WALKER, Patrick Hilton, 1929-
SOIL AND GEOMORPHIC HISTORY IN SELECTED AREAS OF THE CARY TILL, IOWA.

Iowa State University of Science and Technology, Ph.D., 1965
Agriculture, general

University Microfilms, Inc., Ann Arbor, Michigan

SOIL AND GEOMORPHIC HISTORY
IN SELECTED AREAS OF THE CARY TILL, IOWA

by

Patrick Hilton Walker

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Soil Morphology and Genesis

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State University
Of Science and Technology
Ames, Iowa

1965

TABLE OF CONTENTS

LIST OF FIGURES

Page

Page

Page

LIST OF TABLES

I. INTRODUCTION

A. Project Description

The work reported in this thesis was carried out under United States National Science Foundation Grants G22056 and GP2610. The terms of reference of the project are contained in the original research proposal submitted to the Foundation by W. H. Scholtes (Principal Investigator), W. H. Pierre (Head, Agronomy Department), G. M. Browning (Associate Director, Iowa Agricultural Experiment Station), and B. H. Platt (Vice-President, Business and Finance), Iowa State University of Science and Technology.

The submitted project title was:

> Evaluation of Climatic, Vegetational, and Time Factors upon the Genesis of Soils and Soil Landscapes in the Cary and Iowan Drift Areas in Iowa.

The project started in January 1962 under the direction of Dr. W. H. Scholtes, and following a second submission, was renewed in early 1964 for two years under the supervision of Dr. F. F. Riecken, Professor of Soils, Department of Agronomy, Iowa State University, and under Dr. R. V. Ruhe, Research Geologist, United States Department of Agriculture, Soil Conservation Service.

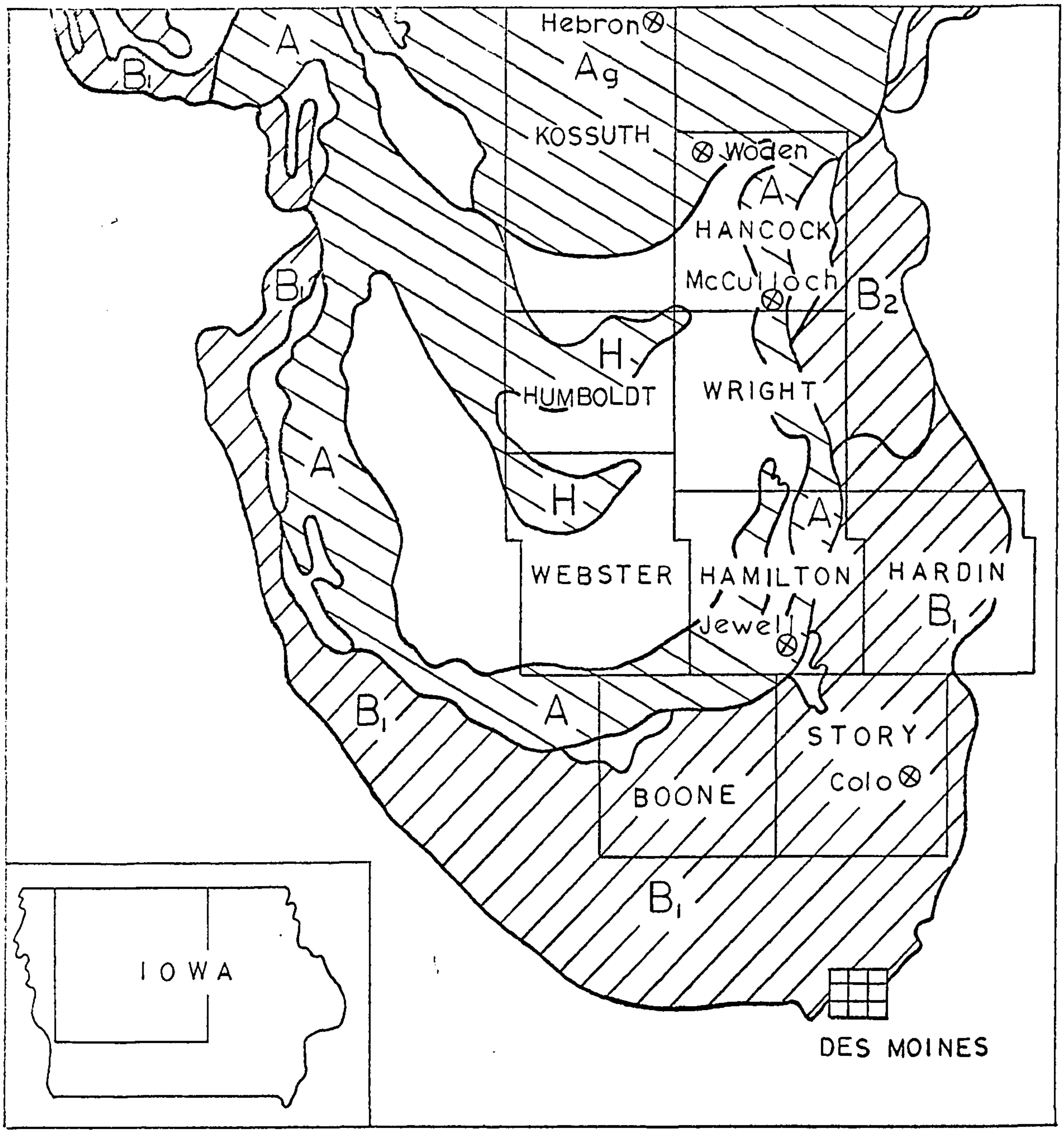
Field work was carried out during the summers of 1962, 1963, and 1964, and was aimed principally at resolving the problems of the Cary drift. It is this part of the project that is reported here.

B. The Problem

The Des Moines lobe of the Cary drift (Figure 1) represents the latest glacial deposition in Iowa, which ended approximately 13,000 years ago. The drift deposits occupy one-fifth of the area of the state, extending from the center, north to the Minnesota border. Soils of the Clarion-Webster association which characterize most of the drift surface, have long been considered the product of a prairie grassland environment similar to that which was found at the time of settlement (Riecken *et al.*, 1947; Riecken, 1965). However, pollen studies by Lane (1931) and ecological studies by McComb and Loomis (1944) in the forest-prairie transition of Iowa, indicate a significant coverage of the Cary drift by coniferous forest during early postglacial time. Radiocarbon dates for bog samples taken at the location of Lane's work indicate that the period represented by dominance of coniferous pollen was 11,800 to 8,200 years ago (Ruhe *et al.*, 1957). Thus the genesis of prairie or brunizem soils under a purely prairie environment on the Cary drift in Iowa is open to question.

It is the purpose of this thesis to establish more clearly the post-Cary history of landscape development in relation to vegetational and climatic changes. With such a framework established, the problems of genesis of prairie soils on the Cary drift can be re-examined.

Figure 1. Map of the Des Moines lobe in Iowa, after Ruhe (1952), showing the four morainal systems. B_1, B_2 = Bemis; A = Altamont; H = Humboldt; A_g = Algona. The five bog locations Colo, Jewell, McCulloch, Woden, and Hebron are also shown.



Hebron
A
Ag
B1
KOSSUTH
Woden
A
HANCOCK
McCulloch
B1
B2
H
HUMBOLDT
WRIGHT
A
H
A
WEBSTER
HAMILTON
HARDIN
Jewell
B1
B1
A
STORY
Colo
BOONE
B1
IOWA
DES MOINES

II. SOIL FORMING ENVIRONMENT ON THE CARY DRIFT[1] - A REVIEW

A. Introduction

Concepts of soil genesis on the Cary drift in Iowa have undergone a succession of refinements since the first soil surveys were made at the beginning of the century. Some changes in concept were a result of developments in geology and ecology; other changes resulted from pedological investigations. The more significant of these developments are discussed below.

B. The Geological Framework

1. Stratigraphy

Early work by Chamberlin (1883) established the presence of at least two glacial epochs in the Pleistocene of North America. Kay and Apfel (1929, p. 14-15) mapped four separate glacial stages in Iowa: the Nebraskan, Kansan, Illinoian, and Wisconsin. Leighton (1933, p. 168) and Kay and Leighton (1933, p. 673) proposed a classification of the Pleistocene in terms of the above glacial stages, and also proposed four substages of the Wisconsin, namely, Iowan, Tazewell, Cary, and Mankato. Leverett (1922, p. 103) mapped two morainal systems in the Des Moines lobe and named the older Bemis and the

---

[1]Terminology used in relation to glacial deposits follows the definitions of the American Geological Institute (1957). Drift refers to the whole range of materials transported and deposited by glacial action, including water-deposited sediments. Till refers to that part of the drift that is stiff and unstratified.

younger Altamont. The details of distribution of these Cary moraines and their relation to other glacial deposits in north central United States is shown in maps compiled by Flint (1945) and Flint *et al.* (1959). The stratigraphic relationships of the drifts and their degree of weathering were discussed by Kay and Graham (1943, p. 250). They used the average of 30-inch depth of leaching for the Mankato in Iowa as a reference by which to determine the degree of weathering and age of other drifts. Kay and Graham (*op. cit.*, p. 239) also showed the delineation of four terminal moraine systems within the Mankato in Iowa. These were named the Bemis, Altamont, Humboldt, and Algona.

Ruhe (1950a) used slope frequency analysis to quantify differences in landform between drifts of different ages; the Cary and Mankato have not been modified greatly by postglacial erosion, whereas the Tazewell, Iowan, and Kansan drift surfaces showed successively greater erosional modification. Ruhe (1952, p. 52) was further able to show that angular topographic discontinuities permitted separation of the Bemis and Altamont moraines of the Des Moines lobe in Iowa, and correlated them with Cary and Mankato respectively. Subsequently, however, Ruhe and Scholtes (1959, p. 590) obtained dates from the base of the Algona outwash which were of comparable age to dates for the Bemis and Altamont moraines. They concluded "...that most, if not all, of the Des Moines lobe in Iowa is of Cary age" (Ruhe and Scholtes *op. cit.*, p. 591). A summary of the Pleistocene stratigraphy for Iowa is shown in Table 1, in which some of the earlier findings are adjusted to later evidence.

Table 1. Summarized statement of the subdivisions of the Pleistocene in Iowa, after Kay and Leighton (1933), Kay and Graham (1943), and Ruhe (1952)

Stage: Glacial	Stage: Interglacial	Substage (glacial)	Moraines
	Recent		
Wisconsin		Mankato (?) Cary	Algona Humboldt Altamont Bemis
		Tazewell Iowan	
Illinoian	Sangamon		
	Yarmouth		
Kansan			
	Aftonian		
Nebraskan			

More detailed information has become available for the Wisconsin stage through radiocarbon dates. In Table 2 a shortened version is given of the dates published by Ruhe and Scholtes (1959, p. 592), with the modification that the short Tazewell-Cary interval is omitted. The presentation also includes dates previously published for a possible postglacial

Table 2. Radiocarbon dates for substages of the Wisconsin in Iowa, using the data of Ruhe and Scholtes (1959)

Stage	Substage	Date (B.P.)	Landscape features
Recent	Post-Cary	0 11,790 ± 250	Post-Cary erosion; possible cycles at 6,600 B.P. and post - 2,000 B.P.
	Cary	12,970 ± 250 13,300 ± 900	Algona Moraine Humboldt Moraine Altamont Moraine Bemis Moraine
	Tazewell	14,700 ± 400 >17,000	
	Farmdale	24,500 ± 800	
	Iowan	>29,000 >37,000	
	Pre-Iowan	>37,000	

gulley cycle at 6,600 to 6,500 years before present (B.P.) which was described by Ruhe et al. (1957, p. 687). Daniels et al. (1963, p. 479) dated a number of erosion and sedimentation cycles on the Wisconsin loess landscapes of the Thompson Creek watershed in western Iowa. They concluded that from 14,000 to 2,000 years B.P., almost continuous erosion and deposition took place, but that three erosion cycles occurred since 2,000 years B.P.

2. Form and origin of the Des Moines lobe

In their map of the geology of Iowa, Kay and Apfel (1929, p. 25) showed the Pleistocene deposits overlying Cretaceous, Permian, Pennsylvanian, and Mississippian sedimentary rocks. They also showed that glacial deposits of Wisconsin age do not extend as far south in Iowa as older deposits such as the Kansan and Nebraskan. One of the earliest descriptions of the Des Moines lobe in Iowa was made by Chamberlin (1883, p. 314-315). His map of the "Terminal Moraine of the Second Glacial Epoch" showed that the drift had its origin in the Keewatin ice center to the west of Hudson Bay, Canada, and the Minnesota Valley glacier that formed the Des Moines lobe, pushed south over the Cretaceous shales of the Missouri Coteau into Minnesota and Iowa. Chamberlin (op. cit., p. 391) observed the greater relief of the terminal moraine compared with the surface towards the center of the drift, and noted that the moraine on the west side of the lobe was 150 to 200 feet higher than the moraine on the east side, a feature that must have influenced the general direction of flow of the Des Moines River and tributaries. Kay and Graham (1943, p. 205) described the general youthfulness of the Des Moines lobe surface in which lateral and recessional moraines were still well defined. The retreat of glacier ice left an irregular topography of undrained depressions. This kind of landscape was referred to as knob and kettle topography. In the morainal belt, deep peat deposits formed in the depressions, while in the open drift plain or ground moraine, the depressions and peat deposits are shallower.

Gwynne (1941, 1942) considered that the characteristic, parallel swell and swale patterns of the drift surface were related to minor oscillations of the ice front. These patterns further indicated that the ice retreated quickest along the line of the river valleys, and the most rapid retreat was from the southeast border of the drift (Gwynne 1942, p. 207). Earlier, Lees (1914, p. 551-555) had observed the difference in drainage patterns on the Wisconsin as against the Kansan drift within the watershed of the Des Moines River. DeKoster et al. (1959, p. 313, 314) showed that contrasting drainage patterns occurred within the late Wisconsin drift surface of the Des Moines River valley. There was less proliferation of the drainage pattern in what they identified as the Mankato compared with the Cary, a result of the somewhat greater age of the latter drift.

The quantitative landform analysis of Ruhe (1950a, 1952) has permitted a useful comparison of the Des Moines lobe and adjacent, older drift surfaces. A feature of the Des Moines lobe is its poorly integrated drainage; this has resulted in the formation of peat bogs which can be seen over much of its surface in Iowa. On both morphological and time bases (Ruhe and Scholtes, 1959), there appears to be no case for making substage separations within the Des Moines lobe in Iowa. Hence the extent of the lobe, as shown here in Figure 1, has the morainal systems delineated by Ruhe (1952, p. 48) as the only internal differentiation, and the entire lobe is called the Cary, as suggested by Ruhe and Scholtes (1959, p. 591).

The literature cited above, dealing with the nature of the drift surfaces, illustrates the progressive changes of geomorphic surface that take place through erosion. In much of Iowa, the older drifts are buried beneath a loess mantle or younger drift, so that the full expression of erosional changes with time cannot be as easily assessed as on the Cary, which has remained exposed since its deposition. Recent studies by Wallace (1961) and Wallace and Handy (1961) of the Cary drift surface present a clearer picture of postglacial erosion effects. Although integrated stream erosion has been minimal, the surface relief of the drift has been substantially modified by surficial processes which have filled adjacent depressions with up to 20 feet of sediment (Wallace 1961, p. 13). The relatively coarse sedimentary properties of the surficials, and the occurrence of associated stone lines indicated that the in-filling materials were of local origin, derived from weathering and surface transportational processes. Wallace and Handy (1961, p. 378) raised the important pedological consideration that many commonly occurring soils of the Cary drift are formed in surficial material derived from the drift rather than in the drift itself. This problem of soil parent materials is discussed later in some detail.

3. Properties of the Cary drift

Some of the earliest analytical data for the Mankato (= Cary) drift was published by Kay and Graham (1943, p. 222-227). They noted that the drift was a typically unconsolidated glacial deposit, 30 to 35 feet in thickness, leached to an average depth of 30 inches, and formed from materials over which the glacier had passed, for example, bedrock, Peorian loess, Iowan drift and Kansan drift. Despite the probable inclusion of previously weathered materials, the Mankato itself appeared relatively unweathered. A pebble analysis of unleached Mankato till from Kay and Graham (1943, p. 222) is shown here in Table 3.

Table 3. Pebble analysis of unleached Mankato (= Cary) till, from Kay and Graham (1943, p. 222)

Nature of pebble	Percentage
Greenstone	19.0
Greenstone schist	1.0
Granite	21.0
Diorite	1.0
Syenite	-
Porphyry	3.0
Other crystallines	3.0
Quartzite	1.0
Quartz	1.0
Sandstone	1.0
Limestone	47.0
Chert	1.0

Kay and Graham (op. cit., p. 222) also presented data for leached Mankato till which were similar to the unleached data of Table 3, except for a complete absence of limestone. Apart from the relatively high proportion of greenstone, these data are comparable with analyses of the Keewatin Cary tills in Dakota County, southern Minnesota, published by Ruhe and Gould (1954, p. 772). The small percentage of relatively coarse shale fragments, as reflected in the above analyses, seems to contradict an early suggestion by Chamberlin (1883, p. 392) that this drift was relatively clayey due to the passage of the ice across Cretaceous shales. It is possible, however, that the action of the ice was sufficiently abrasive to reduce soft shale fragments to a size beyond the scope of pebble analysis.

Differential thermal analyses of Cary drift colloids have been published for near-surface, oxidized materials by Russell and Haddock (1940, p. 93) and by Peterson (1946, p. 469). In both cases a strong dominance of montmorillonite was shown within the soil profile on the drift. Handy (1963, p. 11) published x-ray data for Cary till soils to depths of 7 feet. These data also showed a dominance of montmorillonite (17 Å) with some vermiculite (14 Å) and trace amounts of 10 Å and 7 Å materials. Quartz/feldspar ratios of the till materials varied from 2.11 to 3.89.

A feature of the clay mineral data reported above is that they relate to the upper, relatively oxidized part of the till profile. Droste (1956) showed that for Wisconsin tills in Ohio, a high degree of alteration occurred in the upper profile, characterized by montmorillonite and interstratified vermiculite-illite. Only in the deepest, unoxidized and unleached zone was the composition consistent with unaltered till, namely, chlorite and illite. Droste's data suggest that deeper sampling of the Cary till may be necessary to specify the nature of the original material.

Section descriptions of the Mankato (= Cary) by Kay and Graham (1943, p. 211-220) indicate that it is of variable mechanical composition; often the bouldery clay (till) is interstratified with sand and gravel, while thick upland gravels are abundant. Gwynne (1942, p. 208) and Ruhe (1950b) reported a discontinuous loess cover on the Mankato surface. Ruhe (op. cit., p. 280) found that the loess-like material was coarser and less well sorted than Tazewell loess, and that the mineralogical composition indicated a local origin of these deposits. It seems probable that this loess-like material is related to the extensive surficial materials described for the Cary surface by Wallace and Handy (1961).

Some of the mechanical properties of the Cary till that affect soils have been the subject of pedological investigations. Riecken, et al. (1947, p. 437) showed that the till had a range of $<2\mu$ clay of 15-46 percent with a corresponding range of sand of 5-48 percent. White (1953) proposed that subsoil sediment stratification in Webster soils in Hancock

County was related to re-working of ablation moraine debris. Hidlebaugh (1959) found that in areas of Hamilton County, a fine textured variant of the till gave significantly increased soil profile clay percentages.

The published data show that the Cary drift has a complex composition. Part of this complexity is a result of the inherent nature of the drift deposits. It is probable also that some of the apparent complexity relates to modifications of the surface by erosion and weathering subsequent to deposition of the drift.

C. Present and Past Vegetation and Climate

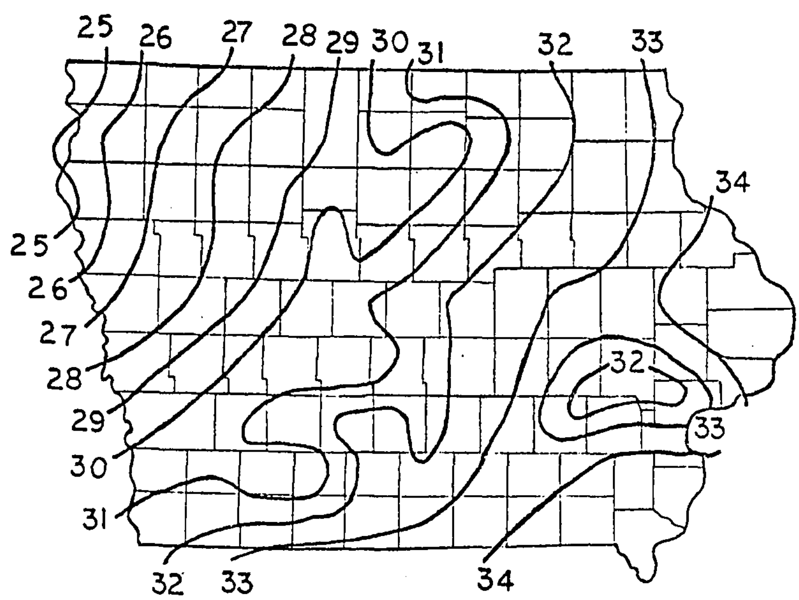
A generalized map of vegetation in central northern United States and southern Canada was published by Wright et al. (1963, p. 1373), in which all of Iowa except the extreme northeast corner was designated as prairie. To the northeast, prairie gives way to a relatively narrow zone of deciduous forest through central Minnesota and then to conifer-hardwood forest in northern Minnesota. A more detailed picture of original vegetation distribution in Iowa was published by The Committee on Forest and Wasteland, Iowa State Planning Board, from data compiled between 1832 and 1859. Oak (Quercus)-hickory (Carya) forest occurs more frequently in the eastern half of the state and is clearly associated with river valleys. The Des Moines lobe is characterized by large expanses of prairie which extend to the west.

This distribution of vegetation within Iowa bears a close relationship to the climatic trend of drier conditions to the west, as shown by the annual rainfall map of Figure 2, after Shaw and Waite (1964, p. 32).

Weaver (1954) reviewed the literature on midwestern prairies extensively. His investigations (Weaver *op. cit.*, p. 271) showed that the true climax prairie of big blue stem (*Andropogon gerardi*) and little blue stem (*Andropogon scorparius*) was very stable under the prevailing climate of western Iowa, southeast Nebraska, and northeast Kansas. Deterioration of the prairie has been brought about through cultivation, burning and excessive grazing.

Weaver and Albertson (1944, p. 475) found that even after the extreme drought conditions of 1933-1940, when areas of original prairie west of the Missouri River lost up to 90 percent of their plant cover, regeneration of annuals and perennials was rapid. Plant density analyses by Robertson (1939, p. 490) during the peak of this drought, in 1936, showed that perennial grasses and other herbs were reduced by as much as 22 percent and that their place was taken largely by annuals, leaving a comparable plant density but a decreased ground coverage. Weaver and Albertson (1940, p. 600) found that areas of original prairie in western Iowa were not greatly affected by the drought; this suggests that the prairies of Iowa in particular, are stable to droughts of the present climate. Although Iowa prairies persist in the

Figure 2. Map of annual rainfall distribution in Iowa, after Shaw and Waite (1964)


25
26
27
28
29
30
31
32
33
34
25
26
27
28
29
30
31
32
33
34
32
33

present climate, there is evidence that oak (*Quercus macrocarpa*) has significantly invaded established prairie within the last one hundred years. McComb and Loomis (1944, p. 48) found that in the vicinity of Indian Creek, central Iowa, the oak-hickory forest had invaded via the broken prairie sod of stream banks. Till soils at the periphery of the forest showed no signs of forest influence, so it was concluded that forest invasion commenced less than 1000 years ago. McComb and Loomis (*op. cit.*, p. 59) concluded that the persistence of oak through the severe drought of 1930-1939 indicated that oak-hickory forest is the true climax vegetation, while prairie is a subclimax, in Iowa.

The first insight into trends of postglacial vegetation in Iowa was given by the pollen data of Lane (1931) for the East McCulloch bog in south Hancock County on the Cary drift. Lane (*op. cit.*, p. 169) interpreted an initial warming phase in the postglacial from basal spruce (*Picea*), pine (*Pinus*), and fir (*Abies*) pollen; oak pollens followed chronologically and were interpreted as a transition vegetation in response to a climatic change to drier and warmer. Eventually grass pollens became dominant and remained so to the surface of the bog. Ruhe *et al*. (1957, p. 687) published radiocarbon dates for a profile from the McCulloch bog, and their conclusions are set out below in Table 4.

Table 4. Summary of postglacial pollen and radiocarbon data, after Lane (1931) and Ruhe, Rubin, and Scholtes (1957)

Pollen strata after Lane (1931)	Radiocarbon dates, Ruhe *et al.* (1957)	Environment
Grassland	Present	Prairie
Grass dominance begins	6,570 ± 200 B.P. 6,580 ± 200 B.P.	Prairie
Deciduous	8,110 ± 200 B.P. 8,170 ± 200 B.P.	Oak forest (warmer)
Conifers	11,660 ± 250 B.P. 11,790 ± 250 B.P.	Coniferous forest (cool)

Another postglacial pollen profile on the Cary drift was published by Walker and Brush (1963, p. 257). They related a regional bog stratigraphy to pollen zones in the Colo bog of Story County, Iowa. The Colo pollen sequence was similar to the McCulloch sequence, and it was observed that the change from forest to grassland pollens occurred near the stratigraphic change from basal peat to upper, dark mineral silts. The evidence of these two bogs and the radiocarbon dates of Table 4 suggests that there was a significant element of coniferous forest on or adjacent to the Cary drift surface for approximately 3,500 years in early postglacial time. A transition period of 1,500 years, marked by mixed forest, led to the prairie environment 6,500 years ago, and this environment continued to the present.

These Iowa pollen data agree well with the regional pollen analyses published by Voss (1934) for Wisconsin, Minnesota, and Illinois. Voss (op. cit., p. 39) found a consistent change from conifers to oaks and maples at one-third of the distance up the bog profile. Pollen diagrams for southeastern Minnesota by Wright, et al. (1963, p. 1379) indicate that arboreal pollens, particularly oak, increase in the near-surface part of the profile, suggesting a late change in climate favoring the advance of forest. This observation is consistent with present-day forest advance described by McComb and Loomis (1944) in Iowa.

In summary, the data above show that the prairie in Iowa at the time of settlement was stable to drought but susceptible to invasion by oak, especially where stream erosion has breached the prairie. Thus the question arises as to the permanence and longevity of the prairie. While the pollen record clearly shows a dominance of conifers in early postglacial time, the probability that such pollens may be heavily over-represented, as shown by Davis (1958, p. 562; 1963, p. 905), leaves the problem of whether the Cary drift surface was sparcely or densely covered by conifers, unanswered. McComb and Loomis (1944, p. 72) seemed to accept the pollen data of Lane (1931) as evidence of a widespread coverage of the Cary surface by conifers. They raised the important pedological question: where are the forest soil features relating to this early environment? They suggested that faunal activity transformed forest soil features to prairie soil features, so that the former are no longer recognizable. This answer to an important pedological question omits at least three important considerations. These are listed as questions below:

1. Does the presence of conifer pollen in bog profiles of the Cary drift indicate a significant stand of conifer forest on the drift surface?

2. If so, was the duration of the conifers sufficient for characteristic forest soil properties to develop?

3. Was the change from forest to prairie environment accompanied by a change of geomorphic surface conditions by erosion, sufficient to remove evidence of prior forest soils?

As yet these questions have not been clearly answered.

D. Soils and the Environmental Framework

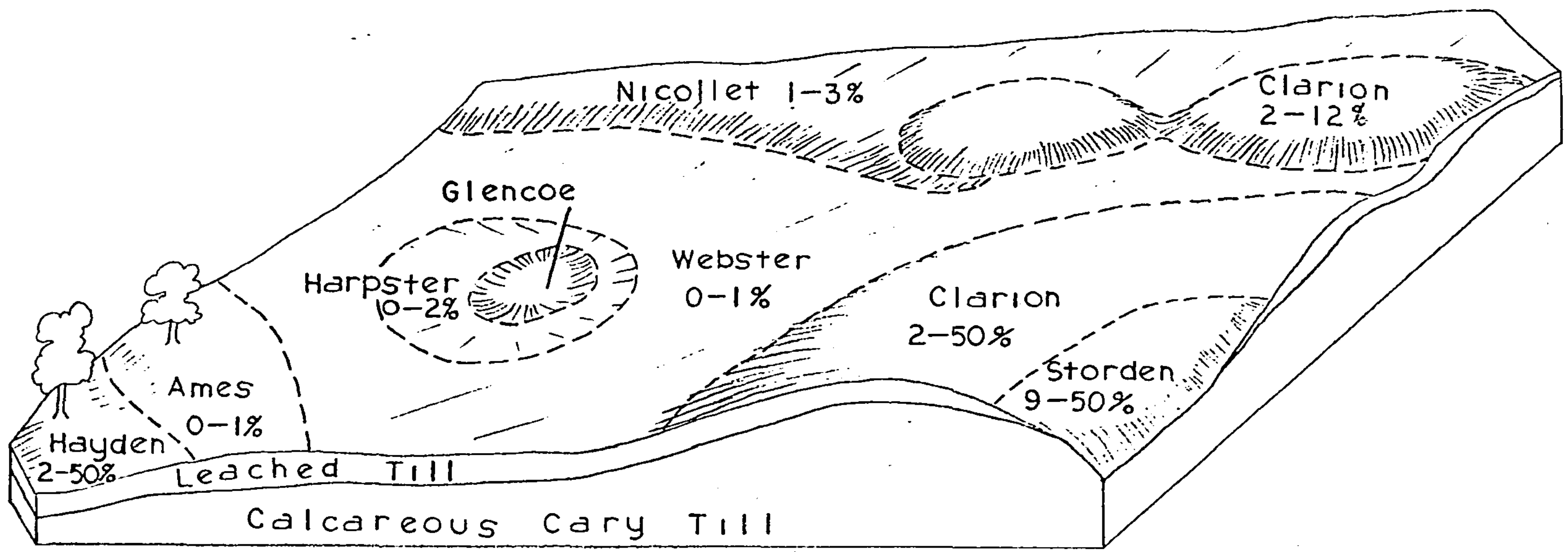
The early soil surveys in Iowa by Marean and Jones (1904) and Ely et al. (1905) separated the soils primarily on the basis of vegetative influences, for example, forest versus prairie. Thus the Marshall series at that time included present-day Clarion-Webster soils on Cary till and Tama-Garwin soils on Wisconsin loess. No attempt was made to separate loess soils from till soils, nor was there a separation on the basis of drainage. The soil surveys of the early 1920's included clear separations of loess and till parent material and recognized drainage sequences on each. The sequence on till was the Clarion series in well-drained positions and the

Webster series in poorly drained positions. The soil survey of Dallas County, Iowa, by Lounsbury and Nordaker (1924) shows the application of these more advanced principles to an area containing both till and loess. An interesting comparison can be made with this soil survey and a slightly earlier soil survey of Webster County on the Cary till by Stevenson et al. (1918), in which the Clarion and Webster series on drift had been separated from the Marshall series on loess, but the Miami series used earlier on both loess and drift was mapped within the area.

A compilation of soil survey data in Iowa by Brown (1936) showed that most of the broad geological separations were reflected in the county soil maps. Gwynne and Simonson (1942, p. 465) showed that the distribution of Clarion and Webster series was a direct result of the glacial depositional pattern of swell and swale. The Clarion series occurred on the higher, coarser glacial deposits of the swell and the Webster series on the lower, finer deposits washed from the drift into the swale. Riecken (1945, p. 320), following the work of McComb and Loomis (1944), developed the concept of the Clarion series as a true prairie soil under grassland while other soils on the Cary surface were developed either under transitional prairie/forest or essentially forest environments. A new series, the Storden, was proposed as a member of the Lithosol great soil group and was characterized by an A/C profile formed directly in the calcareous Cary till. Riecken et al. (1947, p. 438) expanded these concepts into toposequences, using the Clarion series as the "normal" grassland soil on the Cary surface and allowing for four members for each of the prairie, transitional, and forest sequences. The toposequence for the prairie environment, starting with the least well-drained became Webster (Wiesenboden), Nicollet (Intermediate), Clarion (Prairie), and Storden (Lithosol). Riecken _et al_. (_op_. _cit_., p. 438) further proposed a separation of soils on the Iowan drift (Carrington toposequence) and the Cary drift (Clarion toposequence) on the basis of depth of leaching of carbonates. These and other revised concepts of the soil associations in Iowa were described in detail by Riecken and Smith (1949). The topographic positions of series in the Clarion-Webster soil association on the Cary till are shown in Figure 3.

Data relative to the nine series in the biotoposequence on Cary till proposed by Riecken _et al_. (1947, p. 439) was obtained by Cardoso (1957). The utility of the biotoposequence concept, and sets of data, for comparative purposes has been discussed by Riecken (1965, p. 59). It can be seen, however, that while the vegetative and topographic scales of these biotoposequences provide a workable system for comparisons, their accuracy in depicting the genetic pathway of the soil series in each cell rests on assumptions relating to surface age, surface stability, and vegetative history of the post-Cary interval. It is the purpose of this thesis to examine these assumptions.

Figure 3. Topographic positions of soils in the Clarion-Webster soil association on Cary till in Iowa, after Riecken and Smith (1949)


Nicollet 1-3%
Clarion
2-12%
Glencoe
Harpster
0-2%
Webster
0-1%
Clarion
2-50%
Storden
9-50%
Ames
0-1%
Hayden
2-50%
Leached Till
Calcareous Cary Till

III. DESCRIPTION OF STUDY AREAS

A. Procedure

Areas were selected for detailed study following extensive field examination of bog watersheds on the Des Moines lobe. Enclosed bogs were sought since these are a repository of materials relating to vegetational and sedimentational episodes of the past. Further requirements were that the bog sediments should be sufficiently enclosed by the watershed perimeter that most of the depositional record is retained, and that bog sediments be sufficiently deep and organic to facilitate pollen studies and sampling for radiocarbon analysis.

Borings were made in approximately twenty bogs along the north-south axis of the Des Moines lobe. The location of a number of these sites was shown by Walker and Brush (1963, p. 254), specifically those bogs deeper than 8 feet which contained double mineral and organic strata. Shallower bogs were examined but these showed a predominance of silts of low organic matter content.

As a result of these initial investigations, five bogs were chosen which best fulfilled the requirements of closure, depth and nature of the sedimentary column, and which were spaced in such a way as to represent the range of morainal topographies of the lobe. The location and local name of each of the five sites is given in Table 5, together with notes about the morainal topography. The location of the sites is also shown in Figure 1.

Table 5. Description of the five study areas and their location

Bog	Location	Topographic position
Colo	Sections 11, 12, R21W, T83N, Story County	Bemis moraine
Jewell	Section 13, R25W, T86N; Section 18, R24W, T86N, Hamilton County	Altamont moraine
McCulloch	Section 32, R24W, T94N, Hancock County	Altamont moraine
Woden	Section 13, R26W, T97N, Hancock County	Algona moraine
Hebron	Section 27, R27W, T100N, Kossuth County	Algona ground moraine

Of the five bogs, only the McCulloch has been previously studied for pollen and sediments. Lane (1931, p. 169) presented pollen data for this bog, which he named the East McCulloch bog, and Ruhe et al. (1957, p. 687) obtained radiocarbon dates from the same location which they related to significant postglacial vegetational changes suggested by Lane's work. A greater part of the work reported in this thesis relates to Colo and Jewell bogs. The other three bogs were less intensively studied and the data from them is used more as supporting evidence.

B. The Colo Bog

A detailed topographic survey of the Colo bog and its watershed was made in June 1963; the resulting contour map, with elevations based on local datum, is shown in Figure 4a.

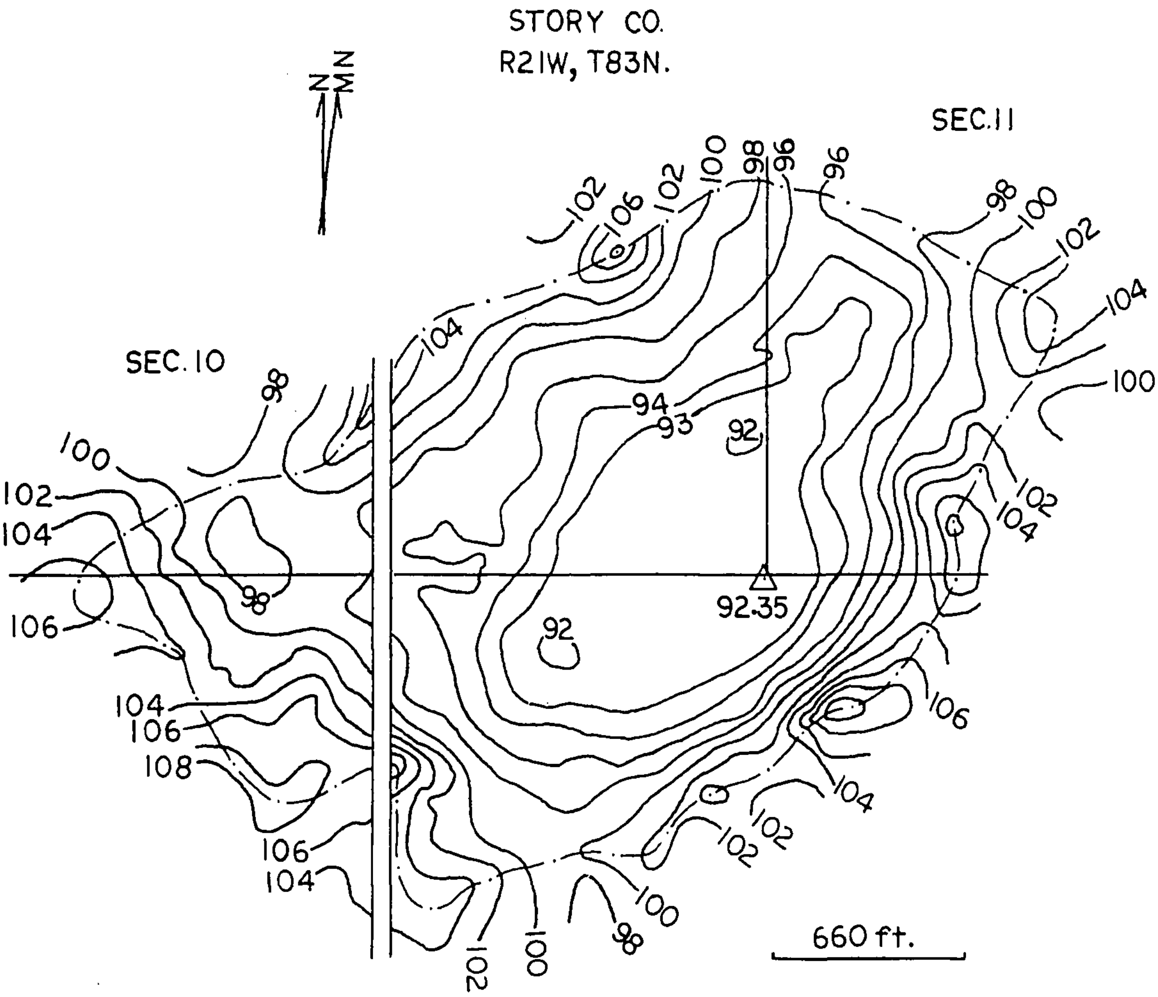
The Colo bog lies in gently undulating, parallel swell and swale topography of the Bemis moraine. Other smaller bogs lie to the northeast and south. Maximum relief in the bog watershed is 20 feet, from the bog center to the perimeter. The perimeter shown in Figure 4a has been placed on the basis of present topography and generally there is a clear break of slope along the perimeter line. However, the characteristic occurrence in this area of oriented chains of bogs suggests that there may have been overflow from one to the other in early postglacial time. A significant feature in this respect is the low level of the perimeter in the northeast of the Colo bog, adjacent to the next bog in the chain. It will be shown later, however, that the main body of bog sediment terminates well within the established perimeter, so that the degree of closure is considered to be satisfactory.

Most of the surface of this bog watershed is cultivated and planted to corn or soybeans. The central bog area below the 94-ft. contour has not been cultivated in the last three years, mainly because deterioration of tile drains has permitted low level flooding of the bog area for two or three

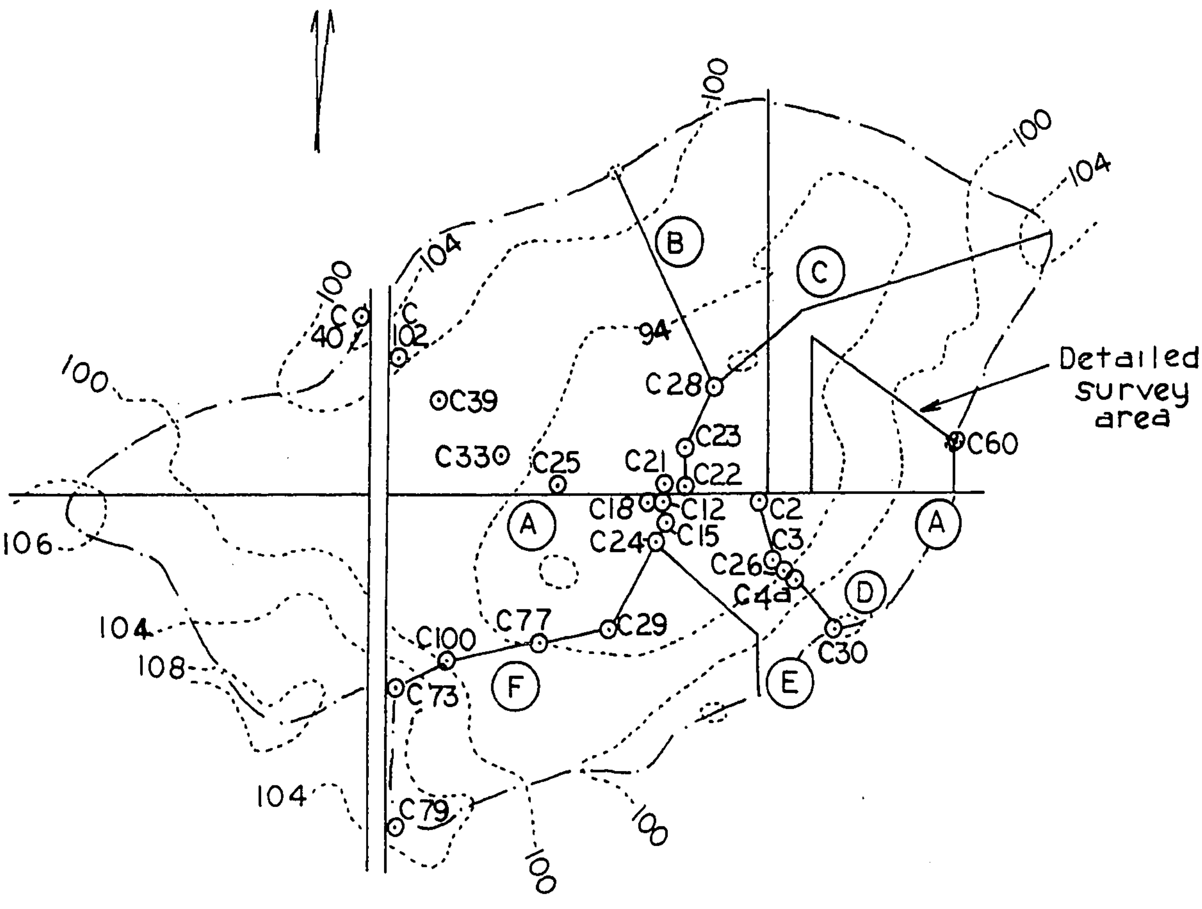
Figure 4a. Map of the Colo bog watershed showing two-foot contours, based on local datum, and the perimeter

A reference ground elevation is shown near the center of the bog.

Figure 4b. Map of the Colo bog watershed showing the location of sample sites, detailed study area, and transects



a.


100
100
104
104
100
C
40
C
102
94
Detailed
survey
area
C28
C39
C33
C23
C25
C21
C22
C60
C18
C12
C2
A
A
B
C
106
C24
C15
C3
C26
C4a
D
104
C100
C77
C29
C30
108
C73
F
E
104
C79
100
100
100

b.

months in the spring and early summer each year.

C. The Jewell Bog

A detailed topographic survey was also made of the Jewell bog in June and July 1963. The contour map, based on local datum, is shown in Figure 5a. The Jewell watershed is larger and of greater relief than the Colo watershed, with up to 45 feet elevation difference between the bog center and the perimeter high points. The difference in bog topographies relates to the difference in morainal topographies; the Altamont moraine typically has steep slopes and considerable relief, whereas the Bemis moraine is gently undulating. The morainal topography is also more complex at Jewell. Smaller, enclosed depressions surround the main bog at higher levels, and higher summits occur within half a mile to the east and north of the delineated perimeter of Figure 5. Indeed, the perimeter line does not represent a true watershed divide in all places. The sedimentary data show, however, that the delineated watershed closely approximates the requirements of closure desired for the present work.

The entire watershed of the Jewell bog is accessible to cropping and cultivation. The central bog area is effectively tiled so that water does not lie on the surface for more than one or two days after heavy rain.

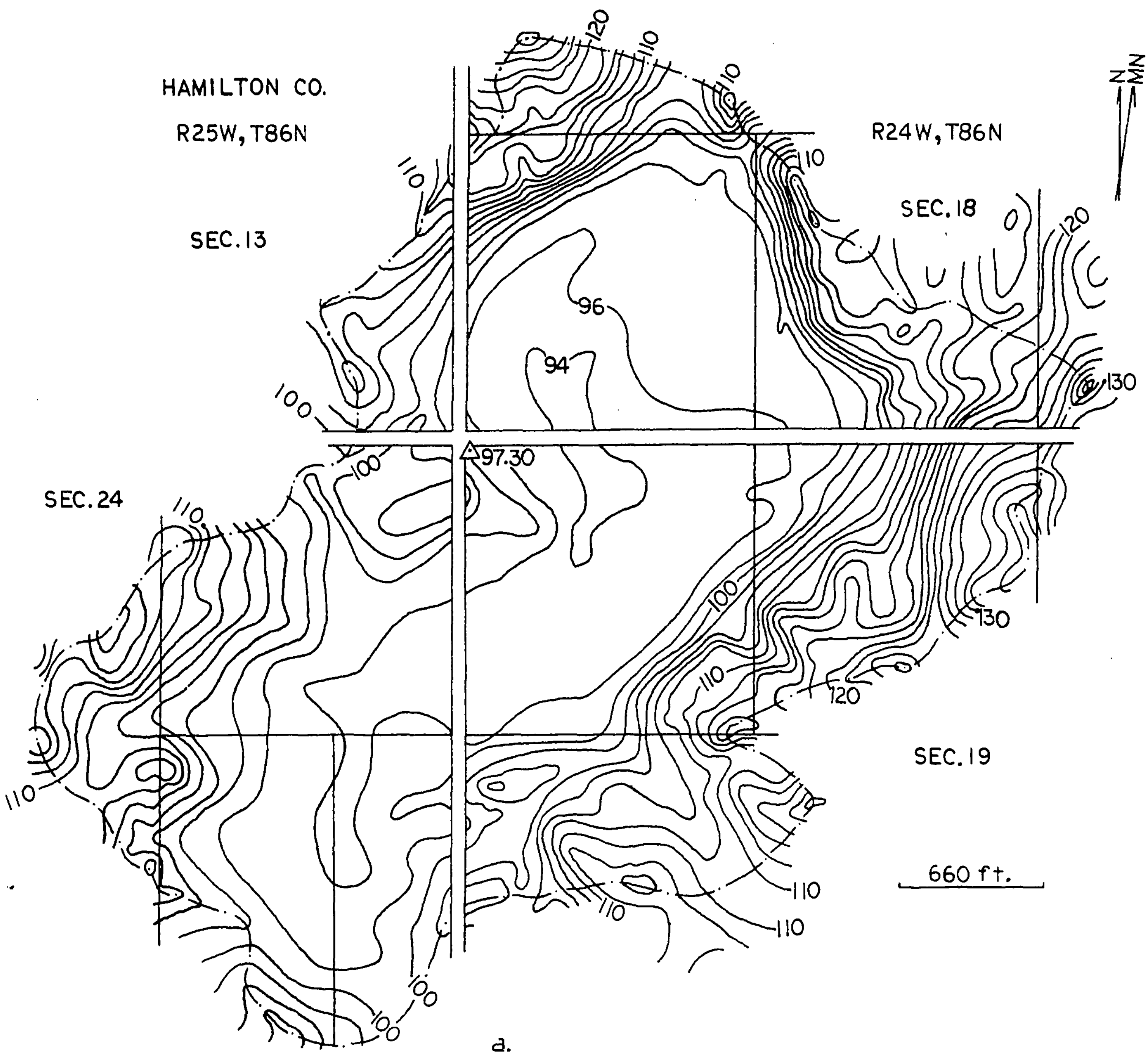
D. The McCulloch Bog

The McCulloch bog lies in the steep Altamont morainal

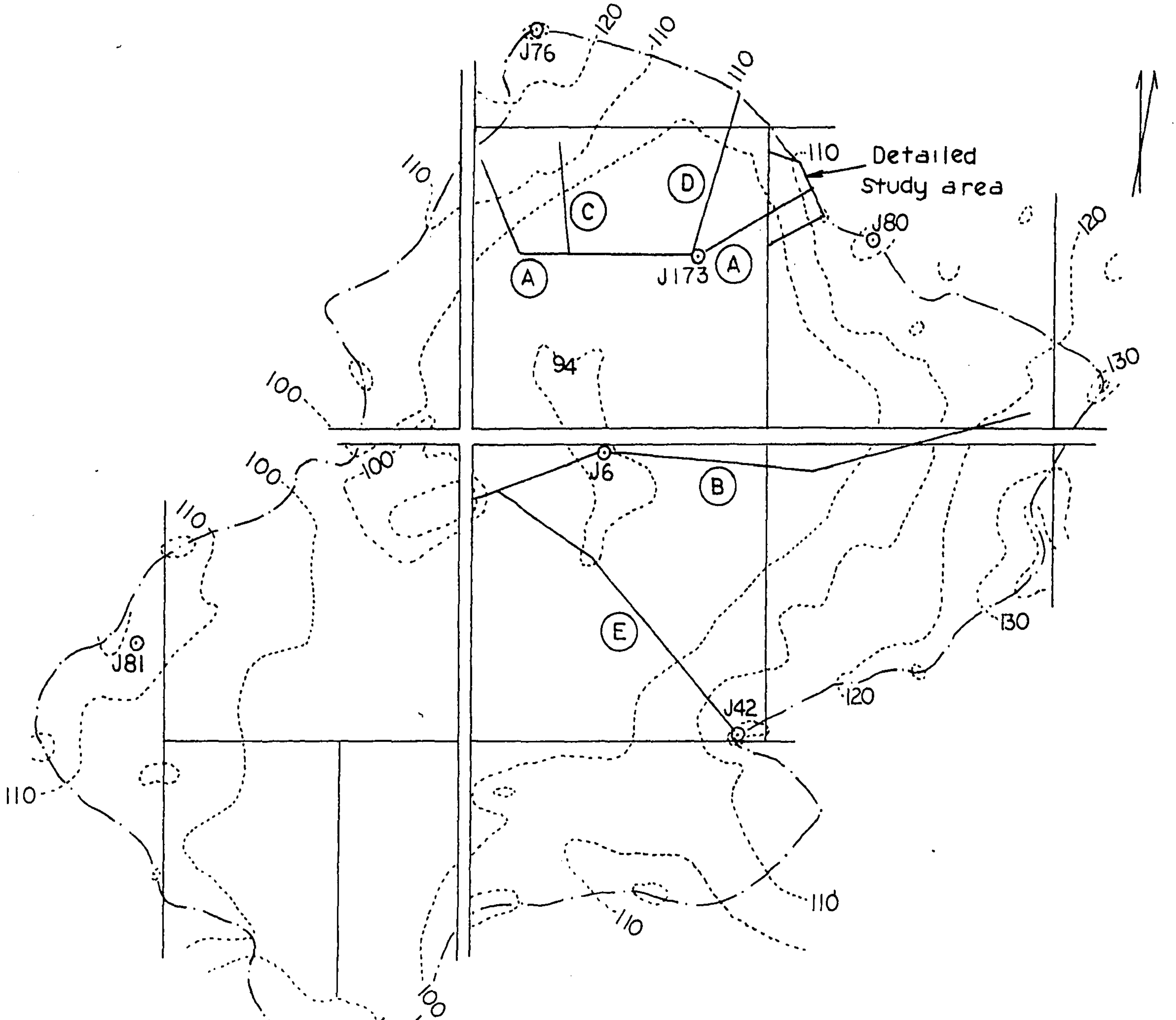
Figure 5a. Map of the Jewell bog watershed showing two-foot contours, based on local datum, and the perimeter

A reference ground elevation is shown near the bog center

Figure 5b. Map of the Jewell bog watershed showing the location of sample sites, detailed study area, and transects


HAMILTON CO.
R25W, T86N
R24W, T86N
SEC. 13
SEC. 18
SEC. 24
SEC. 19
N
MN
120
110
110
110
110
96
94
100
100
97.30
110
130
100
130
110
120
110
110
110
110
100
100
660 ft.

a.



J76
120
110
110
110
110
Detailed
Study area
J80
120
C
D
A
J173
A
94
100
130
100
100
J6
B
110
E
J81
130
120
J42
110
110
110
100
100

b.

landscape in northern Iowa. The watershed has a comparable relief to Jewell, but is of larger area. Field inspection indicated a comparable degree of closure to the Jewell bog. The bog area, rather than consisting of one depression, has several smaller, discontinuous depressions adjacent to the main bog. The latter, however, is the part of interest to this study and is that part which was studied previously by Lane (1931) and Ruhe *et al.* (1957).

The McCulloch watershed is under crop and pasture and the central bog area, although effectively drained, has remained under pasture throughout the period of this study.

E. The Woden Bog

The Woden bog lies in the steep topography of the Algona moraine. Although its watershed is relatively small, the depth of bog sediments is greater than in the other areas of study. The Woden is one of a chain of bogs, some of which have bodies of water which may remain for several years. Entire closure of the bog has not been established in detail, but appears from preliminary field evidence to be satisfactory, except for a low watershed divide in the southwest, adjacent to another small enclosed bog.

Most of the Woden watershed is under cultivation, and the central bog area is drained and cropped more or less continuously.

F. The Hebron Bog

The Hebron bog occurs in the gently undulating landscape of the Algona ground moraine, three miles south of the Iowa-Minnesota border. The watershed has an areal extent and relief comparable with the Colo watershed. This bog was briefly examined and sampled in June 1964.

The entire Hebron watershed is under cultivation and pasture, and the bog center is tiled and was under pasture at the time of sampling.

IV. STRATIGRAPHIC RELATIONSHIPS

A. Colo Bog

1. Bog center profile (C22)

The investigations at each bog started with the location of a central profile which was the deepest bog profile in the watershed and which presumably contained the sedimentary and vegetational history in the most expanded form. The central profile so chosen was sampled to characterize the bog sediments and was subsampled for chemical, physical and pollen analyses. The location of this central core (C22) in relation to the bog watershed is shown in Figure 4b.

The central bog profile at Colo, C22, is described in detail in Appendix A. A summarized version of the strata is given in Figure 12. Although the profile is stratified and complex in detail, the organic materials can be readily separated in the field from those of essentially mineral character. This separation of bog materials is maintained throughout the thesis.

The sequence of bog materials in profile C22 is typical of bog center cores examined in various parts of the Des Moines lobe. The surface horizons are highly organic and are characterized by 6 to 12 inches of black[1] (N 2/0) finely divided, humified muck at the immediate surface, below which is 12 to 36 inches of black (5YR-10YR 2/1) peat in which botanical form

---

[1]The Munsell notation is given for moist soil colors.

is still evident. These horizons are usually noncalcareous at Colo. Usually there is a gradational change through a peaty muck horizon to essentially mineral sediment beneath. For the purpose of this and later discussions, the upper organic-rich horizons are grouped together under the informal designation Upper Muck, abbreviated to UM. The upper muck zone at Colo is thus the Colo UM zone.

The UM zone at Colo passes gradually to essentially mineral sediment which is a black (10YR 2/1) to very dark gray (10YR 3/1) silty clay loam to silty clay, sticky and plastic, calcareous and contains sporadic shell fragments. The only variation in these sediments is the occasional occurrence of light olive gray (5YR 6/2) silty, calcareous sediment. The origin and significance of these thin strata are not known at present. The main body of black calcareous silt is up to 8 feet thick at Colo and is 7 feet thick in the center profile C22. This essentially mineral sediment zone is given the informal designation Upper Silt, which is abbreviated to US.

The US zone at Colo passes gradually to essentially organic materials at depth which are black (10YR-5Y 2/1) friable muck in the upper part becoming dark olive gray (5Y 3/2) sticky muck at depth. This muck zone is up to 6 feet thick, weakly calcareous to noncalcareous, and shell fragments are rare or absent. A degree of broad lamination occurs in these organic materials at Colo and they have the property that the freshly sampled material changes from olive colors to black on exposure to the atmosphere. There is also a concurrent loss of botanical form. This latter property contrasts with the peaty material of the UM zone which maintains its botanical form on exposure. The lower muck zone is given the informal designation LM.

The Colo LM zone passes gradually with depth into essentially mineral sediments which are dark olive gray (5Y 3/2), sticky and plastic, silty clay loam to silty clays in the upper horizons but become dark gray (5Y 4/1) with depth. These sediments are up to 6 feet thick, generally calcareous and shell fragments are rare or absent in the upper part and absent at depth. These lower silty sediments are given the informal designation LS.

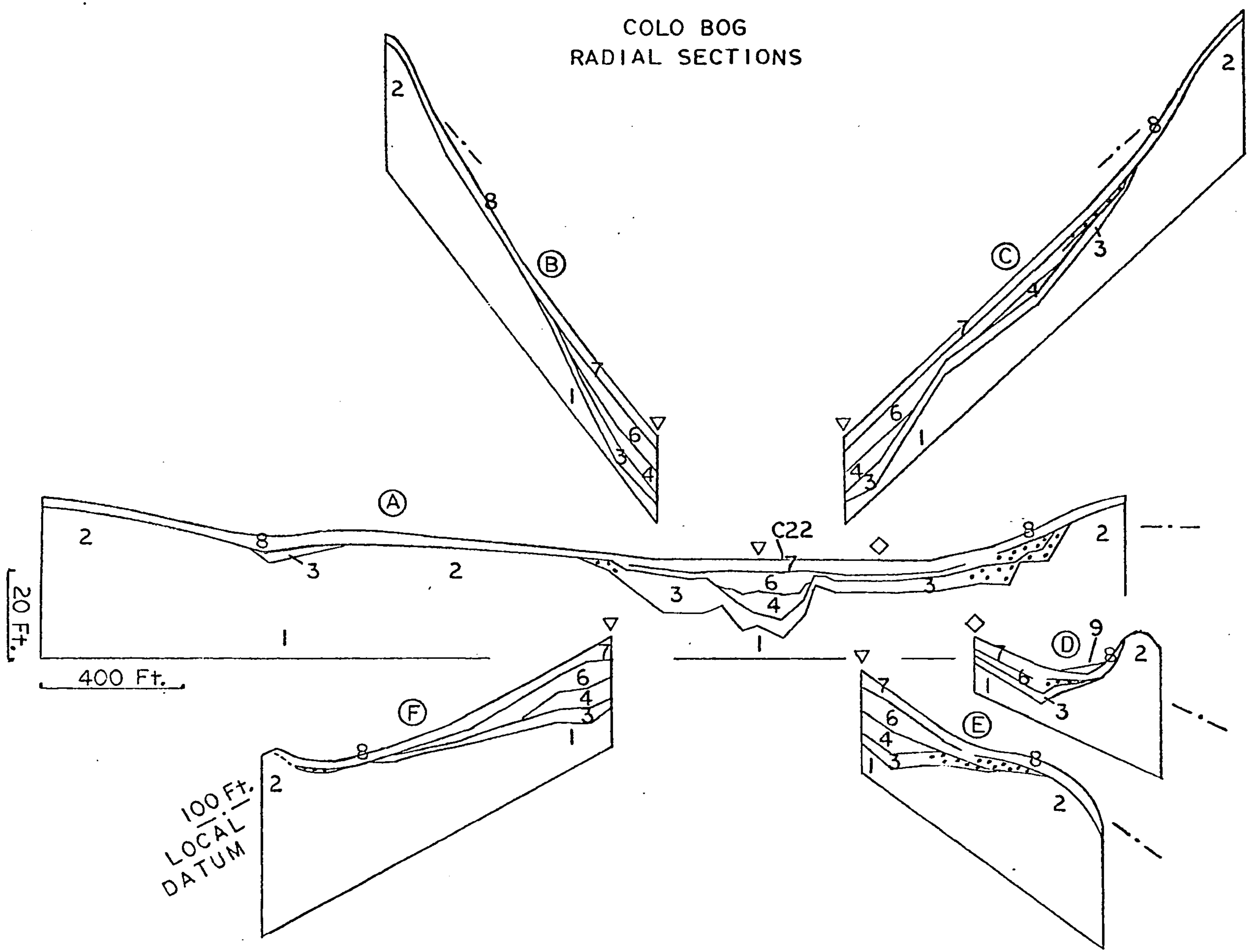
The Colo LS zone passes abruptly at depth to a gray (5Y 5/1) to dark gray (5Y 4/1) gravelly loam which is calcareous and essentially without stratification to a depth of two to three feet below the transition. This material is recognized as the unoxidized unleached Cary till which is the basal reference sediment in the area. A point of difference exists between the profile shown in Figure 12 and the same profile described by Walker and Brush (1963, p. 257). The thin band of what was thought to be relatively organic material at 18 feet was found to be essentially mineral in nature and is thus excluded from the muck category.

2. Strata across the bog

Numerous cores were drilled adjacent to the center profile C22, and transects were made across the bog to establish the continuity of the various strata defined in the previous section. The location of sampled profiles and drilled transects is shown in Figure 4b. From the field data sectional diagrams were drawn to show the stratigraphic relationships in the bog area of the watershed. The full section across the bog and a number of radial sections are shown in Figure 6. The central bog area with UM/US/LM/LS zones occupies a relatively small area within the bog watershed; the LM zone in particular wedges out quickly in all directions from the center. The LS zone extends across the bog and underlies most of the UM and US zones. The nature of these bog materials changes with distance from the bog center. Where the LM zone thins out over the underlying LS sediment the horizons become intensely laminated, tough and generally noncalcareous, compared with the central LM materials, which are soft and broadly laminated. The composition of the UM zone is consistent over much of the bog area. The thickness of the mucky and peaty horizons varies slightly, but the order and kind of horizons is constant until the UM zone merges with surficial mineral sediments at the edge of the bog. The US sediments are relatively uniform and tend to be contiguous with the LS sediments, but wedge out slightly more quickly with distance from the bog center. At the edge of the bog the

Figure 6. Radial sections showing the stratigraphy of the Colo bog watershed: unoxidized and unleached Cary till or drift (1); oxidized and unleached Cary till or drift (2); lower silt zone (3); lower muck zone (4); upper silt zone (6); upper muck zone (7); hillside surficials (8); post-settlement deposits (9)

COLO BOG
RADIAL SECTIONS



US sediments interfinger with the hillside surficial sediments and underlie them extensively on the eastern side of the bog. The LS sediments are also relatively uniform throughout the bog, but in the vicinity of hillsides on the eastern side, interfinger with sandy and gravelly sediment, hereafter referred to as toeslope sands and gravels (TS).

It is concluded that there is an array of organic-rich and mineral sediments characteristic of the main depressional area of the bog watershed, which is distinct from materials associated with the adjacent hillsides. The relationships between the bog and hillside materials have significance since the bog sediments are thought to be derived from erosion of the hillsides. These relationships are discussed in the following section.

3. Bog and hillside stratigraphy

The relationship of bog and hillside sediments was studied on the eastern side of Colo bog in the area designated in Figure 4b which has been surveyed in detail and is shown in Figure 7. The transects which provide the basic data are shown in Figure 8 together with notes on the location of sampled profiles.

Section D shows the presence of glacial drift material near the hill summit (profile C30). Till-like material thickens downslope and soils of firstly the Storden, then cumulic Nicollet series are encountered. The latter are developed

Figure 7. Map of the detailed study area on the east side of the Colo bog watershed, showing the one-foot contours and the location of transects

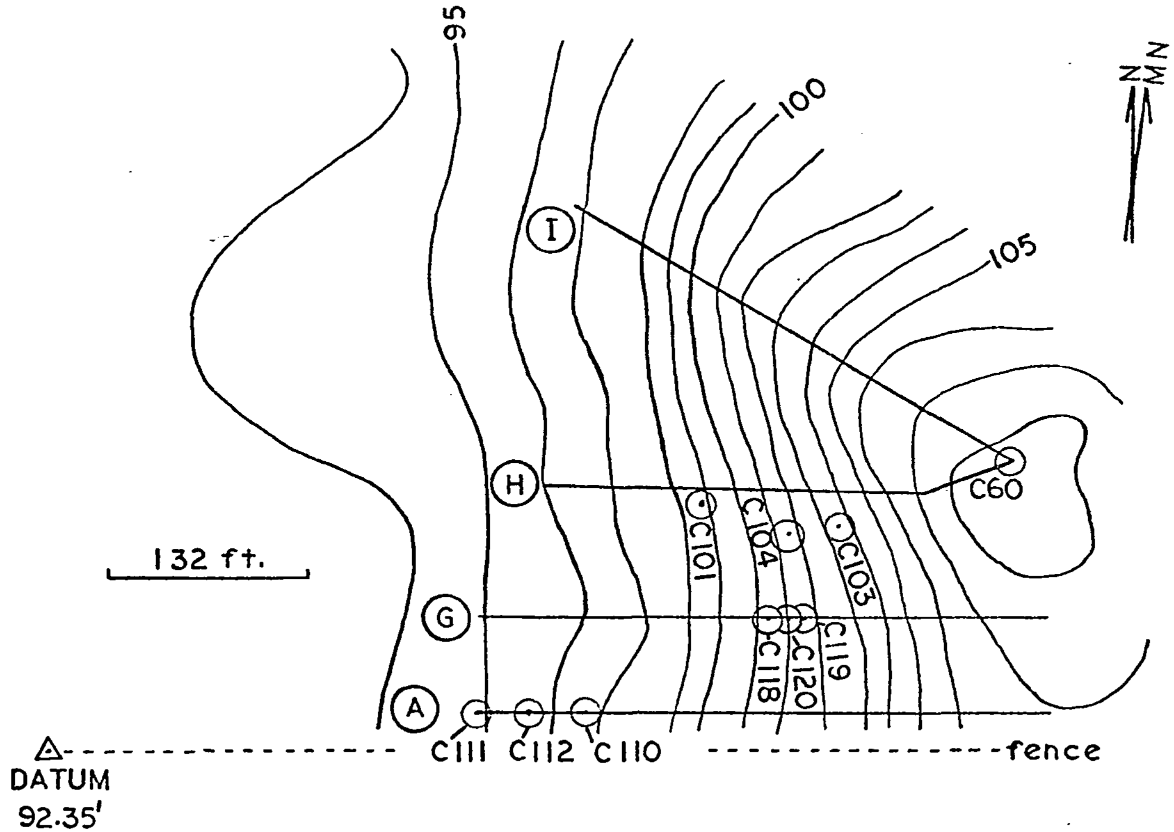
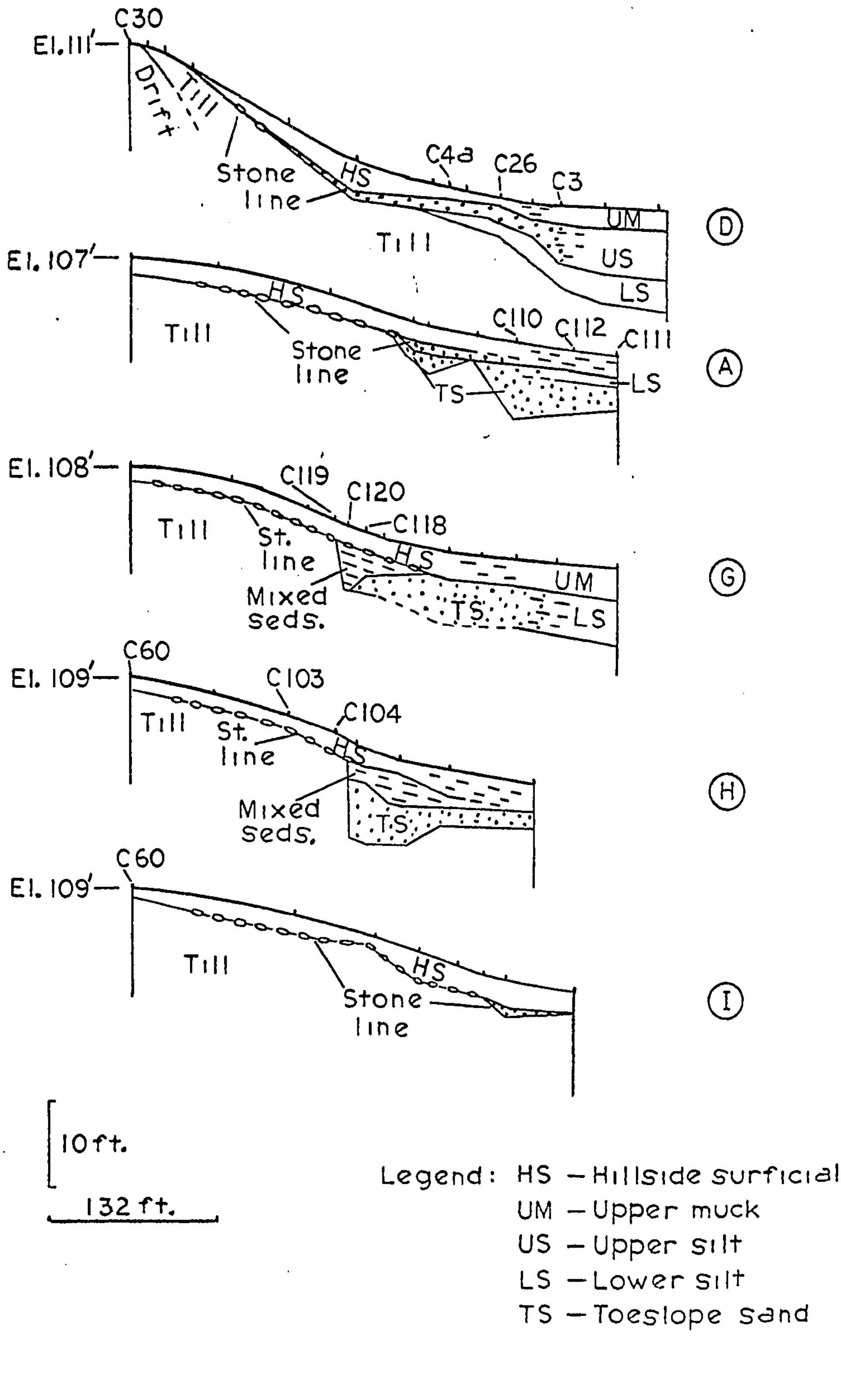

95
100
105
N
MN
I
H
G
A
C101
C104
C103
C60
C118
C120
C119
C111
C112
C110
132 ft.
DATUM
92.35′
fence

Figure 8. Transects across the detailed study area on the east side of the Colo bog watershed showing hillside and bog stratigraphy


C30
El. 111'
Drift
Till
Stone
line
HS
C4a
C26
C3
UM
US
LS
Till
D
El. 107'
Till
HS
Stone
line
C110
C112
C111
TS
LS
A
El. 108'
C119
C120
C118
Till
St.
line
HS
UM
Mixed
seds.
TS
LS
G
C60
El. 109'
C103
C104
Till
St.
line
HS
Mixed
seds.
TS
H
C60
El. 109'
Till
HS
Stone
line
I
10 ft.
132 ft.
Legend: HS – Hillside surficial
UM – Upper muck
US – Upper silt
LS – Lower silt
TS – Toeslope sand

within hillside surficial sediment over a more or less continuous stony zone at the top of the till, which is parallel to the surface and is referred to as a stone line, following the definition of Sharpe (1938, p. 24). In the position of profile C4a (Harpster series) the thickened A horizon becomes stratified with sediment of contrasting particle size and a thin band of bog silt sediment (LS) at 40-58 inches separates the hillside surficial sediment from the underlying till deposit. At site C26, the surface horizon is mucky, but still contains the relatively coarse material identifiable with hillside sediment. The hillside surficial sediments below the surface horizon are stratified loams, clay loams and sandy loams and at 31-42 inches, the gray silty bog stratum (LS) again separates the hillside surficial deposit from the till. At site C3, the characteristic horizonation of the Colo UM zone occurs, but the influence of the surficial hillside sediment can still be seen in the presence of coarse sand particles. Below the UM zone, the dark mineral sediments become finer with depth, indicating a progressive change towards sediments of the US zone. The change to fine textured, gray, calcareous sediments of the LS zone is abrupt at 78 inches, and these sediments continue more or less uniformly until the Cary till contact at 111 inches. Fifty feet on the bog side of profile C3, the coarser fractions in the UM zone are diminished and the hillside influence can no longer be seen in the sediments at the site of profile C2.

The sections A, G, H and I of Figure 8 show an important feature of hillsides generally in the Colo watershed, namely, that the stone line, an erosional phenomenon, can be followed from near the hill crest situations, downslope and into fringing bog sediments. In these hillside sections, the upper slopes are essentially convex (Clarion soils) and there is a simple relationship of surficial sediment over the till with a relatively gravelly interface. Downslope from the surface inflection from convex to concave, soils of the Nicollet series are encountered and the surficial sediments and stone line overrides stratified materials (C118, 119, 120). At depth, thick, light olive brown (2.5Y 5/4) sands and gravels occur. In sections A, G, and H, there is evidence of a notch in the underlying till, so that the stratified sediments and toeslope sands and gravels are set into the till. It is significant that the upper surface of the sands and gravels is at an elevation of 96 feet by local datum. This relationship suggests a lacustrine origin of the coarse sediment. Profiles C104 and C119 are characteristic of soils with thickened surficial sediment in their upper horizons; profile C120 shows clear evidence of the stone line and profile C118 shows the characteristics of the underlying sands and gravels. Downslope the toeslope sands and gravels are interstratified with LS sediments of the bog and the upper surficial stratum becomes progressively more organic. In this position, the stone line at first thickens and then becomes unidentifiable in the top of the underlying stratified deposits. These trends are characterized by profiles C110, C112 and C111 in transect A, Figure 8.

Transect I on the convex nose of the local landscape has the well drained Clarion soils over most of its upper length and the surficial sediment directly overlies a stone line and then till for the entire slope.

The stratigraphic relationships existing between bog and hillside sediments at Colo can be summarized into four propositions which will later be found to have applicability to the other bog watersheds.

a. The surface of the Colo bog watershed is the product of surficial erosion and weathering of hillsides and preferential accumulation of organic residues in the bog. This geomorphic surface can be traced from hillside to bog, and the sediments on which this surface has developed interfinger in a transitional zone which corresponds to the break in slope from hillside to bog depression.

b. The hillside surficial sediments are bounded at their base by a more or less continuous stone line which generally becomes unidentifiable in the landscape position where surficial hillside sediments are differentiated above the toeslope sand deposits. Where the stone line can be followed into the sedimentary transition zone, some upper bog silt sediments occur above and below it. Thus it is concluded that the stone line was formed contemporaneously with the upper part of the bog sediment with which it interfingers, and that the surficial hillside sediment and upper bog silts represent different facies of the one sedimentological system.

c. The surface of the LM zone at Colo could not be related to surfaces beyond the central part of the bog by field studies. Thus no statement can be made about the relationship between the LM zone materials and the adjacent hillside materials.

d. The LS zone at Colo has a definable, contemporaneous, stratigraphic relationship to the toeslope sands and gravels (TS) on the east side of the bog. The relationship between these sediments and their stratigraphic position indicates that prior to development of the hillside surficial and bog sediments on which the watershed surface occurs, there was an earlier sedimentary system, with broadly the same sedimentary facies separations (LS-TS), and with a similar orientation in relation to the center of the bog.

B. Jewell Bog

1. <u>Bog center profiles</u> (<u>J6</u>, <u>J173</u>)

Two profiles were sampled in the central area of the Jewell bog. The location of these profiles is shown in Figure 5b and the strata are represented in Figure 12. Descriptions of both profiles are given in Appendix A. The broad stratigraphic divisions and designations used for Colo are again used here.

