INITIATION AND EXPANSION OF PEATLANDS IN ALBERTA, CANADA

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ABSTRACT

Radiocarbon dates of basal peat deposits from 38 locations across Alberta indicate that peat formation began approximately 8,000-9,000 years ago in nucleation zones along the eastern slope of the Rocky Mountains, Swan Hills-Saulteaux River area, and several northern uplands (Cameron Hills, Caribou, and Birch Mountains). Initial peat development lagged behind deglaciation by several thousand years, corresponding to an "early Holocene warm period". From 6,000-8,000 years ago peat formation expanded eastward paralleling the foothills and southwards from nucleation zones in northern uplands. Southward expansion was particularly extensive in eastern Alberta, reaching mid-latitudes by 6,000 years BP. After 6,000 years BP the trend of southwards and eastwards peatland expansion continued; however, peatland formation was delayed until about 4,000-5000 years BP in the lower elevations of the Peace and Slave River drainage basins. Peatlands are youngest in the Aspen Parkland region, having begun forming only after 3,000-4,000 years BP. The spatial and temporal distribution of peatland initiation over the last 10,000 years verifies Holocene climate simulations generated by GCM models for Alberta. Peatland expansion appears to have occurred at a linear rate, from 8,000 years BP to present. Cover at 4K is about half of modern values, following estimates of paludification rates, suggesting that the majority of carbon stored in peatlands accumulated during the late Holocene.

INTRODUCTION

The occurrence of a Holocene post glacial warm-dry interval in the northern hemisphere is well established. It was originally defined by Deevey & Flint (1957) as a time-stratigraphic unit with time-parallel boundaries at 9,500-2,500 years before present (radiocarbon years before present = 1950). In western Canada, paleoecological studies have shown that grasslands extended north of their present range from 9,500 to 6,500 years ago (Ritchie 1976), while in British Columbia grasslands extended further north until 4,500 years BP (Hebda 1983). In central Alberta, shallow lakes began flooding after 8,000 years BP and were most productive between 9,000-4,000 years BP (Schweger & Hickman 1989). Peatlands are known to have developed prior to 6,000 years BP along the Alberta foothills and in northern areas, while south of 55° latitude, central areas did not develop peatlands until after 6,000 years BP (Zoltai and Vitt 1990). These studies, among many others, suggest that the warm and dry early Holocene period is a geologic-climate unit with time transgressive boundaries (Porter and Denton 1967, Wright 1976).

Holocene GCM models generated using orbital parameters postulate maximum annual and summer insolation around 10,000-9,000 years BP for the northern Hemisphere (Berger 1978, Kutzbach and Guetter 1986). This insolation maximum resulted in shifts in climatic zones; however, due to sea ice/landmass/land ice distribution, climatic zone shifts varied spacially as well as temporally (Kutzbach and Guetter 1986, COHMAP 1988, Wright et al. 1993).

Modern vegetation was established in the Peace River-Clear Hills regions by around 5,000 years BP (White and Mathewes 1986, MacDonald 1987), and in central Alberta by around 3,000 years BP (Vance et al. 1983, Schweger and Hickman 1989). Modern vegetation may have been established as early as 7,500 years BP in some northern Alberta uplands (Vance 1986).

Peatlands are ecosystems that sequester carbon through peat accumulation, with world-wide peat deposits representing about 20% of total terrestrial carbon (Kuhry and Vitt 1995). In Alberta, peatlands cover 121,076 km^2 or 19% of the land (Figure 1, Table 1), representing a continuing large carbon sink (Kuhry and Vitt 1995). Peatlands are particularly extensive in northern Alberta where large areas have > 50% cover (Figure 1). As peatlands represent such a large component of the landscape, their establishment and development will represent an important proxy data set for elucidating vegetative and hence climatic change (Gignac and Vitt 1994), along with changes in the carbon cycle (Gorham 1991).

FIGURE 1: Modern peatland distribution in Alberta modified from Vitt (1992).

