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Abstract: Seven optical ages from two dune fields in northern Alberta and British Columbia record Late Wisconsinan dune activity between about 13.9 and 10.3 ka. Sand dunes in the Fontas River area of British Columbia (NTS 94-I) formed between 13.9 and 11.7 ka. Initial winds blew from the northwest, funnelled between the Laurentide and Cordilleran ice sheets. These were replaced by winds from the west, likely associated with the Pacific air mass. Dunes in the High Level area of Alberta (Mount Watt, NTS 84 K) first formed at about 13.4 ka under transporting winds from the northeast and southeast, probably originating katabatically from the Laurentide Ice Sheet. Subsequent winds between about 11.7 and 11.0 ka were from the southeast, originating from glacial anticyclonic winds generated by a stationary high-pressure centre over the Laurentide Ice Sheet. These dunes were further modified by winds from the east. The High Level dunes stabilized at about 10.3 ka with the onset of boreal forest vegetation cover and reduced wind strength.

Résumé : Deux champs de dunes dans le nord de l'Alberta et de la Colombie-Britannique ont fait l'objet de sept datations par stimulation optique qui ont révélé une activité dunaire au Wisconsinien supérieur, il y a entre environ 13,9 et 10,3 ka. Des dunes de sable dans la région de la rivière Fontas (SNRC 94-I), en Colombie-Britannique, se sont formées il y a entre 13,9 et 11,7 ka. Les vents qui les ont accumulées ont soufflé d'abord du nord-ouest, canalisés entre les inlandsis laurentidien et de la Cordillère. Par la suite, des vents soufflant de l'ouest, vraisemblablement associés à la masse d'air du Pacifique, ont remplacé ces vents du nord-ouest. Les dunes de la région de High Level, en Alberta (mont Watt, SNRC 84 K), se sont formées il y a environ 13,4 ka sous l'effet de vents d'origine katabatique probablement engendrés sur l'Inlandsis laurentidien, qui soufflaient du nord-est et du sud-est. Par la suite, il y a entre environ 11,7 et 11,0 ka, des vents anticycloniques glaciaires, engendrés par un centre de haute pression stationnaire sur l'Inlandsis laurentidien, ont soufflé du sud-est. Ces dunes ont été davantage remaniées par des vents soufflant de l'est. Les dunes de la région de High Level se sont stabilisées il y a environ 10,3 ka à l'apparition de la couverture végétale de la forêt boréale alors que la force des vents à diminué.

INTRODUCTION

Deposits of sand dunes are widespread in western Canada and include more than 130 discrete dune fields (Fig. 1). Source deposits for most of these dune fields are sandy glaciolacustrine or glaciofluvial outwash deposits (David, 1977; Muhs and Wolfe, 1999) deposited by meltwaters from the retreat of the Laurentide Ice Sheet. Consequently, the maximum limiting ages of these dune fields are a function of the timing of deglaciation, subsequent drainage of proglacial lakes, and establishment of postglacial drainage (Wolfe et al., 2006). In western Canada, the chronology of maximum limiting ages of dune fields follows the trend of the receding Laurentide Ice Sheet, with oldest (>15.6 ka) in the southwest and progressively younger deposits toward the northeast (Fig. 1, inset).

Dating past dune activity in western Canada reveals a discrepancy between the timing of deglaciation and the actual ages recorded by eolian sediments (Fig. 1). This discrepancy is due to partial or complete remobilization of eolian sediments, probably as a result of recurrent droughts during the Holocene (Wolfe et al., 2006). This effect is most pronounced in the southern prairies, where dune fields have been remobilized as recently as the last 1000 years (Fig. 1). Consequently, the preservation potential of older late-glacial eolian sediments there is low. In contrast, dune fields in central Alberta (and probably Saskatchewan) retain a preserved record of late-glacial eolian activity (Fig. 1), as they have not been remobilized during the Holocene. These 'relict' dunes occur within the present-day boreal forest and, unlike dunes in the southern prairies, have not encountered significant reductions in vegetation cover due to drought in the Holocene.

The significance of preserved late glacial dune fields is that they may provide age control on postglacial events that are otherwise undated. Dating of these dunes can provide potential age control on the maximum limiting age of deglaciation and drainage, and may provide minimum limiting ages for the establishment of stabilizing vegetation cover. In addition, the morphology and age of these dune fields can provide insight into timing of wind circulation patterns associated with late-glacial climates.

To date, chronology exists only for relict dune fields in central Alberta and one site in the southern Northwest Territories (Fig. 1). No chronology has been established for dune fields in the northern regions of Alberta, Saskatchewan, or British Columbia. This study provides the first chronology for dune fields in northern Alberta and British Columbia. Ages reported herein are used to constrain the timing of late-glacial events and surface wind circulation patterns. In addition, these new ages are placed in the context of the

