# AN INVESTIGATION OF A LATE-GLACIAL DEPOSIT FROM THE MISSOURI COTEAU IN SASKATCHEWAN

A thesis

submitted to

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In partial fulfillment

of the requirements for the degree

Master of Science

by

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I wish also to thank Dr. K. J. McCallum, Professor of Chemistry, University of Saskatchewan for the Carbon-14 dating of submitted samples.

## ABSTRACT

A buried deposit of limnic sediment was excavated from a site in the Missouri Coteau, Saskatchewan. Carbon-14 determinations indicated that it is of late-glacial age, apparently deposited immediately before the Condie re-advance. On the basis of studies of the plant macrofossil remains and pollen an attempt is made to reconstruct the vegetation as follows: the lower sediment levels yielded a fossil flora suggesting a white spruce forest; this was followed by a flora containing a strong element of temperate species, suggesting a mixed boreal forest; the upper levels show a reversion to white spruce predominance. These suggestions are based on the interpretation of 80 entities of plant macrofossils and a pollen diagram.

# I. INTRODUCTION

Studies of late-Pleistocene plant remains are of value both for elucidating the history and development of regional vegetation and flora, and for providing necessary information on the changing environment of the recent past. As Terasmae (1961) has pointed out in a recent review article, while there have been several investigations of late- and post-glacial vegetation in eastern Canada and the adjacent United States, and in the Pacific Northwest, west-central Canada is almost entirely unknown from this point of view.

The aim of the general investigation being conducted currently at the University of Manitoba*, of which this contribution forms a part, is to apply the established procedures of macrofossil studies and pollen analysis to suitable Holocene deposits, with the hope of reconstructing the sequences of vegetation change since deglaciation. From such a reconstruction it might then be possible to make

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palaeoecological inferences. While the number of studies in North America of plant macrofossils in Holocene deposits is small, such an approach has been used to great advantage in N.W. Europe, especially in elucidating the nature of late-glacial vegetation and flora (cf Jessen 1949, Godwin 1956, Iversen 1954). These investigations, and others in Europe, have demonstrated that inadequacies of the pollen record in late-glacial clays can be overcome in part by the macrofossil record. Further, the presence in late-glacial deposits of limnic origin of particular species and genera in the form of macrofossils provides almost unequivocal evidence of their presence at the site, while pollen spectra of late-glacial deposits in Europe have been difficult to interpret in some cases because of problems of over- and under-representation, poor preservation and secondary origin.

The specific objectives of this thesis are to make a thorough examination of the plant macrofossils in organic sediment from the Missouri Coteau of Saskatchewan. Attention was directed to this line of enquiry by several reports of organic sediments of late-glacial age in the region of the Missouri Coteau.

Kupsch (1960) reports on the botanical and zoological material associated with a Carbon-14 dated organic sediment near Herbert, Saskatchewan. This site was located on the east shore of a small saline lake on the bottom of former Glacial Lake Herbert, at an altitude of about 700 m. Kupsch (loc. cit.) describes the stratigraphy of the site as follows: (a) - below the 16.50 m. level, glacial till, (b) - from 16.50 to 6.90 m., sand and silt with no organic material, (c) - from 6.90 m. to the surface is a layer of calcareous silt, gyttja, marl and loam, with the 3.70-3.00 m. stratum particularly rich in organic remains. A sample of *Salix* wood from this level was dated by Carbon-14 measurement as 10,050 ± 300 years B.P. (McCallum and Dyck, 1960). On the basis of the somewhat limited macrofossils (*Chara*, *Potamogeton*, *Picea* and *Salix*), a pollen diagram prepared by Dr. J. Terasmae of the Geological Survey of Canada, Kupsch (l. cit.) concludes that the climate of the area at the time of deposition was considerably cooler and wetter than at present. Christiansen (1961) has revised Kupsch's (l. cit.) conclusion about the proximity of the glacier at the time, suggesting that "the glacier stood about 50 miles north of the Herbert Site 10,000 years ago" (p. 43).

A second late-glacial deposit was discovered accidentally in 1958 (Dew, 1959) and a pollen diagram was prepared from samples by Terasmae (unpublished, personal communication from Dr. Terasmae). The site is located on the Scrimbit Farm, near Kayville, Saskatchewan. Upper and lower samples from a section of organic sediment, 2.5 m. thick and buried by about 2.5 m. of mineral material, indicate that the deposit was formed between 11,700 and 10,400 B.P. (personal comm. Terasmae). A further deposit has been reported (Anon. 1961) from Lillestrom, about 32 km. southwest of Moose Jaw, Saskatchewan. This account mentions several other deposits reported from southern Saskatchewan, apparently of a similar nature to the Herbert and Scrimbit sites, but neither these sites nor that at Lillestrom have been studied in detail.

These discoveries indicated the need for further, more intensive study of the plant macro- and microfossils. Accordingly, exploratory field work was begun in July 1962, with the intention of either examining in more detail the Scrimbit site material, or locating a new site in the same vicinity. The Scrimbit site was examined, but it was found to be no longer suitable for study due to various landscaping and water-level changes. Several other sites were studied and finally the site of the present investigation, on the Hafichuk Ranch (northeast quarter of Section 2, Range 29, Township 16, west of Second Meridian) in the Missouri Coteau, was located and excavated. Preliminary examination of the sediment and associated plant remains suggested that the site was of late-glacial age, and subsequent dating of three samples has confirmed this opinion. The three samples of organic sediment, from upper, middle and lower levels, were dated at the laboratory for radiocarbon dating, University of Saskatchewan, by the courtesy of Dr. K. J. McCallum, Professor of Chemistry, University of Saskatchewan. The dates indicate that the deposit under study was laid down between 11,700 and 10,270 B.P.

This thesis reports on a detailed examination of the plant macrofossils extracted from bulk samples from the excavation, and incorporates the results of a concurrent study of the pollen and spores found in close-interval samples collected from the same excavation. (The pollen analysis of these samples was conducted under the supervision of Dr. J. C. Ritchie and was made available for this thesis to facilitate interpretation of the findings).

Following a brief statement on the geographical features of the Hafichuk site region, and an account of the field and laboratory methods involved in the work, the main part of the thesis deals with the plant remains discovered in the deposit. The thesis is concluded with a section suggesting some interpretation of the results.

## II. GEOGRAPHICAL FEATURES OF THE VICINITY OF THE HAFICHUK SITE

### Geology and landforms

The site is located in the Missouri Coteau, an upland which runs from the vicinity of the Souris River in southeast Saskatchewan in a northwest direction to latitude 53° at the western boundary of the province. The following description has been abstracted from the map entitled "Physiographic Divisions of Saskatchewan" (Acton *et al*, 1960). The primary physiographic features of the Coteau - the escarpment which marks its eastern boundary and the major drainage valleys -

are the result of pre-glacial erosion of soft Cretaceous and Tertiary bedrock. The local prevalent landform of the Hafichuk area is glacial, described and mapped by Christiansen (1961) as Hummocky Moraine. He writes (p. 15-16) "the landscape is characterized by till knobs, kames, kettles, rimmed kettles, moraine plateaus, and small, rimmed depressions which contain lacustine silt and clay". The other main glacial landforms of the region have been mapped (Fig. 1) after Christiansen (l. cit.), showing the disposition of the major end moraines, the glacial channels, and adjacent till and lacustrine plains. The hummocky moraine shows the typical blocked drainage pattern of "dead-ice" or disintegration morainic deposits. The topography is strongly rolling, with the relief varying from 10 to 15 m. The maximum elevation of the hills in the immediate vicinity of the Hafichuk site is 660 m. (above sea level).

Christiansen (1956) concludes, in his discussion of the glacial history of the region, that the Missouri Coteau, a "preglacial topographical high" (p. 27), was one of the first areas in Saskatchewan from which the Wisconsin ice melted. In a later report (Christiansen, 1961) he outlines

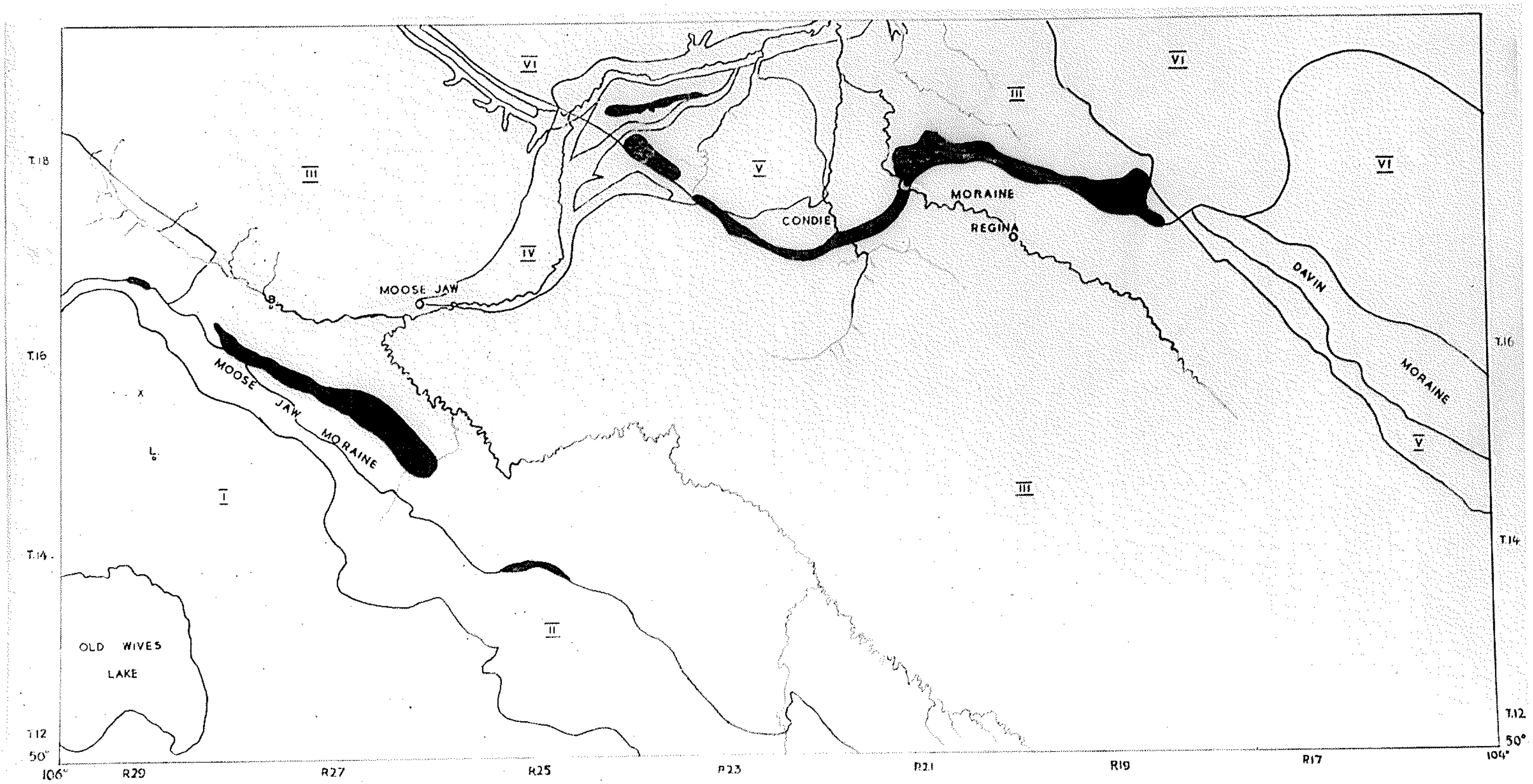



Fig. 1. The location of the Hafichuk site (x) in relation to the Moose Jaw and Condie moraine in south central Saskatchewan (modified version of Christiansen, 1960). I. Hummocky moraine, gentle to strongly rolling, having a knob and kettle topography, II. Ground moraine, undulating to gentle rolling, III. Glacial basin of lake Regina, flat to rolling, IV. Eroded till plains, flat to undulating, V. Fluvio-lacustrine plain, flat to undulating, VI. Wash-board moraine with sub-parallel, discontinuous and generally arcuate ridges.

the stages of the glacial history of the area. During his Phase No. 1 of the glacial history of the Regina area, the glacier had "retreated to a position north of the Moose Jaw and Davin Moraines" (p. 44) (Fig. 1 of thesis), exposing the hummocky moraine in which the Hafichuk site is situated. Following this the ice retreated to a position north of Regina and subsequently (Phase No. 3) advanced to the position of the Condie Moraine (Fig. 1). Christiansen (l. cit.) suggests that this advance is correlative with the Valders advance of the Mid-Western United States, and throws doubt on the conclusion of Elson (1957) that the ice front stood at The Pas Moraine during the Valderan sub-age. Correlating the dates which Christiansen suggests for these events (1961 p. 43), it would appear that the Hafichuk deposit was formed in an episode between deglaciation and the re-advance of the ice to the Condie moraine. This problem of chromology will be discussed more fully in the concluding section of the thesis.

## Climate

The following information on climate has been abstracted from Mitchell et al, (1947), Thomas (1953), Kendrew and Currie (1955), and the Atlas of Canada (1958).

The climate of the prairie region in southern Saskatchewan, including the Missouri Coteau, is continental in character with extreme differences in temperature between summer and winter, and a comparatively low precipitation.

Frequent wide variations are noted between day and night temperatures. Amounts of precipitation vary considerably from year to year. Extremes from 17.5 to 62.5 cm have been recorded (Mitchell et al, 1947). Winters are long and cold, with short, warm to hot, and frequently bright sunny summers. Mitchell (l. cit.) lists as average, annual temperature for Caron, about 14 K.M. north of the Hafichuk site, as 1.46° C and an average precipitation of 34.38 cm. Regina, in the more humid eastern section of the mixed prairie zone, averages 0.67° C and 35,58 cm. Swift Current, in the drier western section of the mixed prairie zone, averages 3.4° C and 37.95 cm. The prevailing winds are westerly, with drying Chinook winds from the south-west, and dry, cold winds from the north-west being typical. These winds are less frequent during the warmer part of the year, being replaced by winds from a north-westerly or north-easterly direction (Kendrew et al, l. cit.). Wind velocity is quite high in the prairie, with the highest in spring, and the lowest in mid-winter and late-summer.

Data obtained at various stations cannot be considered as indicative for a certain region, because of variation in height above soil surface at which measurements were taken. Evaporation from water and land surfaces are greatly influenced by drying winds and strong solar radiation.

## Vegetation

The site under study lies well within the northern boundary of the grasslands vegetation zone. Its position in relation to the major vegetation zones of west-central Canada is shown in Fig. 2.

The following general and brief account of the plant communities of the Missouri Coteau has been abstracted from Coupland (1950 and 1961), supplemented by personal observations in the area.

