Hillslope Sediments and Landscape Evolution in Wanuskewin Heritage Park: A Geoarchaeological Interpretation

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By

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ABSTRACT

Wanuskewin Heritage Park is situated approximately three kilometres north of the City of Saskatoon, Saskatchewan and is the location of 19 precontact archaeological sites. This study examines hillslope sediments and processes at four of the archaeological sites: Cut Arm, Meewasin, Amisk, and Thundercloud. The Cut Arm and Meewasin sites are in the South Saskatchewan River valley and the Amisk and Thundercloud sites are in the Opimihaw Creek valley. The Opimihaw Creek is a tributary of the South Saskatchewan River. The record of postglacial hillslope development is complex and fragmentary because not all erosional and depositional events are preserved at each of the study sites. However, the physical characteristics of the soil and sediment coupled with radiocarbon dates and dates from diagnostic cultural material indicate general trends.

Hillslope activity began before 5.42 ± 0.12 ka BP in the Opimihaw Valley and 3.864 ± 0.055 ka BP in the South Saskatchewan Valley. Opimihaw Valley hillslope activity began during the Altithermal period, a period of aridity and warm temperatures between approximately 9 ka BP and 4 ka BP. In both valleys, numerous but weakly developed buried soils separated by hillslope sediment record repeated episodes of slope erosion and deposition between approximately 4.5 ka BP and 3.5 ka BP. Comparison with prairie lake sediments indicates this phase of slope erosion corresponds to a climatic change from the dry conditions of the Altithermal to a period of maximum Holocene humidity

(ca. 4.5 ka BP to 3 ka BP). In addition, thin intermittent weakly developed soils are generally overlain by thicker soil profiles. The thicker soils suggest longer periods of nondeposition, landscape stability and soil formation and thus, a reduction in the frequency of hillslope erosion and deposition. This reduction in slope activity occurred after approximately 2 ka BP. Prairie paleoenvironmental data suggest the longer periods of landscape stability are related to moister climatic conditions and increased vegetation cover. Lastly, poorly sorted debris flow sediments ranging in size from clay to boulders are generally overlain by fine-grained sediments deposited from overland flow. Therefore, in addition to a reduction in slope activity there is a decrease in the competence of the slope processes in these stratigraphic sequences.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Since the 1930s, Saskatchewan archaeologists have known of the area now called Wanuskewin Heritage Park. The significance of the locale was realized in 1982 when Dr. E. G. Walker conducted an intensive survey of the area and discovered 19 precontact archaeological sites. Detailed excavations and research have been conducted at eight of these sites over the last 22 years. The excavated archaeological sites include FbNp-1 (the former Tipperary Creek site) (Walker *et al.* 1987), Amisk (Amundson 1986), Newo Asiniak (Kelly 1986), Red Tail (Ramsay 1993), Thundercloud (Mack 2000; Webster 1999), Cut Arm (Moon 2004), Meewasin and Dog Child. With the exception of Mack (2000), the research at these sites acknowledged the lithostratigraphy of the sites but did not attempt to integrate the archaeological interpretation with an environmental interpretation. Mack's (2000) research considered the geological data, but was generally limited to postdepositional processes. In addition to the archaeological investigations, a Department of Geography Master's thesis (Burt 1997) analyzed landscape evolution in Wanuskewin Heritage Park. Burt (1997) focussed her research on fluvial sediments and fluvial landforms. This study builds on the model of landscape evolution in Wanuskewin Heritage Park by integrating an examination of hillslope sediments with the archaeological research and Burt's (1997) analysis.

1.1 Research Objectives

The purpose of this study is to describe and interpret the Quaternary geology of four archaeological sites in Wanuskewin Heritage Park—Thundercloud (FbNp-25), Amisk (FbNp-17), Cut Arm (FbNp-22), and Meewasin (FbNp-9). Related to this general research objective are the following principal aims: (1) to define the main depositional processes at the four archaeological sites; (2) to establish a chronologically controlled geologic interpretation of the archaeological sites; and (3) to compare the deposits at the archaeological sites and propose a synthesis of postglacial landscape development in Wanuskewin Heritage Park. Emphasis is placed on interpreting hillslope sediments and processes.

2. SETTING

Wanuskewin Heritage Park is situated approximately three kilometres north of the City of Saskatoon, Saskatchewan (Figure 2.1). The archaeological sites are in the Opimihaw Creek valley and the South Saskatchewan River valley (Figure 2.2). The Thundercloud site (FbNp-25) occupies a toeslope surface on the east side of the Opimihaw Creek and the Amisk site (FbNp-17) occurs along a footslope surface on the west side of the Opimihaw Creek. The remaining two archaeological sites are located on the northwest side of the South Saskatchewan River valley. The Cut Arm site (FbNp-22) occurs on a midslope and the Meewasin site (FbNp-9) occupies a footslope surface. The geomorphic terms are defined in Chapter 3, Figure 3.2.

During the deglaciation of Saskatoon and the surrounding area, the South Saskatchewan River acted as a glacial spillway emptying into glacial Lake Saskatchewan. As the glacier retreated northward and glacial Lake Saskatchewan drained from the Saskatoon area (ca. 11.5 ka BP), the South Saskatchewan River cut through the prairie surface exposing glaciolacustrine and glaciofluvial sand and gravel on the uplands and sandy till along the valley slopes. Postglacial alluvium and colluvium mantle the valley slopes. The Opimihaw Creek is a tributary of the South Saskatchewan River. Glacial and alluvial processes cut the Opimihaw Valley

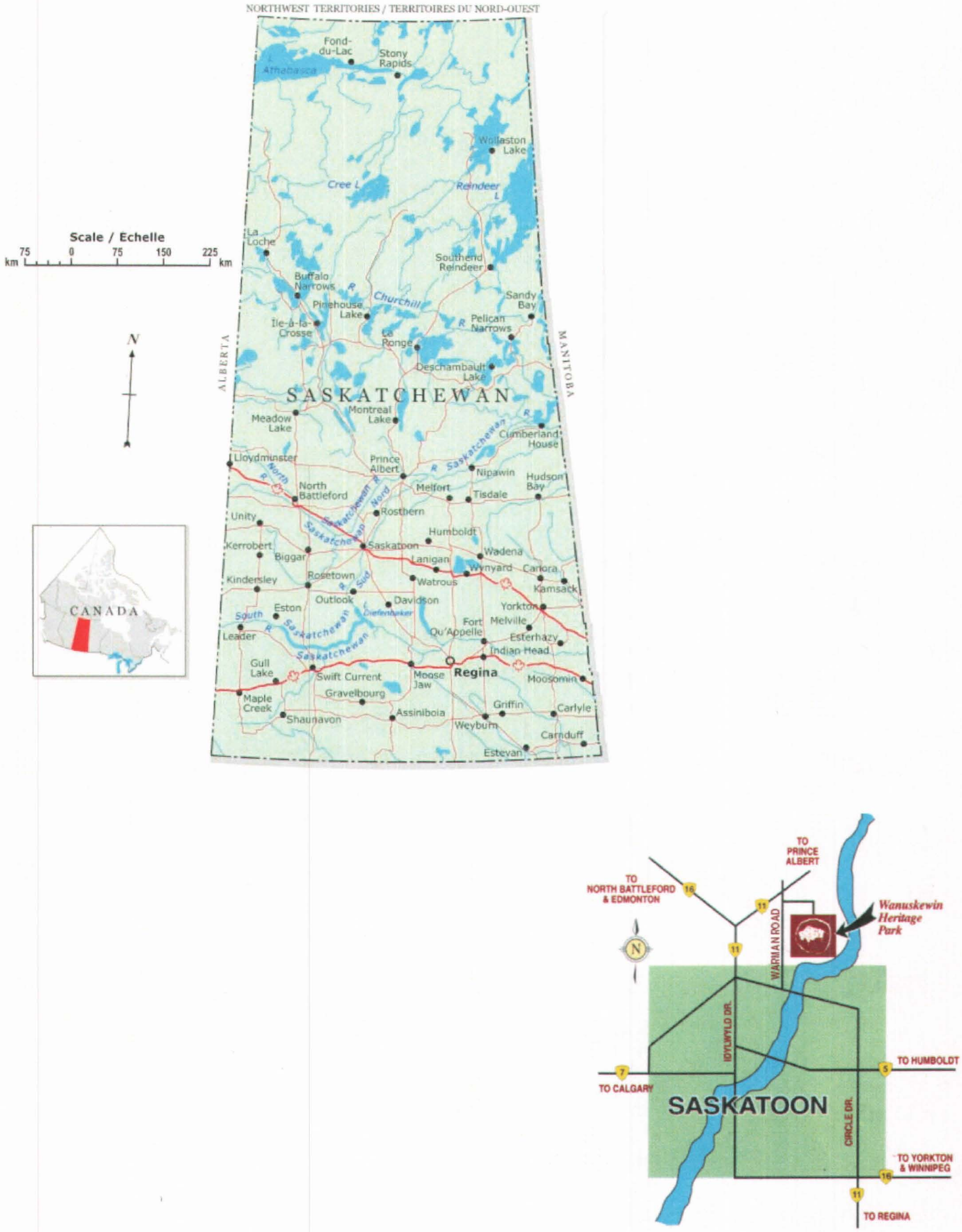


Figure 2.1 The location of Wanuskewin Heritage Park in relation to Saskatoon, Saskatchewan (Modified from http://atlas.gc.ca and http://wanuskewin.com).

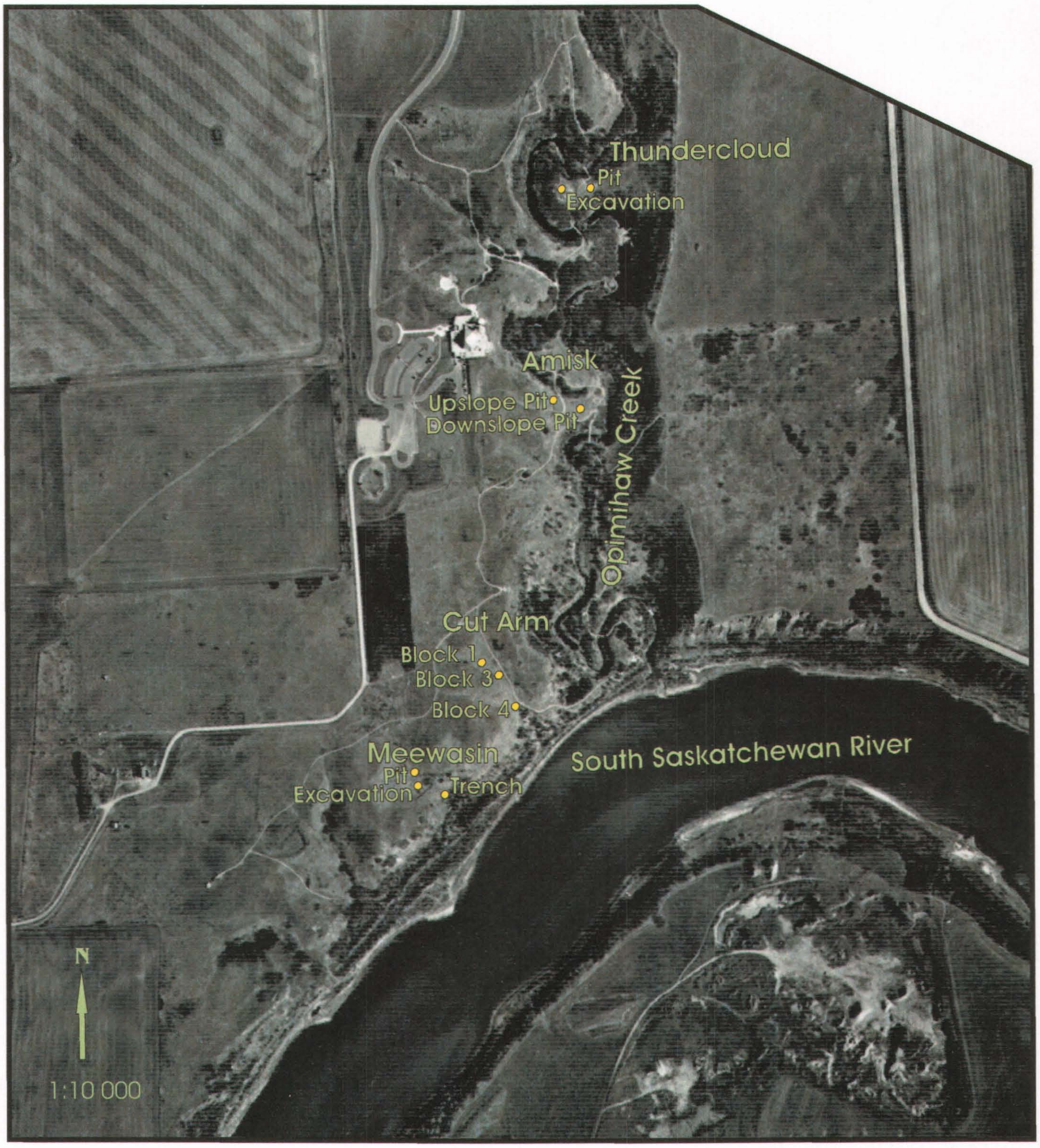


Figure 2.2 Aerial photo (1:10 000 scale) showing the location of the sample sites. Source: Information Services Corporation, OS98007 L11 #140.

and continues to be influenced by alluvial erosion and deposition as well as hillslope processes.

The Saskatchewan Land Resource Centre, University of Saskatchewan (1999) recorded Dark Brown Chernozemic soils as the dominant soil type in the Saskatoon area. Chernozemic soils are well to imperfectly drained and are generally found in cool, subarid to subhumid climates. A Chernozemic soil profile typically includes an A horizon darkened by the accumulation of organic matter representative of grassland and grassland-forest communities (Trenhaile 2004). The A horizon is underlain by a brownish coloured B horizon and a light coloured (grayish) C horizon. Lime carbonate often accumulates in the C horizon and the B and C horizon have high base saturation. Soil development is influenced by factors such as parent material (initial texture and composition of the sedimentary deposit), climate (especially the temperature and precipitation regime), topography (position of soil in relation to elevation, slope angle, and aspect), organisms (floral and faunal assemblages), and time (duration of soil formation) (Waters 1992). For these reasons, buried soils in Wanuskewin Heritage Park are not necessarily Dark Brown Chernozems. In addition, soils on the uplands or in the valley bottom differ from soils developed on the slopes. Since the development of a soil profile requires minimal erosion and deposition, slopes that are subject to mass wasting may yield Regosolic soils. Regosolic soils are weakly developed and have a thin or no A horizon, no B horizon and often only a C horizon. Regosolic soils develop in well to imperfectly drained sites and occur under a wide range of vegetation and climatic conditions. Burt (1997) observed Regosolic soils in some valley bottom and hillslope stratigraphic sequences in Wanuskewin Heritage Park.

3. LITERATURE REVIEW

This chapter summarizes the scientific literature that describes the evolution of the South Saskatchewan River valley and the Opimihaw Creek valley. Furthermore, this chapter discusses hillslope geomorphology and processes and thus, provides a basis for understanding hillslope sedimentation in Wanuskewin Heritage Park.

3.1 Deglaciation of the Saskatoon Area and the Evolution of the Opimihaw Valley

The following glacial and postglacial history of the Saskatoon area begins with the deposition of glacial sediments from the Laurentide Ice Sheet. Christiansen and Sauer's (1998) interpretation of glacial sediments in the Saskatoon area include tills belonging to the Sutherland and Saskatoon group. The Opimihaw Creek valley cuts through tills of the Saskatoon Group that include the Floral and Battleford Formations. The Floral Formation underlies the Battleford Formation and in general, tills in the upper part of the Floral Formation are hard and jointed with yellowish brown and black staining (Christiansen and Sauer 1998). Tills in the Battleford Formation are soft, massive and unstained. A boulder pavement often defines the contact between the Floral and Battleford Formations. The glacier (Laurentide Ice Sheet) that deposited the Battleford till eventually retreated to the northeast. As the Laurentide Ice Sheet withdrew northward, there was a sequential development of proglacial lakes and spillways and the deposition of glaciolacustrine and glaciofluvial sediments. With the northward retreat of the glacial ice, the South Saskatchewan River became integrated into the spillway network (Kehew and Teller 1994). This established a link between waters from the Rocky Mountains and glacial Lake Agassiz to the east. A number of studies such as Klassen (1972), Christiansen (1979), Clayton and Moran (1982), Kehew and Teller (1994), and Christiansen and Sauer (1998) have described the history of deglaciation in Saskatchewan. Of particular importance in the Saskatoon area was the formation and drainage of glacial Lake Saskatchewan. Christiansen (1979) demonstrated that by approximately 12 ka BP the glacier margin was slightly north of what is now known as the city of Saskatoon (Figure 3.1). As was common during Late Wisconsin

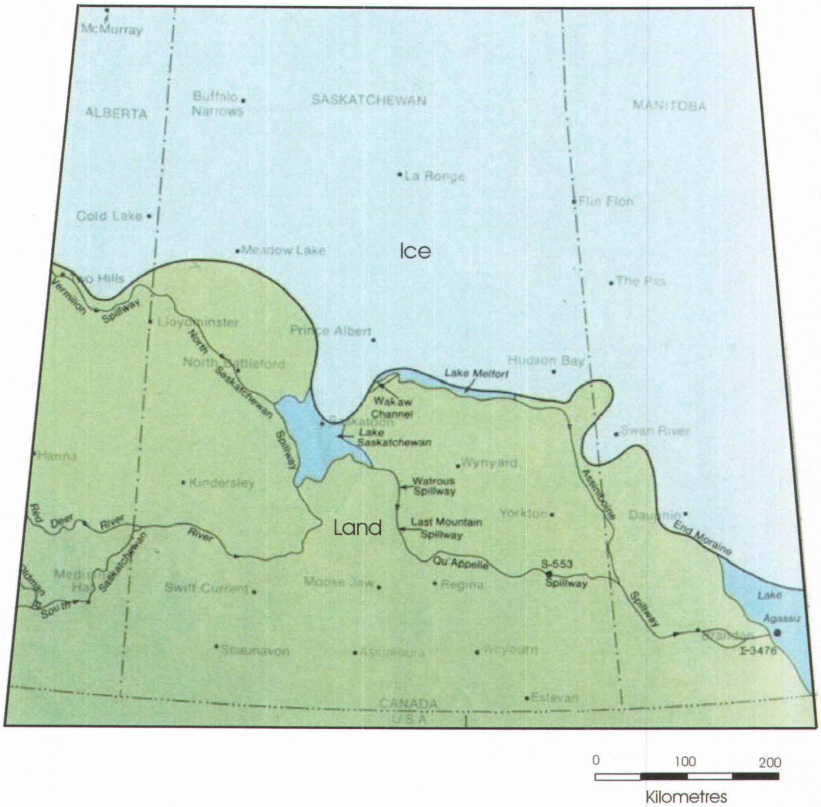


Figure 3.1 Approximate ice marginal position and drainage in Saskatchewan at ca. 12 ka BP (Modified from Christiansen 1979).

deglaciation, a lake ponded against the ice margin. This lake is known as glacial Lake Saskatchewan. The area surrounding Saskatoon including the North and South Saskatchewan River valleys was flooded by glacial Lake Saskatchewan. Christiansen and Sauer (1998) propose that around 11.5 ka BP, the ice retreated northward and Lake Saskatchewan drained from the Saskatoon area into the Prince Albert area. As glacial Lake Saskatchewan drained from the Saskatoon area, water flowed northward through a braided channel system. The channel system included the South Saskatchewan River. Some of the high level channels were later abandoned and the South Saskatchewan River became apart of the modern drainage network of the province. Aitken (2002) showed that between 11 ka BP and 12 ka BP the South Saskatchewan Valley became occupied by a nonglacial river. The channel system developed during the drainage of Lake Saskatchewan initiated the formation of the Opimihaw Creek valley.

Burt (1997) proposed a postglacial model of landscape evolution in the Opimihaw Valley with a focus on alluvial sediments. Burt's (1997) interpretation showed that changes in climate and base level conditions influenced the evolution of the valley. Thus, understanding the postglacial geomorphic history of the Opimihaw Valley first requires an understanding of Holocene climate change. An integral phase of the Holocene climatic record is the Altithermal period. The occurrence of a warm arid Holocene phase (Altithermal period) was first proposed by Antevs (1955). Antevs' Altithermal period spanned the interval from 7.5 ka BP to 4 ka BP and was defined as a gradual increase in temperature and decrease in precipitation. The Altithermal drought was succeeded by a gradual return to moister, cooler climatic conditions. Bryson *et al.* (1970) disputed the Antevs (1955) postglacial transitional model and proposed step-like climatic variation.

Bryson *et al.* (1970) recorded quasi-stable climatic episodes separated by rather rapid transitions. Recent sedimentological studies on the Northern Plains support the idea of episodic Holocene climate change. Sauchyn (1990) interpreted the climatic history of the western Cypress Hills, Saskatchewan. The study was based on variation in pollen and organic matter in Harris Lake core. Sauchyn (1990) showed that the interval between 9.12 ka BP and 7.7 ka BP was warmer and drier than present. The period of the highest Holocene temperatures, Altithermal, occurred between 7.7 ka BP and 5.1 ka BP, with maximum aridity between 7.7 ka BP and 6.8 ka BP. Approximately 5 ka BP marked the end of the Altithermal period and the beginning of the cooler, wetter conditions. The climatic interval between 4.5 ka BP and 3.2 ka BP was moister than present. The present climate and vegetation have existed for approximately 3000 years with an exception between 3 ka BP and 2.4 ka BP. This interval was cooler than present. Similarly, Schweger and Hickman (1989) interpreted the late glacial – Holocene climatic record for central Alberta. Their study analyzed the pollen, diatoms, and sedimentary pigments in sediment cores from 23 lakes and bogs. Schweger and Hickman (1989) showed that the late glacial and early Holocene time was a period of aridity and warmer temperatures, and high evaporation. By ca. 8 ka BP, the balance between precipitation and evaporation had changed and many basins now maintained permanent water. Approximately 5 ka BP marked the end of these conditions and the beginning of an even wetter climate. Present climatic conditions were established by approximately 3 ka BP. Vance *et al.* (1993) analyzed the pollen, plant macrofossils, sediment mineralogy, geochemistry, and lithology of cores from Chappice Lake, southeastern Alberta. Their study interpreted the climatic interval between 7.3 ka BP and 6 ka BP as warmer, drier, and more variable than present. Repeated desiccation of the lake indicated relatively frequent and severe droughts. By 6 ka BP the climate had ameliorated somewhat and the severe droughts had ended. However, until approximately 2.6 ka BP temperatures remained warmer and precipitation lower than present. Between 2.6 ka BP and 1 ka BP Chappice Lake was maintained at water levels higher than present. Severe recurrent drought occurred between 1 ka BP and 0.6 ka BP. The 0.6 ka BP to historic period interval was characterized by a return to relatively high lake levels with periodic brief drought episodes.

Burt's (1997) synthesis of landscape evolution in the Opimihaw Valley discussed geomorphic response to climate change as well as base level. The following is a summary of Burt's (1997) three phase interpretation with some comparison to published Northern Plains research. Phase 1 is the Opimihaw Valley postglacial incision phase. This phase was initiated around 11.1 to 10.4 ka BP and extended to some time before ca. 4.5 ka BP (Burt *et al.* 2004). As previously discussed, prairie records generally suggest that the warmer, drier Altithermal phase occurred between ca. 9 ka BP and 5 ka BP with peak aridity having passed by ca. 6 ka BP. Thus, the postglacial incision phase began during the relatively humid and cool deglacial phase of the early Holocene and continued through the warmer and drier Altithermal period. Walker (1992) suggested that during the Altithermal there was a reduction in flow and sediment discharge within the Saskatchewan River system and a corresponding reduction in flow discharge within the Opimihaw Valley. This decrease in discharge lead to the development of the underfit Opimihaw Creek. The archaeological record suggests the underfit Opimihaw Creek has existed since at least ca. 6 ka BP. The absence of cultural material before ca. 6 ka BP may be related to postglacial high water conditions in the Opimihaw Valley (Ernest Walker, personal communication 2004). Burt (1997) argues that although climate likely influenced the development of the valley, postglacial incision was mainly a response to base level change. The elevation of the South Saskatchewan River is the base level for its tributaries and historical changes in the base level caused corresponding changes in the tributaries (including the Opimihaw Creek). Glacial Lake Saskatchewan was the original base level for the South Saskatchewan River. The northward retreat of the Laurentide Ice Sheet followed by the drainage of glacial lakes resulted in a drop in base level. In response to the change in base level, the South Saskatchewan River incised its valley (Burt 1997:165). Since the South Saskatchewan River is the local base level for the Opimihaw Creek, a corresponding incision phase resulted in the Opimihaw Valley. Rains and Welch's (1988) study of Holocene terraces in the North Saskatchewan River, Edmonton Alberta, and the Whitemud and Strawberry Creek tributary valleys suggest out-of-phase development of the tributary valleys as compared to the main river valley. The North Saskatchewan River rapidly incised much of its valley in the early Holocene whereas the tributary valleys maintained relatively constant but slower rates of Holocene valley incision (Rains and Welch 1988:462). A similar scenario may apply to the South Saskatchewan River and the Opimihaw Creek. Burt (1997) showed that during the postglacial incision phase the precursor to the Opimihaw Creek was likely a sinuous or meandering river. Migration of the stream channel probably caused undercutting and slumping of the valley walls (Burt 1997:169). The incision phase continued as the climate became warmer and drier. Subsequent to the incision phase, aggradation of the Opimihaw Valley channel began sometime before 4.5 ka BP (phase 2) (Burt *et al.* 2004).

The beginning of the aggradation phase corresponds with the conclusion of the Altithermal period (ca. 9 ka BP to 4 ka BP) and thus, a transition to increasingly moist conditions. The aggradation phase likely resulted from high rates of slope erosion and increased sediment delivery to the Opimihaw Creek. Bare or sparse vegetation cover remaining from the drier Altithermal period, coupled with increased precipitation brought about an increase in sediment load. After approximately 4 ka BP, Burt (1997) interpreted a general decline in sedimentation rates and a potential increase in slope stability. A thicker vegetation cover, possibly induced by a gradually moistening climate, may have increased slope stability. However, the Amisk site sedimentary record suggests a return to higher sedimentation rates between 3.8 ka BP and 3.3 ka BP. Increased hillslope erosion may have been triggered by the temporary removal of vegetation. After 3.3 ka BP the Amisk site record suggests very slow sedimentation and periodic landscape stability (Burt 1997:177). Sometime during the past 100 to 200 years, the modern incision stage began and the Opimihaw Creek returned to downcutting (Burt 1997:180). The modern incision phase continues to present day. Burt (1997) showed that the record of environmental change in central Saskatchewan does not correspond with the onset of the modern incision phase. Thus, a drop in base level caused the return to valley incision. Undercutting of the valley walls likely occurred throughout modern incision phase. A summary of the evolution of the Opimihaw Valley and corresponding paleoclimate is presented in Table 3.1.