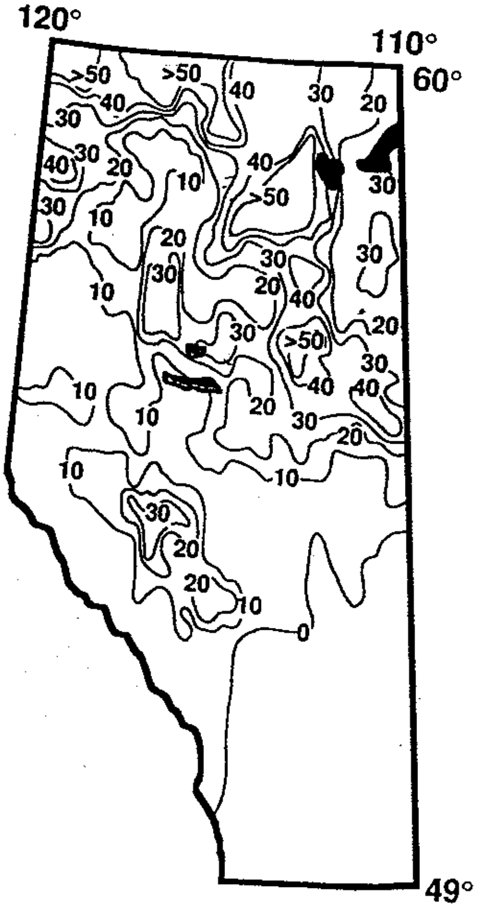

TABLE 1: Peatland cover for Alberta digitized from Vitt (1992).

Peatland Type	Cover	
Patterned fens	5,725 km^2	5%
Open fens	44,757 km^2	37%
Treed fens	40,103 km^2	33%
Bogs	16,160 km^2	13%
Permafrost bogs	14,331 km^2	12%
Total Cover	121,076 km^2	100%

In general, peatlands are currently restricted to areas where precipitation exceeds evaporation, and have mean annual precipitation values > 500mm, and biotemperatures less than 24 (Gignac and Vitt 1994). As peatland distribution is seemingly climatically correlated, the temporal and spatial distribution of peatland initiation can be used to test GCM models that predict Holocene climate. Past distributions of peatland cover can lead to estimates of carbon pools and the role that peatlands have played in the global carbon cycle.

METHODS

Basal dates on peatlands of Alberta were collected from literature and unpublished sources. Only dated samples of bryophyte dominated peat were included; as they represent peatland initiation at the coring site. Basal dates on limnic peat were not included. At sites where multiple cores were taken, the oldest basal date was used. Elevations of peatland sites were estimated from 1:50,000 base maps, when not given by the author. Basal dates were contoured using MacGridzo (Rockware Inc 1991), and modified using a model incorporating elevation and location for regions with inadequate basal date cover. Modern peat cover was extrapolated from Vitt (1992) for a 15' latitude and 30' longitude grid and then contoured. The potential distribution of peatlands at 2K time slices for the Holocene was determined using estimates of paludification rates from Nicholson (1987) and then superimposing these rates on modern cover values for a 15' latitude and 30' longitude grid. Maps of peatland cover at 2K time slices throughout the Holocene were produced by contouring the generated grids in Macgridzo (Rockware Inc. 1991).

TABLE 2: ^{14}C dates of basal peat above limnic peat or mineral.

