Distribution of prairies and solonetzic soils in the Peace River district, Alberta

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A study of 13 native prairie remnants in the Peace River district of Alberta revealed two community types: a Stipa spartea var. curtiseta – Carex spp. – Artemisia frigida community found on steep, south-facing slopes and a more widespread Carex spp. – Danthonia intermedia – Stipa spartea var. curtiseta community situated on solonetzic-order soils. By using early land survey records and recent soil survey data, a close correlation was found between the large tracts of prairie vegetation and the distribution of solonetzic soils. The solonetzic soils appear to support grasslands and not forests because of their unfavorable ratios of Na to Ca, hard, columnar B-horizon, and relatively impermeable clay pan close to the surface.

Study-area description

The Peace River district of Alberta is located approximately 800 km northwest of Edmonton in the southern boreal forest. It remains as one of Canada’s last frontiers and land is still being homesteaded in the region today. At the time of European settlement three large prairies existed in the district: one located on the north bank of the Peace River; one around the town of Spirit River; and one north of the city of Grande Prairie. These luxuriant prairies were dominated by Stipa spp., Carex spp., and Agropyron spp. The remainder of the region was either wooded by Populus tremuloides and Picea glauca or consisted of open peatlands. Agricultural activities and more recently oil and gas exploration have greatly modified the original vegetation cover with the result that few native prairies remain.

Over the years botanists and ecologists (Moss 1952, 1955; Raup 1934, 1935, 1941) have noted the correlation of the native prairies to the dark-colored soils of this region and the forests to the light-colored soils. It was not until 1950 that these dark soils were identified as belonging to the solonetzic order (Odynsky and Newton 1950). This belated recognition of the solonetzic soils and their distinctive characteristics seems to be one of the reasons the edaphic explanation for the existence of these prairies has not been more seriously considered by plant ecologists (North 1976).

Solonetzic soils develop where parent materials are high in sodium salts or in areas of saline groundwater discharge and poor internal drainage. Leaching of the salts causes deflocculation of the sodium-saturated colloids which are carried downward and deposited in the B-horizon. This results in a columnar or prismatic structured B-horizon which is extremely hard when dry and very plastic when wet. The salinity and the relatively impermeable clay pan close to the surface, which limits aeration and water and root penetration, make these soils unfavorable for good tree growth (Fowells 1965; Graham et al. 1963; Maini 1960; Stoekeler 1948).

In this paper, we present further evidence to support the position of Moss and Raup that the distribution of these native prairies in the Peace River district is related to the distribution of dark-coloured (solonetzic) soils. We do this by comparing native prairie distributions as they were at the time of European settlement to contemporary soil surveys of the distribution of solonetzic soils. As remnant prairies were not plentiful enough to be useful in reconstructing prairie distributions, we have used the vegetation information in the land survey records made at the time of European homesteading.
sandstones, shales, and siltstones of Cretaceous age. Surficial deposits of till, fluvial sands, and gravels and lacustrine silts and clays cover most of the bedrock with thicknesses ranging from a few centimetres to several hundred metres (Jones 1966). The most commonly occurring soils are luvisols, found under forest vegetation or in forest–grassland transition zones, and solonetzic soils, which usually occur in areas of prairie vegetation and agricultural development. Brunisols, podzols, chernozems, gleysols, regrads, and organic soils occur less frequently (Odynsky and Newton 1950; Odynsky et al. 1956, 1961; Reeder and Odynsky 1965; Scheelar and Odynsky 1968).

The climate of the Peace River area is continental, characterized by short, warm summers and long, cold winters. The mean annual precipitation is 350 mm at Peace River and 440 mm at Grande Prairie (Atmospheric Environment Service 1973). The high latitude (55°–57°N) results in 15–18 h of daylight from May to August, and the region has roughly the same number of degree-days above 5.6°C (1800–2100) as Calgary (Government of Alberta and University of Alberta 1959). Compared with the more southern Canadian prairies the Peace River region has higher precipitation, less wind, and lower evaporation, resulting in a lower moisture deficit (Harris 1975).

The vegetation of the study area can be divided into four broad native vegetation types: upland forest, parkland (including the prairie), lowland forest, and meadow. The most common tree of the forested mixed wood upland is *Populus tremuloides*, with lesser amounts of *Picea glauca*, *Populus balsamifera*, *Pinus banksiana* (in the eastern portions), and *P. contorta* (in the west and south).

