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DEVELOPMENT OF VEGETATION AND SOIL ON HIGH ELEVATION RECLAIMED LANDS IN SOUTHEASTERN BRITISH COLUMBIA

by

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ABSTRACT

Seeded grasses and legumes become established on waste dumps in the first growing season following seeding and significant growth takes place in the second year. The vegetation appears to be dependent on fertilization for approximately five years. Older reclaimed areas support shoot and root growth, soil CO2 evolution, and available soil organic matter at levels similar to those at undisturbed grasslands. Native soils contain higher levels of humus although reclaimed soils may contain resistant organic matter originally derived from coal or carbonaceous shale. Carbon and nitrogen compounds, indiginous in the waste rock, may play an important role in the development of reclaimed areas.

INTRODUCTION

On Thursday we will be taking a bus tour to the high elevation reclaimed areas on the property of B.C. Coal Ltd. (formerly Kaiser Resources Ltd.) near the town of Sparwood, about one and one-half hour's drive east of Cranbrook. This paper will act as an introduction to that tour, describing some aspects of the development of vegetation on coal mine waste and changes which occur in the spoil materials within the first ten years after their deposition.

THE SETTING

The reclaimed areas under consideration are a byproduct of the open pit coal mining. In recent years, the mine has produced up to seven million tons of metallurgical coal and has generated approximately 70 million tons of waste rock annually. The mine is a truck and shovel operation in which the overburden rock is blasted and then removed by trucks to be deposited in extensive waste dumps.

In preparation for reclamation the dumps are resloped using bulldozers to an angle of approximately 26°. A seed bed is prepared on the dump surface using a heavy pipestem harrow to break surface compaction and to provide microsites to aid in seedling establishment. The seed mix, which includes a number of grass and legume species, is broadcast by helicopter either in the early spring or the late fall. The seeding is followed by a fertilizer application (13-16-10) at 200 kg/ha. After seeding and fertilization, the dumps are reharrowed to incorporate seed and fertilizer in the soil.

The reclaimed areas are refertilized each year at a rate of 200 kg/ha of 13-16-10 fertilizer.

Over the past five years, research has primarily been directed toward the evaluation of the success of fertilizer maintenance, either from the point of view of increasing fertilizer efficiency through the use of different fertilizers, application rates and times or from a long term point of view, assessing the effect of management on the development of reclaimed soils and vegetation. One of the major and continuing problems is to determine the period of time that maintenance will be required before a reclaimed area could be considered self-sufficient.

SAMPLING AREAS

Most of the data presented in this paper has been obtained from a series of sampling plots ranging in age from unvegetated spoil (zero years) to six years old. All of the plots are located in level areas with a south westerly exposure at an elevation of approximately 2000 m. In choosing sampling areas, an attempt was made to ensure homogeneity of vegetation and spoil type between plots.