	Location	Elev.	Date	Lab No.	Depth	Publication
1	50°40'&114°33'	1370	8220±80	GSC-2851	644-650	Mott & Jackson 1982
2	52°27'&115°12'	1021	6380±200	BGS-768	331-337	Zoltai 1989
3	52°51'&116°28'	1356	8600±250	BGS-772	352-357	Zoltai 1989
4	52°50'&116°51'	1560	9000±230	AECV-103C	441-451	Kubiw et al. 1989
5	53°20'&117°28'	1387	8400±270	BGS-775	502-510	Zoltai 1989
6	53°49'&119°09'	838	7705±75	S-1279	533-549	Rutherford et al. 1979
7	54°10'&116°54'	899	8560±170	GSC-525	310-320	Lowden et al. 1967
8	54°13'&116°55'	899	8530±170	GSC-673	270	Lowden & Blake 1968
9	54°34'&116°48'	747	4150±140	GSC-674	320	Lowden & Blake 1968
10	54°42'&116°00'	1158	8320±260	GSC-500	410-420	Lowden et al. 1967
11	54°45'&115°52'	1311	8940±240	BGS-778	548-554	Zoltai et al 1988
12	54°22'&115°06'	747	4850±130	GSC-752	180	Lowden & Blake 1968
13	53°33'&113°30'	671	3870±80	AECV-18C	267-274	Zoltai & Vitt 1990
14	55°01'&114°09'	579	9240±140	AECV-1027C	385-400	Kuhry & Vitt 1995
15	55°08'&114°01'	594	6800±150	BGS-789	224-229	Zoltai & Vitt 1990
16	54°30'&113°10'	617	3900±320	AECV-1094C	440-459	Kuhry unpublished
17	54°37'&112°09'	556	2900±160	BGS-784	236-242	Zoltai & VItt 1990
18	54°10'&111°28'	640	4350±70	WIS-280	195-200	Bender et al. 1969
19	54°38'&110°43'	912	3400± 160	AECV-97C	181-188	Kubiw et al. 1989
20	55°03'&117°00'	686	4740 ± 100	AECV-926C	220-231	Nicholson unpublish.
21	56°17'&117°20'	533	4510 ± 70	WIS-311	130-132	Bender et al. 1969
22	56°11'&115°20'	663	5960 ± 160	BGS-786	416-421	Zoltai &Vitt 1990
23	57°02'&115°08'	470	4380 ± 110	AECV-1215C	258-267	Kuhry unpublished
24	55°54'&112°04'	700	7170 ± 130	AECV-178C	203-218	Nicholson & Vitt 1990
25	56°12'&111°31'	725	7510 ± 110	AECV-182C	192-200	Zoltai et al 1988
26	57°28'&117°11'	480	3450 ± 60	WIS-283	115-120	Bender et al. 1969
27	57°28'&117°30'	663	3410 ± 55	WIS-281	50-52	Bender et al. 1969
28	57°26'&112°57'	790	7950 ± 100	AECV-1900C	108-116	Kuhry 1994
29	57°42' 12°22'	750	8460 ± 150	AECV-1723C	133-140	Halsey unpublished
30	58°18'&19°17'	503	7620 ± 120	AECV-991C	184-190	Zoltai 1993
31	58°25'&119°29'	488	6110 ± 120	AECV-991C	266-273	Zoltai 1993
32	58°32'&119°08'	488	7230 ± 120	AECV-992C	188-197	Zoltai 1993
33	59°01'&118°47'	343	5200 ± 100	BGS-354	128	Reid 1977
34	59°16'&118°41'	625	7870 ± 120	AECV-979C	151-156	Zoltai 1993
35	59°07'&118°37'	373	9170 ± 170	AECV-983C	375-384	Zoltai 1993
36	59°07'&118°09'	358	5840 ± 100	AECV-986V	254-262	Zoltai 1993
37	59°06'&117°42'	328	8400 ± 100	AECV-1425C	236-238	Kuhry 1994
38	59°00'&115°15'	900	8600 ± 100	S-116	335	McCallum 1962

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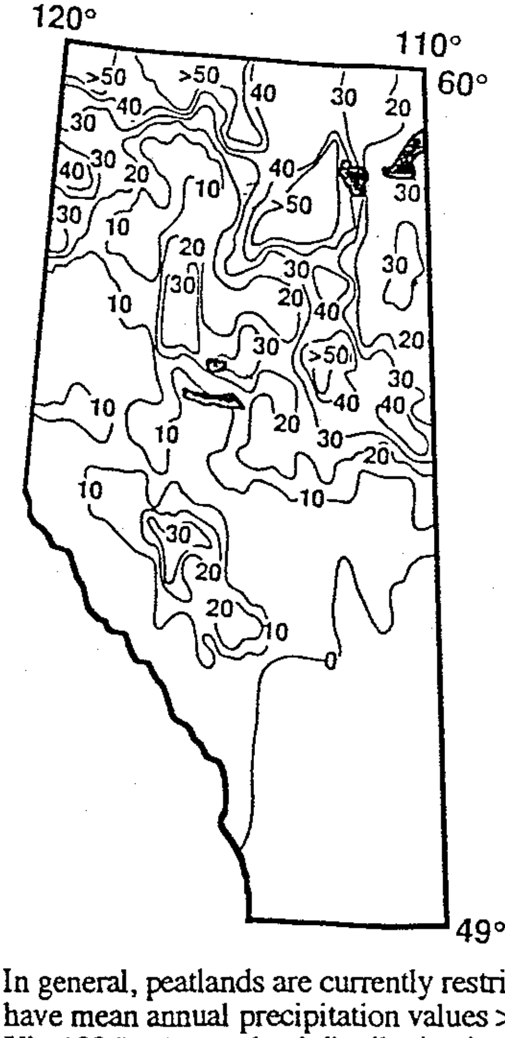

