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Depositional Environments and Archeological Site Formation in the Cypress Hills, Southeastern Alberta

Milieux de sédimentation et conservation de sites archéologiques dans les Cypress Hills, dans le sud-est de l'Alberta

Ambientes sedimentológicos y formación de sitios arqueológicos en la zona de Cypress Hills, en el sudeste de Alberta

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Résumé de l'article

Les recherches antérieures dans les Cypress Hills, au sud-est de l'Alberta et au sud-ouest de la Saskatchewan, démontrent que le paysage a subi des changements importants au cours de l'Holocène. C'est particulièrement le cas dans les chenaux d'eau de fonte flanquant les Cypress Hills qui semblent avoir subi des épisodes de mise en place de sédiments en provenance des versants des collines, en alternance avec des épisodes de stabilité et de formation du sol. Ce contexte a rendu possible la conservation de sites archéologiques comportant de multiples couches stratigraphiquement définies, un phénomène important car les processus géomorphologiques pouvant engendrer de tels phénomènes sont rares dans les Grandes Plaines du Nord. D'abondantes ressources naturelles auraient attiré de nombreux groupes humains préhistoriques dans les Cypress Hills, favorisant ainsi l'existence de tels sites. Cet article présente une méthode élaborée en vue de comprendre l'évolution morphologique des chenaux d'eau de fonte et d'identifier les sites archéologiques ensevelis sous les chenaux. Les résultats préliminaires confirment que les chenaux ont connu, en alternance, des périodes de stabilité et de sédimentation favorisant l'enfouissement stratifié des sites culturels. De plus, le matériel archéologique mis au jour en de nombreux endroits démontre que les chenaux d'eau de fonte représentent un milieu propice à la conservation de sites archéologiques de grande qualité, comprenant de nombreuses couches culturelles bien définies.

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DEPOSITIONAL ENVIRONMENTS AND ARCHEOLOGICAL SITE FORMATION IN THE CYPRESS HILLS, SOUTHEASTERN ALBERTA

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ABSTRACT Previous research on the Cypress Hills of southeastern Alberta and southwestern Saskatchewan suggests that they have experienced a dynamic history of Holocene landscape change. In particular, the meltwater channels flanking the Cypress Hills appear to have experienced intermittent deposition of sediment transported from upslope alternating with episodes of landscape stability and soil formation. This pattern favours the formation of archeological sites containing multiple stratigraphically discrete occupations, an important characteristic because the geomorphic processes necessary to create such interpretively valuable sites are rare across much of the Northern Plains. Furthermore, the rich resources offered by the Cypress Hills suggest that they were attractive to past human groups, a feature that enhances the prospects for such sites. This paper discusses a study designed to investigate the geomorphic history of the meltwater channels and to identify buried archeological sites in these channels. The preliminary results of this study confirm that the channels have experienced a cyclical pattern of stability and deposition favourable to the stratified burial of cultural remains. Moreover, this study has recovered archeological material from numerous locations, strongly suggesting that the meltwater channels represent an excellent environment for the formation of high-quality sites with multiple discrete cultural layers.

RÉSUMÉ *Milieux de sédimentation et conservation de sites archéologiques dans les Cypress Hills, dans le sud-est de l'Alberta.* Les recherches antérieures dans les Cypress Hills, au sud-est de l'Alberta et au sud-ouest de la Saskatchewan, démontrent que le paysage a subi des changements importants au cours de l'Holocène. C'est particulièrement le cas dans les chenaux d'eau de fonte flanquant les Cypress Hills qui semblent avoir subi des épisodes de mise en place de sédiments en provenance des versants des collines, en alternance avec des épisodes de stabilité et de formation du sol. Ce contexte a rendu possible la conservation de sites archéologiques comportant de multiples couches stratigraphiquement définies, un phénomène important car les processus géomorphologiques pouvant engendrer de tels phénomènes sont rares dans les Grandes Plaines du Nord. D'abondantes ressources naturelles auraient attiré de nombreux groupes humains préhistoriques dans les Cypress Hills, favorisant ainsi l'existence de tels sites. Cet article présente une méthode élaborée en vue de comprendre l'évolution morphologique des chenaux d'eau de fonte et d'identifier les sites archéologiques ensevelis sous les chenaux. Les résultats préliminaires confirment que les chenaux ont connu, en alternance, des périodes de stabilité et de sédimentation favorisant l'enfouissement stratifié des sites culturels. De plus, le matériel archéologique mis au jour en de nombreux endroits démontre que les chenaux d'eau de fonte représentent un milieu propice à la conservation de sites archéologiques de grande qualité, comprenant de nombreuses couches culturelles bien définies.

RESUMEN *Ambientes sedimentológicos y formación de sitios arqueológicos en la zona de Cypress Hills, en el sudeste de Alberta.* Estudios previos realizados en la zona de Cypress Hills al sudeste de Alberta y sudoeste de Saskatchewan sugieren que durante el Holoceno hubo cambios dinámicos frecuentes en el paisaje. En particular los canales del agua de fusión que flanquean Cypress Hills parecen haber experimentado un depósito intermitente de sedimentos provenientes de la región cuesta arriba alternados con periodos de estabilidad del paisaje y formación de suelos. Este patrón favorece la formación de sitios arqueológicos que contienen múltiples niveles estratigráficos discretos, una característica importante ya que los procesos geomorfológicos necesarios para crear sitios con tal valor interpretativo son raros en toda el área de las planicies norteamericanas. Además la riqueza de recursos que ofrece Cypress Hills sugiere que estos fueron un sitio de interés para grupos humanos en el pasado, característica que resalta también el potencial de dichos sitios. El presente manuscrito presenta un método diseñando para investigar la historia geomorfológica de los canales de agua de fusión e identificar los sitios arqueológicos sepultados en dichos canales. Los resultados preliminares del estudio confirman que los canales han experimentado patrones cíclicos de estabilidad y sedimentación favorables para la formación de estratos que incluyen sitios de relevancia cultural. Cabe agregar que durante el estudio se ha recolectado material arqueológico proveniente de numerosos sitios, ello sugiere que los canales de agua de fusión representan un excelente ambiente propicio a la formación de sitios de alta calidad que permiten la formación de numerosos estratos culturales bien definidos.

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INTRODUCTION

The Cypress Hills of southern Alberta and Saskatchewan rise approximately 500 m above the surrounding plains. As a result, they incorporate a range of ecological communities and are subject to climatic conditions that differ markedly from adjacent areas of lower elevation (Breitung, 1954; Jungerius, 1969). Furthermore, the topographic features of the Cypress Hills have resulted in a distinctive history of geomorphic change.

The archeology of the Cypress Hills also contrasts with that of the surrounding area. This pattern is exemplified by the Stampede site (DjOn-26), a thick archeological deposit that contains multiple stratigraphically discrete occupations beginning by at least 7245 ± 255 BP (NMC-571; Gryba, 1972, 1975). Sites with extended sequences of clearly separated cultural strata are uncommon on the Northern Plains because the depositional processes necessary to create such sequences are frequently lacking. Such sites provide very high-quality archeological data, making them extremely valuable resources. For this reason, the Stampede site has been selected for investigation by SCAPE (Study of Cultural Adaptations in the Canadian Prairie Ecozone), a multidisciplinary project examining indigenous cultural responses to Holocene changes in the climate and ecology of the Northern Plains.

This paper discusses the preliminary results of a geoarcheological study designed to provide regional context for the Stampede site by determining if additional examples of similar sites are present in the Cypress Hills. This study is based on two hypotheses. First, although the depositional processes necessary to create such sites are rare on the Northern Plains, such processes appear to be more common in the geomorphically dynamic meltwater channels that flank the Cypress Hills. Second, because the unusual ecology and climate of the Cypress Hills support resources unavailable in adjacent areas, they are likely to have been very attractive to the mobile indigenous groups of the Northern Plains. Thus, the region's diverse resources, coupled with its distinctive geomorphic attributes, suggest that it is well suited to the formation of deposits containing archeological remains in extended sequences of clearly separated strata.

With this in mind, subsurface tests were conducted in the Alberta portion of the West Block of the Cypress Hills to find additional examples of such deposits. These tests indicate that the geomorphic processes necessary to create such sequences have, in fact, been active throughout the Holocene, producing multiple locations in which sequences similar to the Stampede site have formed. Furthermore, sediment samples from many of these locations have yielded archeological material. These findings suggest that the West Block of the Cypress Hills merits additional archeological attention, as the presence of multiple locations containing discrete cultural occupations in stratified deposits makes it an exceptional venue for studying past human activity on the Northern Plains.

CLIMATIC, ECOLOGICAL AND GEOMORPHIC BACKGROUND

The Cypress Hills comprise three plateaus, the West, Centre and East Blocks, that extend across southeastern Alberta and southwestern Saskatchewan (Fig. 1). Rising to elevations of about 1 100 m asl to over 1 400 m asl from east to west, they are substantially higher than the adjacent plains, which range from about 700 m asl to 1 100 m asl, respectively (Klassen, 1992).

Due to their relative relief, the Cypress Hills experience a mean annual temperature of about 2.5 ºC and a mean annual precipitation of 460 mm, a sharp contrast to areas 50 km to the north and south, where mean annual temperatures of approximately 5.0 ºC and a mean annual precipitation of about 300 mm are typical (Jungerius, 1969). These relatively cool and wet conditions support fescue prairie, lodgepole pine (*Pinus contorta*) forest, white spruce (*Picea glauca*) forest, trembling aspen (*Populus tremuloides*) woodland, and a range of riparian habitats, in addition to the mixed grass prairie that dominates the adjacent areas of lower elevation (Breitung, 1954; Halladay, 1965; Sauchyn and Sauchyn, 1991).

The elevated plateaus of the Cypress Hills are formed of a resistant Tertiary conglomerate that caps the remnants of Upper Cretaceous and Tertiary bedrock formations. They were left along a postulated drainage divide after late Tertiary erosion lowered the neighbouring plains to their current elevation (Furnival, 1950; Vreeken *et al.*, 1989).

The effects of subsequent Pleistocene glaciation varied across the Cypress Hills. Based on the absence of glacial deposits on the West Block's highest areas, it is widely agreed that approximately 300 km^2 remained a nunatak throughout Wisconsinan glaciation (Stalker, 1965; Westgate, 1965; Catto, 1983; Klassen, 1992, 1993; Sauchyn, 1993, 1999). In contrast, the Centre and East blocks bear scattered clasts from the Canadian Shield, suggesting they were covered by ice during the Early Wisconsinan (Klassen, 1992, 1993, 1994; *cf.* Kulig, 1996).

