SOME EFFECTS OF SMELTER POLLUTION NORTHEAST OF FALCONBRIDGE, ONTARIO[1]

EVILLE GORHAM AND ALAN G. GORDON

Abstract

A study along a line NNE. from the metal smelter at Falconbridge, Ontario, reveals that strong sulphate accumulation in the surface soil occurs only within about one mile of the chimneys emitting sulphur dioxide pollution while effects upon the soil drainage waters are marked to a distance of nearly two miles, and still clearly evident 10 or more miles away. The number of species present in the flora declines sharply within about four miles of the smelter, but certain species (e.g. *Pinus strobus*, *Vaccinium myrtilloides*) disappear at much greater distances. Among the most tolerant species are *Acer rubrum*, *Quercus rubra*, *Sambucus pubens*, and *Polygonum cilinode*.

Introduction

Air pollution and damage to vegetation by sulphur dioxide from metal smelters have been studied in detail at Trail in British Columbia (3), and to a lesser extent at Sudbury in Ontario (2, 4, 6). The present paper reports measurements of sulphate concentration in soils and pond waters, together with an examination of plant distribution, along a transect roughly NNE. from the Falconbridge smelter near Sudbury.

The Falconbridge smelter is about 14 miles NE. of that at Copper Cliff, and about 7 miles NNE. of the Coniston smelter. It is the smallest of the three in the Sudbury area; ore and concentrates charged ranged from 231,000 to 475,000 short tons annually between 1936 and 1946; in comparison the charges at Copper Cliff and Coniston ranged from 1,659,000 to 4,149,000 and 334,000 to 987,000 tons respectively (1). The reasons for choosing the Falconbridge area to examine were varied: firstly, there is a series of small kettle-hole ponds lying NNE., near to the NE. direction of the prevailing summer winds; secondly, the habitats in the direction of the prevailing wind are more uniform, and have been less disturbed by human settlement, than near the other smelters; and thirdly, any pollution emanating from the other smelters will generally be maximal at the beginning of the Falconbridge transect. This accessory pollution should also compensate (to an unknown degree) for the transect being slightly off the prevailing wind direction.

Methods

During June 1959 a series of surface waters was collected from lakes and ponds at varying distances N. and NNE. of Falconbridge. In addition two small lakes were sampled near Emerald Lake, 35 miles to the NE., and on McLean Peninsula of Lake Temagami, 39 miles ENE. of Falconbridge; it is believed that at these distances pollution effects are negligible.

[1]Manuscript received January 22, 1960.
Contribution from the Botany Department, University of Toronto, and the Research Branch, Ontario Department of Lands and Forests.

In the same month plant communities were examined in the same general areas, those chosen being situated on sandy soils in the locations most exposed to air-borne pollution; valleys and protected slopes were avoided. Again sites near Emerald Lake and Lake Temagami were used as controls. The floristic study was conducted by laying out a 20-meter chain at random in each site, and recording the macrophyte species present less than 1 meter from either side of the chain. In addition some 10–20 minutes (depending on the nature of the cover) were spent in listing any accessory species observed in the same habitat near the chain.

Wherever the chains were placed for plant lists, two samples of the humus layer were also collected for measurement of soluble sulphate in the surface soil. Near the smelter such samples were difficult to find, since erosion (due to removal of the plant cover by pollution damage, and secondarily by fire) has eliminated the humus layer almost everywhere in the more exposed situations. This is reflected also in the lower ignition losses (mainly organic matter) of the humus layers near the smelter, which have been much contaminated by blown and drifting mineral soil exposed through erosion. Beyond 10 miles from the smelter ignition losses ranged from 54 to 85% dry weight, while within that distance the range was from 19 to 64%.

The soil samples were dried at just above 100° C, and aliquots were then shaken for 3 hours with 100 times their weight of distilled water. The extracts were filtered, and sulphate estimated by the technique of Mackereth (5), which was also employed on the pond waters. This technique includes any nitrate present along with the sulphate, but nitrates are likely to be of negligible importance in these soils and waters.

