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Pedology as a Tool in Archaeological Investigations

ABSTRACT

It would seem, that in several respects soil investigations could be of particular value to archaeologists. Clearly an appreciation of the pedogenic processes involved in profile formation and horizon differentiation would allow of more rapid and meaningful interpretation of many excavations. In particular, an ability to recognize with certainty buried turf lines (even though they may *appear* to be very indistinct) is obviously a valuable capacity. However, for the environmental archaeologist working in Ontario the recognition of eroded soils and the provision of data on the past vegetation cover would seem to be nothing less than vital.

INTRODUCTION

It is perhaps odd that two disciplines which both take for their medium the soil should have shown so little interaction as pedology and archaeology. The former may be regarded as centering on the formation and evolution of the soil in the light of past and present environmental conditions. In that man has been a prime element of the environment in many parts of the world his activities must clearly be taken into consideration by the pedologist. In return it could be expected that the latter might make some contribution to a more complete understanding of the disturbed soils with which the archaeologist is concerned and of the environment in which "archaeological man" existed. However, such an exchange of ideas has not been very evident save in the notable publications of Dimbleby and of the occasional European worker e.g. Scheys (1962).

Thus while it has been the practice in archaeological literature to record in detail the slightest changes in apparent texture (i.e. silt, clay etc.) and soil colour, very rarely has there been any subsequent meaningful pedological interpretation. Indeed even at this observational level one often wonders whether any standard scale of texture has been adopted since very rarely are the meanings of the terms silt, sand etc. defined. The importance of this point may be emphasized by reference to soil classification where at least three main texture scales are in use. Thus silt has been defined as follows :

Scale	Size Range (effective diameter of grain) in mm.
"International"	0.02 — 0.002
U. S. D. A.	0.05 — 0.002
British Standard	0.06_ 0.002

In the range 0.02 mm - 0.06 mm. occurs most of the wind blown deposit known as loess. Material such at this would, therefore, be described in quite different terms according to the system employed.

Similarly the use of a standard colour scale such as that provided by the Munsell Soil Color Charts (1954) would produce a desirable conformity.

However, it is in interpreting variations in colour, texture and other characteristics in terms of pedogenic processes that the pedologist may prove of most help to the archaeologist. Perhaps the most important tasks therefore, are the recognition and interpretation of (a) horizontal manifestations of soil layers, or horizons, as depicted in Fig. 1. (b) buried profiles, particularly that part represented by the buried turf line or A_o horizon (c) truncated or eroded profiles and (d) information on presettlement vegetation.

HORIZON INTERPRETATION

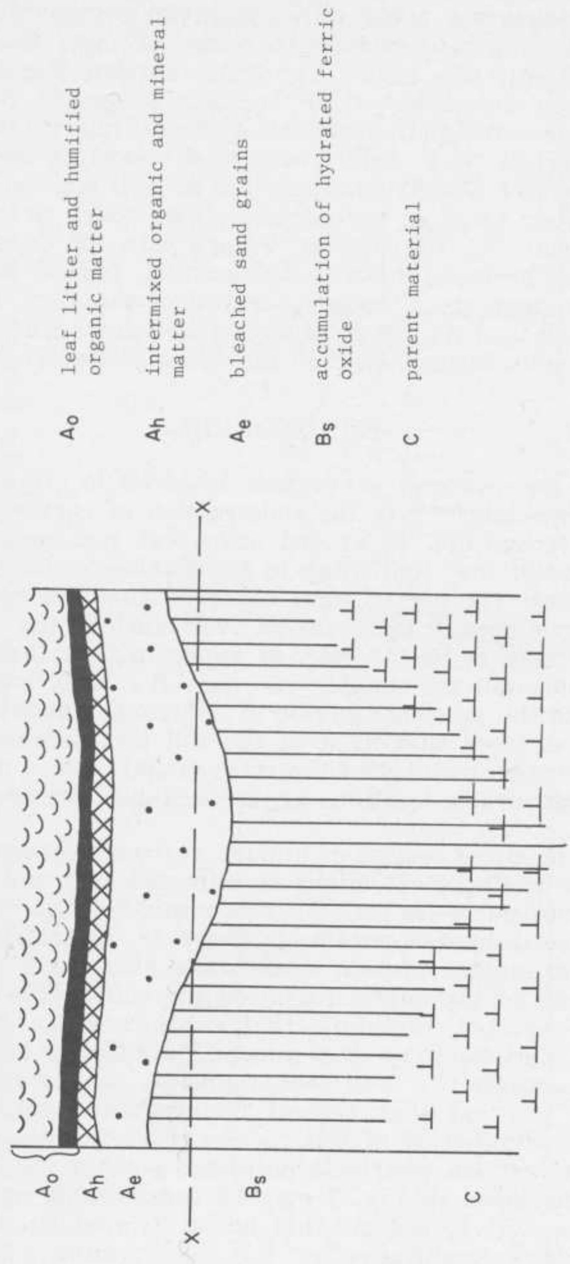
Clearly, this a vast subject which is, in any case, dealt with quite adequately in most pedological texts. Nevertheless one problem, frequently occurs in excavations which merits attention — that of recognizing and explaining the horizontal manifestations of shallow involutions in soil horizons. Suppose that excavation through the podzolic profile shown in Figure 1 has reached level X - X. Small patches of grey ash coloured material thus exposed on the floor of a section may all too easily be thought to be remnants of a hearth area, while consolidations of rich rusty coloration may be taken as indicative of intense heat. In both cases they would be the results of the leaching action of rain water causing the loss of hydrated ferric oxides from the A_e horizon i.e. bleaching, and their accumulation in the B_s i.e. red colouration.