By far the largest proportion of mixed prairie in

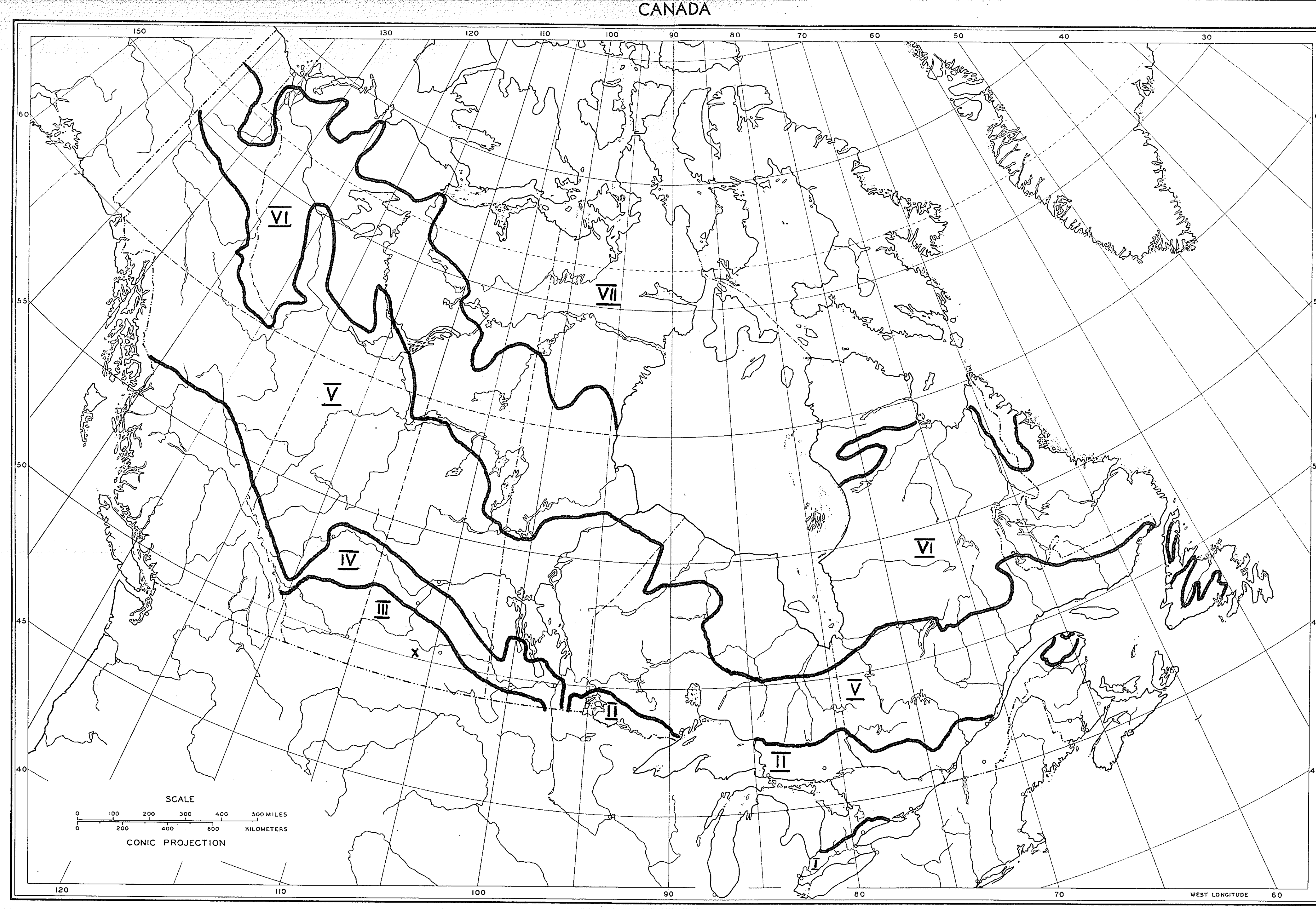



Fig. 2. The general location of the Hafichuk site (x) in relation to the main vegetation regions (modified version of Rowe, 1959). I. Deciduous Forest; II. Great Lakes - St. Lawrence Forest; III. Grasslands; IV. Aspen-Parkland; V. Boreal and Northern Coniferous Forest; VI. Northern transition - Subarctic-Forest and Barren; VII. Tundra.

southern Saskatchewan, including the Missouri Coteau, is occupied by a *Stipa-Bouteloua* faciation. This characteristic climax-type vegetation is developed on medium textured soils over glacial till in the moister brown, and drier dark-brown soil zone. This faciation is pre-climax to the *Stipa-Agropyron* community and post-climax to the *Bouteloua-Stipa* type. In the moister part of the brown soil zone, including the eastern zone of the Coteau, the *Stipa-Bouteloua* faciation, is mainly confined to the intermediate slopes. The upper slopes and top of knolls are occupied by a *Bouteloua-Stipa* type of vegetation, while lower slopes support a *Stipa-Agropyron* community. Local depressions are usually occupied by a mesic vegetation, depending on available soil moisture. Locations of faciation types varies with climatic conditions. Three vegetation strata can be recognized, (i) an upper layer consisting of medium-height grass-culms and flowering stems of various forbs, (ii) a middle layer of *Bouteloua gracilis*, *Carex eleocharis* and associated forbs such as *Malvastrum coccineum*, (iii) a lower layer consisting of *Selaginalla densa* in places.

Trees and shrubs are not common in this community, but do occur locally in favourable habitats where soil texture and topography influence available soil moisture. Populus tremuloides, Elaeagnus commutata, Symphoricarpos occidentalis, Salix and Rosa spp. are the most common species in these habitats. A relationship of certain grass types to differences in soil texture and climatic conditions is significant. Bouteloua gracilis increases, for instance, on clayey loam on steep hill-slopes, as a direct result of shallow penetration of moisture. Agropyron dasystachyum and Koeleria cristata tend to favour more moister localities.

Artemesia frigida and Carex heliophila become dominant in places, particularly on overgrazed lands. The relative abundance of a certain species depends on local variation in climate and soil. The Stipa-Bouteloua faciation, the members of which are made up of dominant, principle and secondary species, are listed below in sequence of abundance. Stipa comata, Stipa spartea var. curtiseta, Bouteloua gracilis, Agropyron dasystachyum, Koeleria cristata, Carex eleocharis, Carex filiformis, Muhlenbergia cuspidata, Poa canbyi, Stipa viridula, Carex obtusata, Artemesia frigida, Malvastrum coccineum, Anemone patens var. wolfgangiana, Gutierrezia diversifolia, Chrysopsis villosa, Artemesia gnaphalodes, Astragalus flexuosis, Liatris punctata, Potentilla bipinnatifida, Erigeron glabellus, Aster ericoides.

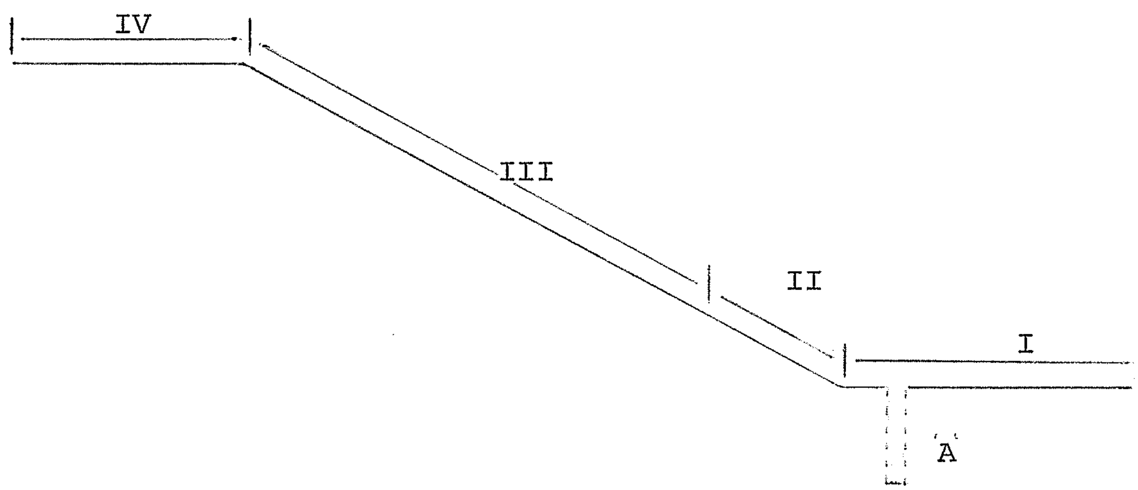



Fig. 3. A simplified profile diagram showing the local topography and related plant community types of the Hafichuk site. The numbered vegetation zones are referred to in the text. 'A' marks the approximate position of the excavation on the rim of the kettle. Approximate scale, 1 cm. = 5 m.

For convenience, the vegetation of the immediate precincts of the excavation is grouped into four types, and their spatial relations are illustrated by the sketch in Fig. 3.

Community I, occupying the level surface of the former kettle, was composed of the following species; listed in approximate order of abundance:- Beckmannia syzigachne, Eleocharis palustris, Carex spp., Deschampsia cespitosa, Rumex mexicanus and Mentha arvensis.

Community II, occupying the foot of the slope, was composed of the following species; listed in approximate order of abundance:- Symphoricarpos occidentalis, Rosa spp., Glycyrrhiza lepidota, Thalictrum dasycarpum, Erigeron philadelphicus, Aster laevis and Sisyrinchium montanum f. albiflorum.

Community III, occupies the intermediate and upper slope and support the following species; listed in approximate order of abundance:- Bouteloua gracilis, Stipa comata, Stipa spartea var. curtiseta, Agropyron smithii, Rosa arkansana, Eleagnus commutata, Glycyrrhiza lepidota, Solidago spp. and Selaginella densa.

Community IV, occupying the top of the knoll was composed of the following species; listed in approximate order of abundance:- Stipa comata, Bouteloua gracilis, Artemesia frigida, Carex filifolia, Aster ericoides and Anemone patens var. wolfgangiana.

The general topography, location of the excavation and vegetation types are illustrated in Fig. 4.

Fig. 4. A photograph showing the excavation of the Hafichuk site at the rim of a small filled-in kettle. The shrub zone at the lower left-hand side extends round the rim of the kettle and corresponds with Zone II of Fig. 3.

## III. FIELD AND LABORATORY PROCEDURES

In the course of the exploratory work, it was pointed out to me that Mr. D. Hafichuk had encountered in a well excavation material which resembled buried organic matter. Accordingly, I discussed this with Mr. Hafichuk and he showed me the exact location of the test hole. On examination of the excavated debris from this hole, distinctly laminated gyttja, wood and moss fragments were found, and it was decided to make a preliminary augering in the same place. For this purpose, a commercial post-hole auger with extension rods was used. The material excavated indicated the presence at the 2.8 to 4.2 m. level of a distinct deposit of organic sediment, with a strongly laminated gyttja layer between the 3.3 and 3.6 m. levels, suggesting that there might be some merit in making a complete excavation of the site.

An open pit, 1.5 m. square, was dug, care being taken to keep the walls vertical. The pit was excavated to a depth of 5.1 m. At this depth further excavation was impossible since water filled the bottom of the pit more rapidly than it could be pumped out. Also, this aggravated the distinct risk of the pit caving in.

Small samples, each about 8 ml, were taken at 5 cm. intervals from the top to the 5.1 m. level. They were collected from a cleaned pit face with an open-end tube, then transferred to sealed plastic vials and sent to the laboratory where they were stored at -3° C. until processed. Continuous bulk samples for macrofossil study were taken from the 2.8 m. level (where organic material was first encountered) to the 5.1 m. level. Some effort was made to take samples of uniform dimensions, and while this was possible with respect to depth, the other dimensions varied due to difficulties in recovering the material. Each sample was 10 cm. in vertical dimension, the other faces were approximately 20 and 25 cm. in length. This yielded blocks of approximately identical volume (5 l.), taken from precisely determined stratigraphic positions. As soon as excavated, each block was coated with pure glycerine to restrict desiccation, and then wrapped tightly in cellophane. They were stored in a cool place until they were moved to the laboratory. There developed on the samples extensive fungal mycelia, but they disappeared completely when the samples were stored at freezing temperatures (in facilities kindly provided by the Canada Department of Agriculture Research Station, Winnipeg).

Prior to analysis, the macrofossil samples were melted overnight at room temperature. A standard size, of 10 cm in vertical dimension, with other faces approximately 15 and 20 cm in length, in macrofossil bulk samples was cut. This yielded blocks of approximately 3 l. volume. Samples were treated with two types of methods, (i) 10% nitric acid, (ii) ordinary tap water. The first method, after Andersson (1892) and described by Godwin (1956, p. 7), was used on laminated gyttja samples, i.e. by keeping them 24-48 hours in a 10% nitric acid solution, and thereafter washing in ample running water, using a copper sieve (1.5 mm). The residual material was then placed in petri dishes and seeds as well as other recognizable macroscopic remains were picked out with foreceps or fine camel brush. The second method was used on samples of non-laminated gyttja from which seeds and fruits were recovered by gentle washing and sieving (cf. Godwin, 1956, p. 7 l. cit.). After examination, macrofossil remains were placed in individual watch glasses.

Final preservation was obtained by placing them in small glass vials with a mixture of 70% alcohol and 15% glycerine.

Embedded leaf fragments were successfully floated off with 10% nitric acid and placed in water. Afterwards, they were mounted in gum-chloral.

The results of this investigation are presented in three sections: stratigraphy, plant macrofossils and a pollen diagram.

The stratigraphy is presented firstly in tabular form (Table I), where materials encountered in the excavation are described in stratigraphic sequence, in terms of the general nature, colour, conspicuous organic or inorganic inclusions, and texture. From this a more generalized stratigraphy is drawn up.

The plant macrofossils are also shown in tabular form (Table II) to indicate the level at which each plant or plant part occurred, the quantity of each plant or plant part at each sample level, (Table III) and the ecological and geographical affinities of each species on the basis of present-day information (Tables IV, V, VI).

The pollen diagram is of the dissolved type (Faegri and Iversen, 1950) in which the total number of pollen grains of each species is expressed as a percentage of the pollen sum for each sample level. The pollen sum excludes aquatic and marsh plants, including Cyperaceae. In the centre of the diagram the total proportions of tree, shrub and herb types are plotted Certain types, of infrequent occurrence, are shown as black circular dots rather than plotted as percentages, merely for clarity of presentation. On the right-hand side of the diagram the values for the pollen sum of each level are shown.

## IV. RESULTS

### Stratigraphy

The data presented here, and their interpretation, are of necessity somewhat superficial, since a thorough analysis of the material is properly the province of a palaeolimnologist. However, an attempt has been made to adduce as much information as possible on the stratigraphy for an initial attempt at correlation with the macrofossil data and the pollen diagram.

The whole deposit consists of a primarily organic, limnic sediment overlain by a mantle of apparently unsorted glacial till. The limnic sediment can be divided initially into a laminated gyttja, and a non-laminated clay-gyttja with intact shells and small angular stones in the lower levels. This indicates strongly that the fossiliferous material has been laid down in situ; thus the value of the material is enhanced, since one can discount the possibility of transport from a distance of the macrofossil material. Likewise, it is probable that the pollen, at least from the organic sediment, is of primary origin.

As Table I shows, distinct layers of charcoal (level 285 cm), and Chara remains (335 and 370 cm) were recorded.

It was observed in the field, and confirmed in the laboratory, that the strata of the organic deposit were consistently oblique. The strata viewed on the east and west walls of the pit, which were directed towards the centre of the kettle, were horizontal. However, the horizons on the north and south walls dipped towards the centre of the kettle consistently at an angle of $\pm$ 25° to the horizontal. Also, the laminations of the gyttja were irregular locally, convoluted in profile view, but always intact. It is presumed that the oblique and locally convoluted lamination, and the overlying unsorted mineral material are related to some event or process which terminated the limnic sedimentation. However, the absence of evidence of destruction of the stratigraphic sequence and of the more delicate fossils (e.g. shells), together with the chronology suggested by the carbon-14 measurements, suggests that the greater part of the deposit has been preserved in its original form.

A further stratigraphic problem, for which there is not an immediate explanation, is the presence at the 490 to 500 cm level of a band of laminated gyttja between layers of non-laminated clay gyttja with small angular stones. It is not clear at present whether this reflects changing sedimentation, possibly controlled by varied environmental conditions, or whether this section of the deposit has not been preserved perfectly *in situ*. Further consideration of these problems will be given in the concluding section of the thesis.

TABLE I

Detailed Stratigraphy

| centimeters | inches | description |
|---|---|---|
| 0 | 0 | Dark brown soil, grading into clayey-loam. |
| 62 | 25 | Clayey-loam, silt and fine sand in places, occasional small angular stones. |
| 120 | 48 | Dark, gray clay (5y 4/1, when wet)*, small shells. Water-table at 125 cm. |
| 220 | 88 | Stiff gray clay (5y 4/1, when wet), fine gravel in places, small shells abundant. Greenish coloration noted in clay. Several vertebrae recovered from the 230 cm level. |
| 270 | 108 | Gritty, black clay (5y 2/2, when wet). |
| 280 | 112 | Dark, gray clay (5y 3/1, when wet, and changing to gray - 5y 5/1, when dry, indicating a high clay content). Numerous assorted shells, well preserved, few angular stones. This unsorted material rested at an angle of 25° to the horizontal, on faint laminated Chara marl, olive-gray (5y 5/2, when wet). A thin (1.5 mm) band of Charcoal at approximate 290 cm. Sample I for radio-carbon dating taken at 285 cm. |
| 290 | 116 | First wood recovered at 295 cm, well preserved with intact bark and presumed to be Coniferous-<u>Picea</u> spp. Laminated, dark, olive-gray (5y 3/2, when wet), |

Table I cont'd

| centimeters | inches | description |
|---|---|---|
| | | clay gyttja. Alternating black gyttja and Chara. Bits of charcoal throughout. Thin laminae of gray, silty gyttja, alternating with black gyttja. Assorted, well preserved shells common. Tree fragment parallel to laminae at 310 cm, well preserved, with bark attached. Presumed to be Coniferous-Picea spp. |
| 330 | 132 | Distinct laminated gyttja. Strong odor, resembling hydrogen sulphide noticeable. Alternating, thin, laminae of Chara and gyttja, with dark, olive-gray overall color. Silty, gray clay alternating with black gyttja in distinct laminae. A band of Chara noticeable at 335 cm and approximately 1 mm wide. Shells present and well preserved. Three tree fragments, superimposed and well preserved between 330-345 cm. Their bark well preserved and recognizable as Coniferous (Picea spp.). |
| 360 | 144 | Dark, olive gray, clay gyttja, faintly laminated, with laminae alternating of silt and black gyttja, (5y 2/1, when wet and very dark gray - 5y 3/1, when dry, indicating a fairly high organic content). Peaty material in places. A noticeable Chara band, approximately 1 mm in thickness at the 370 cm level. Some small angular stones and shells present. Laminae |