Meltwater produced by the glacial retreat is thought to have carved a series of deep channels around and between the blocks of the Cypress Hills (Fig. 1) (Westgate, 1968; Christiansen, 1979; Christiansen and Sauer, 1988; Klassen, 1994; Kulig, 1996). It has been postulated that the walls of these channels were initially steep and unstable, leading to extensive landsliding immediately after they were formed (Goulden and Sauchyn, 1986; Sauchyn and Goulden, 1988; Sauchyn and Lemmen, 1996). This is supported by cores from the Frenchman River Valley showing 40 to 80 m of Holocene fill overlying the bedrock floor of the associated meltwater channel (Christiansen and Sauer, 1988). The fill, comprised of a thick lower unit interpreted as landslide debris and an upper unit interpreted as mixed alluvium and colluvium, returned radiocarbon dates of up to 11 460 ± 250 BP (S-2932) on wood samples from the upper unit, suggesting that the underlying landslide debris was deposited before this time.

Information on subsequent Holocene landscape change in the Cypress Hills has been provided by analysis of pollen, ostracodes, diatoms and sediment in cores from Harris Lake (Sauchyn, 1990; Sauchyn and Sauchyn, 1991; Last and Sauchyn, 1993; Wilson *et al.*, 1997; Porter *et al.*, 1999). Located in a small basin along the meltwater channel north of the West Block, this lake appears to have held water since the early Holocene, providing a continuous record of sedimentation extending from present to about 9000 BP. Data from the cores indicate that, from 9000 to 7500 BP, the area surrounding the lake contained grassland mixed with aspen forest

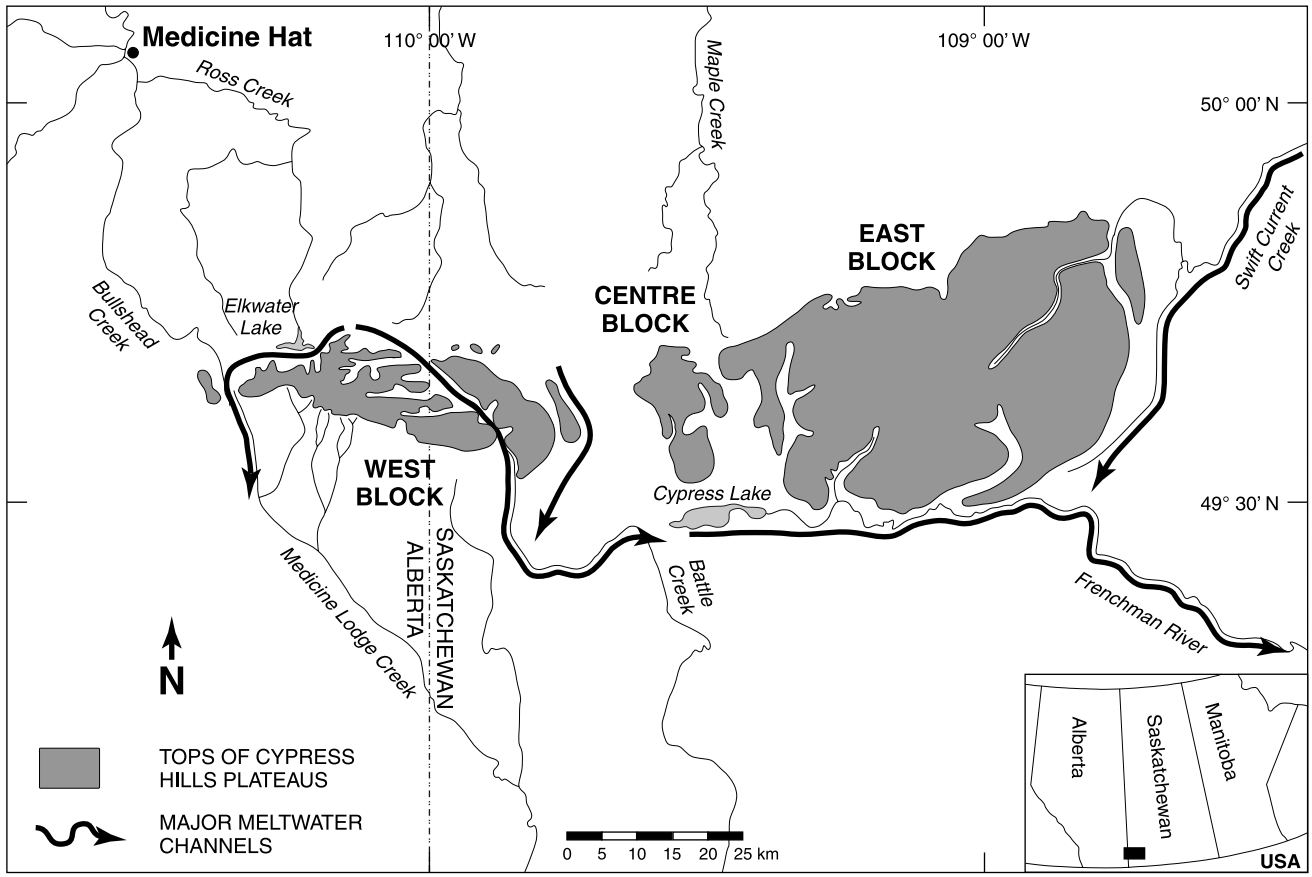

FIGURE 1. Map showing the location of the Cypress Hills, with major meltwater channels as indicated by Kulig (1996).

Localisation des Cypress Hills et des principaux chenaux d'eau de fonte identifiés par Kulig (1996).

and was subject to warmer, drier conditions than at present. From 7500 to 4500 BP, it experienced a shift toward higher temperatures and increased aridity, accompanied by an expansion of grassland species. The period from 4500 BP to present saw the emergence of cooler and wetter conditions, with an accompanying increase in mixed forest species.

Also, the period from 7700 to 5000 BP was characterized by high sedimentation rates, a pattern interpreted as reflecting increased fluvial and eolian erosion due to reduced plant cover caused by the onset of warmer, drier conditions (Sauchyn, 1990). The lake also experienced high sedimentation rates from 5000 to 3000 BP, a trend seemingly inconsistent with the evidence for increased vegetation at this time. However, Sauchyn (1990) suggests that the wetter conditions during this period may have encouraged landslide activity by destabilizing bedrock formations sensitive to increased groundwater. Such activity would have exposed considerable sediment, making it available for transport to areas like Harris Lake. Despite the continuing trend toward cooler, wetter conditions after 3000 BP, Harris Lake began to experience lower sedimentation rates, leading Sauchyn (1990) to suggest that, although the start of these conditions in the preceding period instigated major slope adjustments, the frequency and magnitude of mass movements decreased as more stable slope configurations developed.

Nonetheless, landslide activity has continued to be significant in the Cypress Hills during the late Holocene. This is supported by a study of 17 landslides, all of which are estimated to have occurred after 4000 BP (Goulden and Sauchyn, 1986; Sauchyn and Goulden, 1988; Sauchyn and Lemmen, 1996; Lemmen *et al.*, 1998). The ongoing importance of such mass movements is also demonstrated by the Police Point landslide, an event triggered in the Battle Creek Valley during May 1967 by the rapid melting of a large snow accumulation (Fig. 2). Continued monitoring has demonstrated that the landslide remains unstable, preventing the development of plant cover on its exposed surfaces and allowing ongoing erosion of these surfaces to introduce sediment into Battle Creek (Sauchyn and Lemmen, 1996; Sauchyn and Nelson, 1999; Beaudoin and Lemmen, 2000).

The events of May 1967 also caused a major flood of the Graburn Creek Valley (Fig. 2). With an estimated recurrence interval of at least 50 years, this flood permanently altered the course of the creek, removing more than 40 000 tonnes of sediment from its watershed and creating overbank deposits up to 1 m deep (McPherson and Rannie, 1969). This episode provides ample evidence that processes such as mass movements, as well as fluvial erosion, continue to make the Cypress Hills a geomorphically dynamic environment.