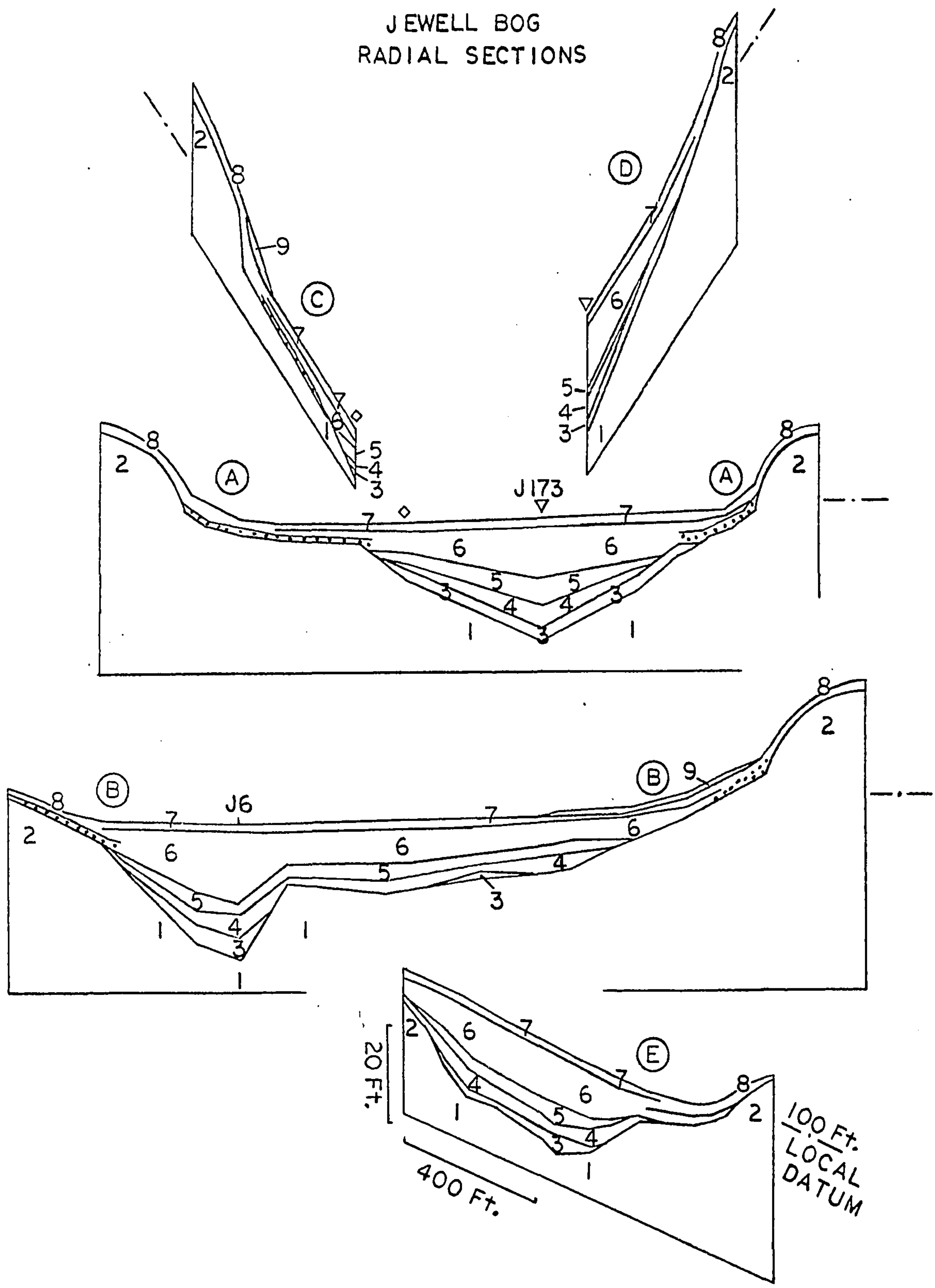
The UM zone at Jewell is thinner than the corresponding zone at Colo. It consists of 6 to 10 inches of muck over 10 to 20 inches of firm peat or mucky peat, both of which are often weakly calcareous. The US zone lies immediately below and is the most significant body of sediment in the Jewell bog, being 13 feet thick in profile J6, and 8 feet thick in profile J173. It is characteristically a black (10YR 2/1) to very dark gray (5Y 3/1) silty clay loam to silty clay, calcareous, sticky and plastic, and with occasional shell fragments. The US zone passes at 10 to 15 feet into the LM zone which characteristically has abundant shells in the upper horizon. The shell-rich stratum varies in thickness from one foot to 4 feet and passes into the main LM zone which is 3 to 5 feet thick, usually black (5Y 2/1) or very dark gray (5Y 3/1) with infrequent shells and is weakly to strongly calcareous. At depth the LM zone becomes soft and finely divided with a tendency to olive coloration. The LS zone at Jewell consists of olive (5Y 4/3) colored to black (10YR 2/1), sticky, plastic, calcareous, silty clay loams to silty clays. In the LS zone of J173, some of the black (N 2/0) sediment reacts strongly to HCl with evolution of H_2S, indicating the presence of sulfides in the sediment. Another common feature of the LS sediment and the lower part of both J6 and J173 profiles is the appearance of brilliant blue flecks and soft nodules which develop on aeration from areas of grayish (5B 6/1) mottle. Similar materials have been described in bog environments by Koch (1956, p. 201) and Wright *et al*. (1963, p. 1377) and has been identified mineralogically as vivianite, an iron phosphate ($Fe_3P_2O_8.8H_2O$). The LS zone sediments are 4 to 8 feet thick and pass abruptly to thin gravelly sediments and dark gray (5Y 4/1) calcareous unoxidized Cary till. At the transition from the LS zone to the Cary till, abundant wood fragments commonly occur, many of which are sufficiently large and well preserved to permit species identification.

2. Strata across the bog

The cross sections at Jewell which contain the two center cores J6 and J173 are shown with radial traverses in Figure 9. There is a strong similarity in the stratigraphy of Colo and Jewell bogs, although the degree of expression of particular strata differs. Points of difference are the widespread occurrence at Jewell of the shell-rich horizon of the LM zone and thicker sandy strata differentiated from the hillside surficial materials at the edge of the bog. The distribution of bog strata is also different at Jewell. The LS zone is sporadic and is not found as close to the lower hillslopes, while the LM zone is thick and widespread, and interfingers with hillside sediments. The US zone at Jewell is thick and frequently interfingers with the surficial hillside sediments while the UM zone is thinner than at Colo.

As is the case at Colo, the strata of the Jewell bog represent a systematic pattern and sequence which is distinct

Figure 9. Radial sections showing the stratigraphy of the Jewell bog watershed: unoxidized and unleached Cary till or drift (1); oxidized and unleached Cary till or drift (2); lower silt zone (3); lower muck zone (4); shell-rich horizon (5); upper silt zone (6); upper muck zone (7); hillside surficials (8); post-settlement deposits (9)


JEWELL BOG
RADIAL SECTIONS
A
B
C
D
E
J173
J6
20 Ft.
400 Ft.
100 Ft.
LOCAL
DATUM

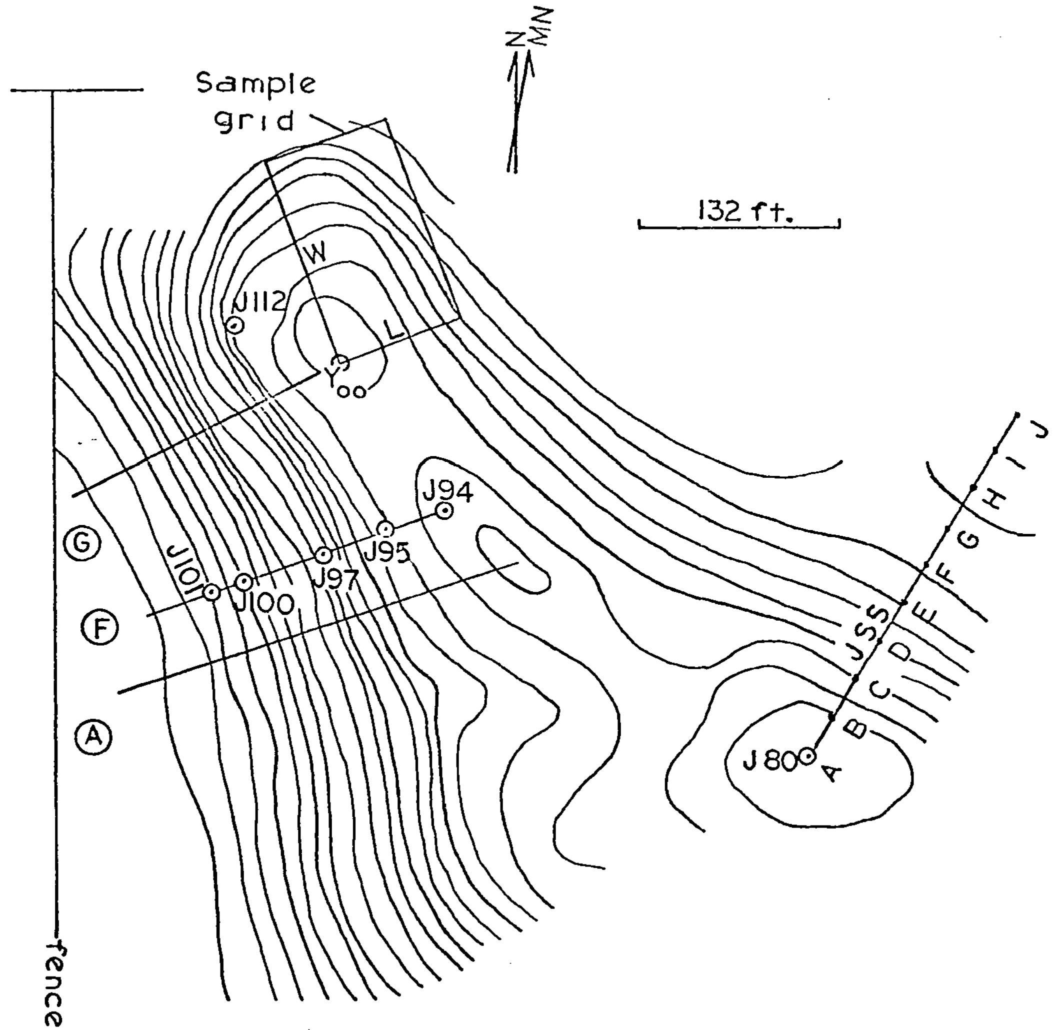
from the adjacent hillsides, but bears a definite stratigraphic relationship to the hillside surficial sediments.

3. Bog and hillside stratigraphy

Details of bog and hillside stratigraphy were studied on the east side of the Jewell bog in the area shown in Figure 5b. The location of traverses and sampling sites in this area are shown in Figure 10 and the details of hillside and bog stratigraphy along the transects are drawn to scale in Figure 11.

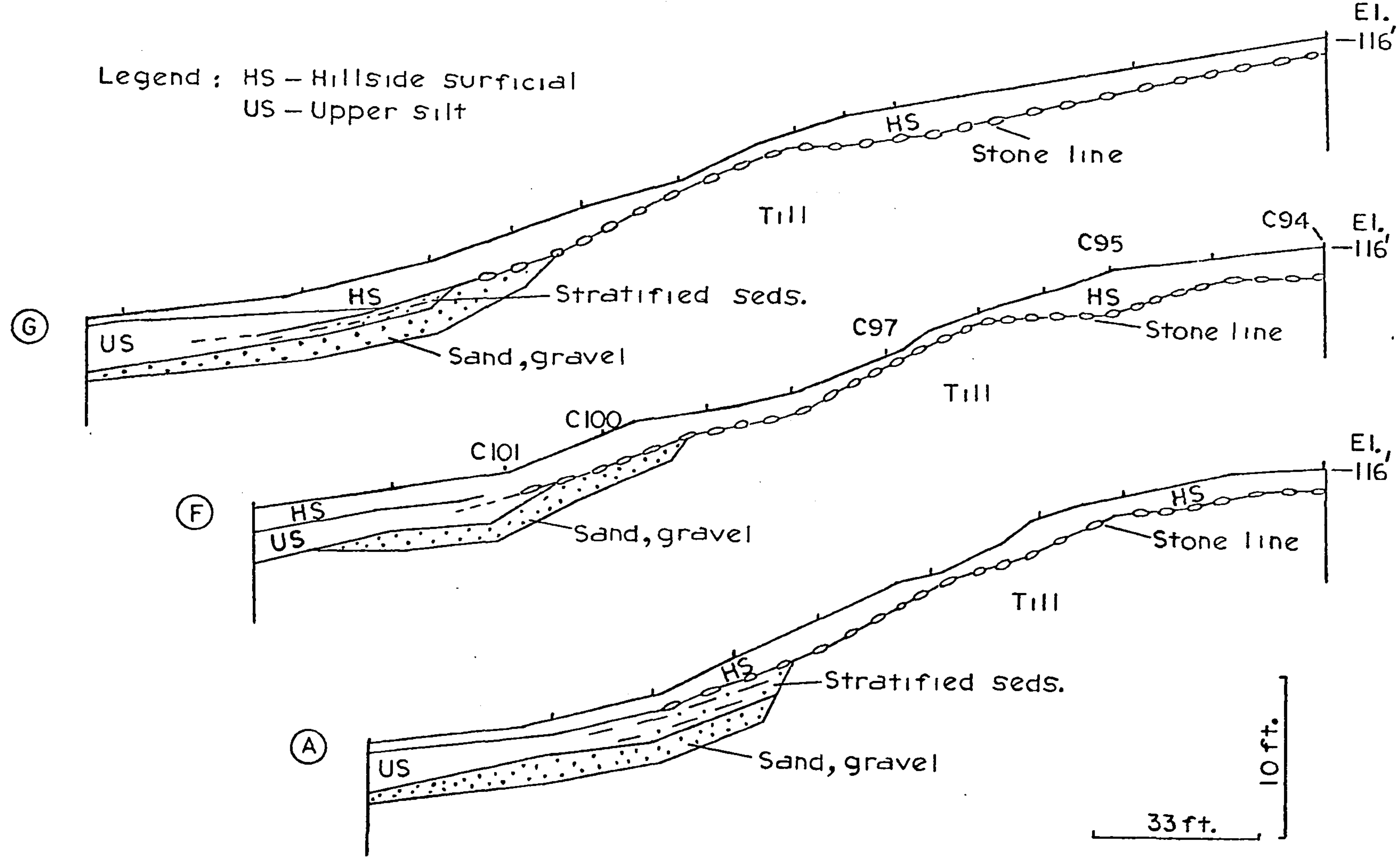
Section F in Figure 11 shows the location of profiles J94, J95, J97, J100 and J101, which were sampled to illustrate the particular features of sediments and soils. The occurrence of a pronounced stone line over much of the hillside, including the summit, provides a ready basis for separating surficial sediment from underlying, oxidized Cary till. Convex, upper slope situations are represented by profiles J94 and J95 (Clarion equivalent on fine textured till) and J97 (Storden series), the latter situation occurring at the break of slope, where erosion has been most severe and the stone line is closest to the surface. The three sample sites listed above have counterparts in each of the other transects G and A. Downslope from J97, the surficial sediment thickens, and the thickness of the stone line itself increases and becomes identified with a thickening stratum of sandy sediment which separates the upper surficial sediment from the underlying

Figure 10. Map of the detailed study area on the east side of the Jewell bog watershed, showing the one-foot contours, the location of transects, and the 10x15 sample grid



Sample grid
N
MN
132 ft.
W
L
Y
J112
J94
J95
J97
J100
J101
G
F
A
J80
A
B
C
D
E
F
G
H
I
J
JSS
fence

Figure 11. Transects across the detailed study area on the east side of the Jewell bog watershed showing hillside and bog stratigraphy


Legend : HS – Hillside surficial
US – Upper silt
El.
–116'
HS
Stone line
Till
HS
Stratified seds.
US
Sand, gravel
G
C94
El.
–116'
C95
HS
Stone line
C97
Till
C100
C101
F
HS
US
Sand, gravel
El.
–116'
HS
Stone line
Till
HS
Stratified seds.
A
US
Sand, gravel
10 ft.
33 ft.

till. At the site of J101 the profile is stratified with coarser hillside sediments and fine bog sediment, containing shells, and the profile is calcareous at the surface (Harpster series). In all three sections of Figure 11, the bog sediments lie above the sandy material immediately on top of the till. The problem arises as to whether the stone line of the upper slopes feathers out into the overlying hillside surficial sediment or is identified with the lower sandy and gravelly zone. Particle size data for J100 and J101 indicate that the latter is probably the case, therefore an element of upper bog sediment overlies the stone line as at Colo.

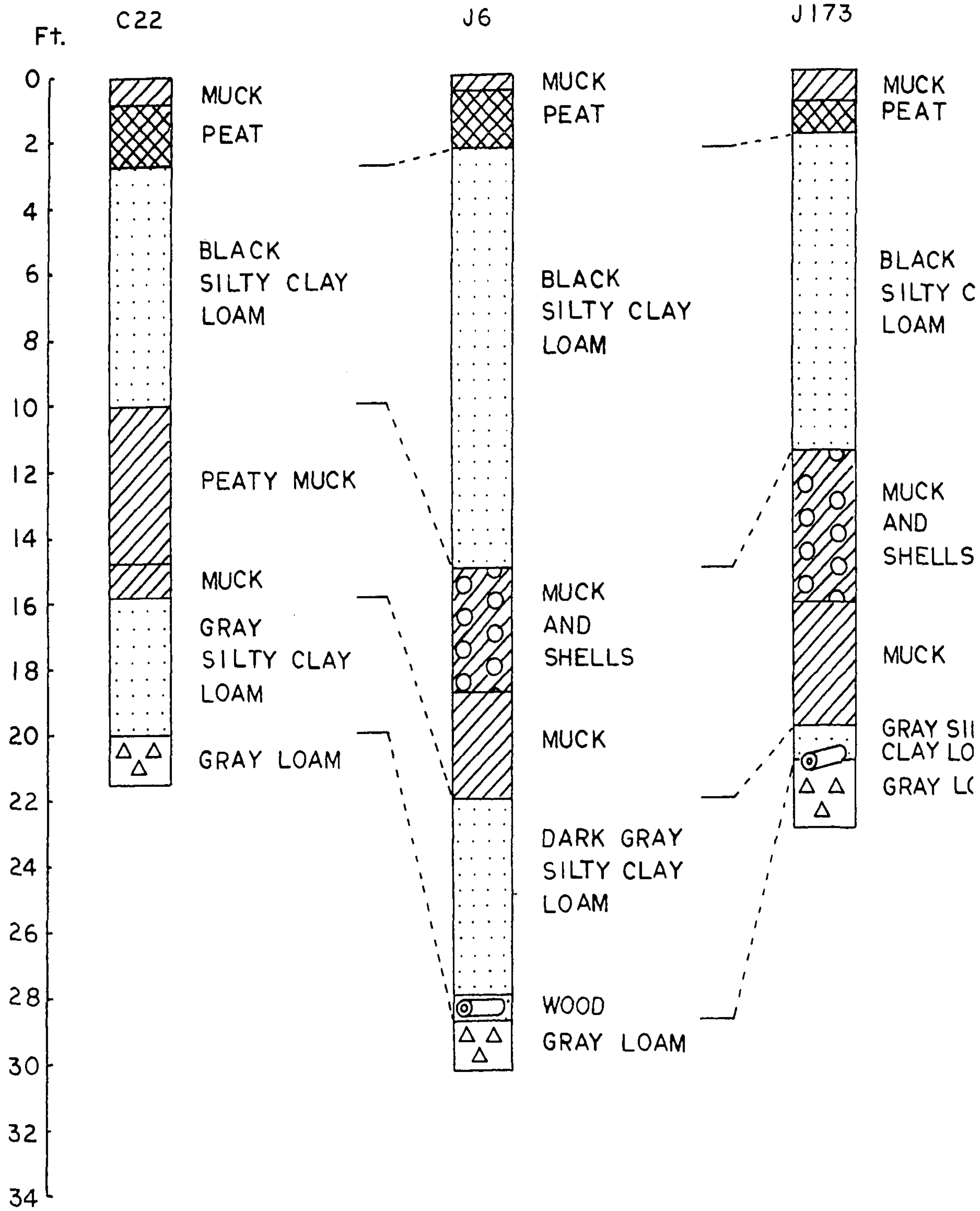
The section data at Jewell do not show significant amounts of the inset toeslope sand and gravel that were evident at Colo. This difference between the two bogs is consistent with the smaller extent of the LS zone at Jewell, with which the toeslope sands and gravels were interstratified.

C. McCulloch Bog

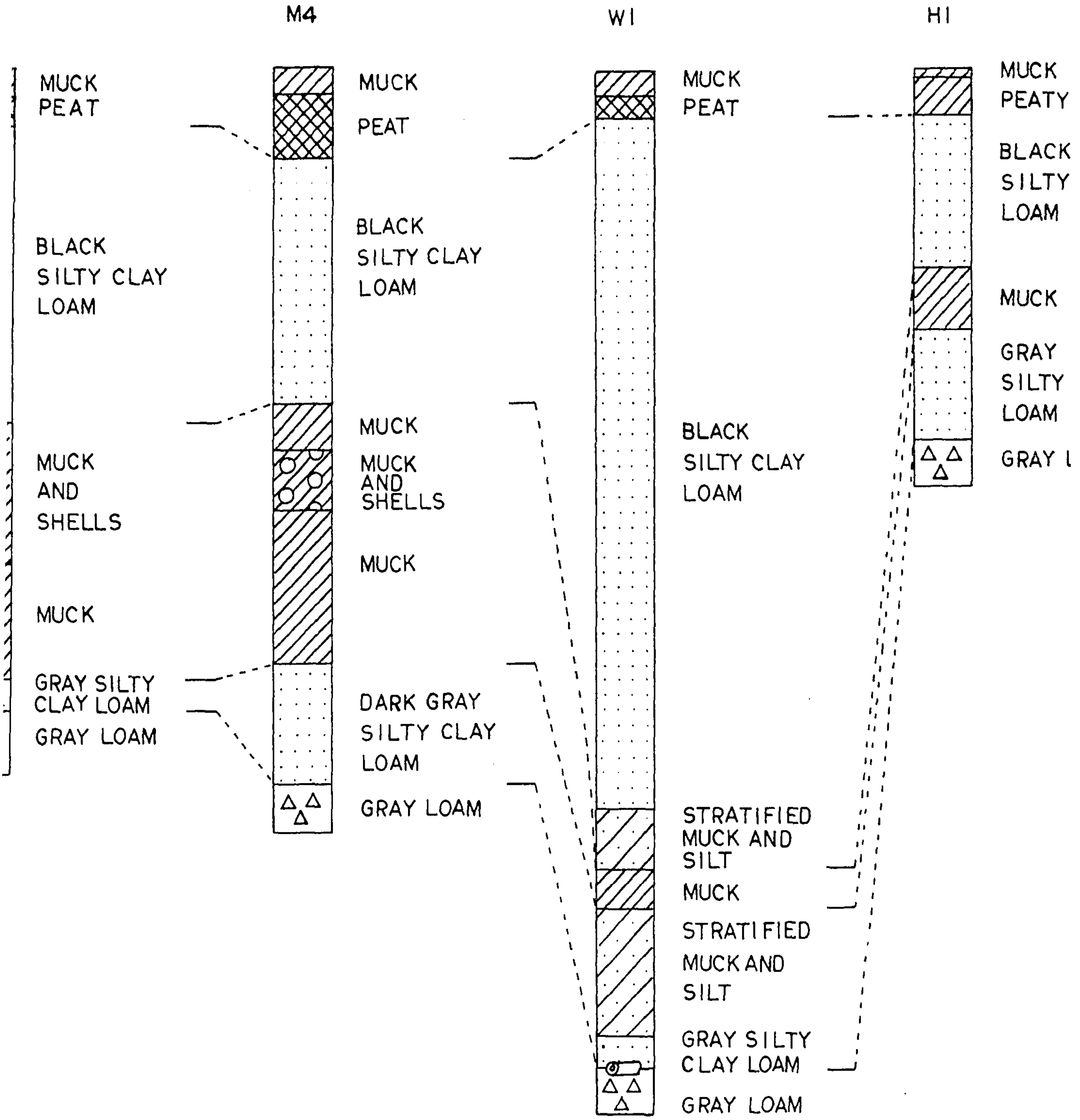
1. Bog center profile (M4)

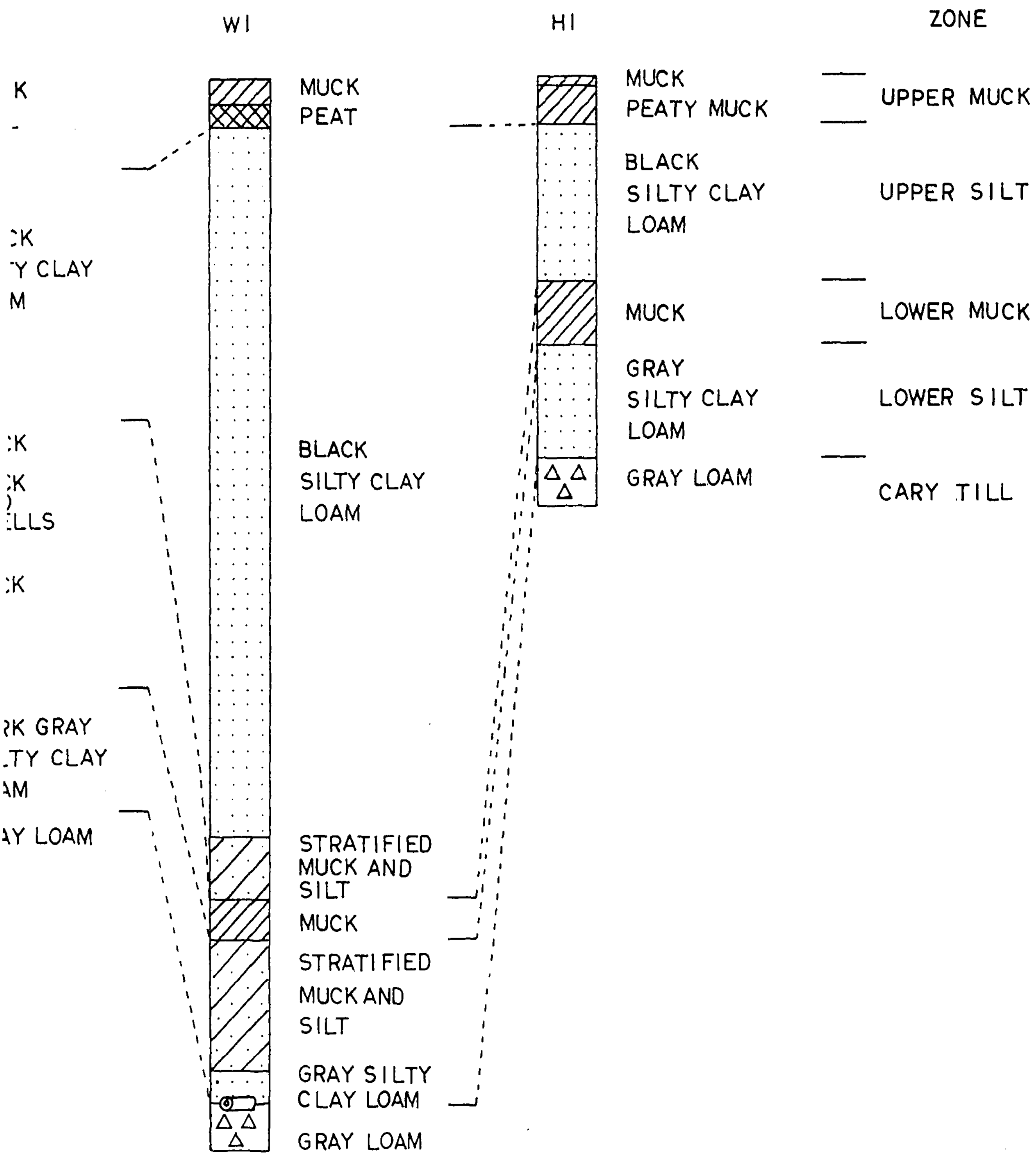
One central core was chosen to characterize the McCulloch bog, and its stratigraphic sequence is shown in Figure 12. The thick UM zone consists of 10 inches of black (N 2/0) muck which is very friable and noncalcareous; it passes into a more peaty horizon 26 inches thick which has brownish (10YR 2/2) colors and in which the botanical form is still evident. The US zone is 8 feet thick and consists of black (5Y-10YR 2/1),

Figure 12. Summary of profile strata at the center of bogs at Colo (C22), Jewell (J6, J173), McCulloch (M4), Woden (W1), and Hebron (H1)



C22
J6
J173
Ft.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
MUCK
PEAT
BLACK SILTY CLAY LOAM
PEATY MUCK
MUCK
GRAY SILTY CLAY LOAM
GRAY LOAM
MUCK
PEAT
BLACK SILTY CLAY LOAM
MUCK AND SHELLS
MUCK
DARK GRAY SILTY CLAY LOAM
WOOD
GRAY LOAM
MUCK
PEAT
BLACK
LOAM
MUCK AND SHELLS
MUCK


M4
W1
H1
MUCK
PEAT
BLACK
SILTY CLAY
LOAM
MUCK
AND
SHELLS
MUCK
GRAY SILTY
CLAY LOAM
GRAY LOAM
MUCK
PEAT
BLACK
SILTY CLAY
LOAM
MUCK
MUCK
AND
SHELLS
MUCK
DARK GRAY
SILTY CLAY
LOAM
GRAY LOAM
MUCK
PEAT
BLACK
SILTY CLAY
LOAM
STRATIFIED
MUCK AND
SILT
MUCK
STRATIFIED
MUCK AND
SILT
GRAY SILTY
CLAY LOAM
GRAY LOAM
MUCK
PEATY
BLACK
SILTY
LOAM
MUCK
GRAY
SILTY
LOAM



WI
HI
ZONE
MUCK
PEAT
BLACK
SILTY CLAY
LOAM
STRATIFIED
MUCK AND
SILT
MUCK
STRATIFIED
MUCK AND
SILT
GRAY SILTY
CLAY LOAM
GRAY LOAM
MUCK
PEATY MUCK
BLACK
SILTY CLAY
LOAM
MUCK
GRAY
SILTY CLAY
LOAM
GRAY LOAM
UPPER MUCK
UPPER SILT
LOWER MUCK
LOWER SILT
CARY TILL

plastic, silty clay loams which are calcareous and contain abundant shell fragments in the lower horizons. An initial organic horizon is separated from the main LM zone by 24 inches of olive gray (5Y 5/2) mucky silty clay loam which is rich in shells. The overall thickness of the LM zone excluding the shell-rich horizon is 78 inches and it varies from black (5Y 2/1) muck in the upper horizon to finely divided dark olive gray (5Y 3/2) muck in the lower horizons. Generally the materials in the LM zone are calcareous. In the LS zone the sediments are uniformly dark olive gray (5Y 3/2), sticky, silty clay loams, noncalcareous and free of shells for the most part. At the base of this zone, impenetrable rock was encountered repeatedly during drilling operations. The point where drilling ceased is taken as the Cary till contact for this profile.

The general similarity of the McCulloch center profile and those of Colo and Jewell is apparent. The main difference is the stratification of the LM zone. This, however, is not considered sufficiently important to warrant reorganization of the stratigraphic nomenclature at McCulloch, especially since surrounding cores were found to be without this banding.

2. Strata across the bog

The location sketch for the transect across the McCulloch bog is given in Figure 13 and the stratigraphy of the transect is shown in Figure 14. The strata in the main bog contain

Figure 13. Location of the center profile at McCulloch bog (M4) and the transect across the bog watershed

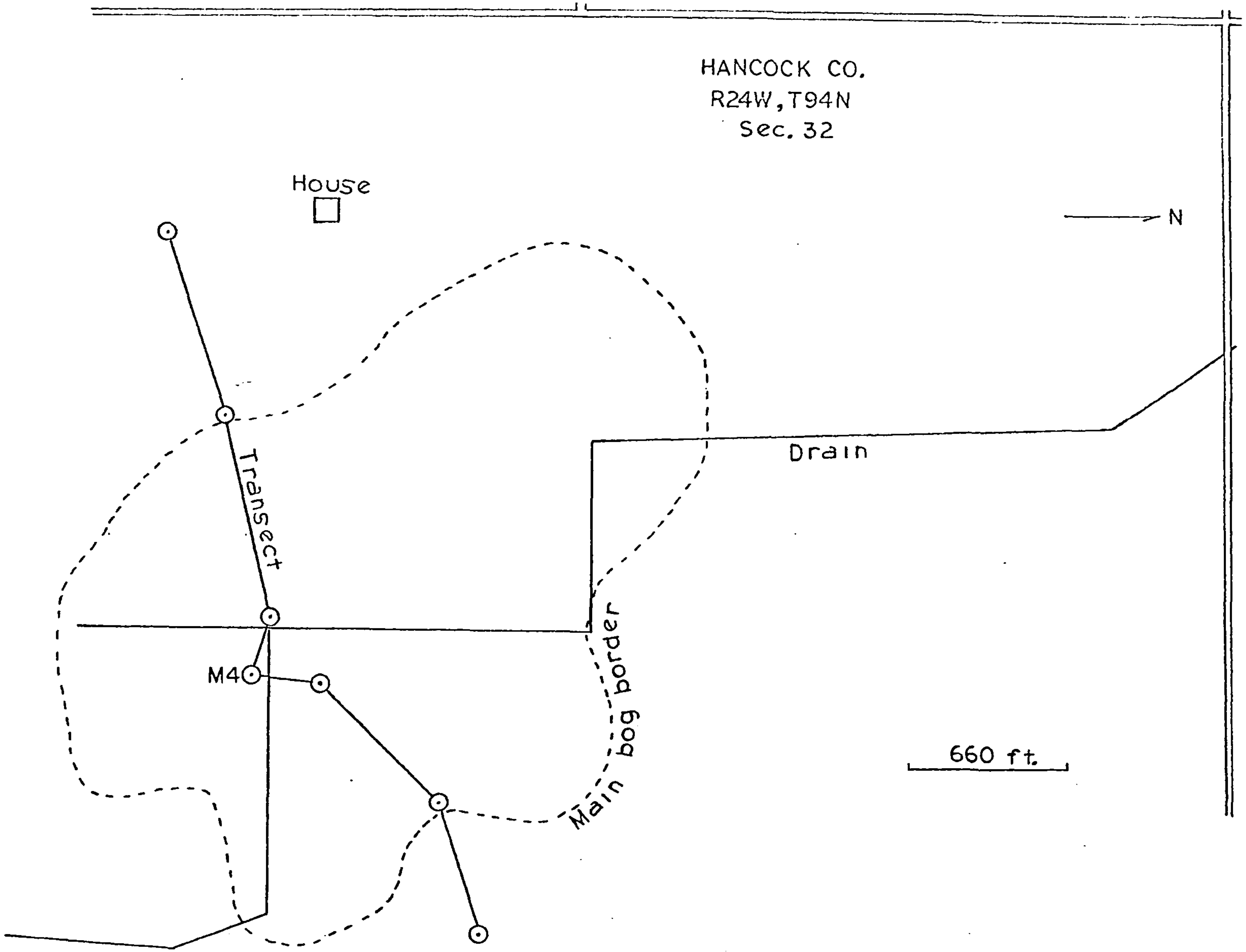
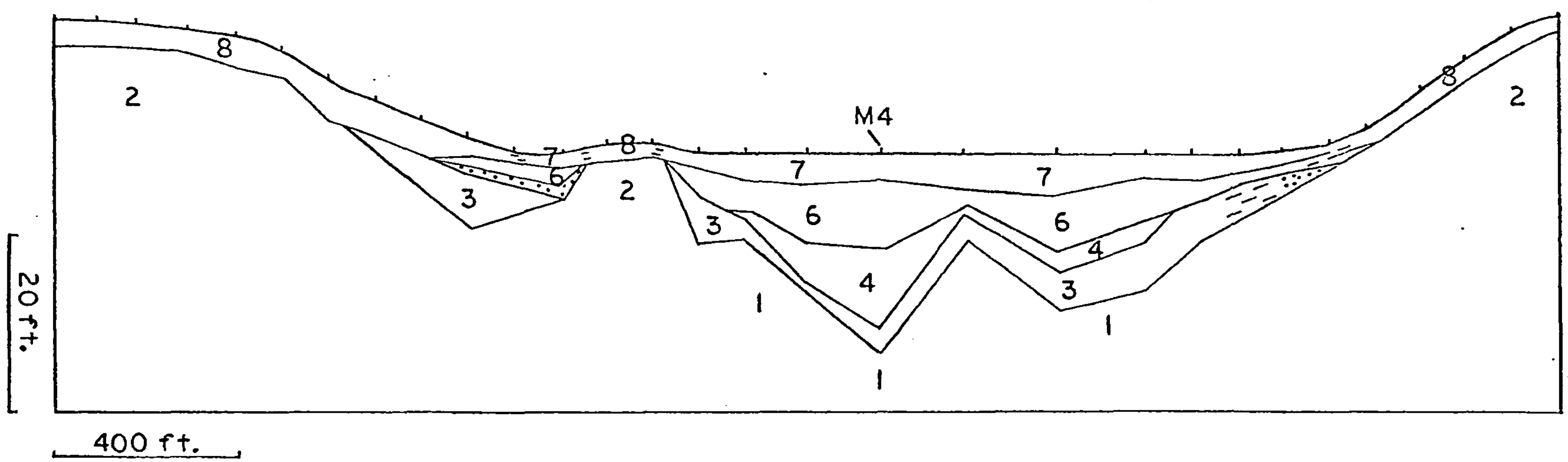

HANCOCK CO.
R24W, T94N
Sec. 32
House
N
Drain
Transect
M4
Main bog border
660 ft.

Figure 14. Section across the McCulloch watershed showing bog and hillside stratigraphy: unoxidized and unleached Cary till or drift (1); oxidized and unleached Cary till or drift (2); lower silt zone (3); lower muck zone (4); upper silt zone (6); upper muck zone (7); hillside surficials (8)


8
2
M4
8
2
7
6
3
7
6
3
4
1
7
6
4
3
1
1
8
2
20 ft.
400 ft.

extensive UM zone materials and a relatively thin US zone, which also occurs in the small depression on the west side. The LM zone is thick at the center of the main bog but wedges out quickly and does not interfinger with hillside sediments in the section. The LS zone is extensive and interfingers with the hillside sediments; in this respect the McCulloch bog is more like the Colo than the Jewell bog.

On the west side of the traverse, hillside surficials have overridden LS and US sediments and a significant thickness of coarse sediment separates the US and UM zones and can be traced back to the stone line on the upper convex slopes. On the east side the surficial hillside deposits interfinger with upper bog sediment and in this case the stone line can be identified with a thin wedge of coarse sediment, at the base of the slope, which underlies the US zone of the bog sediments. Below these sediments the LS zone silts are found to interfinger with coarse deposits somewhat closer to the center of the bog. These observations parallel those at Colo where there was evidence of an earlier sedimentary system of toeslope sands and gravels with adjacent fine LS sediments.

D. Woden Bog, Center Profile (W1)

The position of the Woden profile is given with the profile description in Appendix A. The major strata of the profile are shown in Figure 12. The UM zone consists of a 9-inch surface horizon of black (N 2/0), very friable muck which passes to 9 inches of a black (2.5Y 2/1) peaty horizon, both of which are noncalcareous. The underlying US zone is 294 inches thick; it is a relatively uniform black (5Y 2/1), sticky, silty clay loam, weakly calcareous and passes at 288 inches into a transition zone of finely stratified muck and mineral sediment. The LM zone is less than 24 inches thick, of weakly stratified, very dark gray (5Y 3/1) muck which is weakly calcareous and plastic. The LS zone below the LM zone is a dark gray (5Y 4/1) plastic, calcareous, silty clay loam which passes abruptly into gravelly deposits and unoxidized unleached Cary till at 390 inches. In the LS zone, near the contact with the till, abundant wood fragments were found, most of which were sufficiently large to permit species identification.

The Woden profile differs in several respects from the center cores previously described. The surface muck and peat horizons are relatively thin, the US zone is much thicker, and the LM and LS zones are thinner than in any of the other cores. Despite these differences in magnitude, the sequence and nature of the Woden strata are comparable with the other four bogs.

E. Hebron Bog, Center Profile (H1)

The location of the Hebron bog is given in Appendix A with the description and laboratory data and the characteristics of profile H1 are shown in Figure 12.

The UM zone of the Hebron bog is 19 inches thick and consists of black (10YR 2/1) to very dark grayish brown (10YR 3/2) very friable muck which is noncalcareous. The US zone is 60 inches thick and in its upper horizons is a black (10YR 2/1) mucky, slightly plastic, noncalcareous, silty clay loam; at depth it passes to a very dark grayish brown (1Y 3/2) calcareous, silty clay loam. At the base of the US zone is a shell-rich zone 8 inches thick. The LM zone, immediately below, is only 12 inches thick and is a black (10YR 2/1) to very dark grayish brown (2·5Y 3/2), weakly calcareous muck which is of tough consistence. The LS zone is 56 inches thick and is essentially a dark gray (5Y 4/1) slightly plastic, calcareous, silty clay loam. The LS zone passes abruptly into unoxidized unleached Cary till at 146 inches of total profile depth.

The sequence of strata in the Hebron bog is comparable with the other bogs described and bears a resemblance to profiles near the center of the Colo bog. A relatively thin total profile and absence of muck and peat horizonation in the UM zone are the main points of difference. Otherwise, the main stratigraphic elements are clearly expressed.

F. Discussion of Stratigraphic Relationships

The stratigraphic and sedimentary relationships described in the previous sections show that a highly systematic sequence of mineral sediments and organic materials occurs in five bog watersheds on the Des Moines lobe. The distribution of the bogs is such that the stratigraphy has a regional significance, and can best be explained on the basis of regional control of environmental factors favoring development of alternating mineral and organic layers during postglacial time.

Following retreat of the glacial ice, the first bog episode was one of mineral sedimentation leading to development of the LS zone sediments. As the lowest troughs in the bogs filled with sediment, a period ensued which favored accumulation of organic material in the central depressions of the bog watersheds. The LM zone which developed at this stage has an irregular surface relief, which suggests that the general landscape was not smoothed erosionally from the perimeter to the bog center at that time. Part of the trough shape of the LM surface may be the result of compression due to subsequent loading of US sediment. It seems more likely, however, that in the later stages of development of the LM surface, the amount of organic material was not sufficient to form a complete mat across the bog depression. Complete coverage would have occurred, however, had the stage of bog development been well advanced as defined by Dachnowski (1924, p. 121). The gross amount of sediment of the US zone was such that the original bog topography was completely buried and the depressional area achieved a smooth and nearly horizontal surface. Subsequent development of the UM zone indicates that the latest episode in the bog watersheds has been one of relatively slow mineral deposition, favoring accumulation of organic materials at the bog surface. Since the transition from bog to hillside is characterized by an interfingering of sediments and a smooth surface, there is little doubt that the UM zone was developed contemporaneously with the latest decrement of hillside erosion. The surface so formed is referred to here as the Late Post-Cary surface. Although the detailed studies reported here concern two bogs, the data indicate that a comparable development occurred in the other three bogs studied, and that the basic stratigraphy UM/US/LM/LS/Cary till is widely applicable on the Des Moines lobe in Iowa.

The elements of bog and related hillside stratigraphy are set out below in Table 6, using the informal designations described above and the terminology of the American Commission on Stratigraphic Nomenclature (1961, p. 649). It should be noted that the stone line is included with the main body of hillside surficial sediment; this follows from the definition of stone line as a lag gravel, and its position at the base of pedisediment as described by Ruhe and Daniels (1958, p. 69).

During the course of the work, small thicknesses of mineral sediment were observed on lower slopes at Colo (Section D) and on the edge of the main bog area at Jewell (Section B) which, by their position on the landscape, were considered to be the result of post-settlement erosion. The gross amount of these sediments is negligible, however, when compared with horizons of the bog strata.

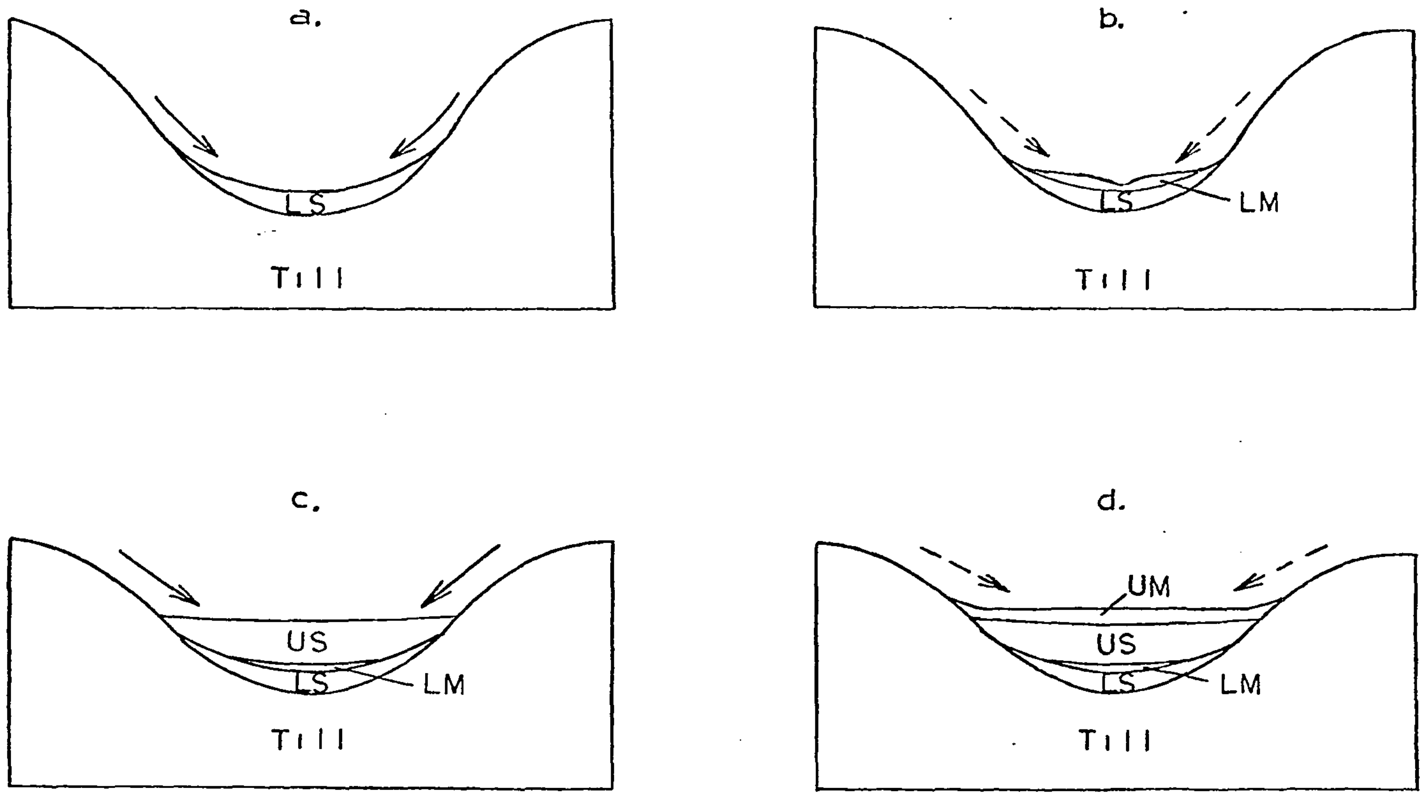
Table 6. Bog and hillside stratigraphy of selected bog watersheds of the Des Moines lobe in Iowa

Substage	Bog member	Bog zone	Hillside zone
Post-Cary	Upper	Muck (UM) Silt (US)	Surficial
	Lower	Muck (LM) Silt (LS)	Toeslope sand and gravel
Cary			

A representation of the development of bogs on the Cary surface during the post-Cary interval is shown in Figure 15. These diagrams are based on the interpretation of strata outlined above. The latest episode is shown as a minor adjustment of the surface of the watershed under the conditions prevailing on the present surface.

Throughout this thesis, the terminology used in describing bog sediments is the same as that used for soil studies by the U.S. Soil Survey Staff (1951). Such a procedure has the advantage of making a uniform presentation of descriptions throughout. Other descriptive methods are available, some specifically for bog sediments. Definitions of bog materials may be found in papers by Dachnowski (1924), Rigg (1940) and Dawson (1956). Wright et al. (1963, p. 1376) used the descriptive system of Troels-Smith for bog strata in southern Minnesota. Brief note is made here of some similarities

Figure 15. Schematic representation of bog development on the Cary till of Iowa, commencing with the earliest post-Cary erosion (a), and ending with stabilization of the surface and development of the upper muck zone (d)


a.
LS
Till
b.
LS
LM
Till
c.
US
LS
LM
Till
d.
UM
US
LS
LM
Till

between materials found in the bogs of the Des Moines lobe and materials described in the literature. The fine gray calcareous materials of the LS zone may relate to the "blue clays" reported to be washed into depressions during the early stages of glacier retreat by Rigg (1940). The finely divided, olive colored materials of the LM zone have similarities with some forms of gyttja as described by Dawson (1956, p. 380) and Wright *et al*. (1963, p. 1377). The black, calcareous, silty strata of the US zone do not seem to have a counterpart in formal bog stratigraphy, but may resemble the silty gyttja sediments described for comparable positions in bog profiles in southern Minnesota by Wright *et al*. (*op*. *cit*., p. 1377). The horizons of the UM zone are comparable with gyttja but are adequately described by existing soil nomenclature. They are classified as either muck (humified), peat (relatively non-humified) or some intergrade, for example, peaty muck.

V. LANDFORM AND SEDIMENT RELATIONS

A. Introduction

The stratigraphic framework developed within bog watersheds on the Des Moines lobe can be utilized to define units of sediment in relation to the landscape. Since the watershed surfaces have been adjusted to the last increments of hillside erosion and deposition in the bogs, the geomorphology is simplified to the one geomorphic surface, namely, a late post-Cary surface. Thus any representation of surface and sediment which is to be useful to soil studies, need be concerned mainly with differences in the nature of the sediments in various parts of the landscape. A distinction is made here between the sediments which owe their origin to surficial processes subsequent to the Cary glaciation and those which originated during glaciation. The criteria set up for differentiating one kind of sediment from the other were developed in the field. Those sediments which showed traceable continuity and/or systematic change across the landscape radially in relation to the bog center and whose lateral counterparts could be traced to the LS zone or strata above it, were considered post-Cary sediments. Those sediments which could not be traced laterally, or whose counterparts could not be traced laterally to the stratigraphic position of the LS zone or above it, were considered Cary glacial sediments.

Within the post-Cary sediments a number of distinctions were made. Surficial sediments above the stone line on convex hillside situations and upper concave slopes have typically homogeneous sedimentary properties. These are separated from hillside surficial deposits of lower concave slopes in which stratification of coarse and fine materials occurs above the stone line. With distance downslope, this group of sediments is associated with the transition from hillside to bog environment. The silty upper bog sediments are interstratified with coarser hillside sediments, but the body of sediment as a whole becomes more silty with depth down the profile. Combinations of these sediments with varying thickness of sediment of the LS zone occur. Within the bog area, there are two main sedimentary bodies, namely, the upper silts and the lower silts. From the standpoint that both upper and lower muck zones are expressions of organic soil development, the mineral sediments within the UM zone are considered with the US zone sediments and the LM sediments with the LS zone.

Hillside surficial and bog sediments of the Colo and Jewell watersheds were grouped according to the principles outlined above, and maps were drawn following detailed field investigations. The maps are presented here as Figure 16 and Figure 17. A brief description of the sedimentary units is included below in Table 7.

Figure 16. Map of the sediments in the Colo bog watershed

Legend: Non-stratified hillside surficial sediments of convex and upper concave slopes, <3 ft. thick (A); stratified hillside surficial sediments on concave slopes, 2-5 ft. thick (B); sediments of the upper silt zone overlying sediments of the lower silt zone in depressions and the main bog area, 5-10 ft. thick (D_1); sediments of the upper silt zone overlying sediments of the lower silt zone in the main bog area, 10-20 ft. thick (D_2); same strata as in D_2, but 20-30 ft. thick (D_3)

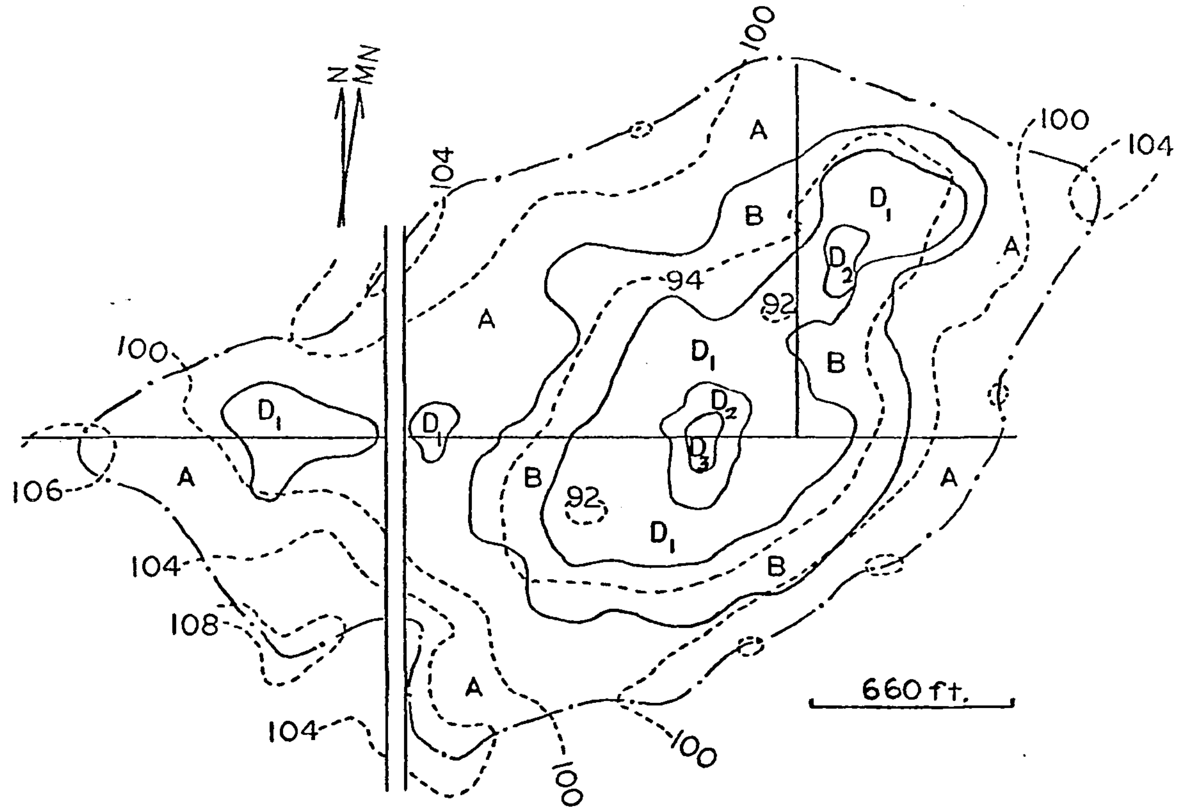
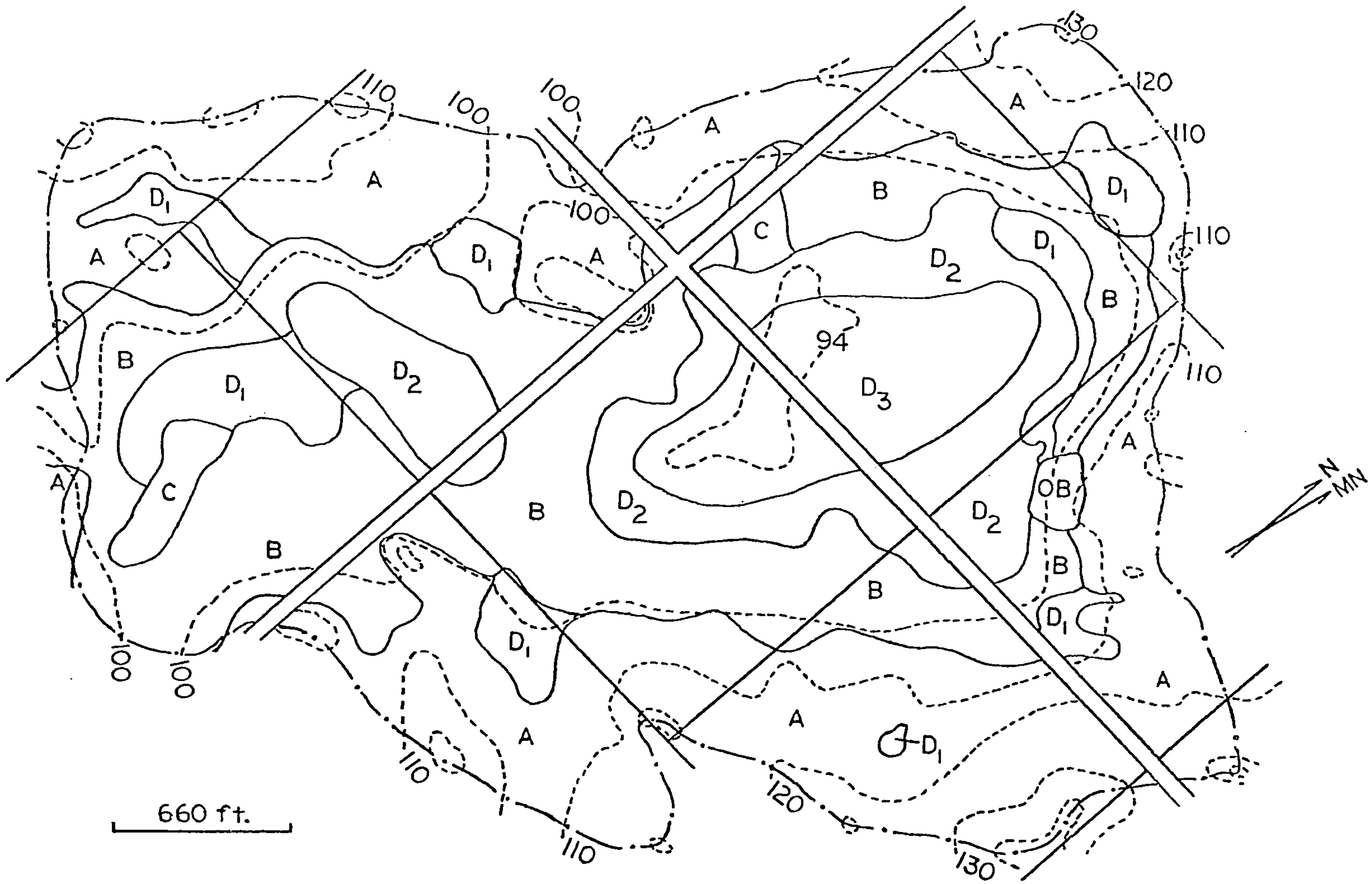

N
MN
100
104
106
108
94
92
A
B
D_1
D_2
D_3
660 ft.

Figure 17. Map of the sediments in the Jewell bog watershed

Legend: Non-stratified hillside surficial sediments of convex and upper concave slopes, <3 ft. thick (A); stratified hillside surficial sediments on concave slopes, 2-5 ft. thick (B); stratified hillside surficial sediments over sediments of the lower silt zone, <5 ft. thick (C); sediments of the upper silt zone overlying sediments of the lower silt zone in depressions and the main bog area, 5-10 ft. thick (D_1); sediments of the upper silt zone overlying sediments of the lower silt zone in the main bog area, 10-20 ft. thick (D_2); same strata as in D_2, but 20-30 ft. thick (D_3); overburden (OB)



660 ft.
N
MN
A
B
C
D_1
D_2
D_3
94
100
110
120
130

Table 7. Description of sedimentary units mapped in Colo and Jewell watersheds

Legend	Sedimentary unit	Topography
A	Hillside surficial, nonstrat. above stone line (depth <3 ft.)	Convex and upper concave slopes
B	Stratified hillside surficials and bog sediment (2 to 5 ft. thick)	Concave slopes in bog-hillside transition
C	Stratified hillside surficials over LS zone sediments (<5 ft.)	Toeslope situations
D_1	US/LS (5-10 ft.)	Bog or depression
D_2	US/LS (10-20 ft.)	Bog
D_3	US/LS (20-30 ft.)	Bog

B. Colo Watershed Sediments

Estimates of the area of the bog watershed and the sedimentary units mapped within it are presented below in Table 8. Estimates were made using a grid area counter; the average thickness data are taken directly from Table 7.

Surficial sediments of convex to gently concave parts of the landscape occupy the greater proportion of the Colo bog watershed. Relatively large proportions are also occupied by stratified surficial sediments of unit B and by shallow bog sediments of unit D_1. Central bog sediments of units D_2 and D_3 occur in very small proportions. An interesting feature of the Colo sediments is their concentric arrangement in relation

Table 8. Area and thickness data for sedimentary units mapped in the Colo bog watershed

Sedimentary unit	Percent of total area	Square miles	Average thickness of sediment (ft.)
A	56.1	0.080	1.5
B	21.3	0.030	3.5
D_1	19.9	0.028	7.5
D_2	2.2	0.003	15.0
D_3	0.5	0.001	25.0
Total area	100	0.142	

to the bog center. The minor depression in the northeastern end of the bog has not oriented sediments strongly in relation to its center and there is an indication that hillside surficials have invaded this depression from the eastern side.

C. Jewell Watershed Sediments

Similar estimates of sediment areas were made within the Jewell bog and these are listed in Table 9.

The bodies of sediment at Jewell have a higher proportion of deeper bog units than at Colo, but have a comparable concentric arrangement of the sedimentary units. The bog sediments of the minor depression at the southern end of Jewell are separated from the major depression by a strip of stratified bog and surficial sediment, unit B. Similarly,

Table 9. Area and thickness data for sedimentary units mapped in the Jewell watershed

Sedimentary unit	Percent of total area	Square miles	Average thickness of sediment (ft.)
A	43.1	0.150	1.5
B	27.4	0.095	3.5
C	1.8	0.006	2.5
D_1	8.0	0.028	7.5
D_2	11.7	0.041	15.0
D_3	7.4	0.026	25.0
Overburden (O.B.)	0.6	0.002	
Total area	100	0.348	

the plugs of silty sediment (unit D_1) entering the bog area along contributing waterways are separated from the main area of bog sediment by stratified sediments of unit B. This suggests that for a considerable part of the post-Cary interval, the outer limits of the bog environment have been well within the perimeter line of the Jewell bog. The amount of sediment in the main bog at Jewell is considerably greater than Colo. This is consistent with the fact that the Jewell hillslopes are steeper and presumably were more susceptible to erosion in the past.

VI. SOIL DELINEATIONS IN COLO AND JEWELL WATERSHEDS

A. Procedure

The field mapping of soils was a part of the project carried out with the co-operation of the United States Department of Agriculture, Soil Conservation Service. The author is indebted to Mr. J. D. Highland and Mr. C. S. Fisher of the Soil Conservation Service for their substantial contribution to the program. In the maps that are discussed in this section, their contribution is measured by the extent of the numbered map legend; the contribution of the author was a much smaller proportion of the total area, with the map legends P, in the bog parts of the watersheds.

A mapping legend was devised to meet the requirements of the project as outlined at the beginning of the thesis, namely, to examine the range of soil properties within the Clarion-Webster toposequence, and to map variations in the soils which reflected differences in landscape position, parent material and other prominent soil forming factors.

The mapping legend was established and the field work carried out during the spring season of 1963 and 1964. During 1964, cores were sampled from the more significant upland mapping units in order to obtain more detailed morphological information. The data so obtained, together with the field mapping of the bog areas, were drawn together into two field sheets with one comprehensive legend. Apart from the topographic differences between Colo and Jewell watersheds which would be expected to affect soil properties, the Cary till at Jewell is significantly finer textured and firmer than at Colo. This led to the establishment of a group of mapping units at Jewell which are not found at Colo. These fine textured soils which form a homologous sequence to Clarion and Nicollet, are similar to those studied by Hidlebaugh (1959) and are given the same series designation, for example, Clarion-FT, and Nicollet-FT. In this case, however, the fine textured designation indicates a separate series rather than a variant. As yet, separate series names have not been given to these soils in Iowa, but the Guckeen series has been proposed for comparable moderately well to imperfectly drained soils in fine lake sediments over till in Clay County, Iowa.[1] The fine textured notation is carried through the Webster series, also, but no proposed series are available for such soils. An exception is found in soils of mapping unit 249, Webster-FT(2). These soils have similar properties to the Marna series established in southern Minnesota for soils in fine lake sediments over till.

The mapping units are listed below in Table 10 in abbreviated form, and the relationship of each to established or proposed soil series is briefly noted. The bog soil legend is kept separate from the other legend and has been designated by

---

[1]R. I. Dideriksen, Assistant State Soil Scientist, S.C.S., Ames, Iowa. Personal communication. 1965.

the letter P rather than by numbers. Each numbered legend has three parts, for example, 1-6-2. The first number refers to the series or series variant; in this case the number, 1, refers to the Clarion series. The second number, 6, refers to the slope phase, in this case 5-9 percent slope. The third number is an erosion class designation, based on thickness of A horizon, in this case 3-7 inches of A horizon. The unit 1-6-2 represents the Clarion series on 5-9 percent slopes, with 3-7 inches of A horizon. The slope classes in Table 10 are coded as follows: depressions (0), 0-2% (1), 1-3% (2), 2-5% (3), 5-9% (6), 9-14% (11), 14-18% (17). The erosion classes in Table 10 are coded as follows: >12 inches of surface (0), 7-12 inches (1), 3-7 inches (2), <3 inches (3). Soils fitting the central range of a series are listed without notation; soils within the series range but with a property at one end of the range, are qualified in parentheses, for example, Clarion soils with shallow carbonates are listed under a legend number 2-6-2 (shallow carbonates). Other soils are closely related to established series, but fall outside the specified range; such soils have been given the designation of variant. An example occurs with the Clarion-like soils on stratified Cary sediments such as mapping units 6 and 8. Still other variations occur where there is a range of soil properties comparable with the established series but also a consistent difference in respect of one important property, for example, stratification of the till in Webster soils.

Table 10. Summarized notes for soil mapping units in the Colo and Jewell watersheds

Unit	Slope and erosion phases	Drainage	Series relations	Comments
1	1-3-1 1-6-1 1-6-2	well	Clarion	
2	2-3-1 2-6-1 2-6-2	well	Clarion	shallow carbonates
3	3-3-1	well	Clarion	deep carbonates
6	6-3-1 6-3-2	well	Clarion (var.)	stratified till at 24-36 in.
8	8-3-1	well	Clarion (var.)	stratified till at 36-48 in.
9	9-11-2 9-17-3	well	Storden	
10	10-11-3	excessive	Storden (var.)	stratified till
11	11-2-1 11-3-1	mod. well	Clarion	mod. well
22	22-3-0	mod. well	Terril	
23	23-3-0	imperfect	Terril	
24	24-3-0	imperfect	Nicollet (var.)	cumulic

Table 10. (continued)

Unit	Slope and erosion phases	Drainage	Series relations	Comments
26	26-1-0 26-3-0	poor	--	local alluvium
31	31-2-0 31-2-1	imperfect	Nicollet	
32	32-2-0	imperfect	Nicollet	shallow carbonates
33	33-2-0	imperfect	Nicollet	deep carbonates
34	34-2-0	imperfect	Nicollet	stratified till
35	35-3-1	imperfect	Nicollet (var.)	calcareous surface
41	41-1-0	poor	Webster	
42	42-1-0	poor	Webster (var.)	calcareous surface
45	45-1-0	poor	Webster (2)	stratified till
46	46-1-0	poor	Webster (2) (var.)	stratified till; calcareous surface
47	47-1-0	poor	Webster (2)	stratified till; carbonates
49	49-1-0	poor	Webster	cumulic; deep carbonates
50	50-1-0	poor	Calco (loamy var.)	local alluvium
61	61-1-0	poor	Glencoe	

Table 10. (continued)

Unit	Slope and erosion phases	Drainage	Series relations	Comments
62	62-0-0	poor	Glencoe (var.)	calcareous surface
63	63-0-0 63-1-0	poor	Glencoe (2)	cumulic; noncalcareous surface
64	64-0-0	poor	Glencoe (2)(var.)	cumulic; calcareous surface
71	71-1-0	poor	Harpster	
72	72-1-0	poor	Harpster (var.)	cumulic
73	73-1-0	poor	Harpster (2)	stratified till
101	101-3-1 101-6-1 101-6-2 101-11-2	mod. well	Clarion-FT	clay loam till
102	102-3-1 102-6-2 102-11-2	mod. well	Clarion-FT	shallow carbonates
103	103-3-1	mod. well	Clarion-FT	deep carbonates
109	109-6-2 109-6-3 109-11-3 109-17-2	mod. well	Storden	clay loam till

Table 10. (continued)

Unit	Slope and erosion phases	Drainage	Series relations	Comments
131	131-1-0 131-2-0 131-3-0 131-6-1	imperfect	Nicollet-FT	
133	133-1-0 133-2-0 133-3-0	imperfect	Nicollet-FT	deep carbonates
141	141-1-0 141-2-0 141-3-0	poor	Webster-FT	clay loam till
142	142-1-0	poor	Webster-FT (var.)	calcareous surface
148	148-1-0 148-2-0 148-3-0	poor	Webster-FT	deep carbonates
149	149-1-0 149-2-0	poor	Webster-FT	cumulic; deep carbonates
201	201-6-1	mod. well	Nicollet-FT (2)	clay loam till
249	249-1-0 249-2-0	poor	Webster-FT (2)	clay loam till
P_1	<2% slope	very poor	--	mucky, calcareous surface; stratified surficials and upper bog sediment

Table 10. (continued)

Unit	Slope and erosion phases	Drainage	Series relations	Comments
P_2	<1% slope	very poor	--	as in P_1; lower bog sediment substratum
P_3	<1% slope	very poor	--	UM/US/LS/till
P_4	<1% slope	very poor	--	US/LM/LS/till (10-20 ft.)
P_5	<1% slope	very poor	--	UM/US/LM/LS/till (10-20 ft.)
P_6	<1% slope	very poor	--	UM/US/LM/LS/till (20-30 ft.)

Such variations are accommodated by placing (2) after the series name. Unit 45-1-0 then becomes Webster (2).

More detailed information for each mapping unit is given separately in Appendix C. Similarly, reproductions of the original field sheets are enclosed in Appendix C with the other information about the maps and mapping units. The parts of the soil maps that fit the delineated watersheds at Colo and Jewell are included in the text as Figure 18 and Figure 19 respectively. At both Colo and Jewell a greater area was mapped than is shown in these figures; comparisons can be made by referring to the complete maps in Appendix C.

B. Colo Soil Map

The Colo watershed soil map shows the characteristic Clarion soil toposequence of the Clarion-Webster association. Clarion and related soils (units 31, 32, 33) occur on upper concave slopes. On lower concave slopes Webster and related soils (units 41, 47) grade into Harpster soils (units 71, 72) which are calcareous at the surface and form a rim around the bog. In local enclosed depressions adjacent to the main bog, relatively fine material has formed heavy textured soils of the Glencoe series (units 62, 63). On traversing into the bog environment, the morphology of the soils is found to be dominated by accumulation of organic matter and the properties of sedimentary materials. On the bog side of the Harpster delineation, stratified hillside surficials and upper bog

Figure 18. Soil map of the Colo bog watershed

The map legend is given in Table 10.

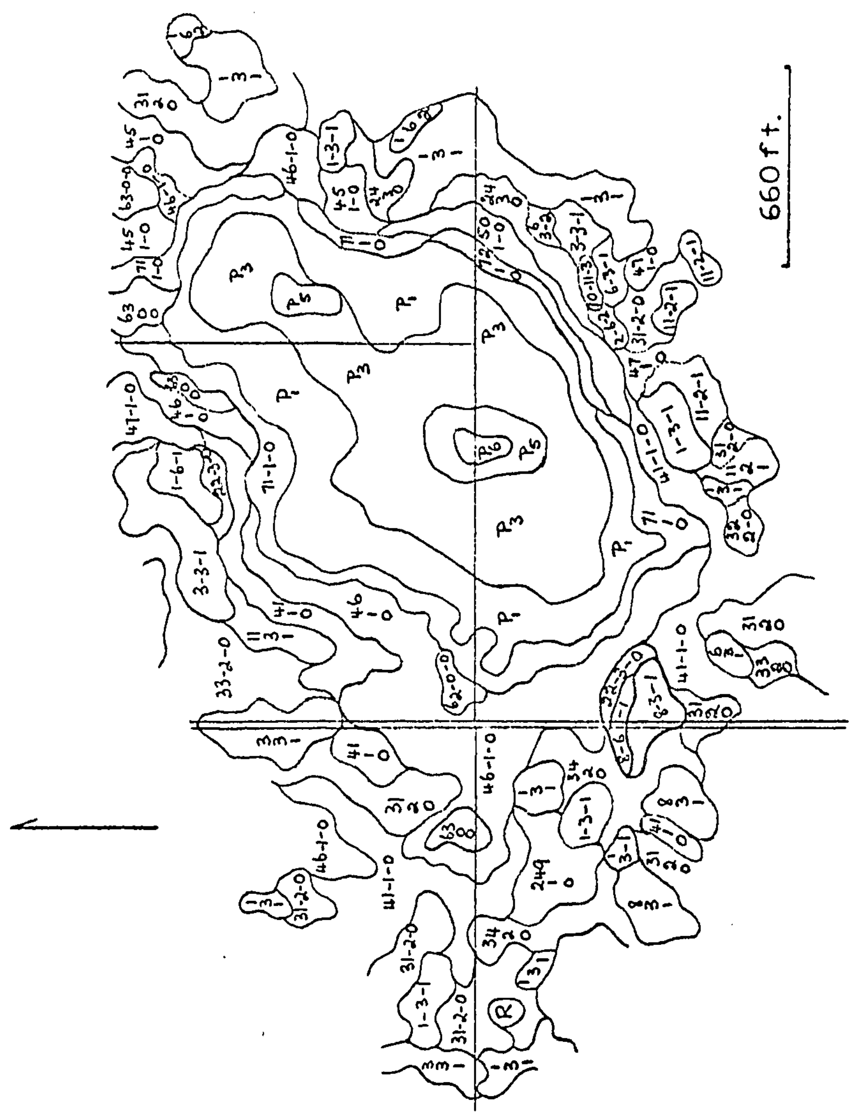
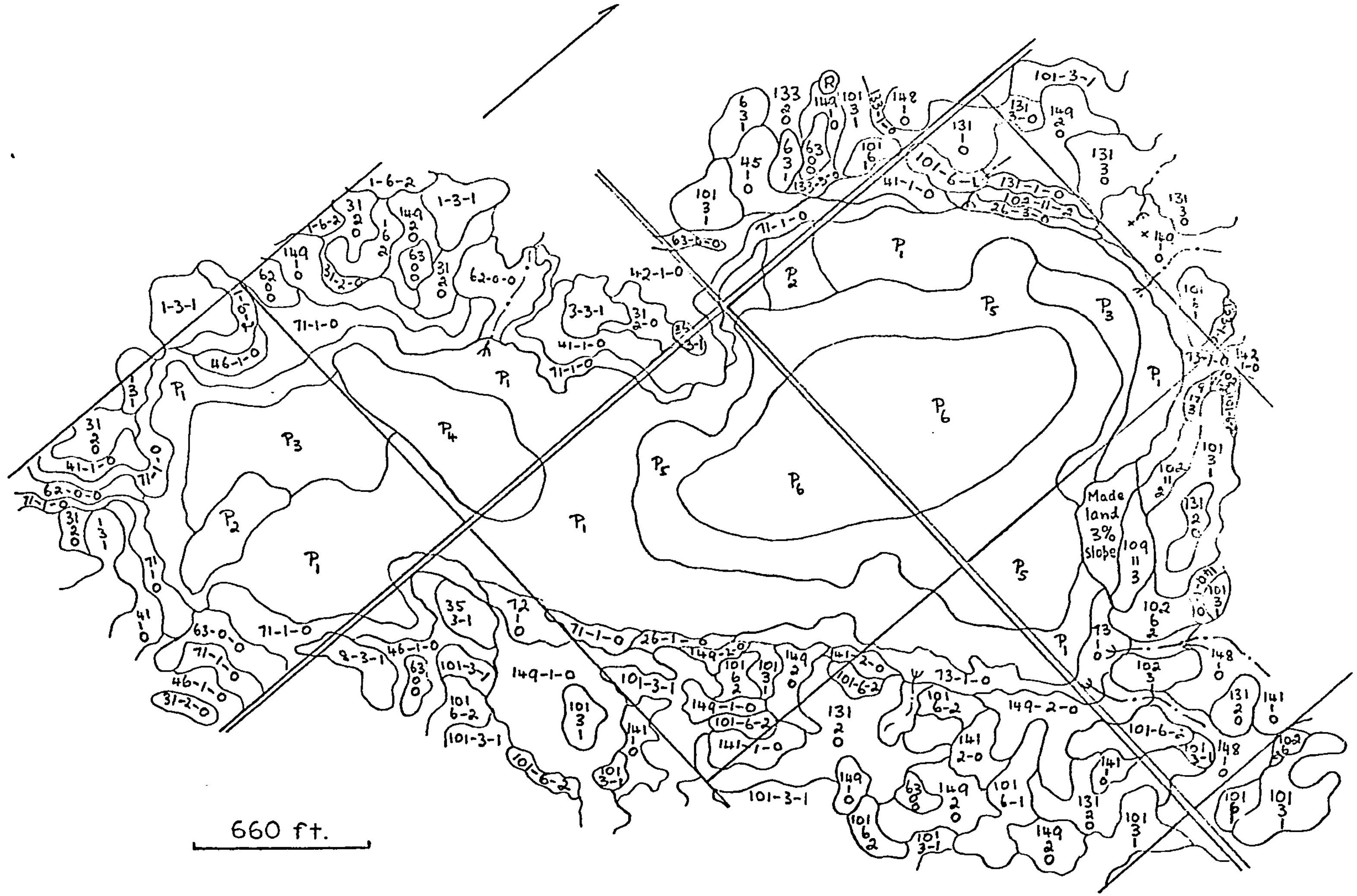

660 ft.

Figure 19. Soil map of the Jewell bog watershed
The map legend is given in Table 10.


