SURFICIAL GEOLOGY AND EROSION POTENTIAL ROCKY MOUNTAINS AND THE FOOTHILLS OF ALBERTA

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prepared for

ALBERTA ENVIRONMENT,
GOVERNMENT OF ALBERTA

by

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SURFICIAL GEOLOGY AND EROSION POTENTIAL

ROCKY MOUNTAINS AND THE FOOTHILLS OF ALBERTA

1:50 000

82G	1						7	8	9	10					15	16
82H			3	4	5	6										
82J	1	2					7	8	9	10	11			14	15	16
82N															15	16
82O	1	2	3			6	7			10	11	12	13	14	15	
83B			3	4	5	6						12				
83C	1	2	3			6	7	8	9	10				14	15	16
83E					5	6	7	8	9	10	11	12	13	14	15	16
83F		2	3	4	5	6						12				
83L			3	4	5											

SURFICIAL GEOLOGY AND EROSION POTENTIAL
ROCKY MOUNTAINS AND THE FOOTHILLS OF ALBERTA

INTRODUCTION

Terms of Reference

The terms of reference are set out in agreements between the Government of the Province of Alberta, Department of the Environment and Bayrock and Reimchen Surficial Geology Ltd., dated April 23rd, 1974, April 30th, 1975 and July 1st, 1976 and the main points are as follows:

1. To outline and describe surficial deposits of the area at a scale of 1:250,000 with work maps at a scale of 1:50, 000.

2. To categorize surficial deposits according to the degree of internal stability.

3. To perform slope analyses in the area using the following classes and subheadings:

   (a) 0 - 14 per cent
   (b) 15 - 29 per cent
   (c) 30 - 44 per cent
   (d) 45 per cent and greater

4. Internal stability classes of surficial deposits are to be combined with the slope classes to give potential erosion categories.

The study was broken down into three phases: Phase I was completed on the first of April 1975 and encompassed the Rocky Mountains and the Foothills north of the 52nd parallel. Phase II was completed on the first of April 1976 and encompassed the Rocky Mountains and the Foothills from the 52nd parallel to the U.S. - Canada border. Phase III, being this report, is essentially a compilation of the two previous reports into the final report with some additional field work on a minor scale.

The final report is accompanied with maps of surficial geology of the study area to a scale of 1:250,000. Erosion Potential, Slope Analyses, and Surficial Geology maps to a scale of 1:50,000 are on open file at the Alberta Research. Erosion Potential maps, 1:250,000 scale, were compiled from the 1:50,000 maps in 1975-1976. The revised Erosion Potential maps generated for this final report (1:50,000 scale) have not been reduced to 1:250,000 scale.

The study area is outlined in Figure 1. It encompasses all the Foothills and Rocky Mountains lying within the Province of Alberta excluding National Parks. Some Indian Reserves are covered in this report but have not been surveyed during the fieldwork phase. The western boundary of the study area is the Alberta - British Columbia border or the Jasper, the Banff, and the Waterton National parks boundaries. The eastern boundary is the outer limit of the Foothills. Because it was found difficult to define the eastern limit of the Foothills, the study area extends a

FIGURE 1: LOCATION OF STUDY AREA

few miles to the east of the Foothills as is apparent from the bedrock structure. The total area surveyed encompasses over 9 million acres or 36.5 thousand square kilometers.

Methodology

1. Surficial deposits of the area were analysed using aerial photographs and the results were plotted on maps to a scale of 1:50,000.

2. Surficial Deposit maps were reduced to a scale of 1:250,000.

3. The small scale maps were used as a basis for field investigations. Helicopter traverses with a spacing of about 3 miles were conducted over the area. Systematically, samples were collected and materials described. Over 700 helicopter landings were made.

4. Additional traverses using the 1:50,000 scale maps were conducted by vehicle over most accessible roads.

5. The samples were analysed for grain size, pebble lithology, genesis, and Atterberg limits.

6. At sampling locations, where possible, surface slopes were measured and erosion of surficial materials determined.

7. Reinterpretation of aerial photographs was performed incorporating the field information.

8. Internal stability classes were determined for the surficial materials using the field data.

9. Slope analyses were performed at scales of 1:50,000 on National Topographical Series maps. The results were combined with the internal stability classes to produce areas of erosion potential.

10. Preliminary reports of the total area with maps to scales of 1:50,000 and 1:250,000 form the open file of surficial geology and erosion potential at the Alberta Research. The final report covering the whole of the area has attached only Surficial Geology maps to a scale of 1:250,000.

Previous Work

The Rocky Mountain House Sheet (83B) has been mapped by Boydell, Bayrock and Reimchen (1974). Some changes have been made on the distribution of surficial deposits because of new data gathered in the area. No previous work of surficial deposits has been done for the Brazeau Sheet (83C), except for a small area around the Big Horn Dam (Reimchen, 1969, Internal Report, Alberta Research). The Mount Robson Sheet (83E) has previous partial coverage only for the Willmore Wilderness Park (Reimchen and Bayrock, 1973, Internal Report, Alberta Research). The Edson Sheet (83F) has been mapped partly by Roed (1970). The Wapiti Sheet (83L) has been mapped on a reconnaissance basis (Bayrock, 1972, Internal Report, Alberta Research).

The Bow River Valley has been mapped in part by Rutter (1972). Some changes have been made on the distribution of surficial deposits in this area because of new data. The Kananaskis Sheet (82J) is presently being mapped by L. Jackson (University of Calgary).

The area of coverage for the present study encompasses the western part of this map sheet. The Fernie Sheet (82G) was mapped by Stalker in 1962. The present study encompasses that area west of the Oldman River and Chain Lakes to the Alberta - B.C. boundary. Some changes have been made on the distribution and interpretation of surficial deposits for this area because of new data and better accessability. The surficial geology of the Fort McLeod Sheet (82H) has been mapped by Stalker (1958). The distribution of surficial deposits for this region has not changed significantly. Only the interpretation of some deposits has been altered to fit new information gathered in the present study.

Field Work

Field work on the study was carried out during the summer months 1974, 1975 and 1976. In 1974 the area north of the 52nd parallel was surveyed by helicopter and ground vehicle. In 1975 the area south of the 52nd parallel and north of the U.S. - Canada border was surveyed by helicopter and ground vehicle. In 1976 the ground vehicle survey of an area south of the Bow River and north of the Highwood River was conducted in order to gather additional information on erosion potential of the surficial materials.

The helicopter survey was conducted on relatively close spaced traverses being from 3 to 4 miles apart. At each helicopter stop the surficial materials were described and sampled. Surficial deposits and geomorphology of the terrain between the stops was described in the helicopter from the air. At each stop the surface slope and erosion characteristics of surficial materials were measured and described wherever possible. The ground vehicle traverses were conducted on most of the accessible roads in the area, and surficial materials were sampled at invervals of 2 to 6 miles. Field work, traverse maps, and sample analyses results are on file at Alberta Research.

Acknowledgements

The authors are grateful to the Research Secretariat, Alberta Environment, Government of the Province of Alberta, for the opportunity to conduct this study. Specific gratitude is expressed to Drs. Stuart B. Smith and Bill McDonald, Research Secretariat, for their administrative efforts and guidance throughout the execution of the project; Dr. R. Green, Alberta Research is acknowledged with thanks for professional supervision and criticism which greatly helped throughout the study. Major funding of the study was by the Research Secretariat, the Alberta Environment, and Alberta Research. Alberta Research is the custodian of the open file of the preliminary reports, the maps and the field notes.

In addition to the two principals, the following personnel of Bayrock and Reimchen Surficial Geology Ltd. were engaged on the project; Larry Pondick - drafting and checking of the maps, Marjorie Pondick - typing and editing of the manuscripts and maps, John Miller - field work - editing of maps and statistical analyses, Ian Thomson - editing of maps and field work, J.D. Root - statistical analyses, field work and editing of maps, David Ginter - field work - editing of maps.

Analyses of the samples were performed by Thurber Consultants (Edmonton) and Dr. John Westgate, Department of Geology, U of A, and Trylowsky Engineering Ltd. (Edmonton).

SURFICIAL DEPOSITS

Surficial deposits of the area as defined in this report are all deposits underlying the surface regardless of origin. They have been classified on the basis of genesis and are grouped on a semi-chronological basis as shown in Table 1. The classification of the deposits as shown in Table 1 is used as a legend for all of the maps of surficial deposits. The distribution of surficial deposits is shown on separate maps to a scale of 1:250,000. Aerial photographs were absent for National Topographic Sheets 83C 11 and 13.

Sample analyses results and erosion stability measurements are given in Appendix 1. A summary of statistical correlations is given in Appendix 2.

Bedrock: (Map Unit 1)

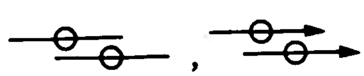
Compilation of bedrock geology for the study area has been performed by M.E. Holter and I.J. McLaws, 1972, Alberta Research. The results of the compilation is given on separate maps to a scale of 1:250,000. These maps have been used in the present study and copies of these form a portion of the open file report of this study held by Alberta Research. As this report is concerned primarily with surficial deposits, description of bedrock geology is consequently not dealt with. The reader is referred to the above mentioned bedrock geology maps for regional considerations.

All bedrock outcrops regardless of stratigraphy or lithology are shown by the same symbol, Map Unit 1, on the surficial geology maps. Bedrock outcrops shown on the map are only those which could be delineated as separate areas on a scale of 1:250,000 (Plates 1,4,19,37 and 44).

TABLE 1

LEGEND FOR SURFICIAL DEPOSITS MAPS

Map Unit	Description
29	Slump and Landslide
28	Rock Slide
27	Talus
26	Rock Defended Terrace
25	Patterned Terrain
24	Colluvium
23	Alluvial Fan
22	Alluvium, Fine
21	Alluvium, Coarse
20	Glaciers
19	Rock Glaciers
18	Cirque Till (Cordilleran) Youngest Age
17	Organic
16	Eolian
15	Glaciolacustrine
15 a.	Hummocky Glaciolacustrine
14	Lag Gravel
13	Valley Train
12	Outwash Plain Pitted
11	Kame, Kame Moraine, Kame Terrace
10	Esker, Esker Complex
9	Outwash Plain
8	Meltwater Channel Deposits
7	Till, Young age (Cordilleran)
7 a.	Till, hummocky (Cordilleran)
7 b.	Till, (Cordilleran)
6	Till, schist (Cordilleran)
6 a.	Till, hummocky (Cordilleran)
5	Till, Young age (Continental)
4	Till, Intermediate age (Cordilleran)
4 a.	Till, hummocky (Cordilleran)
4 b.	Till, (Continental)
4 ba.	Till, hummocky (Continental)
3	Till, Old age (Cordilleran)
2	Tertiary Uplands
1	Bedrock



Directional Feature: unknown, known

Geological Boundary: defined, approximate, assumed.

In a general geomorphic sense the bedrock formations of the Foothills and the Mountains may be divided in respect to erosion, into two groups: competent and incompetent. The competent formations include the majority of the Paleozoic rocks being mainly carbonates and quartzites. The incompetent rocks are predominately of Mesozoic age being shales and sandstones.

The Paleozoic formations weather predominately by physical processes. Chemical weathering is only of a minor nature at the present. The weathering products are coarse, with gravel predominating. The landforms encompass steep slopes and cliffs (Plates 4, 18, 19, 20, 35, and 46).

Mesozoic formations, comprised predominately of shales and sandstone, weather mainly by chemical processes. The weathering products are fine-grained and the landforms have a conspicuous absence of cliffs. Mesozoic formations are found predominately in the Foothills whereas the Paleozoic formations form the Rocky Mountains. (Plates 2, 10, 27, 41 and 50).

Tertiary Uplands (Map Unit 2)

Plateaus covered with quartzitic gravels and old weathered tills are found occasionally along the edge of the foothills. These are remnants of Tertiary erosion plains. Initially, it was thought that the Tertiary uplands would be a separate unit (Map Unit 2). Upon field examination it was found more convenient to classify them under separate headings relating to the overlying surficial materials. Thus, Tertiary uplands (Map Unit 2) is not used on any of the surficial geology maps.

Till (Map Units 3 to 7)

Till is unsorted material deposited directly from a glacier. Particle size, lithologic and mineralogic composition of till is a function of the composition of the bedrock over which the glacier flowed and the distance of transport. In alpine glaciers, particle size composition is also a function of the original location of the debris within the glacier. Basal debris is subject to significant comminution whereas ablation debris may be unaffected.

Most of the tills found within the study area, with the exception of Continental tills, were deposited from glaciers which originated in a proximity of the Continental Divide or in the provenance of Paleozoic Formations. Paleozoic rocks are characterized by an overabundance of carbonates and quartzites, thus Cordilleran tills and other associated deposits contain large proportions of the above-mentioned lithologies.

Continental tills are those which contain some rocks derived from the Canadian Shield. They are thought to have been deposited by glaciers from the Keewatin Centre. These tills are found in the outer Foothills, mainly in the southern portion of the area.

During the course of mapping of surficial deposits it was found that tills underlying the surface have different degrees of leaching of carbonates which varied from a few inches to over 14 feet. At many locations the different depths of leaching of the tills were found to be only very short distances apart, but on tills of different age. Because of the lack of stratigraphic control and consequent age determination of different tills, the depth of leaching is taken as one of the main criteria for relative age determination and stratigraphy of surface tills. Topographic position, surface morphology and lithology, has been used as supplemental criteria for the differentiation of till sheets of different ages.

The depth of leaching of carbonates was determined at most sampling locations. Shallow leaching, 6 inches to 1 foot is associated with the young and youngest (Classical Wisconsin) glacial deposits. With the exception of a small area of Continental till of Classical Wisconsin age near Calgary, all of the Continental tills in the southern area are interpreted as belonging to the intermediate to old age tills (pre-Classical Wisconsin age). Deep leaching, over 5 feet, is associated with tills which do not support typical glacial topography. Leaching of 2-1/2 to 5 feet was found to be associated with tills having very subdued glacial topography. Leaching of 18 inches to 2-1/2 feet was found to be associated with tills having slightly subdued glacial topography. Thus, on the basis of leaching alone, Cordilleran glacial tills are divided into five groups:

1. Youngest till with leaching up to 6 inches (Map Unit 7)

2. Young till with leaching of 6 inches to 1-1/2 feet (Map Unit 7)

3. Young till with leaching of 1-1/2 to 3 feet (Map Unit 7b)

4. Intermediate till with leaching of 2 feet to 5 feet (Map Unit 4).

5. Old tills with leaching of over 5 feet (Map Unit 3).

This division does not take into account the chronological sequence of events or local climatic influence. Thus, old tills may include tills of different glaciations. Intermediate tills represent more than one glaciation both in time and space. Surficial deposits in the southern portion of the Kananaskis sheet are derived from the Cordilleran region to the west as well as from the Canadian Shield. It is probable that a number of Old tills with several feet of leaching are included in the intermediate till classification and vice versa. The division is strictly an arbitrary one based on the leached profiles.

Old Till (Map Unit 3)

Old tills are located on level to gently sloping terrain. They do not support typical glacial topography but blend with a general non-glacial geomorphology of the area. Consequently, it was found difficult to delineate areas underlain by the Old tills as they do not have a characteristic "glacial" signature on aerial photographs (Plates 3 and 5). However, the extensive experience gained by the authors in these regions enables us to separate tills of pre-Classical Wisconsin age from younger tills. Unleached portions of the Old tills are similar in composition to younger tills found in the mountains. The unleached portions are high in carbonate and stony and grey in color. The leached portion of the Old tills contains no carbonates and is brown to grey in color.

Old tills are thin, being on the average of about 5 feet in thickness. They tend to overlie bedrock directly but north of Calgary in the Jumping Pound region, glacial gravels are present below. On Tertiary plateaus, Old tills reflect the composition of underlying materials. Several plateaus are found north of Sundre and Canmore as well as in the Porcupine Hills and south along the Canada - U.S. border, Old tills consist predominately of rounded Tertiary quartzitic gravels. In areas underlain by Cretaceous siltstones, shales and sandstones, Old tills consist predominately of these fine-grained clastic materials.

At several locations, crystalline rocks derived from the Canadian Shield were found in the Old tills. This signifies that during the time of the Old till glaciations, Continental glaciers advanced to and along the edge of the foothills. A definite age or coverage of the glaciers responsible for deposition of the Old tills cannot be assigned at the present time but it is certain that they are of pre-Classical Wisconsin age and possible of Illinoisan age or older.

The topographic position of the Old tills indicates that the glaciers from which these tills were deposited was the most widespread glaciation in the Foothills and Rocky Mountains. The Old tills are found at elevations higher than 5,000 feet and as previously stated, are found only on relatively level uplands. The uplands where the Old tills occur form portions of old erosion levels of the Cordillera (Plate 3). Intervening areas among the areas where the Old till are located are underlain by thin colluvium directly on bedrock.

Only occasional erratics may be found there indicating that all glacial deposits from these areas have been removed by erosion. In the Inner Foothills and the Rocky Mountains are found occasional erratics resting on Mesozoic formations but derived from Paleozoic rocks to the west. These erratics are found on cols or other relatively level high alpine areas. The occurrence of these erratics has been recorded to elevations of 8,500 feet.

The leached portions of the Old tills are sandy in character relative to the unleached portion. Mechanical composition of the matrix of the leached Old tills is given in Appendix 1. At a few locations where the Old tills are relatively thick, the unleached portion of the Old tills was sampled and examined. In all of the cases where the Old tills were examined in the unleached state the carbonate content was quite high. From 20 to 50 percent of the pebbles were carbonate rocks and thus the old unleached tills resemble Young tills.

Intermediate Tills (Map Units 4,4a,4b and 4ba)

All tills intermediate in age between the Old tills and the Young tills are grouped into one unit called Intermediate tills. The basis for differentiation of these tills was firstly the depth of leaching which averages from 2 to 5 feet, and secondly, the presence of subdued glacial topography. In contrast, the Old tills do not have any vestiges of glacial topography. (Plates 7 and 8).

The depth of leaching of 2 to 5 feet is of course overlapping with the depth of leaching of some of the Young tills and the Old tills. The topography served as the ultimate differentiation of these till sheets; in the Young tills glacial topography is fresh, and in the Intermediate tills glacial topography is subdued. In the Old tills glacial topography is absent.

Intermediate tills comprise leached pre-Classical Wisconsin tills derived from both the Cordilleran and Continental ice sheets. The tills south of Chain Lakes and into the Pincher Creek-Cardston area, are derived in part from the Canadian Shield to the northeast as they contain a significant percentage of Precambrian crystalline rocks. They blend westward into Cordilleran tills with similar topography but different compositions.

On the maps of surficial geology Intermediate tills are subdivided as follows: Cordilleran Intermediate till ground moraine - Map unit 4, Cordilleran Intermediate till hummocky moraine - Map unit 4a, Continental Intermediate till ground moraine - Map Unit 4b, and Continental Intermediate till hummocky moraine - Map Unit 4ba.

The leached portion of the Intermediate tills, both Cordilleran and Continental, is similar in texture to the leached portion of the Old tills. Analyses results are given on Appendix 1. The unleached portion of the Intermediate tills have a similar composition to the Young tills.

The topographic position of the Intermediate tills is more difficult to define than the topographic position of the Old tills. The Intermediate tills occur on level to gently sloping ground in broad valleys of the Foothills. Only rarily have they been identified in the Rocky Mountains

(Plate 5, 7, and 8). The Intermediate tills are usually positioned topographically lower than the Old tills wherever they occur in proximity to each other.

The Continental Intermediate tills are present primarily in the southern portion of the area (Plate 24). The Continental Ice Sheet from which these tills were deposited never attained an absolute elevation of over 5,000 feet. This ice sheet penetrated some of the major valleys in the southern Foothills depositing an end moraine at many locations at the point of its furthest advance. No time connotation is given to this advance but it is postulated to have been of pre-Classical Wisconsin age. It is not known on the basis of our studies if the Intermediate tills of Cordilleran and Continental origin were deposited contemporaneously or not. Areas underlain by the Intermediate Cordilleran tills present a discontinuous picture. With minor exceptions Intermediate tills or other associated deposits have been removed from areas of steep slopes.

The Continental origin Intermediate Tills form a nearly continuous till sheet.

Young Tills (Map Unit 5, 6, 7, 7a, and 7b)

All tills with fresh glacial topography and leaching depth from 6 inches to 2 feet are classified as Young tills, the exception being schist till (Map Unit 6), and a Young till with leaching depth from 1.5 to 3 feet, (Map Unit 7b), which will be discussed separately.

The Cordilleran Young Tills (Map Unit 7 and 7a) are tills deposited by Classical Wisconsin glaciers. They have fresh glacial topography. The tills are found mainly in major valleys in the Rocky Mountains and their continuation through the Foothills (Plates 10, 11, 12, 16 and 43). Such major valleys are Smoky, Athabasca, Brazeau, North Saskatchewan, Red Deer, Minnewanka, Bow, Oldman, Crowsnest, and Waterton rivers. Other smaller valleys originating in the Rocky Mountains and continuing through the Foothills had only small glaciers which did not cross the Foothills belt. Small valley glaciers which did not flow beyond the Rocky Mountains are numerous throughout the Mountain belt. Only occasional small valley glaciers are found within the Inner Foothills.

