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QUATERNARY STRATIGRAPHY IN SOUTHERN ALBERTA REPORT III: THE CAMERON RANCH SECTION

A. MacS. STALKER

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QUATERNARY STRATIGRAPHY IN SOUTHERN ALBERTA
REPORT III: THE CAMERON RANCH SECTION

Abstract

The Cameron Ranch Section is the most complete Laurentide Pleistocene section found in southern Alberta. It probably contains the full Laurentide glacial record for the region, including deposits from all the Illinoian and Wisconsin glacier advances. The deposits lack fossils or other materials for dating, and therefore age assignments are made on the basis of correlation with other sections, particularly those near Medicine Hat.

At the base bedrock is overlain by the preglacial Saskatchewan Gravels and Sands. These consist of a lower gravel member that probably is of late Kansan Age, and an overlying silt member laid down as the first Pleistocene ice sheet approached during late Yarmouthian or early Illinoian time. Both units lack the stones brought from the Canadian Shield by glaciers.

The rest of the sequence, consisting of till sheets with interfingering beds of alluvial and lacustrine sand, silt, and clay, is divided into fifteen units, nine or ten of which represent separate Laurentide ice advances; Cordilleran glaciation is not evident. The lowest four units overlying the Saskatchewan Gravels and Sands are mainly till and represent three or four separate glaciations of Illinoian Age. Weathering is displayed on two of the till sheets. A thin Sangamon silt unit separates these units from four Preclassical Wisconsin units, three of which demonstrate separate ice advances. These, in turn, are overlain by a thin, Mid-Wisconsin sand unit followed by five Classical Wisconsinunits, three of which are basically till and record individual ice advances. The top unit in the section consists of lake silt laid down as the last ice sheet was retreating.

The name "Cameron Ranch Formation" is here given to certain previously unnamed deposits that consist mostly of till. It is of Preclassical Wisconsin Age.

Résumé

Le profil Cameron Ranch est le meilleur exemple de profil laurentidien du Pléistocène qui a été découvert dans le sud de l'Alberta. Probablement toute l'histoire de l'inlandsis laurentidien dans cette région y est retracée, grâce notamment à des dépôts laissés par toutes les avancées de fronts glaciaires au cours de l'Illinois et du Wisconsin. Les dépôts sont dépourvus de fossiles ou d'autres matériaux qui nous permettraient d'en faire la datation; c'est pourquoi leur âge a été établi en les mettant en relation avec d'autres profils, en particulier ceux qui se trouvent près de Medicine Hat.

La roche en place est recouverte d'une première couche constituée de sables et graviers préglaciaires de type Saskatchewan. Ce dépôt comprend une première sédimentation constituée de graviers datant probablement de la fin du Kansas. Une seconde sédimentation, qui eut lieu au cours de la première avancée de l'inlandsis (fin du Yarmouthien ou début de l'Illinois), a mis en place une couche de limon. Dans aucunes de ces couches superposées (gravier-limon), on ne rencontre la pierraille apportée du Bouclier canadien par les glaciers.

Le reste de la séquence est constitué de nappes de till où s'enchevêtrent des lits de sable, de limon et d'argile alluviaux et lacustres; on y distingue quinze unités, dont neuf ou dix correspondent à autant d'avancées de l'inlandsis laurentidien. On n'y trouve pas de trace évidente d'une glaciation de la Cordillère. Les quatre unités inférieures qui recouvrent les sables et graviers de Saskatchewan sont surtout constituées de till et représentent trois ou quatre glaciations distinctes de l'Illinois. Deux des nappes de till affichent des signes d'altération. Une mince couche de limon sangamonienne sépare ces unités de quatre unités du Wisconsin préclassique, dont trois rendent compte de progressions glaciaires distinctes. Ces quatre couches sont à leur tour recouvertes par une mince unité de sable datant du milieu du Wisconsin, suivie de cinq unités du Wisconsin classique, dont trois sont constituées essentiellement de till et correspondent à autant d'avancées glaciaires. La couche qui couronne le profil est un limon lacustre déposé au moment du retrait du dernier inlandsis.

Le nom "formation de Cameron Ranch" est donné ici à certains dépôts qui n'avaient pas jusqu'ici de désignation officielle et qui se composent surtout de till. Cette formation remonte au Wisconsin préclassique.

INTRODUCTION

General Statement

This is the third in a series of papers dealing with significant Quaternary sections in southern Alberta. Report I (Stalker, 1963) described 12 sections, mostly from the valleys of Oldman and Castle rivers (Fig. 1, no. 1-12), Report II (Stalker, 1969a) added an additional three sections from the Medicine Hat region (Fig. 1, no. 13-15), whereas this third report describes the Cameron Ranch Section, which is exposed by Oldman River northeast of Lethbridge. Following the identification system of the two previous reports, this is section 16 in the series of described sections (Fig. 1). These reports are designed essentially to provide a framework for further Quaternary studies on the Prairies and to indicate where various deposits can be found. This third paper in the series, though it does follow the general format of the previous ones, furnishes much greater detail and more interpretation and discussion of age and of correlation with deposits elsewhere.

The Cameron Ranch Section provides a fuller coverage of upper Quaternary Laurentide stratigraphy than any other known outcrop in southern Alberta and perhaps any other on the continent. The exposure was first studied in detail in 1961 by my field assistants, John Nunan and Maris Rutulis. Results of that study are contained in an unpublished thesis (Rutulis, 1962), and much information in the present paper is derived from that report. Examination continued in subsequent years, but particularly during 1976 when R.E. Barendregt of the Department of Geography, San Francisco State University, San Francisco, and the writer gave the exposure a second critical examination. The 1961 and 1976 studies, which were fairly closely spaced (Fig. 2), agreed in most respects. They are combined into a composite section that forms the basis of this report (Appendix).

The Cameron Ranch Section is described in detail in the Appendix, and some of the properties of the various units are listed in Table 1. The unit reference letters and subunit reference numbers found in the Appendix are used in Table 1, the figures, and throughout the report. Figure 2 shows a general, panoramic view of the whole bluff, and Figure 3 depicts in more detail the lower and middle parts of the section at the locality where it was studied.

Acknowledgments

The writer is most grateful to Maris Rutulis of the Water Resources Branch, Manitoba Department of Natural Resources, Winnipeg, Manitoba, and to John Nunan, President of Hydrology Consultants, Limited, Missisauga, Ontario, for their enthusiastic co-operation and aid in the field and for their careful study of the exposure in 1961. He also thanks R.E. Barendregt of the Department of Geography, University of Lethbridge, Lethbridge, Alberta for his invaluable help during the 1976 restudy of the section. Dr. L.E. Jackson of the Geological Survey of Canada critically read the manuscript for this report, and many of his helpful suggestions and comments have been incorporated into it. I acknowledge with great gratitude his kind interest and care.

Previous Work

The study of glacial stratigraphy in southern Alberta has a long history. Dawson (1885, 1896) was the first geologist to describe Quaternary deposits exposed along the rivers there. He was followed by Calhoun (1906) and by Alden and Stebinger (1913), all of whom described sections in the same region while engaged in studies of surficial geology in adjacent parts of the United States. Johnston and Wickenden (1931) discussed the Quaternary stratigraphy and gave general descriptions of various sections, including some on Oldman River, during their extensive studies on the Prairies. Horberg (1952) made a detailed study near Lethbridge and described 18 sections, most of them along Oldman River; in 1954 he described another 16 exposures farther southwest, chiefly along Belly and Waterton rivers. Further descriptions, mostly along Oldman River and in the general area of Lethbridge, were made by Murakami (1960), Vernon (1962), and Rutulis (1962). Rutulis included the Cameron Ranch Section amongst those he described. Somewhat later Westgate (1965, 1968) described a number of sections in southeastern Alberta.

In addition to the 15 sections described in Stalker (1963, 1969a) mentioned earlier, Stalker gave detailed descriptions of sections near Taber (1969b), downstream from the Cameron Ranch Section, and near Medicine Hat (1976a).

Site Description

The Cameron Ranch Section is named after the Cameron Ranch, on which the exposure is found. Previously it was refered to as "Elevator Cut" (Rutulis, 1962) because a small grain elevator was present at its base. However, that elevator has long since gone, and in order to avoid confusion with the Elevator Site at Empress, in Alberta and Saskatchewan, the name Cameron Ranch Section is introduced here.

The Cameron Ranch Section lies about 35 km northeast of Lethbridge, 20 km west-northwest of Taber, and 11 km north of Chin Siding, all on the Medicine Hat-Lethbridge line of the Canadian Pacific Railway (Fig. 1). The exact location is lsd. 16 of sec. 31, tp. 10, rge. 18, W4th Mer. (approximately 49°52'12"N, 112°25'10"W). It is near the middle of a steep bluff that extends for about 2.5 km along the north or outer side of a broad bend in Oldman River (at A in Fig. 2). In this district the river follows its ancestral valley or else crosses it at a sharp angle. During the Quaternary Period that old valley received debris from numerous Pleistocene glaciers and from interglacial lakes and rivers. Over time those deposits filled the valley to approximately the general prairie level of the surrounding region, and the modern, postglacial Oldman has now incised through that fill into bedrock. Although at the Cameron Ranch Section the south bank of the valley is gentle, largely overgrown, and shows few outcrops, the steep bluff on its northern side affords a magnificant exposure through its valley fill (Fig. 2).

From a distance, such as from the far side of the river, the overall section presents a most complicated and disordered aspect, and appears at first to make little sense (Fig. 2, 3). Beds thicken, thin, or even disappear along the length of the bluff, and large chunks of bedrock are found here and there amongst the surficial deposits. Parts of the exposure are slumped or folded. However, these irregularities perhaps appear more serious than they really are, although they can cause vexing problems. In general the bottom beds (Appendix, units CRA, CRB) are relatively undisturbed and the upper beds (units CRK-CRR), which typically are exposed up tributary gullies and not seen from near the river, are fairly regular. Thus the worst of the apparent intricacies are confined to units CRC to CRJ (Fig. 3), and many of them vanish with careful study.