660 ft.
Made land 3% slope
P1
P2
P3
P4
P5
P6
71-1-0
149-1-0
101-3-1
149-2-0
1-3-1
3-3-1
42-1-0
63-0-0
62-0-0
46-1-0
31-2-0
41-1-0

sediment become more organic in the surface; this trend is represented by legends P_1, P_2 and P_3. Eventually the profile becomes essentially a muck surface over sediments of the upper and lower silt zones, represented by legend P_4, and in the central bog area the characteristic double muck and double silt zones occur in the sequence UM/US/LM/LS/till to depths of 20 to 26 feet (legends P_5, P_6).

This simplified picture of soil distribution does not hold throughout the Colo watershed. The hillslope soils are not derived from a uniform till parent material and the differential erosion and deposition that was evident in the map of the sediments has a strong influence on soil profile morphology. Thus the mapping legend at Colo contains sedimentary variants of each of the important soil series of the Clarion-Webster toposequence, ranging from overthickened or colluvial variants where soils are strongly influenced by post-Cary sedimentation, to stratified till variants. The Clarion soils, on convex slopes, do not have profiles developed in stratified post-Cary sediment, but do form in stratified Cary sediment. Thus Clarion variants, units 6 and 8 represent shallow stratified till, and deep stratified till respectively. Storden soils, forming on the steepest slopes, do not have cumulic variants, but stratified till variants were mapped, for example, unit 10. Nicollet soils have cumulic and stratified till variants (units 24, 34), while in lower concave slope situations, Webster soils have stratified

Cary sediment (units 45, 46) in the profile, and in still lower situations, soils of unit 50 have developed in thick loamy alluvium. The Harpster and related soils on toeslopes were mapped with a range from unit 71 to cumulic unit 72, the latter being a transition to unit P_1 of the bog edge environment.

C. Jewell Soil Map

Much of the Jewell watershed is developed from heavier textured till than occurs at Colo. The mapping units 101, 131, 141 (Clarion-FT, Nicollet-FT, Webster-FT) on these heavier tills parallels the 1, 31, 41 (Clarion, Nicollet, Webster) sequence on the loam tills of Colo except that unit 101 soils are moderately well drained. With this modification, the pattern of distribution of soils at Jewell can be likened to Colo. Two other important differences occur in the detail of variants of established series. Although the till at Jewell has areas of finer till and loam till, the stratification within these tills is not as significant a feature as it is at Colo. Hence the mapping units at Jewell have fewer of the stratified till variants. On lower hillslopes, however, Webster soils (unit 49) and Harpster soils (unit 73) at Jewell have stratified post-Cary sediment within the colum, which is consistent with the steeper slopes at Jewell and the correspondingly higher proportion of stratified sedimentary materials at the bog edge (see Tables 8, 9).

VII. LABORATORY CHARACTERIZATION OF THE SOILS AND SEDIMENTS

A. Procedure

The laboratory analyses used to characterize the soils are pH, organic carbon, calcium carbonate equivalent, total exchangeable bases, exchangeable hydrogen, bulk density, and particle size analysis of the total sample which has been abstracted to obtain percent clay (<2μ), geometric mean size for the range 2μ to 2 mm., using the Wentworth scale, standard deviation in phi units (Krumbein and Pettijohn, 1938, p. 245-249), and percent >2 mm. The methods used for these analyses are described in Appendix B and the data are tabulated with the corresponding profile descriptions in Appendix A.

To facilitate relating the soil data to established series and mapping units defined in this report, the sampled profiles have been listed in Table 11 with brief notes on the topography, mapping unit and series relationships.

Data for miscellaneous profiles are listed in Appendix A. These include data for bog center profiles at McCulloch (M4), Woden (W1) and Hebron (H1).

B. Data Groups

1. Cary sediments

The materials identified as Cary sediments are of variable chemical and mechanical composition. It is important to differentiate these sediments both on the basis of their position in the weathering profile and on their sedimentary

Table 11. Sampled profiles with notes on topography, mapping units, and series relationships

Sampled profile	Topography	Mapping unit	Series relation
Colo			
C2	outer bog area	P_3	no series name
C3	bog edge, toeslope	P_1	no series name
C4a	toeslope	72	Harpster (2)
C12	bog center	P_5	no series name
C15	bog center	P_6	no series name
C18	bog center	P_5	no series name
C21	bog center	P_6	no series name
C22	bog center	P_6	no series name
C23	bog center	P_5	no series name
C24	bog center	P_5	no series name
C25	bog edge	P_3	no series name
C26	toeslope	P_1	below Harpster
C28	outer bog area	P_3	no series name
C29	bog edge	P_3	no series name
C30	ridge crest	6	Clarion (strat. var.)
C33	bog edge	71	Harpster
C39	low, convex	46	Webster (2), (calc.)
C40	hillcrest	3	Clarion (deep carbonates)
C60	hillcrest	1	Clarion
C73	hillcrest	8	Clarion (strat. var.)

Table 11. (continued)

Sampled profile	Topography	Mapping unit	Series relation
C77	bog edge	P_1	no series name
C79	gently convex summit	41	Webster
C100	mid-concave	22	Terril
C101	mid-concave	31	Nicollet
C102	toeslope	41	Webster
C103	upper concave	1	Clarion
C104	mid-concave	1	Clarion
C110	toeslope	50	Calco (loamy var.)
C111	toeslope	72	Harpster (cumulic var.)
C112	toeslope	72	Harpster (cumulic var.)
C118	mid-concave	24	Nicollet (cumulic var.)
C119	mid-concave	24	Nicollet (cumulic var.)
C120	mid-concave	24	Nicollet (cumulic var.)
Jewell			
J6	bog center	P_6	no series name
J42	hillcrest	101	Clarion-FT
J76	hillcrest	101	Clarion-FT
J80	hillcrest	131	Nicollet-FT
J81	hillcrest	1	Clarion
J94	hillcrest	101	Clarion-FT
J95	upper convex	101	Clarion-FT

Table 11. (continued)

Sampled profile	Topography	Mapping unit	Series relation
J97	steep convex	109	Storden
J100	concave	102-73	Harpster (2) transition
J101	lower concave	73	Harpster (2)
J112	convex	101	Clarion-FT
J173	bog center	P_6	no series name
J174	convex summit	101	Clarion-FT
JSSA	hillcrest	131	Nicollet-FT
JSSB	upper convex	131	Nicollet-FT
JSSC	convex	101	Clarion-FT
JSSD	convex	131-141	Nicollet-FT to Webster-FT (transition
JSSE	concave	142	Webster-FT (calc. surf.)
JSSF	concave	142	Webster-FT (calc. surf.)
JSSG	concave	142	Webster-FT (calc. surf.)
JSSH	depression	142-63	Glencoe transition
JSSI	depression	63	Glencoe (2)
JSSJ	depression	63	Glencoe (2)

properties. The weathering profile designations used are those of Kay and Graham (1943, p. 203) which were later related to the pedological profile by Scholtes *et al*. (1951, p. 296). The geological and pedological profiles are illustrated in Figure 20. The essential horizons, commencing with the deepest, are firstly, the unoxidized and unleached (U/U) zone of the essentially unmodified geological material, the oxidized and unleached zone (O/U), the oxidized and leached zone (O/L) which is equivalent to the C horizon of the pedological profile, the zone of chemical decomposition which is equivalent to soil B horizons, and the organic zone or soil A horizon at the surface. In this discussion, soil A horizons and all demonstrably surficial post-Cary sediments are excluded.

Throughout this discussion and in later sections, particle size mean and standard deviation data are for the range 2µ to 2 mm only. This is justified on two bases. Firstly, the coarse material often found in till ranges from sand (2 mm) to boulders, many feet in diameter. Such material cannot be satisfactorily sampled or analyzed by routine soil laboratory methods, and even pebbles, several inches in diameter, create problems in subsampling for mechanical analysis. A second justification lies in the nature of the particle size distributions of till and till derived materials. In the range 2µ to 2 mm, the distributions are commonly bimodal and reach minima in the vicinity of 2µ and 2 mm. Frequently a peak in the >2 mm range is apparent, but the curve is truncated due to the inadequacies of sampling outlined above. Distributions for a range of Cary sediments are shown in Figure 21 which illustrate these features. It is considered preferable to use

Figure 20. The geological and pedological profiles in till, after Scholtes *et al*. (1951, p. 296)

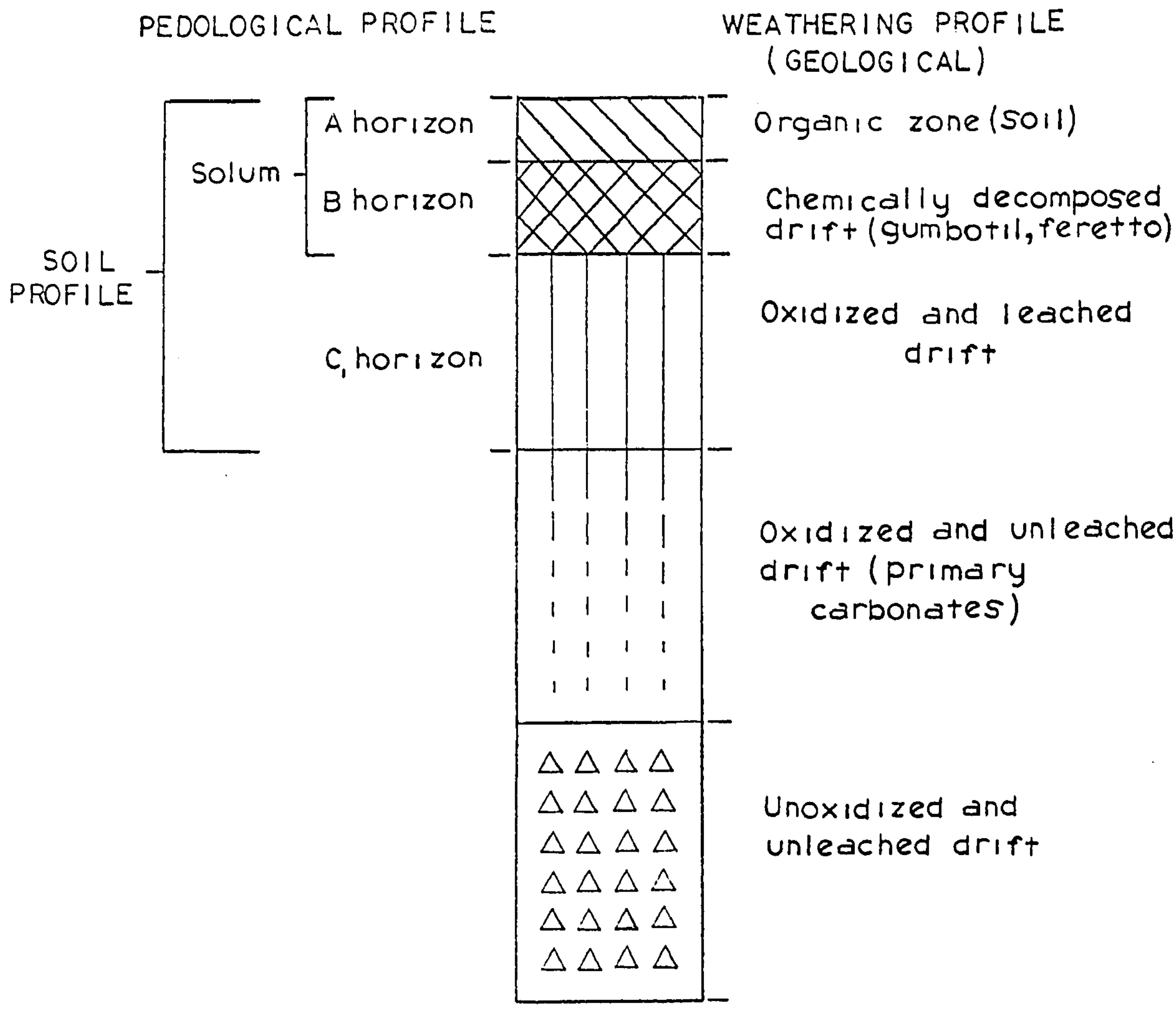
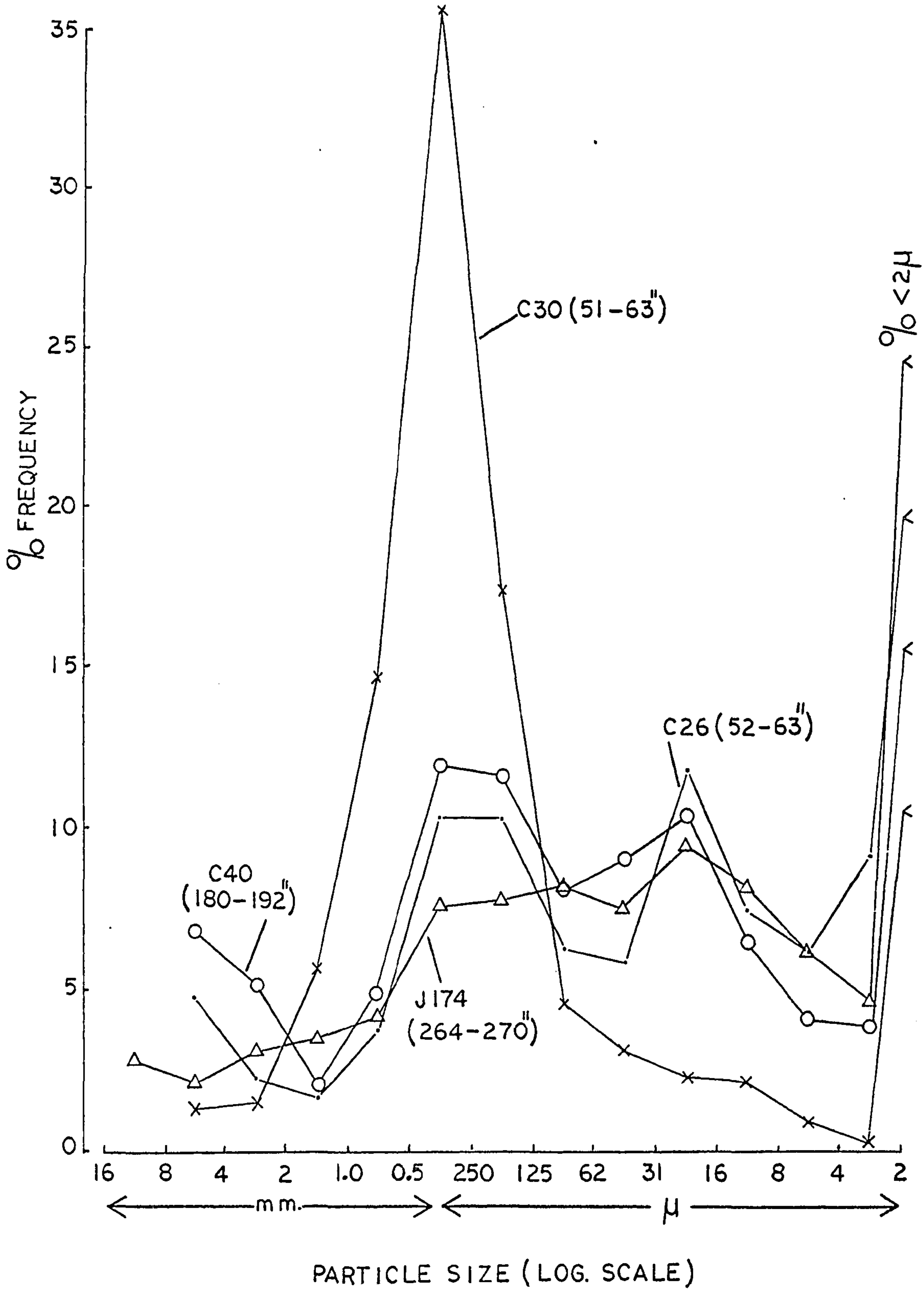

PEDOLOGICAL PROFILE
WEATHERING PROFILE (GEOLOGICAL)
SOIL PROFILE
Solum
A horizon
B horizon
C₁ horizon
Organic zone (soil)
Chemically decomposed drift (gumbotil, feretto)
Oxidized and leached drift
Oxidized and unleached drift (primary carbonates)
Unoxidized and unleached drift

Figure 21. Particle size frequency diagrams for Cary sediments, showing characteristic peaks between 2μ and 2 mm., and minima near 2 mm.


% FREQUENCY
35
30
25
20
15
10
5
0
C30 (51-63")
C26 (52-63")
C40
(180-192")
J174
(264-270")
% <2μ
16
8
4
2
1.0
0.5
250
125
62
31
16
8
4
2
mm.
μ
PARTICLE SIZE (LOG. SCALE)

the range of 2μ to 2 mm. for critical comparison of sediments, rather than the whole available range for >2μ in which the coarse end is not effectively represented.

The particle size data for the weathering zones of Cary sediments are plotted from the data in Appendix A. The following profiles are represented: C2, C4a, C12, C21, C22, C25, C26, C28, C29, C30, C33, C39, C40, C60, C73, C77, C79, C101, C102, C103, C104, C111, C112, C119, C120, J42, J76, J80, J94, J100, J101, J112, J174, JSSA, JSSB, JSSC, JSSD.

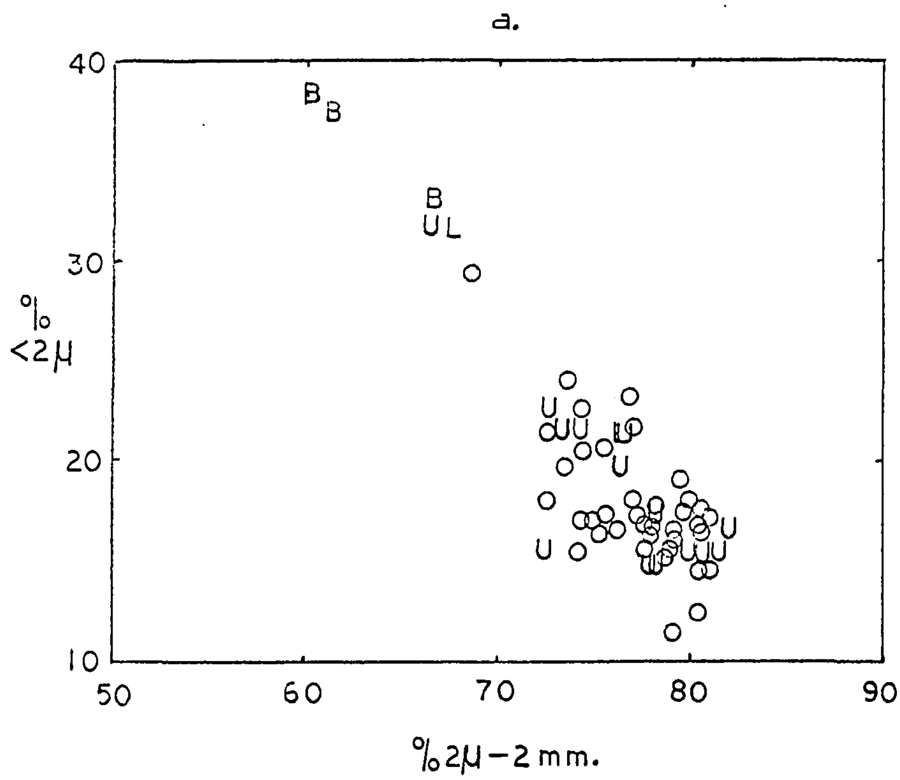
A plot of the material recognized in the field at Colo as till is shown in Figure 22a using percent 2μ to 2 mm. against percent <2μ for the total sample. The sediments in the O/L, O/U and U/U zones of the weathering profile cannot be differentiated as separate groups on this basis, but the B horizon data may represent a separate group reflecting soil development. In Figure 22b, the various zones of the Colo till are shown to fall within narrow limits of sorting, as measured by the standard deviation, but cover a wide range of geometric mean diameter, without separation into clear groups. Thus the Colo tills are a homogeneous group in terms of their clay content and standard deviation with no systematic particle size trends in relation to trends in the geological weathering profile.

By contrast, a similar plot for the stratified drift sediments at Colo in Figure 23 shows a trend and considerable scatter in the standard deviation/geometric mean relationship

Figure 22a. Plot of % <2μ clay against % 2μ - 2 mm. for Cary till at Colo

Figure 22b. Plot of standard deviation against geometric mean for the size range 2μ - 2 mm. for Cary till at Colo

Legend of plotted points: U = unoxidized and unleached till; O = oxidized and unleached till; L = oxidized and leached till; B = soil B horizon


a.
40
30
20
10
%
<2μ
50
60
70
80
90
%2μ-2 mm.

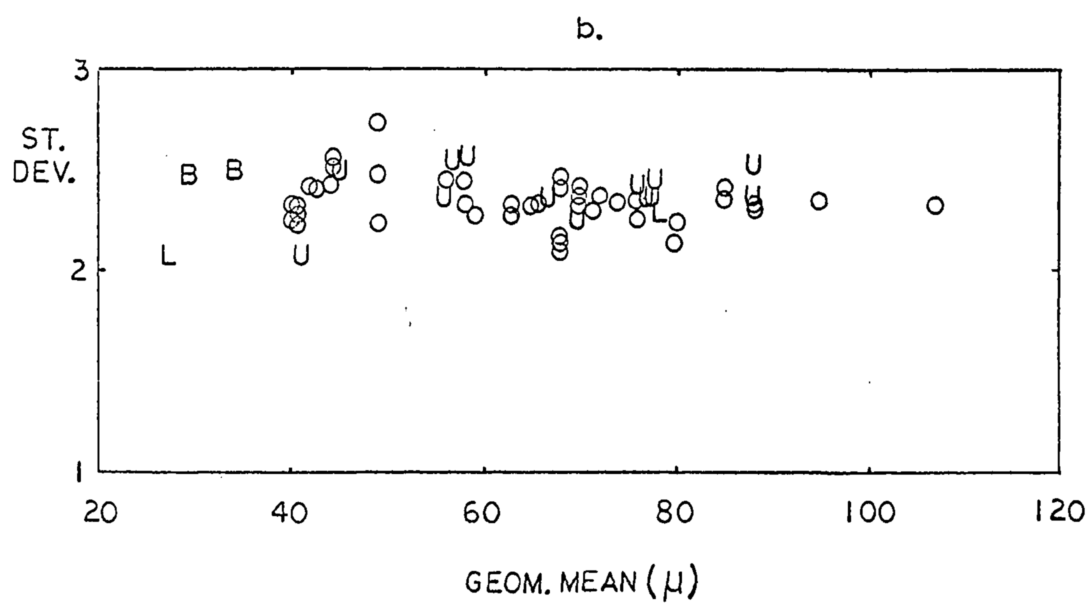
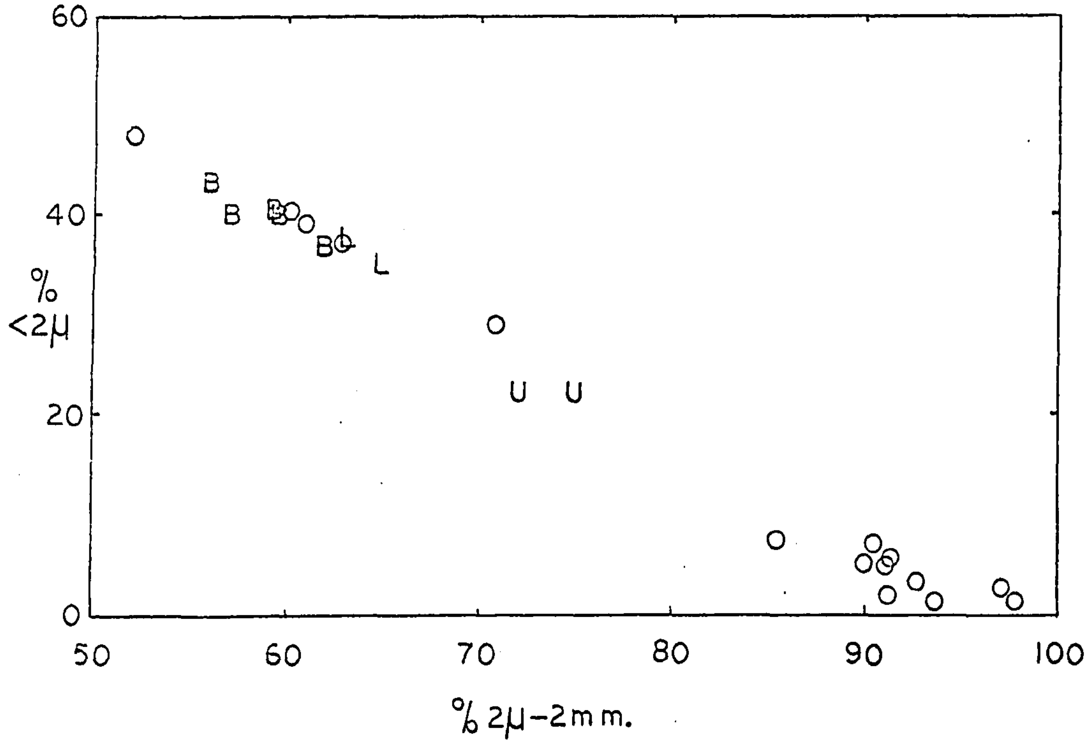

b.
3
2
1
ST.
DEV.
20
40
60
80
100
120
GEOM. MEAN (μ)

Figure 23a. Plot of % <2μ clay against % 2μ - 2 mm. for Cary drift at Colo

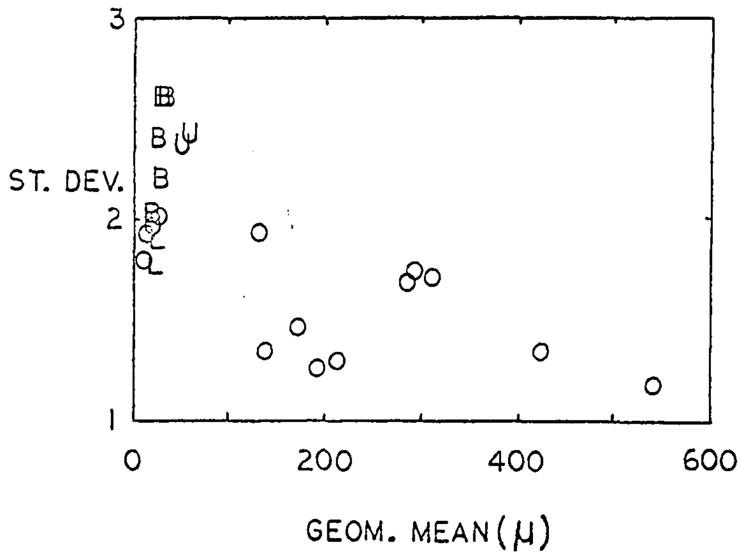
Figure 23b. Plot of standard deviation against geometric mean for the size range 2μ - 2 mm. for Cary drift at Colo

Legend of plotted points: U = unoxidized and unleached drift; O = oxidized and unleached drift; L = oxidized and leached drift; B = soil B horizon

a.


60
40
20
0
%
<2μ
50
60
70
80
90
100
% 2μ–2mm.

b.


3
2
1
ST. DEV.
0
200
400
600
GEOM. MEAN (μ)

which suggests a progressively higher degree of sorting as particle size increases. This is consistent with the geological definition of drift (American Geological Institute, 1957) which includes sediment differentiated by fluvial transport. From the practical standpoint of classifying a particular vertical sequence as a substratum below soils, it is significant that the data of Figures 22 and 23 show the drift as having all of the range of sedimentary properties of the till, and more. Thus in a body of drift, single strata occur which have particle size properties similar to till and may be indistinguishable from it.

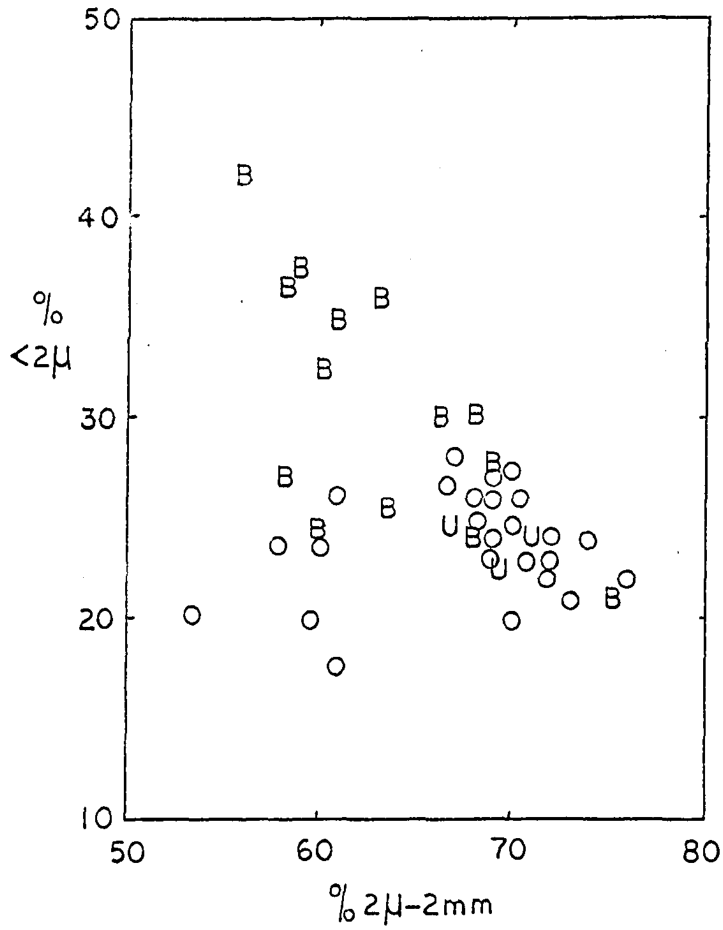
Similar data are plotted for the Jewell till in Figure 24 and show comparable trends to the Colo till, except that the values for percent $<2\mu$ are higher. Insufficient data are available to represent particle size trends for stratified drift materials at Jewell.

The Colo and Jewell till data may be used to illustrate the broad trends of pedological as against geological processes. The geological profile of Cary till is progressively more oxidized closer to the surface and a narrow leached zone occurs in the vicinity of the pedological profile. If the particle size properties of the oxidized and unleached zone (O/U) differed from those of the unoxidized and unleached zone (U/U) due to weathering and production of $<2\mu$ clay from fine silty fractions, the increase in clay would be accompanied by an increase in mean particle size within the range 2μ to 2 mm.

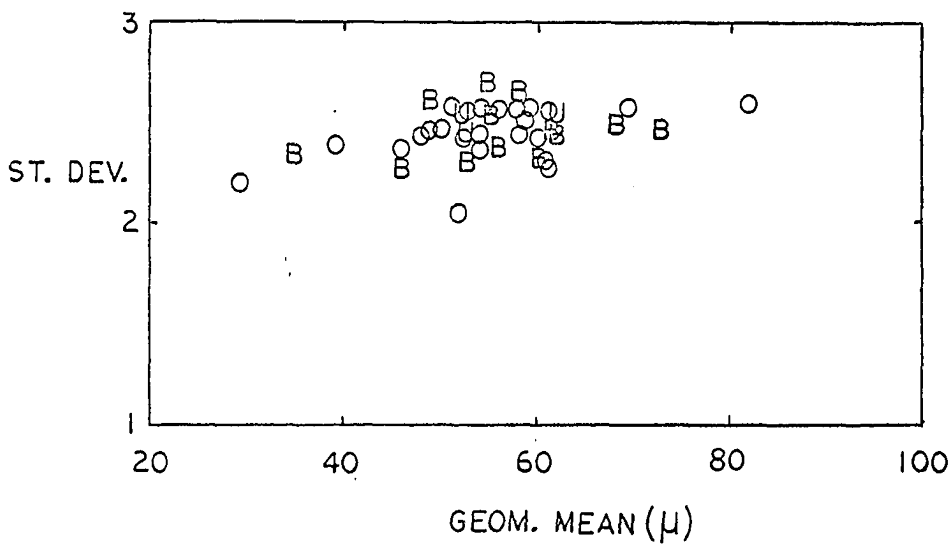
Figure 24a. Plot of % <2μ clay against % 2μ - 2 mm. for Cary till at Jewell

Figure 24b. Plot of standard deviation against geometric mean for the size range 2μ - 2 mm. for Cary till at Jewell

Legend of plotted points: U = unoxidized and unleached till; O = oxidized and unleached till; L = oxidized and leached till; B = soil B horizon



50
40
30
20
10
%
<2μ
50
60
70
80
% 2μ-2mm



3
2
1
ST. DEV.
20
40
60
80
100
GEOM. MEAN (μ)

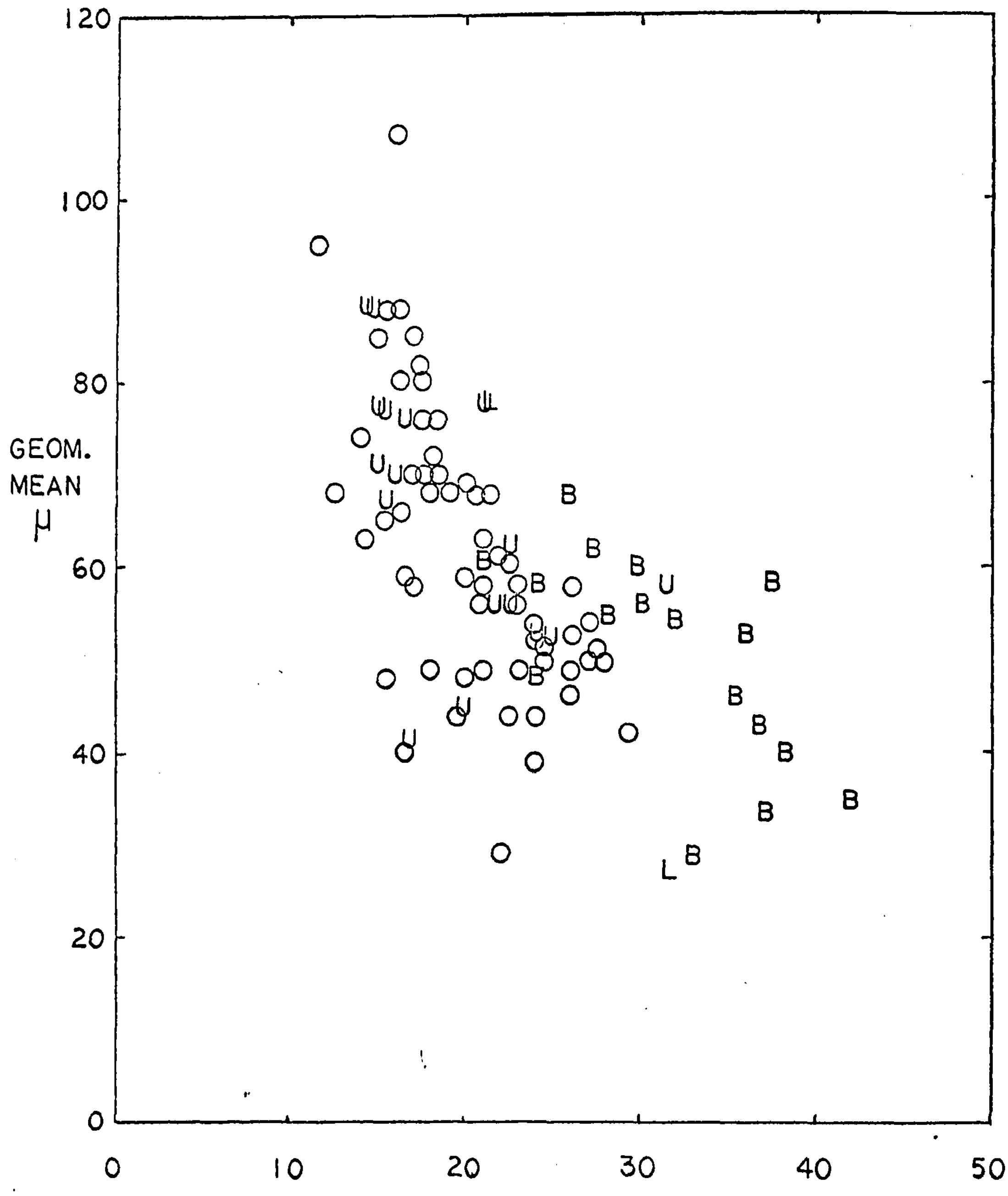
A plot of these data for Colo and Jewell till in Figure 25 shows that the reverse is in fact the case and that there is no consistent grouping of U/U versus O/U zones. Thus, since the trend is not oriented in relation to the surface of weathering, it is considered to be an inherent geological property related to sedimentation. It is significant that B horizon materials plot as an extension of the geological trend; this raises the possibility that the B horizons derived their features from a depositional characteristic of the till rather than by pedogenesis. The problem is complicated for the B horizon situation, however, by loss of coarse carbonate materials through leaching (Kay and Graham, 1943, p. 222). Such losses would change the coarser particle size properties of leached till materials, such as the B horizons, to conform to the general geological trend.

From the practical viewpoint of having to map and classify soils in the field and their Cary sedimentary components, the approach adopted in the field was to classify as till those sediments having a loam to heavy loam texture and relatively poor sorting, as indicated by the intimate mixing of coarse and fine fractions in the hand sample. Samples outside this category, or which were evidently stratified with coarse and fine materials, were grouped separately, depending on texture and degree of stratification.

This procedure seems justified in the light of analytical data presented in this section. Both the percent $<2\mu$, and the

Figure 25. Plot of the geometric mean for the size range 2μ - 2 mm. against % <2μ for Cary till samples at Colo and Jewell

Legend of plotted points: U = unoxidized and unleached till; O = oxidized and unleached till; L = oxidized and leached till; B = soil B horizon


120
100
80
60
40
20
0
GEOM.
MEAN
μ
0
10
20
30
40
50
%<2μ

standard deviation used as a measure of sorting, are sensitive parameters for classifying the Cary sediments, especially when used together. It can be seen from Figure 22 that limits of percent <2μ from 15 to 25 and for standard deviations from 2.0 to 2.6 would exclude more than 80 percent of materials classified as stratified drift at Colo and would include more than 80 percent of samples classified as till. At Jewell (Figure 24) the limits for percent <2μ of 20 to 30 and standard deviation 2.0 to 2.6 would include most materials classified as firm till. Such limits may prove useful when correlated further with field observations.

Other properties of the Cary sediments are summarized in Table 12. These data also show a progressive coarsening of glacial sediments with distance down the profile. The gravel data further indicate small differences between U/U and O/U zones of the geological weathering profile at Colo and no difference at Jewell. The large difference in gravel content between B horizons and zones below them in the weathering profile probably result from losses of coarse carbonate fragments due to leaching. There is, however, some evidence of a decrease in carbonate content in the O/U zone as against the U/U zone which may be attributable to deep leaching effects.

Bulk density data for glacial sediments show a predictably wider spread at Colo than at Jewell. Higher values were not obtained at Jewell due to the fact that local road cuts were not sufficiently deep to permit sampling down to the U/U zone. The values of 1.80 gm/cc for Colo were obtained in a fresh road cut along Highway 30 where the U/U zone was exposed within 1 mile of the Colo bog.

Table 12. Gravel, carbonate, and bulk density data for Cary till and drift samples

Property	Sedimentary group		Average	Range	Number obs.
Gravel (>2 mm.) %	Colo till	B hor.	1.0		3
		O/U	4.8		37
		U/U	5.1		14
	Colo drift	B hor.	2.0		5
		O/U	3.5		12
		U/U	4.5		2
	Jewell till	B hor.	5.9		14
		O/U	8.9		25
		U/U	7.2		3
Calcium carbonate equivalent (%)	Colo till	O/U	15.0	8.7-22.5	36
		U/U	20.0	14.9-39.2	10
	Colo drift	O/U	9.9	1.2-16.7	15
		U/U	15.4	15.0-15.8	2
	Jewell till	O/U	18.9	17.5-18.8	26
		U/U	18.3	11.0-24.6	3
Bulk density gm./cc.	Colo (till & drift)		1.63	1.34-1.80	10
	Jewell (till)		1.62	1.52-1.71	10

2. <u>Soils of upper hillslopes</u>

Topographic situations on upper hillslopes range from gently convex summits to steep slopes which are susceptible to erosion. For convenience in handling the analytical data, the soils of these situations are placed in four groups. The gently convex summit group (Webster C79, Clarion-FT J174) represent soils with least erosion, on gently sloping convex slopes; the rounded summit group (Clarion C60, Clarion-FT J42) represents soils with slight erosion on convex hillcrests; the steep convex group characterized by strong erosion is represented by only one profile, J97, a Storden soil; the upper concave group (Clarion C103, Nicollet C104) represents soils which show moderate to imperfect drainage and slight cumulic characteristics.

The percent <2μ clay data of Figure 26 show the effect of degree of erosion at the site. The greatest amount and depth of clay occurs in gently convex summit sites which approach erosional stability. With increasing influence of erosion, the depth to profile clay maximum decreases and the amount of subsoil clay decreases. Below the point of maximum erosion on steep convex slopes, the upper concave sites show a smaller clay content in the solum than either the rounded summit or gently convex summit profiles. The latter group of profiles appears to have a distinctive clay B horizon but this is not evident in the other profile groups.

The organic carbon data for the upper hillslope soils in Figure 27 show that the gently convex summit profiles have higher organic carbon than the other profiles, but that it is more localized near the surface than in the Clarion or

Figure 26. Percent <2μ clay profiles for groups of soils on convex to upper concave situations

Group (a) = gently convex summit sites; group (b) = rounded summit sites; group (c) = steep convex sites; group (d) = upper concave sites

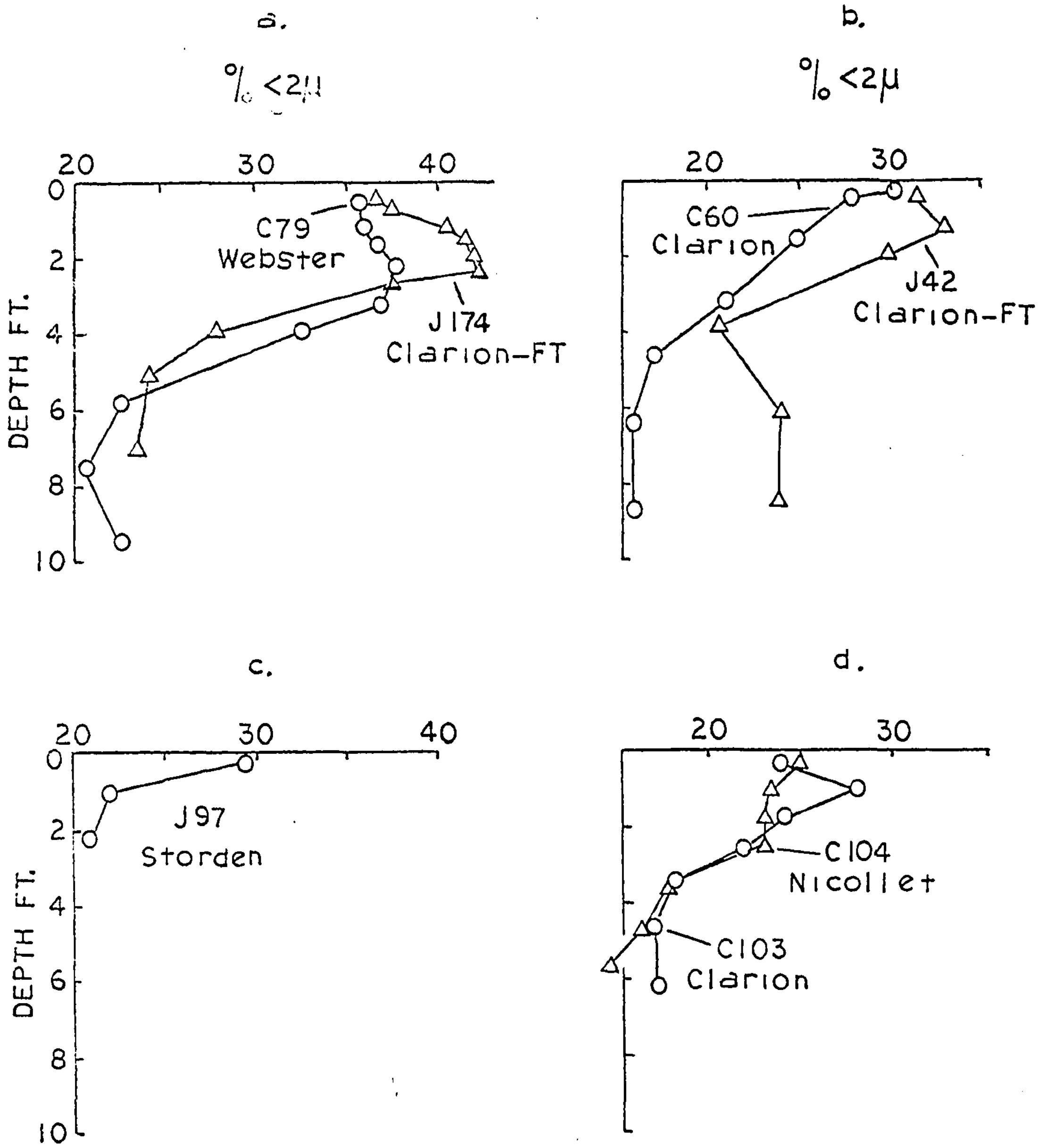
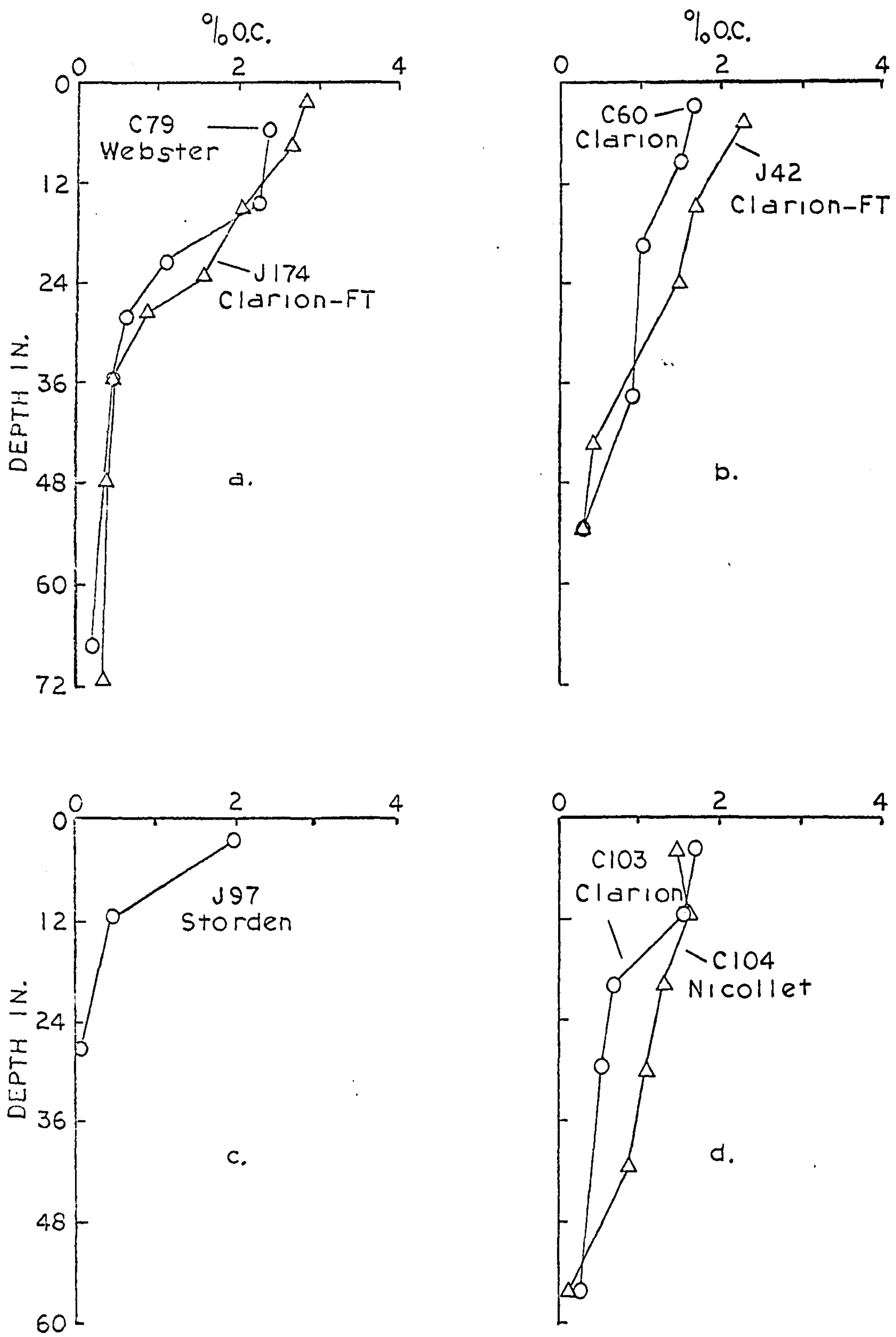

a.
% <2μ
20
30
40
C79
Webster
J174
Clarion-FT
DEPTH FT.
0
2
4
6
8
10
b.
% <2μ
20
30
C60
Clarion
J42
Clarion-FT
c.
20
30
40
J97
Storden
DEPTH FT.
0
2
4
6
8
10
d.
20
30
C104
Nicollet
C103
Clarion

Figure 27. Percent organic carbon profiles for groups of soils on convex to upper concave situations

Group (a) = gently convex summit sites; group (b) = rounded summit sites; group (c) = steep convex sites; group (d) = upper concave sites



%O.C.
0
2
4
DEPTH IN.
0
12
24
36
48
60
72
C79
Webster
J174
Clarion-FT
a.
%O.C.
0
2
4
C60
Clarion
J42
Clarion-FT
b.
0
2
4
DEPTH IN.
0
12
24
36
48
60
J97
Storden
c.
0
2
4
C103
Clarion
C104
Nicollet
d.

Nicollet situations on steeper slopes. The Storden soil in a steep convex slope situation has least depth of organic carbon in the profile, which is consistent with a rapid removal of soil materials from the surface. This rapid removal at the surface has brought about the difference in calcium carbonate equivalent profiles represented in Figure 28. The C79 and J174 soils are the most deeply leached, as evidenced by depth to carbonates, whereas the Storden profile is weakly calcareous at the surface. Clarion and Nicollet soils on steeper convex and concave slopes predictably have carbonate profiles which fall between these two erosional extremes. In general, carbonate profiles in the situations described here do not show a subsoil accumulation to match the near-surface depletion of carbonates. The absence of a carbonate accumulation zone may be explained either by proposing that carbonates are leached and lost from the system into the adjacent bog or were not present in significant quantity in the upper strata of the original deposits. The data are not available to test either hypothesis critically.

Bulk density data for three upper hillslope profiles at Jewell in Figure 29 show the greater uniformity of A horizon material in the range 1·20-1·30 gm./cc. B horizons are generally higher but somewhat more variable, with values up to 1·40 gm./cc. The C horizons have the largest values between 1·40-1·75 gm./cc., which are comparable with the till density for Jewell in Table 12.

Figure 28. Percent calcium carbonate equivalent profiles for groups of soils on convex to upper concave situations

Group (a) = gently convex summit sites; group (b) = rounded summit sites; group (c) = steep convex sites; group (d) = upper concave sites

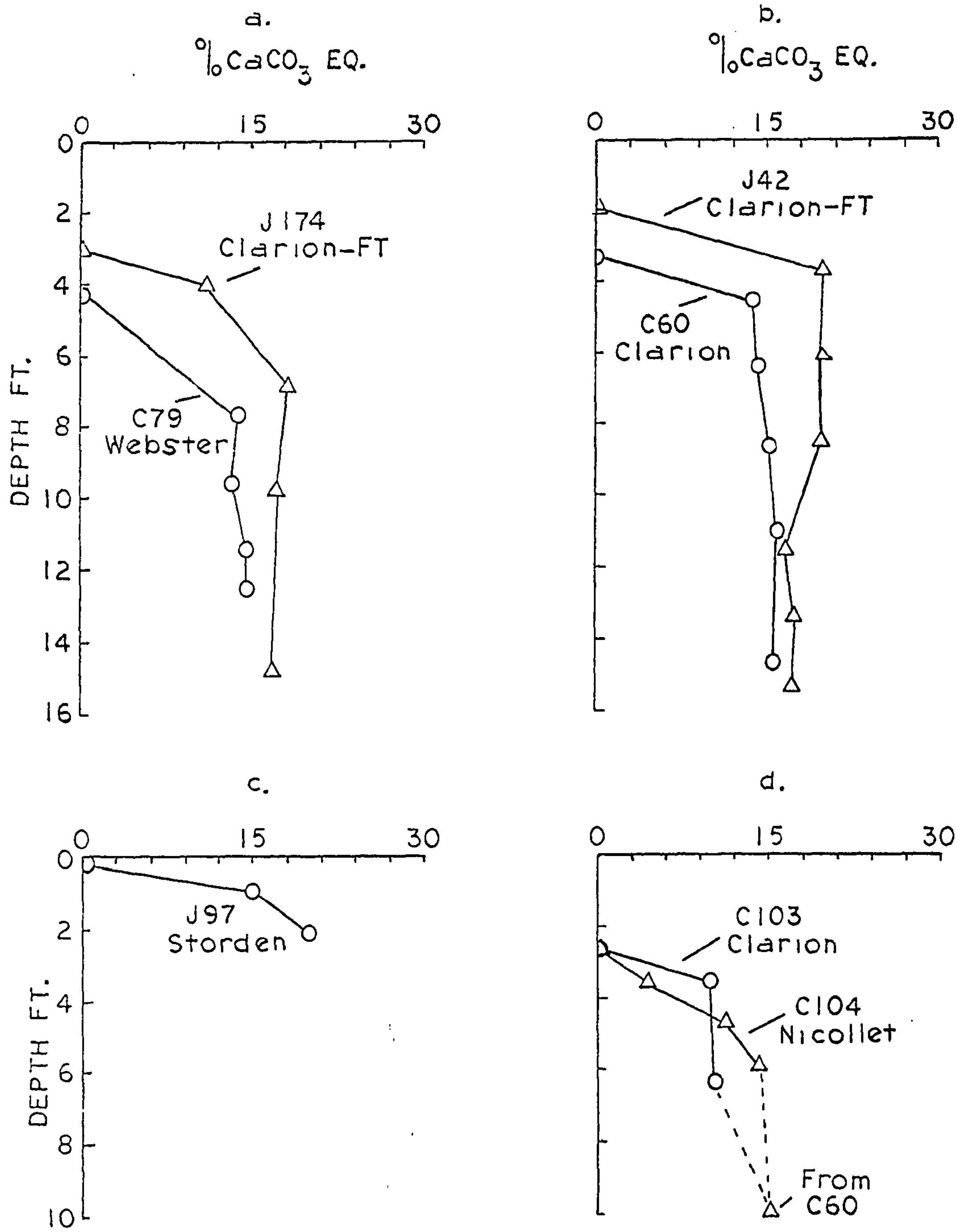
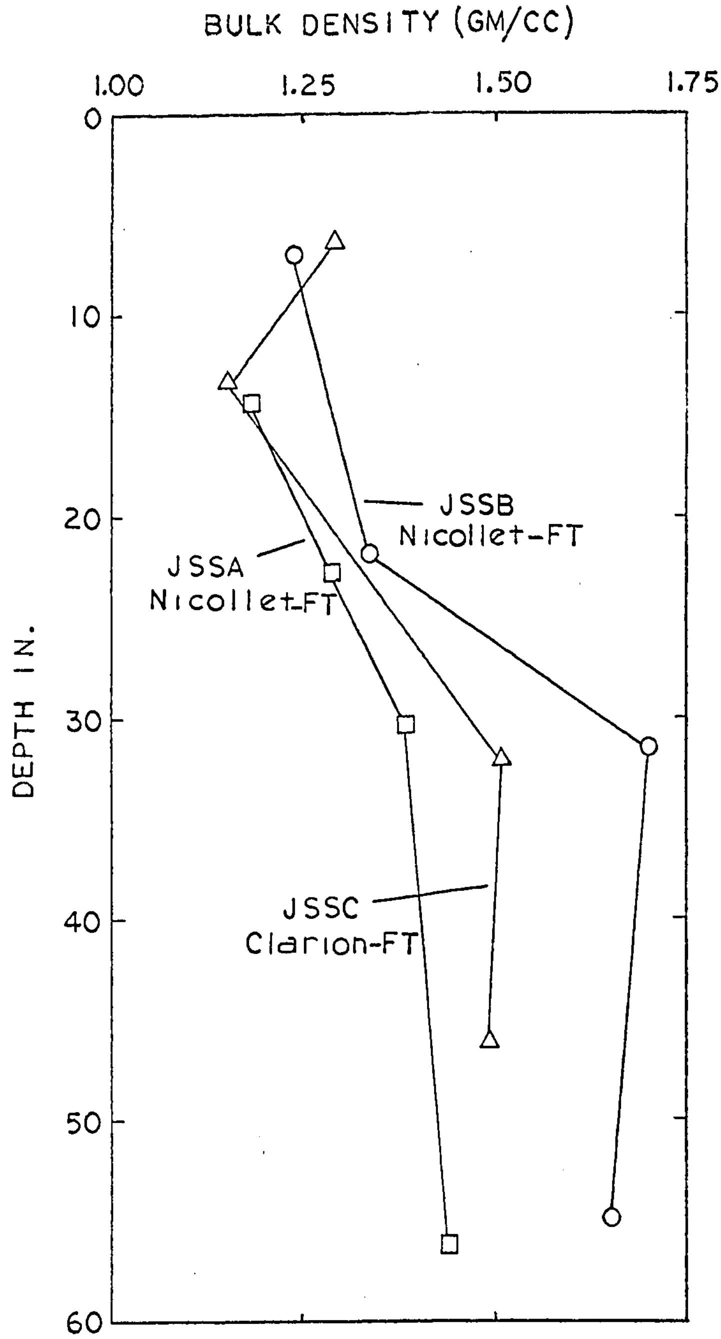

a.
%CaCO$_3$ EQ.
0
15
30
0
2
4
6
8
10
12
14
16
DEPTH FT.
J174
Clarion-FT
C79
Webster
b.
%CaCO$_3$ EQ.
0
15
30
J42
Clarion-FT
C60
Clarion
c.
0
15
30
0
2
4
6
8
10
DEPTH FT.
J97
Storden
d.
0
15
30
C103
Clarion
C104
Nicollet
From
C60

Figure 29. Bulk density profiles for soils on upper convex slopes of the JSS traverse in the Jewell bog watershed


BULK DENSITY (GM/CC)
1.00
1.25
1.50
1.75
0
10
20
30
40
50
60
DEPTH IN.
JSSB
Nicollet-FT
JSSA
Nicollet-FT
JSSC
Clarion-FT

3. Soils of lower hillslopes

Soils in these situations are closely related to Webster, Harpster and Glencoe series and their fine textured equivalents in the Jewell watershed. These are essentially soils showing poor drainage and are developed in surficial sediment which may be interfingered with bog sediment.

In the first group of profiles shown in the following figures, a Webster soil C102, formed in surficial hillside sediment over till, is compared with a Webster soil C39, formed in stratified till on a gently convex slope just above bog level at Colo. A second grouping contains profiles C110 (Calco) and J101 (Harpster), both of which occur in toeslope situations and show stratification in that part of the profile developed in surficial sediment. The Harpster situation is represented by profiles C4a and C33, both formed in surficial sediment over till; the Glencoe soils of enclosed depressions are represented by profiles JSSH and JSSJ.

The percentage $<2\mu$ data of Figure 30 show the high degree of variability associated with stratified till and surficial materials. Only in the depressional Glencoe soils do surficial parent materials approach homogeneity. Organic carbon data in Figure 31 show the progressive build-up of humic materials as soil situations are closer to the bog center. In no instance, however, do surface horizons become sufficiently organic to depth to become muck or peat organic soils.

The carbonate data of Figure 32 are somewhat variable but

Figure 30. Percent <2μ clay profiles for groups of soils on concave slopes and in depressions

Group (a) = Webster soils showing surficial stratification (C102) and till stratification (C39); group (b) = soils on toeslope situations just above Harpster soils; group (c) = Harpster soils; group (d) = Glencoe soils of depressions

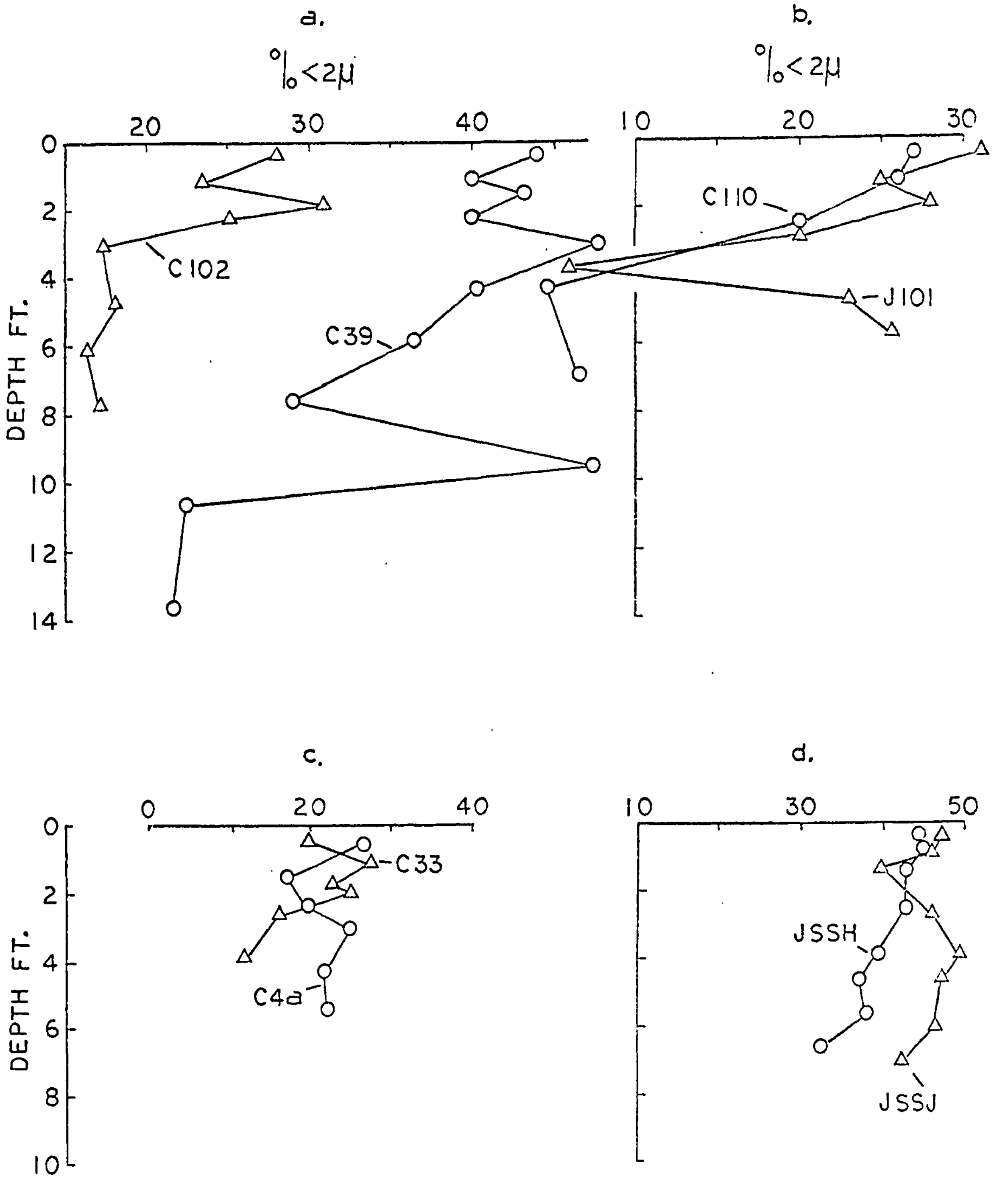
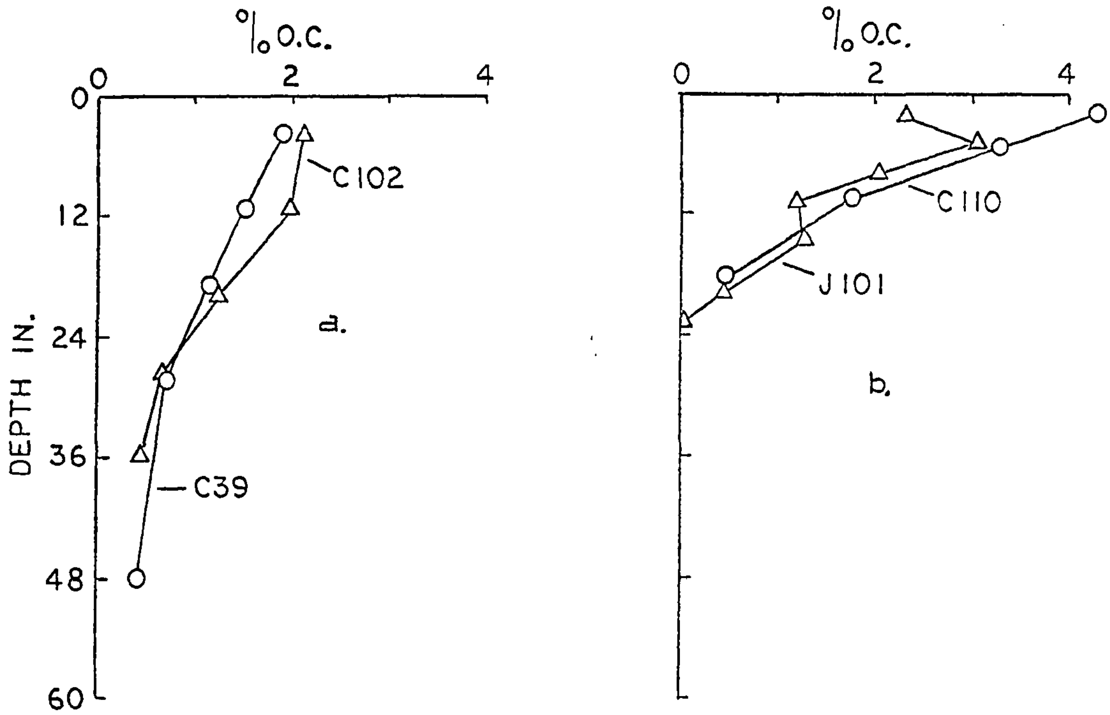

a.
%<2μ
20
30
40
0
2
4
6
8
10
12
14
DEPTH FT.
C102
C39
b.
%<2μ
10
20
30
C110
J101
c.
0
20
40
0
2
4
6
8
10
DEPTH FT.
C33
C4a
d.
10
30
50
JSSH
JSSJ

Figure 31. Percent organic carbon profiles for groups of soils on concave slopes and in depressions

Group (a) = Webster soils showing surficial stratification (C102) and till stratification (C39); group (b) = soils on toeslope situations just above Harpster soils; group (c) = Harpster soils; group (d) = Glencoe soils of depressions


% O.C.
0
2
4
0
12
24
36
48
60
DEPTH IN.
C102
C39
a.
% O.C.
0
2
4
C110
J101
b.

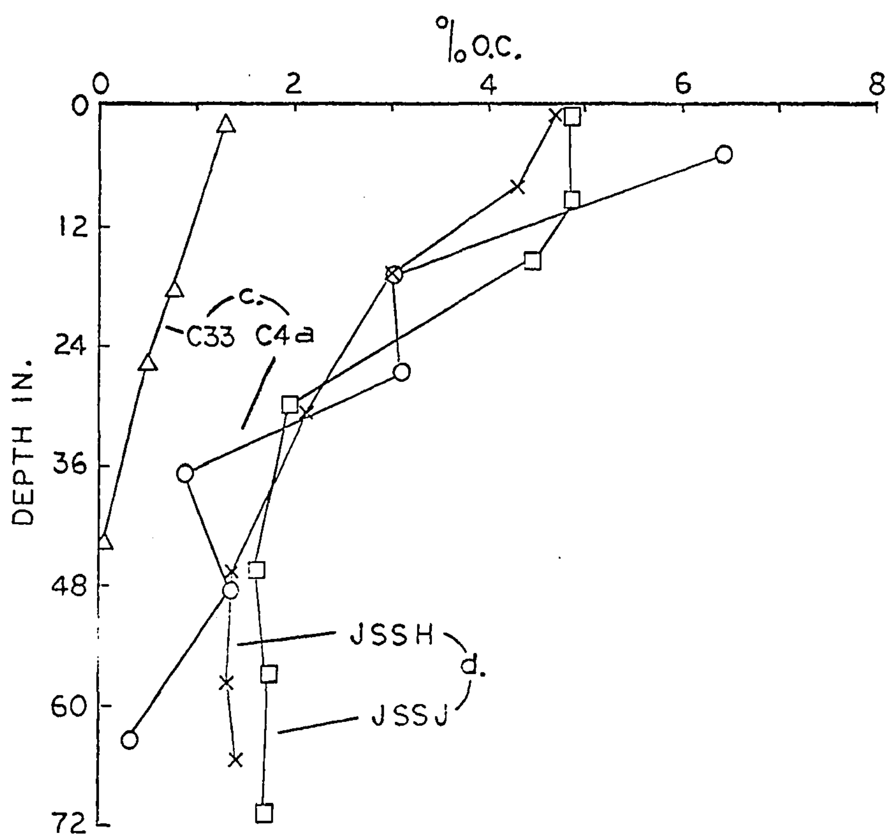
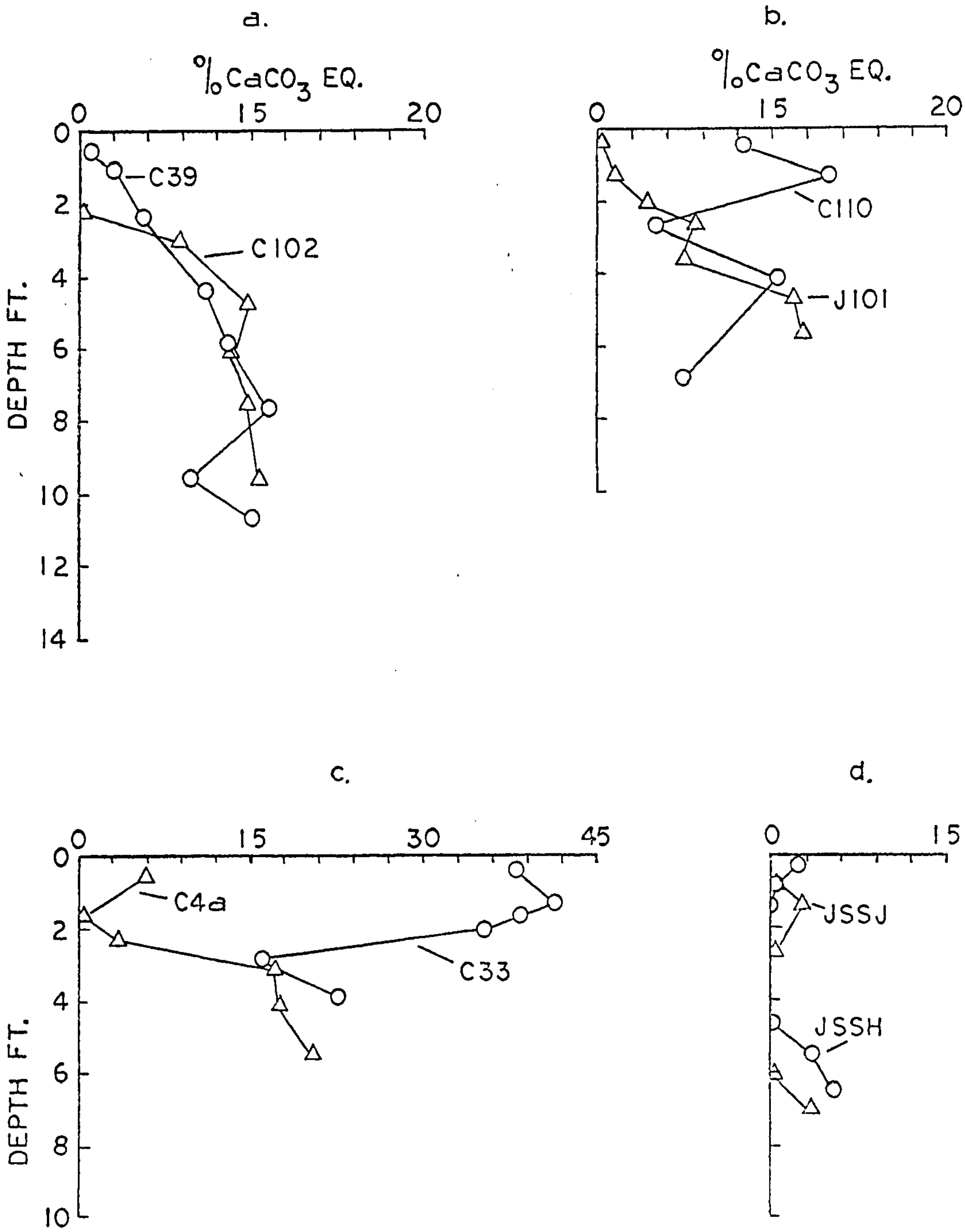

% O.C.
0
2
4
6
8
0
12
24
36
48
60
72
DEPTH IN.
c.
C33
C4a
JSSH
JSSJ
d.

Figure 32. Percent calcium carbonate equivalent for groups of soils on concave slopes and in depressions

Group (a) = Webster soils showing surficial stratification (C102) and till stratification (C39); group (b) = soils on toeslope situations just above Harpster soils; group (c) = Harpster soils; group (d) = Glencoe soils of depressions


a.
%CaCO3 EQ.
0
15
20
0
2
4
6
8
10
12
14
DEPTH FT.
C39
C102
b.
%CaCO3 EQ.
0
15
20
C110
J101
c.
0
15
30
45
0
2
4
6
8
10
DEPTH FT.
C4a
C33
d.
0
15
JSSJ
JSSH

show the characteristic increase in carbonate content of surface horizons between Webster toeslope situations and depression edges, reaching a maximum in Harpster soils. Surface carbonate content then diminishes in the depressions and variants of the Glencoe series may be leached in surface horizons.

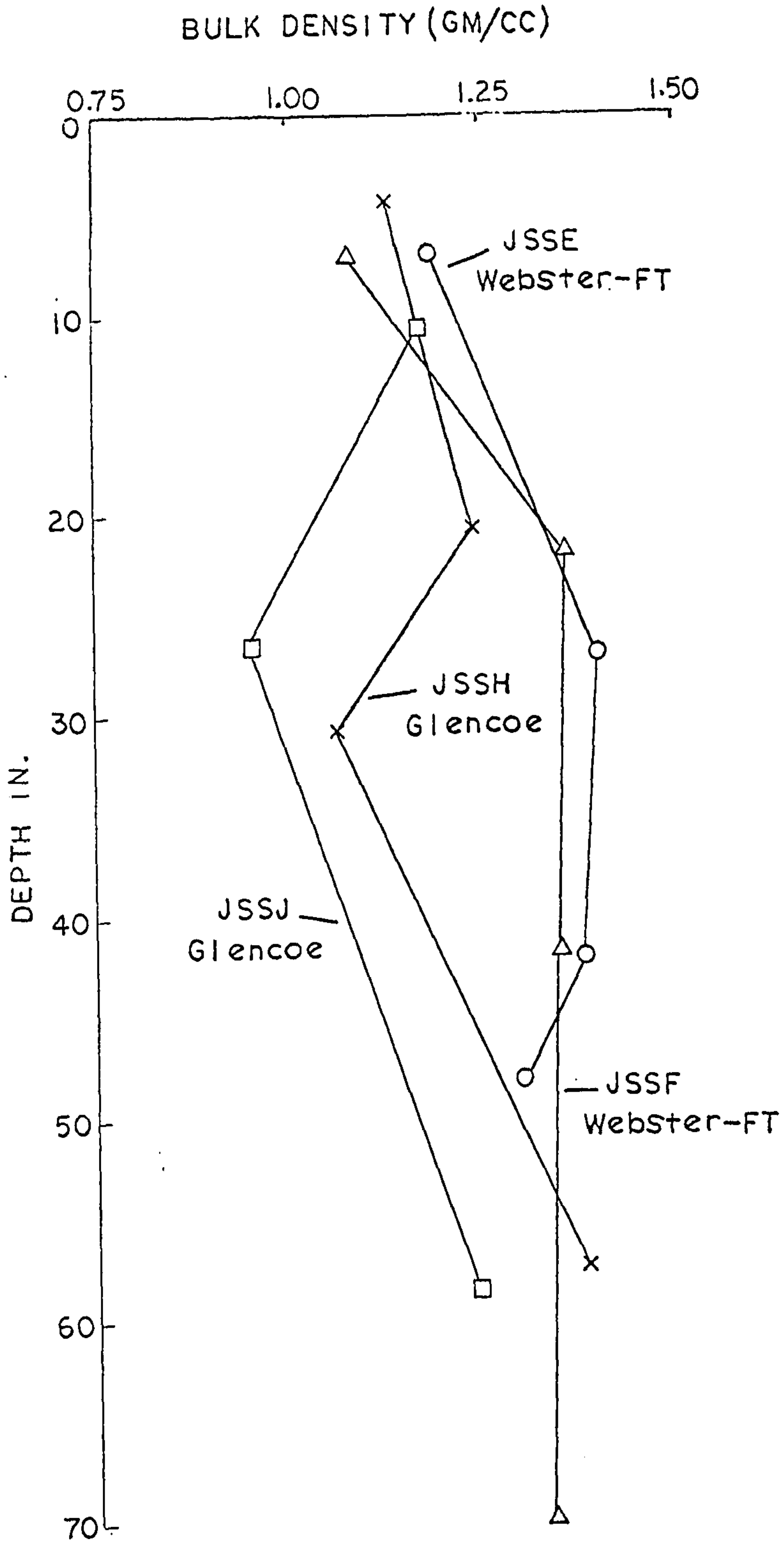
The bulk density data in Figure 33 offer a comparison between two Webster-FT profiles (JSSE, JSSF) and two Glencoe soils (JSSH, JSSJ). These profiles are at the lower end of the traverse containing profiles whose bulk densities are shown in Figure 29. At sites E, F, H and J the thickness of surficial material over the till has increased so that densities are lower throughout. The decrease in density is to some extent related to increase in organic matter content, and it is noticeable that the lower horizons of the Glencoe soils are less dense than in the Webster soils.

