region, and has been well documented throughout North America (Fulton, 1915; Smith, 1987; Treshow and Anderson, 1989; and Aiken, 1994).

Since Sudbury farmers were not satisfied with the settlements offered to them by CCC, they took their case to court. This particular court case provided the foundation for other "sulphur cases". Presented here is a great deal of detail in an attempt to reflect the attitudes of the Judge and the CCC as well as those of the plaintiffs. Judge Middleton describes the formation of the "test" case as the following:

> A large number of actions were brought, and many others threatened against the Canadian Copper Company, for damages supposed to have been sustained from vapours contained in Metallurgical smoke issuing from the roast beds and smelter stacks of that company at Copper Cliff, near Sudbury. A motion was made to consolidate these actions resulting in the choice of four cases which were to proceed and to be regarded as test actions, the others remaining in abeyance in the meantime (Middleton, 1917).

Two actions (Clary and Ostrowski) were also pending against the Mond Nickel Company and it was arranged that those were dealt with at the same time.

The four cases chosen for the "test" case launched against the CCC included:

> 1) An action by J.F. Black, a florist, having a greenhouse and number of small plots upon which market garden produce was grown.
> 2) An action by Jos. Belanger, a farmer, upon a somewhat larger scale than usual for this district, who had claims for damage done to two farms.
> 3) An action by Mona Taillifer, a woman who worked also upon two farms not at all comparable to Belanger's farms, and in a much humbler way.
> 4) An action by the Sudbury Dairy Company, milk dealers, who has a farm upon which their dairy herd was pastured quite close to Copper Cliff.

Originally, all of these claims called for a stop roasting injunction, but at different times, this was abandoned and, in turn, the claims resolved themselves into assessments of crop damage only (Middleton, 1917). It was stated by Judge Middleton:

> If the mines should be prevented from operating, the community could not exist at all-once close the mines; the mining community would be at an end and the farming would not long continue. Any capable farmer would find farms easier to operate and nearer general markets if the local market ceased. It is the consideration of this situation that

> induced the plaintiffs counsel to abandon the claim originally made for an injunction (Middleton, 1917).

Judge Middleton makes a point of mentioning that even if the plaintiffs had continued in seeking a stop working injunction, he would not have granted an injunction "interfering with the carrying on of the works in question". Judge Middleton continues with his strong support of the mining company by verifying that the sulphur smoke is simply "part of the package" where mining is concerned. He continues:

> Smelter smoke may, no doubt, be a nuisance, and in addition to being disagreeable it may cause injury to vegetation and in some circumstances I have no doubt an injunction ought to be granted. For reasons which will appear later, I am of the opinion that the mines cannot be operated without the production of smoke from the roast yards and smelters which contains very large quantities of sulphur dioxide (Middleton, 1917).

Early in Judge Middleton's remarks, he addresses the importance of mining operations to continue for the whole of Canada, even if at the expense of a few. He argues:

> In each case it ultimately becomes a question of degree and in a much modified sense a question of the greatest good to the greatest number. I do not mean by this as I shall show that for the mere purpose of easily producing metal of value the owner of a mine may sacrifice his neighbours, but I think there are circumstances in which it is impossible for the individual to so assert his individual rights as to inflict a substantial injury upon the whole community (Middleton, 1917).
>
> Nickel is essential for many of the world's greatest industries; the metal is only found in a few places; it cannot be mined and placed upon the market without producing a nuisance affecting, at most, a comparatively small area; those going into that area to farm have (in almost all cases) gone there with their eyes open, seeking to avail themselves of a market in which abnormally high prices rule because of the demands created by those mines and their great distance from ordinary sources of supply. Some cases of hardship may exist but according to the statement of counsel the mining companies have always stood ready to purchase the holding of any individual at a price far in excess of the value. In my view the Court ought not to destroy the mining industry even if a few farms are damaged or destroyed, but in all such cases compensation liberally ought to be awarded (Middleton, 1917).

Judge Middleton compliments Mr. Jarvis, Mr. Moorhouse and Mr. Ferguson, who worked for the CCC (later INCO) in the agricultural sector for their "very careful and minute examination of the effect of smoke upon vegetation.....and in the outset, I desire to express my confidence in their work" (Middleton, 1917). He goes further in stating, "Beyond this, they impressed me as fair-minded men who could be relied on" (Middleton, 1917).

2.6.1 Judge accuses farmers of exaggerating claims

A much different tone conveyed Judge Middleton's confidence in the farmers' complaints. He declared the farmers grossly exaggerated their claims of sulphur damage. He states:

> There was, as I have indicated, a not unnatural inclination upon the part of the farmers near the mines and roast beds to attribute all their misfortunes to them. There was also the inclination to exaggerate the possibilities of farming in the north country; but I regret to say this was clearly an endeavour in many instance to so exaggerate the claims put forward that not even the greatest charity and one might almost say the greatest credulity can acquit the claimants of positive dishonesty. This dishonesty was not confined to the parties merely but extended to many of the witnesses. I do not mean to include in this all the parties nor all the witnesses but the presence of so much gross exaggeration had made the task of assessing damages particularly difficult (Middleton, 1917).

Judge Middleton provides an example of this type of exaggeration while referring to the Ostrowski case:

> These people have only been in the country a short time and have no real knowledge of farming under the conditions to be faced near Sudbury. They ran a boarding house for men working in the mines. The land purchased was 36 acres, the price being $650; $150 being represented by a mortgage; $500, the entire balance, being secured by a second mortgage - no money being paid. All this land was rock save at one place, a small valley with steep rocky banks through which a stream made its way. Part of this valley was beaver meadow. None of it well drained as the stream was blocked by a natural dam of rock. This valley was said to contain 25 acres. Survey shows it to be less than half. Just 12 acres. The plan shows this drawn out in a narrow and most irregular manner along the banks of the creek. This was cultivated, in a way, for the two years, 1915 and 1916. The man was most poorly equipped in every way. The claim for loss for the injury done by smoke to this 12 acres in 1915 was over $2 500 and for 1916 $2 727.59. I do not mean by this the lump claim which is sometimes made in pleading but the claim as sworn to (Middleton, 1917).

The onus of proof of damage lay solely with the plaintiff, rather than the defendant, in environmental matters at this time. Judge Middleton continues:

> In each case the damages must be assessed as the evidence as a whole appeals to the Judge and as already said where there is a real element of doubt the plaintiff must, particularly in cases of this kind, be given the benefit of the doubt as against the wrong-doer so long as it can be found as a fact that the injury complained of is in truth the result of the gas emitted from the defendants works; this the plaintiff must prove (Middleton, 1917).

In addition to the plaintiffs being accused of exaggerating their claims, the CCC argues that crop failures are not the result of the sulphur smoke, but rather other causes such as insects and disease, both of which farmers "mistake" for sulphur damage. Judge Middleton describes the following:

> Although the mines have been in operation for many years this is the first time in which actions have come to trial. The explanation given is that some arrangement for compensation has heretofore been made, but now claims have been made and adjustment seems impossible and the Court have been resorted to and much evidence has been given with the view of having it ascertained how far the mines are answerable for the crop failures. The company sets up that many of the things complained of are not the result of the smoke but are to be attributed to entirely other causes, and that the claims are grossly exaggerated (Middleton, 1917).

2.6.2. Mistaking crop disease for sulphur damage

The Selby Report (1915) was produced by an American commission established to investigate the sulphur fumes issue in the United States, and many of their findings have been referred to within this "test" trial. It too found, that farmers had mistaken plant disease for sulphur damage.

> In the Selby Report much of the crop failure attributed by the farmers to the smelter was found to result from plant disease. Many diseases such as root rot and various fungus diseases which prevent a normal not to mention maximum development of the trees exist in the smoke zone. These plant diseases, taken in conjunctions with a general lack of care of the trees with poor cultivation and improper preparation of the soil and the rather low rainfall of the area do not make for any great growth in the trees nor for such productiveness. (Middleton, 1917).

In addition to these plant diseases, the losses farmers experienced were also attributed to climatic conditions by the mining companies. Judge Middleton continues:

> In addition to the other disadvantages and the plant diseases the farmers in 1915 and 1916 has most unfavourable climatic conditions to contend with. As shown in the evidence the seasons were exceptionally bad from the farmer's standpoint. The fungoid and bacterial diseases were actually mistaken for sulphur burning admits of no doubt, as pointed out by Mr. Jarvis, the difference can readily be detected by an expert particularly with the aid of a microscope. Many of the specimens produced by the plaintiffs as grain damaged by sulphur were in truth specimen of fungoid and bacterial disease, I have confirmed this by making careful microscopic examination of many of the exhibits produced (Middleton, 1917).

Examination of these dried specimens were presented in court, and in turn, accepted as proof of damage caused by factors other than sulphur, namely disease.

Damages awarded to the plaintiffs were less than originally offered by the company, out of court, presumably to discourage other farmers from taking their crop damage complaints to provincial court. Judge Middleton awarded the following in damages:

> In all circumstances I make the following awards, which while no doubt disappointing to the plaintiffs, are to be as generous as the evidence warrants.

To Black	$1000
To Taillifer	800
To Sudbury Dairy Company	1000
To Belanger	750
To Clary	1400
To Ostrowski	500

> In view of the fact that these are test cases, I have concluded to award costs in each case but as there was so much exaggeration in the claims presented I shall fix the amount when bills are presented, reducing them, somewhat from what would be allowed upon a taxation under a general award of costs (Middleton, 1917).

The Middleton judgment clearly sent the message that nickel production should continue unimpaired in support of the war effort. Convinced that mining could not continue in the Sudbury region without the roasting process and subsequent smoke production he argued that nickel production brought wealth (economic health) not only to

Sudbury, but Canada as a whole and if a few farms sustained smoke damages, this expense of a few was a small price to pay.

The use of smoke easements was another method used by INCO to pay sulphur damages to farmers. In 1918, the Ontario government passed the Industrial and Mining Lands Compensation Act which authorized a "mine, industry or factory" owner to purchase easements from landowners in the area surrounding their operation. These one time payments were binding for all future owners of the property, and also included all new facilities subsequently constructed by the purchaser. The declaration stated "The payment of compensation under such agreement shall afford a complete answer to any action which may be brought for damages or for any injunction in respect of any matter for which compensation has been made" (Statutes of Ontario, 1918, as cited by Bray, 1984). The mining companies used this legislation and purchased a number of smoke easements from local farmers in subsequent years when approached by farmers (Peters, 1997). The act also proved to be valuable to the provincial government, as the 1915 withdrawal of Crown lands from sale was unpopular with the farming community, the government reopened these lands to settlement in 1921. However, now included within these land transfer agreements were smoke easement clauses prohibiting the new owners from claiming any damages against the mining companies (Cain, 1921 as cited by Bray, 1984).

2.6.3 Evidence that damage may be due to Sulphur, rather than disease:

A letter dated January 21, 1925, sent to Mr. Murray, the Sulphur Fumes Arbitrator, from Mr. Gussow, the Dominion Botanist claims that it is difficult, if not impossible, to determine the cause of damage from dried specimens. He also argued that he could make an equally strong case advocating smoke damage, as disease, and urged that only detailed, long term experiments would give them definitive answers.

> I would suggest that we carry on a more systematic study of these things in Canada, and shall be pleased to spend a few days with you this summer in order to make a general survey. I quite realize that unless one is in a position to give authentic information, one would be unfair to farmers and smelter owners (Gussow, 1925).

Mr. Gussow was familiar with the Sudbury situation of sulphur fume damage being blamed by the farmers and common leaf diseases advocated by the mining company for the cause of damage to crops (Gussow, 1925). He also commented on the dried samples sent to him for examination.

> As regards the strawberries, you will remember that their condition indicated a very sudden interference with otherwise quite normal development. It would be peculiar diseases which would have such a sudden onset. One should not express an opinion on a dried sample at all. I should like to call attention to leaf diseases. Extensive damage very rarely occurs over a whole field or locality from this cause. In the case of fume injury and diseases present, can you determine which occurred first? (Gussow, 1925).

In a letter dated February 19, 1925, Mr. Gussow identifies sulphur smoke damage as being a strong possibility, rather than disease as advocated by the mining companies. Again, he identifies the need to have detailed investigations into the sulphur damage issue.

> I have never known any plant disease to cause such extensive damage in other regions, and this makes me think that diseases are often blamed for what may be really smoke or physiological trouble. I would like, however, to know who determined the presence of diseases in the samples you sent me. What is, for instance, the cause of blade blight? I fear that I would be able to claim just as much for smoke injury as for diseases as shown in the specimens you sent me. If we desire to get to the bottom of this, experiments - and systematic ones - are absolutely essential (Gussow, 1925a).

The information included in the preceding letters was confined to the sulphur fume arbitrator reports and was not presented at court proceedings in support of sulphur damage.

2.6.4 Government attitude of NOT awarding smoke damages (1942, 1943)

The support of the Provincial Government for the mining company was shown when they removed land from settlement to allow the CCC to avoid paying damages in the vicinity of their new roast yard, O'Donnell. This biased support was again later witnessed in 1942, 1943 with two telling letters. On October 29th, 1942, Mr. Murray, the Sulphur Fumes Arbitrator wrote to the Hon. Mr. Laurier, Minister of Mines, in order to ask him to approve the following procedure in awarding sulphur damage claims.

> (a) To award compensation in the case of vegetable gardens injured as to yield or quality, as a result of sulphur bleaching.
> (b) To award no compensation in the case of injury to trees, shrubs, flowers, or grass. (The injury to this type of vegetation is usually of temporary nature, and very rarely are the affected plants killed by an occasional bleaching.) (Murray, 1942)

Complaints had again escalated in 1942 as a result of increased production to meet the Second World War needs. However, this time INCO decided not to make any voluntary settlement offers, as injury to vegetation on urban properties did not endanger the livelihood of the claimants (Murray, 1942). The mining company was of the opinion that it should not have to pay these damages, because of the economic importance mining had for the community. Mr. Murray (the sulphur fumes arbitrator), on behalf of the mining company, stressed the importance of the mining industry in the Sudbury region. "A very large percentage of the residents of Sudbury, and of the suburban communities surrounding it, are employed directly by or are indirectly dependent on the mining, smelting and refining of nickel and copper" (Murray, 1942). Reasons for Mr. Murray's recommendation of awarding compensation for vegetable gardens only included:

> So far as trees, shrubs and flowers are concerned, I believe that the above stand can reasonably be maintained, but a vegetable garden is in a somewhat different category. Such a garden is put in to provide a variety of fresh vegetables, and when these are rendered unfit for use or decreased in yield, I feel that the owner should be reimbursed to the extent of the injury (Murray, 1942).

The response from the Minister of Mines, Robert Laurier, dated April 2, 1943, was the following:

> The position which I take is that it would be inadvisable at the present moment to consider any awards. I feel that should this be done, it would open the door to many claims and there would ensue, I have no doubt, innumerable request for such compensation. In view of this I feel that no awards should be considered, at least for the present (Laurier, 1943).

The provincial government was presumably elected to protect the best interest of "the people", however, the preceding attitude demonstrates that the interests of the company, and the nickel mining industry in general, took precedence. Again, the economic health of the company and the province was the priority during this period. Nickel production was necessary for the second World War, and environmental and human health were not addressed.

2.7 Discussion:

The annual profit for INCO in 1916 was $11,748,278.53 (RONC, 1917). The company maintained that it could not "profitably" process the Sudbury ore without this roasting process, which in turn causes extensive damage to the surrounding vegetation. It also argued that the farming community was dependent upon the mining community for its market, and if it was forced to stop roasting and smelting with present techniques, the mining industry would collapse in the Sudbury region. With the strong support of the provincial government, there was little motivation for INCO to reduce the environmental impact of its mining operations.

Despite the Royal Ontario Nickel Commission recommendations, the Sudbury Board of Trade's unanimous recommendation of winter roasting, and the innumerable protests of the local residents and farmers in 1916, the Canadian Copper Company ran the world's largest open roast bed for 14 years, until it finally closed O'Donnell. Meanwhile, its rival company, Mond, did comply with winter roasting and soon afterwards stopped roasting altogether. The CCC seems to have been indifferent to the local recommendation, complaints, and in fact ignored the Royal Commission's recommendations, apparently with the Ontario government's support.

It was not until 1974 that the Canadian Environmental Law Association (rather than the government) brought a successful action against INCO for air pollution. The company was convicted and was fined $1,500. While this wasn't a substantial amount of money, the conviction indicated that protection of environmental and human health was becoming more important.

3.0 Living conditions at O'Donnell

3.1 The Roasting Yard:

There was a protocol in locating all roast yards that included careful observation of the summer prevailing winds in order to place the roast heaps in selected areas that would have little effect on agriculture. According to Laroche *et al* . (1979), the "type" of environment for location was also a consideration. "The contiguity of cultivated land, or even of valuable forests, would forbid the employment of heap-roasting unless the arguments for its adoption were sufficiently powerful to outweigh the annoyance of constant remonstrances on the part of the land-owners" (Peters 1889, as cited by Laroche et al, 1979).

A description of the Copper Cliff roast yard's effect on the surrounding environment, is found in Professor Coleman's Monograph published by the Dominion Department of Mines in 1912.

He describes the effect upon vegetation as the following:

> These effects of the sulphur fumes upon the surrounding vegetation are disastrous especially to coniferous trees, so that soon after a roast yard is established the nearby cedar swamps show only bare trunks and many plants are killed even two or three miles away in the direction the prevalent winds. It is of interest to note that the maple stands the sulphur fumes best of all the trees so that small clumps may be seen springing up on many of the bare hillsides near Copper Cliff, since the roast yard has been removed a mile to the North behind a group of these. Mr. Turner, President of the Canadian Copper Company, has tested a large number of plants in his garden and finds that some flowers stand the effects of sulphur much better than others. If carefully looked after grass forms a turf once more at Copper Cliff and a good field of Indian corn thrives just behind the hospital. The roast beds send hundreds of tons of sulphur dioxide into the air every twenty-four hours and it is perhaps surprising that this active reagent does not accomplish more destruction than can be observed. Fortunately there is practically no arsenic in this ore so that the gases, though sometimes distressing to breathe, are not poisonous (Coleman, 1912).

He spoke of the smoke in the roast yards as making a "choking atmosphere to breathe, though it is apparently not found unhealthy by the men who work in the roast yards". He added that "the country just around the roast beds is usually of small value as farm land" (Coleman, 1912).

3.2 Site description

The O'Donnell roast yard was located just off the Algoma East railway, and less than a mile away from the Vermilion River. The roast yard was laid out on a flat area 2 km long, next to the parallel railway tracks. The ore was piled onto individual heaps 17m x 29m in dimension, along the continuous thick layer of wood. The work would be carried out end to end, meaning that as the layer of wood was ready, the coarse ore (more than one inch in diameter) would be placed directly on top of the wood and then fine ore (less than once inch in diameter) would be piled on top of the coarse green ore. Gradually, there would be close to 100 of these heaps built along the roasting bed and then the first heap at the far end would be lit. By the time the last green ore heap was built and fired, the others would already be roasting. The individual roasting heaps can be clearly seen in an aerial photograph taken Oct. 20, 1927. The townsite of O'Donnell can also be seen downwind (1.6km) in this photograph (Plate 6). This photo also shows the complete absence of vegetation.

3.3 O'Donnell Employees

A former O'Donnell resident who wishes to remain anonymous (1997) fondly remembers his first job working on the O'Donnell roasting beds "firing on a steam shovel".

> That's where I started to work. I started to work when I was sixteen. I started firing on a steam shovel. It's a boiler on wheels and it was the machine that loaded the ore into the cars to ship to Copper Cliff, then they handled the smelting end of it. My father was the steam locomotive engineer, so I knew a little bit about it before I even went on the job. But I had no trouble and I really liked it, but I didn't last very long when they started to lay off. Oh, it wasn't that bad, they had a couple of steam locomotives, mostly all operated by steam in those days eh, till about 1930. The coal would come in flat cars and then they transferred it from there to the moving machinery, to the steam locomotive, they used to cool them with a steam hoist and the like of that. I don't know exactly (how long the roast heaps would burn), but I know it was months anyway. Then there was a man that looked after them and he poured water, they'd drill a hole and put the pipe of water in and gradually cool them. Then the steam shovel was ahead of them all the time, with the dead beds, the others would be coming behind them, ones that were under control. They'd light fire wood underneath the beds, they'd burn for so long, and that was how they operated. The shovel stayed ahead of them (Anonymous, 1997) (Plate 9).

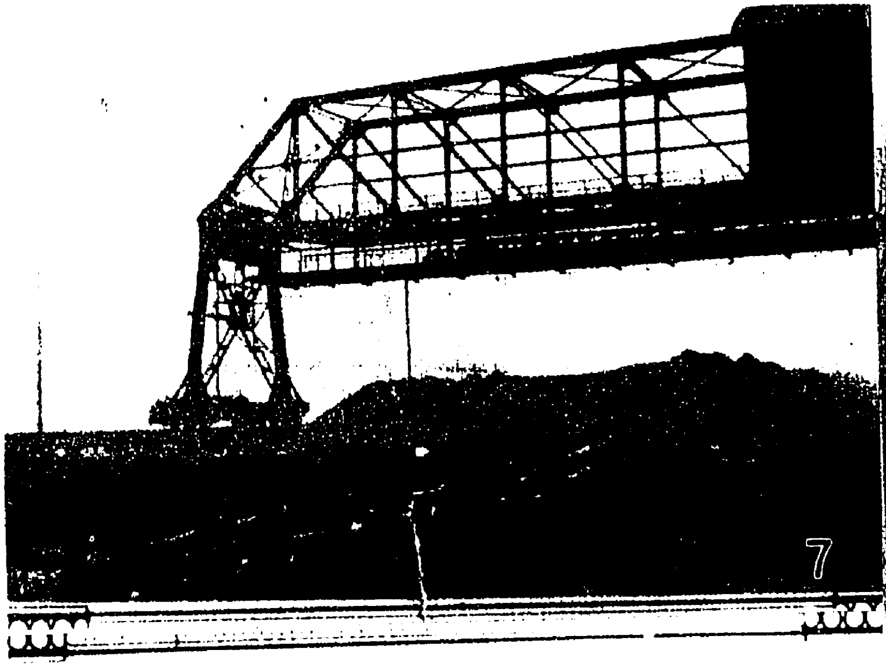
Plate 6. Aerial view of O'Donnell. Picture taken Oct. 20, 1927 at 9000 ft. It shows the "squareness" of the individual roasting heaps. Note the townsite located downwind, approximately 1.6 km. No vegetation can be seen in the vicinity at this time. This aerial photograph (HA467-76) © 1927. Her Majesty the Queen in Right of Canada, reproduced from the collection of the National Air Photo Library with permission of Natural Resources Canada.

Plate 7. O'Donnell roast bed construction, showing mechanized ore bridge. Courtesy of Loretta McPhail.

Plate 8. Individual roasting heap - O'Donnell roast yard. Shows the squareness of the heap of ore on cord wood. Courtesy of Loretta McPhail.

Plate 9. Steam shovel at O'Donnell roast bed, with steam shovel crew. Courtesy of Bob Bryson.

Plate 10. Locomotive at O'Donnell. X mark in background of right side is the location of the water tower at the O'Donnell townsite. Courtesy of Loretta McPhail.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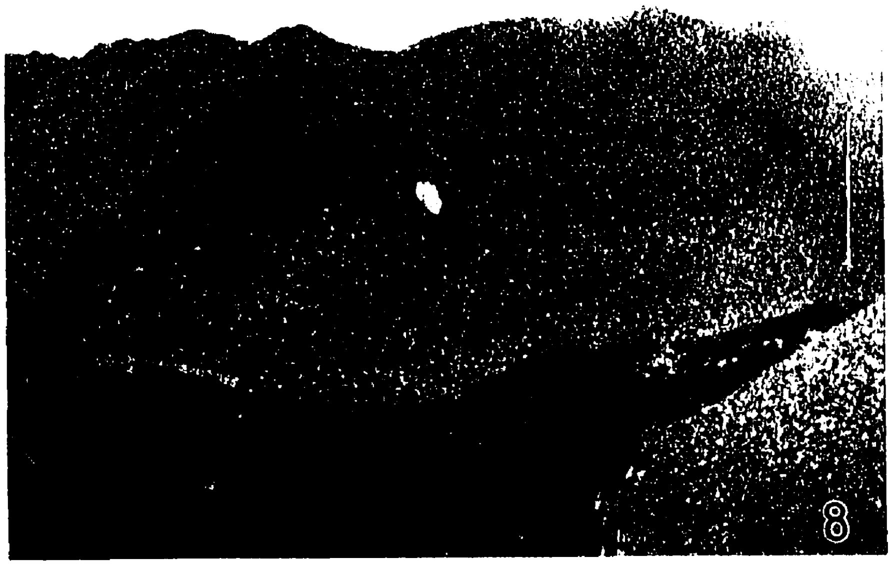
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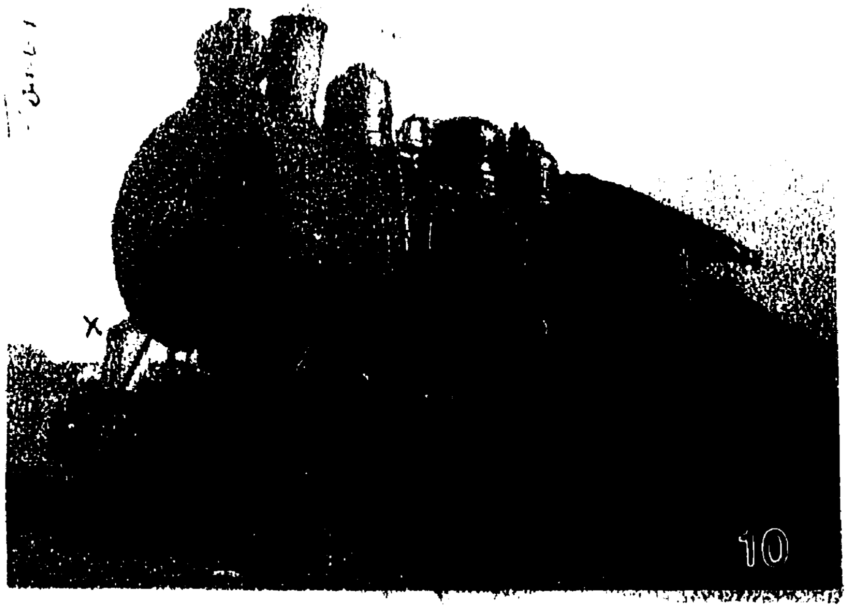
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There were many dangers associated with the roasting process. The ore was sampled throughout this roasting process to determine the sulphur content. When the sulphur content of the ore reached acceptable levels (usually 7-12%) the roasting process was complete. At this time the roasted ore formed a matte of ore, that, in order to remove it, needed to be broken apart into smaller pieces. This was done by using daulin, an early form of dynamite. The most unfortunate accidents occurred when the ore was not allowed to cool properly, and the daulin was introduced while the matte was too hot, leading to premature explosions. To reduce this risk, only the foremen were allowed to set the daulin (Fortin, 1995). A former O'Donnell employee recalls blasting taking place at O'Donnell.