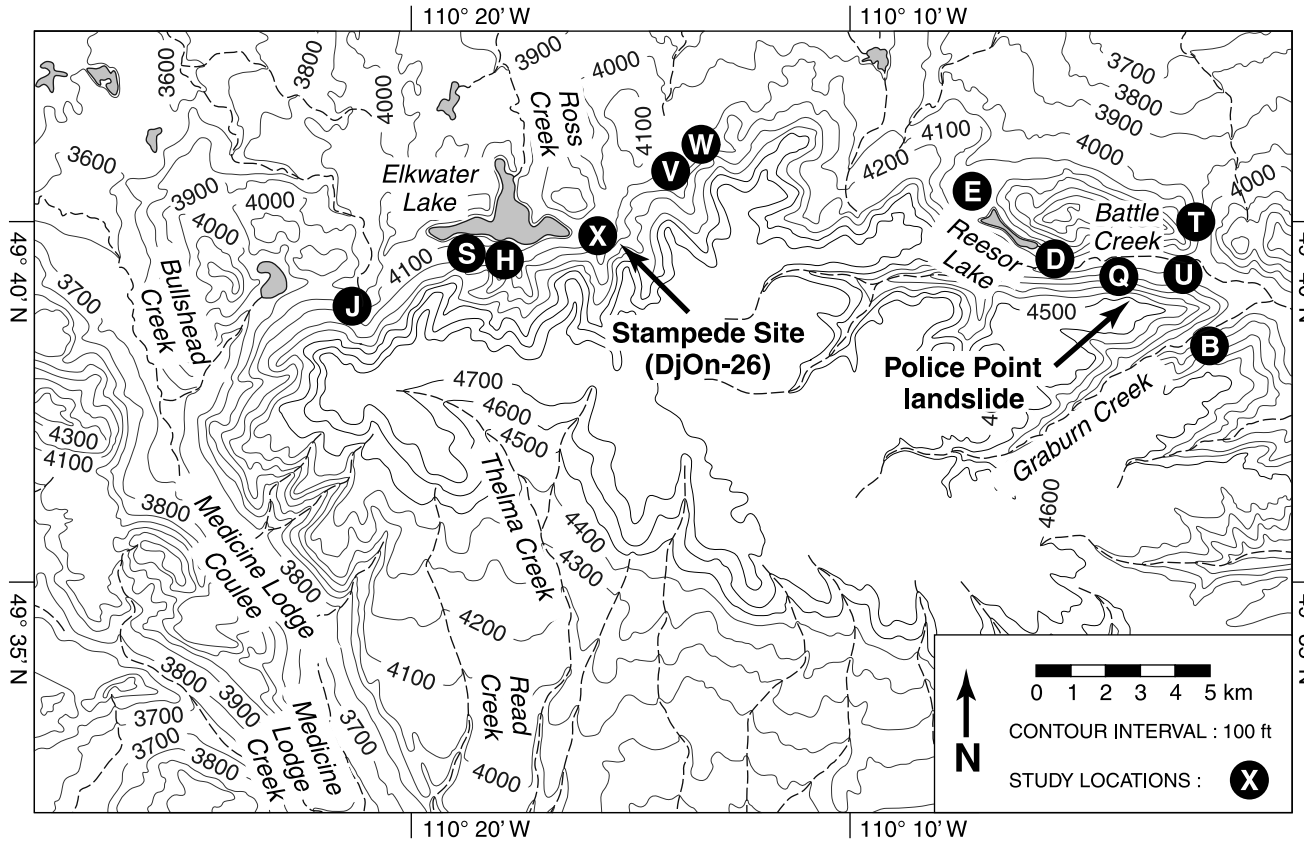

FIGURE 2. Map showing the Alberta portion of the West Block of the Cypress Hills, with key features and study locations indicated: B) Lower Graburn Creek (no site designation); D) DjOm-30; E) DkOm-22; H) DjOn-38; J) DjOo-13 (East Kajewski site); Q) DjOm-18 (East Battle Creek site); S) West Central Day Use Area (no site designation); T) DkOm-23; U) DjOm-31; V) DkOn-48; W) DkOn-47; X) DjOn-26 (Stampede site).

Carte de la partie ouest des Cypress Hills, en Alberta, montrant les principaux éléments du paysage, ainsi que les sites d'étude : B) cours inférieur du Graburn Creek (site non identifié) ; D) DjOm-30 ; E) DkOm-22 ; H) DjOn-38 ; J) DjOo-13 (site Kajewski est) ; Q) DjOm-18 (site Battle Creek est) ; S) West Central Day Use Area (site non identifié) ; T) DkOm-23 ; U) DjOm-31 ; V) DkOn-48 ; W) DkOn-47 ; X) DjOn-26 (site Stampede).

ARCHEOLOGICAL BACKGROUND

Because the study discussed in this paper occurred in the Alberta portion of the West Block, the following summary focuses on this area. The subject of limited archeological survey in the late 1950s and early 1960s, the West Block received greater attention in the mid-1960s, when recognition that it had been a nunatak suggested that it was a promising location for early human occupation of the Northern Plains. With this in mind, archeologists from the University of Alberta undertook a research program in the Alberta portion of the West Block during 1966 and 1967, identifying over 90 sites and conducting excavations at 10 of them (Bonnichsen, 1972; Bonnichsen and Baldwin, 1978). One of these locations, the East Battle Creek site (DjOm-18), was observed to contain multiple archeological occupations in discrete strata within an alluvial fan, a pattern similar to the sequence discovered at the Stampede site a few years later.

Most of the subsequent archeological work conducted in the West Block has been in the form of cultural resource management projects associated with development in and around Cypress Hills Provincial Park. Most of these projects have involved identification of threatened sites through survey, with limited excavation in some cases, a situation that has provided limited information about these sites.

An exception is the Stampede site (DjOn-26). Located in the meltwater channel north of the West Block, about 700 m east of Elkwater Lake (Figs. 2, 3), it was identified based on the presence of lithic debitage associated with stone tool manufacturing, as well as fragmented bone, that had been exposed in the bank of a small stream that runs through the site (Gryba, 1972, 1975). Due to the large quantity of cultural material in this exposure, several 2 by 2 m test pits were opened on the south side of the stream after the site's discovery in 1971. In 1972, one of these pits was expanded to a 4 by 6 m excavation that extended 3.85 m below surface (Gryba, 1975).

These excavations revealed that the deposits at the Stampede site almost exclusively contain fine-grained sediment ranging from silty to sandy loams, with only very rare occurrences of coarser material such as sand and gravel. However, these deposits consist of alternating layers of texturally similar light and dark sediment (Figs. 4, 5 [Location X, auger test # 2]), with high densities of archeological material concentrated in the

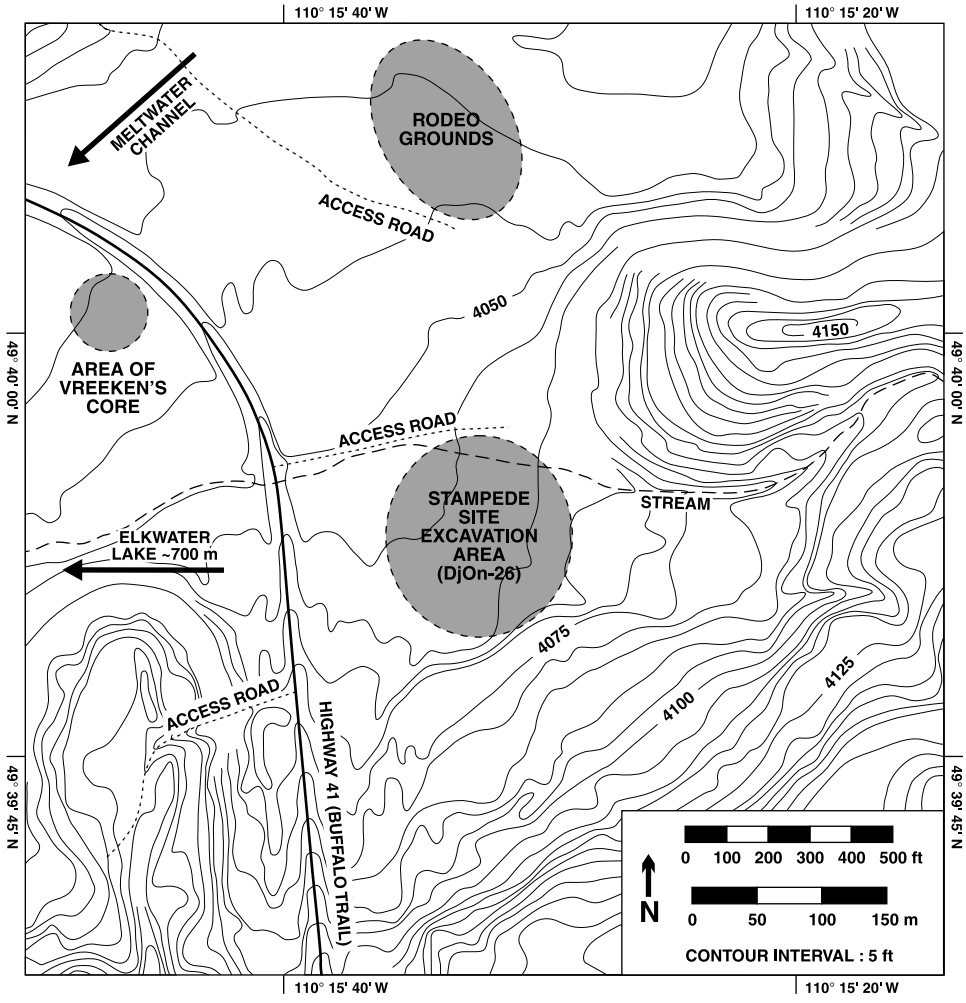

FIGURE 3. Map showing the topography and key features in the area immediately adjacent to the Stampede Site.

Carte montrant la topographie et les principaux éléments du paysage dans l'aire adjacente au site Stampede.

dark bands and virtually no artifacts in the intervening light layers (Gryba, 1972, 1975). The result is an extended sequence of stratigraphically discrete archeological occupations. Such sequences are rare at sites on the Northern Plains, because few locations consistently experience the periodic but regular episodes of deposition necessary to separate multiple occupations by burying the ground surface between them. Moreover, sites with discrete cultural strata are valuable, because clear separation between different occupations makes them much easier to interpret than the temporally conflated bands of mixed archeological material found in sites lacking this type of depositional history. Gryba (1975) postulated that the banded sequence at the Stampede site was an alluvial deposit, interpreting the dark layers as buried soils formed during periods of landscape stability and the light layers as overbank material left by occasional floods from the nearby stream.

Chronological information on the sequence exposed in his 4 by 6 m pit was provided by a radiocarbon date of 7245 ± 255 BP (NMC-571) from a bone sample found in a cultural level 3.5 m below surface (Gryba, 1975), as well as a tephra band from the eruption of Mount Mazama at about 6730 ± 40 BP (Hallett *et al.*, 1997; *cf.* Zdanowicz *et al.*, 1999 for an estimate of 7627 ± 150 cal BP) found 3.0 m below surface. Also, diagnostic projectile points associated with the Bitterroot (7500 to 5000 BP) and Oxbow (5000 to 2500 BP) cultures were recovered from a number of cultural layers that were vertically distributed in a fashion chronologically consistent with the tephra and the radiocarbon date. Although excavations were discontinued in 1972, an auger test conducted in the bottom of the pit at this time revealed additional dark bands, suggesting the possibility of occupations predating 7245 ± 255 BP (Gryba, 1975).

Excavations at the Stampede site were resumed in 2000 as part of SCAPE. They have substantially expanded the horizontal extent of Gryba's 4 by 6 m pit, confirming that the archeological material at the site is not only extremely dense, but also concentrated in stratigraphically discrete bands of dark sediment separated by culturally sterile layers of light sediment. Also, although additional radiocarbon dates are not yet available, the distribution of diagnostic projectile points is consistent with the patterning recorded by Gryba (1972, 1975).

In addition to these excavations, SCAPE research at the site has integrated efforts to understand the depositional history of the Stampede site (*e.g.*, Klassen, 2002). A key issue has been the identification of the processes responsible for forming the archeologically rich dark bands. Because many of these layers are no more than a few centimetres thick and

FIGURE 4. The west wall of Gryba's 4 by 6 m excavation (Gryba, 1975), showing the extended sequence of dark and light bands characteristic of the deposits at the Stampede Site. The increments on the scale at the bottom of the photograph are 0.10 m long. The Mazama tephra, located at 3.0 m below surface, is indicated by the white arrow. The slight downward deflection of the bands reflects minor slumping of the pit's walls in the interval between its original excavation in the early 1970s and the initiation of new work at the site in 2000. These bands are typically more planar when they are undisturbed.