The 1961 and 1976 examinations were made about half way along the exposures on the north side of the river, and at the point where the Quaternary deposits appeared thickest and best exposed (Fig. 2). Exposures in tributary gullies were relied on for information about the upper part of the section. Following previous practice, the maximum observed thickness of a unit normally is given in the description of the section (Table 1 and Appendix).

Figure 1. *Locations of Quaternary sections. Sections 1 to 12 were described by Stalker (1963) and 13 to 15 by Stalker (1969). The Cameron Ranch Section, described here, is number 16.*

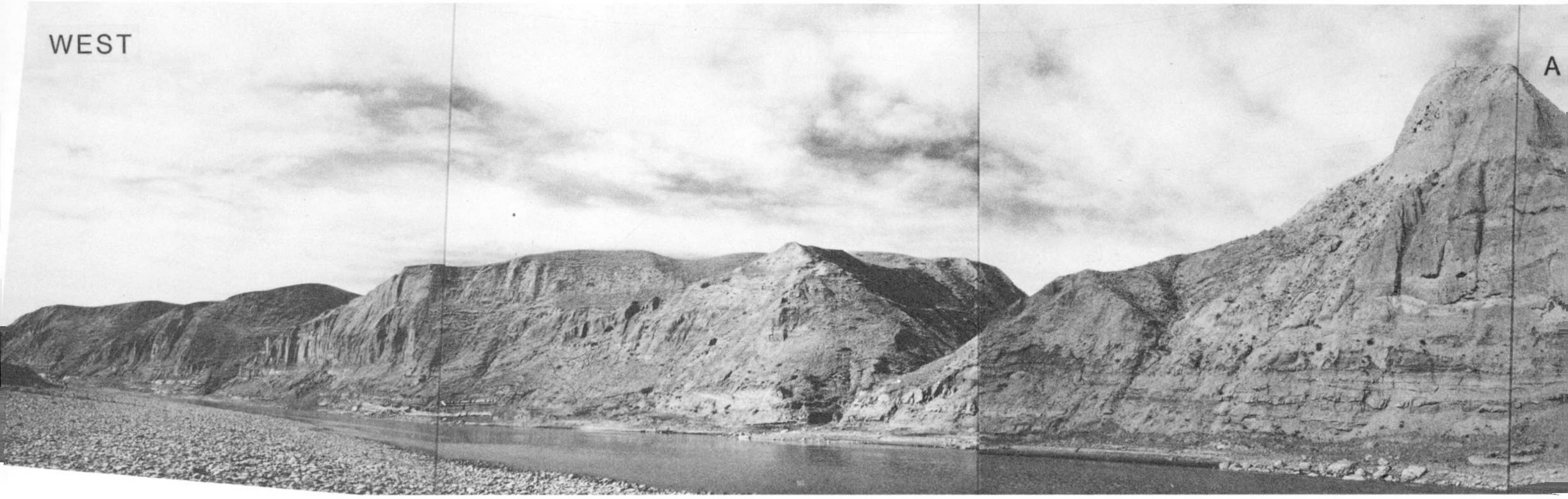


Figure 2. *Panoramic view of Cameron Ranch exposure as seen from the south side of Oldman River. The section was described at point A.*

Age and Correlation

Age assignments of the units, and their correlation with other deposits in southern Alberta, are indicated in Table 2. They are based on the relation of the Cameron Ranch Section to sections previously described at Medicine Hat, Kipp, and Brocket (Fig. 1), all in Alberta. The remarkable exposures near Medicine Hat, on South Saskatchewan River some 170 km to the east (Stalker, 1969a, 1972, 1976a; Stalker and Churcher, 1972, 1982), have provided both the stratigraphic framework for the Laurentide deposits of the region and also, through their abundant vertebrate remains along with some radiocarbon dates from higher levels, valuable information on ages. Upstream from Cameron Ranch, the Kipp and Brocket sections (Stalker, 1963), both found on Oldman River about 45 and 100 km west-southwest, respectively, assist correlation with deposits recognized elsewhere in Alberta, including those of the Cordilleran sequence.

New information has necessitated some changes from previous correlations, particularly in regard to the Brocket Section (Stalker, 1972, p. 63; 1976a, p. 402-405), and these have been incorporated into Table 2. In particular, all units previously assigned to the Classical or Younger Wisconsin at Brocket now are placed in the Preclassical or Older Wisconsin, necessitating changes in correlations with the Kipp and the Medicine Hat sections, and with an earlier composite section of Stalker (1976a, Table 2). These revisions are due largely to the growing realization of the relative weakness of Classical Wisconsin glaciation, and of its general confinement to the east and north of the Lethbridge Moraine (Stalker, 1980). Additional revisions certainly will be required as further information becomes available.

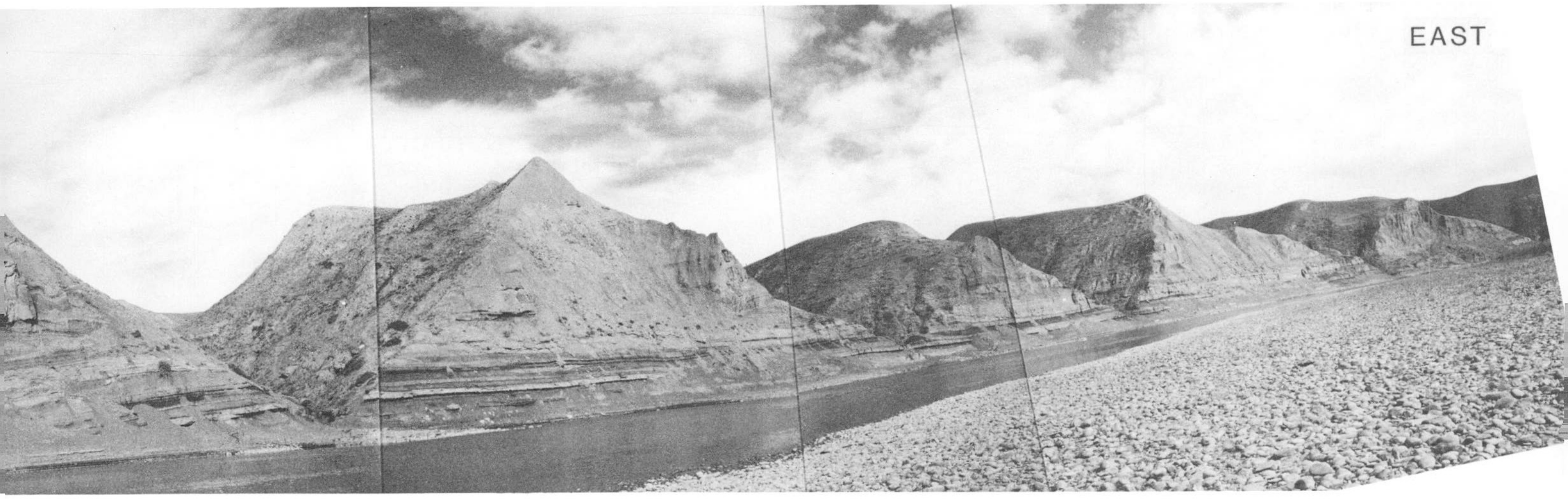
Circumspection is necessary in using or accepting the ages and correlations put forward in Table 2. First, the chronology established at Medicine Hat is based on vertebrate fossils and may not correlate at all age levels with the chronology of glacial geologists, despite use of similar names. Further, even though Cameron Ranch is one of the most complete sections available for the upper part of the Quaternary, deposition still was intermittent and left large gaps in the sedimentary record. Table 2 does, however, indicate the general chronological age of the units and their correlation with units found elsewhere.

Other Information

The surficial deposits at Cameron Ranch had their source in the Prairies, in the Precambrian Shield to the north and east and in its bordering Paleozoic formations, and in the mountains to the west. The Prairie material, which is called "local" in Table 1, is derived mostly from weak and poorly indurated siltstones and shales of Cretaceous and Tertiary age. As a result, except for a few larger fragments of coal and ironstone, this material is found only in the matrix of the tills and the finer fractions of the other sediments. It probably makes up the bulk of both.

Material from the Precambrian Shield is most prominent in the coarser fractions, and stones from that source are referred to as "Shield stones" throughout the report. These, along with carbonates from the Ordovician, Silurian, and Devonian formations abutting the southwest margin of the Shield, have provided about three-quarters of the stones found in the tills at Cameron Ranch. As this material has been moved uphill from source to present position, it could only have been brought into the area by ice flowing from the Shield, and so the lowest occurrence of Shield stones in an exposure indicates when Laurentide ice first reached the site. This material was carried in an overall southwest or south direction, but the number and percentage of Shield stones in a till indicate roughly whether the ice came directly from the Shield or by a more circuitous route, or else whether it was diluted with ice from Cordilleran glaciers arising in the western mountains.

Material from the mountains to the west forms an important part of both the fine and coarse fractions; indeed, it constitutes practically all the preglacial gravels forming the basal part of the surficial deposits. It also provided most of the carbonate found in the matrix of the tills; however, mountain limestones and dolomites are rare amongst the stones at Cameron Ranch, as the site was sufficiently distant from the mountains to cause large carbonate fragments to be destroyed en route, during their river transport. Some of the mountain material may have been brought in by south to southeastward flowing glaciers, which may have contained some ice that originated in the mountains, but most was introduced into the area by rivers flowing directly from the mountains – at Cameron Ranch mainly Oldman River. Some of this alluvium may have started as outwash from mountain glaciers.