> When they used to blast they'd put the shovel up tight against the blast so it wouldn't knock it down. There was one man in charge of it (the blasting), Mr. Dion. And they worked by whistles, eh, when they were going to blast, as a warning. It (the whistle) was on the steam shovel. Once the blast was over, you'd go back to work. What they used to do was get on the train and then back up, maybe half a mile away or something similar to that, so it wouldn't get hit by the blast (Anonymous, 1997) (Plates 9 and 10).

The roasting of green ore started at O'Donnell in February 1916. At this time there were more than 200 workers on the roast bed, with most of the workforce being young single men. Of the five hundred and six cards sampled, one hundred and fifty eight employees were married, while two hundred and fifty six were identified as single, while the other ninety-two were not identified as married nor single. Of those identified as married (using the employee cards only), only three were documented to have their families with them at O'Donnell, while twenty eight had their wives and families elsewhere.

3.3.1 Age distribution of workers at O'Donnell

The age distribution of workers can be seen in Figure 5. Eighty-three percent of the employees (identified within the employee cards) were between the ages eighteen and forty years.

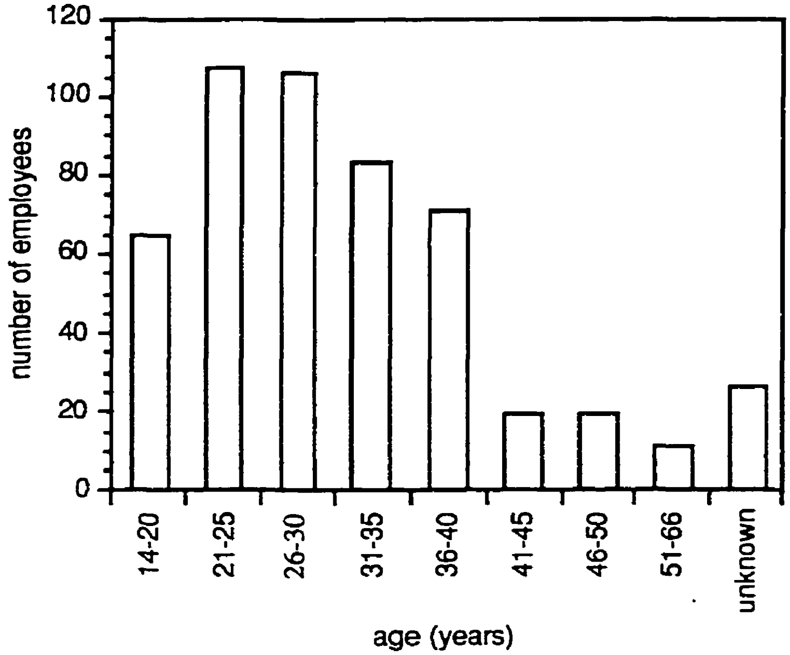

Figure 5. Age distribution of workers at the O'Donnell roast yard (from 506 employee cards).

The sixty hour work week consisted of 10 hours/day, 6 days/week. There were 25 different job titles at O'Donnell in 1916, and the rate of pay varied from fifty-five cents/hr for a steam shovel engineer to ten cents/ton of ore, for green ore unloaders, or twenty-five cents/hr for labourers. The yard boss, green ore boss and steam shovel boss all received thirty-five cents/hr. O'Donnell workers were not paid more than other miners in the area because of the adverse (smoky) conditions under which they worked. Their rates were equal to other company workers. For example, a steam shovel engineer earned 55 cents/hr, whether he worked at the roast yard, or in the mechanical department. Before mechanization, the labourers used picks, shovels and wheelbarrows to transfer the ore between the open roasting beds and the railway cars (Plate 11). With the mechanization of O'Donnell in 1919 an ore loading "bridge" was built over the beds. This bridge moved the length of the railway tracks, up and down the roast bed proper. Raw (green) ore would come in by railway car and be transported to the bridge and then this bridge would move along and deposit the ore in heaps, on top of the wood (Plate 3 and 7). This mechanization dramatically reduced the number of green ore unloaders needed to operate O'Donnell. However, the wood handlers continued to manually build the wood-base foundation, as a former O'Donnell employee describes.

> There were two men, Joe Denomee and (George) Hamilton, I forget Mr. Hamilton's name, he was French anyway, how

he got the name Hamilton, I don't know. They used to bring it (the wood) in by flat cars, box cars, whatever. Those two men would look after piling it, and making the beds. Then they'd put the coarse ore on top of that wood, they laid it on an angle, like on a 45 or something like that, then all around the edges they'd square the pile. This is shown from one of Loretta McPhail's (George Hamilton's daughter) photographs (Plate 8) (Anonymous, 1997).

Camile Lafrombois remembers when his father was in charge of cutting the wood that was used for the foundation (fuel) of the roast beds at O'Donnell.

> In 1927, when my dad was taking contracts from INCO eh, so much a cord for wood, he cut it, and he piled it in the bush, that's when they started the roast bed. Then we went back over there to O'Donnell and he was hauling the wood, hauled the wood for the roast bed, and they piled wood all around and they put the ore inside and it would burn the ore, roast the ore, and then in 1930 when they started the roasters in Copper Cliff here, they closed it down eh? Then they took the town apart. There was a school there, there was a grocery store, there were boarding houses, sidewalks. My dad spent a few winters over there cutting for INCO. Only in the winter, well that was the only time you went there was to bring the wood out of the bush, with a sleigh and horses. Then they would load them onto the cars, and then INCO would switch in and take the cars down to the roast bed, then they would throw the wood onto the roast beds. The wood must have been 10- 12 feet high. The first winter, when I was about 8 or 9 then, I was 10, I was born in 1917, my dad used to drill holes in the ice and flood the water on the river, Vermilion River. By the pump house. To go across with the horses, to haul the wood to the other side. He'd be cutting all over on the other side, cut half way up to Crean Hill pretty near. Wherever the wood was, eh.

3.3.2 Nationality of O'Donnell Employees

During the period of O'Donnell's construction and operation (1915-1930), there were workers from Britain, Bulgaria, Belgium, Scotland, Wales, Italy, Romania, Finland, Norway, Yugoslavia, Ireland, Sweden, France, Germany, Austria, the Ukraine, Poland,

Plate 11. Roasting operation at Copper Cliff Mine, 1890. Non-mechanized operation. This is the type of technology used at O'Donnell when it first opened, until 1919 when the mechanized bridge was built. This photograph (MT6-4) © 1890. Her Majestry the Queen in Right of Canada, reproduced from the collection of the National Air Photo Library with permission of Natural Resources Canada.

H. J. Topley Photo.

Geological Survey Department

Copper Cliff Mine.

CANADIAN COPPER CO.

(Nickel.)

Lot 12, Range II, McKim Township, Sudbury, Ont.

1890.

ROASTING THE ORE.

Russia, U.S.A., and Canada. Canadian workers were the most common nationality overall hired to work at O'Donnell, followed by Austrian, Italian, Finnish, and Russian (Figure 6).

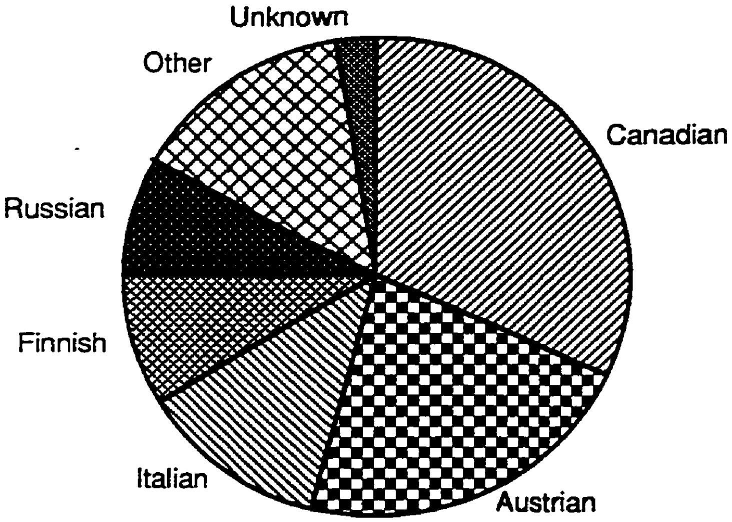

Figure 6. O'Donnell employee nationality of those hired. Taken from INCO employee cards (506 employee cards, 1915-1930).

In 1916, one hundred and twenty-three employees were hired, 35% of which were Austrian workers, 24 % were Italian, 19% were Finnish, while only 10% were Canadian (Table 3). In 1917, of the forty-nine hired, 35% were Canadian, 24% were Italian, and 14% were Austrian. An increase in Austrian representation was seen in 1918. Of the seventy-one hired, 44% were Austrian, 14% were Russian, while both Canadian and Italian nationalities had a representation of 10%. Operations were suspended with the mechanization of the roasting process (1919), and there was a labour surplus after the end of the war in 1919, so it was not a good time for hiring at O'Donnell. In 1919, Canadians represented 39% of the eighteen hired, while Austrian workers accounted for 16%. However, 135 workers were hired in 1920. The majority were Canadians (63%), while Austrians made up 12 % of the workforce hired, Russians 8%, and English only 5% (Table 3). O'Donnell was closed for a period in 1921 and 1922, with hiring beginning again in 1923. Of the sixty-six men hired that year, 39% were Canadian, 14% Austrian, 12% Polish, and 11% Russian. Very few workers were hired between 1924 and 1930, while for thirteen workers, the starting date was not recorded (Table 3).

Table 3. The number and nationality of employees that were hired to work at O'Donnell roastbed (1914-1930).

Nationality	1914	1915	1916	1917	1918	1919	1920	1923	1924	1925	1926	1927	1928	1929	1930	?year	total
Austrian			43	7	31	3	16	9			1					2	112
Italian	1	1	29	12	6	4	2							1		4	60
Finnish		1	23	7	5	1	2	4	1					1			45
Canadian		1	12	17	7	7	85	26	2	1	2			1		5	166
Russian		1	7	4	10		11	7			1	1					42
English		1	1		1	2	7	3								1	16
Swedish		1	2														3
Polish			1		3			8					2	3			17
French			1		2		1										4
German				1													1
Norwegian					1												1
American					2	1											3
Belgian					1												1
Bulgarian					1												1
Irish							5										5
Welsh							1										1
Romanian							2	1							1		4
Ruthenian								1									1
Scottish								1									1
Ukrainian								3	1					1		1	6
Letune														1			1
Yugoslavian													2	1			3
Unknown		1	4	1	1		3	3									13
Total Hired	1	7	123	49	71	18	135	66	4	1	4	1	4	9	1	13	506

Canada's immigration policies dictated the availability of immigrant workers during the early 1900's. "British and English stock American immigrants were readily accorded high occupational and social status in the country. But Eastern and Southern European immigrants were allowed..(into Canada)...because of their brawn and industry and they were granted basic civil rights" (Avery, 1979). The attitudes of their Canadian hosts varied both with time and economic circumstances. According to Avery, language, culture, occupation and place of residence, set the European immigrant apart in Canada, "and this social distance was lengthened by the suspicion and hostility many newcomers felt when they discovered Canada could not deliver what they had come - or been led - to expect" (Avery, 1979). Many of the Europeans thought of the their Canadian residence as temporary, with their wages supporting relatives in Europe and improving the standard of living upon return to the home country (Mckinnen, 1997; Avery, 1979).

However, job security was not offered to the immigrant worker, making it difficult to earn enough money to either return home to a better standard of living, or pay the transportation of waiting family members to Canada (McKinnen, 1997). In one year an immigrant worker might find himself in many different jobs: "In February a lumber worker in Iroquois Falls, ON; in June a railroad navvy along the National Transcontinental; in August a harvester in Grenfell, Saskatchewan; in November a coal miner in Fernie, British Columbia" (Avery, 1979). This varied work experience is reflected in the INCO employee cards within the category of "previous employment". Many workers had recent experience with railway companies, lumber companies, construction, farming (in Canada, as well their home country), paper mills, and other mining and steel companies throughout Canada. The unskilled immigrant worker had a basic commodity to exchange - "his physical strength, his brute force, to carry, pull, push, turn, as a horse would do, or a piston or a wheel" (Stearnes, 1975 as cited by Avery, 1979). The unstable labour market was a result of the employers attitude of the early 1900's as described in an article titled "the Development of the Capitalistic Labour Market in Canada" printed 1959, and quoted by Avery 1979.

> In this market the employer is confident that workers will be available whenever he wants them; so he feels free to hire them on a short term basis, and to dismiss them whenever there is a monetary advantage in doing so .... labour to the employer is a variable cost.... From a broader point of view, the capitalistic labour market represents a pooling of the labour supplies and labour needs of many employers, so that all may benefit by economizing on labour reserves (Pentland, 1959, as cited by Avery, 1979).

These fluctuations in labour demand and the tendency for companies to temporarily discharge unskilled labourers during slack periods, produced deep hostility among immigrant workers. These idle periods not only prevented the accumulation of funds, but the workers were forced to deplete their saving, in turn postponing a profitable return to their home country (McKinnen, 1997; Avery 1979). Bill McKinnen's Finnish grandfather came to Canada and left his family behind in Finland. He visited his family in Finland a number of times before borrowing money from the CCC to send for his family (wife and five daughters) in Finland as he was never able to save enough money working for the Canadian Copper Company (McKinnen, 1997). During O'Donnell's operation, in response to a decrease in nickel demand after the war when steel armaments had caused a large nickel demand, it closed for a period in 1921, laying off most of it's workforce. Maude O'Malley remembers her family living on wild rabbits caught by her father, during that winter.

Often, the European migrant "absorbs at least superficially some of the norms and values of the host society...After about one year, most polyannual [those travelling between their home country and Canada more than once per year] migrants realize that short-term participation in a high-wage economy does not once and for all eliminate their deprivation back home, however spartan their conduct in the country of employment", leading to a significant number of these "target workers" settling in the receiving country. In turn, "the migrant becomes an immigrant" (Bohning 1972 as cited by Avery 1979), and after three years residence could become a Canadian citizen and vote in Canadian elections (Macdonald, 1921 as cited by Avery, 1979).

Canadian immigration policies from 1896 to 1932 were strongly influenced by spokesmen for the labour intensive resource industries and the transportation companies. "Officially, Canada wanted agriculturalists; but in practice thousands of the immigrants who came from Central and Southern Europe became either full-time or part-time industrial workers" (Avery, 1979). Prior to 1914, Canada's immigration policy "emphasized the recruitment of stalwart peasants from Europe" who could both provide the much needed industrial labour on a casual or seasonal basis in the country, as well as help in western frontier agricultural settlement (Avery, 1979). However, few of the prospective agriculturalists had the money to start farming immediately, and in turn entered the industrial wage economy. This "open-door" recruitment of European agriculturalists essentially continued until the Great Depression of the 1930's (Avery, 1979).

In order to supply the Western provinces with their much needed agriculturalists, the Immigration Branch would pay a bonus to steamship agents and colonization organizations for each agricultural immigrant brought into the country. "Unfortunately, there was no way to guarantee that particular immigrants were agriculturalists, or that once in the country they would be available for farm work". Many of these steamship agents assumed no responsibility, in exchange for the bonus. Among the most controversial of these "emigration" organizations was the Salvation Army. In 1903, the army created a Department of Migration and Settlement for the transportation and placement of the "deserving" poor of Great Britain. The Salvation Army persuaded authorities to include them in the bonus scheme for bringing agriculturalists to Canada. "Bonus payments to the Army rose dramatically from $500 in 1903, to $9,052 in 1907 and to $25,000 in 1914, despite continual charges from the Trades and Labour Congress of Canada that most of these "agriculturalists" soon became industrial workers" (Avery 1979).

The working conditions these employment agencies described to the Europeans were often very different than the real situation. Again, this was reflected in the O'Donnell employee cards. Employees argued that "conditions were misrepresented by agents" as this was the documented reason for leaving employment.

Canadian employers endured little internal opposition in their search for unskilled immigrant workers. "Occasionally native [Canadian] workers denounced the influx of large numbers of European agriculturalists through their unions and newspapers, but they never launched a systematic campaign against the practice" (Avery, 1979). Avery argued that few of these English speaking men were interested in the socially undesirable jobs to be found in the mines, lumber camps and "at the end of steel" [railroad workers], therefore making jobs available to the European arrivals.

With the outbreak of World War I in August 1914, the Federal government adopted a set of guidelines for dealing with the "enemy alien" resident of Canada which included registration and often internment. Attitudes of employers and employees were influenced by sides taken in the first World War. Among the persons classified as enemy aliens there were "393,320 of German origin, 129,103 from the Austro-Hungarian Empire, 3,880 from the Turkish Empire, and several thousands from Bulgaria" (Avery, 1979). By the end of the war, over 80,000 of these "enemy aliens" had been registered, and 8,579 interned at twenty-four different camps across Canada (Avery, 1979). In 1915 there was public pressure for companies to dismiss enemy aliens who had jobs, for "patriotic" reasons. However, labour intensive corporations argued that no one else would "undertake the rough, dirty jobs" (Avery, 1979). A compromise was reached at the Crow's Nest Coal Company where all

> naturalized married enemy alien miners were retained; naturalized unmarried enemy aliens were promised work when it was available; the remainder of the enemy alien work force, some 300 in number, were temporarily interned. Within two months, however, all but the "most dangerous" had been released by Dominion authorities (Avery, 1979).

With many young Canadians fighting in the first World War, there were severe labour shortages and immigrant workers were relied upon to carry out the manual labour both at the O'Donnell roast bed and elsewhere. As shown in Table 4, during 1916 and 1918 more than 85% of those hired to work at O'Donnell were immigrant workers, while in 1917 more than 64% of those hired would fall into the foreign working class. From the spring of 1917 onwards foreign workers within Canada found themselves not only wanted by Canadian employers, but actually being drafted into the industrial labour force by the Federal government. In an attempt to address these labour shortages, as of August 1916, all men and women over the age of sixteen were required to register with the Canadian Registration Board, and by April 1918 the anti-loafing act stated that "every male person residing in the Dominion of Canada should be regularly engaged in some useful occupation". A photocopy of one of these registration cards from a former O'Donnell resident has been provided in Appendix B.

Many interned prisoners of war (POW's) were released under contract to selected mining and railway companies, both to cope with labour shortages and to minimize costs of operating the internment camps. However, during 1916 and 1917, there was a series of complaints from POW workers, and on one occasion thirty-two Austrian workers of the Canadian Pacific railway went on strike in the North Bay district in protest of dangerous working conditions and unsanitary living conditions. "The ultimate fate of these workers was to be sentenced to 6 months imprisonment at the Burwash prison farm for breach of contract".

Before mechanization at O'Donnell in 1919 all the work on the roast bed was done manually, requiring a workforce of more than two hundred. With the end of the war, many of these immigrant workers who had enabled mining operations to continue during the war, were laid off, in order to vacate jobs for returning soldiers. "In the early months of 1919, the International Nickel Company dismissed 2,200 of their 3,200 employees, the vast majority of whom were foreigners" (Montreal Gazette, June 14, 1919, as cited by Avery, 1979). Of those workers laid off at the O'Donnell roast bed in early 1919, ninety-two percent were foreigners.

3.3.3. Why workers left employment at O'Donnell

Aside from being laid off, a large number of employees actually left. There were a variety of reasons documented for employees leaving O'Donnell, the most common reason was that they simply quit. Other reasons for employees leaving of their own accord identified on these employee cards were that there was too much smoke at O'Donnell, they didn't like the job, they left because of sickness, the wages were too small, the work was too heavy, they were simply unhappy, and the conditions at O'Donnell were "misrepresented" by placement agents. In addition, for one hundred and twenty employees no reasons were recorded by the employers, for leaving O'Donnell. Seventy eight of the total (15%) were laid off or fired, while 309 of the total (61%) left on their own accord (Figure 7).

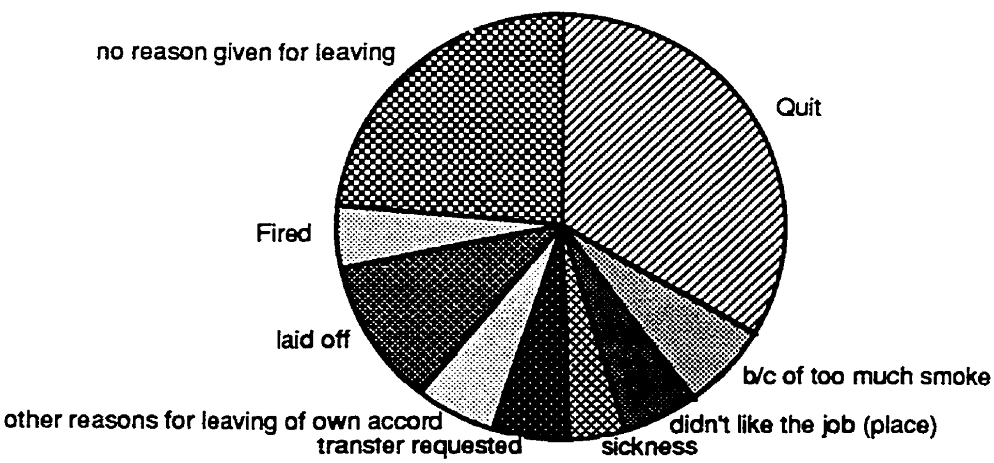

Figure 7. Reasons for leaving employment at O'Donnell, as recorded on INCO employee cards (1915-1930).

Sulphur smoke was simply accepted as one of the working conditions at the roast bed site. The Canadian Copper Company (later INCO) had control over the documentation of their employee cards. The company did not deny that workers quit because of "too much smoke", as they entered this reason on the employee cards themselves. Perhaps the company felt that this was more a reflection on the workers. For example, only those who were "strong, and made of the right stuff" endured the O'Donnell working conditions.

The length of time workers stayed at O'Donnell identified within the employee cards ranged from one day, to eleven years. Of those cards that identified both a starting and stopping date (406 in total), 63% worked for a month or less, 23% stayed longer than a month, but less than 6 months, 5 % stayed more than 6 mos., but less than a year, 5% more than one year, but less than two, and only 4 % stayed working at O'Donnell for more than 2 years. These percentages include both those workers quitting on their own accord, and also those fired/laid off. Most of the parents of the residents that were interviewed, worked at O'Donnell for the duration of its operation (1916-1930). Former O'Donnell residents interviewed lived at O'Donnell for 7-13 years. Eva Macdonald lived at O'Donnell from age 13 till age 20, at which time she moved to North Bay and shortly afterwards she was married. Another former resident lived at O'Donnell for 13 years and working at the roast yard was his first job. He left once O'Donnell was closed and the village was abandoned. Others attended high school in Sudbury, but continued to visit their parents at O'Donnell on weekends. Again, once it was closed most families moved to Copper Cliff (Bryson, 1995).

3.3.4 Working conditions at O'Donnell

The working conditions that have been previously described by A.P Coleman as a "choking environment" are reiterated by former O'Donnell residents. The sulphur smoke coming off the roast beds would have been very acidic, and in addition contained particulate heavy metals and other contaminants. One former employee describes how workers avoided the sulphur smoke while working on the roasting beds.

> The big bridge, it dumped the ore from special made cars. After it was roasted and it had cooled off enough, then they put the steam shovel into it. It was usually ahead of the beds that were firing, so they wouldn't be working in the smoke and that, unless the wind changed, or something like that. Usually, (the smoke) was behind us all the time, we'd be up ahead where the beds were cool and that, and the burning beds were behind us, but it was very seldom the wind was blowing towards where we were working on the shovel. (Anonymous, 1997)

3.4 Smoke quotes

When former O'Donnell residents were asked to describe the sulphur smoke coming off the roast beds, the following were their responses:

> It wasn't very pleasant to breathe, but you could get by. While as long as it was a job, you took what you got. If the sulphur smoke was blowing your way, they just did what they could and if you couldn't see, sometimes it would get real heavy you couldn't breathe, well they'd just lay back and wait. But they'd (the workers) stop when it got real heavy (Anonymous, 1997).

> In the winter time you know what we would have to do? We'd have to crawl on our hands and knees to go to school, because the sulphur smoke didn't come till about a foot from the snow, and we'd put our nose down there and crawl to school. We lived at one end of the street and the school was at the other end. We'd go past the club house and everything (Fox, 1997).

> We were downwind from it (the smoke) all the time, in the winter too. I can remember one day missing school. We lived maybe 50 or 60 yards from school, you think, well, you could do it with you eyes shut. But, I took the sidewalk around and I missed the turnoff to the school. The smoke was that thick. I walked there perpetually and sometimes, you just couldn't see. There were times when you had to hold a handkerchief over your face, that didn't happen very often. You could taste it (the sulphur) all right. The sulphur was bright yellow coming off the roast beds, it was a dense, yellow sulphur fog, as it goes across the country side it loses the yellow and it's only white when it gets to the village (Bryson, 1995).

Eva Macdonald, who was 13 years old when her family moved to O'Donnell describes the sulphur smoke as:

> Thick like a fog, couldn't see your hand in front of your face. No one was ever sick. There were no bugs. The school house wasn't open in the "fog" because the kids couldn't crawl like the men, they had to feel their way (Macdonald, 1995).