Table I cont'd

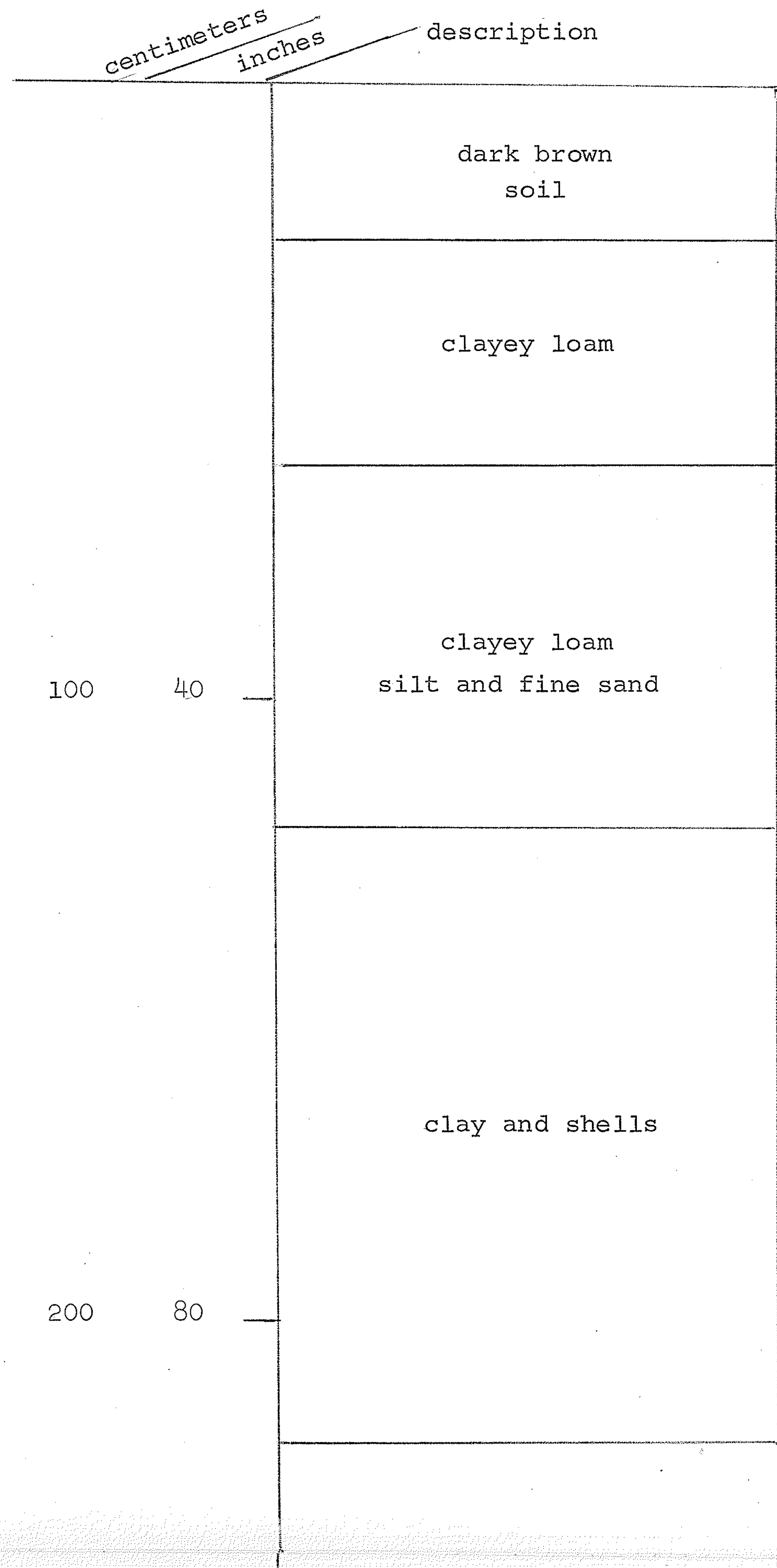
| centimeters | inches | description |
|---|---|---|
| | | easily separated and black in color when wet. The 25° angle still prevalent. Silty clay alternating with dark gyttja with some Chara. |
| 390 | 156 | Sample II for radiocarbon dating, taken at 390 cm. Faintly laminated clay gyttja with some Chara. Rusty-brown colorations noted in clay. Wood fragments parallel to laminae of Chara and black gyttja. Few shell and pebbles. Large charcoal fragments at 395 cm. Well preserved tree fragment with bark still intact at 410 cm and parallel to laminae, presumed to be Picea spp. |
| 420 | 168 | Gyttja becoming non-laminated and very dark-gray. Little Chara, few shells and small angular stones. Charcoal fragments present. Tree fragment perpendicular and poorly preserved (no bark), at 450 cm. |
| 450 | 180 | Stony, non-laminated, clay gyttja, very dark gray when wet and becoming gray when dry. Chara in places. Large angular stone (4 x 3 x 5 cm) recovered at 465 cm. Occasional wood fragments, few assorted, fairly well preserved, shells. |
| 480 | 192 | Dark gray, non-laminated clay gyttja. Abundant Chara and numerous angular stones. Some charcoal fragments. A |

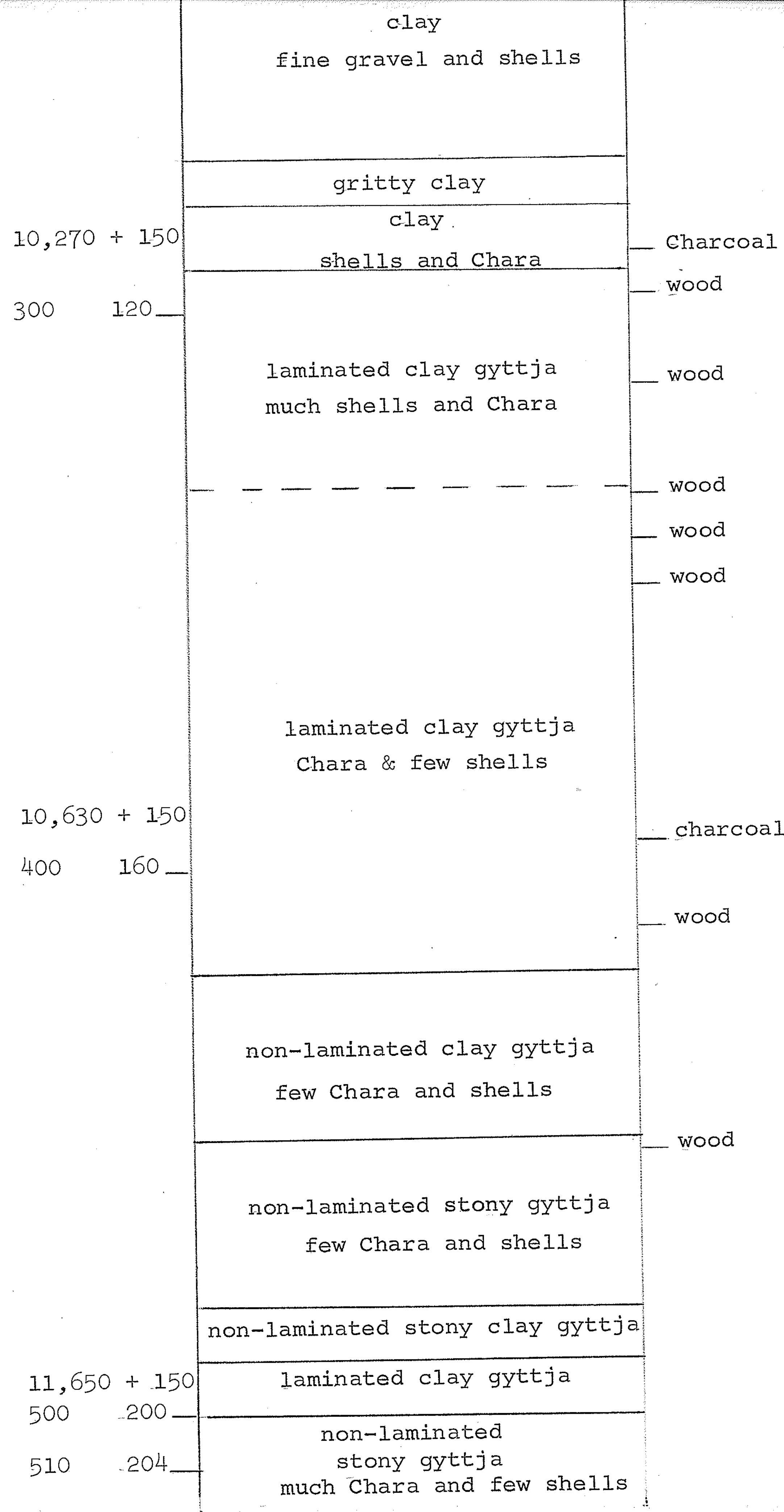
Table I cont'd

| centimeters | inches | description |
|---|---|---|
| | | distinct zone of well laminated, dark gray, clay gyttja between 490-500 cm. Sample III for radiocarbon dating, taken at 495 cm. |
| 510 | 204 | Sediments below this level were not sampled, due to extensive water seepage and added risk of cave-in of excavation. |

*Colour code number as taken from "Munsell Colour Chart".

Fig. 5. General stratigraphy of the Hafichuk Site.





clay
fine gravel and shells
gritty clay
clay
shells and Chara
10,270 + 150
Charcoal
wood
300 120
laminated clay gyttja
much shells and Chara
wood
wood
wood
wood
laminated clay gyttja
Chara & few shells
10,630 + 150
charcoal
400 160
wood
non-laminated clay gyttja
few Chara and shells
wood
non-laminated stony gyttja
few Chara and shells
non-laminated stony clay gyttja
11,650 + 150
laminated clay gyttja
500 200
non-laminated
stony gyttja
much Chara and few shells
510 204

Plant macrofossils

Since the immediate objectives of the investigation were concerned with a reconstruction of terrestrial, and to a lesser extent aquatic vegetation, and because of limitations of time and experience, attention was directed primarily to the identification of Tracheophyta remains. An independent investigation might well be made of the plant and animal plankton preserved in the material. Specimens of molluscs, insects and mosses were recovered, and they are being examined by various specialists, who had not reported their findings at the time of preparing the manuscript of the thesis.

The plant remains were numerous and varied, including wood, twigs, non-woody stems, leaves, vegetative buds, cones and cone scales, catkin bracts, fruits, seeds and spores. The specimens were examined with a low-power binocular microscope, at 10, 20, 30 and 50 magnifications. Only material which has been identified positively has been included. Identification was possible in some cases to species level, and others to family or genus. Seeds and fruits were identified by comparison with a reference collection of modern material, confirmed by reference to several taxonomic treatments and floras. Leaves, buds, bracts, cones, spores and twigs were compared with modern herbarium specimens and with formal taxonomic descriptions. Specimens of wood were cut in transverse and longitudinal section (both radial and tangential) and examined with a compound microscope. They were identified by reference to slides prepared from modern material and the treatise of Greguss (1955, 1959).

A total of 80 entities were identified, and they are listed in the Tables, following the system of Scoggan (1957).

While it is recognized that the relative numbers of types of macrofossils can not be compared directly, as with pollen, the absolute numbers of each fossil type is shown for each sample level, in Table III.

As an aid to subsequent interpretation, an attempt has been made to tabulate the plant macrofossils according to the habitat type and geographical area which they occupy at the present time (Tables IV, V, VI).

TABLE II

A list of late-glacial plant remains recovered from the Hafichuk site.

| Family | Species |
|---|---|
| Hydrodictyaceae | Hydrodictyon sp. |
| Characeae | Chara sp. |
| Mniaceae | Mnium sp. |
| Equisetaceae | Equisetum sylvaticum L.? |
| " | E. sp. |
| Selaginellaceae | Selaginella selaginoides (L.) Link |
| " | S. rupestris (L.) Spring |
| Pinaceae | Picea glauca (Moench) Voss |
| " | P. mariana (Mill) BSP. |
| " | P. sp. |
| " | Juniperus communis L. (Agg.) |
| Typhaceae | Typha sp. |
| Zosteraceae | Zannichellia palustris L. |
| " | Potamogeton filiformis Pers. |
| " | P. pectinatus L. |
| " | P. gramineus L.? |
| " | P. obtusifolius Mert. & Koch. |
| " | P. sp. |
| Juncaginaceae | Triglochin maritima L. |
| Hydrocharitaceae | Elodea canadensis Michx. |
| Gramineae | Puccinellia tenuiflora (Griseb.) Scribn. & Merr. |
| " | Sp. |
| Cyperaceae | Cyperus inflexus Muhl.? |
| " | Eleocharis palustris (L.) R. & S. (Agg.) |
| " | Scirpus americanus Pers. |
| " | S. validus Vahl. |
| " | S. acutus Muhl. |
| " | S. sp. |
| " | Eriophorum sp. |
| " | Carex aurea Nutt.? |
| " | C. lenticularis Michx.? |
| " | C. aquatilis Wahl. |
| " | C. atherodes Spreng. |
| " | C. rostrata Stokes. |

| ft | | 16 | | | 15 | | | 14 | | | 13 | | | 12 | | | 11 | | | 10 | | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Remains / cm | 510-500 | 500-490 | 490-480 | 480-470 | 470-460 | 460-450 | 450-440 | 440-430 | 430-420 | 420-410 | 410-400 | 400-390 | 390-380 | 380-370 | 370-360 | 360-350 | 350-340 | 340-330 | 330-320 | 320-310 | 310-300 | 300-290 | 290-280 |
| Ns | - | x | - | x | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Sh,O | x | x | - | - | x | x | - | x | - | - | x | x | x | x | x | - | x | x | x | x | x | x | x |
| L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | x | - | - | - | - | - |
| Sh | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Sh | - | x | - | - | - | x | x | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| L,Sp | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | - | - | - | - | - | - |
| Sp | - | x | - | - | x | - | - | x | - | - | x | - | x | x | - | - | x | - | x | x | x | - | - |
| Co,L,T | - | x | x | - | x | x | - | x | - | x | x | x | x | x | x | x | x | x | - | x | - | - | - |
| L,T | - | x | x | - | x | - | - | - | - | - | - | - | x | x | x | - | x | x | x | - | - | - | - |
| B,Co,L,S,W | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | - |
| L,T | - | - | - | - | - | - | x | - | x | - | x | - | - | - | x | x | x | x | x | - | - | - | - |
| S | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | x | x | x | x | x | x | x | x |
| F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | x | x | x |
| Fst | x | x | - | x | - | - | x | - | - | - | - | - | - | x | - | - | - | - | - | - | - | x | - |
| Fst | x | x | x | - | - | x | x | - | - | - | - | - | x | - | - | - | - | - | - | x | x | - | - |
| Fst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - |
| Fst | x | x | x | x | - | x | x | x | - | - | - | x | x | - | - | - | - | - | - | - | - | - | - |
| Fst, L | - | x | - | - | x | - | - | - | x | - | x | x | x | x | - | - | - | - | - | - | x | - | x |
| F | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | x | - | - |
| S | - | x | - | - | - | - | - | - | - | - | x | x | - | - | - | - | - | - | - | - | - | - | - |
| F | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | x | x | - | - |
| F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - |
| F | x | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - |
| F | - | - | - | - | - | - | - | - | - | - | - | - | x | - | x | x | x | x | x | - | - | - | - |
| F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | - | x | - | - | - | - | - |
| F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - |
| F | - | - | - | - | - | - | - | - | - | - | - | - | x | x | x | - | - | - | - | x | x | - | - |
| Sh | - | x | x | x | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F | - | - | - | - | - | - | - | - | - | - | - | - | x | - | x | x | - | - | - | - | - | - | - |
| F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | - | - | - | x | - | - | - |
| F | - | x | - | - | - | - | - | - | - | - | - | - | - | x | x | x | - | - | - | x | - | - | - |