4. Soils in bog situations

Series names have not been given to bog soils within Iowa, hence, in this discussion the mapping unit designations and profile numbers are used to refer to the profiles.

Three kinds of bog profile were particularly significant in this study, and together they represent the range of soil properties occurring in the bog environments of the study areas. These profiles are represented in mapping designations P_1, P_3, and P_6.

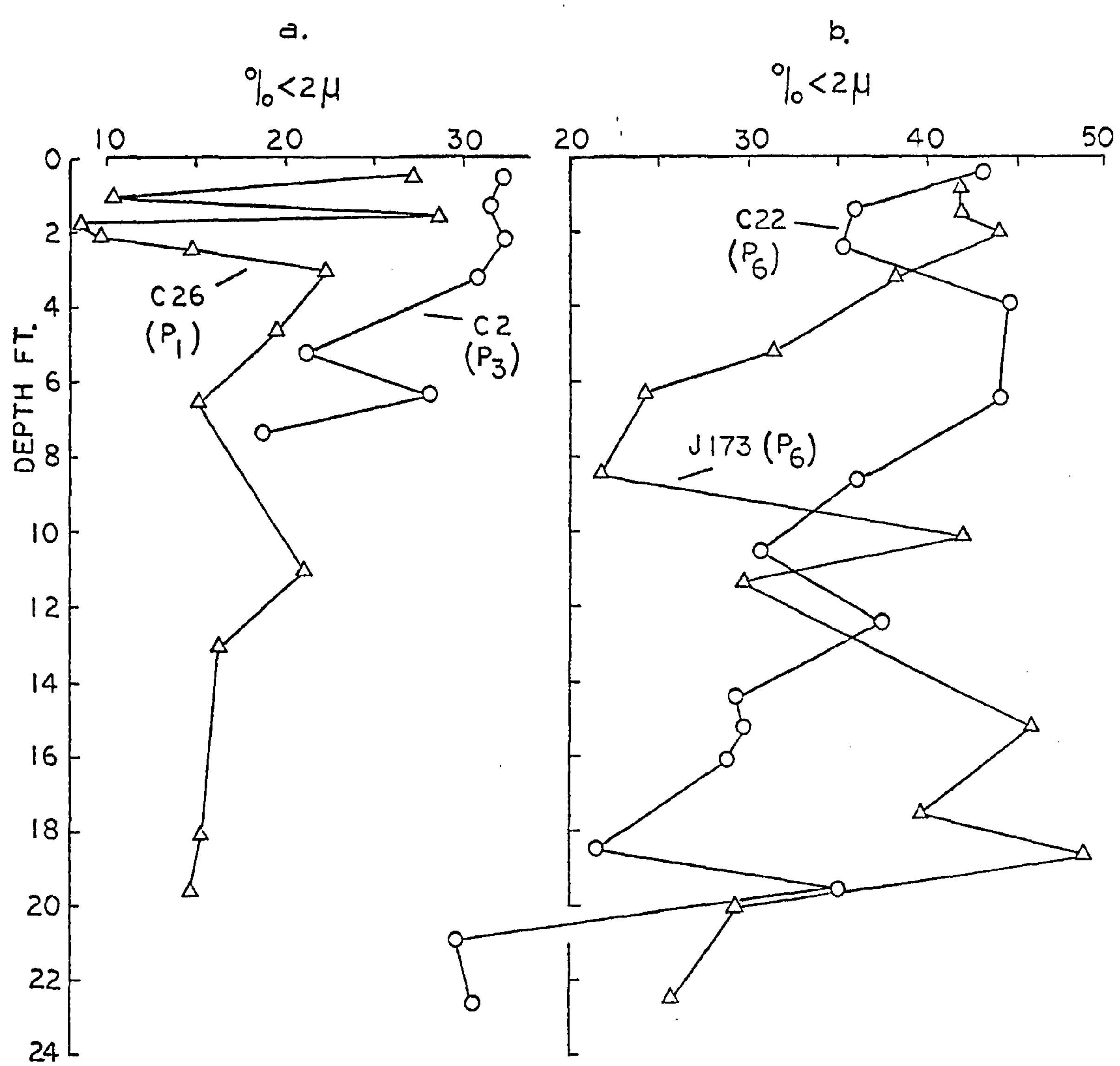
Figure 33. Bulk density profiles for soils on the concave slope and in the depression of the JSS traverse in the Jewell bog watershed


BULK DENSITY (GM/CC)
0.75
1.00
1.25
1.50
0
10
20
30
40
50
60
70
DEPTH IN.
JSSE
Webster-FT
JSSH
Glencoe
JSSJ
Glencoe
JSSF
Webster-FT

The particle size data for these profile groups are shown in Figure 34. Soils of the P_1 group show a characteristic surficial stratification in the upper horizons. Some evidence of stratification can also be seen in the other groups, but the feature of the P_1 group is the sandiness of some of the strata. The center cores C22 and J173 at Colo and Jewell respectively show a tendency to become more clayey nearer the surface, especially in the UM zone of the profile. A second clay maximum also occurs in the position of the LM zone at Jewell, indicating an association there between clay content and organic matter. This is consistent with the other data described earlier which related landscape stability on hillsides with periods of increased organic matter accumulation in adjacent bogs. Under these conditions, relatively finer sediments would be transported from hillsides to the bog center.

The organic carbon data of Figure 35 show that profiles of group P_1, with stratified surface horizons are less organic than profiles of group P_3. The profiles of both groups usually fall within the organic soil category (= histosols) of the U.S. Soil Survey Staff (1960, p. 62). Organic carbon data for a number of bog center profiles in the Colo and Jewell bogs, and from the McCulloch, Woden and Hebron bogs are shown in Figure 36. All these profiles show the characteristic double muck zone. With the exception of the Hebron profile H1, all surface organic zones have a muck horizon (O_2 horizon) at the immediate surface which is somewhat less

Figure 34. Percent <2μ clay profiles for bog soils of mapping units P_1, P_3, and P_6



a.
% < 2 μ
b.
% < 2 μ
DEPTH FT.
C26 (P1)
C2 (P3)
C22 (P6)
J173 (P6)

Figure 35. Percent organic carbon profiles for bog soils of mapping units P_1 and P_3

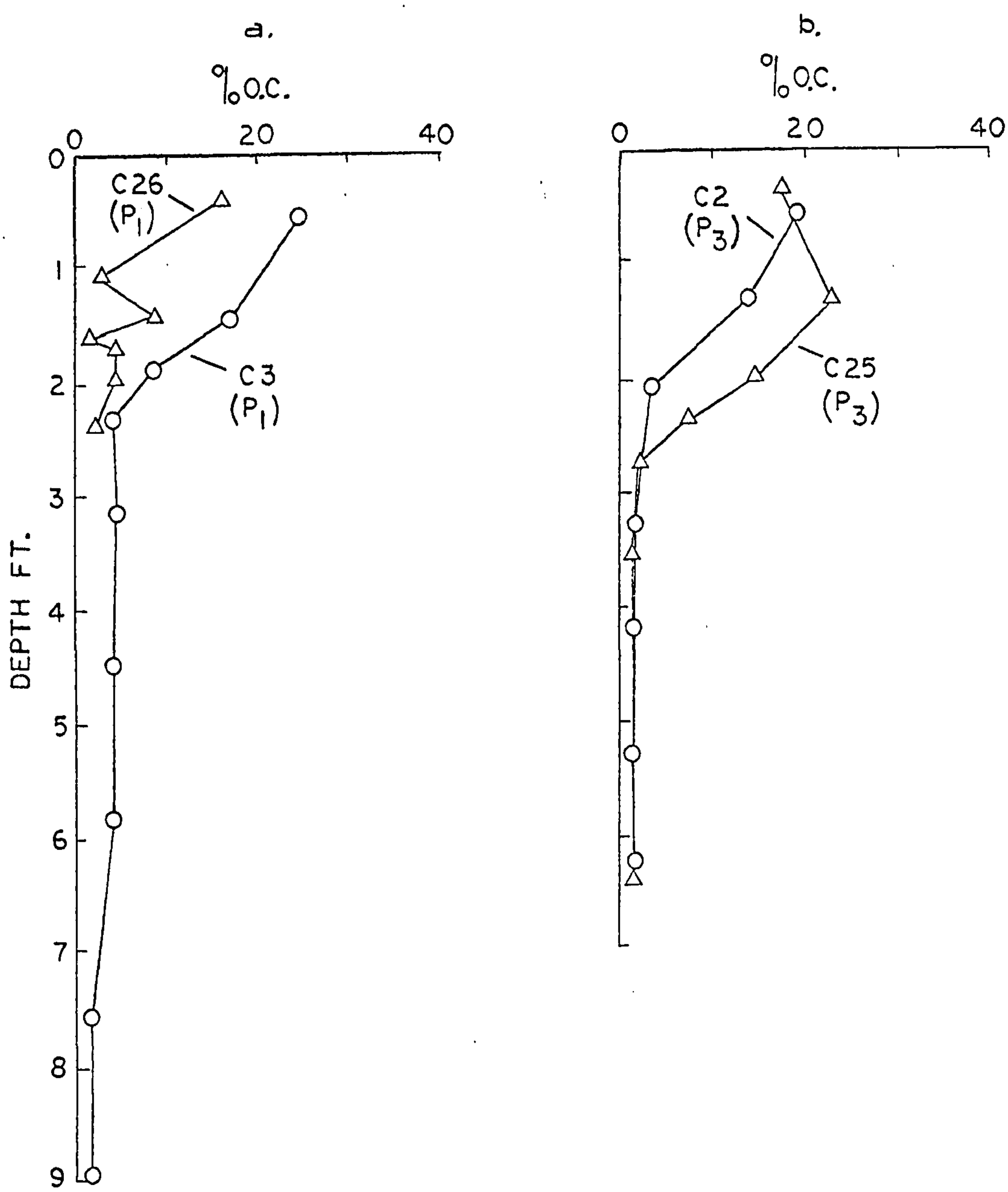
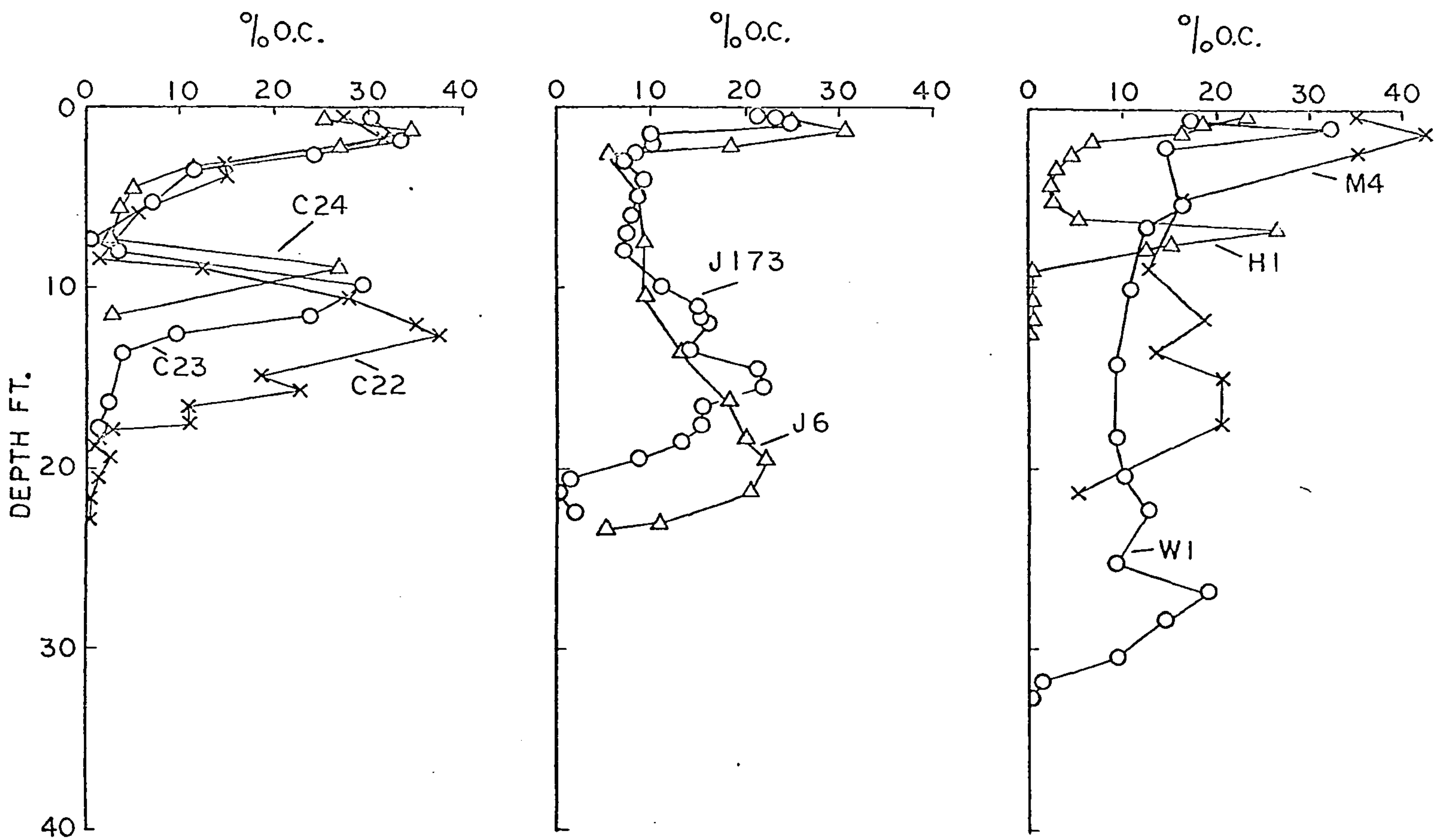

a.
% O.C.
0
20
40
DEPTH FT.
1
2
3
4
5
6
7
8
9
C26
(P_1)
C3
(P_1)
b.
% O.C.
0
20
40
C2
(P_3)
C25
(P_3)

Figure 36. Percent organic carbon for bog center profiles at Colo (C22, C23, C24), Jewell (J6, J173), McCulloch (M4), Woden (W1), and Hebron (H1)



%o.C.
%o.C.
%o.C.
DEPTH FT.
C24
C23
C22
J173
J6
M4
H1
W1

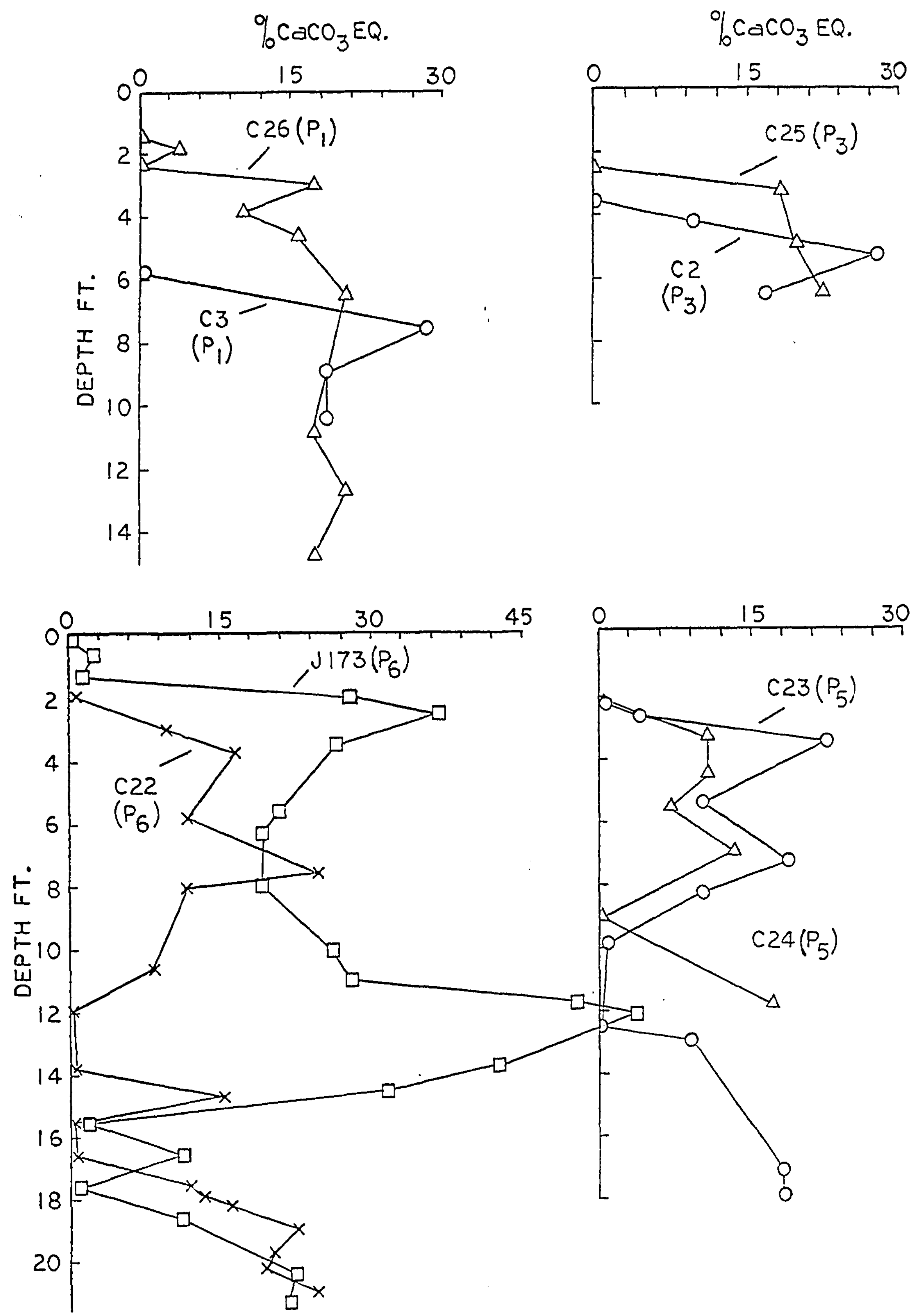
organic than the peaty horizon (O_1 horizon) immediately beneath. All of the profiles would be classified as histosols on the basis of depth and amount of organic carbon, with the exception of the Hebron profile which is somewhat shallower than the others. The lower muck zones of Colo, Jewell and McCulloch center profiles also qualify as histosols both from the amount and depth of organic materials.

The carbonate profiles of Figure 37 confirm the field observations that most of the bog center profiles are non-calcareous in the surface horizons. Most of these profiles have carbonate maxima above the LM zone, but at Jewell (J173) the maximum corresponds to the horizon of abundant shells in the upper part of the LM zone. The pH values of surface muck horizons near neutrality indicates an eutrophic environment for organic matter accumulation.

Density profiles in Figure 38a for center cores at Colo, Jewell and McCulloch show double maxima which correspond to the mineral US and LS zones, whereas the density minima occur at or near the horizons of maximum organic matter content. The relationship between density and organic carbon is plotted for these profiles in Figure 38b.

The density values obtained here for organic and sedimentary bog strata range from 0.13-0.95 gm./cc. and are comparable with other values for peat in Iowa (Richlen, 1957) and the values for a raised bog published by Mattson and Koutler-Andersson (1954, p. 331) of range 0.10-0.82 gm./cc.

Figure 37. Percent calcium carbonate equivalent profiles of bog mapping units P_1, P_3, P_5, and P_6

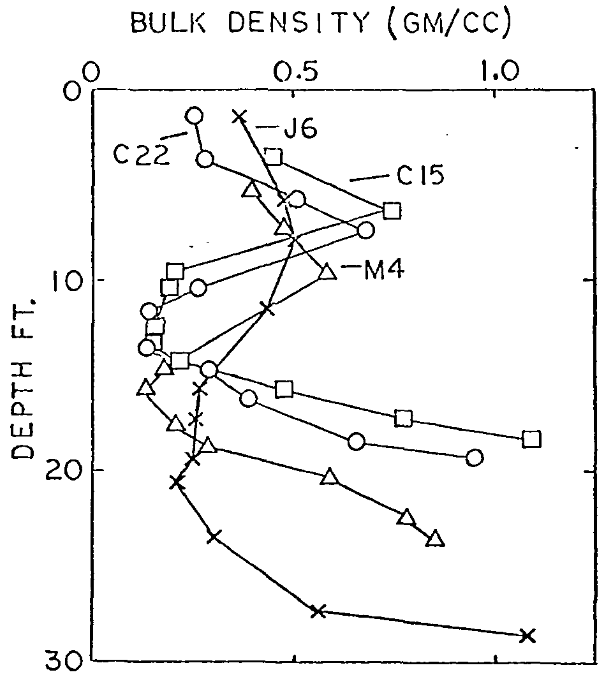


% $CaCO_3$ EQ.
% $CaCO_3$ EQ.
0
15
30
0
15
30
45
DEPTH FT.
DEPTH FT.
0
2
4
6
8
10
12
14
16
18
20
C26 (P_1)
C3 (P_1)
C25 (P_3)
C2 (P_3)
J173 (P_6)
C22 (P_6)
C23 (P_5)
C24 (P_5)

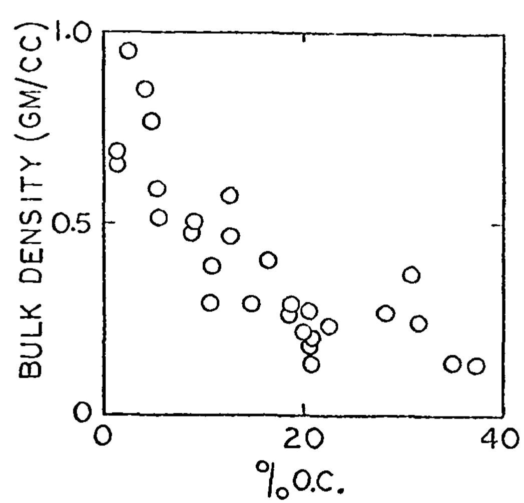
Figure 38a. Bulk density of bog center profiles at Colo (C15, C22), Jewell (J6), and McCulloch (M4)

Figure 38b. Plot of bulk density against percent organic carbon for bog strata at Colo (C22), Jewell (J6), and McCulloch (M4)

a.


BULK DENSITY (GM/CC)
0
0.5
1.0
DEPTH FT.
0
10
20
30
C22
J6
C15
M4

b.


BULK DENSITY (GM/CC)
1.0
0.5
0
0
20
40
%O.C.

C. Discussion

The soil profile data presented above are drawn from a wide range of situations occurring in the Clarion-Webster toposequence. Soils of the gently sloping convex parts of the landscape such as the Webster soil C79 and Clarion-FT J174, show most clay in the B horizon, highest exchange capacity (30-40 m.e. per 100 gm.) through the profile, deepest leaching as indicated by depth to carbonates, and highest surface organic matter of hillside soils. These profile properties are consistent with positions in the landscape where soil development has suffered least disturbance from erosion and deposition during post-Cary time. The Clarion soils of rounded summits and the Storden soils of the steepest convex parts of the landscape, represent successive steps towards maximum erosion of the Cary till surface. Soils of the Storden series are calcareous at or near the surface, and have an A/C profile with only a thin A horizon; these soils represent the extreme effects of erosion on soil profile development on Cary till, and provide the greatest contrast with soils developed on gently sloping summits. Clarion soils on rounded summits have developed under erosional conditions which have been sufficiently slow to permit A/B/C horizon development with accumulation of organic matter and leaching of carbonates, but less exchange capacity (20-30 m.e. per 100 gm.) than in gently convex summit profiles.

Nicollet, Webster, and Storden soils represent successive stages downslope into concave slopes below the point of inflection in the landscape marked by Storden soils. Organic matter is increased in amount and to depth, and a structural and color B horizon is evident. The Harpster soils have a characteristically high carbonate content at the surface and they, with some of the Webster soils in toeslope positions, represent soils in which erosional materials have accumulated. Thus the Webster soils of gently convex summits may need to be separated from those of toeslope situations, since they occur in different erosional situations and are of differing degrees of development.

The chemical and physical data presented here show that depressional soils such as Glencoe, and bog soils such as P_3 and P_6 have high percent silt and clay, and high organic matter which are characteristic of nearly flat, occluded drainage environments. These soils are the depositional counterparts of eroded soils such as the Storden series, and show correspondingly little profile development, apart from organic matter accumulation. The high percent clay of the Glencoe soils is matched by the high exchange capacity of 40-60 m.e. per 100 gm. in the profile, while the strong organic matter influence in the upper horizons of the bog soils is reflected in exchange capacities between 90-100 m.e. per 100 gm.

One of the major problems arising from investigations in the bog watersheds relates to the strong geological trends in soil parent materials which mask the trends of soil profile development. With large sedimentary variations in Cary and post-Cary deposits, it may not be possible to estimate the extent of weathering and clay movement due to pedological processes in many parts of the landscape. Some situations in the watersheds, however, offer better opportunities for examining soil profile trends in the till. Topographic positions such as gently convex surfaces on the watershed perimeter, approaching stable landform, do occur in minor areas at both Colo and Jewell. The sites of profiles C79, J174, and to a less extent J80, are examples of this kind of surface.

Geometric mean and percent $<2\mu$ clay profiles of three summit profiles at Colo are plotted in Figure 39a, b. Profile C79 shows a relatively steady geometric mean throughout, whereas profiles C40 and C60 show an abrupt change to finer sediment through the solum. Hence the occurrence of a clay maximum in profiles C40 and C60 may be related to a fine phase of the Cary rather than being entirely due to pedogenetic processes. Profile C79, by contrast has a clay increase in the solum which appears to be related to pedogenetic processes. A similar plot for profiles in summit positions at Jewell in Figure 40a, b shows that the pronounced clay maximum in profile J174 is also associated with a fine depositional phase of the till, whereas the till at sites J42, J76, and J80 has consistent mechanical properties through the solum, permitting a pedogenetic interpretation of the clay maximum in these profiles.

Figure 39a. Geometric mean data for summit profiles C40, C60 (Clarion) and C79 (Webster) at Colo

Figure 39b. Percent <2μ clay data for the three summit profiles at Colo

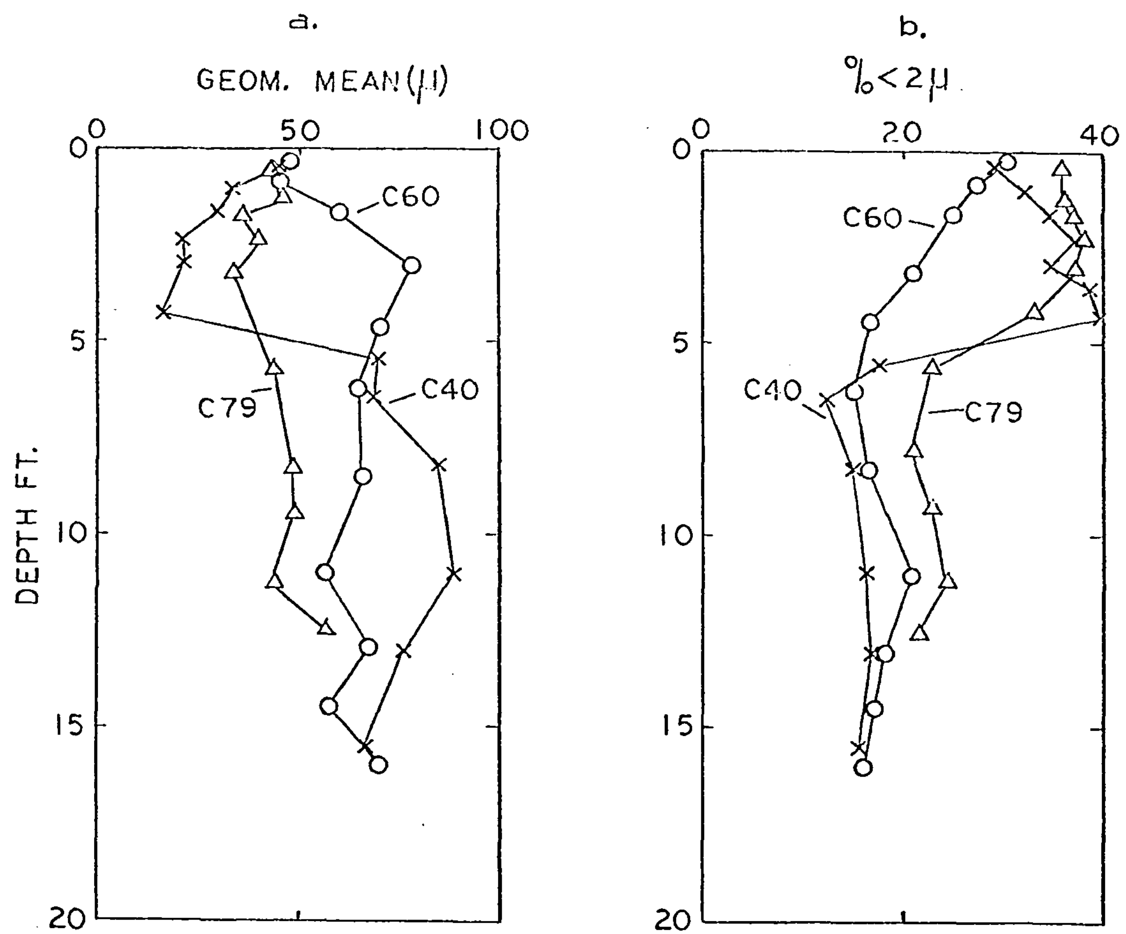
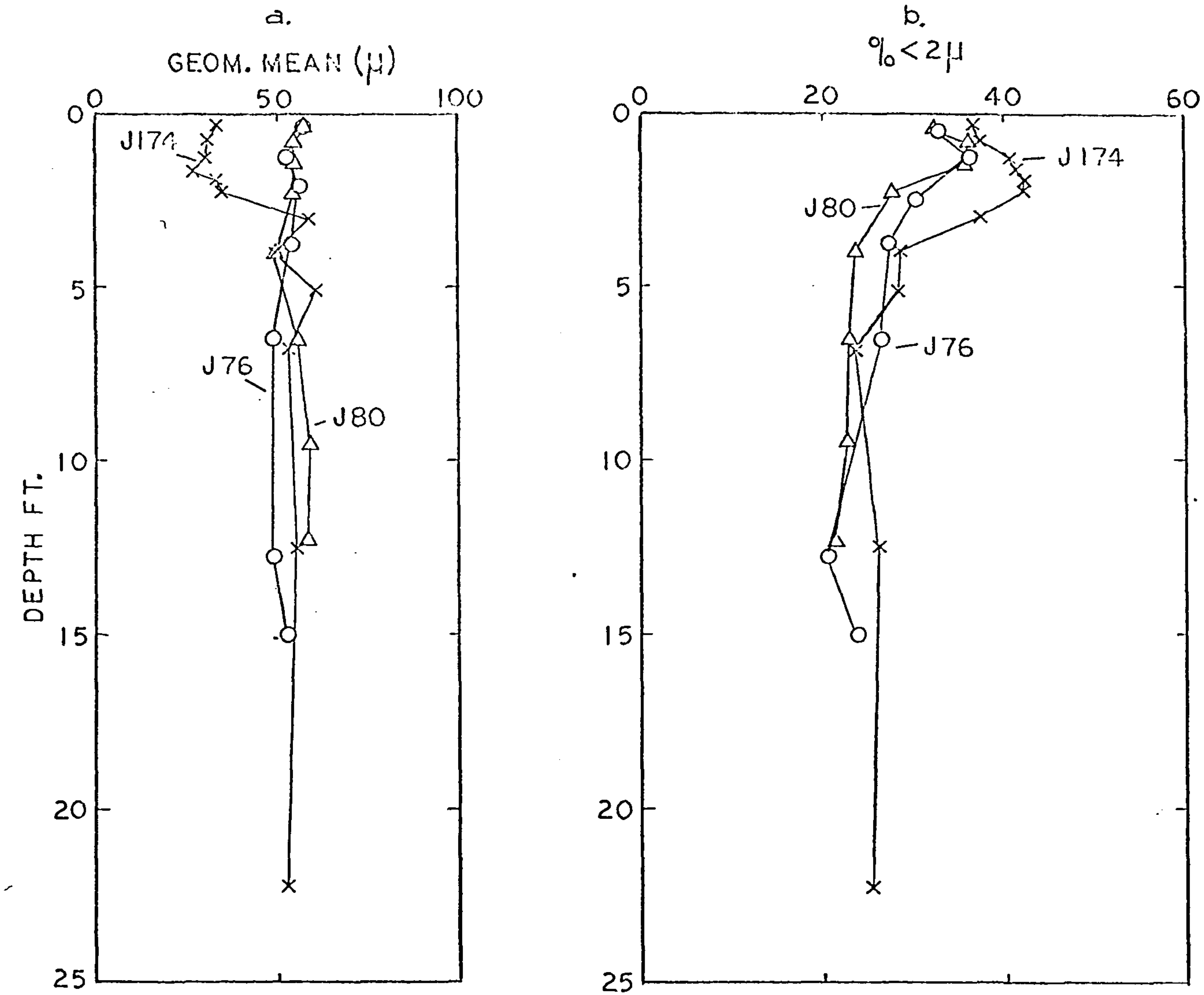

a.
GEOM. MEAN (μ)
0
50
100
0
5
10
15
20
DEPTH FT.
C60
C40
C79
b.
% < 2μ
0
20
40
0
5
10
15
20
C60
C40
C79

Figure 40a. Geometric mean data for summit profiles J76 (Clarion-FT), J80 (Nicollet-FT), and J174 (Clarion-FT) at Jewell

Figure 40b. Percent <2μ clay data for the three summit profiles at Jewell


a.
GEOM. MEAN (μ)
0
50
100
J174
J76
J80
DEPTH FT.
0
5
10
15
20
25
b.
% < 2μ
0
20
40
60
J174
J80
J76
0
5
10
15
20
25

The occurrence of fine sediment of Cary age, capping the Cary till was reported for an adjacent area in Hamilton County, Iowa by Hidlebaugh (1959). A similar capping was also described for soils of the Poinsett-Sinai association in South Dakota by Wilding and Westin (1961, p. 381). In both cases the particle size variation in the Cary till was attributed to distribution of fine materials due to glacial ice wastage.

It was shown earlier that approximately half of the Colo and Jewell watersheds are covered by significant amounts of hillside surficial and bog sediments. If this sediment has come predominantly from the upper convex slopes of sedimentary zone A, previously described, the amount of sediment removed from these parts of the watershed must have been considerable. The magnitude of surficial erosion can be estimated by correcting the thickness of bog strata by a factor of the ratio of the bulk density of the bog strata to the bulk density of till-derived soil material, for example A horizon material of bulk density 1.2 gm./cc. The bog mineral sediment density is taken as the average of all recorded values, namely, 0.6 gm./cc. and the average bulk density of muck zones is 0.2 gm./cc. If it is assumed that all the sediment was derived from sedimentary zone A, and that no substantial change in density occurred until the surficial sediments were differentiated at the inner margins of sediment zone B, the calculations for equivalent A horizon thickness of all surficial and bog sediments can be made as scheduled in Table 13.

The data of Table 13 are then re-arranged to represent the equivalent depth of each stratum in the bog sequence, as shown in Table 14.

Similar calculations have been made for the Jewell bog watershed and these data are shown in Tables 15 and 16.

The thickness values for A horizon calculated above can be converted to till equivalent thickness by multiplying by a factor of 0.75.

The tabulated data show that there has been a substantial modification of the landscape in post-Cary time, particularly at Jewell, where slopes are steeper. The tabulated data also show that the largest amount of erosion in both areas was during the interval represented by the US zone sediments and that the smallest amounts of erosion are represented by muck zones in the bog. An accurate picture of past erosion patterns is not obtained from these data however. Some parts of the landscape, for example, the modern Storden soil situations, are more susceptible to erosion than some of the gently convex summits, so erosional losses can not have been uniform over the upper slope surfaces. A further problem in reconstructing the past landscape, especially at Jewell, is that the perimeter does not include all adjacent high areas, nor is closure of the bog against inflow from outside sources entirely certain. Thus the high calculated value of sediment removal from hillsides at Jewell, while expected from consideration of the steeper slopes, may need to be modified by taking into account

Table 13. Calculation of thickness of soil A horizon, equivalent to the amount of bog and lower slope sediment at Colo

Sed. unit	Area square miles	Stratum equivalent	Equivalent stratum thickness (ft)	Thickness corr. for density (ft)	Product, area x thickness
B	0.030	US	3.5	3.5	0.105
D_1	0.028	UM	2	0.4	0.011
		US	1.5	0.8	0.022
		LS	4.0	2.0	0.056
D_2	0.003	UM	3	0.6	0.002
		LM	2	0.4	0.001
		US	5	2.5	0.008
		LS	5	2.5	0.008
D_3	0.001	UM	3	0.6	0.001
		LM	5	1.0	0.001
		US	10	5.0	0.005
		LS	7	3.5	0.004
					Sum = 0.224

Average thickness on unit A = 2.8 ft.

Table 14. Equivalent thickness of particular bog strata as A horizon material placed on the area represented by sedimentary unit A, Colo

Stratum	A horizon equivalent (ft.)
UM	0.2
US	1.7
LM	0.03
LS	0.9
Total	2.8

Table 15. Calculation of thickness of soil A horizon equivalent to the amount of bog and lower slope sediment at Jewell

Sed. unit	Area square miles	Stratum equivalent	Equivalent stratum thickness (ft)	Thickness corr. for density (ft)	Product, area x thickness
B	0.098	US	3.5	3.5	0.340
C	0.006	US	1.25	1.25	0.075
		LS	1.25	0.6	0.004
D_1	0.028	UM	1	0.2	0.006
		US	4	2.0	0.056
		LS	1.5	0.8	0.022
D_2	0.041	UM	2	0.4	0.016
		LM	5	1.0	0.041
		US	6	3.0	0.123
		LS	2	1.0	0.041
D_3	0.026	UM	2	0.4	0.010
		LM	6	1.2	0.031
		US	15	7.5	0.195
		LS	2	1.0	0.026
					Sum = 0.986
				Average thickness on unit A = 6.6 ft.	

Table 16. Equivalent thickness of particular bog strata as A horizon material placed on the area represented by sedimentary unit A, Jewell

Stratum	A horizon equivalent (ft.)
UM	0.2
US	5.3
LM	0.5
LS	0.6
Total	6.6

a larger source area of sediments. Nevertheless, the data in both areas give the order of magnitude of erosional processes and indicate the relative significance of different phases of erosion in post-Cary time.

Up to this point, the post-Cary sediments have been discussed in relation to units of sediment or certain soil delineations. The sedimentary properties can be better understood if they are considered as an expression of continuous changes in transit from the watershed perimeter to the bog center. The sedimentary data are plotted in Figures 41, 42, and 43 showing the changes in mean particle size as a function of relative distance from the bog center. The Colo bog data in Figure 41 and 43 are for both the upper and lower bog sediments, plotting the UM sediments with the US zone and the LM sediments with the LS zone and using the location of profile C21 (Figure 4) as absolute center. The Jewell data of Figure 42 are incomplete and represent data of profiles along transect F, Figure 11, using the location of bog profile J173 as center.

Just below the point of inflection in the landscape from convex to concave, surficial sediments become differentiated into relatively coarse and fine which is reflected in the broadening of the geometric mean range at a given site. As the bog center is approached, sediments become finer and better sorted, within narrower limits of these particle-size parameters.

The differences existing between upper and lower strata

Figure 41. Plot of the changes in particle size mean with distance of transport across the Colo watershed from perimeter to bog center for upper and lower stratigraphic zones

COLO BOG SEDIMENTS

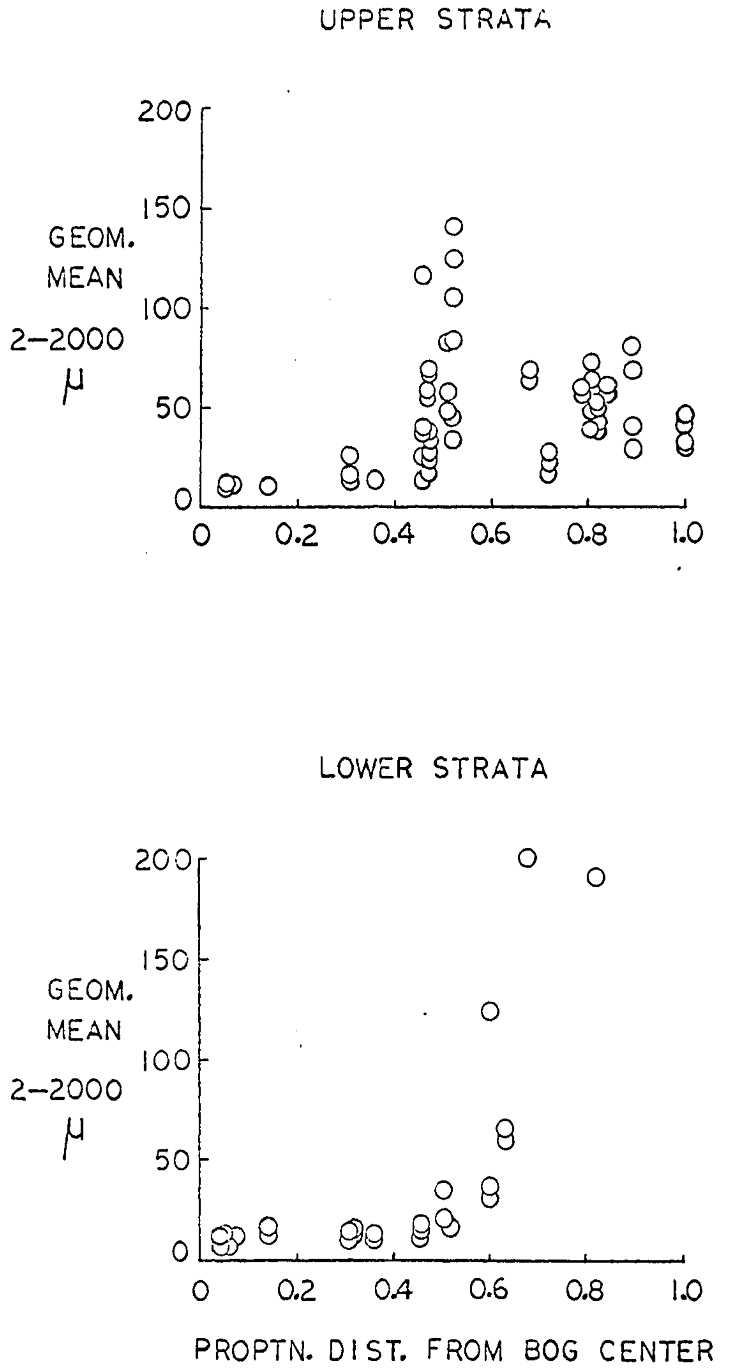


Figure 42. Plot of the changes in particle size mean and standard deviation with distance of transport across the Jewell bog watershed from perimeter to bog center, for the upper stratigraphic zone only

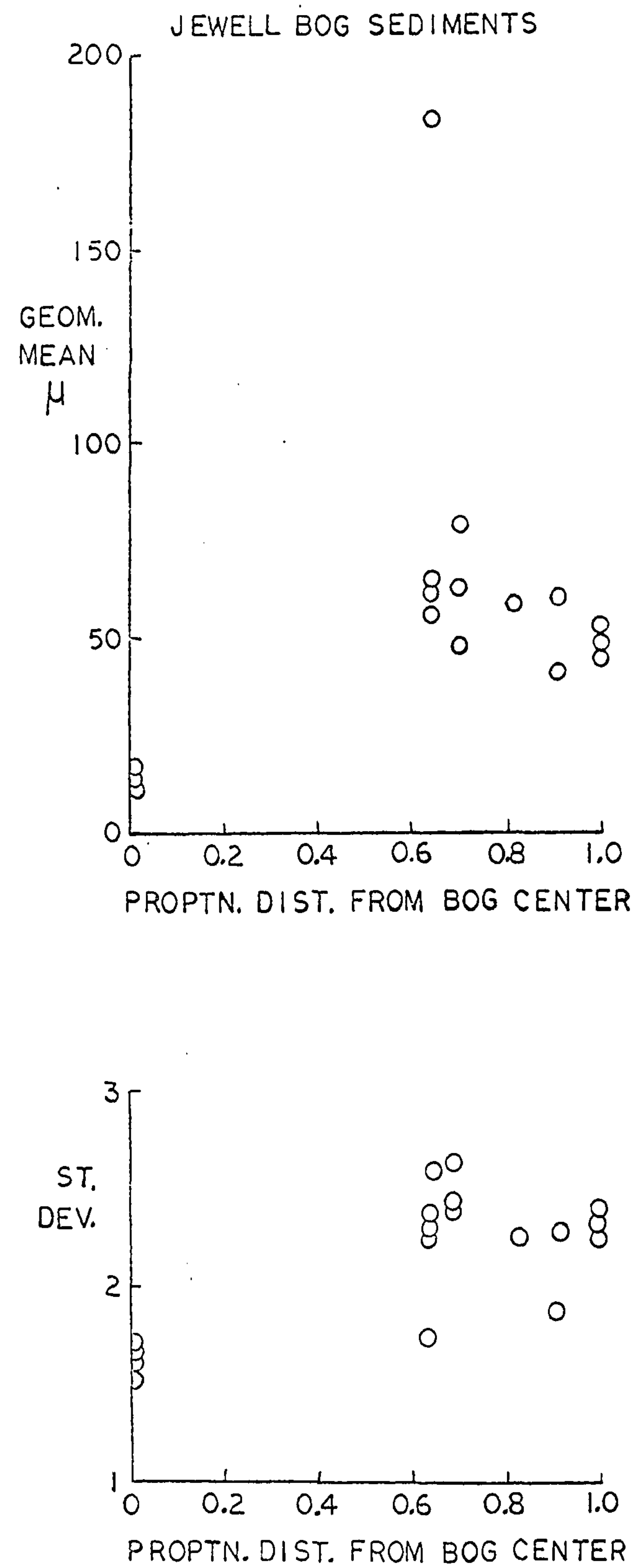
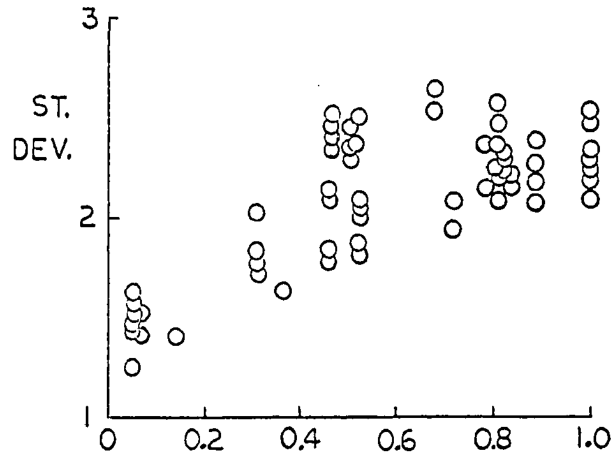

JEWELL BOG SEDIMENTS
200
150
GEOM.
MEAN
μ
100
50
0
0
0.2
0.4
0.6
0.8
1.0
PROPTN. DIST. FROM BOG CENTER
3
ST.
DEV.
2
1
0
0.2
0.4
0.6
0.8
1.0
PROPTN. DIST. FROM BOG CENTER

Figure 43. Plot of changes in standard deviation of sediment with distance of transport across the Colo bog watershed from perimeter to bog center for upper and lower stratigraphic zones

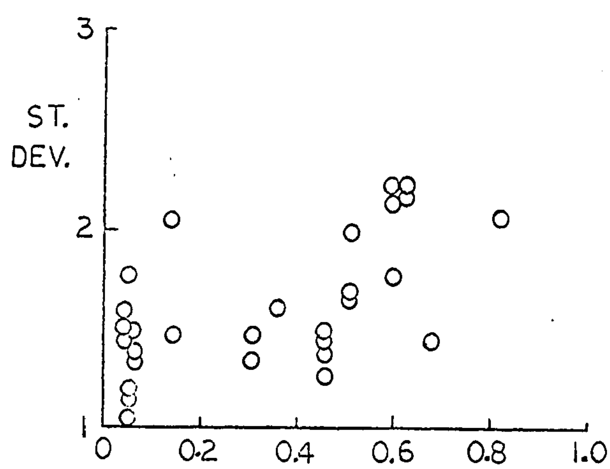
COLO BOG SEDIMENTS

UPPER STRATA



PROPTN. DIST. FROM BOG CENTER

LOWER STRATA



PROPTN. DIST. FROM BOG CENTER

in the Colo bog relate to the different position in which the surficial sediments were differentiated during the earlier erosional episode. The lower strata were differentiated farther away from the bog center and slightly higher in the watershed. Evidence of sections across the eastern side of the Colo bog indicated sedimentary features relating to a lake phase during deposition of the lower strata. In this respect the difference between plots of standard deviation against distance for upper and lower strata at Colo (Figure 43) may be indicative of processes operating at the time. The upper sediments show progressive sorting across the bog to its center, suggesting shallow or intermittent ponding which would cause continuous refinement of the sediment in transit. The more scattered data for the lower sediments suggests that once the fine fractions were differentiated from the coarse at the edge of the bog, they were free to be deposited anywhere across the base of the bog. This is a condition more likely to occur in a more deeply ponded environment, such as a lake.

The sequence of surficial materials above the stone line, from the relatively homogeneous sediment of the upper hillslopes, through a transition zone of interfingering sediments on lower hillslopes, to bog sediment, establishes a local origin and differentiation of materials in the sedimentary system. In this case the Cary sediments were the source of materials differentiated across the hillslopes and in the bog environment.

VIII. VEGETATIONAL AND DATING ANALYSES

A. Pollen Analyses

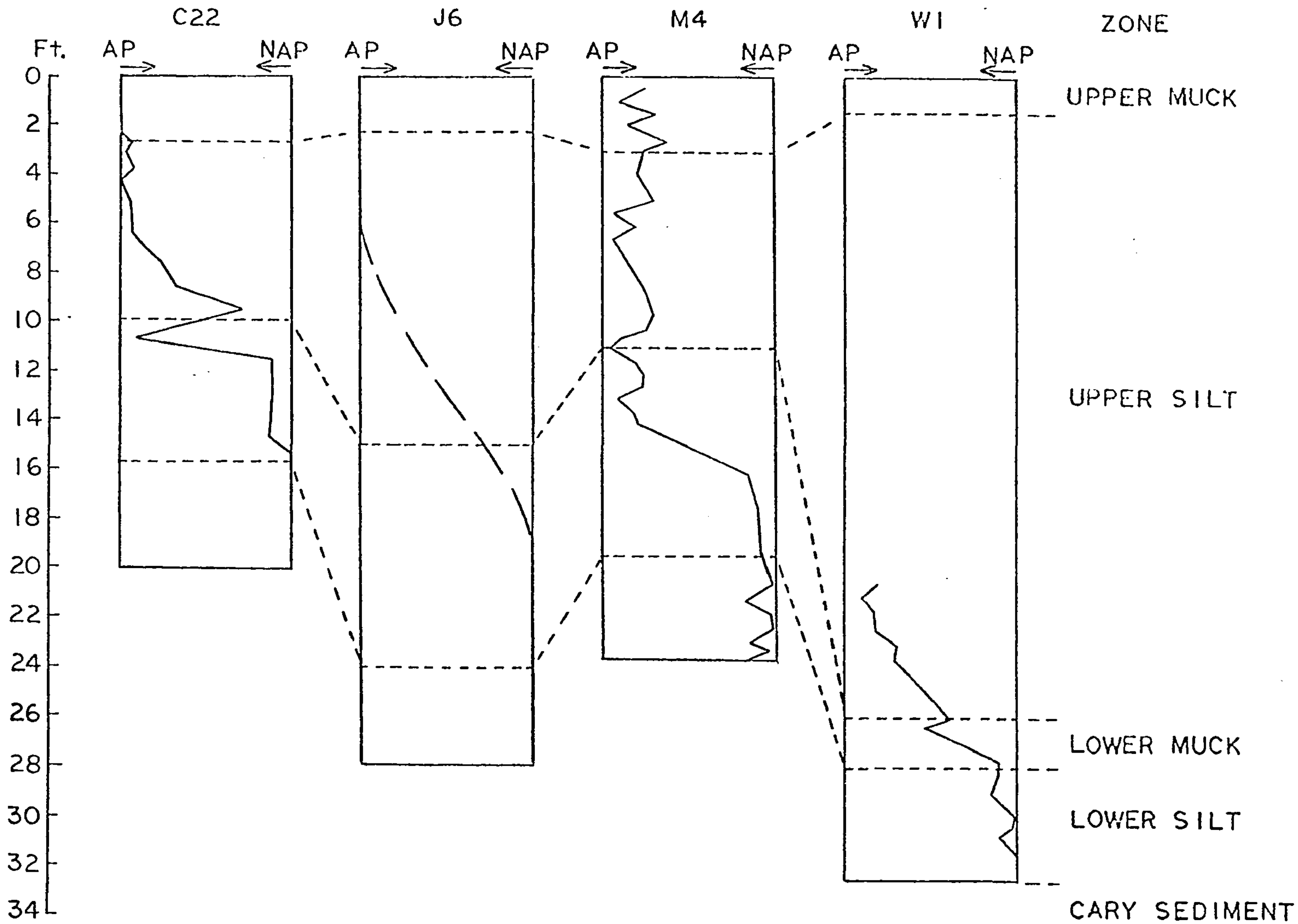
During the course of the project from which this thesis was developed, co-operation of scientific personnel in the botanical field was sought to carry out pollen analysis. The procedure followed was that the author studied the stratigraphy of certain bog areas, and from these data, the location of a suitable bog site for detailed pollen analysis was chosen. It was also the author's responsibility to describe the location and strata of the sampled core and to provide routine analytical data (pH, carbon, carbonates, mechanical analysis) for sediments of the pollen core. All the pollen slides for the Colo (C22), Jewell (J6, J173) and McCulloch (M4) cores were prepared in the soil survey laboratories of the Department of Agronomy, Iowa State University, under supervision of the author and Dr. Grace S. Brush, Iowa City. The method of preparation of samples for pollen separation is given in Appendix B. The pollen analyses of the mounted residues for these profiles were carried out by Dr. Grace S. Brush, Department of Botany, State University of Iowa, Iowa City and presently of Department of Geology, Princeton University, Princeton, New Jersey. A preliminary note of pollen and strata in the Colo bog was published by Walker and Brush (1963, p. 257). The profiles at Woden (W1) and Hebron (H1) were located by the author, and the routine field and laboratory characterization was also done by the author. The sampling of the cores, preparation of the samples for pollen analysis and the pollen analyses were carried out by Dr. L. H. Durkee, Department of Biology, Grinnell College, Grinnell, Iowa.

At the time of writing, detailed data have been made available by Dr. Brush and Dr. Durkee for the Colo, McCulloch and the lower part of the Woden profile. Some preliminary notes on the Jewell core J6 are presented in Table 31. All of the available pollen data are presented in Appendix D.

A summary statement of pollen profiles in terms arboreal pollen (AP) versus nonarboreal pollen (NAP) at Colo (C22), Jewell (J6), McCulloch (M4) and Woden (W1) are given in Figure 44. The data for the Jewell core are not quantitative. A consistent trend from strongly coniferous pollens (Pinaceae) to deciduous species such as birch (Betula), oak (Quercus), and elm (Ulmus) occurs from the base of the profiles to the middle zones. These data are consistent with previous pollen data published in Iowa by Lane (1931) and Walker and Brush (1963). Towards the top of the profile, pollens of the grasses (Gramineae) and herbaceous genera such as Ambrosia and Artemesia become dominant and reach a maximum just below the UM stratigraphic zone. A slight diminution of Gramineae and Chenopodiaceae herbaceous pollens in the near-surface horizons at Colo and McCulloch (Figures 60, 61 in Appendix D) parallels a trend observed in several bogs in Minnesota reported by

Figure 44. Arboreal pollen (AP) and non-arboreal pollen (NAP) profiles for Colo, Jewell, McCulloch, and Woden bogs

The profile at Jewell is sketched from data in Table 31


C22
J6
M4
W1
ZONE
Ft.
AP
NAP
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
UPPER MUCK
UPPER SILT
LOWER MUCK
LOWER SILT
CARY SEDIMENT

Wright et al. (1963, p. 1379). The occurrence of pine (Pinus) pollen throughout the column may not have particular significance, since Davis (1963, p. 899) has shown that the pollens of this genus are commonly overrepresented in pollen separations. The data in Figure 44 also show a notable coincidence between trends of the organic carbon profile and changes in the pollen. The organic carbon maximum of the LM zone is closely associated with the AP maximum and the NAP maximum is associated with the US and UM stratigraphic zones. The UM zone seems to be related to the late amelioration of the climate as indicated by the decrease of herbaceous pollens at the top of the profile.

The broad inference to be drawn from the pollen data is that a regional vegetation change occurred on the Des Moines lobe from forest dominance to grass and other herbs at a time of increased hillslope erosion and mineral deposition of US zone sediments in the bog centers. The coincidence of the major change in pollen and the change in erosional features of the bog watersheds substantiates the view that the erosional stability of the hillslopes was related to changes in the vegetation which were controlled by the environment. A significant depletion in the vegetative cover would be expected with a major vegetational change from forest to grassland, and would result in hillslope instability. Such increased erosion would then continue until the invading vegetation stabilized the landscape under the new environment, or until a significant amelioration of the climate occurred. There is evidence in the pollen data of Figures 44, 60, and 61 that the latter took place.

B. Other Vegetative Evidence

Supplementary evidence to pollen data was sought to verify the trends described above. During the course of field operations, discrete pieces of wood were sampled from cores in a number of bog sites and these were identified at genus level by Dr. D. W. Bensend, Forestry Department, Iowa State University. Details of the identification of wood samples and their position in the bog profiles are shown in Table 17.

The wood samples were collected from a range of stratigraphic positions ranging from the top of the LM zone to the top of the Cary till. The size and abundance of samples leaves little doubt that spruce actually grew in the watersheds of this study during postglacial time. It is possible that occasional small pieces could have been introduced to the area by animals, but not in the quantities found in parts of the Jewell bog particularly. The relative location of several of the Jewell sites is shown in Figure 45 where samples were collected in the main bog and a small enclosed depression to the east. The occurrence of abundant spruce wood at the top of the LM zone proves the existence of spruce well into post-Cary time.

Table 17. Location and identification of wood samples from bog cores

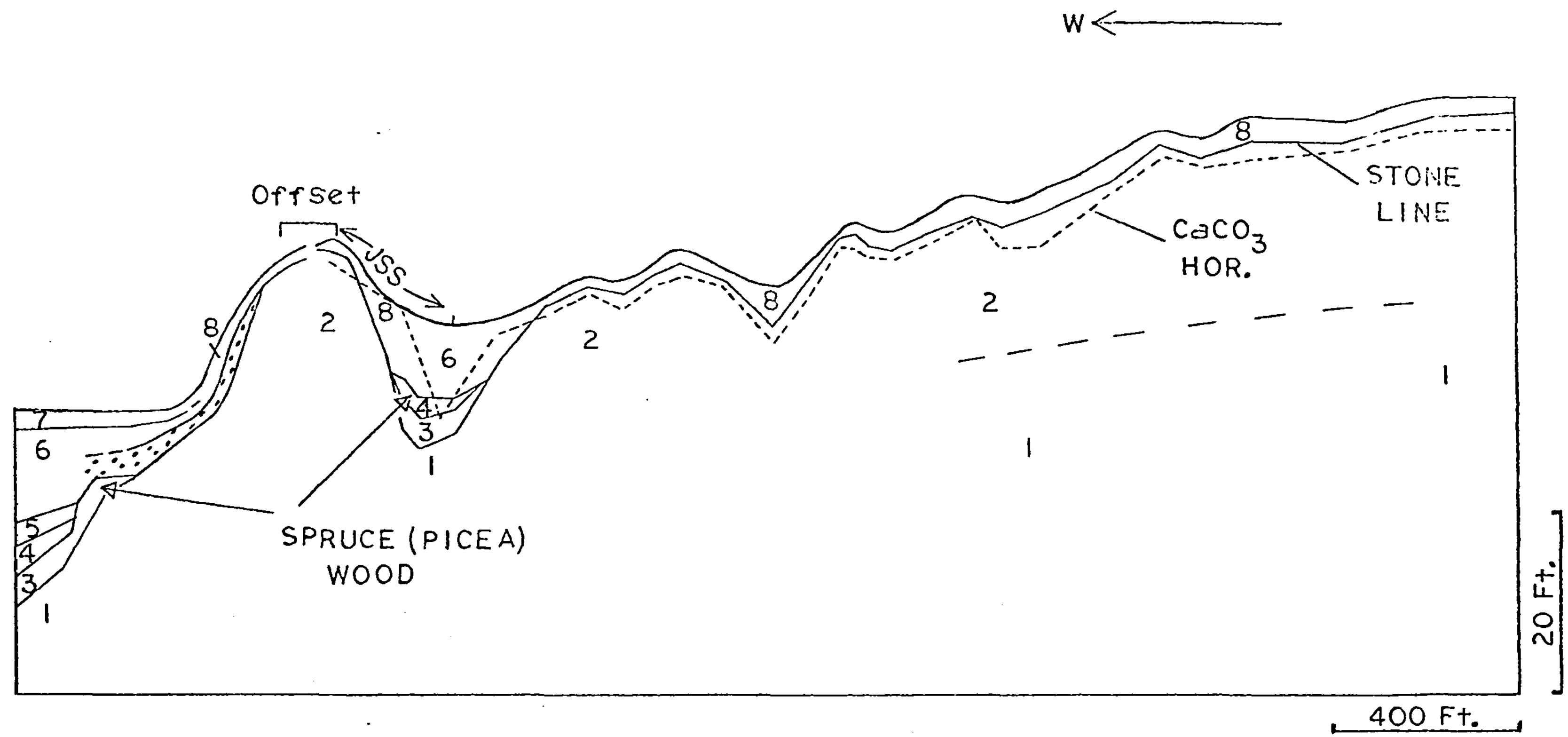
Core	Depth	Strata	Sample	Genus
C22	135 in.	Upper LM	3/4 in. diam. single piece	Spruce (*Picea*)
J6	28 ft. 6 in.	Base LS	2x3/4 in. pieces from many	Spruce (*Picea*)
Survey core J8 (150 ft. W of J6)	22 ft. 6 in.	Base LS	2 in. piece from many	Spruce (*Picea*)
Survey core J121 (Fig. 45)	126 in.	Base LS	2 in. piece from many	Spruce (*Picea*)
Survey core J198	130 in.	Base LS	1 in. piece from many	Spruce (*Picea*)
Survey core J199	102 in.	Upper LM	1 in. piece from many	Spruce (*Picea*)
Woden (W1)	30 ft. 6 in.	LS zone	2 in. piece from many	Spruce (*Picea*), or larch (*Larix*)

C. Radiocarbon Dates

Samples for radiocarbon dating were taken from cores at Colo (C22), Jewell (J6, J173), McCulloch (M4), and Woden (W1). Dating analysis was carried out by Isotopes, Incorporated, Westwood, New Jersey, and each sample was given a project number and Isotopes, Incorporated sample number. The dates

Figure 45. Jewell watershed section, showing the location of two spruce wood samples and the stratigraphy of the JSS transect

JEWELL BOG
SECTION



and relevant information about each sample are given in Table 18. After the first set of dates was obtained for profile J6 at Jewell, a second profile was located in the bog center to check the unexpectedly close dates for samples I1017 and I1018. Both sets of dates are shown in the table.

Table 18. Radiocarbon dates and sample data for Colo, Jewell, McCulloch, and Woden bogs

Profile sample depth (ins.)	Horizon[a]	Project number	Isotopes number	Date B.P.
Colo C22				
34- 36	Transition US-UM	C1	I1013	3,100±130
132-134	Upper LM	C2	I1014	8,320±275
186-189	Base LM	C3	I1015	13,775±300
Jewell J6				
24- 26	Base UM	J1	I1016	2,365±500
210-212	Upper LM	J2	I1017	10,226±400
280-282	Upper LS	J3	I1018	10,670±400
336-342	Base LS (wood)	J4	I1019	11,635±400
Jewell J173				
176-180	Upper LM	24-64	I1417	9,570±180
236-240	Upper LS	25-64	I1418	10,640±270
McCulloch M4				
36- 38	Transition US-UM	19-64	I1412	3,170±190
135-137	Upper LM	20-64	I1413	8,210±260
232-234	Base LM	21-64	I1414	14,500±340
Woden W1				
266-269	Lower US	22-64	I1415	7,050±210
379-384	LS zone	23-64	I1416	11,570±330

[a]Materials are sediment or muck unless otherwise specified.

The sets of data for Colo and McCulloch are in agreement and the basal dates of 13,775 and 14,500 fall within the range of maximum Cary age published by Ruhe and Scholtes (1959, p. 592). These dates probably relate to the Cary glaciation rather than the early post-Cary. The dates for the upper muck zone in these bogs, 8,320 at Colo and 8,210 at McCulloch, represent the time of waning forest influence and the beginning of the strong erosional episode which formed the US sediments. Both of these dates are in excellent agreement with the dates 8,170 and 8,110 for a comparable stratigraphic position at McCulloch, published by Ruhe et al. (1957, p. 687). The dates for the transition from US to UM zones for Colo and McCulloch at 3,100 and 3,170 years B.P. are also in agreement, and these dates represent the beginning of the relatively stable episode on adjacent hillsides.

Several significant discrepancies occur within the set of dates in Table 18. The base date for a wood sample at Jewell of 11,635 years and for basal silt at Woden of 11,570 years are in accord with dates for the beginning of the post-Cary interval (Ruhe and Scholtes, 1959, p. 592) but differ from the Colo and McCulloch dates at about 14,000 years. Such discrepancies could have arisen through contamination.

Contamination of basal bog sediments with older material could occur during the late stages of ice melt if the glacier contained significant amounts of organic materials preserved during ice advance. These materials would settle as an organic-rich veneer, older than post-Cary materials, at the base of the bog. Another explanation may be developed from the suggestion of Wright and Rubin (1956, p. 626) that in some areas, large blocks of glacial ice remained in the deeper depressions, well into the post-Cary. Settlement of sediments and organic debris would thus be prevented until a later time. It is difficult to explain the discrepancy in basal dates on this basis, however, since both the southern pair of bogs, Colo and Jewell, and the northern pair, McCulloch and Woden have offset dates. If the ice block effect were significant in affecting basal dates, it would have been expected to give a younger set of dates in the north, since the ice would have melted less rapidly there.

Since the problem has not been resolved, a date of 13,000 years B.P. is accepted for the end of the Cary. This is consistent with the dates for the Algona outwash and the framework of dates for Iowa published by Ruhe and Scholtes (1959, p. 592).

The anomalous pair of dates for samples I1017 and I1018 at Jewell, 70 inches apart vertically in the stratigraphic column, may be due to sloughing and re-deposition from the relatively steep slope of the bog floor in that location (Figure 9). The site J173 has a smoother bog floor and was used for both radiocarbon and pollen work. The dates for the upper LS zone in J6 and J173 of 10,670 B.P. and 10,640 B.P. agree closely, and the new date in J173 for the upper LM zone of 9,570 B.P.

is more reasonable for the stratigraphic position of such a sample. The sample I1415 at Woden was taken 21 inches above the first appearance of stratified muck, in the position of a rapid change in pollens from oak to grass. If a date is interpolated between the base date of 11,570 years and sample I1415 at 7,050 years, a date of 7,900 B.P. is obtained for the top of the stratified muck zone which agrees closely with dates of 8,200 and 8,300 for the top of the UM zone at Colo and McCulloch. The older dates for the lower UM zone or upper US zone at Jewell may relate to the greater intensity of erosion in that watershed, especially the magnitude of erosion involved in the US sediments. The higher susceptibility of the Jewell slopes to erosion would result in an earlier de-stabilization following the forest phase, and a later re-stabilization in relation to the UM zone. This explanation is in accord with the younger date at the base of the UM zone at Jewell and dates in similar stratigraphic positions at Colo and McCulloch.

D. The Problem of Contamination

Establishment of a dated framework for post-Cary events involved the use of organic sediments and mucks in which the risk of contamination is greater than for wood samples. This contamination may occur through penetration of modern plant roots or by translocation of more soluble humified materials, broadly classified as humic acids (Olson and Broecker, 1958, p. 596).

The magnitude of contamination effects may be ascertained by integrating the appropriate first order rate equation (Sheehan, 1961, p. 547) and solving for varying amounts of "modern" contamination in old samples.

$$-\frac{dN}{dt} = k_1 N \qquad \text{Eqn. 1}$$

integrating

$$-\int_{N_o}^{N} \frac{dN}{N} = k_1 \int_{o}^{t} dt \qquad \text{Eqn. 2}$$

from which

$$\ln\left(\frac{No}{N}\right) = k_1 t \qquad \text{Eqn. 3}$$

where N_o is the modern radioactivity in disintegrations/min./gm. of carbon, and N is the radioactivity of the unknown sample of carbon, of age t years.

Using the half/life ($t_{1/2}$) of carbon of 5,730 years (Libby, 1963, p. 279) rather than the earlier published half-life of 5,568 years (Libby, 1955, p. 9) Equation 3 becomes

$$N = 15.3\, e^{-\frac{0.693t}{5730}} \qquad \text{Eqn. 4}$$

If in one gram of carbon there is a proportion Ca of old carbon of correct age and a proportion Cm of modern contaminating carbon, the number of counts Nc obtained for 1 gm. of contaminated sample will be the sum of counts from the old and the modern materials.

Thus

$$Nc = Na\left(\frac{Ca}{Cm + Ca}\right) + 15.3\left(\frac{Cm}{Cm + Ca}\right) \qquad \text{Eqn. 5}$$

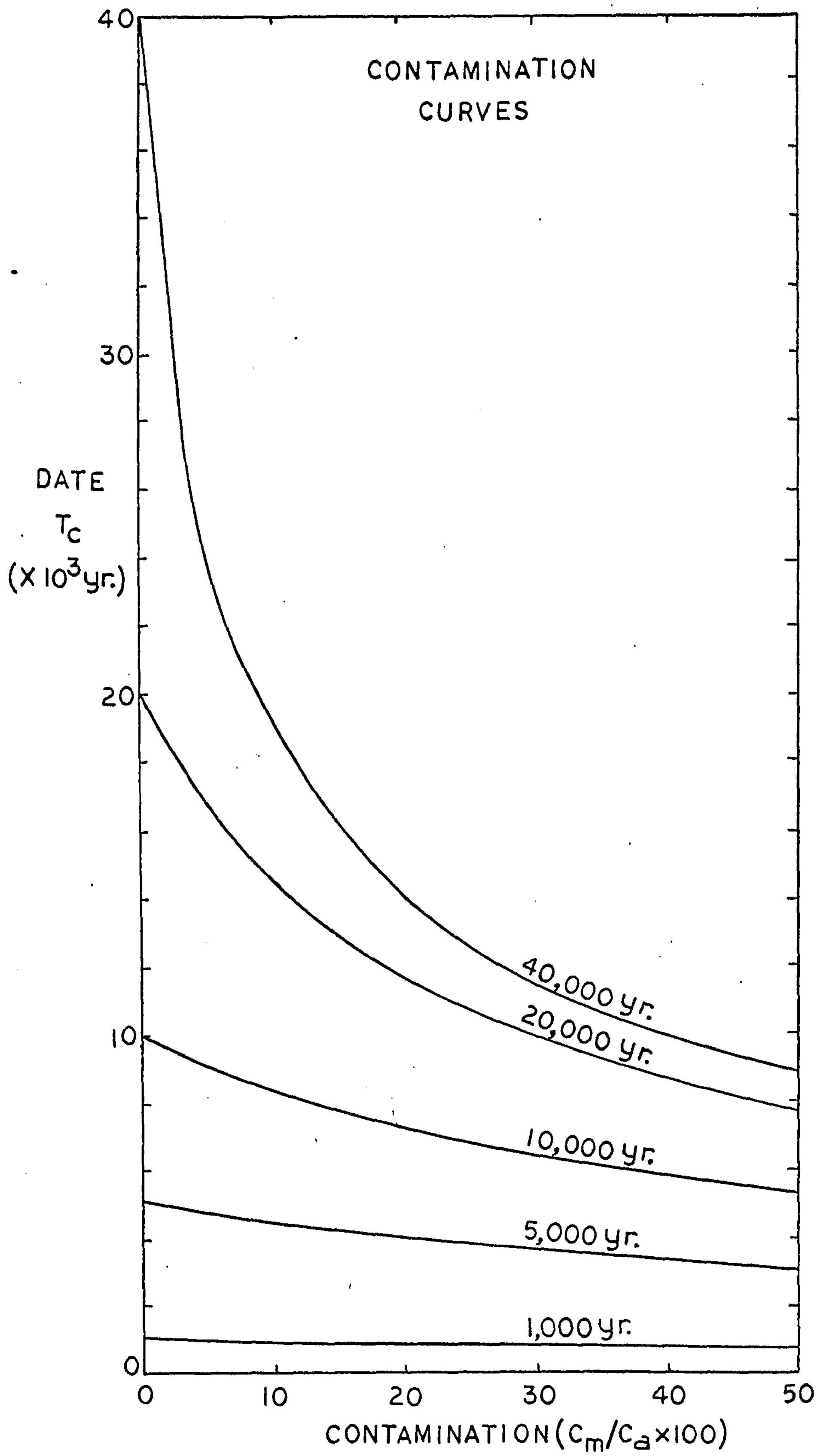
and

$$Nc = \frac{15.3}{Cm + Ca}\left[Ca\ e^{\frac{-0.693ta}{5730}} + Cm\right] \qquad \text{Eqn. 6}$$

Equation 6 can be evaluated for Nc and thence the estimated date tc is obtained for the contaminated sample. A range of values can be substituted for Ca and Cm for samples of known age (ta) and a family of curves drawn as in Figure 46. These curves are similar to those published by Broecker and Kulp (1956, p. 8) but cover a different range of contamination values as a result of using, in this case, Cm/Ca instead of Cm/Cm+Ca.

The great effect of modern contamination on the dates of old samples can be seen in Figure 46. The proportionate effect on samples in the range of interest in this project, is much less, but underestimates of 2,000 years can be expected

Figure 46. Curves showing the effect on radiocarbon dates of the contamination of old carbon by modern carbon


CONTAMINATION
CURVES
DATE
T_c
($\times 10^3$ yr.)
40
30
20
10
0
40,000 yr.
20,000 yr.
10,000 yr.
5,000 yr.
1,000 yr.
0
10
20
30
40
50
CONTAMINATION ($c_m/c_a \times 100$)

for samples with 20 percent contamination when the true age is 10,000 years.

Olson and Broecker (1958, p. 598) dated humic acid extracts and residues for certain samples and found no consistent difference in age between dates of the fractions that would clearly indicate contamination by younger soluble humic materials moving into older soil or peat is a general occurrence. Ruhe et al. (1957) fractionated bog samples from McCulloch and dated the residue and extract, but found no difference between the dates. In a later paper, Ruhe and Scholtes (1959, p. 591) dated adjacent wood and peat samples at the base of the Algona outwash in Hancock County, Iowa and again found no appreciable difference between the contamination-prone peat and the wood. The data discussed above are set out in Table 19.

Table 19. Comparison of dates for materials in which contamination was sought

Source	Sample	Dates (B.P.)	
		Residue	Extract
Lamont	Soil	2,900	2,000
(Olson and Broecker,	Peat	4,650	4,700
1958)	Soil	8,150	5,300
	Peat	7,350	8,350
	Soil	10,600	10,900
	Wood	39,000	39,000
Ruhe et al. (1957)	Peat	11,660	11,790
Ruhe and Scholtes	(a) Wood	12,970	
(1959)	(b) Peat	13,030	

The data of Olson and Broecker (1958) for fractionated soil organic matter show that contamination in these samples may be significant under some circumstances. Materials such as wood and peat are generally free of heavy contamination. Since all the materials sampled in this project were taken below 2 ft. depth in the profile, the possibilities of direct modern root contamination is not a problem except in the samples taken at the base of the UM zone. Even if root contamination was as heavy as 20 percent, and there is no reason to believe that roots are so abundant, the curves of Figure 46 indicate that for samples of 3,000 B.P. true age, the underestimate of age would be approximately 800 years, which is not greatly in excess of the quoted error on such samples in Table 18. Muck samples taken at lower depths are overlain by thick, calcareous sediments which would effectively prevent contamination by downward movement of soluble humic materials (Olson and Broecker, 1958, p. 596).

It is concluded that contamination of samples from the sources described above is not a significant factor in consideration of the dates in this work.