Table 3.1 Evolution of the Opimihaw Valley and the paleoclimate.

Phase	Date	Source
glacial Lake Saskatchewan drained from Saskatoon area	ca. 11.5 ka BP	Christiansen and Sauer (1998)
Opimihaw Valley postglacial incision	initiated some time between ca. 11.1 and 10.4 ka BP	Burt (1997)
climate warmer and drier than present	ca. 9 ka BP to 5 ka BP	Sauchyn (1990)
Opimihaw Valley aggradation	initiated some time before ca. 4.5 ka BP	Burt (1997)
climate moister than present	ca. 4.5 ka BP to 3.2 ka BP	Sauchyn (1990)
climate cooler than present	ca. 3 ka BP to 2.4 ka BP	Sauchyn (1990)
climate drier than present	ca. 1 ka BP to 0.6 ka BP	Vance *et al.* (1993)
Opimihaw Valley modern incision	initiated between ca. 0.1 ka BP and 0.2 ka BP	Burt (1997)

Understanding the deglaciation of the Saskatoon area and the subsequent evolution of the South Saskatchewan River and the Opimihaw Creek valleys is required to interpret the study site stratigraphic profiles. The history indicates glacial, glaciofluvial, glaciolacustrine, and colluvial sediments are the source materials for the hillslope deposits.

3.2 Hillslope Profile

Selby (1993) demonstrated a hypothetical nine unit landsurface model (Figure 3.2). Selby's (1993) model was adapted from Dalrymple *et al.* (1968). The model associates a section of slope with predominant processes. Selby (1993) demonstrated that all slope units may not be present in a profile, an individual unit may be repeated in a single slope profile, and the slope units may not occur in the order presented in the hypothetical model. The slope units most important to this study are the transportational midslope, the colluvial footslope, and the alluvial toeslope. Dalrymple *et al.* (1968) showed that the transportational midslope is the most actively eroding slope unit and the erosion is primarily caused by mass movement processes. Movement can occur by flow, slump, slide, creep, chemical and mechanical eluviation, and to a lesser extent surface wash (Dalrymple *et al.* 1968:65). The colluvial footslope is generally a zone where material from higher up the slope profile is redeposited. However, sediments are sometimes transported across this slope unit. Dalrymple *et al.* (1968:68) defines the alluvial toeslope as a zone where alluvial material is redeposited by a stream or river flowing at right angles to the slope. This unit is not the riverbed but rather, the floodplain. Knowing the current slope unit does not necessarily provide information about the underlying sediments and processes.

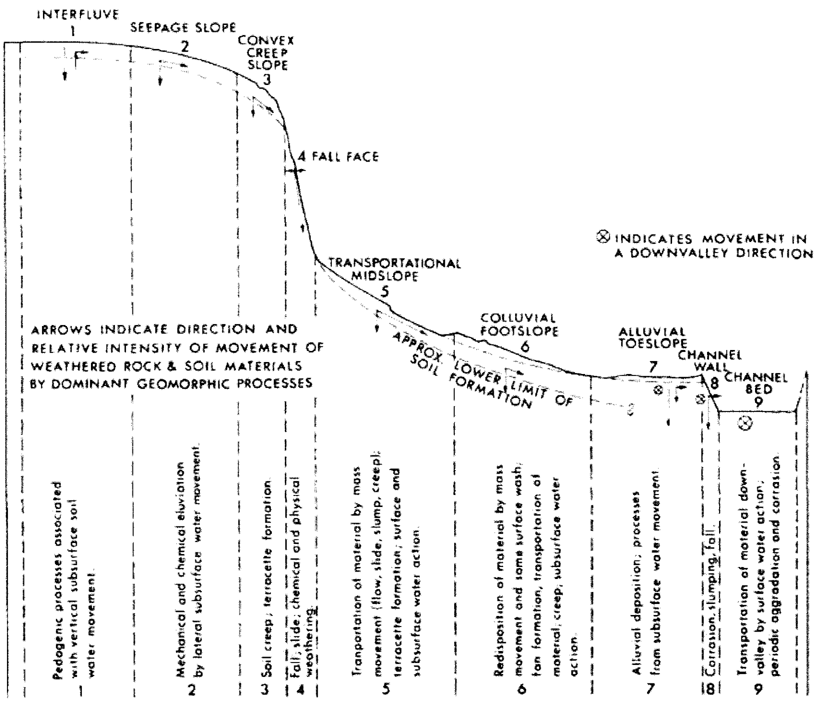


Figure 3.2 A hypothetical nine unit landsurface model defining slope units and corresponding processes (Selby 1993).

3.3 Hillslope Processes

As defined by Preston (2004:524), "hillslope processes are those geomorphic processes that involve the entrainment, transport and deposition of material from, over, and on slopes." There are two main types of hillslope processes: 1) erosion by flowing water and 2) mass movement.

3.3.1 Erosion by Flowing Water

The first set of processes involves the transport of sediment by running water on and below the surface. Throughflow is a type of subsurface flow that is discussed during the present study. Throughflow is "that water which moves laterally through relatively porous soil, above a less permeable body of soil or rock, or above a saturated zone" (Selby 1993:216). Overland flow refers to the flow of water over the surface of the slope. Types of overland flow include sheetwash, rill flow, and gully flow. Sheetwash is the flow of water of more or less homogenous depth and velocity over a surface without marked incision of the slope. However, natural slopes are usually so irregular that uniform sheetwash is a rare occurrence (Selby 1993). The concentration of water as it is diverted around obstacles, causes flow in clearly defined channels. Rills are small channels and are able to transport larger particles than sheetwash. Rills can further concentrate the flow and thus may lead to the development of gullies. Gullies are deeper and wider than rills and are commonly defined as steep sided drainage channels that transmit ephemeral flow. The quantity and size of particles transported by flowing water are related to the velocity and turbulence of the flow and thus, increase as the slope steepens and the depth of flow increases (Selby 1993:231). In addition, greater volumes of sediment are generally eroded and transported when water flows over unprotected soils (little or no vegetation cover) (Preston 2004). Wainwright (1996) demonstrated that overland flow erosion tends to be the dominant process when high intensity rainfall events occur over a period of less than 24 hours. On the other hand, mass movement processes tend to dominate when extreme rainfall events last over several days.

3.3.2 Mass Movement

Mass movement is the downslope movement of rock, sediment and soil in response to gravity. Additional stresses such as alternate freezing and thawing, shrinking and swelling, and the thermal expansion and contraction of the material may contribute to slope movements (Trenhaile 2004). Movement results when the stress on the slope material becomes greater than the strength of the material. A number of studies classify slope movements. The scheme presented in Figure 3.3 was defined by Waters (1992) and is a general classification of the main types of slope movements. Martinsen (1994) demonstrated that slope processes are not necessarily independent of each other. One movement may evolve into another or the depositional effects of one process may trigger another type of movement.

Falls are the rapid dropping, leaping, bouncing, or rolling of material from a steep slope (Trenhaile 2004:87).

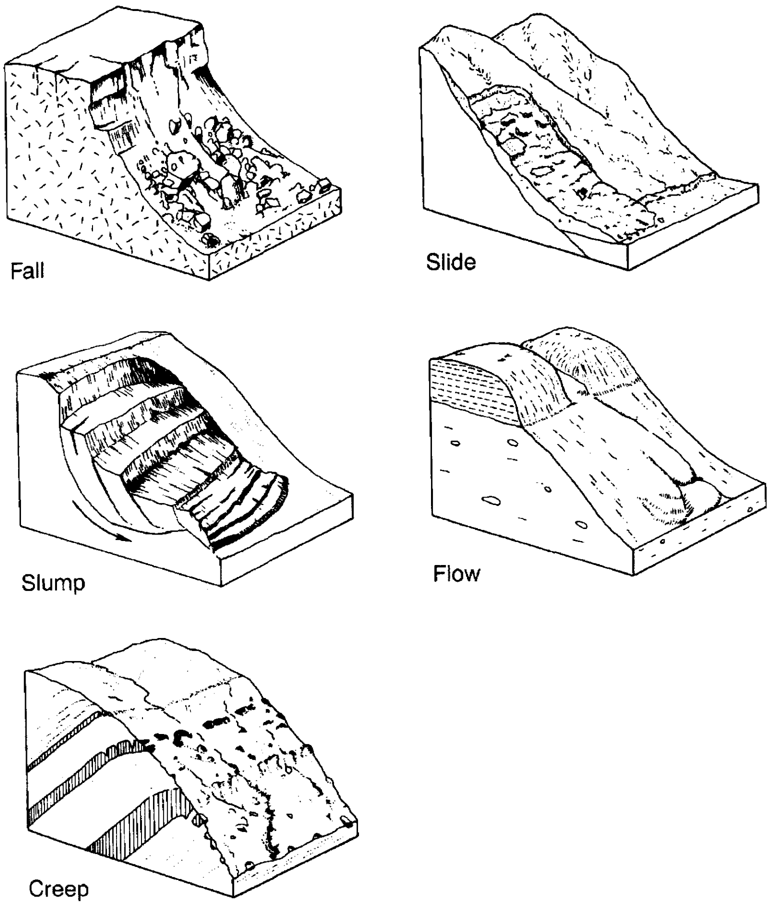


Figure 3.3 Five basic types of movements on slopes (Waters 1992).

Slides involve the downslope slipping of a coherent mass of sediments along a zone of weakness. Martinsen (1994:152) demonstrated that slides result in little or no internal deformation of the transported sediments. Types of slides include rotational slides and translational slides. Rotational slides move over short distances relative to the thickness of the slide sediments, and thus the sliding motion is mainly rotational. Evidence of rotational slides in Wanuskewin Heritage Park is discussed in the following section. Translational slides move for relatively long distances compared to the thickness of the slide and the dominant motion is translational. Trenhaile (2004:88) reported that slides are common in wet, tectonically active and earthquake prone areas with steep relief. However, slides may occur on gentle slopes when there is an increase in water pressure during heavy rains.

Slumps are generated when a coherent mass slides downward and outward along a curved failure plane (Waters 1992:230). Some schemes consider slumps to be a type of slide. Martinsen (1994) classified slumps separate from slides because slumps cause significant internal distortion of the bedding. Slumps generally require the deep percolation of water and thus, tend to occur long after the precipitation event has ended (Trenhaile 2004:90).

Flows are generally the downslope movement of water saturated debris. The material being transported may remain semicoherent or the flow may become dominantly turbulent resulting in jumbled and mixed deposits. Debris flows are of particular importance in Wanuskewin Heritage Park and will be discussed in the following section.

The slowest slope movement is creep. Creep occurs at rates that are usually imperceptible to the naked eye. Creep is often caused by seasonal variation in temperature and moisture. Possible evidence for creep includes the slow movement of isolated boulders, the accumulation of soil on the upside of obstructions, and small terraces roughly parallel to slope contours (Trenhaile 2004).

3.3.3 Dominant Hillslope Processes in Wanuskewin Heritage Park

The following hillslope processes are those most likely to have influenced landscape evolution in Wanuskewin Heritage Park. Selby (1994:83) showed that increasing power, and erosional and transport effectiveness occurs in the following sequence: rill < gully < translational slide < debris flow. The capacity to transport large clasts increases in the same order.

3.3.3.1 Overland Flow

Broad shallow gullies occur on the west side of the Opimihaw Valley. Burt (1997) interpreted the gullies as having formed during her post-glacial incision phase. Narrow gullies incise into the undercut slopes and occur on both the east and west side of the Opimihaw Valley. Burt (1997) demonstrated that gullying has been active throughout the history of valley development.

3.3.3.2 Debris Flows

Debris flows occur when highly concentrated poorly sorted mixtures of sediment (up to boulder size) and water surge down slopes in response to gravitational attraction. The resulting deposit is typically poorly sorted and commonly ungraded although some deposits can be inversely (coarsens upwards) or normally (fines upwards) graded. Though various theories discuss the morphology and dynamics of debris flows, it is generally accepted that subaerial debris flows have a steep snout or head containing the densest mixture and the coarsest particles followed by a gradually tapering body and a thin, more watery tail (Iverson 1997). Sediment concentration and mean grain size tends to decrease toward the tail of a flow (Pierson 1986). Iverson (1997:257) defined debris flows as churning masses of wet concrete with one or more unsteady and nonuniform surges. When an individual debris flow consists of multiple surges, each wave has a snout and tail (Figure 3.4). Major (1997) demonstrated that debris flow deposits might accumulate from several surges and still exhibit a massive, homogenous texture.

Similarly, sediment from separate flow events may produce homogenous, massively textured deposits. Lenses of sorted finer grained material mainly result from pulses that are more fluid during a debris flow episode. Debris flows usually result when an abundant source of material is mobilized by the addition of water (Selby 1993). Commonly, high intensity rainstorms or snowmelt trigger debris flows. The more fluid waves tend to occur during the recessional stage of the hydrologic event. The study site sedimentary records suggest debris flows play a central role in the development of the slopes in Wanuskewin Heritage Park.

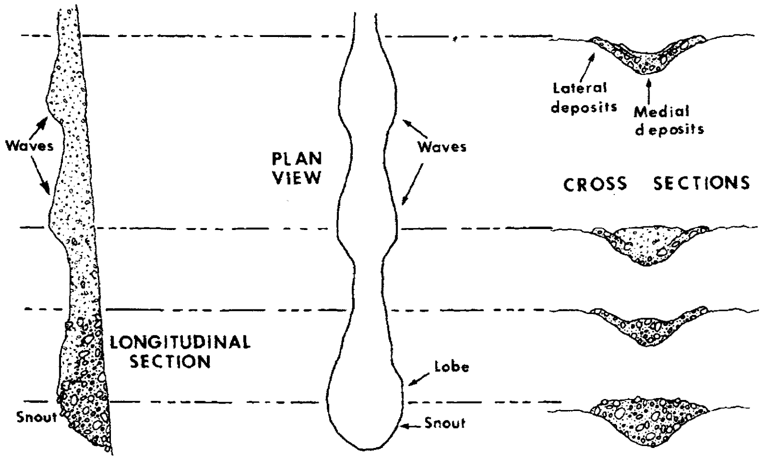


Figure 3.4 Schematic representation of a debris flow with multiple waves (Johnson and Rodine 1984).

3.3.3.3 Rotational Slides

A well preserved rotational slide was observed in the Opimihaw Valley. The slide is situated upstream of the Thundercloud site and near a man-made dam. Burt (1997) demonstrated the slide was likely caused by the undercutting of the base of the valley wall by the Opimihaw Creek. She did not observe structures within the rotational slide sediments. This is not unexpected as the central part of slides generally shows little evidence of the sliding and the basal shear zone can be extremely difficult to detect (Martinsen 1994). The matrix of a rotational slide will be essentially the same as the surrounding undisturbed slope sediments (Dikau 2004). Another slide occurs along the western slope of the Opimihaw Valley. This slope failure is situated west of the Thundercloud site and on the opposite side of the creek. This failure also results from the undercutting of the base of the valley wall by the Opimihaw Creek.

3.3.3.4 Creep

Evidence of creep in Wanuskewin Heritage Park includes small terracettes roughly parallel to slope contours and the accumulation of soil on the upslope side of some boulders. Burt (1997) investigated some terracettes near the mouth of the Opimihaw Creek. No structures were discovered in the terracette sediments. Burt (1997) suggested the formation of the terracettes occurred during her aggradation or modern incision phase.

3.3.4 Discussion

Distinction between hillslope processes is not always evident in the sedimentary record. For example, Selby (1993) reported that many types of evidence believed to be related to soil creep including soil accumulations upslope of obstructions, turf rolls, and cracks in soil may be produced by other processes such as wind, slope wash, or sliding. Complex movements further complicate interpretation of hillslope sediments. Different types of movement may operate within differing parts of the moving mass or one type of movement may develop from another type of movement. Changes in the type of slope movement may result from a downslope increase in the degree of deformation and the amount of water (Trenhaile 2004). When there was insufficient evidence in the study sites to relate a deposit to a specific slope process the sediments were broadly interpreted as the product of hillslope processes.

4. METHODOLOGY

The following methods of investigation were chosen to establish consistency in the sedimentological investigations at Wanuskewin Heritage Park. A benefit of using these particular techniques is that the results are comparable to Burt's (1997) data. The techniques were chosen because they were deemed appropriate for the scope of the study and the range of grain sizes analyzed.

4.1 Field Methods

Field investigations were conducted during the summer of 2000 and 2001. During this time, observations were made and samples were collected from one test pit at the Thundercloud site, two test pits at the Amisk site, archaeological excavations at the Cut Arm site, and one test trench, one test pit and archaeological excavations at the Meewasin site. At each of the four study sites, the stratigraphic profile was described in detail and the following attributes were recorded: colour according to the Munsell colour system, texture by the "feel method", type and depth of stratigraphic unit boundaries, sedimentary structures, and organic and cultural horizons. In addition, field observations included a description of any vertical or lateral trends in the stratigraphic profile, a general description of the exposure (size, shape and quality of the exposure) and a general description of the Quaternary sediments and landforms in the area surrounding the site.

Soil and sediment samples were collected from the units that were thick enough to allow for an uncontaminated sample. If a stratigraphic unit was thicker than 10 cms, the unit was sampled in 10 cm intervals. Sampling at greater depths was achieved by using a hand auger to obtain cores from the sediments underlying the test pits. The hand auger has the potential to extract a 5 cm diameter core in 20 cm sections. The auger is capable of penetrating to a maximum depth of two metres.

Sample locations were plotted on an aerial photograph (1:10 000 scale). The elevations of the sample sites were determined by various means: topographic maps (1:1000 scale, 1m contour interval), survey level, and altimeter. Distance between sample locations was measured by tape.

4.2 Laboratory Methods: Particle Size Analysis

Standard methods of particle size determination (sieve and pipette) were applied in the laboratory. Laboratory analysis began with the drying of the samples. All samples were air dried in a clean laboratory for approximately one week. Oven drying during sample analysis was conducted at low temperature (55°C) to avoid altering particle size distribution. Lewis and McConchie (1994:68) suggest drying samples at temperatures in the range of 40-60°C. Drying at higher temperatures can cause exchangeable ions to bind to their host minerals and form aggregates that cannot be easily dispersed during later particle size analyses. When the samples were dry, the Munsell colour was recorded and the material was disaggregated. Disaggregation techniques used during this study included both physical and chemical methods. The samples were gently ground with a mortar and pestle and the organic matter was removed by chemical means. Burt (1997) identified organic matter and carbonates as the main binding components in the Opimihaw Valley soil and sediment samples. However, Burt (1997) reported that since carbonates are a key constituent of the parent material (till), the reagent used to remove the carbonate cement would also remove some of the sediment. Therefore, only organic matter was removed from the study samples. Hydrogen peroxide (H_2O_2) was used to digest the organic matter. After disaggregation, the study samples were wet sieved. Wet sieving at 63 μm separates the gravel and sand fractions from the silt and clay sized particles. The gravel and sand fractions were analyzed by dry sieving with a nest of sieves. The set of sieves consisted of the following size fractions: 2 mm, 1.4 mm, 1.0 mm, 710 μm, 500 μm, 355 μm, 250 μm, 125 μm, and 63 μm. The sieves were placed on a sieve shaker and shaken for five minutes. The weight of each size fraction was recorded and weight percentages were calculated. Cumulative weight percentages were obtained by incrementally adding the weight percentages. Data on the silt and clay (< 63 μm) size fractions was obtained by pipette analysis. The pipette method, like other settling tube analyses, is based on Stoke's Law:

$$v = Cd^2 \qquad (4.1)$$

where

v = settling velocity of a particle

d = particle diameter with the assumption that the particle is a sphere

$$C = [(ds - df)\, g]/18\eta \qquad (4.2)$$

where

ds = particle density

df = density of the fluid at its particular temperature

g = acceleration of gravity (980 cm/sec^2)

η = viscosity of the fluid at its particular temperature

During pipette analysis, a subsample of a specific volume (20 mL) is extracted with a pipette from a suspension of silt and clay. The subsample is removed at a specified time and depth (10 cm). The sampling times were calculated from the equations and tables presented in Gee and Bauder (1986). The subsamples represent the proportion of the total silt and clay size fractions remaining in suspension above the 10 cm depth at the specified time. Thus, each subsample represents particles that are finer than the size fractions that will have settled to the 10 cm depth at the specified time. The subsample pipette data were used to calculate the percentage of silt and clay size fractions in the research samples. Detailed laboratory procedures are outlined in Appendix A.

4.3 Data Analysis

A number of graphical and statistical methods were used to interpret the grain size data and to infer mode of transport and energy of depositional processes. Cumulative curves provided a means to display and compare grain size data from individual samples. Plotting grain size (phi scale) against cumulative weight percentage on a probability scale generated the cumulative curves. An example is shown in Figure 4.1.

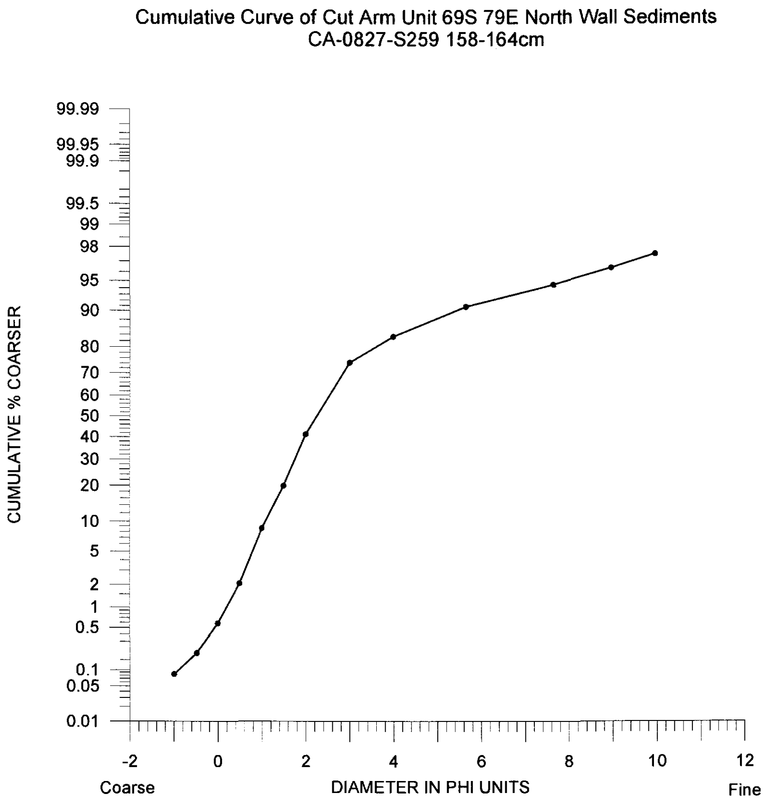


Figure 4.1 Example showing particle size data as a cumulative curve on a log probability scale.

Visher (1969) and Glaister and Nelson (1974) showed the shape of a cumulative curve reflects the nature of the transport processes. Visher (1969) compared cumulative curves of sediments from different environments and concluded that various transport mechanisms and depositional environments produce distinctive cumulative curves. Furthermore, statistical parameters such as standard deviation can be calculated from cumulative curves. The standard deviation (the dispersion of the particle sizes around the mean particle size) of each study sample was derived from the log probability cumulative curves and calculated with Folk and Ward (1957) formula for inclusive graphic standard deviation (equation 4.3).

$$\sigma_1 = \frac{\Phi 84 - \Phi 16}{4} + \frac{\Phi 95 - \Phi 5}{6.6} \qquad (4.3)$$

Folk and Ward's (1957) formula ignores approximately 5% of the distribution at each end and thus, eliminates the coarsest and finest size fractions and any error associated with these fractions. In addition, Folk and Ward (1957) demonstrated that their standard deviation formula produces accurate results even when the grain size data have a complex distribution. Standard deviation is the mathematical expression of sorting. Poorly sorted sediments consist of a wide range of particle sizes and well sorted sediments are comprised of similar sized particles. Folk and Ward's (1957) verbal sorting scale and corresponding standard deviation values are as follows:

Standard deviation	Sorting term
<0.35ϕ	very well sorted
0.35 to 0.50ϕ	well sorted
0.50 to 0.71ϕ	Moderately well sorted
0.71 to 1.0ϕ	Moderately sorted
1.0 to 2.0ϕ	poorly sorted
2.0 to 4.0ϕ	very poorly sorted
>4.0ϕ	extremely poorly sorted

Sorting provides information about transport and depositional processes and may reflect the degree to which sediment has been reworked. In addition to cumulative curves, frequency curves were used to visually display the modal distribution of the samples. The mode is the most frequently occurring particle size class interval. A sample may have a unimodal, bimodal, or polymodal distribution. Plotting grain size (phi scale) against weight percent of the individual size fractions generates the frequency curves. The frequency curves are only used as a pictorial representation of distribution and to demonstrate similarities and differences between samples. These curves do no lend themselves to quantitative assessment and thus, were not used to calculate mode values. Examples of frequency curves produced during this study are provided in the site chapters. Additional information was gained from plotting the weight percentage of gravel, sand, silt and clay against depth below surface. These graphs help detect graded bedding. Deposits whose grain size fines upwards are defined as normally graded and deposits that coarsen upwards are considered inversely graded. Furthermore, the percent of gravel, sand, silt and clay in each sample of sediment was used to attach a textural description to the deposits. The textural classification scheme shown in Figure 4.2 was adopted for this study. This system uses two triangles, one when gravel is present and the other when gravel is absent.