> Ore spread and then they'd light it and that made the sulphur smoke. Choke us to death. That's why I'm healthy I was brought up in a place where it killed germs. You couldn't see your hand in front of you. My dad used to go to work in the morning, you will never believe this, you think I'm not telling the truth, he'd have to lie down on the sidewalk for a few minutes to catch his breath to walk another few minutes,

> to go to work. All the men. It would just be like, oh golly. Inside you were fine, it was outside where there was thick smoke spread. That wasn't every day. No, a dull day like today, you'd have sulphur smoke. They had sulphur smoke, not every day, but particularly on dull days. Every weekend, we would have it (sulphur smoke) once or twice. Their nose would bleed every day. We were the healthiest gang that ever lived. It killed the germs (Macdonald, 1995).

Carman Fielding who visited his brother Frank Fielding who worked as a labourer at the O'Donnell roast bed, relayed a story to me, told to him by his brother Frank:

> A teacher came to O'Donnell and was staying at the boarding house and asked "Why are these storm windows on in the middle of summer?" Well he (Frank) said, "if the wind blows, to keep the sulphur smoke out". He (the teacher) said "I never heard of such a thing and I'm gonna get them windows taken off, can't stand windows in the summer". So, in the meantime, about 12 o'clock or 1 o'clock in the morning the wind swung around, and the teacher started to cough and bark because the smoke was coming in. Frank went over and said "I told ya" he said "we should have them windows on there" he's says "you gotta suffer now", he says, "stay with it". The windows were put back on in the morning, they didn't bother taking the windows off in the summer anymore, cause the sulphur was so "intense" I guess you'd say.
>
> Then he (Frank) tells another story, they'd go in late fall down to Creighton to play hockey and my brother Frank said that he had to stay on the side of the road to guide the car, it was a narrow road to start with, but the smoke was so intense that he couldn't see the road so he'd say "get over to the right, or a little to the left" till they got to Creighton Mine. That's where they ended up playing but as soon as the wind was against you, it got quite severe, quite heavy, you could hardly see through it. But the wind would change and they'd have better days I suppose. (Fielding, 1997). [Note: Creighton is approximately 7 km from the O'Donnell roast bed].

Camile Lafrombois recalls what the sulphur smoke was like when he and his family lived near the O'Donnell roast bed in an old railway box car.

> You'd see the guy there, he didn't last very long, he didn't live very long, he died pretty young, he was right on top of the ore, the shovel would take the ore and dump it on the top eh, and the gas, oh, the gas was so strong there that, when the wind blew from the south, we all had to get into the room and shut all the windows and the door and my mother would make beds out of blankets, you know, hung all around the bed, because, when the wind turned the other

> way, it was beautiful. But the south, when it came from the south, that was it (Lafrombois, 1997).

The smoky environment at O'Donnell was described as unpleasant, but tolerable. The smoke was not constantly inundating O'Donnell, so residents just "put up with it, because it was part of the job". All of the former O'Donnell residents speak fondly of their times at O'Donnell, and sulphur smoke was just part of the place, as was the lack of trees, and any other type of vegetation.

3.5 Health impacts from roasting process:

Direct health impacts of the roasting process at O'Donnell are impossible to define, as with the description of any health impact. There are also many additional uncontrollable factors, such as diet, habits (such as smoking cigarettes), economic status, genetic predisposition, individual sensitivities, etc. It has been estimated that there were substantial quantities of sulphur dioxide emitted from the roasting beds, and this in turn would have a direct impact on the more sensitive individuals (both plants and people) at O'Donnell and the surrounding area. For example, severe bronchospasm can be induced in sensitive individuals by exposure to 5 ppm of sulphur dioxide (Amdur, 1975). At O'Donnell, this level of exposure would have been reached on a frequent basis. For workers at the roast yard, this spasm trigger of several ppm would occur each time they were downwind of the fired heaps. Amdur (1975) argues that industrial exposure of sensitive individuals to sulphur dioxide would not be a problem due to "self selection" by the individual avoiding such working environments. Perhaps this sensitivity is somewhat reflected in the number of employees leaving O'Donnell due to these smoky conditions. The World Health Organization has set a human health based limit for sulphur dioxide exposure of 350 ug/m^3. The effect of sulphur dioxide on plants has already been well established. Ironically, in Norway, the tolerance level for sulphur dioxide is set much lower for the environment (25 ug/m^3), than it is for humans (Norseth, 1992).

Many of the former O'Donnell residents interviewed felt that the smoky environment was actually beneficial to their health. Eva Macdonald at 95 years of age: "That's why I'm healthy, I was brought up in a place where it killed germs". Evelyn Fox states that "nobody had the flu". These beliefs, that sulphur smoke was a blessing, was also shared by other communities. For example, in the United States, at Butte Montana, it was believed that "La Grippe", (flu) was raging in Butte, in a much milder form than elsewhere because of the beneficial effects of sulphur smoke. "It is the opinion of physicians that the sulphur smoke which permeates everywhere had a discouraging effect upon the microbe and causes it to relax its grip". When Butte was considered for becoming the capital, the following argument was put forth.

> I say it would be a great deal better for other cities in the territory if they had more smoke and less diphtheria and other diseases. It has been believed by all the physicians of Butte that the smoke that sometimes prevails there is a disinfectant, and destroys the microbes that constitute the germs of disease....it would be a great advantage for other cities, as I have said to have a little more smoke and business activity and less disease (Clark, as cited by Smith, 1987).

Continuing, this smoke advocate added, that the ladies were "very fond" of Butte "because there is just enough arsenic there to give them a beautiful complexion and that is the reason the ladies of Butte are renowned wherever they go for their beautiful complexions" (Clark, as cited by Smith, 1987).

Others, thought the sulphur smoke may cause some unwanted health impacts, but most of the former O'Donnell residents that have been interviewed saw no harm in the sulphur smoke. "A lot of people, they'd say "it'll [the sulphur smoke] kill you!" I'm still living, and I'm 84 years old. So, I don't know who it killed" (Anonymous, 1997). Maude O'Malley believes that since they all lived "at O'Donnell, that's why we're living so old, because of the sulphur smoke".

Other former residents described the impact of the sulphur smoke on their breathing, as well as their eyes, but none of the residents objected to the presence of the smoke. "Oh, yeah, you'd cough, but that's about all, not too much" (Lalonde, 1997). Loretta McPhail describes the smoke at O'Donnell as the following. "Sulphur smoke, oh remember getting up in the morning and you couldn't see. And it smelt so bad. Strong, you know. Your eyes would water and your nose. But, then you'd get so used to it".

All of the former O'Donnell residents were asked if their noses bled often during their time at O'Donnell since Eva Macdonald spoke of many workers experiencing daily nose bleeds (Macdonald, 1995). Loretta McPhail's response to nose bleeds was the following.

> No, my dad's did though, because he worked right there. He used to come home and his nose was all black and his tongue was black, and he spit up a lot of black stuff. It never hurt him, he died at 93, [he was] never sick, and my mother was the same, never sick. [They were] never in the hospital, no. It was just hard on your nose, and it made you cough. Some of them (workers) got sick. I often wonder if that was what was wrong with Evelyn (Fox), (since) her eyes used to be so sore all the time. She had glasses when she was very young. Her eyes bothered her (McPhail, 1997).

Evelyn Fox is convinced "that's why I've got asthma, I got asthma from the sulphur smoke". Camile Lafrombois responded with "oh, ya, you [would] get a headache you know and your eyes [would] water".

Camile Lafrombois recalls how they helped their horses when the sulphur smoke was "heavy". "They had a canvas bag and you'd put oats in the bag for the horse to feed, well they would just wear that on the horse so their nose wouldn't bleed eh, when the gas (sulphur smoke) was bad". Coping with the smoke at O'Donnell included avoidance, covering the face, closing windows, hanging blankets and other home remedies as described by Evelyn Fox (nee Germa):

> My mother used to keep saucers of liquid ammonia to get the sulphur smoke out of the house. Out of the reach of children. She get rid of the fumes inside the house. She kept the saucers up on top of the buffet. They had to do that. It would be heavy, and that, [but] that was our livelihood, so [we] had to put up with it (Fox, 1997).

According to Thomas (1965), sulphuric acid is partly or completely neutralized by available bases, including ammonia.

The potential health impact of smelter smoke was identified as early as 1915 when air was deemed "unbreatheable" if it contained 70 ppm SO_2. It was viewed that although these levels did not have "a toxic effect", they did cause "a spasmodic contraction of the air cells of the lungs" (Fulton, 1915). Fulton (1915) noted disagreement among authorities, some of which felt these high levels of SO_2 were distinctly harmful, while others argued that "although its (air containing 70 ppm of SO_2) effect is highly disagreeable, and of course not beneficial, the harm done by it is not serious". It was added that visitors found this type of atmosphere "practically unbearable", while workers accustomed to this atmosphere did not "seem to suffer permanent harm from their contact with the gas" (Fulton, 1915).

Beyond the health impacts of the huge amount of sulphur dioxide emitted from the roasting process, O'Donnell residents and particularly workers, would have been exposed to substantial levels of particulate heavy metals in the air. Nickel was first indicated as a causative agent in lung and nasal cancer in nickel refinery workers in Clydach, South Wales. The rate of lung cancer in these workers was 16 times greater than in the general population of England and Wales (Shannon *et al* 1984 as cited by Christie and Katsifis, 1990). The increase in the rate of nasal cancer was even more striking because this is a very rare type of cancer. An excess risk of lung and nasal cancer has also been found in the nickel refinery workers in Ontario, Canada, and Kristiansand, Norway. In the Norwegian study of 3232 refinery workers, the incidence of cases of lung cancer was seven times higher than expected while the incidence of nasal cancer was forty times higher than expected (Pedersen, et al, 1973 as cited by Christie and Katsifis, 1990). Areas surrounding nickel smelters at the Kola peninsula, (Norwegian/Russian border) have experienced significant sulphur dioxide and heavy metal contamination since 1932. At the Zapoljarnij plant in Russia they use a drying process that is operated similarly to that of the historical O'Donnell open roasting process, which causes heavy pollution. It has been estimated that exposure to nickel in the working environment of the roasting departments were regularly between 12mg/m^3 and 20 mg/m^3, but occasionally were more than 10 times these levels (Norseth, 1992). Increased mortality due to cardiovascular disease and cancer have been recorded in two smelter cities in Russia, when compared with a non nickel smelter city (Norseth, 1992). This documentation of nickel as a human carcinogen was very strong and left little doubt as to the relationship between occupational exposure to nickel and an increased incidence of lung and nasal cancer (Christie and Katsifis, 1990).

Higher dietary intake of nickel was found in the Sudbury region in 1975. McIlveen and Balsillie 1977 as cited by Cecutti and Nieboer, 1981, found edible portions of bean, radish and lettuce grown in the immediate vicinity of Sudbury were found to contain on the average, 9, 5, and 3 times, respectively, more nickel than control samples grown 50 km south east of Sudbury. High levels (approximately 300 ug/L) of nickel were also found in the drinking water of the Sudbury region (Flora and Nieboer 1980, as cited by Cecutti and Nieboer, 1981) when compared to levels of 5 ug/L in other U.S. and Canadian cities (Sunderman *et al*, 1975 as cited by Cecutti and Nieboer, 1981). In 1981, it was determined that on average a resident of Sudbury consumed an average of 1850 ug Ni/day, compared with 420 ug for someone from the Winnipeg area (Cecutti and Nieboer, 1981). During the time of O'Donnell's operation, most of the vegetables came from Creighton and would have contained elevated levels of nickel, as reflected in the soil chemistry for Creighton documented in Chapter 4.

3.6 Environmental descriptions of area surrounding O'Donnell:

The environment surrounding the O'Donnell roast bed was devastated, both by the cutting of the huge amount of wood used to fuel the roasting process, as well as the impact of the sulphur on the surrounding vegetation. When former O'Donnell residents were asked what they remembered about the vegetation surrounding O'Donnell, I received the following responses:

> There wasn't any. It wasn't hard to figure that one out. The sulphur smoke killed pretty near everything. There were no flies or mosquitoes in my day, not up there. That sulphur smoke chased them fellas away. [You didn't have any mosquitoes and black flies?] Not that I can remember that much, we might have had a certain day, depending on the wind, how it carried the smoke, the sulphur smoke. We didn't have any gardens are anything like that, no you couldn't grow anything. The trees and that were all cut down, they used it for fire wood. There wasn't any to talk about. Actually we used to call them the "stump dodgers" playing hockey and that, all the trees and that, they had died from the smoke. We had sidewalks all around (Anonymous, 1997).

"There wasn't a blade of grass around anywhere. Not a tree, not a blade of grass. We were there about 20 years ago and it's all grown up, the only way you could find it, was the water pipe, from our house and basements from the three houses with a cement basement" (Fox, 1997).

> It was 5 to 6 miles all the way down from Creighton, all the way down to Crean Hill, that would be 5 or 6 miles, and all around, everything died. There wasn't a tree, there wasn't a grass or nothing there. Everything just burnt to a crisp. Then after about 5 or 6 years after they shut down, then it started growing. You can't believe how big the trees are there now, already there. That's 50, 60 years ago. It was 5 or 6 years before the grass and the trees started growing, small trees. There was nothing there for a long time, nothing for the moose to eat, now they have quite a bit of grass and stuff to eat (Lafrombois, 1997).

> It's a miracle that anything can grow there after all of the sulphur smoke. I planted potatoes in between the houses and they came up so nice, and the sulphur come and they were gone. I was surprised myself, after being there for years and going back I couldn't believe that there were trees and grass, snakes and bears. It's wonderful. The housing was good, I think they were well looked after, we had all our good water and all the ice we wanted. It was all free. The only thing we couldn't have was a garden (McPhail, 1997).

> There was nothing. We went down to the little creek and my dad would say "you can eat these" and he used to call them pomme de terre. Do you remember that? Yeah. We used to dig those near the creek, and they never killed us. No, they were good. I think the Denomees ate them all (O'Malley, 1997).

> [For a] 3 mile radius from the O'Donnell [roast bed, there was] no vegetation. Cherry trees were the first to come up

> from the seeds of eating cherries. [There was] not a blade of grass. If you brought a plant to your house it would get killed from the sulphur smoke. You couldn't keep any greens, it was absolutely barren (Macdonald, 1995).

As a result of the sulphur smoke, there was no possibility of growing vegetables, nor having house plants of any kind. Most of the O'Donnell residents do however, remember having pets in the form of dogs, cats, pigeons and a ground hog.

> The only pet we had was a ground hog. Dad brought him home one day, and we made a pet out of him. Usually, they're supposed to go away in the winter, hibernating, and he made a house under our sink, we had taps but we didn't have anything, no sink or anything, so he made his bed there and stayed all winter. We fed him tomatoes (McPhail, 1997).

The amount of ore roasted and it's impact on its surrounding environment was extensive. With the initial operation at O'Donnell in 1916 there were over 200 workers. 250, 000 tons of ore roasting on its heaps at one time. The process reduced the sulphur from over 60 per cent of its ore down to a sulphur content of 10 to 12 per cent (RONC, 1917). With the building of the ore "bridge" in 1919, even more ore was roasted at one time. This mechanization also had an impact on the social environment of O'Donnell with the work force being substantially reduced, as well as the physical environment, with the amount of ore being roasted increasing dramatically, resulting in a pronounced increase in sulphur fume emissions.

3.7 Examples of similar "roasting damage" in United States:

Haywood (1907) reported on the injury to the vegetation in the region surrounding the copper smelter areas of Redding California, Ducktown Tennessee and Anaconda Montana. Though well aware of the presence of toxic metals in the air and soil, he states that, since the complaints only concerned sulfur dioxide, that is what he studied. At Copper Hill, Tennessee, 17,000 acres were completely devastated. Beyond this zone of devastation, species diversity gradually increased with distance, radiating outwards from the smelters. Damage was greatest on uplands and on slopes facing the smelter (Hutchinson, 1979). Haywood (1907) noted, but did not report on the probability of contaminants such as arsenic, copper, and antimony being emitted and, in turn, contaminating the soil at Ducktown, Tennessee. Thomas (1965) described the impact of open roasting in Ducktown, Tennessee, during the early days of the industry (before 1905). "The sulphur burned off in a concentrated low-lying smoke, which moved with the wind close to the ground over the surrounding country, killing all the vegetation, sometimes for several miles. Erosion of topsoil followed the death of the plants". Fifty years later, there was no evidence of recovery within a five mile radius surrounding this roasting site, in spite of re-plantations by the Government in the 1930's (Thomas, 1965).

The early days of copper smelting in Montana were described by Hartman 1976, as cited by Hutchinson 1979.

> During the early years of copper mining in Butte, the ore was hauled by wagon to Corinne, Utah. From there the ore was shipped to the east coast be rail and on to the smelters at Swansea, Wales. Between 1875 and 1881 many new silver and copper mines began operation in the Butte area. Hauling ore was laborious and expensive. Because of the increased mining, several smelters and concentration plants were established as early as 1886. The smelting process involved the roasting of ore in heaps of open piles. The heap roasting was cheap and reasonably efficient. Large lumps of almost pure sulphide ore were intermixed with layers of logs. The size of the heaps varied, being as long as a city block, as wide as a city street and as high as a man. They were ignited and a slow burning process was begun which removed all but 8% of the sulphur of the ore. Burning lasted for 2-3 weeks, releasing continuous clouds of smoke and fumes.

Taskey, 1972 (as cited by Hutchinson 1979) quotes Davis (1921), who also visited Butte Montana during this period of open roasting:

> We watched a game of faro for a few moments, and then passed on to the barren stretch that led to Butte. What seemed to be a low-hanging cloud hid the camp from view. Only a few mine shacks on the brow of the hill could be seen. Not far along towards the city, ore was being roasted outside in the grounds of the reduction works, the fumes rising in clouds of cobalt blue, fading into gray, as it settled over the town like a pall. Indians called the dumps of ore "stinking piles."
>
> The driver reined his horses as we entered the cloud of stifling sulphur and cautiously guided them up the hill. A policeman, with a sponge over his mouth and nose, to protect him from the fumes, led us to a little hotel in Broadway, for we could not see across the street. Lanterns and torches were carried by some to light the way through the sulphur cloud. (Hartman 1976, as cited by Hutchinson, 1979).

Clearly open roasting in the United States and at Sudbury produced extreme conditions of air pollution. The colour of the smoke indicates sulphur and heavy metal particulates, both having considerable human and environmental health consequences.

3.8 The Community of O'Donnell:

The town of O'Donnell was built by the Canadian Copper Company, for the sole purpose of housing the roast bed workers and their families. It was located along the Algoma Eastern Railway line, approximately 3 miles east of the Vermilion River, and one mile east (downwind) of the O'Donnell Roast Bed (see Figure 3, and Plate 6). The population of O'Donnell was over 200 in the early days of its operation. The four streets were named, Ellis, Vermilion, Foley, and Savage (Figure 8).

O'Donnell originally had a store, post office, jailhouse, club house, boarding houses, and school house in addition to the family dwellings. There was a constable working at O'Donnell from 1915 to 1920 when he was laid off. With the drastic reduction in number of employees, due to the mechanization of the roast bed in 1919, there was no longer a need for the jailhouse to continue to operate (Anonymous, 1997).

The life of the children revolved around the school house, where only English was taught and spoken (Plates 12, 13, 14, 15). Each of the former O'Donnell residents fondly remembers his or her time spent in the one-room school house where they attended until senior fourth (grade 8) before trying their entrance exams in Sudbury and many of them (particularly the boys) then going on to high school there (Plate 18). All grades were taught in the same room, around the large wood stove located in the center of the room. Maude O'Malley fondly remembers reading every book in the school library. Teachers, both male and female, were at O'Donnell for 2 year placements and were all unmarried at that time. Many of the teachers participated in sporting activities, such as hockey, with the children. There was a centrally located skating rink which was very active during the winter months, used by both adults and children (Plates 20 and 22). They also skated on a frozen creek, just to the east of the village. Loretta McPhail remembers skating on the ice over the creek, while watching the running water beneath the ice. The landscape surrounding O'Donnell was such that there were many hills, with no trees, only stumps that had to be avoided during tobogganing (Plate 26). When there was a lot of snow the stumps would be covered, making tobogganing popular in winter. Each Christmas was celebrated at school with a Christmas concert, with the whole village in attendance.

Figure 8. Map of the O'Donnell Townsite. Compare with Plate 6 for location with respect to the roast bed. Courtesy of INCO archives.

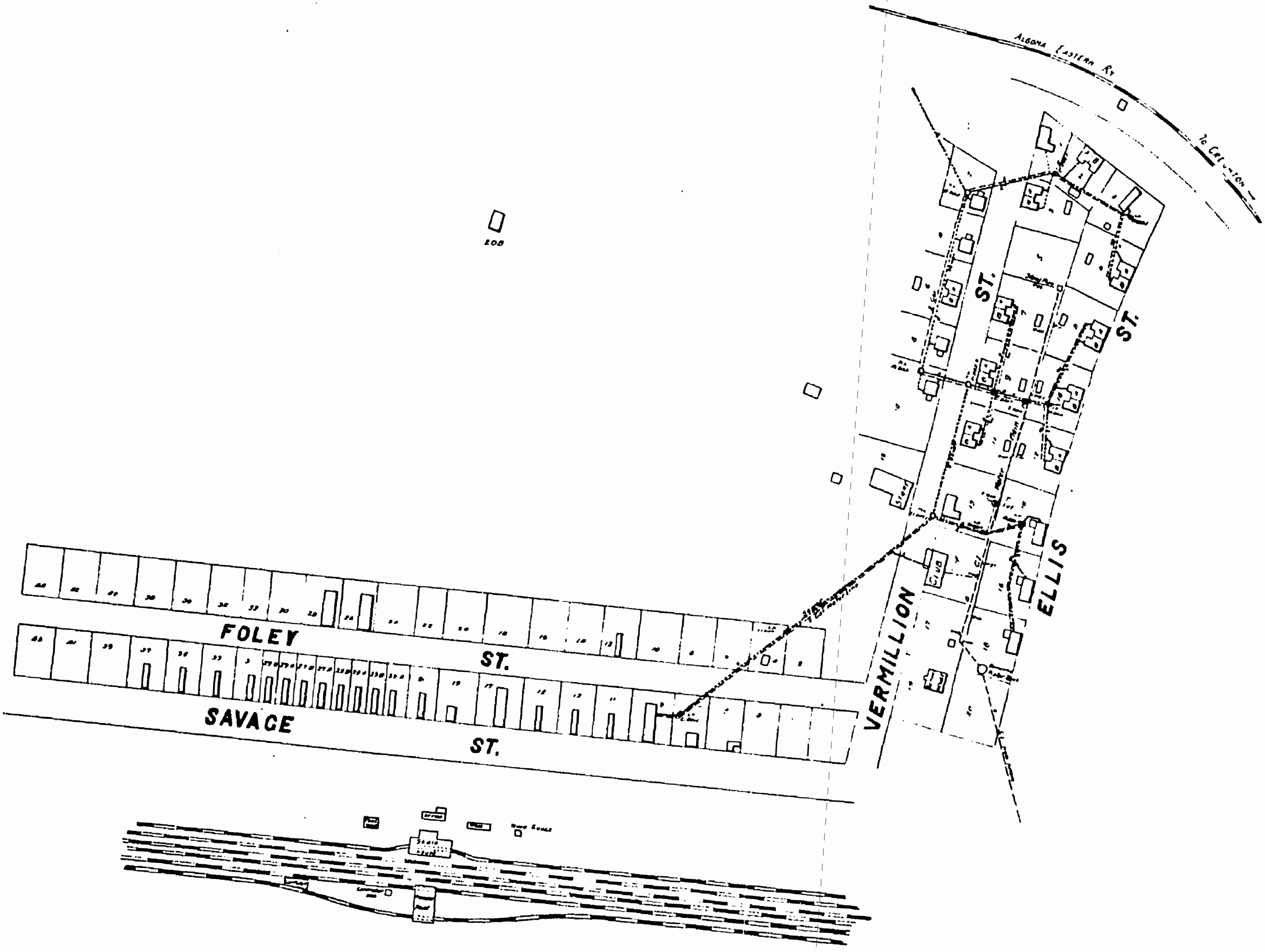
FOLEY ST.
SAVAGE ST.
VERMILLION
ELLIS ST.
ST.
Algoma Eastern Ry
To Creighton

Figure 8.

Plate 12. Young class in front of O'Donnell school house, approximately 1918 Courtesy of Bill McKinnen.

Plate 13. O'Donnell school house, and students - O'Donnell. Courtesy of Bob Bryson.

Plate 14. Children at O'Donnell with school teacher Harry Cooper. Courtesy of Bob Bryson.

Plate 15. Students and teacher (Harry Cooper) sitting on sidewalk with school house in background. Courtesy of Bob Bryson.


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Plate 16. Junior fourth class (1928) Front left - clockwise: Lola Germa, Evelyn Hildebrant, Andy Bryson, Unknown, and Joyce Bray. Courtesy of Bob Bryson.

Plate 17. Small children in front of school house (1920). Notice British flag.

Plate 18. O'Donnell: Senior fourth class (1928) Front left - clockwise: Maude O'Malley (nee Denomme), Leo Lalonde, Bob Bryson, and Evelyn Fox (nee Germa) Courtesy of Bob Bryson.

Plate 19. Children in front of building, some on bicycles. Courtesy of Bob Bryson.


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Plate 20. Hockey players and dog on ice rink at O'Donnell. Courtesy of Loretta McPhail.

Plate 21. Workers fishing at the Vermilion River, just a next to the O'Donnell roast bed. Notice the condition of the birch trees in the background. (Left to right: George Hamilton, Orval Dunsmore, and Gordon Coeff). Courtesy of Loretta McPhail.

Plate 22. Women at O'Donnell trying their hand at hockey. Courtesy of Bob Bryson.

Plate 23. Baseball players at O'Donnell (Lalonde family). Courtesy of Bob Bryson.


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Plate 24. Loretta McPhail and Eddie Lalonde. Notice lack of vegetation in background. Courtesy of Loretta McPhail.

Plate 25. Pet pigeons at O'Donnell with a young Bob Bryson. Courtesy of Bob Bryson.

Plate 26. Eva Macdonald and friend. Notice lack of vegetation (stumps) in background. Courtesy of Maude O'Malley.

Plate 27. George Dunsmore ran the boarding house at O'Donnell, here he is with Don Bray, modeling a "hat exchange" in front of the boarding house on the Dunsmore vehicle. Courtesy of Loretta McPhail.