La paroi ouest de la tranchée de 4 m sur 6 de E.M. Gryba (Gryba, 1975), montrant la séquence de bandes claires et foncées qui caractérisent les dépôts du site Stampede. La graduation sur l'échelle est aux 0,10 m. La flèche montre le tephra de Mazama, à 3,0 m sous la surface du sol. La légère déviation des bandes reflète un léger affaissement des parois entre le moment de l'excavation, au début des années 1970, et des nouveaux travaux entrepris en 2000. Les bandes sont davantage planes lorsqu'elles se trouvent en contexte sédimentaire plus stable.

lack clearly developed horizons, it has been argued that at least some of them are not soils, but instead represent organically rich sediments transported from upslope locations (G.L. Running, personal communication, 2002). However, the artifacts in the dark bands are frequently found closely associated with immovable cultural features such as hearths and pits. Also, diagnostic projectile points indicative of progressively earlier cultures consistently occur in progressively lower levels. For these reasons, the majority of the dark bands at the site are most easily explained as buried soils separated by culturally sterile light layers reflecting depositional events that gradually built the sequence at the site by covering these previously stable surfaces and providing new ones for subsequent episodes of soil formation and human occupation.

The processes responsible for depositing these light bands also represent an important issue. Gryba's original hypothesis regarding the role of flooding from the nearby stream remains tenable. However, the site is closely flanked by slopes to the south and east (Fig. 3), a situation that, when coupled with the proximity of a stream channel draining these slopes, is conducive to the formation of alluvial fan deposits. Also, in the past, other streams draining different sections of the nearby slopes may have contributed to alluvial fan and overbank deposition in this location, particularly considering the substantial changes to local slope and channel morphology suggested by the several metres of deposition that have occurred at the site since the mid-Holocene. Additionally, given the adjacent topography, landslides may have played a significant role, both by depositing material directly over the site and by exposing sediment, making it available for transport to the site by processes such as slope wash and fluvial erosion. Similarly, eolian processes have been active in the Cypress Hills during the Holocene (Catto, 1983; Vreeken, 1987). In addition to depositing sediment directly over the site, such process may have made easily erodable material available for transport by other processes.

The role of Elkwater Lake in the formation of the deposits at the Stampede site represents another area of debate. Questions about its influence have emerged based on research conducted by Vreeken (1987) on a core from the area between the east end of the lake and the site (Fig. 3). Vreeken indicates that, although the upper section of this core is consistent with an alluvial fan, its lower portion reflects deposition in a lacustrine environment, implying that the area covered by the lake was closer to the site in the past and may, in fact, have been immediately adjacent to or covering it, a scenario that suggests that lacustrine deposition may have played a role in its formation (Wiseman *et al.*, this volume).

STUDY HYPOTHESES AND OBJECTIVES

The present study was developed to provide regional context for the investigations at the Stampede site by determining if similar sequences of alternating dark and light bands containing stratigraphically discrete archeological occupations are present at additional locations in the Alberta portion of the West Block of the Cypress Hills. The study was based on two hypotheses.

First, previous geomorphic research, coupled with the data from the Stampede site, strongly suggests that the processes

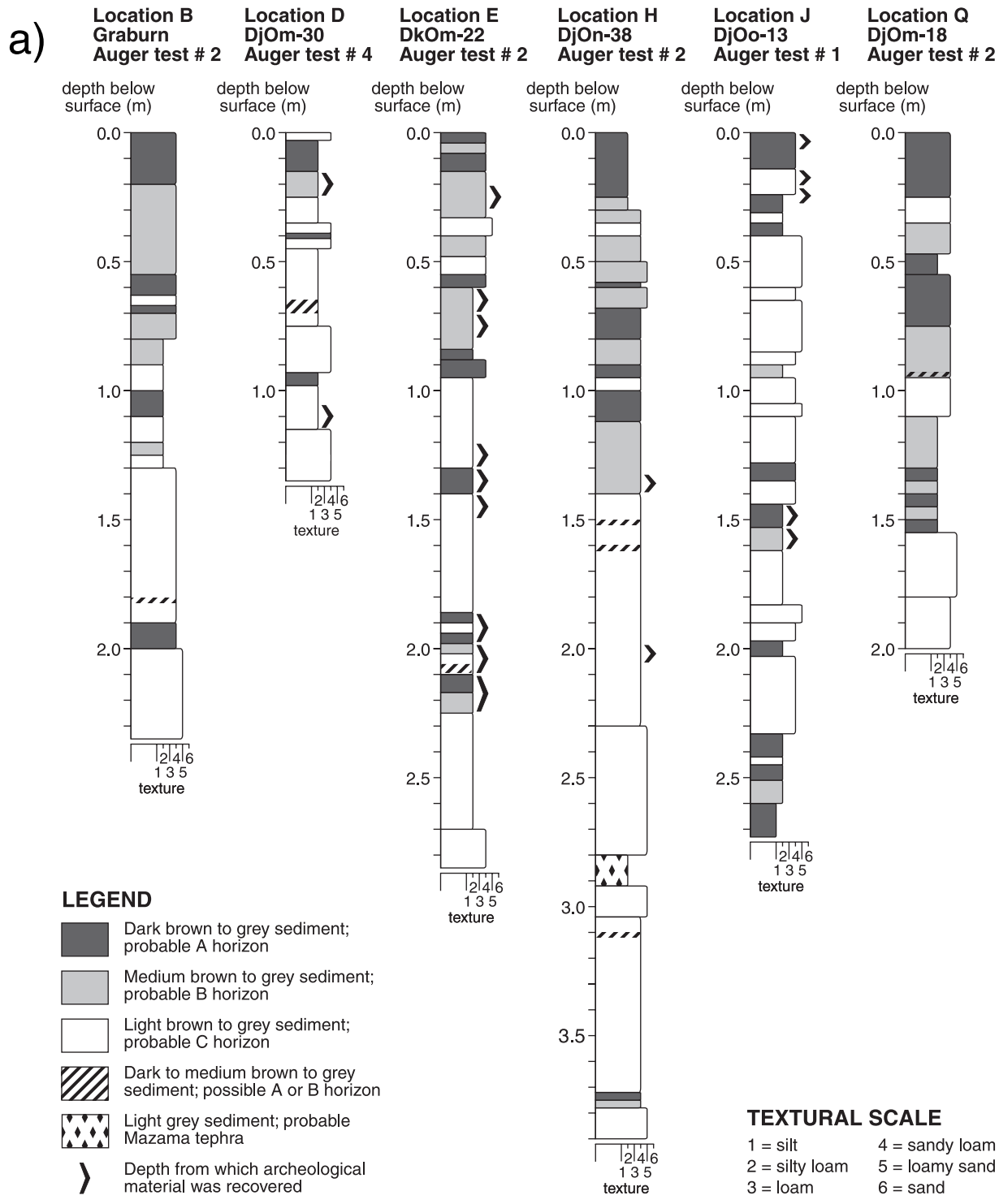

FIGURE 5. The stratigraphy of representative auger tests from the study locations, with occurrences of archeological material indicated.

La stratigraphie des sondages à la tarière représentatifs, aux différents sites d'étude ; la profondeur des artéfacts est indiquée.

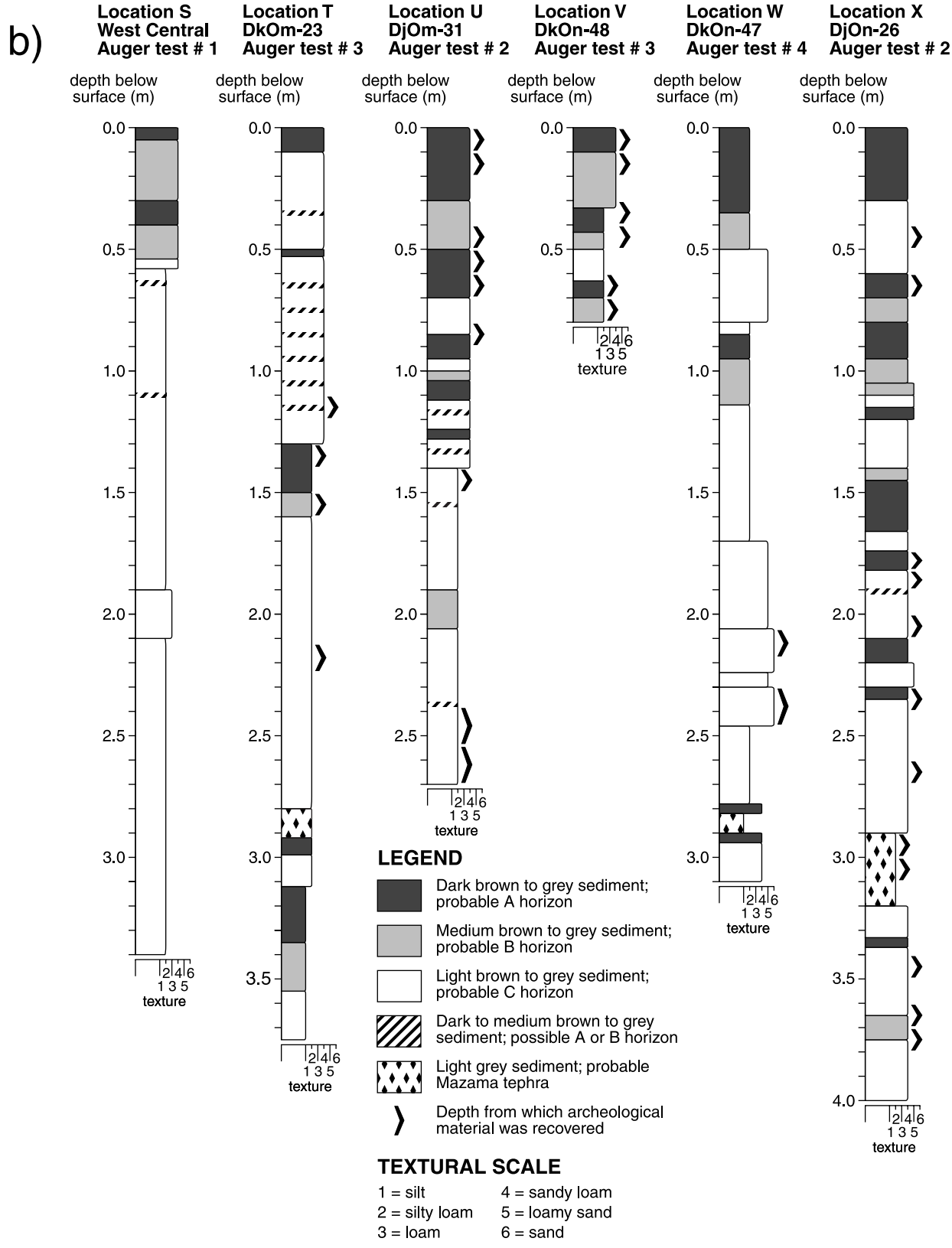

FIGURE 5 (suite).

responsible for creating the deposits at the site have been active in the Cypress Hills throughout the Holocene. Specifically, the elevated plateaus appear to have been sediment sources, while the nearby meltwater channels seem to have acted as receiving areas for material transported from upslope and deposited by a variety of processes, including mass wasting, slope wash and alluvial fan building, with additional contributions from vertical and lateral accretion associated with stream flooding and migration, as well as eolian deposition. The banded sequences at the Stampede site and the East Battle Creek site suggest that these processes did not operate continuously. Instead, these sites appear to have experienced episodes of deposition separated by periods of stability during which vegetation developed and soils formed, a pattern which, if common throughout the meltwater channels, would have created numerous locations containing similar sequences.