The Classical Wisconsin glaciation in the Rocky Mountains during the maximum extent of glaciers has the pattern of valley glaciation of the dendritic form. In contrast to this, the Intermediate till was deposited from glaciers approaching the reticulated form, and the Old tills were deposited most likely from a mountian ice sheet through which numerous nunataks were protruding.

The Map Unit 7 encompasses ground moraine, and lateral moraine of Wisconsin age. Map Unit 7a encompasses hummocky moraine including end moraine of the same age. No subdivisions of separate Cordilleran Young Till advances are shown on the maps. Classical Wisconsin age tills deposited by the Continental Glacier (Map Unit 5) have been recognized only in one location, a few miles north of Calgary.

Depth of leaching of Young tills, Map Unit 5, 7, and 7a, is generally from 6 inches to 1.5 feet. The depth of leaching of the Young Continental till may be somewhat deeper. In areas of the alpine zone Young tills of Wisconsin age may have leaching depths less than 6 inches on tills of very high carbonate content.

Young tills of Wisconsin age originating from cirques entirely within the Foothills or the provenance of Mesozoic formations may have leaching depth of over 1.5 feet because of the very low carbonate content of the parent material.

All Young Cordilleran Tills with the exception of schist till (Map Unit 6) and tills from glaciers originating entirely within the Foothills are stony to very stony. The carbonate content as determined by pebble counts is over 10 percent and may be as high as over 60 percent. This also applies to the unweathered portions of the Intermediate and Old tills. Young tills originating within the Foothills belt are generally less stony and have a carbonate content less than 10 percent, similarly to the Continental Wisconsin till (Plates 13 and 14).

Texture analysis of the till sample matrix is given in Appendix 1.

Schist till (Map Unit 6) occurs only in one location which is in the headwater region and vicinity of Sheep Creek in the Willmore Wilderness Park. At that location, on the Continental Divide, the bedrock is made of mica schists and related rocks. The till produced from these rocks lacks carbonate, is generally fine-grained and contains an over-abundance of mica. This till is of Wisconsin age and belongs to the young till category. It has been delineated separately because of the drastically different lithology, being composed of over 50 percent of schist with no carbonate.

A young Cordilleran till (Map Unit 7b) with a depth of leaching from 1.5 to 3 feet forms another separate unit in the area. It is found along the headwaters of the Bragg Creek area. This till is very similar to the Cordilleran Young till except that it has somewhat deeper leaching profile. Tentatively it is assigned to Early Classical Wisconsin glaciation.

Glaciofluvial Deposits (Map Units 8 to 14)

Glaciofluvial deposits of the study area are composed predominately of gravel, and gravel and sand. No glaciofluvial deposits composed predominately of sand are present in the area. On the basis of genesis, glaciofluvial deposits are divided into seven groups which comprise the following: meltwater channel deposits (Map Unit 8), outwash plain (Map Unit 9), esker, esker complex (Map Unit 10), kame, kame moraine, kame terrace (Map Unit 11), pitted outwash plain (Map Unit 12), valley train (Map Unit 13), and lag gravel (Map Unit 14).

Meltwater channel (Map Unit 8), deposits are composed predominately of gravel with minor sand. The meltwater channels present in the Foothills and Rocky Mountains are usually short and discontinuous channels cut in bedrock. Most of the channels have valley walls underlain by bedrock directly or having only a thin veneer of glaciofluvial deposits. Terraces are absent as a rule. The floors of the channel usually are underlain by a coarse gravel from 5 to 10 feet in thickness. Many of the channels support lakes or muskegs. Economically the gravels in the meltwater channels are unimportant firstly because of the relatively thin gravel deposit and secondly because of the presence of lakes and muskegs.

Outwash plains (Map Unit 9) are relatively level plains not bounded by topography and covered with glacio-fluvial deposits (Plate 17 and 22). In mountaneous terrain, it was found difficult to define an outwash plain because of the control of topography in all cases. Thus, outwash plains in the area have been defined on the basis of broad expanses of outwash in valleys which were thought to be too wide to have come under the definition of a valley train.

Without exception all the outwash plains in the Foothills and Rocky Mountains are located in broad valleys, as for example, along Athabasca, Brazeau, Red Deer, North Saskatchewan, Bow, Livingstone,Crowsnest and Waterton river valleys.

The outwash plains are composed of rounded pebbles and cobbles derived predominately from the Paleozoic formations outcropping in the Rocky Mountains (Plate 22). The carbonate content of the outwash gravels vary from 20 to over 60 percent, the remainder being mainly quartzites. Most of the outwash plains are overlain by variable thicknesses, 2 to 10 feet, of sand and silts forming the last depositional phase of the outwash plains. Along the major rivers such as Athabasca, Red Deer, Bow, Livingstone,Crowsnest and Waterton the sand overlay may be related to processes similar to flood plain silt deposition. It is certain that the outwash plain gravels are of glacial age but the sands and silts overlying the gravels may be in part probably of an immediate post-glacial age.

Outwash plain gravels are variable in thickness from 10 to over many hundreds of feet. Valley glaciers descending down the major valleys from the mountains into the Foothills produced erosion of the bedrock in the valley bottoms exceeding hundreds of feet.

The topography of the outwash plains is generally level. At some locations specifically along the Athabasca River and the Red Deer River are present numerous terraces.

The outwash plain north of the Crowsnest River and west of the Livingstone River has kettle holes indicating that the deposit of the outwash was laid down at a time when remnants glacial blocks were still present. Along the Brazeau and the Cardinal rivers the outwash plains in places contain also such numerous kettle holes.

Eskers (Map Unit 10) are sinuous ridges composed of glaciofluvial material. According to accepted theories eskers are produced by deposition from subglacial rivers flowing in tunnels. Esker complexes are numerous eskers approaching anastomotic patterns. Eskers are rare throughout the area. They are present mainly along major valleys.

The eskers are composed of rounded pebbles and cobbles with minor sand. In width the eskers are variable from about 300 to 500 feet. Generally, they are about 50 feet high but in places exceed 100 feet. The eskers may be important locally as they constitute a good supply of construction aggregate.

A kame (Map Unit 11) is an ice contact fluvial deposit having a positive relief. Any knoll or hummock composed of glaciofluvial material is classified as a kame. Two or more kames in proximity are classified here as a kame moraine. A kame terrace is essentially a lateral moraine composed of glaciofluvial material and supporting numerous kettle holes. Generally, under this heading are classified glaciofluvial deposits which have rough local relief (Map Unit 11).

Kames are relatively common throughout the area. They are present mainly along major valleys. Only occassional kames are present outside the major valleys (Plate 21 and 23).

The kames, kame moraines and kame terraces are composed predominately of well-rounded glaciofluvial gravels. Nevertheless, in places they contain significant proportions of other materials such as silts, till or rubble. Generally, sorting of the materials in the kames is poor as the kames have received materials not only from flowing water but also superglacial debris by slumping and mud flows from the surface of the glacier. For this reason, the kames, although constituting a major supply of construction aggregate, may not be economically desireable because of the heterogeneous composition.

Pitted outwash plains (Map Unit 12) are outwash plains with numerous kettle holes. Outwash plains are relatively rare throughout the area. The major outwash plain is present in the vicinity of Jarvis Lake and in the proximity of Brule Lake. Other pitted outwash plains are associated with valley trains or outwash trains along the major valleys throughout the area.

Pitted outwash plains are composed of well sorted and rounded glaciofluvial gravel. Generally, the thickness of the gravel is over 50 feet. Pitted outwash plain gravel is made of well rounded pebbles to cobbles. Lithologically, pitted outwash plain gravel is similar to outwash plain gravel, it contains a large proportion of carbonate rocks.

Valley train (Map Unit 13) is glacial outwash situated in a mountain valley and is confined in the valley by the valley walls. Most of the valley floors of major valleys in the mountains and the Foothills are floored with outwash which is the valley train (Plate 18 and 20). The outwash was deposited during separate halts of the valley glaciers. As the glaciers retreated upstream, previously deposited valley trains have been dissected by later valley trains. Thus, most of the valley trains as mapped in the mountains and the Foothills are terraced. No attempt has been made to correlate the individual terraces or document the individual retreatal stages of the glaciers.

The valley train materials are composed predominately of well rounded pebbles to cobbles with a large proportion of carbonate rocks. The thickness of valley train materials is variable exceeding in places 50 feet. The division between valley train and outwash plain is arbitrary, and the discussion on outwash plain gravel applies also to valley train gravels.

Economic importance of outwash plains and valley trains lies in the fact that these deposits are an excellent source of construction aggregate, have great groundwater potential, and are excellent for construction of roads, buildings and other structures.

Lag gravel (Map Unit 14) is generally rare throughout the area. It is represented by thin gravel deposits, 2 to 5 feet in thickness overlying bedrock directly on some of the terraces along rivers in the mountains and the Foothills. It is believed that this gravel was the result of washing of till rather than original deposition of outwash from meltwater streams. Lag gravel is economically unimportant because it is relatively rare and thin.

Glaciolacustrine Deposits (Map Unit 15 and 15a)

Glaciolacustrine deposits are deposits of glacial materials in lakes or other standing bodies of water. The majority of glaciolacustrine deposits are found in the Foothills, specifically the Outer Foothills. These glaciolacustrine deposits are the result of damming of streams issuing from the Foothills and mountains by the Continental glacier.

Glaciolacustrine deposits not related to Continental glacier are relatively rare. These are represented mainly by small bodies of lacustrine silts deposited in tributary valleys. At these locations small lakes were produced by the damming effect of major valley glaciers on small tributary streams.

Glaciolacustrine deposits are divided into two groups: those with relatively level surface (Map Unit 15), and those with hummocky surface (Map Unit 15a). The level surface glaciolacustrine deposits form the majority of glaciolacustrine plains throughout the area (Plates 24, 25 and 26). Hummocky glaciolacustrine deposits (similar to pitted deltas) are the result of glaciolacustrine deposition in contact with glacial ice or against a glacier. A major hummocky glaciolacustrine plain is present in the vicinity of Millarville. It is made of silt with a significant proportion of sand and small gravel lenses. The surface is pitted with numerous kettle holes but in places the topography assumes a hummocky expression not too dissimilar from a normal hummocky moraine. Generally, the thickness of the lacustrine sediments in the hummocky glaciolacustrine plain is over 50 feet.

Glaciolacustrine plains with level topography form the majority of glaciolacustrine deposits of the area. The deposits are varved but near the surface, 1 to 5 feet, these varves may be absent. It is believed that soil forming processes have destroyed the varves near the surface.

Silt forms the predominant material in the glaciolacustrine plains, being over 43 percent. Sand is relatively minor forming on the average only 20 percent of the deposit. All of the lacustrine deposits contain carbonates.

The thickness of glaciolacustrine deposits is generally from 10 to 20 feet (Plate 25). Hummocky glaciolacustrine deposits have a local relief in excess of 30 feet and a thickness of the sediments in excess of 60 feet. Glaciolacustrine deposits in tributary valleys to the major valleys in the Rocky Mountains and the Inner Foothills are generally about 10 feet in thickness.

Eolian Deposits (Map Unit 16)

Eolian deposits are relatively rare in the Foothills and the Mountains. The major location of the eolian deposits is adjacent on the south side of Lake Brule. As shown on the accompanying map of surficial deposits, the area underlain by the eolian sediments is limited only to sand. This sand was derived by waves and the consequent wind action of the beach sands of Lake Brule. To the south and east of the sand area is an area of equivalent size of thin loess. The loess overlies till directly. Generally, the loess is thin being from 6 inches to 2 feet, and has been derived from the eolian sand area.

A very small area of thin loess and some eolian sand is spread south of the Castle River and north of Waterton Park. Small sand dunes and associated eolian sediments are also present along the Bow River near Seebee.

Organic Deposits (Map Unit 17)

Organic deposits, fenland and peat bogland are generally small in area and distributed more-or-less uniformly throughout the region. Practically all of the organic deposits are present at or near the bottoms of valleys. Many of the organic deposits are believed to be deep, exceeding 15 feet in thickness. The peat boglands are believed to contain permafrost at higher elevations. Fenlands do not contain permafrost.

Cirque Till (Map Unit 18)

Many of the cirques, specifically in the Rocky Mountains, have till present throughout the basin or at the threshold. This till is assumed to have been deposited during relatively recent times, when the cirques were occupied by small glaciers. Many of the cirques still contain glaciers.

Also under this classification are grouped tills in front of existing larger glaciers. The time of deposition of these tills has not been deciphered in detail but is thought to represent glacial advances since the Altithermal period. At least 3 different sets of moraines comprise this unit. The cirque tills are extremely stony in character approaching rubble. The thickness is variable generally being thin near the centre of the cirque but at the periphery the till may be from 50 to 100 feet. Most of the cirques are positioned in Paleozoic formations, and lithologic composition of the till is a reflection of the bulk composition of the formations. Thus, in limestone terrain, cirque till is made predominately of limestone (Plates 38 and 39).

Rock Glaciers (Map Unit 19)

Rock glaciers are accumulations of angular talus which are subject to slow glacier-like movement. All of the rock glaciers shown on the accompanying maps are active, that is they are subject to slow motion, have no vegetation cover, and receive additional material at the upper portions.

Although there are numerous rock glaciers present throughout the area, they are relatively unimportant because they comprise only a small proportion of the total area. All of the rock glaciers are located in the Rocky Mountains proper at relatively high elevations. The accumulation areas of all of the rock glaciers is positioned below talus slopes in the alpine zone or vegetation-free zone. Some of the rock glaciers advance into the forest zone at lower elevations (Plates 29, 30 and 31).

Inactive rock glaciers have been classified with talus because of similar composition and the difficulty to separate them from proper talus by landforms.

Glaciers (Map Unit 20)

Numerous glaciers are present in the area. They are concentrated primarily in two areas; the headwaters of the Brazeau and North Saskatchewan Rivers and in the Willmore Wilderness Park near the Resthaven ice field. All of the glaciers are small and may be described as cirque glaciers. Large glaciers of the Rocky Mountains are located within National Park Boundaries and consequently excluded from this study (Plates 39 and 40).

Without exception, all of the glaciers in the study area are in a state of recession. In front of the glaciers invariably are present small ice cored moraines. Most of the glaciers also have small moraines in front of the ice cored moraines.

Careful analyses of glaciers on the maps of surficial geology accompanying this report and National Topographic Series maps to scales of 1:50,000 and 1:250,000 shows some discrepancies. Some glaciers as shown on NTS maps are not present as revealed by our field checking, also additional glaciers are shown on surficial geology maps which are not shown on the NTS maps. The NTS maps were compiled directly by interpretation by aerial photographs. The surficial geology maps are based on actual field investigation.

Stream Alluvium (Map Unit 21 and 22)

Alluvial deposits are non-glacial stream deposits of sand and gravel or finer materials. In contrast, glaciofluvial deposits are similar sediments deposited from glacial meltwater. The division between the two types of deposits is arbitrary, e.g. alluvial deposits along the North Saskatchewan River grade into glacial outwash deposits and valley trains at the Saskatchewan Glacier. Stream deposits showing ice contact features or having a very heterogeneous nature were classified as a glacial origin.

Alluvial deposits are classified into two groups depending on grain size. Coarse alluvial deposits (Map Unit 21) are composed primarily of gravel (Plates 19, 27 and 28). Fine alluvial deposits (Map Unit 22) comprise sand, silt and clay with minor gravel.

Alluvial deposits of coarse texture are present along most of the streams in the Rocky Mountains and along major streams in the Foothills. The thickness of the gravel alluvial deposits is variable, generally being over 10 feet. The gravels are well-rounded and may be overlain by 1 to 5 feet of fine alluvium. Coarse alluvium may attain considerable thicknesses along major rivers in the Foothills such as the Athabasca River, the North Saskatchewan River, the Red Deer River, the Bow River and the Oldman River.

A large portion of the coarse alluvium is present adjacent to the streams and forms terraces. Some of the terraces may be positioned in excess of 100 feet above the streams.

Major lithologic components of the alluvial gravels are derived from the Paleozoic formations in the Rocky Mountains and are quartzites and limestones. In the Foothills, additional lithologies derived from Mesozoic formations are present. Generally, the alluvial gravels form the most important source of construction aggregate throughout the area.

Alluvial deposits composed of sand or finer materials are found along small streams in the Foothills. These deposits are generally silty and clayey and underlie the lowlands along the minor streams. Small organic deposits are associated with this alluvium. In thickness the fine alluvium ranges from 5 to 20 feet.

Alluvial Fan (Map Unit 23)

Alluvial fans are accumulations of sediments at the location of emergence of steep gradient streams from mountaneous terrain. The sediments are deposited in the fan shape with the apex at the point of emergence of the stream from the mountain. Alluvial cone is a similar feature to an alluvial fan except that it is relatively small and steep. Alluvial fans and alluvial cones are classified on the surficial geology maps under the heading Alluvial Fan (Map Unit 23).

Most alluvial fans are located along the sides of major valleys in the Rocky Mountains and the Inner Foothills. The Outer Foothills have only rare alluvial fans mainly because steep slopes are not common in that area (Plates 19, 27, and 28).

The majority of alluvial fans in the Rocky Mountains are relatively steep. In the Foothills the alluvial fans have generally relatively gentle slopes. In the Rocky Mountains alluvial fans quite often produce continuous alluvial aprons through the coalescent of individual fans and cones.

Alluvial fans and cones in the Rocky Mountains are composed of angular to subrounded gravel and rubble having a relatively high permeability. The steep-sided alluvial fans may contain in addition to gravel a significant proportion of sand or finer materials and also large blocks of angular rubble. The fine and very coarse materials is deposited by mud flows. Mud flow type of deposition in alluvial fans is relatively rare in the Foothills.

The thickness of alluvium in the fans often exceeds 100 feet. It should be pointed out that alluvial fans are of postglacial origin and thus they may overlie previous glacial deposits such as outwash material in the valley bottoms.

Colluvium (Map Unit 24)

Soil and rock creep material on steep slopes is classified in this report as colluvium. It is present on slopes beginning at about 15 percent. On very steep slopes colluvium is absent and rock outcrops occur. On the accompanying maps of surficial deposits, colluvium is shown only for areas where it is at least 3 feet in thickness. Furthermore, as shown on the maps, colluvium overlies bedrock directly. Where colluvium is derived from other surficial deposits, such as till, it is classified with the underlying materials.

The bedrock underlying colluvium ranges from Paleozoic to Cretaceous deposits. The stratigraphy and lithology of the bedrock formations is not the subject of this report.

Compilation of bedrock geology for the Foothills and the Mountains is present as an open file at Alberta Research, Edmonton, Alberta.

The bedrock underlying colluvium is weathered and the weathering depth ranges from a few feet for Paleozoic formations to over 30 feet for Mesozoic fine-grained clastics. Mesozoic formations form the greater portion of the bedrock of the Foothills. Thus, wherever colluvium is shown on the map, the underlying bedrock formations are expected to be weathered to a considerable depth.

The texture and lithology of weathered bedrock depends primarily on original composition of the formations. Siltstone weathers into the fine-grained unconsolidated silt, shale weathers into clay with fragments of the original shale and sandstone weathers mainly into angular sandstone fragments with some sand. Some sandstone formations decompose completely into sand. Conglomerates upon weathering may produce gravel deposits. Paleozoic formations weather predominately by physical weathering producing gravel size rubble.

The thickness of colluvium is variable. It is generally thin at high elevations. It averages about 5 feet in thickness on slopes between 15 and 45 percent, but may exceed 10 feet near the base of long slopes.

Colluvium is derived from the weathered portions of the underlying deposits by slow downhill creep of the near-surface portions. Colluvium derived from sandstone is composed of sandstone fragments in a matrix of sand and some finer materials. Colluvium derived from shale and siltstone is generally fine-grained. As the underlying formations are never uniform in lithologic composition, the colluvial deposits represent a mixture of all the lithologies. Thus, colluvium may be described as having coarse and fine fragments and approaching till in composition. Colluvium differs from till in that it is derived only from the formation present up slope and also by having poorly or well-defined layering parallel to the surface (Plates 6, 42, 44, 45, 47, 48 and 49).

The colluvium map unit as described above occupies the largest area of all the surficial deposits in the Foothills and Mountains.

Patterned Terrain (Map Unit 25)

In alpine regions above tree line and on flattened mountain tops is present a terrain of periglacially sorted ground in the shape of polygons, stripes, and other associated features. The patterned terrain is relatively common throughout the Inner Foothills and Mountains but usually it underlies such small areas that these could not be shown even on map scales of 1:50,000 (Plate 1, 33 and 34). Large areas of patterned terrain are relatively rare because large relatively flat areas at elevations above the tree line are relatively rare.

Most of the patterned terrain is subject to cryoturbation by seasonal frost or permafrost. Patterned terrain on the Plateau Mountain is thought to be inactive at the present time (Plate 33 and 34). It is thought to have formed by periglacial cryoturbation during Classical Wisconsin glacial time.

Rock Defended Terrace (Map Unit 26)

A rock defended terrace is defined here as a river terrace made almost entirely of bedrock except for a thin alluvial veneer of lag gravel. Only one rock defended terrace has been mapped in the study area. It is located near the Town of Entrance on the Athabasca River.

Talus (Map Unit 27)

Talus is an accumulation of coarse rock debris derived predominately by frost shattering from cliff-forming bedrock. Large accumulations of talus cover the lower portions of steep cliffs predominately in the Rocky Mountains proper. The Foothills generally do not have well developed talus slopes because bedrock formations are less subject to erosion and because of lower elevations.