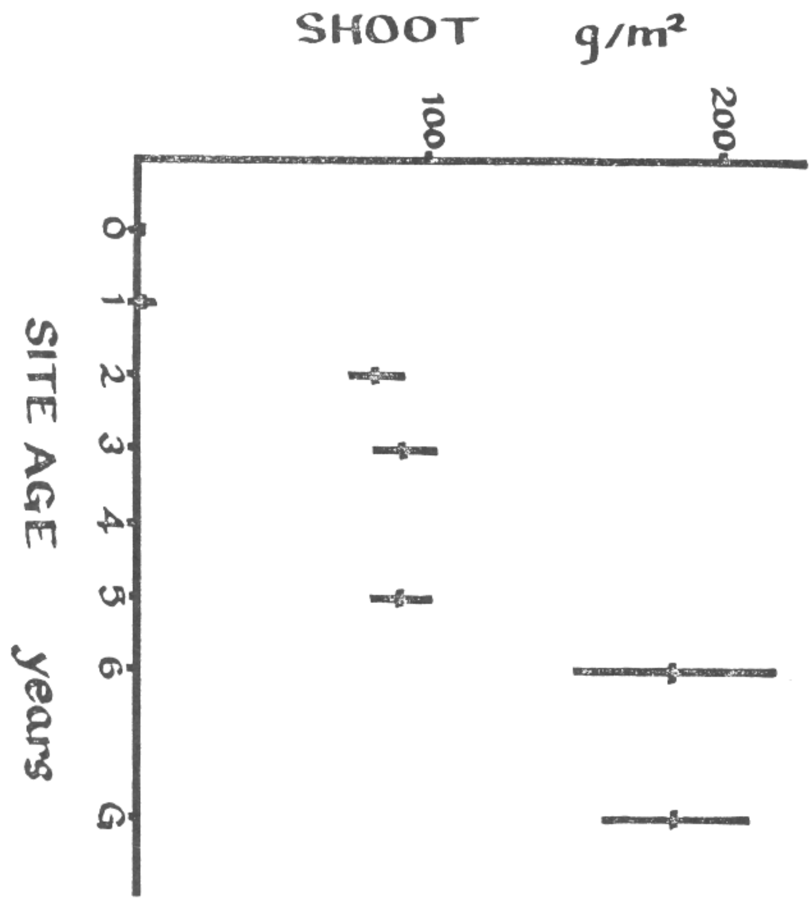
Since the oldest reclaimed site was only six years in age, an undisturbed native grassland adjacent to the reclaimed areas was included in the sampling as an example of a well established community which had developed under conditions similar to those of the reclaimed areas- Although the original parent material of the grassland soil was probably similar to that of the reclaimed areas, the site was located on a steep, southeasterly facing slope. In addition, the composition of the vegetation differed significantly from the reclaimed areas as it consisted entirely of native grasses, forbs and shrubs rather than agricultural species.

RESULTS AND DISCUSSION

The data shown in Figure 1 demonstrates that the establishment of vegetation is accomplished in the first growing season following seeding but actual shoot growth is very low until the second year. In the few

FIGURE 1

SHOOT GROWTH ON RECLAIMED AREAS OF DIFFERENT AGES AND THE NATIVE GRASSLAND (G). DATA POINTS IN THIS AND FOLLOWING FIGURES REPRESENT MEANS WITH 95% CONFIDENCE INTERVALS.



years following, it appears that growth remains relatively constant. The level attained is roughly that which would be expected with an input of 2 g/m^2 to 3 g/m^2 of nitrogen. Since this is the rate of annual fertilizer application we feel that this period of uniform growth is probably the result of the dependence of the vegetation on fertilizer nitrogen during the early years.

The shoot growth on the six year site is considerably higher than the other reclaimed areas despite the fact that it was not fertilized in the year of sampling. This suggests that the processes of nutrient storage and cycling are taking place on this site to a degree that will allow substantial growth of vegetation without the fertilizer nutrient supply.

The similarity in the levels of shoot growth measured on the six year site and the natural grassland may indicate that, at least in the year of sampling, growth in these areas was limited more by climatic conditions than by nutrient supply.

We found a number of close similarities between the undisturbed grassland and the six year site, some of which are shown in Figure 2. In addition to shoot growth discussed above, there are comparable levels of root biomass in the surface 10 cm of these sites. The slightly higher root density measured in the reclaimed site has been found in other reclaimed areas as well and may be caused by the stimulation of surface root growth by annual top dressing with fertilizer.

The evolution of CC>2 from the soil surface in the field can be broadly interpreted as an index of the overall metabolism of below ground organisms including micro-flora and fauna, and larger organisms such as arthropods and worms as well as plant roots (Macfadyen 1971). We measured very similar levels of CC>2 evolution from the soils of the oldest reclaimed site and the undisturbed grassland (Figure 2).

In addition to similarities in biological parameters between the reclaimed and undisturbed areas we found the concentrations of several soil nutrients, including available phosphorus, potassium and other exchangeable cations, to be comparable in the two soils.