Second, because the unusual physiography of the Cypress Hills provides resources unavailable in the surrounding area, they are likely to have been attractive to the indigenous populations of the Northern Plains, a hypothesis supported by the importance of these resources to aboriginal groups during the historic period (Bonnichsen and Baldwin, 1978). This may, in turn, have encouraged frequent, extended or intensive use of the Cypress Hills, resulting in the deposition of high densities of archeological material.

Because the cyclical pattern of deposition and stability in the meltwater channels would have periodically buried any archeological material left by human activity, formation of archeological sites in these areas is favoured. Moreover, at sites used on more than one occasion, this pattern would have resulted in the creation of clearly separated cultural strata like those at the Stampede site. Thus, the unusual ecology and climate of the Cypress Hills, coupled with their dynamic geomorphic history, suggest that they are likely to contain multiple archeological sites with extended sequences of discrete cultural strata like those at the Stampede site.

By attempting to locate such sites, this study offered a means to clarify the depositional history of the Stampede site and to understand the significance of the Stampede site's exceptionally rich archeological occupations by providing comparative data from similar locations. Moreover, given the Northern Plain's lack of archeological sites with multiple stratigraphically discrete occupations, this study provided an opportunity to ascertain if the dynamic geomorphology of the Cypress Hills has made them a context in which the presence of such valuable sites can be reliably predicted and identified.

SELECTION OF STUDY LOCATIONS

Twelve locations (Fig. 2) were selected for study based on the geomorphic and archeological literature available on the Cypress Hills, maps and air photos of the West Block, and the stratigraphic data from the Stampede site, as well as firsthand assessment of potential locations. Several criteria guided the selection. First, for reasons outlined above, most of these locations are situated in meltwater channels. Second, many are near streams that drain the adjacent slopes, because the presence of streams increases the likelihood of alluvial deposition and some forms of mass wasting. However, places where prominent lobes of landslide material were clearly evident on the surface were avoided, because these thick mantles of overburden complicated subsurface testing. Additionally, although the fact that Graburn Creek Valley extends from the unglaciated centre of the West Block's plateau indicates that it was not created by meltwater (McPherson and Rannie, 1969; W. Vreeken, personal communication, 2003), one location in its watershed (Location B) was selected to determine if topographic lows formed by other agents experienced the type of episodic deposition of interest to this study. Also, given the debate regarding the role of Elkwater Lake in the formation of the Stampede site (Wiseman *et al.*, this volume), two locations near its south shore (Locations H and S) were selected to learn more about its influence on deposition in adjacent areas.

Because this study involved both the identification of banded deposits and of any cultural material in such deposits, the selection of locations near resources of interest to archeological groups was a key consideration. For this reason, the proximity of many promising locations to features such as streams, as well as the protection offered by the low-lying meltwater channels, was fortuitous, because this ensured that these locations had the geomorphic characteristics necessary to build stratified deposits, while also providing water and shelter.

However, to enhance the possibility of finding stratified deposits containing cultural material, two locations were chosen based on their proximity to previously reported archeological sites containing artifacts in buried contexts similar to the Stampede site (Locations J [DjOo-13, the East Kajewski site], and Q [DjOm-18, the East Battle Creek site]). The presence of such material suggested that these locations may have been established points on the cultural landscapes of past human groups, making them more likely to have experienced repeated use than locations with appropriate geomorphic features but with no evidence of archeological occupation. Additionally, the Stampede site (Location X [DjOn-26]) was selected, because the information gathered by the excavations at the site offered a point of comparison for the data provided by the more limited subsurface testing conducted at the other study locations.

Also, locations adjacent to the north slope of the Alberta portion of the West Block and in the Battle Creek Valley were chosen as the focus of this study, because significant sections of the meltwater channels associated with these areas fall within the public lands of Cypress Hills Provincial Park, minimizing logistical issues associated with land access.

METHODOLOGY

Unlike the Stampede site, where a cutbank allowed the archeological strata to be seen, most of the locations selected for this study lacked such exposures. For this reason, investigation of these locations required the use of a subsurface testing strategy capable of revealing the presence of banded sequences, as well as recovering archeological material. With this in mind, three different methods were employed.

The deposits at each location were initially characterized by using a 10 cm diameter bucket auger to conduct one to five subsurface tests measuring 1 to 5 m in depth. Although the

bucket auger disturbed the structure of the deposits, it retrieved enough sediment to determine if these deposits incorporated extended sequences of light and dark bands. Additionally, the volume of sediment retrieved proved sufficient to check for archeological remains. This was done by using pressure water to sieve each sample through 2 mm mesh. Any items left in the mesh were collected and examined under low magnification to determine if they were lithic debitage generated by stone tool manufacturing, fire broken rock created by the relatively high temperatures produced by hearth fires, or fragments of bone associated with animal processing. Some of these bone fragments were submitted for radiocarbon analysis to date the strata from which they were derived.

Based on the auger testing, nine locations (Locations B, E, H, J, Q, T, U, W and X) were selected for additional investigation. Specifically, two to five cores measuring 3 cm in diameter and approximately 3 to 10 m in depth were taken from these locations. This was done with a Geoprobe, a truck-mounted percussion coring system that minimizes disturbance to the sediment, allowing more detailed characterization of its structure. These cores also provided sample material for laboratory analysis. Methods employed have included or will include particle size analysis, loss-on-ignition, phytolith analysis, stable isotope analysis and radiocarbon dating.

In addition to the cores, shovel tests were dug at three locations (Locations E, T and U) where auger testing indicated the presence of banded sequences and yielded relatively large quantities of archeological material. Six pits measuring 50 cm by 50 cm at the surface and 80 cm in depth were excavated at each location. Also, the sediment retrieved from these test pits was dry screened through 6.35 mm mesh. Any items left in the mesh were washed and examined under low magnification to determine if they were archeological. Because the pits were excavated in 10 cm levels, it was possible to examine the distribution of the cultural material retrieved using the screen relative to the strata observed in the test pits.

RESULTS AND DISCUSSION

The auger tests conducted for this project indicated that the subsurface deposits at 11 of the 12 study locations (Locations B, D, E, H, J, Q, T, U, V, W and X) incorporate extended sequences of fine-grained sediment containing alternating light and dark bands that generally range from silty to sandy loams and show relatively little textural variation. This finding is supported by the test pits dug at Locations E, T and U (Figs. 5, 6). Analysis of the cores is in progress, but preliminary examination of their contents confirms the presence of such sequences at the nine locations where they were collected (Fig. 7).

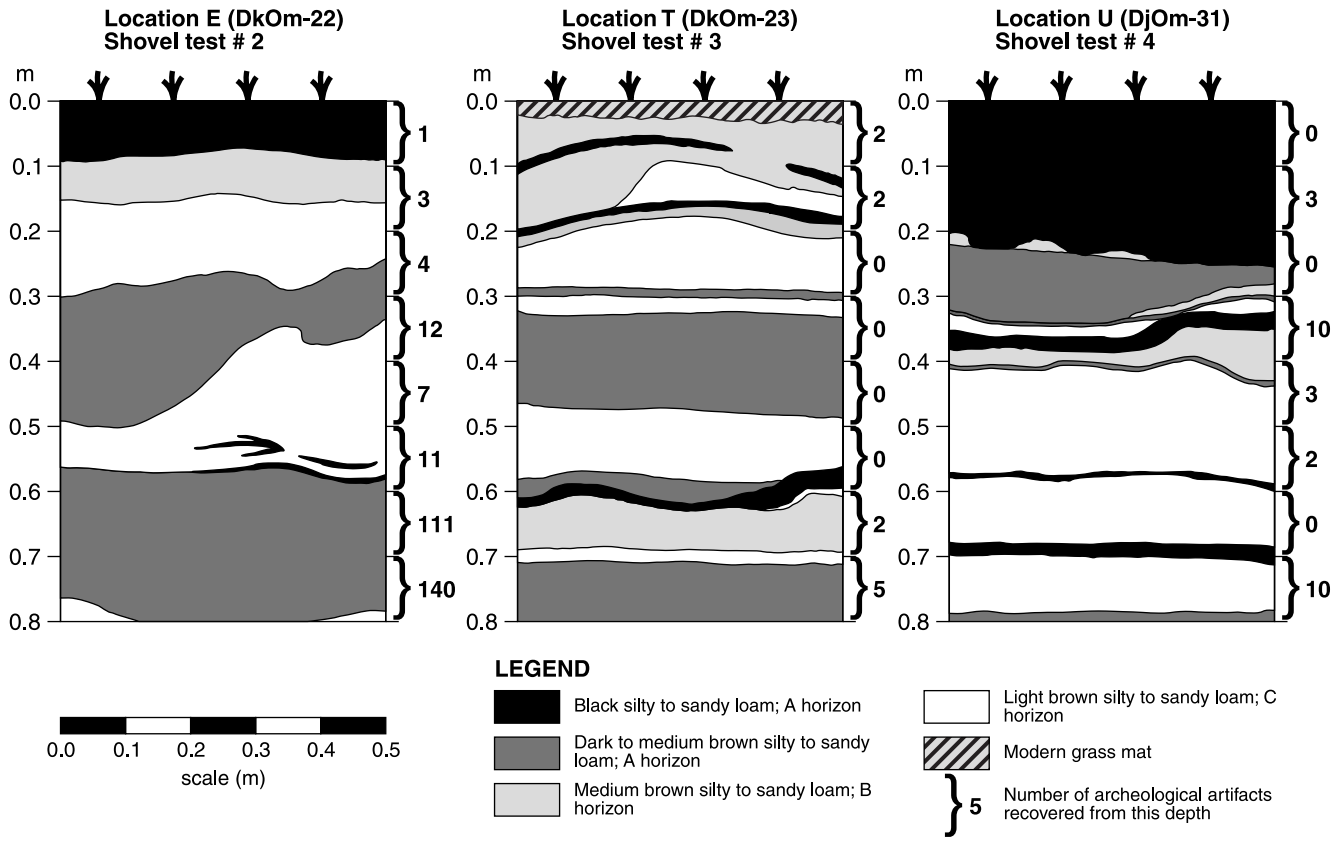

FIGURE 6. The stratigraphy of representative shovel tests from Locations E (DkOm-22), T (DkOm-23) and U (DjOm-31), with associated artifact counts indicated.