IX. DISCUSSION OF THE HISTORICAL-ENVIRONMENTAL FRAMEWORK

A. Landscape and Vegetation Changes with Time

A summary of data relating to the historical-environmental framework is given in Table 20. The data used here for the beginning of the post-Cary at 13,000 B.P. relates to the Algona outwash date of Ruhe and Scholtes (1959, p. 592). It is a maximum date for this stratigraphic situation within post-Cary sediments on the Algona moraine surface, but post-glacial sediments on the surface of the older moraines of the Des Moines lobe will be somewhat older, as is evidenced by the older basal dates at McCulloch and Colo bogs.

The first post-Cary interval from 13,000 to 10,000-11,000 B.P. is ill-defined in terms of the dating framework of Table 18 and is based on dates from profiles J6 and J173. The interval represents the initial erosion of the Cary till surface prior to stabilization under a vegetative cover. The occurrence of dominantly coniferous pollens in this LS zone may be the result of heavy contamination from the glacial debris or from forests bordering the Cary glacier. The generally low organic carbon levels in these sediments suggests that there was a sparse vegetative cover on the landscape and/or more rapid erosion, but there is no evidence of an early postglacial tundra of high NAP such as described in eastern United States by Martin (1958, p. 494).

The transition from LS to LM zones relates to the

Table 20. General representation of the environmental framework and related soil landscapes

Substage	Stratigraphic zone	Environment	Soil landscapes	Dates B.P.
		Present		Modern
	Upper Muck (UM)	Oak invading, prairie subclimax Prairie	Relative hillside stability; Clarion-Webster upper solums develop (late post-Cary surface)	3,000
Recent (Post-Cary)	Upper Silt (US)	Prairie (warm, dry, herbaceous maximum)	Intense erosion; earlier soils truncated or buried	8,000
	Lower Muck (LM)	Oak, elm, birch (warming) Conifers (pine, fir, spruce)	Relative hillside stability (forest soils?)	10,000-11,000
	Lower Silt (LS)	Conifers (cool)	Hillside erosion	13,000
Cary	Cary till and drift	Glacial		

beginning of stabilization of the hillside landscape under the invading forest. The phase of stability is represented in bog profiles by the LM zone. Pollen profiles and carbon dates indicate that coniferous forest remained on the stabilized landscape for no longer than 3,000 years. The climate during this period is thought to have been one of cool temperatures and highly effective soil moisture conditions, at least comparable with the mixed coniferous forest areas of northern Minnesota and southern Canada, and possibly cooler (Wright et al., 1963, p. 1373). Mixed forest species appeared on the landscape as the conifers gave way to the prairie.

The date of 8,000 years BP represents the onset of surface instability which resulted from this vegetative change from forest to prairie. This is the date obtained at both Colo and McCulloch for the uppermost horizon of the UM zone. It also corresponds with the dates obtained for the same vegetative transition at McCulloch bog by Ruhe et al. (1957, p. 687). The warmer, drier conditions at the time favored rapid onset of erosion to give the US zone sediments in the bogs, and by 7,000 B.P., the floristic composition of vegetation on the till surface was dominated by herbaceous species. Throughout the interval of US zone deposition, erosion of adjacent hillsides proceeded, indicating a somewhat sparser vegetative cover than exists under modern prairie. This relatively warmer and drier interval of increased erosion from 8,000 to 3,000 B.P. spans a shorter period than that proposed for the postglacial hypsithermal interval 9,500-2,500 B.P. by Deevey and Flint (1957, p. 183).

The erosion of hillsides which gave rise to the US sediments removed the equivalent of 5.3 feet of soil from the upper slopes at Jewell and 1.7 feet from the upper slopes at Colo. The data of Cardoso (1957, p. 48) show that in the strongly differentiated forest soils on the Cary till in Iowa such as the Hayden series, the B horizon clay maximum occurs above 30 inches in the profile. The amount of erosion represented in the US sediments is therefore sufficient to have truncated much of a solum of this thickness at Colo, and all of it at Jewell. Thus if forest soils of this magnitude developed during the period 11,000 to 8,000 B.P., subsequent erosion has been sufficient to remove most or all of the solum developed at that time on upper slopes, and to have buried lower slope forest soil equivalents.

The latest major episode represented in the bog watersheds is a change to relatively stable conditions on the hillsides following a slight amelioration of the climate to conditions comparable with the present climate of central Iowa. It is during this period of 3,000 years that most of the soils of the Clarion-Webster toposequence have developed a major part of their characteristic prairie or brunizem solum. Parts of the landscape will lose more or less surface material, depending on their position, for example, an actively eroding slope such as in the modern Storden soil situation will lose more surface than a gently convex summit. Other topographic positions in concave parts of the landscape have accumulated the products of slope erosion, and so soils such as the Webster series have developed part of their profile in surficial sediment.

The climate of the post-Cary interval, as interpreted from the pollen and sedimentary record, may have equivalents in the modern climatic pattern of north central United States. Climatic data for northern Minnesota, central Iowa, and western Kansas are shown in Table 21. They represent the modern range from mixed coniferous forest, through prairie, to the dry end of the prairie. A climate comparable with that in northern Minnesota prevailed during early post-Cary time, but swung to warmer and drier conditions between 8,000 and 3,000 B.P. which may have been comparable with western Kansas. Strong climatic contrasts of this magnitude during the post-Cary seem reasonable in view of the marked changes in vegetation and landscape evident in bog watersheds.

The rates of erosion and deposition in bog watersheds can be calculated using the data for sediment thickness, equivalent soil thickness, and the radiocarbon dates of Table 18.

Rates of accumulation in the bog centers have been calculated for Colo, Jewell and McCulloch profiles and are presented in Table 22.

These rates are comparable with bog accumulation rates calculated by Durno (1961, p. 350). His values for moss-rich

Table 21. Annual normal precipitation and temperature data (U.S. Weather Bureau, 1960) for selected locations

Location	Precipitation (inches)	Temperature °F
North Central Minnesota	27.94	45.8
Central Iowa	31.63	49.2
West Central Kansas	18.01	56.2

Table 22. Accumulation rates for bog center profiles

Stratum	Colo bog in./100 yr.	Jewell bog in./100 yr.	McCulloch bog in./100 yr.
UM (organic)	1.13	1.06	1.16
US (mineral)	1.89	2.10	1.98
LM (organic)	1.06	6.00	1.54
LS (mineral)		1.30	
Total	1.45	2.16	1.61

peats ranged from 1.2 to 11.1 cm./100 years whereas the bog accumulation rates in Table 22 range from 2.2 to 15.2 cm./100 years. Mattson and Koutler-Andersson (1954, p. 361) calculated rates of accumulation ranging from 3.4-6.9 cm./100 years for peat deposits dating from 4,000 B.P. to the present.

These values are somewhat higher than rates for the UM zone of similar age. The data above show that material in the US zone has accumulated more quickly than UM zone materials and that the Jewell rates are the highest of all the bogs.

The geological complement of bog sedimentation is hillside erosion. Rates were calculated for hillside erosion, using the data of Tables 14 and 16 for Colo and Jewell watersheds, and the radiocarbon dates of Table 18. These rates are shown in Table 23.

Table 23. Erosion rates for Colo and Jewell watersheds in terms of A horizon equivalent

Stratum	Colo watershed		Jewell watershed	
	in./1000 yr.	tons/acre /yr.	in./1000 yr.	tons/acre /yr.
UM (organic)	0.72	0.1	1.08	0.2
US (mineral)	4.08	0.7	8.76	1.5
LM (organic)	0.07	0.01	6.00	1.0
LS (mineral)	5.4	0.9	7.20	1.2
Total	2.58	0.5	6.60	1.1

An interesting feature of Table 23 is that the Jewell data show continuously high rates of erosion throughout the post-Cary interval until the latest stabilization of the landscape in that watershed, 2,300 years ago. By contrast, the interval represented by the LM zone at Colo, resulted in a negligible erosional loss from hillsides. In both bogs the change from US to UM zones represents a change from the climax of erosion to a relatively stable condition.

The rates of removal of soil from the till watersheds in Table 24 was converted to tons per acre per year by using a value of 2,000 tons per acre foot of soil (Lyon et al. 1952, p. 27). The highest values obtained for the Jewell bog are less than the rates of 5 to 59 tons per acre per year published by Bennett (1939, p. 162) for corn and fallow on Marshall silt loam of 9 percent slope. The lowest values of the bog watershed are slightly greater than most rates under natural vegetation (0.002-0.08 tons per acre per year) for a wide range of environments (Bennett, op. cit., p. 163). The maximum rates of erosion for the bog watersheds are comparable with the lowest rates of pre-settlement erosion of 6 to 44 inches per 1000 years, calculated for loess landscapes of western Iowa by Ruhe and Daniels (ca. 1965).

B. Profile Characteristics of the Clarion Toposequence

The findings in the previous section have direct application to the biotoposequence of the Cary till, as defined by Cardoso (1957, p. 49) and Riecken (1965, p. 59). In answer to a question raised at the beginning of the thesis about the possibility of significant forest influence in the development of the Clarion toposequence, it can be stated that for landscapes of the kind studied here, this effect is likely to be small or negligible. Consequently, soils of the Clarion-Nicollet-Webster sequence are considered to be the product of 3,000 years of prairie environment. From both morphological and genetic viewpoints, the soils are readily classified in the Mollisol order of the U.S. Soil Survey Staff (1960, p. 168). At sub-group level the Clarion is an orthic-hapludoll, the Nicollet an aquic-hapludoll, and the Webster is an orthic-haplaquoll. The classification nomenclature expresses the increasing effect of poor drainage through the sequence.

The genetic pathway for Clarion, Nicollet, and Webster series is thus primarily related to accumulation of organic matter in the surface horizons and the state of oxidation of the subsoil as affected by drainage. It is of interest that the radiocarbon dates for surface soils of Clarion (440±120 B.P.) and Webster (270±120 B.P.) published by Simonson (1959, p. 154) suggest a relatively rapid cycling of organic matter near the surface. If cycling of organic matter in 12 inches of Mollisol A horizon is completed in approximately 400 years, that is, at the average rate of 3 inches per 100 years, this is greater than the maximum rate of surface soil removal calculated for the bog watersheds of 0.9 inches per 100 years at Jewell. Consequently, throughout the interval 7,000 B.P. to the present, a mollic epipedon could have existed over most of the hillslopes. The existence of such a mollic epipedon is indicated by the black (10YR 2/1) to very dark gray (10YR 3/1) color of the upper silt zone sediments which relate to hill-side erosion during this interval.

Comparable data are not avilable for rates of weathering, formation of clay, and movement of clay in Mollisol profiles. Riecken's (1965, p. 59) B/A clay ratios for the Clarion topo-sequence indicate that negligible clay movement from A to B has occurred in these profiles, yet there is a B/C ratio of 1.4 throughout the sequence. Apparently a considerable degree of subsoil weathering has taken place, which decreases with depth down the profile from B to C horizon but which is not indicative of clay movement from the A horizon. The B/A ratios of summit profiles C79, J42, J76, J80, and JSSA, which have relatively uniform particle size in the parent material, range from 0.9 to 1.1 whereas the B/C ratios range from 1.4 to 1.7, the latter values relating to C horizon samples taken in unoxidized, unleached till. Some of the B/A ratios show that a slight movement of clay may have taken place, but not so much as to give ratios greater than 1.2, which are needed to classify the B horizon as argillic (U.S. Soil Survey Staff, 1960, p. 35).

The presence of a pronounced stone line at depth in pro-files J80 and JSSA is indicative of an early period of erosion and deposition which affected the summit at this site. The general mobility of the surface during post-Cary time in the Jewell watershed was so great that earlier topographic high points could have been preferentially reduced to relatively low points, so that now, only the more resistent cores of glacial sediment form the ridge topographies. This kind of surface change during the post-Cary could explain the appearance of stone lines in hillcrest situations which seems anomalous in relation to the present surface. In profiles J80 and JSSA, the pedogenetic relationship of the B horizon to the A horizon can be questioned despite the relatively uniform, coarser particle size properties through the profiles. The clay in the B horizon may relate to an earlier surface and A horizon than the one in place at present. This earlier surface could have formed during the relatively stable period 11,000 to 8,000 BP under forest vegetation. During the course of the project, numerous relatively undisturbed soil cores were examined to find whether some morphological feature such as gray coatings to ped surfaces (= silans) in subsoils occur frequently, and so indicate prior forest influence (Arnold, 1963, p. 94-97). Only two profiles from the 43 sampled across various parts of the landscape showed any sign of these features, and in these two profiles from mapping units 101 and 131, the expression of gray ped surfaces was minimal.

It appears, therefore, that a considerable degree of B horizon clay, in excess of C horizon clay, originates from the prairie rather than the earlier forest environment.

X. A SOIL LANDSCAPE MODEL FOR THE CARY TILL

A. Enclosed System

Pedogenesis on the Cary till has been complicated by differential rates of erosion over the landscape under changing climatic and vegetational regimes. The magnitude of hillside erosion between 8,000 and 3,000 years B.P., however, makes it reasonable to conclude that the influence of early forest vegetation in the areas of study is negligible. Furthermore, the pronounced decrease in the rate of hillside erosion at 3,000 years B.P. is taken as a common starting point of increased profile development for many soils of the Clarion-Webster association. Therefore, for a wide range of soils on Cary till, the variables of pedogenesis can be resolved into sedimentary variations within the Cary till, sedimentary variations within the hillside surficial and bog sediments, and the influence of topography on the internal drainage of the soils. Variations within the till, such as stratification, are not systematic in relation to the surface, whereas surficial sediment properties and drainage effects are systematic and their relation to the surface can be readily described. For a given area of soil landscape, the remaining source of variation relates to differential erosion of the surface during post-Cary time.

From a consideration of these factors, an idealized model of the soil landscapes of the Cary till is represented in

Figure 47. A simple convex to concave hillslope system is represented in the foreground with soils ranging from Clarion to Nicollet to Webster on the upper slopes to bog edge and muck soils on lower slopes and in the depression. In the background a situation is represented in which a gently convex summit breaks to steeper slopes, the whole sequence from summit to toeslope showing poorly drained members at each end and well drained members on steeper, centrally placed slopes. The foreground sequence is intended to represent a uniformly eroded hillslope of relatively uniform surface age, whereas the background sequence contains summit slopes and lower slopes of varying degrees of erosion.

The soil landscapes of Figure 47 can be represented in terms of the soil landscape model proposed by Ruhe (1960, p. 165) the essentials of which are shown here in Figure 48. The upland is least affected by erosion and is expected to show the strongest evidence of profile development. At the break of slope, erosion is greatest and soils there have least profile development. Soils of the footslopes and toeslopes, however, are in a more favorable position to show development. Consequently, a plot of soil profile properties across the landscape such as organic carbon, percent $<2\mu$, and depth to carbonate, would be expected to show parabolic curves of the kind illustrated at the bottom of Figure 48.

A feature of the Cary till surface is the widespread occurrence of enclosed depressions of the kind studied in this

Figure 47. Soils and stratigraphy of the Clarion toposequence showing a rounded summit in the foreground and a gently convex summit in the background

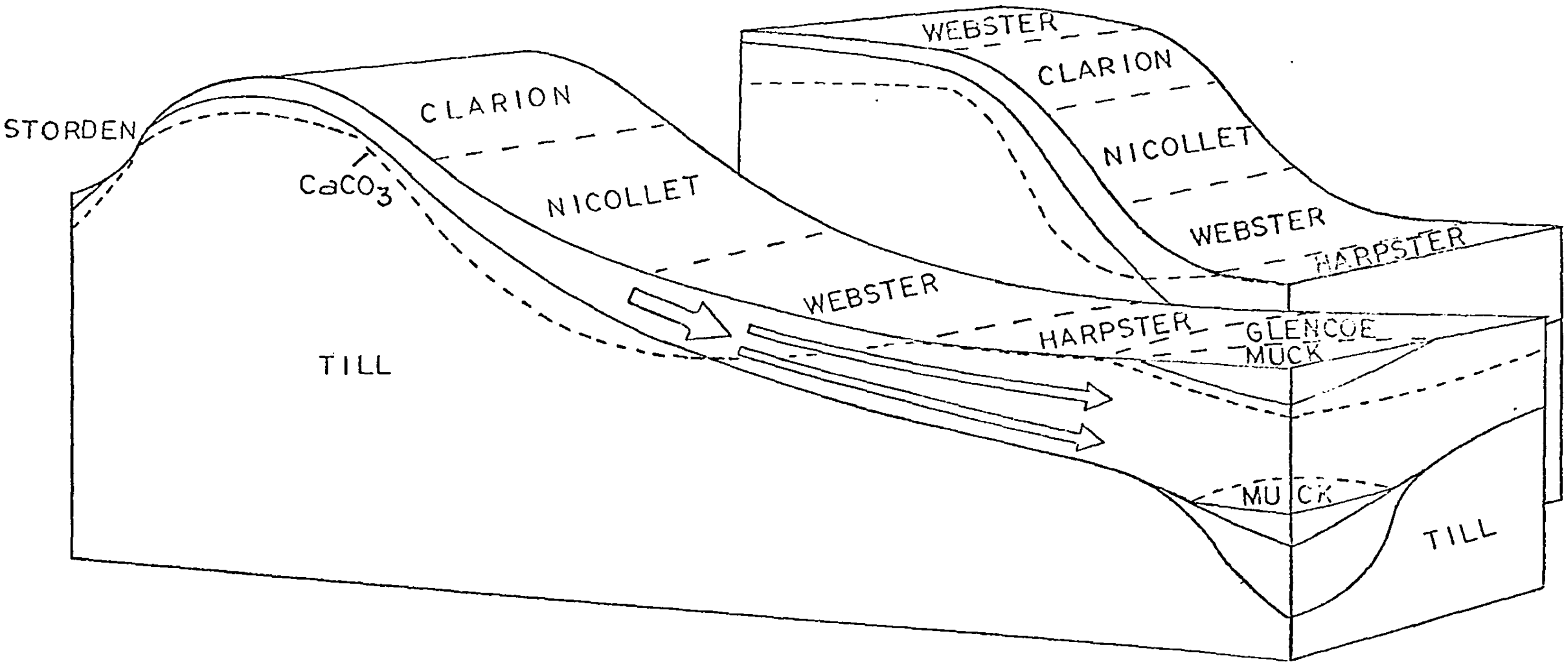
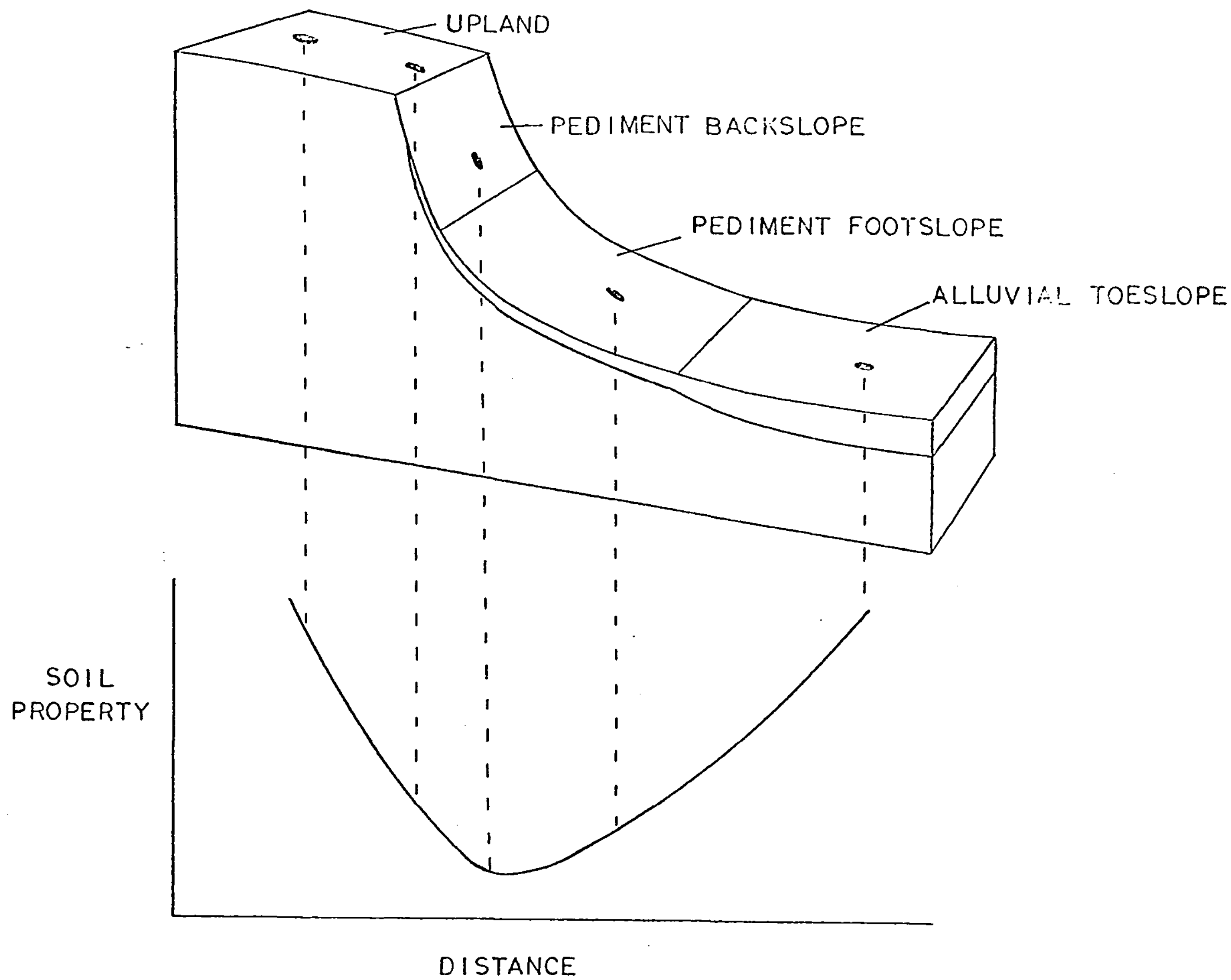

STORDEN
CaCO3
CLARION
NICOLLET
WEBSTER
HARPSTER
GLENCOE
MUCK
TILL
WEBSTER
CLARION
NICOLLET
WEBSTER
HARPSTER
MUCK
TILL

Figure 48. The soil landscape model of Ruhe (1960, p. 165) with the parabolic function expressing the trend of soil properties

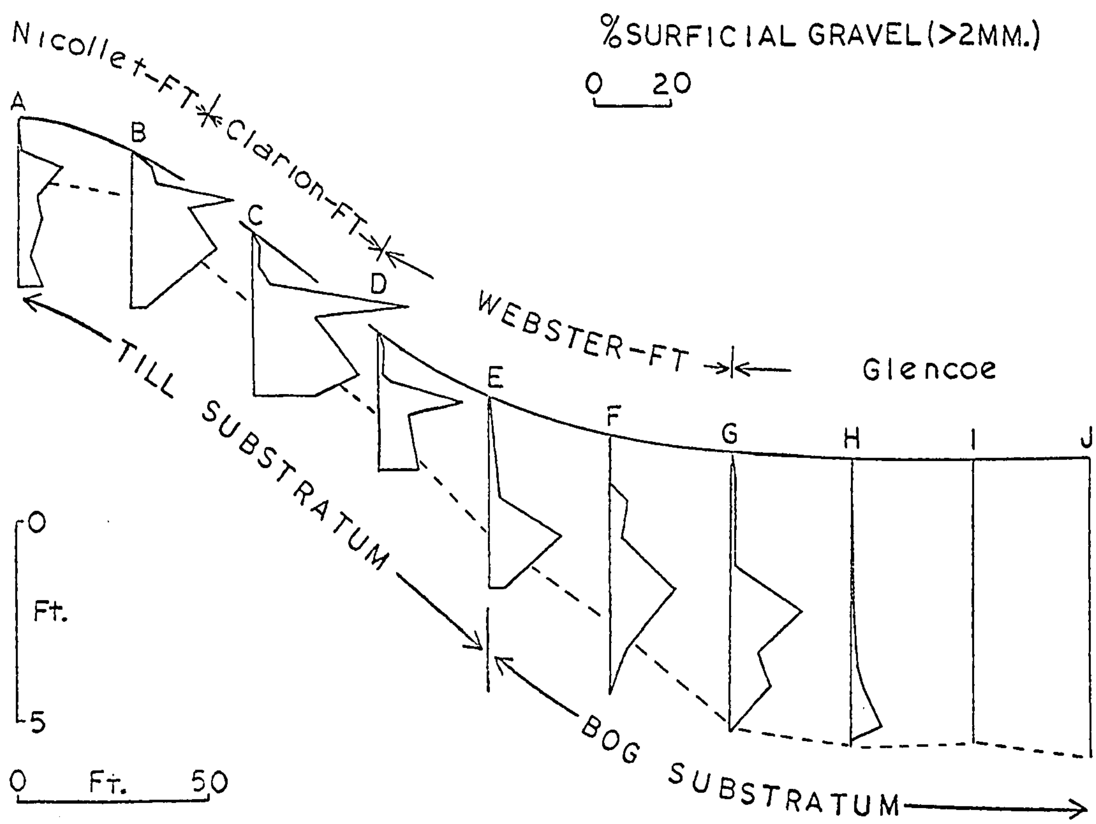

UPLAND
PEDIMENT BACKSLOPE
PEDIMENT FOOTSLOPE
ALLUVIAL TOESLOPE
SOIL PROPERTY
DISTANCE

project. In these landscapes, the products of erosion do not move out of the system but are accumulated on lower slopes. Systems of this kind permit the study of all erosional and depositional components and may be considered as a model pedological system. A small unit of hillslope and enclosed depression were examined in detail on the east side of the Jewell watershed (Figure 10). A transect was sampled from hillcrest to depression center across soils representing clay loam till variants Nicollet-FT and Clarion-FT, calcareous Webster-FT series with thick surface horizons and Glencoe soils in the depression. This is described as the JSS transect in Appendix A.

The stratigraphy of this transect was broadly defined in Figure 45 and is shown in detail in Figure 49. A pronounced stone line, identified in the field, is represented in Figure 49 as an accumulation of >2 mm. gravel in the soil profiles. In the hillcrest soil the stone line occurs at the boundary between surficial sediment and till and is a buried feature related to an early phase of surficial erosion and deposition. At sites B and C the coarse properties of the stone line impinge on the surface soil. Further down the slope, stone line gravel becomes interstratified between finer bodies of sediment, all of which overlie the LM bog stratum. The appearance of stone line gravel in the depression underlain by fine surficial sediment further establishes the nature of the stone line as a "lagging" component in surficial erosion and

Figure 49. Plot of percent gravel (>2 mm.) in the surficial sediment of transect JSS at Jewell

JEWELL TRAVERSE (SS)



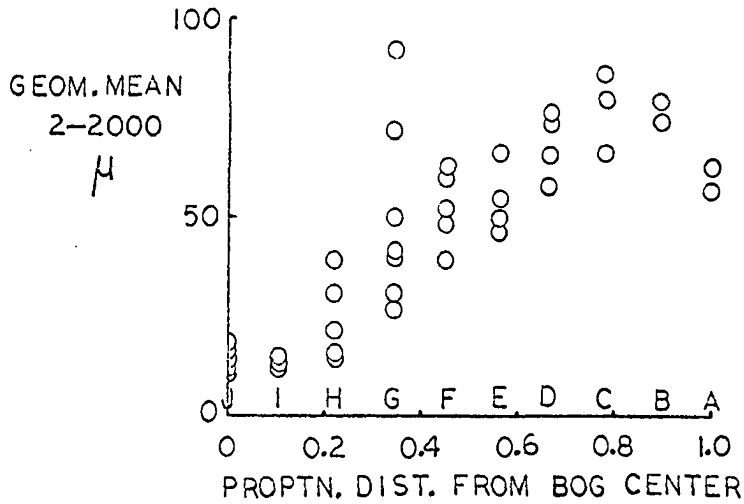
deposition processes as described by Ruhe (1956, p. 71). Similar stone line features have been reported for the Cary till by Wallace (1961, p. 13).

Trends within the body of surficial sediment, excluding the stone line at sites A, B, and C, are shown in Figure 50. Both particle size geometric mean and standard deviation data show comparable trends to the main bog surficials (Figures 41, 42, 43). The geometric mean data show the same spread of particle size in the zone of surficial differentiation which results from the stratification of the sediment into coarse and fine. The overall effect of transport down the slope is to produce a finer, better sorted sediment in the depression.

The plot of percent $<2\mu$ profiles in Figure 51a illustrates the overall increase in clay from hillcrest to depression. The clay profiles on the upper part of the slope are characteristic of soils with eluviated A horizons, whereas the profiles at the base of the slope have clay-enriched A horizons. It is probable that the clay curves of upper slope profiles are partly the result of a lateral movement of finer hillside surficial sediment to the depression. This is confirmed by the contoured geometric mean data of Figure 51b which show that the latter stages of surficial erosion and deposition resulted in a steady decrease in particle size from the midslope position to the depression.

Contoured calcium carbonate equivalent and organic carbon data are shown in Figure 52. The carbonate data illustrate a

Figure 50. Plot of geometric mean and standard deviation along the JSS transect at Jewell


100
GEOM. MEAN
2–2000
μ
50
0
J I H G F E D C B A
0 0.2 0.4 0.6 0.8 1.0
PROPTN. DIST. FROM BOG CENTER

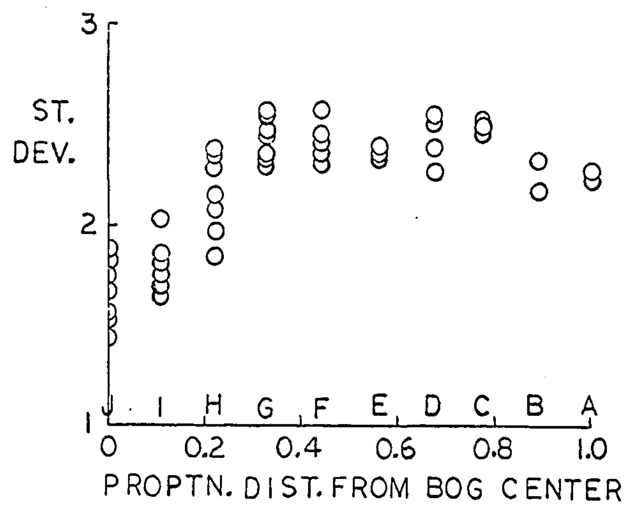

3
ST.
DEV.
2
1
J I H G F E D C B A
0 0.2 0.4 0.6 0.8 1.0
PROPTN. DIST. FROM BOG CENTER

Figure 51a. Plot of percent <2μ profiles of the JSS transect at Jewell

Figure 51b. Contoured geometric mean profile data of the JSS transect at Jewell

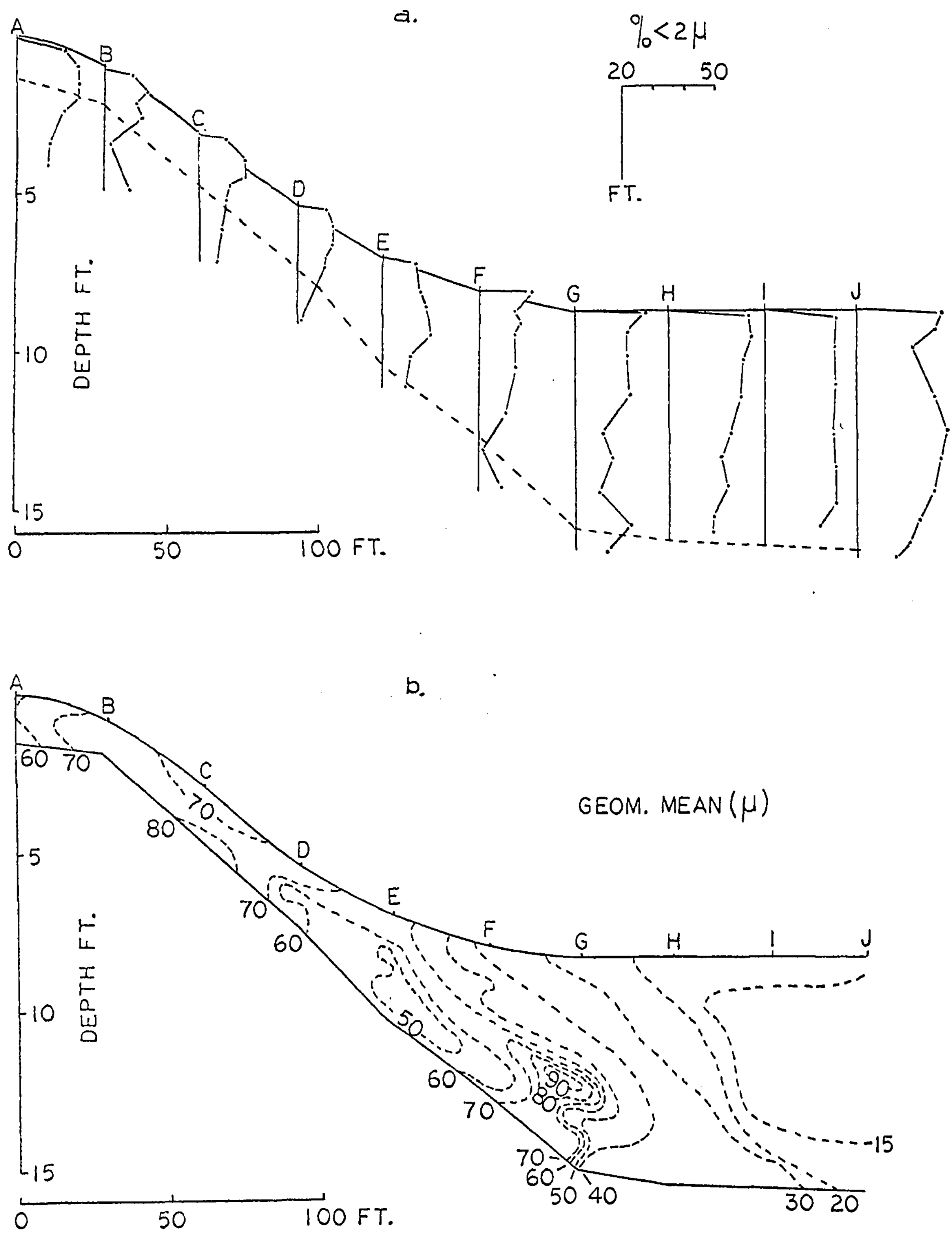
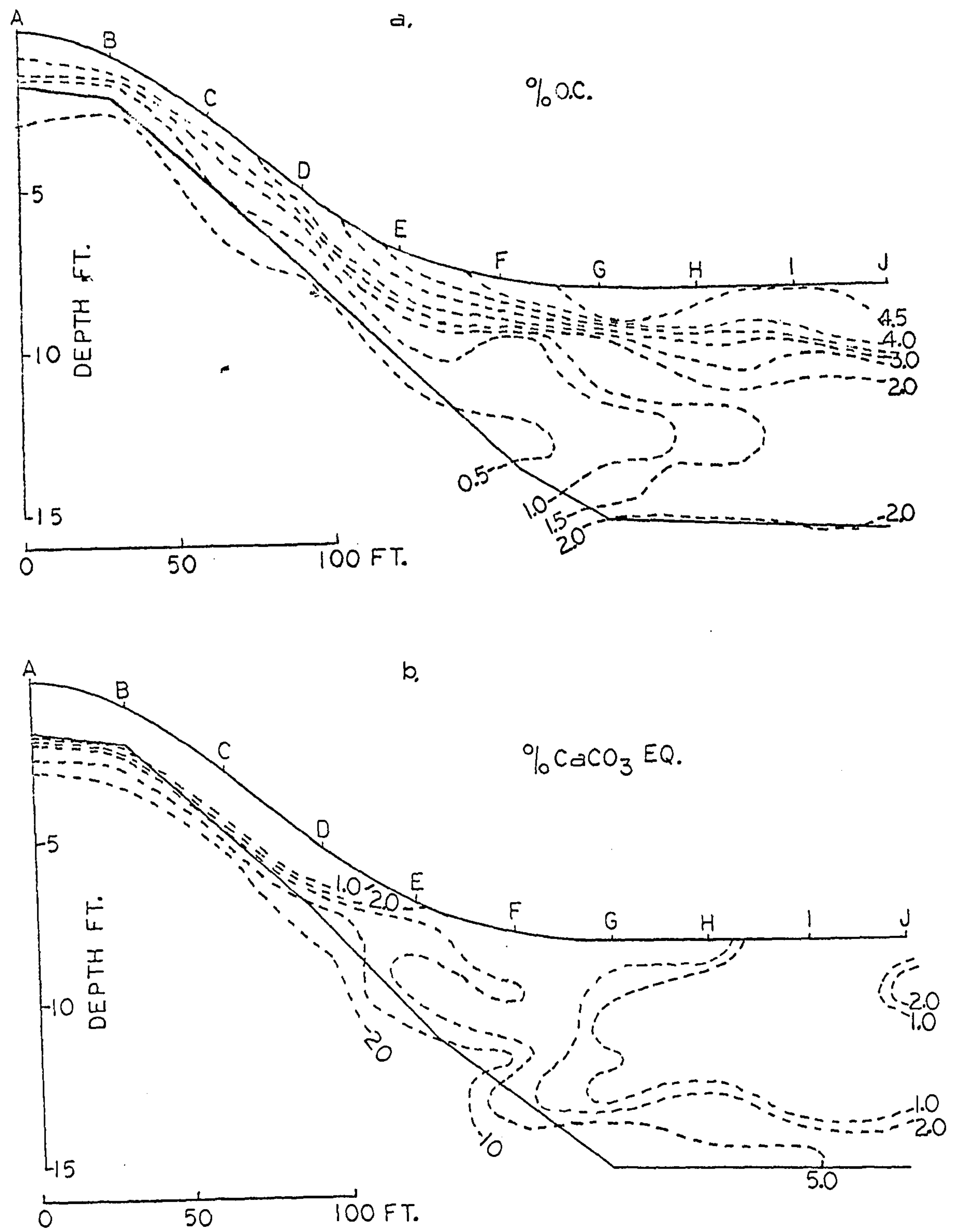

a.
%<2μ
20
50
FT.
A
B
C
D
E
F
G
H
I
J
DEPTH FT.
5
10
15
0
50
100 FT.
b.
GEOM. MEAN (μ)
60
70
80
50
90
40
30
20
-15

Figure 52a. Contoured percent organic carbon profiles of the JSS transect at Jewell

Figure 52b. Contoured percent calcium carbonate equivalent profiles of the JSS transect at Jewell


a.
% O.C.
A
B
C
D
E
F
G
H
I
J
DEPTH FT.
5
10
15
0
50
100 FT.
0.5
1.0
1.5
2.0
4.5
4.0
3.0
2.0
2.0
b.
% $CaCO_3$ EQ.
A
B
C
D
E
F
G
H
I
J
DEPTH FT.
5
10
15
0
50
100 FT.
1.0
2.0
20
10
5.0
2.0
1.0
1.0
2.0

distribution downslope which occurs widely in the till landscape. A surface enrichment by carbonates occurs in the toeslope position just above the depression, whereas on higher and lower slopes, the soil surface is leached. In this case the Webster soil is enriched, but more often the Harpster bog-rim soils occupy this situation. The occurrence of such an enrichment probably results from the effects of the low permeability of the clay soils of the Glencoe series to groundwater movement.

The organic carbon content of the soils increases appreciably downslope both in total amount and to depth. In the situation of surficial differentiation and stratification between sites E and G, a relationship between the contours at depth of organic carbon and geometric mean indicates that lower organic carbon is associated with coarser particle size.

The distribution of some soil properties downslope in the transect under discussion can be represented mathematically by fitting least squares polynomial curves to the data. Curve fitting is facilitated by the use of tabular polynomial values published by Anderson and Houseman (1942) and DeLury (1950). A selection of fitted polynomials is shown in Figures 53 and 54 for soil data within the surficial deposit. The systematic trends across the landscape confirm the view that an enclosed system of this kind is a suitable field representation of the soil landscape model for the Clarion-Webster soils from which to establish principles of general applicability to the till

Figure 53. Plot of weighted mean percent 62-2,000μ and surficial thickness across the JSS transect at Jewell

JEWELL TRAVERSE (SS)

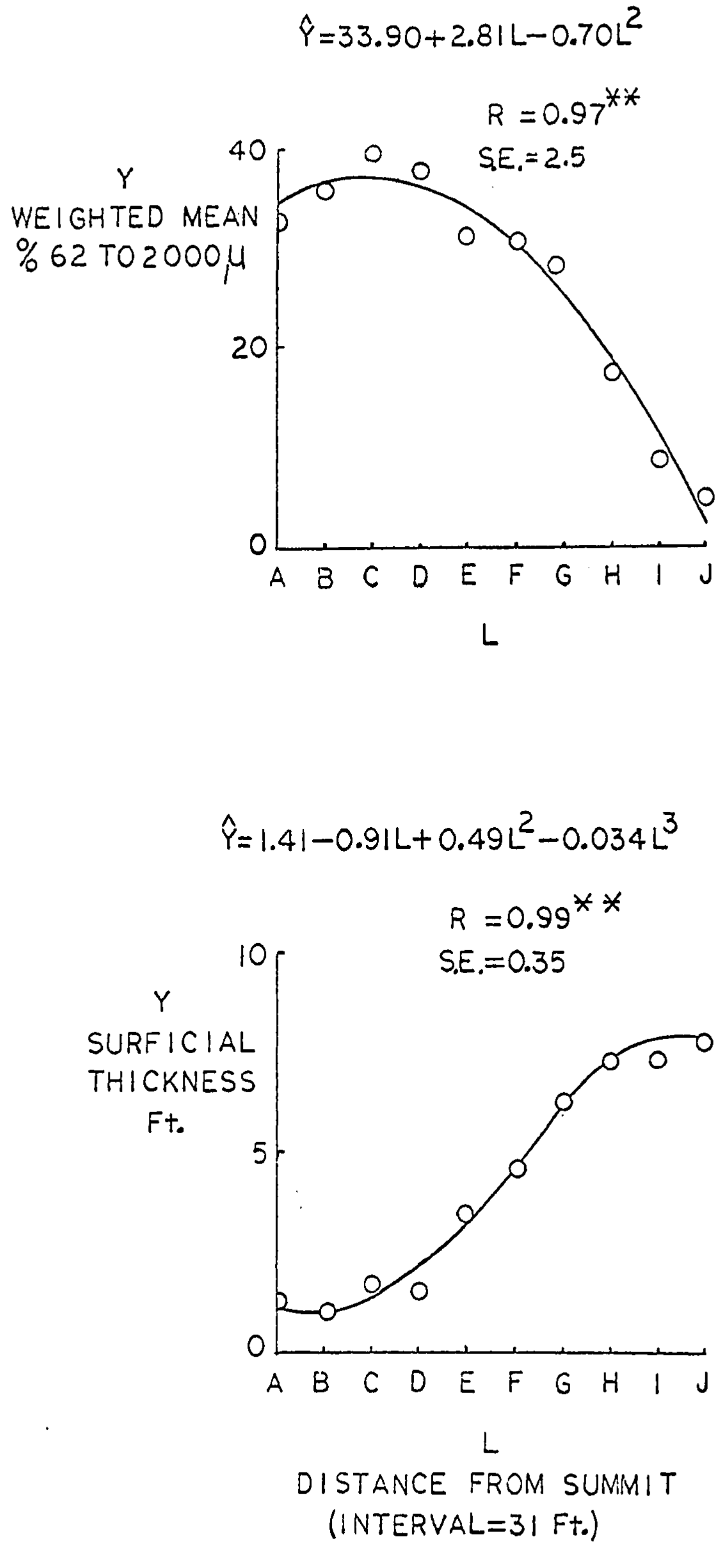
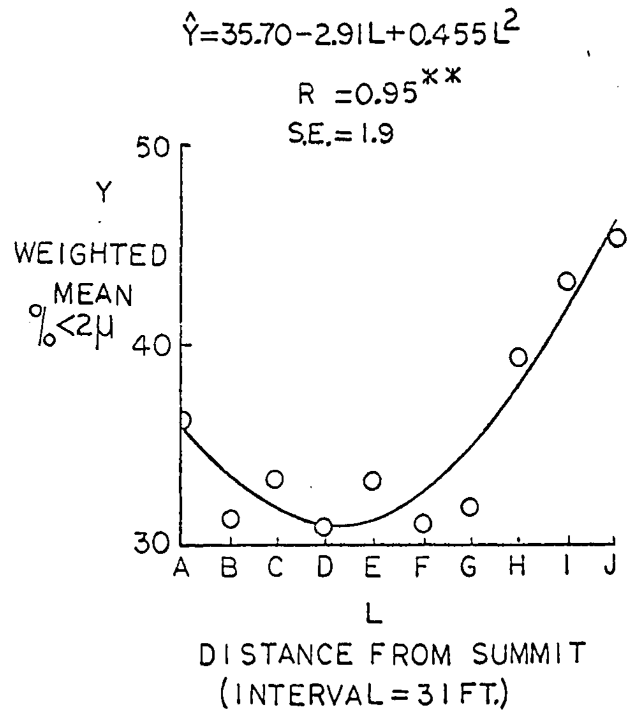
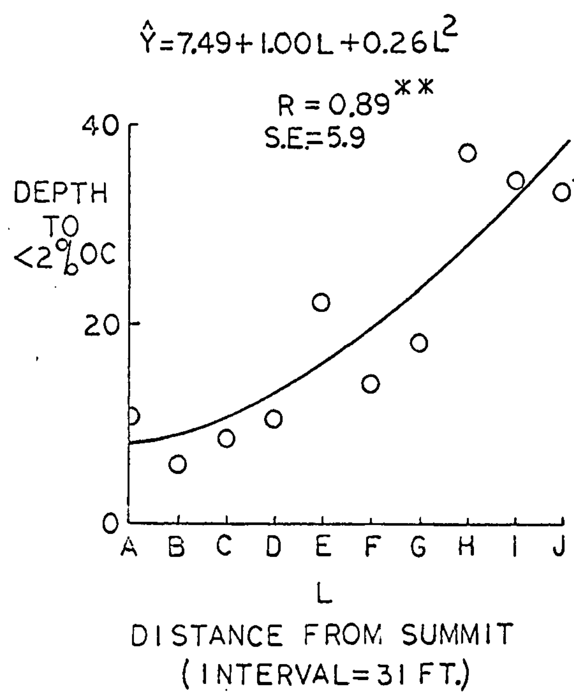


Figure 54. Plot of weighted mean percent <2μ and depth <2 percent organic carbon across the JSS transect at Jewell



Ŷ=35.70−2.91L+0.455L²
R =0.95**
S.E.= 1.9
50
40
30
Y
WEIGHTED
MEAN
%<2μ
A B C D E F G H I J
L
DISTANCE FROM SUMMIT
(INTERVAL=31 FT.)



Ŷ=7.49+1.00L+0.26L²
R = 0.89**
S.E.=5.9
40
20
0
DEPTH
TO
<2%OC
A B C D E F G H I J
L
DISTANCE FROM SUMMIT
(INTERVAL=31 FT.)

landscape. The trends show the distinct nature of the soil at the summit, and the relationships of its properties to those of soils in sideslope and toeslope situations. Viewed as a continuously changing pattern of soil properties, the JSS transect data show the trends expected from a consideration of the soil landscape model proposed by Ruhe (1960, p. 165). While the details of soil property trends may be expected to differ from slope to slope on the Cary till landscape, the basic soil landscape model should be applicable to most situations.

B. Open System

1. Procedure

The kinds of situation described here differ from those of the previous section in that there is no enclosed depression at the foot of the slope. In place of the depression there is a natural drainage line transverse to the slope direction. Thus the products of hillslope erosion are free to move from their slope of origin.

Since the topographies of open systems are likely to range from convex to concave slopes, an analysis was planned which included such a range within a small segment of landscape. A site was chosen along the perimeter of the Jewell watershed adjacent to transect JSS as shown in Figure 10.

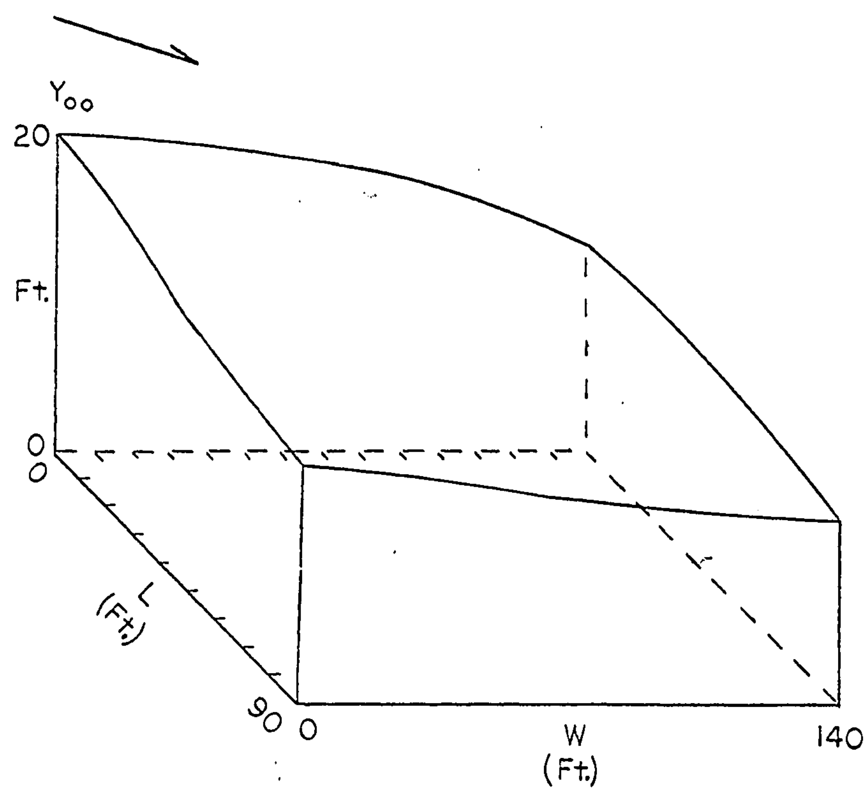
The objective in this study was to examine the relationship between the trends of soil properties measured in the field and the modern soil landscape surface, that is, to attempt to answer the question: How systematically do soil properties vary across a complex landscape? A second stage of the study was to examine various features of the landscape and to evaluate them individually and in groups as factors of soil formation.

The segment of landscape chosen for detailed study extends from a local hillcrest to a toeslope with transverse drainage and includes both convex summit and nose slope components, at the northern end, and a concave sideslope component in the southern part. The area, shown in Figure 55, was surveyed in detail to permit 0.25 ft. contours to be drawn and a 10 x 15 sampling grid in terms of length (L) and width (W) was measured, using the hillcrest position as the Y_{oo} point of the sample grid. The grid spacing was 10 feet in both directions so that the final area 90 ft. x 140 ft. contained 150 sample points. At each point the elevation (Y_e) was measured and the soil profile examined for thickness of A horizon (Y_m), thickness of surficial layer (Y_s), depth to carbonate horizon (Y_c), and depth to gray mottles (Y_g). Samples were also taken for soil pH measurement at 0-3 inches (Y_a) and 30-33 inches (Y_b) for each profile.

The geomorphic parameters measured were essentially those listed by Aandahl (1948) in a study of soil nitrogen and landscape relationships in loess soils of western Iowa. In the present case, however, an attempt was made to develop methods

Figure 55. Segment of hillside at Jewell showing the sample grid (10x15) and length (L) and width (W) coordinates

JEWELL HILLSIDE



of measurement based on precise ground control, and several different approaches to slope gradient were assessed in the analysis. The following is a list of geomorphic parameters measured at each grid point:

Elevation relative to the grid summit (E)

Slope gradient (S)

(i) Slope gradient through the point (S_1)

(ii) Slope gradient above the point (S_2)

(iii) Slope gradient below the point (S_3)

Slope length direction (D)

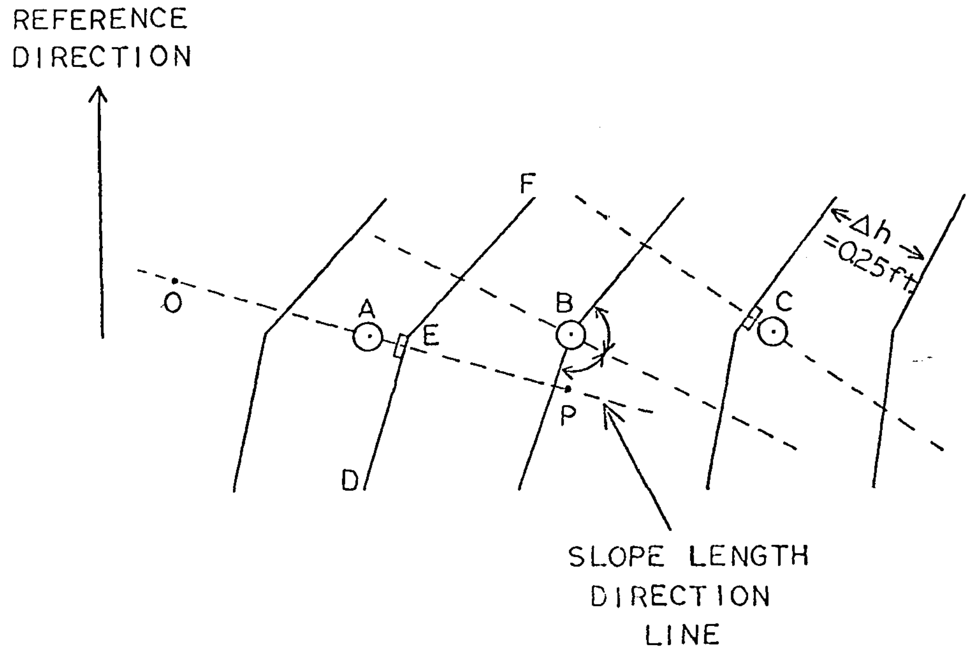
Slope length curvature (C)

Slope width curvature (Cw)

Distance from summit (O)

All the parameters were determined from the 0.25 ft. contour map in which the contours were drawn as straight line segments between points and not smoothed. Sample points in the grid occur in three different kinds of situations relative to the contour lines as shown for a convex-up landscape element at points A, B and C in Figure 56. Point A lies closer to a contour line upslope, so a normal is dropped to this contour. The normal represents the slope length direction along which slope gradient and slope length curvature are measured. Point C has the nearer contour downslope, so the normal dropped to this line represents the slope length direction at the point. Point B is a sample point about which a contour line is drawn; in this case the bisector of the

Figure 56. Geometric constructions showing the derivation of values for geomorphic parameters on sample grid at Jewell


REFERENCE
DIRECTION
F
Δh
=0.25 ft
O
A
B
C
E
P
D
SLOPE LENGTH
DIRECTION
LINE

contour angle is the slope length direction.

After the slope length direction is located, the slope gradient is determined by laying off an interval either side of the sample point, equal in distance to the grid spacing, as shown for point A in Figure 56. The elevation at O and P is obtained by interpolation and the difference in elevation between the two points is used as a coded measure of slope gradient through the point (S_1). The elevation difference between A and P is similarly a measure of the slope gradient above the point A, (S_2), and the difference in elevation between A and O is a measure of the slope gradient below the point (S_3).

Slope length direction (D) is a measure of the angle between some arbitrarily chosen reference direction and the downslope projection of the slope length direction line. It is a value coded in such a way as to avoid zero or near zero values and the discontinuity from 360° to 0° at due north. In this case, slope length direction was measured clockwise from the reference direction 270° in relation to magnetic north.

Slope length curvature (C) is measured along the slope length direction line, for example, the line PAO in Figure 56. The value of carvature is the ratio of the elevation difference between A and P to the elevation difference between A and O. This value equals the ratio of the slope gradient above A to the slope gradient below A, as defined here. Values of slope length curvature greater than unity indicate concavity and values less than unity indicate convexity.

Distance from the summit (O) is a direct measure in feet of the distance of a grid point from the absolute summit of the hillside. In this case, the summit point in the corner of the grid, and the farthest point diagonally opposite, are points of landscape inflection and the data at these points was not included in the analysis.

2. Soil trends in relation to landscape surface

The trends of soil data within the sample grid can be conveniently fitted by the use of orthogonal polynomials in which the independent variables are in terms of the grid co-ordinates of length (L) and width (W). This is an extension of the method of fitting the transect data which was discussed in the previous section. Orthogonal polynomials have been used to represent geophysical data by Oldham and Sutherland (1955) and Krumbein (1959). The procedure of curve fitting is facilitated by the use of tabular polynomial values published by Anderson and Houseman (1942), DeLury (1950), and Fisher and Yates (1963). The method followed in the analysis of the soil data presented in this thesis is essentially that of DeLury (1950, p. 10). The soil data collected at each grid point are tabulated in Appendix E, Section A, and the tabular form of a set of data, together with the polynomial values for computer card punching, is illustrated in Appendix E, Section B.

The soil data were processed with a regression program on the IBM 7074 High Speed Computer at Iowa State University.

Table 24 contains a summary of fitted polynomial equations for soil trends over the segment of Cary till landscape described above. The equations were fitted from the formulae of Anderson and Houseman (1942, p. 598). The polynomial model for all soil properties, except depth to carbonates, was the quadratic form since this was indicated both by the soil landscape model of Ruhe (1960) and the kinds of curves that were found appropriate in the previous section. The cubic model for the depth to carbonate horizon data takes into account the tendency of carbonates to be closer to the surface in toeslope than in sideslope situations, but carbonate is not found at the surface, as in the toeslope situation described for transect JSS of the previous section.

The high R^2 for surface elevation indicates that the greatest proportion of the variation has been fitted by the polynomial equation in this case. Smaller R^2 values were obtained with the other soil properties and the smallest R^2 values occurred with the soil pH values, the analyses of which are shown in Appendix E, Section C.

From an examination of the F tests it could be concluded that the relatively simple polynomial models which were formulated have been found to represent all the data at high significance levels. It is useful, however, to examine the discrepancies between expected values ($\hat{Y}$) computed from the prediction equation and observed values (Y). These residuals ($\hat{Y}$-Y) are plotted at each grid point to produce a residual map. Examination of the residuals will generally show whether or not a large systematic trend remains. A parallel check can also be made of the correlation matrices set out in Appendix E, Section D, to see whether elements of large magnitude, representing higher order polynomial terms, can reasonably be fitted. This method of inspection and separation into trend components versus error has been described by DeLury (1950, p. 12). It should be noted, however, that such "afterthought" changes of the model modify the probabilities under which the statistical tests are made. Ideally, a new model should be formulated and examined using a new set of data.

As an illustration of this method of adjustment following inspection of the data, the residuals for A horizon thickness are considered for the quadratic polynomial shown in Table 25.

Although a highly significant fit of the data is obtained with the quadratic equation, a substantial amount of unexplained variation remains. In Table 26 the relevant part of the A horizon correlation matrix is shown (signs omitted) in which the R_{rs} elements of the quadratic polynomial are separated with a broken line and a chosen polynomial of higher degree is separated with a heavy line. This new polynomial has the following form:

$$
\begin{aligned}
Y_m = {} & 19.45 + 13.84L - 13.54L^2 + 5.61L^3 - 0.44L^4 \\
& + 0.022L^5 + 0.17W - 0.11W^2 - 0.002W^3 + 0.55LW \\
& - 0.30LW^2 + 0.14L^2W + 0.02LW^3 + 0.05L^2W^2 \\
& - 0.002L^2W^3 + 0.09L^3W + 0.006L^4W
\end{aligned}
$$

for which

$$R^2 = 0.84;$$
$$F = 42.5;$$
$$\text{st. error} = 3.7 \text{ inches}$$

The accompanying statistical data, in particular the R^2 value, show that this new equation represents more of the A horizon depth variation within the grid system than the quadratic equation. However, the means of selecting the polynomial terms from the correlation matrix is rather arbitrary and is to some extent a compromise between explaining as much variation as possible and avoidance of a cumbersome equation. The question arises as to whether the inclusion of additional polynomial terms beyond quadratic is justified. A similar situation exists for the other soil properties, with the exception of surface elevation; higher degree polynomials reduce the residual sums of squares, and highly significant terms are fitted up to fifth degree on length and third degree on width.

On the basis of available data, there appears to be no pedological justification for fitting more complex models than

Table 24. Summarized analyses for the soil data on till

Soil property	Model polynomial	Fitted polynomial[a]	F	R^2	St. error	$\bar{Y}$
1. Surface elevation (Y_{oo} = 20.00 ft.)	Quadratic in L & W	$Y_e = 20.4 - 0.13L - 0.19W + 0.24LW - 0.03L^2 - 0.02W^2$	1274 **	0.98	0.34	15.71
2. A horizon thickness in inches	Quadratic in L & W	$Y_m = 26.96 - 3.28L - 1.64W + 0.22LW + 0.38L^2 + 0.06W^2$	36.7**	0.56	5.8	22.5
3. Depth to gray mottles in inches	Quadratic in L & W	$Y_g = 43.16 - 3.57L - 2.30W + 0.31LW + 0.19L^2 + 0.07W^2$	22.6**	0.44	4.9	30.4
4. Depth to carbonate horizon in inches	Cubic in L & W	$Y_c = 22.70 + 10.08L - 2.13L^2 + 0.13L^3 + 3.13W - 0.22W^2 + 0.005W^3 - 1.99LW + 0.177L^2W + 0.049LW^2$	24.5**	0.61	8.4	29.9
5. Thickness of surficial deposit in inches	Quadratic in L & W	$Y_s = 31.35 - 4.68L - 1.95W + 0.24LW + 0.48L^2 + 0.07W^2$	31.2**	0.52	5.9	22.2

[a]In this and following tables, and in the text, the coefficients of the polynomial terms have been rounded in order to condense the presentation.

Table 25. Residuals ($\hat{Y}-Y$) of A horizon thickness on the till landscape fitted by the quadratic equation, $Y_m = 26.96 - 3.28L - 0.19W + 0.24LW - 0.03L^2 - 0.02W^2$

Average magnitude of residuals = 4.4 inches

		W														
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
L	0	9	9	7	3	0	-2	-5	-6	0	-5	-5	5	5	-1	0
	1	4	3	2	-1	-2	-4	-5	-6	-3	-7	1	-2	-3	-4	2
	2	7	6	4	0	-4	-4	-5	-3	-1	-4	2	2	-2	0	-3
	3	-1	3	4	2	-2	-4	-2	-1	4	2	5	2	6	2	2
	4	3	4	2	2	0	1	4	1	2	0	6	9	8	7	1
	5	-10	-6	-4	-6	-6	2	3	2	2	-2	0	4	4	0	-4
	6	-9	-9	-2	-13	-6	-6	-1	0	-11	-2	4	6	3	-3	-4
	7	-3	-2	-3	-5	-14	6	5	5	0	5	3	6	7	7	7
	8	-2	0	-1	2	1	4	5	5	6	5	6	3	9	3	3
	9	4	5	6	6	7	11	9	8	-3	-11	-13	-22	-14	-12	-13

Table 26. Correlation matrix (signs omitted) for A horizon data showing quadratic polynomial terms and a chosen higher degree polynomial

		W					
		0	1	2	3	4	5
	0		0.098	0.119	0.066	0.054	0.034
	1	0.574	0.318	0.191	0.088	0.099	0.064
	2	0.325	0.292	0.067	0.130	0.068	0.004
L	3	0.027	0.225	0.006	0.082	0.041	0.008
	4	0.046	0.126	0.068	0.041	0.036	0.070
	5	0.227	0.065	0.025	0.032		
	6	0.037	0.026	0.060			

quadratic to A horizon, mottle, and surficial observations on this till landscape, and cubic or quartic equations to carbonate data.

3. <u>The relationship between geomorphic parameters and soil properties</u>

The relationships between soil profile properties and the geomorphic parameters were tested in various combinations in a series of regression analyses.

The data from the resulting correlation matrix shown in Table 27 allows an assessment of the geomorphic parameters singly as they relate to particular soil properties. As a result, the number of parameters fitted in regression may be

Table 27. Correlation coefficients (r) for the relationship between soil properties on the till grid and geomorphic parameters[a]

Soil properties	Correlation of soil properties and listed parameters							
	E	S_1	S_2	S_3	C	C_w	D	O
Ym	-0.43	-0.34	-0.24	-0.37	+0.20	+0.09	+0.21	+0.27
Yg	-0.02	-0.46	-0.41	-0.40	-0.00	-0.05	+0.05	-0.01
Yc	-0.16	-0.38	-0.34	-0.33	+0.02	+0.04	-0.01	+0.10
Ys	-0.31	-0.43	-0.33	-0.44	+0.16	+0.09	+0.14	+0.16
Ya	-0.21	+0.28	+0.28	+0.20	+0.12	+0.11	+0.12	+0.18
Yb	-0.13	+0.29	+0.33	+0.18	+0.19	+0.19	+0.29	+0.06

[a]The significance levels for correlation coefficients are 0.16 at 5 percent, and 0.21 at 1 percent.

Table 28. Correlations (r) between geomorphic parameters within the sample grid on till

	E	S_1	S_2	S_3	C	Cw	D	O
E	1.00							
S_1	-0.20	1.00						
S_2	-0.36	+0.90	1.00					
S_3	+0.04	+0.87	+0.57	1.00				
C	-0.52	+0.11	+0.51	-0.36	1.00			
Cw	-0.35	+0.27	+0.47	-0.01	+0.59	1.00		
D	-0.01	+0.23	+0.24	+0.17	+0.15	+0.26	1.00	
O	-0.91	+0.20	+0.31	+0.04	+0.37	+0.24	-0.26	1.00

reduced, or the regression arranged to contrast certain groups of parameters for each soil property. Because of the exploratory nature of the analyses, involving successive fitting and rearrangement of the parameters, the statistics are shown without the usual significance notation. In Table 28 the matrix data show the correlation between geomorphic parameters in each sampled area. This draws attention to the highly correlated parameters, which then may need to be examined separately in regressions as well as together in the same regression. In the case of the slope categories, the high correlations indicate that only one or two kinds of slope need be used. The high correlation between elevation (E) and distance from the summit (O) suggests that these parameters should be separated also.

The overall results of the regression analyses are summarized in Table 29. Under the heading "Useful geomorphic parameters" are listed those parameters which consistently explained a substantial proportion of the variation and showed t values on the B coefficients greater than 2 when different combinations of parameters were fitted. The parameters omitted for a particular soil property are those which can be replaced by another parameter and/or gave low t values.

4. Discussion

An attempt has been made here to determine how well the

Table 29. The results of regression analyses for soil properties and groups of geomorphic parameters

Soil properties	Useful geomorphic parameters	Parameters fitted for maximum regression	Max. R	St. error	$\overline{Y}$
Ym	E[a], S_1, C, D, O[a]	E, S_1, S_2, C, C_w, D, O	0.70	5.9 in.	22.5 in.
Yg	S_1, D	E, S_1, S_2, C, C_w, D, O	0.51	5.3 in.	30.4 in.
Yc	E[a], S_1, C, C_w, O[a]	E, S_1, S_2, C, C_w, D, O	0.49	10.9 in.	29.9 in.
Ys	E[a], S_1, D, O[a]	E, S_1, S_2, C, C_w, D, O	0.65	6.1 in.	22.2 in.
Ya	E, S_1	E, S_1, S_2, C, C_w, D, O	0.33	0.18	6.0
yb	S_1, C, D	E, S , S , C, C_w, D, O	0.40	0.43	7.8

[a]The pairs of parameters shown thus should be fitted separately in regressions.

variation of soil properties of the "depth to" and "thickness of" kind, and pH at specified intervals, can be explained in terms of grid co-ordinates and by using geomorphic parameters. An examination of R^2 values shows that soil data are more closely fitted by polynomials than by linear terms of the geomorphic parameters; furthermore, the standard error values are also somewhat greater for the analysis with the geomorphic parameters. Of the soil properties measured, the field data show greater R^2 than the pH values.

Further regressions were computed for all soil properties using both the geomorphic parameters and the quadratic terms from the polynomials. There was, however, only a small increase in the sums of squares accounted for in regression, indicating that factors other than surface position and geomorphic surface features explain the remaining variation.

This degree of unexplained variation in the open system contrasts markedly with the closer fit of soil data by polynomials in the enclosed system discussed earlier. The latter case represents a pedological system in which erosional and parent material factors are simplified. The open system described in this section represents conditions of erosional complexity, and the use of a sampling grid rather than a transect increases the possibility of lateral variation of important factors such as parent material.

The data allow an evaluation of the geomorphic parameters, for example, elevation, slope gradient, slope length curvature, slope length direction and overland distance all show r values equal to or greater than the 1 percent significance level, when correlated with A horizon thickness. This relationship between A horizon and surface geometry is to be expected since the A horizon is sensitive to conditions prevailing at the surface. Depth to gray mottles and depth to carbonate data, however, are clearly related to slope gradient but not to other geomorphic parameters, whereas the thickness of surficial sediment data show a set of relationships comparable with the A horizon. These correlation data indicate that A horizon and thickness of surficial sediment data are more closely related to the present surface features than carbonate and mottle features, which presumably relate more to subsurface conditions.

XI. CONCLUSION

The occurrence of a common stratigraphic sequence in a number of enclosed bogs on the Cary till has provided a basis for defining a regional bog stratigraphy for the Des Moines lobe in Iowa. The dated bog stratigraphy in condensed form is: upper muck zone 0-3,000 BP / upper silt zone 3,000-8,000 BP / lower muck zone 8,000-11,000 BP / lower silt zone 11,000-13,000 BP / Cary till >13,000 BP. The silt zones represent high rates of hillside erosion, equivalent to as high as 9 inches per 1000 years or 1.5 tons per acre per year in the Jewell watershed. The muck zones represent relatively slow rates of hillside erosion; these rates become less than 1 inch per 1,000 years at Colo, or <0.1 tons per acre per year. Vegetative data support the view that these changes in rates of erosion are related to climatic changes which influenced the stability of the landscape through modification of the vegetative cover. While the pollen data reflect extra-regional as well as regional and local changes, the bog strata and rates of erosion reflect local changes. These local changes are more important in determining the history of soil and landscape in bog watersheds on the Des Moines lobe. Thus the emphasis in the presentation of the stratigraphy here is on the sedimentological sequence rather than the vegetative sequence as indicated by pollen data. This approach differs from the paleobotanical approach of recent investigations by Wright (1964, p. 636) who proposed that the sequence of main Wisconsin phases in Minnesota should terminate with replacement of spruce forest shortly after the Valders maximum of 10,500 BP. The sedimentological change from Cary to post-Cary on the Des Moines lobe in Iowa is clearly expressed in the difference between the Cary till and the sediment of the lower silt zone. This separation can be readily made in the field, and the lower silt zone sediments can be traced laterally from the bog center to adjacent hill-side toeslopes. The base of the lower silt zone is therefore a key horizon in defining the end of the Cary (13,000 BP) and the beginning of post-Cary surficial erosion on adjacent hillsides.

The relationship between upper bog strata and surficial hillside sediments establishes the continuity of the erosional and depositional system across the bog watersheds. This upper system relates to a period 8,000 to 3,000 BP which ended with the formation of the late post-Cary surface and soils under a prairie environment. If an earlier soil system occurred on upper hillslopes relating to the lower silt and lower muck zones, its main horizons have been removed by erosion.

On the basis of the stratigraphic and geomorphic principles outlined above, the Clarion-Nicollet-Webster toposequence of Riecken (1965, p. 59) on Cary till is considered to be the end-product of 5,000 years of relatively severe erosion on the landscape followed by 3,000 years of minimal erosion of the late post-Cary surface. Variations within the till, such as finer particle size towards the surface, mask some of the pedological effects on the landscape. However, geometric mean particle size data of some profiles in summit positions, such as the Webster profile C79, indicate that pedogenetically-derived clay B horizons do occur on the least unstable surfaces of the bog watersheds. The occurrence of a stone line at depth in some summit profiles (J80, JSSA), raises the problem of the pedogenetic relationship between A and B horizons in these soils. The JSS transect at Jewell was used as a model system representing pedogenesis on the late post-Cary surface in the one body of sediment with an enclosed depression at the lower end. Soil trends across this landscape were predictably systematic, and were readily plotted as parabolic curves. The principles established for this system have general applicability to similar enclosed systems on the Cary till of Iowa. There is evidence that the clay B horizon maximum of upper slope profiles is in part due to lateral sedimentary changes within the surficial layer causing depletion of clay from the A horizons on upper slopes and clay enrichment of the A horizons of lower slope and depression soils.

In open situations, where the products of erosion are free to move from the base of the slope, lateral soil profile variations are more complex, and there is evidence that soil properties such as depth to carbonates, depth to gray mottles, and soil pH values, are not as closely related to present surface geometry as thickness of A horizon. This is readily explained by the fact that cycling of organic matter is a rapid process and sensitive to modification of the surface, whereas properties such as depth to gray mottles relate more to subsoil groundwater characteristics. In the open system, these kinds of soil properties may relate more to earlier conditions than conditions of the present.

XII. BIBLIOGRAPHY

Aandahl, A. R.
1948 The characterization of slope positions and their influence on the total nitrogen content of a few virgin soils of western Iowa. Soil Sci. Soc. America Proc. 13: 449-454.

American Commission on Stratigraphic Nomenclature.
1961 Code of stratigraphic nomenclature. Am. Assoc. Petrol. Geologists Bull. 45: 645-665.

American Geological Institute.
1957 Glossary of geology and related sciences. Nat. Acad. Sci. National Research Council Publ. 501.

Anderson, R. L. and Houseman, E. E.
1942 Tables of orthogonal polynomial values extended to N=104. Iowa Agr. Expt. Sta. Res. Bull. 297.

Arnold, R. W.
1963 Silans in some brunizem soils. Unpublished Ph.D. thesis. Library, Iowa State University of Science and Technology, Ames, Iowa.

Bennett, H. H.
1939 Soil conservation. McGraw-Hill Book Co., New York, New York.

Black, C. A.
1961 Laboratory methods of soil investigation: soil fertility. (Mimeo.) Dept. Agronomy, Iowa State University of Science and Technology, Ames, Iowa.

Broecker, W. S. and Kulp, J. L.
1956 The radiocarbon method of age determination. Am. Antiquity 22: 1-11.

Brown, P. E.
1936 Soils of Iowa. Iowa Agr. Expt. Sta. Special Rept. 3.

Cardoso, J. V.
1957 Sequence relationships of Clarion, Lester, and Hayden soil catenas. Unpublished Ph.D. thesis. Library, Iowa State University of Science and Technology, Ames, Iowa.

Chamberlin, T. C.
1883 Preliminary paper on the terminal moraine of the second glacial epoch. U.S. Geol. Survey Ann. Rept. 3: 291-402.

Dachnowski, A. P.
1924 The stratigraphic study of peat deposits. Soil Sci. 17: 107-124.

Daniels, R. B., Rubin, M., and Simonson, G. H.
1963 Alluvial chronology of the Thompson Creek watershed, Harrison County, Iowa. Am. Jour. Sci. 261: 473-487.

Davis, Margaret B.
1958 Three pollen diagrams from Central Massachusetts. Am. Jour. Sci. 256: 540-570.

________.
1963 On the theory of pollen analysis. Am. Jour. Sci. 261: 897-912.

Dawson, J. E.
1956 Organic soils. Adv. in Agronomy 8: 377-401.

Deevey, E. S. and Flint, R. F.
1957 Postglacial hypsithermal interval. Science 125: 182-184.

DeKoster, G. R., Hussey, K. M., and Munson, R. D.
1959 The varied character of the Des Moines River valley in Central Iowa. Iowa Acad. Sci. Proc. 66: 312-316.

DeLury, D. B.
1950 Values and integrals of orthogonal polynomials up to n=26. Ontario Res. Foundation, Univ. Toronto Press, Toronto, Canada.

Droste, J. B.
1956 Alteration of clay minerals by weathering in Wisconsin tills. Geol. Soc. America Bull. 67: 911-918.

Durno, E. S.
1961 Evidence regarding the rate of peat growth. Jour. Ecology 49: 347-351.

Ely, C. W., Coffey, G. N., and Griffen, A. M.
1905 Soil survey of Tama County, Iowa. Bur. Soils, U.S. Dept. Agr., Washington, D.C.

Fisher, R. A. and Yates, F.
1963 Statistical tables for biological, agricultural and medical research. 6th ed. Hafner Publ. Co. Inc., New York, New York.

Flint, R. F.
1945 Glacial map of North America. Part 2. Bibliography and explanatory notes. Geol. Soc. America Special Paper 60.

________, Colton, R. B., Goldthwait, R. P., and Willman, H. B.
1959 Glacial map of the United States east of the Rocky Mountains. Geol. Soc. America, New York, New York.

Gwynne, C. S.
1941 Motion of the ice in Story County. Iowa Acad. Sci. Proc. 48: 289-292.

________.
1942 Swell and swale pattern of the Mankato lobe of the Wisconsin drift plain in Iowa. Jour. Geology 50: 200-208.

________ and Simonson, R. W.
1942 Influence of low recessional moraines on soil type pattern of the Mankato drift plain in Iowa. Soil Sci. 53: 461-466.

Handy, R. L.
1963 X-ray diffraction of highway materials: final report. (Mimeographed) Iowa Eng. Expt. Sta., Ames, Iowa.

Hidlebaugh, A. R.
1959 Variations in Mankato glacial till and related soil types in Hamilton County, Iowa. Iowa Acad. Sci. Proc. 66: 272-279.

Kay, G. F. and Apfel, E. T.
1929 The pre-Illinoian Pleistocene geology of Iowa. Iowa Geol. Survey 34: 1-304.