Large accumulations of talus are in the form of cones. The individual cones may coalesce to form talus aprons at the lower portions of long cliffs (Plates 18, 35 and 37).

Talus is relatively thin in the upper portions but at the base of the slopes talus accumulations may exceed 50 feet. At some locations the lower portions of talus slope may have ridges or other similar large accumulations of the debris. At such locations the thickness of talus may exceed 100 feet.

Inactive talus slopes presently covered by forests have been classified as colluvium. The reason for this classification is that such talus slopes are extremely difficult to recognize. Thus all talus slopes as shown on the maps pertain to active or unvegetated talus accumulations.

Composition of the talus is a reflection of the composition of the bedrock formations from which it is derived. Most of the talus in the study area has been derived from carbonate Paleozoic rocks. Talus derived from quartzites, sandstone, conglomerates, and other consolidated formations is relatively rare and is present mainly along the divide where early Paleozoic and Proterozoic quartzites occur. Talus composed of schistose rocks is present near the headwaters of Sheep Creek, Muddy Water River and Jackpine River in the Willmore Wilderness Park.

Rock Slide (Map Unit 28)

Rock slides are accumulations of extremely coarse rubble derived by rapid movement of detached portions of bedrock on steep mountains. Rock slides originate from bedrock which is competent and cliff-forming, thus most of the rock slides occur in the Rocky Mountains and only occasional ones are present in the Foothills. The distribution of the individual rock slides diminishes with decrease of local relief from the Continental Divide to the east (Plates 20, 32, 35, 36 and 37).

One of the best known rockslides in the Rocky Mountains is the Frank Slide which occurred in 1903 (Plate 36). The Frank Slide is described as a large slide and at least 12 other slides of the same size or larger have been mapped by the authors in the study area. It should be pointed out that the study area does not encompass the Banff and Jasper National parks and Waterton National Park. In these areas many slides of comparable and larger size than the Frank Slide are present.

It is difficult to estimate the time of occurrence of individual slides in the study area. It is believed that most of the slides occurred a short time after the withdrawal of glaciers from the area. This is based on the fact that many of the slides are covered with old forests and support well developed soil profiles.

Slump and Landslide (Map Unit 29)

Slump and landslide are mass-movement of materials involving a rotational displacement of consolidated to unconsolidated materials. Slump and landslide topography is characteristic of step-like topography in the upper reaches and mud flow type of topography near the base. Thus, slump and landslide deposits are mainly concentrated in the Outer Foothills.

Two types of slump and landslide deposits are present in the area. The first, is slumping of steep river banks in unconsolidated deposits involving glacial or Recent deposits. The second type is present in the Outer Foothills and involves the sliding of mountain sides. The two types of slump and landslide deposits are classified as one on the accompanying maps of surficial deposits. Numerous small slumps and slides in unconsolidated materials are present throughout areas underlain by glaciolacustrine deposits. Generally, these areas are too small to be shown on the maps (Plate 9, 15, and 26).

GLACIAL AND RECENT HISTORY

Tills of the Study Area

The main objective of the present survey was the identification and mapping of surficial deposits. Stratigraphic descriptions of exposures showing the succesions of glaciations and history of post-glacial deposits were omitted. Nevertheless, the location of all of the sections encountered during field work are given in the transcribed field notes held on open file at Alberta Research.

During the coarse of mapping of surficial deposits, tills underlying the surface immediately were differentiated on the basis of lithology, degree of weathering, surface topographic expression and topographic position. On the basis of these criteria tills deposited by glaciers of different provenance and at different times can be differentiated in a general manner. This forms the basis of Glacial and Recent stratigraphy and history as set out in this report.

Till is unsorted material deposited directly from a glacier. Lithologic composition of the till is a function of the composition of the bedrock over which the glacier flowed. Thus, lithologic composition of till is a reflection on the area of origin of the glaciers from which the particular till was deposited. Continental glaciers which covered the plains of Alberta originated in the Keewatin District of the Canadian Shield and consequently Continental glacial deposits contain rocks derived from the Canadian Shield. The presence or absence of Canadian Shield rocks served as the main criteria for the differentiation between till deposited by Cordilleran or Laurentide glaciers.

Schist till (Map Unit 6) is a till deposited by Wisconsin glaciers in the headwater regions of Sheep Creek in the Willmore Wilderness Park. This till is characterized by an overabundance of schist material and lack of carbonate rocks. It was differentiated by other younger tills primarily on the basis of this lithologic composition.

The depth of leaching of carbonates is a weathering phenomenon. Different depths of leaching are functions of past climates, original carbonate content, and time. It was assumed during the course of the study,,with minor exceptions, that the depth of leaching was primarily a reflection of time rather than original composition or climate. The depth of leaching of till encountered during the survey ranged from virtually zero to over fourteen feet.

On the basis of the depth of leaching the tills were subdivided into three broad groups:

(1) Young till, leaching from 0-3 feet.

(2) Intermediate till, leaching from 2-5 feet.

(3) Old tills, leaching over 5 feet.

The young tills are subdivided in three additional groups on the basis of leaching, 0 - 6 inches - Map Unit 18; 6 inches to 18 inches - Map Unit 7; 18 inches to 3 feet - Map Unit 7b and 5.

Surface topographic expression or freshness of topography of glacial deposits is a function of time or the duration of erosion processes which tend to eliminate surface irregularities. Relatively young glacial deposits are characterized by fresh topography in contrast to old glacial deposits which have no expression of the original glacial topography. The topographic expression was thus used in a broad sense of differentiation of till sheets as young, intermediate and old.

Topographic position of individual till deposits has been used to differentiate some of the tills. Young tills occur predominately at low elevations or associated with cirques. Old tills are invariably present on high plateaus on the eastern edge of the Foothills.

On the basis of the above criteria, tills of the study area have been divided into three broad groups connoting age: Young tills, Intermediate tills and Old tills. Each individual subgroup has been further divided into sub-units. Table 2 shows the criteria used for the differentiation of tills in the area.

Previous Research

West of Dawson Creek, British Columbia, in the northern Rocky Mountain Foothills, Reimchen and Rutter (1972) recorded evidence for three major advances of Cordilleran glaciers and one advance of Continental ice. A possible earlier advance of Continental ice was suggested by the presence of deeply weathered erratics of Shield origin at higher elevations. The glacial sediments of the earliest Cordilleran advance were extremely weathered and did not exhibit a "fresh" appearance of glaciated landscapes. Glacial sediments attributed to the youngest

TABLE 2

DIFFERENTIATION CRITERIA FOR TILL

MAP UNIT	AGE	PROVENANCE LITHOLOGY	LEACHING	SURFACE TOPOGRAPHY	TOPO. POSITION
18	very Young	Cordilleran	0-6 inches	fresh	in cirques
7	Young	Cordilleran	6-18 inches	fresh	valleys
7a	Young	Cordilleran	6-18 inches	fresh hummocky	valleys
7b	Young	Cordilleran	18-36 inches	fresh	valleys
6	Young	Cordilleran	No carbonate present	fresh	valleys
5	Young	Laurentide	18-36 inches	fresh	Outer Foothills
4	Inter-mediate	Cordilleran	2-5 feet	subdued	plateaus and high valleys
4a	Inter-mediate	Cordilleran	2-5 feet	subdues hummocky	plateaus and high valleys
4b	Inter-mediate	Laurentide	2-5 feet	subdued	Outer Foothills
4ba	Inter-mediate	Laurentide	2-5 feet	subdued hummocky	Outer Foothills
3	Old	Cordilleran	5 feet	non-glacial	high plateaus

Cordilleran glaciation were present in major valleys extending out beyond the edge of the Foothills. Glacial sediments of Cordilleran origin with intermediate weathering profiles, and glacial aspects, were present at higher elevations between the major river valleys. The earliest Continental glaciation was noted only by the occasional weathered erratics of Canadian Shield provenance. These erratics rest on glacial sediments belonging to the intermediate weathered glacial sediments. The youngest Continental glaciation has glacial sediments interfingering with glacial sediments of the youngest Cordilleran glaciation in the Rocky Mountain Foothills.

Roed (1975) completed a study of the glacial geology of the Hinton - Edson area, Alberta. He described five Cordilleran and two Continental advances. For the upper North Saskatchewan River Valley, Reimchen (1969, unpublished) described three glacial tills separated by outwash for the area above the Big Horn Dam. McPherson (1970) describes two glacial tills from this area separated by interglacial sediments. Eastward, from this area, Boydell (1970, 1972) and Boydell, Bayrock and Reimchen (1974) described the surficial deposits of the Rocky Mountain House area, Alberta. They recorded evidence of three Cordilleran glacial advances and one Continental advance.

Rutter (1972) working in the Banff area of the Rocky Mountains recorded four major ice advances.

Stalker (1963), Alley (1973) present stratigraphic evidence for three Cordilleran and possible four glaciations and three Continental glaciations in the Crowsnest area of southwestern Alberta. The oldest Cordilleran till is underlain by quartzitic gravels of preglacial status, termed Saskatchewan Gravels.

Present Study

The Wisconsin Cordilleran glaciers starting at elevations in the Rocky Mountains of around 8,500 feet flowed eastward and coalesced to form major piedmont glaciers near the outer edge of the Foothills. The earliest pre-Wisconsin glaciations whose sediments have extreme weathered profiles are the most extensive and occupy much of the terrain between the major river valleys. The glaciers, part of a Rocky Mountain ice sheet, covered all of the Foothills and Rocky Mountains. More recent glaciations (Wisconsin) have deposited sediments which exist mainly in the major river valleys. The earliest Wisconsin glaciers formed part of a reticulate ice sheet which covered the majority of the Rocky Mountains with only small nunataks exposed. The latest Wisconsin glaciers were large valley glaciers with expanded-foot or piedmont type glaciers. They occupied major mountain valleys such as the Athabasca, Bow River or North Saskatchewan river valleys. During the latest glacial maximum, over 90 percent of the area between major mountain valleys in the Rocky Mountains and Foothills was ice free, as can be attested to by the lack of glacial deposits.

Several minor resurgences of these valley glaciers are evident as end moraines can be found at successively higher elevations in most of the major mountain valleys. In general, up to four minor readvances of these small alpine glaciers can be shown with the latest glacial advance being confined to the cirque basin.

The Pleistocene stratigraphy of the Rocky Mountains and Foothills can be divided into five geographic areas for purposes of discussion.

1. Smoky River to Rock Lake

2. Athabasca River to Robb

3. Brazeau River to North Saskatchewan River to Red Deer River

4. Bow Valley to Longview

5. Crowsnest Area

Evidence for four major glacial advances of Cordilleran origin and two minor ones have been documented for this region. Extremely weathered glacial erratics of Shield provenance have been found in some areas near the Berland River, near Robb, and in the Crowsnest area - evidence for a period of major continental glaciation.

Smoky River to Rock Lake

Glacial deposits of this area can be classified into four major Cordilleran glaciations (Map Units 3, 4, 6 and 7) and one Continental advance ("erratics"). Two minor cirque advances (Map Unit 18) are recorded (Figure 2).

Glacial sediments belonging to ancient glacial advances (Map Units 3 and 4) are present on uplands generally above 5,000 feet of the Nose Creek, Kakwa River, Sheep Creek, and Muddy Water River valleys. In addition, the Smoky River Valley below the junction of the Wolverine Creek is filled with glacial sediments from these ancient advances. Old tills are present around the Town of Grande Cache and south-eastward along the edge of the Foothills at elevations up to approximately 5,000 feet as far south as the Wild Hay River. Westward glacial sediments that can be attributed to these glacial advances become obscure as they have been obliterated by glacial advances of younger ages. The wide-spread extent of glacial sediments belonging to these ancient advances suggest that the glaciers which deposited them were derived from a more massive Rocky Mountain ice sheet and/or reticulate ice sheet to the west. Separation of these two glacial advances in this area is not complete due to insufficient data. Many of the glacial materials are shown as belonging to the oldest glacial advance (Map Unit 3) and only a remnant of Map Unit 4 is delineated in the headwaters of Sheep Creek. As a result, the farthest extent of Map Units 3 and 4 or their delineation can not be ascertained with accuracy at present. Separation of the young glacial advance (Map Unit 7) from that of the old glacial sediments (Map Unit 3 and 4) is relatively easy due to the differences in morphology and weathering.

TIME-DISTANCE SCHEMATIC

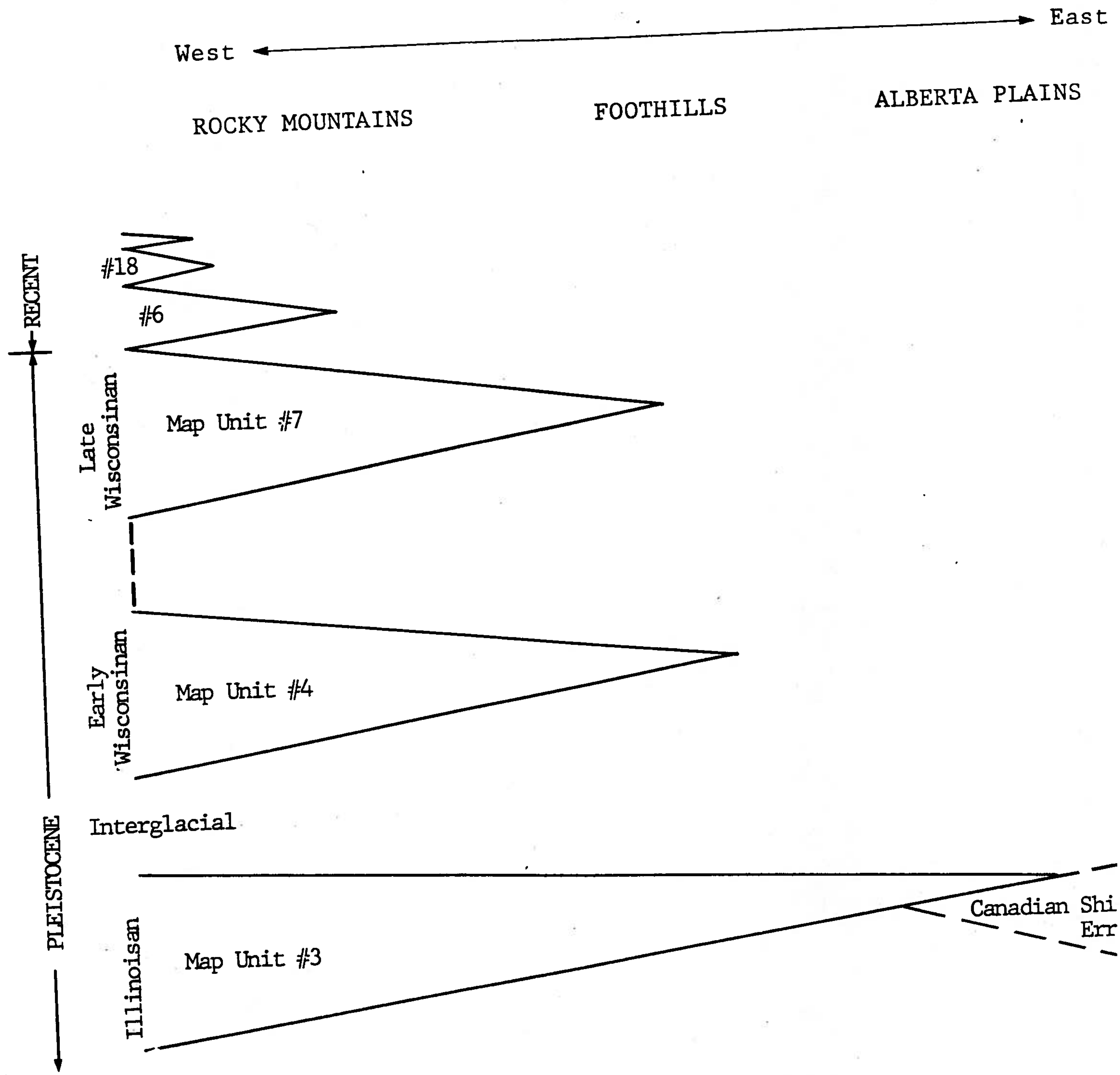


FIGURE: 2 Glacial Stratigraphy: Smoky River to Rock Lake atypical of glacial slopes with more heterogeneous compositions.

Minor readvances of small valley glaciers of short duration are recorded in the large composite and single cirque basins (Map Unit 18). In most cases, evidence of two advances are noted, a readvance of a generally less than 5 miles from the cirque basin and a shorter advance often marked by an end moraine near the lip of the cirque. All glaciers within the map area appear to be receeding at the present time.

Igneous erratics of Canadian Shield origin are found at elevations of approximately 5,000 feet along the edge of the Foothills north of the Berland River. These erratics are located in glacial sediments assigned to a pre-Classical Wisconsin age. The evidence of these erratics is proof for an advance of Continental ice that is of pre-Classical Wisconsin age. Deposits of Continental origin that could be assigned to the Classical Wisconsin were not located.

The extensive outwash deposits near Wild Hay River and Rock Lake area are all attributed to the latest (Classical Wisconsin) ice advance. Postglacial sand dunes are present south of the Wild Hay River. In Recent times, fine-textured alluvium was deposited over coarse glacial outwash in all major stream valleys. Recent organic sediments have formed in many of the low lying areas on the eastern edge of the Foothills. Colluvial processes are active on all slopes so that greater than 60 percent of this area is underlain by non-glacial sediments.

Extensive areas of colluvium mantle the slopes of this area. Excepting in valleys, glacial sediments are non-existent except as isolated remnants on the tops and sides of ridges. All of the streams within these areas contain glacial erratics attributed to ice advances from the west. Some of the larger tributary valleys such as the headwaters of the Berland and Sulphur rivers contain extensive deposits of outwash gravels in the form of valley trains. When these outwash deposits are traced westward, to their source area, they abut against glacial sediments with shallow leaching and weathering profiles. These glacial sediments have been attributed to small but widespread glacial advances of valley glaciers during the Late Wisconsin time (Map Unit 7) Kvass Creek, a high level stream between Sulphur River and Smoky River contains glacial sediments that are deeply weathered and leached (Map Unit 3). Glacial sediments in the Smoky and Jackpine Rivers downstream to the junction of the Wolverine Creek have a fresh glacial topography. They have shallow leaching and weathering profiles and are attributed to a large valley glacier of Late Wisconsin time. Near the junction of Wolverine Creek and the Smoky River these glacial sediments transect glacial deposits of an older age.

The young (Late Wisconsin, Map Unit 7) glacial sediments in the Jackpine River valley and the older glacial sediments in the headwaters of the Muddy Water River and Sheep Creek valleys have been transected by glacial deposits with a unique lithology (Map Unit 6). Greater than 75 percent of the clasts in sediments attributed to this advance are composed of chlorite and serecite schists. The slopes of glacial topography in this area are very gentle, and completely

Athabasca River to Robb

Glacial deposits of this area are classified into three major and possible four Cordilleran glaciations (Map Units 3, 4 and 7) and two Continental glaciations (Map Unit 5 and "erratics"). Two minor cirque advances were noted (Map Unit 18 - Figure 3).

The glacial deposits have been separated primarily on the basis of weathering and carbonate leaching as well as geomorphic landforms and topographic position. In the Foothills the topography, up to elevations of about 4,500 feet, is dominated by glacial sediments belonging to the youngest glaciation. Up to two advances in this unit (Map Unit 7) were noted by leaching depths but their areal distribution was not delineated. They have all been classified as young tills of Late Wisconsin age (Map Unit 7). Above this elevation up to approximately 5,300 feet are glacial sediments that have extreme weathering profiles and great thicknesses of carbonate leaching. Up to 14 feet of carbonate leaching has been recorded in these old glacial sediments along the "new" Hinton-Luscar highway. This is in contrast to the shallow leaching profiles of less than 18 inches below elevations of 4,500 feet in the Athabasca River Valley.

Glacial sediments with intermediate depths of weathering and carbonate leaching (Map Unit 4) are present north of Pepper Lake, and east of Gregg Lake. In addition, remnants of this glacial till is also located southwest of Pepper Lake, where it has been truncated by sediments of a younger glacial age (Map Unit 7).