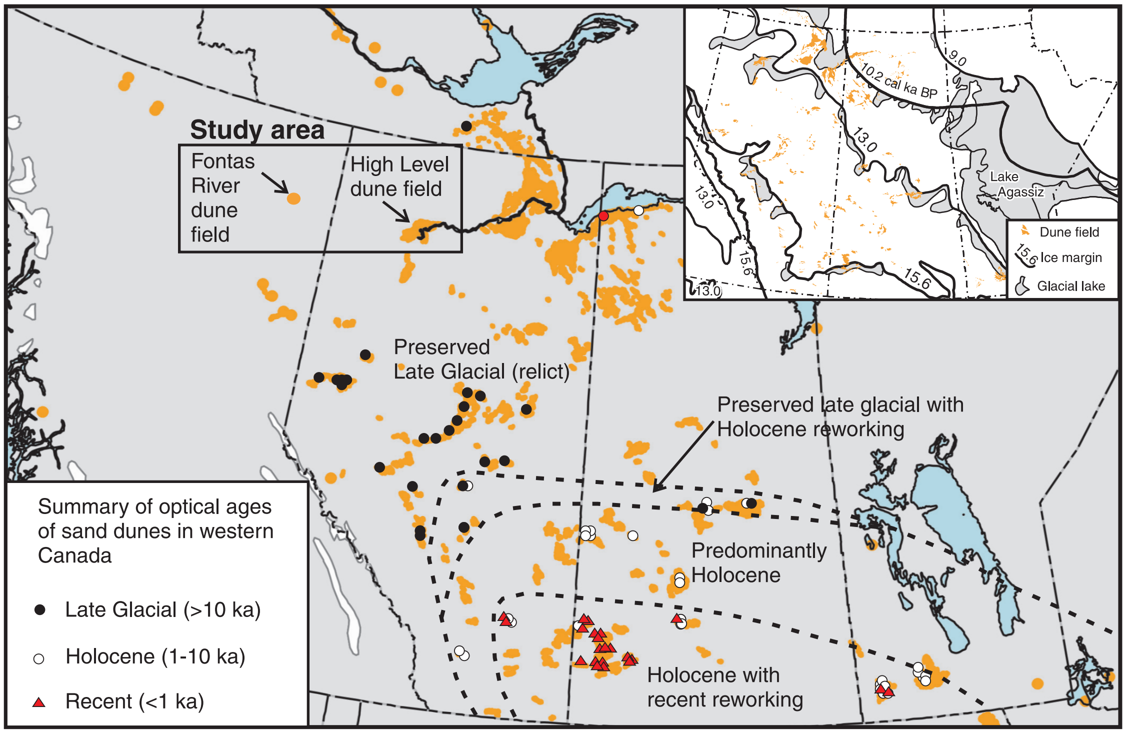

Figure 1. Dune fields of western Canada and location of study area. The main map includes relative chronology of dune sands in western Canada derived from optical ages (*after* Wolfe et al., 2002, 2005, 2006). The inset map shows glacial limits and proglacial lakes at 15.6, 13.0, 10.2, and 9.0 cal ka BP (*after* Dyke et al., 2003) and the distribution of dune fields (*after* Wolfe, 2001).

existing late-glacial eolian chronology (Wolfe et al., 2005, 2006) to establish a broader understanding of postglacial environmental history for western Canada.

STUDY AREA

The study area consists of two separate dune fields, one in northwestern Alberta and one northeastern British Columbia (Fig. 1). The first is the High Level dune field in Alberta, located immediately south and east of High Level, in the Mount Watt map area (NTS 84 K). The second is the Fontas River dune field in British Columbia, south and east of the Fontas River, in the Fontas River map area (NTS 94-I), approximately 110 km southeast of Fort Nelson, British Columbia.

The High Level dune field occurs on the west side of the Peace River and is also referred to as the 'Fort Vermilion sand hills' (David, 1977). The dune field covers an area of about 715 km^2, with a smaller dune field (~130 km^2), known as the 'La Crête sand hills', on the east side of the Peace River (Fig. 2a). The dunes are typically covered by jack pine, white spruce, aspen, and alder, with a ground cover of lichen, cranberry, and wild rose. The interdune areas within the dune field are primarily bog with minor fens. According to David (1977), the sand dunes were probably derived from shallow-water glaciolacustrine deposits. Recent mapping, however, indicates that the dune source sediments are likely derived from alluvial terraces because the dunes are confined to the broader extent of the Peace River valley (Paulen and Plouffe, 2007; Plouffe and Paulen, 2007). The hypothesized sequence of postglacial events includes multiphase drainage of glacial Lake Peace, initial rapid aggradation of Peace River sediments, and eolian remobilization and deposition. Further incision of fluvial sand and gravel occurred in the Peace River valley, leaving dunes on the uppermost terraces of the Peace River valley.

The High Level dune field has formed in an area of high sediment supply, which is reflected in the size of the dunes that range in height from 4 to 12 m. The orientations and morphology of the dunes indicate that several wind directions prevailed during time of formation (Fig. 3a). Although an exact relative chronology of wind directions is difficult to determine, David (1977) recognized the following three sets of transverse dunes in the area: first, a set of transverse dunes formed by winds blowing from the southeast; second, a modification of these dunes, and deposition of new dunes, formed by winds blowing from the northeast; third, a set of transverse dune formed by winds blowing from the east. The partial modification of several dune sets indicates that the dunes were partially reoriented by changing wind directions prior to their complete stabilization by vegetation. Parabolic dunes also occur in the area. These dunes are either superimposed on the transverse dunes, or have developed in areas without transverse dunes, such as the uppermost terraces of the Peace River valley. The parabolic dunes are oriented with winds blowing from the east and were probably the last dunes to form.