However, the pedologist's method of approach and analytical tools which he uses are likely to be most useful in the field of environmental archaeology. Thus, familiarity with the "normal", complete and undisturbed profile to be expected on a particular parent material (i.e. geological deposit) in a specific climatic, vegetational and topographic environment should enable buried and eroded soils, to be recognized.

BURIED TURF LINES

While buried turf lines have often been plotted on the basis of colour differences this becomes increasingly difficult as the organic material is decomposed. However, very simple tests such as ignition of a series of

Fig. 1: Podzolic profile of the type occurring over much of central and northern Ontario.



samples at c. 850°C will soon reveal whether any organic material is present. Losses in weight on ignition, it should be pointed out, are principally attributable to the breakdown of organic matter, but may also occur if carbonates or clays are present in any quantity. Thus, except where the soil is highly calcareous, losses of more than c. 5% would suggest the presence of a buried A_o or A_h horizon. Recognition of buried profiles is made the easier where horizons below the A. (i.e. organic material) possess distinctive characteristics. Thus in the case of soils of the Tioga series — a weakly developed podzol of the type shown in Fig. 1 — of Simcoe County, the presence of well marked A_e (bleached) layer immediately provides an indicator from which to locate any buried organic material. At the Huron Village site at *Cahiague* somewhat indistinct A_o. horizons have been located, buried beneath slumped material on a steep slope, largely because of the very obvious presence of a buried, bleached Ae layer immediately below. Similar remarks may be applied to soils formed beneath midden material at the same site.

ERODED SOILS

Although the presence of organic material is often of considerable importance, especially where the construction of earthworks is involved, it is in the recognition of eroded soils that pedological analysis may be of the greatest use. Returning to the *Cahiague* site, Heidenreich and and Cruickshank (in press) have observed that the upper horizons of the Tioga podzol appear to be absent over much of the village area. The loss, if this proves to be the case, of approximately three to four inches of A_e horizon, and presumably A_h and A_o also, may, of course, be correlated with the presumed period of occupance (about 10 to 15 years). If it can be assumed that most of the soil loss occured while the area was settled some assessment of the rates of soil erosion might be made in particularly favourable locations as, for instance, under certain middens.

A highly idealized section of midden overlying an easily eroded sandy soil is shown in Fig. 2. It might be expected that the pre-existing soil would be preserved in its entirety where midden material was deposited immediately settlement commenced. However, in trafficed areas in the vicinity of the midden erosion would take place until such time as the outward spread of the debris fossilized the soil profile in that position. It would be expected, therefore, that a bleached A_e horizon, thinning towards the periphery of the midden, would be .observed. In some exploratory sections this has been found to be the case. Nevertheless, it should be stressed that several factors may cause variations, and perhaps, total elimination of this picture. Clearly human trampling may be confined to certain restricted pathways so that the uniform wedging of the A_e displayed in Fig. 2 may be considerably modified. Similarly it may not be wise to assume that burial by midden waste only 12" — 18" thick causes fossilization of the soil forming processes and thus preservation of the existing profile. It is quite conceivable that certain constituents e.g. iron compounds, and carbonates, found in middens may be leached downwards and deposited in the buried soil profile. These possibilities notwithstanding, the evidence to date (e.g. Dimbleby, 1962, pp. 10 — 16) suggests that fossilization and preservation are more likely