La stratigraphie des sondages à la pelle représentatifs aux sites E (DkOm-22), T (DkOm-23) et U (DjOm-31), ainsi que le nombre d'artéfacts recouvrés selon la profondeur.

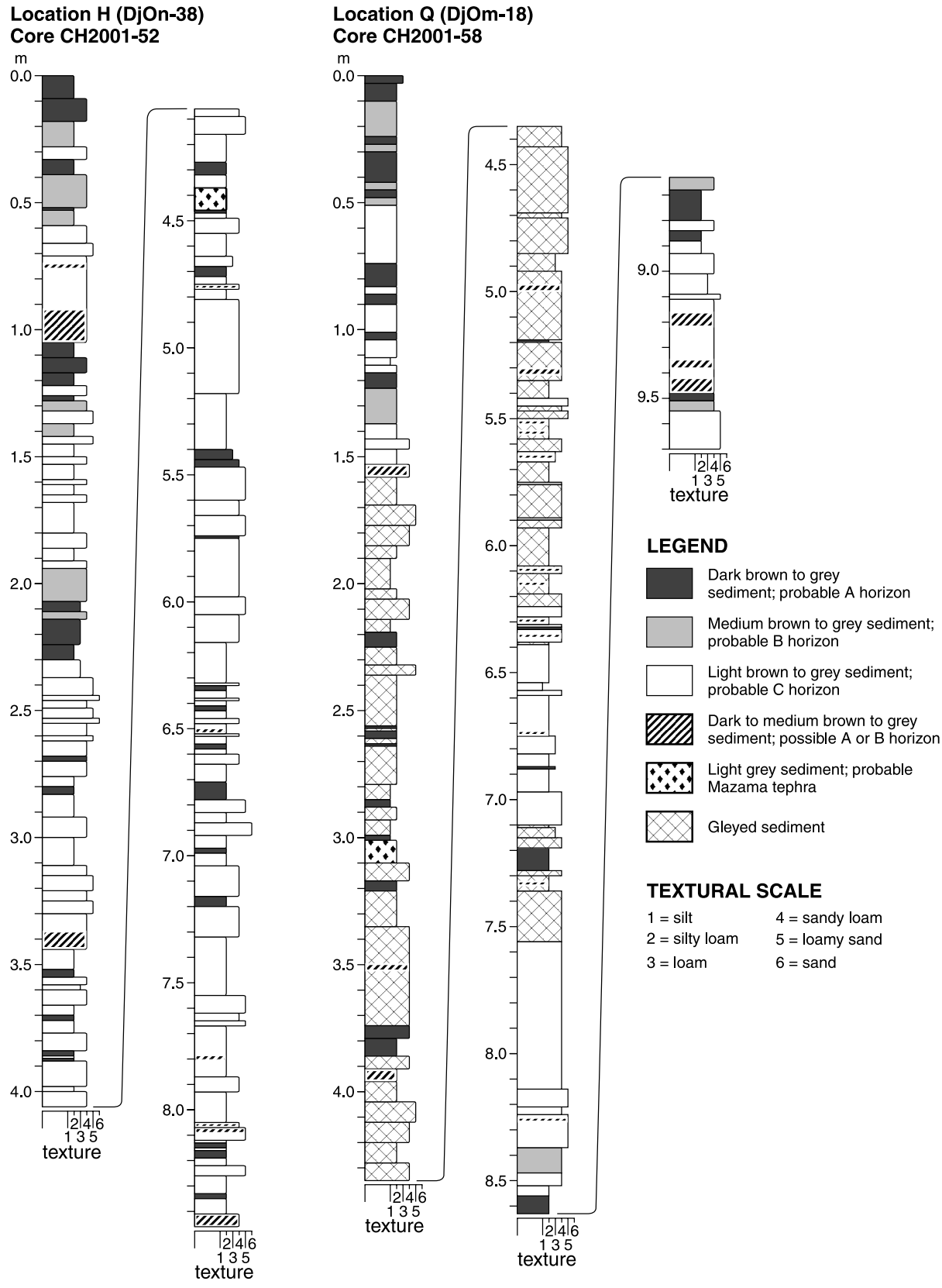

FIGURE 7. The stratigraphy of representative cores from Locations H (DjOn-38) and Q (DjOm-18).

La stratigraphie des carottes représentatives aux sites H (DjOn-38) et Q (DjOm-18).

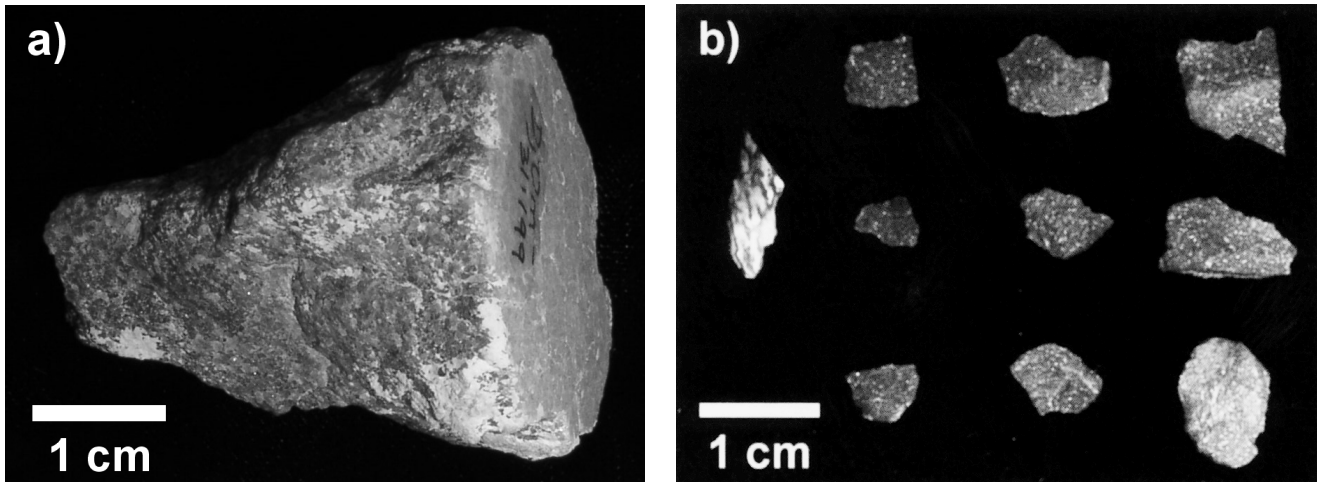

FIGURE 8. Examples of archeological material recovered during auger testing: a) fire broken rock from Location U (DjOm-31, auger test # 2, 80-90 cm below surface); b) on left, one bone fragment and on right, nine pieces of quartzite debitage from Location X (DjOn-26, auger test # 2, 182-190 cm below surface).

Exemples d'artéfacts recouvrés lors des sondages à la tarière : a) éclat de pierre chauffée au site U (DjOm-31, sondage nº 2, à 80-90 cm sous la surface du sol) ; b) à gauche, fragment d'os ; à droite, neuf éclats de débitage de quartzite au site X (DjOn-26, sondage nº 2, à 182-190 cm sous la surface).

The ubiquity of these banded deposits suggests that, as hypothesized, the meltwater channels in the Cypress Hills have experienced a dynamic history of deposition characterized by intermittent deposition of sediment transported from upslope, with intervening periods of landscape stabilization and soil formation. Moreover, the presence of such sequences in numerous locations other than the Stampede site suggests that the geomorphic dynamism of the meltwater channels makes them well suited to the formation of stratified archeological sites.

Screening of the sediment recovered by the auger tests demonstrated the ubiquity of archeological material in these deposits. In fact, it indicated that all three of the locations situated near previously recorded archeological sites (Locations J [DjOo-13], Q [DjOm-18] and X [DjOn-26]), as well as seven of the nine locations situated in areas lacking previously identified archeological sites (Locations D [DjOm-30], E [DkOm-22], H [DjOn-38], T [DkOm-23], U [DjOm-31], V [DkOn-48] and W [DkOn-47]), contain evidence for past human use, including lithic debitage associated with stone tool manufacturing, bone fragments indicative of animal processing and fire broken rock formed by the high temperatures typical of fires built by humans (Figs. 8a, 8b; Table I). Unfortunately, this material did not include any chronologically diagnostic tools such as projectile points.

Although the test pits dug at three of these locations (Locations E, T and U) were only able to access the top 80 cm of the banded deposits, they yielded many additional artifacts, confirming the archeological occupations suggested by the much smaller auger samples (Table II). Furthermore, these pits revealed a marked tendency for the artifacts to be concentrated in the dark bands (Fig. 6), a pattern suggested by the auger tests and similar to the distribution of artifacts at the Stampede site. The presence of this pattern at these three study locations suggests that, as postulated for the Stampede site, episodes of human occupation at these sites occurred during periods of landscape stability and soil formation, with the burial of the resulting cultural detritus taking place during subsequent episodes of deposition. Moreover, it implies that, in many instances, archeological material from temporally discrete occupations at these sites is likely to be stratigraphically separated by the culturally sterile sediment deposited during such episodes.