The Fontas River dune field is located south and east of the Fontas River (Fig. 2b). The dune field is small and separated into three areas covering about 31 km^2. The dunes are currently covered by small open stands of lodgepole pine and aspen with a thick lichen cover and local herbaceous plants. Some blowouts are found in the area. The interdune areas are covered by either open stands of aspen, or bogs and fens. The latter occur where eolian sands form only a thin veneer overlying relatively impermeable clay-rich till. Recent mapping indicates that the sand dunes are likely derived from an extensive veneer of sand deposited in the earliest phases of an ice-contact glacial Lake Hay that stretched from the British Columbia-Alberta border westward toward the Fontas channel, covering an area of 1100 km^2 (Smith, in press; Trommelen and Smith, in press). The Hay River delta formed in this glacial lake; it measures 180 km^2, with sediment thickness up to 32 m. There is a single, 5 m bed of open-work, well rounded cobbles supported by a medium to coarse sand matrix situated 14 m below the upper delta surface, near the delta apex. Otherwise, the Hay River delta is composed almost entirely of well sorted medium- to coarse-grained sand, with rare dropstones. The sand is considered to have originated from the regional glacial erosion of poorly indurated Dunvegan Formation sandstone and from the decantation of glacial Lake Peace westward into glacial Lake Hay. The dunes in the main dune field are compound parabolic dunes and a few smaller individual parabolic dunes (Fig. 2b and 3b). Their orientations indicate that wind directions were predominantly from the northwest and west during time of formation. The western dune field consists of individual and compound parabolic dunes formed by winds blowing from the northwest (Fig. 2b). At all dune fields, the sediment supply appears relatively low, as the dunes are narrow and the interdune areas are distinctive. The dunes reach a maximum height of 4 to 5 m.

A number of other small isolated dune fields are located east of the main Fontas River dune field; they cover an area of 22 km^2 and indicate wind directions from the northwest. These parabolic dunes are generally smaller (1–4 m high) than those of the Fontas River dune field and are situated within the broad sand sheet deposit. Large areas of the Hay River delta have also been remobilized by winds from the northwest into dune fields that cover 31 km^2. These parabolic dunes are also generally smaller (2–5 m high) than those of the Fontas River dune field. None of the dune fields identified here in British Columbia have previously been noted or mapped.

METHODS

Optical dating was used to determine the timing of eolian activity (Aitken, 1998; Huntley and Lian, 1999). Optical dating measures the time elapsed since mineral grains were last exposed to sunlight, which usually corresponds to the time since those grains were buried. By assessing the radiation dose received by the grains, termed the ‘paleodose’ (P in Gy), and the radiation dose received by year, termed the ‘dose-rate’ ($\dot{D}$ in Gy/ka), one can obtain a burial age using $P/\dot{D}$. Paleodoses were measured on sand-sized K-feldspar grains (180–250 µm diameter) using the single aliquot regeneration (SAR) protocol with infrared stimulation. Details of the experimental procedures are similar to those described in Huot and Lamothe (2003), as bleaching of the aliquots was carried out before each radiation dose steps in the SAR