Ostensible buried soils were recognized by their overall, gross features, such as appearance, weathering, texture, and carbonate content, and by their representing a hiatus in deposition that saw plant growth. They are not classified as to type of soil, nor have they been subject to the intensive study of their chemistry, opal content, and other properties that would normally be given them by soil scientists, and which are necessary to confirm them as true paleosols according to the standards of soil scientists.

The section has been divided into units prefixed by CR (see Appendix), in some cases rather arbitrarily. Only three of the till units are formed by a single till sheet, the others are multiple and consist of two to five tills separated, in most cases, by beds of sand, silt, and clay. In all, 26 tills are recorded. The reason for the multiplicity of tills is not definitely established, but the author considers that most represent separate ice advances, generally minor. This area, being near the limits of most of the glaciers, was subjected to numerous such minor ice advances and retreats as the ice margins oscillated. It is here suggested that most of the lower (Illinoian) units record separate glaciations, each consisting of several large advances or stadials. The three Preclassical Wisconsin till units and three Classical Wisconsin till units, on the other hand, probably represent two separate glaciations with their various distinct, lesser ice advances. Depending upon how one treats them, four to six separate glaciations appear to be recorded, and it is unlikely that other major ice advances reached southern Alberta during Illinoian and Wisconsin time. In general, most of the glaciations in the area began with southeast ice flow, but changed to southwesterly flow in later stages or readvances, as shown in Stalker (1980, Fig. 1) for the Classical Wisconsin.

NOMENCLATURE

The till units in the Cameron Ranch Section (Table 1 and Appendix) are assigned to the Labuma, Maunsell, and Brocket tills, the Cameron Ranch Formation, and the Buffalo Lake Till, whereas the silt unit CRH is assigned to Mitchell Bluff Formation. The Labuma, Maunsell, and Buffalo Lake tills were named by Stalker (1960), the Brocket Till by Stalker (1963), and the Mitchell Bluff Formation by Stalker (1976a, p. 397-399). The name Cameron Ranch Formation is new here. The correlations of the tills here with the Labuma, Maunsell, and Brocket tills are fairly straightforward and cause little trouble; relations with the Buffalo Lake Till are more complex.

The name Buffalo Lake originally was proposed by Stalker for the till of the last Laurentide glacier to move into the Buffalo Lake area of Alberta, and at the type area in sec. 6 of tp. 40, rge. 20, W4th Mer. (Richmond, 1977, p. 3) all the till is from that advance, which was of Classical Wisconsin Age. At Cameron Ranch the deposits of that age (units CRN to CRR) include several till sheets (in units CRN, CRO, CRQ), but as these are practically indistinguishable in most respects in the field, they all are classed as Buffalo Lake Till. All display the prominent characteristics of that till, such as negligible or only minor compaction, along with medium to light brown or buff colours – the lightest in tone of any tills in the sequence. Farther east, beyond areas uncovered during interstadial retreats, they undoubtedly unite into one till unit and would be inseparable or else form facies of that single till sheet.

When Stalker proposed the name Buffalo Lake, Wisconsin time comprised only the present Classical or Younger Wisconsin, and had not been extended backwards to include the Preclassical or Older Wisconsin. However, certain tills now regarded as Preclassical Wisconsin have, at times, been classed as Buffalo Lake (e.g., Stalker, 1963, sections 4, 5, 7, 8). This confusion arose partly from overestimation (discussed later) of the strength and coverage of Classical Wisconsin glaciers. Most of those misidentified tills have turned out to be beyond, and in some instances far beyond, the true limits of those glaciers but, as they were at or near the surface, they originally were assumed to be young. Also, as these older tills in those areas were not overridden by subsequent glaciers, their degree of compaction and their structure and texture commonly resembled that of Buffalo Lake Till, further adding to the confusion. In this report the name Buffalo Lake is used in its original sense, and so the Buffalo Lake Till here is of Classical Wisconsin Age. This, in turn, leaves unnamed those tills and associated deposits that lie between the Brocket and Buffalo Lake tills.

The name "Cameron Ranch Formation" is here given to the three till units (CRI, CRJ, CRL), the proglacial lake unit CRK, and the various other lake, stream, and outwash sediments associated with those units, that lie between either the Brocket Till or Sangamon deposits (units CRG, CRH) and the Buffalo Lake Till. It is named after the Cameron Ranch, and the Cameron Ranch Section in lsd. 16 of sec. 31, tp. 10, rge. 18, W4th Mer. (49°52'12"N, 112°25'10"W) is here designated the type section. This section displays the most

Table 1. Some properties of the various units of the Cameron Ranch Section, along with a proposed correlation with the units of Rutulis (1962). Stone counts and carbonate contents are after Rutulis with minor revisions and are assigned to their most probable positions in the section. Subunits are shown only where necessary to position the sample locations of Rutulis; boundaries between them are not necessarily correct as to depth.

Depth (m)	Unit	Subunit	Material	Rutulis (1962) Till Unit	Rutulis (1962) Sample Number	Till Fabric* (Estimated Direction)	Stone Counts (approximate percentage): Local	Shield	Limestone	Dolomite	Quartzite Sandstone Conglomerate	Chert	Argillite	Rocky Mountain Igneous	Carbonate Content (%) 0.074mm (200 mesh): Calcite	Dolomite	Total	Calcite Dolomite Ratio
	CRR		silt	A														
	CRQ		light brown till	A	16	S 58° E	2.0	41.0	7.5	42.5	3.5	3.5	0.0	0.0	3.7	10.3	14.0	0.36
5	CRQ		light brown till	A	17	S 58° E	9.5	32.5	10.0	37.0	8.5	2.5	0.0	0.0	2.0	2.9	4.9	0.69
10	CRP		sand silt	A														
15	CRO	iii	buff till	A	44		11.0	38.5	7.0	25.5	13.5	4.5	0.0	0.0	0.9	4.7	5.6	0.17
	CRO	iii	buff till	A	43		8.0	37.0	12.0	20.0	17.5	5.5	0.0	0.0	1.9	5.0	6.9	0.38
20	CRO	i	buff till	B	42	S 50° W	9.0	25.0	17.5	8.0	35.0	0.0	4.0	2.0	2.5	5.4	7.9	0.46
	CRO	i	buff till	B	41	S 50° W	3.0	27.5	13.5	11.0	32.0	11.0	3.0	0.0	2.4	5.7	8.1	0.42
25	CRN		buff till	B	18		9.0	30.0	13.0	6.5	35.5	6.0	0.5	0.0	2.5	5.6	8.1	0.45
	CRM		sand															
30	CRL		blue-grey till	C	40		2.5	41.5	3.5	26.5	15.5	10.5	0.0	0.0	2.6	6.6	9.2	0.39
	CRL		blue-grey till	C	19		6.0	40.0	7.0	35.0	8.5	3.0	0.0	0.0	2.9	6.8	9.7	0.42
35	CRK		varved silt	C														
40	CRJ		medium brown till	C ?	39	S 20° W	4.5	50.0	4.5	23.0	12.0	5.5	0.0	0.0	2.0	6.8	8.8	0.30
45	CRI	x	dark blue till	D	38	S 35°W(?)	0.0	34.0	8.5	57.0	0.0	1.0	0.0	0.0	2.1	5.2	7.3	0.40
	CRI	i,iii,v, vii	dark brown till	D	37	S 35°W(?)	0.0	48.0	4.5	47.0	1.0	0.0	0.0	0.0	3.1	12.5	15.6	0.25
	CRH																	
50	CRG	v,vi	dark brown till		20		0.5	35.0	7.0	54.0	2.0	2.0	0.0	0.0	2.7	11.3	14.0	0.24
	CRG	i,iii	dark brown till	E	36		4.0	48.5	13.5	26.0	6.0	2.0	0.0	0.0	2.4	7.2	9.6	0.33
55	CRF	iii	blue-grey till	E	35	S 30° E	4.5	45.5	12.5	28.5	8.0	0.0	1.0	0.0	2.8	7.3	10.1	0.38
	CRF	i	blue-grey till	E	15		4.5	36.0	8.0	45.0	5.0	1.0	0.0	0.5	2.8	7.7	10.5	0.36
	CRE	iii	very dark brown till	F	34	S 35° W	6.0	44.0	25.0	17.0	4.5	4.0	0.0	0.0	2.1	5.2	7.3	0.40
60	CRE	i	very dark brown till	F	33	S 35° E	5.0	41.0	19.0	12.0	16.0	7.0	0.0	0.0	2.2	5.1	7.3	0.43
	CRD	vii	dark grey till	G	32	S 33° E	0.0	30.0	17.5	47.0	4.0	1.0	1.0	0.0	2.3	13.1	15.4	0.18
	CRD	i	dark grey till	G	31		1.5	24.0	10.0	18.5	30.5	3.5	7.5	5.5	2.7	8.0	10.7	0.34
65	CRC		silt sand															
70	CRB		gravel		30		1.0	0.0	6.5	3.0	44.0	12.0	17.5	16.0				
75																		
80	CRA		bedrock															
85																		

*Fabric studies by J. Nunan; the approximate sampling depths in the section and within the units are indicated.