Table II cont'd

| Family | Species | Remains | 16 | | | 15 | | | 14 | | | 13 | | | 12 | | | 11 | | | 10 | | | 9 | ft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 510-500 | 500-490 | 490-480 | 480-470 | 470-460 | 460-450 | 450-440 | 440-430 | 430-420 | 420-410 | 410-400 | 400-390 | 390-380 | 380-370 | 370-360 | 360-350 | 350-340 | 340-330 | 330-320 | 320-310 | 310-300 | 300-290 | 290-280 cm |
| Cyperaceae | C. retrorsa Schwein. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | - | - | - | - | - | - | - | - |
| " | C. sp. | F | x | x | - | - | - | - | - | - | - | - | - | - | x | x | x | x | x | x | x | x | x | - | - |
| Lemnaceae | Lemna trisulca L. | L | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | x | x | x | x | x | x | - | - |
| " | Wolffia punctata Griseb. | L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | x | x | x | x | - | - |
| Juncaceae | Juncus sp. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | x | - | - | - |
| Salicaceae | Populus tremuloides Michx. | B, L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | x | x | x | x | x | - |
| " | P. balsamifera L. | B,Br,L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | - | - | - | x | x | x | - |
| " | P. deltoides Marsh. | Br, L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | - | - | - | x | - | - | - |
| " | P. sp. | B,L,W | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | x | x | x | x |
| " | Salix sp. | L,W | x | x | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Polygonaceae | Rumex maritimus L. var. fueginus (Philippi) Dusén | F | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | - | - | x | x | x | x | - | - |
| Chenopodiaceae | Suaeda depressa (Pursh) S. Wats.? | S | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| " | Chenopodium capitatum (L.) Asch. | S | - | - | - | - | - | - | x | - | - | x | x | - | - | - | - | - | - | - | - | - | - | - | - |
| " | C. rubrum L.? | S | - | - | - | - | - | - | - | - | - | - | - | - | x | - | x | x | x | x | - | - | - | - | - |
| " | C. glaucum L. var. salinum (Standl.) Boivin? | S | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | x | x |
| " | C. hybridum L. var. gigantospermum (Aellen)Rouleau? | S | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x |
| " | C. album L. | S | - | - | - | - | - | - | x | - | - | x | - | x | - | x | - | - | - | x | - | - | - | x | - |
| Caryophyllaceae | Arenaria sp.? | S | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - |
| Ceratophyllaceae | Ceratophyllum demersum L. | L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - |
| Ranunculaceae | Ranunculus sceleratus L. | F | - | x | - | - | - | x | x | x | x | - | x | - | - | - | x | - | x | - | x | x | x | x | x |
| Cruciferae | Subularia aquatica L. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x |
| " | Barbarea sp. | F | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - |
| Rosaceae | Rosa blanda Ait. | Fst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | - | - |
| " | Potentilla tridentata Ait.? | F | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| " | P. palustris (L.) Scop.? | F | - | - | - | - | - | x | x | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| " | P. norvegica L.? | F | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| " | P. gracilis Dougl. var. pulcherrima (Lehm.) Fern. | F | - | - | - | - | - | - | x | x | x | x | x | - | x | x | - | - | - | - | - | - | - | - | - |
| " | Rubus idaeus L. (Agg.) | Fst | x | x | x | - | x | x | x | x | x | x | x | x | x | x | x | x | x | x | - | x | x | x | x |
| " | R. sp. | Sh | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Elaeagnaceae | Shepherdia canadensis (L.) Nutt. | S | - | - | - | - | - | - | - | - | - | - | - | x | - | x | x | - | - | - | - | - | - | - | - |
| " | S. sp. | L,W | - | - | - | - | - | x | x | - | x | x | - | x | x | - | - | - | - | - | - | - | - | - | - |
| Onagraceae | Epilobium sp. | S | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Haloragaceae | Myriophyllum exalbescens Fern.(M.spicatum Am.Auth.) | F | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| " | M. spicatum L. f. muricatum Ahlf. | F | x | x | x | x | x | x | x | x | - | - | x | - | - | - | x | - | - | - | - | - | - | - | - |
| " | M. sp. | L | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | - | - | - | - | - | - |

Table II cont'd

| Family | Species | Remains | 16 ft | | | 15 | | | 14 | | | 13 | | | 12 | | | 11 | | | 10 | | | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cm | 510-500 | 500-490 | 490-480 | 480-470 | 470-460 | 460-450 | 450-440 | 440-430 | 430-420 | 420-410 | 410-400 | 400-390 | 390-380 | 380-370 | 370-360 | 360-350 | 350-340 | 340-330 | 330-320 | 320-310 | 310-300 | 300-290 | 290-280 |
| Hippuridaceae | Hippuris vulgaris L. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | x | x | x | x | x | x | x | x | - | - |
| Araliaceae | Aralia nudicaulis L. | L | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - |
| Umbelliferae | Cicuta maculata L. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - | - |
| Cornaceae | Cornus racemosa Lam. | Fst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - |
| Ericaceae | Arctostaphylos Uva-Ursi (L.) Spreng. | Fst | - | - | - | - | - | - | - | - | - | x | - | - | x | - | - | - | - | - | - | x | x | - | - |
| Labiatae | Lycopus americanus Muhl. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - |
| " | Mentha arvensis L. var. agg. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | x | x | x | - |
| Scrophulariaceae | Rhinanthus borealis (Sterneck) Chabert? | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - |
| Caprifoliaceae | Symphoricarpos albus (L.) Blake | Fst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x | - | - | - | - | - |
| " | Lonicera sp.? | Fst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | x |
| Compositae | Erigeron philadelphicus L. | L | - | - | - | - | - | - | x | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

The following abbreviations are used:-
B = bud, Br = bract (of ament), Co = cone, F = fruit, Fst = fruit-stone, L = leaf, NS = netlike structure, O = oogonium, S = seed, Sh = shoot, Sp = spores, T = twig, W = wood.

## TABLE III

A list of late-glacial plant remains recovered from the Hafichuk site showing the actual numbers of specimens at each sample level.

| | ft | 16 | | | 15 | | | 14 | | | 13 | | | 12 | | | 11 | | | 10 | | | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Remains | 510-500 | 500-490 | 490-480 | 480-470 | 470-460 | 460-450 | 450-440 | 440-430 | 430-420 | 420-410 | 410-400 | 400-390 | 390-380 | 380-370 | 370-360 | 360-350 | 350-340 | 340-330 | 330-320 | 320-310 | 310-300 | 300-290 | 290-280 cm |
| Equisetum sylvaticum L.? | Sh | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Selaginella selaginoides (L.) Link | L | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| | Sp | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 20 | 6 | - | - | - | - | - | - |
| S. rupestris (L.) Spreng | Sp | - | 21 | - | - | 8 | - | - | 10 | - | - | 61 | - | 4 | 24 | - | - | 8 | - | 4 | 69 | 11 | - | - |
| Picea glauca (Moench) Voss | Co | - | - | - | - | - | - | - | 3 | - | 4 | - | - | - | 1 | - | - | - | - | - | 4 | - | - | - |
| | L | - | 26 | 7 | - | 11 | 13 | - | - | - | - | - | 9 | 32 | 35 | 8 | 15 | 40 | 1 | - | - | - | - | - |
| | T | - | 13 | 1 | - | - | 5 | - | 4 | - | - | 8 | - | 2 | 7 | 2 | - | - | - | - | - | - | - | - |
| P. mariana (Mill) BSP. | L | - | 4 | 8 | - | 5 | - | - | - | - | - | - | - | 1 | - | 4 | - | 13 | 3 | 8 | - | - | - | - |
| | T | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - |
| Juniperus communis L. (Agg.) | L | - | - | - | - | - | - | 11 | - | 2 | - | 1 | - | - | - | 1 | 4 | 12 | 4 | 6 | - | - | - | - |
| | T | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 8 | 13 | 8 | 15 | - | - | - | - |
| Typha sp. | S | - | - | - | - | - | - | - | - | - | - | - | - | - | 19 | 7 | 11 | 26 | 28 | 50 | 44 | 23 | 168 | 50 |
| Zannichellia palustris L. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | 2 | 170 | 12 |
| Potamogeton filiformis Pers. | Fst | 4 | 2 | - | 1 | - | - | 2 | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | 13 | - |
| P. pectinatus L. | Fst | 13 | 3 | 1 | - | - | 2 | 4 | - | - | - | - | - | 1 | - | - | - | - | - | - | 3 | 28 | - | - |
| P. gramineus L.? | Fst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | - | - |
| P. obtusifolius Mert. & Koch. | Fst | 5 | 3 | 6 | 2 | - | 1 | 3 | 1 | - | - | - | 3 | 2 | - | - | - | - | - | - | - | - | - | - |
| Triglochin maritima L. | F | - | - | - | - | - | - | - | - | - | 14 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Elodea canadensis Michx. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 9 | 11 | - |
| Puccinellia tenuiflora (Griseb.) Scribn. & Merr. | S | - | 1 | - | - | - | - | - | - | - | - | 11 | 2 | - | - | - | - | - | - | - | - | - | - | - |
| Cyperus inflexus Muhl.? | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - |
| Eleocharis palustris (L.) R. & S. (Agg.) | F | 1 | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| Scirpus americanus Pers. | F | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 5 | 2 | 1 | 1 | 1 | - | - | - | - |
| S. validus Vahl. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | 1 | - | 1 | - | - | - | - | - |
| S. acutus Muhl. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | - |
| Carex aurea Nutt.? | F | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C. lenticularis Michx.? | F | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C. aquatilis Wahl. | F | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | 5 | 1 | - | - | - | - | - | - | - |
| C. atherodes Spreng. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 1 | - | - | - | 1 | - | - | - |
| C. rostrata Stokes | F | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 | 6 | 1 | - | - | - | 1 | - | - | - |
| C. retrorsa Schwein | F | - | - | - | - | - | - | - | - | - | - | - | - | - | 8 | 5 | - | - | - | - | - | - | - | - |
| Lemna trisulca L. | L | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 12 | 55 | 48 | 17 | 32 | 17 | 1 | - | - |
| Wolffia punctata Griseb. | L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | 5 | 32 | 46 | 6 | - | - |

Table III cont'd

| Species | Remains | 16 | | | 15 | | | 14 | | | 13 | | | 12 | | | 11 | | | 10 | | | 9 | ft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 510-500 | 500-490 | 490-480 | 480-470 | 470-460 | 460-450 | 450-440 | 440-430 | 430-420 | 420-410 | 410-400 | 400-390 | 390-380 | 380-370 | 370-360 | 360-350 | 350-340 | 340-330 | 330-320 | 320-310 | 310-300 | 300-290 | 290-280 cm |
| Populus tremuloides | B | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 17 | - | - | - | 24 | - |
| | L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 9 | 5 | 2 | - | - |
| P. balsamifera L. | B | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 3 | - |
| | Br | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| | L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | 2 | - | - | - |
| P. deltoides Marsh | Br | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - | - |
| | L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | - | - | - |
| Rumex maritimus L. var. fueginus (Philippi), Dusén | F | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | 1 | 1 | 3 | 4 | - | - |
| Suaeda depressa (Pursh) S. Wats.? | S | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Chenopodium capitatum (L.) Asch. | S | - | - | - | - | - | - | 1 | - | - | 31 | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| C. rubrum L.? | S | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 2 | 2 | 3 | 1 | - | - | - | - | - |
| C. glaucum L. var. salinum (Standl.) Boivin? | S | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - | - | 1 | - |
| C. hybridum L. var. gigantospermum (Aellen) Rouleau? | S | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| C. album L. | S | - | - | - | - | - | - | 1 | - | - | 1 | - | 1 | - | 1 | - | - | - | 6 | - | - | - | 2 | - |
| Ceratophyllum demersum L. | L | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 14 | - | - | - |
| Ranunculus sceleratus L. | F | - | 1 | - | - | - | 1 | 5 | 100 | 1 | - | 2 | - | - | - | 2 | - | 2 | - | 1 | 9 | 5 | 5 | 1 |
| Subularia aquatica L. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 245 | 38 |
| Rosa blanda Ait. | Fst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - |
| Potentilla tridentata Ait.? | F | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P. palustris (L.) Scop.? | F | - | - | - | - | - | 1 | 1 | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P. norvegica L.? | F | - | - | - | - | - | 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P. gracilis Dougl. var. pulcherrima (Lehm.) Fern. | F | - | - | - | - | - | - | 13 | 20 | 3 | 13 | 185 | - | 2 | 1 | - | - | - | - | - | - | - | - | - |
| Rubus idaeus L. (Agg.) | Fst | 29 | 6 | 2 | - | 8 | 6 | 11 | 10 | 6 | 47 | 40 | 8 | 4 | 5 | 6 | 1 | 2 | 1 | - | 1 | 12 | 34 | 30 |
| Shepherdia canadensis (L.) Nutt. | S | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 | - | - | - | - | - | - | - | - |
| Myriophyllum exalbescens Fern. (M. spicatum Am. Auth.) | F | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| M. spicatum L. f. muricatum Ahlf. | F | 1 | 1 | 1 | 3 | 2 | 2 | 5 | 2 | - | - | 1 | - | - | - | 1 | - | 2 | - | - | - | - | - | - |
| Hippuris vulgaris L. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | 6 | 6 | 1 | 7 | 12 | 3 | 28 | 4 | - | - |
| Aralia nudicaulis L. | L | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - |
| Cicuta maculata L. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - |
| Cornus racemosa Lam. | Fst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - |
| Arctostaphylos Uva-Ursi (L.) Spreng. | Fst | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - | - | - | 1 | 1 | - | - |
| Lycopus americanus Muhl. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - |
| Mentha arvensis L. var. agg. | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 3 | 10 | 7 | - |
| Rhinanthus borealis (Sterneck) Chabert? | F | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| Symphoricarpos albus (L.) Blake | Fst | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - |
| Erigeron philadelphicus L. | L | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

The following abbreviations are used:-
B = bud, Br = bract (of ament), Co = cone, F = fruit, Fst = fruit-stone, L = leaf, S = seed, Sh = shoot, Sp = spores, T = twig.

TABLE IV

A list of late-glacial plant remains recovered from the Hafichuk site, according to their present-day habitat.

Hydrophytes:

Zannichellia palustris - alkaline waters.
Potamogeton filiformis - calcareous waters.
P. pectinatus - calcareous waters.
P. gramineus - lakes and ponds.
P. obtusifolius - cold springs and lakes.
Elodea canadensis - quiet waters, often calcareous.
Lemna trisulca - ponds and springy places.
Wolffia punctata - quiet waters.
Ceratophyllum demersum - quiet waters.
Myriophyllum exalbescens (M. spicatum Am. Auth.) incl. f. muricatum - calcareous pools and ponds.

Helophytes:

Typha spp. - marshes; shallow waters, shores.
Triglochin maritima - marshes, shores, often saline soils.
Cyperus inflexus - damp sands; alluvial flats.
Eleocharis palustris - margin ponds, shallow waters.
Scirpus americanus - saline shores and marshes.
S. validus - shallow waters.
S. acutus - margins of ponds.
Carex lenticularis - gravelly shores; meadows.
C. aquatilis - shallow pools.
C. atherodes - calcareous shores.
C. rostrata - shallow waters, wet shores.
Rumex maritimus v. fueginus - saline marshes, shores.
Chenopodium rubrum - saline marshes.
Ranunculus sceleratus - slough margins, springy places.
Subularia aquatica - sandy, gravelly margins of lakes, often submerged.
Potentilla palustris - inundated meadows, margins of lakes and ponds.
P. gracilis var. pulcherrima - slough margins, meadows.

Table IV cont'd

Hippuris vulgaris - shallow pools, lake margins.
Mentha arvensis - damp open soils, shores.
Erigeron philadelphicus - alluvial, shores, springy places.

Terrestial:

Equisetum sylvaticum - openings in woodlands, also thickets.
Selaginella selaginoides - damp, often calcareous shores.
S. rupestris - dry sandy soils.
Picea glauca - woods, on good soils.
P. mariana - cool slopes, margins of bogs.
Juniperus communis - poor, dry, often rocky soils.
Puccinellia tenuiflora - saline marshes and drier, open places.
Carex retrorsa - rich low grounds, alluvial woods.
Populus tremuloides - dry open woods, recent burns.
P. balsamifera - river banks, stream or lake margins.
P. deltoides - river banks, bottom lands.
Suaeda depressa - saline soils, open areas.
Chenopodium capitatum - open places, recent burns.
C. glaucum var. salinum - open places.
C. hybridum var. gigantospermum - open places in woods.
C. album-open places.
Rosa blanda - dry slopes, calcareous shores, rocky soils.
Potentilla tridentata - dry, open, gravelly, sandy soils.
P. norvegica - thickets, open places.
Rubus idaeus - river banks, thickets, ledges near lake margins.
Shepherdia canadensis - calcareous banks, sandy slopes.
Aralia nudicaulis - woodlands.
Cicuta maculata - meadows, low thickets, moist prairie.
Cornus racemosa - moist open places.
Arctostaphylos Uva-Ursi - exposed gravelly slopes.
Lycopus americanus - low grounds, meadows, stream margins.
Rhinanthus borealis - slopes and shores.
Symphoricarpos albus - calcareous ledges, gravelly shores.