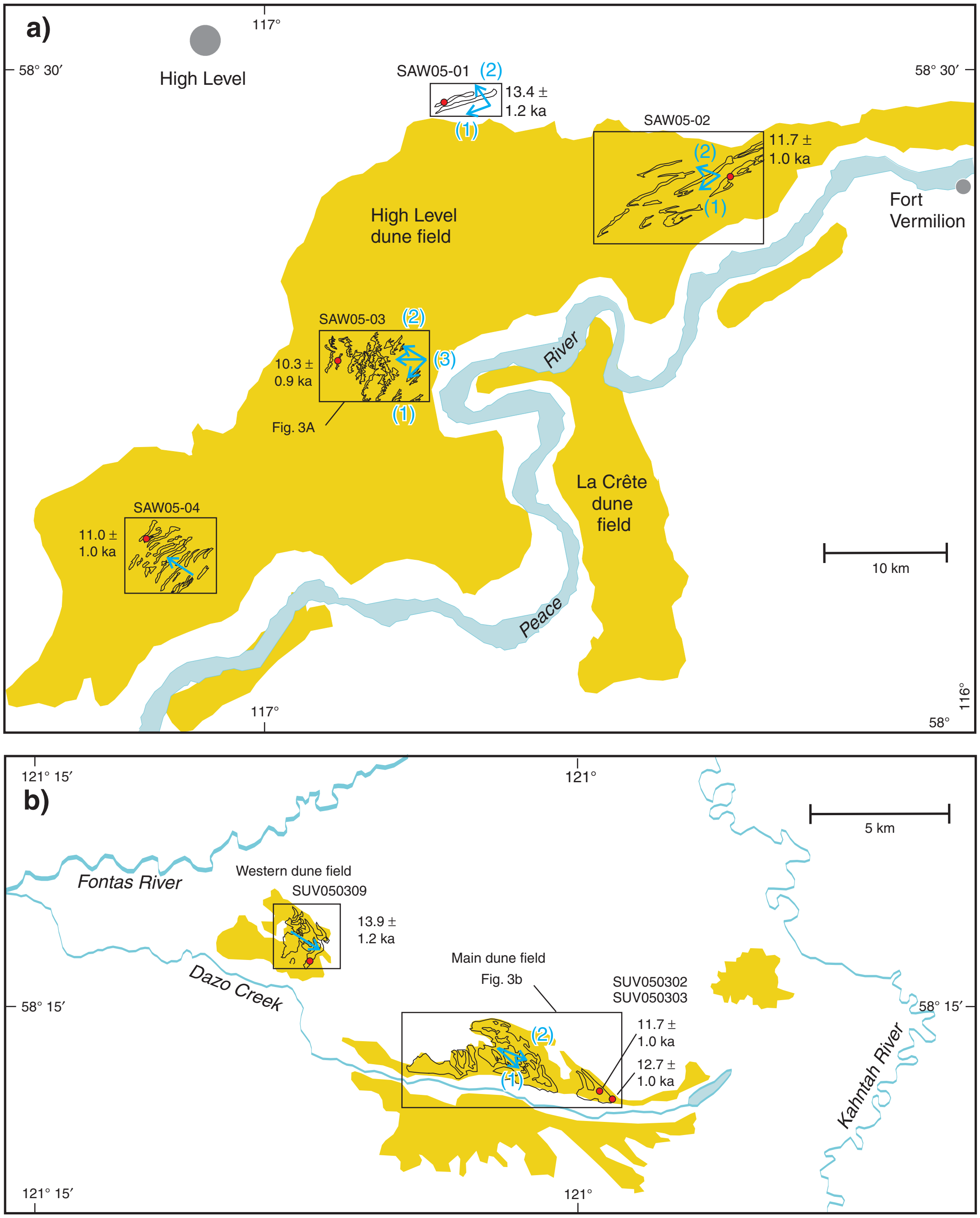

Figure 2. Morphology and ages of dune sands sampled in the High Level and Fontas River dune fields. The figure includes interpretation of relative timing and direction of transporting winds based on the surface morphology of stabilized sand dunes.

routine. Optical ages were corrected for anomalous fading following the Huntley and Lamothe (2001) method. Fading rates were measured on sample SUV05302 using SAR (Auclair et al., 2003) and method 'b' of Huntley and Lamothe (2001). Delay following irradiation reached about one month. The g value of 4.0 ± 0.5% has been applied to the other samples using the fading correction of Huntley and Lamothe (2001).

Seven sediment samples for optical dating were obtained from stabilized sand dunes (Table 1) that were recognizable on airphotos and on the ground. Four samples were collected from the High Level dune field at elevations ranging from about 280 to 340 m a.s.l. The La Crête dune field was not sampled. Three samples were collected from the Fontas River dune field at elevations between 435 and 450 m a.s.l.

Samples were collected from a depth of about 1 m, in shallow pits excavated into the surface of stabilized dunes to avoid potential mixing of the parent dune sands with overlying, pedogenically altered sediment. These near-surface samples are meant to provide ages relevant to deposition just prior to dune stabilization, rather than the onset of activity. Stratigraphy was described at each sample site, noting depth of pedogenesis and orientation of bedding planes, if any, within eolian sediments. Dune orientations, reflecting the dominant

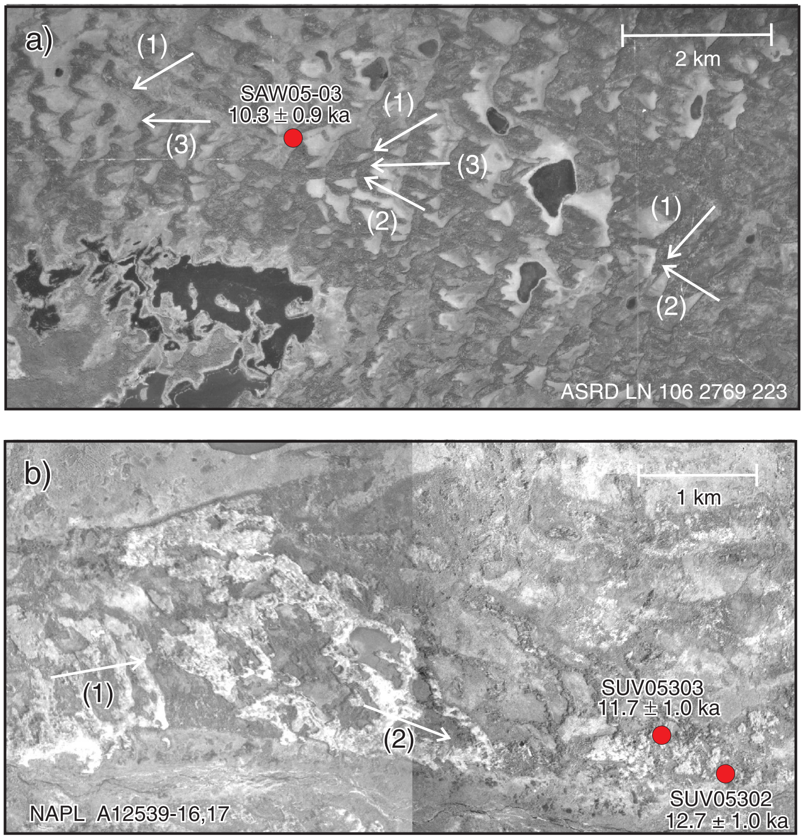

Figure 3. Stabilized sand dunes in the High Level and Fontas River areas showing optical age locations and interpretation of transporting wind directions and relative timing. **a**) Parabolic and transverse sand dunes in the central portion of the High Level dune field (airphoto reproduced with the permission of Alberta Sustainable Resource Development); **b**) compound parabolic dunes in the Fontas River area.