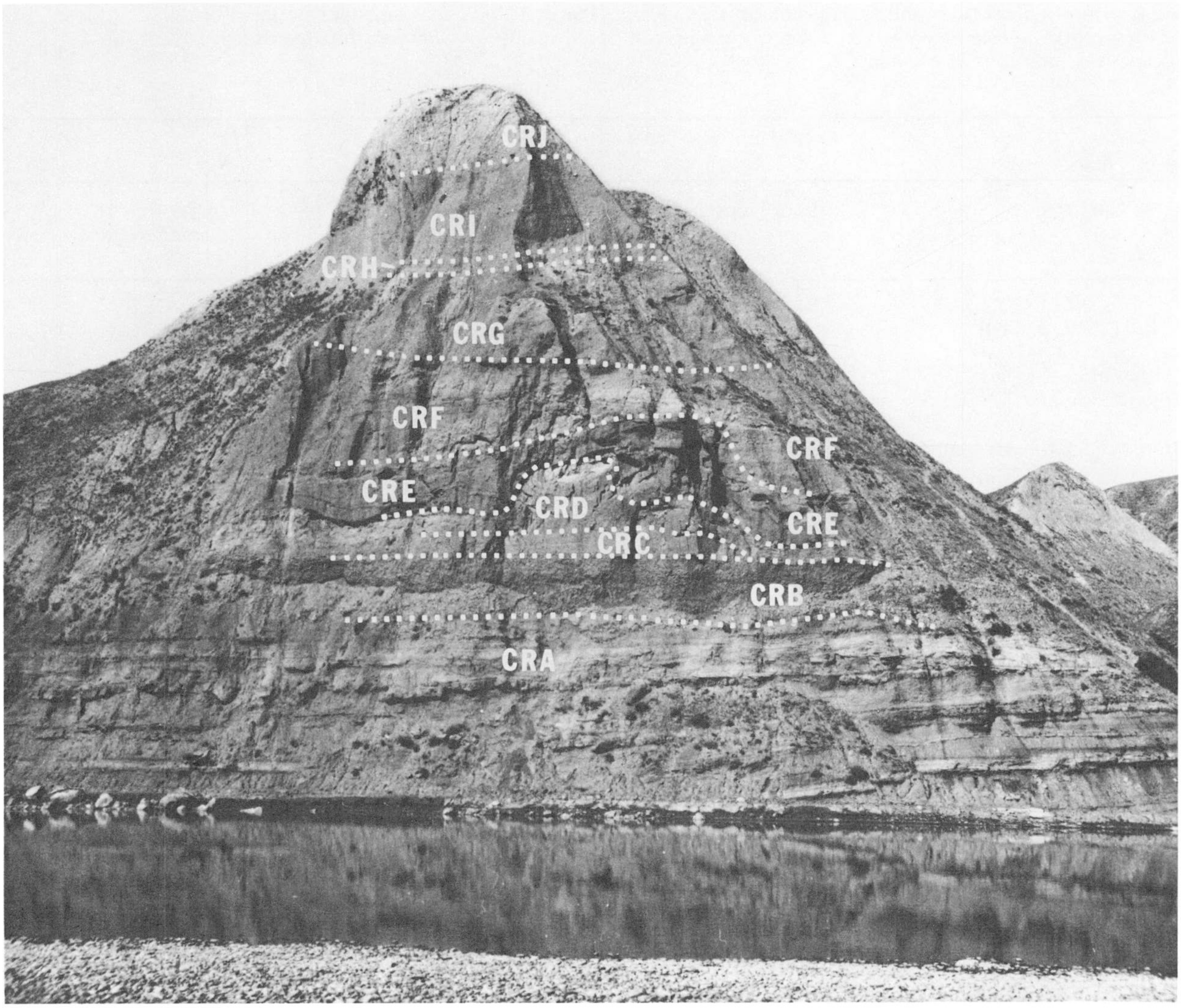


Figure 3. *The bottom and middle parts of the Cameron Ranch Section at the point where it was described (A on Fig. 2). The unit reference letters are as in the Appendix. The part of the section seen here includes the bedrock (CRA), preglacial deposits (CRB, CRC), Illinoian deposits (CRD to CRG), Sangamon deposits (CRH), and the basal Preclassical Wisconsin units CRI and CRJ. The other Preclassical Wisconsin units, the mid-Wisconsin and Classical Wisconsin units, and the postglacial deposits are found farther up the tributary gully and in the hills in the background. GSC 189526*

complete and one of the thickest exposures through the Preclassical Wisconsin deposits known to the author. The formation there is about 21 m thick, extending from about 35 to 56 m above normal level of Oldman River, and its top is about 35 m below the general Prairie level; only the bottom part of the section is visible in Figure 2. Island Bluff and Brocket sections, which are somewhat more accessible and more readily studied, are chosen as reference sections. The first, on the northeast bank of South Saskatchewan River about 12 km north of Medicine Hat, in SW¼ of sec. 4, tp. 14, rge. 5, W4th Mer. (50°8'15"N, 110°38'20"W), is Section 15 of Stalker (1969a, p. 24-28; Fig. 1), and in that section the Cameron Ranch Formation is considered to consist of units IBI, IBK, and probably IBL, and is about 25 m thick. The second, which is Section 5 of Stalker (1963, p. 27-31; Fig. 1), is on northwest bank of Oldman River about 7 km north of the town of Brocket, in S½ of sec. 34, tp. 7, rge. 28, W4th Mer. (approximately 49°36'N, 113°43'W). There the formation apparently consists of the top till in the section (Unit J), and of the next lower (Unit G), along with some associated outwash. However, the large boulders on the surface there (Unit P), which belong to the Foothills Erratics Train, undoubtedly were brought in by a late advance of one of the Cameron Ranch Formation glaciers, as discussed below. Of the units found at the Brocket Section between J and P, all but N and O probably consist of Laurentide outwash or proglacial lake deposits and also belong to the formation. The interfingering units N and O (not shown in Table 2) consist largely of outwash from Cordilleran glaciers and of material brought in by streams flowing from the west.

Till generally forms the bulk and certainly the most significant part of the Cameron Ranch Formation. The various till sheets found in this formation at the Cameron Ranch Section are described in the Appendix, their properties are listed in Table 1, and their correlations to deposits at other sections are given in Table 2. These Laurentide tills are typically medium brown to medium bluish or greyish brown – noticeably lighter in colour than the underlying Labuma, Maunsell, and Brocket tills but significantly darker than overlying Buffalo Lake Till; some of these differences in value are evident in Figures 2 and 3. In the same manner

Table 2. Stratigraphic denominations of the units at the Cameron Ranch Section and their suggested correlation with other sections and stratigraphies in southern Alberta. Units that are merely local or otherwise non-correlatable are omitted. Suggested ages are based mainly on vertebrate paleontology. (See Figure 1 for locations of sections.)

UNIT DESCRIPTION				
Name	Major Constituents at Cameron Ranch	Suggested Age	Section 16 Cameron Ranch	*Section 1 Wolf Island
	silt	Classical Wisconsin to Holocene	CRR	K,L,
Buffalo Lake Till	till	Classical Wisconsin	CRQ	J
	silt, sand	Classical Wisconsin	CRP	
Buffalo Lake Till	till	Classical Wisconsin	CRO	I?
Buffalo Lake Till	till	Classical Wisconsin	CRN	
	sand	Mid-Wisconsin	CRM	
Cameron Ranch Formation	till	Preclassical Wisconsin	CRL	
Cameron Ranch Formation	sand, clay, silt	Preclassical Wisconsin	CRK	
Cameron Ranch Formation	till	Preclassical Wisconsin	CRJ	
Cameron Ranch Formation	till, sand, silt	Preclassical Wisconsin	CRI	
Mitchell Bluff Formation	silt, sand	Sangamon	CRH	
Brocket Till	till, sand	Illinoian	CRG	
Maunsell Till	till	Illinoian	CRF	G
Labuma Till	till	Illinoian	CRE	E
Labuma Till?	till	Illinoian	CRD	
Saskatchewan Gravels and Sands	silt	Late Yarmouthian	CRC	C,D
Saskatchewan Gravels and Sands	gravel	Early Pleistocene	CRB	B
Bedrock	shale, siltstone, sandstone	Cretaceous and Tertiary	CRA	A

* Described in Stalker, 1963
** Described in Stalker, 1969

they generally are less compact, less indurated, and have a less developed structure than the lower tills, but more so than the higher ones. The rate of cliff retreat across them is also intermediate, as is their degree of oxidization in exposures. At Cameron Ranch these tills are fairly stony, but deficient in local or mountain type stones with correspondingly greater numbers of stones from the Shield and its adjoining Paleozoic rocks; in some cases these latter constitute up to 99% of the stones (Table 1). They also contain numerous sand and silt beds or stringers; these may contribute to the general weakness of the tills, and water seepage through them may have caused much of the oxidization.

Many of the above traits, such as the compaction, structure, and cliff face retreat, are due mainly to consolidation caused by the weight of subsequent overriding glaciers. Thus, in general, the features here described for the Cameron Ranch Formation are those found in areas where the formation was subjected to later glaciation, as at Island Bluff (Fig. 1, Section 13). Beyond such areas, as at Brocket where the Cameron Ranch Formation is at the top, the same degree of consolidation should not be expected and is not displayed; in those places its till can be weak and show rapid cliff face retreat.

Both the lower and upper contacts of the Cameron Ranch Formation normally are erosional and disconformable, and such is the case at its type section. The formation normally is underlain by lake or stream deposits of Sangamon Age, as at Cameron Ranch, but in valleys developed during Sangamon time it may lie directly on bedrock. Generally, mid-Wisconsin sediments and Buffalo Lake Till (Classical Wisconsin) overlie it, as at Cameron Ranch, but beyond the reach of Buffalo Lake glaciation the Formation commonly is at the surface and forms a fairly continuous cover. Altogether, it is widespread in southern Alberta, where it extends into the Foothills of the Rocky Mountains; it probably is extensive farther north in Alberta and in western Saskatchewan, but within the limits of Classical Wisconsin glaciation it typically is confined to buried valleys, in which it was largely protected against the onslaughts of the later glaciers. In those places it now is exposed locally where modern streams cut through the valley fill, but in many places the mid-Wisconsin or postglacial rivers have removed it completely.