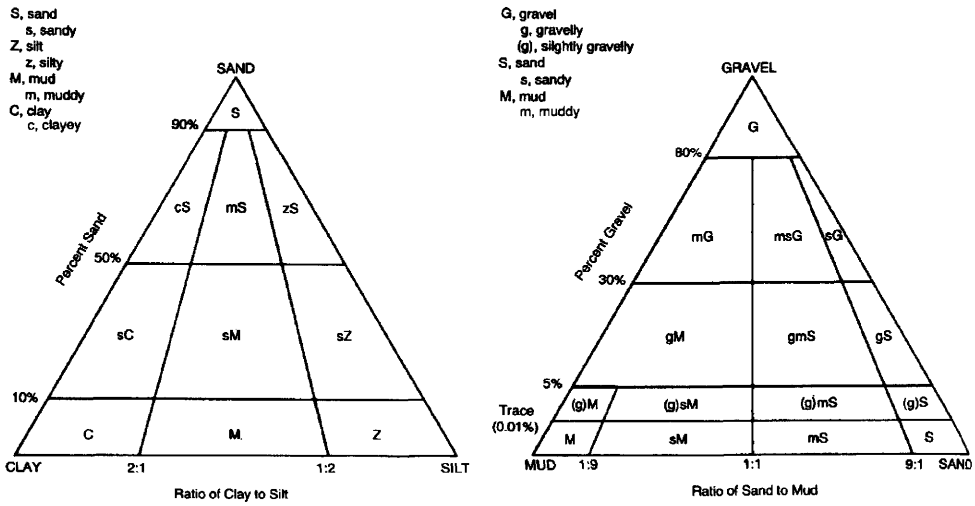


Figure 4.2 Textural classification of sediments. (Modified from Folk 1968)

4.4 Facies Definition and Classification Scheme

A facies is "a bed or group of beds showing lithologic, geometric and sedimentologic characters which are different from those of adjacent beds. A facies is considered to be the product of a specific depositional mechanism or several related mechanisms acting at the same time" (Mutti and Ricci Lucchi 1975). The facies defined in this research study were derived from field observations and laboratory data. Letter codes are used to describe the sorting, grain size and internal structure of the deposits. The facies classification scheme is shown in Table 4.1 is derived from Folk (1968), Miall (1977), Eyles *et al.* (1983), and Nelson (1992). The scheme is a three part facies code. The primary lithological categories are defined by an upper case letter and were based on sorting. As discussed in the preceding section, sorting was determined from cumulative curves and Folk and Ward's (1957) formulae. Very well sorted, well sorted, moderately well sorted, and moderately sorted deposits were described as gravel, sand, or fines (mud). The dominant grain size determined the primary lithological code. Poorly sorted, very poorly sorted, and extremely poorly sorted deposits were described as diamictons. The lower case letter before the upper case primary lithological code is a lithologic unit modifier. If the primary lithology was gravel, sand, or fines the modifier code was derived from Folk's (1968) triangular classification diagram (Figure 4.2). If the primary lithology was diamicton and the deposit contained >50% mud the sediments were defined as a muddy diamicton. Deposits with >50% sand are sandy diamictons and deposits with >30% gravel are gravelly diamictons. The boundaries for the diamicton modifier codes were extrapolated from Folk's (1968) textural classification system. Lower case internal structure codes follow the upper case primary lithological code. Internal characteristics discovered at the study sites included massive sediments, normally graded and inversely graded deposits, deposits containing lenses of sandy or gravelly sediment, deposits containing lenses of silty or clayey sediment, and deposits showing soft-sediment deformation. Massive sediments are more or less homogenous and lack internal stratification and vertical grain size grading. Normally graded deposits display a gradual fining up in grain size and inversely graded sediments display a gradual coarsening up. The internal structure code was based on field observations and trends revealed in the grain size data.

Table 4.1 The three part facies code used to describe the facies in the present study.

Lithologic Unit Modifier	Primary Lithology	Internal Structure
(g) slightly gravelly	D diamicton	m massive
g gravelly	G gravel	n normally graded
s sandy	S sand	i inversely graded
z silty	F mud (silt and clay)	d evidence of soft-sediment deformation
c clayey		y contains lenses of sandy or gravelly sediment
		f contains lenses of silty or clayey sediment
Examples: (g)Sm: slightly gravelly sand, massive mDi: muddy diamicton, inversely graded		

4.5 Radiocarbon Dates

The Wanuskewin Heritage Park radiocarbon dates utilized in this study were obtained from archaeological investigations (Amundson 1986; Mack 2000; Moon 2004; and Webster 1999) as well as Morlan (2002). The radiocarbon dates have been corrected for isotopic fractionation and thus, are reported as normalized dates. Uncorrected and normalized dates are summarized in Appendix C. All radiocarbon dates except one were derived from bone samples. Amisk radiocarbon date S-2537 was determined from a charcoal sample.

5. CUT ARM SITE

The Cut Arm site (FbNp-22) occupies a shallow depression formed on the northwest side of the South Saskatchewan River valley. The site is situated along a backslope (or transportational midslope) surface. Sedimentological and archaeological excavations were conducted during the 2000 and 2001 field seasons and included two Department of Archaeology field schools. A Department of Archaeology Master's thesis (Moon 2004) is examining the archaeology of the Cut Arm site. Presently, the archaeological interpretation indicates occupation between the Mummy Cave complex (ca. 6.0 ka BP) and the Historic period (<0.5 ka BP).

The present interpretation was based on data collected from three archaeological excavations along the Cut Arm slope (Figures 5.1 and 5.2). The first study site is block 1. In this block, archaeologists excavated six units down to 50 cm below surface. During the present study, bock 1 unit 20S 18E was further excavated to 130 cm below surface and samples were collected from the west wall. Approximately 35 m to the southeast and further downslope is block 3. Here, archaeologists excavated five units to 100 cm below surface. Block 3 unit 32S 51E was further excavated to 145 cm below surface and samples were collected from the west wall. Block 4 is approximately 45 m southeast of block 3 and is the largest study section. At the time of sampling, archaeologists excavated six units to approximately 230 cm below surface. Samples were collected from the north wall of unit 69S 79E. Particle size analysis was conducted on all Cut Arm samples. The grain size data are presented in Appendix B.

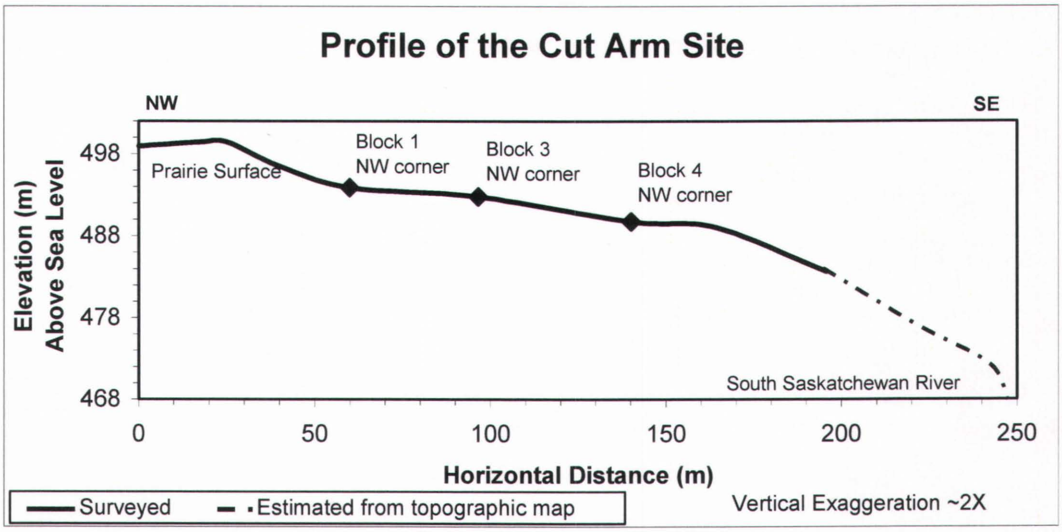


Figure 5.1 Slope profile of the Cut Arm site, showing location of archaeological excavations.

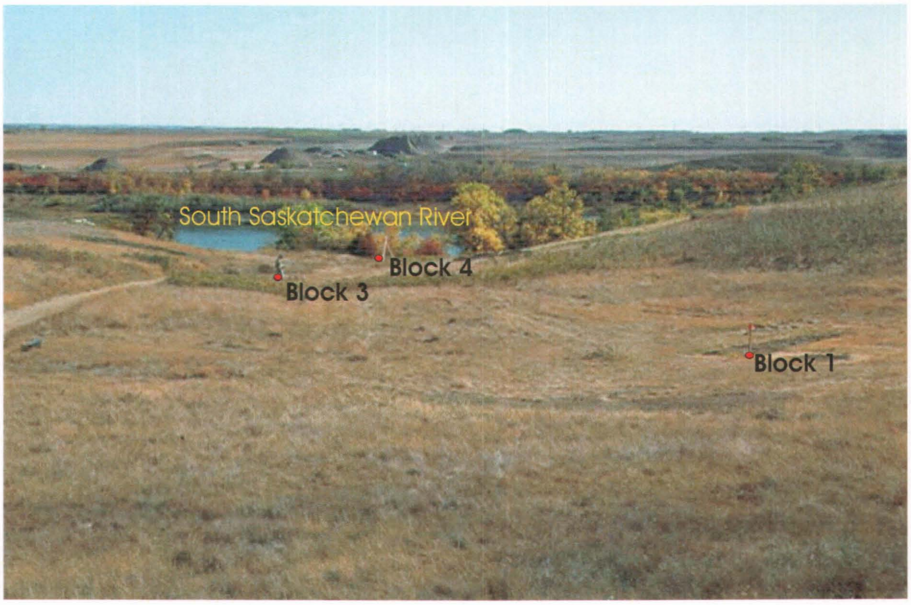


Figure 5.2 Photograph of the Cut Arm slope showing location of Blocks 1, 3, and 4. View to the southeast toward the South Saskatchewan River.

5.1 Facies Characteristics

The facies are divided into massive and graded diamictons as well as diamicton with sand and mud lenses and massive sands. Facies codes are explained in Table 4.1.

5.1.1 Massive Diamictons (sDm, mDm)

Massive diamictons consist of matrix rich, poorly to very poorly sorted, slightly gravelly muddy sand and slightly gravelly sandy mud. Their colour is mainly greyish brown to grey although some beds are olive brown. The thickness of sedimentation units generally is between 6 cm and 34 cm and many beds exhibit upslope thinning. Buried soils developed in this facies contain archaeological material. Massive diamicton sequences were observed at block 4.

5.1.2 Normally Graded Diamictons (gDn, sDn)

The normally graded diamicton facies consist of matrix rich and poorly to very poorly sorted sediments composed of gravelly sand or gravelly muddy sand grading up into slightly gravelly muddy sand. The colour is mainly grey to brown, although some beds are olive brown or yellowish brown. The olive brown and yellowish brown beds mainly occur at the base of the graded beds. Unit thickness ranges from 11 to 67 cm. Archaeological material was discovered within buried soils developed in this facies. Normally graded diamicton was observed in all Cut Arm exposures.

5.1.3 Diamicton with Lenses of Sandy and Muddy Sediment (sDfy)

A diamicton facies with mud and sand lenses was observed in block 3. The deposit is a matrix rich diamicton with a measured unit thickness of 13 cm. This facies varies from poorly sorted, slightly gravelly muddy sand to very poorly sorted, sandy mud. The colour is mainly greyish brown, although the sand rich lenses are yellowish brown. The measured sand lenses are up to 5 cm in thickness and the mud lenses are up to 10 cm in thickness. No archaeological material was discovered in this facies.

5.1.4 Massive Sands ((g)Sm)

The massive sand facies was observed at the base of block 1 and in block 4. The massive sands are moderately to moderately well sorted slightly gravelly sands. Their colour is olive brown. The block 1 sand unit is 73 cm in thickness and the block 4 sand unit is lenticular in shape and up 11 cm in thickness. No archaeological material was discovered in this facies.

5.2 Facies Interpretation

The characteristics of the facies and the archaeological data indicate the slope sediments are a product of hillslope and glacial processes.

5.2.1 Hillslope Sediment

Hillslope sediments are divided into massive and normally graded diamicton, diamicton with sand and mud lenses and massive sand. Based on their physical attributes, some of the deposits are the product of debris flow sedimentation.

Characteristics of debris flows found at this site include lenticular beds (Nemec and Kazanci 1999; Van Steijn and Coutard 1989), poorly sorted sediment (Iverson 1997; Major 1997; Van Steijn *et al.* 1995), bimodal grain size distribution (Pierson 1986; Scott 1971; Vallance and Scott 1997), and a structure that varies from massive to normally graded (Blikra and Nemec 1998; Major 1997). The texture of debris flow sediments is primarily controlled by the texture of the sediments in the source area and the water content of the flow. Blikra and Nemec (1998:918) demonstrated that "colluvial debris flows, although derived mainly from glacial till, have shown considerable variation." The variation is due to the heterogeneous texture of glacial material and the rheological behaviour of debris flows. The characteristics of a debris flow are highly sensitive to relatively minor changes in the water content of the flow (Blikra and Nemec 1998). Figure 5.3 illustrates the bimodal distribution of three Cut Arm samples. The grain size distribution of these sediments is typical of the distribution found in Cut Arm hillslope deposits.

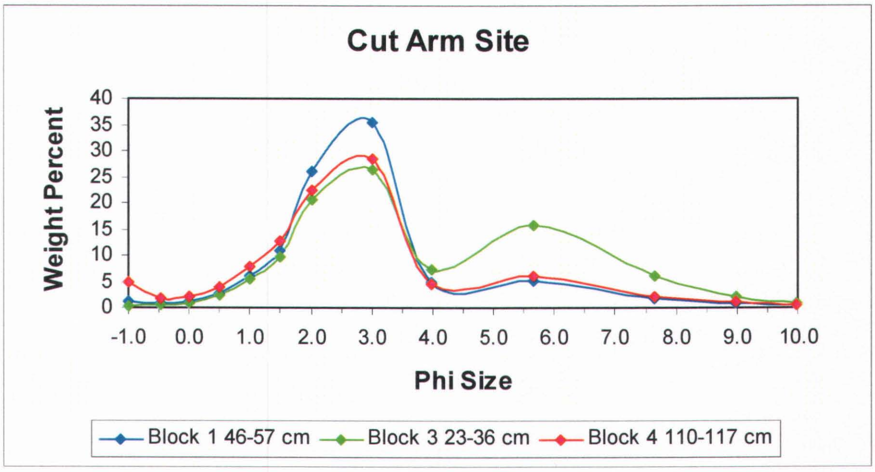


Figure 5.3 An example of bimodal grain size distribution in Cut Arm hillslope sediments.

5.2.1.1 Massive Diamictons

Matrix rich, poorly sorted massive hillslope deposits were observed in block 4. The massive sediments formed a downslope thickening wedge and consisted of larger clasts randomly distributed in a finer grained matrix were interpreted as debris flow sediments. Massive debris flow deposits are common, as the flow is a mixture of poorly sorted debris. The remaining massive diamictons were deposited by hillslope processes but, were not attributed to a particular type of movement. The sediments are likely the product of creep, slides, or flows.

5.2.1.2 Normally Graded Diamictons

Matrix rich normally graded diamictons were observed in blocks 1, 3 and 4. The normal grading corresponds with a transition from poorly to very poorly sorted sediment. Normal graded bedding is often attributed to the waning stages of a flow. A decrease in sediment supply or the progressive settling out of different size fractions may account for the grading. Deposits with a large range of particle sizes and angular clasts suggest deposition by debris flows. Normal graded bedding in debris flow deposits may result when sediment deposited from the tail of the debris flow overlies sediment deposited from the front of the flow. The tail tends to be finer grained, more poorly sorted and have a higher water content (Vallance and Scott 1997; Martinsen 1994). In addition, Major (1997), showed debris flows are not necessarily deposited en masse but rather as successive overlapping waves. Johnson and Rodine (1984:266) demonstrated that successive layers within lobes formed during a single episode of debris flow activity generally are progressively finer grained. The origin of the normal graded bedding is not fully understood.

5.2.1.3 Diamictons with Lenses

Diamictons with sand and mud lenses were observed in block 3. These lenses are the product of debris flow or overland flow sedimentation. Selby (1993:305) demonstrated that "lenses of sorted and weakly bedded pebbly silts or sands may occur within the main bodies of debris flow as a result of deposition from thinner more fluid pulses between passages of lobate debris." Similarly, wash and rill deposits may form alternating lenses of coarser and finer grained sediments related to fluctuations in discharge during a precipitation event (Selby 1994:73).

5.2.1.4 Massive Sands

A sand lens was observed in block 4. The lens of sorted sand suggests erosion and deposition by overland flow. Alternatively, the massive sand may be attributed to a shift in the locus of erosion with glaciofluvial sands as opposed to glacial till now serving as the source material.

5.2.2 Glacial Sediment

Glacial deposits at the Cut Arm site include glacial till and glaciofluvial sand.

5.2.2.1 Glacial Till

A massive, matrix rich muddy diamicton was observed at the base of the block 3 exposure. This material is similar in its lack of sorting and bedding to the deposits associated with hillslope processes. However, the sediments show some variation from the massive colluvial diamictons. For example, samples from the base of block 3 have a greater quantity of fines (Figure 5.4). In addition, there is a boulder concentration along the upper contact and no cultural material was discovered in the deposit. Based on the characteristics this diamicton is attributed to glacial processes. The boulder concentration (stone line) may represent a relict of a former lag subsequently covered by hillslope sediment. The lag likely developed when flowing water removed the fine grained sediment from the glacial deposit.

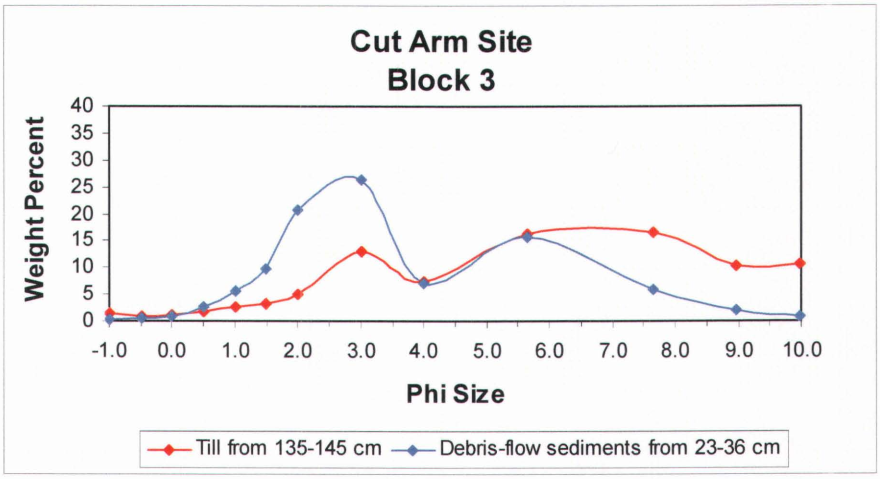


Figure 5.4 Comparison of the grain size distribution observed in a sample of glacial till sediments versus sediment deposited by hillslope processes.

5.2.2.2 Glaciofluvial Sediments

A moderately to moderately well sorted sand unit was mapped at the base of block 1. Figure 5.5 illustrates the grain size distribution of these sediments. For comparison, curves from glacial till and hillslope sediments are also provided. No archaeological material was discovered in the unit. Boulders occurred within the sand deposit as well as along the upper contact. The boulder concentration defines a transition to glacial sediments and results from the erosion of the glacial till. The massive sand in block 1 is probably glaciofluvial sediment deposited around boulders. Christiansen and Sauer (1998) showed that glacial till in the Saskatoon area can be overlain by glaciolacustrine and glaciofluvial sediments. Alternatively, the sorted sand may represent a boulder lag subsequently buried by hillslope sediments. In this scenario, the hillslope sediments were likely derived from a glaciofluvial deposit and retained many of the characteristics of the original source material. However, Amundson (1986) demonstrated that the transition to glacial sediments in Opimihaw Valley sedimentary exposures is generally marked by a boulder concentration. Thus, the sand deposit is best explained by glacial sedimentation.

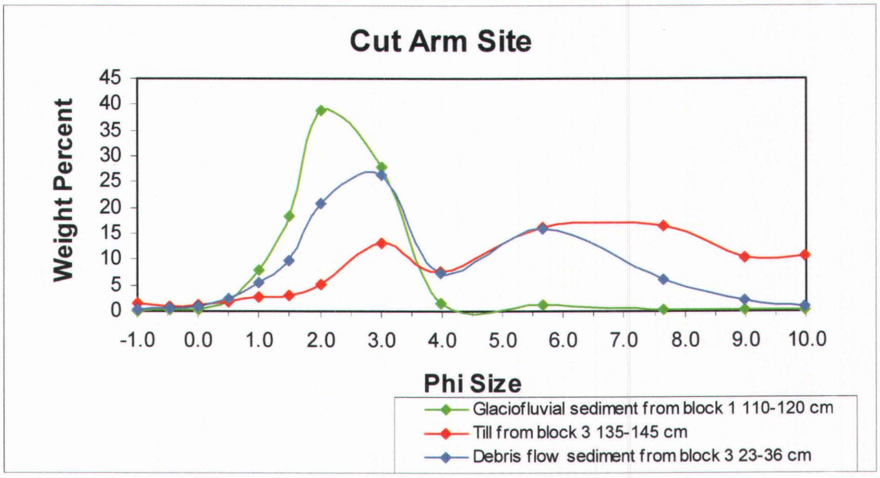


Figure 5.5 Comparison of the grain size distribution of glaciofluvial, till and debris flow sediment.

5.3 Stratigraphy

Representative stratigraphic sections and accompanying photographs are shown in Figure 5.6 to Figure 5.10. The fining and coarsening up symbols are diagrammatic and the particle size data are a representative sample. A complete listing of the particle size data is provided in Appendix B.

5.3.1 Block 1 Unit 20S 18E

Block 1 stratigraphic section is shown in Figure 5.6. The lowermost facies is slightly gravelly sand and extends from 130 cm to 57 cm below surface. The sediment is a glaciofluvial deposit. Boulders occur within the unit as well as along the upper contact. Normally graded hillslope sediments were mapped from 57 cm to 4 cm below surface. Between 57 cm and 35 cm, the deposit is a gravelly diamicton and between 35 cm and 4 cm, it is a sandy diamicton. The normal graded bedding suggests deposition from a waning debris flow. The upper 4 cm is an organic horizon.

5.3.2 Block 3 Unit 32S 51E

The stratigraphic profile of block 3 Unit 32S 51E is illustrated in Figures 5.7 and 5.8. The lowermost facies, muddy diamicton, is glacial till and extends from 145 cm to 111 cm below surface. The upper contact is defined by a boulder concentration. A normally graded diamicton occurs between 111 cm and 80 cm below surface. Based on the characteristics, the sediment is attributed to a debris flow. The normal grading is best explained as deposition during the waning stages of a debris flow event. A buried soil extends from 84 cm to 80 cm. The buried soil indicates a period of landscape stability. A sandy diamicton with clay and sand lenses was mapped between80 cm and 67 cm below surface. The lenses are the product of erosion and deposition from overland flow. From 67 to 23 cm is a normally graded sandy diamicton deposited by hillslope processes.

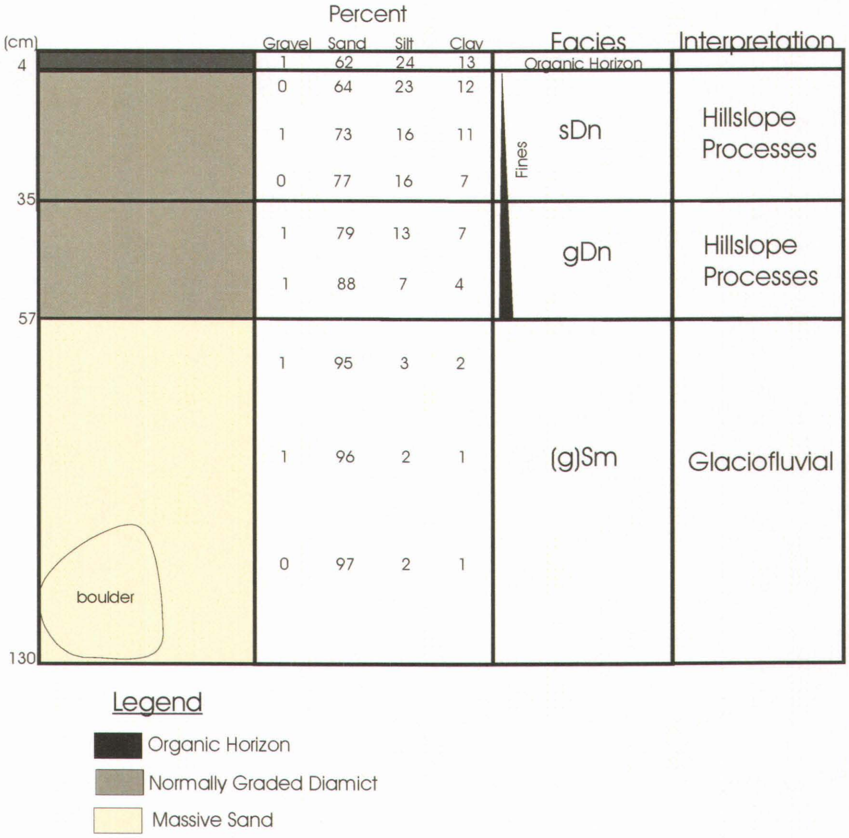


Figure 5.6 Diagram showing the stratigraphy of Cut Arm site block 1 unit 20S 18E west wall.

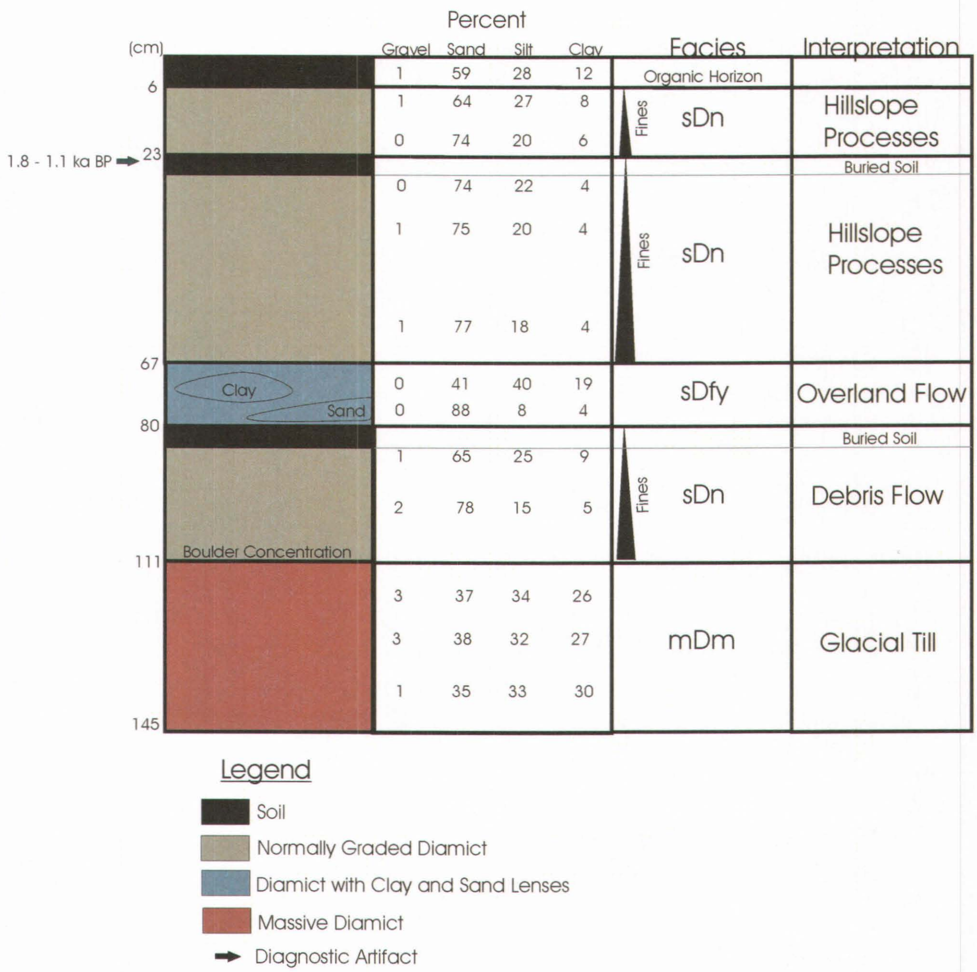


Figure 5.7 Diagram showing stratigraphy of the Cut Arm site block 3 unit 32S 51E west wall.