Table 1. Sample location and dune attributes.

Sample number	Location	Latitude (NAD 83)	Longitude (NAD 83)	Elev. (m)	Wind direction (from)
SAW05-01	High Level	58°25'21"	116°45'39"	300	NE-SE
SAW05-02	High Level	58°24'01"	116°17'31"	280	NE-SE
SAW05-03	High Level	58°15'15"	116°50'38"	320	NE-SE-E
SAW05-04	High Level	58°07'02"	117°10'37"	340	SE
SUV05302	Fontas River	58°13'49"	120°55'50"	450	WNW-W
SUV05303	Fontas River	58°13'52"	120°56'16"	450	WNW-W
SUV05309	Fontas River	58°16'07"	121°06'03"	435	WNW

transporting directions during formation, were determined in the field. The morphology and orientation of dunes were also derived from airphotos.

RESULTS

Dunes sediments at all sites consisted of medium-grained, well sorted sands. Surface organic layers range from less than 5 cm to 10 cm thick and form Brunisolic soils. The sands were typically oxidized and mottled to a maximum depth of about 70 cm. The colour of underlying C-horizon sands transitioned from olive-brown (Munsell 2.5Y 4/4) at between 70 and 125 cm depth, to greyish-brown (Munsell 2.5Y 5/2), unoxidized sand below. Tree roots were common in the upper 20 to 30 cm, with rare root casts observed at lower depths. No bedding or buried soils were observed in any of the sample pits. A significant difference between the two dune fields was the vegetation cover. Dunes in the Fontas River area currently have less tree cover, which includes lodgepole pine, indicating a more arid climate than in the High Level area. In addition, blowouts occur on some dune crests at Fontas River, indicating that eolian transport processes still occur to some extent in the area.

Optical ages range from 13.9 to 10.3 ka (Tables 2 and 3). The average analytical uncertainty in the optical ages is about 9% of the reported age at 1σ, with about half of this uncertainty being derived from uncertainty in the fading rates.

High Level dune field

Four ages provide chronology of sand-dune activity in the High Level dune field (Fig. 2a). A sample from the northern edge of the dune field (SAW05-01) at an elevation of 300 m a.s.l. returned the oldest age of 13.4 ± 1.2 ka. The dunes are elongate parabolic dunes that have been modified by variable winds. Transporting winds were from the northeast and then from the southeast, prior to dune stabilization. A relatively low sediment supply probably resulted in earlier vegetation stabilization of these dunes compared to dunes within the interior of the dune field where the volume of sediment is greater. An age of 11.7 ± 1.0 ka was obtained along the eastern margin of the dune field (SAW05-02) at an elevation of 280 m a.s.l. These dunes are also elongate parabolic dunes modified by variable winds. Again, transporting winds were initially from the northeast and then the southeast prior to dune stabilization. An age of 11.0 ± 1.0 ka was obtained in the southwestern portion of the dune field (SAW05-04) at an elevation of 340 m a.s.l. These dunes are predominantly

Table 2. Sample depth, K, Th, and U concentrations, alpha activity, and water contents of samples used for dosimetry.

Sample number	Sample depth (m)[a]	K (%) ± 0.05%	Th (ppm) ± 10%	U (ppm) ± 6%	Alpha activity (counts/ks/cm^2) ± 3%	Water content (%)[b]
SAW05-01 Sample	1.05	1.00	4.7	1.5	0.516	9.2
Above	0.90	1.01	4.4	1.6	0.493	9.7
Below	1.20	0.91	2.9	1.0	0.376	3.2
SAW05-02 Sample	1.10	0.89	3.2	1.2	0.320	3.6
Above	0.95	0.86	3.0	1.1	0.321	3.8
Below	1.25	0.90	3.7	1.3	0.368	3.9
SAW05-03 Sample	1.05	1.06	4.1	1.6	0.468	6.0
Above	0.95	0.77[c]	2.1[c]	0.8[c]	0.440	5.6
Below	1.20	0.93	3.4	1.4	0.358	5.6
SAW05-04 Sample	1.25	0.94	3.6	1.3	0.425	7.6
Above	1.05	1.02	3.3	1.3	0.445	6.7
Below	1.40	0.96	3.2	1.2	0.307	6.1
SUV05302 Sample	1.10	0.69	3.1	1.1	0.348	4.7
Above	1.00	0.85	3.8	1.8	——	3.9
Below	1.20	0.77	3.0	1.3	——	4.3
SUV05303 Sample	1.10	0.77	3.5	1.2	0.362	3.8
Above	1.00	0.60	4.6	1.3	——	4.1
Below	1.20	0.72	2.9	1.0	——	3.6
SUV05309 Sample	1.10	0.84	2.7	1.0	0.381	4.4
Above	1.00	0.92	2.6	1.5	——	4.1
Below	1.20	0.80	3.2	1.1	——	4.3

[a] Sample depth beneath the ground surface.