As it typically is underlain by Sangamon deposits and overlain by Classical Wisconsin ones, the Cameron Ranch Formation is of Preclassical Wisconsin Age. This is best shown at Island Bluff (Fig. 1, Section 13) and some other sites near Medicine Hat, where the directly underlying deposits contain vertebrate fossils of Sangamon Age, and bones in overlying beds indicate a Classical Wisconsin Age (Stalker, 1969a, p. 6-11; 1976a, p. 397-401; Stalker and Churcher, 1972, p. 112-115).

STRATIGRAPHY

Bedrock (unit CRA) is not discussed here. The overlying surficial units, for purposes of description, are arranged according to age into six major groups. These groups are "Preglacial" (units CRB, CRC), Illinoian (units CRD to CRG), Sangamon (unit CRH), Preclassical Wisconsin (units CRI to CRL), Mid-Wisconsin (unit CRM), and Classical Wisconsin (units CRN to CRR). Units CRA to CRJ are shown in the foreground on Figure 3, where some of the higher units are also displayed in the background. During this discussion of the stratigraphy, the Appendix should be referred to for further information on the units and individual beds.

UNIT REFERENCE LETTERS OR NUMBERS					
*Section 3 Kipp	*Section 5 Brocket	**Section 14 Mitchell Bluff	**Section 15 Island Bluff	Stalker and Churcher, 1972	Stalker, 1976a
Q,R,S		MBM	IBP	T	XXVII
			IBO	S	XXVI
			IBN	R	
P			IBM	Q	XXIII
		MBL	IBM	Q	XXIII
J,K,L,M,N					XX, XXI
	P		IBL	O, P	XIX
	K,L,M				XVIII
	I,J	MBK	IBK	N?	XVII
	G	MBI	IBI	L	XVII
		MBF-MBH	IBF-IBH	K	XV
H,I	F				
E	E				
C	D			H,J	XI,XIV
					X
B		MBD	IBC,IBD		VIII, IX
B	B	MBB,MBC	IBB,IBC	D	VI
A	A	MBA	IBA	A	I

Preglacial Deposits (CRB and CRC)

The preglacial deposits are the oldest and lowest surficial deposits in the section. They consist of the Saskatchewan Gravels and Sands, and units CRB and CRC can be considered as two members of that formation. These units were laid down, in late Tertiary or Quaternary time, long after deposition of the Cretaceous bedrock of the region but prior to first coverage by ice, although the initial glacier strongly influenced deposition of the upper unit (CRC). Both units consist of material carried eastward by the ancestral Oldman River, along with some local material, and both lack debris brought from the Precambrian Shield by ice. Some of their material probably originated as outwash from glaciers in the Rocky Mountains to the west but, if so, distance of transport was sufficient to cause it to be well sorted and the stones to be rounded. Neither unit has yielded fossils; in the lower unit this may be due partly to the coarseness of the gravel and the swiftness of the current that laid it down, which would have tended to destroy large fossils and wash away smaller ones. As bones are abundant in equally coarse gravel near Medicine Hat, however, the lack of fossils in both units more likely arises from quick deposition of the units under cold conditions that lowered the ability of the region to sustain an abundant flora and fauna.

Unit CRB consists basically of a loose, clean, well sorted and well bedded, round to subround river gravel with a sand matrix. Due to its lack of either fossils or other datable material, its age is uncertain and can only be estimated by indirect methods. Correlation with the Medicine Hat sections is of little use, although similar beds there do contain a late Kansan mammalian fauna, for deposition of the Saskatchewan Gravels and Sands took place through a remarkably long time, and so the Medicine Hat deposits are not necessarily of the same age as the Cameron Ranch ones, but could, to the contrary, represent either a much older or younger part of the formation.

A minimum age for deposition of unit CRB can be estimated from the general rate of drainage lowering during preglacial times. The base of the unit is about 11 m above the level of the present river, and so by using the rate determined by Stalker (1960, p. 55) for general lowering of the Prairie surface this far from the mountains of about 1 m every 30 000 years, the unit would appear to have been laid down at least 300 000 years before onset of glaciation in this region. Further, as the deposits at Medicine Hat that yielded the late Kansan fauna are close to present river level, or relative to river level about 11 m below the similar deposits at Cameron Ranch, the Cameron Ranch gravel of unit CRB would appear to be about 300 000 years older than the Medicine Hat basal gravels. This estimate can be confirmed only through discovery of fossils in unit CRB.

The fine deposits of unit CRC, on the other hand, were laid down quickly as Laurentide ice advanced and blocked the ancestral Oldman to form a proglacial lake in its valley. They would, therefore, seem to be substantially younger than those of unit CRB, and apparently by at least 300 000 years. Though the contact between the two units does not demonstrate such a major hiatus, it could represent as much time as was involved in deposition of the rest of the section.

Units similar to CRB and CRC are found elsewhere, amongst other places, at the Wolf Island Section (Fig. 1, Section 1; Dawson, 1885, p. 141c; Stalker, 1963, p. 12-15, units B, C; Westgate, 1968, p. 69, Wolf Island Sediments) and towards the base of the more distant Medicine Hat sections described by Stalker (1969a; Table 2; Fig. 1, Sections 13, 14, 15). At the latter, they locally reach much greater thicknesses and contain late Kansan and Yarmouthian mammal faunas respectively. Also at Medicine Hat, a fission-track age of 430 000 ± 70 000 years from an ash bed in deposits corresponding to unit CRC (Westgate et al., 1978, p. 514-515) supports a Yarmouthian Age for that unit there. Both the Yarmouthian deposits at Medicine Hat and unit CRC were laid down during approach of the same initial glacier,and so they should be close in age. As a result, unit CRC is here considered to be Yarmouthian in age.

Illinoian Deposits (CRD to CRG)

Four mainly till units, which include many intervening and interfingering sand beds, are assigned to this group. They are classed as Illinoian because they overlie Yarmouthian deposits, as just indicated, and underlie a unit (CRH) that is correlated with the Sangamon beds at Medicine Hat (see Sangamon Deposits, below). Both dark brown and grey or bluish-grey tills are present; the former are considered to represent ice advance south or southeastward over the Tertiary and youngest Cretaceous beds found near the mountain front, the latter apparently represent southwest flow across the Cretaceous marine beds of the central Prairies. The tills of the group typically are well compacted and resistant.

The Illinoian sequence started when the glacier that had blocked Oldman River and forced deposition of unit CRC finally advanced over the area. Deposition of the oldest till unit in the sequence (CRD), therefore, followed closely upon deposition of unit CRC, although perhaps not immediately as locally this latter unit shows surface erosion, probably by streams from the advancing glacier, with deposition of stony silt by those streams. The oxidization displayed along the contact (see Appendix) is considered merely a subsequent effect of groundwater, rather than marking a span of time. As it represents the first Laurentide glacier to reach the area, unit CRD contains the lowest Shield stones in the Cameron Ranch Section.

Unit CRD is a problem unit. It has been observed only locally along Oldman River from east of Lethbridge to west of Taber; in other places the still higher, typical Labuma Till (CRE) lies directly on the Saskatchewan Gravels and Sands. Unit CRD is distinguished from typical Labuma Till by its lighter grey or brown colour, a lack of columnar structure, and by its tendency to break into much larger fragments. The degree to which these traits are caused by included sand beds or by its incorporation of a large amount of silt derived from the underlying unit CRC is not known. However, Table 1 shows that the till of subunit i, unit CRD, contains proportionately many more stones from the western mountains, such as sandstones, and fewer from the Shield, than either the higher subunit vii or the till of the overlying unit CRE. This, undoubtedly, is chiefly due to a high content of material from the underlying Saskatchewan Gravels and Sands of unit CRB. Although unit CRD is separated from the overlying Labuma Till of unit CRE by a sharp and distinct contact, here it is considered to be merely an early facies of that till, which was laid down by an initial, southeast-flowing phase of the Labuma glacier. Also, it is here regarded as a facies of the Labuma Till for reasons of simplicity, in order to lessen the number of glaciations reported from the section. If it is truly an early phase of the Labuma glaciation, then three Illinoian ice advances are represented in the section; if it represents a distinct ice advance then the number is four. No matter how it is classified, this unit remains an enigma and the reason why it contains so much material from the Saskatchewan Gravels and Sands and why it differs so strongly from the Labuma Till that directly overlies those deposits elsewhere is not understood. Certainly this till is not widespread in the region, and the early glacial advance that deposited it did not progress much beyond this point.

The other three till units of this group (CRE, CRF, CRG) are equated with the main Labuma, Maunsell, andBrocket tills, respectively. They show the characteristic properties of these tills, as described by Stalker (1960, p. 22, 23; 1963, p. 7), and can also be traced from section to section along the river to exposures where they were previously described (e.g., Stalker, 1963, sections 1, Wolf Island; 3, Kipp; 5, Brocket). Unit CRE has three till subunits, with the characteristics of subunits i and iii resembling both each other and typical Labuma Till, although subunit iii does contain a much higher percentage of carbonate stones and correspondingly fewer quartzites and cherts. These two subunits are separated by the oxidized subunit ii; the oxidization probably arose from groundwater seepage along the thin sand beds contained in it. Ice flow apparently altered, during deposition of this subunit, from the southeast found in subunit i – a direction much the same as in unit CRD – to the southwest shown by subunit iii.

The weathered zone in the top half of subunit iii resembles the lower horizons of a buried soil. If it is the remnant of such a soil, it denotes a significant lapse of time before onset of the next glaciation. The sand subunit iv could equally well be placed in overlying unit CRF. It consists of outwash or water-worked material left behind as the preceding glacier retreated or the following one advanced; its only significance is that it separates the till sheets of units CRE and CRF and also denotes a lapse of time between glaciations.