TABLE V

The general geographical range (1) of late-glacial plant remains recovered from the Hafichuk site, and their present range in Saskatchewan (2).

| Species | 1 | 2 | 3 |
|---|---|---|---|
| Equisetum sylvaticum L.? | B | b | |
| Selaginella selaginoides (L.) Link | S | b | |
| S. rupestris (L.) Spring | BT | b | |
| Picea glauca (Moench) Voss | B | bt | |
| P. mariana (Mill.) BSP. | B | b | |
| Juniperus communis L. (agg.) | B | bt | |
| Zannichellia palustris L. | T | t | |
| Potamogeton filiformis Pers. | SB | b | |
| P. pectinatus L. | BT | bt | |
| P. gramineus L.? | SB | b | |
| P. obtusifolius Mert. & Koch. | BT | b | |
| Triglochin maritima L. | SB | bt | |
| Elodea canadensis Michx. | BT | t | |
| Puccinellia tenuiflora (Griseb.) Scribn. & Merr. | BT | bt | |
| Cyperus inflexus Muhl.? | T | t | |
| Eleocharis palustris (L.) R. & S. (agg.) | SB | bt | |
| Scirpus americanus Pers. | T(B) | t(b) | |
| S. validus Vahl. | BT | bt | |
| S. acutus Muhl. | T | t | |
| Carex aurea Nutt.? | BS | b | |
| C. lenticularis Michx.? | B | b | |
| C. aquatilis Wahl. | AB | bt | |
| C. atherodes Spreng. | T(B) | t(b) | |
| C. rostrata Stokes | SB | bt | |
| C. retrorsa Schwein | B | b | |
| Lemna trisulca L. | BS | bt | |
| Wolffia punctata Griseb. | T | ns | |
| Populus tremuloides Michx. | B | bt | |
| P. balsamifera L. | B | bt | |
| P. deltoides Marsh. | T | ns? | |
| Rumes maritimus L. var. fueginus (Philippi) Dusen | T(B) | t(b) | |
| Suaeda depressa (Pursh) S. Wats.? | T | t | |

Table V cont'd

| Species | 1 | 2 | 3 |
|---|---|---|---|
| Chenopodium capitatum (L.) Asch. | BT | t | |
| C. rubrum L.? | BT | t | |
| C. glaucum L. var. salinum (Standl.) Boivin? | T | t | |
| C. hybridum L. var. gigantospermum (Aellen) Rouleau? | BT | t | |
| C. album L. | T | t | I |
| Ceratophyllum demersum L. | T | t | |
| Ranunculus sceleratus L. | B | bt | |
| Subularia aquatica L. | BS | b | |
| Rosa blanda Ait. | T | ns? | |
| Potentilla tridentata Ait.? | BS | bt | |
| P. palustris (L.) Scop.? | SB | b | |
| P. norvegica L.? | BT | t | |
| P. gracilis Dougl. var. pulcherrima (Lehm.) Fern. | T | t | |
| Rubus idaeus L. (agg.) | BT | t | |
| Shepherdia canadensis (L.) Nutt. | BT | bt | |
| Myriophyllum exalbescens Fern.(M. spicatum Am.Auth.) | B | bt | |
| M. spicatum L. f. muricatum Ahlf. | B | bt | |
| Hippurus vulgaris L. | AB | bt | |
| Aralia nudicaulis L. | T | t | |
| Cicuta maculata L. | BT | bt | |
| Cornus racemosa Lam. | T | t | |
| Arctostaphylos Uva-Ursi (L.) Spreng. | BS | bt | |
| Lycopus americanus Muhl. | BT | bt | |
| Mentha arvensis L. var. agg. | BT | bt | |
| Rhinanthus borealis (Sterneck) Chabert? | S | ns | |
| Symphoricarpos albus (L.) Blake | T | t | |
| Erigeron philadelphicus L. | BT | bt | |

Key to abbreviations:

Column 1: A = arctic, S = subarctic, B = boreal, T = temperate
Column 2: b = boreal, t = temperate, ns = not in Saskatchewan
Column 3: I = introduced in Saskatchewan

TABLE VI

A list of late-glacial plant remains recovered from the Hafichuk site according to their specific geographical range and habitat.

Subarctic:

Selaginella selaginoides - damp, often calcareous, shores.
Rhinanthus borealis - slopes and shores.

Boreal:

Equisetum sylvaticum - openings in woodlands, thickets.
Picea glauca - woods, on good soils.
P. mariana - cool slopes, margins bogs.
Juniperus communis - poor, dry soil, often rocky.
Carex lenticularis - gravelly shores; meadows.
C. atherodes - calcareous shores.
C. retrorsa - rich low grounds; alluvial woods.
Populus tremuloides - dry open woods, recent burns.
P. balsamifera - river banks, stream or lake margins.
Rumex maritima var. fueginus - saline marshes and shores.
Ranunculus sceleratus - slough margins, springy places.
Myriophyllum exalbescens (M. spicatum Am. Auth.) incl. fl. muricatum - calcareous pools and ponds.

Temperate:

Zannichellia palustris - alkaline waters.
Cyperus inflexus - damp sands, alluvial flats.
Scirpus acutus - marshes, pond-margins.
Wolffia punctata - quiet waters.
Populus deltoides - river banks and bottom lands.
Suaeda depressa - saline soils in open areas.
Chenopodium glaucum var. salinum - open places.
C. album - open places.
Ceratophyllum demersum - quiet waters.
Rosa blanda - dry slopes; calcareous shores, often rocky.
Potentilla gracilis var. pulcherrima - slough margins, wet meadows.
Aralia nudicaulis - woodlands.
Cornus racemosa - moist open places.
Symphoricarpos albus - calcareous ledges and gravelly shores.

# V. INTERPRETATION

## Chronological position

The Carbon-14 age measurements of the Hafichuk section indicate that it is similar in age to the Two Creeks Interstadial of the mid-western United States (Wilson, 1932, 1936; Deevey, 1958) and, less precisely, to the $A_1$ - $A_2$ - $A_3$ - $A_4$ interstadial of the northeastern United States (Deevey l. cit. and Davis, 1961). Further, it shows some degree of chronological correlation with the well established Dryas-Allerod-Dryas late-glacial episode of northwest Europe (Iversen, 1953; Barendsen et al, 1957). In a more general context, the section under study fits conformably into that important time span, from about 12,000 to 10,200 years B.P. when a major fluctation in climatic conditions occurred on a world-wide scale (Broecker et al, 1960). Accordingly, it would seem appropriate to refer this section to the late-glacial.

## Related glacial events

As suggested earlier in the thesis, the entire section appears to be pre-Condie in age, on the basis of its position in relation to the Condie moraine and on the basis of the suggestion of Christiansen (1961 p. 43 and 47) that the Condie re-advance took place about 10,000 B.P. The same author suggests that, prior to the Condie re-advance, the ice had retreated from the Moose Jaw Moraine (Fig. 1) "to a position north of the Regina area" (l. cit. p. 47).

On the basis of the Carbon-14 dates, it is suggested, merely as a highly tentative working hypothesis, that the fossiliferous sediment between the 5.1 m. and 2.65 m. levels was deposited in the episode between the Moose Jaw and Condie stadials. The evidence is strong that the termination of sedimentation, at the 2.85 m. level, coincided more or less with the Condie re-advance. The tentative suggestion that the onset of organic sedimentation can be correlated with the retreat from the Moose Jaw Moraine lacks a factual basis, since Christiansen (1961) has available no dated material with which to correlate this glacial event.

## Attempted reconstruction of the vegetation, with tentative palaeoecological inferences

It is recognized widely that the proper interpretation of Holocene plant remains, both in the form of pollen spectra and plant macrofossil records, requires a sound basis of facts on the contemporary ecology and distribution of the plants in question. Further, it is necessary to have available data on the relations, if any, between contemporary pollen spectra and present-day vegetation. At present, in North America generally, and also in west-central Canada, the available information on these topics is inadequate, although a start has been made to investigate present-day pollen spectra in west-central Canada (Ritchie and Lichti-Federovich, 1963).

Accordingly, the present interpretation is couched in conservative, tentative terms, but it is hoped that future investigations in the area, of both modern and Holocene phenomena, will provide the basis for more refined and precise interpretation.

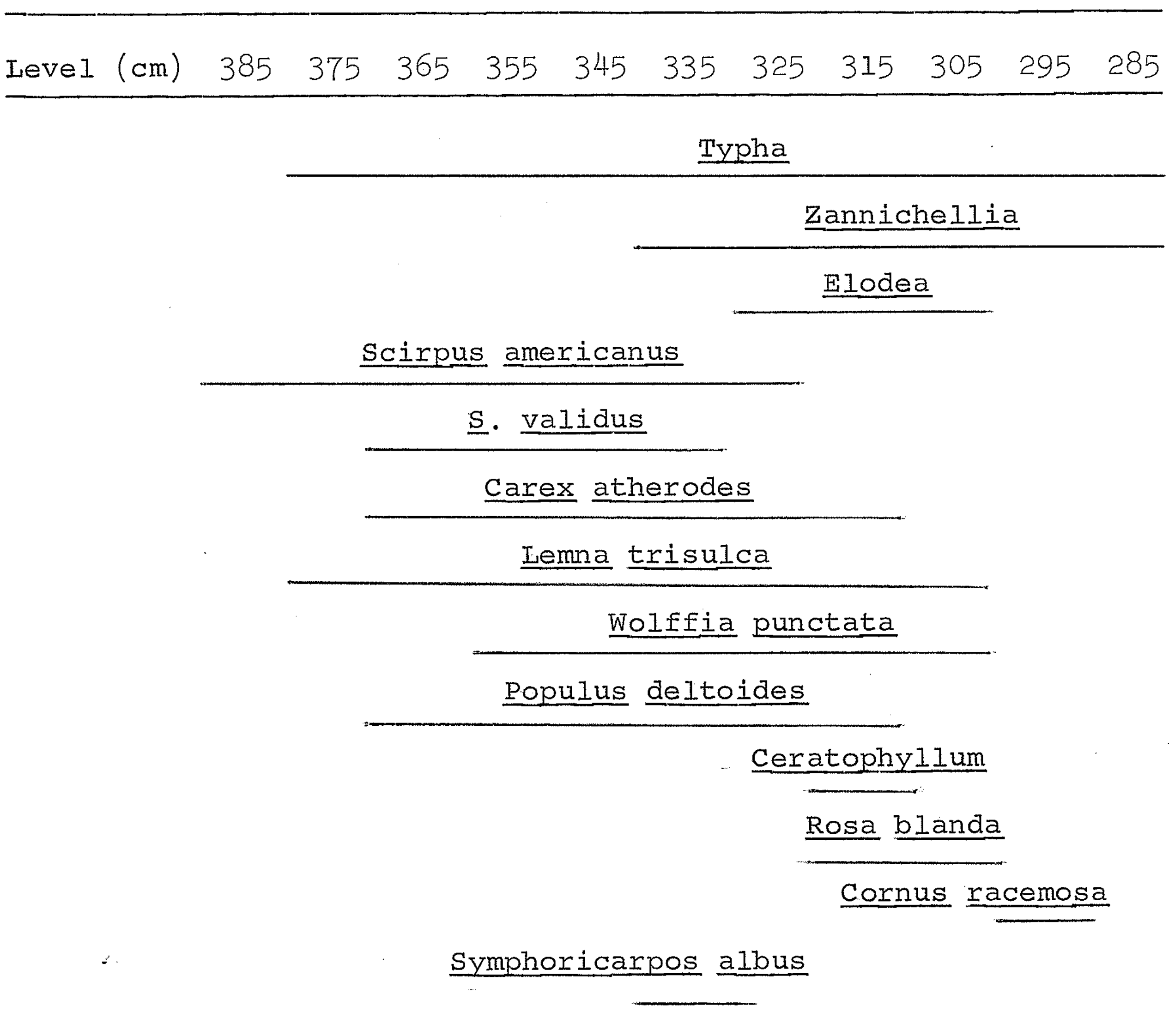
Three lines of evidence can be drawn on in reconstructing the vegetation. Two - the pollen diagram and the record of macrofossils - provide direct evidence, and the other - the sediment types - yields only indirect evidence.

Considering firstly the macrofossils (Tables II - VI), it is clear that there is great variation in both the distribution throughout the sediments and the value as indicators of past conditions. However, there is a group of plants which occur today as either complete aquatics growing in predominantly hard or brackish water or as marsh plants, whose present distribution is confined more or less to the temperate zone, and which show a strong measure of restriction to a certain segment of the section. In addition, there are four species of terrestrial plants which are confined in occurrence to the same general segment of the section, and whose centre of modern distribution coincides with the temperate zone of North America. These aquatic, marsh and terrestrial plants are listed in Table VII, and the extent of their vertical distribution in the section is shown.

Further, it is noteworthy, that this part of the section, between approximately the 3.8 and 2.8 m. levels, yielded the greatest number and the greatest diversity of macrofossils. By contrast, the lower part of the section, from the 5.1 to 3.9 m. levels, yielded a less varied record

TABLE VII

A summary of the vertical distribution of those aquatic, marsh and terrestrial plants which appear to have value as indicators of past conditions



of aquatics, and the species themselves are less informative about either the limnological or climatic conditions which might have prevailed. However, the predominance of Potamogeton species with Myriophyllum might suggest conditions of deeper, less basic water than the shallow, brackish waters suggested by such species as Lemna, Wolffia, Scirpus, Elodea and Zannichellia.

Records of terrestrial plants of value in establishing the composition of the vegetation are those of Populus, including buds and leaves (Fig. 14) of P. tremuloides, bracts from staminate catkins, buds (Figs. 16, 19) and leaves of P. balsamifera, bracts from staminate catkins and leaves (Figs. 8, 20) of P. deltoides. One sample of wood was identified as Populus sp., on the basis of the homogeneous xylem ray parenchyma, associated with otherwise typical Salicaceae wood characteristics. It is of interest that the macrofossil material of Populus occurred in the 365 to 285 cm levels, although the less reliable evidence of poplar pollen is scattered between the 5.1 to 2.65 m. levels. The macrofossils of poplar constitute unequivocal evidence for the existence of the trees, while the pollen record is difficult to interpret because of the familiar problem of differential preservation (cf. Erdtman, 1943). Cones of *Picea glauca* were identified with certainty, on the basis of the margin of the scale and the shape of the cone. Leaves of *Picea mariana* were distinguished on the basis of broader upper bands of stomata; in white spruce the upper and lower stomatal bands are equal. The direct evidence of *Juniperus communis* (Fig. 12) is of interest, although pollen grains of this genus did not appear in the samples. The presence of twigs, leaves (Fig. 15), and seeds (Fig. 6, #23) of *Shepherdia canadensis* confirms the evidence from the pollen diagram that this shrub was a conspicuous element in the terrestrial vegetation.

The evidence provided by the pollen diagram conforms reasonably with the findings of Terasmae from the Herbert Site (reported in Kupsch, 1956) and from the Scrimbit Site (Terasmae, personal communication). Referring to the diagram (Fig. 7) the *Picea* curve declines gradually from the 4.65 m. level to the 2.9 m. level where it rises sharply to almost 60% at the 2.65 m. level. There is a parallel increase in the relative amount of non-arboreal pollen,

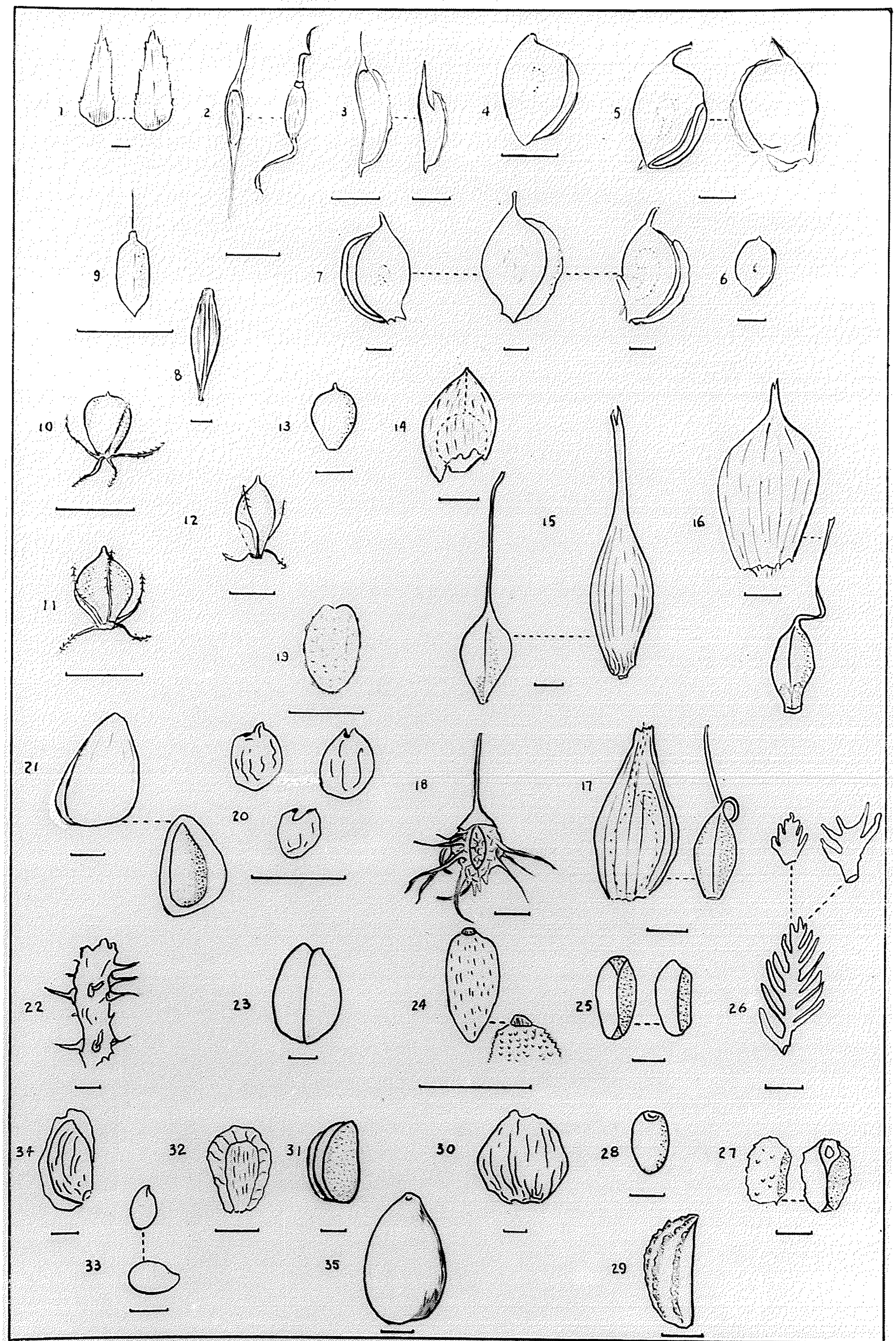


Figure 6. Characteristic macroscopic plant remains from the Hafichuk site.