________ and Graham, J. B.
1943 The Illinoian and post-Illinoian Pleistocene geology of Iowa. Iowa Geol. Survey 38: 1-262.

________ and Leighton, M. M.
1933 Eldoran epoch of the Pleistocene period. Geol. Soc. America Bull. 44: 669-674.

Koch, L. E.
1956 Phosphate mineralization in alluvials near Cobargo. Aust. Jour. Sci. 18: 200-202.

Krumbein, W. C.
1959 Trend surface of contour-type maps with irregular control-point spacing. Jour. Geophys. Res. 64: 823-834.

________ and Pettijohn, F. J.
1938 Manual of sedimentary petrography. Appleton-Century Co., New York, New York.

Lane, G. H.
1931 A preliminary pollen analysis of the East McCulloch peat bed. Ohio Jour. Sci. 31: 165-171.

Lees, J. H.
1914 Physical features and geologic history of the Des Moines Valley. Iowa Geol. Survey Ann. Rept. 25: 423-615.

Leighton, M. M.
1933 The naming of the subdivisions of the Wisconsin glacial age. Science New Ser., 77: 168.

Leverett, F.
1922 What constitutes the Altamont moraine. (Abstract) Geol. Soc. America Bull. 38: 102-103.

Libby, W. L.
1955 Radiocarbon dating. Univ. Chicago Press., Chicago, Illinois.

________.
1963 Accuracy of radiocarbon dates. Science 140: 278-280.

Lounsbury, C. and Nordaker, P. E.
1924 Soil survey of Dallas County, Iowa. Bur. Soils, U.S. Dept. Agr., Washington, D.C.

Lyon, T. L., Buckman, H. O., and Brady, N. C.
1952 The nature and properties of soils. Macmillan Co., New York, New York.

Marean, H. W. and Jones, G. B.
1904 Soil survey of Story County, Iowa. Bur. Soils, U.S. Dept. Agr., Washington, D.C.

Martin, P. S.
1958 Taiga-tundra and the full-glacial period in Chester County, Pennsylvania. Am. Jour. Sci. 256: 470-502.

Mattson, S. and Koutler-Andersson, Elisabeth.
1954 Geochemistry of a raised bog. Roy. Agr. Coll. Sweden Annals 21: 321-366.

McComb, A. L. and Loomis, W. E.
1944 Subclimax prairie. Torrey Bot. Club Bull. 71: 46-76.

Mendell, F. H.
1927 A chemical and biological study of some peat soils. Unpublished M.S. thesis. Library, Iowa State University of Science and Technology, Ames, Iowa.

Oldham, C. H. G. and Sutherland, D. B.
1955 Orthogonal polynomials: their use in estimating the regional effect. Geophys. 20: 295-306.

Olson, E. A. and Broecker, W. S.
1958 Sample contamination and reliability of radiocarbon dates. New York Acad. Sci. Trans. 20: 593-604.

Peterson, J. B.
1946 Relation of parent material and environment to the clay minerals in Iowa soils. Soil Sci. 61: 465-475.

Richlen, E. M.
1957 Profile characteristics of depression topography soils in Humboldt County, Iowa. Unpublished M.S. thesis. Library, Iowa State University of Science and Technology, Ames, Iowa.

Riecken, F. F.
1945 Selection of criteria for the classification of certain soil types of Iowa into Great Soil Groups. Soil Sci. Soc. America Proc. 10: 319-325.

________.
1965 Present soil-forming factors and processes in temperate regions. Soil Sci. 99: 58-64.

________, Allaway, W. H., and Smith, G. D.
1947 Some soil classification and mapping problems in the Wisconsin drift area in Iowa. Soil Sci. Soc. America Proc. 12: 432-440.

_______ and Smith, G. D.
1949 Principal upland soils of Iowa: Agronomy 49. Agr. Ext. Service, Iowa State University of Science and Technology, Ames, Iowa.

Rigg, G. B.
1940 The development of sphagnum bogs in North America. Bot. Review 6: 663-693.

Robertson, J. H.
1939 A quantitative study of true prairie vegetation after three years of extreme drought. Ecology Mon. 9: 431-492.

Ruhe, R. V.
1950a Graphic analysis of drift topographies. Am. Jour. Sci. 248: 435-443.

_______.
1950b Petrographic notes on the loesses of the Des Moines drift lobe. Iowa Acad. Sci. Proc. 57: 277-281.

_______.
1952 Topographic discontinuities of the Des Moines lobe. Am. Jour. Sci. 250: 46-56.

_______.
1956 Landscape evolution in the High Ituri Belgian Congo. Institut National Etude Agronomique Congo Belge Publ. Ser. Sci. 66.

_______.
1960 Elements of the soil landscape. Internat. Congr. Soil Science, 7th, Trans. 23: 165-170.

_______ and Daniels, R. B.
1958 Soils, paleosols, and soil-horizon nomenclature. Soil Sci. Soc. America Proc. 22: 66-69.

_______ and _______.
ca. 1965
Landscape erosion, geologic and historic. (to be published) Jour. Soil Water Cons.

_______ and Gould, L. M.
1954 Glacial geology of the Dakota County area, Minnesota. Geol. Soc. America Bull. 65: 769-792.

_______, Rubin, M., and Scholtes, W. H.
1957 Late Pleistocene radiocarbon chronology in Iowa. Am. Jour. Sci. 255: 671-689.

_______ and Scholtes, W. H.
1959 Important elements in the classification of the Wisconsin glacial stage: a discussion. J. Geology 67: 585-593.

Russell, D. A.
1958 Laboratory manual for soil fertility students. 3rd ed. Brown Co., Dubuque, Iowa.

Russell, M. B. and Haddock, J. L.
1940 The identification of the clay minerals in five Iowa soils by the thermal method. Soil Sci. Soc. America Proc. 5: 90-94.

Scholtes, W. H., Ruhe, R. V., and Riecken, F. F.
1951 Use of the morphology of buried soils in the Pleistocene of Iowa. Iowa Acad. Sci. Proc. 58: 295-306.

Sharpe, C. F. S.
1938 Landslides and related phenomena. Columbia Univ. Press, New York, New York.

Shaw, R. H. and Waite, P. J.
1964 The climate of Iowa. III. Monthly, crop season and annual temperature and precipitation normals for Iowa. Iowa Agr. Expt. Sta. Special Rept. 38.

Sheehan, W. F.
1961 Physical chemistry. Allyn and Bacon, Inc., Boston, Massachusetts.

Simonson, R. W.
1959 Outline of a generalized theory of soil genesis. Soil Sci. Soc. America Proc. 23: 152-156.

Smith, G. D., Allaway, W. H., and Riecken, F. F.
1950 Prairie soils of the Upper Mississippi Valley. Adv. in Agronomy 2: 157-205.

Stevenson, W. H., Brown, P. E., Howe, F. B., and Corson, G. E.
1918 Soil survey of Iowa, Webster County soils. Iowa Agr. Expt. Sta. Soil Survey Rept. 4.

Tanner, C. B. and Jackson, M. L.
1947 Nomographs of sedimentation times for soil particles under gravity or centrifugal acceleration. Soil Sci. Soc. America Proc. 12: 60-65.

U.S. Geological Survey.
1960 Preparation procedure for fossil pollens and spores. (Mimeo.) Paleontology and Stratigraphy Branch, Denver, Colorado.

U.S. Soil Survey Staff.
1951 Soil survey manual. U.S. Dept. Agr. Handbook 18.

________.
1960 Soil classification: a comprehensive system. 7th approximation. U.S. Government Printing Office, Washington, D.C.

U.S. Weather Bureau.
1960 Decennial census of United States climate: monthly averages for state climatic divisions, 1931-1960. U.S. Dept. of Commerce Climatography of the United States 85.

Voss, J.
1934 Postglacial migration of forests in Illinois, Wisconsin, and Minnesota. Bot. Gazette 96: 3-43.

Walker, P. H. and Brush, Grace S.
1963 Observations on bog and pollen stratigraphy of the Des Moines glacial lobe, Iowa. Iowa Acad. Sci. Proc. 70: 253-260.

Wallace, R. W.
1961 Initial erosion effects on Cary drift plain, central Iowa. Unpublished M.S. thesis. Library, Iowa State University of Science and Technology, Ames, Iowa.

________ and Handy, R. L.
1961 Stone lines on Cary till. Iowa Acad. Sci. Proc. 68: 372-379.

Weaver, J. E.
1954 North American prairie. Johnsen Publ. Co., Lincoln, Nebraska.

________ and Albertson, F. W.
1940 Deterioration of grassland from stability to denudation with decrease in soil moisture. Bot. Gazette 101: 598-624.

________ and ________.
1944 Nature and degree of recovery of grassland from the great drought of 1933 to 1940. Ecology Mon. 14: 393-479.

White, E. M.
1953 Subsoil textural variations on the Clarion-Webster experimental farm as related to the Mankato glacial deposit. Iowa Acad. Sci. Proc. 60: 438-441.

Wilding, L. P. and Westin, F. C.
1961 Characterization of the Sinai soils. Soil Sci. Soc. America Proc. 25: 380-384.

Wright, H. E.
1964 The classification of the Wisconsin glacial stage. Jour. Geology 72: 628-637.

_______ and Rubin, M.
1956 Radiocarbon dates of Mankato drift in Minnesota. Science 124: 625-626.

_______, Winter, T. C., and Patten, H. L.
1963 Two pollen diagrams from southeastern Minnesota: problems in the regional Lateglacial and Postglacial vegetational history. Geol. Soc. America Bull. 74: 1371-1396.

XIII. ACKNOWLEDGMENTS

The author wishes to acknowledge the helpful advice and criticism of Dr. R. V. Ruhe throughout the course of the study, and during the preparation of the manuscript. The counsel of Dr. F. F. Riecken has been appreciated both with respect to the technical aspects of the study and the organization of National Science Foundation resources for the field and laboratory research. The author is grateful to Dr. W. H. Scholtes for his direction in the early stages of the project.

The author also wishes to acknowledge the technical assistance given to the project by Mrs. Helen Arnold and Mr. William Jackson, Jr.

The encouragement and help given the author by his wife, Valda, is sincerely appreciated.

XIV. APPENDIX A

A. Soil Profile Data

This appendix contains field descriptions and laboratory data for all profiles on which analyses were carried out. Each profile is designated according to the particular area of study, and then according to its serial position in the sampling schedule, for example, at Colo, profiles number C1, C2, etc., and at Jewell, J1, J2, etc. In the overall arrangement of data, Colo profiles appear first, then Jewell, McCulloch, Woden and Hebron in that order. The field descriptions for each profile are followed immediately by tabulated laboratory data.

The terminology of field descriptions follows that in U.S. Soil Survey Staff (1951) and soil horizon nomenclature is according to the U.S. Soil Survey Staff (1960). All soil colors are described in terms of the Munsell notation for moist soils.

<u>AREA</u>: Colo bog | <u>PROFILE NUMBER</u>: C2

<u>Soil series</u>: not named; mapping unit P_3

<u>Location</u>: 25 ft. W and 6 ft. S of SE corner of SW¼ of NW¼, Section 11, R-21W, T-83N, Story County, Iowa

<u>Parent material</u>: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-14	N 2/0, muck
I C_{11}	14-19	5YR 2/1, CL
I C_{12}	19-32	10YR 2/1, SiCL
I C_{13}	32-48	10YR 2/1, 2.5Y 4/4, SiCL
II C_2	48-54	5Y 4/1, 5YR 4/8, SiCL, calc.
II C_3	54-74	5Y 5/1, 5YR 3/4, SiL, calc.
II C_4	74-80	5Y 4/1, 5YR 4/8, SiCL, calc.
III C_5	80-96	N 5/0, 5Y 4/3, L, calc.

Profile Number: C2

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-14	6.5	--	19.8	16	1.71
14-19	6.0	--	13.2	15	1.84
19-32	6.4	--	3.1	26	2.01
32-48	6.9	--	1.8	15	1.75
48-54	8.0	10.0	1.4		
54-74	8.1	28.2	0.9	14	1.34
74-80	7.8	17.4	0.9	11	1.47
80-96	8.1			68	2.18

Mechanical Analysis % frequency for intervals given by upper size limit

Depth (inches)	μ <2μ	4	8	16	31	62	125	250	mm. 0.5	1.0	2	4	8	16
0-14	32.5	5.4	14.8	15.1	15.8	10.5	2.1	1.2	1.2	0.9	0.5			
14-19	31.9	10.8	11.4	14.5	13.8	8.8	3.7	2.5	2.0	0.5	0.1			
19-32	32.5	5.2	8.1	12.7	15.8	9.2	5.1	6.0	4.0	1.2	0.2			
32-48	31.0	10.1	10.6	17.6	15.1	7.4	3.0	2.9	1.6	0.4	0.2	0.1		
54-74	21.5	8.0	15.7	18.1	22.2	12.5	1.2	0.4	0.3	0.1				
74-80	28.1	13.5	14.6	16.7	16.6	9.1	1.5	0.6	0.3	0.1				
80-96	19.0	1.7	5.3	8.0	13.3	9.5	9.8	13.0	12.4	5.0	1.6	1.4		

AREA: Colo bog PROFILE NUMBER: C3

Soil series: not named; mapping unit P_1

Location: 28 ft. E, 198 ft. S of SE corner of SW¼ of NW¼ of Section 11, R-21 W, T-83N, Story County, Iowa

Parent material: interstratified upper bog sediment and hillside surficial sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-14	5YR 2/1, muck
I O_1	14-20	5YR 2/1, peat
I C_{11}	20-24	10YR 2/1, SL
I C_{12}	24-32	10YR 2/1, SL
I C_2	32-46	10YR 2/1, L
II C_3	46-62	10YR 2/1, SiL
II C_4	62-78	10YR 3/1, 2.5Y 5/2, SiL
III C_5	78-104	5Y 4/1, 2.5Y 8/1, SiL, calc.
III C_6	104-111	5Y 4/1, SiL, calc.
IV C_7	111-138	5Y 4/1, L, calc.

Profile number: C3

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. Carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-14	6.7		25.0		
14-20	6.6		17.3		
20-24	6.9		8.1		
24-32	7.3		3.7	117	1.79
32-46	6.9		4.0	38	2.08
46-62	7.1		3.0	25	1.82
62-78	6.2		3.5	14	1.45
78-104	8.3	29.1	1.3	12	1.28
104-111	7.9	19.2	1.5	17	1.47
111-138	7.6	19.2	--	57	2.12

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
24-32	11.4	4.2	4.9	2.5	11.8	16.2	23.3	19.0	5.1	1.3	0.3			
32-46	15.8	5.7	6.7	11.4	14.0	14.6	11.9	10.8	6.7	1.8	0.4	0.2		
46-62	18.6	5.9	8.6	15.1	19.8	13.8	8.3	5.5	2.9	0.8	0.1	0.4		
62-78	20.2	9.5	13.6	22.3	20.4	10.3	1.6	1.2	0.7	0.2				
78-104	26.5	8.9	13.8	20.9	21.8	6.6	0.8	0.3	0.2	0.1	0.1			
104-111	23.8	7.5	10.9	16.2	21.1	15.8	3.1	0.7	0.6	0.2	0.1			
111-138	20.3	4.7	5.1	7.2	9.3	12.0	9.9	18.4	11.9	1.0	0.2			

AREA: Colo bog PROFILE NUMBER: C4a

Soil series: Harpster (2), weakly calcareous; mapping unit 72

Location: 90 ft. E, 265 ft. S of SE corner of SW¼ of NW¼, Section 11, R-21W, T-83N, Story County, Iowa

Parent material: stratified hillside surficial over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-14	N 2/0, L, calc.
I A_{11}	14-21	N 2/0, 5Y 3/1, SL
I A_{12}	21-33	N 2/0, 5Y 3/1, SL, calc.
II C_1	33-40	5Y 5/2, L, calc.
II C_2	40-58	7.5YR 4/4, 5Y 5/1, SiL, calc.
III C_3	58-69	5Y 4/1, 5YR 4/6, L, calc.

Profile number: C4a

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-14	7.3	5.8	6.5	48	2.46
14-21	7.0	--	3.1	82	2.34
21-33	7.3	3.3	3.2	58	2.28
33-40	8.0	16.6	0.9	35	1.98
40-58	7.8	17.4	1.5	21	1.68
58-69	7.9	20.8	0.4	68	2.41

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-14	26.3	5.5	6.9	8.6	11.9	9.3	7.0	8.3	9.5	4.9	1.9	(0.4%>2mm)		
14-21	16.7	4.0	3.8	6.7	9.8	9.8	10.1	14.9	15.6	5.8	1.5	1.3		
21-33	19.3	4.3	4.6	8.7	11.9	11.6	11.1	12.6	10.4	3.5	0.9	1.1		
33-40	24.1	4.6	6.1	9.5	15.5	17.0	10.1	6.1	4.6	1.9	0.6	(0.6%>2mm)		
40-58	21.5	8.2	10.5	4.6	30.1	14.4	6.2	2.2	1.3	0.5	0.2	0.3		
58-69	21.3	3.7	5.3	7.6	7.9	8.9	8.5	11.7	11.7	5.4	2.1	2.8	3.1	

AREA: Colo bog PROFILE NUMBER: C12

Soil series: not named; mapping unit P_5

Location: 380 ft. W, 15 ft. S of SE corner of SW¼ of NW¼, Section 11, R-21W, T-83N, Story County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-12	N 2/0, muck
I O_1	12-20	10YR 2/1, peat
I C_{11}	20-72	10YR 2/1, SiCL, calc.
I C_{12}	72-114	10YR 2/1, SiCL, calc.
II O_{21b}	114-123	10YR 2/1, SiL, calc.
II O_{22b}	123-129	10YR 2/1, muck
II O_{11b}	129-138	5Y 3/2, peat
II O_{12b}	138-156	10YR 2/1, peat
II C_{1b}	156-180	5Y 4/1, SiCL
II C_{2b}	180-210	5Y 5/1, SiC, calc.
III C_{3b}	210-216	5Y 5/1, CL, calc.

Profile number: C12

Depth (inches)	pH	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-12	6.8		
12-20	6.6		
20-70	7.8		
72-114	7.7		
114-123	7.8		
123-129	6.8		
129-138	6.4		
138-156	6.8		
156-180	6.6		
180-210	8.5	13	1.51
210-216	8.5	58	2.54

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
180-210	40.5	8.0	11.9	14.6	15.8	6.5	0.8	0.6	0.6	0.4	0.1	0.1		
210-216	31.3	3.8	7.8	7.6	7.1	6.9	6.4	9.5	10.4	4.9	2.1	2.2		

AREA: Colo bog PROFILE NUMBER: C15

Soil series: not named; mapping unit P_6

Location: 338 ft. W and 110 ft. S of SE corner of SW¼ of NW¼, Section 11, R-21W, T-83N, Story County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-10	N 2/0, muck
I O_{11}	10-24	5YR 2/2, peat
I O_{12}	24-30	10YR 2/1, peat
I C_{11}	30-80	10YR 2/1, SiCL, calc.
I C_{12}	80-96	10YR 2/1, 5Y 4/1, SiL, calc.
II O_{21b}	96-114	10YR 2/1, SiL, calc.
II O_{22b}	114-126	10YR 2/1, muck, calc.
II O_{11b}	126-144	10YR 2/2, peat
II O_{12b}	144-162	10YR 5/2, peat, calc.
II C_{1b}	162-192	5Y 2/1, SiL, calc.
II C_{2b}	192-216	5Y 4/1, SiCL, calc.
II C_{3b}	216-243	5Y 5/1, SiCL, calc.
III C_{4b}	243-249	5Y 5/1, L, calc.

Profile number: C15

Depth (inches)	Bulk Density (gm./cc.)
36-42	0.44
72-78	0.74
114-120	0.21
120-126	0.18
144-150	0.15
156-162	0.15
174-180	0.21
186-192	0.47
204-210	0.77
216-222	1.09

<u>AREA</u>: Colo bog   <u>PROFILE NUMBER</u>: C18

<u>Soil series</u>: not named; mapping unit P_5

<u>Location</u>: 415 ft. W and 15 ft. S of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

<u>Parent material</u>: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-14	5YR 2/1, muck
I O_1	14-24	5YR 2/1, peat
I C_1	24-48	10YR 2/1, SiL, calc.
I C_2	48-58	2.5Y 6/2, SiCL, calc.
I C_3	58-76	5Y 2/1, SiCL, calc.
I C_4	76-90	2.5Y 5/2, SiL, calc.
II O_{2b}	90-102	10YR 2/1, muck, calc.
II C_{1b}	102-108	5Y 4/2, SiL, calc.
II C_{2b}	108-126	5Y 4/2, 5Y 8/1, SiL, calc.
II C_{3b}	126-138	5Y 4/1, SiL, calc.
III C_{4b}	138-144	5Y 4/1, SiL, calc.

Profile number: C18

Depth (inches)	pH	2μ to 2 mm. Geom. mean (μ)	Std. dev. phi units
0-14	7.2		
14-24			
24-48	7.6		
48-58			
58-76	7.5	12	1.41
76-90	7.9	12	1.52
90-102	7.9		
102-108			
108-126	7.4	12	1.33
126-138		7	1.37
138-144			

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
58-76	29.6	9.9	14.0	22.3	16.7	6.0	0.5	0.4	0.4	0.2				
76-90	24.9	10.7	14.6	20.4	19.3	6.0	1.5	1.3	0.9	0.4				
108-126	24.2	10.1	14.2	19.6	19.7	11.6	0.1	0.1	0.2	0.1	0.1			
126-138	58.4	15.2	11.8	7.7	4.3	1.7	0.2	0.3	0.3	0.1				

AREA: Colo bog — PROFILE NUMBER: C21

Soil series: not named; mapping unit P_6

Location: 350 ft. W, 13 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-12	5YR 2/1, muck
I O_{11}	12-29	5YR 2/2, peat
I O_{12}	29-36	10YR 2/1, peat
I O_{13}	36-50	10YR 2/1, peat, calc.
I C_1	50-63	10YR 2/1, SiL, calc.
I C_2	63-64½	2.5Y 5/2, FSL, calc.
I C_3	64½-66	10YR 2/1, SiL, calc.
I C_4	66-68	2.5Y 5/2, FSL, calc.
I C_5	68-87	10YR 2/1, SiCL, calc.
I C_6	87-88	5Y 5/1, SiL, calc.
Transition	88-103	10YR 2/1, SiL, calc.
II O_{21b}	103-122	10YR 2/1, muck, calc.
II O_{22b}	122-130	10YR 2/1, muck
II O_{23b}	130-159	5Y 2/2, muck, calc.
II O_{24b}	159-171	10YR 2/1, muck, calc.
II C_{1b}	171-189	5Y 3/2, FSL, calc.

AREA: Colo bog PROFILE NUMBER: C21

(continued)

Horizon	Depth (inches)	Description
II C_{2b}	189-192	5Y 4/1, SiCL, calc.
III C_{3b}	192-204	5Y 4/1, L, calc.

Profile number: C21

Depth (inches)	pH	2μ to 2 mm.	
		Geom. mean (μ)	Std. dev. phi units
0-12	6.5		
12-29	6.9		
29-36	7.7		
36-50	7.7		
50-63	7.8		
63-64½	8.1		
66-68	7.6		
68-87	7.7		
87-88	7.7		
88-103	7.7		
103-122	7.4		
122-130	6.8		
130-158	7.0		
159-171	7.5		
171-189	7.5		
189-192	7.7	12	1.60
192-204	7.4	56	2.36

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
189-192	31.8	11.2	14.2	14.5	16.6	7.2	1.2	1.3	0.9	0.4	0.1	0.6		
192-204	22.7	4.6	5.7	8.1	9.1	9.2	8.2	11.9	12.1	1.4	2.5	3.8	0.7	

AREA: Colo bog PROFILE NUMBER: C22

Soil series: not named; mapping unit P_6

Location: 278 ft. W, 13 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-9	N 2/0, muck
I O_1	9-32	5YR 2/1, peat
I C_1	32-38	10YR 2/1, CL, calc.
I C_2	38-52	10YR 3/1, C, calc.
I C_3	52-89	10YR 2/1, SiC, calc.
I C_4	89-90	5Y 6/2, SiL, calc.
I C_5	90-120	10YR 2/1, SiCL, calc.
II O_{21b}	120-134	10YR 2/1, muck, calc.
II O_{22b}	134-154	5Y 2/1, muck
II O_{23b}	154-177	5Y 2/1, muck
II O_{24b}	177-179	5Y 4/3, muck, calc.
II O_{25b}	179-189	5Y 2/1, muck
II C_{1b}	189-206	5Y 3/2, SiCL
II C_{2b}	206-209	5Y 2/1, SiCL, calc.
II C_{3b}	209-216	5Y 4/1, SiL, calc.
II C_{4b}	216-221	10YR 2/1, SiL, calc.

AREA: Colo bog PROFILE NUMBER: C22

(continued)

Horizon	Depth (inches)	Description
II C_{5b}	221-230	5Y 4/1, SiL, calc.
II C_{6b}	230-240	5GY 4/1, SiCL, calc.
III C_{7b}	240-246	5Y 5/1, L, calc.
III C_{8b}	246-276	5Y 5/1, L, calc.

Profile number: C22

Depth (inches)	pH	Exch.H m.e. %	Tot.Exch. Cat.m.e.%	%$CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std.dev. phi units	Density Depth (inches)	Density gm/cc
0-9	6.8	21.5	118.0	--	27.3	11	1.57		
9-32	6.9	12.4	96.0	--	31.5	13	1.63	at 18"	0.25
32-38	7.5			10.0	14.6				
38-52	8.1			16.7	14.9	11	1.26	42-48	0.28
52-89	7.9			11.7	5.8	13	1.46	66-72	0.51
89-90	8.1			25.0	1.2			84-90	0.68
90-120	8.2			12.5	12.1	12	1.47		
120-134	7.8			8.3	28.0	13	1.61	120-126	0.26
134-154	7.1			--	34.6	10	1.44	138-144	0.14
154-177	6.4			--	37.2	14	1.47	162-168	0.14
177-179				15.0	18.6			174-180	0.28
179-189	5.8			--	23.3	15	1.78		
189-206	6.2			--	10.6	10	1.15	192-198	0.39
206-209	7.4			11.7	10.8				
209-216	8.2			13.3	3.0				
216-221	8.0			15.8	1.6	12	1.18	216-222	0.65
221-230	8.1			22.5	1.4			228-234	0.95
230-240	8.2			20.0	2.6	7	1.03		
240-246	8.1			21.7	1.2				
246-264	8.0			25.2	--	88	2.38		
264-276	8.0			39.2	--	71	2.37		

Profile number: C22 (continued)

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-9	43.4	7.3	18.3	13.1	9.5	4.6	1.6	1.3	1.2					
12-18	35.8	8.6	15.7	13.9	13.8	7.1	2.2	1.5	1.6					
24-30	35.5	8.9	19.0	14.7	13.6	4.6	1.2	1.0	1.5					
45-51	45.2	8.8	12.1	14.0	13.6	6.4								
72-84	44.3	6.2	12.5	14.2	14.3	5.8	0.8	0.9	1.0					
96-108	36.1	8.9	14.1	19.1	13.6	5.3	0.9	1.0	1.1					
120-131	31.3	13.1	9.2	16.3	18.7	6.4	2.2	1.8	1.1					
144-150	37.6	11.4	15.6	14.5	11.9	7.1	0.6	1.4						
168-174	29.5	9.8	10.8	18.9	14.7	13.8	0.8	1.0	0.7					
180-186	30.3	9.0	13.3	17.8	13.8	6.4	3.7	3.8	2.0					
192-198	29.5	8.6	19.2	17.2	20.2	5.2								
216-220	22.1	8.2	15.9	19.7	25.0	9.1								
232-240	35.8	14.3	28.5	11.3	8.9	1.2								
246-264	14.3	2.8	5.0	6.2	9.1	7.8	8.7	13.6	14.5	6.7	3.7	4.9	2.7	
264-276	15.1	3.2	6.8	6.7	9.8	9.8	9.2	13.4	13.2	6.0	2.5	3.6	0.7	

AREA: PROFILE NUMBER: C23

Soil series: not named; mapping unit P_5

Location: 278 ft. W, 145 ft. N of SE corner of SW$\frac{1}{4}$ of NW$\frac{1}{4}$ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-11	10YR 2/1, muck
I O_1	11-24	10YR 2/1, peat
I O_2	24-41	10YR 2/1, muck, calc.
I C_1	41-43	5Y 5/2, SiL, calc.
I C_2	43-86	10YR 2/1, SiCL, calc.
I C_3	86-89	5Y 3/1, SiL, calc.
I C_4	89-106	N 2/0, SiL, calc.
II O_2b	106-135	10YR 2/1, muck
II O_2b	135-146	5Y 2/1, muck
II C_1b	146-158	5Y 3/1, SiL
II C_2b	158-175	5Y 3/1, SiL, calc.
II C_3b	175-213	5Y 4/1, SiL, calc.
III C_4b	213-216	5Y 4/1, L, calc.

Profile number: C23

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2 to 2 mm. Geom. mean (μ)	2 to 2 mm. Std. dev. phi units
0-11	6.8	--	30.3		
11-24	6.7	--	33.7		
24-41	7.9	5.0	24.2		
41-43	7.7	22.5	11.9		
43-86	8.3	10.0	7.6		
86-89	8.3	18.3	--		
89-106	8.0	10.0	3.8		
106-135	6.9	--	29.3		
135-146	6.5	--	23.9		
146-158	6.7	--	9.8		
158-175	7.8	8.3	4.0		
175-213	8.4	17.5	2.7	12	1.48
213-216	8.2	17.5	1.3		

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
175-213	27.7	11.5	14.3	20.6	16.3	6.7	0.9	0.8	0.8	0.4				

<u>AREA</u>: Colo bog PROFILE <u>NUMBER</u>: C24

<u>Soil series</u>: not named; mapping unit P_5

<u>Location</u>: 410 ft. W, 160 ft. S of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

<u>Parent material</u>: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-9	10YR 2/1, muck
I O_1	9-22	5YR 2/1, peat
I O_2	22-29	10YR 2/1, muck
I C_1	29-51	10YR 2/1, SiCL, calc.
I C_2	51-57	2.5Y 5/4, SiL, calc.
I C_3	57-77	10YR 3/1, SiCL, calc.
I C_4	77-94	5Y 5/3, SiCL, calc.
II O_{21b}	94-120	10YR 2/1, muck
II O_{22b}	120-126	5Y 2/2, L
II C_{1b}	126-156	5Y 3/1, SiL, calc.
III C_{2b}	156-162	5Y 4/1, L, calc.

Profile number: C24

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-9	7.3	--	25.2		
9-22	7.2	--	34.1		
22-29	7.2	--	26.8		
29-51	7.6	10.8	11.2		
51-57	7.9	10.8	5.5		
57-77	7.5	6.7	3.9	11	1.41
77-94	7.7	13.3	2.6		
94-120	6.7	--	26.5		
126-156	8.0	16.7	2.3	17	2.05

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
57-77	30.9	10.5	13.4	19.7	18.0	5.2	0.8	0.7	0.5	0.2	--	0.1		
126-156	21.9	10.0	13.8	18.8	18.2	8.4	2.0	2.1	1.9	1.1	0.5	1.3		

AREA: Colo bog PROFILE NUMBER: C25

Soil series: not named; mapping unit P_3

Location: 572 ft. E, 18 ft. N of SW corner of NW$\frac{1}{4}$ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: thin upper bog sediments over lower bog sediments over Cary till

Horizon	Depth (inches)	Description
I O_{21}	0-10	N 2/0, muck
I O_{22}	10-22	5YR 2/1, muck
I C_1	22-27	10YR 2/1, SiCL
I C_2	27-31	N 2/0, SiCL
I C_3	31-36	10YR 3/1, SiCL
II C_4	36-48	5Y 5/2, SiCL, calc.
II C_5	48-73	5Y 4/1, 2.5YR 5/3, SiCL, calc.
III C_6	73-78	5Y 4/1, 2.5YR 5/3, L, calc.

Profile number: C25

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2µ to 2 mm. Geom. mean (µ)	2µ to 2 mm. Std. dev. phi units
0-10	6.9	--	17.7	16	1.71
10-22	6.1	--	22.7	15	1.84
22-27	6.5	--	14.3	26	2.01
27-31	6.5	--	7.0	15	1.75
31-36	6.5	--	2.1		
36-48	8.4	18.3	0.4	14	1.34
48-73	8.0	20.0		11	1.47
73-78	8.1	22.5	0.3	68	2.18

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.					
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
36-48	27.6	9.2	14.7	15.6	14.4	11.1	2.2	2.4	2.1	0.5	0.1			
48-73	30.9	13.2	12.4	14.6	9.4	3.9	3.8	4.3	3.7	1.4	0.6	0.9	0.9	
73-78	20.8	5.5	7.1	11.4	8.6	10.4	7.5	9.9	9.9	3.9	1.5	1.9	1.8	

AREA: Colo bog PROFILE NUMBER: C26

Soil series: not named; borders Harpster on lower sides; mapping unit P_1

Location: 65 ft. E, 230 ft. S of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: hillside surficials over lower bog sediments over Cary till

Horizon	Depth (inches)	Description
I O_2	0-10	N 2/0, muck
I A_{11}	10-15	10YR 2/1, SL
I A_{12}	15-19	10YR 2/1, 10YR 4/1, CL
I A_{13}	19-19½	10YR 4/1, S
I A_{14}	19½-20½	10YR 2/1, SL
I A_{15}	20½-26	2.5Y 2/1, SL, calc.
I A_{15}	26-31	2.5Y 2/1, SL
II C_1	31-42	5Y 5/1, 7.5YR 4/4, SiL, calc.
II C_2	42-52	5Y 5/1, 5Y 5/4, SL, calc.
III C_3	52-84	5Y 5/1, 5YR 4/6, L, calc.
III C_4	84-144	5Y 3/1, L, calc.
III C_5	144-180	5Y 4/1, L, calc.
III C_6	180-240	5GY 4/1, L, calc.

Profile number: C26

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-10	6.7	--	15.2	45	2.49
10-15	7.6	--	2.8	141	1.97
15-19	6.9	--	8.3	34	2.07
19-19½	6.9	--	1.6		
19½-20½		--	3.1	125	1.80
20½-26	7.7	4.2	3.2	105	1.85
26-31	6.6	--	1.9	84	2.05
31-42	7.8	17.5	--	17	1.64
42-52	8.4	10.0	--		
52-63	7.7	15.8		44	2.58
72-84	8.0	20.4		88	2.32
120-144	7.8	17.5		78	2.44
144-168	7.9	20.8		76	2.43
168-192	7.9	17.9			
192-216	7.6	20.8		77	2.38
216-240				88	2.51

Profile number: C26 (continued)

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-10	27.5	6.4	7.1	9.7	8.8	10.3	6.4	8.3	9.4	4.6	1.5	0.1		
10-15	10.2	0.6	2.8	4.3	6.5	5.5	11.5	19.8	22.1	9.1	3.3	2.3	2.0	
15-19	28.8	6.1	7.0	10.1	14.5	12.2	7.6	7.1	3.5	1.7	1.5	(1%>2mm)		
19½-20½	8.3	1.8	2.5	0.5	9.3	17.5	13.4	21.2	17.2	5.2	1.2	1.9		
20½-26	9.9	2.0	2.4	4.0	5.1	13.4	15.8	22.2	15.8	5.5	1.7	0.8	1.4	
26-31	15.1	2.4	3.3	5.7	9.9	11.0	14.9	17.4	13.9	5.3	1.4	(1.5%>2mm)		
31-42	22.2	7.3	10.8	19.5	21.6	10.8	2.7	2.7	1.7	0.4	0.2	0.1		
52-63	19.7	9.2	6.2	7.6	12.0	5.8	6.4	10.3	10.3	3.9	1.6	2.2	4.8	
72-84	15.4	2.5	7.1	2.9	7.4	10.0	8.7	15.2	15.7	6.2	2.2	3.0	3.7	
120-144	21.2	4.3	5.3	6.6	4.7	9.0	8.1	13.4	13.7	5.8	2.3	3.6	2.0	
144-168	16.3	3.3	5.3	11.1	3.9	9.2	8.7	13.2	14.4	6.1	2.8	3.5	2.2	
192-216	15.5	3.7	6.0	7.0	8.3	9.4	9.5	14.1	14.6	6.5	2.6	2.8		
216-240	14.9	4.2	4.5	6.4	10.6	4.2	8.5	12.3	12.6	12.6	2.3	4.6	2.3	

AREA: Colo bog PROFILE NUMBER: C28

Soil series: not named; mapping unit P_3

Location: 177 ft. W, 390 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-9	5YR 2/1, muck
I O_1	9-24	5YR 2/2, peat
I C_{11}	24-36	N 2/0, SiL
I C_{12}	36-45	N 2/0, SiCL
II C_2	45-58	5Y 7/1, 5YR 4/3, SiL, calc.
II C_3	58-72	5Y 4/1, 2.5YR 4/6, SiCL, calc.
III C_4	72-81	5Y 5/1, L, calc.

Profile number: C28

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-9	6.6	--	28.2		
9-24	6.4	--	26.7		
24-36	5.6	--	14.0		
36-45	6.5	--	3.9	14	1.61
45-58	8.0	23.3	1.9	11	1.35
58-72	7.9	15.8	1.4	12	1.60
72-81	8.3	15.8		45	2.49

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
36-45	28.3	9.3	12.7	17.4	19.7	6.1	2.0	2.1	1.5	0.6	0.1	0.2		
45-48	24.6	10.7	15.5	22.1	20.1	4.7	0.8	0.7	0.5	0.2	--	0.1		
58-72	30.7	10.6	16.1	15.3	14.7	8.4	1.4	1.4	1.0	0.3	0.1			
72-81	19.9	5.3	9.1	11.8	9.2	9.4	6.2	9.1	10.0	4.6	1.8	2.0	1.6	

AREA: Colo bog PROFILE NUMBER: C29

Soil series: not named; mapping unit P_3

Location: 580 ft. W, 422 ft. S of SE corner of SW$\frac{1}{4}$ of NW$\frac{1}{4}$ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-10	5YR 2/1, muck, calc.
I O_1	10-19	5YR 2/1, peat
I C_1	19-27	10YR 2/1, SiL
I C_2	27-46	N 2/0, L, calc.
II C_{31}	46-54	5Y 4/1, 5YR 4/8, SiL, calc.
II C_{32}	54-78	5Y 4/1, 5YR 3/4, SiL, calc.
III C_4	78-96	5Y 5/1, 10YR 4/4, L, calc.

Profile number: C29

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-10	7.7	11.7	22.0		
10-19	6.4	--	30.2		
19-27	6.6	--	13.2		
27-46	8.0	7.5	3.4	41	2.13
46-54	8.4	27.5	1.6		
54-78	8.6	29.2	0.7	14	1.37
78-96	8.1	21.7	0.6	40	2.26

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
27-46	20.4	5.9	6.8	8.4	12.9	14.4	9.8	12.2	7.3	1.6	0.2	0.1		
54-78	25.5	9.3	12.8	30.3	7.4	12.4	1.0	0.7	0.4	0.2				
78-96	16.8	5.8	8.2	11.1	11.7	12.1	8.8	11.0	7.9	2.6	1.0	1.2	1.8	

AREA: Colo bog PROFILE NUMBER: C30

Soil series: Clarion, stratified variant; mapping unit 6

Location: 243 ft. E, 455 ft. S of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: sand from the Cary glacier

Horizon	Depth (inches)	Description
A_p	0-2	10YR 2/1, SL
A_{11}	2-16	10YR 2/1, SL
A_{12}	16-30	10YR 3/1, SL
A_{13}	30-44	10YR 3/1, SL
A_{14}	44-51	10YR 3/1, SL
B	51-63	10YR 4/2, SL, calc.
B	63-90	10YR 4/2, LS, calc.
C_{11}	90-100	10YR 5/4, S, calc.
C_{12}	100-115	10YR 5/4, S, calc.
C_2	115-118	7.5YR 4/4, 5Y 7/1, S, calc.
C_3	118-138	10YR 5/4, S, calc.
C_4	138-180	10YR 4/2, S, calc.

Profile number: C30

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-2	7.2	--	1.03	158	2.17
2-16	7.5	--	1.10		
16-30	7.1	--	1.09	242	1.74
30-44	6.9	--			
44-51	8.5	--	1.00	209	1.78
51-63	8.3	1.2			
63-90	8.6	5.8		283	1.69
90-100	8.5	6.7			
100-115	8.6	5.8		425	1.35
115-118	8.1	17.5			
118-138	8.9	7.9		295	1.75
138-160	8.3	8.3			
160-180	8.8	9.2		309	1.72

Profile number: C30 (continued)

Mechanical analysis % frequency for intervals given by upper size limits

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-2	8.9	3.8	2.1	3.4	5.2	2.7	6.2	18.9	31.9	10.0	2.8	4.1		
2-16	11.3	1.0	2.4	3.6	3.2	4.8	6.1	17.7	31.2	10.7	2.8	4.6	0.6	
16-30	9.5	0.3	1.1	4.4	2.5	2.2	3.8	14.9	37.1	14.4	4.6	4.6	0.6	
30-44	10.0	0.8	1.5	3.2	2.3	5.9	4.8	18.0	36.0	11.2	3.0	3.3		
44-51	10.1	0.9	2.1	3.4	1.8	3.9	4.8	18.2	37.7	11.0	2.8	1.6	1.7	
51-63	10.6	0.2	0.9	2.2	2.2	3.0	4.7	17.6	35.7	14.6	5.5	1.5	1.3	
63-90	7.4	3.0	0.2	0.5	0.7	2.4	3.1	14.9	43.1	18.3	4.4	2.0		
90-100	3.7	0.5	0.7	0.1	3.0	0.4	3.7	19.6	47.4	17.1	2.8	1.0		
100-115	2.6	1.8	-	1.6	1.7	1.7	4.5	26.2	52.6	6.6	0.4	0.2		
115-118	7.4	3.4	5.2	10.2	15.0	11.3	7.4	18.9	16.8	3.6	0.4	0.4		
118-138	1.4	-	3.6	0.4	0.4	1.4	2.1	13.0	48.3	25.8	2.9	0.7		
138-160	7.2	0.5	2.9	2.2	-	1.5	3.9	17.2	34.4	24.4	3.7	2.1		
160-180	5.1	1.0	2.4	1.3	-	2.3	2.7	14.7	34.4	22.4	7.9	5.8		

AREA: Colo bog PROFILE NUMBER: C33

Soil series: Harpster; mapping unit 71

Location: 375 ft. E, 125 ft. N of SW corner of NW$\frac{1}{4}$ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: hillside surficial sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-10	10YR 3/1, L, calc.
I A_{11}	10-16	10YR 3/1, L, calc.
I B_{21}	16-21	5Y 3/1, L, calc.
I B_{22}	21-28	5Y 3/1, 2.5Y 5/4, L, calc.
II C_{11}	28-36	5Y 4/1, 10YR 4/4, SL, calc.
II C_{12}	36-50	5Y 5/1, 10YR 5/4, SL, calc.

Profile number: C33

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-10	8.2	37.9	1.34	35	2.50
10-16	8.5	41.7		29	2.46
16-21	8.5	38.7	0.86	37	2.95
21-28	8.5	35.8	0.60	40	2.58
28-36	8.3	15.8		58	2.45
36-52	8.4	22.5		95	2.35

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-10	19.7	8.6	10.6	10.3	11.4	8.4	6.5	8.9	8.9	3.4	1.4	1.9		
10-16	27.1	9.5	10.1	9.2	8.4	7.4	5.1	6.4	6.2	2.9	1.2	3.6	3.2	
16-21	22.4	8.9	8.1	10.9	9.7	9.6	5.4	7.2	7.2	3.6	1.3	2.8	2.9	
21-28	24.7	8.4	8.2	8.4	8.5	8.9	6.2	7.8	8.7	4.0	1.8	2.0	2.4	
28-36	15.5	5.0	6.0	8.4	7.7	9.4	9.6	10.7	9.8	5.2	2.3	7.8	2.6	
36-52	11.4	2.2	5.4	7.3	8.6	7.0	8.9	13.9	15.0	7.5	3.3	5.4	4.1	

AREA: Colo bog PROFILE NUMBER: C39

Soil series: Webster (2), calcareous; mapping unit 46

Location: 310 ft. N, 172 ft. E of SW corner of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: stratified Cary till

Horizon	Depth (inches)	Description
A_p	0-8	N 2/0, SiC
A_1	8-14	N 2/0, CL, calc.
B_1	14-24	5Y 4/1, N 2/0, C, calc.
B_{21}	24-30	5Y 5/2, 5Y 3/1, SiC, calc.
B_{22}	30-42	5Y 5/1, C, calc.
B_{31}	42-60	5Y 4/1, 10YR 5/6, C, calc.
B_{32}	60-78	5Y 4/1, 10YR 5/6, SiCL, calc.
C_{11}	78-100	5Y 5/1, 10YR 5/6, CL, calc.
C_{12}	100-120	5Y 5/2, 5Y 4/1, C, calc.
C_2	120-144	5Y 5/2, L, calc.
C_3	144-156	5Y 5/1, SiCL, calc.
C_4	156-168	5Y 5/1, L, calc.

Profile number: C39

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-8	7.7	1.1	1.92	27	2.07
8-14	7.6	4.0	1.52	17	1.94
14-24	8.0		0.7	21	2.14
24-30	7.8	5.8		24	2.22
30-42	8.1			24	2.62
42-60	8.0	11.2	0.55	26	2.62
60-78	7.9	13.3		21	2.42
84-96	8.1	16.7		20	2.05
108-120	8.0	9.2	0.30	9	1.80
120-132	7.9	15.0		52	2.38
156-168	7.9	15.8		60	2.42

Profile number: C39 (continued)

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.					
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-8	44.1	5.0	8.6	11.9	11.7	7.0	3.1	3.7	3.2	1.2	0.6	(0.6% 2mm)		
8-14	39.8	8.5	10.2	12.5	13.5	6.1	2.9	2.9	2.4	1.0	0.3			
14-24	43.4	6.9	7.9	12.6	11.1	6.0	2.9	3.7	3.7	1.3	0.3	0.2		
24-30	40.3	8.2	5.5	14.1	10.1	6.9	3.2	3.6	3.5	1.6	0.5	1.3	1.2	
30-42	48.4	10.8	7.4	5.2	9.6	3.8	3.2	4.0	3.9	2.4	1.3	(5.1% 2mm)		
42-60	40.5	10.5	10.0	9.8	5.7	3.7	3.7	5.7	6.3	2.6	0.7	0.8		
60-78	36.7	9.8	12.5	10.7	7.6	4.3	4.3	5.4	5.0	1.9	0.5	1.3		
84-96	29.1	10.5	10.9	11.9	12.0	9.3	6.9	6.2	2.7	0.4	0.1			
108-120	47.8	14.3	15.1	12.4	2.8	1.1	1.5	1.4	0.6	0.2	0.3			
120-132	22.4	7.0	7.9	7.5	6.4	7.8	7.4	10.4	11.1	4.8	1.7	2.6	3.0	
156-168	21.8	4.7	5.6	7.6	10.5	9.4	7.4	11.1	11.9	4.9	1.8	3.3		

AREA: Colo bog PROFILE NUMBER: C40

Soil series: Clarion, deep carbonates; mapping unit 3

Location: 600 ft. N, 12 ft. W of SE corner of NE$\frac{1}{4}$, Section 10, R-21W, T-83N, Story County, Iowa

Parent material: Cary till (stratified)

Horizon	Depth (inches)	Description
A_p	0-10	10YR 2/1, CL
A_1	10-16	10YR 2/1, CL
A_3	16-24	10YR 2/1, 10YR 3/2, CL
B_1	24-32	10YR 4/2, 10YR 3/2, SiCL
B_{21}	32-40	1Y 5/4, SiCL
B_{22}	40-48	2.5Y 5/4, SiCL
B_{23}	48-56	2.5Y 5/4, SiC
B_{31}	56-70	2.5Y 5/4, 5Y 6/2, L, calc.
B_{32}	70-84	2.5Y 5/4, 5Y 6/2, SL, calc.
C_{11}	84-114	2.5Y 5/4, 5Y 6/2, SL, calc.
C_{12}	114-144	2.5Y 5/4, 5Y 6/2, SL, calc.
C_{13}	144-168	2.5Y 5/4, 5Y 6/2, SL, calc.
C_2	168-180	5Y 4/1, 10YR 4/4, L, calc.
C_3	180-192	5Y 4/1, L, calc.

Profile number: C40

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-10	6.5	--	2.5	45	2.18
10-16	5.9	--	1.7	33	2.21
16-24	5.9	--	1.65	30	2.08
24-32	5.8	--	1.15	21	1.76
32-40	6.5	--	0.65	22	1.87
40-48	6.8	1.2		20	1.96
48-56	7.2	--		17	1.94
56-70	8.4	10.8	0.4	70	2.39
70-84	8.1	13.7		68	2.13
84-114	8.5	15.4		85	2.35
114-144	8.2	15.8		88	2.32
144-168	8.1	14.6	<0.1	76	2.37
180-192	8.0	15.0		67	2.34

Profile number: C40 (continued)

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-10	29.5	3.3	5.4	10.2	15.3	7.7	6.3	9.9	9.4	2.7	0.3			
10-16	32.0	4.8	7.3	10.9	15.0	8.4	4.6	6.9	7.6	2.2	0.3			
16-24	34.6	4.0	7.4	11.5	15.0	9.6	4.7	5.8	5.3	1.8	0.2	0.1		
24-32	37.4	5.4	7.1	11.8	17.6	11.2	3.9	2.7	2.1	0.6	0.1	0.1		
32-40	35.0	6.5	7.1	12.1	15.4	12.6	5.7	3.0	2.0	0.4	0.1	0.1		
40-48	38.5	7.7	10.1	8.9	15.6	7.9	3.9	3.8	3.0	0.5	-	0.1		
48-56	40.0	11.1	5.9	13.7	12.7	7.4	3.6	3.0	2.1	0.4	0.1			
56-70	17.7	3.9	6.7	5.4	10.3	8.1	9.7	13.2	13.0	6.0	2.0	2.5	1.5	
70-84	12.4	2.9	4.6	6.9	11.1	9.3	13.8	16.2	10.9	3.9	1.3	2.2	4.5	
84-114	15.0	3.7	3.7	6.4	8.6	9.0	9.9	13.3	13.6	7.1	3.1	4.0	2.6	
114-144	16.2	3.4	5.0	1.1	13.8	7.9	8.4	12.0	13.1	7.2	3.4	4.9	3.6	
144-168	17.2	4.2	3.8	6.7	10.4	8.0	8.8	13.4	13.6	6.1	2.4	4.9	0.5	
180-192	15.6	3.9	4.1	6.6	10.4	9.0	8.1	11.7	12.0	4.8	1.9	5.1	6.8	

AREA: Colo bog **PROFILE NUMBER:** C60

Soil series: Clarion; mapping unit 1

Location: 640 ft. E, 190 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: Cary till

Horizon	Depth (inches)	Description
A_p	0-6	10YR 2/1, CL
A_1	6-14	10YR 2/2, CL
B_2	14-27	10YR 3/3, L
B_{31}	27-48	2.5Y 4/3, L
B_{32}	48-63	2.5Y 4/3, SL, calc.
C_1	63-87	2.5Y 5/4, SL, calc.
C_2	87-120	2.5Y 5/4, 5Y 5/1, SL, calc.
C_2	120-144	2.5Y 5/4, 5Y 5/1, SL, calc.
C_3	144-166	5Y 5/2, 7.5YR 4/4, SL, calc.
C_4	166-180	5Y 4/1, 2.5YR 3/3, SL, calc.
C_5	180-204	5Y 4/1, SL, calc.

Profile number: C60

Depth (inches)	pH	Exch.H m.e. %	Tot.Exch. Cat.m.e.%	$\%CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
						Geom. mean (μ)	Std. dev. phi units
0-6	5.8			-	1.7	47	2.27
6-14	5.7			-	1.5	45	2.31
14-27	6.2	8.3	15.2	-	1.05	60	2.09
27-48	6.2	7.1	14.3	-	1.0	78	2.29
48-63	8.1			14.1	0.3	70	2.34
63-87	8.2			14.5		65	2.31
87-120	8.2			15.8	0.1	66	2.33
120-144	8.0			16.2		56	2.44
144-166				15.4		68	2.48
166-180	8.3			15.8		58	2.33
180-204	8.0			14.9		70	2.27

Profile number: C60 (continued)

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-6	30.2	3.2	5.4	10.0	17.4	4.6	6.1	9.1	9.8	3.4	0.6	0.2		
6-14	27.7	5.2	5.6	8.9	13.6	9.1	6.5	9.8	9.7	3.2	0.7			
14-27	25.4	2.9	10.7	1.6	8.6	9.3	8.5	12.3	11.3	4.1	1.0	2.9	1.4	
27-48	21.1	4.0	4.5	4.6	8.2	10.4	10.0	14.0	13.8	4.9	2.1	2.4		
48-63	16.9	3.6	4.2	8.9	9.5	9.7	8.6	12.4	12.6	6.1	2.2	2.4	2.9	
63-87	15.3	3.8	4.0	6.9	15.1	9.8	7.8	11.4	12.6	5.1	2.3	2.0	3.8	
87-120	16.4	4.6	5.5	6.5	9.9	11.1	10.0	13.2	12.6	4.9	1.9	1.8	1.6	
120-144	20.7	5.0	6.1	8.2	10.0	10.5	7.2	9.8	10.9	4.6	2.3	3.4	1.3	
144-166	18.0	6.0	4.5	6.9	3.6	12.9	8.1	10.4	12.3	5.4	2.6	4.0	5.3	
166-180	17.1	4.2	4.4	8.6	10.6	10.7	7.6	10.8	11.8	5.0	1.9	2.6	4.7	
180-204	16.2	3.5	4.6	6.8	8.0	14.9	8.0	12.2	12.7	5.4	1.9	2.7	3.0	

AREA: Colo bog PROFILE NUMBER: C73

Soil series: Clarion, stratified variant; mapping unit 8

Location: 645 ft. S, 16 ft. E of SW corner of NW$\frac{1}{4}$ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: sand of the Cary drift

Horizon	Depth (inches)	Description
A_p	0-14	10YR 2/1, SL
A_1	14-27	10YR 2/2, SL
B	27-38	10YR 3/3, SL, calc.
C_1	38-66	10YR 5/4, LS, calc.
C_{21}	66-90	10YR 5/4, S, calc.
C_{22}	90-114	10YR 5/4, S, calc.
C_3	114-130	10YR 5/4, S, calc.
C_{41}	130-133	2.5Y 5/4, S, calc.
C_{42}	133-156	2.5Y 5/4, S, calc.

Profile number: C73

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-14	7.8	--	1.35	127	1.92
14-27	7.9	--	1.15	135	1.86
27-38	8.2	2.9	1.0	133	1.86
38-66	8.5	9.1	0.6	134	1.94
66-90	8.7	9.1	0.6	138	1.31
90-114	8.6	11.2	0.15	193	1.27
114-130	9.0	16.2		542	1.19
130-133	8.8	13.8	<0.1	173	1.48
133-156	8.9	8.3		212	1.30

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-14	12.9	2.1	0.2	3.9	7.6	6.6	13.0	19.8	18.0	7.2	2.2	4.5	2.0	
14-27	12.2	0.9	2.9	1.6	5.3	7.6	14.2	21.3	17.6	7.3	2.5	5.2	1.4	
27-38	11.3	1.6	2.4	1.6	3.9	8.6	17.9	21.9	15.3	7.6	3.3	4.6		
38-66	7.5	2.2	1.7	1.8	5.1	7.1	16.2	23.2	18.5	6.9	2.7	3.3	3.8	
66-90	2.0	0.6	0.4	0.5	1.2	1.9	11.1	31.7	30.9	8.2	3.6	4.5	3.3	
90-114	4.7	-	0.1	0.7	1.9	4.5	19.2	29.4	24.7	8.5	2.4	2.0	1.9	
114-130	1.3	0.8	-	0.8	0.1	1.2	2.8	19.0	46.0	19.0	3.7	2.6	2.5	
130-133	5.4	1.1	1.2	1.8	0.9	3.4	16.1	36.7	20.3	6.5	3.2	3.4		
133-156	3.1	0.8	-	1.4	1.9	1.7	9.3	35.4	32.8	7.5	1.8	3.0	1.3	

AREA: Colo bog PROFILE NUMBER: C77

Soil series: not named; mapping unit P_1

Location: 505 ft. S, 520 ft. E of SW corner of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: stratified hillside surficial deposit and upper bog sediment over lower bog sediment over till

Horizon	Depth (inches)	Description
I A_{11}	0-12	10YR 2/1, CL, calc.
I A_{12}	12-14	10YR 3/1, L, calc.
I A_{13}	14-24	10YR 2/1, L
II A_{14}	24-42	10YR 2/1, SiL
II A_{15}	42-43	2.5Y 4/4, SiL
II A_{16}	43-48	10YR 2/1, SiCL
II A_{17}	48-58	10YR 2/1, CL
III C_{11}	58-80	5Y 5/2, 5Y 5/4, SiCL
III C_{12}	80-100	5Y 5/2, 5Y 5/4, SiCL
III C_2	100-114	5GY 4/0, SiCL
III C_{31}	114-140	5GY 4/0, SiL, calc.
III C_{32}	140-168	5GY 4/0, SiL, calc.
III C_4	168-180	5GY 4/0, SiCL, calc.
III C_5	180-198	5Y 4/1, L, calc.

Profile number: C77

Depth (inches)	pH	2μ to 2 mm.	
		Geom. mean (μ)	Std. dev. phi units
0-12	7.5	58	2.40
12-24	7.1	70	2.32
24-42	7.0	56	2.42
43-48	7.0	17	1.72
48-58	7.3	26	1.97
58-80	7.6	16	1.67
100-114	7.9	13	1.29
114-140	7.6	17	1.61
168-180	7.8	13	1.52
180-198	7.9	41	2.08

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-12	28.2	4.2	6.1	7.8	11.6	8.8	7.2	9.4	11.1	4.6	1.0	(0.6%>2mm)		
12-24	21.8	3.0	5.2	8.0	10.9	8.2	8.0	12.4	14.3	6.3	1.2	0.7		
24-42	23.7	3.9	7.7	6.5	11.4	9.8	5.4	10.2	12.1	5.4	1.4	1.3	2.2	
43-48	28.9	7.2	10.4	15.0	21.5	10.3	1.3	1.7	2.0	1.0	0.3	0.4		
48-58	27.7	4.5	7.5	14.5	17.1	11.8	4.4	6.6	4.4	1.2	0.2	0.1		
58-80	28.4	6.2	11.1	21.2	20.5	6.4	0.8	1.5	2.0	0.9	0.3	0.7		
100-114	27.0	8.1	12.5	21.8	21.5	6.9	0.5	0.5	0.6	0.3	0.2	0.1		
114-140	23.9	7.2	12.1	17.4	19.0	14.1	2.9	1.7	1.0	0.5	0.2	-		
168-180	29.8	8.2	13.3	17.9	22.6	2.3	3.3	1.3	0.9	0.4				
180-198	16.6	4.5	6.4	10.4	13.9	17.7	9.9	9.9	6.5	2.4	0.9	0.5	0.9	

AREA: Colo bog PROFILE NUMBER: C79

Soil series: Webster; mapping unit 41

Location: 1095 ft. S, 6 ft. E of SW corner of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: Cary till

Horizon	Depth (inches)	Description
A_p	0-12	10YR 2/1, CL
A_1	12-17	10YR 2/1, CL
A_3	17-24	10YR 3/1, CL
B_1	24-32	5Y 4/1, 10YR 3/1, CL
B_2	32-45	5Y 4/1, CL
B_3	45-62	5Y 4/1, 2.5Y 5/4, CL
C_{11}	62-75	5Y 5/1, 10YR 4/4, L, calc.
C_{12}	75-108	5Y 5/1, 2.5Y 5/4, L, calc.
C_2	108-117	5Y 3/1, 2.5Y 4/4, L, calc.
C_3	117-123	5Y 4/1, SL, calc.
C_4	123-128	5Y 4/1, SiL, calc.
C_5	128-140	5Y 4/1, 10YR 5/6, L, calc.
C_6	140-160	5Y 4/1, L, calc.

Profile number: C79

Depth (inches)	pH	Exch.H m.e. %	Tot.Exch. Cat.m.e.%	$\%CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
						Geom. mean (μ)	Std. dev. phi units
0-12	6.2	10.2	29.7	--	2.40	44	2.46
12-17	6.5			--	2.35	46	2.53
17-24	7.1	6.6	29.2	--	1.15	36	2.29
24-32	6.9			--	0.65	40	2.30
32-45	7.1	5.7	29.2	--		34	2.50
45-58	7.8			--		29	2.47
62-75	7.9			10.8	0.3	44	2.55
75-108	8.0			13.7		49	2.49
108-117	8.0			13.3		49	2.71
128-140	8.0			14.9	0.25	44	2.41
140-160	8.0			14.9		57	2.52

Profile number: C79 (continued)

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-12	35.9	5.2	5.1	12.3	8.6	5.4	5.5	8.1	9.3	3.8	0.7	0.1		
12-17	36.3	4.4	6.6	9.6	11.7	2.2	5.9	8.0	8.5	4.1	1.6	1.2		
17-24	37.3	4.7	4.8	11.7	12.6	6.5	4.6	6.0	6.4	2.6	0.8	2.0		
24-32	38.2	2.9	6.9	9.9	10.3	8.6	5.3	6.0	6.2	2.8	1.2	1.7		
32-45	37.3	7.3	9.4	7.2	7.0	7.6	6.1	7.3	6.2	2.6	0.9	1.1		
45-48	33.1	8.2	11.2	10.0	7.0	8.2	5.5	6.7	6.4	2.7	0.7	0.3		
62-75	22.7	7.9	9.7	7.5	6.9	8.5	7.4	10.8	10.1	4.3	1.0	1.5	1.7	
75-108	21.1	6.4	7.9	6.8	3.6	8.1	9.5	14.6	13.0	4.8	1.9	2.3		
108-117	23.0	9.0	11.4	5.5	9.7	8.9	9.0	10.4	8.5	2.7	0.8	1.1		
128-140	24.2	6.9	8.4	7.3	7.8	9.2	9.8	11.7	8.4	3.1	0.9	1.0	1.3	
140-160	21.6	5.8	7.2	8.0	6.9	8.3	8.5	11.6	10.9	4.9	2.1	3.5	0.7	

AREA: Colo bog   **PROFILE NUMBER:** C100

Soil series: Terril; mapping unit 22

Location: 555 ft. S, 190 ft. E of SW corner of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: surficial hillside sediment over toeslope sandy sediment

Horizon	Depth (inches)	Description
I A_p	0-7	10YR 2/1, L
I A_1	7-22	10YR 2/1, CL
I A_3	22-28	10YR 3/1, SiCL
I B_2	28-48	2.5Y 4/2, L, calc.
I C_1	48-54	5Y 5/1, 10YR 5/8, S, SiL, calc.
II C_2	54-66	5Y 5/3, 10YR 5/6, SL, calc.
II C_3	66-96	5Y 5/3, 5Y 5/1, SL, calc.
II C_4	96-110	5Y 4/1, 7.5YR 5/6, SL, calc.
III C_5	110-120	5Y 4/1, L, calc.

Profile number: C100

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-7	7.1	--	2.4	64	2.35
7-22	6.8	--	1.4	47	2.56
22-28	7.4	--	0.95	39	2.46
28-48	8.2	3.7	0.4	72	2.22
48-54	8.1	12.9	0.25	72	2.36
54-66	8.3	13.7		83	2.22
66-96	8.3	14.5	<0.1	97	2.27
96-110	8.2	13.7		72	2.38
110-120	8.2	15.8		79	2.43

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-7	23.5	3.8	5.0	9.0	9.7	8.3	7.0	12.5	14.0	4.8	0.9	1.5		
7-22	27.8	4.9	7.3	10.4	12.4	4.9	5.3	9.5	10.9	4.5	1.2	0.9		
22-28	30.1	6.1	5.9	10.6	17.0	6.2	1.6	8.6	8.9	3.5	0.9	0.6		
28-48	18.1	2.9	4.1	6.9	12.0	10.1	9.2	14.3	12.7	5.3	1.6	2.0	0.8	
48-54	19.1	3.7	4.7	7.7	9.6	10.0	8.6	13.0	13.4	5.7	2.2	1.8	0.5	
54-66	14.6	3.0	3.8	5.9	9.9	7.8	10.4	13.5	14.7	6.1	1.9	4.9	3.5	
66-96	8.7	4.2	2.8	5.3	9.3	8.0	10.3	18.0	18.0	7.3	2.7	2.6	2.8	
96-110	10.0	6.5	2.3	5.9	9.7	10.7	10.3	13.4	12.2	5.8	2.5	7.5	3.2	
110-120	12.9	3.2	2.8	6.5	8.7	7.2	6.4	10.1	10.6	5.5	3.2	5.3	11.9	5.7

AREA: Colo bog PROFILE NUMBER: C101

Soil series: Nicollet

Location: 455 ft. E, 172 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: hillside surficial over toeslope sand over Cary till

Horizon	Depth (inches)	Description
I A_p	0-9	10YR 2/1, L
I A_1	9-20	10YR 2/1, L
I A_3	20-28	10YR 3/1, L
I B_2	28-42	2.5Y 4/2, L
I B_3	42-54	5Y 5/1, 2.5Y 5/4, SL, calc.
II C_1	54-66	5Y 5/1, SL, calc.
II C_{21}	66-100	2.5Y 5/4, LS, calc.
II C_{22}	100-130	2.5Y 5/4, LS, calc.
III C_3	130-144	5Y 4/1, 2.5Y 5/4, SL, calc.
III C_4	144-168	5Y 4/1, L, calc.

Profile number: C101

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-9	6.4	--	2.5	57	2.14
9-20	5.9	--	2.85	60	2.36
20-28	6.2	--		61	2.38
28-42	7.1	--	0.8	55	2.35
42-54	8.0	9.1		78	2.11
54-66	8.9	13.7		90	1.96
66-100	8.5	11.6		186	1.76
100-130	8.5	12.0		157	1.82
130-144	8.6	15.8		88	2.32
144-168	8.2	15.8		77	2.35

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-9	23.4	3.7	4.5	9.7	13.6	7.8	6.7	11.0	14.0	4.8	0.6	0.2		
9-20	24.0	3.7	4.0	9.5	12.4	10.8	5.1	9.3	14.7	4.6	0.9	1.0		
20-28	25.0	3.0	4.4	10.5	13.3	8.6	4.1	8.1	14.8	4.9	2.1	1.2		
28-42	23.1	3.7	4.9	10.0	16.1	10.2	2.2	7.0	18.3	3.9	0.5	0.1		
42-54	12.9	2.0	3.4	6.1	14.3	17.8	5.9	8.4	21.5	6.6	0.6	0.5		
54-66	9.9	1.5	2.9	4.5	10.6	18.1	9.6	13.3	18.2	6.1	1.7	2.5	1.1	
66-100	5.0	1.2	1.2	2.5	3.5	5.0	10.5	23.8	27.5	9.9	4.0	4.3	1.6	
100-130	7.1	1.5	1.7	2.9	4.0	7.8	12.8	22.1	23.8	9.2	3.1	2.5	1.5	
130-144	13.3	3.3	4.8	5.3	6.6	9.1	10.9	14.7	13.7	6.4	3.2	3.8	4.9	
144-168	15.1	3.9	5.0	6.8	9.3	8.6	10.3	13.6	14.4	6.4	2.4	4.3		

AREA: Colo bog PROFILE NUMBER: C102

Soil series: Webster; mapping unit 41

Location: 430 ft. N, 15 ft. E of SW corner of NW$\frac{1}{4}$ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: hillside surficial sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-8	10YR 2/1, CL
I A_1	8-16	10YR 2/1, L
I A_3	16-24	5Y 3/1, 5Y 5/1, CL
I B_2	24-30	5Y 4/1, 5Y 5/3, L
II B_3	30-42	5Y 5/3, SL, calc.
II C_1	42-54	5Y 5/2, 10YR 5/8, SL, calc.
II C_{21}	54-66	5Y 5/3, 7.5YR 5/8, L, calc.
II C_{22}	66-78	5Y 5/3, 7.5YR 5/8, L, calc.
II C_3	78-96	5Y 5/3, 7.5YR 5/8, L, calc.
II C_3	96-120	5Y 5/3, 7.5YR 5/8, L, calc.

Profile number: C102

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2µ to 2 mm.	
				Geom. mean (µ)	Std. dev. phi units
0-8	6.7	--	2.15	29	2.06
8-16	7.2	--	2.00	40	2.38
16-24	7.2	--	1.25	55	2.40
24-30	7.8	--	0.70	70	2.35
30-42	8.1	8.7	0.45	79	2.39
54-60	8.3	14.6		72	2.38
66-78	8.3	13.3		107	2.32
84-96	8.1	14.6		85	2.41
96-120	8.1	15.8		70	2.40

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.					
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-8	28.0	8.1	7.3	10.3	13.9	10.2	5.0	7.8	6.3	2.3	0.4	0.4		
8-16	23.2	6.7	7.6	10.3	12.5	10.0	6.1	9.5	9.7	3.7	0.7			
16-24	31.3	3.4	5.3	9.1	11.3	7.8	6.7	9.0	9.5	4.1	2.4	(0.8%>2mm)		
24-30	24.9	3.6	4.0	7.6	9.1	8.6	7.8	11.9	12.3	5.0	2.0	3.2		
30-42	17.1	4.6	3.9	6.4	8.2	9.6	9.3	13.1	14.2	6.3	2.6	3.4	1.3	
54-60	18.0	4.7	4.5	7.1	8.8	9.6	9.7	13.8	13.5	6.1	2.0	2.2		
66-78	16.2	4.2	4.7	5.3	7.2	8.6	8.7	12.7	15.1	8.1	4.2	4.3	0.7	
84-96	17.0	4.1	4.7	6.8	6.7	8.6	8.0	12.6	14.5	6.8	2.2	2.6	5.4	
96-120	16.9	4.0	5.4	6.6	8.7	9.1	8.1	12.1	12.9	5.4	2.3	4.3	4.2	

AREA: Colo bog PROFILE NUMBER: C103

Soil series: Clarion; mapping unit 1

Location: 515 ft. E, 160 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: surficial hillside sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-8	10YR 2/1, L
I A_3	8-16	10YR 2/1, 2.5Y 4/2, L
I B_2	16-25	10YR 4/4, 10YR 3/2, L
I B_3	25-36	10YR 4/3, L, calc.
II C_{11}	36-48	5Y 6/2, 10YR 5/6, SL, calc.
II C_{12}	48-66	5Y 6/2, 10YR 5/6, LS, calc.
II C_2	66-84	5Y 6/1, 2.5Y 5/4, L, calc.

Profile number: C103

Depth (inches)	pH	Exch.H m.e. %	Tot.Exch. Cat.m.e.%	%$CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
						Geom. mean (μ)	Std. dev. phi units
0-8	6.4	9.1	17.3	--	1.75	69	2.27
8-16	6.1			--	1.60	81	2.16
16-24	6.2	8.1	13.8	--	0.75	85	2.24
26-36	6.8			0.8	0.6	83	2.23
36-48	7.8			10.4		76	2.24
48-66	8.0			10.8	0.35	71	2.30
66-84	8.0			10.8		80	2.22

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-8	24.0	3.3	4.1	6.8	10.4	9.3	7.7	12.5	13.2	4.7	1.0	1.1	1.9	
8-16	28.2	2.0	3.2	6.0	9.1	8.1	8.5	13.0	13.5	4.8	1.0	2.0	0.6	
16-24	24.1	2.4	4.4	5.0	7.6	10.6	8.3	13.3	13.8	6.6	1.4	2.5		
26-36	21.7	3.0	3.5	5.9	8.7	9.5	9.8	14.1	14.3	5.3	1.9	2.3		
36-48	18.3	4.2	4.0	6.4	8.1	10.1	9.0	13.7	14.5	5.7	1.4	3.7	0.9	
48-66	17.3	3.0	5.9	6.5	8.5	11.5	10.0	13.8	14.4	5.7	1.8	1.6		
66-84	17.4	2.2	5.4	6.5	9.2	10.6	9.1	13.7	14.4	6.3	2.1	3.1		

AREA: Colo bog PROFILE NUMBER: C104

Soil series: Clarion; mapping unit 1

Location: 478 ft. E, 148 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: surficial hillside sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-8	10YR 2/1, L
I A_{11}	8-16	10YR 2/1, L
I A_{12}	16-26	10YR 2/1, L
I B_2	26-36	10YR 2/2, 2.5Y 4/4, L
II B_3	36-50	5Y 6/1, 10YR 5/6, L, calc.
II C_{11}	50-63	5Y 6/2, 7.5YR 5/6, SL, calc.
II C_{12}	63-75	5Y 5/1, 7.5YR 4/4, SL, calc.

Profile number: C104

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2µ to 2 mm. Geom. mean (µ)	2µ to 2 mm. Std. dev. phi units
0-8	6.2	--	1.45	61	2.16
8-16	6.2	--	1.75	58	2.17
16-26	7.4	--	1.4	60	2.22
26-36	6.9	--	1.2	60	2.17
36-50	8.0	4.6	1.0	65	2.12
50-63	8.1	11.2	0.2	80	2.12
63-75	8.3	14.6		74	2.34

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.					
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-8	25.0	3.0	4.7	7.1	11.3	11.0	9.2	12.6	11.9	3.3	0.6	0.3		
8-16	23.4	4.1	4.2	7.6	11.5	11.1	9.0	12.5	10.8	3.5	0.6	0.6	1.1	
16-26	23.1	4.3	4.2	7.1	11.2	12.0	9.3	12.0	11.4	3.9	0.9	0.6		
26-36	23.0	2.2	5.8	7.5	11.4	10.9	10.3	12.3	10.3	3.7	1.0	1.6		
36-50	17.4	4.2	4.9	6.8	9.8	12.8	10.6	13.4	12.2	4.6	1.7	1.6		
50-63	16.4	2.6	4.0	6.1	8.6	11.0	12.7	15.9	12.5	5.0	2.4	4.1	0.5	
63-75	14.4	5.3	3.9	5.4	10.3	11.0	11.1	14.3	13.2	5.0	1.3	1.9	2.9	

AREA: Colo bog PROFILE NUMBER: C110

Soil series: Calco; mapping unit 50

Location: 356 ft. E, 30 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: surficial hillside sediment over toeslope sand

Horizon	Depth (inches)	Description
I A_{11}	0-10	10YR 2/1, L, calc.
I A_{12}	10-20	10YR 3/1, L, calc.
I A_{13}	20-40	10YR 2/1, 10YR 3/1, S, SiCL, calc.
II C_1	40-66	5Y 5/2, S, calc.
II C_2	66-96	5Y 5/2, 7.5YR 5/6, S, calc.

Profile number: C110

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2µ to 2 mm.	
				Geom. mean (µ)	Std. dev. phi units
0-10	7.7	12.6	4.36	63	2.54
10-20	8.3	20.3	3.15	68	2.64
20-40	8.5	5.0	1.8	90	2.40
40-66	9.2	15.4	0.5	225	1.44
66-96	9.0	7.5		200	1.69

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.					
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-10	27.4	4.8	5.7	8.5	10.1	6.5	5.5	10.4	12.8	6.3	2.2	(2.0% 2 mm.)		
10-20	26.0	5.3	6.7	8.2	8.0	5.6	4.8	11.2	14.8	7.0	2.5	(2.7% 2 mm.)		
20-40	20.4	4.7	2.3	7.2	8.7	5.6	5.0	15.5	18.3	6.6	1.8	3.3	0.6	
40-66	4.6	0.6	0.2	2.5	1.0	1.9	9.3	31.5	29.9	11.1	3.7	3.7		
66-96	6.1	1.6	1.0	2.0	1.8	2.6	10.8	29.4	25.0	12.0	3.7	4.0		

AREA: Colo bog PROFILE NUMBER: C111

Soil series: Harpster (cumulic); mapping unit 72

Location: 280 ft. E, 30 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: surficial hillside sediment over lower bog sediment and toeslope sand over Cary till

Horizon	Depth (inches)	Description
I A_{11}	0-12	N 2/0, L, calc.
I A_{12}	12-33	N 2/0, 10YR 4/1, S, SL, calc.
II C_1	33-40	5Y 4/3, L, calc.
II C_2	40-62	5Y 5/1, 10YR 4/4, SiL, calc.
III C_3	62-72	5Y 5/1, 2.5Y 4/4, SL, calc.
IV C_4	72-78	5Y 5/1, 2.5Y 4/4, L, calc.

Profile number: C111

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-12	7.4	1.7	5.35		
12-33	7.3	0.8	1.5		
33-40	8.2	7.9	0.65	37	2.21
40-62	8.1	14.6		31	1.76
62-72	8.5	15.8		123	2.12
72-78	8.2	17.1		49	2.23

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
33-40	24.6	4.2	6.0	11.5	18.1	8.4	5.5	9.1	8.2	3.1	0.7	0.6		
40-62	23.2	5.0	5.2	11.3	15.8	17.7	12.6	6.3	2.0	0.5	0.2	0.2		
62-72	13.6	3.0	1.7	4.7	6.7	7.0	11.5	20.0	18.0	8.3	3.0	2.5		
72-78	17.7	3.2	5.9	11.8	15.2	10.7	7.8	10.2	11.5	3.3	1.3	1.4		

AREA: Colo bog PROFILE NUMBER: C112

Soil series: Harpster (cumulic); mapping unit 72

Location: 303 ft. E, 30 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: surficial hillside sediment over lower bog sediment interstratified with toeslope sand over Cary till

Horizon	Depth (inches)	Description
I A_{11}	0-12	N 2/0, L, calc.
I A_{12}	12-33	N 2/0, 10YR 4/1, S, SL, calc.
II C_1	33-54	2.5Y 4/4, 5Y 5/2, FSL, calc.
III C_{21}	54-72	5Y 5/1, 7.5YR 5/6, SL, calc.
III C_{22}	72-80	5Y 4/1, 5Y 4/3, SL, calc.
IV C_3	80-90	N 4/0, 2.5Y 4/4, L, calc.