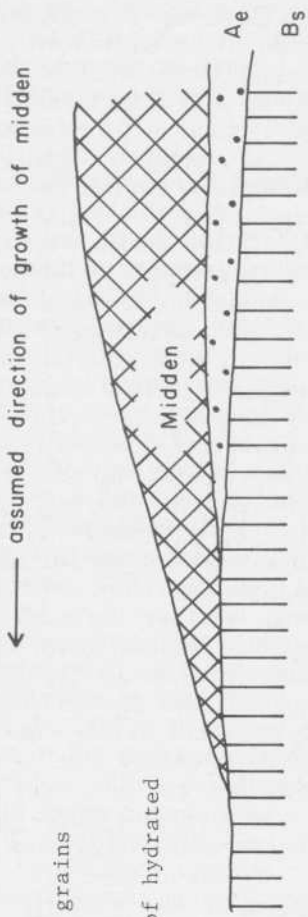


Fig. 2: Wedging of upper horizons of podzol buried beneath midden.

Ae bleached sand grains

Bs accumulation of hydrated ferric oxide to be the rule. If this is the case and the period of occupance (or, more precisely, the period of midden construction) can be determined, say, from documentary records, then a more precise indication of the rate and amount of erosion may be obtained.

In these ways it is possible to elucidate the detailed pattern of erosion at a given site. However, it is often more useful to ascertain the picture over a more extensive area in which case simple, yet informative, methods must be adopted. Unfortunately, the soils of southern Ontario provide difficult material for this type of work since they are often lacking in well marked vertical differentiation of their main constituents. But soils in central and northern Ontario which have developed on fluvio-glacial outwash sands or similar free draining materials, especially where a coniferous vegetation cover has existed, are likely to show a podzolic profile e.g. the Tioga series which occur extensively in Simcoe and Renfrew counties. In strongly developed cases each horizon is well marked especially where ferric compounds have been leached away or have accumulated. Not surprisingly this situation is rather the exception than the rule in that staining by humic material frequently masks any vertical variation in iron content. While precise though time-consuming laboratory analyses (see Appendix) will expose the pattern of iron accumulation rapid and informative methods have been employed with success by Dimbleby (1962, pp. 8 - 9). If a subjective assessment will suffice -- and this is often the case -- the organic matter may be driven off by ignition in a crucible or muffle furnace at c. 850°C. Construction of a profile model, using the ignited material, on an adhesive tape backing will immediately show whether there are clearly defined A_e and B_s horizons, whether there is a uniformly distributed iron coloration suggesting little translocation, or whether the surface layers have a very high concentration. In the latter case it may be that the highly leached A_e horizon has, at some stage, been stripped leaving the iron rich B_s as the apparent surface horizon. "Ignited profiles" from adjacent locations may be mounted side by side so that ready comparison of iron .contents is possible. For the most part this will be a subjective comparison although van Diepen (1956) has shown that it is possible to analyze such samples quantitatively using colorimetric apparatus.

While consideration of the pattern and amount of ferric oxide accumulation may prove satisfactory in areas where the soils show an advanced state of podzolization, the converse holds for most of southern Ontario. In this area most of the freely draining soils are characterized not by variations in iron content with depth but by an accumulation of clay in the B horizon, usually referred to as the B_1 or B textural, horizon (see, for instance Presant, Wicklund and Matthews, 1965, p. 23). Under favourable circumstances it may be possible to ascertain whether erosion has taken place on such profiles. Clay which has been moved through the profile frequently is deposited on aggregate faces in the B_1 horizon forming distinctive glossy skins or "cutans". In well developed eases it is possible to break open the aggregate, therefore exposing the cutan in section. A hand lens (x10) is recommended to recognize these features easily. In that the clay which makes up these cutans has been translocated from the A horizon such soils possess two distinctive characteristics — (i) there is a marked increase in clay content in passing from the A to the B_1 (ii) the glossy cutans are only present in the B_1 not in the A. However, it should be emphasized that these diagnostic features are only likely to be clearly displayed where the sand fraction represents less than c. 60% of the total. Erosion, may, therefore, be suspected if clay sheathed aggregates appear at or close to the surface. Likewise an undifferentiated clay profile might suggest that only the B1 horizon is present, but interpretation of this particular feature is dependent on the presence or absence of several others. The opinion of an experienced pedologist should, therefore, be sought.