⎯⎯ represents 1 mm.

Explanation to Figure 6

Fig. 1. Selaginella selaginoides, two leaves; 5.10-5 m.
Fig. 2. Typha sp., two fruits; 3.80-3.70 m.
Fig. 3. Zannichellia palustris, two fruits; 3-2.90 m.
Fig. 4. Potamogeton filiformis, a fruit-stone; 5.10-5 m.
Fig. 5. P. pectinatus, two fruit-stones; 3.10-3 m.
Fig. 6. P. gramineus ?, a fruit-stone; 3.10-3 m.
Fig. 7. P. obtusifolius, three fruit-stones; 4-.390 m.
Fig. 8. Triglochin maritima, a fruit; 4.20-4.10 m.
Fig. 9. Cyperus inflexus ?, a fruit; 3.40-3.30 m.
Fig. 10. Scirpus americanus, a fruit; 3.90-3.80 m.
Fig. 11. S. validus, a fruit; 3.70-3.60 m.
Fig. 12. S. acutus, a fruit; 3.70-3.60 m.
Fig. 13. Carex lenticularis ?, a fruit; 5.10-5 m.
Fig. 14. C. aquatilis, perigynia with achene; 3.70-3.60 m.
Fig. 15. C. atherodes, a fruit (3.70-3.60 m.) and perigynia; 3.60-3.50 m.
Fig. 16. C. rostrata, perigynia and fruit; 3.60-3.50 m.
Fig. 17. C. retrorsa, perigynia with achene and a fruit; 3.70-3.60 m.
Fig. 18. Rumex maritimus var. fueginus, a fruit; 3.80-3.70 m.
Fig. 19. Barbarea sp., a seed; 4.10-4 m.
Fig. 20. Subularia aquatica, three fruits; 3-2.90 m.
Fig. 21. Rosa blanda, a fruit-stone and interior of same; 3.10-3 m.
Fig. 22. Rubus sp., stem fragment; 5-4.90 m.
Fig. 23. Shepherdia canadensis, a fruit-stone; 3.70-3.60 m.
Fig. 24. Epilobium sp., a seed; 5-4.90 m.
Fig. 25. Myriophyllum exalbescens (M. spicatum Am. Auth.), two nutlets; 4.70-4.60 m.
Fig. 26. M. sp., leaf fragments; 5-4.90 m.
Fig. 27. M. spicatum f. muricatum, two nutlets; 4.10-4 m.
Fig. 28. Hippuris vulgaris, a nutlet; 3.70-3.60 m.
Fig. 29. Cicuta maculata, a fruit; 3.50-3.40 m.
Fig. 30. Cornus racemosa, a fruit-stone; 3-2.90 m.
Fig. 31. Arctostaphylos Uva-Ursi, a fruit-stone; 3.20-3.10 m.
Fig. 32. Lycopus americanus, a fruit; 3.40-3.30 m.
Fig. 33. Mentha arvensis, a fruit; 3.10-3 m.
Fig. 34. Rhinanthus borealis ?, a fruit; 3.10-3 m.
Fig. 35. Symphoricarpos albus, a fruit-stone; 3.40-3.30 m.

although *Artemisia* shows an irregular peak at 4 m. *Shepherdia canadensis* occurs consistently throughout the section, sometimes making up more than 10% of the pollen sum; since this plant is not a prolific pollen producer, this suggests that it was common in the terrestrial vegetation.

Combining the evidence from the macrofossils and the pollen diagram, two phenomena are conspicuous. The first is a clear trend, in both the pollen and macrofossil record, between the 5.1 level and 3.0 m. level, marked by the following apparent changes: (i) a steady increase in the numbers and diversity of macrofossils, with a conspicuous appearance of types indicating more temperate conditions; these are listed in Table VII and they tend to be confined to the 3.6 to 3.0 m. segment. (ii) a steady decline in the relative amount of *Picea* pollen and an equivalent rise in the proportions of non-arboreal types. (iii) the appearance in the pollen record of types which suggest an amelioration of climate, in particular, *Symphoricarpos occidentalis*, *S. albus* (also found as a macrofossil), Compositae-Tubuliflorae and Liguliflorae.

The second notable fact is the sharp reversion in the pollen diagram, marked by the spruce rise and non-arboreal decline from the 2.9 m. level. It was found at this level that the macrofossil flora declined sharply and the conditions of preservation deteriorated. Many fruits and seeds of *Potamogeton* were found at the 2.85 m. level, but their condition was so poor that they could not be identified to species.

The consistently low values of *Betula*, *Alnus* and *Corylus* pollen indicate that they were never significant components of the late-glacial vegetation at this site. The sporadic occurrence of pollen of *Ulmus*, *Juglans*, *Carya*, *Tsuga* and *Ephedra*, not unusual in Holocene deposits, has no significance for reconstructing the local vegetation and is probably the result of long-distance transport.

While the non-arboreal total proportion exceeds the arboreal between the 3.3 and 2.9 m. levels, this is not interpreted as reflecting directly a greater amount of treeless than forest vegetation. The macrofossil remains of *Populus*, the ecology of the assemblage of plants at these levels, and the notoriously unreliable nature of the *Populus* pollen record (poplar produces large amounts of pollen but is seldom recorded in recent sediments, because of poor preservation, cf. Ritchie and Lichti-Federovich, 1963) lead one to suggest that *Populus* probably was quite common at the time. Consequently the composite arboreal and non-arboreal curves, at least at the 3.3 to 2.9 m. levels, are somewhat misleading if interpreted directly.

Conclusions about past vegetation, on the basis of data from a single deposit, must be regarded as highly tentative, and the following suggestions might well require modification as further investigation proceeds.

It is suggested that the first vegetation recorded by the sediment, and of course this was not necessarily the first terrestrial vegetation following deglaciation, was made up chiefly of closed white spruce forests on the till soils of the moraine slopes and bottom-lands, with herbaceous pioneers, *Salix* and *Populus* communities forming successional stages, and with *Shepherdia canadensis* common in association with the spruce. The moderate proportions of non-arboreal herbs (20-30%) chiefly represented in the pollen diagram by *Artemisia*, probably reflect the prevalence of pioneer communities of vigorous herbs which were the initial colonisers of mineral substrata, and which might have persisted in very exposed or highly unstable situations. Such an assemblage of communities is found today in parts of boreal and subarctic Canada, as described for example from southwest Mackenzie District by Raup (1947) and for northern Manitoba by Ritchie (1960). No more than a general resemblance is suggested, for it is entirely possible that no vegetation entirely analagous with that of the late-glacial is extant. The chief tree, white spruce, has two important ecological attributes which lead one to such an interpretation. It is a vigorous pioneer tree, colonising recent mineral substrata (cf. Rowe, 1956) and it is relatively long-lived. Thus it is equipped to occupy freshly exposed terrain and to maintain itself.

Both the pollen diagram and macrofossil record suggest that such a forest vegetation prevailed at the Hafichuk site for almost 1000 years. It appears from the more limited information from the Herbert and Scrimbit sites (Kupsch, 1960 and Terasmae, personal communication) that approximately similar vegetation occurred. However, until more sites are examined in detail, it would be premature to draw general palaeoecological conclusions.

Regarding the 3.6 to 3.0 m. levels, it is suggested that a more mixed spruce-poplar forest prevailed, with representation of plants of more temperate affinity. Further the lake vegetation shows a change, indicating the development of marsh-type communities in shallow, hard waters. These changes suggest a gradual amelioration of the climate, perhaps corresponding in general terms with the differences between the climates of the northern, coniferous part of the present-day boreal forest in west-central Canada and the southern mixed-woods section. The high values of non-arboreal pollen, although almost certainly giving a partly spurious impression because of the erratic and low representation of poplar pollen in the spectra, might indicate persistent herbaceous communities on the most exposed upland sites.

The upper part of the pollen diagram suggests a reversion to less favourable climatic conditions, with increased spruce and decreased herb proportions, and such an interpretation can be reconciled fully with the glacial history (Christiansen, 1961) which envisages a re-advance of the ice sheets.

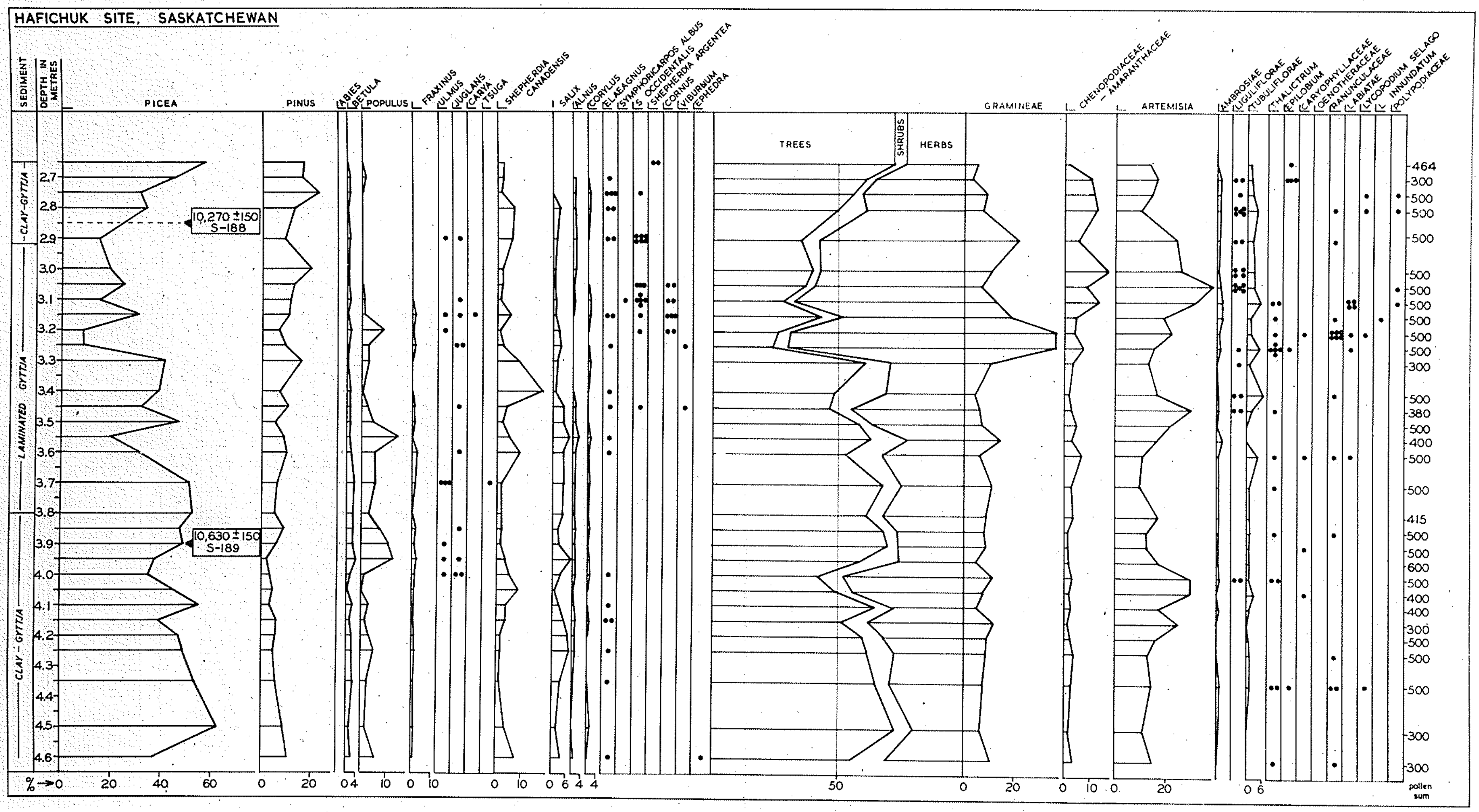



Figure 7. Pollen diagram of the Hafichuk Site.

It is suggested that this final deterioration in climate, correlative with the Condie re-advance, might have caused slumping of the upland mineral soil into the lake, by solifluction or some related soil-frost phenomenon, terminating the sedimentation process. However, a more certain explanation must await the outcome of intensive studies of the glacial geology and limnology of the site.

## VI. SUMMARY

1. A buried deposit of organic material was excavated on the Hafichuk ranch, Missouri Coteau, Saskatchewan. The material studied was buried under a deposit of unsorted, mineral substratum, apparently a calcareous glacial till. The limnic origin of the deposit and the excellent preservation of the more delicate plant and animal fossils suggest they have been retained _in situ_.

2. The site lies well within the Grasslands vegetation zone, occurring in the Mixed Prairie region. The landform is hummocky moraine, giving strongly rolling, blocked drainage terrain, with many knolls and kettles.

3. Age measurements on upper, middle and lower

samples of the section suggest deposition during an interstadial (11,700 to 10,300 approximately) and correlation with the findings of glacial geologists who have worked in the area suggests that the termination of sedimentation at the site coincided with the Condie ( = Valders) re-advance.

4. The plant macrofossils and pollen spectra of systematic samples of the deposit suggest the prevalence at the site of a white spruce forest with abundant *Shepherdia canadensis* and non-arboreal vegetation on exposed and unstable sites; willow and poplar probably formed seral stages of this forest. This vegetation persisted for the first 1000 years of sedimentation and was followed by a trend towards a more temperate, mixed deciduous-coniferous forest, indicated by terrestrial macroflossils of such plants as *Populus* (3 species) and an assemblage of aquatic and semi-aquatics indicative of temperate climate and hard water. At about 10,300 B.P. there is evidence that the original white spruce forest type of vegetation was restored and the remains indicating temperate conditions disappear.

5. While no information is available on the stage

immediately following deglaciation, the data suggests a cool moist climate with a pioneer white spruce forest, a gradual amelioration to a more temperate forest climate with a mixed forest and more grassland on exposed sites, culminating in a reversion to cool conditions before the Condie re-advance.

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# APPENDIX A

Remarks on certain late-glacial macroscopic plant remains recovered from the Hafichuk Site in regards to their specific morphology as a valuable aid in identification.

Selaginella selaginoides:- Both megaspores and microspore of this species can be found in late glacial deposits. While the latter can be readily identified in slides made up for pollen analysis, the former is readily recognizable among the smaller fruits and seeds by its characteristic pale yellow color and low tubercles on the commissural faces (Fig. 21). Leaves of this plant are recognized by the spinulose margin, with spaced placing of 1-3 spinules (Fig. 6, #1).

Picea spp.:- While macroscopic remains are numerous and widely varied, difficulty remains in the identification of the individual species. Cones (Fig. 13) are by far the most reliable macro-fossil in identification of species, by their distinct morphologic structure. Cone-scales, although often altered in appearance due to varied preservation, can also be of significant value. To a much lesser extent can the width of the lines of the stomata be used. White spruce has an equal width of these lines on each face of the needle, while Black spruce possesses broader lines on the upper face than on the lower face.

Juniperus communis (agg.):- Needles of this species are by far the most reliable source of positive identification. Their boat-shape keel with subulate and acute apex and broad stomatal band on the upper face (Fig. 26), makes them easily recognizable.

Potamogeton spp.:- The late-glacial deposits yielded mostly only the fruitstones of the drupaceous nutlets, the fleshy pericarpium having disappeared. The prerequisite for positive identification is to compare fully developed fossil material with full mature recent material, a not so easy task, and not always possible. Use has been made to some extent by following a key as given in Jessen's (1949, pp. 205-208). Close attention was paid to such critical diagnostic features as:- length and form of the dorsal lid, shape of embryo, placement of style, presence or absence of low spines or warts and appearance of dorsal and ventral margins.

Puccinellia tenuiflora:- The outstanding diagnostic feature of this species was the presence of a rusty-brown spot towards the apex of the more or less elongated seed body (Fig. 24), a feature consistently noticeable in the remaining species of this genus.

Scirpus spp.:- The recovered specimens as a rule were well preserved and in most instances the presence of barbed bristles together with the thick plano-convex body of the fruit made identification possible to the specific level.