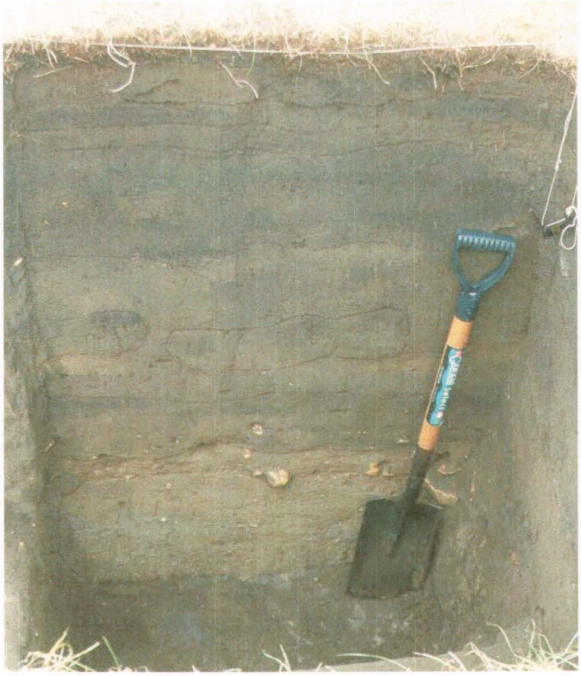
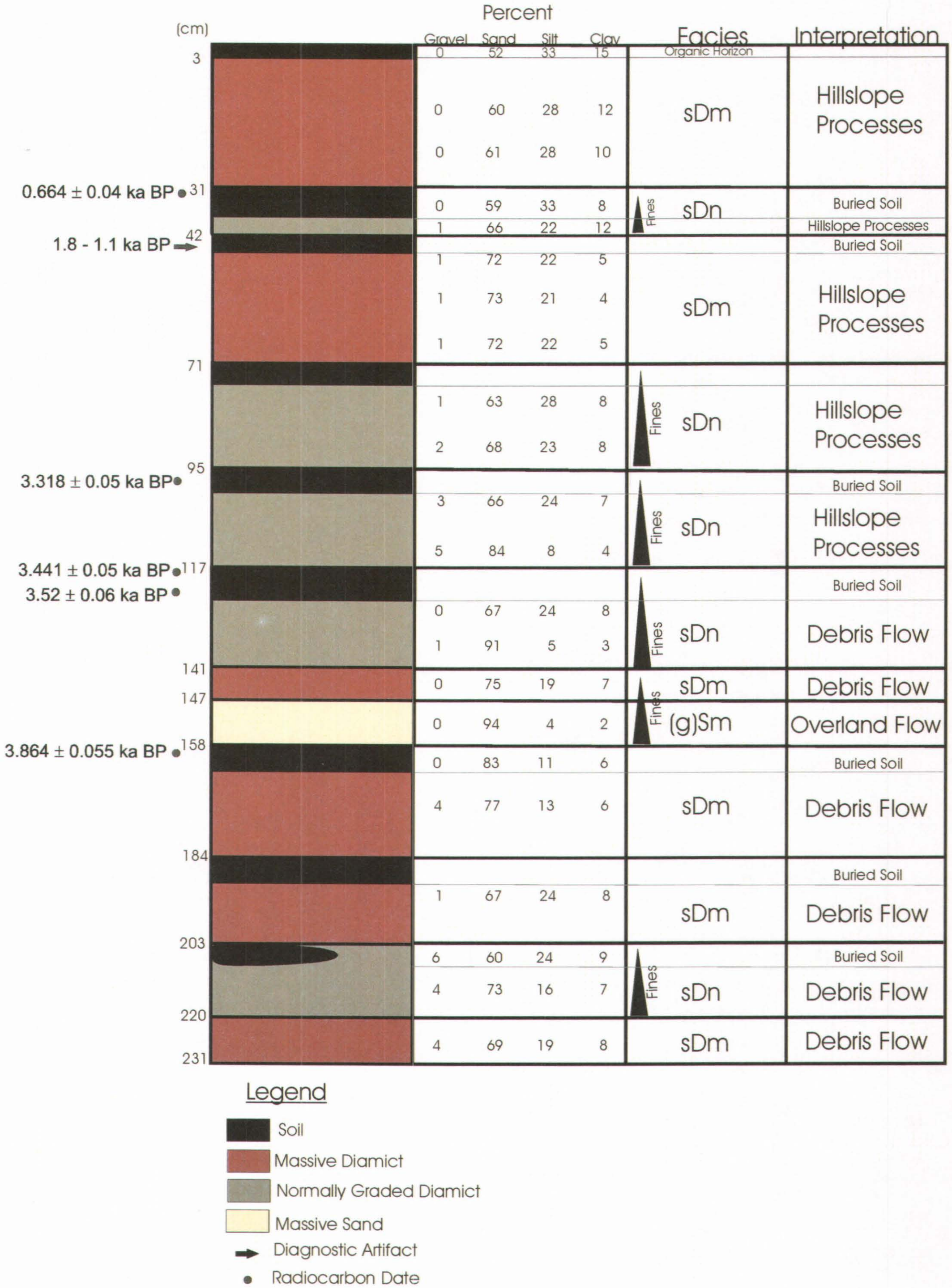


Figure 5.8 Photograph showing block 3 unit 32S 51E west wall of the Cut Arm site. The profile is 145 cm in depth.

The diamicton with lenses (67 to 80 cm) and the normally graded diamicton (23 to 67 cm) may be related to the same precipitation event and thus, represent a transition from one type of hillslope process to another. The upper contact of a buried soil occurs at 23 cm and an Avonlea projectile point (ca. 1.8-1.1 ka BP) was discovered at 24 cm below surface. The soil and presence of cultural material indicates deposition ceased and landscape stability occurred. The normally graded diamicton from 23 cm to 6 cm below surface is the product of hillslope sedimentation. An organic horizon occurs between 6 cm and surface.

5.3.3 Block 4 Unit 69S 79E

The block 4 stratigraphic profile is illustrated in Figures 5.9 and 5.10. The lowermost facies extends from 231 cm to 220 cm and is a massive sandy diamicton. Boulders randomly distributed in a fine grained matrix and the downslope thickening of the sediments are some of the attributes that suggest deposition by a debris flow. Unless otherwise stated, sediments interpreted as debris flow sediments are matrix rich, poorly sorted, have a texture that ranges from clay to boulders, and exhibit downslope thickening. A normally graded sandy diamicton extends from 220 cm to 203 cm and an intermittent weakly developed buried soil was mapped between 208 cm and 203 cm. These sediments and the underlying deposit may have been deposited during a single debris flow event. The buried soil corresponds with Moon's (2004) occupation level 11. A massive sandy diamicton was recorded between 203 cm and 184 cm below surface. A buried soil from 189 cm to 184 cm defines the upper contact of this unit. The buried soil corresponds with Moon's (2004) occupation level 10. The massive deposit results from debris flow deposition. A massive, sandy diamicton from 184 cm to 158 cm is also the product of debris flow sedimentation. A buried soil between 164 cm and 158 cm below surface corresponds with Moon's (2004) occupation level 9. Moon (2004) obtained a radiocarbon date of 3.864 ± 0.055 ka BP (BGS-2385) from a bone sample collected from 160 cm below surface. A sand lens was mapped between 158 cm and 147 cm. The origin of the sand deposit is not fully understood but two interpretations have been suggested. These are a shift in the locus of erosion or deposition from overland flow. Between 147 cm and 141 cm is a massive sandy diamicton and between



Depth (cm)	Gravel	Sand	Silt	Clay	Facies	Interpretation
3	0	52	33	15	Organic Horizon	
	0	60	28	12	sDm	Hillslope Processes
	0	61	28	10		
31	0	59	33	8	sDn	Buried Soil
	1	66	22	12		Hillslope Processes
42						Buried Soil
	1	72	22	5	sDm	Hillslope Processes
	1	73	21	4		
	1	72	22	5		
71	1	63	28	8	sDn	Hillslope Processes
	2	68	23	8		
95						Buried Soil
	3	66	24	7	sDn	Hillslope Processes
	5	84	8	4		
117						Buried Soil
	0	67	24	8	sDn	Debris Flow
	1	91	5	3		
141	0	75	19	7	sDm	Debris Flow
147	0	94	4	2	(g)Sm	Overland Flow
158	0	83	11	6		Buried Soil
	4	77	13	6	sDm	Debris Flow
184						Buried Soil
	1	67	24	8	sDm	Debris Flow
203	6	60	24	9		Buried Soil
	4	73	16	7	sDn	Debris Flow
220	4	69	19	8	sDm	Debris Flow
231						

Figure 5.9 Diagram showing stratigraphy of the Cut Arm site block 4 unit 69S 79E north wall.

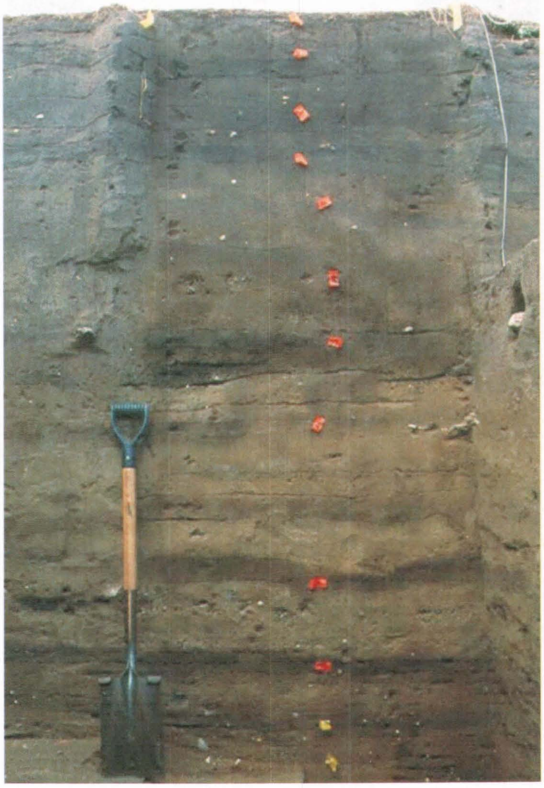


Figure 5.10 Photograph showing block 4 unit 69S 79E north wall of the Cut Arm site. The profile is 231 cm in depth.

141 cm and 117 cm is a normally graded sandy diamicton. These diamictons are the product of debris flow processes. The sand lens, massive sandy diamicton, and normally graded sandy diamicton may be related to the same triggering event with the 158 cm to 117 cm deposit reflecting a transition from flowing water to a debris flow. A buried soil from 125 cm to 117 cm corresponds with Moon's (2004) occupation level 8. Moon (2004) showed that a bone sample from 121 cm yielded a radiocarbon date of 3.441 ± 0.05 ka BP (BGS-2383) and a bone sample from 118 cm produced a date of 3.52 ± 0.06 ka BP (BGS-2384). Debris flow beds between the base of the stratigraphic profile (231 cm) and 117 cm below surface show a pronounced increase in thickness in

the downslope direction. The normally graded debris flow sediments may be the product of deposition during the waning stages of flow. A normally graded sandy diamicton from 117 cm to 95 cm is a hillslope deposit. A buried soil from 100 cm to 95 cm compares with Moon's (2004) occupation level 6. Moon (2004) obtained a radiocarbon date of 3.318 ± 0.05 ka BP (BGS-2382) from a bone sample collected from 100 cm below surface. A normally graded sandy diamicton between 95 cm and 71 cm is considered to have been deposited by hillslope processes. An intermittent buried soil between approximately 76 cm and 71 cm corresponds with Moon's (2004) occupation level 5c. A massive sandy diamicton was recorded between 71 cm and 42 cm. A buried soil was mapped between 46 cm and 42 cm below surface. This soil compares with Moon's (2004) occupation level 4. Moon (2004) associated this level with Avonlea occupation (ca. 1.8 – 1.1 ka BP). A hillslope deposit in the form of a normally graded sandy diamicton occurs between 42 cm and 31 cm below surface. The buried soil from 37 cm to 31 cm corresponds with Moon's (2004) occupation level 3. Moon (2004) recorded a bone sample from 33 cm below surface with a radiocarbon date of 0.664 ± 0.04 ka BP (BGS-2381). The massive sandy diamicton between 31 cm and 3 cm below surface is considered a hillslope deposit. An organic horizon occurs between 3 cm and surface. The sediment between 117 cm and surface compared to sediments between 117 cm and 231 cm did not contain as many large clasts and did not exhibit downslope thickening.

5.4 Hillslope Evolution

Exposures along the Cut Arm slope suggest Late Pleistocene till and glaciofluvial sediments were successively buried by colluvium. Christiansen and Sauer (1998) demonstrated that by approximately 11.5 ka BP the glacier had retreated and Glacial Lake Saskatchewan had drained to the northeast. Radiocarbon dates in block 4 indicate debris flow deposition began before 3.864 ± 0.055 ka BP. Hillslope erosion and deposition continued throughout the Cut Arm valley's history of development. The hillslope sediments are matrix rich and frequently normally graded. The normally graded debris flow sediments are best explained as deposition during the waning stages of flow and thus, indicate the onset of landscape stability.

The repeated soils developed in colluvial sediment records cycles of stability and instability. The buried soils were generally weakly developed and intermittent. Selby (1993) demonstrated that this is characteristic of transportational midslope surfaces. Soils on transportational midslopes are regularly stripped during erosional events and thus, completely removed or have a patchy distribution (Selby 1993:192). Soils that are present commonly display weak development and thin profiles. Radiocarbon dates from some of the buried soils indicate stable phases occurred around 3.864 ± 0.055 ka BP, 3.52 ± 0.06 to 3.441 ± 0.05 ka BP, 3.318 ± 0.05 ka BP, and 0.664 ± 0.04 ka BP. In addition, diagnostic cultural material indicates a stable landscape phase occurred sometime between 1.8 and 1.1 ka BP.

6. MEEWASIN SITE

The Meewasin site (FbNp-9) occupies a colluvial footslope surface in a deep drainage basin on the west side of the South Saskatchewan River valley. In 1999, the University of Saskatchewan, Department of Archaeology began a field school at the Meewasin site. The following interpretation utilizes information from the 1999, 2000 and 2001 archaeological field schools. The archaeological material indicates McKean (ca. 4.1 – 3.1 ka BP) through Historic (<0.5 ka BP) occupation. During the 2000 and 2001 field seasons sedimentological data were collected from one test pit, one test trench and the archaeological excavations. The test pit was a 1 m X 1 m unit located 18 m north and upslope of the northwest corner of the main excavation and was excavated to 129 cm below surface. Samples were collected from the west wall of the pit. The test trench was originally excavated in 1982 as part of an archaeological assessment of Opimihaw Creek valley. In 2000, the trench was reopened, expanded, and sampled. The examined exposure was 236 cm in length and 160 cm high. The trench is located approximately 40 m southeast of the northeast corner of the archaeological excavations. In the main excavation, samples were collected from unit 22S 0E west wall, unit 22S 6E south wall, unit 22S 7E east wall, unit 22S 8E east wall, and unit 20S 7E north wall. The location of Meewasin study sites is shown in Figures 6.1 and 6.2. Particle size analysis was conducted on all Meewasin samples (Appendix B).

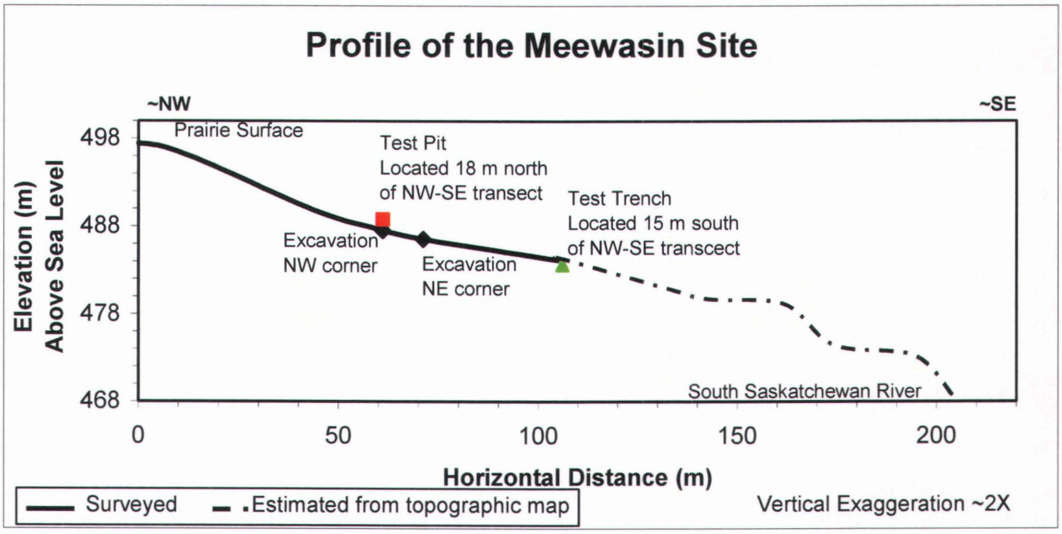


Figure 6.1 Slope profile of the Meewasin site, showing sample and excavation locations.

Figure 6.2 Photograph of the Meewasin slope showing location of the archaeological excavation and the test trench. View to southeast toward the South Saskatchewan River.

6.1 Facies Characteristics

The Meewasin facies are divided into massive, normally graded and inversely graded diamictons and massive sands.

6.1.1 Massive Diamictons (sDm)

The massive diamicton facies is matrix rich, very poorly sorted, slightly gravelly muddy sands. Their colour varies from black to very dark greyish brown. The beds range from 4 to 18 cm in thickness. No archaeological material was discovered in this facies. Massive diamictons were observed in both the main excavation and the test trench. This facies is rare in the Meewasin valley.

6.1.2 Normally Graded Diamictons (sDn, mDn)

The normally graded diamicton sediments are matrix rich and grade from poorly to very poorly sorted. Their texture mainly fines upwards from slightly gravelly muddy sand to slightly gravelly sandy mud. Their colour is primarily black to dark greyish brown however, some beds are olive brown or yellowish brown. The olive brown and yellowish brown beds occur at the base of normally graded diamicton sequences. Unit thickness ranges from 16 to 109 cm. In the main excavation, some of the normally graded diamicton deposits are lenticular in shape. This facies is the most extensive and was observed at the test pit, the archaeological excavation and the test trench. Archaeological material was discovered within buried soils developed in this facies.

6.1.3 Normally Graded Diamicton with Evidence of Soft Sediment Deformation (sDnd)

A normally graded diamicton with evidence of soft sediment deformation was observed between 112 cm and 135 cm in the western portion of the archaeological excavation. The deposit is matrix rich, poorly sorted slightly gravelly sand. Convolute laminae provide evidence of soft sediment deformation. The sediments are olive brown and no archaeological material was discovered in the facies.

6.1.4 Inversely Graded Diamictons (mDi, sDi)

The inversely graded sediments are matrix rich, very poorly sorted slightly gravelly sandy mud and slightly gravelly muddy sand. Unit thickness ranges from 12 to 45 cm. Their colour is mainly black to dark greyish brown though some beds are olive brown. This facies was observed in the test pit, main excavation and test trench. Some of the beds in the main excavation are lenticular. Buried soils and archaeological material were discovered in this facies.

6.1.5 Massive Sands ((g)Sm)

A sand facies was observed at the base of unit 22S 0E west wall. The deposit is a 15 cm thick moderately sorted yellowish brown slightly gravelly sand. No archaeological material was discovered in this facies.

6.2 Facies Interpretation

The diamicton and sand at the Meewasin site are the product of hillslope sedimentation. Selby (1993) demonstrated that footslopes of low inclination (such as the

Meewasin slope) are generally zones of colluvial accumulation. The characteristics of the colluvial sediments indicate some deposits are the product of debris flow processes. Distinguishing debris flow features include lenticular beds, poorly sorted sediment defined by large clasts randomly distributed in a fine grained matrix and bimodal grain size distribution. Figure 6.3 illustrates the bimodal size distribution detected in many of the Meewasin hillslope sediments.

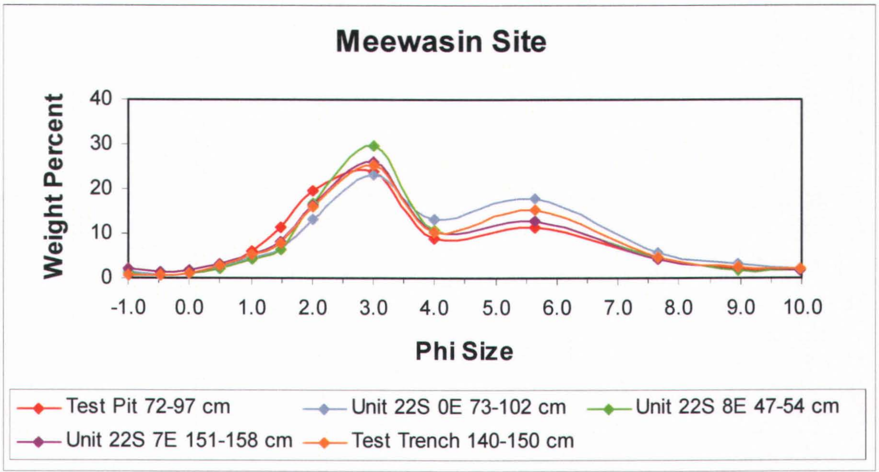


Figure 6.3 An example of the bimodal grain size distribution in Meewasin hillslope deposits.

6.2.1 Massive Diamictons

Matrix rich, massive hillslope deposits were observed in the main excavation and test trench. The presence of cultural material indicates these diamictons were not deposited by glacial processes but rather, are a product of hillslope sedimentation. The massive diamictons were not attributed to a specific hillslope process.

6.2.2 Normally Graded Diamictons

Matrix rich normally graded diamictons were observed in the test pit, main excavation and the test trench. As discussed with the Cut Arm site the normal graded hillslope sediments have been attributed to deposition during the waning stages of flow.

6.2.3 Normally Graded Diamictons with Evidence of Soft Sediment Deformation

Convolute laminae between 112 cm and 135 cm in the western extent of the main excavation suggest soft sediment deformation. The deformation results from a loss of shear strength in the sediments. An increase in pore fluid pressure (commonly water) can cause a reduction in the shear strength of sediment. Collinson (1994) demonstrated that convolute laminae are often localized within an otherwise intact sediment unit and in many instances the liquefaction and resulting loss of strength result from the early postdepositional condition of the sediment.

6.2.4 Inversely Graded Diamictons

The origin of the inverse grading is not fully understood and may be the product of hillslope and soil formation processes. Inverse grading has been attributed to the rheological mechanisms in debris flows (Naylor 1980). Alternatively, this grading may result from deposition in rising flow conditions or an increase in sediment supply during a mass movement. Clay translocation during soil formation may also produce inversely graded bedding.

6.2.5 Massive Sands

Massive sand was observed at the base of unit 22S 0E west wall. The sand suggests deposition result from a fluid hillslope process. The sediments were sampled with an auger and thus, there is insufficient textural and structural evidence to attribute the deposit to a specific depositional process.

6.3 Stratigraphy

Representative stratigraphic sequences and accompanying photographs are shown in Figures 6.4 to 6.9. The sequences reveal multiple episodes of hillslope erosion and deposition alternating with periods of landscape stability.

6.3.1 Test Pit

The test pit stratigraphic sequence is illustrated in Figure 6.4. The lowermost facies extends from 129 to 20 cm below surface and is a normally graded hillslope deposit. This unit is divided into a poorly sorted sandy diamicton from 129 cm to 116 cm and a very poorly sorted sandy diamicton from 116cm to 20 cm. Bone fragments were discovered at 26 cm and 30 cm below surface. The presence of archaeological material suggests a stable landscape and possible soil formation. However, current pedological processes have obscured potential evidence of a buried soil at the top of the normally graded deposit. An inversely graded sandy diamicton occurs between 20 cm and 8 cm below surface. The graded bedding may result from hillslope sedimentation. However, surface soil horizons have developed in this unit and clay translocation may have

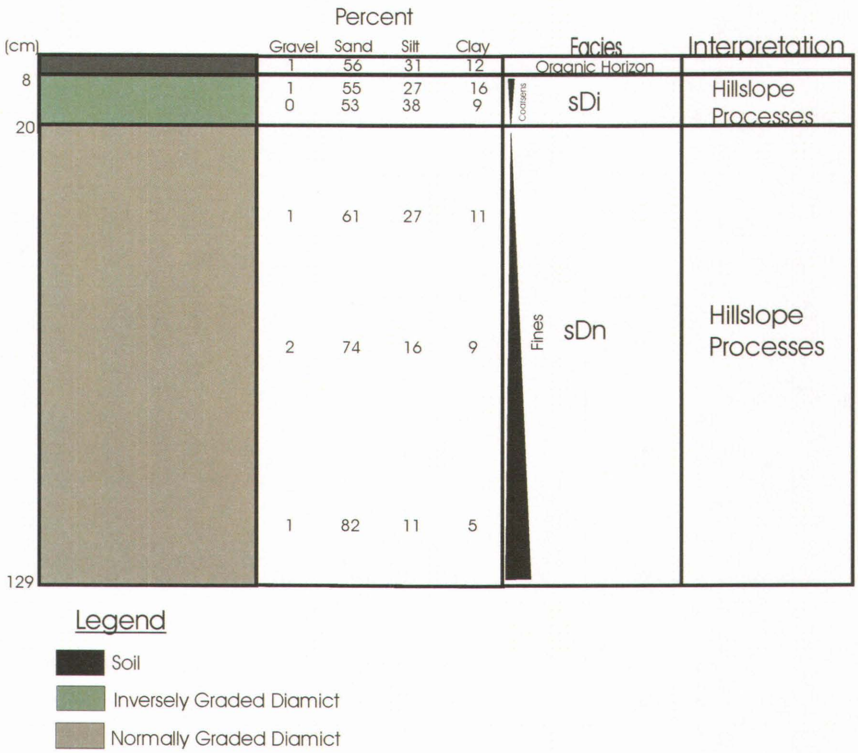


Figure 6.4 Diagram showing stratigraphy of the Meewasin test pit.

influenced the grain size distribution. An organic horizon was mapped between 8 cm and surface.