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Peatlands that initiated between 6,000-8,000 years ago range in depth from about 1-7m, while younger peatlands are generally < 4m in depth. Older, deeper sites reflect rapid peat accumulation resulting from reduced decomposition rates associated with relatively cooler, wetter areas with elevations above 1000m (Table 2, Figure 4). Older, shallow peatlands occur in northern uplands where dry, permafrost dominated, peat plateaus have higher fire frequencies resulting in sporadic, though increased removal of the peat column by combustion (Kuhry 1994). Younger and older, mid-boreal sites have intermediate depths (Figure 4).

Estimates of paludification rates from time slice maps of Nicholson (1987) leads to a significant regression: % Peat Cover = (0.013)(-age) + (98.85) $r^2 = 0.984$. The topography of much of the Alberta boreal forest is minimal due to the abundance of past glacial lakes. Though bands of hummocky terrain with terrestrialized peatland sites are present, they represent a small part of total peatland cover in Alberta. Thus, linear paludification rates are representative of peatland expansion for Alberta. Potential peatland cover maps at 2K time slices for the Holocene are shown in Figures 5 to 8.

FIGURE 4: Age vs peat depth for 38 peatland sites. Cirlces represent relatively cooler, wetter sites above 1000m, squares are dry, permafrost dominated peat plateaus that have a high fire frequency, and triagnles are other peatland sites.