Carex spp.:- In most cases a positive identification is possible only when the perigynia as well as the fruit within are present. In several instances this was the case (Fig. 6, #14, 15, 16 & 17). Carex aquatilis can be recognized by its flat achene and more or less blotched utricle. Carex rostrata is recognizable as such by its small trigonous achene with a curved stylar base and inflated ribbed utricle (Fig. 6, #14 and 16).

Lemna trisulca:- The outstanding diagnostic feature of this species is the asymmetrical oval to oblong leaves with three obscure veins and a long stipe. Specimens in the budding stage were often recovered (Fig. 17 and 18).

Populus spp.:- Several macroscopic remains were recovered including wood, buds, leaves and staminate cone-scales. Leaves of Populus tremuloides are recognized as such by the abruptly short acuminate apex, and strongly ascending basal-latero veins, giving the venation an apparently palmate appearance. Bracts of staminate catkins were readily distinguisable between Populus balsamifera and P. deltoides. Their deeply incised and copiously fimbriate lobes, showed marked differences as is clearly illustrated in Fig.19 and 20). The typical long and sharp pointed terminal buds, which were recovered from the organic sediments, were identified beyond doubt as P. balsamifera (Fig. 16).

Rumex maritimus var. fueginus:- The identity of this species was based on the extremely well preserved fruit, with its long pedicel and triangular ovate valves with 2-3 long divergent marginal bristles and narrowly triangular free tip (Fig. 6, #18).

Rubus idaeus:- Fruit-stones of this species were frequently recovered and identified as such by their deeply alveolate appearance and with the upper end often drawn out into a beak (Fig. 25). In many instances the fruit stones are semi-circular in form.

Myriophyllym exalbescens (M. spicatum Am. Auth.):- In the typical form the nutlets are smooth (Fig. 6, #25), while in forma muricatum the nutlets possess warts or low spines on back and edges (Fig. 6, #27). The possibility that the smooth nutlets might belong to M. verticillatum exists, but recovered leaf segments suggest in most instances M. exalbescens rather than M. verticillatum.

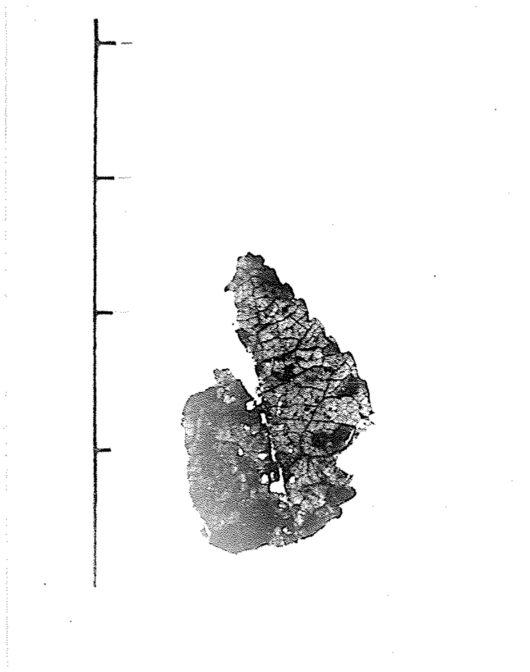

Figure 8. Populus deltoides.
A leaf x 2

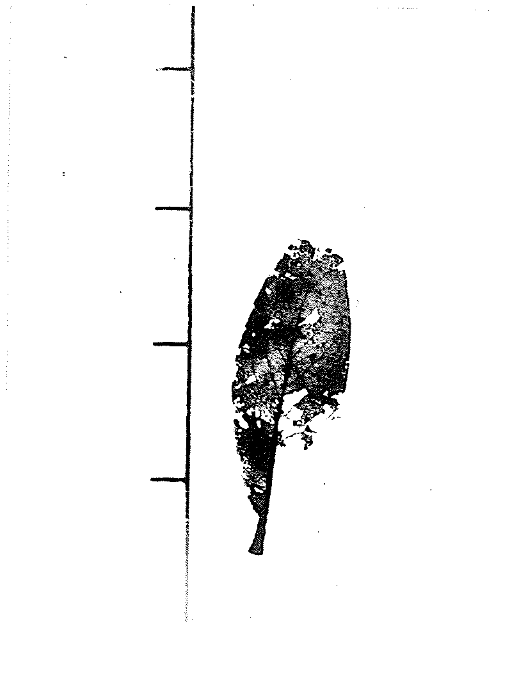

Figure 9. Salix species.
A leaf x 2

Figure 10. Aralia nudicaulis.
A leaf x 2

Figure 11. Picea species x 2.
Branchlet with
needles.

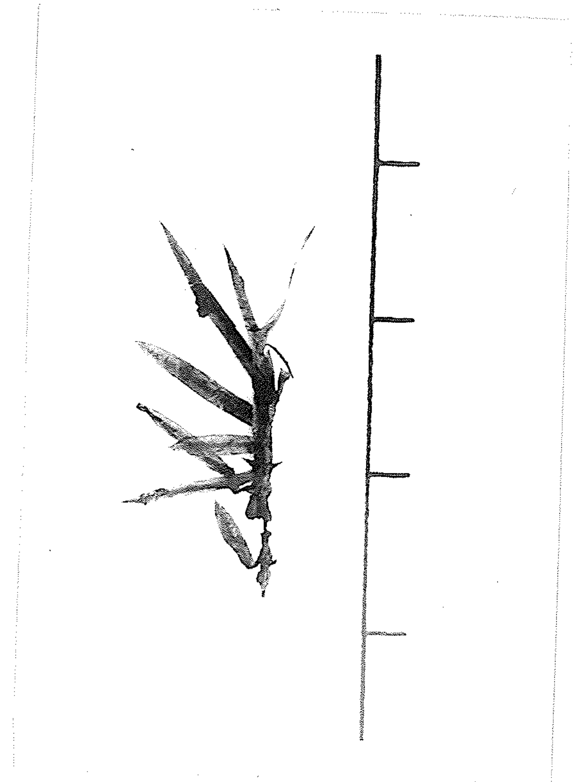

Figure 12. Juniperus communis x 2.
Branchlet with needles.

Figure 13. Picea glauca x 2.
Cone.

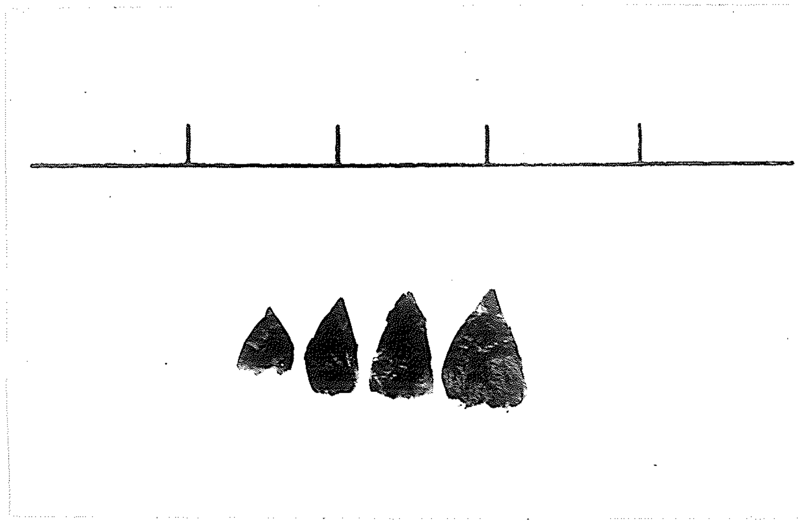

Figure 14. Populus tremuloides.
Winter buds x 2.

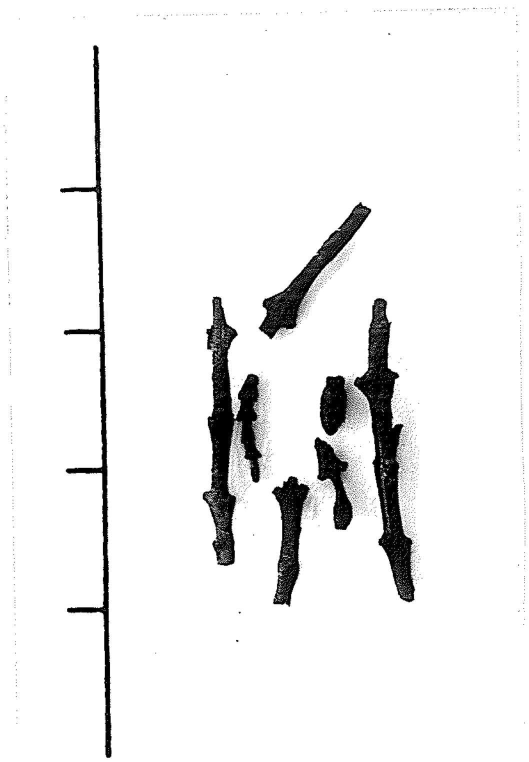

Figure 15. Shepherdia canadensis.
Leaf and twigs x 2.

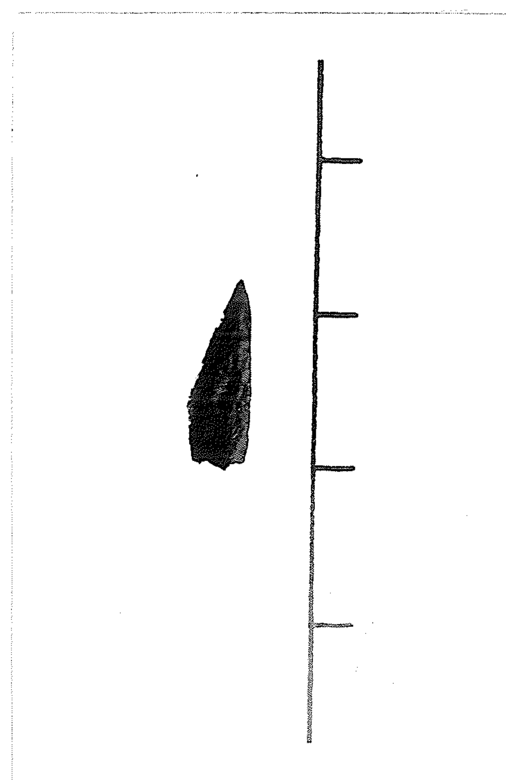

Figure 16. Populus balsamifera.
Terminal winter
bud x 2.

Figure 17. Lemna trisulca.
Budding leaf x 26.

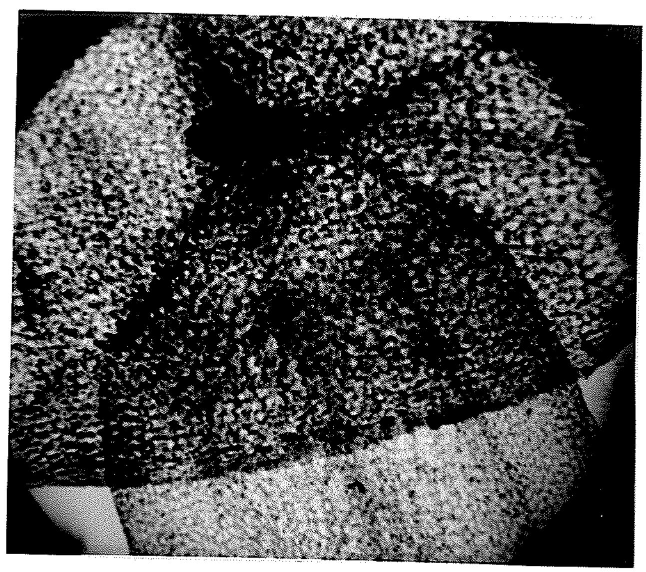

Figure 18. Lemna trisulca.
Leaf with obscure
veins x 26.

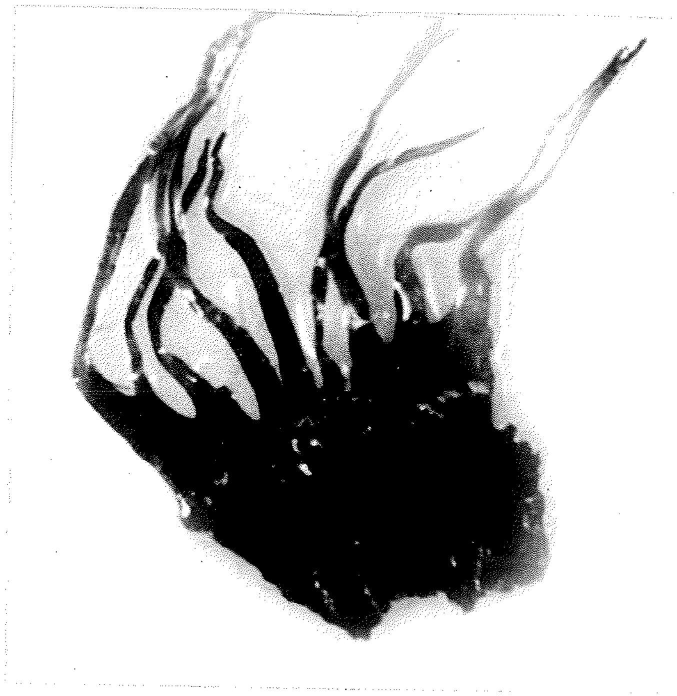

Figure 19. Populus balsamifera.
Bract of staminate ament x 26.

Figure 20. Populus deltoides.
Bract of staminate ament x 26.

Figure 21. *Selaginella selaginoides*. Megaspores with characteristic tubercles on commissural faces x 26.

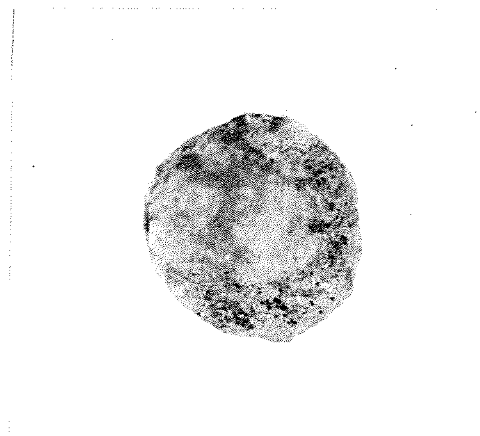

Figure 22. *Ranunculus sceleratus*. Achene x 26.

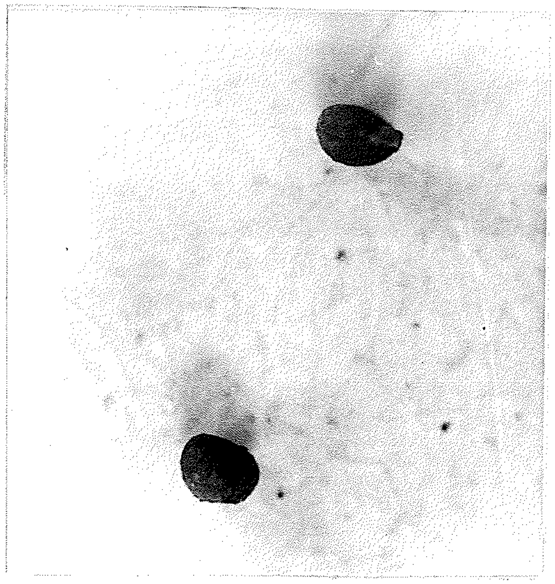

Figure 23. Selaginella rupestris. Megaspores x 26.

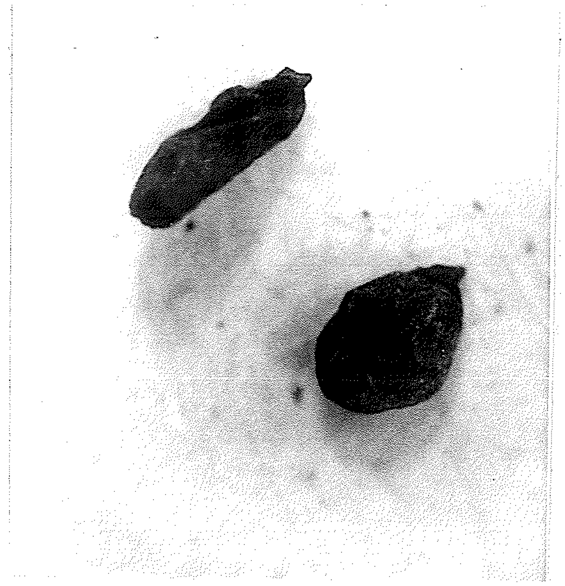

Figure 24. Puccinellia tenuiflora. Seeds x 26.