6.3.2 Unit 22S 0E

The stratigraphic profile of unit 22S 0E is depicted in Figure 6.5. The lowermost unit extends from 229 cm to 112 cm below surface and fines upwards. Within the fining upward sequence, slightly gravelly sand extends from 229 to 214 cm and sandy diamicton extends from 214 cm to 112 cm. The characteristics of the sediments suggest deposition by debris flows. Distinguishing features include angular to subangular clasts and poorly sorted sediment ranging in particle size from clay to boulder. The sand as compared to the overlying diamicton was deposited by flow that is more fluid and may represent a separate hillslope event. The normally graded diamicton is the product of deposition during the waning stages of a debris flow. A weakly developed intermittent soil extends from 120 cm to 112 cm below surface. This soil as well as other soils in the Meewasin stratigraphy suggests periods of nondeposition and landscape stability. Localized convolute laminae between 112 cm and 135 cm are deformation structures. The laminae are deformed organic rich layers. This indicates deformation occurred after the soil developed. A normally graded sandy diamicton extends from 112 cm to 56 cm. This deposit is a product of hillslope processes. A buried soil was mapped between 73 cm and 56 cm. According to the archaeological record, occupation level 5 occurs at the base of the buried soil and occupation level 4 occurs at the top of the buried soil. Occupation level 5 is associated with the McKean complex (ca. 4.1 - 3.1 ka BP). A muddy inversely graded diamicton extends from 56 cm to 11 cm and a buried soil

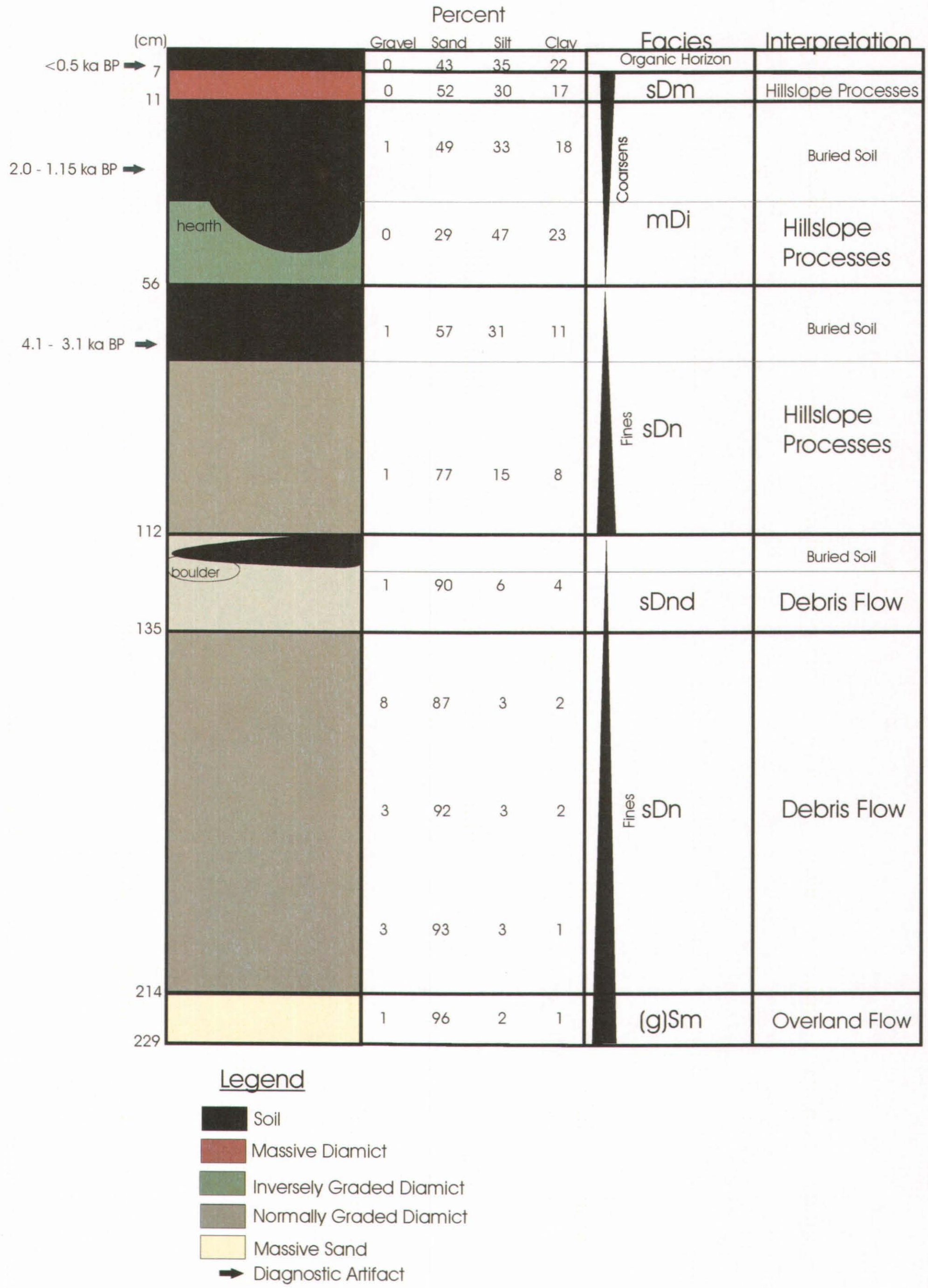


Figure 6.5 Diagram showing the stratigraphy of Meewasin site unit 22S 0E west wall.

occurs between 38 cm and 11 cm. The sediment is the product of hillslope processes. Archaeological investigations record occupation level 3 and occupation level 2 within the 38 cm to 11 cm buried soil. Occupation level 2 is associated with the Besant complex (ca. 2.0 – 1.15 ka BP). A sandy diamicton was mapped between 11 cm and 7 cm and results from hillslope sedimentation. An organic horizon is present between 7 cm and surface. According to the archaeological record, occupation level 1 occurs within the surface soil horizon. Occupation level 1 is associated with Historic habitation (< 0.5 ka BP).

6.3.3 Unit 22S 8E and Unit 22S 7E

The stratigraphic profile of units 22S 8E and 22S 7E is shown in Figures 6.6 and 6.7. The lowermost facies is a normally graded sandy diamicton and is interpreted as a hillslope deposit. Correlation with debris flow sediments in unit 22 S 0E suggests these poorly sorted sediments are a product of debris flow sedimentation. The normal grading may result from deposition during the waning stages of a debris flow. A buried soil extends from 165 cm to 158 cm. This soil is intermittent and contains archaeological material. According to archaeological investigations, this buried soil is associated with occupation level 6. A normally graded sandy diamicton occurs between 158 cm and 130 cm and an inversely graded sandy diamicton occurs between 130 cm and 113 cm. These deposits are the product of hillslope processes. A buried soil corresponds with the inversely graded deposit (113 – 130 cm) suggesting clay translocation may have effected the grain size distribution. Archaeological investigations associate the buried soil with the McKean complex (occupation level 5). The McKean complex dates from

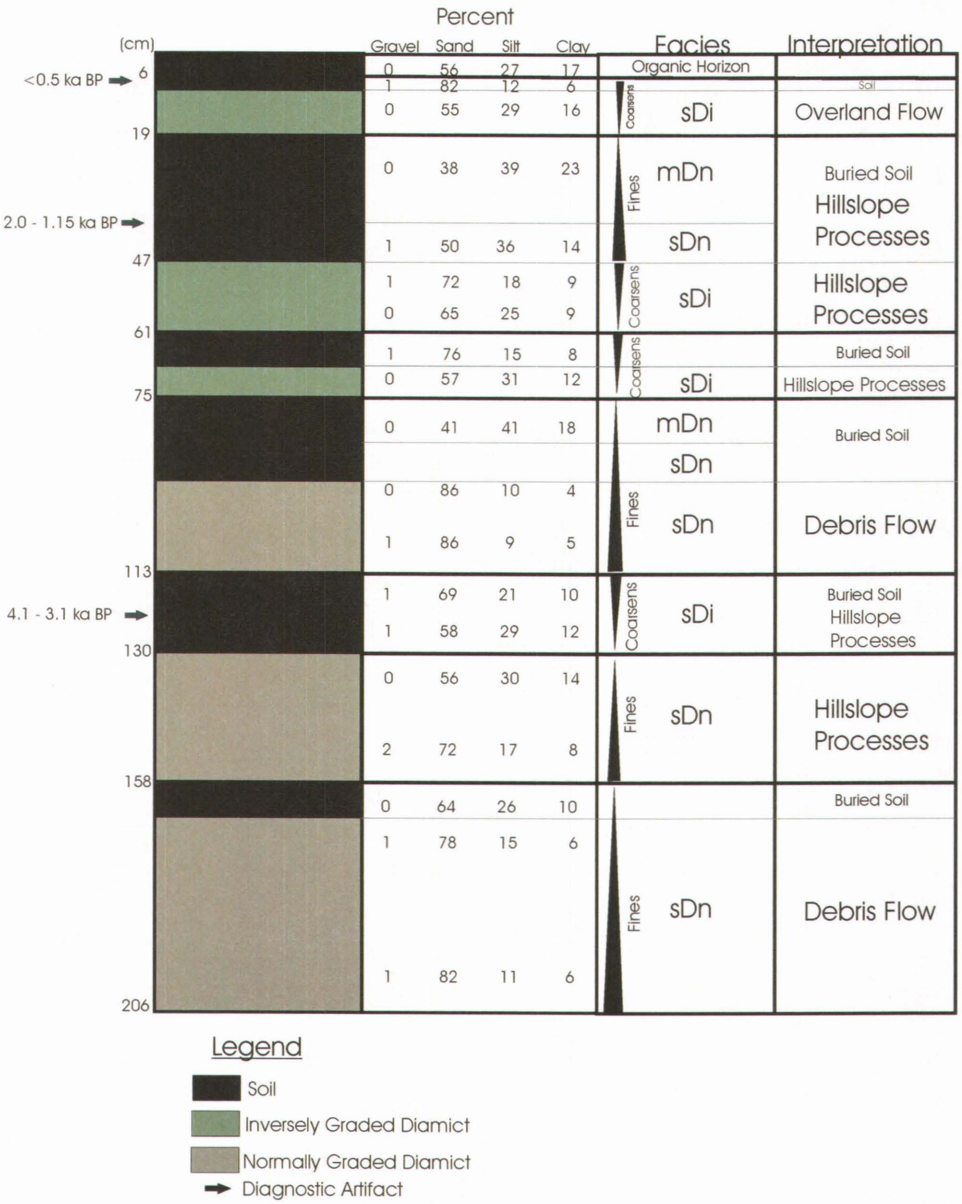


Figure 6.6 Diagram showing the stratigraphy of the Meewasin site unit 22S 8E east wall 0 to 99 cm and unit 22S 7E east wall 96 to 206 cm.

Figure 6.7 View of the east wall of unit 22S 8E and unit 22S 7E at the Meewasin site. Unit 22S 8E profile extends from 0 to 99 cm and unit 22S 7E profile extends from 96 cm to 206 cm.

about 4.1 ka BP to 3.1 ka BP. A normally graded diamicton was mapped between 113 cm and 75 cm below surface. This unit is defined as a sandy diamicton between 113 cm and 83 cm and a muddy diamicton between 83 cm and 75 cm. This deposit is only present in the eastern section of the main excavation and is lenticular in shape. The sediments are the product of debris flow sedimentation and may reflect the waning stages of a debris flow event. The normal grading is best explained by incremental deposition by progressively finer grained and more watery debris flow surges. A buried soil occurs between 93 cm and 75 cm below surface. The archaeological record indicates this buried soil is occupation level 4. An inversely graded sandy diamicton was recorded between 75 cm and 61 cm. This deposit was only observed in the eastern section of the main excavation, is lenticular in shape and is the product of hillslope sedimentation. A buried soil occurs between 69 cm and 61 cm. Archaeological investigations associate the soil with occupation level 3a. The inverse grading likely reflects the sedimentation processes but may have been further enhanced by clay translocation. An inversely graded sandy diamicton extends from 61 cm to 47 cm and a normally graded diamicton extends from 47 cm to 19 cm. The normally graded diamicton is a sandy diamicton from 47 cm to 37 cm and a muddy diamicton from 37 cm to 19 cm. The sediments are the product of hillslope processes. A buried soil extends from 47 cm to 19 cm. Archaeological investigations recorded occupation level 3 at the base of this soil layer and occupation level 2 at the top of the soil layer. Occupation level 3 represents the Besant complex (ca. 2.0 – 1.15 ka BP). An inversely graded sandy diamicton from 19 cm to 6 cm is considered to have been deposited by hillslope processes. In adjacent archaeological units, this deposit is more clearly defined as mud overlain by sorted sand. This indicated the sediments are a product of overland flow. The inverse graded bedding may result from rising flow conditions. The archaeological record situates occupation level 1 between 10 cm and 6 cm and associates the occupation with Historic habitation (< 0.5 ka BP). An organic horizon occurs between 6 cm and surface.

6.3.4 Test Trench

The test trench stratigraphic profile is illustrated in Figures 6.8 and 6.9. The lowermost facies extends from 160 cm to 140 cm and is an inversely graded sandy diamicton. This deposit is the product of hillslope sedimentation. A normally graded

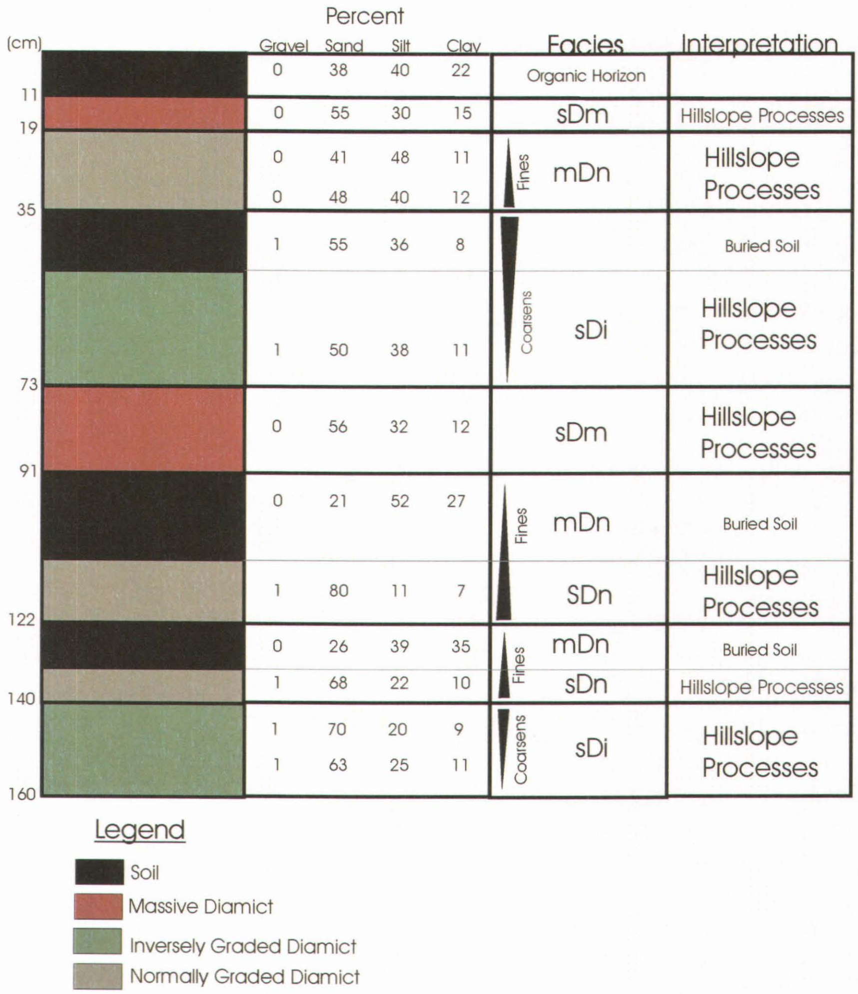


Figure 6.8 Diagram showing the stratigraphy of the Meewasin test trench south wall.

Figure 6.9 Photograph showing test trench south wall at the Meewasin site.

diamicton extends from 140 cm to 122 cm. This unit consists of a sandy diamicton from 140 cm to 132 cm and a muddy diamicton from 132 to 122 cm. The graded sediments result from deposition by hillslope processes. A buried soil extends from 132 cm to 122 cm and archaeological material was discovered within this soil layer. A normally graded diamicton occurs between 122 cm and 91 cm. The unit consists of a sandy diamicton from 122 cm to 110 and a muddy diamicton from 110 cm to 91 cm. This deposit is a product of hillslope sedimentation. A buried soil extends from 110 cm to 91 cm. A massive sandy diamicton was mapped between 91 cm and 73 cm and an inversely graded sandy diamicton extends from 73 cm to 35 cm. A buried soil extends from 49 cm to 35 cm. The sediments are the product of hillslope sedimentation. The massive and inversely graded sediments originate from one or more hillslope events. The massive texture reflects sedimentary processes whereas soil formation processes may have effected the inverse grading. A muddy normally graded diamicton between 35 cm and 19 cm and a massive sandy diamicton between 19 cm and 11 cm are the product of hillslope sedimentation. An organic horizon occurs between 11 cm and surface.

6.4 Hillslope Evolution

The development of a chronologically controlled history of slope evolution at the Meewasin site was limited by a lack of radiocarbon datable material. The relative history of slope development begins with normally graded debris flow sediments. The grading suggests deposition during the waning stages of a debris flow. Soil (occupation level 6) developed at the top of this colluvial deposit. Deformation of the soil in the western extent of the excavation indicates a loss of shear strength in the deposit. In the main excavation, the overlying unit is a normally graded hillslope deposit. In the test trench, the corresponding unit is inversely graded hillslope sediments overlain by a normally graded slope deposit. Vreeken (1994) demonstrated that slopes of different surface morphology and orientation might present different sedimentary records. A soil (occupation level 5) developed at the top of the hillslope deposit. Occupation level 5 is associated with the McKean complex (ca. 4.1 – 3.1 ka BP). The test trench and eastern extent of the main excavation record a normally graded hillslope deposit between occupation level 5 and the subsequent buried soil (occupation level 4). The attributes of the main excavation sediments suggest the deposit is the product of debris flow sedimentation. The fining upward sequence may result from deposition in a waning debris flow. Above occupation 4, there is poor correlation between the test trench and the main excavation sediments. Thus, discussion of overlying sediments will focus on the main excavation stratigraphic sequence. In the eastern portion of the excavation an inversely graded hillslope deposit and a buried soil (occupation level 3a) overlie occupation level 4. Above occupation level 3a in the eastern section of the excavation and above occupation level 4 in the western portion of the excavation is an inversely graded hillslope deposit. Soil (occupation level 3 and occupation level 2) developed at the top of the inversely graded deposit. Occupation level 3 is associated with the Besant complex (ca. 2.0 – 1.15 ka BP). A colluvial deposit occurs above occupation level 2. Throughout the Meewasin site, this deposit varies from inversely graded to massive. Lenses of finer and coarser grained sediment indicate erosion and deposition by overland flow. A soil (occupation level 1) developed at the top of this colluvial deposit.

7. AMISK SITE

The Amisk site (FbNp-17) occupies a colluvial footslope surface on the west side of the Opimihaw Creek valley (Figure 7.1). The site was the focus of a Department of Archaeology Master's thesis (Amundson 1986) and one of the sites studied in a Department of Geography Master's thesis (Burt 1997). The original excavation by Amundson (1986) occurred over two field seasons commencing in the spring of 1984 and finishing in the fall of 1985. Amundson (1986) excavated three units each connected by trenches. Unit A was located in the northwest section of the site, unit B was eight metres east of unit A and unit C was south of both unit A and B. An east-west trench connected units A and B and a north-south trench connected the east-west trench to excavation unit C. In addition, Amundson (1986) excavated two test pits: test pit 1 in the eastern extremity of the archaeological site and test pit 2 along the southern boundary of the site. A total of 42 square meters were excavated down to Amundson's (1986) glacial till unit. In unit A (the western most excavation) Amundson (1986) identified till at 210 cm below surface and in test pit 1 (the eastern most excavation) till was recorded at 88 cm below surface. Amundson (1986) recorded seven occupation levels representing a possible nine separate occupations. The archaeological study reported radiocarbon dates spanning from 5.42 ± 0.12 ka BP (S-2768) to 0.56 ± 0.07 ka BP (S-2531). Amundson (1986) also mapped the geologic stratigraphy of four walls: the north wall of the east-west trench, the east wall of the north-south trench, the west wall of test unit 1, and the south wall of test unit 2. Burt (1997) re-excavated and mapped the geologic stratigraphy of the western most wall of the original excavation. The examined exposure was 265 cm in depth. During the 2000 field season, the present investigation examined two 1m X 1m test pits. Since the original excavation has long since been backfilled, the location of the test pits in relation to the excavation is an approximation. Using the western extent of the excavation as the reference point, the upslope test pit was located around 15 m to the west and the downslope test pit was located about 25 m to the east (Figures 7.1 and 7.2). The upslope test pit was sampled down to 181 cm below surface and the downslope test pit was sampled down to 165 cm below surface. Particle size analysis was conducted on all test pit samples

(Appendix B).

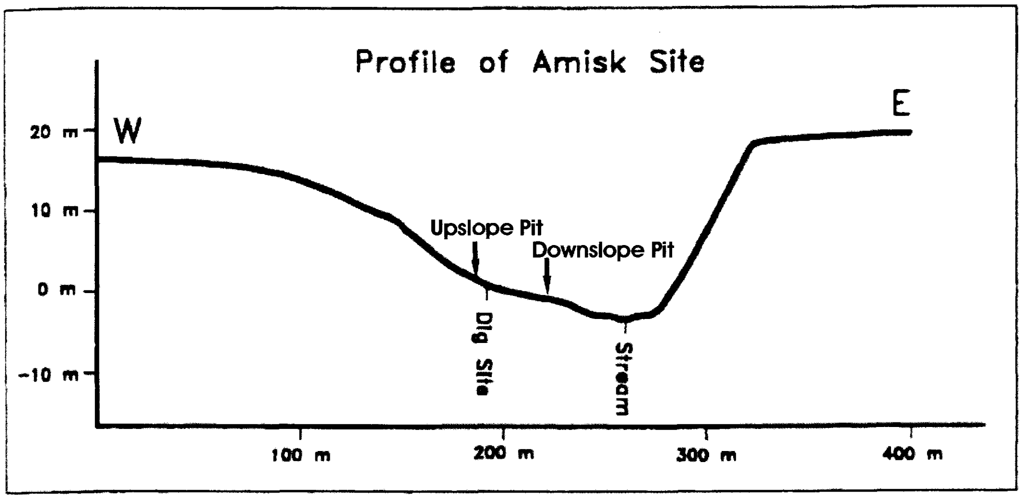


Figure 7.1 Slope profile of the Amisk site. Sample locations indicated with a red arrow (Modified from Burt 1997).

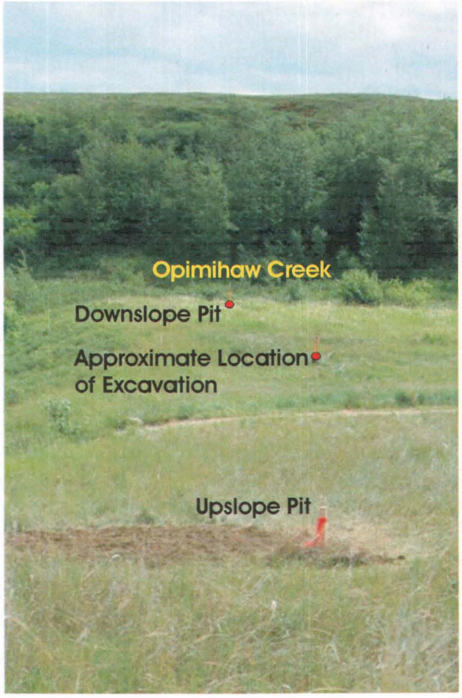


Figure 7.2 Photograph of the Amisk slope showing location of the upslope and downslope test pits and the approximate location of Amundson's (1986) archaeological excavation. View to the east toward the Opimihaw Creek.

7.1 Facies Characteristics

Amisk facies are divided into massive and graded diamicton and diamicton with mud lenses.

7.1.1 Massive Diamictons (sDm)

The massive diamicton facies consists of matrix rich, very poorly sorted, slightly gravelly muddy sands and gravelly muddy sands. The deposit is dark greyish brown and olive brown in colour and was observed throughout the entire depth of the upslope test pit. Most of the cobbles and pebbles were partially coated with pedogenic carbonate. No archaeological material was discovered in this facies.

7.1.2 Normally Graded Diamictons (gDn, sDn)

The normally graded diamicton facies was observed in the downslope test pit. This facies consists of matrix rich very poorly sorted sediments. The texture fines upwards from either gravelly muddy sand to slightly gravelly muddy sand or from muddy sandy gravel to gravelly muddy sand. The colour is greyish brown, olive brown and yellowish brown. Unit thickness ranges from 22 to 43 cm. Some of the cobbles and pebbles were partially coated with pedogenic carbonate. The carbonate coating is less prevalent in the downslope test pit as compared to the upslope test pit. Archaeological material was discovered in this facies.

7.1.3 Diamictons with Lenses of Muddy Sediment (sDf)

Layers of matrix rich very poorly sorted slightly gravelly muddy sand and slightly gravelly sandy mud were observed in the downslope test pit. In the test pit profile examined during the present study, the muddy layers do not exhibit a lenticular geometry. However, Amundson (1986) mapped sandy sediment with lenses of gravel and clay at a similar depth. Thus, this facies is considered a sandy diamicton with lenses of muddy sediment. The colour of the sediments varies from black to greyish brown. Measured unit thickness ranges from 14 to 46 cm and the mud lenses are up to 16 cm in thickness. Some of the cobbles and pebbles were partially coated with pedogenic carbonate. Archaeological material was discovered in this facies.

7.2 Facies Interpretation

The deposits at this site were typically poorly sorted sediments ranging in size from clay to cobble and had a texture that varied from massive to normally graded. The limited exposures at the Amisk site made it difficult to determine the specific depositional processes. However, the textural properties of the sediments and the presence of archaeological material suggest hillslope processes deposited the sediment. The grain size distribution curves illustrated in Figure 7.3 indicates the Amisk site slope sediments, as opposed to the Cut Arm and Meewasin sites, tend not to have a bimodal distribution.

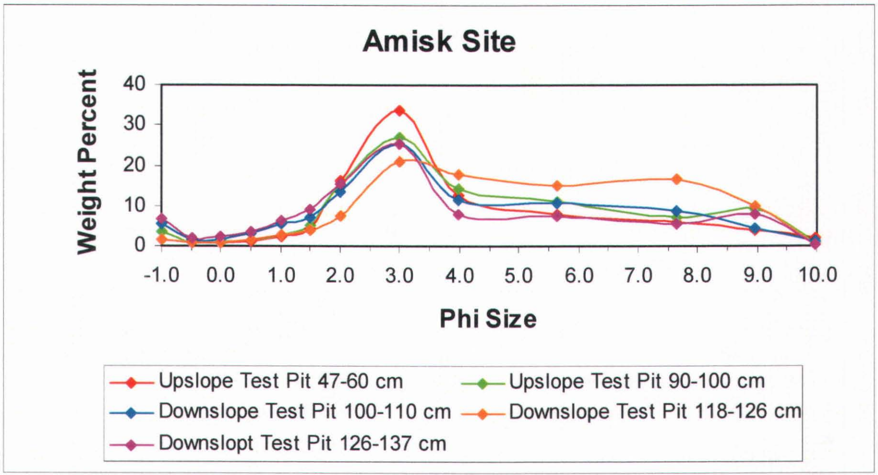


Figure 7.3 An example of the grain size distribution in Amisk debris flow deposits.