TIME-DISTANCE SCHEMATIC

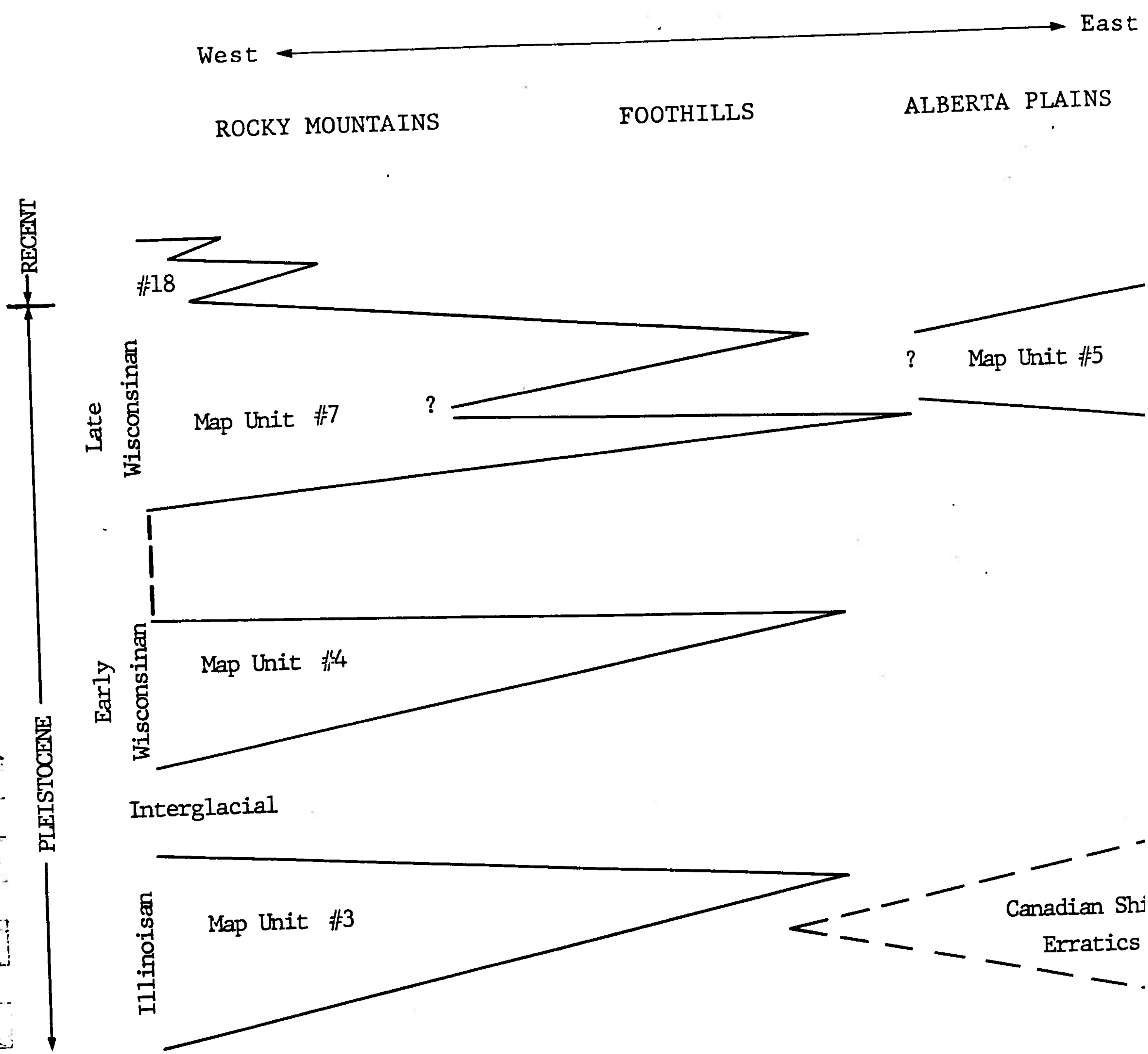


FIGURE: 3 Glacial Stratigraphy: Athabasca River - Robb

The area east of High Divide Ridge and below elevations of 4,500 feet is characterized by glacial sediments with variable thicknesses of weathering and carbonate leaching. These sediments have been classified as one unit (Map Unit 7) but it is probable that they represent deposits of two ages.

The extensive area from Luscar to Mountain Park to Robb is underlain by glacial deposits of an ancient glacial advance (Map Unit 3). In these areas, the glacial aspect is virtually nonexistent and glacial sediments are difficult to recognize. They are thoroughly weathered, with leaching profiles up to greaterthan 14 feet in thickness. To the west old glacial sediments are overlain by end moraines of small valley type and cirque glaciers representative of at least two different ice advances (Map Units 7 and 18). These old glacial sediments probably contain tills with intermediate weathered profiles and depths of carbonate leaching. They have not been delineated due to an insufficient data base.

In summary, this area has been glaciated by an early Cordilleran advance (Map Unit 3) which extended beyond the confines of the Athabasca River Valley, both to the northwest and southeast. Weathered Canadian Shield erratics are present in glacial tills of Map Unit 4 at elevations above 4,500 feet along the eastern edges of the Foothills. This suggests an early Continental advance prior to this time. An advance of Cordilleran glaciers occurred again depositing Intermediate-age glacial sediments (Map Unit 4). No equivalent advance of the Continental Glaciers was observed.

The advance of large piedmont-type valley glaciers in Late Wisconsin times (Map Unit 7) eroded most of the evidence of previous glaciations. The Late Wisconsin advance probably contains sediments belonging to two different ages as suggested by leaching depths but these have not been separated due to an insufficient data base. Subsequent to the advance of the Late Wisconsin Glaciers (Map Unit 7) there was renewed activity for two recogniz able periods of cirque glaciation (Map Unit 18). The extensive terrace levels have been documented by Stene (1966) formed in postglacial times. Eolian activity has continued from sub-Recent to the present on the eastern side of Brule Lake. Numerous organic deposits have and are accumulating in the area south and east of the Athabasca River at low elevations.

Brazeau River to North Saskatchewan River to Red Deer River

Glacial deposits of this area can be subdivided on the basis of weathering and carbonate leaching, degree of dissection and geomorphic position. They can be classified into three major Cordilleran glaciations (Map Units 3, 4 and 7) and two Continental glaciations (Map Unit 5 - "Erratics") (Figure 4).

Deposits of the earliest Cordilleran glaciation are found between major river valleys on the uplands. They are characterized by deeply leached profiles (up to 12 feet) and a conspicuous absence of glacial topography. These ancient glacial deposits (Map Unit 3) do not occur west of the eastern edge of the Rocky Mountains as they have been obliterated by younger glacial advances. Extensive deposits of this map unit are found on plateaus east of the Brazeau and Ram ranges at elevations above 4,200 feet.

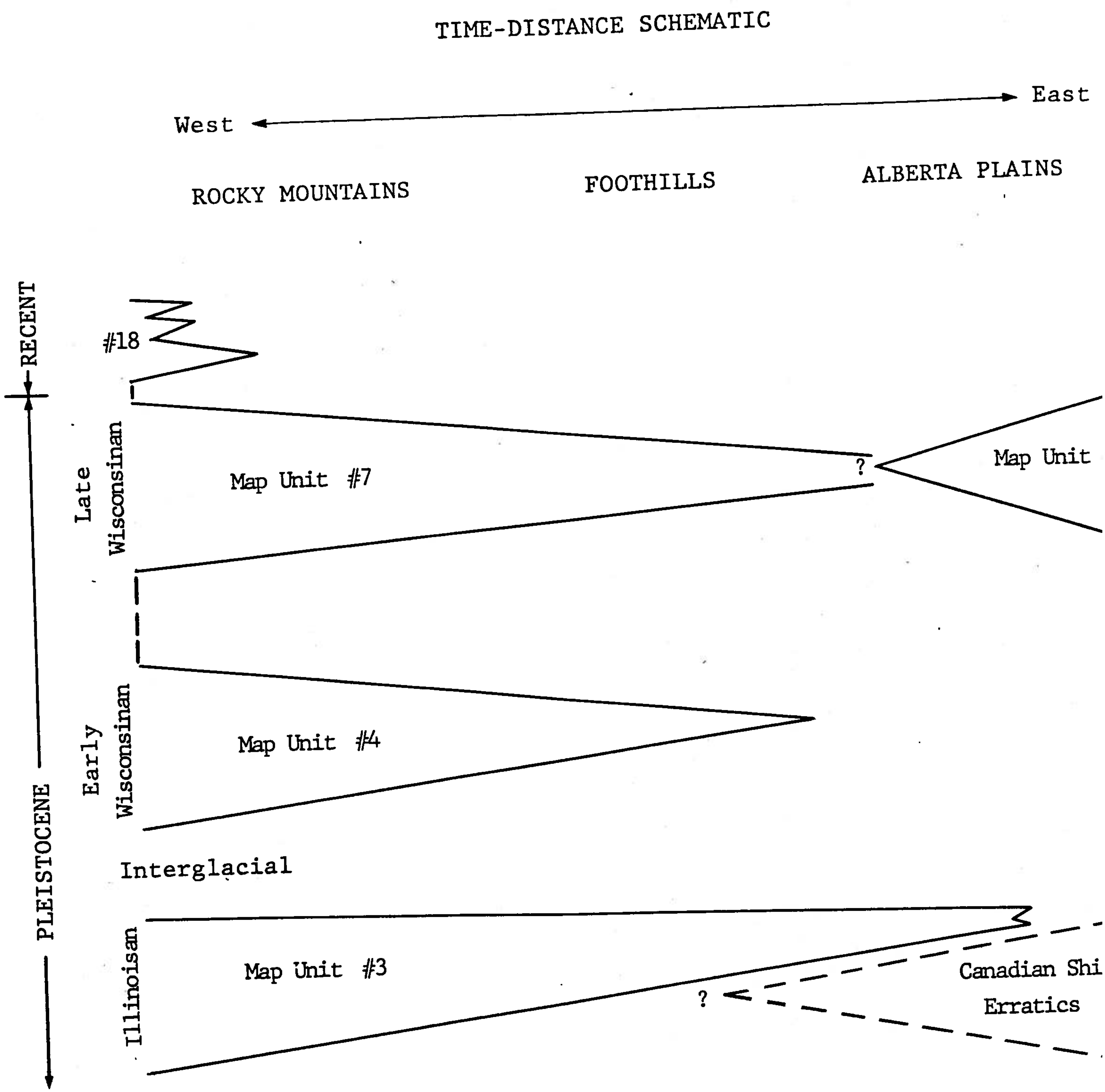


FIGURE: 4 Glacial Stratigraphy: Brazeau River to North Saskatchewan River to Red Deer River

They also occur at higher elevations north and south of the Brazeau River systems. These ancient glacial deposits can be traced southward along the edge of the Foothills to a position just north of Cochrane. In some areas rare Canadian Shield erratics are present in these deposits.

Surficial deposits that can be attributed to a younger Cordilleran advance (Map Unit 4) are found on uplands between the major river systems. Extensive glacial deposits that can be attributed to this glaciation can be found on both sides of the Big Horn Range and on the Ram River. In addition, these deposits can be traced southward along the edge of the Foothills and above elevations of 4,500 feet. They abut against glacial deposits belonging to an earlier glacial advance (Map Unit 3). The demarcation of these two deposits is often difficult. It is based firstly on carbonate leaching and secondly on freshness of glacial topography on the depth. As a result, in many areas especially on slopes, these ancient glacial deposits are difficult to differentiate near their margins.

Surficial deposits which can be attributed to the youngest major Cordilleran glaciations (Map Unit 7) are found in the Brazeau, North Saskatchewan, Clearwater and Red Deer River systems. The glacial landforms of this major alpine advance truncate older glacial deposits in the Foothills. Weatward deposits attributed to this glacial advance can be traced into major composite cirques. In upland areas between the major river systems such as the area west of the Big Horn Range or the headwaters of the Clearwater River young glacial deposits with similar leaching profiles can be found (6-18 inches) These young glacial deposits probably were deposited at the same time as alpine glaciers in the major valleys. At elevations below 4,500 feet near Watervalley, north of Calgary, are found glacial deposits with numerous Canadian Shield erratics. These glacial deposits exhibit a fresh glacial aspect on aerial photographs and mark the edge of a Continental ice sheet. Although these deposits do not encounter glacial deposits attributed to the youngest Cordilleran advance, they are assumed to be of similar ages.

Evidence for three minor cirque glaciations (Map Unit 18) are present in the Rocky Mountains north of the Cline River and south of Siffleur Creek. These minor advances are characterized by glacial deposits with no evident leaching profiles. The youngest advances are confined to the cirque basin whereas an older advance moved 2 to 3 miles out of the cirque. Modern glaciers within the area are presumed to be receeding.

Ice marginal lakes are present along tributaries of some of the rivers. Pitted glaciolacustrine deposits are present between the James and Red Deer river systems at the eastern edge of the Foothills.

Major glaciofluvial deposits are all realted to the youngest major glacial advance (Map Unit 7) with the exception of outwash in the South Ram River which is attributed to an ancient glacial advance.

Bow River to Longview

The distribution and stratigraphy of surficial deposits in the Bow River and Highwood River valleys reveal evidence of four major Cordilleran advances (Map Unit 3, 4, 7 and 7b) and one Continental advance ("Erratics") - Figure 5 . Two minor cirque advances were noted (Map Unit 18).

Mapping of the deposits reveals evidence that much of the area of the Rocky Mountains was not covered by glaciers during the Late Wisconsin time. No evidence other than a few scattered erratics of Canadian Shield origin were found within the area mapped. The earliest Cordilleran glacial advance (Map Unit 3) is marked by glacial deposits on high level plateaus north and east of Exshaw and in minor tributaries of Bragg Creek and the Highwood River. These deposits exhibit deep weathering and leaching profiles and do not have a characteristic glacial expression. Other surficial deposits attributed to this early glacial advance can be found north of Cochrane near Dogpound Creek.

Surficial deposits that can be attributed to another ancient glacial advance (Map Unit 4) are located north of Ghost River and south of Bragg Creek. These deposits can be traced westward to the main ranges of the Rocky Mountains. They are characterized by more shallow weathering profiles than the earliest glacial advance, however, evidence of "fresh" glacial landforms are nearly absent.

Surficial deposits belonging to the glacial advances attributed to the Classical Wisconsin (Map Units 7 and 7b) are found in all of the major river valleys including the Ghost, Bow, Kananaskis, Spray and Highwood river valleys. In addition, small valleys between these river systems contain glacial deposits attributed to these advances.

TIME-DISTANCE SCHEMATIC

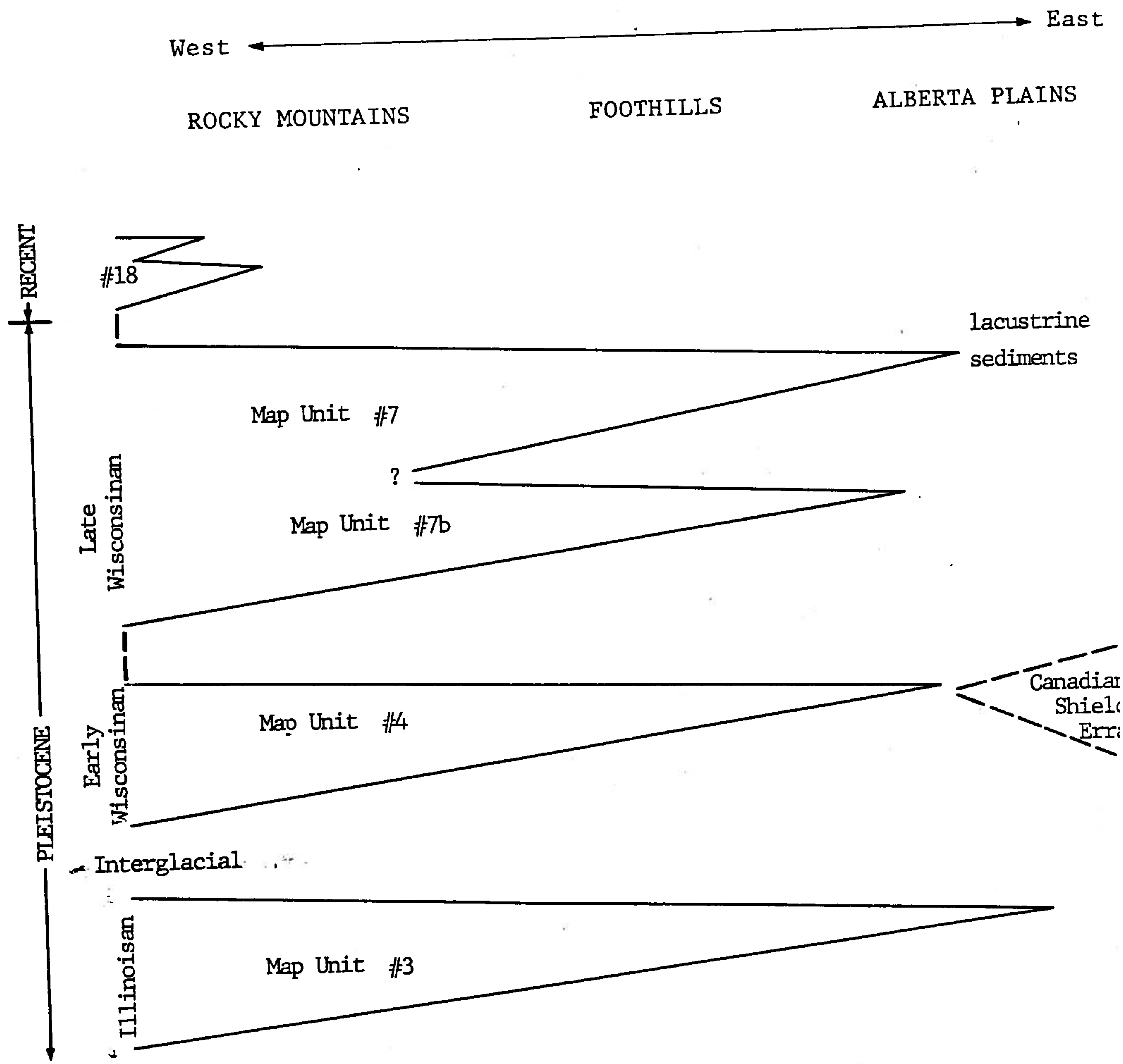


FIGURE: 5 Glacial Stratigraphy: Bow River - Longview

Immediately south of Morley are glacial deposits that are attributed to an advance immediately preceeding the major Classical Wisconsin advance. These deposits (Map Unit 7b) are characterized by deeper weathering and occur at elevations generally above 4,500 feet in the Bow Valley and above 4,300 feet at Turner Valley. They have been truncated by a later advance (Classical Wisconsin - Map Unit 7).

The youngest Cordilleran advances (Map Unit 18) are recorded by two discontinuous end moraines associated with cirques. An older advance is characterized by an end moraine up to several miles outside of the cirque basin. The youngest moraine is actually marked by a series of three to five ridges but all are within the cirque basin.

Little evidence of Continental glacial deposits was found within this area. Scattered erratics of Canadian Shield origin were found along tributaries of the Elbow and Highwood Rivers. The Elbow river is located mainly in an area that has been glaciated by an ancient glacier (Map Unit 4). Since igneous rocks of Canadian Shield origin were found, in this river system, this implies a previous Continental advance at this time.

Glaciolacustrine deposits mantle much of the area south of Canmore to Black Diamond up to elevations of approximately 4,150 feet. These deposits are occassionally of a pitted nature which suggest deposition in and around ice blocks. Presumably the continental glacier which blocked eastward drainage of this glacial lake, was some distance to the east at this time.

Glaciofluvial deposits are present along the Bow and Ghost River systems in the form of valley train. The valley train in the Bow River Valley is deposited in and around drumlins deposited during the Classical Wisconsin advance (Map Unit 7).

Two steep-sided meltwater channels, east of the Kananaskis Research Station, drained meltwater from the Classical Wisconsin Ice. The meltwater deposited in part the extensive fluvial sediments that occur along Jumping Pound Creek.

Crowsnest Area

Surficial deposits of the Crowsnest area can be related to three Cordilleran and one Continental glacial advance. (Map Units 3, 4, 4b and 7).