The data presented above suggests that management practices have been successful in developing a reclaimed soil/vegetation system which, in many respects, resembles an undisturbed condition. Differences,

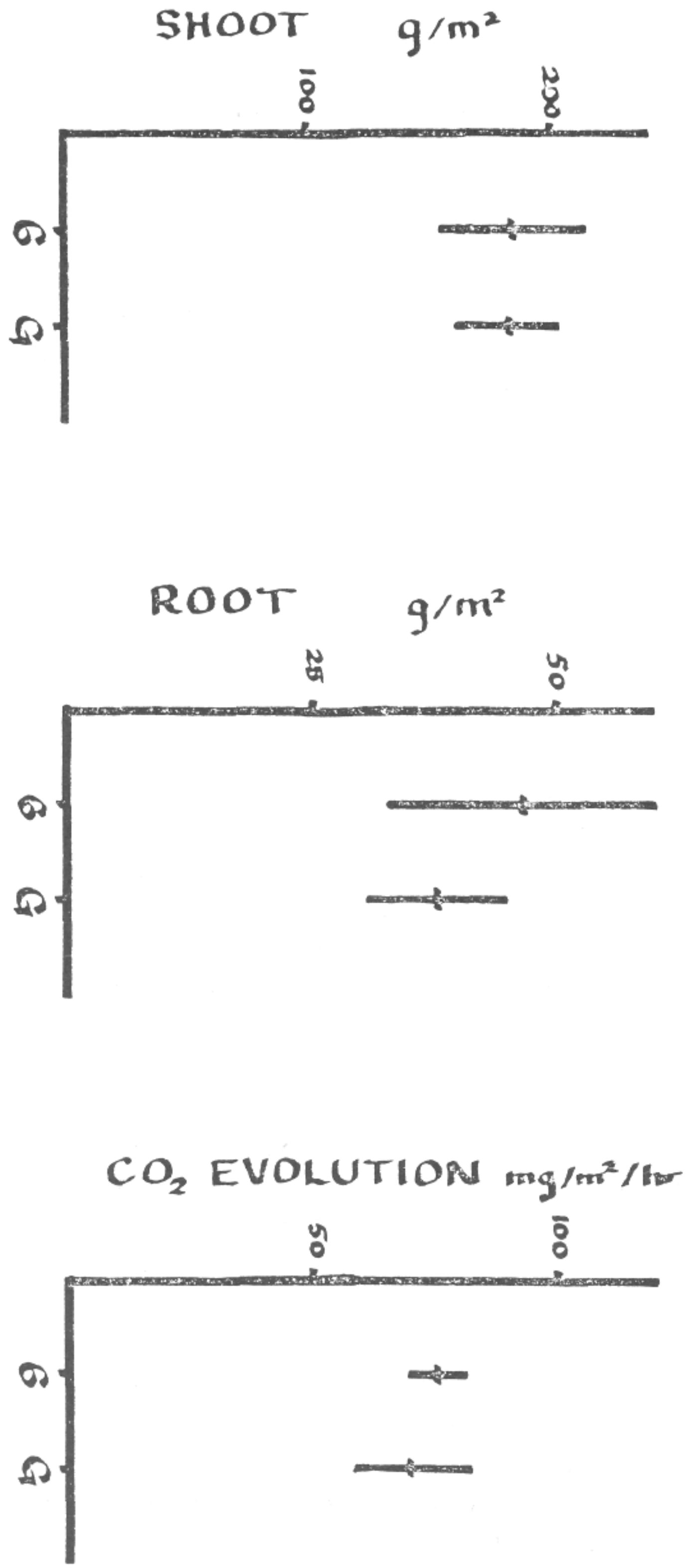


FIGURE 2

SHOOT AND ROOT GROWTH AND CO_2 EVOLUTION OF SOIL IN THE FIELD IN THE SIX YEAR OLD RECLAIMED SITE AND THE NATIVE GRASSLAND (G) however, were found in the soil organic matter and nitrogen contents of the two soils and these require further considerations.

Initially, we expected that both soil organic matter and nitrogen would increase as reclaimed areas developed, since it has been a rule of thumb that fresh mine waste is low in both of these soil constituents. We found, however, that the reclaimed soils contained relatively high levels of total nitrogen which did not increase with time (Figure 3). In addition, fertilizer inputs could account for only 2% to 3% of the total nitrogen measured in the oldest reclaimed site. Further analysis indicated that the native rock which made up the mine waste contained up to 0.18% nitrogen.