However, there are some important contrasts between the archeological occupations at the Stampede site and the other study locations. In particular, the auger tests at the Stampede site (Location X) yielded larger quantities of cultural material than the other study locations (Table I). Although the limited samples provided by the auger tests strongly suggest that these data should be interpreted cautiously, they indicate that the Stampede site may have experienced more intense human use than other sites in the Cypress Hills, a scenario that finds some corroboration in the exceptionally high frequency of artifacts and features encountered during excavations at the Stampede site. An important exception to this pattern is Location E (DkOm-22), where the relatively large numbers of artifacts recovered by the auger and shovel tests approach the density of artifacts found at the Stampede site. Nonetheless, the relative paucity of the archeological material at the other study locations does not obviate the fact that most of them yielded such material. This, in turn, implies that, as originally hypothesized, the Cypress Hills not only have the geomorphic features necessary for the formation of extended banded sequences, but also appear to have been attractive to indigenous groups, producing many locations where cultural material left by these groups has been buried in, and preserved by, such deposits.

At several locations, chronological information on the banded sequences and the associated archeological occupations has been provided by radiocarbon dates on bone fragments recovered during auger testing (Table III). This information is supplemented by the presence of a layer tentatively identified as Mazama tephra in a number of auger tests and during preliminary inspection of several cores (Table IV).

TABLE I

Archeological material recovered from auger tests

Location	Auger test number	Artifact count			Total artifacts
		Lithic debitage	Fire broken rock	Bone and tooth fragments	
D (DjOm-30)	4	2			2
	Total	2			2
E (DkOm-22)	1	1	2	2	5
	2	5	2	31	38
	3	1	1	6	8
	Total	7	5	39	51
H (DjOn-38)	1	2			2
	2	2			2
	4			1	1
	Total	4		1	5
J (DjOo-13)	1		4	5	9
	2	2	2	3	7
	Total	2	6	8	16
Q (DjOm-18)	3	1			1
	Total	1			1
T (DkOm-23)	1	3		6	9
	2			1	1
	3	1		5	6
	Total	4		12	16
U (DjOm-31)	1		1	2	3
	2	2	3	21	26
	3		2		2
	Total	2	6	23	31
V (DkOn-48)	1	1		5	6
	2			2	2
	3	12		3	15
	4		1	1	2
	5	5	3	4	12
	Total	18	4	15	37
W (DkOn-47)	2	2			2
	3			1	1
	4	1		1	2
	Total	3		2	5
X (DjOn-26)	1			15	15
	2	24		31	55
	3	10		3	13
	Total	34		49	83
Total for all auger		77	21	149	247

Radiocarbon dates for deposits below these tephra bands are not yet available, so rates of early Holocene deposition are unknown. However, the existing chronological data make it possible to estimate sedimentation rates for the subsequent periods (Table V). Locations at which the Mazama tephra is present appear to have experienced sedimentation ranging from 4.16 to 6.61 cm/100 years since the tephra's deposition at about 6730 BP. However, the availability of radiocarbon dates for Locations T and E allow more precise estimates of mid- to late Holocene sedimentation. Location E experienced rates of 4.92 and 4.69 cm/100 years during the periods from present to 1320 BP and 1320 to 4570 BP, respectively, while Location T experienced rates of 6.92 and 3.03 cm/100 years during the periods from present to 1950 BP and 1950 to 6730 BP, respectively. These values suggest an increase in deposition rates from the mid-Holocene to present, a finding that contrasts with data from Harris Lake, which suggest decreasing sedimentation rates during this period (Sauchyn, 1990).

However, the postulated episodic nature of the deposition at the study locations differs from the continuous sedimentation in

TABLE II

Archeological material recovered from shovel tests

Location	Shovel test number	Artifact count			Total artifacts
		Lithic debitage	Fire broken rock	Bone and tooth fragments	
E (DkOm-22)	1	2	3	21	26
	2	40	22	227	289
	3	14	2	46	62
	4	17	20	188	225
	5	21	12	0	33
	6	12	3	47	62
	Total	106	62	529	697
T (DkOm-23)	1	19	4	0	23
	2	2	0	0	2
	3	2	0	9	11
	4	7	3	1	11
	5	9	7	0	16
	6	9	4	0	13
	Total	48	18	10	76
U (DjOm-31)	1	14	15	12	41
	2	6	20	6	32
	3	0	1	5	6
	4	2	5	21	28
	5	7	3	11	21
	6	11	10	37	58
	Total	40	54	92	186
Total for all shovel tests		194	134	631	959

TABLE III

AMS radiocarbon dates of samples from auger tests

Location	Auger test number	Depth below ground surface (m)	Sample type	Age (BP)	Laboratory sample number
E (DkOm-22)	2	0.60 to 0.70	Bone	1320 ± 70	TO-10015
E (DkOm-22)	2	2.10 to 2.25	Bone	4570 ± 70	TO-10017
T (DkOm-23)	3	1.30 to 1.40	Bone	1950 ± 70	TO-10018
T (DkOm-23)	1	3.30 to 3.40	Tooth	6610 ± 70	TO-10019

TABLE IV

Occurrences of bands identified as Mazama tephra

Location	Subsurface test type	Subsurface test number	Depth of tephra below surface (m)
H (DjOn-38)	Auger test	2	2.80 to 2.92
H (DjOn-38)	Auger test	3	4.45 to 4.55
H (DjOn-38)	Geoprobe core	CH2001-52	4.37 to 4.46
Q (DjOm-18)	Geoprobe core	CH2001-56	2.89 to 2.96
Q (DjOm-18)	Geoprobe core	CH2001-58	3.01 to 3.10
T (DkOm-23)	Auger test	3	2.80 to 2.92
W (DkOn-47)	Auger test	4	2.82 to 2.88
X (DjOn-26)	Auger test	2	3.00 to 3.10

TABLE V

Sedimentation rates for study locations calculated using radiocarbon dates and occurrences of Mazama tephra

Location	Subsurface test type	Subsurface test number	Period (BP)	Sedimentation rate (cm/100 years)
E (DkOm-22)	Auger test	2	0-4570	4.76
E (DkOm-22)	Auger test	2	0-1320	4.92
E (DkOm-22)	Auger test	2	1320-4570	4.69
T (DkOm-23)	Auger test	3	0-6730	4.16
T (DkOm-23)	Auger test	3	0-1950	6.92
T (DkOm-23)	Auger test	3	1950-6730	3.03
T (DkOm-23)	Auger test	1	0-6610	5.07
H (DjOn-38)	Auger test	2	0-6730	4.16
H (DjOn-38)	Auger test	3	0-6730	6.61
H (DjOn-38)	Geoprobe core	CH2001-52	0-6730	6.49
Q (DjOm-18)	Geoprobe core	CH2001-56	0-6730	4.29
Q (DjOm-18)	Geoprobe core	CH2001-58	0-6730	4.47
W (DkOn-47)	Auger test	4	0-6730	4.19
X (DjOn-26)	Auger test	2	0-6730	4.45

Harris Lake, complicating comparison. This type of episodic deposition also complicates efforts to calculate sedimentation rates, particularly in a case such as this, when the limited number of chronological control points may bridge multiple depositional events. Nonetheless, the distribution of the light and dark bands in the auger tests can be used to suggest a scenario that is more consistent with Sauchyn's model for Holocene landscape change in the Cypress Hills. Interpretation of the dark bands is made more difficult by questions that remain regarding the processes that created them. However, for reasons noted above, the sequence at the Stampede site is most easily explained by interpreting the majority of the dark bands as buried soils, suggesting that such an approach is reasonable for other sequences in comparable contexts.

The vertical distribution, thickness and frequency of these dark bands are also difficult to interpret. Certainly, if these bands are regarded as buried soils, variation in these attributes may reflect a number of formative influences, including sedimentation rate, parent material, topography, vegetation, climate and time, as well as processes of degradation, such as loss of organic matter due to oxidation in the burial environment. However, if organic degradation is assumed to be minimal and if the limited differences in topography and parent material generated by the similar settings of the study locations are recognized, variability in the dark bands can be seen as the product of changing sedimentation, vegetation and climate, as well as time available for soil formation. These factors are difficult to disentangle, but this does not preclude using the patterning of the dark bands to comment on their influence.

The data provided by the auger tests (Fig. 5), coupled with preliminary examination of two cores (Fig. 7), indicate that, although dark bands are present in the sections immediately

above and below the Mazama tephra, they tend to be relatively thin and infrequent. In contrast, the dark bands closer to the current surface are more prominent and comparatively thick, a pattern confirmed by the test pits (Fig. 6). The trend toward fewer thinner dark bands around the Mazama tephra is also evident in the large exposures created by the current excavations at the Stampede site (Fig. 4).

If the majority of these dark bands represent buried soils, then this patterning suggests that episodes of soil formation during the mid-Holocene may have been less frequent and less conducive to the production of thick soil horizons than those during the late Holocene. This is not necessarily inconsistent with the increases in late Holocene deposition suggested by the sedimentation rates at Locations E and T, despite the fact that increased sedimentation rates suggest shorter time frames for episodes of soil development. Instead, it implies that the climate and/or vegetation associated with mid-Holocene soil formation episodes were less able to form thick soil horizons than those experienced during the late Holocene. This scenario is consistent with Sauchyn's interpretation of Harris Lake (Sauchyn 1990), which suggests that the mid-Holocene in the Cypress Hills was characterized by higher temperatures, lower precipitation and less established vegetation than the late Holocene.

Although such broad patterns can be observed in the subsurface sequences at the study locations, these patterns do not indicate that periods of deposition and stability in the meltwater channels were synchronized. In fact, the banded deposits at these locations contain individual and distinct series of dark and light bands. As a result, these bands cannot be correlated between the study locations, nor can they be interpreted to reflect contemporaneous geomorphic events that simultaneously affected the Cypress Hills as a whole. Rather, the specific depositional sequences at these locations appear to be products of highly local geomorphic influences, such as adjacent topography, nearby vegetation and previous depositional history, as well as localized disturbances, such as fire. Nonetheless, they also reflect the impacts of regional controls, such as climate, allowing broad similarities in these sequences to be interpreted in terms of supralocal trends.

CONCLUSIONS

Further study of the cores will provide additional information on the history of landscape development in the meltwater channels of the West Block of the Cypress Hills. However, the data provided by the auger tests and test pits clearly demonstrate the ubiquity of banded deposits in these channels, suggesting that they have experienced a geomorphic history characterized by periodic deposition of sediment from the adjacent slopes, alternating with episodes of landscape stabilization and soil formation. These tests also revealed that the banded deposits at most of the study locations contain archeological material. Furthermore, they indicated that such material tends to be clustered in the dark bands thought to represent buried soil surfaces and is generally absent from the light bands thought to represent episodes of deposition.