The parkland, most of which is now in agricultural production, supported at the time of settlement a native vegetation of predominantly grasses (*Agropyron spp.*, *Siga spp.*, *Poa spp.*, *Carex spp.*, and forbs, dotted with groves of *Populus tremuloides* and occasional *Picea glauca* (Horetzky 1874; Dawson 1879 as quoted in Macoun 1904; Kelly 1910; Kitto 1928; Wright 1930). At the present time the parkland appears as a mosaic of cultivated and pasture land interspersed with stands of *Populus tremuloides*. The poorly drained lowland forests consist primarily of *Picea mariana* and *Larix laricina*, whereas lowland meadows support large populations of *Calamagrostis canadensis* and *C. expansa*, *Carex rostrata*, and *C. lasiocarpa var. latifolia*.

**Methods**

It was initially hoped that remnants of the original native prairies could be discovered and their locations used to trace the distribution of prairies before European settlement. However, after extensive searches only 13 suitable prairie remnant sites were found from topographic maps, aerial photographs, and interviews with government personnel, local residents, and landowners. Many of the normal refuges of small remnant prairies such as fence lines, cemeteries, and road and rail right-of-ways were not suitable for analysis. This is probably due to the small areas of original prairies and their intense agricultural utilization since settlement.

The 13 remnants located were at least 0.5 ha in size, dominated by native grasses and with no previous cultivation or evidence of heavy grazing. Each of the sites was sampled by 20 × 50 cm microplots placed at 2 m intervals along parallel transects, the number (27–80) depending on the size of the site. Percent cover was visually estimated for all vascular plants in a microplot, using the scale of Daubenmire (1959). The sites were then arranged according to their compositional similarity, using a technique of tabular comparison (cf. Mueller-Dombois and Ellenberg 1974).

Although the prairie remnants provided species composition information (Table 1), it was impossible to use these very few, small, scattered areas to assess accurately the correlation between the prairies and the distribution of solonetzic soil. Therefore the extent of the prairies at the time of early settlement was determined using the written descriptions of the Department of the Interior Land Survey published in 1916 (3rd edition) supplemented by the descriptions contained in historical accounts (Bezanson 1907; Dawson and Murchie 1934; Kelly 1910; Kitto 1928; MacGregor 1952; Macoun 1882; Macoun 1904; Mair 1908).

The objective of the land survey was “to place in the hands of prospective settlers reliable up-to-date information, which will enable them to form a correct idea of the country in which they wish to take up land, and the easiest and most economical method of reaching it” (Department of the Interior 1916). The 1916 survey consists of the compilation of individual surveys done by different surveyors between 1902 and 1916. The survey included brief written descriptions of the vegetation, soil, topography, and capacity for agricultural development taken from the field notes of surveyors who laid out township and section lines (Fig. 1). For each surveyed township there is an accompanying plan (Fig. 2) compiled by the Department of the Interior based on the surveyor’s field notes (Department of the Interior 1913).

The surveyors’ descriptions of the prairie areas are very general and contain such phrases as “considerable prairie,” “prairie openings,” “prairie with scattered poplar and willow bluffs.” However, the intention of this study requires only very general physiognomic separation of the vegetation for a map of scale 1 cm to 10 km. Within these constraints the land survey is adequate (see Archibold and Wilson 1980 for a similar approach). Figure 3 gives the distribution of prairies as determined from the land survey. The vegetation has been subdivided into three classes: (i) prairie with poplar and (or) willow bluffs; (ii) lightly wooded with prairie openings; and (iii) wooded or “muskeg” (peatland).

The distribution of the prairies was then compared with the occurrence of solonetzic soils (Fig. 3) as described in the soil surveys by Odynsky and Newton (1950), Odynsky et al. (1956, 1961), Reeder and Odynsky (1965), and Scheelar and Odynsky (1968). The areas we have outlined as solonetzic soils in Fig. 3 are composed of predominantly solonetz, solodized solonetz, or black solod soil series. Areas of solodic dark grey or solodic grey wooded soils have not been included unless they occurred as part of a complex with more strongly solonetzic soil series. Small pockets (less than half a township) of solonetzic soil types have also been omitted.