RECONSTRUCTION OF PAST VEGETATION

It is evident, therefore, that much information on soil conditions prior to and after human occupance can be obtained, especially from buried profiles. From undisturbed fossil soils (i.e. pre-settlement) it may be possible to draw inferences regarding the nature of the vegetation cover at that time. However, so little precise information is available on soil profile response to specific environmental inputs e.g. a cover of pine for a given time period, that it is much more satisfactory to obtain direct evidence on the pre-existing vegetation. Under certain conditions this is possible on account of the preservation of pollen grains, spores and other micro-fossils in the soil. However, there are severe problems to be faced in interpreting the pollen suites obtained, not to mention the many difficulties involved in extracting these micro-fossils from the soil mass (Smith, 1966, Faegri and Iversen, 1964 ; pp. 99 - 123).

Pollen is one of the most resistant of plant components, decaying only through the action of certain aerobic bacteria and by oxidation. Accordingly, it is extremely well preserved in peat bogs, lake muds and similar stratified, anaerobic deposits. In that such areas are rarely tree covered it has been assumed that most of the tree pollen contributed to the deposit stems from the area round about while a small proportion (of the order of up to 20%) may originate from distant sources. The work of Davis and Goodlet (1960), tends to confirm this assumption. Unfortunately such an integrative type of pollen accumulation rarely suffices for the needs of archaeologists and pedologists since it is the vegetation in the immediate vicinity of their investigations which is often of interest. Accordingly, attempts have been made to extract pollen from mineral soils which have remained undisturbed (Dimbleby, 1961). Bacterial decomposition of the pollen exine apparently decreases rapidly once the soil pH falls below 5.0 so that pollen may be recovered from soils more acid than this. However, above this value pollen preservation is, at best, species selective and, at worst, non-existent. Attempts to date to isolate pollen from some soils of the podzolic, and thus usually acidic, Tioga series have not proved successful. This may possibly be attributable to the translocation of calcium carbonate from midden material overlying the sample site.

Nonetheless it would be expected that some archaeological sites in eastern Canada e.g. in Northern Ontario, Newfoundland or Quebec, would be productive of pollen. In these instances valuable data relating to the vegetational history may be available. But, interpretation of this data is a most treacherous operation. (Fig. 3) In principle, the position of the pollen in the soil section provides a stratigraphic scale. Thus pollen near the surface may be expected to be younger than that at a lower level since pollen, like most soil constitutents, is leached downwards by percolating water. Unfortunately several conditions must be imposed on this very simple assumption.

In the first place pollen and fern spores vary in size from about 10p to 100µ Accordingly the grains from different species migrate at different rates. Little experimental work has been directed to this problem so that no categorical statements on rates of movement of specific pollen types can be made. Suffice it to say that no contemporaneity of different pollens at the same level can be assumed.

Superimposed upon this picture is that of the continual decay of spores and grains by bacterial digestion. For example, a slide prepared from material from the upper few inches of the profiles may in favourable circumstances, contain several hundred micro-fossils, that from a twelve inch depth is unlikely to contain more than a few dozen. Therefore, a decrease in the pollen count for a species with depth does not necessarily imply a decrease in the ground area covered by that plant or its abundance at the time of pollen dispersal.

Again the exine of pollen grains and spores varies greatly in thickness and resistance to decay. It is not unusual, therefore, to find that Populus pollen is rarely found at lower levels while spores of Polypodium, although at no times frequent, occur throughout.

A simple interpretation of a soil pollen diagram in terms of direct comparisons between different species at different levels in the profile is therefore invalid since: (1) the pollens of different species are translocated at different rates so that contemporaneous materials now occur at different position in the profile. (2) decay causes a relative decline in the count for all species. (3) in that some grains are more resistant to decay than others some species will show a relative increase in importance with depth.

In addition, plants do not produce anything approaching the same quantities of pollen grains. This remark applies .especially to the production of arboreal pollen. Thus superimposed on the variables already listed is that of between species variation in the amount of pollen initially received at the soil surface.