The next unit, CRF, consists of two till subunits separated by a sand stringer and, once again, capped by a thin sand bed. The till of both subunits is much alike and appears to be typical Maunsell Till, although the higher till (subunit iii) does have a much higher proportion of Shield stones and limestones, and correspondingly fewer dolomites. Ice flow in subunit iii, which forms the bulk of the unit, has again reverted to south-southeast; the direction in subunit i has not been ascertained. The sand overlying subunit iii has little significance; it may represent local ponding or alluviation as the ice retreated.

A sharp contact, changes in colour, in texture, and in fragment size and shape, along with a decreasing calcite to dolomite ratio in the matrix, mark the transition from unit CRF to unit CRG. There is nothing, however, to indicate the lapse of time represented by the contact. Once again, as in units CRD and CRF, in unit CRG several till bands are separated by sand beds of various thicknesses. The till of this unit in most respects resembles typical Brocket Till (Table 2). Nevertheless, there are marked differences between the tills of subunits i and iii, on the one hand, and those of subunits v and vi on the other, particularly in stone lithology, for the upper subunits show a doubling in the proportion of dolomites and a corresponding decrease in limestones, quartzites, Shield stones, and local types. Possibly the unit should be divided into two units at subunit iv; on the other hand, if the weathering on top of subunit v is the remnant lower part of a buried soil, which would denote a hiatus in deposition, a break into two units could be made equally well at the top of subunit v. For the present subunits i to vi are retained as one unit, partly to avoid increasing the complexity of the section, partly because of the stronger indications of soil formation on top of subunit vi, but mostly because all the till resembles Brocket Till. The paleosol on subunit vi appears to be the best developed paleosol in the Cameron Ranch Section, and in this report is regarded as a soil formed during Sangamon time. It must be remembered, however, that here, as elsewhere in the section, these weathered horizons have not been confirmed as soils; further, the upper parts of them have generally been eroded away.

Sangamon Deposits (CRH)

Unit CRH is considered to be the only Sangamon deposit in the section. This unit occurs in a most confusing part of the section and showed the most discrepancy between the 1961 and 1976 studies. This is probably because it represents an interglacial (Sangamon), with all the vagaries in climate and deposition that such a stage can provide over the long time represented. CRH is given the status of a discrete unit partly because it is difficult to assign to either the underlying or the overlying unit, but mainly because the apparent paleosol under it and the local removal of the unit by erosion indicate that hiatuses separated it from both the underlying and overlying units. Furthermore, the buff and brown mottling within it suggests that the Sangamon soil-forming processes continued throughout its deposition and that it was deposited slowly. This unit probably contains much loess and wind-blown sand, some of which may have fallen into local lakes but at least part of which fell on dry land that was continually vegetated.

The rare pieces of chipped or flaked chert found in this unit are an important feature. They resemble chert chips found in the Sangamon unit at Medicine Hat (Stalker, 1969a, p. 6, 7). The chips are small, and it is not known whether they are of natural or artificial origin. No matter which, they are not found below these beds either here or at Medicine Hat. The unit is correlated with the Mitchell Bluff Formation of Sangamon Age found in exposures near Medicine Hat (Stalker, 1976a, p. 397-399), and these chips are one of the main reasons for the correlation. This correlation further indicates, that any soil developed atop unit CRG is of Sangamon Age.

The lesser compaction and strength of the tills above unit CRH, as compared with those below, further indicates that this unit represents a major change in the sequence. The alteration in character of the overlying tills probably results from their having been compacted by fewer and thinner glaciers than the lower tills, and also perhaps from the shorter time they had in which to become slightly cemented and also indurated by changes in clay mineralogy. Much of unit CRH evidently was removed by streams before onset of the next glacier, leaving in places merely a lag of stones. Other material from the unit was probably stripped off by advancing ice.

Preclassical Wisconsin Deposits (CRI to CRL)

Three mainly till units and one intertill sand and clay unit are classed as Preclassical Wisconsin and assigned to the Cameron Ranch Formation. The lowest unit (CRI) is by far the most complex, for not only does it contain five till bands, separated by silt, sand, and clay beds, but the till itself is of two distinct types. In particular, the dark brown till towards the base (particularly subunits iii, v) has a much higher ratio of Shield stones, with correspondingly fewer carbonates, than the dark blue till of the higher subunit x which contains the highest proportion of carbonate stones of any till in the section. Also, the matrix of the dark blue till has a much higher calcite to dolomite ratio (Table 1). Although a good case could be advanced for dividing this unit into two or more units, the differences could also be explained as due to fluctuations in direction of ice movement during the same glaciation, with the dark brown till representing an early south or southeast flow over Tertiary beds near the mountain front, and the blue, top subunit reflecting a later southwest movement across the sombre marine shales and brackish-water silts of the central part of the Prairies. Until it can be demonstrated that more than one discrete ice advance is represented, the two facies of till are retained within the single unit. The complexity of the unit, with its alternation of till, sand, and silt subunits, indicates that the glacier was near its maximum extent at which time its margin underwent many minor advances and retreats.

The next unit, CRJ, shows a reversion to brown till, a drastic drop in percentage of carbonate stones, and a rise in Shield stones to the highest percentage found in any till in the section, along with a marked increase in quartzites, sandstones, and cherts. The unit consists of two major till subunits (i, iii) separated by a thin zone of extremely stony, oxidized till (subunit ii). This oxidization probably resulted from seepage of groundwater through the coarser, and so more permeable, till of subunit ii. The oxidization on top of subunit iii also is regarded as the work of groundwater, in this case water that seeped through the sand at the base of unit CRK.

This is a structurally weak till across which the cliff face retreats rapidly, but it also is one of the thickest and most massive tills in the section. Either it or the succeeding till of unit CRL, but probably this one, represents the stongest Preclassical Wisconsin glaciation of the region, and the one that extended farthest west and south.

The short-lived proglacial lake represented by the varves of unit CRK tells little about the time span between deposition of units CRJ and CRL. Because unit CRK coarsens and becomes stonier upward, and because its lower contact is sharp and its upper one diffuse, it appears related with the advance of the ice of unit CRL rather than with retreat of the glacier that formed unit CRJ.

The thick till of unit CRL appears only locally along the bluff. This unit is a puzzle. Its strong contortion, included sand and silt lenses, and near-surface banding may be the effects of permafrost. On the other hand, the possibility that this unit is a megablock (Stalker, 1975, 1976b) that was deformed during transportation cannot be discarded, though the presence of bedded and sorted sediments, rather than till, both above and below it renders this improbable. Most likely this is a till sheet that was deformed, contorted, and locally destroyed along the bluff by a subsequent glacier. It is, however, difficult to fit into any known Laurentide stratigraphic or glacial chronological scheme, or to correlate with any till sheet recognized in other sections. In those respects it resembles the lowest till (unit CRD) in the section. Most likely the glacier that deposited the till of unit CRL was the one that advanced westward to the approximate line of the Foothills Erratics Train (Stalker, 1957), controlled the southward direction of flow of the blocks of that train, and so determined its position. The chance that it was the glacier of unit CRJ that did these things, while possible, is less likely.

Mid-Wisconsin Deposits (CRM)

The thin sand unit CRM is considered to be the only Mid-Wisconsin deposit in the section. It is assigned this age because it overlies Preclassical Wisconsin deposits and underlies Classical Wisconsin deposits (see below). This assignation is corroborated through correlation with Medicine Hat sections (Stalker, 1976a, p. 401) and through comparison of the number of Wisconsin till units below and above at the two places (Table 2). This is not an important unit; it gives no information about the then prevailing climate or environment nor about the length of time required for its deposition, and it is of interest only because of its Mid-Wisconsin position. As it has a lower disconformable contact, it would appear to be closer timewise to the overlying unit CRN than to the underlying unit CRL.

Classical Wisconsin Deposits (CRN to CRR)

The deposits here assigned to the Classical Wisconsin include three till units (CRN, CRO, CRQ), an inter-till sand unit (CRP), and a silt unit (CRR) that was mostly laid down as the last glacier retreated. The three till units have major similarities and, as a group, form a marked contrast with tills lower in the section. They are the only buff to light brown tills present, they are poorly indurated and are weak, they all display marked cliff face retreat, and they habitually are poorly exposed. Furthermore, in comparison with underlying tills, they typically have higher proportions of local stones and of mountain quartzites and cherts, a much lower percentage of dolomites from the east, and somewhat fewer Shield stones. They also exhibit a high calcite to dolomite ratio in the matrix.

Till unit CRO ends at the Lethbridge Moraine, which marks the extreme limit of Classical Wisconsin ice advance (Stalker, 1977), and the till of underlying unit CRN is considered to represent an early advance of the same glacier, as described below. Both tills, therefore, would be of Classical Wisconsin Age and closely related timewise. Obviously, the till of the yet higher unit CRQ must also be Classical Wisconsin. Stalker (1977), largely on the basis of finite ^{14}C dates obtained from beneath them, considered that the equivalents of these deposits at Medicine Hat and elsewhere represented the complete Classical Wisconsin glacial sequence for the region, and that any underlying tills were of earlier age. It appears unlikely that there were other Classical Wisconsin advances in the region that are not represented here.

The first pulse of Classical Wisconsin glaciation laid down the thin till of unit CRN, which apparently does not reach the Kipp Section (Stalker, 1963, p. 19-22) and probably does not extend much beyond Cameron Ranch. Probably this first advance was a weak, preliminary oscillation of the glacier responsible for deposition of unit CRO. Its till has the highest percentage of quartzites and sandstones of any till in the section; only till subunit i in CRO is close to it in that respect. Minor sandy outwash (subunit ii) was laid down as this early pulse receded, and subsequent seepage of groundwater through that sand oxidized the top of subunit i.