**Results**

**Prairie remnant sampling**

Table 1 gives for the 13 prairie remnant sites the average percent cover for the vascular plant species,
selected environmental information, and the number of microplots. The two community types (Table 1) reflect differences in topographical and edaphic conditions. The *Stipa spartea* var. *curtiseta*—*Carex* spp.—*Artemisia frigida* community type occurs on steep, south-facing slopes having well-drained, well-aerated brunisolic soils underlain by colluvium at Heart River and till at the other three sites. These slope sites are relatively homogenous in composition with 9–13 species (possessing cover greater than 1%) per site. *Stipa spartea* var. *curtiseta* and *Carex heliophila* are dominant. *Koeleria cristata*, *Stipa viridula*, and *Artemisia frigida* are common throughout the stands. Species of lesser importance include *Agropyron dasystachyum*, *Astragalus striatus*, *Vicia sparsifolia*, *Anemone patens*, *Sphaeralcea coccinea*, *Linum lewisii*, *Allium cernuum*, *Erigeron caespitosus*, and *Rosa* spp. *Opuntia fragilis* was frequent at the airport site, but its pads were brown and shrivelled and no flowering was observed in 1978 or 1979.

The *Carex* spp. — *Danthonia intermedia* — *Stipa spartea* var. *curtiseta* community type occurs on level to slightly undulating sites which have imperfectly drained and aerated solonetzic-order soils (except at Umbach). Although most sites in this community type would be expected to have temporary periods of poor drainage as a result of the solonetzic nature of the soil, only the Kleskun Hills East site showed evidence of gleying in the B-horizon. The vegetation of this community type has higher average cover with 18–25 species (with more than 1% cover per site) and more variability of composition than the slope sites. The dominant species are *Carex foenea*, *C. obtusata*, *C. xerantica*, *C. eleocharis*, *Danthonia intermedia*, and *Stipa spartea* var. *curtiseta*. Most carices seen were in a vegetative state, which often made identification to species impossible. *Koeleria cristata* is frequent here but had lower cover than in the previous community type. *Agropyron subsecundum*, *Poa interior*, and *P. pratensis* are quite common and *Helictotrichon hookeri* is occasional at each site. Abundant herbs include *Gailium boreale*, *Achillea millefolium*, *Erigeron glabellus*, *Geum triflorum*, *Aster ciliolatus*, and *Solidago* spp. Locally abundant species are *Agrostis scabra* at Cochrane, Klimack, and Kleskun Hills West and *Calamagrostis inexpecta* at Kleskun Hills East and Dimsdale.

**Land survey**

Using the land survey (1916) and early explorers' accounts, there appear to have been three major presettlement prairies.

**The Peace River prairie**

Located north of the Peace River, this prairie extended for approximately 80–100 km east to west from the town of Peace River to Dunvegan and for 16–48 km north from the banks of the Peace River (Kitto 1928; MacGregor 1952). The banks of the Peace River appear to have formed the south, east, and west boundaries of the prairie, while the Whitemud Hills limit its extent in the north. Macoun (1904) and Mair (1908) estimated this prairie to have covered approximately 1600–2000 km². The vegetation was described as a vast rolling park country, 75% prairie and the remainder scrub bluffs consisting of small poplar and a few spruce, while the soil was described as a blue clay with a top soil of sandy loam to rich black loam (Department of the Interior 1916; Kelly 1910). The most recent soil surveys indicate that the soil of these prairies varies from solonet to solod and is primarily developed on weakly saline, lacustrine to lacustrine-till parent material (Scheelar and Odynsky 1968).

**The Spirit River prairie**

This smaller prairie was centred around the town of Spirit River, beginning about 8 km south of Dunvegan beyond the hilly, wooded south banks of the Peace River and extending southward for approximately 3 km (Kelly 1910) to the Saddle Hills (Dawson and Murchie 1934). It appears to have been bordered on the east by the Burnt River and on the west by smaller tributaries of the Peace River. The size of the Spirit River prairie was estimated at 1500 km² by Bezanson (1907) and 2300 km² by Kelly (1910). This land was described as approximately 80% prairie with the remainder scrub and was located on sandy loam to black loam (Department of the Interior 1916; Mair 1908). The prairie occurs primarily on solods and solodized solonetzic soils developed on till and lacustrine parent materials as described in contemporary soil surveys (Odynsky and Newton 1950).