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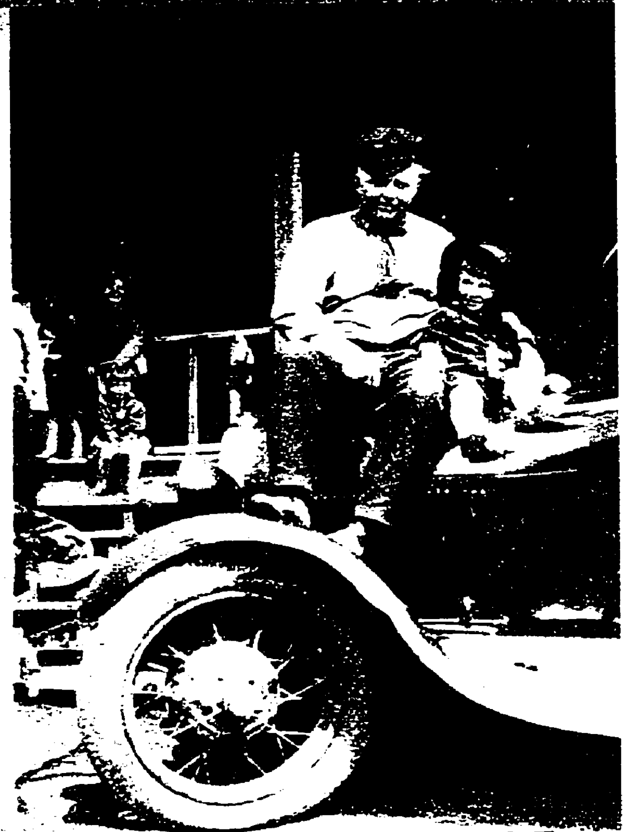

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In the summer the skating/hockey rink would be converted into a baseball field, with the boys and girls all playing together. Swimming, both in the creek and at the Vermilion River were also favourite summer activities (Plate 21 and Plate 23).

The Sudbury region's acidic soils are well known for their growth of blueberries. O'Donnell residents had to walk miles, to the western side of the Vermilion River to have access to these berries. Blueberry picking was an activity in which every child at O'Donnell participated. The mothers would make pies and some O'Donnell residents would make wine, not only from blueberries, but choke cherries as well (Lawrence Lalonde, 1997).

The centrally located club house provided a space for dances, which were held every two weeks, on Friday night, in addition to being a boarding house for 12 single, English speaking men. The men would pay for the three man orchestra to come from Creighton and the women would provide the "lunch" (Macdonald, 1995). The store/post office was operated by George Dunsmore. Former O'Donnell residents Eva Macdonald and Maude O'Malley both have fond memories of their time spent working for him (Plate 27).

> Well, I worked for Mr. Dunsmore for 10 years. I was still at school and he went to my dad one day, and I was short and tiny, there was nothing to me those days, he went to my dad and said "once Eva graduates to entrance class, is she going to go to high school?" My dad said "I'm sorry, but we can't afford to send our kids from here to board in Sudbury, 15 miles out, and pay their own way and all that, he said, no she won't be going to no high school she'll have to educate herself some other way" So he said "well, she's going to work for me". "Oh" he said, "no she's not, she's too tiny and we need her at home" But Mr. Dunsmore won. The day I quit school, he put me in the store and there was a Post office (Macdonald, 1995).

Many workers would send money orders home to their families in other countries and if Eva Macdonald didn't know how to spell the address she would ask the workers if they minded her giving them the receipt after work and would then look up the correct spelling in the dictionary.

> Did I ever educate myself. There was all nations and they'd come and they'd send money orders home. "Do you mind if I give you the receipt at noon". They always came and bought their tobacco and whatever they needed before they went to work. They'd say "oh no". Cause I couldn't spell the word that they were giving me and I wanted to look up in the dictionary. Money orders, you can't make mistakes. They'd send hundreds of dollars. And they trusted me. I'm a good writer. When you get older you lose memory, but I

> don't. I'm getting wiser and wiser everyday (Macdonald, 1995).

Eva Macdonald would open the store in the morning for the men to get their cigarettes, before work and she would then close it during the day while the men were at work.

> The men would all go to work, they couldn't buy all day. Then the women at home would have from 4 p.m. till as late as they wanted to buy for their supper. I'd open the store just around 4 p.m. So the store would be closed all day, so to pass the time I would go to the Club house and do all the ironing. I'd iron the sheets, pillow cases. Had to do something to earn your money, $25/month and board and room, it was big wages those days. When I quit [to get married] I earned $45/month. I left when it closed (Macdonald, 1995).

After the final closure of the store at O'Donnell, groceries were brought by Sam Ferra, from Creighton twice per week (Plate 28).

Maude O'Malley's duties at the club house included looking after the youngest Dunsmore child, Evelyn. Even after O'Donnell closed, Maude went to Copper Cliff and continued to live with the Dunsmores (Plate 30). O'Donnell had additional large boarding houses which also housed single men. Eva Macdonald (1995) remembers that each boarding house had a ethnic group. For example all of the Italian workers lived in one, all of the Finnish workers in another and so on. Workers that spoke the same language would not only live together in these boarding houses, but would also work on the same crew. Although not directly reflected in the number of employee cards documented in this thesis, perhaps those workers who benefited from this type of fellowship chose to stay working O'Donnell for a longer period of time than those without this type of community bond.

The map of the town of O'Donnell (Figure 8) shows a butcher shop, a "dry" where men would shower after work, a jail house, ten larger single family dwellings, another 10 houses divided into two separate dwellings, and 17 old railway box cars that were used as houses. All of these buildings were rented to O'Donnell employees. The rent for a family would typically range from $2.00 to $9.00 per month. Bill McKinnen's Finnish relatives lived in a box car, and paid a monthly rent of $2.00. These box cars were located closer to the roasting process than the rest of the town and today the indentations are still present in the ground where the box cars were placed. Of the former O'Donnell residents I've spoken to, few of them remember those who lived in the box cars. Evelyn Fox (nee Germa) 1997 remembers going to give English lessons to a Ukrainian women, living in one of the box cars, who had married an employee of the O'Donnell roast bed. Housing areas were

Plate 28. Johnny Zanier delivery wagon similar to the one used at O'Donnell. Courtesy of Tom Davies.

Plate 29. The Bryson Family on the steps of their house at O'Donnell. Courtesy of Bob Bryson.

28

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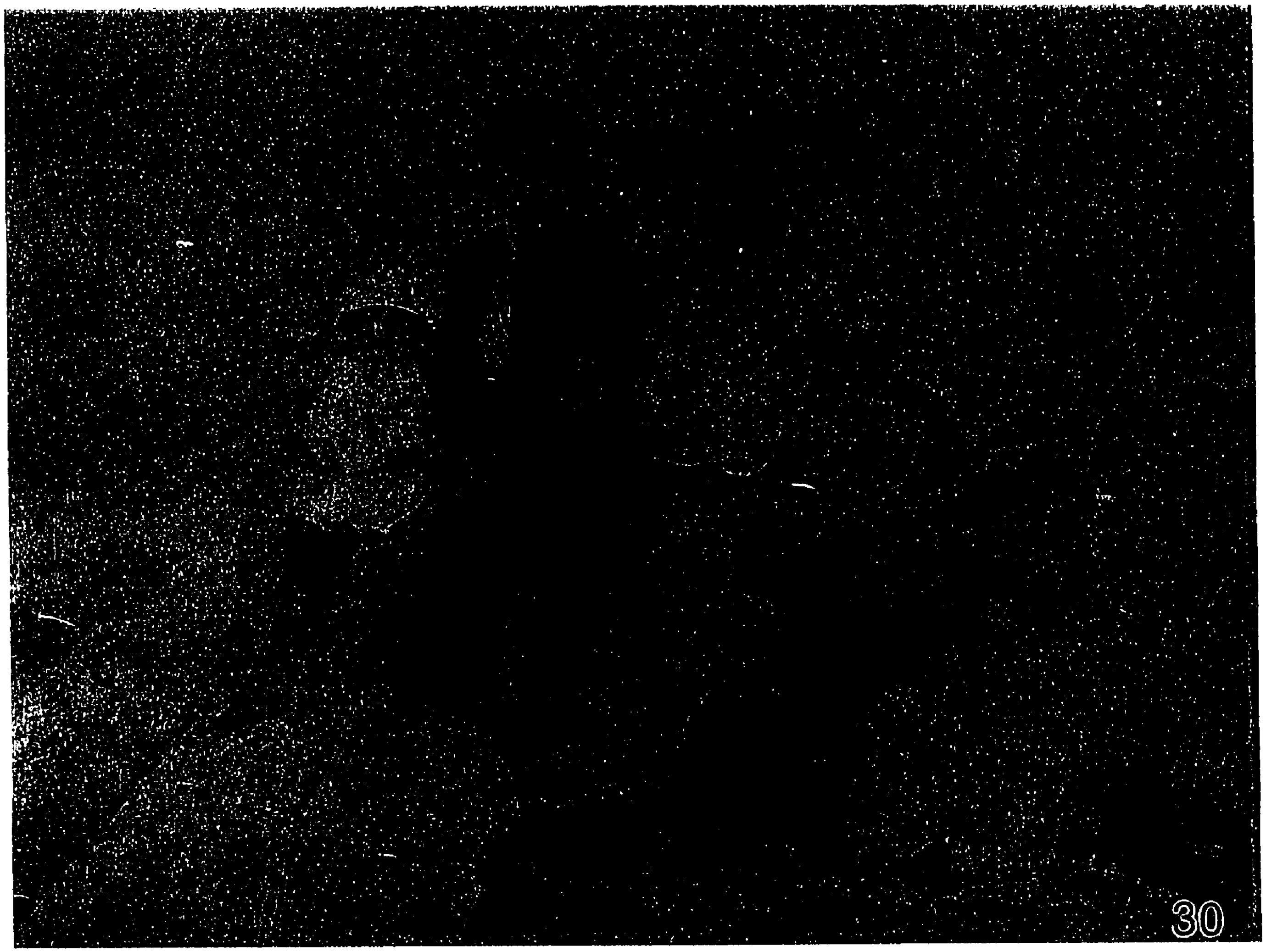
Plate 30. Maude O'Malley with her sister, mother and father. Maude is the youngest. This picture was taken on the rock just in front of their house at O'Donnell. Courtesy of Maude O'Malley.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differentiated both economically and socially. At O'Donnell, the supervisors were provided with large, cement foundation dwellings, while the immigrant workers were housed in "renovated" box cars (Plates 31, 32, 33 and 34). This type of segregation was common in early mining communities (Alanen, 1979; Goltz, 1989). Another example that all workers may not have been treated equally, or simply a difference in economic status is demonstrated by one former O'Donnell resident recalling that coal was provided for domestic use, while another remembers that she and her siblings stole coal from the coal pile, to bring home for her parents to use.

Former O'Donnell residents describe the local community that existed as being one big family where everyone got along and they functioned as a unit. However, the language barriers many of the workers and their children would have experienced must have put a strain on close interaction. Many times former residents talk of "everyone" coming to a function such as the dances (Eva Macdonald) and the school concerts (Maude O'Malley, Bob Bryson) but when asked if the people who lived in the box cars attended the response was "Oh, no, not them, we didn't have much to do with those people" (Macdonald, 1997). Eva Macdonald attributed this to the fact that they didn't speak the same language and that "they (the immigrants) did their own thing". Even though her family only spoke French at home, they didn't seem to have the same problems with speaking English.

The townsite was laid out, as many mining communities were at that time, in an organized standardized fashion (Alanen, 1979). It was located next to the railway, within walking distance of the roast yard, but far enough away to enable blasting to take place at the roast yard, without injury to O'Donnell residents (Bryson, 1995). As a former O'Donnell resident mentioned "the location of the roast yard was most important, the location of the community was secondary". If the townsite had been located on the other side of the Vermilion River, at equal distance, the residents would have had many fewer sulphur smoke fumigations.

As a teenager at O'Donnell, Loretta McPhail sold a prize winning number of greeting cards and won a camera for her efforts. This camera proved valuable in recording history at O'Donnell.

> You know, I don't even remember how come I started selling Christmas cards. I don't remember that at all. I must have gotten the name from somewhere and sent away. They used to send them to me all the time, I didn't order them, they used to send me all the time. I'd send the money back, and I got that camera as a gift. I was so pleased with that camera (McPhail, 1997).

Plate 31. Eddie Lalonde on steps with boss Richardson's house in the background Courtesy of Loretta McPhail.

Plate 32. Loretta McPhail as a young girl on the O'Donnell sidewalk. Notice the row of buildings in the background. Courtesy of Loretta McPhail.

Plate 33. Loretta McPhail when she lived at O'Donnell. Notice the size of building in the background. Compare this size of building to that found in Plate 31. Courtesy of Loretta McPhail.

Plate 34. Blanche Hamilton on sidewalk at O'Donnell. Notice lack of vegetation, and sidewalks joining the houses. Courtesy of Loretta McPhail.


31


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Plate 35. O'Donnell roast bed workers on their way to work. Left: Sandy Butler, and right: George Mapes. Courtesy of Loretta McPhail.

Plate 36. Children at O'Donnell. Courtesy of Bob Bryson.

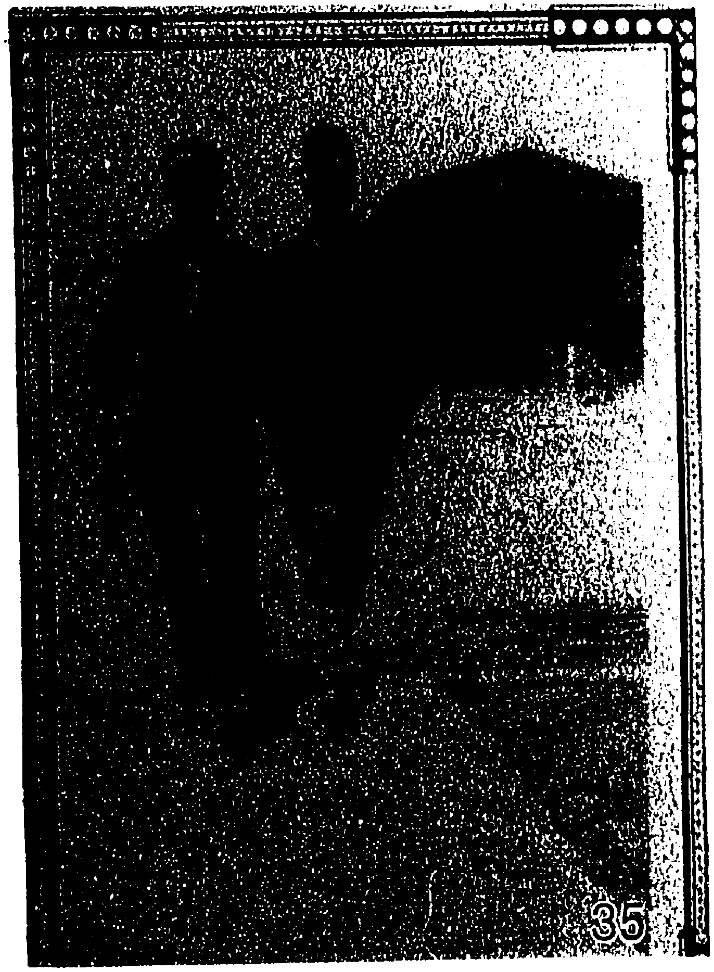

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Plate 37. Aerial view showing vegetational recovery surrounding the O'Donnell roast bed, 1979.

Plate 38. Ground View of O'Donnell, 1995 (Symington Sager)

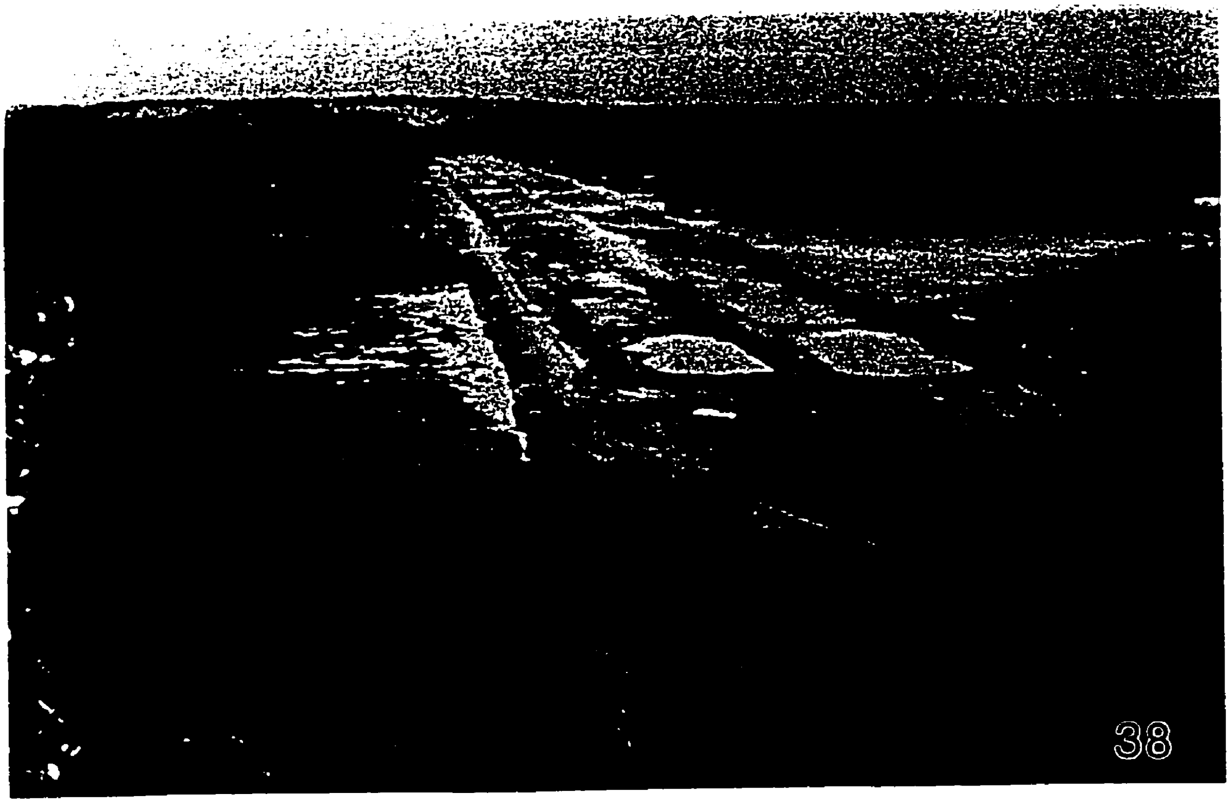
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Plate 39. Aerial view of recovery surrounding the O'Donnell roast bed, 1979.

Plate 40. Bob Bryson with remnant house foundations at the O'Donnell townsite, 1979. Very few houses had these foundations, most houses had wooden post foundations (INCO).

Plate 41. O'Donnell townsite club house remnants, 1997 (Symington Sager).

Plate 42. O'Donnell townsite school house remnants, 1997 (Symington Sager).


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Loretta's pictures of the O'Donnell town site show the type of buildings, the sidewalks and the lack of vegetation in the surrounding area (Plates 21, 24, 25, 26, 27, 31, 32, 33, 34 and 35). With this lack of vegetation, there was nothing to hold the clay-like soil together and it would literally turn into quick sand with any rain fall (Bryson, 1996). Within the town itself, an extensive system of wooden sidewalks connected all of the buildings and streets.

The mining company exerted "control" over their workers through housing, employment and patronage as shown by the following Copper Cliff example.

> A.P. Turner, president of the Canadian Copper Company, in 1902, was determined to gain complete control of the town of Copper Cliff, and following the introduction in 1903, of more stringent land leases, he openly used the threats of dismissal, eviction, and lease cancellation to control town inhabitants, who firmly believed that even voicing political views contrary to those held by the company would result in either or both penalties being applied. (Town of Copper Cliff, Council Minutes, 1905 as cited by Goltz, 1989).
>
> Wielding lease cancellation and dismissal from employment as weapons, Turner destroyed the mayor's retail business in 1905, eliminated him from the CCC workforce, halted his career in municipal politics, and insured that the town council become and remain a company agent. The mayor, a dry goods merchant and smelter foreman, had successfully opposed a company candidate for the mayoralty, and in retaliation, Turner had withdrawn company patronage from the mayor's store, dismissed him from his smelter position, canceled his land ease, and given him four months to leave town. As a non-resident, the merchant could not retain his municipal office (Goltz, 1989).

Carman Fielding remembers his father seeking compensation for crop damage in 1916. The first question INCO officials would ask his father George Fielding, was "how many sons do you have working for us?" Here, again, they attempted to control sulphur damage complaints with the implicit threat of his sons' dismissal from employment.

Former O'Donnell residents speak highly of INCO. While they lived at O'Donnell they felt that they were well taken care of and that the company "provided" for them. Everything from a skating rink, to fire wood, to flush toilets and garbage collection. This reliance on the company has been demonstrated in many company towns in North America. Often company town residents failed to realize that they were "trading their social and political rights for the perceived benefits of company sponsored programs" (Alanen, 1979). O'Donnell workers endured heavy sulphur fumigations which made it difficult to breathe and in addition to preventing any vegetation from growing in the area. However, these workers were not financially compensated nor provided with additional incentive beyond wages to endure these adverse conditions at O'Donnell.

Public perceptions towards environmental damage and pollution in general, with respect to industrialization, have changed over time. During the early part of this century, smoke and pollution was viewed as a sign of prosperity and progress and in turn was widely accepted as the price of wealth. This acceptance is reflected in the information included on the INCO employee cards. The CCC (later INCO) made no attempt to hide the fact that their employees left because of the unfavourable "smoky" working conditions at O'Donnell. These smoke filled conditions were accepted by both workers and residents of O'Donnell simply as a requirement of the mining process and "part of the job". This type of community acceptance was investigated in 1968 in a mining town in the United States, that was dependent on a nearby steel mill. Community residents were asked about how they felt about the pollution the steel mill produced. The study asked the question "Is there an air pollution problem in your city?" Eighty per cent of the residents not economically dependent on the steel mill were bothered by air pollution, while only 17% of those dependent on it "perceived a problem" (Creer, 1968 as cited by Treshow and Franklin, 1989). Again, economic stability was a primary concern and if residents were financially dependent upon the polluter, they were willing to accept this pollution as part of the package.

Visiting the historic site of O'Donnell is an incredible experience and one that is hard to describe. The site of the roast bed is now a dramatic, predominant red scar, that resembles a landing strip in the middle of a birch forest (Plates 37, 38 and 39). Today, over sixty-eight years after INCO stopped roasting at this site, when one walks around the abandoned yard there is still a strong sulphur odor. It's an incredible place, where one's imagination can recreate the smells and sounds of the working environment of O'Donnell.

4.0 Present status of Residual Environmental Impact of the O'Donnell Roast Bed

An assessment of the present-day contamination of the roast yard and surrounding terrestrial area.

4.1 Introduction:

During the operation of the O'Donnell roast yard (1916-1929) the immediate natural surroundings were devastated. It was stated by former O'Donnell residents that there was no green vegetation within a three mile radius. The abrupt closure and abandonment of the O'Donnell roast yard in 1929 with it's associated town site, provided an unusual opportunity for "natural" recovery of the surrounding ecosystem to occur away from urban and highway stresses. Sixty-nine years after the closure of O'Donnell, the roast yard itself is still a striking unvegetated 2 km, "landing strip" in the middle of a birch-dominated forest (Plate 37, 38 and 39), but the birch forest now has re-grown to the edge of this roast yard.

The objectives of this chapter are both to document the ecological recovery of the roast bed and its surroundings, and to determine if residual environmental toxicity persists at this site. Soil chemistry and pH were assessed to determine the relative phytotoxicity of the region. Since soils provide the foundation upon which all vegetation establishes they must provide a hospitable environment for plant growth. The vegetational communities presently at O'Donnell are described for the roast bed and the surrounding area. In addition, cores were taken of some older trees and their tree rings were chemically analyzed (dendrochemistry) to help reconstruct the pollution history of the region since operations at the roast bed ceased.

Dendrochronology as defined by Fritts, 1976 is "the science that deals with the dating and study of annual growth layers in wood". It is based on the concept that trees lay down annual rings which are the result of varying physiological conditions that affect the cells formed throughout a growing season. "At the beginning of growth in the spring, large thin-walled cells are produced. As the end of the season nears, smaller cells with thicker walls are formed. The ring boundary is the abrupt change in cell size between the small cells formed at the end of one growing season and the large cells formed at the beginning of the next" (Fritts, 1976). These annual rings can be measured to determine the years growth and it has also been shown that varying climatic conditions such as severe frost have been recorded in these annual rings (Fritts, 1976).

Dendrochemistry has been defined as combining "techniques in dendrochronology, soil chemistry and plant physiology for monitoring environmental change (Guyette et al.

1992, as cited by Watmough, 1997). Dendrochemistry assumes that the chemical composition of an annual tree ring at least partially reflects the chemistry of the environment to which it was exposed during the year in which it was formed (Amato, 1988, as cited by Watmough, 1997). The pathways by which a chemical may be deposited within an annual ring include: 1) via root uptake from the soil, 2) deposition on the trunk followed by transport through the bark, and 3) foliar uptake from the atmosphere.