7.2.1 Massive Diamictons

Poorly sorted, matrix rich, massively textured sediments were observed throughout the entire depth of the upslope test pit. The range of particles sizes and the lack of sorting

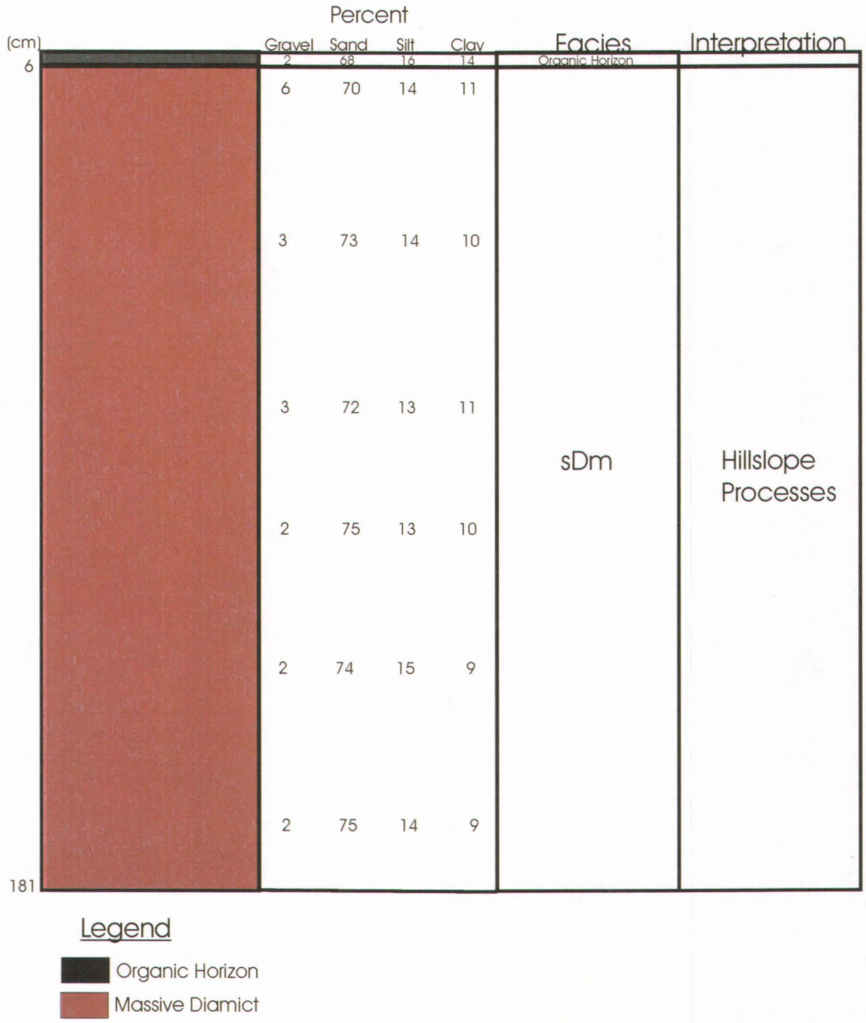


Figure 7.4 Diagram showing the stratigraphy of the Amisk upslope test pit.

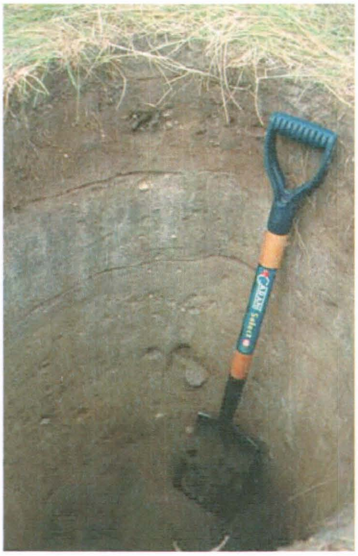


Figure 7.5 Photograph showing upslope test pit at the Amisk site. The profile is 110 cm in depth.

An organic horizon was mapped between 6 cm and surface. The upslope sediments are interpreted as hillslope deposits because the material is similar to the hillslope deposits in the downslope test pit. Alternatively, the upslope sediment is the product of glacial processes and the downslope sediment is the product of hillslope processes. A short distance of transport may result in the hillslope sediments retaining many of the characteristics of the parent material (glacial sediment).

The carbonate coating on pebbles and cobbles observed in the upslope pit is an indication of carbonate redistribution. Vreeken (1994) demonstrated that a redistribution of carbonates might reflect prevalent throughflow (subsurface flow of water) during soil forming phases. Vreeken's (1994, 1996) study of the soil-geomorphic evolution of a hillslope in southwestern Saskatchewan suggests a transition from overland flow (water that flows over the surface) to throughflow may be climate driven. If the changes are climate driven, overland flow can reflect aridity and corresponding bare or sparsely and bedding suggest these sediments are likely hillslope or glacial deposits. Related deposits support a colluvial interpretation for these sediments.

7.2.2 Normally Graded Diamictons

Matrix rich normally graded diamictons were observed in the downslope test pit. The normal graded bedding may result from deposition during the waning stages of a flow. However, the origin of the grading is not fully understood and thus, specific hillslope processes have not been identified at this site.

7.2.3 Diamictons with Lenses

Diamictons with lenses of muddy sediment were mapped in the downslope test pit. These lenses are the product of overland flow erosion and deposition.

7.3 Stratigraphy

Representative stratigraphic sequences and photographs are shown in Figures 7.4 to 7.7.

7.3.1 Upslope Test Pit

The stratigraphy of this test pit is illustrated Figures 7.4 and 7.5. A massive sandy diamicton extends from the bottom (181 cm) to the top of the upslope test pit. The massive diamicton is considered to have been deposited by hillslope processes. The absence of buried soils indicates the landscape was not stable enough for soil formation to occur or the soil was removed during subsequent periods of erosion and deposition.

vegetated slopes. On the other hand, throughflow can indicate moister soil forming conditions (Vreeken 1994, 1996). Evidence of carbonate redistribution occurred throughout the entire depth of the upslope test pit.

7.3.2 Downslope Test Pit

The stratigraphic profile of the downslope test pit is shown in Figures 7.6 and 7.7. The lowermost facies extends from 165 cm to 143 cm and is a normally graded diamicton. The sediments are defined as gravelly diamicton from 165 cm to 160 cm and sandy diamicton from 160 cm to 143 cm. This deposit may result from hillslope sedimentation. However, some of the samples were obtained by auger and thus, distinguishing between a hillslope and glacial deposits was difficult. A sandy normally graded diamicton extends from 143 cm to 110 cm. These normally graded sediments are considered to have been deposited by hillslope processes and may be related to the underlying normally graded sediments. A bone fragment was discovered at 113 cm below surface. The bone did not appear to be contained within a buried soil. A normally graded sandy diamicton occurs between 110 cm and 67 cm. These sediments reflect deposition by hillslope processes. A buried soil developed within this unit extends from 91 cm to 67 cm below surface. Bone fragments were discovered at 98 cm, 88 cm and 78 cm below surface. The bone at 98 cm was not contained within a buried soil. The bone at 88 cm and 78 cm were found within the 91 cm to 67 cm buried soil.

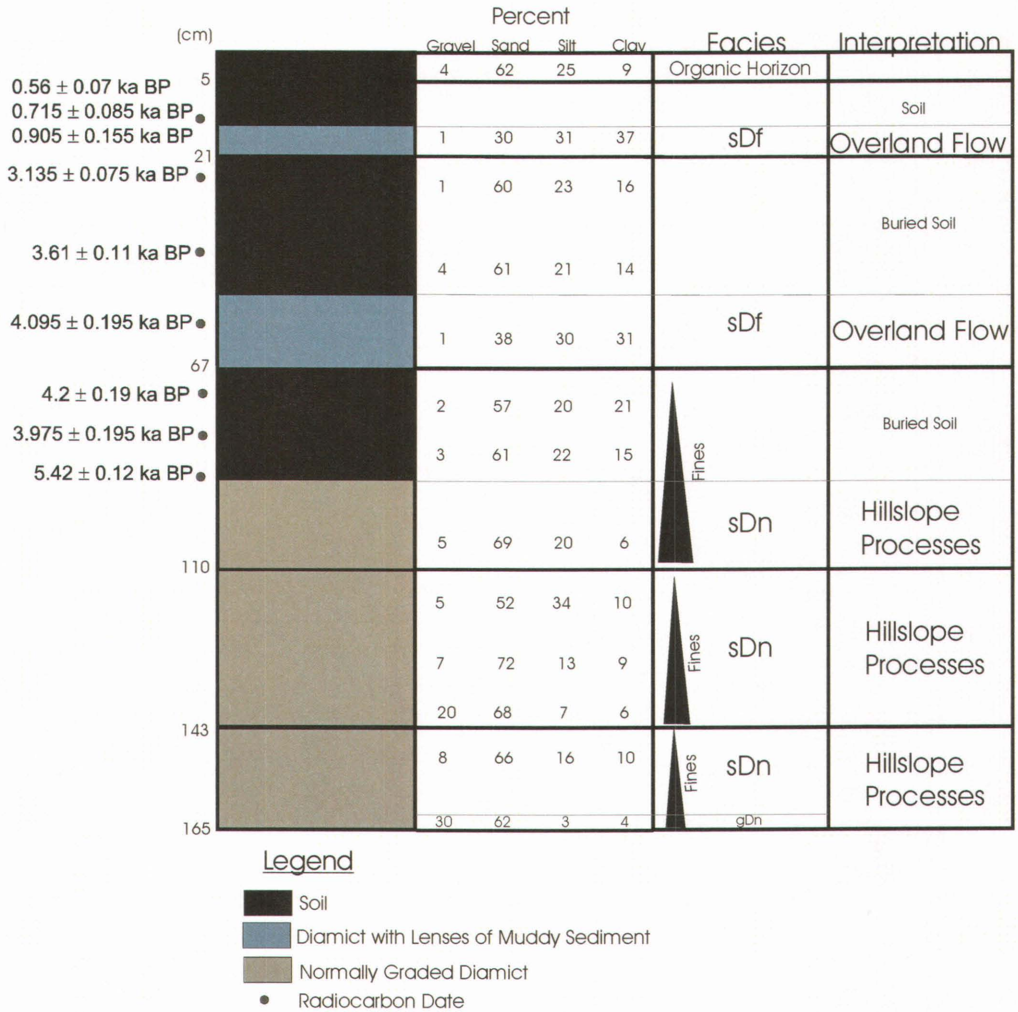


Figure 7.6 Diagram showing the stratigraphy in the Amisk downslope test pit.

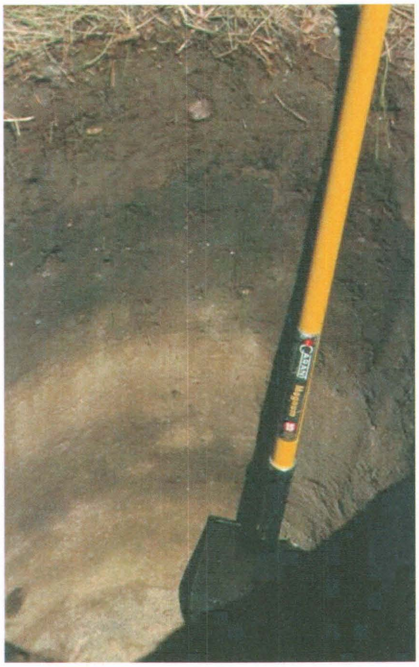


Figure 7.7 Photograph showing downslope test pit at the Amisk site. The profile is 118 cm in depth.

Amundson (1986) recorded an occupation level 7 at 88 cm below surface in the eastern extent of his excavations. Amundson (1986) recorded a bone sample from occupation level 7 with a radiocarbon date of 5.42 ± 0.12 ka BP (S-2768). Since the downslope test pit is located east of the original excavation, the remainder of the stratigraphy will be compared to Amundson's (1986) eastern excavation measurements. The bone sample from 78 cm below surface appears to correspond with Amundson's (1986) occupation level 6. Amundson (1986) reported occupation level 6 at 80 cm below surface with an associated radiocarbon date of 3.975 ± 0.195 ka BP (S-2534). In addition, Amundson (1986) recorded a 10 to 15 cm thick occupation level 5 at approximately 70 cm below surface. Bone material from occupation level 5 recorded a radiocarbon date of

4.2 ± 0.19 ka BP (S-2535). A sandy diamicton with a lense of muddy sediment was mapped between 67 cm and 21 cm. The finer grained layer extends from 67 cm to 51 cm. The 67 cm to 21 cm deposit is the product of deposition from overland flow. The lenses of finer and coarser sediment may represent fluctuation in discharge during a precipitation event. A buried soil extends from 51 cm to 21 cm and bone fragments were discovered at 46 cm, 36 cm, 28 cm, and 25 cm. The bone at 46 cm corresponds with Amundson's (1986) occupation level 4. Amundson (1986) defines occupation level 4 as a 10 to 15 cm layer at approximately 55 cm below surface. A radiocarbon date of 4.095 ± 0.195 ka BP (S-2536) was obtained from occupation level 4. The radiocarbon date from occupation level 6 (3.975 ± 0.195 ka BP) appears to be younger than the dates from the overlying occupation level 5 (4.2 ± 0.19 ka BP) and occupation level 4 (4.095 ± 0.195 ka BP). The range of error associated with the radiocarbon dates may explain the discrepancy. The bone discovered at 36 cm and 28 cm appears to correspond with Amundson's (1986) occupation level 3. Amundson (1986) describes occupation level 3 as a 10 to 15 cm layer located approximately 41 cm below surface. Amundson (1986) showed that a bone sample from occupation level 3 produced a radiocarbon date of 3.61 ± 0.11 ka BP (S-2767). The bone fragment at 25 cm likely yields from Amundson's (1986) occupation level 2. Amundson (1986) recorded occupation level 2 at 23 cm below surface. A bone sample from occupation level 2 provides a radiocarbon date of 3.135 ± 0.075 ka BP (S-2769). A sandy diamicton with a lense of muddy sediment extends from 21 cm to 5 cm. This deposit is the product of overland flow sedimentation. These sediments are similar to the underlying diamicton with a mud lense (67 to 21 cm).

The 21 cm to 5 cm deposit and the 67 cm to 21 cm deposit arise from similar depositional conditions. A soil extends from 15 cm to 5 cm. This soil occurs at about the same depth below surface as Amundson's (1986) occupation level 1. Amundson (1986) describes occupation level 1 as a 10 cm layer with a lower boundary at 12 cm below surface. Radiocarbon dates of 0.56 ± 0.07 ka BP (S-2531) and 0.715 ± 0.085 ka BP (S-2770) were obtained from bone samples and charcoal sample provides a date of 0.905 ± 0.155 ka BP (S-2537) (Amundson 1986:58). An organic horizon extends from 5 cm to surface.

7.4 Hillslope Evolution

The history of landsurface development at the Amisk site reveals an accumulation of hillslope sediments and subsequent soil development. The repeated layers of soil developed in hillslope sediments documents periods of erosion and deposition followed by periods of nondeposition and landscape stability. This study supports Burt's (1997) colluvial interpretation of the Amisk site. Burt (1997) demonstrated that the sedimentary deposits result from slopewash and mass wasting processes. Fluvial processes did not play a role in site development. Conclusions from this study vary from Amundson's (1986) interpretation. Amundson (1986) mapped colluvial sediment above occupation level 7 and glacial sediments below occupation level 7. Amundson (1986) interpreted the sediments underlying occupation level 7 as glaciofluvial or glaciolacustrine coarse sand underlain by till. Investigations during this study revealed that occupation level 7 is underlain by diamicton. There was no evidence of a sand deposit. It is possible the diamicton underlying occupation level 7 is glacial sediment. However, in the downslope test pit archaeological material was encountered at 98 cm and 113 cm below surface. The archaeological material discovered during the present study appears to underlie Amundson's (1986) occupation level 7. Since it is unlikely that the cultural material is contained within glacial sediments, the test pit record indicates colluvial sediments extend deeper then occupation level 7.

As interpreted from the Amisk test pits, hillslope erosion and deposition has occurred throughout the formation of the Amisk site. Correlation between the downslope test pit and Amundson's (1986) radiocarbon dates indicate deposition by hillslope processes began prior to 5.42 ± 0.12 ka BP. Amundson's (1986) radiocarbon dates and this study's corresponding buried soils indicate the landsurface was stable around 5.42 ± 0.12 ka BP, 3.975 ± 0.195 ka BP, 4.2 ± 0.19 ka BP, 4.095 ± 0.195 ka BP, 3.61 ± 0.11 ka BP, 3.135 ± 0.075 ka BP, and between 0.905 ± 0.155 ka BP and 0.560 ± 0.07 ka BP. The hillslope deposits observed in the downslope test pit are matrix rich and either normally graded or sandy diamictons with lenses of muddy sediment. The normal graded bedding may result from deposition during the waning stages of a hillslope event. The finer and coarser grained lenses may represent fluctuations in discharge during a precipitation event. The absence of buried soils in the upslope test pit suggests erosion processes stripped the soil layers. Alternatively, though the sediment in the upslope and the downslope test pits is similar, the absence of soils may indicate the upslope sediments are the product of glacial sedimentation.

8. THUNDERCLOUD SITE

The Thundercloud site (FbNp-25) occurs along an alluvial toeslope surface on the east side of the Opimihaw Creek. The site was the focus of two Department of Archaeology Master's theses (Mack 2000; Webster 1999), six Department of Archaeology field schools and one of the sites studied in a Department of Geography Master's thesis (Burt 1997). Archaeological excavation began in 1993 and ended after the 1998 field season. During this time, 44 ½ square meters were excavated to approximately 80 cm below surface. Excavations discovered seven occupation levels representing at least ten separate occupations. The archaeological interpretation indicates occupation occurred between the Oxbow cultural complex (ca. 5.0-3.1 ka BP) and the Historic period (<500 BP). A radiocarbon date of 4.145 ± 0.09 ka BP (S-3645) was obtained from 48 cm below surface. During the 1995 field season, Burt (1997) mapped and sampled the south face of the Thundercloud excavation and examined two shallow test pits located approximately 30 m east and upslope of the excavation. The examined south face exposure was approximately 120 cm in depth. As a part of this investigation, a 1m X 1m test pit was excavated in July 2000. Although the archaeological excavation had been backfilled, it is estimated the test pit was located 50 m east and upslope of the excavation. The test pit was mapped and sampled down to a depth of 96 cm below surface. Figures 8.1 and 8.2 show the location of the test pit in relation to Burt (1997), Webster (1999), and Mack's (2000) study sites. Particle size analysis was conducted on all test pit samples (Appendix B).

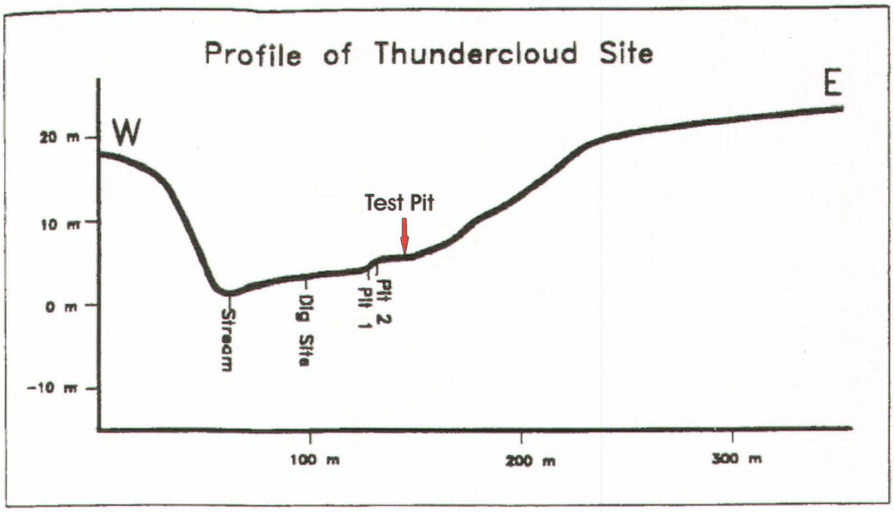


Figure 8.1 Slope profile of the Thundercloud site showing Burt's (1997) sample locations and the present study's test pit (red arrow) (modified from Burt 1997).

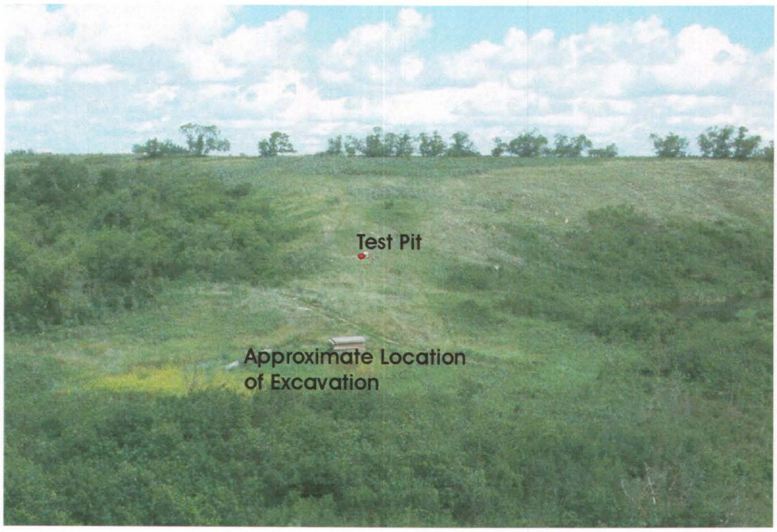


Figure 8.2 Photograph of the Thundercloud slope showing location of the test pit and the approximate location of Mack (2000) and Webster's (1999) archaeological excavation. View to the east away from the Opimihaw Creek.

8.1 Facies Characteristics

The facies are divided into normally and inversely graded diamicton.

8.1.1 Normally Graded Diamictons (mDn)

A normally graded diamicton facies was observed in the Thundercloud test pit between 56 cm and 116 cm below surface. This facies consists of matrix rich very poorly sorted sediments. The texture shows a slight fining up from gravelly sandy mud to slightly gravelly sandy mud. Some of the cobbles and pebbles were partially coated with pedogenic carbonate. The colour of the sediment is olive yellow and yellowish brown. No archaeological material was discovered in this facies.

8.1.2 Inversely Graded Diamictons (mDi)

An inversely graded diamicton facies was observed between 7 cm and 56 cm below surface. The sediments are matrix rich, very poorly sorted slightly gravelly sandy mud and gravelly sandy mud. The colour of this facies is yellowish brown and olive brown. Some of the cobbles and pebbles were partially coated with pedogenic carbonate. No archaeological material was discovered in this facies.

8.2 Facies Interpretation

The sediments in the Thundercloud test pit are very poorly sorted matrix supported mixtures ranging in size from clay to cobbles. Their texture varies from normal to inversely graded. Similar to the Amisk site, the limited exposures made it difficult to determine the specific depositional processes. Hillslope and glacial sediments can have similar textures and sedimentary structures. The occurrence of hillslope deposits on other slopes in Wanuskewin Heritage Park support a colluvial interpretation for the Thundercloud test pit. In addition, within the archaeological excavation Burt (1997) recorded a possible colluvial deposit between 24 cm and 30 cm. Burt's (1997) sedimentary interpretation and the present study suggest hillslope erosion and deposition has played a role in the development of the Thundercloud site.

The Thundercloud hillslope sediments are similar to the Amisk hillslope sediments in that they do not have a distinct bimodal distribution (Figure 8.3).

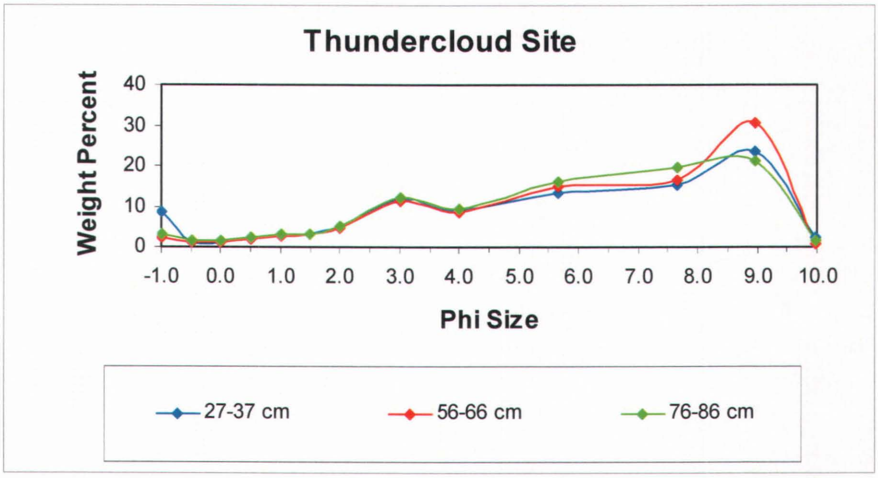


Figure 8.3 An example of the grain size distribution in Thundercloud hillslope deposits.

8.2.1 Normally Graded Diamicton

The normal graded bedding results from the sedimentary processes.

8.2.2 Inversely Graded Diamicton

The inverse grading may reflect sedimentation and soil formation processes.

8.3 Stratigraphy

A representative stratigraphic sequence and photograph are shown in Figures 8.4 and 8.5.

8.3.1 Test Pit

A matrix rich normally graded diamicton was observed between 56 cm and 116 cm below surface. This deposit may be the product of hillslope sedimentation. A matrix rich inversely graded diamicton was observed between 56 cm and 7 cm below surface. These sediments may result from hillslope processes. Since this deposit occurs at the top of the stratigraphic profile, current soil formation processes may have influenced the grading.

Pedogenic alteration in the form of carbonate redistribution suggests a prevalence of throughflow during soil formation. A dominance of throughflow as compared to overland flow suggests the surface was protected by vegetation. Throughout the depth of the Thundercloud sedimentary sequence, carbonate coatings on pebbles and cobbles indicate carbonate redistribution. An organic horizon extends from 7 cm to surface.