Three minor Cordilleran advances are also recorded (Map Unit 18 - Figure 6). The earliest advance (Map Unit 3) is recorded by glacial till deposits south of the Highwood River along the Alberta - B.C. border and on the eastern edge of Waterton Park. Surficial deposits attributed to an old Cordilleran glacial advance (Map Unit 4) are found in major north-south valleys in the Rocky Mountain Foothills west of the Porcupine Hills. In addition, deposits of this glaciation can be found along the Castle River and immediately west of Waterton Park along the Canada - U.S. border. They abut against glacial deposits of Continental origin. These latter deposits (Map Units 4b and 4ba) are characterized by numerous erratics derived from the Canadian Shield. They have intermediate weathering and leaching profiles and exhibit a "smoothened" glacial aspect. These Continental glacial deposits were overriden by Cordilleran glaciers (Map Unit 7) attributed

TIME-DISTANCE SCHEMATIC

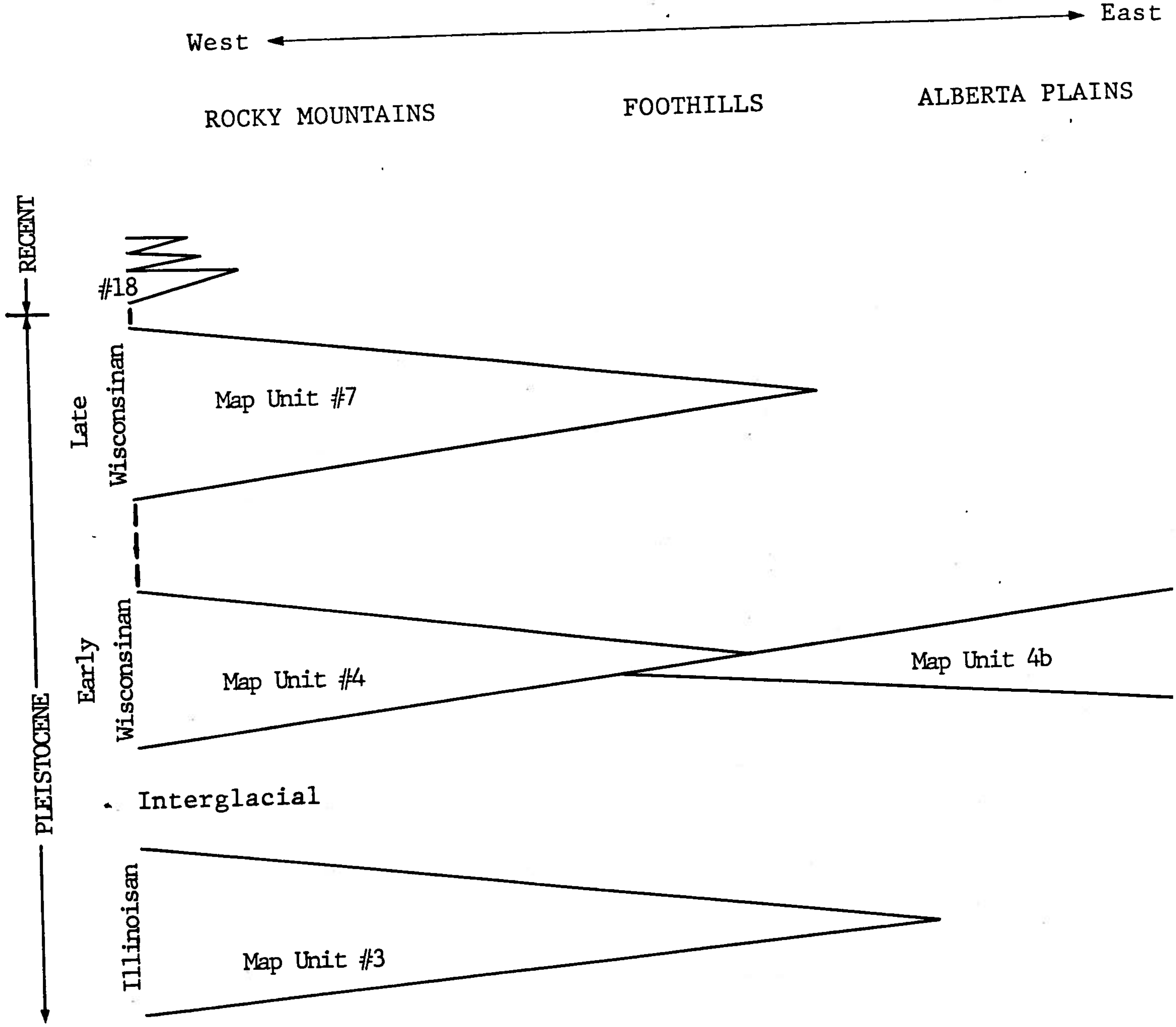


FIGURE: 6 Glacial Stratigraphy: Crowsnest Area to the Late Wisconsin time. These young deposits which occur in all of the major river mountain valleys have coalesced along the mountain front into an extensive till sheet. These deposits exhibit a young fresh glacial aspect to the land-fomrs and have shallow weathering and leaching profiles (less than 18 meters). These young glacial deposits can be traced westward into their cirque basins. Near the headwaters of each of these valleys up to three advances can be recorded. The youngest advance is confined to the cirque basin and contains several minor end morainal ridges. The oldest advance is marked by an end moraine a few miles outside of the cirque basin.

Glaciolacustrine deposits are present along the eastern edge of the Foothills from the Oldman River to the Castle River and around the Belly and Waterton rivers. The lacustrine deposits range up to 4,300 feet on the Oldman River and 3,900 feet on the Belly River. The deposits overlie glacial till deposits belonging to a Continental glacial advance of intermediate ages (Map Unit 4b).

Major glaciofluvial deposits are present along the Oldman, Crowsnest, and Castle river systems. The outwash deposits have been terraced in postglacial time except for those on the Oldman River. These glaciofluvial deposits seem to be mainly associated with glacial advances of intermediate age.

Suggested Correlation With Previous Work

The recognition of at least three Continental glacial advances appear to agree with the threefold division proposed for southwestern Alberta by Horberg, 1952, Stalker, 1963 and Alley 1973. However, due to the regional nature of this project, only relative correlations can be made. The earliest Continental advance inthe study area is only postulated by deeply weathered Canadian Shield erratics found in glacial tills belonging to the oldest Cordilleran advance. It is thought to be pre-Sangamon in age (Table 3). The erratics are generally found above 5,000 feet north of the 52nd parallel and ranging down to 4,500 feet in the Crowsnest area.

Glacial till deposits of Continental origin (Map Unit 4b) assigned to the Early Wisconsin occur in the Crowsnest area. The deposits occur up to 4,700 feet in the Outer Foothills. The western limit could not be confidently mapped as it has been obliterated by younger glacial advances

Glacial till deposits of Continental origin (Map Unit 5) that are assigned to the Late Wisconsin occur between Calgary and Hinton below elevations of 4,500 feet (Figure 3 and 4). They have not been recognized anywhere else in this study area. The occurrence of three major Cordilleran glaciations in the Foothills of western Canada agrees with Horberg, 1954; Stalker, 1958; Reimchen, 1969 (unpub.); Rutter 1972; Reimchen and Rutter 1972; Alley, 1973; Boydell, Bayrock and Reimchen 1974; and Roed, 1975. (Table 3).

The earliest Cordilleran glaciation recognized by widespread deposits (Map Unit 3) is thought to pre-date the Sangamon Interglaciation. In this report it is assigned to the Illinoisan

Glacial Age. The widespread deposits of this glaciation suggest a large ice mass or Rocky Mountain Ice Sheet to the west. Probable correlatives of this advance have been recognized by all workers (Table 3).

Glacial till deposits (Map Unit 4) of lesser extent that occur on the uplands between major mountain valleys are thought to belong to a reticulate glacier of Early Wisconsin Age. These deposits are difficult to recognize but possible correlatives have been found (Table 3).

Glacial deposits (Map Unit 7, and 7b) that occur in all of the major valleys of the Mountains and Foothills are assigned to the Late Wisconsin. Two glacial stades have been recognized although no stratified interstadial deposits were noted (Figure 3 and 5). Stratigraphic evidence presented by Roed 1968, 1975; Rutter 1972; Alley, 1973; Boydell, Bayrock and Reimchen 1974; agrees with this division (Table 3). Minor glacial deposits of a very-later Wisconsin readvance or a Recent advance (Map Unit 6) appear to have correlatives in the Athabasca and Bow River Valleys (Table 3).

Up to three minor Neoglacial advances are recorded in the Rocky Mountains (Figures 4 and 6).

TABLE 3

SUGGESTED CORRELATION CHART OF ROCKY MOUNTAIN AND FOOTHILL STRATIGRAPHY, CANADA

	CORDILLERAN ORIGIN										LAURENTIDE ORIGIN				
AUTHOR	Rutter (1974) (in Roed)	Rutter and Reimchen (1972)	Roed (1975)	Reimchen (1969)	Boydell, Bayrock and Reimchen (1974)	Rutter (1972)	Alley (1973)	Stalker (1958)	Horberg (1952, 1954)	Bayrock and Reimchen (This Report)	Bayrock and Reimchen (This Report)	Roed (1975)	Boydell, Bayrock and Reimchen (1974)	Alley (1973)	Stalker (1958)
AREA	Peace River B.C.	Pine Pass B.C.	Athabasca Valley	N. Saskatchewan River	Rocky Mountain House	Banff	Crowsnest	Crowsnest	Waterton	Alberta Rocky Mountains and Foothills	Alberta Rocky Mountains and Foothills	Athabasca Valley	Rocky Mountain House	Crowsnest	
RECENT	Deserter's Canyon		Drystone Creek			Eisenhower				Neoglacial II Neoglacial I Cirque Till (18) Schist Till (6)					
PLEISTOCENE – Wisconsin Glaciation – Late	Late Portage Mountain	Young	Obed - - - - - Marlboro	Upper	Jackfish Creek - - - - - Lamoral	Canmore - - - - - Bow Valley	Hidden Creek - - - - - Ernst	- - - - -	Late Wisconsin	Young Till (7) - - - - - Young Till (7b)	Young Till (5)	Edson - Mayberne	Sylvan Lake	Buffalo Lake	- - - - -
PLEISTOCENE – Wisconsin Glaciation – Early	Early Portage Mountain	Intermediate	Valley Glacier	Middle	Baseline	pre-Bow Valley ?	Maycroft	Map Unit 6,8	Early Wisconsin	Intermediate Till (4)	Intermediate Till (4b)	Marsh Creek		Maunsell	Map Units 5,7
PLEISTOCENE – Sangamon Interglacial	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////	//////
PLEISTOCENE – Illinoisan Glaciation		Old	Early Cordilleran	Lower	Hummingbird	"Erratics"	Albertan	Map Unit 3,4	Kennedy	Old Till (3)	"Canadian Shield Erratics"			Labuma	

EROSION POTENTIAL STUDY

Erosion potential as defined here is the property of a certain unconsolidated or semiconsolidated deposit to undergo erosion upon disturbance. The deposits are classified into three categories as having low, medium and high erosion potential.

Erosion depends on many factors such as the surface materials and their physical and chemical properties, topography and slope, climate, microclimate, surface and subsurface hydrology, vegetation and age of the exposure of the surface site. No existing system of erosion estimation successfully encompasses all these features. Some of the recent work in this field in Alberta is summarized below.

Rutter (1968) qualitatively evaluated the key inherent erosion factors of soil-types and then determined the overall erosion hazard of soils in their natural settings of the Rocky Mountain Forest Reserve by considering external factors. Inherent erosion factors included infiltration rate, grain-size characteristics (texture), carbonate cement content and silt and clay binding strength; external factors considered were vegetation, slope and precipitation. Three erosion hazard classes (low, moderate and high erosion risk) are distinguished, separated on the basis of slope angle and soil rating (a term which includes the various soil properties).

St. Onge (1974) produced an erosion susceptibility classification based on materials, slopes and the revegetation rate (this term modified by whether or not top-soil removal has occurred with deforestation) in the Wallace Mountain region of the Swan Hills. A twelve category system was developed and erosion susceptibility rated in four classes:

A - No gullying,
B - Very shallow gullying, self arresting,
C - Deep very dense gullying,
D - deep dense gullying and mud flows

Kathol and McPherson (1974) classified a small area of Swan Hills region to susceptibility to erosion. Their approach is similar to St. Onge's, whom they consulted. They rate each deposit separately and discuss it at length. Nevertheless, they also do not present original data on which they based their critical slope angles or erosion susceptibility. Most important they do not give a map of erosion susceptibility but the reader has to arrive at the results himself, after examination of the site in question.

Procedure

Bayrock and Reimchen (1975) and Reimchen and Bayrock (1976) conducted erosion potential of all the Foothills and Mountains in Alberta. Field identification and measurements of surficial materials and erosion characteristics were conducted. It was found that rill and gully development on exposed ground surfaces was the major form of surface erosion - slides, slumps and rock falls being relatively rare. The rill and gully erosion was rated as:

1. No erosion.

2. Erosion just beginning (small rills, generally less than 4 inches deep) (Plate 13)

3. Severe erosion (large rills and gullies present) (Plate 45).

The development of tills occurred at different slope angles was noted for different materials. It was felt that the point where erosion begins occurs at a critical slope angle. Below this critical angle the material is stable while above it moderate to severe erosion occurs.

Four slope classes were chosen to provide an indication of the general value of the critical slope angle and be compatible with the slope categories adopted for forest harvesting practices in the Foothills and Mountains of Alberta.[1] The slope classes chosen were:

Class 1	0-14%	(0-9°)
Class 2	15-29%	(9-16°)
Class 3	30-44%	(16-23°)
Class 4	45%+	(23°+)

In comparing with previous work, Rutter (1968) used 0-5°, 5-20° and greater than 20° slope classes; St. Onge used 0-5°, 5-10° and greater than 10° slope classes, and Kathol and McPherson employed 0-10° and greater than 10° slope classes. Maps of surface slope classes were produced from 1:50,000 and 1:60,000 topographic base maps.

1 Dept. of Lands and Forests, Alberta: "Environmental Effects of Timber Harvesting Operations in the Edson-Grande Prairie Forests of Alberta", by C.D. Schultz and Company Limited, 1973, Internal Report.

Field sampling in 1974, 1975 and 1976 provided a total of 677 measurements relating slope, surficial materials and erosion characteristics. From these measurements a classification of surficial deposits and their erosion potential of an exposed or disturbed surface was developed.

In summarizing the measurements some of the surficial deposits were grouped together to provide a larger data base. For example, the 'Outwash' of the erosion potential includes map units 8-14 (meltwater channel deposits, outwash plain, esker, kame, valley train and lag gravel). Table 4 presents the combined measurements breaking down the number of occurrences of each erosion class within each materials-slope class category.

TABLE 4

EROSION CLASS MEASUREMENTS
1974, 1975, 1976

GEOLOGIC MATERIALS	SLOPE CLASS 0-14%			15-29%			30-44%			45%+			No. of Measurements
	STABILITY CLASS												
	1	2	3	1	2	3	1	2	3	1	2	3	
OLD TILLS	21	0	1	9	8	1	14	2	4	16	3	4	88
INTERMEDIATE TILLS	8	0	0	12	2	1	8	3	9	21	6	1	71
YOUNG TILLS	14	1	0	8	2	1	29	13	3	70	17	16	174
OUTWASH	18	0	0	8	0	0	14	1	2	27	6	1	77
COLLUVIUM	10	0	1	2	5	2	13	3	2	28	2	3	71
GLACIOLACUSTRINE	9	0	0	13	10	10	13	17	15	3	13	14	117
ALLUVIAL FAN	10	0	0	3	0	0	1	0	0	1	3	0	18
ALLUVIUM	7	0	0	2	0	0	0	0	0	2	0	0	11
WEATHERED BEDROCK	0	0	2	3	5	3	8	4	9	5	9	7	55

From these data the number of measurements in each erosion class was converted to a percentage of the total erosion measurements within each materials-slope category. These figures are presented in Table 5.

By combining the erosion class two and three measurements in each materials-slope category, an erosion potential (stability) rating is developed. A stability class one ('Stable') is given when the sum of erosion class two and three measurements is less than 20 percent of the total erosion class measurements. Stability class two ('Metastable') occurs when erosion classes two and three account for 20-50 percent of the total erosion class measurements. When more than 50 percent of the total erosion class measurements fall in erosion classes two and three a class three stability ('Unstable') is given. A fourth stability class designates terrain which was not considered in the study (ie. bedrock units). The erosion potential ratings are summarized below:

<u>Erosion Potential Rating</u>

Stability Class		
0	-	Terrain not considered
1	-	Stable terrain; the probability of surface erosion occurring is 0-20% (0-2 of 10 exposures will show rill and gully development).

TABLE 5

EROSION CLASS DATA

(EXPRESSED AS PERCENTAGE

OF TOTAL IN EACH MATERIALS-SLOPE CLASS CATEGORY)

GEOLOGIC MATERIALS	SLOPE											
	0-14%			15-29%			30-44%			45%+		
	Stability Class											
	1	2	3	1	2	3	1	2	3	1	2	3
Old Tills	95	0	5	50	44	6	70	10	20	70	13	17
Intermediate Tills	100	0	0	80	13	7	40	15	45	75	21	4
Young Tills	93	7	0	73	18	9	64	29	7	68	16	16
Outwash	100	0	0	100	0	0	82	6	12	79	18	3
Colluvium	91	0	9	22	56	22	72	17	11	85	6	9
Glaciola-custrine	100	0	0	39	30	30	29	38	33	10	43	47
Alluvial Fan	100	0	0	100	0	0	100	0	0	25	75	0
Alluvium	100	0	0	100	0	0	--	--	--	100	0	0
Weathered Bedrock	0	0	100	27	45	27	38	19	43	24	43	33

Stability Class

2 - Metastable terrain; the probability of surface erosion occurring is 20-50% (2-5 of 10 exposures feature rills and gully development).

3 - Unstable terrain; the probability of surface erosion is greater than 50% (more than 5 of 10 exposures are rilled and gullied).

Table 6 shows the final erosion potential ratings arrived at following the described method with some adjustments.

Erosion potential maps for the entire Foothills and Mountains region were then produced by superimposing slope class maps produced from 1:50,000 and 1:63,360 topographic base maps over surficial geology maps and designating the erosion potential ratings (stability) according to the materials-slope class relationship which has been developed.

A review of the erosion potential rating for each surficial deposit follows, and the results are summarized in Table 7.

TABLE 6

EROSION POTENTIAL (STABILITY) RATINGS

GEOLOGIC MATERIALS	SLOPE CLASS			
	0-14%	15-29%	30-44%	45%+
Old Till	1	2	2	2
Intermediate Till	1	1	2	2
Young Till	1	2	2	2
Outwash	1	1	1	2
Colluvium	1	2	2	2
Glaciolacustrine	1	3	3	3
Alluvial Fan	1	1	2	2
Alluvium	1	1	2	2
Weathered Bedrock	3	3	3	3

TABLE 7

STABILITY OF SURFICIAL DEPOSITS

SURFICIAL DEPOSITS	STABILITY			
	SLOPE CLASS			
	0-14%	15-29%	30-44%	45%+
Indurated Bedrock (1) Glacier (20)	0	0	0	0
Cirque Till (18) Continental Till (4b,4ba) Outwash (8 to 14)	1	1	1	2
Intermediate Till (4) Alluvial Gravels (21) Alluvial Fan (23) Rock Slide (28) Patterned Ground (25)	1	1	2	2
Young Till (5,7,7a,7b) Old Till (3,3a) Rock Glacier (19) Colluvium (24) Talus (27)	1	2	2	2
Glaciolacustrine (15,15a) Eolian Sand (16) Alluvial Sand (22) Slump, Landslide (29)	1	3	3	3
Schist Till (6) Organics (17)	2	3	3	3
Weathered Bedrock	3	3	3	3

Old Till (Map Units 3 and 3a)

Old tills exhibit a leaching depth of at least 5 feet and this weathered portion shows stability characteristics similar to those of the Young till. Based on 88 measurements the Old till is considered stable in the 0-14% slope class and metastable beyond.

Intermediate Till (Map Units 4, 4a, 4b and 4ba)

These tills are found to be stable up to 29%, unstable for 30-44% slopes and metastable beyond 45%. In view of the larger number of measurements in the 45%+ slope class (28 versus 20) the 30-44% slope class stability is adjusted to be metastable. A total of 71 measurements are available for this unit.

Young Tills (Map Units 5, 5a, 7, 7a and 7b)

Young tills are stable in the 0-14% slope class and metastable beyond. A total of 174 measurements are available on this unit yielding the best control of any group.

Schist Till (Map Unit 6)

No measurements are available for stability of the schist till. This till is lacking in carbonates and has abundant slippery mica flakes. It is considered to be metastable on slope angles up to 14% and unstable beyond.

Glacial Outwash (Map Units 8 - 14)

Meltwater channel deposit (Map Unit 8), outwash plain (Map Unit 9), esker and esker complex (Map Unit 10), kames and kame moraines (Map Unit 11), pitted outwash (Map Unit 12), valley train (Map Unit 13) and lag gravel (Map Unit 14) are all glacial outwash deposits composed of sand and gravel, 77 measurements are available for the unit and it is considered stable up to 44 percent, beyond this value a metastable rating is applicable.

Glaciolacustrine Deposits (Map Units 15 and 15a)

Glaciolacustrine deposits are composed of silt and sand. A total of 117 measurements are available for glaciolacustrine deposits and suggest that the deposits are stable up to 14 percent and unstable beyond.

Eolian Deposits (Map Unit 16)

Eolian sand deposits take the form of small dunes and relatively thin sheet sand between dunes. The sand has practically no fines to act as a binding agent and the unit is assigned a stable rating up to 14 percent and unstable beyond.

Organic Deposits (Map Unit 17)

Organic deposits comprise muskeg and bogs which occur mainly on nearly level ground. Stability measurements are lacking for this deposit and it is assumed that organic deposits are metastable on slope angles up to 14 percnet and unstable beyond.

Rock Glacier (Map Unit 19)

Rock glaciers are glacier-like tongues of ice-cemented debris moving slowly downhill on steep ground. No stability measurements are available for this unit and it is assumed to be stable up to 14 percent and metastable beyond.

Glaciers (Map Unit 20)

Glaciers are not considered in the stability classification and are assigned a stability number of zero.

Alluvium (Map Unit 21 and 22)

Recent alluvium consists of gravel and sand with some silt and clay. Only 11 measurements are available, mostly in gravel bed rivers, and the alluvial gravels (Map Unit 21) are assigned a stable rating up to 29 percent and a metastable rating beyond this. Fine grained stream alluvium (Map Unit 22) is considered to be less stable and is assumed to be unstable above 14 percent and stable below.

Alluvial Fan (Map Unit 23)

Eighteen measurements are available and these lie mostly in the 0 - 14 percent and 15 - 29 percent slope classes where a stable rating is given. Above 30 percent the material is considered to be metastable.

Weathered Bedrock (No Map Unit)

Weathered bedrock (this term includes unconsolidated and semi-consolidated bedrock) was found to be exposed in numerous places on trails and seismic cutlines. Only 16 of 55 measurements exhibited no rill or gully erosion characteristics and the unit is considered unstable at any slope. The rilling and gullying of exposed shales and sandstone was found to be intense even at low slope angles and continued erosion of these lithologies is aided by the fact that revegetation occurs only slowly.

Colluvium (Map Unit 24)

Soil and rock creep material (colluvium) underlies the surface of most of the terrain. Colluvium is generally thin and overlies the bedrock directly. Seventy-one stability measurements are available on this unit. The unit is considered stable on slopes up to 14 percent and metastable on steeper slopes.