Within the terrestrial system the absence of vegetation was an obvious result of the mining processes. Prior to the late 1960's, this lack of vegetation was mainly attributed to the impact of sulphur alone. Early studies by Katz (1939) documented the effects of sulphur dioxide from metal smelters on vegetation at Trail in British Columbia, while Linzon (1958) explored the influence of smelter fumes on the growth of white pine in the Sudbury region. In 1944, Sulphur Dioxide Investigation was inaugurated by the Dept. of Lands and Forests. The first conference included representatives from the Dept. of Lands and Forests, the Dept. of Mines, INCO and Falconbridge Nickel Mines. The purpose of this meeting was: "1) To investigate the alleged injury to forest growth by smelter fumes. 2) If injury exists, to determine the area affected. 3) To suggest measures leading to the reduction or elimination of the causes of the injury" (Haddow, 1945). Research focused on meteorology, atmospheric sulphur dioxide levels, conifer foliage sulphur content, controlled fumigation studies, lichen distribution and overall assessment of forest damage. Starting in 1939, there were fire towers that made observations of sulphur dispersal. Visual observations gave information on the distribution of sulphur dioxide and "the sense of smell provided a rough way of estimating the strength of fumigations" (Haddow, 1945). Haddow recorded observations in the course of extensive travel both by car and airplane. An example of these observations is the following:

> On July 18th, in the early morning, the writer observed smoke, presumably from Copper Cliff, from Bear Island, Temagami. It lay as a billowy stratum, in almost calm air, stretching NE-SW, the base at about 1000-1500 feet. The margin, which was just west of Bear Island, showed irregular wisps of light bluish smoke, while the central part of the stream, whose width was several miles, appeared as a succession of long, dark brownish, curved billows or rolls, roughly parallel, and at right angles to the direction in which the smoke had been carried. Without knowledge of this observation. Chief Ranger Hoffman later reported to me that he had smelled the smoke very strongly over the lake at 8 o'clock that morning, at about 1,200 feet, while en route to Sudbury (Haddow, 1945).

Expenditures by the Ontario Dept. of Lands and Forests on sulphur fumes investigation totalled $55, 862.55 during the period April 1944-March 1949. Intensive investigations were also conducted during the summers of 1942 and 1944, when the smelters were in peak production for the W.W.II effort. During this period, Sudbury smoke could be seen from fire towers located more than 120 km away, and the smell of the sulphur could be detected at a distance of 60 km (Murray and Haddow, 1945). "Severe burns" of tree foliage had occurred at 35 km to the northeast, 20 km to the north, and 20 km to the south of the smelters (Winterhalder, 1995). Linzon (1958, 1971) documented white pine sensitivity to sulphur dioxide as well as describing increased mortality and decreased growth of white pine as far as 40 km northeast of the ore smelters (Winterhalder, 1995).

Gorham and Gordon (1960a) determined sulphate concentrations in soils and pond water and examined the plant distribution along a NNE transect from the Falconbridge smelter near Sudbury. The number of macrophyte species declined sharply within 6.4-11.2 km of the smelters, while the amount of bare ground increased as distance to the smelter decreased. As distance from the smelter increased, sulphate levels decreased in both the terrestrial and aquatic environments (Gorham and Gordon 1960a). Also, in 1960, these same authors reported on the fall-out pattern of sulphur dioxide from smelter fumes and its impact upon both vegetation and lake water (Gorham and Gordon, 1960b). They identified the extent of crown damage of trees using the following categories: not obvious, moderate, considerable, severe, and very severe damage. The tree species present in the severe damage category were red maple, red oak and white birch, with only red maple and red oak in the very severe damaged areas. Extensive damage to vegetation was restricted to the area within 8 km of the smelters, which was the same area within which extremely high levels of sulphur fall-out were observed (Gorham and Gordon, 1960b).

Problems of heavy metal accumulation in soils and vegetation as a result of air borne contaminants from stack emissions from smelting complexes have been documented as early as 1907 in the USA, (Haywood, 1907). However it was not the focus of research in the Sudbury region prior to 1968. Heavy metal content in the soils was explored in the Sudbury area by Whitby and Hutchinson in the late 1960's when they asked the following:

> ...whether sulphur dioxide is the only pollution problem of the region or are there others which may continue and/or affect the ability of the vegetation to recolonise the damaged areas? An obvious possibility in any smelting operation is the release of heavy metals into the environment. Is this a complicating factor at Sudbury? (Hutchinson and Whitby, 1974).

Their findings concluded that the levels of soil copper and nickel were elevated to concentrations capable of preventing plant growth of any kind in the immediate area surrounding the Sudbury smelters. At this time, surface soils had pH values as low as 3.1 within a kilometer of the Coniston smelter, increasing with distance to pH 4.8 greater than 50 km away from the smelter (Hutchinson and Whitby, 1974). According to Tom Peters, formerly of INCO, this was one of the first, if not the first independent studies indicating the extent of the accumulation of heavy metals in the soils in the vicinity of the Sudbury smelters. He was quoted as saying "We at INCO were disturbed by Tom Hutchinson's reports but as he had supported his statements with well documented field research, we had no choice but to take notice". Tom Peters suggested that prior to this study, INCO was unaware of the extent and levels of the soil contamination from heavy metals by the smelter operations. Tom Hutchinson's work led to the initiation of expanded research programs by INCO and other institutions on the impact of heavy metals from smelter emissions on terrestrial and aquatic systems in the early 1970's (Peters, 1997).

In the Sudbury region distinct zones of vegetation around the smelters have been identified by Amiro and Courtin (1981). They describe a 170-km^2 zone of industrial barren land that is essentially devoid of vegetation. Adjoining these "barrens" is a 720-km^2 semi-barren area, referred to as a transition zone between the barrens and the "natural" vegetation of the region. These two zones are a direct result of the regions' mining activity, and neither is found as a natural successional stage of the eastern hemlock-white pine-northern hardwood forest that was once typical of the Sudbury area (Sharpe and Brodie, 1930). The transition zone is made up of two monocultural communities, one dominated by paper birch (*Betula papyrifera*) and the other by red maple (*Acer rubrum*) (Amiro and Courtin, 1981). This birch dominated transition forest can be found surrounding the O'Donnell roast bed "barrens" and is characterized by individual slow growing trees that have multiple stems. They are best described as "coppiced". Historically forest managers in Britain and Holland used tree coppicing as a severe pruning technique to promote additional shoot growth. The birch transition forest of the Sudbury region shows this same coppicing effect, except that the mode of biomass removal is not direct as would be the case with cutting, but rather it is the indirect result of sulphur dioxide destruction of the growing points i.e. shoot meristems (Courtin, 1995). The net result of year after year of meristem destruction is the development of numerous side shoots developing from shoots low on the branches, and eventually the "trees" resemble bushes with no leader. Examples of these widely spaced, highly coppiced birch trees are found within 300 m of the O'Donnell roast bed (Plates 43 and 44).

Plate 43. View of coppiced birch trees on the O'Donnell roast bed (Watmough).

Plate 44. View of coppiced birch trees up to the edge of the O'Donnell roast bed. (Watmough).

4.2 Methods:

4.2.1 Soils:

To determine whether residual chemical residues from the days of active roasting are still present, soil samples were collected along two transects. One transect ran perpendicular to the roast bed itself, eastward to a distance of 20 km and the other more intensively sampled transect ran perpendicular to the roast bed in a western direction out to 300m (Figure 3). In addition, 10 x 10m permanent sampling plots were established at three different sites along the roast bed: 1) a vegetated site containing four different species (RB1), 2) a non-vegetated site (RB2) and 3) a vegetated site dominated by the grass *Deschampsia cespitosa*. (RB3). This was done to investigate potential differences in soil chemistry on the roast bed which is largely unvegetated but has a few patches of vegetation now on it which have established in the past 20 years (T.C. Hutchinson and K. Winterhalder, personal communication). In addition, permanent plots were established at 10m, 30m, 50m, 80m, 100m, 300, 1km, 3km, 4km, 7km 10km and 20km from the roast bed edge (Figure 3). At each of these 10m x 10m plots, five surface soil samples were randomly obtained and one soil profile to a depth of 40 cm was collected at 5 cm depth intervals. All soils were sieved, ground, and a 0.2g subsample was digested by concentrated nitric acid at a temperature of 120 C for 8 hours. Following digestion, samples were diluted with distilled deionized water (DDH_2O) and then analyzed by inductively coupled plasma emission - mass spectrophotometry (ICP-MS) for Na, Mg, Al, P, K, Ca, Mn, Fe, Co, Ni, Cu, Zn, As, Mo, Ag, Cd, and Pb. Three replicates were done for each total digest.

Water extractable ions of the soils were obtained by shaking 5 grams of dried soils in 50 ml of DDH_2O for one hour and then analyzing the supernatant for elemental content by ICP-MS. Three replicates were done for each water extract. Soil pH was determined by diluting 5 g of sieved soil with 20 ml of DDH20. This slurry was mixed for 45 minutes. After waiting 15 minutes, the pH of the slurry was measured using a glass electrode.

Soil organic content was determined by placing a measured amount of oven-dried surface soil from each site (approximately 1.0 - 1.5 g) in a crucible and heating it to 500 C for 8 hours. Each crucible was allowed to cool and the remaining ash was re-weighed. Percent organic content was calculated using the following formula:

$$[(\text{initial soil wt (g)} - \text{ash weight (g)}) / \text{initial soil weight (g)}] * 100.$$

4.2.2. Bioassay:

The relative ability of soils from the transects to support (or inhibit) plant growth under controlled conditions was assessed by means of a greenhouse bioassay as follows;

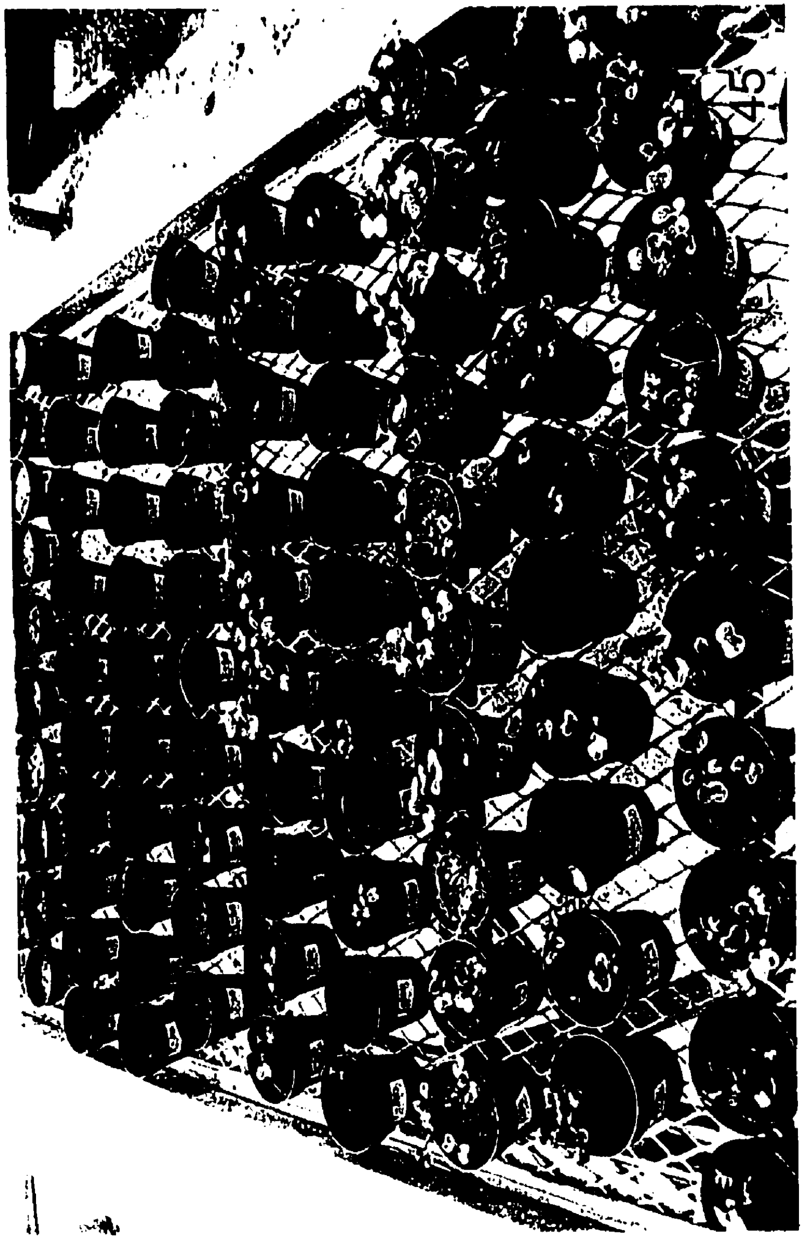
Bulk surface soils (0-5 cm) were collected from the roast bed itself in addition to permanent plots at 10m, 30m, 50m, 80m, 100m, 300m, 1 km., 3 km, 4 km, 7 km, 10 km and 20 km (Figure 3). Soil from each site was placed in 10 cm diameter pots, with 10 replicate pots used per site. The control treatment used was common potting soil. On January 27, 1997, four radish seeds (variety Cherry Belle) were placed in each treatment replicate. The bioassay was carried out in the greenhouse at Trent, with temperature maintained at 21-25°C, and the treatments were exposed to a 15 hour, 9 hour light/dark regime (Plates 45, and 46). The plants were harvested after 14 days (Feb., 11, 1997), and % emergence, root and shoot length (mean of 4 seeds per pot) were recorded. In addition, the shoots were dried at 60°C for 24 hours, and their dry weights were obtained to further assess growth on each soil treatment.

4.2.3. Tree core (growth rates and dendrochemistry):

Since the roast yard fumigations had killed all vegetation over a wide surrounding area, finding trees dating back to its active operation was very difficult. Accordingly, in the fall of 1995, tree cores were taken at breast height from two large red oak trees (*Quercus rubra*) located at the Creighton site, approximately 7 km from the roast bed in addition to a control tree cored at Dwight ON (approximately 150 km south of O'Donnell) (Figure 3). No suitable large trees were found closer (to the O'Donnell roast yard) than the Creighton town site. Individual tree ring widths were measured to determine annual growth. The tree core was then very lightly scraped and rinsed with DDH_2O and cut into 5 year segments. These segments were then oven dried at 60°C, weighed and ashed at 480°C for 6 hours and subsequently digested in nitric acid at 80°C for 6 hours. Samples were diluted to 12.5 ml with DDH_2O and analyzed by ICP-MS for the following elements: Na, Mg, Al, P, K, Ca, Mn, Fe, Co, Ni, Cu, Zn, As, Mo, Ag, Cd, and Pb.

Plate 45. Conditions under which bioassay at Trent greenhouse were carried out. Although not shown in the photo, all pots were randomly placed. Courtesy of Eric Sager.

Plate 46. Bioassay pots, note difference in growth between the plants growing on the control soils (dark soils) versus the lack of growth in the roast bed soils (light coloured soil. Courtesy of Eric Sager.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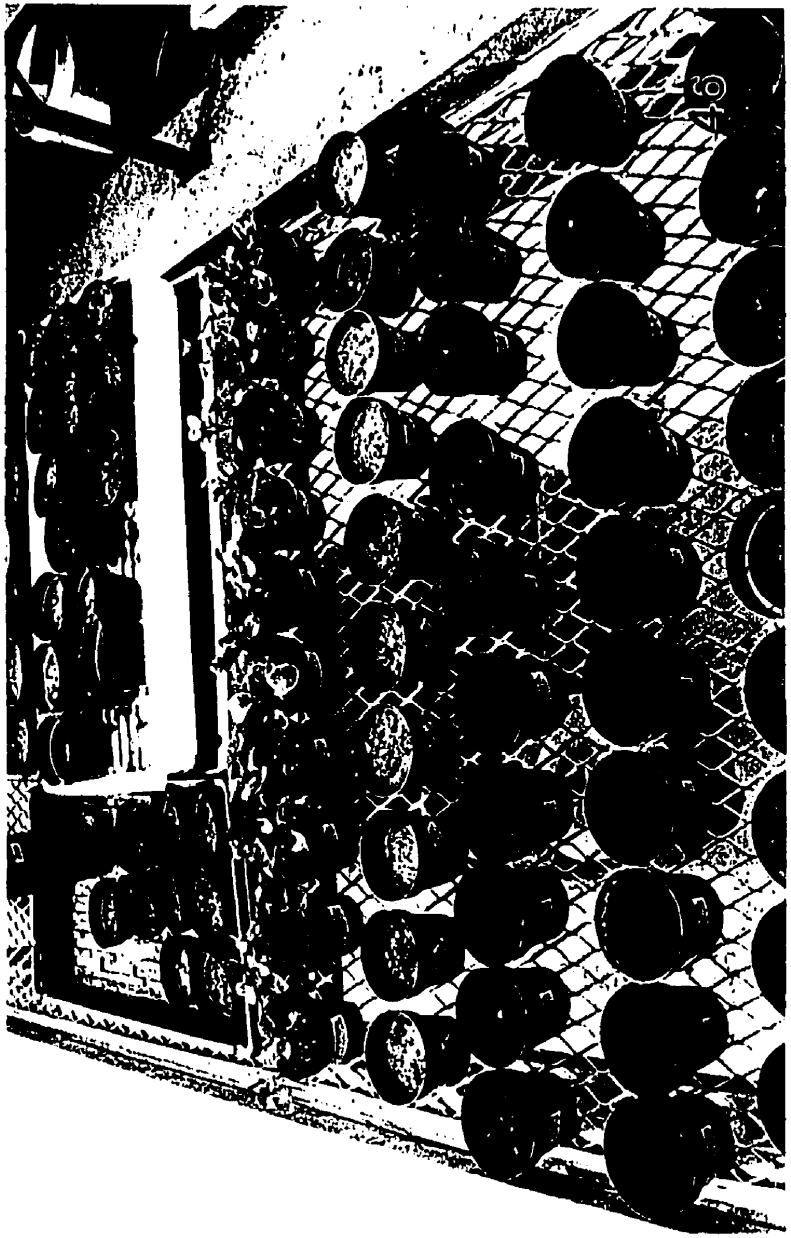
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4.3 Results and Discussion:

4.3.1 Soils:

Soil pH and chemistry:

The soil was a very acidic pH 3.4 on the roast bed itself, increasing to pH 4.5 at 4 km from the roast bed (Table 4), with most sites having a pH between 4.0 and 4.5. An exception to the general acidity was the permanent plot established at Court where the pH was 3.9. This site is located on an exposed hilltop and is probably influenced by sulphur smoke from Copper Cliff. The pH of the control potting soil used in the bioassay was 6.8.

All the roast bed sites showed very high concentrations of several metals, but there were marked differences in total metal concentrations between the sites on the roast bed itself. As shown in Table 4, high levels of the toxic metals Ni, Cu, and Co exist at the vegetated site which is dominated by the tufted hair grass *D. cespitosa*. (RB3) (ie. Ni=8885 ppm; Cu=10,051 ppm). Perhaps important to the ability of the grass to establish is that this site also has the highest pH of the three roast bed sites (pH 4.4). RB1 contains a number of species in addition to tufted hair grass, and has the lowest metal concentrations (ie. Ni=2069 ug/g; Cu= 1728 ug/g). RB2 also has extremely elevated metal levels (ie. Ni=6672 ug/g; Cu 3648 ug/g), but a much lower pH (3.4), (Table 4). The roast bed sites differed in their Ca and Mg content as well. The two vegetated sites (RB1 and RB3) had soil concentrations of Mg of 8.4 mg/g and 7.8 mg/g respectively. These levels were nearly two times greater than the unvegetated site (RB 2) (Table 4). Also, the level of Ca at the site dominated by *D. cespitosa* is 21.3 mg/g which is almost 4 times the levels of other transect sites (Table 4). Levels of both Ca and Mg are elevated when compared to uncontaminated soils.

Average levels of these metals in uncontaminated soils as cited by Bowen (1966) include:

Ni=40 ug/g, Cu=20 ug/g, Co=8 ug/g, Ca=13.7 mg/g, and Mg=5 mg/g.

Copper and nickel levels dramatically decreased by a factor of ten within 10 m of the roast bed proper, and in general, continued to decrease as distance from the roast bed increased. However, as seen in Table 4, metals levels increase somewhat at the Creighton and Hwy 144 sites and if the O'Donnell roast bed was the sole source of these metals, the increase is an aberration. However, we have recently discovered that there was another very small and older roast bed and smelter (Gertrude) located between the O'Donnell roast bed and these two sites, so the unusually high Ni, Cu and Co soil levels at Creighton and Hwy 144 may, in fact, be due to the accumulation of metals from this small historical roast yard (Figure 3). This realization only came with new information collected in 1998.

On the 300m transect it should be noted that even in the birch forest at 100m and 300m from the roast bed, residual soil metal levels are still very high compared with uncontaminated sites ie. at 283-352 ppm Ni and 238-388 ppm Cu, while "normal" levels might be 20-40 ppm at an uncontaminated Shield site (Bowen, 1966). This is a 'residual' foot-print of metals about ten times background levels.

Table 4. Mean (with standard error) surface soil pH, and total soil element concentrations (units: either ug/g or mg/g) at distances away from the O'Donnell roast bed (1994) (n=3)

Site	pH	Ni	Cu	Co	Ca	Mg
		(ug/g)	(ug/g)	(ug/g)	(mg/g)	(mg/g)
RB1	3.9	2069+/-968	1728+/-812	58+/-21	5.5+/-1.3	8.4+/-1.2
RB2	3.4	6672+/-2959	3648+/-211	167+/-76	4.3+/-0.5	4.4+/-1.3
RB3	4.4	8885+/-4397	10051+/-6727	299+/-162	21.3+/-8.0	7.8+/-2.5
10 m	3.9	217+/-56	308+/-76	14+/-2	6.0+/-0.5	6.7+/-0.2
30 m	4.1	355+/-237	499+/-261	12+/-5	5.1+/-0.0	2.7+/-0.1
50 m	4.4	115+/-46	149+/-37	5+/-2	3.9+/-0.6	1.3+/-0.4
100 m	4.0	352+/-85	388+/-113	11+/-2	2.9+/-0.3	1.4+/-0.0
300 m	4.0	283+/-94	338+/-125	8+/-2	2.9+/-0.0	1.0+/-0.2
1 km	4.2	221+/-55	188+/-26	14+/-4	5.3+/-1.4	4.3+/-1.5
3 km	4.1	223+/-50	259+/-93	12+/-1	5.9+/-1.0	4.1+/-1.2
4 km	4.5	353+/-100	302+/-67	16+/-3	5.2+/-0.8	2.8+/-0.6
Creighton	4.4	579+/-43	592+/-27	31+/-1	7.7+/-0.8	4.4+/-0.1
Hwy 144		1633+/-292	905+/-160	60+/-16	5.9+/-0.5	1.8+/-0.2
Court	3.9	770+/-21	623+/-48	24+/-2	5.0+/-0.4	1.7+/-0.1

Soil Water Extracts:

Elemental water extractions also dramatically decrease away from the roast bed proper. RB 2, with the lowest pH, also showed the highest levels of extractable Ni, Cu, Zn and Co, (Table 5).

Table 5. Surface soil water extracts of the O'Donnell Roast Bed and surrounding area, 1994. Values shown are a mean of 3, with standard error.

SITE	Ca	Mn	Co	Ni	Cu	Zn
	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
RB1	37±13.8	1.1±0.2	0.2±0.1	7.9±3.1	11.9±3.5	0.3±0.1
RB2	386±26.5	7.7±1.9	8.0±2.6	42.5±1.2	50.8±1.3	4.8±1.0
RB3	585±223.0	1.0±0.2	1.0±0.2	26.7±6.8	41.9±4.0	0.9±0.1
10 m	15±2.8	1.2±0.2	0.1±0.0	4.9±1.6	3.4±1.1	0.5±0.1
30 m	5±1.0	0.2±0.1	0.0	1.8±0.8	1.8±0.4	0.3±0.2
50 m	9±2.9	0.4±0.1	0.0	1.1±0.5	1.1±0.2	0.3±0.1
100 m	22±6.2	0.6±0.2	0.0	1.0±0.3	3.2±0.7	0.3±0.1
300 m	10±0.3	2.1±0.4	0.0	0.5±0.1	1.0±0.2	0.3±0.2
1Km	13±0.6	2.4±0.6	0.0	0.7±0.0	1.6±0.2	0.3±0.1
3Km	16±3.3	2.6±0.5	0.0	0.7±0.1	1.4±0.5	0.4±0.2
4Km	26±0.1	6.3±2.6	0.1±0.0	1.4±0.3	2.8±0.2	0.2±0.1
Creighton	32±1.2	2.3±0.7	0.1±0.0	2.4±0.4	2.8±0.4	0.5±0.2
Hwy144	40±1.0	7.4±3.7	0.1±0.0	1.8±0.5	2.3±0.4	0.7±0.1
Court	46±6.0	4.7 ±0.6	0.0	1.7 ±0.1	3.0±0.5	1.0±0.1

Table 5 shows concentrations of elements in distilled water-extractions, which correspond more closely to plant available metal levels than the concentrated nitric acid digestion analyses. Cu at all sites exceeds 1ppm, as does Ni at nearly all the sites. Since 1ppm of Cu in soil solution (and 5 ppm Ni) are generally regarded as phytotoxic, the presence of vegetation at the transect site, ie. a birch forest, suggests strong metal tolerance in the invading species (Whitby and Hutchinson, 1974). The occurrence of *Deschampsia cespitosa* at RB3, with water extracts containing 42 ppm Cu and 27 ppm Ni, is remarkable even for this metal-tolerant grass (Cox and Hutchinson, 1980). Note also that water extractable phosphorus (P) is more than 10 times lower on the roast bed than on the transect sites (Appendix D). Levels of 0.02 ug/g of P would represent a severely P deficient situation. High aluminum at the low pH levels of the roast bed would add to the P deficiency since Al interferes with P uptake and translocation. Ca, Mg, and K (Appendix D) increases with distance from 10 metres, which indicates historic acidic leaching from fumigations. High Ca and Mg on the actual roast bed probably indicates where cement blocks and building foundations occurred. Total Ca at RB2, the non-vegetated site was lower than at the other two vegetated sites of RB1 and RB3.

Soil organic content:

Organic matter in soils collected on the roast bed and surrounding area are shown in Figure 9. There does not appear to be any clear correlation between percent levels of organic matter and the concentrations of metals, eg. Ni, Cu, Co, etc. (see Tables 4 and 5 with Figure 9).