Unit CRO represents the strongest Classical Wisconsin advance, and it contains two, nearly equally thick, till sheets separated in places by a poorly sorted sand unit. Both till sheets are thick. Composition of the till varies markedly, particularly in relative amounts of chert, quartzite, argillite, and Shield stones; these internal differences can be much greater than those with the overlying and underlying tills. Generally the proportion of Shield and carbonate stones, is lower, and the proportion of local bedrock fragments and of quartzites and cherts higher, than in most of the other tills. This, along with the highest percentage of argillites in the section, indicates addition of material from the western mountains. As such material evidently was not brought into the area by Cordilleran ice, it probably was picked up from material introduced by rivers in Mid-Wisconsin time.

The local sand of subunit ii in unit CRO is not accorded much importance; it may indicate minor glacier retreat with a subsequent change of ice flow pattern from southwest below to south or southeast above.

The silt and sand of unit CRP was laid down in a proglacial lake, apparently during retreat of the glacier of unit CRO, for the two units are gradational. Apart from its significance in denoting an ice-free interval during Classical Wisconsin time, this unit has little significance. Stalker (1977, p. 2619) reported a similar ice-free interval in the Classical Wisconsin sequence at Medicine Hat that lasted several thousand years and represented large-scale ice withdrawal. In 1980 (p. 11) he further suggested that the preceding and succeeding pulses of Classical Wisconsin glaciation reached their maxima there about 22 000 and 17 000 years ago, respectively, and that the mid-point of the ice-free interval was about 19 000 or 20 000 years ago.

Above this unit the face of the cliff retreats rapidly, is largely covered with vegetation and slump, and the rest of the section is difficult to decipher. As a result, less is known about the characteristics of units CRQ and CRR than of any other unit in the section. Unit CRQ represents the last ice advance over the region, which Stalker (1977) erroneously inferred was the strongest Classical Wisconsin advance and the one that reached the Lethbridge Moraine; he corrected this in 1980 when he recognized that the earlier advance responsible for unit CRO was the stong one. It is unlikely that the last pulse (unit CRQ) progressed much beyond Cameron Ranch.

The till of unit CRQ, being the top till and so not compacted by later ice sheets, is weak and poorly indurated, resulting in the rapid retreat of the cliff face, the slumping, and the enhanced plant growth mentioned above. Sandstones and cherts are much less important here than in the till of unit CRO, but carbonates much more so. The S58°E stone orientation (Table 1) indicates that for a while, at least, this glacier had the strongest eastward component of flow recognized in the section.

The silt of unit CRR was laid down in a proglacial lake during retreat of the glacier depositing unit CRO. Little is known about the lake, but its draining ended all significant deposition at the Cameron Ranch Section. Subsequent time has seen only wind erosion and deposition, along with the gullying that proceeded as Oldman River carved its postglacial valley (Fig. 2, 3).

REFERENCES

Alden, W.C. and Stebinger, E.

1913: Pre-Wisconsin glacial drift in the region of Glacier National Park, Montana; Geological Society of America Bulletin, v. 24, p. 529-572.

Calhoun, F.H.H.

1906: The Montana lobe of the Keewatin Ice Sheet; United States Geological Survey, Professional Paper 50.

Dawson, G.M.

1885: Report on the region in the vicinity of the Bow and Belly Rivers, Northwest Territory; Geological Survey of Canada, Report of Progress, 1882-84, Part C.

1896: Glacial deposits of southwestern Alberta in the vicinity of the Rocky Mountains; Geological Society of America Bulletin, v. 7, p. 31-66.

Horberg, L.

1952: Pleistocene drift sheets in the Lethbridge Region, Alberta, Canada; Journal of Geology, v. 60, p. 303-330.

1954: Rocky Mountain and continental Pleistocene deposits in the Waterton Region, Alberta, Canada; Geological Society of America Bulletin, v. 65, p. 1093-1150.

Johnston, W.A. and Wickenden, R.T.D.

1931: Moraines and glacial lakes in southern Saskatchewan and southern Alberta, Canada; Transactions, Royal Society of Canada, Series 3, Section 4, v. 25, p. 29-44.

Murakami, S.S.
1960: Till fabric comparisons of the Pleistocene deposits in southwestern Alberta and Toronto; unpublished B.Sc. thesis, University of Toronto, 63 p.

Richmond, G.R.
1977: Quaternary stratotypes of North America, Volume 1; International Union for Quaternary Research, Subcommission on North American Quaternary Stratigraphy, 114 p.

Rutulis, M.
1962: The differentiation of tills in southern Alberta; unpublished B.Sc. thesis, University of Western Ontario, Department of Geology, 117 p.

Stalker, A. MacS.
1957: The Erratics Train; Foothills of Alberta; Geological Survey of Canada, Bulletin 37, 28 p.

1960: Surficial geology of the Red Deer-Stettler map-area, Alberta; Geological Survey of Canada, Memoir 306, 140 p.

1963: Quaternary stratigraphy in southern Alberta; Geological Survey of Canada, Paper 62-34, 52 p.

1969a: Quaternary stratigraphy in southern Alberta; Report II: Sections near Medicine Hat; Geological Survey of Canada, Paper 69-26, 28 p.

1969b: Geology and age of the early man site at Taber, Alberta; American Antiquity, v. 34, p. 425-428.

1972: Southern Alberta; in Quaternary geology and geomorphology between Winnipeg and the Rocky Mountains; ed. N.W. Rutter and E.A. Christiansen; 24th International Geological Congress (Montreal), Guidebook, Field Excursion C-22, p. 62-79.

1973: Surficial geology of the Drumheller area, Alberta; Geological Survey of Canada, Memoir 370, 122 p.

1975: The large interdrift bedrock blocks of the Canadian Prairies; in Report of Activities, Part A, Geological Survey of Canada, Paper 75-1A, p. 421-422.

Stalker, A. MacS. (cont.)
1976a: Quaternary stratigraphy of the southwestern Canadian Prairies; in Quaternary Stratigraphy of North America, ed. W.C. Mahaney; Dowden, Hutchinson & Ross, Stroudsburg, Pa., p. 381-407.

1976b: Megablocks, or the enormous erratics of the Albertan Prairies; in Report of Activities, Part C, Geological Survey of Canada, Paper 76-1C, p. 185-188.

1977: The probable extent of Classical Wisconsin ice in southern and central Alberta; Canadian Journal of Earth Sciences, v. 14, p. 2614-2619.

1980: The geology of the ice-free corridor: The southern half; Canadian Journal of Anthropology, v. 1, no. 1, p. 11-13.

Stalker, A. MacS. and Churcher, C.S.
1982: Ice Age deposits and animals from the southwestern part of the Great Plains of Canada; Geological Survey of Canada, Miscellaneous Report No. 31.

1972: Glacial stratigraphy of the southwestern Canadian Prairies; the Laurentide record; 24th International Geological Congress (Montreal), Section 12, p. 110-119.

Vernon, P.
1962: Tills of the Lethbridge area, Alberta, their stratigraphy, fabric and composition; unpublished M.Sc. thesis, Carleton University, Ottawa, 107 p.

Westgate, J.A.
1965: The Pleistocene stratigraphy of the Foremost-Cypress Hills Area, Alberta; in Cypress Hills Plateau, ed. R.L. Zell; Alberta Society of Petroleum Geologists, 15th Annual Field Conference, Guidebook, Part 1, p. 85-111.

1968: Surficial geology of the Foremost-Cypress Hills area, Alberta; Research Council of Alberta, Bulletin 22, 122 p.

Westgate, J.A., Briggs, N.D., Stalker, A. MacS., and Churcher, C.S.
1978: Fission-track age of glass from tephra beds associated with Quaternary vertebrate assemblages in the southern Canadian plains; Geological Society of America, Abstracts with programs, v. 10, no. 7, p. 514-515.

APPENDIX

DESCRIPTION OF CAMERON RANCH SECTION

Section 16 (Cameron Ranch Section). Northeast (left) bank of Oldman River in lsd. 16 of sec. 31, tp. 10, rge. 18, W4th Mer. (49°52'12"N, 112°25'10"W). The section is described from top downward. Thicknesses indicated for each unit are generally the maxima seen, and so the total thickness of the section is exaggerated. True vertical distance from river to prairie level is about 75 m. Relation to the units of Rutulis (1962) and information about properties of some of the units are given in the text and in Table 1; information about age and correlation is given in Table 2; and the bottom and middle parts of the section are shown on Figure 3. Slopes recorded for cliff face retreat are from the vertical.