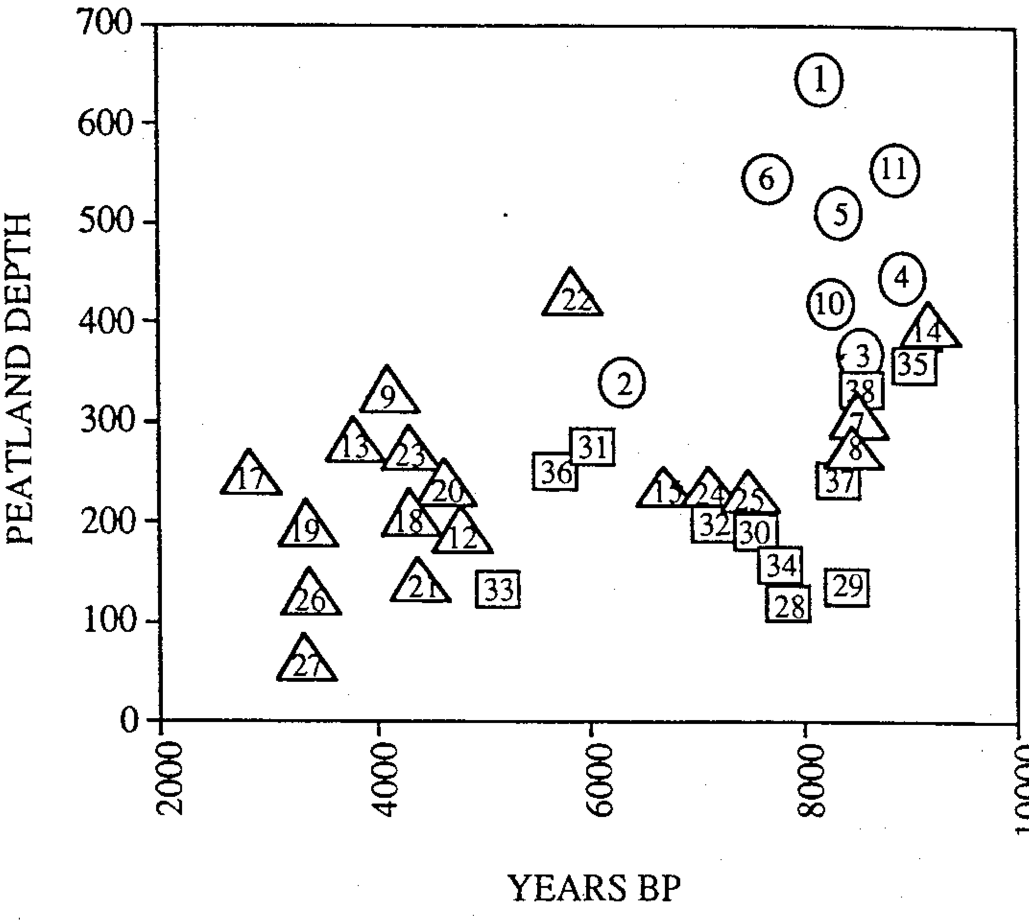


FIGURE 5: Peatland distribution at 2K. Isopleths represent percent cover. Contour interval is 10%.

FIGURE 6: Peatland distribution at 4K. Isopleths represent percent cover. Contour interval is 5%.

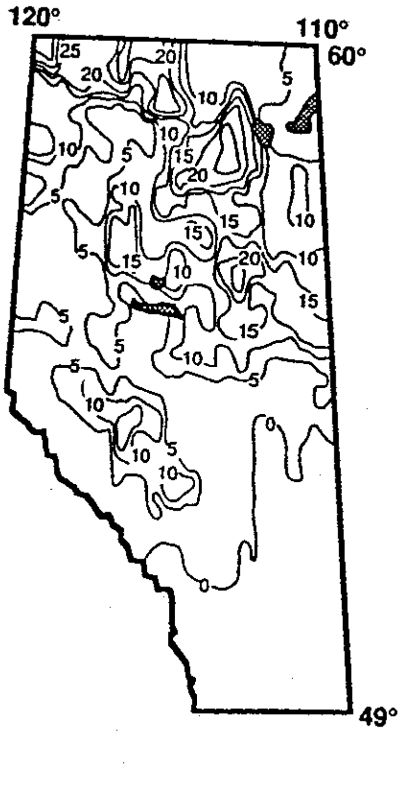


FIGURE 7: Peatland distribution at 6K Isopleths represent percent cover. Contour interval is 5%.

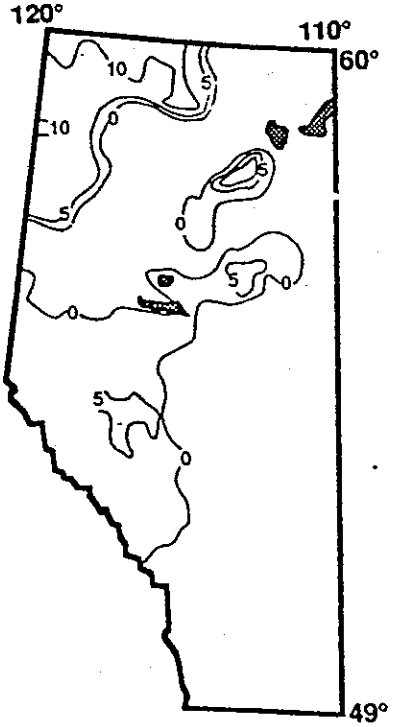
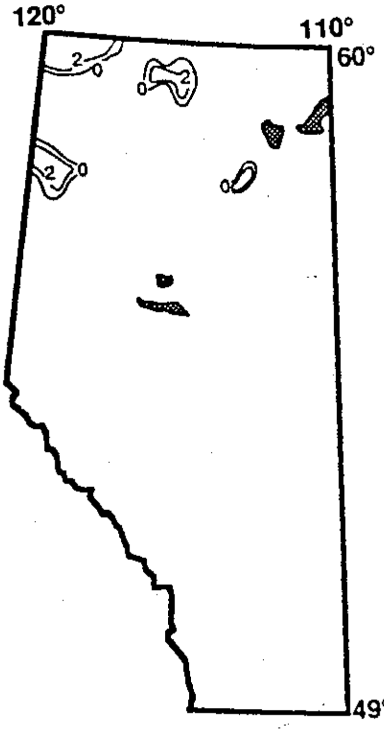


FIGURE 8: Peatland distribution at 8K. Isopleths represent percent cover. Contour interval is 2%.