The level of total nitrogen measured in the undisturbed grassland soil is far greater than any of the reclaimed sites. We attribute this high level to a natural accumulation over time rather than a base level determined by the composition of the local rock as suggested for the reclaimed areas.

Three different aspects of carbon in the soil were examined. The Walkley Black wet oxidation method (Allison 1965) measures the quantity of carbon that is readily oxidized, and assumed to participate in soil functions but not necessarily readily available for microbial use. A respiration study (Waksman and Starkley 1924) was used to estimate how much soil carbon was available for utilization by micro-organisms and a dry combustion method measured the total carbon which includes those forms which are met readily oxidizable and are assumed to be inert.

The levels of readily oxidizable carbon in the soils studied followed a pattern similar to that of total nitrogen. These data (Figure 4) indicate that even unvegetated spoil contains a relatively large proportion of readily oxidizable carbon. This carbon is probably contained in coal or carbonaceous shale and may be associated with the indigenous nitrogen discussed above. The native grassland soil contains a much higher level of Walkley Black carbon than the reclaimed sites, again, probably a result of natural accumulation. An incubation method was used to provide an index of the amount of available organic matter in each soil. In this method, the CO_2 evolved by soil samples incubated in sealed containers were measured, and assumed to be proportional to the amount of carbon in the soil easily utilized by micro-organisms. This type of organic matter consists mainly of compounds derived from living, or recently living plant or animal material.

FIGURE 3

TOTAL SOIL NITROGEN IN RECLAIMED AREAS OF DIFFERENT AGES
AND THE NATIVE GRASSLAND (G)

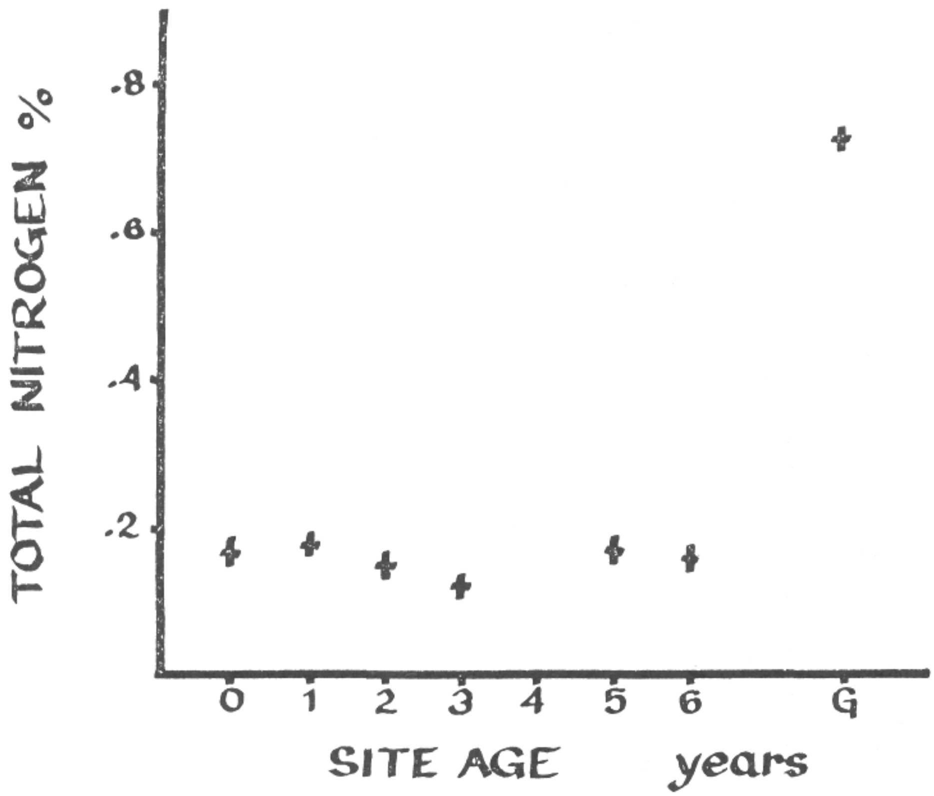
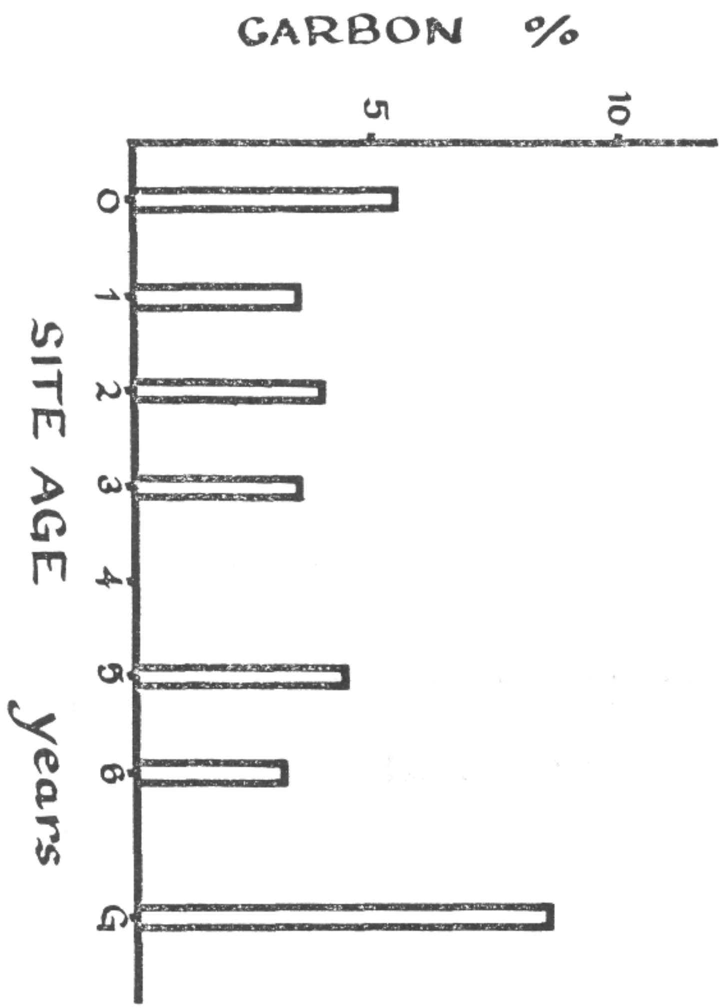