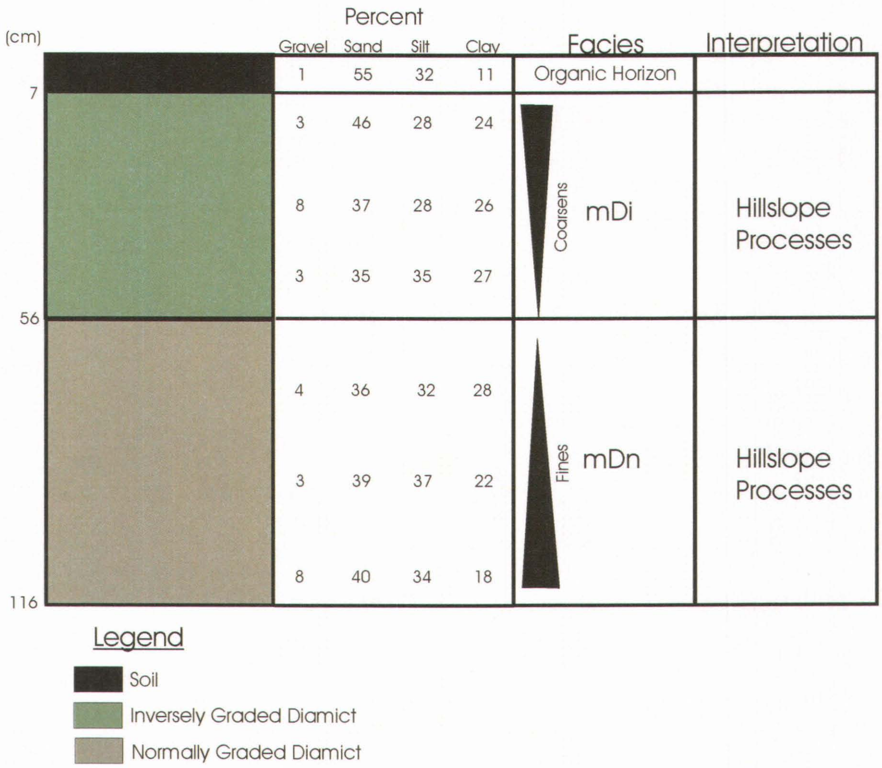


Figure 8.4 Diagram showing the stratigraphy in the Thundercloud test pit.

Figure 8.5 Photograph showing test pit at the Thundercloud site. The profile is 96 cm in depth.

8.4 Hillslope Evolution

Burt (1997) interpreted the Thundercloud excavation sediment as a product of predominantly fluvial processes. However, Burt (1997) also mapped a thin colluvial deposit between 24 and 30 cm below surface. Burt's (1997) interpretation in conjunction with the present study suggests hillslope processes assume a role in the formation of the Thundercloud site. In addition, previous archaeological investigations (Mack 2000;Webster 1999) comment on the intermittent nature of occupation level 4. Occupation level 4 underlies Burt's (1997) colluvial deposit and thus, the buried soil could have been partially stripped during a hillslope event.

9. LANDSCAPE EVOLUTION

The soil, sediment, and geomorphology of the Thundercloud, Amisk, Cut Arm, and Meewasin sites indicates hillslope processes play a central role in site formation. Hillslope processes identified in the study area include overland flow, debris flows, creep, and slides. The physical attributes of the sediments reflect the transport and depositional conditions and thus, suggest paleoenvironmental conditions.

9.1 Hillslope Evolution and Paleoclimate

Radiocarbon data on Holocene hillslope processes in Wanuskewin Heritage Park are limited by the lack of datable material at some archaeological sites. The available dates are primarily derived from bone samples in buried soils. The buried soils mainly separate hillslope deposits from underlying hillslope material or glacial sediments. When the study sites are compared to each other, there is limited direct correlation between the sites. However, there is general evidence about the timing of hillslope processes in Wanuskewin Heritage Park. The dates suggest erosion of the hillslopes began before 5.42 ± 0.12 ka BP in the Opimihaw Creek valley and before 3.864 ± 0.055 ka BP in the South Saskatchewan River valley. Burt (1997) demonstrated that an increase in sediment load resulting from increased slope activity triggered an aggradation phase in the Opimihaw Valley. This study indicates slope activity began before 5.42 ± 0.12 ka BP in the Opimihaw Valley suggesting Burt's (1997) aggradation phase may have begun earlier than her estimated 4.5 ka BP. Prairie paleoenvironmental records indicated an interval of increased warmth and aridity occurred between ca. 9 ka BP and 4.4 ka BP with maximum warmth and aridity between 7.7 ka BP and 5.1 ka BP (Vreeken 1994). Interpretation of the hillslope sediments in Wanuskewin Heritage Park indicates slope erosion in the Opimihaw Valley (before ca. 5.4 ka BP) began during this period of aridity and warmer temperatures (Altithermal). Sauchyn's (1990) interpretation of Harris Lake sediments showed that the landscape was relatively stable from 9.12 ka BP to 7.7 ka BP. However, between 6.8 ka BP and 5.12 ka BP the rate of sedimentation in Harris Lake was close to the Holocene maximum. He suggested that incomplete surface cover and episodic, accelerated erosion characterized the Altithermal period in the Cypress Hills. Similarly, Vance *et al.'s* (1993) analyses of core from Chappice Lake showed that between 7.3 ka BP and 6 ka BP the lake experienced extreme water level changes. The lake ranged from complete desiccation to relatively high lake levels. Vance *et al.* (1993) suggested the lake level fluctuation were the result of a climatic regime that was more variable than present and included relatively frequent and severe droughts. Between 6 ka BP and 4 ka BP the climate ameliorated somewhat but Chappice Lake continued to experience pronounced seasonal water fluctuations. Thus, the Altithermal hillslope events in the Opimihaw Valley and the South Saskatchewan Valley may result from the variable Altithermal climate. Bettis (1992) demonstrated that the highest rates of Holocene slope erosion were a function of decreased vegetation cover combined with high-intensity thunderstorms.

Poorly developed closely spaced soils separated by hillslope sediments indicate a period of frequent landscape instability between ca. 4.5 ka BP and 3.5 ka BP in both the Opimihaw and South Saskatchewan valleys. Saunchyn's (1990) Harris Lake study demonstrated that there was significant mid-Holocene climate change. A transition from the dry conditions of the Altithermal to maximum humidity occurred during the 4.5 ka BP to 3 ka BP climatic interval. Schweger and Hickman's (1989) study of 23 lakes and bogs in central Alberta showed that after 5 ka BP the climate became wetter. Similarly, Vance *et al.'s* (1993) interpretation of cores from Chappice Lake showed that a moistening trend began by approximately 4.4 ka BP. Sauchyn (1990) demonstrated that in Harris Lake this mid-Holocene climate change caused a transition in sedimentary processes. There was change from fluvial and aeolian erosion before 5.1 ka BP to rotational landsliding after 4.5 ka BP. The interval of increased slope activity on the Opimihaw and South Saskatchewan slopes (ca. 4.5 ka BP to 3.5 ka BP) correlates well with the transition to moister climatic conditions and Sauchyn's (1990) interpretation.

Intermittent weakly developed soils at the base of the stratigraphic profiles are often overlain by thicker and darker soils. The transition to better developed soils occurs around 2 ka BP. The thicker and darker soil horizons represent longer and/or moister soil forming conditions (Vreeken 1996). Last and Schweyen's (1985) interpretation of sediment cores from Waldsea Lake, Saskatchewan showed a transition to high water conditions around 2 ka BP with little evidence of major lake level fluctuations over the last 2000 years. Vance *et al.* (1993) demonstrated that the longest high-water stand of Chappice Lake took place between 2.6 ka BP and 1 ka BP. Thus, the thicker and darker soils in the study area may result from moister conditions. In addition, the increased precipitation would have fostered greater vegetation cover. Vegetation intercepts raindrops and thus, prevents the drops from reaching and eroding the soil or absorbs the impact and minimizes the erosional effectiveness of the drops. Vegetation also reduces runoff velocities and thus, reduces the water's capacity to entrain sediment. Root networks increase soil strength, granulation, and porosity (Selby 1993). These effects help protect the soil and reduce erosion. Thus, the increased vegetation cover likely resulted in longer periods of landscape stability and soil formation.

The study sites also record a stable phase around 0.7 ka BP overlain by hillslope sediments. Vance *et al.* (1993) record low water levels related to significant drought between 1 ka BP and 0.6 ka BP and Last and Schweyen (1985) report a slightly lower water level around 0.7 ka BP. This indicates the hillslope sediments are a function of decreased vegetation cover caused by the drought coupled with a return to moister conditions.

9.2 Landscape Evolution and the Archaeological Record

In the study sites, the well developed soils suggest long periods of nondeposition and landscape stability and thus, may represent successive occupations. The weakly developed soils indicate shorter durations of landscape stability and thus, have a greater potential for representing discrete occupations (Holliday 1992).

Schweger and Hickman (1989) demonstrated that a late glacial – early Holocene arid period existed in central and southern Alberta and Saskatchewan. After about 6 ka BP, progressively less arid conditions prevailed. They suggested that early Holocene to mid-

Holocene valley-bottom occupations might have been destroyed through erosion or inundated by rising water levels. Similarly, this transition to a wetter climate and the readjustment of the hillslopes may have disturbed early to middle Holocene occupations on the slopes. This may explain the absence of cultural material older than 6 ka BP in Wanuskewin Heritage Park.

10. SUMMARY AND CONCLUSIONS

Interpretation of the Thundercloud, Amisk, Meewasin, and Cut Arm sites indicates hillslope sedimentation influenced the formation of these archaeological sites. The history of hillslope evolution in Wanuskewin Heritage Park is limited by the absence of datable material at some of the archaeological sites. This sedimentological investigation coupled with available radiocarbon dates, dates from diagnostic cultural material and comparison to published prairie paleoenvironmental data indicates the following main conclusions.

Erosion of the hillslopes began before 5.42 ± 0.12 ka BP in the Opimihaw Valley and before 3.864 ± 0.055 ka BP in the South Saskatchewan Valley. The Opimihaw Valley slope activity began during a period of aridity and warm temperatures (Altithermal). An interval of frequent hillslope erosion and sedimentation occurred in both valleys between approximately 4.5 ka BP and 3.5 ka BP. This interval of slope activity correlates well with climate change on the prairies. A transition from the dry conditions of the Altithermal to moister conditions occurred around 4.5 ka BP. Decreased vegetation cover resulting from the dry Altithermal period coupled with increased precipitation best explains the increased hillslope activity. Thicker and darker soil layers overlie intermittent weakly developed soils at the base of the stratigraphic profiles. The thicker and darker soils reflect longer periods of nondeposition, landscape stability and soil formation and thus, a decrease in the frequency of hillslope events. Diagnostic cultural material suggest the transition to better developed soils occurs around 2 ka BP. This correlates with a late Holocene high water conditions in some prairie lakes. Thus, the longer intervals of landscape stability may result from moister conditions and increased vegetation cover. In additions, sediments deposited from overland flow generally overlie debris flow sediments at the base of the stratigraphic profiles. The overland flow deposits as compared to the debris flow sediments reflect lower energy phenomena. The transition to overland flow sediments also suggests a decrease in the duration of the precipitation events. Prairie lake core records indicate the 0.7 ka BP stable phase overlain by sediments deposited by hillslope processes are related to increased precipitation following drought conditions. Lastly, when the study sites are compared there is limited direct correlation between individual sites. This indicates the landscape of each site adjusted in its own way to similar climatic conditions.

10.1 Future Research

Understanding the Wanuskewin Heritage Park hillslope record requires examination of more extensive exposures within the individual study sites and analyses of additional similar localities on the Northern Plains. In addition, sedimentological and paleobotanical data from lakes within closer proximity to the study area would help define the paleoenvironmental conditions.

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APPENDIX A

Modified Particle Size Analysis
Procedures and Calculations

Methods of Particles Size Analysis

The following methods were obtained from Burt (1997), Day (1965), Gee and Bauder (1986), Kunze and Dixon (1986), and Lewis and McConchie (1994).

Laboratory Procedures
Sample Treatment Techniques

Drying
1. Air-dry sample in a clean laboratory.
2. Record dry Munsell colour.

Physical Disaggregation
3. If necessary, gently grind the sample with a porcelain mortar and pestle. Break up clods to less than 2 mm.

Sample Splitting
4. Subsample the sediment by pouring the sample onto a flat sheet of glazed paper. Use a knife to split the cone of sediment into quarters. Carefully move the quarters apart and combine opposite quarters to produce two equivalent subsamples. Continue to split the subsamples until an approximately 100 g subsample is produced.

Removal of Organic Matter
5. Place sample in a 1-L beaker.
6. Just cover sample with distilled water.
7. Add 5 mL of 30% hydrogen peroxide (H_2O_2).
8. Stir the suspension and allow time for any strong frothing to subside.
9. Continue adding H_2O_2 in small quantities until the sample ceases to froth. Transfer the sample to a hot plate and heat slowly to 65 to 70°C. Do not heat samples in excess of 70°C, as it will result in the decomposition of the H_2O_2.
10. During heating, watch the sample closely for 10 to 20 min or until danger of any further strong reaction has passed. Continue heating the sample until most of the water has evaporated. Do not take the sample to dryness.
11. Continue the peroxide and heat treatment until most of the organic matter has been destroyed. The reaction of soil with H_2O_2 is essentially complete when the soil loses its dark colour or when conspicuous frothing ceases.
12. Use distilled water to transfer the sample to centrifuge tubes. Make sure to remove all particles from the sides of the beaker.
13. Balance pairs of tubes and centrifuge the tubes at 1600 to 2200 rpm for 10 to 15 min
14. Decant and discard the supernatant (brownish) liquid.
15. Fill the tubes with distilled water and stir until the sample is completely mixed.
16. Balance pairs, centrifuge, and decant the supernatant liquid.
17. If the supernatant liquid is relatively clear use distilled water to transfer the sample to a 250-mL beaker and cover with a watch glass. Otherwise, repeat the centrifuge procedures. If H_2O_2 is present in the sample at the time of the centrifuge procedure,

the continuous decomposition of the H_2O_2 will make it difficult to obtain a clear supernatant liquid. It may be necessary to destroy the excess peroxide by boiling the samples for a few minutes.

Physical Disaggregation

18. Prepare a sodium hexametaphosphate (calgon) stock solution. The concentration of the stock solution is 50 g of calgon per 1000 L of distilled water.
19. Cover the sample with a small quantity of distilled water plus 10 mL of the calgon solution. Use (rubber-gloved) fingers to gently break up the sample. Rinse mud off the gloves back into the beaker.

Sieve Analysis

Wet Sieving

20. Separate the gravel and sand fractions from the silt and clay fractions by wet-sieving the sample through a 63-µm sieve. This is accomplished by pouring the sample through a 63-µm sieve placed in a large funnel above a 1-L column. Wash all fines into the column using as little distilled water as possible.
21. Transfer (using distilled water) the entire gravel and sand fractions retained on the sieve to a tared beaker.
22. Dry the sand and gravel at approximately 55°C, leave to cool for 1hr, and weigh to 0.001 g. Drying at temperatures greater than 60°C can cause the formation of aggregates which cannot be easily dispersed during later analyses. In addition, cooling should be conducted in a desiccator chamber.

Dry Sieving

23. Transfer the dried sand and gravel to a nest of sieves arranged from top to bottom with decreasing size and in the following order: 2.0-mm, 1.4-mm, 1.0-mm, 710-µm, 500-µm, 355-µm, 250-µm, 125-µm, and 63-µm. It is best to divide the sieves in half and run two separate nests of sieves. The coarser nest includes the 2.0-mm, 1.4-mm, 1.0-mm, 710-µm, and 500-µm sieves and the finer nest include the 355-µm, 250-µm, 125-µm, and 63-µm sieves as well as the pan fraction.
24. Place the sieves on a sieve shaker and run the shaker for 10 min and at a speed of 4-5.
25. Weigh each gravel and sand fraction as well as the residual silt and clay that passed through the 63-µm sieve (pan fraction). Record the weight to 0.001 g and add the pan fraction to the silt and clay already in the 1-L column.
26. If greater than 5% of the sample is lost during sieving operations, the whole process must be repeated.

Pipette Analysis

27. Add exactly 10 mL of the calgon stock solution to each 1-L column.

28. Later calculations require that the exact weight of calgon added to each sample be known. Therefore, add exactly 20 mL of calgon (the total added to each sample) to a tared beaker, dry the beaker and record the weight of the calgon to 0.001 g.
29. Thoroughly stir the column with a brass stirring rod and top the column up to 1 L with distilled water.
30. Place the column containing the silt and clay suspension in a water bath.
31. Cover the column with a watch glass and let it stand overnight to equilibrate with the water bath temperature.
32. Label and weigh to 0.001 g, five small beakers per sample (total suspension (time zero), 20 μm (≈4 min), 5 μm (≈1 hr), 2 μm (≈7 hr), and 1 μm (≈30 hr)).
33. Take the temperature of the water in the water bath and look up the corrected sampling times (Table A.1). Monitor and adjust for any temperature changes during the pipette analysis.

Table A.1 Sampling times calculated for a 10-cm sampling depth, assuming a particle density of 2.60 Mg/m^3 and dispersion with a 0.5 g/L calgon solution. (Modified from Gee and Bauder 1986:Table 15-1 and15-3)

Temperature (°C)	20 μm	5 μm	2 μm	1 μm
20	4 min 48 sec	1 hr 16 min 48 sec	8 hr 0 min 0 sec	31 hr 51 min
21	4 min 42 sec	1 hr 15 min 0 sec	7 hr 49 min 12 sec	31 hr 10 min
22	4 min 36 sec	1 hr 13 min 12 sec	7 hr 37 min 48 sec	30 hr 28 min
23	4 min 30 sec	1 hr 11 min 30 sec	7 hr 27 min 36 sec	29 hr 23 min
24	4 min 24 sec	1 hr 9 min 54 sec	7 hr 16 min 48 sec	28 hr 18 min
25	4 min 18 sec	1 hr 8 min 18 sec	7 hr 7 min 12 sec	28 hr 18 min

34. Mark a line exactly 10 cm from the bottom of the 20-mL pipette.
35. Have a large beaker of distilled water ready for rinsing.
36. Starting at 1 min 30 sec before the initial withdrawal time, begin to stir the sample with a brass stirring rod. Start with short, quick strokes at the bottom and then proceed to long vigorous strokes. While stirring the sample, be careful not to mix air in with the suspension. Stir for 1 min, withdraw the stirrer, lower the pipette to 10 cm, and at precisely time zero extract a 20-mL sample.
37. Empty the pipette into the respective tared beaker. Rinse the pipette with distilled water and empty the rinse water into the same beaker. Repeat the rinse procedure and wash the outer part of the pipette.

38. With the exception of stirring, repeat the above pipette sampling techniques for all subsequent withdrawals. Stirring only occurs prior to the time zero extraction and during the remaining withdrawals it is important to avoid creating turbulence.
39. Between withdrawals, cover the 1-L column with a watch glass.
40. Oven-dry the samples at 105°C. No further analysis is required so the samples may be dried at a higher temperature.
41. Remove dry beakers from the oven, cool for 1 hr in a desiccator chamber, and record weight to 0.001 g.
42. Test the accuracy of the laboratory methods by repeating every tenth sample.

Calculations

Gravel and Sand Fractions (>63 μm)

1. Calculate weight percentage of each gravel and sand fraction:

$$100 \times \frac{\text{weight of gravel or sand on sieve}}{\text{total sample weight (gravel and sand plus mud)}} \quad \text{A.1}$$

2. Calculate percent total gravel (>2 mm) and total sand (1.4 mm, 1 mm, 710 μm, 500 μm, 355 μm, 250 μm, 125 μm and 63 μm)
3. Add the percentages incrementally to obtain cumulative weight percentages.

Silt and Clay Fractions (<63 μm)

4. Correct for addition of dispersant agent (Calgon):

Mass of calgon in 20 mL pipette sample= [(mass of calgon in cylinder)/1000 mL] x 20 mL A.2

Corrected pipette weight = 20 mL pipette sample weight -weight of Calgon in 20 mL sample A.3

5. Compute the weight percentage of mud intervals. Note, each pipette sample represents the silt or clay fractions in suspension finer than a certain grain size and thus, require the following calculations to obtain the weight percentage of each mud fraction.

$$\text{Percent of silt and clay in suspension at } n \text{ time} = \frac{\text{corrected weight of pipette sample at } n \text{ time}}{\text{corrected total mud (time zero) per 20 mL}} \times 100 \quad \text{A.4}$$

$$\text{Percent change from previous reading} = \text{previous \% in suspension at } n \text{ time} - \text{\% in suspension at } n \text{ time} \quad \text{A.5}$$

$$\text{Weight percentage of each mud fraction in the total sample} = \frac{\text{percent change x percent mud in total sample}}{100} \qquad \text{A.6}$$

6. Calculate weight percentage of colloidal clay.

$$\text{Percent colloidal clay} = \text{percent total mud} - (20\ \mu\text{m} + 5\ \mu\text{m} + 2\ \mu\text{m} + 1\ \mu\text{m}) \qquad \text{A.7}$$

7. Calculate total silt weight percentage (20 μm and 5 μm) and total clay weight percentage (2 μm, 1 μm, and colloidal clay).
8. Add mud percentages cumulatively to obtain the cumulative percentages.

APPENDIX B

Detailed Sample Description
Colour, Particle Size, Statistical Parameters, and Facies Classification

Colour
Described as moist and dry Munsell colour.

Percent Gravel, Sand, Silt and Clay
Determined by sieve and pipet procedures outlined in Appendix A.

Sorting Class
Based on standard deviation. Formula and detailed discussion provided in Chapter 4.

Textural Classification
Based on the Folk two triangle classification system (Figure 4.2).

Facies Classification
Classification scheme and codes explained in Chapter 4.

Sample Number	Depth (m)	Moist Colour	Dry Colour	% Gravel	% Sand	% Silt	% Clay	Sorting	Textural Class	Facies
Amisk Site										
Upslope Test Pit										
AM-0627-S034	0-6	10YR3/1	10YR3/2	1.98	67.88	16.24	13.90	very poorly sorted	(g)mS	organic horizon
AM-0627-S033	6-23	10YR3/2	10YR3.5/2	5.56	70.20	13.67	10.57	very poorly sorted	gmS	sDm
AM-0627-S032	23-37	10YR4/2	2.5Y5/2	1.98	74.82	14.52	8.69	very poorly sorted	(g)mS	sDm
AM-0627-S031	37-47	2.5Y5/2	2.5Y5/2.5	1.79	75.81	13.42	8.97	very poorly sorted	(g)mS	sDm
AM-0627-S030	47-60	2.5Y5/3	2.5Y5/2.5	3.46	72.59	13.82	10.14	very poorly sorted	(g)mS	sDm
AM-0627-S029	60-70	2.5Y5/3	2.5Y5/3.5	2.48	71.26	16.19	10.08	very poorly sorted	(g)mS	sDm
AM-0627-S028	70-80	2.5Y5/4	2.5Y5/3.5	5.77	72.79	13.11	8.33	very poorly sorted	gmS	sDm
AM-0627-S027	80-90	2.5Y5/4	2.5Y5/3.5	3.24	72.48	13.32	10.96	very poorly sorted	(g)mS	sDm
AM-0627-S026	90-100	2.5Y5/4	2.5Y5/3.5	3.46	68.06	18.00	10.48	very poorly sorted	(g)mS	sDm
AM-0627-S025	100-110	2.5Y5/3	2.5Y5/3.5	3.20	70.02	16.19	10.59	very poorly sorted	(g)mS	sDm
AM-0703-S060	110-130	2.5Y4/3	2.5Y5/3	2.18	75.18	12.99	9.66	very poorly sorted	(g)mS	sDm
AM-0703-S061	130-140	2.5Y5/4	2.5Y6/4	1.54	72.58	14.83	11.04	very poorly sorted	(g)mS	sDm
AM-0703-S062	140-145	2.5Y5/4	2.5Y5.5/3	2.37	69.93	17.09	10.62	very poorly sorted	(g)mS	sDm
AM-0703-S063	145-155	2.5Y5/3	2.5Y6/4	1.59	74.34	14.84	9.22	very poorly sorted	(g)mS	sDm
AM-0703-S064	155-163	2.5Y5/4	2.5Y6/5	1.70	71.95	15.94	10.41	very poorly sorted	(g)mS	sDm
AM-0703-S065	163-177	2.5Y5/4	2.5Y6/5	3.70	75.67	12.60	8.03	very poorly sorted	(g)mS	sDm
AM-0703-S066	177-181	2.5Y5/4	2.5Y5/4	1.76	74.78	14.17	9.29	very poorly sorted	(g)mS	sDm
Downslope Test Pit										
AM-0629-S059	0-5	2.5Y3/2	10YR3/2	3.97	62.28	25.10	8.65	very poorly sorted	(g)mS	organic horizon
AM-0629-S058	5-15	2.5Y3/2	10YR3/2	3.01	60.65	26.87	9.47	very poorly sorted	(g)mS	sDf
AM-0629-S058 duplicate	5-15	2.5Y3/2	10YR3/2	4.83	61.37	26.66	7.15	very poorly sorted	(g)mS	sDf
AM-0629-S057	15-21	10YR3/2	10YR3/1.5	0.66	30.47	31.38	37.50	very poorly sorted	(g)sM	sDf
AM-0629-S056	21-31	10YR2/1	10YR3/1.5	1.25	60.28	22.63	15.84	very poorly sorted	(g)mS	sDf
AM-0629-S055	31-41	10YR2/1	10YR3/1.5	2.44	61.60	25.11	10.85	very poorly sorted	(g)mS	sDf
AM-0629-S054	41-51	10YR3/1	2.5Y3.5/2	3.94	60.88	20.84	14.35	very poorly sorted	(g)mS	sDf
AM-0629-S053	51-67	2.5Y6/2	2.5Y6/2	0.84	38.23	30.14	30.78	very poorly sorted	(g)sM	sDf
AM-0629-S052	67-81	2.5Y4/2	2.5Y4.5/2	2.04	56.92	20.20	20.85	very poorly sorted	(g)mS	sDn
AM-0629-S051	81-91	2.5Y4/1	2.5Y4.5/2	2.92	60.63	21.76	14.69	very poorly sorted	(g)mS	sDn
AM-0629-S050	91-100	2.5Y5/2	2.5Y5.5/2	6.42	70.25	15.79	7.54	very poorly sorted	gmS	sDn
AM-0629-S049	100-110	2.5Y5/2	2.5Y6/2.5	5.43	69.01	19.72	5.83	very poorly sorted	gmS	sDn
AM-0629-S048	110-118	2.5Y6/3	2.5Y7/2	4.48	52.05	33.78	9.69	very poorly sorted	(g)mS	sDn
AM-0704-S072	118-126	2.5Y6/3	2.5Y6.5/2	1.39	56.20	31.87	10.54	very poorly sorted	(g)mS	sDn
AM-0704-S073	126-137	2.5Y5/3	2.5Y6.5/2	6.59	71.86	12.93	8.62	very poorly sorted	gmS	sDn
AM-0703-S068	133-143	2.5Y6/3	2.5Y6/3.5	19.56	68.07	6.61	5.77	very poorly sorted	gmS	sDn
AM-0703-S069	143-151	2.5Y5/4	2.5Y6/2	7.85	66.44	15.94	9.76	very poorly sorted	gmS	sDn
AM-0703-S070	151-160	2.5Y6/4	2.5Y6.5/3	22.60	70.14	3.94	3.31	very poorly sorted	gS	sDn
AM-0703-S071	160-165	2.5Y6/4	2.5Y6.5/3	30.25	62.46	3.39	3.90	very poorly sorted	msG	gDn
Cut Arm Site										
Block 1 Unit 20S 18E West Wall										
CA-0705-S209	0-4	2.5Y3/2.5	2.5Y3.5/2	1.04	61.59	24.26	13.10	very poorly sorted	(g)mS	organic horizon
CA-0705-S208	4-11	10YR4/2	2.5Y3.5/2	0.17	64.49	22.87	12.47	very poorly sorted	(g)mS	sDn
CA-0705-S207	11-16	10YR3/2	2.5Y3/2.5	0.43	70.07	18.32	11.18	very poorly sorted	(g)mS	sDn
CA-0705-S206	16-24	2.5Y3/2.5	2.5Y3.5/2	0.74	72.74	15.94	10.58	very poorly sorted	(g)mS	sDn
CA-0705-S205	24-32	2.5Y3/2	2.5Y3.5/2	0.40	74.42	17.47	7.70	very poorly sorted	(g)mS	sDn
CA-0705-S204	32-35	10YR3/2	2.5Y3.5/2	0.46	76.81	15.75	6.98	very poorly sorted	(g)mS	sDn
CA-0705-S203	35-46	2.5Y3.5/2.5	2.5Y4.5/3	0.73	79.43	12.63	7.20	very poorly sorted	(g)mS	gDn