[b] Water content = [(mass water)/(dry mineral mass)x100], and corresponds to the in-situ value. Longer term water content estimates used in dating were 1.5x the in-situ values.

[c] Values appear suspicious and were not considered in the dose-rate calculation.

Notes:
U, Th, and K contents are from neutron activation analyses.
K and Rb contents of the K-feldspar grains are assumed to be 12.5% and 350 ppm respectively.

Table 3. Total dose rates ($\dot{D}$), equivalent doses (De), and optical ages.

Sample number	$\dot{D}$ [a] (Gy/ka)	Number of aliquots	D_e [b] (Gy)	Uncorrected optical age (ka)	Corrected optical age[c] (ka)
SAW05-01	2.36 ± 0.13	24	20.3 ± 0.8	8.6 ± 0.6	13.4 ± 1.2
SAW05-02	2.21 ± 0.10	24	17.7 ± 0.5	8.0 ± 0.4	11.7 ± 1.0
SAW05-03	2.45 ± 0.12	21	17.4 ± 0.6	7.1 ± 0.4	10.3 ± 0.9
SAW05-04	2.27 ± 0.12	21	17.1 ± 0.7	7.5 ± 0.5	11.0 ± 1.0
SUV05302	2.05 ± 0.09	24	17.8 ± 0.3	8.7 ± 0.4	12.7 ± 1.0
SUV05303	2.13 ± 0.10	24	17.1 ± 0.9	8.0 ± 0.6	11.7 ± 1.0
SUV05309	2.16 ± 0.10	24	20.5 ± 0.5	9.5 ± 0.5	13.9 ± 1.2

[a] Total dose rate, $\dot{D} = Dc + D_{\alpha,\beta,\gamma}$, where $D_{\alpha,\beta,\gamma}$, is the dose rate due to α, β, and γ radiation and D_c is the cosmic-ray dose rate. D_c is evaluated at 0.15 ± 0.02 Gy/ka.

[b] Equivalent dose measured on K-feldspar using the single aliquot regeneration (SAR) protocol with infrared stimulation. The delay between laboratory irradiation and equivalent dose measurement is in the order of a few minutes.

[c] Optical ages corrected for anomalous fading following the Huntley and Lamothe (2001) method; g value used (corresponding to the percentage fading loss per decade of time) is 4.0 ± 0.5 % / decade.

transverse, formed by winds from the southeast with the least degree of variability. The youngest age of 10.3 ± 1.0 k was obtained from within the centre of the dune field (SAW05-03). The dunes have a transverse morphology, are compound parabolic dunes, and were formed by highly variable winds. Winds were initially from the northeast, then from the southeast, and finally from the east.

Fontas River dune field

Three ages provide chronology of sand-dune activity in the Fontas River dune field (Fig. 2b). A sample west of the main dune field (SUV05309) returned the oldest age of 13.9 ± 1.2 ka. The dunes are compound parabolic dunes indicating transporting winds from the northwest. As with the oldest dunes in the High Level area, a relatively low sediment supply probably resulted in earlier vegetation stabilization of these dunes compared to those within the main dune field. Ages of 12.7 ± 1.0 (SUV05302) and 11.7 ± 1.0 ka (SUV05303) were obtained for dunes within the main dune field. These dunes are compound parabolic dunes, some of which are aligned transversely. The transporting winds were initially from the northwest, but terminated with winds from the west.

DISCUSSION AND CONCLUSIONS

Ages obtained for dunes in the High Level and Fontas River areas indicate that, as for dunes in central Alberta, they are relict Late Wisconsinan dune fields. Thus, the chronology and orientations of these dune fields can be placed into context with the Late Wisconsinan deglacial chronology (Dyke et al., 2003). In doing so, it is important to note the analytical uncertainty in the optical ages (up to 9% of the reported age at 1σ). Therefore, the results focus on several large time intervals, between 15.6 and 10.2 cal ka (Fig. 4). In some instances, dune fields appear to predate deglaciation because of the time steps used (Fig. 4). However, the optical ages are consistent with the deglacial chronology and other dune field ages for western Canada (Wolfe et al., 2005, 2006) when the uncertainties of the ages are considered.

Initial dune formation in the Fontas River area probably occurred in close proximity to the receding Laurentide Ice Sheet. The dunes were probably first formed in an herb or shrub tundra environment in an ice-proximal setting, prior to 13.0 ka (Dyke, 2006). If initial winds were from the east, these are not recorded in the dune morphology. Rather, the dunes record transport directions from the northwest, similar to those within most of central Alberta (Fig. 4). This suggests that katabatic winds, funnelled between the Cordilleran and Laurentide ice sheets, influenced dune development during early stages of deglaciation.With continued ice retreat, vegetation cover in the Fontas River area changed to shrub or forest tundra by about 11.5 ka (Dyke, 2006). Wind directions from the northwest and west between about 12.9 and 11.7 ka recorded in the dune morphology suggest that the climate was increasingly influenced by the Pacific air mass at that time. The dunes stabilized after about 11.7 ka, probably with the transition to boreal forest cover (Dyke, 2006).