FIGURE 4

READILY OXIDIZABLE SOIL CARBON IN RECLAIMED AREAS
OF DIFFERENT AGES AND THE NATIVE GRASSLAND



We found that CO_2 evolution increased significantly with age in reclaimed soils (Figure 5) and that the soil of the six year reclaimed site evolved CO_2 at a rate similar to that of the undisturbed grassland soil. Considering the high level of readily oxidizable organic matter in the grassland soil discussed above (Figure 4), and the comparatively low level of available carbon implied by the CO_2 evolution data, it is apparent that this soil must contain a large proportion of carbon which is readily oxidized but not easily utilized by micro-organisms.

The soil substances which are generally referred to as humus are the end or byproducts of the decomposition of organic matter, and are resistant to further microbial degradation. Although only 2% to 3% turnover of soil humus can be expected annually (Janssen 1972) these substances play an important role in nutrient storage and exchange and strongly affect soil texture, structure, and moisture holding capacity (Brady 1974). Analysis of soil samples for humic and fulvic acids, major constituents of humus, confirmed that the soil of the native grassland contained a much higher proportion of humus than the reclaimed soils.

In simplified terms, the organic matter of the grassland soil can be described as a small pool of readily available carbon compounds in association with a large pool of resistant humic substances (Figure 6). A reclaimed soil, in comparison would have a similar sized available pool with a much smaller pool of resistant material.