Profile number: C112

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-12	7.5	2.5	2.95		
12-33	7.5	0.8	2.05		
33-54	8.3	13.3	0.2	60	1.86
54-72	8.5	18.7		64	2.20
72-80	8.3	16.7		77	2.19
80-90	8.6	17.1		63	2.29

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
33-54	15.0	4.5	1.9	6.9	9.2	14.4	18.8	20.4	5.8	1.0	0.3	0.5	1.3	
54-72	16.9	3.5	4.5	7.2	10.7	11.2	11.2	12.2	10.2	5.3	1.4	2.6	3.1	
72-80	15.8	2.8	5.0	6.0	8.4	10.6	11.9	15.4	13.7	4.8	1.6	2.2	1.8	
80-90	14.6	3.6	6.1	8.2	11.9	8.7	10.0	13.9	12.6	4.5	1.5	3.3	1.1	

AREA: Colo bog PROFILE NUMBER: C118

Soil series: Nicollet (cumulic); mapping unit 24

Location: 469 ft. E, 92 ft. N of SE corner of SW¼ of NW¼ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: hillside surficial over toeslope sand over Cary till

Horizon	Depth (inches)	Description
I A_1	0-24	10YR 2/1, L
I A_3	24-36	10YR 3/1, L
(I) B	36-60	5Y 5/1, 10YR 4/4, SL, calc.
II C_1	60-75	2.5Y 4/3, 10YR 2/1, SL, calc.
II C_2	75-90	10YR 4/4, S, calc.
III C_3	90-94	5Y 6/1, 2.5Y 5/4, SL, calc.

Profile number: C118

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2µ to 2 mm.	
				Geom. mean (µ)	Std. dev. phi units
0-24	6.5	--	1.55	49	2.23
24-36	7.2	--	1.05	52	2.32
36-60	7.7	2.9	0.65	133	2.21
60-75	8.5	12.5	0.3	136	2.08
75-90	8.7	15.4		190	2.05
90-94	8.8	17.5		120	2.36

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.					
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-24	26.3	3.8	4.9	10.9	11.1	11.1	6.6	10.1	10.5	3.1	0.5	0.5	0.5	
24-36	24.4	4.0	5.8	9.4	12.9	8.9	6.8	10.8	11.3	3.8	1.1	0.8		
36-60	10.3	3.5	1.4	4.4	5.7	7.1	8.3	17.1	21.5	9.5	3.6	5.3	2.3	
60-75	10.5	2.6	3.0	3.9	4.7	5.3	9.2	22.4	23.0	8.8	2.4	3.5	0.7	
75-90	5.2	1.7	1.9	3.9	2.6	3.0	5.5	16.5	26.2	11.7	4.3	6.6	10.9	
90-94	10.9	2.9	3.3	4.8	5.7	5.5	8.3	16.0	19.9	8.1	3.3	4.9	6.4	

AREA: Colo bog PROFILE NUMBER: C119

Soil series: Nicollet (cumulic); mapping unit 24

Location: 502 ft. E, 92 ft. N of SE corner of SW$\frac{1}{4}$ of NW$\frac{1}{4}$ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: hillside surficial over Cary till

Horizon	Depth (inches)	Description
I A_{11}	0-12	10YR 2/1, CL
I A_{12}	12-22	10YR 2/1, CL
I A_3	22-26 (Stone line)	10YR 2/1, 10YR 3/1, CL
II B_2	26-36	5Y 5/3, 10YR 3/1, CL
II B_3	36-72	5Y 5/2, 10YR 5/8, L, calc.
II C	72-84	5Y 5/1, 7.5YR 4/4, L, calc.

Profile number: C119

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-12	6.0	--	3.45	45	2.24
12-22	5.7	--	1.55	37	2.29
22-26	6.0	--	1.15	31	2.13
26-36	6.5	--	0.6	27	2.03
36-72	8.0	8.7	0.35	63	2.32
72-84	8.5	12.9		59	2.29

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-12	27.3	3.7	6.3	9.8	13.8	10.6	5.6	9.3	10.1	3.1	0.4			
12-22	30.2	4.4	6.7	11.7	14.8	8.1	4.9	7.4	8.4	2.6	0.7	0.1		
22-26	32.3	3.7	7.8	11.5	16.9	8.9	3.8	5.5	5.7	2.4	0.5	0.1	0.7	
26-36	31.5	4.4	7.7	12.1	18.1	10.5	3.4	4.7	4.6	1.7	0.6	0.1	0.6	
36-72	21.1	2.8	8.0	4.7	12.1	10.1	8.4	11.5	11.7	5.2	1.6	2.8		
72-84	16.6	3.0	4.2	7.5	10.7	11.5	9.3	12.1	10.9	4.6	1.8	2.8	5.0	

AREA: Colo bog PROFILE NUMBER: C120

Soil series: Nicollet (cumulic); mapping unit 24

Location: 492 ft. E, 92 ft. N of SE corner of SW$\frac{1}{4}$ of NW$\frac{1}{4}$ of Section 11, R-21W, T-83N, Story County, Iowa

Parent material: hillside surficial over stratified sediment over Cary till

Horizon	Depth (inches)	Description
I A_{11}	0-20	10YR 2/1, L
I A_{12}	20-25	10YR 2/1, 7.5YR 4/4, L
II A_3	25-36	10YR 3/1, 5Y 5/3, L
II B	36-48	5Y 6/1, 7.5YR 6/6, SiL, calc.
II C_1	48-80	5Y 6/1, 7.5YR 5/6, SiL, calc.
III C_2	80-100	5Y 5/1, 10YR 5/4, CL, calc.

Profile number: C120

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-20	6.1	--	1.55	50	2.24
20-25	6.7	--	1.40	44	2.33
25-36	6.2	0.8	0.90	41	2.12
36-48	7.6	17.5	0.30	19	1.63
48-80	7.5	15.0		28	1.50
80-100	7.1	12.9		42	2.42

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-20	25.1	4.3	4.9	7.1	17.1	9.6	6.4	10.3	11.0	3.6	0.6			
20-25	25.1	4.9	5.8	14.4	10.1	8.7	6.9	7.9	7.1	2.7	0.8	1.5	4.1	
25-36	24.8	3.5	5.3	12.4	14.0	12.6	8.4	7.7	6.8	2.8	0.9	0.8		
36-48	20.3	5.7	11.7	16.1	18.4	15.5	6.4	2.0	0.8	0.5	0.3	0.2	2.1	
48-80	14.0	2.9	7.1	15.9	17.0	26.1	10.5	3.7	1.7	0.6	0.2	0.3		
80-100	29.3	7.0	6.1	7.7	11.3	7.9	7.6	8.9	7.9	3.3	1.1	1.2	0.7	

AREA: Jewell bog   PROFILE NUMBER: J6

Soil series: not named; mapping unit P_6

Location: 620 ft. E, 20 ft. S of NW corner of NW¼ of Section 19, R-24W, T-86N, Hamilton County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-6	10YR 2/1, muck
I O_{11}	6-22	5YR 2/1, peat
I O_{12}	22-26	5YR 2/1, peat
I C_1	26-34	2.5Y 6/2, SiL, calc.
I C_2	34-72	5Y 4/1, SiCL, calc.
I C_{31}	72-108	5Y 3/1, SiCL, calc.
I C_{32}	108-144	5Y 3/1, SiCL, calc.
I C_{33}	144-180	5Y 3/1, SiCL, calc.
II O_{21b}	180-210	5Y 3/1, muck, calc.
II O_{22b}	210-225	5Y 4/1, muck, shells
II O_{23b}	225-243	2.5Y 5/2, muck, calc.
II O_{24b}	243-264	5Y 3/1, muck, calc.
II C_{1b}	264-288	5Y 3/1, SiCL, calc.
II C_{2b}	288-297	5Y 4/3, SiCL, calc.
II C_{3b}	297-306	N 2/0, SiCL, calc.
II C_{4b}	306-312	5Y 3/1, SiCL, calc.

AREA: Jewell bog (continued) PROFILE NUMBER: J6

Horizon	Depth (inches)	Description
II C_5b	312-336	N 2/0, SiCL, calc.
II C_6b	336-344	5Y 3/1, SiL, calc.
III C_7b	344-352	5Y 4/1, L, calc.

Profile number: J6

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units	Depth (inches)	Density (gm/cc.) Duplicates a.	Density (gm/cc.) Duplicates b.
0-6	6.3	--	25.5					
6-22	6.1	--	30.7					
22-26		--	18.9			at 18"	0.37	
26-34	8.1	23.3	5.9					
34-72	8.1	25.8	8.9			66-72	0.43	0.52
72-108	8.0	18.3	9.4			90-96	0.50	0.50
108-144		18.3	9.4			138-144	0.45	0.40
144-180	7.8	22.5	13.5					
180-210	7.9	29.2	18.3			186-192	0.26	0.27
210-225	7.9	41.7	20.0			204-210	0.20	0.24
225-243	7.6	38.3	22.2			234-240	0.21	0.25
243-264	7.5	12.5	20.4			246-252	0.22	0.19
264-288	7.5	24.2	10.7			282-288	0.28	0.29
288-297	7.7	17.5	5.5					
312-336	7.6					324-330	0.48	0.62
336-344	7.9							
344-352	8.1			91	2.23	344-352		1.08

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
344-352	14.0	2.5	4.5	6.7	8.1	9.2	10.1	16.6	17.0	6.9	2.2	2.2		

AREA: Jewell bog PROFILE NUMBER: J42

Soil series: Clarion-FT; mapping unit 101

Location: 10 ft. N, 140 ft. W of SE corner of NW¼ of NW¼ of Section 19, R-24W, T-86N, Hamilton County, Iowa

Parent material: Cary till (fine textured variant

Horizon	Depth (inches)	Description
A_p	0-10	10YR 2/1, CL
A_3	10-20	10YR 2/1, 10YR 3/2, CL
B_2	20-28	10YR 4/4, CL, calc.
B_3	28-60	1Y 5/4, L, calc.
C_1	60-86	2.5Y 5/4, 10YR 5/6, L, calc.
C_2	86-120	2.5Y 5/4, 5Y 5/1, L, calc.
C_{31}	120-138	2.5Y 5/3, 10YR 5/8, L, calc.
C_{31}	138-148	2.5Y 5/3, 10YR 5/8, L, calc.
C_4	148-184	2.5Y 4/2, L, calc.
C_5	184-192	5Y 3/1, L, calc.

Profile number: J42

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2µ to 2 mm. Geom. mean (µ)	2µ to 2 mm. Std. dev. phi units
0-10	6.0	--	2.3	60	2.20
10-20	6.0	--	1.75	65	2.28
20-28	6.7	0.8	1.55	60	2.33
28-60	8.2	20.0	0.45	61	2.46
60-86	8.2	20.4		54	2.44
86-120	8.3	19.6	<0.1	54	2.57
120-138	8.2	20.4		52	2.04
138-148	8.1	17.5		61	2.26
148-184	8.2	17.5		60	2.41
184-192	8.0	17.1		62	2.51

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.					
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-10	31.7	2.8	4.8	7.6	8.0	11.0	9.0	11.0	9.6	3.8	0.7			
10-20	33.0	3.4	4.8	6.8	6.7	9.0	8.7	10.5	9.7	3.8	1.3	1.5	0.8	
20-28	29.9	2.3	7.4	6.2	8.4	8.7	8.7	10.3	9.6	4.1	1.6	2.1	0.7	
28-60	20.7	5.0	6.4	6.1	8.3	12.2	8.4	10.1	9.8	5.1	3.2	2.0	2.7	
60-86	24.5	4.4	6.8	8.5	7.6	10.4	8.2	9.4	9.2	4.7	1.9	3.9	0.5	
86-120	24.0	4.5	6.5	8.7	7.3	9.2	8.2	9.2	9.2	4.3	2.2	3.8	2.9	
120-138	24.0	4.9	6.1	6.9	11.7	8.8	8.6	9.5	9.7	4.7	1.2	3.0	0.9	
138-148	21.7	5.0	6.3	8.9	8.5	9.8	9.2	10.6	10.4	5.2	2.3	2.1		
148-184	22.7	4.1	5.7	7.8	9.5	9.4	8.8	10.1	9.8	4.7	2.0	3.6	1.8	
184-192	22.4	6.7	4.5	4.8	7.6	8.8	9.1	10.7	10.1	4.9	2.2	2.8	5.4	

AREA: Jewell bog PROFILE NUMBER: J76

Soil series: Clarion-FT; mapping unit 101

Location: 415 ft. N, 278 ft. E of SW corner of NW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: Cary till (fine textured variant)

Horizon	Depth (inches)	Description
A_p	0-10	10YR 2/1, CL
B_2	10-20	10YR 4/3, 10YR 2/1, CL
B_3	20-30	2.5Y 5/4, CL, calc.
C_1	30-60	2.5Y 5/4, 10YR 5/6, CL, calc.
C_{21}	60-96	2.5Y 5/3, 5YR 4/4, L, calc.
C_{22}	96-174	2.5Y 5/3, 5YR 4/4, L, calc.
C_3	174-188	5Y 3/1, L, calc.

Profile number: J76

Depth (inches)	pH	Exch.H m.e. %	Tot.Exch. Cat.m.e.%	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	Std. dev. phi units
0-10	6.1	9.5	20.9	--	2.9	59	2.29
10-20	6.1	4.9	20.9	--	1.75	53	2.30
20-30	7.1			2.5	1.15	56	2.39
30-60	8.2			15.8	0.2	54	2.32
60-96	8.5			19.2	0.35	49	2.45
96-132	8.1			17.5			
132-174	8.2			17.1		48	2.41
174-188	7.6			17.5		53	2.46

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-10	33.6	3.3	5.6	6.1	8.4	10.1	8.2	10.0	9.3	4.2	1.0	0.2		
10-20	36.1	3.6	5.6	6.7	7.8	9.5	8.1	9.5	8.6	2.5	1.3	0.7		
20-30	30.3	5.0	4.9	7.4	8.4	9.1	8.1	9.3	8.5	4.1	1.6	1.3		
30-60	27.3	5.7	7.1	8.2	8.3	9.4	7.5	8.8	8.3	4.1	1.9	3.4		
60-96	26.3	5.5	6.4	7.8	9.0	9.7	7.9	8.8	8.3	3.9	2.0	2.2	2.3	
132-174	20.3	4.4	5.4	7.4	8.2	7.8	7.1	7.4	7.0	3.3	1.5	4.2	0.8	15.2
174-188	23.9	4.6	6.6	7.6	8.9	10.7	8.1	8.8	8.4	4.5	2.4	3.8	1.7	

AREA: Jewell bog PROFILE NUMBER: J80

Soil series: Nicollet-FT; mapping unit 131

Location: 820 ft. N, 475 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: surficial deposit over Cary till

Horizon	Depth (inches)	Description
I A_p	0-7	10YR 2/1, CL
I A_1	7-14	10YR 2/1, CL
I A_3	14-22	10YR 2/1, 10YR 3/2, CL
I B_2	22-34	1Y 5/4, 10YR 2/1, L, calc.
II B_3	34-60	2.5Y 5/4, L, calc.
II C_1	60-96	2.5Y 4/3, 10YR 5/6, L, calc.
II C_2	96-162	2.5Y 4/3, 2.5YR 3/4, L, calc.

Profile number: J80

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	Std. dev. phi units
0-7	5.7	--	2.05	58	2.32
7-14	5.3	--	1.9	59	2.41
14-22	5.4	--	1.7	54	2.22
22-34	7.4	3.3	1.35	54	2.60
34-60	7.7	28.3	0.8	49	2.66
60-96	7.1	22.5		56	2.54
96-132	8.1	24.2		59	2.50
132-162	8.1	17.9		58	2.45

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-7	32.7	3.7	5.5	6.8	9.5	8.1	7.7	10.5	10.3	4.4	0.6	0.2		
7-14	36.2	3.0	4.9	7.2	8.1	9.0	7.4	9.3	9.3	4.0	1.3	0.3		
14-22	36.1	3.8	5.9	6.9	7.1	7.1	7.2	8.9	8.7	3.9	1.4	2.3	0.7	
22-34	26.9	5.3	5.0	6.7	6.6	7.8	6.3	7.3	7.1	3.8	3.3	4.5	3.5	5.9
34-60	23.8	8.1	6.5	4.9	9.1	8.0	6.7	8.2	8.6	4.7	2.8	4.3	4.3	
60-96	23.1	5.2	7.6	5.7	9.0	9.9	7.3	8.7	9.1	5.2	3.1	5.2	0.9	
96-132	22.6	4.5	6.9	6.1	9.1	7.9	7.5	9.6	9.6	5.4	2.3	4.8	3.7	
132-162	21.1	5.8	4.7	7.5	9.1	10.3	8.3	9.9	9.9	5.2	2.1	4.0	2.1	

AREA: Jewell bog PROFILE NUMBER: J81

Soil series: Clarion; mapping unit 1

Location: 812 ft. S, 132 ft. W of NW corner of NE¼ of NE¼ of Section 24, R-25W, T-86N, Hamilton County, Iowa

Parent material: stratified Cary till

Horizon	Depth (inches)	Description
A_p	0-9	10YR 2/1, L
A_1	9-18	10YR 2/2, L
B_1	18-28	10YR 3/2, 10YR 4/3, L
B_2	28-42	10YR 4/4, L
C_1	42-60	5Y 5/2, 7.5YR 5/8, SiCL, calc.
C_2	60-84	5Y 6/1, 7.5YR 5/8, SiL, calc.
C_{31}	84-114	2.5Y 5/3, 7.5YR 5/6, L, calc.
C_{32}	114-156	2.5Y 5/3, 2.5YR 3/6, L, calc.
C_4	156-180	5GY 3/1, 5YR 4/6, SL, calc.
C_5	180-192	5GY 3/1, L, calc.

Profile number: J81

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	$>2\mu$ to 2 mm. Geom. mean (μ)	Std. dev. phi units
0-9	5.5	--	1.85	59	2.25
9-18	5.2	--	1.5	58	2.31
18-28	5.5	--	1.05	63	2.29
28-42	6.3	--	1.05	71	2.33
42-60	6.6	3.3		19	1.95
60-84	8.4	15.0		18	1.88
84-114	7.9	16.2	0.1	56	2.44
114-156	7.3	16.7		68	2.33
156-180	7.4	16.2		80	2.28
180-192	7.2	17.9		69	2.48

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	$<2\mu$	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-9	26.2	3.2	5.5	9.2	7.8	12.0	8.0	11.7	11.4	4.2	0.7	0.1		
9-18	26.9	4.1	5.4	8.0	9.6	9.5	8.1	11.3	11.1	4.1	0.9	0.3	0.7	
18-28	27.7	3.0	5.7	7.3	8.6	9.6	8.6	11.8	11.1	4.4	1.2	0.9		
28-42	24.7	3.2	5.5	5.2	8.7	9.4	8.9	12.3	10.8	4.7	2.3	3.1	1.2	
42-60	29.0	8.2	11.9	14.0	13.5	10.6	5.2	3.7	2.4	0.9	0.3	0.3		
60-84	21.4	9.2	13.3	15.3	16.8	12.3	4.3	3.4	2.3	1.0	0.2	0.5		
84-114	17.1	5.5	7.2	7.0	7.7	12.6	8.4	11.1	10.0	5.0	2.1	2.2	4.2	
114-156	14.1	4.0	6.9	5.2	9.0	13.2	10.0	13.3	12.8	5.5	2.3	2.3	1.4	
156-180	11.4	3.4	4.6	5.5	9.2	9.2	10.6	14.5	13.6	5.8	2.1	1.9	8.2	
180-192	15.0	4.1	5.6	7.2	9.5	10.1	10.2	13.3	12.6	6.1	2.1	4.2		

AREA: Jewell bog PROFILE NUMBER: J94

Soil series: Clarion-FT; mapping unit 101

Location: 286 ft. S, 258 ft. E of NW corner of SE¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: thin surficial sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-9	10YR 2/1, CL
I A_1	9-18	10YR 2/1, CL
I A_3	18-26 (Stone line)	10YR 2/1, 10YR 5/4, CL
II B_2	26-42	10YR 5/4, CL
II C	42-48	1Y 5/4, 10YR 5/6, L, calc.

Profile number: J94

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	Std. dev. phi units
0-9	5.7	--	1.95	52	2.31
9-18	5.7	--	1.95	46	2.26
18-26	5.7	--	1.4	47	2.38
26-42	6.0	--	0.8	46	2.25
42-48	7.3	12.1	--	46	2.38

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-9	32.7	4.2	5.0	7.9	9.4	9.7	7.3	9.6	9.4	3.9	0.7	0.2		
9-18	36.2	4.8	3.6	9.1	11.9	7.2	6.3	8.3	8.4	3.6	0.3	0.3		
18-26	36.8	4.5	3.5	9.9	9.9	7.5	5.9	7.4	7.6	3.5	1.3	1.6	0.6	
26-42	35.4	4.2	6.2	6.0	10.2	5.5	7.2	8.4	7.7	4.1	1.5	1.9	1.7	
42-48	26.2	3.8	6.0	7.8	9.1	7.7	7.6	7.7	5.3	3.3	1.9	5.7	0.2	7.2

AREA: Jewell bog PROFILE NUMBER: J95

Soil series: Clarion-FT; mapping unit 101

Location: 294 ft. S, 214 ft. E of NW corner of SE¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: hillside surficial sediment over Cary till

Horizon	Depth (inches)	Description
I A_1	0-12	10YR 2/1, CL
I A_3	12-20	10YR 2/1, 10YR 3/1, CL
I B_2	20-32	2.5Y 4/2, 10YR 2/1, CL
II C	32-45	5Y 6/1, 10YR 5/6, L, calc.

Profile number: J95

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-12	5.1	--	2.25	42	2.26
12-20	6.0	--	1.5	58	1.87
20-32	6.7	--	1.2	44	2.61
32-45	7.7	17.5	0.15	80	2.69

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-12	33.0	3.6	6.5	8.9	13.2	7.6	6.4	8.9	8.0	3.2	0.6	0.1		
12-20	37.0	3.6	6.8	11.4	15.4	5.3	4.7	5.9	6.1	3.0	0.6	0.4		
20-32	34.6	4.5	6.8	10.3	11.8	5.1	4.4	5.6	6.8	5.3	2.5	2.3		
32-45	18.7	4.7	4.3	3.2	11.9	7.5	7.0	8.9	10.0	7.7	4.8	6.0	5.3	

AREA: Jewell bog PROFILE NUMBER: J97

Soil series: within mapping unit 102; more like Storden, unit 9

Location: 315 ft. S, 176 ft. E of NW corner of SE¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: very thin surficial sediment over Cary till

Horizon	Depth (inches)	Description
I A	0-6	10YR 2/1, CL, calc.
I C_1	6-18 (stone line)	1Y 5/4, L, calc.
II C_2	18-36	1Y 5/4, 5Y 6/1, L, calc.

Profile number: J97

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-6	7.4	0.8	2.0	57	2.28
6-18	8.0	15.0	0.45	57	2.26
18-36	8.0	20.4	<0.1	57	2.45

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-6	29.6	4.0	4.2	8.0	9.2	8.0	7.1	9.8	9.3	3.9	1.5	3.2	2.2	
6-18	22.0	4.7	5.9	7.0	8.8	7.2	7.5	9.5	9.3	4.9	1.9	3.5	7.8	
18-36	20.9	5.2	4.5	7.7	9.9	8.2	8.3	9.6	9.4	4.6	2.2	2.9	6.6	

AREA: Jewell bog PROFILE NUMBER: J100

Soil series: Intergrade near Harpster; mapping unit 102-73

Location: 330 ft. S, 122 ft. E of NW corner of SE$\frac{1}{4}$ of SW$\frac{1}{4}$ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: stratified hillside surficial sediment over Cary till

Horizon	Depth (inches)	Description
I A_{11}	0-24	10YR 2/1, CL
I A_{12}	24-28	10YR 2/1, CL
I A_{13}	28-38	N 2/0, L
II C_1	38-48	5Y 5/1, 10YR 2/1, SL, calc.
III C_2	48-64	5Y 5/1, 5Y 5/4, L, calc.
III C_3	64-72	5Y 4/1, 10YR 4/4, L, calc.

Profile number: J100

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
0-12	6.4	--	2.2	60	2.28
12-24	6.6	--	3.25	49	2.38
24-28	6.7	--	2.65	62	2.60
28-38	6.5	--	2.25	79	2.40
38-48	7.8	17.9	--	113	2.18
48-64	7.8	18.7		71	2.30
64-72	7.8	18.7		58	2.56

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-12	29.3	3.7	5.0	7.9	8.7	7.6	9.2	12.4	11.2	3.9	0.5	0.6		
12-24	32.7	3.4	7.5	8.1	10.3	7.2	6.7	9.2	9.5	3.8	0.9	0.7		
24-28	27.6	6.3	5.8	6.9	7.9	6.6	6.0	9.8	13.9	6.3	1.6	1.3		
28-38	24.3	3.5	4.4	6.4	10.0	4.0	8.2	12.7	13.8	6.4	1.7	1.8	2.8	
38-48	10.3	1.7	3.3	3.8	6.5	5.0	10.9	16.2	13.7	6.5	3.4	5.3	3.9	9.5
48-64	20.9	4.4	4.4	6.0	9.5	8.1	8.2	11.1	11.6	6.2	2.3	4.2	3.1	
64-72	26.1	4.2	6.4	8.0	10.0	5.8	7.2	8.8	8.9	5.2	3.1	4.5	1.8	

AREA: Jewell bog PROFILE NUMBER: J101

Soil series: Harpster (2); mapping unit 73

Location: 337 ft. S, 103 ft. E of NW corner of SE¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: surficial sediment stratified with upper bog sediment over Cary till

Horizon	Depth (inches)	Description
I A_{11}	0-10	10YR 2/1, CL, calc.
I A_{12}	10-20	10YR 2/1, SiL, calc.
I A_{13}	20-28	N 2/0, L, calc.
II C_1	28-36	N 2/0, 5Y 6/3, L, calc.
III C_2	36-52	5Y 5/1, LS, calc.
IV C_3	52-60	5Y 5/2, L, calc.
IV C_4	60-70	5Y 4/1, 10YR 5/6, L, calc.

Profile number: J101

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units
0-10	7.0	0.8	2.3	56	2.27
10-20	7.3	1.7	3.1	34	2.58
20-28	7.5	4.2	2.1	64	2.34
28-36	7.5	8.7	1.2	63	2.29
36-52	7.8	7.5	1.25	183	1.71
52-60	7.6	17.1	0.45	63	2.38
60-72	7.5	17.5	0.1	53	2.41

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-10	31.3	2.9	4.7	9.4	8.6	11.0	7.6	9.3	9.2	4.2	1.1	0.7		
10-20	25.3	12.0	5.8	9.1	11.3	7.2	6.8	8.1	8.7	4.2	1.0	0.5		
20-28	28.3	4.0	5.3	6.7	8.7	6.6	10.7	12.9	11.9	4.3	0.8	(2.95%>2 mm.)		
28-36	20.0	4.6	4.6	7.3	7.1	8.1	12.2	14.0	10.2	3.4	1.4	2.0	5.1	
36-52	5.9	1.2	1.5	1.3	3.3	3.4	13.1	25.8	23.4	9.2	4.0	4.4	3.5	
52-60	23.2	4.1	5.8	7.3	9.1	9.5	9.3	11.2	10.3	5.4	2.1	2.7		
60-72	25.8	4.2	6.8	8.0	10.0	8.3	8.3	9.9	9.0	4.2	1.8	3.1	0.6	

AREA: Jewell bog PROFILE NUMBER: J112

Soil series: Clarion-FT; mapping unit 101

Location: 152 ft. S, 117 ft. E of NW corner of SE¼ of SW¼ of Section 18, R-21W, T-86N, Hamilton County, Iowa

Parent material: hillside surficial sediment over Cary till

Horizon	Depth (inches)	Description
I A_1	0-10	10YR 2/1, CL
I A_3	10-20	10YR 2/1, 2.5Y 5/2, CL
I B_{21}	20-30	1Y 5/4, L, calc.
II B_{22}	30-38	1Y 5/4, L, calc.
II C	38-45	1Y 5/4, 10YR 5/6, L, calc.

Profile number: J112

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	Std. dev. phi units
0-10	6.2	--	1.5	49	2.30
10-15	6.3	--	1.65	48	2.19
15-20	6.7	--	1.3	43	2.37
20-30	7.5	16.7	<0.1	35	2.31
30-38	7.6	24.6	--	29	2.20
38-45	7.5	21.2	--	39	2.39

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-10	30.4	4.6	4.2	6.4	9.1	9.4	7.2	8.1	8.0	2.8	0.8	1.1	7.9	
10-15	33.8	4.4	4.8	6.0	11.7	10.5	6.8	7.5	7.1	3.2	1.4	1.4	1.4	
15-20	33.3	4.0	6.0	6.9	14.0	9.7	6.6	6.7	6.3	2.9	1.6	2.0		
20-30	23.2	5.5	7.0	9.0	12.6	12.6	5.3	4.8	4.7	3.1	1.8	4.6	5.8	
30-38	22.4	6.8	8.4	11.4	15.9	11.6	5.7	5.1	4.9	2.4	1.2	3.4	0.8	
38-45	23.6	5.6	8.7	10.1	10.4	12.8	6.9	7.3	7.0	3.6	2.0	2.0		

AREA: Jewell bog PROFILE NUMBER: J173

Soil series: not named; mapping unit P_6

Location: 740 ft. N and 317 ft. W of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_{21}	0-2	5YR 2/1, muck
I O_{22}	2-10½	5Y 2/1, muck, calc.
I O_1	10½-20	5YR 2/1, peat, calc.
I C_1	20-28	10YR 3/1, SiC, calc.
I C_2	28-36	10YR 3/1, SiC, calc.
I C_3	36-69	10YR 2/1, SiCL, calc.
I C_4	69-111	10YR 2/1, SiL, calc.
I C_5	111-138	10YR 2/1, SiCL, calc.
II O_{21b}	138-176	2.5Y 4/2, muck, shells
II O_{22b}	176-194	2.5Y 3/1, muck, calc.
II O_{23b}	194-231	5Y 2/1, muck, calc.
II $C_{1}b$	231-238	5Y 2/1, SiC, calc.
II $C_{2}b$	238-251	5Y 5/1, SiCL, calc.
III $C_{3}b$	251-270	5Y 4/1, L, calc.

Profile number: J173   using some of the sampling intervals chosen for pollen analysis

Depth (inches)	Pollen interval (inches)	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
				Geom. mean (μ)	Std. dev. phi units
	0-1	--	21.9		
2-10	3-4	2.5	21.7	13	1.65
	6-7	2.1	23.1		
	9-10	2.0	23.1		
12-18	13-14	1.2	25.1	14	1.59
	18-19	24.6	10.0		
20-28	25-26	27.5	10.3	11	1.66
	31-32	36.8	8.3		
36-42	37-38	26.7	7.2	13	1.47
	49-50	23.3	9.3		
60-66	61-62	20.8	8.2	13	1.67
72-78	73-74	19.2	7.9	11	1.49
	85-86	19.6	7.7		
96-102	97-98	18.7	7.2	14	1.67
120-126	121-122	26.2	11.1	14	1.54
132-138	133-134	27.5	15.4	15	1.44
	139-140	50.8	15.1		
	145-146	55.8	16.1		
	163-164	42.5	14.3		
	175-176	31.2	21.9		
180-186				12	1.76
	187-188	2.1	22.2		
198-204	199-200	10.8	15.6	13	1.74
	211-212	0.4	15.5		
216-222				11	1.45
	223-224	10.4	13.4		
	235-236	7.5	8.7		
240-246				14	1.50
	247-248	21.7	1.5		
252-258		21.2			
264-270		26.7	1.95	40	2.43

Profile number: J173 (continued)

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
2-10	41.8	9.0	12.4	14.1	13.4	4.7	1.9	1.1	1.2	0.4				
12-18	41.9	5.2	14.8	14.1	14.9	3.7	2.6	1.4	1.1	0.4				
20-28	43.7	12.4	11.9	13.4	13.0	1.4	2.2	0.7	0.9	0.6				
36-42	38.1	7.2	14.3	15.0	14.4	7.8	2.2	0.4	0.4	0.3				
60-66	31.7	11.9	11.4	16.5	14.6	8.0	4.4	0.8	0.6	0.2				
72-78	24.8	14.9	15.7	15.0	17.7	8.3	2.6	0.6	0.4	0.2				
96-102	21.9	13.3	12.2	15.1	17.0	14.0	4.1	1.1	0.9	0.4				
120-126	42.2	7.0	9.2	14.0	17.8	6.7	1.2	0.5	0.9	0.6				
132-138	29.9	8.5	9.3	15.7	22.3	11.3	1.6	0.7	0.5	0.3				
180-186	46.3	10.6	11.7	9.9	14.7	2.8	1.0	0.6	1.2	1.1				
198-204	39.8	15.6	8.4	10.4	17.0	3.6	1.3	0.2	0.4	3.3				
216-222	49.2	7.5	11.2	16.4	10.3	2.6	1.6	0.4	0.5	0.3				
240-246	29.7	8.8	12.0	19.6	16.7	8.1	3.7	0.8	0.5	0.3				
264-270	26.4	5.8	6.5	9.6	11.0	8.6	8.9	8.5	1.7	4.3	2.3	3.8	3.0	

AREA: Jewell bog PROFILE NUMBER: J174

Soil series: Clarion-FT; mapping unit 101

Location: 430 ft. N of SE corner of SW¼ of SE¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: Cary till (fine textured variant)

Horizon	Depth (inches)	Description
A_p	0-5	10YR 2/1, CL
A_{11}	5-12	10YR 2/1, CL
A_{11}	12-17	10YR 2/1, C
A_3	17-21	10YR 2/1, 10YR 2/2, C
B_1	21-24	10YR 3/2, 10YR 2/1, C
B_2	24-31	10YR 3/3, 10YR 3/1, C
B_3	31-42	10YR 4/4, 10YR 4/1, CL
C_1	42-55	10YR 5/5, 10YR 5/1, CL, calc.
C_2	55-68	10YR 4/4, 2.5Y 4/1, L, calc.
C_3	68-96	10YR 5/3, 7.5YR 5/6, L, calc.
C_{41}	96-120	2.5Y 5/2, 7.5YR 5/6, L, calc.
C_{42}	120-168	2.5Y 5/2, 7.5YR 5/6, L, calc.
C_5	168-180	2.5Y 4/2, 7.5YR 5/6, L, calc.
C_6	264-270	2.5Y 3/1, L, calc.

Profile number: J174

Depth (inches)	pH	Exch.H m.e. %	Tot.Exch. Cat.m.e.%	%$CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.	
						Geom. mean (μ)	Std. dev. phi units
0-5	5.4	10.2	23.3	--	2.85	33	2.37
5-12	5.6			--	2.7	32	2.38
12-17	5.7			--	2.1	30	2.23
17-21	5.8			--		27	2.22
21-24	6.0			--	1.6	33	2.25
24-31	5.9	9.3	28.0	--	0.9	35	2.32
31-42	6.5	6.8	26.6	--	0.5	59	2.51
42-55	7.3			11.0	0.4	50	2.47
55-68	7.5					61	2.51
68-96	7.3			18.6	0.4	53	2.57
96-120	7.5			17.2	0.5		
120-168	7.5					55	2.57
168-180	7.5			16.8	0.7		
264-270	7.7			19.8	0.6	52	2.51

Profile number: J174 (continued)

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.						
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16	32
0-5	36.7	8.6	6.3	6.1	15.6	7.5	5.5	6.0	5.0	2.3	0.4				
5-12	37.4	6.8	6.7	9.8	12.6	5.7	5.5	6.1	5.9	3.0	0.6				
12-17	40.7	4.7	6.9	11.2	11.9	6.9	5.2	5.0	4.5	2.2	0.7				
17-21	41.4	4.4	6.7	9.7	11.7	6.9	5.4	5.4	4.7	2.1	0.6	1.0			
21-24	42.3	4.5	6.9	9.3	12.1	6.9	5.5	5.1	4.6	2.2	0.9				
24-31	42.2	4.4	6.4	8.3	10.4	6.9	5.7	5.8	4.8	2.2	1.2	0.1	1.7		
31-42	37.5	4.2	5.6	6.4	7.7	6.6	7.6	7.9	7.0	3.6	2.6	2.2	1.0		
42-55	28.3	4.6	6.4	7.9	9.5	8.5	8.0	7.9	7.4	4.3	2.6	2.4	1.3	0.8	
55-68	24.5	4.2	5.8	7.0	8.9	8.1	8.5	8.8	8.3	5.1	3.5	3.8	2.7	0.8	
68-96	23.8	4.3	5.7	6.8	7.8	6.6	6.4	6.7	6.9	3.9	2.9	3.3	1.7	2.9	10.2
96-120												3.4	2.2	1.8	
144-156	26.0	5.3	6.5	8.4	8.3	8.3	7.7	7.7	7.4	4.1	3.6	2.4	2.9	1.4	
168-180												6.6	2.3	3.4	25.2
264-270	24.6	4.7	6.2	8.2	9.7	7.7	8.3	7.8	7.5	4.1	3.4	3.0	2.1	2.9	

AREA: Jewell bog PROFILE NUMBER: JSS A

Soil series: Nicollet-FT; mapping unit 131

Location: 820 ft. N, 475 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: thin surficial sediment over Cary till (fine textured variant)

Horizon	Depth (inches)	Description
I A_p	0-7	10YR 2/1, CL
I A_1	7-15	10YR 2/1, CL
I A_3	15-19	10YR 2/1, 1Y 3/2, CL
II B_{21}	19-26	1Y 4/3, 10YR 2/1, CL, calc.
II B_{22}	26-32	1Y 4/3, CL, calc.
II B_3	32-46	2.5Y 5/4, L, calc.
II C	46-60	5Y 5/2, 10YR 4/3, L, calc.

Profile number: JSS A

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units	Depth (inches)	Density gm/cc
0-7	5.5	--	2.45	62	2.28		
7-15	5.5	--	2.0	56	2.26	13-16	1.19
15-19	6.4	--	1.6	63	2.48		
19-26	6.7	0.9	0.9	73	2.44	21-24	1.28
26-32	7.1	6.5	0.9	55	2.54	30-31	1.38
32-46	8.1	22.3	0.25	55	2.70		
46-60	8.1	19.5	0.45	51	2.58	55-58	1.44

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-7	33.7	3.1	5.4	7.0	8.9	7.5	8.8	10.2	10.5	4.3	0.6			
7-15	38.6	3.9	5.0	6.3	8.4	7.1	8.2	9.0	8.7	3.5	1.4			
15-19	32.4	2.7	4.9	4.6	7.3	5.7	6.8	6.8	6.8	3.8	2.6	2.0	1.0	12.5
19-26	36.8	2.2	6.1	5.0	8.5	5.3	7.6	8.0	8.1	4.7	3.1	3.6	1.0	
26-32	32.3	5.3	4.1	7.2	10.1	3.7	8.0	8.1	8.1	4.2	2.5	1.9	3.4	1.2
32-46	27.4	5.5	8.3	6.8	9.1	7.0	6.9	7.4	8.0	5.3	4.7	1.6	2.0	
46-60	26.7	5.6	7.3	6.6	8.9	7.7	7.2	7.9	7.7	4.8	3.1	1.3	5.2	

AREA: Jewell bog PROFILE NUMBER: JSS B

Soil series: Nicollet-FT; mapping unit 131

Location: 846 ft. N, 488 ft. E of SE corner of SW$\frac{1}{4}$ of SW$\frac{1}{4}$ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: thin hillside surficial sediment over Cary till (fine textured variant)

Horizon	Depth (inches)	Description
I A_p	0-6	10YR 2/1, CL
I A_3	6-13	10YR 2/1, 1Y 3/2, CL
I B_1	13-15	2.5Y 3/2, 10YR 2/1, CL, calc.
II B_2	15-19	1Y 4/3, 10YR 3/1, CL, calc.
II B_3	19-26	1Y 5/4, 10YR 4/4, L, calc.
II C	26-56	5Y 5/1, 10YR 4/4, L, calc.

Profile number: JSS B

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units	Depth (inches)	Density gm/cc
0-6	6.5	--	2.5	72	2.32		
6-13	6.7	--	1.4	78	2.18	6-8	1.24
13-15	6.8	0.8	1.0	106	2.58		
15-19	7.6	8.3	0.8	62	2.44	21-23	1.34
26-38	7.7	21.8	0.3	82	2.58	30-33	1.70
38-56	7.7	17.7	0.5	50	2.47	54-56	1.65

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-6	29.3	2.9	4.6	5.1	8.1	8.1	9.1	10.7	10.7	4.4	2.1	0.9	3.7	
6-13	33.1	2.8	5.1	5.6	6.1	6.3	8.0	9.2	10.0	5.0	2.8	3.0	2.9	
13-15	22.1	2.9	3.0	3.5	3.9	5.0	6.1	7.6	8.2	6.5	4.8	6.0	5.2	15.3
15-19	27.1	2.9	5.6	5.7	7.3	7.0	7.4	7.8	7.4	4.2	2.9	4.1	2.7	7.9
26-38	17.4	2.5	5.4	5.4	6.4	6.6	6.6	7.5	9.3	6.7	4.4	5.2	6.6	9.8
38-56	27.4	4.5	7.8	7.9	9.3	8.1	8.2	8.4	9.0	4.3	1.9	2.1	0.9	

AREA: Jewell bog | PROFILE NUMBER: JSS C

Soil series: Clarion-FT; mapping unit 101

Location: 872 ft. N, 508 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: surficial sediment over Cary till (fine textured variant)

Horizon	Depth (inches)	Description
I A_p	0-6	10YR 2/1, CL
I A_{11}	6-14	10YR 2/1, CL
I A_{12}	14-20	10YR 2/1, CL, calc.
I A_3	20-23	10YR 3/1, 1Y 4/3, CL, calc.
II B_2	23-27	1Y 4/3, 10YR 3/1, CL, calc.
II B_3	27-39	2.5Y 4/4, 5Y 5/1, CL, calc.
II C	39-52	2.5Y 5/4, 10YR 4/4, L, calc.

Profile number: JSS C

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm.		Depth (inches)	Density gm/cc
				Geom. mean (μ)	Std. dev. phi units		
0-6	6.4	--	2.2	66	2.50	5-8	1.29
6-14	6.6	--	1.9	79	2.50	12-15	1.15
14-20	6.7	0.9	1.4	85	2.49		
20-23	7.8	7.4	1.1	71	2.52		
23-27	7.8	20.5	0.65	58	2.68	31-34	1.51
39-45	7.9	18.2	0.6	59	2.52		
45-52	7.7	20.8	0.15	56	2.54	45-48	1.49

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.						
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16	32
0-6	27.6	6.7	4.7	4.7	7.7	6.9	9.1	11.6	12.7	5.8	1.3	1.0	0.2		
6-14	34.7	4.3	4.4	6.2	4.7	3.5	9.0	11.2	12.2	5.9	2.9	1.7	0.3		
14-20	33.5	3.5	4.2	6.1	6.8	5.3	7.5	8.9	10.0	5.8	3.7	3.2	1.5		
20-23	18.1	1.7	3.8	3.7	5.4	5.2	4.7	5.0	5.9	3.7	2.5	4.7	4.0	10.9	20.7
23-27	24.1	5.0	6.3	5.8	6.1	8.6	6.0	6.1	6.7	5.4	4.0	4.9	2.0	9.0	
39-45	20.1	3.0	5.6	4.8	7.3	5.8	6.3	6.5	6.7	3.8	2.6	2.9	2.8	21.7	
45-52	23.4	5.0	4.7	6.8	8.6	7.4	7.0	7.7	7.7	4.3	2.9	3.2	4.2	7.1	

AREA: Jewell bog PROFILE NUMBER: JSS D

Soil series: Nicollet-FT, Webster-FT transition; mapping unit 102

Location: 898 ft. N, 521 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: surficial hillside sediment over Cary till (fine textured variant)

Horizon	Depth (inches)	Description
I A_p	0-6	10YR 2/1, CL
I A_{11}	6-12	10YR 2/1, CL
I A_{12}	12-17	10YR 2/1, CL, calc.
I A_3	17-21	10YR 2/1, 2.5Y 3/2, CL, calc.
II B_2	21-27	5Y 3/1, 5Y 5/2, CL, calc.
II C	27-45	5Y 5/2, 7.5YR 5/6, L, calc.

Profile number: JSS D

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units	Depth (inches)	Bulk density gm/cc
0-6	6.8	--	2.8	76	2.29		
6-12	6.8	--	2.2	57	2.54	6-8	1.19
12-17	7.0	0.8	1.5	65	2.40		
17-21	8.0	7.9	0.9	73	2.52		
21-27	8.0	12.1	0.7	68	2.50	25-27	1.20
27-45	7.8	23.3	0.3	69	2.58	36-38	1.63

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-6	28.4	4.1	2.7	6.6	8.5	7.1	9.5	12.7	13.3	5.4	1.0	0.8		
6-12	30.7	6.7	5.1	5.5	8.9	7.4	8.6	10.0	9.9	5.3	1.4	0.3		
12-17	30.2	4.4	4.3	6.2	8.3	7.4	9.5	10.1	9.8	4.7	2.1	2.1	1.0	
17-21	22.4	3.6	3.2	5.0	6.9	6.4	6.8	7.8	8.0	4.8	3.4	6.2	3.5	11.9
21-27	25.7	4.9	4.1	5.6	8.2	7.2	8.2	9.3	9.8	5.4	2.8	2.8	2.1	3.7
27-45	19.9	6.1	4.2	6.0	7.7	7.5	8.8	9.8	10.3	5.8	3.7	4.0	2.3	4.0

AREA: Jewell bog PROFILE NUMBER: JSS E

Soil series: Webster-FT, calcareous surface; mapping unit 142

Location: 924 ft. N, 536 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: surficial sediment over Cary till (fine textured variant)

Horizon	Depth (inches)	Description
I A_p	0-6	N 2/0, CL, calc.
I A_{11}	6-12	N 2/0, CL, calc.
I A_{12}	12-20	N 2/0, CL, calc.
I A_{12}	20-30	N 2/0, 10YR 3/1, CL, calc.
I A_{31}	30-39	N 2/0, 10YR 3/1, CL, calc.
I A_{32}	39-45	5Y 3/1, N 2/0, CL, calc.
II C	45-51	5Y 5/1, 5Y 4/1, CL, calc.

Profile number: JSS E

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units	Depth (inches)	Bulk density gm/cc
0-6	7.4	2.0	3.6	66	2.39	6-8	1.19
12-20	7.4	6.2	2.8	46	2.37		
20-30	7.3	4.6	2.0	54	2.37	25-29	1.40
30-39	7.5	3.7	1.4	49	2.37		
39-45	7.4	6.7	0.9	57	2.43	35-38	1.38
45-51	7.0	17.1	0.5	42	2.55	45-48	1.30

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.						
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16	32
0-6	30.7	3.9	4.4	6.7	9.9	6.8	8.2	9.8	11.9	5.9	1.1	0.7			
12-20	32.9	4.4	6.7	8.8	10.1	7.1	7.9	8.4	8.1	3.7	1.0	1.0			
20-30	33.2	4.0	5.9	6.5	10.1	7.4	8.2	9.0	9.0	3.9	1.4	1.5			
30-39	34.8	4.2	2.9	10.6	11.3	6.5	6.8	7.1	7.5	3.9	1.7	1.8	0.9		
39-45	24.5	2.9	4.9	6.6	8.6	5.8	6.0	7.5	8.6	3.7	1.7	1.4	1.4	--	16.3
45-51	27.0	7.4	6.0	8.6	12.8	6.2	6.1	7.3	8.2	4.1	2.2	1.7	2.4		

AREA: Jewell bog PROFILE NUMBER: JSS F

Soil series: Webster-FT, calcareous surface; mapping unit 142

Location: 950 ft. N, 553 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: hillside surficial sediment (stratified) over Cary till (fine textured variant)

Horizon	Depth (inches)	Description
I A_p	0-6	N 2/0, CL, calc.
I A_{11}	6-10	N 2/0, CL, calc.
I A_{12}	10-11	10YR 2/1, CL, calc.
I A_{13}	11-16	N 2/0, CL, calc.
I A_{14}	16-29	5Y 3/1, CL, calc.
I A_{15}	29-39	2.5Y 3/1, 5Y 4/2, CL, calc.
I A_{16}	39-45	2.5Y 3/1, 2.5Y 4/4, L, calc.
I A_{17}	45-55	5Y 5/1, L, calc.
II C_1	55-76	5Y 4/1, 2.5Y 4/4, L, calc.
II C_2	76-87	5Y 4/1, 2.5Y 4/4, SiL, calc.

Profile number: JSS F

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units	Depth (inches)	Bulk density gm/cc
0-6	7.3	3.3	4.1	39	2.41		
10-11	7.4	4.4	3.3	60	2.58	6-9	1.08
11-16	7.3	1.7	2.1	52	2.35		
16-29	7.9	8.7	0.85	48	2.42	20-24	1.36
29-39	7.8	4.2	1.0	62	2.34	40-43	1.31
45-55	7.9	10.4	0.6	52	2.35		
55-76	7.8	2.1	0.4	66	2.20	69-71	1.34
76-87	7.9	7.1	0.6	19	1.65	78-80	1.48

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-6	38.2	4.1	7.9	8.3	11.2	6.9	6.0	6.0	6.3	3.6	1.1	0.5		
10-11	29.9	3.3	5.6	7.8	9.4	8.3	8.7	10.3	10.2	4.5	1.5	0.4		
11-16	34.5	4.9	4.9	7.3	10.6	6.9	7.2	9.0	9.5	4.2	1.0	0.1		
16-29	30.5	4.8	6.9	7.2	9.1	7.0	7.8	8.8	8.8	3.4	1.2	0.5	0.5	3.3
29-39	32.1	2.3	5.3	7.6	9.1	7.2	8.2	9.5	9.7	4.3	1.9	1.2	1.7	
45-55	24.7	3.5	4.9	6.6	9.1	7.1	7.6	7.3	7.4	3.4	1.3	2.6	2.4	12.1
55-76	21.3	3.5	4.2	7.8	7.8	10.0	13.3	13.3	10.2	3.7	1.7	1.0	2.4	
76-87	28.6	5.8	9.4	16.9	20.4	9.9	4.2	2.7	1.4	0.5	0.2			

AREA: Jewell bog PROFILE NUMBER: JSS G

Soil series: Webster-FT, calcareous surface; mapping unit 142

Location: 976 ft. N, 568 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: fine textured, stratified hillside surficial over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-5	N 2/0, C, calc.
I A_{11}	5-15	N 2/0, CL, calc.
I A_{12}	15-26	10YR 2/1, CL, calc.
I A_{12}	26-38	10YR 2/1, CL, calc.
I A_{13}	38-54	10YR 2/1, L, calc.
I A_{14}	54-63	10YR 2/1, CL, calc.
I A_{15}	63-76	10YR 3/1, 10YR 4/1, CL, calc.
I A_{16}	76-83	N 2/0, 2.5Y 4/2, SiCL, calc.
II A_{11b}	83-94	2.5Y 3/1, SiCL, calc.
II A_{12b}	94-110	2.5Y 3/1, SiCL, calc.

Profile number: JSS G

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units	Depth (inches)	Bulk density gm/cc
0-5	7.3	3.3	4.9	27	2.36		
5-15	7.4	2.0	4.7	30	2.30	5-7	1.17
15-26	7.3	1.2	1.7	39	2.34	21-24	1.30
26-38	7.4	0.4	1.9	41	2.45		
38-54	7.4	1.7	0.8	92	2.57	38-41	1.39
54-63	7.4	0.5	0.9	50	2.47	50-53	1.39
63-76	7.3	7.1	1.1	72	2.55	64-67	1.36
76-83	7.3	0.8	1.5	19	1.85		
83-94	7.0	4.2	5.7	15	1.75		
94-110	7.6	8.3	3.2	14	1.42	100-103	1.10

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-5	42.5	6.3	8.2	10.5	9.5	6.6	4.1	4.1	4.5	2.1	1.0	0.5		
5-15	36.3	5.2	6.7	15.8	8.9	7.1	4.8	5.1	5.6	2.2	0.9	0.3	1.0	
15-26	37.7	4.9	6.2	9.1	9.7	8.2	6.4	6.5	6.4	2.7	1.2	1.1		
26-38	38.2	4.6	6.6	9.6	10.0	6.2	5.5	6.4	7.0	3.7	1.2	1.1		
38-54	22.6	2.8	3.9	5.4	6.2	4.9	5.7	8.1	11.1	6.7	4.1	4.2	3.0	11.1
54-63	31.2	4.4	5.6	7.8	8.9	7.2	7.4	7.0	7.4	4.0	2.1	3.2	2.4	1.4
63-76	25.4	3.6	5.2	6.8	7.3	6.3	6.9	8.9	10.3	6.1	3.3	3.0	3.7	3.4
76-83	38.9	6.8	8.9	12.6	15.6	7.0	4.5	3.0	2.1	0.6	0.1			
83-94	30.4	9.8	12.1	15.5	17.4	7.5	3.1	2.3	1.3	0.3	0.4			
94-110	30.3	8.1	11.2	18.8	20.0	8.6	2.0	0.5	0.3	0.2	0.2			

AREA: Jewell bog PROFILE NUMBER: JSS H

Soil series: Transition Webster-Glencoe; mapping unit 142-63

Location: 1002 ft. N, 583 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: differentiated hillside sediment (equivalent of upper bog sediment) over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-6	N 2/0, C, calc.
I A_{11}	6-11	N 2/0, C, calc.
I A_{12}	11-22	N 2/0, C
I A_{13}	22-40	N 2/0, C
I A_{14}	40-53	10YR 2/1, CL
I A_{15}	53-60	10YR 2/1, 2.5Y 4/4, CL
I A_{16}	60-72	10YR 2/1, 2.5Y 4/4, CL, calc.
I A_{16}	72-87	10YR 2/1, 2.5Y 4/4, CL, calc.
II A_b	87+	2.5Y 3/1, muck, CL, calc.

Profile number: JSS H

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2μ to 2 mm. Geom. mean (μ)	2μ to 2 mm. Std. dev. phi units	Depth (inches)	Bulk density gm/cc
0-6	7.3	2.1	4.7	16	1.98	3-6	1.14
6-11	7.4	0.8	4.3	15	1.85		
11-22	7.1	--	3.1	22	2.09	20-22	1.24
22-40	7.1	--	2.2	22	2.17	29-32	1.07
40-53	7.2	--	1.4	32	2.38		
53-60	7.3	--	1.4	39	2.37	55-59	1.38
60-72	7.4	3.3	1.5	31	2.42		
72-87	7.4	5.0	1.7	37	2.43		

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	μ								mm.					
	<2μ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-6	44.5	8.6	8.7	12.8	10.9	5.5	2.3	2.1	2.2	0.9	0.3	1.1		
6-11	45.8	7.9	9.4	13.5	11.3	5.1	2.1	1.9	1.8	0.6	0.1	0.4		
11-22	42.8	7.1	7.5	10.8	12.7	6.6	4.4	3.8	2.7	1.1	0.5	0.1		
22-40	42.3	7.6	7.7	11.4	10.8	5.9	4.4	4.0	3.5	1.2	0.4	0.8		
40-53	39.3	6.5	7.3	9.5	9.7	5.8	6.1	6.5	6.0	2.1	0.7	0.6		
53-60	36.7	5.9	6.4	8.7	9.0	6.9	7.0	7.4	6.5	2.7	1.3	1.5		
60-72	37.8	7.1	7.5	9.2	10.2	5.7	5.9	6.2	4.9	2.4	1.1	0.7	1.2	
72-87	31.6	6.7	6.8	7.7	9.6	6.8	7.4	7.0	5.4	2.2	0.9	1.0	2.8	4.2

AREA: Jewell bog PROFILE NUMBER: JSS I

Soil series: Glencoe; mapping unit 63

Location: 1028 ft. N, 598 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: hillside surficial sediment differentiated into upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-8	N 2/0, SiC
I A_{11}	8-16	N 2/0, SiC
I A_{12}	16-38	10YR 2/1, SiC
I A_{12}	38-51	10YR 2/1, SiC
I A_{12}	51-66	10YR 2/1, SiC
I A_{13}	66-72	10YR 2/1, SiC, calc.
I A_{14}	72-87	10YR 2/1, 10YR 3/1, CL, calc.
II A_b	87+	10YR 3/1, SiCL, calc.

Profile number: JSS I

Depth (inches)	pH	% $CaCO_3$ equiv.	% Org. carbon	2µ to 2 mm. Geom. mean (µ)	2µ to 2 mm. Std. dev. phi units	Depth (inches)	Bulk density gm/cc
0-8	7.1	--	4.4	15	1.66		
8-16	7.2	--	4.1	15	1.75	8-10	1.09
16-38	7.1	--	2.15	14	1.81	20-24	1.16
38-51	6.9	--	1.7	14	1.86	32-35	1.35
51-66	7.2	--	1.9	13	1.71	49-51	1.37
66-72	7.4	0.8	1.9	15	2.03	58-60	1.22
72-87	8.0	5.4	1.65	31	2.40		

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.					
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-8	44.5	7.0	8.9	13.1	15.5	6.5	1.7	1.1	1.0	0.4	0.3			
8-16	43.9	8.2	10.5	11.7	13.9	5.5	2.6	1.9	1.3	0.3	0.1			
16-38	44.5	8.8	9.9	12.1	13.1	4.8	2.7	2.1	1.3	0.3	0.3			
38-51	43.0	10.4	10.1	11.0	12.6	6.2	2.8	2.0	1.4	0.5	0.1			
51-66	44.9	9.6	10.3	11.7	12.1	5.5	3.1	1.8	0.7	0.2				
66-72	43.7	11.0	9.1	10.2	12.2	5.9	3.3	2.0	1.5	0.6	0.3			
72-87	37.3	7.1	6.9	9.8	11.5	6.6	5.5	5.5	5.3	2.4	1.4	0.3	0.4	

AREA: Jewell bog PROFILE NUMBER: JSS J

Soil series: Glencoe; mapping unit 63

Location: 1054 ft. N, 613 ft. E of SE corner of SW¼ of SW¼ of Section 18, R-24W, T-86N, Hamilton County, Iowa

Parent material: hillside surficial sediment differentiated into upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I A_p	0-7	N 2/0, SiC
I A_{11}	7-13	N 2/0, SiC
I A_{12}	13-19	10YR 2/1, SiCL, calc.
I A_{13}	19-40	10YR 2/1, SiC, calc.
I A_{13}	40-51	10YR 2/1, SiC, calc.
I A_{13}	51-63	10YR 2/1, SiC, calc.
I A_{13}	63-79	10YR 2/1, SiC, calc.
I A_{14}	79-87	10YR 2/1, SiC, muck, calc.
I A_{15}	87-92	10YR 2/1, SiC
II A_b	92-107	5Y 4/2, SiCL

Profile number: JSS J

Depth (inches)	pH	Exch.H m.e. %	Tot.Ex. Cat. m.e. %	%$CaCO_3$ equiv.	% Org. carbon	2µ to 2 mm. Geom. mean(µ)	2µ to 2 mm. Std. dev. phi units	Depth (inches)	Bulk density gm/cc
0-7	6.7	8.3	50.4	--	4.9	14	1.66		
7-13	6.9	6.9	53.2	--	4.9	16	1.73	9-12	1.17
13-19	7.4			2.9	4.5	13	1.74		
19-40	7.2			0.4	2.0	14	1.81	25-28	0.94
40-51	7.3			--	1.7	12	1.52	40-43	1.06
51-63	7.2	5.2	39.7	--	1.8	12	1.45	57-60	1.24
63-79	7.3			--	1.8	12	1.57		
79-87	7.6			3.3	1.9	18	1.89	79-82	1.17
87-92	7.3			--	3.4	12	1.55		
92-107	7.2			--	4.6	15	1.66	100-104	1.09

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.					
	<2µ	4	8	16	31	62	125	250	0.5	1.0	2	4	8	16
0-7	46.9	7.5	8.6	12.2	14.9	5.0	2.1	1.2	1.0	0.5				
7-13	44.7	6.5	8.6	12.9	15.4	5.9	2.3	1.7	1.5	0.5	0.1			
13-19	38.3	10.2	12.8	13.2	13.5	6.6	2.1	1.6	1.0	0.8				
19-40	46.2	8.1	10.3	11.6	12.8	5.1	2.1	1.5	1.3	0.5	0.3			
40-51	48.7	7.3	11.1	12.1	12.9	4.8	1.6	0.9	0.6	0.1				
51-63	47.0	8.0	11.1	13.7	12.5	5.1	1.5	0.7	0.3	0.1				
63-79	46.0	9.0	10.4	13.4	12.1	5.2	2.0	1.2	0.6	0.1				
79-87	41.9	7.8	9.8	11.1	11.9	7.2	4.2	3.3	2.2	0.6	0.1			
87-92	40.1	9.2	11.9	14.9	14.4	6.3	1.4	0.9	0.6	0.3	0.1			
92-107	33.8	9.0	10.4	14.0	17.3	9.6	3.6	1.4	0.7	0.2				

AREA: McCulloch bog PROFILE NUMBER: M4

Soil series: not named; similar to mapping unit P_6

Location: 1175 ft. N, 220 ft. E of SW corner of SE¼ of Section 32, R-24W, T-94N, Hancock County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_2	0-10	N 2/0, muck
I O_{11}	10-22	10YR 2/2, peat
I O_{12}	22-36	10YR 2/1, peat
I C_1	36-84	10YR 2/1, SiCL, calc.
I C_2	84-132	5Y 2/1, SiCL, calc.
II $O_{21}b$	132-150	5Y 2/1, muck, calc.
II C_1b	150-174	5Y 5/2, SiC, shells
II $O_{22}b$	174-186	10YR 4/2, muck, calc.
II $O_{23}b$	186-234	5Y 3/2, muck
II C_2b	234-280	5Y 3/2, SiCL

Profile number: M4

Depth (inches)	pH	Exch. H m.e. %	Tot. Exch. Cat. m.e. %	% CaCO equiv.	% Org. carbon	Depth (inches)	Bulk density gm/cc
0-10	6.7	10.8	125.4	--	34.9	60-66	0.40
10-22	6.8	11.5	108.3	--	42.2	84-90	0.47
22-36	7.0			--	35.1	114-120	0.57
36-84	8.3			13.3	16.5	174-180	0.18
84-132	8.4			25.8	12.6	186-192	0.13
132-150	8.4			30.0	18.7	210-216	0.20
150-174	8.5			56.6	13.4	222-228	0.28
174-186	8.2			25.8	20.7	240-246	0.59
186-234	7.8			8.3	20.2	264-270	0.78
234-274	7.0			--	5.1	276-282	0.85
274-280	7.3			--	4.1		

Profile number: M4 (continued)

Mechanical analysis % frequency for intervals given by upper size limit

Depth (inches)	µ								mm.		2µ to 2 mm.	
	<2µ	4	8	16	31	62	125	250	0.5	1.0	Geom. mean (µ)	Std. dev. phi units
0-3	30.2	9.5	13.1	19.3	15.2	11.7	1.0	0.6	0.8		13	1.43
12-15	28.2	9.9	11.4	16.4	25.9	5.3	0.9	0.7	1.3	0.1	13	1.29
24-27	31.7	11.3	7.5	16.3	23.5	5.7	2.4	0.9	0.9		14	1.48
42-45	33.5	9.5	14.6	13.1	18.6	8.8	1.1	0.4	0.4		12	1.40
69-72	36.3	8.3	12.0	17.3	15.4	5.2	1.2	1.6	2.1	0.6	14	1.70
84-87	37.5	11.6	12.2	15.8	15.6	6.2	0.4	0.3	0.3	0.3	11	1.42
105-108	35.6	10.0	13.0	17.5	16.4	5.1	1.0	0.6	0.8	0.1	12	1.43
117-120	39.1	10.3	13.7	19.0	15.4	1.8	0.2	0.2	0.1	0.1	10	1.20
144-147	49.6	11.3	10.6	12.5	10.7	3.7	0.7	0.8			10	1.41
165-168	38.9	26.3	14.4	10.7	6.8	0.6	0.7	1.1			6	1.34
198-201	34.9	13.2	9.4	15.2	14.3	8.9	1.5	1.7	0.9		12	1.41
213-216	46.2	9.5	12.2	13.9	12.3	5.0	0.3	0.2	0.4	0.1	10	1.37
228-231	37.2	10.5	14.1	18.4	17.0	2.5	0.1	0.1	0.1		11	1.46
240-243	34.0	11.2	13.5	21.2	17.0	3.0	0.1				10	1.14
252-255	34.7	9.7	15.4	16.8	18.3	4.9	0.1	0.1	0.1		10	1.23

<u>AREA</u>: Woden bog PROFILE NUMBER: W1

<u>Soil series</u>: not named; similar to mapping unit P_6

<u>Location</u>: 543 ft. E of NE corner of pig yard at Feldman's farm - R-26W, T-97N, Section 13, Hancock County, Iowa

<u>Parent material</u>: upper bog sediment over lower bog sediment over Cary

Horizon	Depth (inches)	Description
I O_2	0-9	N 2/0, muck
I O_1	9-18	2.5Y 2/1, peat
I C_1	18-45	10YR 2/1, SiCL, calc.
I C_2	45-72	N 2/0, SiCL, calc.
I C_3	72-84	10YR 2/1, SiCL
I C_4	84-144	10YR 2/1, SiCL, calc.
I C_{51}	144-192	5Y 2/1, SiCL, calc.
I C_{52}	192-228	5Y 2/1, SiCL, calc.
I C_6	228-252	2.5Y 2/1, SiCL, calc.
I C_7	252-288	10YR 2/1, SiCL, calc.
I C_8	288-312	5Y 3/1, SiCL, muck, calc.
II O_2b	312-327	10YR 2/1, muck, calc.
II C_1b	327-354	5Y 3/1, SiCL, muck, calc.
II C_2b	354-372	5Y 3/1, SiCL, muck, calc.
II C_3b	372-378	5Y 4/1, SiCL, muck, calc.

AREA: Woden bog (continued) PROFILE NUMBER: W1

Horizon	Depth (inches)	Description
II $C_{4}b$	378-390	5Y 4/1, SiCL, calc.
III $C_{5}b$	390-396	5Y 5/1, L, calc.

Depth (inches)	% $CaCO_3$ equiv.	% Org. carbon
0-9	--	17.5
9-18	--	30.2
18-45	1.2	14.3
45-72	1.2	16.4
72-84	5.4	12.6
84-144	6.2	10.8
144-192	11.2	9.5
192-228	9.2	9.4
228-252	8.3	10.2
252-288	7.9	12.7
288-312	12.5	9.5
312-327	10.4	19.2
327-354	13.7	14.1
354-372	17.5	9.0
378-390	11.2	1.7
390-396	16.7	0.8

AREA: Hebron bog PROFILE NUMBER: H1

Soil series: not named; similar to mapping unit P_5

Location: 850 ft. S, 675 ft. E of NW corner of SW¼ of NW¼ of Section 27, Hebron Township, Kossuth County, Iowa

Parent material: upper bog sediment over lower bog sediment over Cary till

Horizon	Depth (inches)	Description
I O_{21}	0-3	10YR 2/1, muck
I O_{22}	3-12	10YR 3/2, muck
I O_{22}	12-19	10YR 3/2, muck
I C_1	19-28	10YR 2/2, SiCL
I C_2	28-33	10YR 2/1, SiCL
I C_3	33-45	N 2/0, 1Y 3/3, SiCL
I C_4	45-56	N 2/0, 1Y 3/3, SiCL
I C_5	56-70	1Y 3/2, 2.5YR 3/4, SiCL, calc.
I C_6	70-78	5Y 6/1, 7.5YR 5/6, SiCL, calc.
II O_{21b}	78-82	10YR 2/1, muck, calc.
II O_{22b}	82-90	2.5Y 3/2, muck
II C_{1b}	90-100	2.5Y 3/2, SiCL, calc.
II C_{2b}	100-120	5Y 4/1, SiCL, calc.
II C_{2b}	120-134	5Y 4/1, SiCL, calc.
II C_{3b}	134-146	5Y 4/1, SiL, calc.
III C_{4b}	146-152	5Y 4/1, L, calc.

Profile number: H1

Depth (inches)	% $CaCO_3$ equiv.	% Org. carbon
0-3	--	23.5
3-12	--	18.6
12-19	--	16.5
19-28	--	6.8
28-33	--	4.8
33-45	--	3.4
45-56	2.9	2.5
56-70	4.6	2.4
70-78	45.4	5.5
78-82	1.7	26.3
82-90	--	15.5
90-100	5.4	12.2
100-120	14.2	0.8
120-134	15.4	0.9
134-136	18.7	0.8
146-152	16.2	0.5

XV. APPENDIX B

A. Laboratory Methods

The following laboratory analyses were made:

1. Soil pH
2. Total carbon
3. Calcium carbonate equivalent
4. Organic carbon (by difference)
5. Particle size distribution
6. Bulk density
7. Total exchangeable bases and exchangeable hydrogen
8. Pollen separation

Notes on each method are given below.

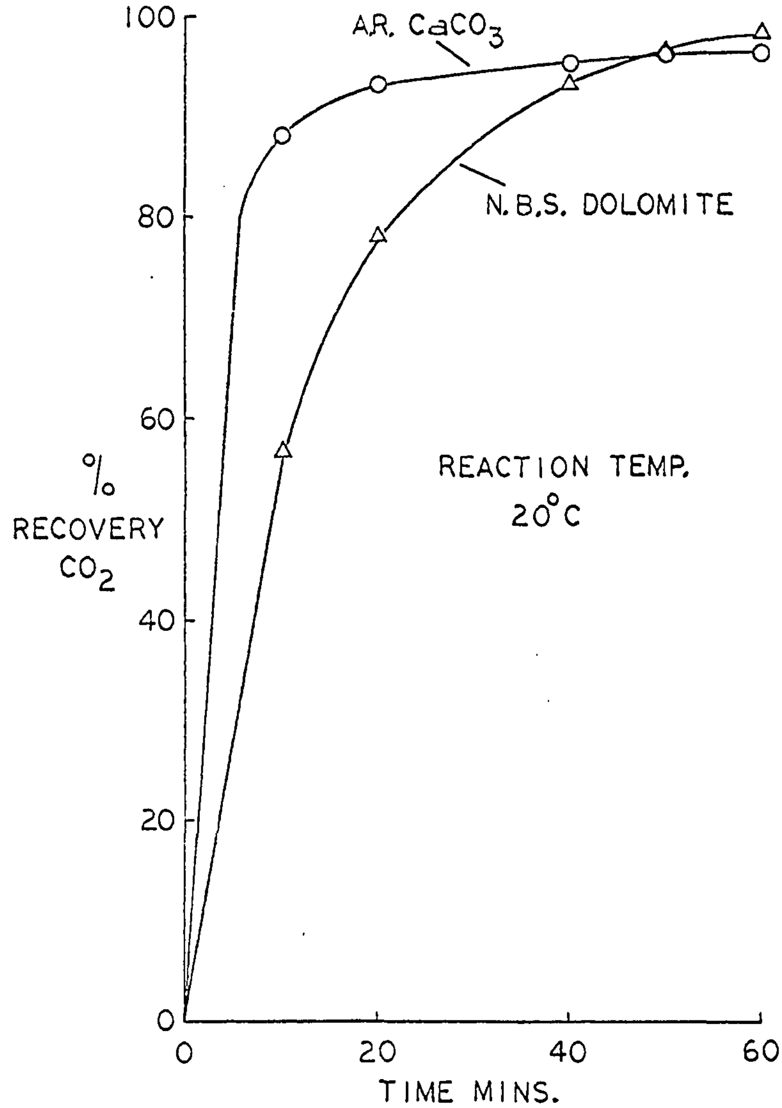
1. Soil pH

Soil pH was determined using a Beckman glass electrode pH meter on a 1:2 soil to water mixture. Since most values were known to lie within a pH range of 5 to 9, a buffer of pH 7.0 was used to standardize the meter during a series of determinations. A period of one hour was allowed to elapse from the time of initial mixing to the time of pH measurement.

2. Total carbon

Total carbon content was determined by combustion of a 0.1-0.5 gm soil sample (sieved to pass a 0.25 mm screen) in a carbon train furnace at 900-950°C for 10 minutes. The laboratory equipment and procedure have been described in detail by

Figure 57. Recovery-time curves for A.R. calcium carbonate and dolomite (47.25 percent CO_2)



100
80
60
40
20
0
%
RECOVERY
CO_2
A.R. $CaCO_3$
N.B.S. DOLOMITE
REACTION TEMP.
20°C
0
20
40
60
TIME MINS.

Black (1961, p. 12). The method measures the weight of CO_2 evolved from combustion and absorbed on granulated ascarite.

3. Calcium carbonate equivalent

Carbonate content was determined by treatment of 0.5 gm samples of soil, ground to pass a 0.25 mm sieve, with 1:3 HCl. The soil was placed on the bottom of a 50 mls Erlenmeyer flask and 3 to 5 mls of the acid was introduced into a test tube, fused to the wall of the flask. A stopper was loosely set in place and the whole assembly accurately weighed. The contents of the flask were mixed thoroughly and subsequently shaken occasionally over a period of one hour. The loss in weight of the assembly after one hour was the loss of CO_2 from the soil sample. For all analytical runs, a blank of HCl alone was weighed in order to obtain a correction for loss of HCl vapor. Recovery-time curves for this method are shown in Figure 57 using Analytical Reagent $CaCO_3$ and National Bureau of Standards dolomite of 47.25 percent CO_2.

4. Organic carbon (by difference)

This value was computed by subtracting the carbon content, estimated by the calcium carbonate equivalent method, from the total carbon content, estimated by combustion.

5. Mechanical analysis

Particle size was determined by treating 20 gms of soil with peroxide and 1 percent acetic acid until the soil became pale colored and presumably depleted in organic matter. Excess peroxide was boiled off and the suspension was then treated with 20 mls of calgon (38 gms calgon + 8 gms Na_2CO_3 in 1 ℓ distilled water) and shaken overnight.

The analysis was carried out by pipetting 25 ml aliquots from the suspension made up to 1000 mls with water and by drying and weighing these. The following particle size intervals were separated: <2μ, 2-4, 4-8, 8-16, 16-31, 31-62, 62-125, 125-250, 250-500, 500-1000μ, 1-2 mm, 2-4, 4-8, 8-16, 16-32 mm. All fractions up to 62μ were determined by sedimentation using the times shown in the nomographs of Tanner and Jackson (1947). Fractions greater than 62μ were estimated by sieving.

6. <u>Bulk density</u>

These data were obtained by taking undisturbed soil samples with either a brass ring of volume 59.27 ccs, a Davis peat sampler of volume 36.1 ccs, and a 2-inch diameter hydraulic probe sampler.

The brass ring was used for surface samples and subsoil samples taken from road cuttings. The probe sampler was used for deep subsoil samples in till. The Davis sampler was used to collect deep organic and mineral sediment samples in the bogs.

In each case the samples were taken at field moisture, dried overnight at 105°C and weighed. The results are expressed as gms of oven dry soil per cc of sample volume at field moisture.

7. <u>Total exchangeable bases and exchangeable hydrogen</u>

The methods employed here are essentially those of Russell (1958, p. 6; p. 13). For the exchangeable bases, the soil was leached with neutral 1N ammonium acetate; the extractant was then evaporated to dryness, ashed, taken up in 0.1N HCl, filtered, and back titrated with 0.1N NaOH.

Exchangeable hydrogen was determined by leaching the soil with neutral 1N barium acetate and titrating the leachate with 0.1N NaOH to an endpoint of pH 7.0.

8. <u>Pollen separation</u>

The procedure follows most of the steps outlined in the publication of the U.S. Geological Survey (1960). Some modifications were made, however, consequently the procedure is set out briefly below as a laboratory flow sheet.

1. Preparation

   Weigh desired amount of ground and sieved sample (0.25 mm) and place in Pyrex beaker.

   (Amounts of reagents given here are suitable for 0.5 gm sample.)

2. Removal of carbonates

   Treat overnight with about 15 mls 10% hydrochloric acid.

3. Breakdown of organic materials

   Wash with water and add about 20 mls hydrogen peroxide C.P. 30% with 3 drops of glacial acetic acid. Warm until bubbles form on sides of beaker. Remove from heat and let stand an hour or until all visible activity has ceased.

4. Removal of silicates

   Wash with water several times and transfer to plastic beakers. Treat overnight with about 10 mls conc. hydrofluoric acid.

   Wash with 10% HCl and then wash with water 4 times.

5. Acetolysis - for dissociation of cellulose, in fume hood, with gloves and shield

   Wash sample twice with glacial acetic acid, centrifuge and decant each time.

   <u>CAUTION</u>. Make acetolysis reagent just prior to use by adding one part conc. sulfuric acid to nine parts acetic anhydride. Add about 5 mls of this mixture to sample and mix. Leave stirring rod in tube and place in a water bath which can be maintained at 90°C for 3 minutes.