**The Grande Prairie**

The largest of the three major Peace River prairies, the Grande Prairie extended from approximately the centre of township 74 just south of the Saddle Hills to about 13 km north of the Wapiti River and from about 24 km east of Bear Lake approximately to the Beaverlodge River (Department of the Interior 1916). It has been estimated at 9300 km² by Bezanson (1907) and as occupying approximately 24 townships of mainly open land (Wright 1930). About 85% of this prairie was open and the rest scrub (Department of the Interior 1916). As with the other prairies, growth of grasses and forbs was luxuriant (Bezanson 1954) and the rolling prairie was interspersed with "bluffs" of poplar and willows (Kelly 1910; Macoun 1904). On the eastern and western boundaries trees became gradually dominant. The soil, described by the land surveyors as sandy to black loam (Department of the Interior 1916), is recorded by Odynsky et al. (1956) as mainly of the solonetzic order, developed on slightly saline lacustrine-till and lacustrine parent material. The Kleskun Hills region is situated on primarily
### Table 1. Average percent cover for species* in 13 remnant prairies

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Misery Mountain</th>
<th>Heart River</th>
<th>Dunevegan</th>
<th>Airport</th>
<th>Umbrach</th>
<th>Sankaton Island</th>
<th>Cochrane</th>
<th>Klinak</th>
<th>Kleskun Hills West</th>
<th>Kleskun Hills East</th>
<th>Linden South</th>
<th>Linden North</th>
<th>Dimsdale</th>
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<tr>
<td>Aspect</td>
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<td>190° SSW</td>
<td>162° SSE</td>
<td>121° SE</td>
<td>16°</td>
<td>22°</td>
<td>22°</td>
<td>25°</td>
<td>16°</td>
<td>22°</td>
<td>22°</td>
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**Soil type**
- Brunisol
- Brunisol
- Brunisol
- Brunisol
- Chernozem
- Solod
- Solodized solumetz
- Solodized solumetz
- Solodized solumetz
- Solodized solumetz
- Solodized solumetz
- Solodized solumetz
- Solodized solumetz
- Solodized solumetz
- Solodized solumetz
- Solod

**Wide tolerance species**
- *Carex spp.*
- *Stipa spartea var. curtisea*
- *Koeleria cristata*
- *Rosa spp.*
- *Agropyron dasystachyum*
- *Stipa columbiana/viridula*
- *Symphoricarpus occidentalis*
- *Anemone spp.*
- *Astragalus spp.*

**Species used to differentiate community types (presence 15–77%)**
- *Artemisia frigida*
- *Vicia sparsifolia*
- *Sphaeralcea coccinea*
- *Linum lewisii*
- *Allium cernuum*
- *Erigeron canadensis*
- *Galium boreale*
- *Achillea millefolium*
- *Erigeron glabellus*
- *Geum triflorum*
- *Agropyron subsecundum*
- *Dianthus intermedia*
- *Agrostis scabra*
- *Aster ciliolatus*
- *Poa spp.*
- *Solidago spp.*

*CAN. J. BOT. VOL. 61, 1983*
<table>
<thead>
<tr>
<th>Species</th>
<th>Misery Mountain†</th>
<th>Heart River</th>
<th>Dunvegan</th>
<th>Airport</th>
<th>Umbach</th>
<th>Saskatoon Island</th>
<th>Cochrane</th>
<th>Klimack</th>
<th>Kleskun Hills West</th>
<th>Kleskun Hills East</th>
<th>Linden South</th>
<th>Linden North</th>
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*Species with an average cover of less than 1% omitted.*

†Exact location: Misery Mountain, NW 30-83-21-W5; Heart River, NE 29-83-21-W5; Dunvegan, SE 20-80-5-W6; Airport, SE 17-83-22-W5; Umbach, lot 34, Shastebury settlement; Saskatoon Island, SE 1-72-8-W6; Cochrane, SW 13-72-S-W6; Klimack, NE 23-72-4-W6; Kleskun Hills, SW 26-72-4-W6; Linden, SE 1-72-8-W6; Dimsdale, SW 16-71-7-W6.
and alluvial material. Approaching the Beaverlodge
responding to the occurrence of till and aeolian,
northern, eastern, and southern boundaries roughly cor-
to distribution of lacustrine surficial deposits, with the

The extent of the Grande Prairie corresponds closely
to solonetzic soil distribution. However, this
correlation between the occurrence of “prairies” on the
and Davis (1971) studied the Black Belt prairies
west-central Alabama where prairies and savannas
exist in a region which is predominantly forested with
Quercus, Carya, and Pinus. Using the land survey
records for 1832 and 1845–1846 they found a good
correlation between the occurrence of “prairies” on the
survey maps and the distribution of upland, alkaline clay
soils. Forests were primarily confined to lowland and
acid soils as determined from contemporary (1957) soil
maps.