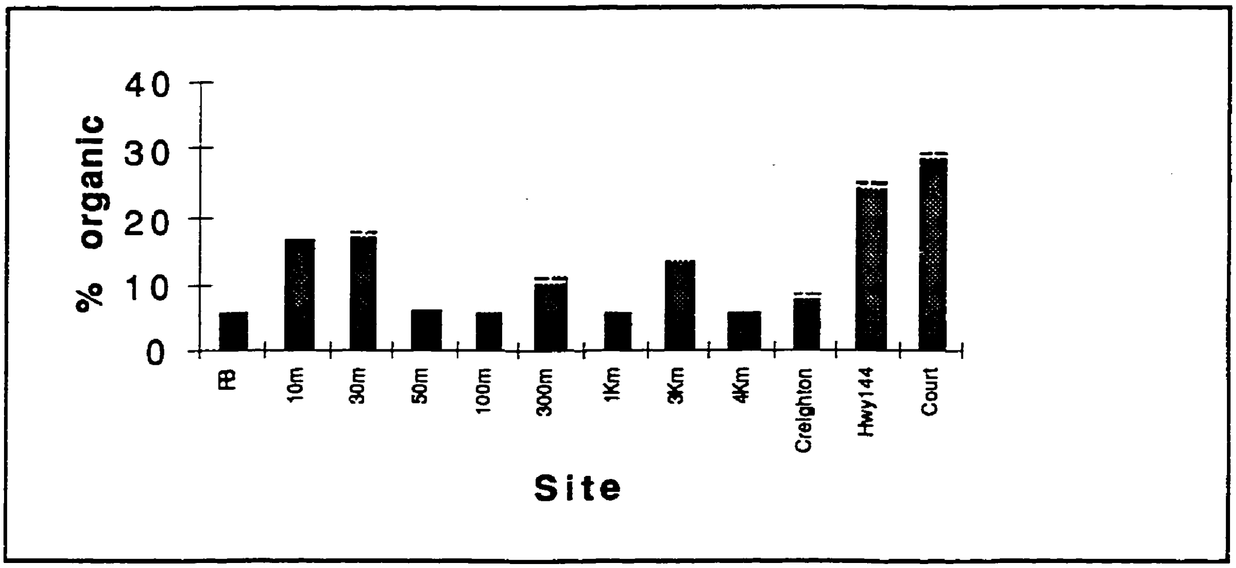


Figure 9. Percent of organic content of roast bed transect soils. Mean of 3 with standard error bars.

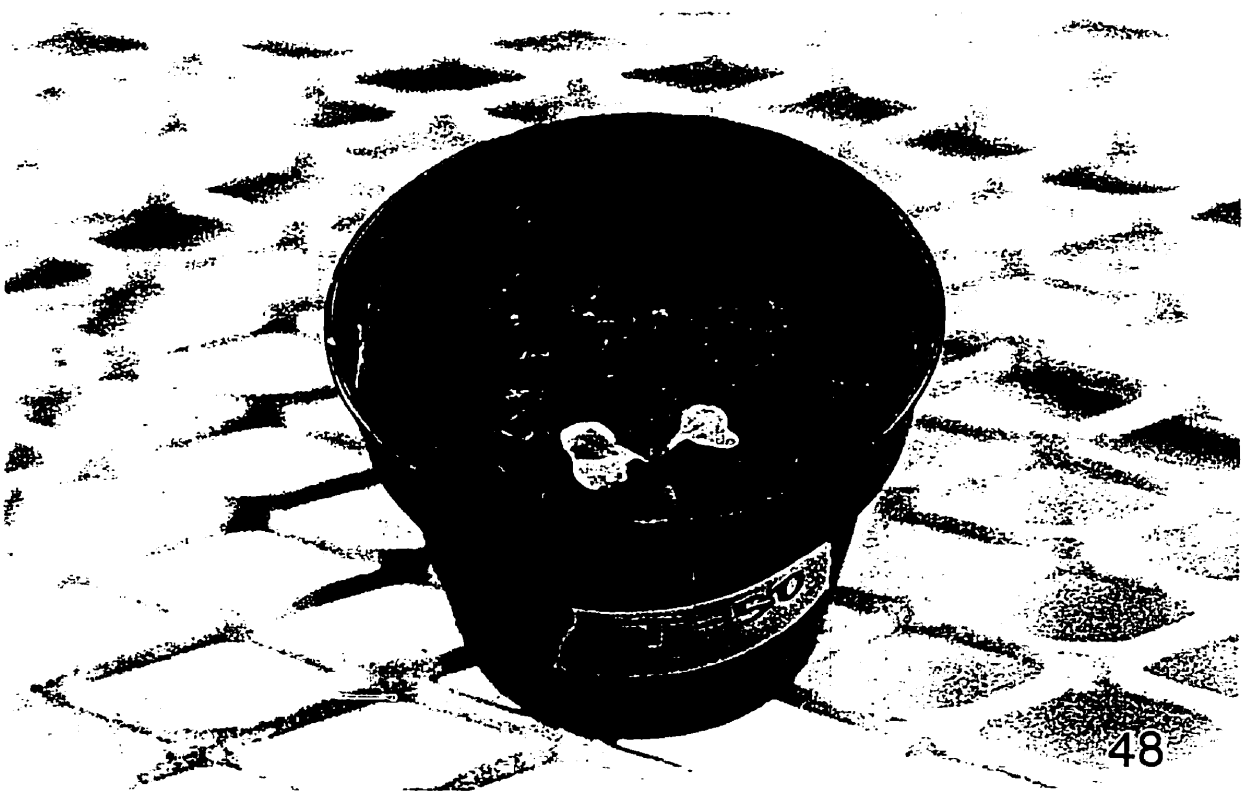
4.3.2 Bioassay:

None of the 40 radish seeds germinated (emerged) on the roast bed 'soil' itself, nor at the site 30 m from the roast bed, while four seeds out of 40 germinated at 10 metres, and one seed germinated on the soil taken 50 metres from the edge of the roast bed (Figure 11, Plates 47 and 48). In total, very few seeds germinated on the soils collected out to 300 metres, with the exception of the site at 100 metres. This last site may have been better drained over the years. The mean root length of germinated seeds at sites along the transect ranged from 0.17 cm +/- 0.07 (se) at 300 metres from the roast bed to 3.52 cm +/- 0.41 at Court more than 20 km from the roast bed. The mean root length of the seedlings in the control treatment was much longer at 15.18 cm +/- 0.47, see Figure 11, Plates 49 and 50. The differences shown between the control and the roast bed soils would perhaps be exaggerated as a result of the greater organic content and structure of the potting soil. Although there were no measurable root lengths at 10 and 50 metres from the roast bed, these two sites had mean shoot lengths of 0.17cm +/- 0.07 and 0.08 cm +/- 0.08 respectively. Shoot length steadily increased as the distance from the roast bed increased, with the site at 300 metres being the exception (Figure 11). Dry weights of the shoots of the roast bed sites were well below that of the control treatment. The average shoot weight

Plate 47. Bioassay: radish growth on soil collected 10 metres from roast bed edge Courtesy of Eric Sager.

Plate 48. Bioassay: radish growth on soil collected 50 metres from roast bed edge Courtesy of Eric Sager.

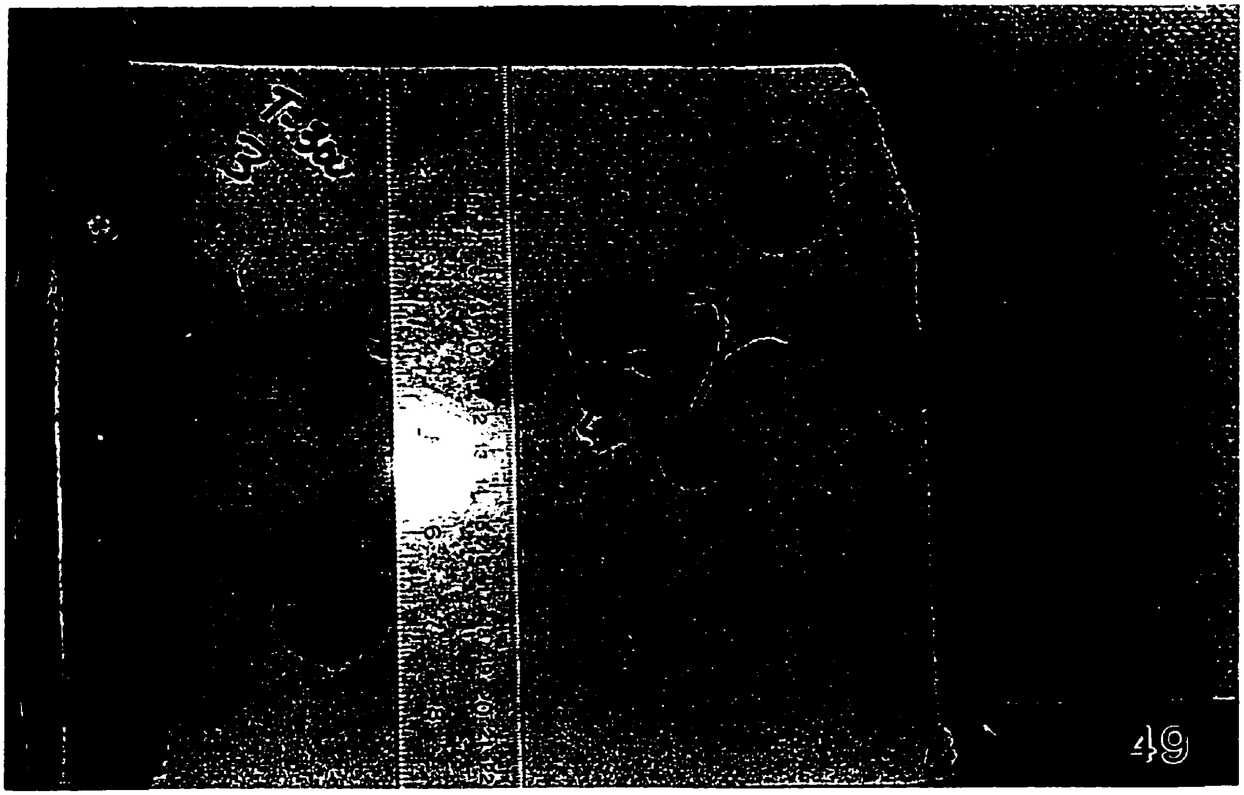
47



48

Plate 49. Bioassay: Root and shoot growth of radish seeds grown in soil collected 300 metres from roast bed edge. Note visual difference when compared to Plate 50. Courtesy of Eric Sager.

Plate 50. Bioassay: Root and shoot growth of radish seeds grown in control potting soil. Note difference when compared with Plate 49 Courtesy of Eric Sager.



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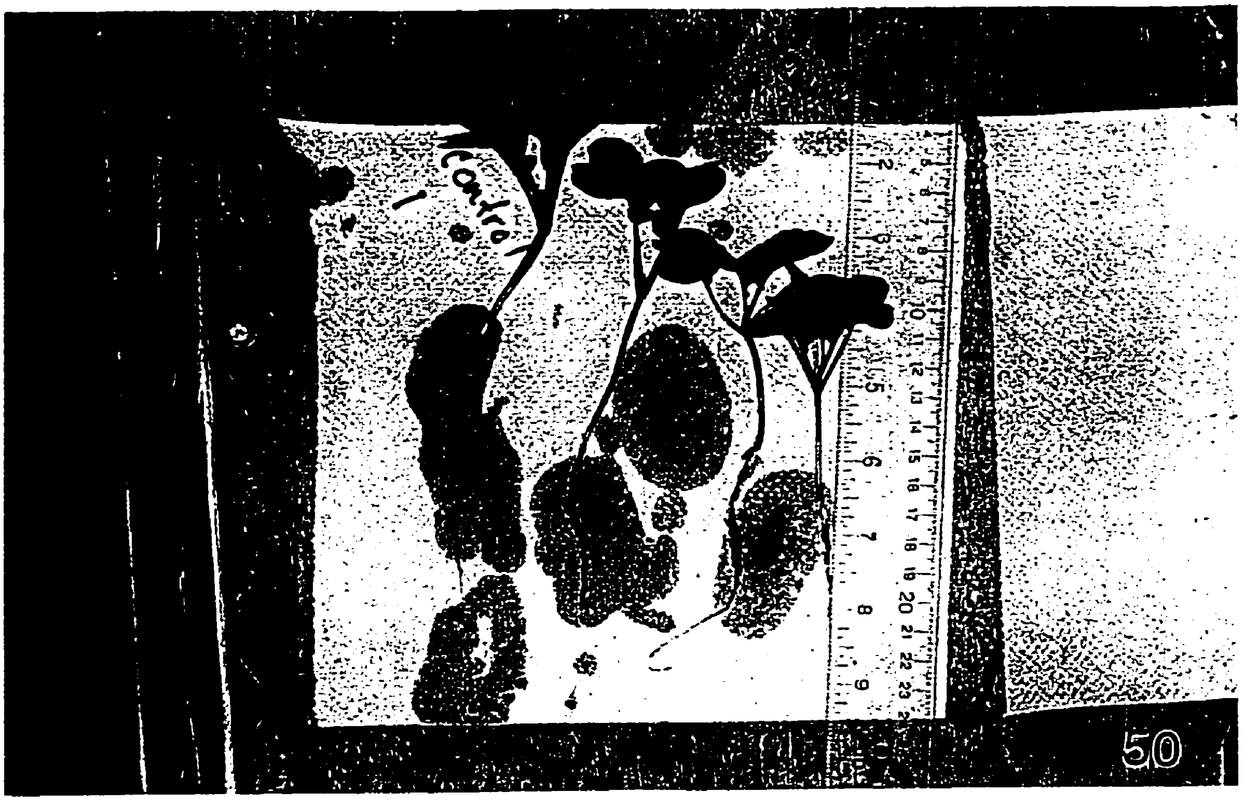

50

at 10 metres from the roast bed was .001g +/- 0, increasing to .002g +/- 0.001 at the 300 metre site, and 0.027g +/- 0.002 at the Court site. The average shoot weight of the control was 0.077 g +/- 0.004, see Figure 10.

4.3.3 Tree ring cores:

Growth of trees:

The reference tree from Dwight had a smaller diameter at breast height (DBH) although it was comparable in age to the others from Creighton. This is reflected in much smaller annual ring widths of the reference tree. Creighton tree #1 (Cr#1) was approximately 71 years old and Creighton tree #2 (Cr#2) was approximately 52 years old while the reference tree was approximately 63 years of age (Figure 11).

There was a slight decrease in annual width of the individual tree rings in recent years in all three trees cored. The average annual ring width of Cr#1's two cores were 3.46mm +/- 1.8 and 3.95mm +/- 1.78. Cr#2 had average annual ring widths of 4.79mm +/- 2.19 and 4.48mm +/- 2.05, while the tree from Dwight had a lower average annual ring growth of 2.47mm +/- 0.76. The Creighton trees were growing in a small wooded area of the town site, and exhibited better growth on an annual basis when compared to the reference tree (Figure 11). The oldest tree which has rings formed during the year of an active roast yard at O'Donnell (Cr#1) showed a very low rate of growth until the mid 1940's. A growth peak occurred in 1956, with a gradual decline since. Cr#2 tracks this gradual decline from its initial annual ring of 1953.

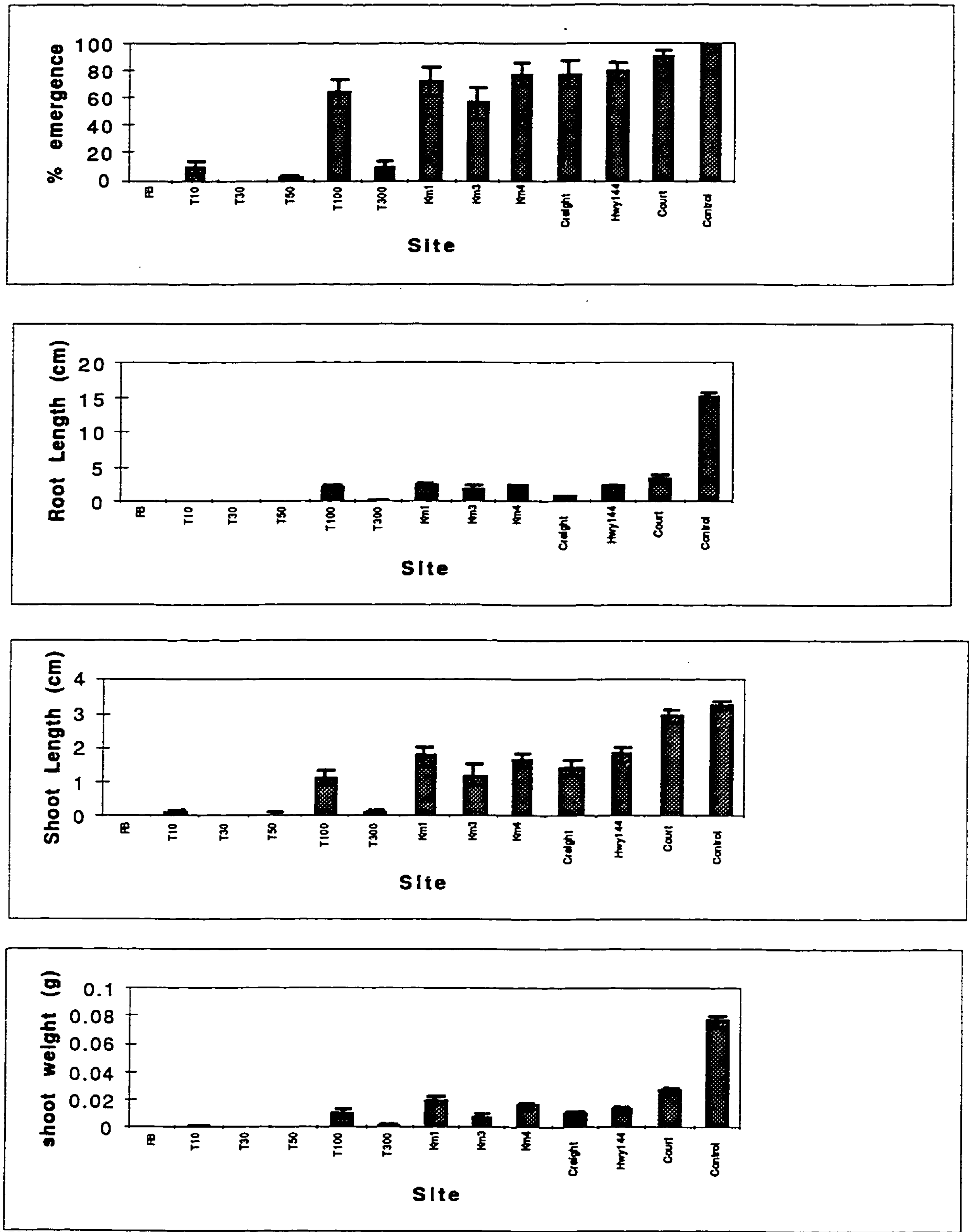

Figure 10. Bioassay results. Percent emergence, root and shoot length (cm) and also the shoot dry weight (g) Mean of 10, with standard error. Radish seeds (variety Cherry Belle) grown on soils collected along a transect out from the roast bed.

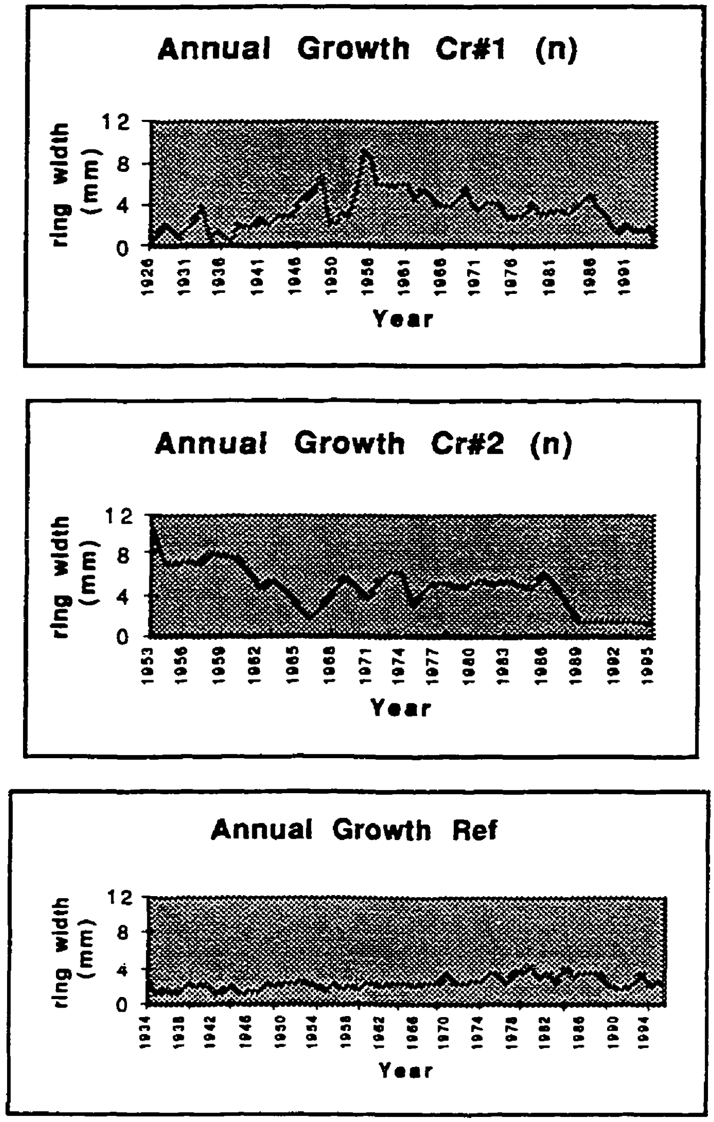

Figure 11. Individual tree ring widths (mm), representative of annual growth.

Chemistry of trees rings:

Nickel and copper content in the Creighton tree rings were much higher than those of the reference site. Creighton trees ranged from 1 to 19 ppm for Ni, 1 to 14 for Cu and 1 to 30 for Zn, while the Dwight control tree range was 0 to 2 for Ni, below the detection limit to 1ppm for Cu and 25 to 130 for Zn. CR#1 showed very high levels of Ni in the rings formed during O'Donnell's operation. The overall Zn levels contained in the control tree were much higher than those existing at Creighton (Figure 12). Ni, Cu and Zn content was higher in the outer rings as there is the radial tendency of element concentration from pith to bark (Watmough, 1997). See Appendix E for complete chemical analyses results.

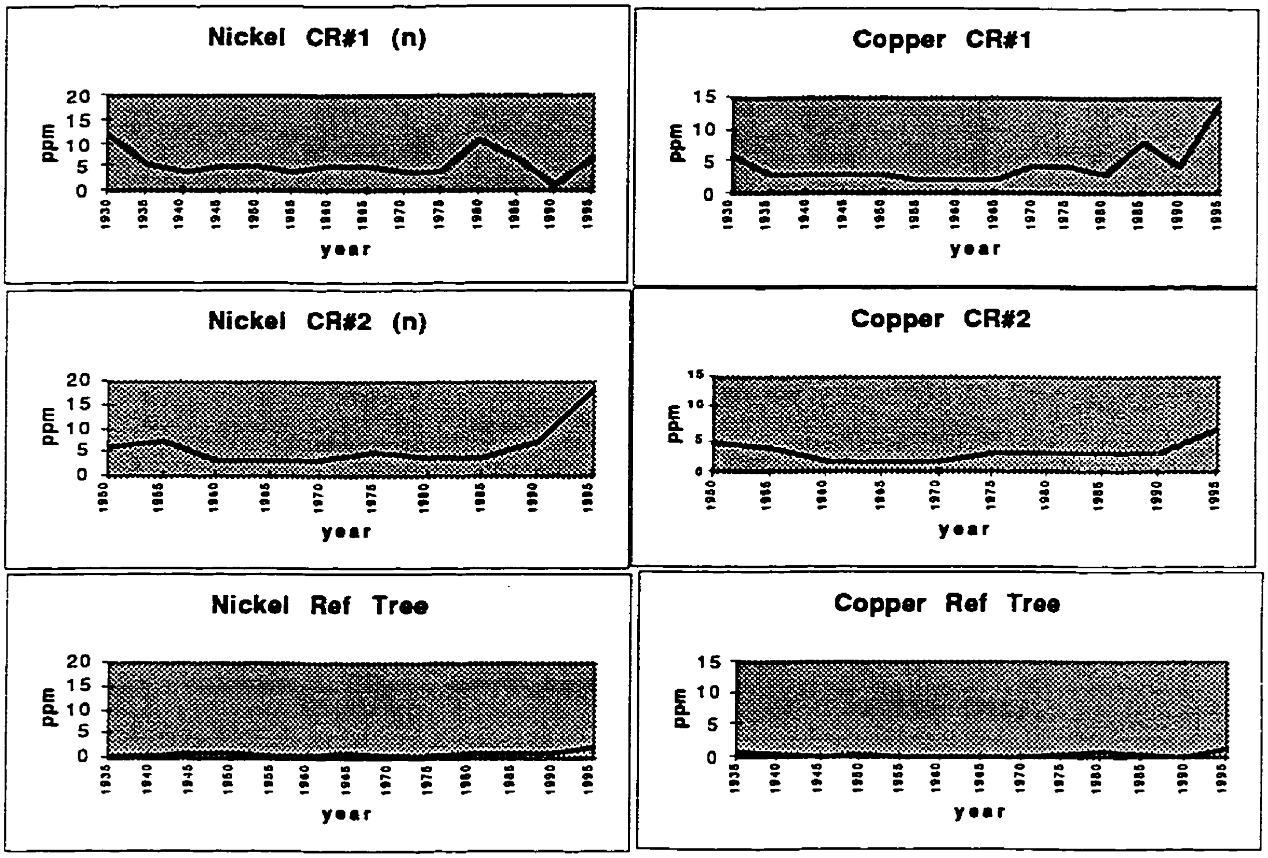

Figure 12. Ni and Cu content of annual tree rings (each value is a 5 year segment).

Earlier studies documenting soil pH and metal composition have been used in comparison with present day levels of nickel and copper, in an attempt to determine changes (if any) over the last 20 years. This not only provides a history of environmental change but provides information about the rate of ecosystem recovery of the area surrounding the O'Donnell roast bed.

Soils:

The soil conditions on the roast beds are still extreme, both in the excessively high levels of nickel and copper they contain and in their high acidity (low pH), making them inhospitable and phytotoxic to plants. As distance increases from the roast bed itself, metal levels dramatically decrease and conditions become more tolerable for plant growth.

Unda (1980) carried out both total soil digests and water extractable analyses on O'Donnell roast bed soils and surrounding area. Total soil Ni and Cu have decreased very little, if at all, since 1979, nor has the soil pH changed over this time period. However, water extractable Ni and Cu have dramatically decreased over time (Figures 13 and 14), perhaps a reflection of an increasing organic content in the soils as the sites revegetate.