It should be stressed that although colluvial materials are relatively stable, the underlying weathered bedrock is not. Any disturbance which removes the colluvial cover and exposes the underlying weathered bedrock is liable to result in accelerated erosion as the weathered bedrock is unstable even at low slope angles.

Talus (Map Unit 27)

Talus is a gravity controlled deposit which consists, in the study area, of rubble-like materials. Stability of the deposit varies according to factors such as rock size and angularity. Natural stable repose slopes exist up to 60 - 70 percent (30 - 35°). Talus is considered to be stable up to 14 percent and metastable above.

Rock Slide (Map Unit 28)

Rock slides are composed of very coarse and angular rock rubble which may be up to 100 meters thick and contain blocks with dimensions of the order of tens of meters (Cruden, 1975). No stability measurements are available for this unit although the debris is assumed to be stable on angles up to 44 percent and metastable beyond this value. Cruden (1975) provides a review of some of the major rock slides inthe Rocky Mountains and an indication of the expected stability of rock masses.

Slump and Landslide (Map Unit 29)

Slumping and landsliding occur on relatively steep slopes. The slumped and landslide debris are considered stable on slopes up to 14 percent and unstable above.

Use of Erosion Potential Maps

Erosion potential maps for the whole of the study area are on open file at Alberta Research. The maps show areas of different erosion potentials as described previously in this report.

Each individual erosion potential unit as shown on the maps outlines an area of equal erosion potential hazard. In areas of Low Erosion Potential (Map Unit 1) disturbance of surficial materials will not cause severe erosion in most localities. Some erosion may be expected in low erosion potential areas but the statistical probability is low.

In High Erosion Potential areas (Map Unit 3) the probability is high that severe erosion of surficial materials will be initiated following disturbance. Areas designated as having Intermediate Erosion Potential (Map Unit 2) may have severe erosion following disturbance if no precautions are taken.

In our opinion, Low Erosion Potential areas are suitable for development. Areas of Intermediate Erosion Potential are also suitable for development provided precautions are taken to minimize erosion following disturbance. Areas of High Erosion Potential should be treated with extreme care in order to avoid future erosion following development.

The erosion potential maps are statistical in character. They show the probability of erosion hazard but do not state that erosion will or will not occur at any one location.

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APPENDIX 1

SAMPLE ANALYSES RESULTS
AND
EROSION STABILITY MEASUREMENTS

Explanation of Headings Used in the Data Summary

SMPL	This is the sample number as determined from the original field notes. A hyphen should be inserted between the last digit to the right and second digit from the right. For example, 202 will read 20-2. Those proceeded by zero represent data collected in September 1976 and 0105 reads as location 105.
SND	Percentage of sand (of the less than 2 mm. size fraction) as determined by dry sieving grain-size analysis.
SLT	Percentage of silt (of the less than 2 mm. size fraction) as determined by dry sieving or hydrometer method of grain size analysis.
CLY	Percentage of clay (of the less than 2 mm. size fraction) determined as a residual.
LQL	This is Atterberg's liquid limit evaluation (see A.S.T.M. D423).
PLL	This is Atterberg's plastic limit evaluation (see A.S.T.M. D424).
PLI	This is Atterberg's plastic index evaluation (see A.S.T.M. D424). It is the difference between the liquid limit and plastic limit.

Note:	For the sand, silt and clay percentages, liquid limit, plastic limit and plastic index a decimal point should be inserted between the last digit to the right and the second digit to the right in each column. For example, 159 will read as 15.9% and 12 as 1.2%.
LITH	This is an identification code of surficial deposits. 1 - Old Till 2 - Intermediate Till 3 - Young Till 4 - Colluvium 5 - Lacustrine 6 - Loess 7 - Alluvium 8 - Alluvial Fan 9 - Outwash 10 - Eolian 11 - Volcanic Ash
SLP	This is the value of the slope expressed as a percentage((vertical increment/horizontal increment) X 100%). Vertical slopes are assigned a value of 200%.
STAB	This term indicates the class of erosion characteristics exhibited (0 - no data, 1 - no rills, 2 - small rills and gullies, 3 - deep rills and gullies).
LENGTH	The length of the slope, measured in feet.
V	The letter V indicates the sample site was vegetated

TITLE = OLD TILL STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
43	423	397	180				1	1	10	1	
61	556	304	140	258	175	83	1	1	0	1	
62	728	222	50	226	173	53	1	1	0	1	
71	730	180	90	229	151	78	1	1	30	1	
121	459	331	210	336	247	89	1	1	34	1	
123	581	319	100	203	192	11	1	1	40	1	
131	744	250	60	322	223	99	1	1	0	1	
132	490	360	150	280	202	78	1	1	0	1	
133	591	279	130				1	1	0	1	
161	356	554	90	206	166	40	1	1	30	1	
162	314	506	180	269	217	52	1	1	28	1	
182	705	225	70	235	188	47	1	1	0	1	
183	500	410	90	232	212	20	1	1	40	1	
191	571	309	120	291	189	102	1	1	28	1	
243	505	245	250	339	193	146	1	1	0	1	
251	566	294	140	227	183	44	1	1	0	1	
273	320	290	390	506	266	240	1	1	15	1	
282	412	388	200	265	138	127	1	1	0	1	
403	505	315	180				1	1	0	1	
451	520	340	140	240	191	49	1	1	0	1	
501	730	190	80	307	250	57	1	1	40	1	
511	610	260	130	334	258	76	1	1	12	1	
641	480	380	140	306	223	83	1	1	0	1	
642	323	458	220	282	186	96	1	1	27	1	
682	400	390	210	260	196	64	1	1	0	1	
701	387	473	140	222	213	9	1	1	35	1	
712	588	312	100	242	218	24	1	1	0	1	
753	625	255	120	300	219	81	1	1	65	1	
801	547	353	100				1	1	15	1	
831	624	296	80	260	204	56	1	1		1	
913	640	200	160	229	205	24	1	1	0	1	
1192	250	440	310	332	242	90	1	1	0	1	
1211	464	416	120	257	213	44	1	1	0	1	
1342	290	270	440	536	195	341	1	1	30	1	
1672	541	329	130	302	211	091	1	1	100	1	
1673	836	149	015				1	1		1	
1741	565	265	170	285	179	106	1	1	40	1	
1832	382	498	120	254	141	113	1	1	70	1	
1952	480	38	0140	217	173	44	1	1	35	1	
1961	484	366	150	245	158	87	1	1	45	1	
1962	400	300	300	408	278	130	1	1	40	1	
1971	660	190	150	273	180	93	1	1	55	1	
1972	512	318	170	301	182	119	1	1	50	1	
1981	251	449	300	43	8						
1991	360	340	300	359	180	179	1	1	80	1	

2001	586	334	80				1	1	50	1		
2061	502	408	090				1	1		1		
2082	731	199	070	266	205	061	1	1	50	1		
2084	534	316	150				1	1	80	1		
22	783	186	30				1	3	40	1	50	75
82	200	420	380	512	216	296	1	1	35	1	18	75
101	690	220	90	297	166	131	1	1	55	1	15	75
152	455	305	240	299	143	156	1	1	25	1	80	75
153	380	320	300	416	177	239	1	4	25	1	80	75
352	620	190	190	385	225	160	1	1	70	1		75
471	480	320	200	206	155	51	1	1	30	1		75
501	540	290	170	288	184	104	1	1		1		75
702	665	225	110	226	187	39	1	1		1		75
822	420	370	210	376	249	127	1		35	1	2000	75
852	480	380	140	260	190	70	1	1	25	1		75
853	485	400	115	216	166	50	1	2	40	1		75
861	565	315	120	252	168	84	1	2	50	1	60	75
921	440	390	170	228	167	61	1		65	1	1000	75
1132	400	315	285	356	198	158	1		5	1		75

TITLE = OLD TILL STABILITY CLASS 2

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
232	438	242	196	438	242	196	1	1	20	2		
281	400	430	170	200	222	68	1	1	30	2		
441	545	285	170	360	230	130	1	1	20	2		
461	496	354	150	257	183	74	1	1	45	2		
672	418	452	130	287	213	74	1	1	17	2		
1201	666	164	170	416	283	133	1	1	55	2		
1221				322	231	91	1	1	20	2		
1281	170	460	370	333	215	118	1	1	15	2		
1811	483	327	190	254	148	106	1	1	45	2		
21	480	280	240	256	154	102	1	1	40	2	50	75
42	410	350	240	237	140	97	1		40	2	100	75
1232	460	340	200	352	190	162	1	1	55	2	15	75

TITLE = OLD TILL STABILITY CLASS 3

231	540	290	170	269	197	72	1	1	15	3		
332	350	450	200	336	227	109	1	1	10	3		
632	700	210	90	295	235	60	1	1		3		
1872	421	409	170	306	218	88	1	1	35	3		
862	529	341	130	262	198	64	1	2	70	4		
942	448	432	120				1	1	30	4		
1131	270	360	370	350	171	179	1	1	30	4		
1881	426	414	160	277	181	96	1	1	35	4		
2083	350	430	220				1	1	50	4		
121	380	420	200	273	168	105	1		75	4		75D

TITLE = OLD TILL NC STABILITY CLASS DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
42	46C	29C	25C	364	245	119	1	1			
81	690	200	110	255	203	52	1	1			
222	353	347	30C	326	179	147	1	1			
291				352	280	72	1	1			
302	281	449	227	332	137	195	1	1			
541	44C	42C	140	246	221	25	1	1			
612	364	486	150	296	241	55	1	1			
621	76C	200	040				1	1			
631	618	292	090				1	1			
671	700	230	70				1	1			
731	75C	185	65	246	212	34	1	1			
941	542	378	80	234	189	45	1				
1151	483	427	90				1	1			
1152	382	428	19C	253	192	61	1	1			
1181	452	408	14C	254	202	52	1	1			
1241	304	346	350	329	213	116	1	1			
1351	46C	28C	26C	304	153	151	1	1			
1402	395	285	320	288	183	105	1	1			
1441	156	524	320				1				
1662	486	374	140	278	213	C65	1	1			
1701	681	319	000	300	208	092	1				
1751	297	373	330	437	288	149	1				
1843	415	355	230	285	158	127	1	1	55		
1963	499	261	240	316	167	149	1	1			
1871	492	358	15C	326	188	138	1	1			
2012	130	545	325	426	221	205	1	1	50		75
121	560	27C	170	318	4	144	1	1			75
251	310	52C	170	394	244	150	1	2			75
252	360	320	320	390	209	181	1	1			75
322	840	145	15		14		1				75
371	595	305	100	322	215	107	1	4			75L
111	320	460	220	245	185	60	1				75L
191	505	305	190	312	213	99	1	1			75
1361	550	290	160	249	168	81	1	1	45		75
1362	430	280	290	318	174	144	1	1	45		

TITLE = INTERMEDIATE TILL STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
202	275	345	38C				2	4	30	1		
252	443	347	210	239	175	64	2	4	00	1		
272	39C	35C	260	304	209	95	2	1	0	1		
483	630	310	60	226	209	17	2	2		1		
652	380	420	200				2	3	0	1		
521	445	28C	275	34C	222	118	2	1	0	1		
661	115	535	350	314	217	97	2	3	60	1		
1073	571	229	200	285	187	98	2	4	0	1		
1082	45C	41C	14C	208	117	91	2	4	0	1		
1121	772	188	40	204	183	21	2	1		1		
1182	336	484	180	229	162	67	2	4	15	1		
1261	309	441	250	419	249	170	2	1	55	1		
1651	618	322	060	366	260	106	02	1	050	1		
11	30C	440	260	312	206	106	2	0	30	1	25	75
41	340	285	375	553	248	305	2	1	001	1		75
61	713	197	90	201	151	50	2	3	100	1	15	75
113	43C	21C	36C	163	129	34	2	4	25	1	200	75
3011	690	280	30	199			2		25	1		75
423	78C	14C	80	213			2	3	30	1		75
442	57C	37C	60	323			2	3	70	1	4	75
621	630	220	150	253	149	104	2		20	1	1000	75
672	47C	290	240	319	174	145	2	3	200	1	6	75
673	360	340	30C	286	209	77	2	1	200	1	6	75
831	530	380	90	220			2	1	17	1	800	75
851	630	270	100	221	142	79	2	4	20	1	500	75
922	520	340	140	424	268	156	2	2	35	1		75
963	400	380	220	406	226	180	2		30	1		75
1001	810	120	70	337	197	140	2	1	15	1		75
1012	390	320	290	348	244	104	2		100	1		75
1321	610	270	120	255	169	86	2	2	45	1	20	75
1351	670	210	120	265	168	97	2	1	55	1		75
21	320	430	250	316	203	113	2	4	25	1	150	75D
81	360	41C	23C	258	15C	1C8	2		80	1		75L
201	325	415	260	336	206	130	2	2	200	1	6	75L
0068							2		14	1	101	
0195							2		78	1	10	
0196							2		76	1	16	
0197							2		37	1	12	
0198							2		55	1	14	

TITLE = INTERMEDIATE TILL STABILITY CLASS 2

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
1161	426	414	16C	252	195	57	2	3	65	2		
791	540	410	50	247			2	2	20	2	1000	75
812	380	450	170	344	246	98	2		35	2	2000	75
1271	26C	30C	44C	501	233	268	2	4	45	2		75
1352	320	420	260	354	206	148	2	1	55	2		75
152	700	26C	40	186	161	25	2		85	2		75D
92							2	0	20	2	300	75
0194							2		54	2	18	
0232							2		33	2	20	

TITLE = INTERMEDIATE TILL STABILITY CLASS 3

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
911	558	292	150	291	189	102	2	1	40	4		
1883	334	476	190	223	164	59	2		35	4		
132	250	390	36C	452	221	231	2	1	30	3		75
211	505	250	245	304	194	110	2	3	20	3	400	75
631	34C	38C	28C	432	196	236	2		80	3	4	75
632	580	330	90	217	160	57	2	2	30	3		75
633	66C	26C	80	211	157	54	2	1	30	3		75
0231							2		35	3	16	
0233							2		32	3	16	

TITLE = INTERMEDIATE TILL NO STABILITY CLASS DATA

SMPL	SND	SLT	CLY	LCL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
211	800	100	100	213	179	34	2	4				
261	542	248	210	287	174	113	2	3				
662				251	203	48	2					
943	586	284	130	233	142	91	2	3				
1122	524	386	90	216	222		2	3				
1262	298	412	29C	362	225	137	2					
1412	581	229	190	223	151	72	2	2				
1561	36C	410	230	373	301	72	2					
1852	72C	21C	70				2	3				
111	530	330	140	220	162	58	2	4		0		75
301	450	290	260	344	198	146	2	3				75
481	27C	46C	27C	274	194	80	2					75
911	295	435	270	320	206	114	2	4	20			75
13	34C	35C	310	519	190	329	2					75D
41	270	560	170	330	223	107	2					75D
101	530	277	200	250	165	85	2	3				75L
131	76C	16C	8C				2	4				75L

TITLE = NEW TILL STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
91	573	367	60				1	4	0	1	
101	738	161	100	220	137	83	3	4	60	1	
111	424	496	80	244	210	34	3	4	0	1	
112	577	303	120	203	169	34	3	4		1	
122	416	464	120	351	200	151	1	4	34	1	
151	590	340	70	305	261	44	3	4		1	
271	590	320	90	185	186		3	4	10	1	
311	665	205	130				3	3		1	
352	530	290	180				3	4	40	1	
381	707	188	105	216	139	77	3	4	50	1	
382	663	217	120	206	167	39	3	4	75	1	
391	650	260	90	218	174	44	3	4	200	1	
401	372	458	170				3	4	0	1	
402	743	147	110				3	4	045	1	
411	815	115	070				3	4	0	1	
431	233	537	230	276	236	40	3	4	35	1	
452	420	340	240	280	158	122	1	2	0	1	
471	480	310	210	244	151	93	3	2		1	
571	670	220	110	290	226	64	3	3	40	1	
572	360	360	180	302	204	98	3	3		1	
651	635	235	130	229	174	55	1	3	70	1	
681	504	336	160	333	213	120	1	2	60	1	
741	751	199	50	192	174	18	3	4	60	1	
752	512	388	100	414	353	61	3	4	60	1	
872	486	414	100	282	222	60	3		70	1	
971	425	345	230	187	134	53	3	4	100	1	
1011	627	273	100	159	147	12	3	4	200	1	
1022	400	350	250				3	3	60	1	
1023	674	236	090				3	3	30	1	
1032	282	428	290	200	155	45	3	4	80	1	
1041	604	326	70	434	362	72	3	4		1	
1042	865	075	060				3	4	200	1	
1051	379	351	270	320	220	100	3	4	80	1	
1081	709	191	100	285	232	53	3	4	50	1	
1091	539	361	100	135	118	17	3	4	200	1	
1251	493	337	170	281	209	72	3	4	0	1	
1291	462	388	150	304	236	68	3	4	40	1	
1321	722	238	40	413	354	59	3	4		1	
1372	711	244	045				3	4	100	1	
1422	93	427	48	381	2 7	174	3	4	20	1	
1432	288	392	320	384	202	182	03	4	000	1	
1472	382	498	120	187	148	039	03	4	000	1	
1481	154	466	380	335	198	137	03	3	000	1	
1482	132	588	280				3	4	10	1	
1491	69	451	480				3	4	60	1	

1521	354	366	280	183	113	070	03	4	075	1		
1531	368	442	190	231	169	C62	3		75	1		
1702	367	423	210	309	222	087	03	4	050	1		
1822	283	437	28C	244	191	C53	C3	0	060	1		
1891	375	415	210	226	123	103	3	4	80	1		
1892	214	556	230				3	4	065	1		
1902	735	200	065				3	4	100	1		
1911	471	399	130	219	153	66	3	4	40	1		
1912	621	289	9C	131	97	34	3	4	50	1		
1951	475	335	190	264	151	113	3	4	35	1		
1983	465	375	160				3	3	40	1		
2021	45C	29C	26C	333	197	136	3	4	85	1		
2022	488	302	210	314	209	105	3		90	1		
2032	607	263	130	263	221	42	3	4	60	1		
2041	626	294	80				3	4	40	1		
2042	562	358	80	160	154	6	3	4	70	1		
2081	397	353	25C	254	146	1C8	03	0	055	1		
2091	504	346	150				03	0	040	1		
2092	264	416	320	331	150	181	3	3	45	1		
2101	50C	37C	13C	257	204	53	3	2	85	1		
52	625	220	155	233	153	80	3	4	100	1	30	75
62	360	47C	170	131			3	4	60	1	15	75
102	440	350	210	182	125	57	3	4	100	1		75
103	440	415	145	165			3	4	200	1	100	75
141	445	405	15C	17C			3	0	65	1		75
151	450	390	160	284	23C	54	3	4	60	1	15	75
182	3	387	61C	144			3	4	50	1	40	75
3023	68C	28C	4C				3		68	1		75
321	880	50	70				3	3	60	1		75
331	750	195	55	330	241	89	3	4	18	1		75
382	480	38C	140	284	212	72	3		60	1		75
383	660	250	90	197	172	25	3	4	70	1		75
451	715	215	70				3		50	1		75
482	440	360	200	335	24C	95	3		30	1		75
492				282	208	74	3	4	30	1	3	75
503	46C	330	21C	23C	126	104	3	4	60	1		75
531	210	465	325	395	199	196	3	4	30	1		75
571	305	390	305	371	187	184	3		40	1	70	75
572	445	365	190	347	210	137	3	4	70	1		75
593	340	480	180	233	187	46	3		45	1	8	75
622	490	41C	10C	211			3	4	30	1		75
662	560	26C	180	214	124	90	3	4	70	1	25	75
692	655	270	75	167			3	2	40	1	30	75
701	79C	160	5C	174	118	56	3	4	70	1	15	75
732	380	340	280	288	169	119	3	3	81	1	10	75
783	540	400	60	274	167	107	3	2	30	1		75
821	760	220	2C				3	4	25	1	1000	75
962	570	310	120	216	155	61	3	2	70	1	20	75
981	305	39C	305	345	206	139	3		25	1		75
982	647	268	85	228			3	3	30	1	300	75
993	330	330	340	403	314	89	3		100	1		75
1022	340	40C	26C	330	184	146	3		30	1		75
1031	185	515	300	408	232	176	3		100	1	4	75
1032	390	45C	160	367	233	144	3	4	40	1		75

1161	43C	350	220	194	137	57	3	4	45	1	8	75
1201	780	180	40	221	184	37	3		72	1	15	75
1211	410	330	260	238	160	78	3	2	58	1		75
1241	76C	20C	40	284	214	70	3	2	55	1	10	75
1251	530	340	130	248	168	80	3	4	42	1		75
1281	360	390	250	278	180	98	3	4	55	1		75
1342	410	35C	240	282	181	101	3	4	55	1	200	75
1343	550	370	80	348	262	86	3	4	60	1		75
1372	53C	350	120	171	136	35	3	4	30	1	30	75
51	275	435	290	303	185	118	3		30	1		750
0003							3		70	1	12	
0004							3		15	1	300	
0006							3		42	1	19	
0007							3		75	1	11	
0008							3		21	1	100	
0009							3		70	1	21	
0012							3		39	1	100	
0017							3		68	1	36	
0018							3		12	1	100	
0021							3		9	1	100	
0028							3		58	1	75	
0085							3		35	1	40	
0091							3		28	1	80	
0166							3		19	1	16	
0191							3		32	1	27	
0192							3		50	1	30	
0217							3		8	1	500	
0240							3		37	1	24	