Flow Sheet 1. Laboratory Flow Sheet

5. (continued)

   Remove from heat and fill tube with glacial acetic acid. Centrifuge and decant.

   Wash with glacial acetic acid again.

   Wash with water 6 times until there is no acetic odor.

6. Removal of organic residues

   Transfer sample to Pyrex beaker with 10% potassium hydroxide, using about 20 mls.

   Simmer 5 minutes, then allow to stand 10 min. Double volume with addition of water and let stand 1-2 hours.

   Decant and wash with water 4-5 times, or until clear.

7. Mounting residue

   Transfer residue to centrifuge tubes with 25% ethyl alcohol. Centrifuge and decant.

   Wash with 50% ethyl alcohol. Centrifuge and decant.

   Wash with 95% ethyl alcohol. Centrifuge and decant.

   Drop desired amount of residue-alcohol mixture on cover glass and allow alcohol to evaporate.

   Drop AYAF on the nearly-dry residue and mix. Allow to dry.

   Turn cover glass down into Permount on cleaned slide.

   Write identification on slide.

   Allow to dry overnight.

Flow Sheet 1. (continued)

XVI. APPENDIX C

A. Soil Maps and Description of Mapping Units

The soil maps and mapping units have already been described in body of the thesis. In this appendix, reproductions of the field mapping sheets of Colo and Jewell are shown as Figures 58 and 59 respectively. Following these, in Table 30, a listing of the soil mapping units is given with some details of topography and profile for each unit. Where possible, the relationship between the soils of a unit and established series are stated or footnoted; however, some of these relationships are based on field evidence alone, and are therefore tentative. In all descriptions, the Munsell color notation is for moist soils.

Figure 58. Soil map of the Colo bog watershed


N
680 ft.

Figure 59. Soil map of the Jewell bog watershed

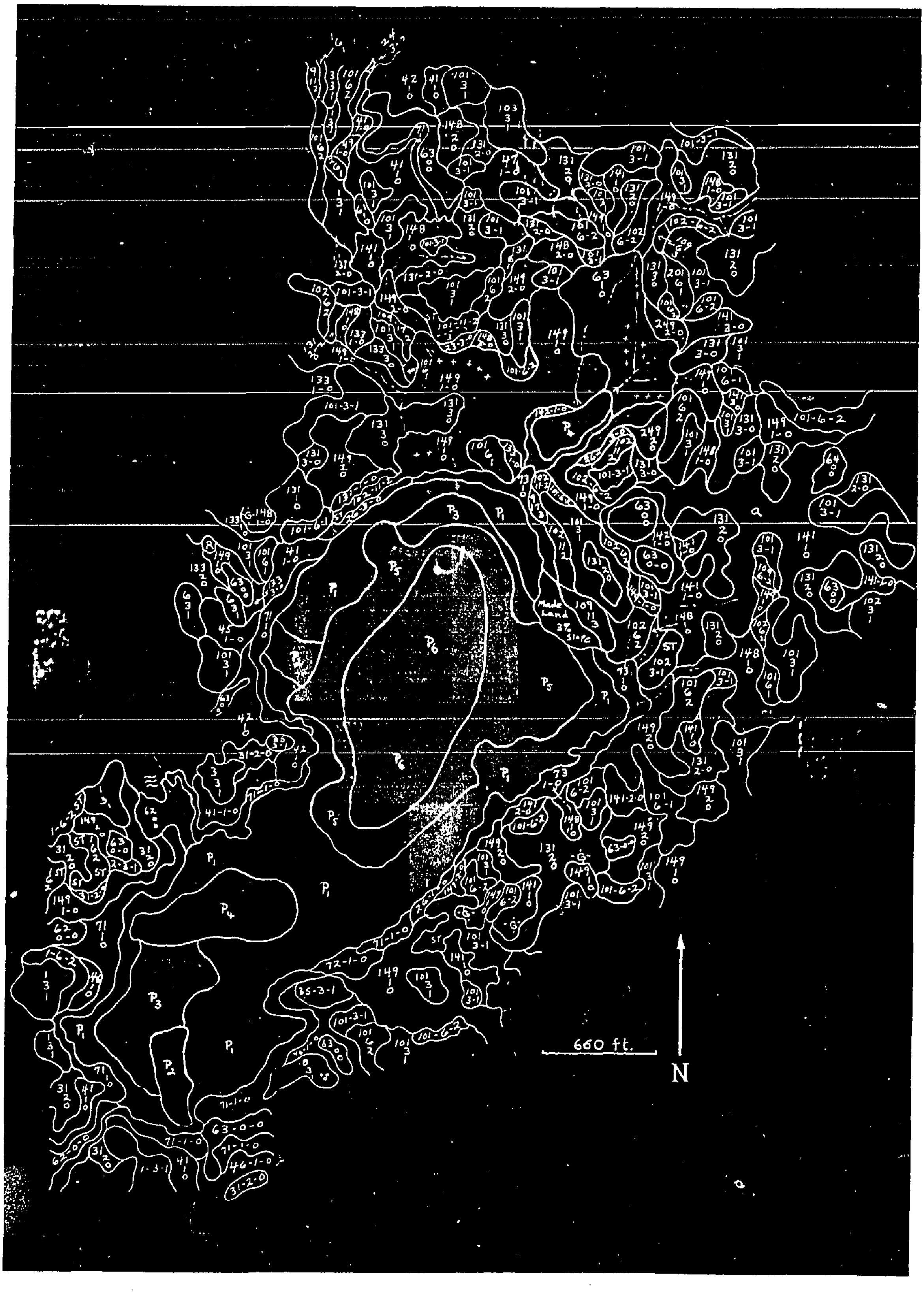

660 ft.
N

Table 30. Generalized profile characteristics for the soil mapping legend in the Colo and Jewell bog watersheds with series designations

Soil Features	Unit 1-3-1 Clarion	Unit 1-6-1 Clarion	Unit 1-6-2 Clarion
Topography	Convex slopes	Convex slopes	Convex slopes
% Slope	2-5	5-9	5-9
Erosion	Slight	Slight	Moderate
Drainage	Well	Well	Well
Parent material	L till	L till	L till
A horizon			
Thickness	7-14"	7-14"	3-7"
Color (A1)	10YR 2/1,2/2	10YR 2/1,2/2	10YR 2/2,3/2
Texture	L	L	L
B horizon			
Color (B2)	10YR 4/3,4/4	10YR 4/3,4/4	10YR 4/3,4/4
Texture	L	L	L
Depth to:			
Carbonates	24-40"	24-40"	24-40"
Stratification			
Mapped:			
At Colo	+	+	+
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit 2-3-1 Clarion (shallow CO_3)	Unit 2-6-1 Clarion (shallow CO_3)	Unit 2-6-2 Clarion (shallow CO_3)
Topography	Convex slopes	Convex slopes	Convex slopes
% Slope	2-5	5-9	5-9
Erosion	Slight	Slight	Moderate
Drainage	Well	Well	Well
Parent material	L till	L till	L till
A horizon			
Thickness	7-14"	7-14"	3-7"
Color (A1)	10YR 2/1,2/2	10YR 2/1,2/2	10YR 2/2,3/2
Texture	L	L	L
B horizon			
Color (B2)	10YR 4/3,4/4	10YR 4/3,4/4	10YR 4/3,4/4
Texture	L	L	L
Depth to:			
Carbonates	12-24"	12-24"	12-24"
Stratification			
Mapped:			
At Colo			+
At Jewell	+	+	

Table 30. (continued)

Soil features	Unit 3-3-1 Clarion (deep CO_3)	Unit 6-3-1 Clarion (strat. var.)	Unit 6-3-2 Clarion (strat. var.)
Topography	Convex slopes	Convex slopes	Convex slopes
% Slope	2-5	2-5	2-5
Erosion	Slight	Slight	Moderate
Drainage	Well	Well	Well
Parent material	L till	Strat. till	Strat. till
A horizon			
Thickness	7-14"	7-14"	3-7"
Color (A1)	10YR 2/1,2/2	10YR 2/1,2;2	10YR 2/2,3/2
Texture	L	L	L
B horizon			
Color (B2)	10YR 4/3,4/4	10YR 4/3,4/4,5/4	10YR 4/3,4/4,5/4
Texture	L	L & SL	L & SL
Depth to:			
Carbonates	40-50"	>36"	>36"
Stratification		24-36"	24-36"
Mapped:			
At Colo	+	+	+
At Jewell	+	+	

Table 30. (continued)

Soil features	Unit 8-3-1 Clarion (strat. var.)	Unit 8-6-1 Clarion (strat. var.)	Unit 9-11-2 Storden
Topography	Convex slopes	Convex slopes	Convex slopes
% Slope	2-5	5-9	9-14
Erosion	Slight	Slight	Moderate
Drainage	Well	Well	Well
Parent material	Strat. till	Strat. till	L till
A horizon			
Thickness	7-14"	7-14"	3-7"
Color (A1)	10YR 2/1,2/2	10YR 2/1,2/2	10YR 2/2,3/3
Texture	L	L	L
B horizon			
Color (B2)	10YR 4/3,4/4	10YR 4/3,4/4	(C1) 10YR 4/4,5/4
Texture	L & SL	L & SL	(C1) L
Depth to:			
Carbonates	>36"	>36"	<12"
Stratification	36-48"	36-48"	
Mapped:			
At Colo	+	+	
At Jewell	+		+

Table 30. (continued)

Soil features	Unit 9-17-3 Storden	Unit 10-11-3 Storden (strat. var.)	Unit 11-2-1 Clarion (mod. well)
Topography	Convex slopes	Convex slopes	Convex to concave
% Slope	14-18	9-14	1-3
Erosion	Severe	Severe	Slight
Drainage	Well	Excessive	Mod. well
Parent material	L till	Strat. till	L till
A horizon			
Thickness	<3"	<3"	6-14"
Color (A1)	10YR 3/2,3/3	10YR 3/2,3/3	10YR 2/1
Texture	L	L & SL	L
B horizon			
Color (B2)	(Cl) 10YR 4/4,5/4	(Cl) 10YR 4/4,5/4	1Y 4/2,5/3
Texture	(Cl) L	(Cl) L & SL	L-CL
Depth to:			
Carbonates	<12"	<12"	24-40"
Stratification		20"	
Mapped:			
At Colo		+	+
At Jewell	+		

Table 30. (continued)

Soil features	Unit 11-3-1 Clarion (mod. well)	Unit 22-3-0 Terril	Unit 23-3-0 Terril
Topography	Convex to concave	Convex to concave	Convex to concave
% Slope	2-5	2-5	2-5
Erosion	Slight	None	None
Drainage	Mod. well	Mod. well	Imperfect
Parent material	L till	Local alluvium	Local alluvium
A horizon			
Thickness	6-14"	20-30"	30-40"
Color (A1)	10YR 2/1	10YR 2/1,2/2	10YR 2/1
Texture	L	L	L-CL
B horizon			
Color (B2)	1Y 4/2,5/3	10YR 3/3,4/3	2.5Y 3/2,5/3
Texture	L-CL	L-CL	L-CL
Depth to:			
Carbonates	24-40"	30-40"	>40"
Stratification			
Mapped:			
At Colo	+	+	
At Jewell			+

Table 30. (continued)

Soil features	Unit 24-3-0 Nicollet (cum. var.)	Unit 26-1-0 Unnamed (local alluv.)	Unit 26-3-0 Unnamed (local alluv.)
Topography	Concave slopes	Concave slopes	Concave slopes
% Slope	2-5	0-2	2-5
Erosion	None	None	None
Drainage	Imperfect	Poor	Poor
Parent material	L till	Local alluvium	Local alluvium
A horizon			
Thickness	20-30"	>30"	>30"
Color (A1)	10YR 2/1	2/0, 10YR 3/1	2/0, 10YR 3/1
Texture	L	CL-SiCL	CL-SiCL
B horizon			
Color (B2)	2.5Y 4/2,5/2	2.5, 5Y 3/2,5/2	2.5, 5Y 3/2,5/2
Texture	L-CL	L-CL	L-CL
Depth to:			
Carbonates	24-40"	>36"	>36"
Stratification			
Mapped:			
At Colo	+		
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit 31-2-0 Nicollet	Unit 31-2-1 Nicollet	Unit 32-2-0 Nicollet (shallow CO_3)
Topography	Concave to convex	Concave to convex	Concave to convex
% Slope	1-3	1-3	1-3
Erosion	None	Slight	None
Drainage	Imperfect	Imperfect	Imperfect
Parent material	L till	L till	L till
A horizon			
Thickness	12-20"	10-14"	12-20"
Color (A1)	2/0, 10YR 2/1	2/0, 10YR 2/1	2/0, 10YR 2/1
Texture	L	L	L
B horizon			
Color (B2)	1Y, 2.5Y 4/2	1Y, 2.5Y 4/2	1Y, 2.5Y 4/2
Texture	L-CL	L-CL	L-CL
Depth to:			
Carbonates	24-40"	24-40"	12-24"
Stratification			
Mapped:			
At Colo	+		+
At Jewell	+	+	

Table 30. (continued)

Soil features	Unit 33-2-0 Nicollet (deep CO_3)	Unit 34-2-0 Nicollet	Unit 35-3-1 Nicollet (calc. var.)
Topography	Concave to convex	Concave to convex	Concave to convex
% Slope	1-3	1-3	2-5
Erosion	None	None	Slight
Drainage	Imperfect	Imperfect	Imperfect
Parent material	L till	Strat. till	L till
A horizon			
Thickness	12-20"	12-20"	12-20"
Color (A1)	2/0, 10YR 2/1	2/0, 10YR 2/1	2/0, 10YR 2/1
Texture	L	L	L
B horizon			
Color (B2)	1Y 4/2, 2.5Y 4/2	1Y, 2.5Y 4/2	1Y, 2.5Y 4/2
Texture	L-CL	L & SiCL	L-CL
Depth to:			
Carbonates	40-50"	40-60"	--
Stratification		30-40"	
Mapped:			
At Colo	+	+	
At Jewell			+

Table 30. (continued)

Soil features	Unit 41-1-0 Webster	Unit 42-1-0 Webster (calc. var.)	Unit 45-1-0 Webster(2)
Topography	Concave slopes	Concave slopes	Concave slopes
% Slope	0-2	0-2	0-2
Erosion	None	None	None
Drainage	Poor	Poor	Poor
Parent material	L till	L till	Strat. till
A horizon			
Thickness	14-24"	14-24"	14-24"
Color (A1)	2/0, 10YR 2/1	2/0, 10YR 2/1	2/0, 10YR 2/1
Texture	CL-SiCL	CL-SiCL	CL-SiCL
B horizon			
Color (B2)	5Y 4/1,5/2	5Y 4/1,5/2	5Y 4/1,5/2
Texture	CL	CL	CL
Depth to:			
Carbonates	24-40"	--	24-40"
Stratification			>40"
Mapped:			
At Colo	+		+
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit 46-1-0 Webster(2) (calc. var.)	Unit 47-1-0 Webster(2) (deep CO)	Unit 49-1-0 Webster (cumulic,deep CO_3)
Topography	Concave slopes	Concave slopes	Concave slopes
% Slope	0-2	0-2	0-2
Erosion	None	None	None
Drainage	Poor	Poor	Poor
Parent material	Strat. till	Strat. till	L till
A horizon			
Thickness	14-24"	14-24"	20-30"
Color (A1)	2/0, 10YR 2/1	2/0, 10YR 2/1	2/0, 10YR 2/1
Texture	CL-SiCL	CL-SiCL	CL-SiCL
B horizon			
Color (B2)	5Y 4/1,5/2	5Y 4/1,5/2	5Y 4/1,5/2
Texture	CL	CL	CL
Depth to:			
Carbonates	--	40-55"	40-55"
Stratification	>40"		
Mapped:			
At Colo	+	+	
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit 50-1-0 Calco (loamy var.)	Unit 61-1-0 Glencoe	Unit 62-0-0 Glencoe (calc. var.)
Topography	Concave slopes	Depression	Depression
% Slope	0-2	0-2	<1
Erosion	None	None	None
Drainage	Poor	Very poor	Very poor
Parent material	Local alluvium	Local alluvium	Local alluvium
A horizon			
Thickness	30-40"	30-40"	30-40"
Color (A1)	2/0, 2/1	2/0	2/0
Texture	L-SL	SiCL	SiCL
B horizon			
Color (B2)	5Y 4/1	10YR 3/1	10YR 3/1,4/1
Texture	L	SiCL	SiCL
Depth to:			
Carbonates	--	>30"	--
Stratification			
Mapped:			
At Colo	+		+
At Jewell		+	+

Table 30. (continued)

Soil features	Unit 63-0-0 Glencoe(2)	Unit 63-1-0 Glencoe(2)	Unit 64-0-0 Glencoe(2) (calc. var.)
Topography	Depression	Slight concave	Depression
% Slope	<1	0-2	<1
Erosion	None	None	None
Drainage	Very poor	Very poor	Very poor
Parent material	Local alluvium	Local alluvium	Local alluvium
A horizon			
Thickness	>40"	>40"	>40"
Color (A1)	2/0	2/0	2/0
Texture	SiCL	SiCL	SiCL
B horizon			
Color (B2)	--	--	--
Texture			
Depth to:			
Carbonates	>40" (?)	>40" (?)	--
Stratification			
Mapped:			
At Colo	+		
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit 71-1-0 Harpster	Unit 72-1-0 Harpster (cum. var.)	Unit 73-1-0 Harpster(2)
Topography	Concave slopes	Concave slopes	Concave slopes
% Slope	0-2	0-2	0-2
Erosion	None	None	None
Drainage	Poor	Poor	Poor
Parent material	L till	L till	Strat. till
A horizon			
Thickness	12-20"	20-36"	24-36"
Color (A1)	2/1,3/1	2/1,3/1	2/1,3/1
Texture	L	L	L-SL
B horizon			
Color (B2)	5Y 4/1,5/2	5Y 4/1,5/2	5Y 4/1,5/2
Texture	L-CL	L-CL	L-CL
Depth to:			
Carbonates	--	--	--
Stratification			15-30"
Mapped:			
At Colo	+	+	
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit 101-3-1[a] Clarion-FT	Unit 101-6-1[a] Clarion-FT	Unit 101-6-2[a] Clarion-FT
Topography	Convex slopes	Convex slopes	Convex slopes
% Slope	2-5	5-9	5-9
Erosion	Slight	Slight	Moderate
Drainage	Mod. well	Mod. well	Mod. well
Parent material	CL till	CL till	CL till
A horizon			
Thickness	7-14"	7-14"	3-7"
Color (A1)	10YR 2/1,2/2	10YR 2/1,2/2	10YR 2/2,3/2
Texture	CL	CL	CL
B horizon			
Color (B2)	10YR, 1Y 4/2,4/3	10YR, 1Y 4/2,4/3	10YR, 1Y 4/2,4/3
Texture	CL	CL	CL
Depth to:			
Carbonates	24-40"	24-40"	24-40"
Stratification			
Mapped at:			
Colo			
Jewell	+	+	+

[a]Comparable with Guckeen series.

Table 30. (continued)

Soil features	Unit 101-11-2[a] Clarion-FT	Unit 102-3-1[a] Clarion-FT (shallow CO_3)	Unit 102-6-2[a] Clarion-FT (shallow CO_3)
Topography	Convex slopes	Convex slopes	Convex slopes
% Slope	9-14	2-5	5-9
Erosion	Moderate	Slight	Moderate
Drainage	Mod. well	Mod. well	Mod. well
Parent material	CL till	CL till	CL till
A horizon			
Thickness	3-7"	7-14"	3-7"
Color (A1)	10YR 2/2,3/2	10YR 2/1,2/2	10YR 2/2,3/2
Texture	CL	CL	CL
B horizon			
Color (B2)	10YR, 1Y 4/2,4/3	10YR, 1Y 4/2,4/3	10YR, 1Y 4/2,4/3
Texture	CL	CL	CL
Depth to:			
Carbonates	24-40"	12-24"	12-24"
Stratification			
Mapped:			
At Colo			
At Jewell	+	+	+

[a]Comparable with Guckeen series.

Table 30. (continued)

Soil features	Unit 102-11-2[a] Clarion-FT (shallow CO_3)	Unit 103-3-1[a] Clarion-FT (deep CO_3)	Unit 109-6-2 Storden
Topography	Convex slopes	Convex slopes	Convex slopes
% Slope	9-14	2-5	5-9
Erosion	Moderate	Slight	Moderate
Drainage	Mod. well	Mod. well	Mod. well
Parent material	CL till	CL till	CL till
A horizon			
Thickness	3-7"	7-14"	3-7"
Color (A1)	10YR 2/2,3/2	10YR 2/1,2/2	10YR 2/2,3/2
Texture	CL	CL	CL
B horizon			
Color (B2)	10YR, 1Y 4/2,4/3	10YR, 1Y 4/2,4/3	(C1)10YR,1Y 4/3,5/3
Texture	CL	CL	(C1) L-CL
Depth to:			
Carbonates	12-24"	40-55"	<12"
Stratification			
Mapped:			
At Colo			
At Jewell	+	+	+

[a]Comparable with Guckeen series.

Table 30. (continued)

Soil features	Unit 109-6-3 Storden	Unit 109-11-3 Storden	Unit 109-17-2 Storden
Topography	Convex slopes	Convex slopes	Convex slopes
% Slope	5-9	9-14	14-18
Erosion	Severe	Severe	Moderate
Drainage	Mod. well	Mod. well	Mod. well
Parent material	CL till	CL till	CL till
A horizon			
Thickness	<3"	<3"	3-7"
Color (A1)	10YR 3/2,3/3	10YR 3/2,3/3	10YR 2/2,3/2
Texture	CL	CL	CL
B horizon			
Color (B2)	(C1)10YR,1Y 4/3,5/3	(C1)10YR,1Y 4/3,5/3	(C1)10YR,1Y 4/3,5/3
Texture	(C1) L-CL	(C1) L-CL	(C1) L-CL
Depth to:			
Carbonates	<12"	<12"	<12"
Stratification			
Mapped:			
At Colo			
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit 131-1-0[a] Nicollet-FT	Unit 131-2-0[a] Nicollet-FT	Unit 131-3-0[a] Nicollet-FT
Topography	Convex to concave	Convex to concave	Convex to concave
% Slope	0-2	1-3	2-5
Erosion	None	None	None
Drainage	Imperfect	Imperfect	Imperfect
Parent material	CL till	CL till	CL till
A horizon			
Thickness	7-14"	7-14"	12-20"
Color (A1)	2/0, 10YR 2/1	2/0, 10YR 2/1	2/0,2/1
Texture	CL	CL	CL
B horizon			
Color (B2)	2.5Y 4/2,5/2	2.5Y 4/2,5/2	2.5Y 4/2,5/2
Texture	CL	CL	CL
Depth to:			
Carbonates	24-40"	24-40"	24-40"
Stratification			
Mapped:			
At Colo			
At Jewell	+	+	+

[a]Comparable with Guckeen series.

Table 30. (continued)

Soil features	Unit 131-6-1[a] Nicollet-FT	Unit 133-1-0[a] Nicollet-FT (deep CO_3)	Unit 133-2-0[a] Nicollet-FT (deep CO_3)
Topography	Convex to concave	Convex to concave	Convex to concave
% Slope	5-9	0-2	1-3
Erosion	Slight	None	None
Drainage	Imperfect	Imperfect	Imperfect
Parent material	CL till	CL till	CL till
A horizon			
Thickness	7-12"	12-20"	12-20"
Color (A1)	10YR 2/1	2/0,2/1	2/0,2/1
Texture	CL	CL	CL
B horizon			
Color (B2)	2.5Y 4/2,5/2	2.5Y 4/2,5/2	2.5Y 4/2,5/2
Texture	CL	CL	CL
Depth to:			
Carbonates	24-40"	40-55"	40-55"
Stratification			
Mapped:			
At Colo			
At Jewell	+	+	+

[a]Comparable with Guckeen series.

Table 30. (continued)

Soil features	Unit 133-3-0[a] Nicollet-FT (deep CO_3)	Unit 141-1-0 Webster-FT	Unit 141-2-0 Webster-FT
Topography	Convex to concave	Concave slopes	Concave slopes
% Slope	2-5	0-2	1-3
Erosion	None	None	None
Drainage	Imperfect	Poor	Poor
Parent material	CL till	CL till	CL till
A horizon			
Thickness	12-20"	14-24"	14-24"
Color (A1)	2/0,2/1	2/0,2/1	2/0,2/1
Texture	CL	SiCL-CL	SiCL-CL
B horizon			
Color (B2)	2.5Y 4/2,5/2	5Y 3/1,5/2	5Y 3/1,5/2
Texture	CL	HCL	HCL
Depth to:			
Carbonates	40-55"	24-40"	24-40"
Stratification			
Mapped:			
At Colo			
At Jewell	+	+	+

[a]Comparable with Guckeen series

Table 30. (continued)

Soil features	Unit 141-3-0 Webster-FT	Unit 142-1-0 Webster-FT (calc. var.)	Unit 148-1-0 Webster-FT (deep CO_3)
Topography	Concave slopes	Concave slopes	Concave slopes
% Slope	2-5	0-2	0-2
Erosion	None	None	None
Drainage	Poor	Poor	Poor
Parent material	CL till	CL till	CL till
A horizon			
Thickness	14-24"	14-24"	14-24"
Color (A1)	2/0,2/1	2/0,2/1	2/0,2/1
Texture	SiCL-CL	SiCL-CL	SiCL-CL
B horizon			
Color (B2)	5Y 3/1,5/2	5Y 3/1,5/2	5Y 4/1,5/2
Texture	HCL	HCL	HCL
Depth to:			
Carbonates	24-40"	--	40-55"
Stratification			
Mapped:			
At Colo			
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit 148-2-0 Webster-FT (deep CO_3)	Unit 148-3-0 Webster-FT (deep CO_3)	Unit 149-1-0 Webster-FT (cum.,deep CO_3)
Topography	Concave slopes	Concave slopes	Concave slopes
% Slope	1-3	2-5	0-2
Erosion	None	None	None
Drainage	Poor	Poor	Poor
Parent material	CL till	CL till	CL till
A horizon			
Thickness	14-24"	14-24"	24-36"
Color (A1)	2/0,2/1	2/0,2/1	2/0,2/1
Texture	SiCL-CL	SiCL-CL	SiCL-CL
B horizon			
Color (B2)	5Y 4/1,5/2	5Y 4/1,5/2	5Y 4/1,5/2
Texture	HCL	HCL	HCL-SiCL
Depth to:			
Carbonates	40-55"	40-55"	40-55"
Stratification			
Mapped:			
At Colo			
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit 149-2-0 Webster-FT (cum., deep CO_3)	Unit 201-6-1 Nicollet-FT(2)	Unit 249-1-0[b] Webster-FT(2)
Topography	Concave slopes	Concave slopes	Concave slopes
% Slope	1-3	5-9	0-2
Erosion	None	Slight	None
Drainage	Poor	Imperfect	Poor
Parent material	CL till	CL till	CL till
A horizon			
Thickness	24-36"	6-14"	20-30"
Color (A1)	2/0,2/1	10YR 2/1,2/2	2/0,2/1
Texture	SiCL-CL	SiCL	SiCL-SiC
B horizon			
Color (B2)	5Y 4/1,4/2	1, 2.5Y 4/2	5Y 3/1,5/2
Texture	HCL-SiCL	SiC	SiC
Depth to:			
Carbonates	40-55"	24-30"	>48"
Stratification			
Mapped:			
At Colo			+
At Jewell	+	+	

[b]Comparable with Marna series.

Table 30. (continued)

Soil features	Unit 249-2-0[b] Webster-FT(2)
Topography	Concave slopes
% Slope	1-3
Erosion	None
Drainage	Poor
Parent material	CL till
A horizon	
Thickness	20-30"
Color (Al)	2/0,2/1
Texture	SiCL-SiC
B horizon	
Color (B2)	5Y 3/1,5/2
Texture	SiC
Depth to:	
Carbonates	>48"
Stratification	
Mapped:	
At Colo	
At Jewell	+

[b]Comparable with Marna series.

Table 30. (continued)

Soil features	Unit P_1 Unnamed (strat. sed.)	Unit P_2 Unnamed (strat. sed.)	Unit P_3 Unnamed (silty sed.)
Topography	Bog	Bog	Bog
% Slope	0-2	<1	<1
Erosion	None	None	None
Drainage	Very poor	Very poor	Very poor
Mineral parent material	Alluvium, silty bog seds.	Alluvium, silty bog seds.	Silty bog seds.
Surface horizon	Mucky loam to muck, calcareous (18-24")	Mucky loam to muck, calcareous (18-24")	Muck to mucky peat, noncalcareous (24-36")
Subsurface horizon	Stratified sediment, sandy loam to silt loam (upper bog), over till	Stratified sediment, sandy loam to silt loam (upper and lower bog), over till	Calcareous upper bog seds., over lower bog seds, over till
Mapped:			
At Colo	+		+
At Jewell	+	+	+

Table 30. (continued)

Soil features	Unit P_4 Unnamed (silty sed., 10-20 ft.)	Unit P_5 Unnamed (silty sed., 10-20 ft.)	Unit P_6 Unnamed (silty sed., 20-30 ft.)
Topography	Bog	Bog	Bog
% Slope	<1	<1	<1
Erosion	None	None	None
Drainage	Very poor	Very poor	Very poor
Mineral parent material	Silty bog seds.	Silty bog seds.	Silty bog seds.
Surface horizon	Mucky, weakly calcareous silty clay loam (24-36")	Muck to mucky peat, noncalcareous (24-36")	Muck to peaty muck, noncalcareous (24-36")
Subsurface horizon	Calcareous upper bog seds., over lower muck, over lower bog seds., over till	Calcareous upper bog seds., over lower muck, over lower bog seds., over till	Calcareous upper bog seds., over lower muck, over lower bog seds., over till
Mapped:			
At Colo		+	+
At Jewell	+	+	+

XVII. APPENDIX D

A. Summary of Pollen Analyses

In this appendix, pollen data for Colo Profile C22, Jewell Profile J6, McCulloch Profile M4, and Woden Profile W1 are presented. The data for Profiles C22 and M4, in Figures 60 and 61 respectively, were communicated to the author by Dr. Grace S. Brush, Department of Geology, University of Princeton, Princeton, New Jersey. The data of J6, in Table 31, are brief notes from a rapid scan of the pollen slides by Dr. Brush. The Jewell pollen data are currently being revised by Dr. Brush, using samples from Profile J173. The pollen data for the Woden profile, Figure 62, were communicated to the author by Dr. L. H. Durkee, Department of Biology, Grinnell College, Grinnell, Iowa.

Figure 60. Pollen diagram for the Colo bog Profile C22

COLO POLLEN DIAGRAM

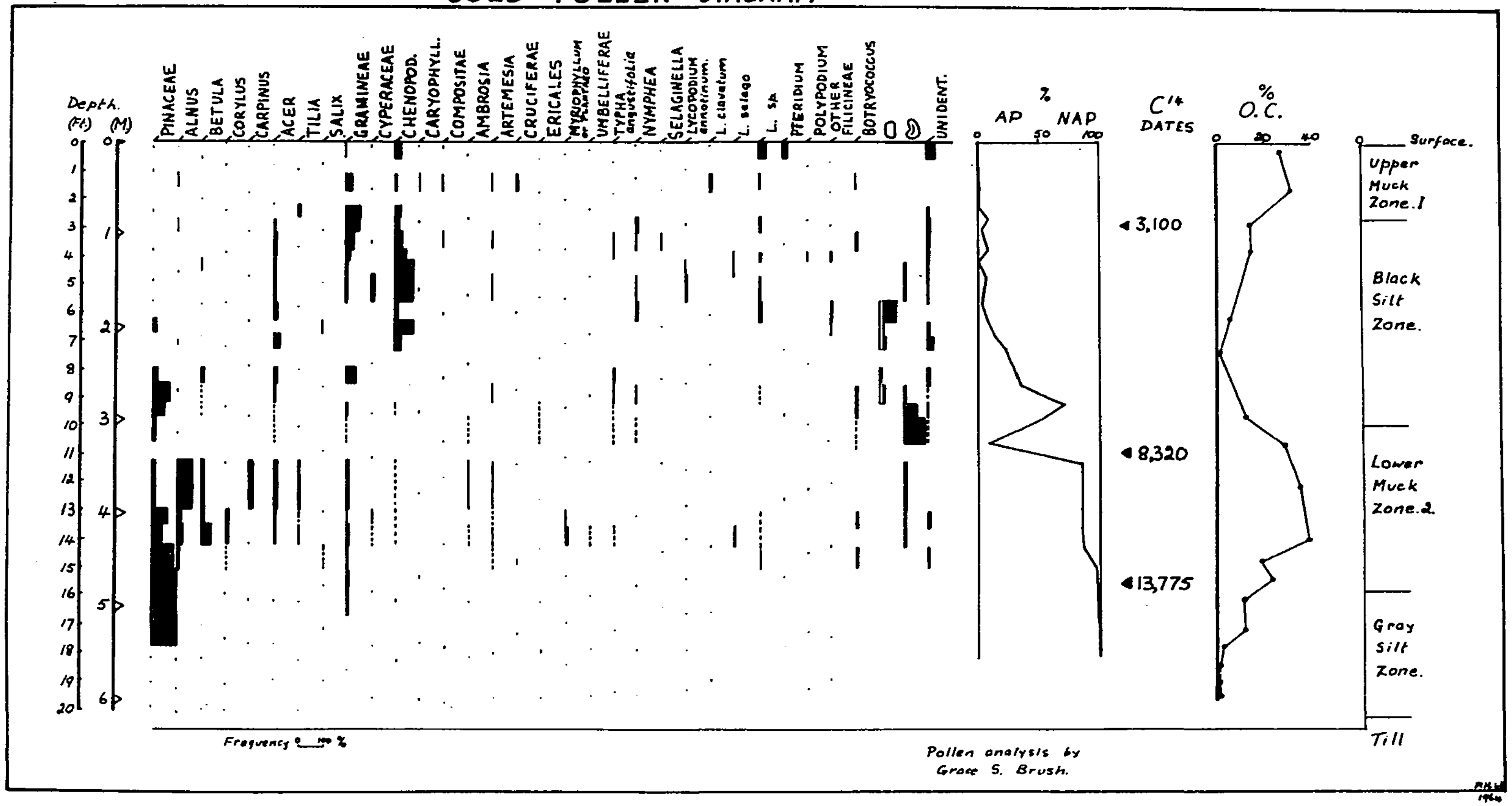
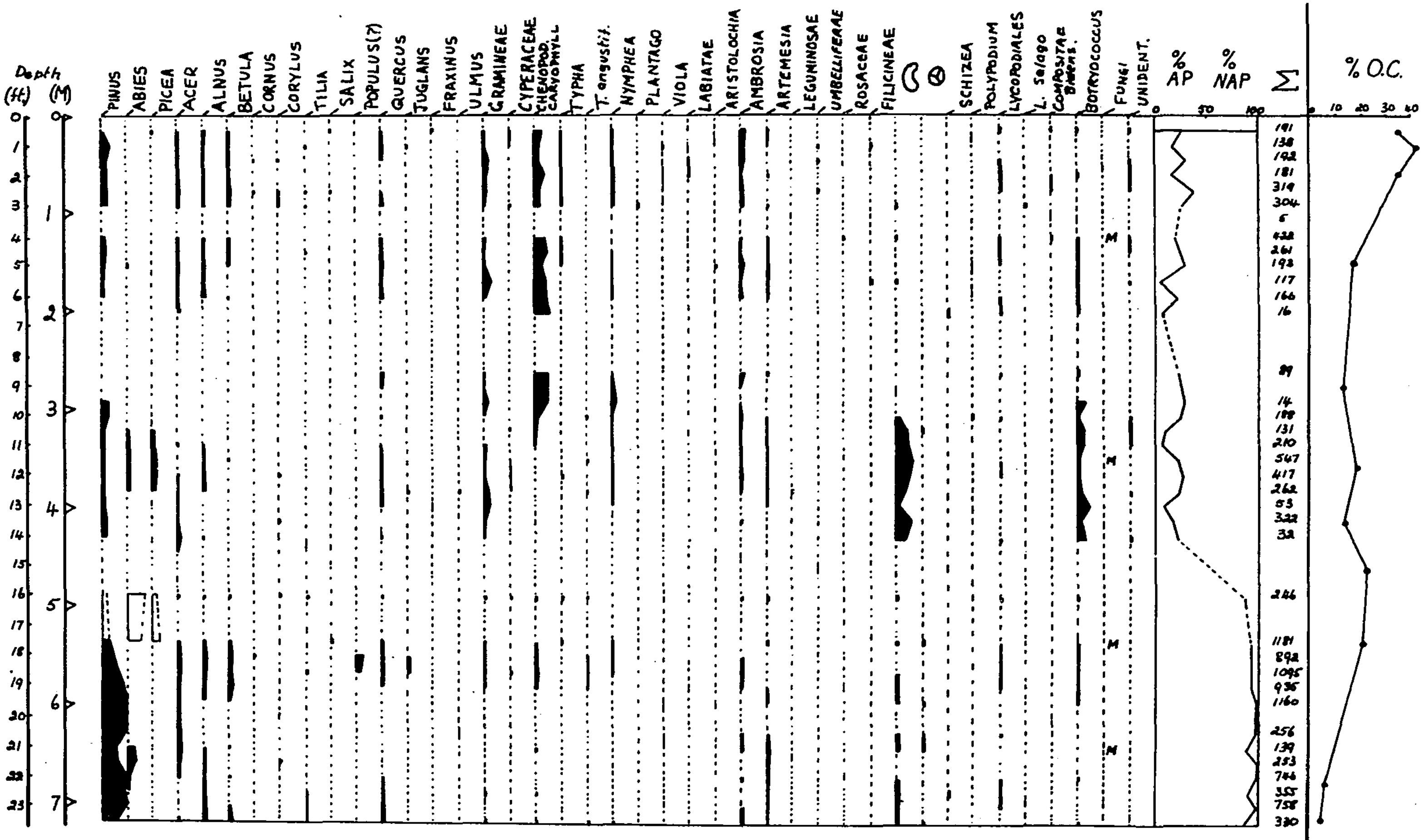


Figure 61. Pollen diagram for the McCulloch bog Profile M4

Mc CULLOCH POLLEN DIAGRAM.



Frequency 0 — 100%, M= Many.

Pollen analysis by Grace S. Brush.

Figure 62. Pollen diagram for the lower part of the Woden bog Profile W1

WODEN BOG POLLEN

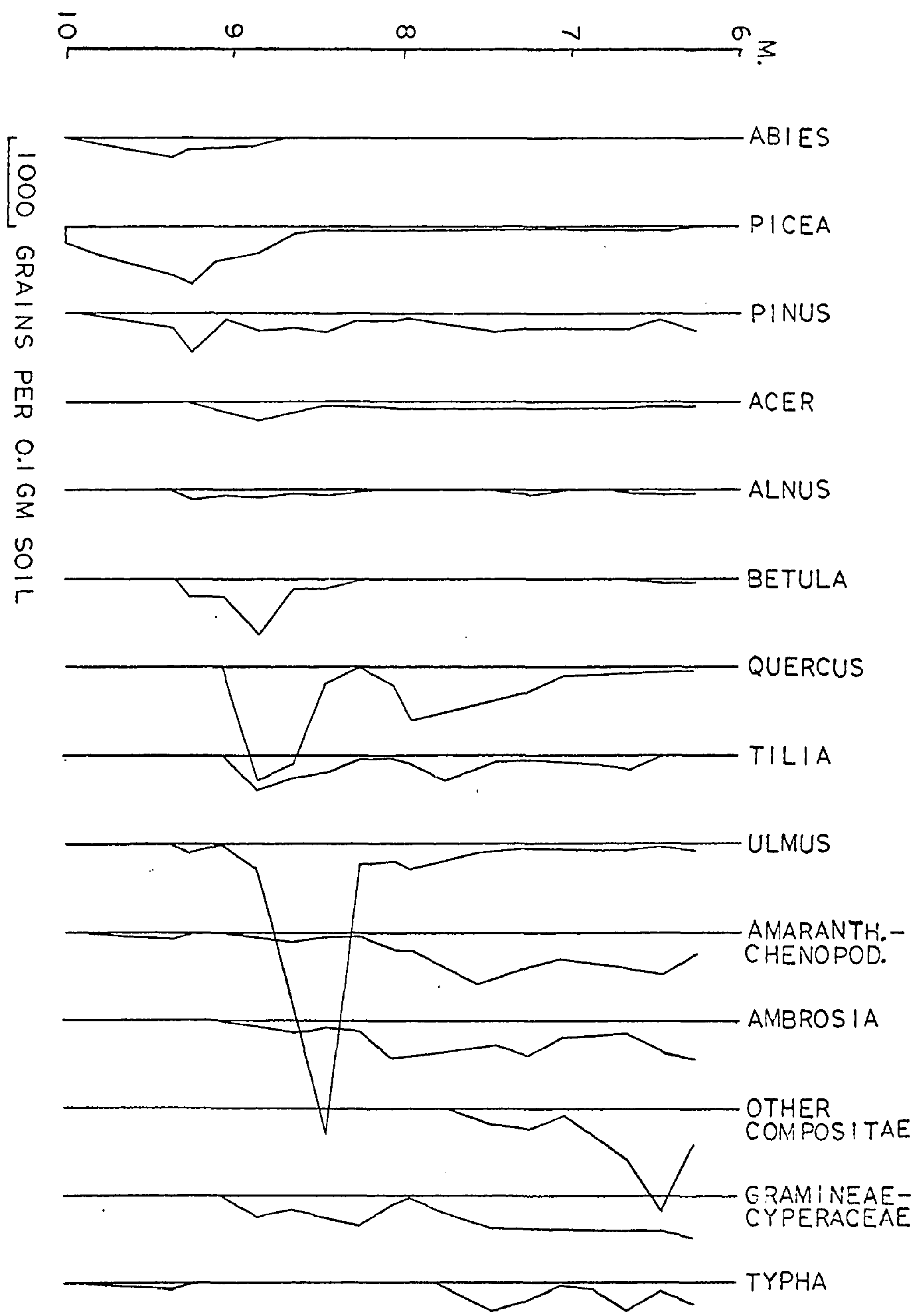


Table 31. Pollen notes on Profile J6

Sample depth	Notes
5-6"	No pollen visible
11-12"	Organic debris; no pollen
17-18"	Few grass pollen; Chenopod., Typha
23-24"	Botryococcus, Nymphea, Alnus, Chenopod., Lycopodium
29-30"	No pollen
35-36"	No pollen
41-42"	Abundant organic matter, a few pollen
47-48"	Lot of Lycopodium, Chenopod.
53-54"	Chenopod., only a few pollen
59-60"	Abundant organic matter, no pollen
65-66"	No pollen
71-72"	Few Chenopod., abundant organic matter
77-78"	Chenopod., Alnus.
83-84"	Lycopodium abundant
89-90"	Chenopod., oak, Lycopodium, Ambrosia
95-96"	Chenopod., Juglans, Caryophyllaceae, sedges
101-102"	Chenopod., Lycopod., oak, pollen abundant
107-108"	No pollen
113-114"	Chenopod., Botryococcus, Alnus, Pinus
119-120"	No pollen
125-126"	No pollen
131-132"	Artemesia, Pine
137-138"	Sedges(?), few pollen
143-144"	No pollen
149-150"	Pine, fir, grass(?), Lycopod.
155-156"	Conifers, Salix, Lycopod., Chenopod.
161-162"	Chenopod., Typha
167-168"	Chenopod.

Table 31. (continued)

Sample depth	Notes
173-174"	Bean-shaped fern spores as at Colo, Chenopod., *Alnus*, *Acer*, conifers
179-180"	No pollen
185-186"	Few pollen
191-192"	No pollen
197-198"	Few pollen
203-204"	No pollen
209-210"	*Alnus*, ferns
215-216"	*Tilia*, pine, Chenopods, *Acer*
221-222"	No pollen
227-228"	Bean-shaped fern spores, *Acer*
233-234"	Fern spores, conifer bladders
239-240"	No pollen
245-246"	Grass, *Tilia*, ferns
251-252"	Hazelnut, conifers, alder, *Betula*
257-258"	*Betula*, *Typha*, fir, grass, *Salix*(?)
263-264"	Fern spores, spruce, fungal spores(?)
269-270"	Conifers, *Betula*, abundant pollen
275-276"	Pine
281-282"	Much conifer pollen
287-288"	Much conifer pollen--spruce
293-294"	Spruce, fir
299-300"	Few conifers
323-324"	Few spruce
329-330"	Few spruce

XVIII. APPENDIX E

A. Soil Grid Data with Tabulations for Computer Analysis

1. Soil data

Observations of surface elevation (Y_e), thickness of A horizon (Y_m), depth to gray mottles (Y_g), depth to carbonate horizon (Y_c), thickness of surficial sediment (Y_s), pH in 0-3 inches (Y_a), and pH in 30-33 inches (Y_b), are listed below in the order given.

Table 32. Grid elevation data, rounded to 0.1 ft. (Y_e)

Hillcrest	W^a														
	20.0	19.8	19.7	19.4	19.2	19.0	18.7	18.3	17.8	17.4	16.7	15.9	15.0	14.3	13.2
	19.6	19.7	19.6	19.5	19.2	18.9	18.6	18.3	17.8	17.2	16.7	16.0	15.4	14.4	13.5
	19.3	19.0	18.9	19.0	18.9	18.8	18.4	18.0	17.5	17.1	16.5	15.8	15.2	14.3	13.7
	18.6	18.6	18.4	18.3	18.0	18.0	17.9	17.7	17.2	16.6	16.1	15.5	14.8	14.1	13.4
L^a	17.9	17.9	17.8	17.6	17.4	17.3	16.8	16.7	16.6	16.2	15.8	15.1	14.4	13.7	13.4
	17.2	17.0	17.0	16.9	16.7	16.5	16.1	15.8	15.4	15.1	15.0	14.5	14.1	13.5	13.1
	16.6	16.4	16.2	16.0	16.0	15.8	15.5	15.0	14.7	14.3	14.0	13.6	13.4	13.1	12.8
	16.1	15.8	15.6	15.3	15.1	14.6	14.4	14.2	14.0	13.6	13.4	13.0	12.8	12.4	12.2
	15.4	15.3	15.0	14.7	14.3	14.0	13.7	13.4	13.2	13.1	12.8	12.7	12.4	12.1	11.9
	14.9	14.6	14.3	14.1	13.9	13.6	13.2	13.0	12.8	12.5	12.4	12.3	12.0	11.9	11.6

[a]Grid directions: L = 60° E of magnetic N; W = 30° W of magnetic N.

Table 33. Thickness of A horizon in inches (Y_m)

	Hillcrest							W							
	18	16	17	19	21	22	24	24	18	22	22	11	11	17	16
	20	20	23	21	21	22	23	23	20	23	15	18	19	20	14
	15	15	16	19	22	21	22	20	17	20	14	14	18	17	20
	22	17	15	16	20	21	19	18	13	15	12	15	12	16	17
L	17	23	17	16	18	17	14	17	16	18	12	10	12	13	22
	30	26	23	25	25	17	16	17	18	22	21	18	18	23	38
	30	30	23	34	27	27	22	22	33	25	30	19	23	30	32
	26	25	26	28	37	18	19	20	26	22	25	23	23	25	26
	27	25	27	24	26	23	23	24	24	26	26	31	26	34	36
	24	24	23	24	24	21	24	26	38	47	51	62	55	54	58

Table 34. Depth to gray mottle in inches (Y_g)

	Hillcrest							W							
	43	38	33	39	34	35	34	34	26	28	27	23	23	25	21
	32	36	41	35	32	35	34	33	29	34	26	28	32	29	26
	34	31	32	26	32	34	33	27	28	26	33	34	25	30	25
	33	29	30	30	27	29	26	26	29	28	29	27	24	23	29
	33	32	35	29	26	27	26	24	26	29	24	17	26	28	30
L	35	32	27	30	33	28	25	24	25	29	24	32	25	34	44
	35	36	29	35	34	34	29	30	38	35	27	31	33	32	36
	27	26	32	28	37	24	30	33	36	33	31	26	31	32	33
	30	29	27	24	26	24	26	26	29	33	30	32	26	34	35
	25	26	23	24	21	20	22	24	38	45	51	58	49	54	56

Table 35. Depth to carbonate horizon in inches (Y_c)

	Hillcrest							W							
	38	28	30	30	28	38	37	36	42	44	33	25	26	33	21
	30	33	30	26	32	34	34	33	28	26	33	32	37	32	33
	24	24	32	29	32	32	33	24	21	21	21	34	38	30	41
	25	36	24	26	29	30	26	21	15	15	12	13	20	23	29
	21	25	32	29	34	33	31	28	26	21	12	11	12	14	22
L	35	32	30	30	33	24	22	20	23	26	23	20	22	19	25
	38	38	35	35	33	27	22	23	38	30	20	19	23	26	27
	34	42	34	33	35	18	21	23	26	23	25	21	23	25	26
	36	36	33	24	28	24	24	21	27	32	32	32	31	37	43
	35	29	23	26	26	24	27	30	54	72	76	99	67	94	91

Table 36. Thickness of surficial sediment in inches (Y_s)

	Hillcrest						W								
	19	20	21	23	22	30	29	26	20	22	23	14	13	20	20
	22	24	28	21	22	20	28	22	22	20	13	19	20	20	11
	20	21	20	13	19	15	22	18	15	20	12	16	22	23	22
	20	24	17	20	21	24	16	15	11	15	11	9	11	17	24
L	13	15	21	24	26	25	21	17	17	11	11	8	10	13	22
	32	23	25	30	28	19	11	15	18	25	14	10	22	23	24
	26	24	20	35	31	27	19	20	27	22	18	14	20	24	27
	25	22	22	24	27	17	18	15	22	22	23	21	22	24	25
	24	23	23	22	25	21	21	18	24	27	25	32	28	37	37
	27	23	21	26	24	24	25	28	36	45	50	55	55	54	55

Table 37. pH in the 0-3 inch zone (Y_a)

	Hillcrest							W							
	5.8	5.8	5.9	5.8	5.7	5.7	5.7	5.7	5.8	5.9	6.0	6.1	5.9	5.9	6.3
	6.0	5.9	6.0	5.8	5.8	5.8	5.8	6.1	5.9	5.9	6.0	5.4	5.9	6.0	5.9
	6.0	6.1	6.3	5.7	5.8	5.9	6.1	5.9	5.8	5.7	5.8	6.3	5.9	5.9	5.8
	6.0	6.1	5.8	5.9	6.1	5.9	5.8	5.8	6.0	6.1	6.4	6.5	6.3	5.8	5.8
L	5.9	6.1	5.8	6.1	6.2	6.1	5.8	6.1	6.1	5.8	5.9	6.4	6.4	6.0	6.3
	5.8	6.0	5.9	6.1	5.8	5.9	5.9	6.0	6.1	6.1	6.3	6.0	6.2	6.3	5.8
	5.9	5.7	5.9	5.9	5.9	6.2	6.0	5.7	6.1	5.7	6.0	6.3	5.9	6.3	5.9
	5.7	5.8	6.0	5.9	5.9	6.0	6.1	6.0	5.9	6.0	6.0	6.0	6.0	5.9	5.8
	6.0	6.0	6.1	6.0	6.1	6.0	6.0	6.0	6.0	6.2	5.9	6.1	5.6	5.6	5.0
	5.9	6.2	6.2	6.1	5.7	6.3	6.2	6.0	6.1	6.0	5.9	6.0	5.9	6.1	7.0

Table 38. pH in the 30-33 inch zone (Y_b)

Hillcrest								W							
	6.9	8.0	7.7	8.1	8.0	7.1	6.6	7.0	6.6	6.9	7.1	7.8	8.1	7.4	8.2
	7.8	7.0	8.1	7.7	7.4	7.3	6.9	7.1	8.1	8.1	6.9	8.1	6.9	7.1	7.3
	8.3	8.2	6.9	8.1	7.7	7.7	7.3	8.2	8.3	8.2	8.1	7.2	7.2	7.6	7.0
	8.4	7.7	8.1	8.1	8.0	8.2	8.1	8.3	8.1	8.5	8.4	8.3	8.2	8.1	8.0
	8.2	8.1	7.9	8.0	7.2	8.0	7.7	8.0	8.1	8.0	8.1	8.1	8.1	8.2	8.1
L	7.5	8.0	7.9	8.0	7.6	8.1	8.0	8.2	8.1	8.2	8.4	8.1	8.2	8.0	7.9
	7.0	7.3	6.8	7.5	7.7	8.1	8.3	8.2	7.1	7.9	8.0	8.2	8.3	8.4	7.4
	7.9	7.6	7.3	8.0	7.9	8.2	7.9	8.2	8.2	8.1	8.1	8.3	8.0	8.0	8.2
	7.7	8.0	7.9	8.3	7.9	8.3	8.1	8.1	8.1	8.1	8.3	7.9	8.2	7.8	7.1
	7.7	8.2	8.1	7.9	8.1	8.1	8.0	8.2	7.5	7.1	7.6	6.9	7.4	6.8	7.0

2. Tabulation of data for the computer

In Table 39 below, soil A horizon data are used to illustrate a convenient arrangement of soil data for card punching in relation to polynomial curve fitting. The data for 150 grid positions are given together with the ξ' matrix elements of the tabular polynomials published by DeLury (1950). The matrix values remain the same for analysis of all sets of soil data. In setting up the program, the soil data (dependent variables) were arbitrarily numbered 1 to 7 as follows: A horizon = 1; depth to gray = 2; depth to carbonate = 3; surficial thickness = 4; 0-3 inch pH = 5; 30-33 inch pH = 6; elevation = 7. The matrix variables were then numbered as shown in the table and the regression analyses were carried out on the computer for a set of soil data against the selected polynomial terms.

Table 39. Thickness of A horizon data set out for computer analysis with elements of the n=10 ξ' polynomial array (DeLury 1950)

Variable number		1	8	9	10	11	12	13	14	15	16
		A hor.					ξ' Matrix				
Length 1											
Width	1	18	-9	-6	-42	18	-6	3	-9	1	-1
	2	16									
	3	17									
	4	19	(The same matrix values are used for all Length 1, A hor. values.)								
	5	21									
	6	22									
	7	24									
	8	24									
	9	18									
	10	22									
	11	22									
	12	11									
	13	11									
	14	17									
	15	16									
Length 2											
Width	1	20	-7	2	14	-22	14	-11	47	-7	9
	2	20									
	3	23									
	4	21									
	5	21									
	6	22									
	7	23									
	8	23									
	9	20									
	10	23									
	11	15									
	12	18									
	13	19									
	14	20									
	15	14									

Table 39. (continued)

Variable number		1	8	9	10	11	12	13	14	15	16
		A hor.				ξ' Matrix					
Length 3											
Width	1	15	-5	-1	35	-17	-1	10	-86	20	-36
	2	15									
	3	16									
	4	19									
	5	22									
	6	21									
	7	22									
	8	20									
	9	17									
	10	20									
	11	14									
	12	14									
	13	18									
	14	17									
	15	20									
Length 4											
Width	1	22	-3	-3	31	3	-11	6	42	-28	84
	2	17									
	3	15									
	4	16									
	5	20									
	6	21									
	7	19									
	8	18									
	9	13									
	10	15									
	11	12									
	12	15									
	13	12									
	14	16									
	15	17									

Table 39. (continued)

Variable number		1	8	9	10	11	12	13	14	15	16
		A hor.					ξ' Matrix				
Length 5											
Width	1	17	-1	-4	12	18	-6	-8	56	14	-126
	2	23									
	3	17									
	4	16									
	5	18									
	6	17									
	7	14									
	8	17									
	9	16									
	10	18									
	11	12									
	12	10									
	13	12									
	14	13									
	15	22									
Length 6											
Width	1	30	1	-4	-12	18	6	-8	-56	14	126
	2	26									
	3	23									
	4	25									
	5	25									
	6	17									
	7	16									
	8	17									
	9	18									
	10	22									
	11	21									
	12	18									
	13	18									
	14	23									
	15	38									

Table 39. (continued)

Variable number		1	8	9	10	11	12	13	14	15	16
		A hor.				ξ' Matrix					
Length 7											
Width	1	30	3	-3	-31	3	11	6	-42	-28	-84
	2	30									
	3	23									
	4	34									
	5	27									
	6	27									
	7	22									
	8	22									
	9	33									
	10	25									
	11	20									
	12	19									
	13	23									
	14	30									
	15	32									
Length 8											
Width	1	26	5	-1	-35	-17	1	10	86	20	36
	2	25									
	3	26									
	4	28									
	5	37									
	6	18									
	7	19									
	8	20									
	9	26									
	10	22									
	11	25									
	12	23									
	13	23									
	14	25									
	15	26									

Table 39. (continued)

Variable number		1	8	9	10	11	12	13	14	15	16
		A hor.				ξ' Matrix					
Length 9											
Width	1	27	7	2	-14	-22	-14	-11	-47	-7	-9
	2	25									
	3	27									
	4	24									
	5	26									
	6	23									
	7	23									
	8	24									
	9	24									
	10	26									
	11	26									
	12	31									
	13	26									
	14	34									
	15	36									
Length 10											
Width	1	24	9	6	42	18	6	3	9	1	1
	2	24									
	3	23									
	4	24									
	5	24									
	6	21									
	7	24									
	8	26									
	9	38									
	10	47									
	11	51									
	12	62									
	13	55									
	14	54									
	15	58									

Table 40. Elements of the n=15 ξ' polynomial array

Variable numbers													
18	19	20	21	22	23	24	25	26	27	28	29	30	31
-7	91	-91	1001	-1001	143	-13	91	-91	91	-7	7	-1	1
-6	52	-13	-429	1144	-286	39	-377	494	-624	59	-71	12	-14
-5	19	35	-869	979	-55	-17	415	-901	1631	-205	313	-65	91
-4	-8	58	-704	44	176	-31	157	344	-1724	356	-766	208	-364
-3	-29	61	-249	-751	197	-3	-311	659	-159	-253	1067	-429	1001
-2	-44	49	251	-1000	50	25	-275	-250	1568	-121	-649	572	-2002
-1	-53	27	621	-675	-125	25	125	-675	-27	297	-363	-429	3003
0	-56	0	756	0	-200	0	350	0	-1512	0	924	0	-3432
1	-53	-27	621	675	-125	-25	125	675	-27	-297	-363	429	3003
2	-44	-49	251	1000	50	-25	-275	250	1568	121	-649	-572	-2002
3	-29	-61	-249	751	197	3	-311	-659	-159	253	1067	429	1001
4	-8	-58	-704	-44	176	31	157	-344	-1724	-356	-766	-208	-364
5	19	-35	-869	-979	-55	17	415	901	1631	205	313	65	91
6	52	13	-429	-1144	-286	-39	-377	-494	-624	-59	-71	-12	-14
7	91	91	1001	1001	143	13	91	91	91	7	7	1	1

3. <u>Polynomials for soil pH values</u>

Fitted quadratic polynomials in length (L) and width (W) for pH in 0-3 inch and 30-33 inch samples were omitted from the main body of the thesis, but are given below with relevant statistical data. For the 0-3 inch data, where mean $\bar{Y} = 5.97$

$$Y_a = 5.83 + 0.037L + 0.002W - 0.0004LW - 0.002L^2 + 0.006W^2$$

for which, R = 0.292**, and standard error = 0.196. For the 30-33 inch data, where mean $\bar{Y} = 7.82$

$$Y_b = 7.23 + 0.260L + 0.051W - 0.002LW - 0.024L^2 - 0.003W^2$$

for which R = 0.444**, and standard error = 0.422.

4. <u>Correlation matrices for polynomial terms</u>

In Table 41, the arbitrary numbers assigned to the polynomial terms are shown for length, width, and cross products up to seventh degree. In the tables that follow, the r values relating each soil property to the particular polynomial terms are shown as a matrix.

Table 41. Polynomial terms and assigned numbers, up to seventh degree

L \ W	0	1	2	3	4	5	6	7
0		W	W^2	W^3	W^4	W^5	W^6	W^7
1	L	LW	LW^2	LW^3	LW^4	LW^5	LW^6	LW^7
2	L^2	L^2W	L^2W^2	L^2W^3	L^2W^4	L^2W^5	L^2W^6	L^2W^7
3	L^3	L^3W	L^3W^2	L^3W^3	L^3W^4	L^3W^5	L^3W^6	L^3W^7
4	L^4	L^4W	L^4W^2	L^4W^3	L^4W^4	L^4W^5	L^4W^6	L^4W^7
5	L^5	L^5W	L^5W^2	L^5W^3	L^5W^4	L^5W^5	L^5W^6	L^5W^7
6	L^6	L^6W	L^6W^2	L^6W^3	L^6W^4	L^6W^5	L^6W^6	L^6W^7
7	L^7	L^7W	L^7W^2	L^7W^3	L^7W^4	L^7W^5	L^7W^6	L^7W^7

L \ W	0	1	2	3	4	5	6	7
0		18	19	20	21	22	23	24
1	8	32	33	34	35	36	37	38
2	9	41	42	43	44	45	46	47
3	10	50	51	52	53	54	55	56
4	11	59	60	61	62	63	64	65
5	12	68	69	70	71	72	73	74
6	13	77	78	79	80	81	82	83
7	14	86	87	88	89	90	91	92

Table 42. Correlation matrix for A horizon thickness (Y_m)

		W							
		0	1	2	3	4	5	6	7
	0		0.10	0.12	0.07	0.05	0.03	0.05	-0.06
	1	0.57	0.32	0.19	-0.09	-0.10	0.06	0.08	-0.01
	2	0.33	0.29	-0.07	-0.13	-0.07	-0.00	0.02	0.01
L	3	0.03	0.23	0.01	-0.08	-0.04	-0.01	0.01	0.07
	4	0.05	0.13	0.07	-0.04	0.04	0.07	0.03	0.02
	5	0.23	0.07	0.03	-0.03	-0.04	0.02	0.00	-0.04
	6	0.04	0.03	-0.06	0.00	-0.01	-0.04	0.03	-0.02
	7	-0.08	-0.05	-0.04	-0.04	-0.04	-0.00	-0.00	0.01

Table 43. Correlation matrix for depth to gray mottles (Y_g)

		W							
		0	1	2	3	4	5	6	7
	0		0.03	0.18	-0.02	-0.03	0.07	0.04	-0.06
	1	0.11	0.59	0.13	-0.11	-0.02	0.12	0.05	-0.05
	2	0.21	0.21	-0.01	-0.15	-0.08	0.01	0.01	0.01
L	3	0.03	0.29	0.06	-0.12	-0.10	0.06	0.05	0.05
	4	0.04	0.10	0.16	-0.02	0.01	0.02	0.06	-0.01
	5	0.26	0.14	0.01	0.02	-0.06	-0.00	-0.01	0.01
	6	0.08	0.05	-0.10	-0.06	0.00	-0.03	0.04	0.01
	7	-0.03	-0.02	-0.07	0.03	-0.03	0.06	-0.05	-0.08

Table 44. Correlation matrix for depth to carbonate horizon (Y_c)

		W							
		0	1	2	3	4	5	6	7
	0		0.05	0.14	0.03	0.01	0.04	0.01	-0.01
	1	0.23	0.27	0.18	-0.11	-0.06	0.10	0.06	-0.05
	2	0.47	0.43	0.04	-0.21	-0.01	0.03	0.03	-0.04
L	3	0.17	0.34	0.08	0.01	-0.05	-0.03	0.05	0.08
	4	0.10	0.09	-0.06	-0.06	0.04	0.02	0.02	-0.07
	5	0.18	0.11	0.02	-0.08	-0.04	0.01	0.03	-0.02
	6	0.05	0.04	0.03	-0.00	-0.03	-0.00	-0.00	-0.02
	7	-0.05	0.02	-0.05	-0.03	0.02	0.01	0.01	-0.04

Table 45. Correlation matrix for thickness of surficial sediment (Y_s)

		W							
		0	1	2	3	4	5	6	7
L	0		0.04	0.14	0.13	0.02	-0.03	0.03	-0.08
	1	0.44	0.36	0.16	-0.11	-0.08	0.03	0.12	-0.05
	2	0.42	0.33	-0.04	-0.17	-0.03	0.02	-0.02	0.06
	3	0.08	0.20	0.06	-0.07	-0.03	0.00	-0.03	0.07
	4	0.10	0.05	-0.02	0.06	0.04	0.01	0.07	-0.03
	5	0.17	-0.02	-0.02	-0.09	-0.05	-0.01	-0.01	-0.06
	6	0.01	0.06	0.02	-0.03	0.03	0.01	0.01	0.03
	7	-0.07	-0.05	-0.07	0.03	-0.01	0.01	0.02	0.04

Table 46. Correlation matrix for soil pH in 0-3 inches (Y_a)

		W							
		0	1	2	3	4	5	6	7
L	0		0.17	0.04	-0.02	-0.08	0.08	0.04	0.11
	1	0.22	-0.05	0.06	0.01	-0.02	-0.08	0.17	0.10
	2	-0.08	-0.01	0.16	0.20	0.22	0.21	-0.00	-0.02
	3	0.19	-0.06	0.11	0.04	0.04	0.06	-0.05	0.12
	4	0.19	0.27	0.14	0.07	-0.03	0.02	0.05	0.05
	5	-0.04	-0.02	0.10	0.06	0.06	0.11	0.08	-0.08
	6	-0.03	0.06	0.02	-0.02	-0.08	-0.05	0.02	0.13
	7	0.03	-0.14	0.08	-0.02	0.03	0.03	-0.01	0.04

Table 47. Correlation matrix for soil pH in 30-33 inches (Y_b)

		W							
		0	1	2	3	4	5	6	7
L	0		-0.00	-0.12	-0.07	-0.05	-0.00	0.03	-0.01
	1	0.21	-0.05	-0.21	0.01	0.06	-0.11	-0.11	0.10
	2	-0.36	-0.24	0.08	0.18	-0.13	0.05	0.06	0.05
	3	0.04	-0.28	-0.07	-0.11	0.16	0.07	-0.04	-0.11
	4	0.00	-0.02	0.01	-0.07	0.02	0.05	-0.00	-0.00
	5	-0.26	0.03	-0.12	0.14	-0.10	-0.00	-0.05	0.14
	6	0.00	0.03	-0.01	0.02	0.08	-0.09	0.00	0.05
	7	0.06	0.04	0.10	0.03	0.05	0.03	0.09	-0.02

Table 48. Correlation matrix for surface elevation (Y_e)

		W							
		0	1	2	3	4	5	6	7
L	0		-0.65	-0.13	-0.01	0.00	0.00	0.01	0.00
	1	-0.72	0.14	0.11	0.01	-0.01	0.00	0.00	0.00
	2	-0.09	-0.03	0.01	-0.01	-0.01	-0.00	-0.00	-0.00
	3	0.08	0.00	-0.02	-0.00	0.00	-0.00	-0.00	0.00
	4	0.00	0.01	-0.01	-0.00	0.00	0.00	0.00	0.00
	5	-0.00	0.00	0.00	0.01	-0.00	-0.01	-0.00	0.00
	6	-0.00	-0.01	-0.00	0.00	0.02	-0.01	-0.00	-0.00
	7	-0.00	-0.01	-0.00	-0.01	-0.00	0.01	-0.01	-0.00

5. Grid data for the geomorphic parameters

Data for the geomorphic parameters at each sample point are listed in the table below under an arbitrarily designated variable number. This is the form in which the data were submitted to the Computer Center, except that elevation (variable 7) was also included as a geomorphic parameter. For each regression analysis a set of soil data (dependent variable) was tabulated against the sets of geomorphic parameters.

Table 49. Data for the geomorphic parameters

			D (36)	S_1 (37)	S_2 (38)	S_3 (39)	C (40)	O (41)	C_W (42)
Length 1.	Width	1	--	--	--	--	--	--	--
		2	74	0.28	0.14	0.14	1.0	10	147
		3	107	0.34	0.12	0.22	0.55	20	147
		4	90	0.42	0.22	0.20	1.10	30	175
		5	96	0.44	0.20	0.24	0.83	40	163
		6	56	0.47	0.14	0.33	0.42	50	110
		7	99	0.67	0.30	0.37	0.81	60	148
		8	88	0.90	0.37	0.53	0.70	70	187
		9	87	0.91	0.53	0.38	1.39	80	201
		10	90	1.06	0.36	0.70	0.51	90	138
		11	88	1.54	0.68	0.86	0.79	100	143
		12	69	1.72	0.85	0.87	0.98	110	165
		13	75	1.82	1.04	0.78	1.33	120	207
		14	68	1.91	0.78	1.13	0.69	130	158
		15	71	2.00	1.04	0.96	1.08	140	180

Table 49. (continued)

			D (36)	S_1 (37)	S_2 (38)	S_3 (39)	C (40)	O (41)	C_W (42)
Length 2.	Width	1	175	0.76	0.42	0.34	1.24	10	191
		2	185	0.79	0.10	0.69	0.14	15	174
		3	167	0.76	0.09	0.67	0.13	27	169
		4	114	0.50	0.15	0.35	0.43	32	93
		5	95	0.65	0.33	0.32	1.03	42	140
		6	119	0.65	0.30	0.35	0.86	51	180
		7	138	0.75	0.28	0.47	0.60	61	138
		8	120	0.86	0.34	0.52	0.65	71	154
		9	98	1.10	0.50	0.60	0.83	81	180
		10	105	1.16	0.59	0.57	1.04	91	184
		11	97	1.24	0.51	0.73	0.70	101	164
		12	93	1.38	0.73	0.65	1.12	111	185
		13	50	1.22	0.42	0.80	0.53	120	108
		14	81	1.84	0.86	0.98	0.88	130	180
		15	86	1.86	0.98	0.88	1.11	140	204
Length 3.	Width	1	156	0.94	0.31	0.63	0.49	20	163
		2	176	1.09	0.69	0.40	1.73	23	207
		3	176	1.27	0.69	0.58	1.19	28	186
		4	182	1.24	0.53	0.71	0.75	36	171
		5	173	1.17	0.29	0.88	0.32	45	150
		6	108	0.63	0.27	0.46	0.59	54	118
		7	111	0.91	0.38	0.53	0.72	63	143
		8	136	1.11	0.48	0.63	0.76	73	171
		9	144	0.97	0.46	0.51	0.90	82	168
		10	122	1.17	0.48	0.69	0.70	92	115
		11	108	1.47	0.67	0.80	0.84	102	169
		12	115	1.54	0.77	0.77	1.00	112	193
		13	94	1.46	0.60	0.86	0.70	122	151
		14	115	1.47	0.80	0.67	1.19	131	182
		15	109	1.66	0.77	0.89	0.87	141	174

Table 49. (continued)

			D (36)	S_1 (37)	S_2 (38)	S_3 (39)	C (40)	O (41)	C_W (42)
Length 4.	Width	1	171	1.36	0.63	0.73	0.86	30	181
		2	164	1.18	0.47	0.71	0.66	34	174
		3	169	1.20	0.58	0.62	0.94	39	181
		4	165	1.42	0.70	0.72	0.97	46	177
		5	176	1.50	0.88	0.62	1.42	54	192
		6	173	1.55	0.75	0.80	0.94	63	179
		7	168	1.74	0.64	1.10	0.58	72	177
		8	147	1.29	0.48	0.81	0.59	81	162
		9	118	1.26	0.62	0.64	0.97	90	154
		10	119	1.27	0.65	0.62	1.04	100	195
		11	121	1.46	0.72	0.74	0.97	109	173
		12	123	1.52	0.75	0.77	0.97	119	182
		13	124	1.42	0.71	0.71	1.00	129	150
		14	97	1.51	0.77	0.74	1.04	138	190
		15	117	1.36	0.75	0.61	1.23	148	204
Length 5.	Width	1	179	1.49	0.73	0.76	0.96	40	179
		2	178	1.62	0.67	0.95	0.71	41	171
		3	170	1.46	0.63	0.83	0.76	45	176
		4	169	1.42	0.70	0.72	0.97	50	183
		5	168	1.41	0.65	0.76	0.86	57	171
		6	156	1.72	0.75	0.97	0.77	64	167
		7	173	1.81	1.10	0.71	1.54	72	204
		8	174	1.94	0.96	0.98	0.98	81	174
		9	167	1.94	0.73	1.21	0.60	90	176
		10	140	1.82	0.89	0.93	0.96	99	158
		11	144	1.36	0.54	0.82	0.66	106	140
		12	117	1.56	0.82	0.74	1.11	117	184
		13	123	1.42	0.67	0.65	1.03	126	188
		14	94	1.10	0.70	0.40	1.75	136	218
		15	127	1.28	0.55	0.73	0.75	146	144

Table 49. (continued)

			D (36)	S_1 (37)	S_2 (38)	S_3 (39)	C (40)	O (41)	C_W (42)
Length 6.	Width	1	175	1.34	0.76	0.58	1.31	50	178
		2	164	1.58	0.94	0.64	1.47	51	195
		3	179	1.60	0.81	0.79	1.03	63	176
		4	175	1.64	0.71	0.93	0.76	67	170
		5	168	1.55	0.75	0.80	0.94	72	177
		6	162	1.67	0.85	0.82	1.04	79	174
		7	159	1.68	0.84	0.84	1.00	85	189
		8	159	1.86	1.01	0.85	1.19	92	179
		9	153	2.12	1.28	0.84	1.52	100	195
		10	165	2.00	1.14	0.86	1.32	108	184
		11	160	2.09	0.93	1.16	0.80	117	161
		12	153	1.97	0.89	1.08	0.82	125	173
		13	141	1.30	0.58	0.72	0.81	134	164
		14	117	1.19	0.68	0.51	1.33	145	185
		15	116	1.11	0.58	0.53	1.09	152	170
Length 7.	Width	1	164	1.13	0.57	0.56	1.01	60	167
		2	163	1.25	0.61	0.64	0.95	61	181
		3	163	1.40	0.75	0.65	1.15	64	185
		4	168	1.62	0.91	0.71	1.28	67	195
		5	167	1.75	0.79	0.92	0.86	72	168
		6	169	1.82	0.73	1.09	0.67	78	179
		7	148	1.78	0.79	0.99	0.80	85	192
		8	156	1.66	0.89	0.77	1.16	93	184
		9	158	1.67	0.84	0.83	1.01	100	180
		10	155	1.60	0.86	0.74	1.16	108	181
		11	157	1.75	1.02	0.73	1.40	117	184
		12	163	1.67	1.06	0.61	1.74	125	166
		13	160	1.54	0.87	0.67	1.30	134	181
		14	160	1.29	0.64	0.65	0.98	143	180
		15	143	1.17	0.48	0.69	0.70	152	158

Table 49. (continued)

			D (36)	S_1 (37)	S_2 (38)	S_3 (39)	C (40)	O (41)	C_W (42)
Length 8.	Width	1	156	1.11	0.43	0.68	0.63	70	149
		2	164	1.17	0.62	0.55	1.13	71	185
		3	167	1.31	0.62	0.69	0.90	73	167
		4	162	1.35	0.70	0.65	1.08	77	191
		5	157	1.64	0.82	0.82	1.00	81	175
		6	151	1.76	1.06	0.70	1.51	86	193
		7	165	1.85	1.09	0.76	1.43	93	183
		8	162	1.63	0.81	0.82	0.99	99	169
		9	155	1.59	0.80	0.79	1.01	106	168
		10	151	1.37	0.78	0.59	1.32	114	183
		11	135	1.17	0.65	0.52	1.25	122	157
		12	145	1.14	0.71	0.43	1.65	131	198
		13	147	1.08	0.64	0.46	1.39	139	175
		14	144	1.07	0.72	0.35	2.06	148	202
		15	146	1.01	0.56	0.45	1.24	157	186
Length 9.	Width	1	180	1.17	0.68	0.49	1.39	80	161
		2	159	1.28	0.57	0.71	0.80	81	174
		3	154	1.35	0.65	0.70	0.92	83	168
		4	151	1.23	0.57	0.66	0.86	86	185
		5	154	1.30	0.74	0.56	1.32	90	183
		6	150	1.36	0.81	0.55	1.47	95	191
		7	150	1.27	0.76	0.51	1.49	100	191
		8	156	1.30	0.83	0.47	1.77	106	188
		9	162	1.29	0.78	0.51	1.53	114	183
		10	159	1.21	0.64	0.57	1.12	121	173
		11	167	1.03	0.62	0.41	1.51	128	187
		12	157	0.89	0.40	0.49	0.82	136	147
		13	136	0.83	0.43	0.40	1.08	145	204
		14	154	0.78	0.45	0.33	1.36	153	176
		15	125	0.88	0.40	0.48	0.83	161	203

Table 49. (continued)

	D	S_1	S_2	S_3	C	O'	C_W
	(36)	(37)	(38)	(39)	(40)	(41)	(42)
Length 10. Width 1	160	1.18	0.47	0.71	0.66	90	186
2	157	1.35	0.66	0.69	0.96	91	180
3	153	1.32	0.71	0.61	1.16	93	173
4	159	1.32	0.67	0.65	1.03	95	181
5	159	1.19	0.60	0.59	1.02	99	162
6	145	1.02	0.57	0.45	1.27	103	178
7	138	0.94	0.55	0.39	1.41	109	174
8	146	0.89	0.49	0.40	1.23	115	180
9	147	0.90	0.48	0.42	1.14	121	179
10	153	0.86	0.54	0.32	1.69	128	190
11	163	0.82	0.47	0.35	1.34	135	170
12	157	0.69	0.33	0.36	0.91	143	174
13	145	0.70	0.49	0.21	2.33	150	192
14	104	0.54	0.28	0.26	1.08	158	219
15	--	--	--	--	--	--	--