Unit Reference Letters	Subunit Reference Number	Description	Thickness (m) Subunit	Unit	Cumulative
		General Prairie Level			
CRR		GLACIAL			
		Silt, buff to yellowish brown; typically massive and stone free; generally hidden by slump and overgrowth and so thickness only estimated (proglacial ponding)	2.00	2.00	2.00
		Contact covered by vegetation and slump			
CRQ		GLACIAL			
		Till, light brown on dry surface, medium brown where damp; stony, with many large boulders; this is the least indurated and weakest till in the section, cliff face retreats rapidly; typically the unit is overgrown and poorly exposed	4.00	4.00	6.00
		Contact generally obscured by vegetation and slump			
CRP		GLACIAL			
	ii	Silt, minor clay beds, rare scattered stones; typically massive (proglacial ponding?); present only locally	3.00		
	i	Alternating beds of coarse sand and silt in about equal parts; typically a rusty yellow (pond deposits near ice front?)	2.00	5.00	11.00
		Contact generally horizontal but locally distorted by slumping; typically gradational through 25 cm of alternating beds of clayey silt or fine sand, and of till			
CRO		GLACIAL			
	iii	Till, buff to very light brown on surface, yellowish brown if damp; stony; breaks into rectangular fragments about 5 cm long, the fragments characteristically are larger than in most of the other tills; upwards the till becomes less indurated and silt bands appear; cliff face retreats at 45° near base of unit, at 30° near top	6.00		
	ii	Sand, medium, with coaly bands; generally a yellow-buff but more rust coloured near top; glacial-fluvial?; present only locally	0.70		

Unit Reference Letters	Subunit Reference Number	Description	Thickness (m) Subunit	Unit	Cumulative
		Sharp to gradational, but distorted, contact; where overlying sand of subunit ii is absent, it commonly is represented merely by a stony zone or boulder pavement in the till			
	i	Till, buff to light bluish grey where dry, medium brown if damp, joints oxidized to rust colour; stones plentiful and mostly rounded, few large and most 2 to 10 cm long; breaks into sharp, angular pieces about 4 cm long; cliff slopes 35° at base of unit, 45° near top	6.00	12.70	23.70
		Sharp, horizontal contact			
CRN		GLACIAL			
	ii	Coarse sand and grit, buff colour; stony near top with many coal fragments; represents outwash deposited from east; present only locally	0.15		
		Contact commonly obscure, elsewhere sharp and undulating, with surface of underlying bed eroded and oxidized to a rusty brown			
	i	Till, buff to very light brown; moderate number of stones but mostly small; breaks into rectangular blocks of sundry sizes, but typically about 1 cm long; cliff face moderately steep	2.00	2.15	25.85
		Sharp, horizontal contact locally distorted by slumping			
CRM		NONGLACIAL (?)			
		Sand, medium to fine, buff to light grey; stone free, crossbedded; cliff face retreats rapidly (alluvial)	1.50	1.50	27.35
		Sharp, horizontal contact that truncates underlying beds			
CRL		GLACIAL			
		Till, medium blue-grey on surface, particularly towards top, browner towards base, medium brown where damp; darker than underlying till, partly oxidized; contains moderate number of stones, along with pockets and lenses of sand and grit; breaks into angular pieces 3 to 5 cm long; banded towards top; face steepens to 30° near top; this is the most contorted and deformed till in section; unit occurs only locally; possibly, though unlikely, it may have been transported into place en mass as a megablock; thickness ranges from 1 to 6 m	6.00	6.00	33.35
		Contact undulating and disturbed by slumping			
CRK		GLACIAL			
	x	Sand, medium to coarse, pebbly in places; alluvium	0.25		
		Stone-free silt, fine sand, minor clay, varved (proglacial lake deposits); as follows:			

Appendix (cont.)

Unit Reference Letters	Subunit Reference Number	Description	Thickness (m) Subunit	Unit	Cumulative
	ix	Clay	0.01		
	viii	Sand, buff	0.10		
	vii	Clay	0.01		
	vi	Sand, buff to rusty yellow	0.08		
	v	Clay	0.01		
	iv	Silt, sand, rusty yellow	0.60		
	iii	Clay	0.01		
	ii	Silt, sand, rusty yellow	0.90		
	i	Sand, medium, light grey; stone free	0.12	2.09	35.44
		Sharp contact			
CRJ		GLACIAL			
	iii	Till, as in subunit i, but becoming oxidized towards top; cliff face retreats at 45°	2.50		
	ii	Till, extremely stony and bouldery, oxidized	0.40		
	i	Till, dark to medium brown; stony with many boulders 20 to 30 cm long; crumbly, and breaks into rectangular pieces 2 cm long; cliff face retreats at 60°	3.00	5.90	41.34
		Gradational contact			
CRI		GLACIAL			
	x	Till, dark blue; scattered small stones but no boulders; forms steep cliff face	0.80		
		Gradational contact			
	ix	Clay, scattered small stones	0.10		
	viii	Sandy gravel, with stones to 10 cm but mostly 2 cm long; rusty yellow	0.10		
	vii	Till, dark brown, with sand stringer near centre	0.20		
	vi	Sand, stony; rusty yellow	0.12		
		Sharp contact			
	v	Till, dark brown; breaks into cubes 2 to 3 cm on a side	1.00		
		Sharp, horizontal contact			
	iv	Sand, medium, buff to rusty yellow; massive, mostly stone free but capped by 3 cm-thick pebble band with stones to 2 cm (alluvium?)	0.40		
		Sharp contact			
	iii	Till, dark brown with oxidized rusty streaks, resembles till of underlying subunit i; cliff face retreats rapidly	0.80		
		Sharp, even contact			

Appendix (cont.)

Unit Reference Letters	Subunit Reference Number	Description	Thickness (m) Subunit	Unit	Cumulative
	ii	Silt, clayey fine sand; buff to rusty yellow; stone free; cliff face steep; crossbedding indicates deposition from west (alluvium)	1.50		
		Sharp contact			
	i	Till, dark brown, with scattered small stones	0.40	5.42	46.76
		Sharp, horizontal contact; erosional, and locally marked by lag of stones where underlying sand has been removed			
CRH		NONGLACIAL			
		Silt, fine sand; mottled buff and brown, becoming greyer and more clayey upward; rare and scattered chipped pieces of chert present (lake deposit or loess)	0.20	0.20	46.96
CRG		GLACIAL			
	vi	Till, dark brown; platy texture; becomes very dark in upper 5 cm, where stones commonly are weathered, and this upper part of the subunit resembles a buried soil	0.50		
		Horizontal contact denoted by sharp colour change			
	v	Till, brown; becomes more clayey upward and this top part may represent former surface weathering	0.90		
	iv	Sand, medium grey	0.01		
	iii	Till, as at base of unit	0.30		
	ii	Sand, white to buff; stone free; bed extremely variable in thickness and locally absent, normally about 7 cm thick	0.70		
		Sharp, fairly horizontal contact			
	i	Till, dark brown; markedly different from till in underlying unit; breaks into angular fragments 7 cm long, 2 cm wide; contains horizontal sand and silt stringers	2.40	4.81	51.77
		Sharp, horizontal contact			
CRF		GLACIAL			
	iv	Sand, fine, white; stone free; generally 3 to 5 cm thick, locally absent	0.35		
	iii	Till, resembles that at base of unit but somewhat browner, breaks into bigger fragments, and cliff face retreats at 40°	2.30		
	ii	Sand, fine, white; stone free;	0.01		

Unit Reference Letters	Subunit Reference Number	Description	Thickness (m) Subunit	Unit	Cumulative
	i	Till, light blue-grey on surface, dark brown where damp, weathered to a light brown in top 0.5 to 1.0 m; generally lighter colour than till of underlying unit; shows incipient columnar structure; extremely hard, but breaks into sharp, angular fragments 3 cm long, 1 cm thick; stonier than any of the underlying tills, with boulders 50 to 100 cm long moderately common; cliff face retreats at 25°	1.20	3.86	55.63
		Sharp, undulating contact			
CRE		GLACIAL			
	iv	Sand, fine; scattered stones	0.30		
		Contact mostly gradational			
	iii	Till, bottom half dark brown and resembles till at base of unit, top half weathered to a rusty, yellowish brown; overall somewhat more bouldery than till of subunit i, with stones about 25 cm long common	1.00		
	ii	Till, oxidized to a rusty yellow brown, otherwise similar to underlying till; crossed near centre by two 1 cm-thick stringers of stone free, medium sand	0.50		
	i	Till, very dark brown to black where damp, dark blue-grey if dry; shows marked columnar structure on cliff face, which retreats at about 45°; platy texture, and breaks into small, hard and sharp, pieces 1 to 2 cm long; a large proportion of the few stones present are from the Shield; large boulders not seen	3.00	4.80	60.43
		Contact indicated by sharp change in colour and fracture pattern; also a compositional change			
CRD		GLACIAL			
		Interbedded till and sand. The till is dark grey on surface, dark brown underneath where damp; blocky texture and breaks into pieces 7 cm or so long; moderately stony and contains Shield stones, most stones subangular; till only moderately indurated, and cliff face retreats at about 25°. The sand is fine, light grey, and stoneless. The section shows:			
	vii	Till	1.00		
	vi	Sand	0.05		
	v	Till	0.15		
	iv	Sand	0.03		
	iii	Till	0.10		
	ii	Sand	0.03		
	i	Till, contains first Shield stones in section	0.80	2.16	62.59
		Contact generally horizontal, sharp; where underlain by varved silt and clay or stony silt, the contact may be more gradational and indicated chiefly by oxidization and a sharp colour change			

Appendix (cont.)

Unit Reference Letters	Subunit Reference Number	Description	Thickness (m) Subunit	Unit	Cumulative
CRC		PREGLACIAL			
		Silt, sand, minor clay; an extremely variable unit that is locally absent and elsewhere ranges from 0.7 to 4.5 m in thickness; a typical section is as follows:			
	ii	Silt, minor clay, stone free, varved with about 6 varves ranging from 5 cm thick at bottom to 3 cm at top (proglacial lake deposit)	0.30		
	i	Silt and sand, typically beds of massive silt, 0.5 to 1 m thick, forming a near vertical cliff face with columnar structure; elsewhere sand with a few scattered stones (alluvium at base; proglacial lake deposits towards top)	4.00	4.30	66.89
		Contact generally sharp and horizontal, but where unit CRC is missing, the underlying gravel is locally capped by up to 0.5 m of stony silt with till-like appearance			
CRB		PREGLACIAL			
		Gravel, local thin sand beds and lenses; stones up to 20 cm long, but generally 6 cm near base and 3 cm towards top; stones subangular to round; Shield stones lacking; thickness 2 to 7 m	7.00	7.00	73.89
		Sharp, generally horizontal, contact			
CRA		BEDROCK			
		Foremost Formation: indurated to nonindurated sandstone, dark grey shale, and includes a 50 cm-thick coal seam; horizontally bedded and not deformed, but the top 3 m typically is weathered and oxidized; surface of bedrock, as seen in tributary gullies, rises to the north away from the main Oldman valley	11.00	11.00	84.89
		Normal level of Oldman River			
		Total thickness	84.89	84.89	84.89