A comparable situation exists in southern Illinois
(Fehrenbacher et al. 1963). Here solonetzic soils occupy
irregular patches of up to 40 ha, associated with loess
deposits high in sodium. The complicated distribution of
the solonetzic soils, reminiscent of patterns in parts of
the Peace River district (see Toogood and Cairns 1978),
created a complicated pattern of natural vegetation.
However, from Vestal’s studies of presettlement vegeta-
tion (1934) Fehrenbacher et al. (1963) believe the
solonetzic soils were occupied by prairie vegetation and
not forest.

The specific effects of solonetzic soils on vegetation

solkometz to solodized solonetz soil derived from some-
what modified, saline, sandy shales.

The extent of the Grande Prairie corresponds closely
to distribution of lacustrine surficial deposits, with the
northern, eastern, and southern boundaries roughly cor-
responding to the occurrence of till and aeolian, outwash
and alluvial material. Approaching the Beaverlodge
River, the deposits remain primarily lacustrine, but the
soil is better drained (Odynsky et al. 1961) and trees
were more prevalent.

Discussion

The Stipa spartea var. curtiseta—Carex spp.—Arte-
misia frigida community type appears to be a result of the
hot, dry microclimate produced on the steep,
south-facing slopes. In contrast, the Carex spp.—Dan-
thonia intermedia—Stipa spartea var. curtiseta community
type occurs on level to slightly undulating sites
which have imperfectly drained and aerated solonetzic-
order soils (except at Umbach which appears to be
covered with prairie vegetation because of the excessive
drainage of river terrace coarse gravel).

The relationship between the distribution of the
prairies and the occurrence of solonetzic soils can be
more strongly presented using the early survey informa-
tion. A strong correlation exists between the extent of
the Spirit River and Grande Prairie prairies and the
distribution of solonetzic soils (Fig. 3). The prairie north
of the Peace River does not appear to be as closely
correlated to solonetzic soil distribution. However, this
may be accounted for by the fact that the land survey
descriptions are particularly vague for this region and
townships classed on the map (Fig. 3) as prairie are

Fig. 2. Plan of township 77, range 5, west of the 6th meridian as described in Fig. 1. from the Interior Land Survey, 1916 (3rd edition).

other than cultivated crop species are not adequately documented. However, several characteristics of these soils would seem to produce unfavourable conditions for tree growth, particularly for Populus tremuloides (Fowells 1965; Maini 1960; Stoeckeler 1948). The hard, columnar structure of the B-horizon and the presence of a shallow, impermeable layer would slow air and water infiltration. The result could be inhibited root growth and concentration of the roots in the surface layers where they are more susceptible to moisture extremes. The
impermeable layer also results in saturated and flooded conditions in the surface layer for short periods, particularly in the spring and during wet weather. Conversely, water may evaporate from the soil surface before it can percolate through the relatively impermeable B-horizon, resulting in lower water availability to plant roots in times of moisture stress (Toogood and Cairns 1978).

High salt concentration would produce a more negative soil water potential resulting in a potential decrease in water uptake by plant roots and an increase in soil moisture tension as the soil becomes drier (Richards 1954). In addition, the chemical composition of the solonetzic soils, particularly the high ratios of sodium to calcium, may adversely affect nutrient uptake. Excess sodium ions may induce deficiencies of other elements, particularly calcium (Bernstein 1975; Carter et al. 1979; Chang and Dregne 1955) and nitrogen (Cairns 1971). The amount of sodium in the B-horizon may slow development or select against certain plants, particularly woody species (Bernstein 1975).

Trees appear to be gradually encroaching into prairie areas of the Peace River district where the unfavourable characteristics of solonetzic soil have been ameliorated owing to agricultural practices such as the construction of ditches and drainage systems and the addition of fertilizers and organic matter. These treatments significantly decrease soil breaking strength and soluble and exchangeable sodium levels and increase exchangeable calcium levels, nutrient uptake, infiltration, and solodization (Bowser 1971; Dormaar and Cairns 1978; Toogood and Cairns 1978).

In conclusion, it appears that the role of solonetzic soil in creating and maintaining prairies in areas which are otherwise forested may be more important and widespread than originally thought. For example, the smaller prairies which extend northeast from the Peace River region into Wood Buffalo National Park also appear to be underlain by solonetzic soils (Raup 1941; E. A. Johnson, personal observation). Many of these are the “subarctic prairies” of Seton (1911). However, further research into the effects of solonetzic soil conditions on noncrop plant species and the postglacial history and pedogenesis is required to shed more light on this problem.

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