Results

Some effects of smelter pollution upon the vegetation and its environment are shown in Table I and in Figs. 1 and 2. The first figure shows that the normal sulphate concentration in pond waters of the region is probably in the vicinity of 0.3 meq/l., to judge from the two samples collected at Emerald Lake and Lake Temagami, and also a sample from Wanapitei Lake, which drains extensive areas to the north and east of Sudbury and contained 0.34 meq of sulphate per liter on the date sampled. Owing to fall-out and oxidation of sulphur dioxide from the chimney stacks, sulphate levels rise gradually on approaching the smelter, to about 0.6 meq/l. at 3 miles distance, and then very sharply indeed nearer the smelter, concentrations of 1.2 to 1.5 meq/l. being recorded between 1.0 and 1.5 miles away. It may be added that two waters collected at 0.8 to 0.9 miles S. of the smelter exhibited sulphate levels of 3.5 and 2.8 meq/l., without apparently receiving other than aerial pollution. The point of inflection for the sulphate curve in Fig. 1 would appear to be at about 2 miles from the pollution source.

In the case of the humus layers, soluble sulphates varied from about 2 to 5 meq per 100 g dry weight of soil over the whole range of sites between 1 and 40 miles from the smelter, as shown in Fig. 2(*a*). Only at 1 mile or less were

TABLE I

Distribution of ground flora species in relation to air pollution by sulphur dioxide

Species present in more than three of the 17 sites	Distance of site from smelter (miles)																
	0.7	0.8	1.0	1.0	1.1	1.5	2.0	2.4	3.2	4.5	5.3	7.6	11	16	19	35	39
Sambucus pubens	*	*		*		+	*				*						
Polygonum cilinode	*	+		*			*			*	+		*				
Comptonia peregrina			*		*	*		*			*						
Epilobium angustifolium				*			*	*	+	+	+	+	*				
Salix humilis				+	*	*	*	*	+	+	*	*	*	+			
Populus tremuloides				*			+	*	+	*	+	+	*	*			
Acer saccharum				*		+	+	*	*							*	
Populus grandidentata				*	*	*	+	*	*	+	+					+	
Smilacina racemosa						*	+		*	+	*						
Apocynum androsaemifolium									*	*	*	+					
Danthonia spicata										+	*	+			*		
Acer rubrum	*	*	*	+	+	*	*	+	+	+	+	+	+	+	+	+	
Quercus rubra	*	*	*	+	+	+	+	+		+	*			+	+	*	
Diervilla lonicera		*	*	*	*	+	+	+	+	+	+	+	*	+		+	+
Lonicera canadensis		*		*		+	+	*	+	*	+	+	+	*		+	+
Aster macrophyllum		*		+		*	+	*	+	+	+	+		+	+	+	+
Maianthemum canadense		*		*		*	+	*	+	+	+	+	+	+	+	+	+
Corylus cornuta			+	+	+	+	+	+	+	+	+	*		+	+	+	+
Vaccinium angustifolium			+		*		*	+	+	+	+	+	+	+	+	+	+
Aralia nudicaulis			*			+	*		+	+	+	+	+	+	+	+	+
Cornus canadensis				*					+	*		+		+	+	+	+
Prunus pensylvanica				*	*	*	+	*	*	+	+	+		+			*
Betula papyrifera				+				*	+	+	+	+	+	+	+	+	+
Oryzopsis asperifolia						+	+	+	+	+	*				+	*	
Acer spicatum						*			*		*	+	+	+		*	*
Amelanchier sanguinea						*						+	*		+		+
Pteridium aquilinum							*	+	*	+	+	*		+	+	+	+
Clintonia borealis									*	*	*			+	+	+	+
Lycopodium obscurum									+	+	*	*	*	*			+
Picea mariana												*	+	+	+	+	+
Abies balsamea												*	+	+	+		+
Pyrus decora												*	+		+	*	+
Trientalis americana												+	+	+	+	+	+
Linnaea borealis												+	+	+	+	*	+
Pinus strobus														*	+	+	+
Vaccinium myrtilloides														+	+	*	+
Total no. species per quadrat	0	1	2	6	3	8	12	7	16	21	19	26	19	31	26	19	30
Total no. species per site	5	9	8	18	9	20	26	21	24	32	34	40	37	42	31	29	36

NOTE: + signifies presence in 20 m × 2 m quadrat, * signifies presence outside the quadrat.