What conclusions may, therefore, be drawn from pollen analysis of a mineral soil? The most soundly based will undoubtedly be concerned with one genus only. With a knowledge of the approximate rate of decay, it is possible to ascertain whether a given genus has increased or declined in abundance during the period represented by the pollen record. Such deductions should be particularly sensitive when data derived from the upper three or four inches of the soil are being employed. Attempts to

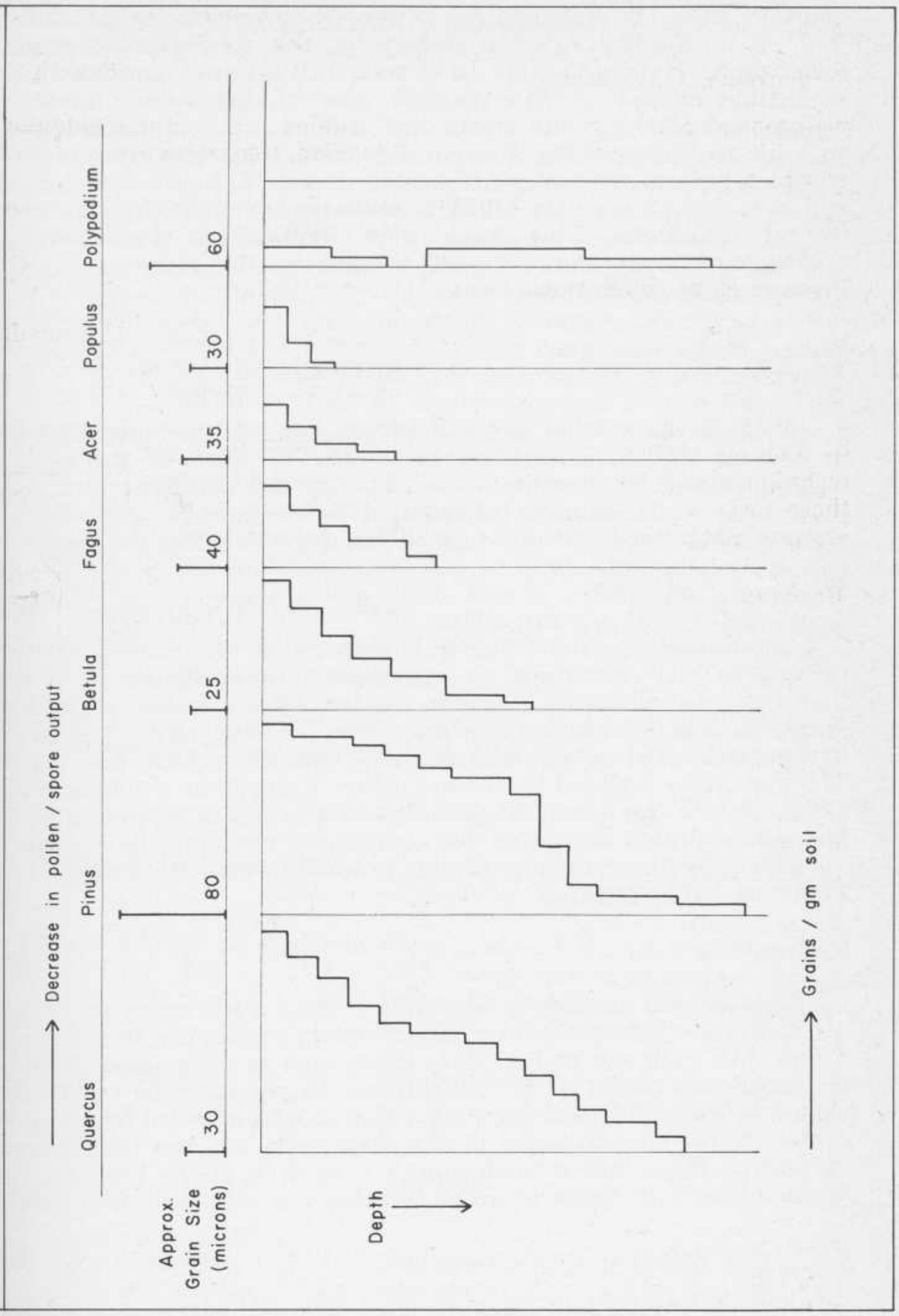


Fig. 3: Hypothetical pollen diagram from a site in which all genera were equally abundant.

determine the relative abundance of each genus in the community at a point in time are liable to be extremely unreliable on account of the lack of uniformity between genera in the stratigraphic scale. Also, differing resistances to exine decay make this type of reconstruction almost impossible, except in the possible case of the recent record where differential leaching and decay are still of minimal importance. Even such limited information is often of considerable value since a knowledge of which genera, or in very favourable circumstances species, have existed and over what time period can provide much insight into past environmental conditions. This has direct implications for environmental archaeologists and indirectly sheds light on the soils developed under these varying vegetation covers.

APPENDIX

Most of the routine methods of soil analysis are described in detail in Jackson (1958). However, an outline of some of the most useful techniques will be presented here. For the archaeologist and pedologist those tests which provide information on the presence, or otherwise, of organic matter and on the extent of leaching are by far the most valuable.