Soils collected by Cox and Hutchinson (1979) from the uncontaminated pastures of Hay Bay on the Bruce Peninsula, located 150 km from Sudbury were analyzed for total and extractable metals. Their uncontaminated soil had a total Ni = 22ug/g, and Cu = 19 ug/g, while water extractables from the same soils gave the following: Ni = 0.1 ug/g and Cu = 0.2 ug/g. The roast bed and the entire surrounding area soils still dramatically exceed these levels (see Tables 4,5). Since it is known from other Sudbury area work (Gundermann and Hutchinson, 1995) that metal levels even over the 20 years 1971-1991 have fallen quite sharply in soils, it follows that at the time of closure of the O'Donnell truly massive levels of Ni, Cu, and Co must have occurred over a very wide area, to still leave residuals of 300-1500 ppm sixty-eight years later.

Factors affecting metal availability for water extraction include soil pH and percent organic material. A low pH can increase metal availability, while high organic content can reduce metal leaching in that these metals bind tightly to this organic material (Gregory and Bradshaw, 1965). This effect of pH can be seen at the RB2 site, where a pH of 3.4 facilitates Cu, Ni and Co extraction. The high organic content at the Hwy 144 may prevent high levels of Ni and Cu available for extraction when compared with the Creighton site, which has a much lower organic content, and in turn higher extractable Ni and Cu levels. Copper in particular, is so strongly bonded by organic components such as humus, that many peaty soils contain too little soluble copper to support the growth of crops (Bowen, 1966). However, Mn, Ca and Mg are very loosely bonded to organic matter and are readily leached from the surface soil (Bowen, 1966). Again, soil organic content will have increased over the last 20 years, because of increased vegetation growth contributing to the water extractable metal reduction in 1994 compared to 1979 (Unda, 1980; Hutchinson and Symington 1997).

Figure 13. **a.** Comparison of total soil nickel concentrations of the area surrounding the O'Donnell roastbed, 1979 vs. 1994.

b. Comparison of water extractable nickel ion of the area surrounding the O'Donnell roastbed, 1979 vs. 1994.

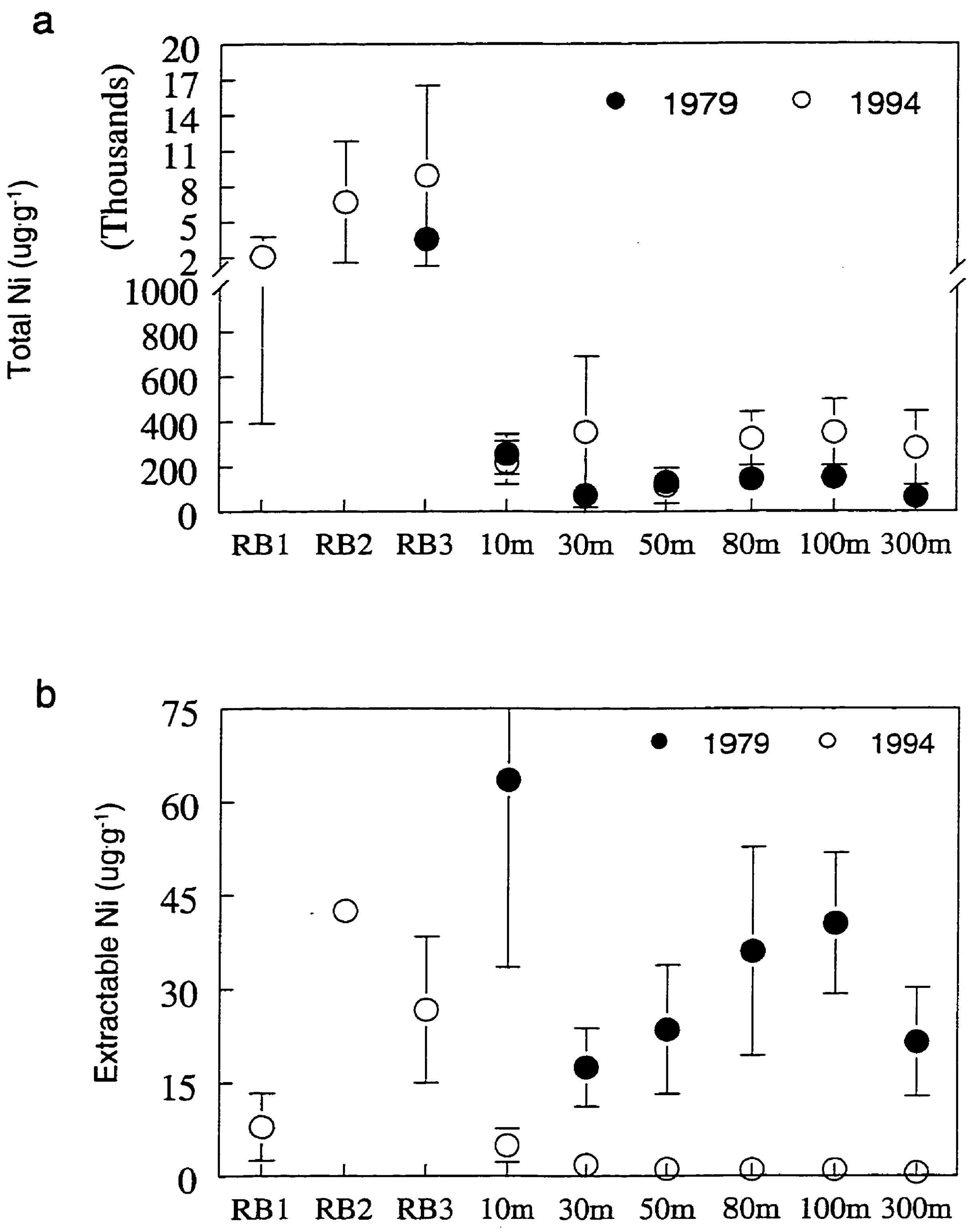

Figure 13. Comparison of total (a) and extractable (b) soil Ni concentrations of the area surrounding the O'Donnell Roast Bed in 1979 and 1994.

Figure 14. **a.** Comparison of total soil copper concentrations of the area surrounding the O'Donnell roastbed, 1979 vs. 1994.

b. Comparison of water extractable copper ions of the area surrounding the O'Donnell roastbed, 1979 vs. 1994.

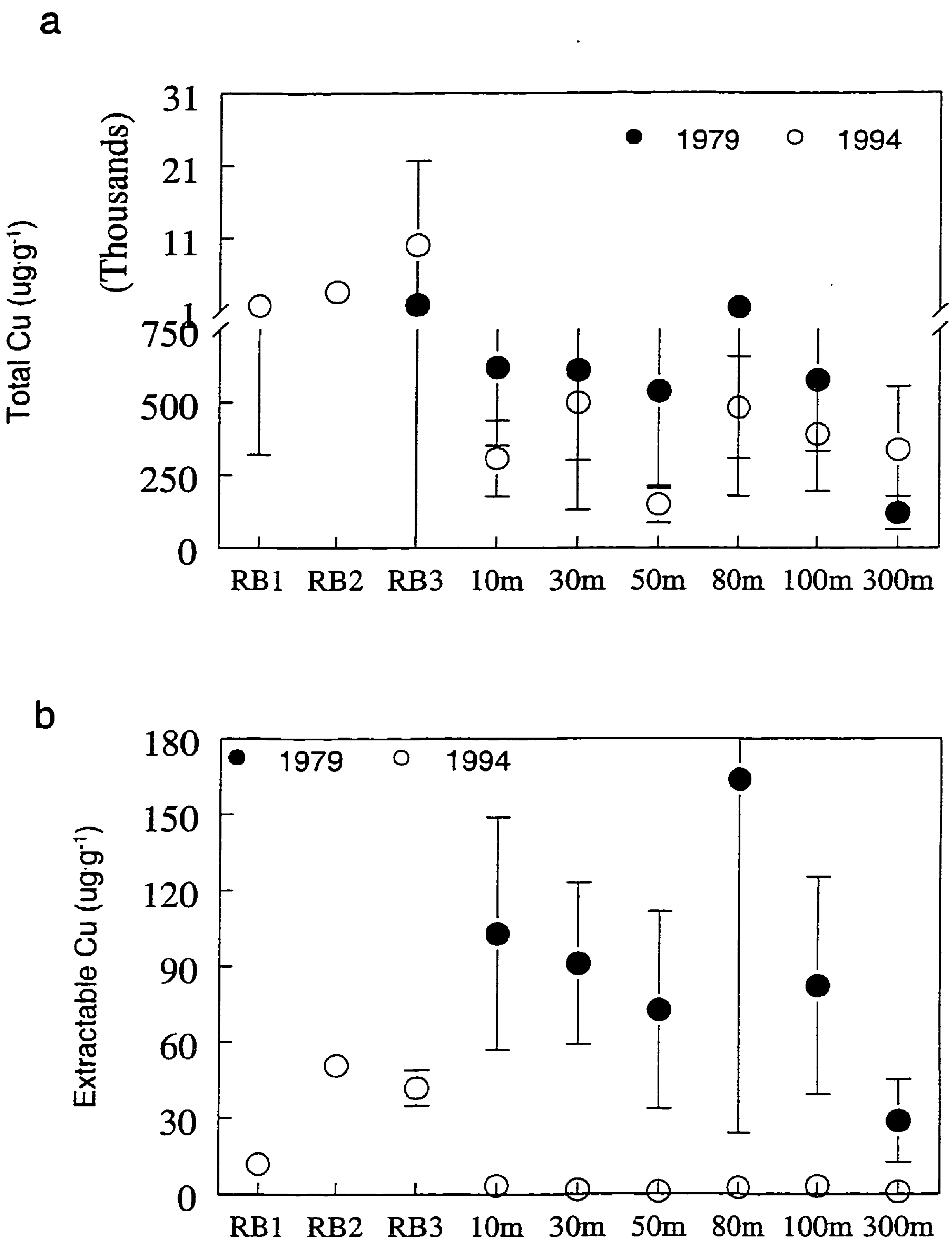

Figure 14. Comparison of total (a) and extractable (b) soil Cu concentrations of the area surrounding the O'Donnell Roast Bed in 1979 and 1994.

Vegetation:

There is still virtually no vegetation on the roasting beds themselves (<5 percent cover). However, in the last 20 years, a few very tolerant species have been able to re-colonize these contaminated areas, in patches. Tolerance refers to a plant being able to survive the effects of a stress (i.e., high levels of heavy metals) and is described as a reflection of specific physiological mechanisms which collectively enable a plant to function normally even in the presence of high concentrations of potentially toxic elements (Baker, 1987). The birch forest has encroached to within thirty metres of this roast bed (Plates 37, 38 and 39) and the town site that housed the O'Donnell workers (1.2 km away from the roast yard) has also been completely re-vegetated naturally over the last sixty-nine years (Plates 40, 41 and 42).

Tolerant species known to establish on O'Donnell's inhospitable soils include *Pohlia nutans* (moss), *Deschampsia cespitosa* (tufted hair grass), *Agrostis scabra* (tickle grass) and *Agrostis gigantea* (bent grass) (Hogan *et al* 1977; Cox and Hutchinson, 1979; Rauser and Winterhalder, 1985; Von Frenckell-Insam and Hutchinson 1993; and Archambault and Winterhalder, 1995). Other less tolerant species such as sheep laurel (*Kalmia angustifolia*) and paper birch (*Betula papyrifera*) establish themselves on the remains of these pioneering plants as they die off, apparently using them as a buffer to the toxic soils below. Subsequently, when these plants die, they leave behind additional organic material as a base upon which other species establish. As this process continues, the soils becomes more hospitable for plant growth and, in turn, the number of plants and biological diversity increase, both over time and space. This increase in both number and diversity would resemble that of an inverted pyramid.

An increase in plant diversity with distance has been shown surrounding the O'Donnell roast bed, with the number of plant species increasing from zero on the roast bed itself to 25 at 300 meters from the roast bed edge (Hutchinson, and Symington, 1997). Metal-tolerant grasses, sedges and the moss *Pohlia nutans* are the pioneer colonizers, while a change in vegetation occurs from 30 to 50 m with the entry of the dwarf shrub *Kalmia angustifolia* , which becomes dominant, together with a thick moss cover of *Polytrichum commune* and *Pohlia nutans*. The acid-tolerant woodland grass *Deschampsia flexuosa* can be found at a distance of 80 m and beyond. The number of lichen species suddenly increases from 1 to 5 at a distance of 100 m from the roast bed. The number declines there after, but rises to 7 species 300m from the roast bed edge. These shifts in vegetation are accompanied by a decline in bare ground and an increase in litter accumulation, see Table 6 (Hutchinson and Symington, 1997). This type of vegetational pattern as a response to point source pollution was first identified by Gorham and Gordon (1960a) along a NNE transect from the Falconbridge smelter. They concluded that plants tolerant of sulphur dioxide, not commonly found in mature forests, were able to colonize the ground once competition from normal forest species was reduced due to air pollution. Then as distance from the source of pollution increased, less tolerant species were able to survive, with the most sensitive species present at distances greater than 25 km (Gorham and Gordon, 1960a).

The contrast between the tolerances of the two *Deschampsia* species to heavy metals and to acidity has been noted several times previously in the Sudbury area (Freedman and Hutchinson 1980, Cox and Hutchinson 1980, 1981 and Howson, 1984). *D. flexuosa* is a very widely distributed acid woodland species in Europe and has a similar ecological position in Canada. It was, and is, present in the forests around Sudbury and was undoubtedly a dominant forest floor species at the time of the commencement of the O'Donnell roast yard. However, while in Europe it has been described as a metal-tolerant species and could reasonably have been expected to be a principal re-colonizer of the contaminated lands around the smelters and roast yards, it was the much less common and less likely species *D. cespitosa* that did this. While Howson (1984) showed *D. flexuosa* could tolerate great soil acidity and high associated aluminum and manganese concentrations, it was *D. cespitosa* with a normal distribution on basic and calcareous soils around the Great Lakes that colonized the most barren acidic and metal-contaminated lands (Cox and Hutchinson 1979, 1980). Experiments showed that the Sudbury populations of *D. cespitosa* had simultaneous tolerance to very high concentrations of Ni, Cu, Co, As, Ag, Pb, Cd, Zn, and Al. At the O'Donnell roast yard, this general Sudbury differentiation between the tolerance and ecological niches of these species is repeated. *D. cespitosa* is only on the severely metal-contaminated roast yard and is a recent invader, while *D. flexuosa* is absent from the roast yard itself, but begins to be a major forest floor species in the birch forest at 80m from the roast bed edge, where the soil is still strongly acidic but where the nickel and copper levels are lower. Nevertheless, even at 80-300m where *D. flexuosa* now occurs, it is showing perhaps greater Ni and Cu tolerance than elsewhere in it's Sudbury occurrences.

The other species on the roast yard and in the open area of 50m from the roast yard include the moss *Pohlia nutans* which is reported from the UK and from Canada as having a remarkable Cu tolerance (Hutchinson, 1979) and the grass *Agrostis scabra* which Hogan *et al.*, 1977 showed to be both Ni and Cu tolerant on the roast yard. Clearly the most toxic and open locations at O'Donnell have been invaded by only the most remarkably metal-tolerant species. As the metal levels decreased over time, the land then allowed invasion and re-colonization by less extreme stress-tolerant species which eventually form the birch transition forest. This forest appears normal at casual examination but is, nonetheless, in the second stage of recovery, and has evolved on soils which still present major challenges of phytotoxicity.

Table 6. O'Donnell Roast Bed Percent Ground Cover of Vegetation - 1994 (from Hutchinson and Symington 1997). Note: + represents "presence".

	DISTANCE FROM ROAST BED (m)									
SPECIES	0	0	10	30	50	80	100	150	200	300
Pohlia nutans (moss)	15	1	52	93	26	-	-	-	-	-
Agrostis scabra (tickle grass)	9	-	2	3	-	-	-	-	-	-
Carex spp (sedges)	3	-	2	+	-	-	-	-	-	-
Deschampsia cespitosa (tufted hair grass)	-	9	-	-	-	-	-	-	-	-
Betula papyrifera (paper birch)	-	-	7	1	5	2	1	1	-	+
Kalmia angustifolia (sheep laurel)	-	-	+	1	43	84	67	3	4	33
Polytrichum commune (hair-cap moss)	-	-	-	1	41	22	+	-	1	+
Deschampsia flexuosa (wavy hair grass)	-	-	-	-	-	+	+	+	-	12
Ledum groenlandicum (labrador tea)	-	-	-	-	-	-	-	62	12	-
Fragaria virginiana (wild strawberry)	-	-	-	-	-	-	-	2	14	-
# lichen spp	1	-	1	1	1	1	5	2	3	7
OTHER ASPECTS OF GROUND COVER (percent of ground occupied)										
Bare ground	65	90	-	3	-	-	-	-	-	-
Dead wood	+	1	6	2	5	6	1	10	23	3
Leaf litter	7	1	2	4	10	75	96	100	98	90

Bioassay:

Even though seedlings of more tolerant species are now present at the sites off the roast yard, the soils are still toxic to the variety of radish (Cherry Belle) used in the bioassay, indicating that there is a prerequisite for metal and acid tolerance in order to establish in the area surrounding the O'Donnell roast bed. This lack of metal tolerance in the bioassay test species (radish) is demonstrated by the inhibition of root growth shown throughout the bioassay results.

Metal Content in Vegetation surrounding O'Donnell:

Relatively tolerant species such as paper birch trees have been able to colonize on soils of low pH and high metal concentrations. Unda (1980) and Hutchinson and Symington (1997) investigated the accumulation of heavy metals in the leaves of paper birch trees growing in the area surrounding the O'Donnell roast bed. Their combined results show a dramatic decrease in Cu uptake in 1994 when compared to 1979, reflecting the decrease in water-extractable Cu during this same time period. The Ni content however does not follow the same trend in that it slightly increases from 1979 to 1994 (Table 7). The organic content of soils has presumably increased in the last twenty years, and since copper binds tightly to this organic component in soil, less would be available for uptake by plants.

Table 7. *Betula papyrifera* (paper birch) foliar content: (1979 data from Unda 1980, 1994 data from Hutchinson and Symington, 1997). bdl=below detection limit

	1979		
	ug/g	Range	n
Cu	274.2+/-227.8	6-2546.6	11
Ni	37.1+/- 6.2	8.4-77.2	11
Zn	64.8+/- 6.9	35.9-94.3	11
	1994		
	ug/g	Range	n
Cu	4.4+/-2.0	bdl-7.4	10
Ni	47.5+/-26.5	19.2-102.6	10
Zn	101.4+/-61.2	19.2-220.8	10

These metal levels found in the birch leaves around O'Donnell are high when compared to other studies. For example, nickel concentrations in plants growing on uncontaminated soils are usually lower than 10 ppm (ug/g). Hutchinson (1981) found citrus plants demonstrated toxic symptoms when their leaves contained 55 ppm. Halstead *et al*, 1969 as quoted by Hutchinson 1981 found a decrease in growth of straw when it contained 28 ppm and alfalfa showed a reduction in growth when its foliar levels were greater than 44 ppm of Ni. The levels of Ni found in birch leaves in 1994 (ranging from 19 to 102 ppm) are approaching the level of toxicity demonstrated in other plants.

Trees:

Tree rings have been used as useful biomonitors of historical heavy metal pollution and acidification in a number of different species, describing the behaviour of a variety of elements (Eklund 1995a,b; Jonsson *et al*, 1997; Guyette, *et al*, 1991; and Dickinson, *et al*, 1996). For an evaluation of the use of dendrochemical analyses in environmental monitoring see Watmough (1997).

Very few trees were growing in the vicinity of O'Donnell during its operation. Therefore the use of dendrochemical techniques to reconstruct O'Donnell's impact is not possible immediately adjacent to the roast bed. The closest trees that were living at the time of operation were found at Creighton (7km from the roast yard), and cored in hopes of reconstructing part of the pollution history of the O'Donnell roast bed. Elevated levels of both Ni and Cu are seen in annual rings at Creighton, compared to those at the control site. There is a distinctive metal elevation, particularly with respect to Ni, within the rings formed during O'Donnell's operation. The overall elevated levels reflected in the annual rings at Creighton may indicate a level of metal tolerance in red oak.

5.0 Concluding Discussion

In seeking to understand how and why past events came about, including such things as the decisions to build the O'Donnell roast yard and the townsite, and the decision 13 years later to close it, it is useful to determine, as best one can, the motives and pressures on the decision makers of the time. Five steps can be used to begin to understand the behaviour of INCO, the provincial government, independent scientists and community members of that time. These are their: 1) Awareness 2) Information 3) Knowledge 4) Attitude, and 5) Behaviour.

As early as the late 1800's during the discovery of the Mond process, it was realized that metals could be volatilized quite readily at comparatively low temperatures. However, this information was not translated into an awareness that roasting ore in open heaps would volatilize heavy metals to be subsequently deposited in a wide area surrounding the smelters, until the late 1960's (70 years later). The elevated levels of Ni and Cu in the soils immediately surrounding the O'Donnell roast bed were deposited by aerial deposition during the roasting process. O'Donnell workers would have breathed this air, laden not just with sulphur but also with significant levels of nickel and copper. The impacts on human health of such mining and smelting operations were investigated in Wales as early as 1933, when nickel was identified as a carcinogen. Yet, impacts on human health were not seriously explored in the Sudbury area until the 1970's.

In numerous cases, including the effects of lead and mercury exposure and the significant effects of exposure to asbestos fibres, information about human and environmental health impacts was needed before action was taken to minimize exposure. Often this involved pressure for governmental legislation from the newly informed community. It is indeed rather rare for scientific findings to be embraced directly by a company generating a pollution problem. The steps to increased awareness need to reach government and the community before ameliorative action is taken. Often the knowledge itself was not obtained until new analytical techniques allowed a better definition of human exposure to take place. Examples of recognition of problems being dependent upon analytical advances are identification of polychlorinated biphenyls and dioxins as organic contaminants following the development of high performance liquid chromatography and the introduction of atomic absorption spectrophotometry allowing detection of heavy metals. Many toxic trace-metal problems were identified in the 1960's when atomic absorption equipment became available commercially (Willis, 1975). This relatively simple and inexpensive analytical tool enabled scientists to explore questions of heavy metal contamination, with accuracy and detection limits much better than those previously available.

During the operation of the O'Donnell roast bed (1916 - 1929) there were many complaints filed by area farmers for crop damage due to the roasting process. Although the environment was described as "choking" and one in which it was hard to breathe, no complaints were filed with regards to the impact of this roasting on human health, either during O'Donnell's operation or afterwards. This would seem to suggest a lack of concern of the effect on human health. However, the large number of workers that quit within a few days of arriving at O'Donnell did suggest the working conditions were unacceptable to many.

Productions rates of nickel were greatly increased in the first World War to meet the allies need for nickel for armaments. INCO had a monopoly over Canadian nickel and at this time Canada was the leading world producer of nickel at about 75-80% of world production. In the early days nickel was used for coinage, during the first World War in steel production for armaments, and afterwards in the aviation industry. Since INCO roasted 60 percent of it's ore, and the O'Donnell roast yard was it's only roasting operation, a massive amount of ore would have been roasted at this site during the years 1916-1929. This level of production devastated the vegetation of the entire area surrounding O'Donnell and exposed workers to a massive amount of air pollution. It is clear that the importance of contributing to a national war effort was a priority that overrode all else. The contribution of personnel for the armed forces was one priority area, while two others included workers for the war industries and workers for food production. Interestingly, in the Soviet Union during the Second World War, 50% of all steel manufactured for tanks, shells, etc., was produced at Magnetigorsk in the Ural Mountains. To accomplish this, enormous sacrifices had to be made. The town and its workers received the Order of the Soviet Union and large statues were erected outside the steel works in their honour. Neither the community of Sudbury, nor O'Donnell, have been nationally recognized for their contribution to the allied World War effort through the production of nickel, even though the workers in these communities certainly have earned such recognition, especially in view of the adverse conditions in which they toiled and lived.

Once O'Donnell closed, the roast yard and townsite were abandoned. At this time, there was no vegetation for a three-mile radius. Ironically, this abrupt closure left the O'Donnell roast yard as an excellent case study, enabling unique research into the mechanisms of natural ecosystem recovery to take place. According to Smith (1987) there is mining's (or miner's) response to nature, as well as nature's response to mining. With respect to O'Donnell, mining operations dominated the environmental concerns. Land, air and water were contaminated in the name of economic necessity through mining operations. Determining present day contamination levels allows one to document "nature's response to the roasting process" as well as to reconstruct historical levels of pollution, to which the community of O'Donnell and its workers would have been exposed. In 1994, the Ni and Cu contents on the roast bed itself were still several thousand ppm (1728-10051 ug/g Ni), and still several hundred ppm (115-1633 ug/g Cu) in the area surrounding O'Donnell, while uncontaminated soils average 22 ppm for nickel and 19 ppm for copper (Cox and Hutchinson, 1979). In the last twenty years the soils have increased in their organic content which binds copper and prevents it from being taken up by plants. This is reflected in the amount of total copper and nickel not substantially decreasing over time, whereas the water-extractable portion seems to have decreased since 1979. Since these highly toxic levels are the result of aerial deposition from the roasting process, substantial amounts of these particulate heavy metals would have been in the air and subsequently breathed in by both workers and area residents. More than 68 years after the operation has closed, metal levels of the soil are still phytotoxic as shown by the bioassay results. Very few radish seeds were able to germinate on soils collected within 300 m of the roast bed itself, indicating that the plants able to establish in this area must be tolerant of the low pH and high heavy-metal content of the soils.

Ecological assessment of this site in 1994 led to the conclusion that there is a remarkable physical "footprint" left by the roasting process that can be clearly seen 68 years after its closure. If these present day chemical analyses of soils surrounding O'Donnell were given to an ecologist, and this ecologist was asked to predict from these data what plants would be growing there, the ecologist's educated prediction would be "none". The fact that a birch forest has re-colonized the area shows an extraordinary evolutionary capacity of these plants and the entire ecosystem, to adapt to and to tolerate these toxic conditions. Understanding these mechanisms of natural ecosystem recovery under such polluted conditions is important in rehabilitating contaminated areas after these types of stresses have been alleviated.