Dune formation in the High Level area was initiated soon after that in the Fontas River area, following retreat of the Laurentide Ice Sheet and partial drainage of glacial Lake

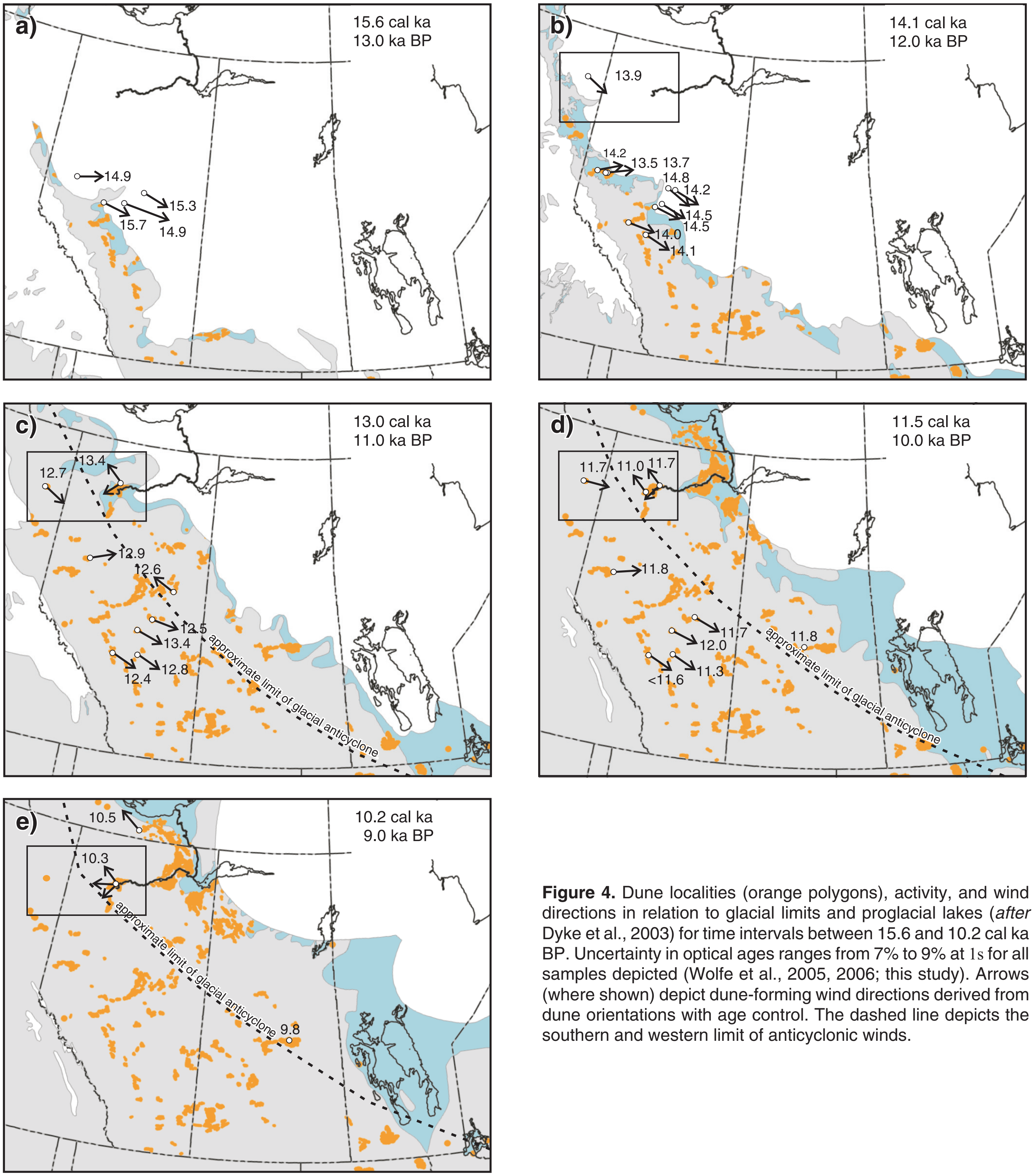

Figure 4. Dune localities (orange polygons), activity, and wind directions in relation to glacial limits and proglacial lakes (*after* Dyke et al., 2003) for time intervals between 15.6 and 10.2 cal ka BP. Uncertainty in optical ages ranges from 7% to 9% at 1s for all samples depicted (Wolfe et al., 2005, 2006; this study). Arrows (where shown) depict dune-forming wind directions derived from dune orientations with age control. The dashed line depicts the southern and western limit of anticyclonic winds.