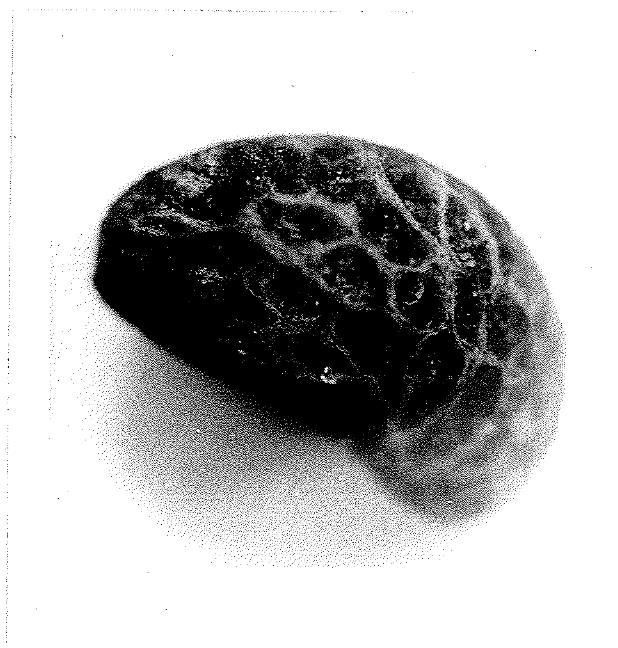

Figure 25. Rubus idaeus. Carpel x 26.

Figure 26. Juniperus communis. Leaf fragment with characteristic broad stomatal band x 26.

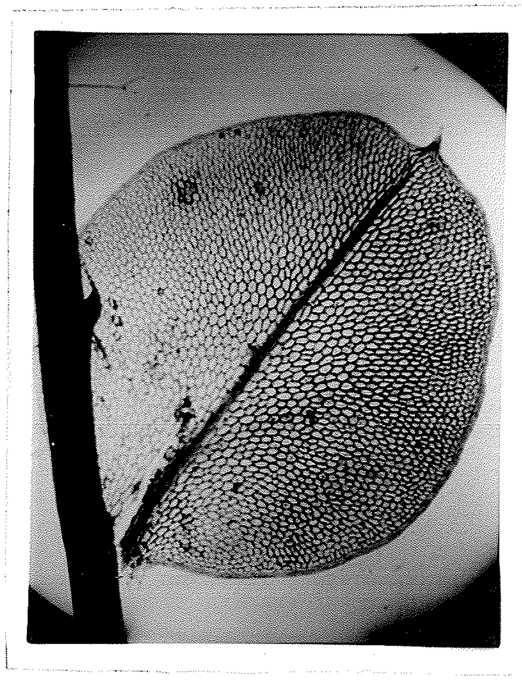

Figure 27. Mnium species. A leaf x 26.

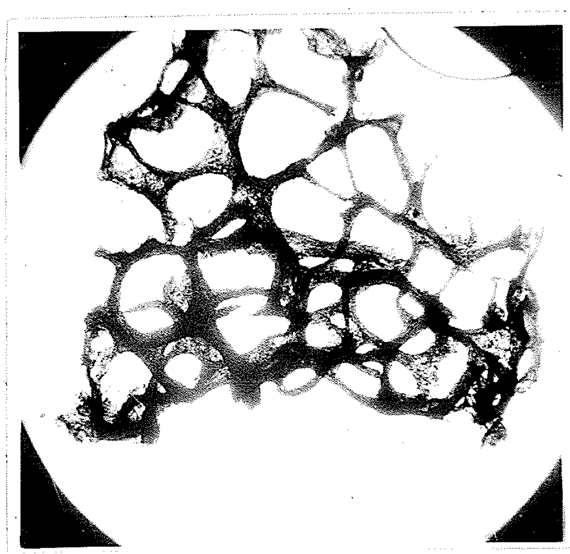

Figure 28. Hydrodictyon species. Net-like structure x 26.

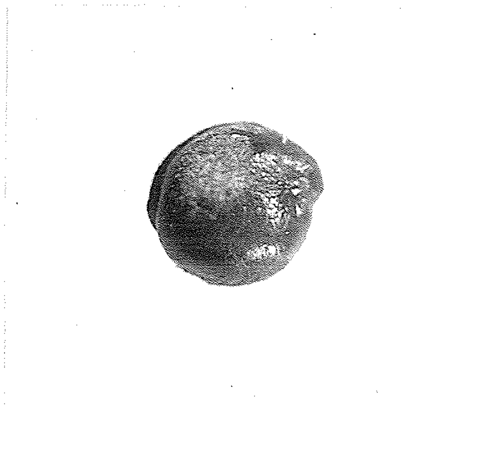

Figure 29. Chenopodium album. Seed x 26.

Figure 30. Potentilla gracilis var. pulcherrima. Achene x 26.

Figure 31. Chenopodium capitatum. Seed x 26.

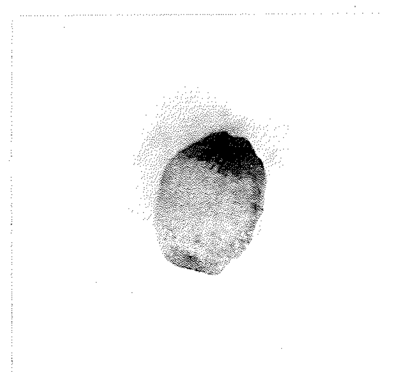

Figure 32. Juncus species. Fruit x 26.

# APPENDIX B

As was pointed out earlier in this Thesis, several other sites were studied in the Missouri Coteau, in order to locate a suitable site for a major excavation. In addition a series of test-drillings was started, in order to obtain samples, and ascertain their organic contents. Upon this evidence, the possibility of a major excavation would be based. A listing and description of these sites is given in this section.

A more or less superfluous description of present-day vegetation and local topography of the immediate precincts of these sites is given in the form of a simplified profile diagram, showing the local topography and related plant community types of the Wrusu and Paranuik sites (Fig. 33 and 34).

For convenience, the vegetation of the immediate precincts of the sites, is grouped into several types, and their spatial relations are illustrated by the sketch in Fig. 33 and 34 .

The species are listed in approximate order of abundance, following the system of Scoggan (l. cit. 1957).

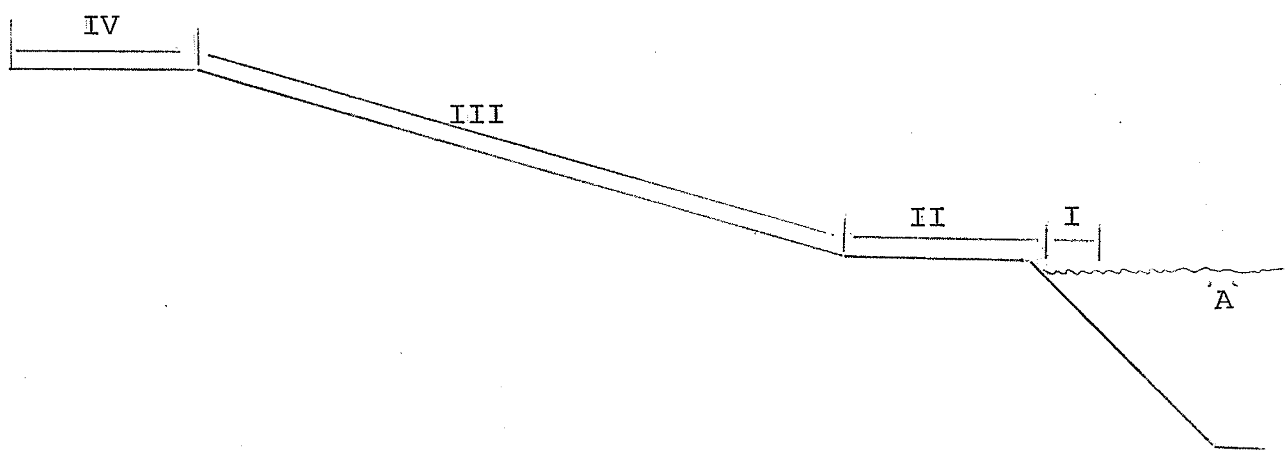


Fig. 33. A simplified profile diagram showing the local topography and related plant community types of the Wrusu site. The numbered vegetation zones are referred to in the text. 'A' marks the approximate location of the excavation on the rim of a kettle. Approximate scale, 1 cm = 5 m.

Community I, occupying the shore of the site and mainly composed of *Typha latifolia*.

Community II, occupying the marginal zone of the site, was composed of the following species:- *Beckmannia syzigachne*, *Calamagrostis inexpansa*, *Carex* spp., *Potentilla anserina*, *Ranunculus cymbalaria*, *Rumex mexicanus* and *Mentha arvensis*.

Community III, occupying the gentle slopes near the site, was composed of the following species:- Stipa spartea var. curtiseta, Stipa comata, Agropyron smithii, Bouteloua gracilis, Erigeron asper and Potentilla pennsylvanica var. arida.

Community IV, occupying the upland, was composed of the following species:- Stipa comata, Artemesia frigida, Carex eleocharis, Bouteloua gracilis, Anemone patens var. wolfgangiana, and Aster ericoides.

Listing and description of sites

The Wrusu site is located in the north west quarter of section 11, range 24, township 9, west of second Meridian, at an approximate distance of 1.5 KM west from the village of Kayville, in the eastern section of the Missouri Coteau. The site occupies the west shore of a large kettle and is now a 'dugout'.

A total of five sites were drilled by commercial auger in the immediate vicinity of this site in an effort to locate a suitable location for an extensive investigation.

W.I:- East of Wrusu site at an approximate distance of 15 m. General samples were taken from this site and examined. The stratigraphy of these samples was: 205 cm dark brown soil grading into sandy clay, 205-280 cm sand and gravel, 280-+ cm light gray clay, extensive water seepage. Further sampling was not possible because samples became very watery.

W.II:- South of Wrusu site, at approximate 15 m. General samples were obtained and examined. The stratigraphy of these samples was: 240 cm dark soil grading into sandy clay, 240-285 cm light gray clay with several fragments of charcoal and some water-worn small stones, 285-400 cm blue gray clay of great plasticity. Further sampling was not possible.

W.III:- South-west of Wrusu site, at an approximate distance of 7.5 m. The depth of this site was approximately 450 cm and the stratigraphic sequence is as follows: 100 cm dark soil grading into clayey loam with limestone fragments, 100-205 cm dark gray clay with an admixture of fine sand. A few small stones and some greenish colorations noted in this zone, 205-300 cm sandy clay, water table reached, 300-350 cm gritty, dark gray clay, 350-380 cm dark gray clay gyttja, faintly laminated, fragments of wood, charcoal and mosses, 380-390 cm well laminated clay gyttja, recovered organic material included well preserved fragments of moss spp., needles of *Picea* spp., and fruitstones of *Potamogeton* spp. Shells were quite numerous and intact, 390-445 cm non-laminated sandy gyttja, with traces of organic residue, some small unbroken shells and wood fragments. A few small angular stones noted, 445-450 cm heavy textured, dark gray clay, with numerous small stones. Texture of clay prohibited further sampling.

W.IV:- West of Wrusu site at an approximate distance of 5 m. Stratigraphic sequence of several general samples from this site is: 230 cm dark brown soil grading into light gray clay, with limestone fragments, 230-300 cm sandy clay, water table reached, 300-335 cm gritty, dark gray clay, 335-355 cm faintly laminated clay gyttja with traces of organic residue, 355-420 cm non-laminated clay gyttja with an admixture of fine sand, poor in organic residue, 420-+ plastic, dark gray clay, which prohibited further sampling.

W.V:- South of Wrusu site at an approximate distance of 396 m. and approximately 4.5 m. from the north shore of a large inundated kettle. General samples taken from this site revealed the following stratigraphic sequence: 210 cm dark brown soil, clayey loam grading into light gray clay, 210-300 cm gray clay with an admixture of fine sand, water table reached, 300-480 cm plastic, blue gray clay, with some large shells. Further sampling was not possible due to great plasticity of clay.

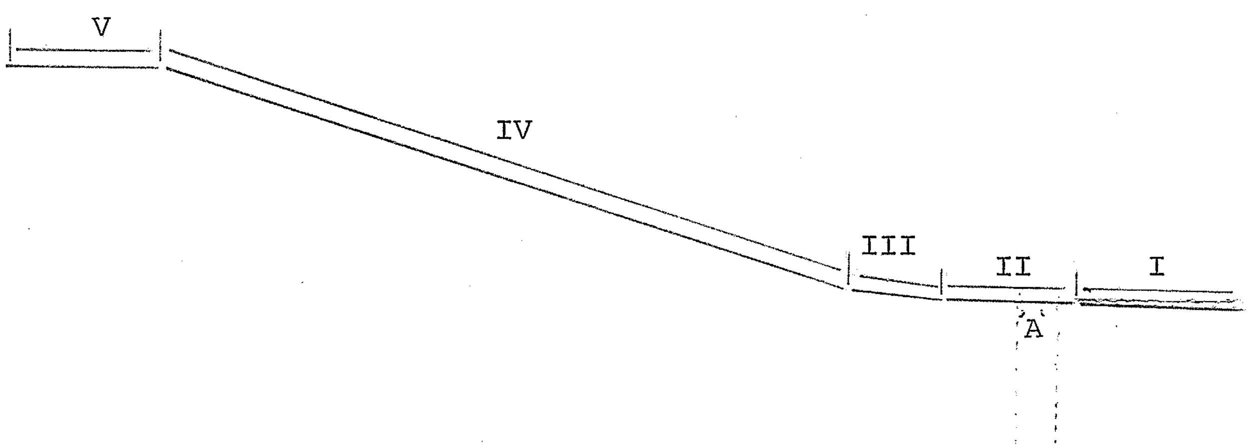


Fig. 34. A simplified profile diagram showing the local topography and related plant community types of the Paranuik site. The numbered vegetation zones are referred to in the text. 'A' marks the approximate location of the site. Approximate scale, 1 cm = 5 m.

Community I, occupying the inundated part of the kettle, was composed of the following species: Alopecurus aequalis, Carex spp., Juncus longistylis and Mentha arvensis.

Community II, occupying the outer rim of the kettle, was composed of: _Penstemon procerus_, _Beckmannia syzigachne_, _Alopecurus aequalis_, _Eleocharis palustris_, _Rumex_ spp. and _Sisyrinchium angustifolium_.

Community III, occupying the base of the gentle slope consisted of: _Symphoricarpos occidentalis_, _Rosa_ spp., _Elaeagnus commutata_, _Amelanchier alnifolia_, _Aster laevis_ and _Zizea aptera_.

Community IV, occupying the gentle slope, was composed of the following species: _Agropyron smithii_, _Bouteloua gracilis_, _Erigeron asper_, _Phlox hoodii_ and _Psoralea argophylla_.

Community V, occupying the upland, was composed of: _Stipa comata_, _Agropyron smithii_, _Carex filifolia_, _Cerastium arvense_ and _Comandra pallida_.

The Paranuik site is located at the south shore of a small inundated kettle in the south-west quarter of section 33, range 23, township 10, west of second Meridian, is approximately 19 KM north-east from Kayville and in the eastern section of the Missouri Coteau.

A total of six sites were augered in the vicinity of the site in an effort to locate a gyttja deposit suitable for further intensive exploration.

P.I:- North-east of Paranuik site, at an approximate distance of 15 m. and at the rim of the kettle. General samples taken from this site revealed the following stratigraphic sequence: 215 cm dark brown soil grading into clayey-loam with traces of sand, small shells and limestone fragments, water seepage, 215-280 cm light gray clay with small water-worn stones and traces of sand, 280-385 cm trace of clay gyttja, stiff dark gray clay, 385-425 cm hard, dark gray clay, which made further sampling impossible.

P.II:- South-east of Paranuik site at a distance of approximately 15 m. and at the rim of the kettle. Several samples gave the following stratigraphy: 215 cm dark brown soil grading into clayey loam with traces of sand and gravel. Water seepage, 215-320 cm clay with an admixture of sand and gravel, 320-415 cm trace of dark gray clay gyttja, dark gray stiff clay. Large water-worn stone. Further sampling was not possible due to a coarse gravel zone.

P.III:- South-east of Paranuik site at an approximate distance of 7.5 m. and at the rim of the kettle. The stratigraphic sequence as shown by general samples is as follows: 195 cm dark brown soil grading into light gray clay with an admixture of sand and fine gravel, 195-280 cm sandy clay with numerous charcoal fragments, 280-400 cm non-laminated clay gyttja with stiff dark gray clay, trace of organic residue, 400-495 cm stiff dark gray clay with coarse gravel. Further sampling was not possible.

P.IV and P.V:- South-west of Paranuik site at a distance of approximately 7.5 m. and at the rim of the kettle. These two sites were about 3 m. apart from each other and showed a resemblance in stratigraphy. General samples gave the following stratigraphic sequence:- 50 cm dark brown soil grading into clayey loam, 50-140 cm light gray clay with an admixture of fine sand and gravel, 140-175 cm much coarser gravel and wet sand. Further sampling was not possible.

P.VI:- North-west of Paranuik site at an approximate distance of 24 m. and at the rim of the kettle. Several general samples gave the following stratigraphy: 200 cm dark brown soil grading into clayey loam with traces of sand and fragments of limestone, 200-260 cm water seepage, light gray clay with an admixture of sand and some gravel, 260-380 cm hard dark gray clay which made sampling impossible beyond this level.