Despite these polluted conditions the former O'Donnell residents who have been interviewed were very happy living there. They felt lucky to grow up in O'Donnell, and many were very sad to leave when it closed. They had very strong social bonds and community pride. They felt they had struggled to good effect and had raised families to their own satisfaction. They did not feel that they, or their families, were at risk from pollution effects on human health.

Impacts on both environment and human health continued at O'Donnell during its 13 years of operation despite available information that could or should have motivated the Canadian Copper Company to change its behaviour, i.e., close O'Donnell. For example, it was well known to the mining company, government, farmers and community that the roasting process killed all vegetation in the immediate vicinity. There was a level of awareness from reports on other similar areas that had been investigated by both the company and provincial government as to how these other operations dealt with community complaints (i.e. the Selby commission in the U.S). Attitudes towards this type of information vary with the associated value placed upon it. This can be demonstrated by using the previous example of SO_2 killing vegetation.

1) The farmer who is dependent on his crops for his livelihood would place a very high value on vegetation.
2) The community member who depends on the Canadian Copper Company (CCC) for his or her livelihood would place a very high value on his income, and probably very little on vegetation.
3) The community member who does not depend upon the CCC for their livelihood would perhaps place value on their gardens, trees or flowers, more so than those financially dependent on the CCC.
4) The Company - CCC is interested in mining and places a high value on economic stability and, in turn, little value on vegetation.
5) The Government would value mining because it makes money for the province as a whole, and would not place much value on vegetation, unless of course it could also be profitable, i.e. white pine trees. This would then cause a conflict in values.

These attitudes are then translated into behaviours. For example:

1) The farmers whose crops have been damaged from sulphur fumes by roasting seek appropriate compensation.
2) The community financially dependent upon CCC accepts this lack of vegetation as 'part of the job'.
3) The community member not financially dependent upon CCC object to the pollution.
4) CCC argues that their process is not able to continue without killing vegetation and if operations ceased, everyone would "lose".
5) The provincial government supports CCC, and investigates the potential impacts on white pine.

However, these attitudes change with circumstances. For example, the demand for nickel during the first World War substantially strengthened CCC's position. Supplying nickel for the war effort took precedence, and during this period O'Donnell's workers, residents and surrounding ecosystems literally paid the price. Again, at O'Donnell, there was the perception that there were no long-term human health consequences resulting from the roasting process. The air was at times unbreatheable, and workers had very frequent nose bleeds, but because there was no perceived risk to human health (lack of awareness), no change in attitude, or behaviour resulted.

One becomes very familiar with ones surroundings and grows accustomed to what one experiences on a regular basis. Former O'Donnell residents have commented that they didn't think O'Donnell was an awful polluted place because "it was all they knew". Often it takes someone like Tom Hutchinson, coming from outside, who had the awareness that Sudbury in general was a very polluted place. This was based on his own working knowledge of other polluted systems in the U.K. and Europe and was used to initiate research into an aspect (heavy-metal toxicity to vegetation), previously unexplored at Sudbury. Then over time, as new information was accumulated and communicated a new knowledge base was used to modify attitudes and lead to changes in the behaviour of others. As Tom Peters (formerly of the agricultural sector at INCO) indicated, Tom Hutchinson and his graduate student Leslie Whitby presented the first detailed study of the substantial contamination of the Sudbury area by heavy metals and their phytotoxic consequences to the ecosystems in preventing re-vegetation.

Federal policies had little effect on CCC's behaviour. With the initial rights to mine in Canada, Samuel Ritchie agreed to refine his product in Canada. But he didn't do so. It took over 30 years before a refinery was established in Port Colbourne. In 1885, Ritchie, of Ohio, was given the right to mine in Canada if he agreed to refine the nickel and copper ore in Canada. Ore was instead sent to New Jersey U.S. for refining. However, during the first World War concern developed over Sudbury nickel being supplied to German forces, via the United States. It was because of this national and commonwealth pressure that INCO established the facility for refining at Port Colbourne in southwestern Ontario, in 1917.

In 1916 and 1917 there was substantial local, provincial and federal pressure to stop open heap roasting. However, this practice continued at O'Donnell until 1929 when the roast bed closed. Open-heap roasting was the cheapest (excluding the environmental impact) technology available to reduce the sulphur content of the ore. Mining companies other than CCC abandoned the practice in favour of other technologies long before CCC closed the O'Donnell roasting yard. Sulphuric acid production started in the Sudbury region in 1925, which somewhat reduced the amount of sulphur released to the surroundings. At the time of O'Donnell's closure a new smelter was erected at Copper Cliff, with the financial help of the Provincial government.

The first lawsuits taken to provincial court as a result of the roasting and smelting processes of the Sudbury area were in 1916. Throughout the assessment of damages at the time of O'Donnell's operations, the visibility of damage was the focus. The judge expressed confidence in information presented by company scientists and officials. This information included the claim that this amount of sulphur may actually be beneficial to plants, that farmers mistook disease for sulphur damage and that claims were exaggerated by farmers. The provincial court did award damages to the farmers. However, these awards were much less than the amount claimed by the farmer for damage. It was not until

1974 that the Canadian Environmental Law Association (CELA) "won" against INCO. INCO was convicted of air pollution and fined $1500.

It is clear that attitudes towards environmental protection are changing and this can be supported by INCO's behaviour as of late. Recently, Charlie Ferguson of INCO spoke at the Sudbury restoration workshop about their recent purchase of a nickel deposit at Voisey Bay in Labrador. He described the environmental impact assessment taking place for the project proposal and suggested that had such an assessment been done at Sudbury, there would be no need for a Sudbury "restoration" workshop. The onus is now on the company to "prove" that there will be minimal environmental impacts as a result of their operations, prior to the mining taking place.

Economic considerations continue to be important to INCO. This has been recently demonstrated by the Voisey Bay project. In 1995, when INCO bought this massive deposit and nickel was worth $3.50 a pound, they agreed to build a smelter and refinery in Newfoundland (NFLD). However, when prices dropped below $2.00 a pound, INCO decided it would be more profitable to ship the nickel to their existing refineries in Sudbury, Ontario, and Thompson, Manitoba. INCO argues that it is not financially worthwhile to build a refinery in Argentia, NFLD. Brian Tobin, the premier of NFLD, has however denied INCO mining rights unless they refine locally, and talks between INCO and the provincial government broke off in July 1998 (Harvey, 1998).

During O'Donnell's operation and afterwards the provincial government of Ontario had such close interaction with INCO that there was no room for appropriate assessment of INCO's operations with respect to pollution control. It is however encouraging that in this type of situation, outside university scientists and environmental groups such as the Canadian Environmental Law Association were able to force INCO to address relevant issues leading to changes in attitudes and behaviour with respect to air pollution reduction during the 1960's and 1970's.

In considering my own approach to the subject of the O'Donnell roast yard, both historical and scientific analytical approaches were combined. It is useful to reflect on the value of this divergent methodology. Others have described such a situation as the following:

> Both history and ecology may be defined as the study of organisms in all their relations, living together, the differences between plant, animal, and human ecology or history being primarily a matter of emphasis (Malin, 1950 as cited by Whitney, 1997).
>
> One of the anomalies of modern ecology is that it is the creation of two groups, each of which seems barely aware of the existence of the other. The one studies the human

> community almost as if it were a separate entity, and calls its findings sociology economics, and history. The other studies the plant and animal community, [and] comfortably relegates the hodge-podge of politics to "the liberal arts." The inevitable fusion of these two lines of thought will, perhaps, constitute the outstanding advance of the present century (Meine, 1988).
>
> But above all it is ecology, which examines the interactions among organisms and between them and their physical environments, that offers the environmental historian the greatest help (Worster, 1988).

To document the environmental response to O'Donnell, both the human and plant communities were explored. Former O'Donnell residents were asked to describe environmental conditions during their time at O'Donnell and inevitably their present day view was part of the discussion. Then to assess present environmental conditions and the residual ecological footprint of the O'Donnell operation, a scientific analytical approach was used.

Documentary evidence of the environmental and social impact of O'Donnell included local histories, government documents, employee cards, oral histories, legal documents, scientific literature, maps and photographs. Field evidence of O'Donnell's impact was documented through soil analyses, plant community composition and tree ring analyses. Each type of evidence provided a different piece of the O'Donnell puzzle, and each document has its strengths and limitations. The field evidence shows that this site was exposed to severe levels of air pollution over a wide area surrounding the roast bed, and this extensive pollution, 68 years later is still having a toxic effect on the soil and its associated plant community. Nature's response to O'Donnell has been remarkable, and perhaps unexpected. An ecologist would not expect vegetation to be able to tolerate present soil conditions of toxicity at O'Donnell, yet the surrounding area is vegetated by a birch dominated forest.

The documentary evidence of early descriptions of the environment surrounding O'Donnell and other roast beds indicated that the government, company and local residents were aware heap roasting ore killed vegetation. The photographs provided by former O'Donnell residents as well as the 1927 aerial photograph show this complete lack of vegetation surrounding O'Donnell. Scientific documentation addressed the impacts of mining with focus on the sulphur dioxide damage during O'Donnell's operation and in the 1960's included heavy metal contamination. Former O'Donnell residents were happy living there and developed strong social bonds that were more important than environmental and human health consequences due to the roasting process. The combination of these types of evidence is useful in documenting the impact of this roasting process and then in turn assessing the speed of ecosystem recovery from such a severe stress. The scientific investigation indicate what polluted conditions were like but cannot report on the response of those who lived through them. The other types of historical and social documentation describe the community's response, but contained no evidence of the actual degree and complexity of the pollution to which people were exposed.

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Appendix A

An example of the employee card used at the O'Donnell Roast Yard (1916-1930)

THE INTERNATIONAL NICKEL CO. OF CANADA, LIMITED

Form No. 123

MINING AND SMELTING DIVISION

Employment Number: 5101

Date: OCT 8 - 1920

Previous Employment Record: Barnes & David Steel Co. Toronto Ont.

Name ...

Nationality Canadian

Occupation Laborer

Rate 50ct per hr Year Born June 26, 1902

Department O'Donnell Ont.

Employee's Signature

Hired by Foreman	O.K. Supt.	Examined by Dr.
RR	WM	

Ent'rd by Time Ck.	Stencil Cut By	Rate O.K. Paym'ter
EJB	H	[illegible]

Date Left Employ Oct 9/20 4002

Reason Jumped. Work was misrepresented by agent in Toronto

THE INTERNATIONAL NICKEL CO. OF CANADA, LIMITED

Form No. 123

MINING AND SMELTING DIVISION

Employment Number: 5070

Date: JUL 23 1920

Previous Employment Record: Hydro Electric Co Niagara Falls Ont.

Name ...

Nationality Irish

Occupation Laborer

Rate 50¢ per hr Year Born Aug 3, 1878

Department O'Donnell Ont.

Employee's Signature

Hired by Foreman	O.K. Supt.	Examined by Dr.
RR		

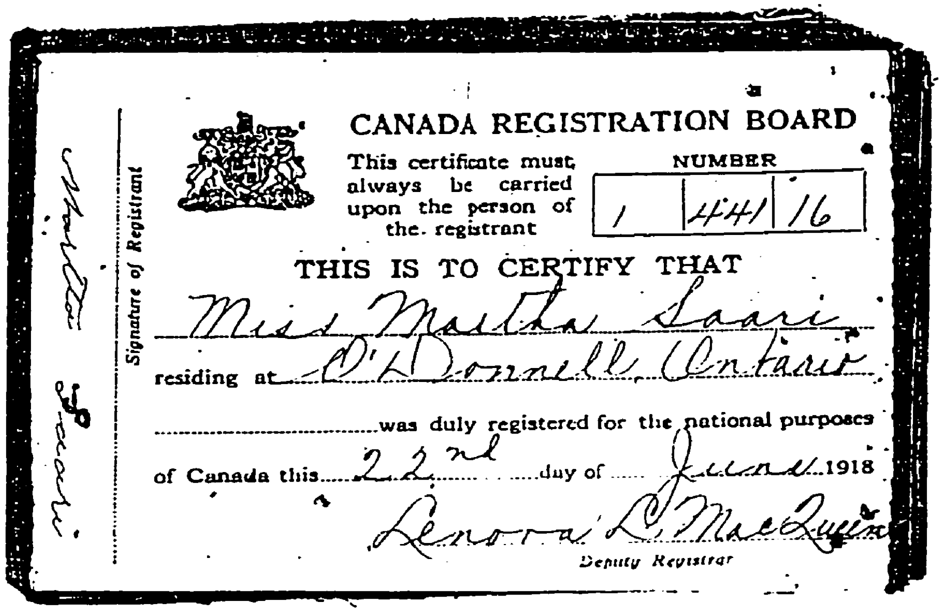
Ent'rd by Time Ck.	Stencil Cut By	Rate O.K. Paym'ter
EJB	[illegible]	[illegible]

Date Left Employ July 26/20 2841

Reason Can't stand the smoke

Appendix B

A photocopy of the Canada Registration Board card



CANADA REGISTRATION BOARD

This certificate must always be carried upon the person of the registrant

NUMBER 1 | 441 | 16

THIS IS TO CERTIFY THAT

Miss Martha Saari

residing at O'Donnell, Ontario

.... was duly registered for the national purposes of Canada this 22nd day of June 1918

Lenora L. MacQueen

Deputy Registrar

Signature of Registrant: Martta Saari

O'Donnell Roast Bed Total Soil Digests (1994) (ug/g):
Mean +/- standard error (n=3)

SITE	pH	Ni	Cu	Co	Zn	Ca	Mg	Na
RB1	3.9	2069+/-968	1728+/-812	58+/-21	98+/-23	5462+/-1351	8350+/-1251	999+/-164
RB2	3.4	6672+/-2959	3648+/-211	167+/-76	176+/-64	4327+/-463	4453+/-1288	1991+/-103
RB3	4.4	8885+/-4397	10051+/-6727	299+/-162	203+/-101	21328+/-8003	7820+/-2480	1716+/-878
10m	3.9	217+/-56	308+/-76	14+/-2	102+/-9	6019+/-546	6667+/-248	356+/-12
30m	4.1	355+/-237	499+/-261	12+/-5	47+/-0	5122+/-42	2737+/-113	330+/-40
50m	4.4	115+/-46	149+/-37	5+/-2	48+/-32	3896+/-566	1309+/-418	230+/-20
100m	4	352+/-85	388+/-113	11+/-2	29+/-6	2908+/-351	1403+/-99	158+/-15
300m	4	283+/-94	338+/-125	8+/-2	35+/-6	2978+/-90	993+/-185	203+/-78
1km	4.2	221+/-55	188+/-26	14+/-4	96+/-40	5357+/-1462	4340+/-1550	323+/-54
3km	4.1	223+/-50	259+/-93	12+/-1	64+/-11	5956+/-1060	4058+/-1196	379+/-38
4km	4.5	353+/-100	302+/-67	16+/-3	60+/-5	5155+/-846	2845+/-555	306+/-39
Creighton	4.4	579+/-43	592+/-27	31+/-1	88+/-12	7736+/-802	4422+/-119	403+/-26
Hwy144		1633+/-292	905+/-160	60+/-16	156+/-16	5866+/-550	1789+/-239	137+/-34
Court	3.9	770+/-21	623+/-48	24+/-2	94+/-9	5012+/-422	1680+/-137	193+/-39

	pH	P	K	Mn	As	Mo	Cd	Pb
RB1	3.9	200+/-30	4799+/-585	395+/-90	7+/-2	0.5+/-0.1	0.3+/-0.2	26+/-8
RB2	3.4	92+/-16	4916+/-721	218+/-48	3+/-1	0.5+/-0.05	0.4+/-0.06	20+/-4
RB3	4.4	82+/-14	2342+/-412	373+/-120	2+/-1	0.3+/-0.1	1+/-0.6	9+/-2
10m	3.9	326+/-34	2554+/-348	2887+/-2444	5+/-1	0.7+/-0.3	0.2+/-0.03	12+/-3
30m	4.1	247+/-57	1129+/-98	221+/-59	7+/-4	0.8+/-0.3	0.2+/-0.01	29+/-18
50m	4.4	108+/-20	668+/-75	92+/-7	5+/-2	0.1+/-0.1	0.1+/-0.04	14+/-4
100m	4	171+/-38	728+/-57	92+/-8	22+/-6	1.2+/-0.1	0.3+/-0.1	46+/-9
300m	4	215+/-20	837+/-64	135+/-7	9+/-1	0.5+/-0.1	0.7+/-0.3	38+/-8
1km	4.2	262+/-78	1997+/-468	446+/-137	13+/-2	0.4+/-0.2	0.4+/-0.09	43+/-6
3km	4.1	287+/-21	1698+/-83	451+/-107	16+/-5	0.7+/-0.3	0.7+/-0.2	45+/-12
4km	4.5	218+/-16	1347+/-210	616+/-161	17+/-3	1.2+/-0.3	0.6+/-0.1	56+/-16
Creighton	4.4	278+/-9	1900+/-53	771+/-228	22+/-4	1.4+/-0.03	1+/-0.05	88+/-7
Hwy144		606+/-103	1659+/-223	2109+/-1743	31+/-12	1.9+/-0.3	3+/-0.3	222+/-59
Court	3.9	331+/-19	964+/-78	397+/-162	31+/-5	1.2+/-0.1	1.7+/-0.2	133+/-2

O'Donnell Roast Bed Soil Water Extracts (1994) (ug/g):

Mean +/- standard error (n=3)

SITE	Ni	Cu	Co	Zn	Ca	Mg	Na
RB1	7.9+/-3.1	11.9+/-3.5	0.2+/-0.1	0.3+/-0.1	37+/-13.8	14+/-5	13+/-3
RB2	42.5+/-1.2	50.8+/-1.3	8.0+/-2.6	4.8+/-1.0	386+/-26.5	120+/-26	40+/-10
RB3	26.7+/-6.8	41.9+/-4.0	1.0+/-0.2	0.9+/-0.1	585+/-223.0	89+/-18	17+/-4
10m	4.9+/-1.6	3.4+/-1.1	0.1+/-0.0	0.5+/-0.1	15+/-2.8	5+/-0.8	9+/-1
30m	1.8+/-0.8	1.8+/-0.4	0+/-0	0.3+/-0.2	5+/-1.0	2+/-0.5	6+/-1
50m	1.1+/-0.5	1.1+/-0.2	0+/-0	0.3+/-0.1	9+/-2.9	3+/-1.0	4+/-0.7
100m	1.0+/-0.3	3.2+/-0.7	0+/-0	0.3+/-0.1	22+/-6.2	10+/-3	7+/-0.9
300m	0.5+/-0.1	1.0+/-0.2	0+/-0	0.3+/-0.2	10+/-0.3	3+/-0.3	8+/-0.8
1km	0.7+/-0.0	1.6+/-0.2	0+/-0	0.3+/-0.1	13+/-0.6	4+/-0.3	7+/-4
3km	0.7+/-0.1	1.4+/-0.5	0+/-0	0.4+/-0.2	16+/-3.3	5+/-0.9	6+/-0.3
4km	1.4+/-0.3	2.8+/-0.2	0.1+/-0.0	0.2+/-0.1	26+/-0.1	6+/-0.8	9+/-0.7
Creighton	2.4+/-0.4	2.8+/-0.4	0.1+/-0.0	0.5+/-0.2	32+/-1.2	9+/-1.3	10+/-3
Hwy144	1.8+/-0.5	2.3+/-0.4	0.1+/-0.0	0.7+/-0.1	40+/-1.0	13+/-0.8	18+/-5
Court	1.7 +/-0.1	3.0+/-0.5	0+/-0	1.0+/-0.1	46+/-6.0	11+/-2.2	14+/-3

SITE	P	K	Mn	As	Mo	Cd	Pb
RB1	.02+/-.006	20+/-2	1.1+/-0.2	0+/-0	bdl	0+/-0	0+/-0
RB2	.02+/-.003	4+/-1	7.7+/-1.9	0+/-0	bdl	.05+/-.01	0+/-0
RB3	.04+/-.02	15+/-7	1.0+/-0.2	0+/-0	bdl	.03+/-.01	0+/-0
10m	.06+/-.01	20+/-2	1.2+/-0.2	0+/-0	0+/-0	0+/-0	0+/-0
30m	.3+/-.1	14+/-4	0.2+/-0.1	0+/-0	0+/-0	0+/-0	0+/-0
50m	.7+/-.2	22+/-2	0.4+/-0.1	0.01+/-0.0	0+/-0	0+/-0	0+/-0
100m	3+/-1	47+/-9	0.6+/-0.2	0.1+/-0.04	.01+/-.004	0+/-0	0.03+/-0
300m	5+/-1.6	36+/-8	2.1+/-0.4	0.1+/-0.05	.01+/-.004	0+/-0	0.02+/-.004
1km	2+/-0.7	53+/-3	2.4+/-0.6	0.05+/-0.02	0+/-0	0+/-0	0.04+/-.01
3km	5+/-2	44+/-8	2.6+/-0.5	0.1+/-0.08	.005+/-0	0+/-0	0.05+/-.02
4km	6+/-4	52+/-5	6.3+/-2.6	0.2+/-0.1	.01+/-0	0+/-0	0.05+/-.02
Creighton	4+/-1	50+/-8	2.3+/-0.7	0.1+/-0.05	0+/-0	.01+/-.003	0.05+/-.01
Hwy144	20+/-6	59+/-1	7.4+/-3.7	0.4+/-0.1	.01+/-.001	.01+/-.001	0.09+/-.008
Court	13+/-2	53+/-0.6	4.7 +/-0.6	0.4+/-0.1	0+/-0	0.01+/-.002	0.2+/-.04

Creighton Tree rings (ug/g) 1995 rings - Red Oak (each sample = five annual rings)												
CR #1	Mg	Al	P	K	Ca	Mn	Fe	Ni	Cu	Zn	Pb	
95-91	122	2	10	1959	768	92	92	7	14	12	1	
90-86	95	0	4	1512	546	72	28	1	4	3	0	
85-81	118	1	0	1970	771	84	31	7	8	4	0	
80-76	96	1	1	1580	586	58	62	11	3	5	0	
75-71	80	1	3	1470	369	47	37	4	4	3	0	
70-66	55	3	3	1255	298	19	29	4	4	3	0	
65-61	48	1	4	1074	202	13	50	5	2	2	0	
60-56	39	1	4	926	190	10	43	5	2	2	0	
55-51	35	2	1	866	184	9	25	4	2	2	0	
50-46	29	2	0	825	191	8	23	5	3	23	0	
45-41	24	1	0	808	229	7	21	5	3	3	0	
40-36	22	1	0	772	233	5	20	4	3	2	0	
36-31	51	bdl	13	1123	252	5	23	6	3	7	0	
30-26	156	bdl	103	3337	483	15	63	12	6	14	1	
CR#2												
95-91	114	4	152	2700	350	28	61	18	7	12	1	
90-86	19	5	12	982	197	9	28	7	3	5	0	
85-81	8	0	1	640	158	6	117	4	3	10	0	
80-76	11	2	2	699	177	6	22	4	3	2	0	
75-71	19	1	2	777	209	5	30	5	3	3	0	
70-66	17	1	1	739	199	4	19	3	2	1	0	
65-61	17	1	3	772	194	5	24	3	2	4	0	
60-56	16	bdl	2	781	182	6	27	3	2	2	0	
55-51	45	7	22	1898	425	17	37	7	4	2	1	
50-46	58	17	19	2338	444	40	83	6	5	2	0	

Red Oak - Creighton Tree rings (ug/g) 2nd core (1995)													
CR#1	Na	Ca	Al	Mg	Mn	P	K	Fe	Ni	Cu	Zn	Cd	Pb
95-91	26	449	95	120	21	120	2182	98	12	3	30	bdl	1
90-86	19	330	1	69	9	25	1100	45	6	1	29	bdl	1
85-81	34	288	3	27	5	5	750	43	4	1	5	bdl	0
80-76	20	281	2	38	8	6	779	44	5	1	3	0	0
75-71	36	117	2	36	9	6	831	32	5	2	3	0	0
70-66	2	219	1	40	11	4	815	41	4	1	4	bdl	0
65-61	41	292	2	53	14	5	913	50	5	1	5	bdl	0
60-56	23	221	1	57	18	5	982	50	5	1	7	0	0
55-51	32	598	6	94	46	9	1268	71	10	4	8	2	0
50-46	28	292	1	73	43	5	1094	35	4	2	4	0	0
45-41	22	774	3	81	59	7	1198	52	4	1	2	0	0
40-36	37	464	1	96	74	3	1381	95	2	2	1	0	0
CR#2													
95-91	56	456	12	121	17	114	2001	98	19	5	6	0	1
90-86	6	165	3	14	8	6	462	39	6	2	1	bdl	0
85-81	5	121	1	10	5	4	525	30	4	2	0	bdl	0
80-76	1	160	2	14	7	5	499	24	4	2	0	bdl	0
75-71	12	147	2	16	6	4	578	37	4	2	0	bdl	0
70-66	14	181	2	20	6	8	749	86	3	2	1	bdl	0
65-61	14	173	2	20	8	4	815	112	4	2	1	bdl	0
60-56	22	207	1	24	11	bdl	975	90	5	2	1	0	0

Reference Red Oak Tree - Hwy 35 Below Dwight (concentrations in ug/g) 1997												
Year	Na	Mg	Al	P	K	Ca	Mn	Fe	Ni	Cu	Zn	As
96-92	118	125	5	51	1352	867	26	147	2	1	130	0
91-87	79	29	1	16	1027	548	9	152	1	0	107	0
86-82	75	5	1	3	664	207	3	99	1	0	66	0
81-77	46	10	2	4	808	178	5	74	1	1	51	0
76-72	37	11	0	5	773	179	6	44	0	0	54	0
71-67	32	8	0	5	802	225	6	37	0	0	27	0
66-62	69	10	5	6	898	239	9	48	1	0	34	0
61-57	12	6	bdl	7	909	277	12	54	0	bdl	49	0
56-52	17	13	1	7	935	378	19	44	0	bdl	45	0
51-47	37	34	5	12	1082	728	50	42	1	0	46	bdl
46-42	54	34	6	15	1027	673	50	44	1	bdl	30	bdl
41-37	14	30	bdl	9	896	523	36	35	0	0	25	0
36-34	39	51	2	15	1237	1136	56	36	1	1	65	0