Sample Number	Depth (m)	Moist Colour	Dry Colour	% Gravel	% Sand	% Silt	% Clay	Sorting	Textural Class	Facies
CA-0705-S202	46-57	2.5Y4/4	2.5Y4.5/4	1.33	87.82	6.78	4.06	poorly sorted	(g)mS	gDn
CA-0705-S201	57-65	2.5Y5/5	2.5Y5.5/5	0.19	95.05	3.17	1.59	moderately sorted	(g)S	(g)Sm
CA-0705-S200	65-73	2.5Y5/5	2.5Y5/5	0.71	95.29	2.49	1.51	moderately sorted	(g)S	(g)Sm
CA-0705-S200 duplicate	65-73	2.5Y5/5	2.5Y5/5	0.36	95.08	2.95	1.61	moderately sorted	(g)S	(g)Sm
CA-0705-S199	73-88	2.5Y5/6	2.5Y5/5	0.15	93.85	3.99	2.02	moderately sorted	(g)S	(g)Sm
CA-0705-S198	88-100	2.5Y5/6	2.5Y5/5	0.63	96.04	2.43	0.90	moderately sorted	(g)S	(g)Sm
CA-0705-S197	100-110	2.5Y5/6	2.5Y5.5/5	1.11	95.48	2.24	1.16	moderately sorted	(g)S	(g)Sm
CA-0705-S196	110-120	2.5Y5/6	2.5Y6/6	0.12	97.01	1.79	1.08	moderately well sorted	(g)S	(g)Sm
CA-0705-S195	120-130	2.5Y5/6	2.5Y5.5/6	0.23	97.54	1.39	0.84	moderately well sorted	(g)S	(g)Sm
Block 3 Unit 32S 51E West Wall										
CA-0726-S236	0-6	10YR3.5/1	2.5Y3/2	0.84	59.36	27.94	11.86	very poorly sorted	(g)mS	organic horizon
CA-0726-S235	6-14	10YR3.5/2	2.5Y3/2	0.58	64.20	26.84	8.38	very poorly sorted	(g)mS	sDn
CA-0726-S234	14-18	10YR3.5/1.5	10YR3/1.5	0.35	72.24	20.12	7.29	very poorly sorted	(g)mS	sDn
CA-0726-S233	18-23	2.5Y3/1.5	2.5Y3/2	0.40	73.86	20.11	5.63	very poorly sorted	(g)mS	sDn
CA-0726-S232	23-36	10YR3/1	10YR3/1	0.33	73.75	21.82	4.10	poorly sorted	(g)mS	sDn
CA-0726-S232 duplicate	23-36	10YR3/1	10YR3/1	0.15	77.51	18.62	3.72	poorly sorted	(g)mS	sDn
CA-0726-S231	36-49	10YR3/1	10YR3/1	1.19	74.62	19.77	4.42	poorly sorted	(g)mS	sDn
CA-0726-S230	49-58	10YR3.5/1	2.5Y3/2	0.64	76.36	19.73	3.27	poorly sorted	(g)mS	sDn
CA-0726-S229	58-67	2.5Y3/2	2.5Y3/2	1.44	76.69	18.06	3.81	poorly sorted	(g)mS	sDn
CA-0726-S228	67-77	2.5Y3.5/2	2.5Y4/2	0.05	40.83	39.98	19.14	very poorly sorted	(g)sM	sDfy
CA-0726-S227	75-80	10YR4/4	2.5Y4.5/3	0.12	87.47	8.06	4.35	poorly sorted	(g)mS	sDfy
CA-0726-S226	80-87	10YR3.5/2	2.5Y3.5/2	0.69	65.29	25.42	8.60	very poorly sorted	(g)mS	sDn
CA-0726-S225	87-92	10YR3/2	2.5Y3/2	0.68	73.95	20.46	4.90	very poorly sorted	(g)mS	sDn
CA-0726-S224	92-103	10YR3.5/3	2.5Y4.5/3	1.64	77.81	15.08	5.48	very poorly sorted	(g)mS	sDn
CA-0726-S223	103-111	10YR3.5/4	2.5Y4/4	6.50	75.03	13.75	4.72	very poorly sorted	gmS	sDn
CA-0726-S222	111-125	2.5Y5/5	2.5Y6/3	2.63	37.32	33.94	26.11	very poorly sorted	(g)sM	mDm
CA-0726-S221	125-135	2.5Y4.5/4	2.5Y6/2.5	3.12	38.13	32.14	26.61	very poorly sorted	(g)sM	mDm
CA-0726-S221 duplicate	125-135	2.5Y4.5/4	2.5Y6/2.5	3.62	36.28	32.71	27.40	very poorly sorted	(g)sM	mDm
CA-0726-S220	135-145	2.5Y4.5/4	2.5Y6/3	1.45	35.37	32.97	30.21	very poorly sorted	(g)sM	mDm
Block 4 Unit 69S 79E North Wall										
CA-0827-S283	0-3	2.5Y3/2	2.5Y3/2	0.43	51.83	32.73	15.01	very poorly sorted	(g)mS	organic horizon
CA-0827-S282	3-17	2.5Y3.5/2	2.5Y3/1.5	0.50	62.23	23.84	13.43	very poorly sorted	(g)mS	sDm
CA-0827-S281	17-22	2.5Y3.5/2	2.5Y3/1.5	0.16	60.49	27.64	11.72	very poorly sorted	(g)mS	sDm
CA-0827-S280	22-31	2.5Y3/1.5	2.5Y3/2	0.24	61.29	28.07	10.41	very poorly sorted	(g)mS	sDm
CA-0827-S279	31-37	10YR3/1	2.5Y3/1	0.51	59.34	32.59	7.56	very poorly sorted	(g)mS	sDn
CA-0827-S279 duplicate	31-37	10YR3/1	2.5Y3/1	0.39	61.47	30.12	8.02	very poorly sorted	(g)mS	sDn
CA-0827-S278	37-42	10YR3/1.5	2.5Y3/2	0.71	65.70	22.07	11.51	very poorly sorted	(g)mS	sDn
CA-0827-S277	42-46	10YR3/1	10YR3/1	0.52	68.27	25.88	5.32	very poorly sorted	(g)mS	sDm
CA-0827-S276	46-51	2.5Y3/2	2.5Y3/2	0.70	71.84	22.11	5.35	very poorly sorted	(g)mS	sDm
CA-0827-S275	51-54	2.5Y3/2	2.5Y3/2	1.10	72.89	21.62	4.38	very poorly sorted	(g)mS	sDm
CA-0827-S274	54-59	2.5Y3.5/2	2.5Y3.5/2	1.03	73.36	21.38	4.23	very poorly sorted	(g)mS	sDm
CA-0827-S273	59-62	2.5Y3/2	2.5Y3/2	1.15	70.35	23.87	4.63	very poorly sorted	(g)mS	sDm
CA-0827-S272	62-71	2.5Y3.5/2	2.5Y4/2	0.79	71.77	22.04	5.40	very poorly sorted	(g)mS	sDm
CA-0827-S271	71-83	2.5Y3.5/2	2.5Y3.5/2	1.38	62.88	27.51	8.22	very poorly sorted	(g)mS	sDn
CA-0827-S270	83-95	2.5Y3.5/2	2.5Y4/2	1.93	67.78	22.63	7.66	very poorly sorted	(g)mS	sDn
CA-0827-S269	95-100	10YR3.5/1	2.5Y3/1.5	0.79	52.82	36.27	10.12	very poorly sorted	(g)mS	sDn
CA-0827-S269 duplicate	95-100	10YR3.5/1	2.5Y3/1.5	0.34	54.21	35.26	10.19	very poorly sorted	(g)mS	sDn
CA-0827-S268	100-105	2.5Y3.5/2	2.5Y3.5/2	2.89	65.89	24.26	6.96	very poorly sorted	(g)mS	sDn

Sample Number	Depth (m)	Moist Colour	Dry Colour	% Gravel	% Sand	% Silt	% Clay	Sorting	Textural Class	Facies
CA-0827-S267	105-110	2.5Y3/2	2.5Y3/2	2.45	80.47	12.77	4.31	poorly sorted	(g)mS	sDn
CA-0827-S266	110-117	2.5Y4/3	2.5Y4/4	4.71	83.52	8.24	3.54	poorly sorted	(g)mS	sDn
CA-0827-S265	117-121	2.5Y4/2	2.5Y4/2.5	0.29	58.33	30.25	11.13	very poorly sorted	(g)mS	sDn
CA-0827-S264	121-125	2.5Y3.5/2	2.5Y4/2	0.16	67.48	24.02	8.34	very poorly sorted	(g)mS	sDn
CA-0827-S263	125-135	2.5Y4/3	2.5Y4/3	0.18	75.59	17.51	6.72	very poorly sorted	(g)mS	sDn
CA-0827-S262	135-141	2.5Y5/3	2.5Y5/3.5	1.21	91.00	4.93	2.86	poorly sorted	(g)S	sDn
CA-0827-S261	141-147	2.5Y4.5/3	2.5Y4/3	0.04	74.49	18.83	6.63	poorly sorted	(g)mS	sDm
CA-0827-S260	147-158	2.5Y5/4	2.5Y5.5/4	0.01	93.94	3.69	2.36	moderately sorted	(g)S	(g)Sm
CA-0827-S259	158-164	2.5Y3.5/3	2.5Y3.5/3	0.08	83.19	11.18	5.55	poorly sorted	(g)mS	sDm
CA-0827-S258	164-174	2.5Y4/3	2.5Y4/3	3.99	77.10	13.18	5.73	very poorly sorted	(g)mS	sDm
CA-0827-S258 duplicate	164-174	2.5Y4/3	2.5Y4/3	5.83	75.82	12.58	5.77	very poorly sorted	gmS	sDm
CA-0827-S257	174-184	2.5Y4/3	2.5Y4.5/3	1.00	79.71	13.48	5.81	very poorly sorted	(g)mS	sDm
CA-0827-S256	184-189	2.5Y3/2	2.5Y3/2	1.43	66.81	23.65	8.10	very poorly sorted	(g)mS	sDm
CA-0827-S255	189-203	2.5Y4/3	2.5Y4/3	1.21	68.94	21.50	8.35	very poorly sorted	(g)mS	sDm
CA-0827-S254	203-208	2.5Y3.5/3	2.5Y4.5/2.5	6.10	60.06	24.38	9.46	very poorly sorted	gmS	sDn
CA-0827-S253	208-220	2.5Y4/4	2.5Y4.5/3	4.25	72.71	16.03	7.01	very poorly sorted	(g)mS	sDn
CA-0827-S252	223-231	2.5Y4/4	2.5Y4.5/3	3.89	68.92	19.01	8.18	very poorly sorted	(g)mS	sDm
Meewasin Site										
Upslope Test Pit (Unit 0S 0E)										
MW-0602-S018	0-8	2.5Y3/2	10YR3/1.5	0.68	56.45	31.04	11.83	very poorly sorted	(g)mS	organic horizon
MW-0602-S017	8-15	10YR2/1	10YR3/1.5	1.38	55.04	27.27	16.32	very poorly sorted	(g)mS	sDi
MW-0602-S016	15-20	2.5Y3/2	10YR3.5/2	0.21	53.32	37.57	8.91	very poorly sorted	(g)mS	sDi
MW-0602-S015	20-37	10YR3/1	10YR2.5/1	0.69	54.39	34.58	10.33	very poorly sorted	(g)mS	sDn
MW-0602-S014	37-48	10YR3/1	10YR2.5/1	1.27	60.55	26.78	11.40	very poorly sorted	(g)mS	sDn
MW-0602-S013	48-72	10YR3/2	10YR3/2	0.60	68.61	21.89	8.90	very poorly sorted	(g)mS	sDn
MW-0602-S012	72-97	2.5Y5/4	2.5Y4.5/4	1.58	73.87	15.76	8.79	very poorly sorted	(g)mS	sDn
MW-0605-S019	97-116	10YR5/8	2.5Y4.5/4	3.37	75.69	14.90	6.03	very poorly sorted	(g)mS	sDn
MW-0605-S019 duplicate	97-116	10YR5/8	2.5Y4.5/4	0.86	78.29	14.59	6.26	very poorly sorted	(g)mS	sDn
MW-0605-S020	116-129	10YR5/6	10YR5/4	1.10	82.11	11.39	5.40	poorly sorted	(g)mS	sDn
Unit 22S 0E West Wall										
MW-0531-S010	0-7	10YR3/1	10YR3/1	0.13	42.60	34.84	22.43	very poorly sorted	(g)sM	organic horizon
MW-0531-S009	7-11	10YR3/2	2.5Y4/2	0.38	52.12	30.22	17.27	very poorly sorted	(g)mS	sDm
MW-0531-S008	11-38	10YR2/1	10YR3/1	0.65	48.70	32.63	18.02	very poorly sorted	(g)sM	mDi
MW-0531-S007	38-56	10YR2/1	10YR3/1	0.11	29.35	46.80	23.74	very poorly sorted	(g)sM	mDi
MW-0531-S006	56-73	10YR2/1	2.5Y3/1	0.90	56.66	30.95	11.49	very poorly sorted	(g)mS	sDn
MW-0531-S005	73-102	10YR4/3	2.5Y5/3	1.47	64.83	23.79	9.92	very poorly sorted	(g)mS	sDn
MW-0531-S004	102-112	2.5Y4/4	2.5Y5/3	0.90	76.55	14.53	8.02	very poorly sorted	(g)mS	sDn
MW-0531-S003	112-135	2.5Y5/6	2.5Y5/4	0.87	89.79	5.67	3.67	poorly sorted	(g)S	sDnd
MW-0531-S011	154-174	2.5Y5/6	2.5Y5/4	7.73	86.73	3.20	2.34	poorly sorted	gS	sDn
MW-0605-S021	174-194	10YR4/6	10YR5/4	3.13	91.58	3.30	1.98	poorly sorted	(g)S	sDn
MW-0605-S021 duplicate	174-194	10YR4/6	10YR5/4	2.45	91.82	3.72	2.02	poorly sorted	(g)S	sDn
MW-0605-S022	194-214	10YR5/6	10YR5/4	2.88	93.18	2.94	1.01	poorly sorted	(g)S	sDn
MW-0605-S023	214-229	10YR5/6	10YR5/4	0.96	96.38	1.63	1.04	moderately sorted	(g)S	(g)Sm
Unit 22S 7E East Wall										
MW-0927-S168	96-103	2.5Y3/2.5	2.5Y4.5/2	1.02	78.54	14.25	6.19	poorly sorted	(g)mS	sDn
MW-0927-S167	103-113	2.5Y3.5/3	2.5Y4.5/3	0.59	85.52	9.32	4.57	poorly sorted	(g)mS	sDn
MW-0927-S166	113-123	10YR2.5/1	2.5Y3/2	0.47	68.59	20.57	10.37	very poorly sorted	(g)mS	sDi
MW-0927-S165	123-130	2.5Y2.5/1	10YR3/1	0.67	58.25	29.29	11.79	very poorly sorted	(g)mS	sDi

Sample Number	Depth (m)	Moist Colour	Dry Colour	% Gravel	% Sand	% Silt	% Clay	Sorting	Textural Class	Facies
MW-0927-S164	130-143	2.5Y4/2	2.5Y5.5/3	0.36	55.56	30.39	13.69	very poorly sorted	(g)mS	sDn
MW-0927-S163	143-151	2.5Y3/2	2.5Y5/2.5	3.60	63.12	22.77	10.51	very poorly sorted	(g)mS	sDn
MW-0927-S162	151-158	2.5Y4/2.5	2.5Y5/3	2.16	72.41	16.98	8.45	very poorly sorted	(g)mS	sDn
MW-0927-S161	158-170	10YR3.5/2	2.5Y4.5/3	0.46	63.77	25.94	9.83	very poorly sorted	(g)mS	sDn
MW-0927-S161 duplicate	158-170	10YR3.5/2	2.5Y4.5/3	0.41	62.43	26.23	10.92	very poorly sorted	(g)mS	sDn
MW-0927-S160	170-186	2.5Y4/4	2.5Y5/3	0.94	77.76	14.89	6.42	very poorly sorted	(g)mS	sDn
MW-0927-S159	186-196	2.5Y4/4	2.5Y5.5/4	0.50	80.38	13.39	5.73	very poorly sorted	(g)mS	sDn
MW-0927-S158	196-206	2.5Y5/5	2.5Y6/5	1.01	81.68	11.23	6.08	very poorly sorted	(g)mS	sDn
Unit 22S 8E East Wall										
MW-0923-S157	0-6	2.5Y3/2	10YR3.5/1	0.08	55.82	26.95	17.15	very poorly sorted	(g)mS	organic horizon
MW-0923-S156	6-10	2.5Y3.5/2	2.5Y4/2	0.52	81.54	11.78	6.16	very poorly sorted	(g)mS	sDi
MW-0923-S154	12-19	2.5Y3/2	10YR4/2	0.15	55.11	28.61	16.13	very poorly sorted	(g)mS	sDi
MW-0923-S153	19-27	2.5Y2.5/1	2.5Y3/1.5	0.08	38.24	38.72	22.97	very poorly sorted	(g)sM	mDn
MW-0923-S152	27-37	10YR2/1	2.5Y3/1	0.08	47.19	37.02	15.70	very poorly sorted	(g)sM	mDn
MW-0923-S151	37-47	10YR2/1	10YR3/1	0.44	50.49	35.55	13.52	very poorly sorted	(g)mS	sDn
MW-0923-S150	47-54	2.5Y3/2.5	2.5Y4/2	1.03	72.01	17.67	9.28	very poorly sorted	(g)mS	sDi
MW-0923-S149	54-61	2.5Y3/2.5	10YR4/2	0.16	65.42	25.15	9.27	very poorly sorted	(g)mS	sDi
MW-0923-S148	61-69	10YR2.5/1	10YR3.5/1	0.50	75.82	15.30	8.38	very poorly sorted	(g)mS	sDi
MW-0923-S147	69-75	2.5Y3/2	10YR4/2	0.39	56.60	30.68	12.33	very poorly sorted	(g)mS	sDi
MW-0923-S146	75-83	10YR2/1	10YR3/1	0.26	41.12	40.95	17.67	very poorly sorted	(g)sM	mDn
MW-0923-S146 duplicate	75-83	10YR2/1	10YR3/1	0.24	40.16	40.41	19.19	very poorly sorted	(g)sM	mDn
MW-0923-S145	83-93	10YR2/1	2.5Y3/1.5	0.38	60.47	30.06	9.10	very poorly sorted	(g)mS	sDn
MW-0923-S144	93-99	2.5Y3/3	2.5Y5/2.5	0.24	85.56	9.81	4.39	poorly sorted	(g)mS	sDn
Test Trench										
MW-0725-S108	0-11	10YR3/1.5	10YR3/2	0.12	37.98	39.76	22.14	very poorly sorted	(g)sM	organic horizon
MW-0725-S107	11-19	10YR2.5/1	2.5Y4/3.5	0.11	55.26	29.56	15.07	very poorly sorted	(g)mS	sDm
MW-0725-S106	19-22	10YR2.5/1	10YR3/1.5	0.20	40.82	47.68	11.30	very poorly sorted	(g)sM	mDn
MW-0725-S105	22-28	10YR2.5/1	10YR2.5/1	0.14	44.78	43.90	11.18	very poorly sorted	(g)sM	mDn
MW-0725-S104	28-35	10YR3/1.5	10YR3/1.5	0.07	47.60	39.87	12.46	very poorly sorted	(g)sM	mDn
MW-0725-S103	35-49	10YR2.5/1	10YR2.5/1	0.84	55.19	35.76	8.21	very poorly sorted	(g)mS	sDi
MW-0725-S102	49-63	10YR3/1.5	10YR3/1.5	0.12	50.48	37.04	12.36	very poorly sorted	(g)mS	sDi
MW-0725-S101	63-73	10YR3/1.5	10YR3/1.5	0.53	50.49	37.95	11.03	very poorly sorted	(g)mS	sDi
MW-0725-S100	73-81	10YR3/1.5	10YR3/1	0.20	56.10	32.07	11.63	very poorly sorted	(g)mS	sDm
MW-0725-S100 duplicate	73-81	10YR3/1.5	10YR3/1	0.56	56.07	32.51	10.86	very poorly sorted	(g)mS	sDm
MW-0725-S099	81-91	10YR3/1.5	2.5Y3/1.5	0.28	54.29	32.98	12.44	very poorly sorted	(g)mS	sDm
MW-0725-S098	91-100	10YR2/1.5	10YR3.5/1	0.04	20.86	51.91	27.19	very poorly sorted	(g)sM	mDn
MW-0725-S097	100-110	10YR2/1.5	10YR3/1.5	0.26	29.67	41.78	28.29	very poorly sorted	(g)sM	mDn
MW-0725-S096	110-122	2.5Y3/2.5	10YR3.5/2	1.28	80.44	10.89	7.39	very poorly sorted	(g)mS	sDn
MW-0725-S095	122-132	10YR2.5/2	2.5Y3/2	0.20	25.65	39.36	34.78	very poorly sorted	(g)sM	mDn
MW-0725-S094	132-140	2.5Y4/3.5	2.5Y4.5/3	0.76	67.65	21.53	10.06	very poorly sorted	(g)mS	sDn
MW-0725-S093	140-150	2.5Y4/3.5	2.5Y4.5/3	0.84	69.84	20.08	9.24	very poorly sorted	(g)mS	sDi
MW-0725-S092	150-160	2.5Y4/3.5	2.5Y4/3	0.57	63.32	24.88	11.23	very poorly sorted	(g)mS	sDi
Thundercloud Site										
Test Pit										
TC-0710-S083	0-7	10YR2/1	10YR3.5/2	1.35	55.40	31.79	11.46	very poorly sorted	(g)mS	organic horizon
TC-0710-S082	7-17	2.5Y5/3	2.5Y5.5/3	2.48	45.61	27.74	24.17	very poorly sorted	(g)sM	mDi
TC-0710-S081	17-27	2.5Y5/3	2.5Y6/3.5	2.89	44.15	26.17	26.76	very poorly sorted	(g)sM	mDi
TC-0710-S080	27-37	2.5Y5/4	2.5Y6/3.5	8.38	36.75	28.30	26.24	very poorly sorted	gsM	mDi

APPENDIX C

Radiocarbon Dates

Sample Number	Depth (m)	Moist Colour	Dry Colour	% Gravel	% Sand	% Silt	% Clay	Sorting	Textural Class	Facies
TC-0710-S079	37-46	2.5Y6/3	2.5Y6/3.5	2.05	36.63	33.99	27.18	very poorly sorted	(g)sM	mDi
TC-0710-S078	46-56	2.5Y6/3	2.5Y6/3.5	2.87	35.27	34.73	26.97	very poorly sorted	(g)sM	mDi
TC-0710-S077	56-66	2.5Y6/3	2.5Y6.5/3	2.42	35.32	31.12	31.12	very poorly sorted	(g)sM	mDn
TC-0710-S076	66-76	2.5Y6/3	2.5Y6/3.5	3.86	36.36	31.78	28.16	very poorly sorted	(g)sM	mDn
TC-0710-S075	76-86	2.5Y6/4	2.5Y6/3.5	3.35	37.81	35.79	23.14	very poorly sorted	(g)sM	mDn
TC-0710-S074	86-96	2.5Y6/3	2.5Y6/4	2.89	38.76	36.84	21.51	very poorly sorted	(g)sM	mDn
TC-0710-S084	96-106	2.5Y6/6	2.5Y6/4	5.66	39.28	36.63	18.73	very poorly sorted	gsM	mDn
TC-0710-S084 duplicate	96-106	2.5Y6/6	2.5Y6/4	5.18	38.62	38.13	18.13	very poorly sorted	gsM	mDn
TC-0710-S085	106-116	2.5Y6/6	2.5Y6/4	7.97	39.79	34.24	18.12	very poorly sorted	gsM	mDn

Published and unpublished radiocarbon dates within the study site. Normalized ages were used in this study.

Site	Sample Number	Material	Uncorrected age (BP)	Normalized age (BP)	Depth below surface (cm)	Source
Amisk FbNp-17	S-2531	Bone	480 ± 65	560 ± 70	12	Amundson 1986; Morlan 2002
Amisk FbNp-17	S-2770	Bone	635 ± 85	715 ± 85	12	Amundson 1986; Morlan 2002
Amisk FbNp-17	S-2537	Charcoal	905 ± 155	905 ± 155	12	Amundson 1986; Morlan 2002
Amisk FbNp-17	S-2769	Bone	3055 ± 70	3135 ± 75	23	Amundson 1986; Morlan 2002
Amisk FbNp-17	S-2767	Bone	3530 ± 110	3610 ± 110	41	Amundson 1986; Morlan 2002
Amisk FbNp-17	S-2536	Bone	4015 ± 195	4095 ± 195	55	Amundson 1986; Morlan 2002
Amisk FbNp-17	S-2535	Bone	4120 ± 190	4200 ± 190	70	Amundson 1986; Morlan 2002
Amisk FbNp-17	S-2534	Bone	3895 ± 195	3975 ± 195	80	Amundson 1986; Morlan 2002
Amisk FbNp-17	S-2768	Bone	5340 ± 120	5420 ± 120	88	Amundson 1986; Morlan 2002
Cut Arm FbNp-22	BGS-2381	Bone	524 ± 40	664 ± 40	33	Moon 2004
Cut Arm FbNp-22	BGS-2381	Bone	3178 ± 50	3318 ± 50	100	Moon 2004
Cut Arm FbNp-22	BGS-2384	Bone	3448 ± 60	3520 ± 60	118	Moon 2004
Cut Arm FbNp-22	BGS-2383	Bone	3387 ± 50	3441 ± 50	121	Moon 2004
Cut Arm FbNp-22	BGS-2385	Bone	3802 ± 55	3864 ± 55	160	Moon 2004
Thundercloud FbNp-25	S-3645	Bone	4040 ± 90	4145 ± 90	46	Mack 2000; Morlan 2002; Webster 1999.

Note: Depth below surface for Amisk radiocarbon dates were derived from the recorded depth for occupation levels in the eastern part of the Amisk excavation. Cut Arm radiocarbon dates were obtained from block 4 of the Cut Arm excavation.