Peace. Initial activity probably occurred in an herb tundra setting at about 13 ka (Dyke, 2006). In contrast to the Fontas River area, transporting winds at that time were predominantly from the northeast and southeast, and probably generated by katabatic or anticyclonic winds off the Laurentide Ice Sheet (Fig. 4). Between about 11.7 and 11.0 ka, winds were predominantly from the southeast, and most likely originated from anticyclonic winds generated by a stationary high-pressure centre over the ice sheet (Bryson and Wendland, 1967). Biome cover at that time was probably boreal parkland or forest tundra (Dyke, 2006). Dune activity continued until about 10.3 ka, at which time winds were more variable (Fig. 4), probably due to the diminishing effect of anticyclonic winds associated with the retreating Laurentide Ice Sheet. Dune activity probably terminated with transition to a boreal forest cover and reduced wind strength soon after 10.3 ka.

These ages from the Fontas River and High Level dune fields are significant as they provide a northern extension to the existing chronology presently concentrated in central Alberta. They are consistent with the deglacial chronology for western Canada, and provide chronological control of late-glacial paleoenvironmental change and surface wind directions. Most significantly, the ages reported herein provide chronological control on the timing and extent of glacial anticyclonic circulation in western Canada.

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REFERENCES

Aitken, M.J.
1998: An Introduction to Optical Dating; Oxford University Press, Oxford, U.K., 267 p.

Auclair, M., Lamothe, M., and Huot, S.
2003: The measurement of anomalous fading for feldspar RSL using SAR; Radiation Measurements, v. 37, p. 487–492.

Bryson, R.A. and Wendland, W.M.
1967: Tentative climatic patterns for some late glacial and post-glacial episodes in central North America; *in* Life, Land and Water, (ed.) W.J. Mayer-Oakes; Proceedings, 1966 Conference on Environmental Studies of the Glacial Lake Agassiz Region, Department of Anthropology, University of Manitoba, Occasional Paper no. 1, University of Manitoba Press, p. 271–298.

David, P.P.
1977: Sand dune occurrences of Canada: a theme and resource inventory study of eolian landforms of Canada; Department of Indian Affairs and Northern Development, National Parks Branch, Contract no. 74-230, 183 p.

Dyke, A.S.
2006: Late Quaternary vegetation history of northern North America based on pollen, macrofossil, and faunal remains; Géographie physique et Quaternaire, v. 58, p. 211–262.

Dyke, A.S., Moore, A.J., and Robertson, L.
2003: Deglaciation of North America; Geological Survey of Canada, Open File 1574.

Huntley, D.J. and Lamothe, M.
2001: Ubiquity of anomalous fading in K-feldspars, and the measurement and correction for it in optical dating; Canadian Journal of Earth Sciences, v. 38, p. 1093–1106.

Huntley, D.J. and Lian, O.B.
1999: Using optical dating to determine when a mineral grain was last exposed to sunlight; *in* Holocene Climate and Environmental Change in the Palliser Triangle: A Geoscientific Context for Evaluating the Impacts of Climate Change in the Southern Canadian Prairies, (ed.) D.S. Lemmen and R.E. Vance; Geological Survey of Canada, Bulletin 534, p. 211–222.

Huot, S. and Lamothe, M.
2003: Variability of infrared stimulated luminescence properties from fractured feldspar grains; Radiation Measurements, v. 37, p. 499–503.

Muhs, D.R. and Wolfe, S.A.
1999: Sand dunes of the northern Great Plains of Canada and the United States; *in* Holocene Climate and Environmental Change in the Palliser Triangle: A Geoscientific Context for Evaluating the Impacts of Climate Change on the Southern Canadian Prairies, (ed.) D.S. Lemmen and R.E. Vance; Geological Survey of Canada, Bulletin 534, p. 183–197.

Paulen, R.C. and Plouffe, A.
2007: Surficial geology of the La Crête Area (NTS 84K/SE); Alberta Energy and Utilities Board, EUB/AGS Map 412, and Geological Survey of Canada, Open File 5526, scale 1:100 000.

Plouffe, A. and Paulen, R.C.
2007: Surficial geology, Caribou Creek, Alberta (NTS 84SK/SW); Geological Survey of Canada, Open File 5460, and Alberta Energy and Utilities Board, EUB/AGS Map 415, scale 1:100 000.

Smith, I.R.
in press: Surficial geology, Kahntah River, British Columbia; Geological Survey of Canada, Open File 5540, scale 1:100 000.

Trommelen, M. and Smith, I.R.
in press: Surficial geology, Dazo Creek, British Columbia; Geological Survey of Canada, Open File 5527, scale 1:100 000.

Wolfe, S.A.
2001: Eolian deposits in the Prairie Provinces of Canada; Geological Survey of Canada, Open File 4118.

Wolfe, S.A., Huntley, D.J., and Lian, O.B.
2002: Holocene eolian activity in south-central Saskatchewan and the southern Canadian prairies; Géographie physique et Quaternaire, v. 56, p. 215–227.

Wolfe, S.A., Huntley, D.J., and Ollerhead, J.
2005: Relict Late Wisconsinan dune fields of the northern Great Plains, Canada; Géographie physique et Quaternaire, v. 58, p. 323–336.

Wolfe, S.A., Ollerhead, J., Huntley, D.J., and Lian, O.B.
2006: Holocene dune activity and environmental change in the prairie parkland and boreal forest, central Saskatchewan, Canada; The Holocene, v. 16, p. 17–29.

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