Mechanical Analysis

Determination of the physical composition of a soil necessitates the removal of all "cementing" or aggregate forming agents. It is common, therefore, to eliminate organic matter by oxidation with hydrogen peroxide. Any free carbonates may then be removed by treatment with hydrochloric acid while exchangeable calcium, which also encourages flocculation, is replaced by sodium using "Calgon" or a similar dispersing agent. Before the sand, silt and clay fractions are separated by sieving and sedimentation the suspension is dispersed mechanically in a milk-shake machine. Complete details of the procedure may be found in *British Standard* 1377 (1961).

Soil Acidity

This is most accurately determined using a pH meter and a 1:1 soil: distilled water paste. However, approximate results can be obtained using a universal indicator and a colour chart such as is available from Soiltest Inc., 2205 Lee Street, Evanston, Illinois. In any case the results achieved should be viewed with caution since they can be affected by many factors, especially the concentration of the suspension and the time lapsed since saturation. Since only a small sample is used (c. 20 gm.) several determinations should be made in order to achieve a representative value.

Free Carbonates

For the most rapid assessment of free carbonates it is advisable to use a calcimeter such as the Collin's type marketed by A. Gallenkamp and Co. and distributed in Canada by Central Scientific of Toronto. The volume of carbon dioxide generated during a reaction between the carbonate and hydrochloric acid is observed at atmospheric pressure and constant temperature. It is then a straightforward matter to calculate the weight of CO_2 and the equivalent weight of carbonate.

Total Iron and Aluminum

In that most of the iron and aluminum in soil is present as hydrated oxides it is possible to obtain a good estimate of these constituents by extracting with a 20% solution of HCl. The mixture is boiled for one hour when all extractable iron and aluminum should be in solution. Filtration allows the remaining solids to be discarded. In that the filtrate contains not only the chlorides of iron and aluminum but also of calcium and magnesium (derived from limestone, dolomite, shells etc.) it is necessary to transform the latter into stable complexes which will not precipitate on subsequent treatment. This is achieved by adding a small quantity of 2% ammonium chloride. Transformation of the chlorides of iron and aluminum into the hydroxide form is then accomplished by reaction with a small quantity of concentrated nitric acid followed by the addition of 5% ammonia solution until the suspension (now showing a precipitate) just shows an alkaline reaction to litmus. The precipitated hydroxides are finally extracted by filtration. However, before calculations of the content of iron and aluminum can be made this precipitate must be converted to the original oxide form. This is most easily achieved by ignition (i.e. oxidation) at c 850°C in a muffle furnace. Direct comparisons are then possible between the weight of extracted oxides and the oven dry weight of the initial soil sample.

Not only is this method suitable for soil analyses but it may also be used with advantage to analyze and even locate ochre beds in burials.

REFERENCES

British Standards Institude (1961) *The testing of soils:* British Standard 1377. B. S. I., London.

Davis, M. B. and J. C. Goodlett (1960). Comparison of the present vegetation with pollen spectra in surface samples from Brownington Pond, Vermont. *Ecology,* 41, 346 - 357.

Diepen, D van (1956). The ignition method as a means of iron analysis in sandy soils. *Boor en Spade,* 8, 160 - 173.

Dimbleby, G. W. (1961). Soil pollen analysis. *J. Soil Sci.* 12 (1), 1 - 11.

Dimbleby, G. W. (1962). *The development of British heathlands and their soils.* Oxford Forestry Memoir No. 23, Oxford U. P.

Faegri, K. and J. Iversen (1964). *Textbook of pollen analysis.* Hafner, New York.

Jacksn, M. L. (1958). *Soil chemical analysis.* Prentice Hall, New-York.

Heidenreich, C. E. and Cruickshank, J. G. (in press). Pedological Investigations at the Huron Indian Village of Cahiague. *The Canadian Geographer.*

Munsell Soil Color Charts (1954). Munsell Color Company, Baltimore, Md., 21218.

Presant, E. W., R. E. Wicklund and B. C. Matthews (1965). *Soils of Wentworth County.* Ontario Soil Survey Rept. No. 32, Canada Dept. of Agric., Ottawa and Ontario Dept. of Agric., Toronto. Scheys, G. (1962). Pedological investigations of an early Neolitine Site on the Straberg in Rosmer (in Flemish), *Pedologie,* 12 (1), 50 - 65.

Smith, R. T. (1966). Some refinements in the technique of pollen and spore extraction from soil. *Laboratory Practice,* 15 (10), 1120 - 1123.