DISCUSSION

Holocene climatic models generated from orbital parameters suggest that maximum annual and summer insolation for the northern Hemisphere occurred from 9,000-10,000 years BP (Berger 1978, Kutzbach and Guetter 1986), with winter values reaching present values around 3,000 years BP and summer insolation decreasing until the present day (Kutzbach and Guetter 1986). Peatlands did not begin to develop in Alberta east of the Rocky Mountain foothills until shortly before 8,000 years BP. The post-deglaciation lag in peatland initiation is a result of increased summer insolation in the northern mid-latitudes at this time verifying GCM models.

Climatic models of annual precipitation-minus-evaporation suggest that during 9,000 to 6,000 years BP aridity increased, reaching a peak at 6,000 years BP centered around 50° latitude corresponding to an increase in July temperatures (Kutzbach and Guetter 1986). This temporal and spatial peak in aridity is reflected in the general trend of southeasterly migration of peatland initiation and in limiting peatland formation in the lower elevations of Alberta until after 5,000 years BP.

Peatland expansion has substantially altered the landscape of Alberta throughout the Holocene. Estimates based on paludification rates used here suggest that only half of Alberta's peatlands were present by 4,000 years BP, and thus the late Holocene represents a time of rapid carbon accumulation in Alberta

CONCLUSIONS

The initiation and development of peatlands in Alberta was limited until shortly before 8,000 years BP west of the Rockies by increased summer insolation. Peatland initiation migrated southeastwards being limited spatially and temporally by increased summer temperatures that resulted in an annual precipitation-minus-evaporation maximum around 6,000 years ago centered on 50° latitude. This increase in evaporation relative to precipitation resulted in delayed peatland formation in the lower elevations of the Peace and Slave River Valleys. Initial peatland formation in Alberta is youngest at its current southeastern limit. Peatland formation in Alberta corroborates Holocene climatic models generated by orbital parameters and sea ice/landmass/land ice distribution interactions. This information could also be used to anticipate changes in peatland ecosystems due to future climatic change.

Maximum potential peatland cover at 4K represents just under half of present day coverage, being concentrated in northern uplands and in east-central Alberta. Examination of the stratigraphy of selected sites in different ecoregions of Alberta, in conjunction with peat cover at 2,000 year time slices, will provide a better understanding of the contribution that Alberta's peatlands have played in the global carbon cycle.

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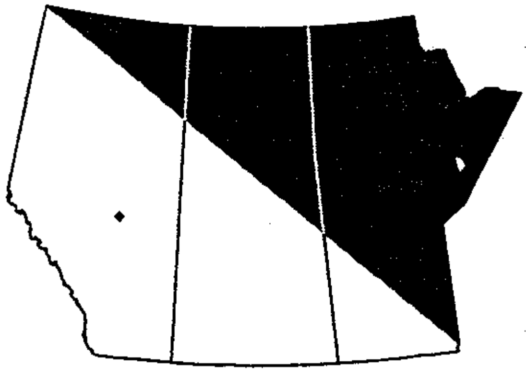
Proceedings



May 8-10, 1995
Edmonton

Sponsored by the Canadian Forest Service and the Department of Geography of the University of Alberta

Climate, Landscape
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This meeting was intended to bring together researchers, policy makers, and others with various perspectives on climate change in the Canadian prairie provinces. The idea for the meeting grew out of the observation that there are many different perspectives on climate change issues, and that these perspectives rarely have the opportunity to meet and interact. The twelve papers in this volume represent some of that diversity.

This proceedings volume was compiled from unedited, unreviewed, camera-ready copy supplied by the authors on the first day of the meeting. It was produced by photocopying on the second day, and distributed to meeting participants on the third day. This highly informal publication is intended to facilitate the rapid dissemination of information, but also to allow a more relaxed and informal style. As with the meeting as a whole, the primary purpose of the proceedings volume is to serve as an introduction to different perspectives for those who have an interest in climate change in the prairies. It is hoped that their appearance here will not preclude publication of the same articles in more traditional journals and other outlets.

The meeting was generously sponsored by the Canadian Forest Service, Northwest Region, and the Department of Geography of the University of Alberta; the wine and cheese of the Tuesday evening was sponsored by the Palliser Triangle Global Change Project of the Geological Survey of Canada. The organisers thank these agencies for their support and encouragement.

Ian D. Campbell, Canadian Forest Service
Celina Campbell, University of Alberta
Don Lemmen, Geological Survey of Canada
Bob Vance, Geological Survey of Canada