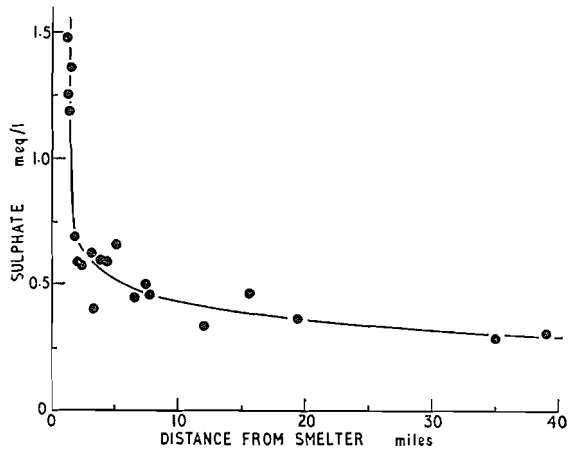

FIG. 1. Sulphate concentrations in surface waters at various distances NNE. and N. of the Falconbridge smelter (curve fitted freehand).

higher values recorded, ranging up to 20 meq per 100 g at the site nearest the pollution source, but still about 0.75 miles away. The secondary rise in sulphate beyond 10 miles distance, which coincides with a marked increase in soil ignition loss, suggests that the organic fraction is the important source of sulphate in these soils, and that a more valid expression of sulphate concentration might be given by expressing it per 100 g of ignition loss. This is done in Fig. 2(*b*), which reveals approximately the same picture as Fig. 2(*a*), except that the sulphate levels from 1 to 10 miles distance appear slightly higher than those beyond this limit. The soil extracts ranged in pH from 3.9 to 7.1, values below 4.9 were recorded only at 1 mile or less from the smelter, where however values up to the maximum were also observed.

As might be expected, the floristic studies showed a marked decrease in the number of species as the smelter was approached. In the case of the quadrats (20 m × 2 m), the more distant sites gave a range of 19 to 31 species, the number falling rapidly below the above minimum within 4 miles of the source of pollution, so that at less than 1 mile away only one species was present in one of the two random quadrats (Table I). The total species lists for each site gave a generally similar picture, with the distant sites ranging between 29 and 42 species, and those within about 4 miles of the smelter exhibiting a marked decline in numbers. In the two sites examined at less than a mile away, the widely scattered plants belonged to only 10 species.

It may be remarked that while species numbers remain above the minimum for the distant sites until within about 4 miles of the smelter, curves indicating the general trends appear to inflect at about 7 miles distance. Which distance should be taken as the true point of inflection may at present be regarded as a matter of choice. The numbers of species in the total lists are maximal at about 8 miles from the Falconbridge smelter. While the tendency to high numbers at intermediate distances may be accidental, the sites in this area