The pool of resistant organic matter in the reclaimed soil may have been derived from plant residues and more available substances but may also have originated as indigenous carbon in coal or carbonaceous shale. In order to study this problem further we collected samples of unvegetated carbonaceous spoil which had been exposed to weathering on the dump surface for varying periods of time ranging up to ten years. The samples were analysed for total carbon using dry combustion and for readily oxidizable carbon as a previous analyses. We found that in our youngest samples less than 35% of the total carbon was in a readily oxidizable form while almost 80% was easily oxidized in our most weathered spoil (Figure 7). The CO_2 evolution of similar samples, innoculated with soil suspension, suggested that this increase in ease of oxidation was not accompanied by an increase in available organic matter. These data suggest that indigenous carbon is altered by weathering to form less inert compounds which, while not easily utilized by micro-organisms, may be more likely to participate in soil

FIGURE 5

CO_2 EVOLUTION OF SOILS OF RECLAIMED AREAS OF DIFFERENT AGES AND NATIVE GRASSLAND (G) MEASURED UNDER LABORATORY CONDITIONS

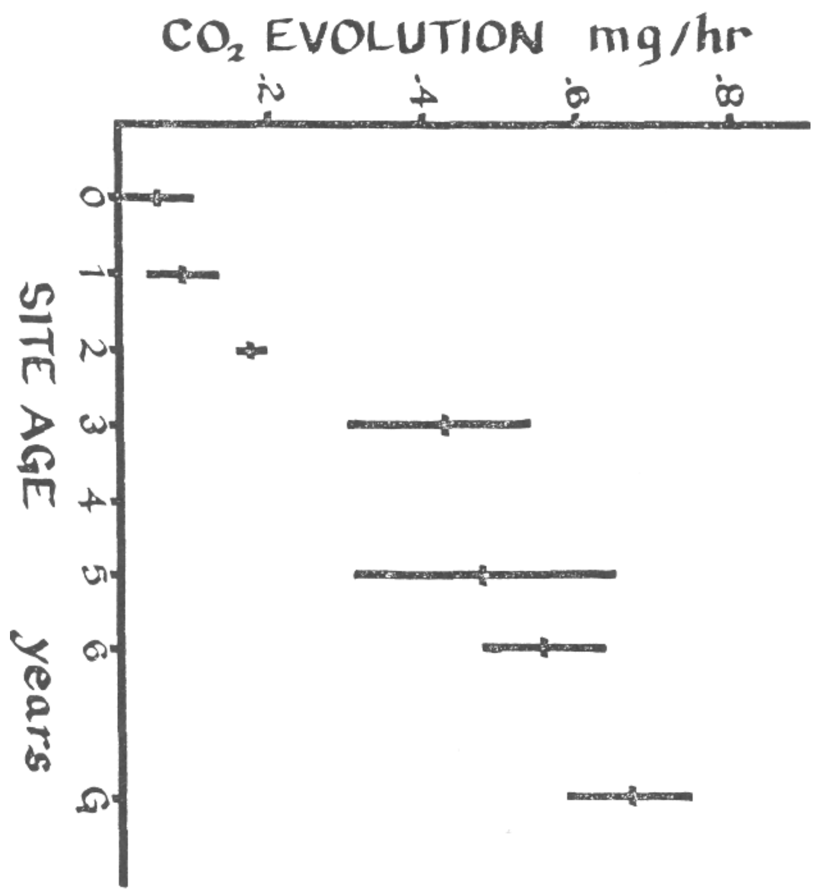


FIGURE 6

DIAGRAMATIC REPRESENTATION OF THE ORGANIC MATTER (O.M.)
OF RECLAIMED AND UNDISTURBED SOILS

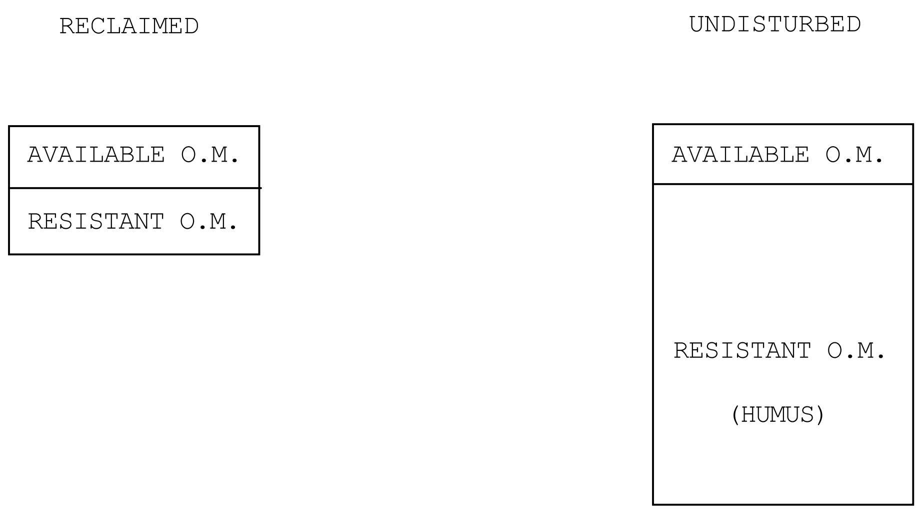
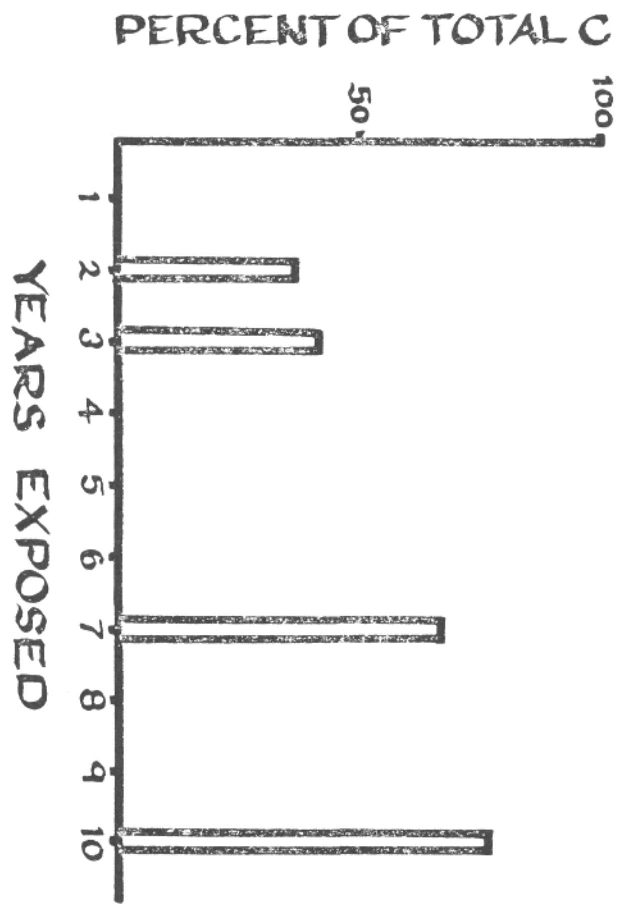


FIGURE 7

THE PERCENT OF THE TOTAL CARBON WHICH IS READILY OXIDIZED
IN SPOILS EXPOSED TO WEATHERING FOR VARYING PERIODS OF TIME



functions. Although the data are preliminary it seems clear that any investigation of organic matter in soils developing on carbonaceous spoil must consider the influence of indigenous carbon sources, as well as conventional decomposition pathways.

CONCLUSION

Our research has shown that the ecological development of reclaimed mine waste is rapid under annual fertilizer maintenance. Although the reclaimed areas appear to be dependent on fertilization for several years, they rapidly reach a condition which is similar in many respects to undisturbed grassland soils. The major difference between native and old reclaimed soils appears to be in the amount of humus accumulation. Reclaimed soils seem to have low levels of humic materials and, although they may contain resistant organic matter originally derived from indigenous carbon compounds, the function of these substances in soil processes is not clearly understood. Carbon and nitrogen compounds contained in the spoil materials represent a large reservoir of potentially available nutrients and organic matter which could have a significant influence on the development of a truly nutrient self-sufficient vegetation/soil system on reclaimed mine waste. Further research is required to provide a better understanding of the role of soil organic matter in the nutrient self-sufficiency of reclaimed areas and of the effect of weathering on the availability of indigeneous carbon and nitrogen.

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