TITLE = NEW TILL STABILITY CLASS 2

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
11	541	339	120				3	4		2		
171	690	230	80	168	167	1	3	4	35	2		
361	525	365	11C	249	222	27	3	2	10	2		
1002	739	171	90	277	195	82	3	1	15	2		
1361	340	385	275	360	239	121	3	3	25	2		
1431	287	463	250	371	249	122	3	2	25	2		
1492	067	463	470	426	218	208	3	4	60	2		
1532	792	148	6C	177	127	50	3	4	75	2		
1723	513	367	120	185	155	030	3	4		2		
1771	643	297	060				3	4	50	2		
1801	512	398	09C	185	163	022	3	3	75	2		
1901	405	335	260				3	4	065	2		
1913	404	346	250	257	124	133	3	4	90	2		
1953	361	429	21C	307	182	125	3	4	80	2		
2011	168	572	260	426	221	205	3	3	50	2		
2062	49	671	280	287	159	128	3	4	50	2		
73	510	30C	190	252	153	99	3	3	80	2	100	75
441	620	310	70	146			3		40	2	40	75
541	625	265	11C	191	146	45	3	4	70	2	30	75

721	420	360	220	215	166	49	3	3	50	2	40	75
1072	465	345	190	205	127	78	3		66	2		75
1081	915	55	30	245	169	76	3	4	50	2		75
1171	240	480	280	342	193	149	3		32	2		75
1203	420	420	160	160			3	4	85	2		75
1381	470	470	60	229			3		45	2		75
0002							3		65	2	45	
0073							3		44	2	12	
0074							3		78	2	25	
0086							3		38	2	36	
0088							3		36	2	32	
0089							3		41	2	31	
0090							3		31	2	45	
0094							3		32	2	43	
0158							3		38	2	31	
0186							3		36	2	58	
0242							3		33	2	45	
0247							3		35	2	29	

TITLE = NEW TILL STABILITY CLASS 3

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
1792	562	298	140				3	3	25	3		
2033	564	306	130	182	145	37	3	4	100	3		
551	200	600	200	214	181	33	3	3		4		
1612	366	374	260				3	1	75	4		
1842	484	286	230	264	144	120	3	4	50	4		
1922	583	417					3	4	50	4		
612	495	320	185	153	128	25	3	4	65	3		75
941	480	300	220	303	167	136	3	4	45	3		75
1101	360	360	280	300	211	89	3	3	36	4	10	75
0072							3		46	3	70	
0075							3		58	3	66	
0087							3		50	3	26	
0160							3		49	3	25	
0161							3		55	3	21	
0162							3		63	3	18	
0163							3		72	3	15	
0164							3		68	3	27	
0165							3		42	3	31	
0187							3		46	3	11	
0188							3		150	3	7	
0190							3		38	3	69	
0193							3		47	3	36	

TITLE = NEW TILL NC STABILITY DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
32	533	367	100	429	324	105	3	4	100			
41	482	328	190	222	173	49	3	4				
172	6C8	282	110	258	179	79	3	4				
212	612	298	9C	352	250	102	3	4				
322	183	547	270	330	231	99	3	4				
342	472	348	180	291	173	118	3	1				
351	773	162	065				3	4				
482	563	297	140	238	122	116	3	2				
532	767	163	7C	461	415	46	3	3				
591	414	456	130	199	175	24	3	3			SHIST TILL	
772	650	290	60	282	228	53	3	1			SHIST TILL(?)	
782	589	361	5C	285	212	73	3	1			SHIST TILL	
791	854	126	20				3	1				
852	501	409	9C	189	126	63	3	4				
932	859	111	30				3	3				
1171	513	367	12C	139	126	13	3	3				
1232	55	545	400	475	247	228	3	4				
1362	595	294	110	199	166	33	3					
1571	400	360	240	331	166	165	3	4				
1621	822	148	030				3	4				
1761	404	506	090	757	702	055	3	4				
1831	792	158	C5C				3	4				
1862	320	28C	200				3	3				
2102	302	398	300	301	183	118	3	4				75
181	63C	18C	190	210			3	4				75
202	730	220	50				3	4				75
303	66C	320	020	444	304	140	3					75
3022	77C	23C	0C				3					75
341	550	320	130	507	357	150	3					75
362	56C	350	90	146			3	4				75
421	660	280	60	442	361	81	3	4	15			75
432	620	280	100	111			3					75
491	190	335	475	44C	226	214	3	4				75
611	130	500	370	323	193	130	3		60			75D
111	240	37C	390	480	247	233	3					75D
151	89C	70	40				3		75			75L
151				222	183	39	3	4				75
511	470	450	80	283	217	66	3					

TITLE = MIXED TILL STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
3012	710	270	20	213			15	4	50	1		75
391	340	390	270	243	178	65	15	4	40	1	20	75
401	230	360	410	412	325	87	15	4	25	1	1000	75
713	650	260	90	245	180	65	15	2	30	1		75
991	390	305	305	303	181	122	15		100	1		75
992	430	280	290	408	195	213	15		100	1	6	75
1021	420	310	270	403	189	214	15		15	1		75

TITLE = MIXED TILL STABILITY CLASS 2

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
1371	630	230	140	217	152	65	15	2	40	2		75

TITLE = MIXED TILL STABILITY CLASS NO DATA

971	350	410	240	279	155	124	15		75
61	370	360	270	300	152	142	15	3	750
71	150	460	390	347	177	170	15		750
81	550	260	190	192	125	67	15		750
102	340	410	250	319	177	142	15		75J

TITLE = CONTINENTAL TILL STABILITY CLASS NO DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
1392	400	390	211	367	207	160	16					75
101	410	360	230	153	146	7	16		35		30	75J
1401	420	430	150				16					75

TITLE = COLLUVIUM STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB		LENGTH	
31	632	318	50	351	304	47	4	1	60	1	V		
241				335	295	40	4		35	1			
213	366	464	17C	3C9	203	106	4	1	40	1	V		
242	585	285	130	297	246	51	4		0	1			
481				355	305	50	4	1	60	1	V		
492				238	220	18	4	1	100	1			
561	745	135	120	333	231	102	4	1		1			
592	379	481	140	299	173	126	4	3	100	1			
722	645	335	20				4	1	45	1			
742	538	352	110	262	245	17	4	1	0	1			
743	535	395	70	259	229	30	4	1	0	1			
811	529	321	150	316	205	111	4	1	35	1	V		
812				307	250	57	4	1	0	1			
821	862	98	40	331	243	88	4	1	12	1			
822	726	234	40	233	219	14	4	1	55	1			
833	630	345	025				4	1	0	1			
851	513	480	70				4	3	3	1			
882	280	640	80				4	1	45	1			
891	69C	240	7C	303	266	37	4	1	60	1	V		
893	562	348	90				4		0	1			
952	214	556	230	263	232	31	4	3	55	1			
1001	760	190	50	262	219	43	4	1	70	1	V		
1092	517	403	80	248	223	25	4	1	34	1			
1111	345	375	28C	26C	195	65	4	1	70	1			
1191	522	398	80	293	265	28	4	1	60	1			
1222	323	517	160	288	205	83	4	1		1			
1231	298	392	310	398	230	168	4	1	8	1			
1311	482	428	90				4	1		1			
1322	441	429	130				4	1	5	1			
1331	465	395	14C				4	1	041	1			
1501	256	534	210	247	182	065	4	4		1			
1541	628	312	060	272	242	030	4		65	1			
1581	504	346	150	273	241	C32	4	1		1			
1711	648	282	070	214	169	045	4	1	60	1	V		
1882	525	245	23C				4		35	1			
1963	610	270	120				4	1	80	1			
2071	57C	320	110				4	1	55	1			
2072	77C	19C	040				04	1	050	1			
191	800	150	50	261	206	55	4	1	70	1		15	75
363	82C	160	20	205			4	4		1			75
381	575	285	14C	386	325	61	4		60	1			75
402	820	140	40	296	166	130	4	2	55	1			75
472	79C	16C	5C	204	192	12	4		100	1			75
542	590	260	150	417	257	160	4	1	30	1			75

581	57C	300	130	255	153	1C2	4		30	1	60	75
591	340	610	50	321			4	4	20	1		75
592	905	60	35				4		30	1		75
711	600	275	125	397	273	124	4	1	50	1		75
712	440	400	160	308	207	101	4	1	30	1	500	75
741	500	370	130	249	213	36	4	1	18	1	2000	75
742	46C	41C	130	256			4		35	1		75
743	785	195	20	260			4	1	62	1		75
892	490	355	155	240	160	80	4		70	1		75
901	790	185	25	368			4	4	30	1	1000	75
912	770	180	50	229			4		60	1	1000	75
961	795	19C	15	38C			4	1	30	1	1000	75
1231	900	80	20				4		45	1		75
1242	44C	39C	170	113	102	11	4		100	1		75
181	58C	37C	50	295	197	98	4	4	80	1		75L

TITLE = COLLUVIUM STABILITY CLASS 2

SMPL	SND	SLT	CLY	LOL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
432	68C	230	90	255	178	77	4	2	22	2		
802	284	536	180	302	222	80	4	1	40	2		
1312	582	288	130				4	1	23	2		
1391	569	371	60	326	290	36	4	1	20	2		
1401	918	067	C15	237	24C	000	4	1	20	2		
1864	471	419	110				4	2	45	2		
91	43C	37C	200	418	237	181	4	1	25	2	600	75
671	750	220	30	250	193	67	4		55	2		75
693	750	17C	80	228	150	78	4	1	70	2	50	75
731	840	150	10	418	331	87	4	1	40	2		75

TITLE = COLLUVIUM STABILITY CLASS 3

SMPL	SND	SLT	CLY	LCL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
301	565	260	175	323	251	72	4	1	32	3		
303	728	187	085				4	1	32	3		
871	253	637	110	277	227	50	4	1	50	3		
321	14C	500	360				4	0	010	4		
1411				269	224	45	4	1	20	4		
1713	536	384	080	205	185	020	4	3	25	4		
192	410	240	350	370	202	168	4	1	50	3	400	75

TITLE = COLLUVIUM STABILITY CLASS NO DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
292	480	400	120	267	241	26	4	1				
313	110	440	450	714	368	346	4					
371	745	205	50	589	328	261	4					
392				330	290	40	4					
421	808	142	050				4	1				
531	406	544	50				4	1				
601	300	550	150	407	239	168	4	1				
781	364	546	90	442	381	61	4	1				
832	354	466	180	365	268	97	4	1				
861	568	382	50	209	187	22	4	1				
1021	520	320	160	271	176	95	4	3				
1101	832	128	40	245	203	42	4	1				
1102	532	358	110				4	1				
1332	873	082	045				4	4				
1451	749	211	040				4					
1582	608	282	110				4					
1611	902	098	000	342	293	049	4					
1712	326	554	120				4	1				
1851	286	484	230				4	1				
112	770	230	00	610			4	4		0		75
161	600	310	90	287			4	1				75
183	985	15	00	294			4	0				75
241	710	180	110	338	254	84	4	1				75
3031	940	60	00				4					75
361	850	140	10	278			4					75
411	980	20	00				4	2	15			75
412	500	400	100	280			4	2	40			75
422	730	210	60	345			4		100			75
452	465	470	65	396			4					75
461	820	160	20				4	4				75
552	670	225	105	291	221	70	4		70			75
601	870	120	10	325	251	74	4	2	26		1000	75
691	765	195	40	380	271	109	4	1				75
781	620	300	80	472	337	135	4		15		1000	75
782	870	130	00				4					75
891	980	20	00				4		45			75
131	600	250	150	431	258	173	4					75D
121	805	135	60				4					75L

TITLE = WEATHERED BEDROCK STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
131	570	250	180	250	156	94	13	1	45	1	4	75
171	800	180	20	196			13	1	70	1	30	75
172	81C	10C	90	282			13	1	30	1	100	75
201	670	230	100	348	210	138	13	1	20	1		75
212	715	235	50				13		70	1		75
291	705	205	90	352	268	84	13	1	40	1		75
512	905	80	15	421	281	140	13	2	40	1		75
521	270	31C	42C	565	291	274	13		30	1		75
871	540	360	100	409	282	127	13	1	30	1		75
881	870	120	10				13	4	20	1	1000	75
0221							13		58	1	20	
0226							13		55	1	17	
0239							13		41	1	19	
0248							13		37	1	133	

TITLE = WEATHEREC BEDROCK STABILITY CLASS 2

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
722	310	520	170	204			13		50	2	40	75
751	750	200	50	370	278	92	13		30	2	10	75
1141	690	250	70				13		35	2		75
1221	560	290	150	340	218	122	13		45	2		75
231				260	190	70	13		50	2		75L
683	54	526	420				13		15	2		75
0105							13		37	2	52	
0205							13		48	2	62	
0218							13		125	2	6	
0222							13		47	2	26	
0223							13		45	2	34	
0229							13		66	2	30	
0235							13		29	2	60	
0237							13		28	2	55	
0238							13		29	2	43	
0249							13		51	2	65	

TITLE = WEATHERED BEDROCK STABILITY CLASS 3

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
1073	715	250	35	292	228	64	13		62	3	20	75
0203							13		44	3	36	
0204							13		44	3	39	
0206							13		52	3	51	
0207							13		82	3	8	
0208							13		54	3	28	
0216							13		68	3	41	
0234							13		31	3	24	
0236							13		28	3	54	
0241							13		31	3	37	
0243							13		59	3	10	
0244							13		40	3	57	

TITLE = WEATHERED BEDROCK STABILITY CLASS NO DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
162	740	190	70	386	266	120	13	0	8			75
222	420	260	320	473	253	220	13					75
302	425	395	180	296	218	78	13	2				75
311	660	310	30	488	378	110	13					75
332	860	130	10	376			13					75
373	920	70	10				13					75
502	845	155	00	267			13					75
551	330	670	00	955			13					75
651	330	490	180	415	283	132	13	1				75
653	575	275	150	270	213	57	13					75
661	980	20	00				13					75
823	920	80	00				13					75
841							13					75

TITLE = LACUSTRINE MATERIALS STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
331	375	410	215				5	1	0	1		
1263	5	635	360	358	248	110	5	2	0	1		
31	30	410	560	590	216	374	5	0	53	1		75
872	80	340	580	455	236	219	5		10	1		75
1341	180	310	510	557	251	306	5		20	1	20	75
52	300	360	340	366	184	182	5		35	1		75D
82	20	450	530	562	297	265	5		50	1		75L
0093							5		3	1	1000	
0095							5		4	1	300	
0096							5		2	1	600	
0099							5		25	1	13	
0100							5		16	1	28	
0101							5		23	1	24	
0108							5		30	1	21	
0110							5		43	1	17	
0111							5		31	1	22	
0113							5		29	1	23	
0114							5		42	1	19	
0115							5		33	1	18	
0116							5		22	1	50	
0123							5		43	1	52	
0126							5		30	1	25	
0143							5		28	1	22	
0147							5		29	1	35	
0148							5		25	1	25	
0149							5		27	1	26	
0150							5		6	1	100	
0152							5		37	1	12	
0157							5		7	1	300	
0159							5		42	1	16	
0167							5		16	1	200	
0171							5		23	1	11	
0173							5		64	1	11	
0175							5		33	1	38	
0179							5		39	1	12	
0183							5		30	1	16	
0184							5		29	1	14	
0185							5		13	1	300	

TITLE = LACUSTRINE MATERIALS STABILITY CLASS 2

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
901	215	465	320	357	226	131	5		40	2		
1421				444	239	205	5	3	20	2		
1002	120	590	290	471	325	146	5		20	2	100	75
1091	70	490	440	384	204	176	5		60	2	15	75
0092							5		42	2	23	
0097							5		29	2	28	
0098							5		28	2	27	
0102							5		37	2	22	
0103							5		35	2	29	
0107							5		30	2	28	
0109							5		41	2	27	
0112							5		28	2	35	
0125							5		37	2	43	
0129							5		30	2	17	
0130							5		38	2	27	
0135							5		25	2	14	
0136							5		40	2	44	
0144							5		29	2	27	
0146							5		27	2	34	
0155							5		27	2	16	
0156							5		44	2	14	
0168							5		41	2	26	
0170							5		49	2	17	
0172							5		72	2	12	
0176							5		43	2	16	
0177							5		32	2	14	
0178							5		24	2	16	
0180							5		48	2	17	
0181							5		42	2	19	
0199							5		50	2	12	
0200							5		49	2	13	
0201							5		48	2	11	
0202							5		47	2	21	
0210							5		50	2	10	
0211							5		45	2	10	
0213							5		58	2	16	
0219							5		36	2	13	
0220							5		40	2	13	
0224							5		53	2	12	
0253							5		49	2	25	

TITLE = LACUSTRINE MATERIALS STABILITY CLASS 3

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
1442	3	397	600	588	316	272	5		20	3		
192	8	472	510	411	199	212	5		20	4		
691	27	493	480	369	207	162	5	2	60	4		
1721	309	291	400	420	255	165	05	0	020	4		
1812	037	443	520	407	246	161	05	0	015	4		
1841	155	675	170	268	219	049	05	0	035	4		
1921	686	274	040				5		40	4		
1941	256	704	40				5			4		
771	180	500	320	513	319	194	5		15	3		75
1311	140	220	640	600	275	325	5		40	3	40	75
1331	280	700	20				5		22	3		75
1151	320	530	150	310	182	128	5		38	4		75
182	645	295	60	577	274	303	5		28	4	600	75L
0084							5		54	3	27	
0104							5		31	3	32	
0106							5		35	3	42	
0124							5		30	3	29	
0131							5		58	3	18	
0132							5		34	3	18	
0133							5		47	3	52	
0134							5		44	3	42	
0138							5		36	3	130	
0139							5		106	3	12	
0140							5		43	3	46	
0141							5		26	3	39	
0142							5		41	3	34	
0145							5		38	3	34	
0153							5		62	3	11	
0154							5		60	3	14	
0169							5		37	3	27	
0174							5		46	3	15	
0182							5		62	3	26	
0189							5		37	3	33	
0209							5		52	3	15	
0212							5		15	3	97	
0225							5		25	3	34	
0227							5		68	3	17	
0228							5		54	3	25	
0230							5		78	3	20	
0254							5		46	3	22	

TITLE = LACUSTRINE MATERIALS NO STABILITY CLASS DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
312	8	222	770	786	295	491	5	1			
341	8	612	380	608	344	264	5	1			
611	170	460	370	459	299	160	5				
732	482	418	100	247	203	44	5	1	15		
771	264	606	130	280	179	101	5	1			
1271	220	660	120	265	254	11	5	3			
1572	393	467	140	281	241	40	5				
1661	005	645	350	423	290	133	5				
351	130	550	320	404	217	187	5	2			75
772	30	570	400	470	220	250	5		17		75
1181	100	280	620	628	231	397	5				75

TITLE = ALLUVIUM STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
1543	854	146	000				7			1		
221	440	380	180	303	200	103	7					75L
652	790	170	40	343	262	81	7	1				75
0005							7		8	1	150	
0013							7		4	1	34	
0014							7		1	1	300	
0026							7		1	1		
0034							7		54	1	16	
0035							7		4	1	300	
0036							7		48	1	36	
0137							7		2	1	600	
0151							7		23	1	36	

TITLE = ALLUVIUM STABILITY CLASS 2

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
952	610	340	50	318			7	1	15	2	500	75

TITLE = ALLUVIUM STABILITY CLASS 3

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
1264	928	72					7			3	

TITLE = ALLUVIUM STABILITY CLASS NO DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
751	613	277	110	262	245	17	7	4			
892	805	195					7				
1731	975	025	000				7				

TITLE = ALLUVIAL FAN STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
372	625	275	10C	222	197	25	8	4	50	1		75
951	945	45	10				8	1	35	1	1000	75
0010							8		8	1	400	
0011							8		12	1	60	
0016							8		2	1	200	
0019							8		6	1	300	
0020							8		4	1	250	
0032							8		7	1	120	
0077							8		17	1	600	
0078							8		13	1	1000	
0079							8		21	1	800	
0080							8		11	1	500	
0081							8		17	1	800	
0082							8		6	1	800	
0083							8		8	1	600	

TITLE = ALLUVIAL FAN STABILITY CLASS 2

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
1471	727	273					8	4	50	2		
1542	927	073	000				08	0	065	2		
832	620	300	80	220	175	45	8	4	60	2	50	75

TITLE = ALLUVIAL FAN STABILITY CLASS NO DATA

SMPL	SND	SLT	CLY	LCL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
472	149	621	230				8					
491	540	400	060				8	1				
912	263	487	250				8					
1252	2CC	5CC	300				8		1			
1802	879	121	000				8					
71	850	90	60	204	153	51	8	4	70	0	100	75