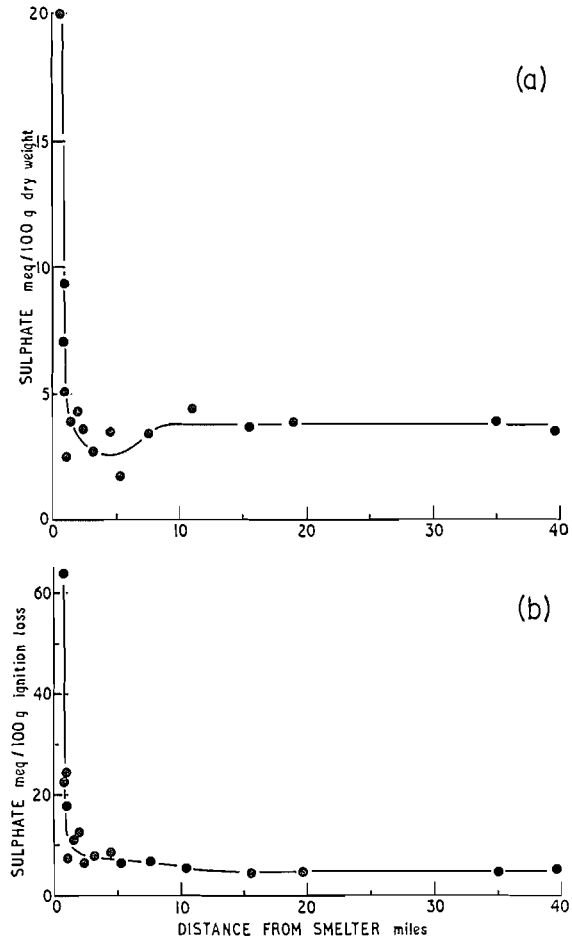

FIG. 2(*a*). Soluble sulphate in humus layers at various distances NNE. and N. of the Falconbridge smelter, expressed on dry weight basis (curve fitted freehand).
FIG. 2(*b*). Soluble sulphate in humus layers at various distances NNE. and N. of the Falconbridge smelter expressed on humus basis (curve fitted freehand).

appear to have been burned more frequently than those farther away from Falconbridge, so that the higher total numbers of species may equally well reflect a greater openness in the plant cover, with a consequent lessening of competition.

A detailed picture of the influence of air pollution upon the ground flora is also given by Table I, which lists the presence in the 17 sites of all species recorded in more than three of them (trees of more than 2 in. basal diameter being excluded). At the top of the list is a group of plants, most of which are not common in the more mature forests of the region, but are enabled by their relative tolerance of sulphur dioxide to colonize the ground once competition from normal forest species is reduced owing to air pollution. As might be expected, these are mainly seral species, and of these *Sambucus pubens* and *Polygonum cilinode* appear to be the most tolerant.

Following this group of plants is a series of species which are able to exist both in the normal mature forest and in more or less heavily polluted situations. *Acer rubrum* and *Quercus rubra* are the most characteristic of these, the first being almost ubiquitous. Reading down the list, species of lesser tolerance are encountered, until finally the most sensitive species appear. Among these last are *Vaccinium myrtilloides* and, unfortunately, *Pinus strobus*, a tree of great economic importance. The latter species was first observed at 16 miles along the transect NNE. of Falconbridge, but it may be noted that Linzon (4) was able to find a suitable plot for the study of this tree's response to air pollution at about 11 miles N. of this smelter, where however considerable damage was observed. At both 16 and 19 miles distance in the present study the white pines were commonly chlorotic.

Finally it may be worth remarking that the following species were recorded in three of the five sites more than 10 miles NNE. along the transect from the Falconbridge smelter: *Picea glauca*, *Viburnum cassinoides*, *Ribes glandulosa*, *Gaultheria procumbens*, *Polypodium virginianum*, and *Dicranum majus*. Ferns (three species, in four of the five sites) were observed only beyond 10 miles distance, but were nowhere abundant.

Acknowledgments

We are much indebted to Mr. Keith Acheson, Regional Director of the Ontario Department of Lands and Forests, for kindly arranging the use of a helicopter; and to the pilot, Mr. R. F. Ross, for so readily placing us in so many difficult situations.

References

1. COLE, R. J. 1949. The removal of sulphur gases from smelter fumes, 1947. A report by the Ontario Research Foundation. The King's Printer, Toronto.
2. DREISINGER, B. R. 1959. Interim report for 1958 to the Special Sulphur Dioxide Committee. Atmospheric sulphur dioxide measurements and the effect of the gas upon vegetation in the Sudbury area. Mimeographed. Dept. of Mines, Sudbury, Ontario.
3. KATZ, M. *et al.* 1939. Effect of sulphur dioxide on vegetation. Prepared for the Assoc. Committee on Trail Smelter Smoke. Natl. Research Council of Canada. N.R.C. No. 815, Ottawa.
4. LINZON, S. 1958. The influence of smelter fumes on the growth of white pine in the Sudbury region. Joint publication of Ont. Dept. of Lands and Forests and Ont. Dept. of Mines, Toronto.
5. MACKERETH, F. J. H. 1955. Ion-exchange procedures for the estimation of (I) total ionic concentration, (II) chlorides and (III) sulphates in natural waters. Mitt. Intern. Ver. Limnol., No. 4.
6. MCCALLUM, A. W. 1959. Report on field examination of the Sudbury area, July 11–18, 1958. Mimeographed. Dept. of Agriculture, Ottawa.