These findings have several implications. First, the frequency with which archeological material was encountered at the study locations strongly suggests that the rich array of resources offered by the unusual climate and ecology of the Cypress Hills was, in fact, very attractive to indigenous groups, leading to a pattern of heavy use that generated a high density of cultural detritus. Second, the cycles of stability and deposition experienced by the meltwater channels resulted in the periodic burial of such detritus, leading to the formation of many archeological sites. Furthermore, at sites occupied on multiple occasions, this ongoing pattern of episodic deposition favoured the preservation of these occupations in stratigraphically discrete cultural layers. As mentioned previously, such sites are interpretively valuable and relatively rare in many parts of the Northern Plains, strongly suggesting that the meltwater channels of the Cypress Hills offer an exceptional opportunity to study past cultures in this region and merit much greater archeological attention. Additionally, this study suggests that using geomorphic criteria to identify settings likely to contain under-represented classes of archeological sites is a viable strategy and should be given greater consideration in archeological research.

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REFERENCES

Beaudoin, A.B. and Lemmen, D.S., 2000. Late Quaternary History and Geoarchaeology of Southeastern Alberta and Southwestern Saskatchewan. GeoCanada 2000, Field Trip Guidebook 3, Calgary, 55 p.

Bonnichsen, R., 1972. Proposal for the Evaluation of Known Archaeological Resources in the Cypress Hills Provincial Park. Parks Division, Department of Lands and Forests, Government of Alberta, Edmonton, 11 p.

Bonnichsen, R. and Baldwin, S.J., 1978. Cypress Hills Ethnohistory and Ecology. Archaeological Survey of Alberta, Occasional Paper 10, Edmonton, 87 p.

Breitung, A.J., 1954. A botanical survey of the Cypress Hills. The Canadian Field-Naturalist, 68: 55-92.

Catto, N.R., 1983. Loess in the Cypress Hills, Alberta, Canada. Canadian Journal of Earth Sciences, 20: 1159-1167.

Christiansen, E.A., 1979. The Wisconsinan deglaciation of southern Saskatchewan and adjacent areas. Canadian Journal of Earth Sciences, 16: 913-938.

Christiansen, E.A. and Sauer, E.K., 1988. Age of the Frenchman Valley and associated drift south of the Cypress Hills, Saskatchewan, Canada. Canadian Journal of Earth Sciences, 25: 1703-1708.

Furnival, G.M., 1950. Cypress Lake Map Area, Saskatchewan. Geological Survey of Canada, Ottawa, Memoir 242, 161 p.

Goulden, M.R. and Sauchyn, D.J., 1986. Age of rotational landslides in the Cypress Hills, Alberta-Saskatchewan. Géographie physique et Quaternaire, 40: 239-248.

Gryba, E.M., 1972. Preliminary Report on the 1971 Field Season at Site DjOn-117. B.A. honours thesis, Department of Anthropology, University of Alberta, Edmonton, 191 p.

_____ 1975. The Stampede Site (DjOn-26): A Deeply Stratified, Multi-component Site in the Cypress Hills Provincial Park of Alberta. Alberta Parks Planning Division, Parks Branch, Alberta Department of Parks, Recreation and Wildlife, Edmonton, 186 p.

Halladay, I.R., 1965. A survey of the natural history, p. 37-54. *In* R.L. Zell, ed., Cypress Hills Plateau, Alberta and Saskatchewan. Alberta Society of Petroleum Geologists, 15th Annual Field Conference Guidebook, Part 1, Calgary, 288 p.

Hallett, D.J., Hills, L.V. and Clague, J.J., 1997. New accelerator mass spectrometry radiocarbon ages for the Mazama tephra layer from Kootenay National Park, British Columbia, Canada. Canadian Journal of Earth Sciences, 34: 1202-1209.

Jungerius, P.D., 1969. Soil evidence of postglacial tree line fluctuations in the Cypress Hills area, Alberta, Canada. Arctic and Alpine Research, 1: 235-246.

Klassen, J., 2002. Depositional processes and soil formation at the Stampede archaeological site (DjOn-26), Alberta. Geological Association of Canada-Mineralogical Association of Canada Joint Annual Meeting (Saskatoon, Saskatchewan), Abstracts, 27: 62.

Klassen, R.W., 1992. Nature, origin, and age relationships of landscape complexes in southwestern Saskatchewan. Géographie physique et Quaternaire, 46: 361-368.

_____ 1993. Landscape complexes and their relationships to the Late Tertiary and Quaternary geology of southwestern Saskatchewan, p. 1-19. *In* D. J. Sauchyn, ed., Quaternary and Late Tertiary Landscapes of Southwestern Saskatchewan and Adjacent Areas: Field Trip Guidebook for the INQUA Commission on Formation and Properties of Glacial Deposits Field Conference, University of Regina, 113 p.

_____ 1994. Late Wisconsin and Holocene history of southwestern Saskatchewan. Canadian Journal of Earth Sciences, 34: 1822-1837.

Kulig, J.J., 1996. The glaciation of the Cypress Hills of Alberta and Saskatchewan and its regional implications. Quaternary International, 32: 53-77.

Last, W.M. and Sauchyn, D.J., 1993. Mineralogy and lithostratigraphy of Harris Lake, southwestern Saskatchewan, Canada. Journal of Paleolimnology, 9: 23-39.

Lemmen, D.S., Vance, R.E., Campbell, I.A., David, P.P., Pennock, D.J., Sauchyn, D.J. and Wolfe, S.A., eds., 1998. Geomorphic Systems of the Palliser Triangle, Southern Canadian Prairies: Description and Response to Changing Climate. Geological Survey of Canada, Ottawa, Bulletin 521, 72 p.

McPherson, H.J. and Rannie, W.F., 1969. Geomorphic effects of the May 1967 flood in Graburn watershed, Cypress Hills, Alberta, Canada. Journal of Hydrology, 9: 307-321.

Porter S.C., Sauchyn, D.J. and Delorme, L.D., 1999. The ostracode record from Harris Lake, southwestern Saskatchewan: 9200 years of local environmental change. Journal of Paleolimnology, 21: 35-44.

Sauchyn, D.J., 1990. A reconstruction of Holocene geomorphology and climate, western Cypress Hills, Alberta and Saskatchewan. Canadian Journal of Earth Sciences, 27: 1504-1510.

_____ 1993. Quaternary and Late Tertiary landscape evolution in the western Cypress Hills, p. 46-58. *In* D. J. Sauchyn, ed., Quaternary and Late Tertiary Landscapes of Southwestern Saskatchewan and Adjacent Areas: Field Trip Guidebook for the INQUA Commission on Formation and Properties of Glacial Deposits Field Conference, University of Regina, 113 p.

_____ 1999. Geomorphology of the western Cypress Hills: Climate, process, stratigraphy and theory, p. 239-247. *In* D.S. Lemmen and R.E. Vance, eds., Holocene Climate and Environmental Change in the Palliser Triangle: A Geoscientific Context for Evaluating the Impacts of Climate Change on the Southern Canadian Prairies. Geological Survey of Canada, Ottawa, Bulletin 534, 295 p.

Sauchyn, D.J. and Goulden, M.R., 1988. The role of landsliding in the evolution of the Cypress Hills, p. 63-80. *In* A.H. Paul and R.W. Widdis, eds., The Moose Mountain Papers. Regina Geographical Studies. 5, Department of Geography, University of Regina, 145 p.

Sauchyn, D.J. and Lemmen, D.S., 1996. Impacts of landsliding in the western Cypress Hills, Saskatchewan and Alberta. Geological Survey of Canada, Ottawa, Current Research 1996-B: 7-14.

Sauchyn, D.J. and Nelson, H.L., 1999. Origin and erosion of the Police Point landslide, Cypress Hills, Alberta, p. 257-265. *In* D.S. Lemmen and R.E. Vance, eds., Holocene Climate Change and Environmental Change in the Palliser Triangle: A Geoscientific Context for Evaluating the Impacts of Climate Change on the Southern Canadian Prairies. Geological Survey of Canada, Ottawa, Bulletin 534, 295 p.

Sauchyn, M.A. and Sauchyn, D.J., 1991. A continuous record of Holocene pollen from Harris Lake, southwestern Saskatchewan, Canada. Palaeogeography, Palaeoclimatology, Palaeoecology, 88: 13-23.

Stalker, A.M., 1965. Pleistocene ice surface, Cypress Hills area, p. 116-130. *In* R.L. Zell, ed., Cypress Hills Plateau, Alberta and Saskatchewan. Alberta Society of Petroleum Geologists, 15th Annual Field Conference Guidebook, Part 1, Calgary, 288 p.

Vreeken, W.J., 1987. Quaternary events in the Elkwater Lake area of southeastern Alberta. Canadian Journal of Earth Sciences, 24: 2024-2038.

Vreeken, W.J., Klassen, R.W. and Barendregt, R.W., 1989. Davis Creek silt, an Early Pleistocene or Late Pliocene deposit in the Cypress Hills of Saskatchewan. Canadian Journal of Earth Sciences, 26: 192-198.

Westgate, J.A., 1965. The Pleistocene stratigraphy of the foremost-Cypress Hills area, p. 85-111. *In* R.L. Zell, ed., Cypress Hills Plateau, Alberta and Saskatchewan. Alberta Society of Petroleum Geologists, 15th Annual Field Conference Guidebook, Part 1, Calgary, 288 p.

_____ 1968. Surficial Geology of the Foremost-Cypress Hills Area, Alberta. Alberta Research Council, Bulletin 22, Edmonton, 122 p.

Wilson, S.E., Smol, J.P. and Sauchyn, D.J., 1997. A Holocene paleosalinity diatom record from southwestern Saskatchewan, Canada: Harris Lake revisited. Journal of Paleolimnology, 17: 23-31.

Wiseman, D.J., Running IV, G.L. and Freeman, A., 2002. A paleoenvironmental reconstruction of Elkwater Lake, Alberta. Géographie physique et Quaternaire, 56: 279-290.

Zdanowicz, C.M., Zielinski, G.A. and Germani, M.S., 1999. Mount Mazama eruption: Calendrical age verified and atmospheric impact assessed. Geology, 27: 621-624.