TITLE = OUTWASH STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
721	970	30					9	2	5	1		
881	953	47					9		20	1		
1071	990	10					9	3	0	1		
1373	936	64					9	4	75	1		
1381	983	17					9	4		1		
1973	772	228					9	4	75	1		
2031	847	153					9	4	70	1		
681	890	100	10				9		30	1		75
682	845	85	70				9	2	40	1	50	75
811	800	130	70	319	213	106	9		55	1		75
1011	926	64	10	408			9		100	1		75
0015							9		70	1	42	
0022							9		55	1	63	
0023							9		65	1	53	
0024							9		86	1	85	
0025							9		66	1	53	
0027							9		82	1	50	
0029							9		68	1	38	
0030							9		6	1	200	
0031							9		58	1	45	
0033							9		48	1	46	
0037							9		65	1	60	
0038							9		53	1	100	
0039							9		1	1	500	
0040							9		2	1	500	
0041							9		17	1	83	
0042							9		17	1	140	
0043							9		19	1	61	
0044							9		4	1	200	
0045							9		18	1	31	
0046							9		36	1	15	
0047							9		63	1	21	
0048							9		49	1	42	
0049							9		1	1	250	
0050							9		52	1	44	
0051							9		1	1	1000	
0052							9		44	1	18	
0053							9		9	1	33	
0054							9		39	1	21	
0055							9		3	1	300	
0056							9		10	1	150	
0057							9		16	1	23	
0058							9		72	1	27	
0059							9		61	1	14	
0060							9		5	1	50	
0061							9		42	1	13	
0062							9		37	1	15	
0063							9		1	1	59	

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
0064							9		3	1	81
0065							9		14	1	17
0066							9		50	1	23
0067							9		21	1	24
0069							9		10	1	36
0070							9		58	1	16
0071							9		10	1	16
0076							9		34	1	20
0117							9		70	1	8
0118							9		7	1	200
0121							9		70	1	39
0122							9		32	1	41
0127							9		35	1	46
0128							9		31	1	64
0214							9		37	1	8
0245							9		35	1	120
0246							9		47	1	11
0250							9		19	1	53
0252							9		40	1	54
0255							9		58	1	16

TITLE = OUTWASH STABILITY CLASS 2

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
921	508	272	220				9	4	40	2		
931	987	13					9	4	60	2		
922							9		80	2		
923							9		60	2		
1071	340	530	130	184			9		45	2		75
0120							9		85	2	21	
0251							9		76	2	8	

TITLE = OUTWASH STABILITY CLASS 3

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
181	860	140					9	1	40	3	
0119							9		60	3	27
0215							9		40	3	36

TITLE = OUTWASH NO STABILITY CLASS DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
622	437	463	100				9	1			
951	914	86					9	1			
1141	771	149	80				9				
1162	967	33					9	3			
1272	992	8					9				
1352	993	7					9				
1622	965	035	000				9	4			
1642	547	453	000				9				
1652	971	029	000				9				
1671	972	028	000				9				
1722	944	056	000				9				
1781	313	687	000				9				
1861	812	128	60				9	4			
973	170	680	150	250	214	36	9				75

TITLE = LOESS STABILITY CLASS 1

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
752	62C	240	140	282	167	115	10		53	1	30	75

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH
12	901	89					10	3			
1641	588	C12	COC				10	0	000	4	

TITLE = AEOLIAN MATERIALS NO STABILITY CLASS DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
152	485	415	10C	213	231		6					
153	893	107					10					
1202	470	510	20				10					75

TITLE = VOLCANIC ASH STABILITY CLASS NO DATA

SMPL	SND	SLT	CLY	LQL	PLL	PLI	LITH	CRB	SLP	STAB	LENGTH	
241	266	414	320	355	185	170	11					75L

APPENDIX 2

SUMMARY OF STATISTICAL CORRELATIONS

MATERIAL: Young Till

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	50.0	18.98	91.2	180
Silt	33.5	11.05	62.1	180
Clay	16.5	----	61.0	180
Liquid Limit	27.3	9.47	64.6	145
Plastic Limit	19.7	7.19	60.5	132
Plastic Index	8.7	5.02	23.2	131

CORRELATIONS

(I) DIRECT	r	r^2	α	n
Liquid Limit and Plastic Limit	0.84	0.71	0.001	132
Clay and Plastic Index	0.69	0.47	0.001	129
Liquid Limit and Plastic Index	0.63	0.40	0.001	131
Silt and Clay	0.54	0.29	0.001	179

(II) INVERSE	r	r^2	α	n
Sand and Silt	-0.87	0.77	0.001	180
Sand and Clay	-0.87	0.76	0.001	179
Sand and Plastic Index	-0.59	0.34	0.001	129

MATERIAL : Intermediate Till

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	47.9	16.38	69.5	64
Silt	33.0	9.93	46.0	64
Clay	19.1	9.97	41.0	64
Liquid Limit	29.6	8.54	39.0	61
Plastic Limit	19.3	3.79	18.4	56
Plastic Index	11.0	6.51	31.2	55

CORRELATIONS

(I) DIRECT	r	r^2	α	n
Liquid Limit and Plastic Index	0.91	0.83	0.001	55
Liquid Limit and Plastic Limit	0.69	0.48	0.001	56
Clay and Plastic Index	0.61	0.38	0.001	54
Clay and Liquid Limit	0.61	0.38	0.001	60
(II) INVERSE	**r**	**r^2**	**α**	**n**
Sand and Clay	-0.82	0.68	0.001	64
Sand and Silt	-0.82	0.68	0.001	64
Sand and Liquid Limit	-0.54	0.29	0.001	60

MATERIAL : Old Till

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	48.9	14.70	71.0	120
Silt	33.4	9.11	40.9	120
Clay	17.7	9.33	51.5	120
Liquid Limit	30.3	7.19	34.2	105
Plastic Limit	19.7	-----	----	105
Plastic Index	10.4	6.06	33.2	105

CORRELATIONS

(I) DIRECT	r	r^2	α	n
Liquid Limit & Plastic Index	0.88	0.77	0.001	105
Clay and Plastic Index	0.77	0.59	0.001	103
Clay and Liquid Limit	0.71	0.50	0.001	103

(II) INVERSE	r	r^2	α	n
Sand and Clay	-0.80	0.64	0.001	120
Sand and Silt	-0.78	0.60	0.001	120
Sand and Plastic Index	-0.50	0.25	0.001	103

MATERIAL: Colluvium

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	60.2	20.17	87.5	108
Silt	30.0	14.82	62.5	108
Clay	9.8	8.09	45.0	108
Liquid Limit	31.4	9.13	60.1	82
Plastic Limit	23.5	5.28	27.9	68
Plastic Index	7.8	6.00	34.6	68

CORRELATIONS

(I) DIRECT	r	r^2	α	n
Liquid Limit and Plastic Index	0.83	0.68	0.001	68
Liquid Limit and Plastic Limit	0.77	0.59	0.001	68
Clay and Plastic Index	0.53	0.28	0.001	62
Silt and Clay	0.51	0.26	0.001	108

(II) INVERSE	r	r^2	α	n
Sand and Silt	-0.94	0.88	0.001	108
Sand and Clay	-0.78	0.61	0.001	108

MATERIAL : Lacustrine

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	18.4	17.88	68.3	34
Silt	46.9	14.04	48.4	34
Clay	34.7	20.05	75.0	34
Liquid Limit	44.7	12.95	53.9	31
Plastic Limit	24.8	4.52	16.5	31
Plastic Index	19.9	10.93	48.0	31

CORRELATIONS

(I) DIRECT	r	r^2	α	n
Liquid Limit and Plastic Index	0.94	0.89	0.001	31
Clay and Plastic Index	0.75	0.57	0.001	30
Clay and Liquid Limit	0.72	0.52	0.001	30
Liquid Limit and Plastic Limit	0.59	0.35	0.001	31

(II) INVERSE	r	r^2	α	n
Sand and Clay	-0.73	0.54	0.001	34
Silt and Plastic Index	-0.67	0.45	0.001	30
Silt and Liquid Limit	-0.58	0.34	0.001	30

MATERIAL Eolian (Includes Loess)

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	66.0			7
Silt	25.5			7
Clay	8.3			7
Liquid Limit	28.3			3
Plastic Limit	19.4			3
Plastic Index	9.5			3

CORRELATIONS

(I) DIRECT r r^2 α n

(II) INVERSE r r^2 α n

MATERIAL : Alluvium

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	75.2	18.21	53.5	8
Silt	20.1	12.47	35.5	8
Clay	4.7	----	18.0	8
Liquid Limit	30.7	3.40	8.1	4
Plastic Limit	23.6	3.20	6.2	3
Plastic Index	6.7	4.47	8.6	3

CORRELATIONS

(I) DIRECT	r	r^2	α	n
Silt and Clay	0.81	0.66	0.025	6

(II) INVERSE	r	r^2	α	n
Sand and Silt	-0.98	0.95	0.001	8
Sand and Clay	-0.92	0.84	0.005	6

MATERIAL: Alluvial Fan

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	61.1	29.37	79.6	11
Silt	29.0	19.51	57.6	11
Clay	9.9	----	30.0	11
Liquid Limit	21.5	0.99	1.8	3
Plastic Limit	17.5	2.20	4.4	3
Plastic Index	4.0	1.36	2.6	3

CORRELATIONS

(I) DIRECT	r	r^2	α	n
Clay and Plastic Limit	1.00	1.00	0.001	3
Silt and Clay	0.87	0.76	0.001	10
Sand and Slope	0.73	0.53	0.031	7

(II) INVERSE	r	r^2	α	n
Plastic Limit and Slope	-1.00	1.00	0.001	3
Sand and Liquid Limit	-0.99	0.99	0.038	3
Sand and Silt	-0.98	0.96	0.001	11
Sand and Clay	-0.94	0.89	0.001	10
Clay and Slope	-0.79	0.63	0.030	6

MATERIAL : Outwash

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	80.6	23.58	82.3	29
Silt	16.3	20.12	68.0	29
Clay	3.1	-----	22.0	29
Liquid Limit	29.0	9.5	22.4	4
Plastic Limit	21.4	0.07	0.1	2
Plastic Index	7.1	4.95	7.0	2

CORRELATIONS

(I) DIRECT	r	r^2	α	n

(II) INVERSE	r	r^2	α	n
Sand and Silt	-0.98	0.96	0.001	29
Clay and Liquid Limit	-0.92	0.84	0.042	4
Sand and Clay	-0.59	0.35	0.008	16

MATERIAL Volcanic Ash

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	26.6			1
Silt	41.4			1
Clay	32.0			1
Liquid Limit	35.5			1
Plastic Limit	18.5			1
Plastic Index	17.0			1

CORRELATIONS

(I) DIRECT r r^2 α n

(II) INVERSE r r^2 α n

MATERIAL : Weathered Bedrock

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	64.1	23.44	92.6	28
Silt	25.5	15.45	65.0	28
Clay	10.4	11.80	42.0	28
Liquid Limit	37.3	15.99	75.9	22
Plastic Limit	25.1	5.19	22.2	16
Plastic Index	12.0	5.71	21.7	16

CORRELATIONS

(I) DIRECT	r	r^2	α	n
Liquid Limit and Plastic Index	0.83	0.70	0.001	16
Liquid Limit and Plastic Limit	0.80	0.63	0.001	16
Clay and Plastic Index	0.74	0.55	0.001	15
Silt and Liquid Limit	0.52	0.27	0.008	21

(II) INVERSE	r	r^2	α	n
Sand and Silt	-0.90	0.80	0.001	28
Sand and Clay	-0.81	0.66	0.001	28
Liquid Limit and Slope	-0.60	0.36	0.012	14
Sand and Plastic Index	-0.50	0.25	0.028	15

MATERIAL : Mixed Till (Not Used In Report)

QUANTITY	MEAN	STD. DEV.	RANGE	NO. OF OBSERVATIONS
Sand	42.8	16.52	56.0	13
Silt	33.1	7.19	23.0	13
Clay	24.1	10.97	39.0	13
Liquid Limit	29.9	7.65	22.0	13
Plastic Limit	18.2	4.91	20.0	12
Plastic Index	12.3	5.55	14.9	12

CORRELATIONS

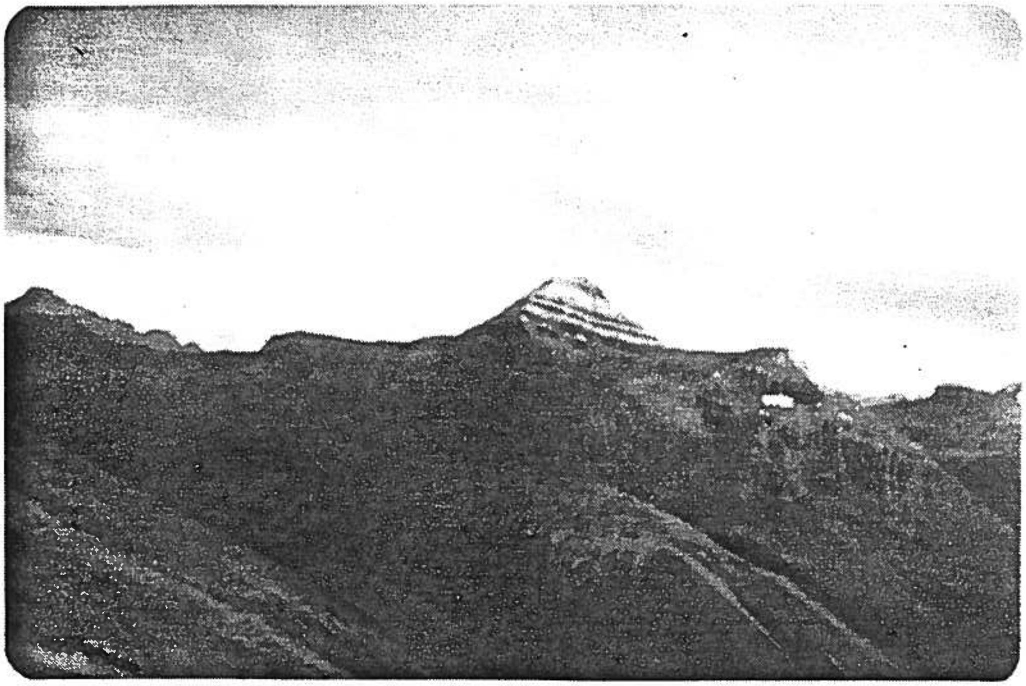
(I) DIRECT	r	r^2	α	n
Liquid Limit and Plastic Index	0.76	0.58	0.002	12
Clay and Liquid Limit	0.74	0.55	0.002	13
Liquid Limit and Plastic Limit	0.67	0.45	0.008	12
Silt and Clay	0.64	0.41	0.009	13
Clay and Plastic Limit	0.60	0.36	0.020	12

(II) INVERSE	r	r^2	α	n
Sand and Clay	-0.94	0.89	0.001	13
Sand and Silt	-0.86	0.74	0.001	13
Sand and Liquid Limit	-0.64	0.41	0.009	13

APPENDIX 3

PLATES 1 - 50

PLATE 1



THFR

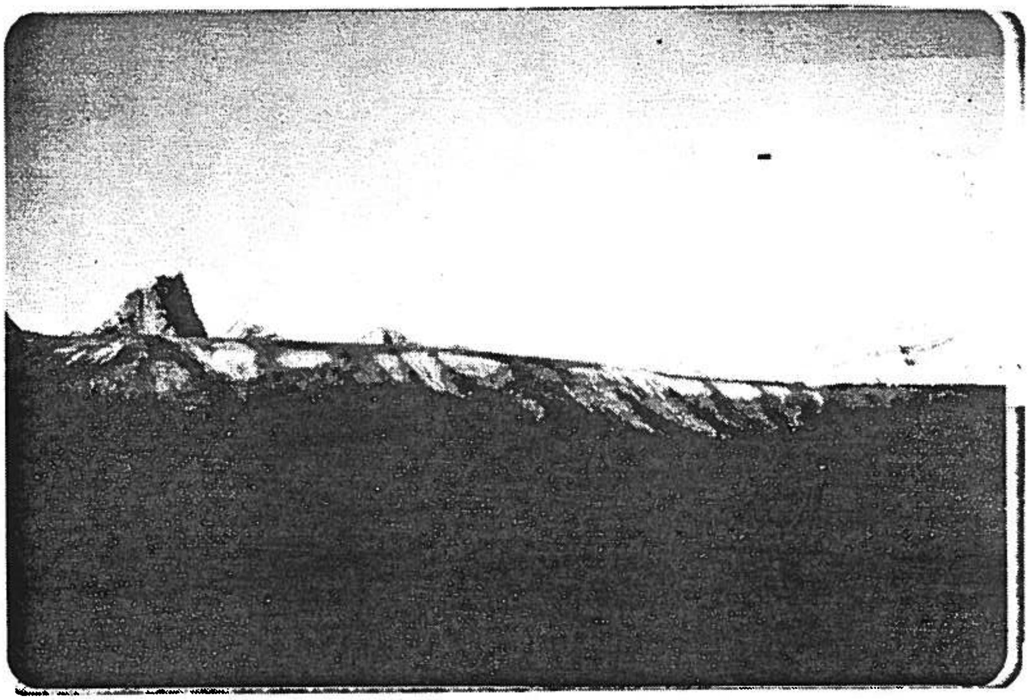
Mt. Aylmer (10,375 feet). Patterned ground (25) on tops of rounded mountains, talus cones (27) on slopes, bare rock (1) and colluvium (24). Twp. 27, Rge. 11, W5M.

PLATE 2

THFR

Vertical Foothill structure in Twp. 6, Rge. 1, W5M looking north towards Porcupine Hills.

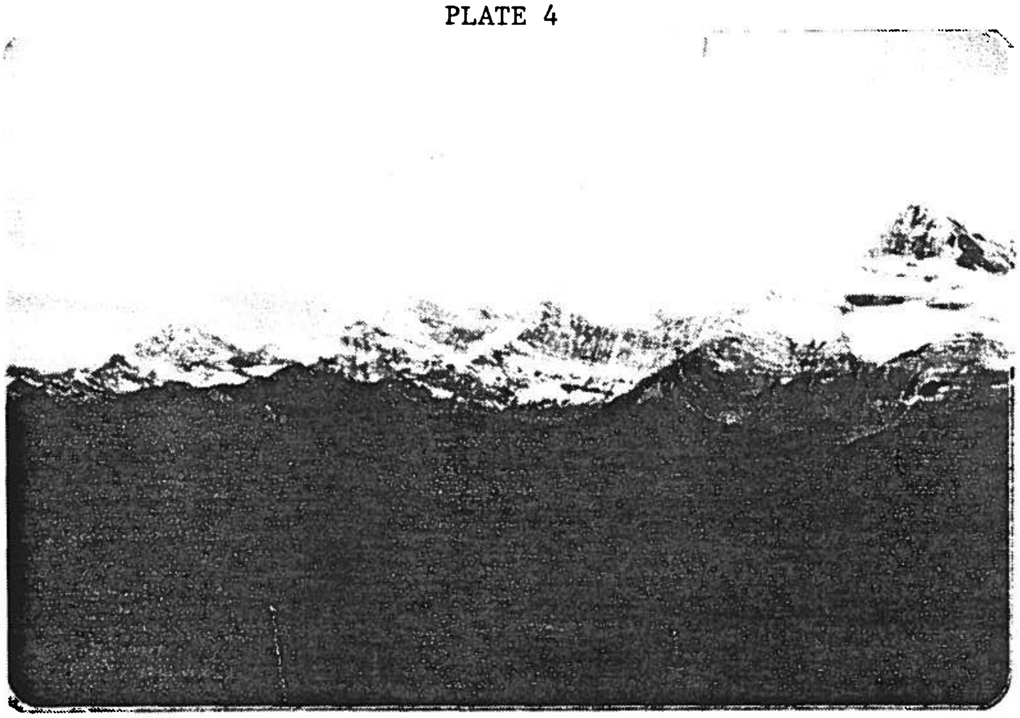
PLATE 3



THFR

Old till (3) on erosion remnant in inner Foothills. Old till is undergoing disturbance by frost action in Twp. 14, Rge. 6, W5M, west of Livingstone.

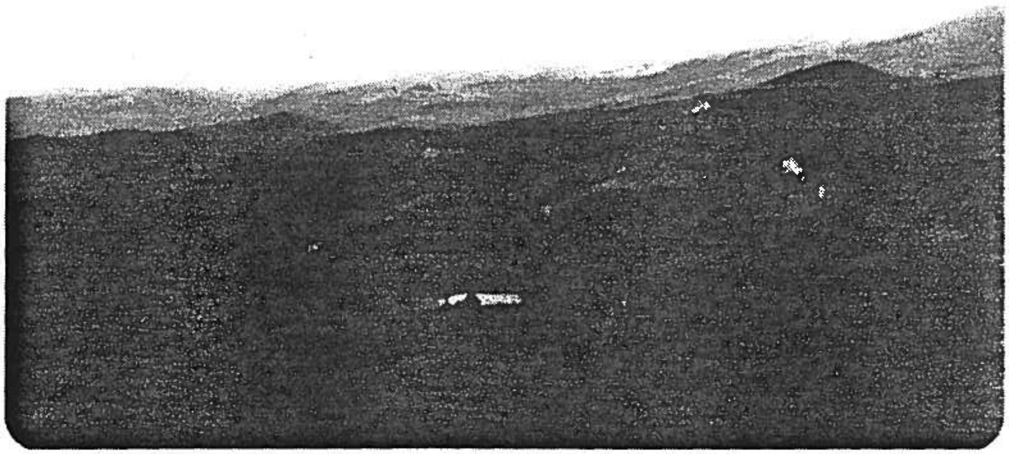
PLATE 4



THFR

View looking south from Coleman toward Flathead Range mountains. Intermediate mountain till (4) on level areas and colluvium (24) on slopes.

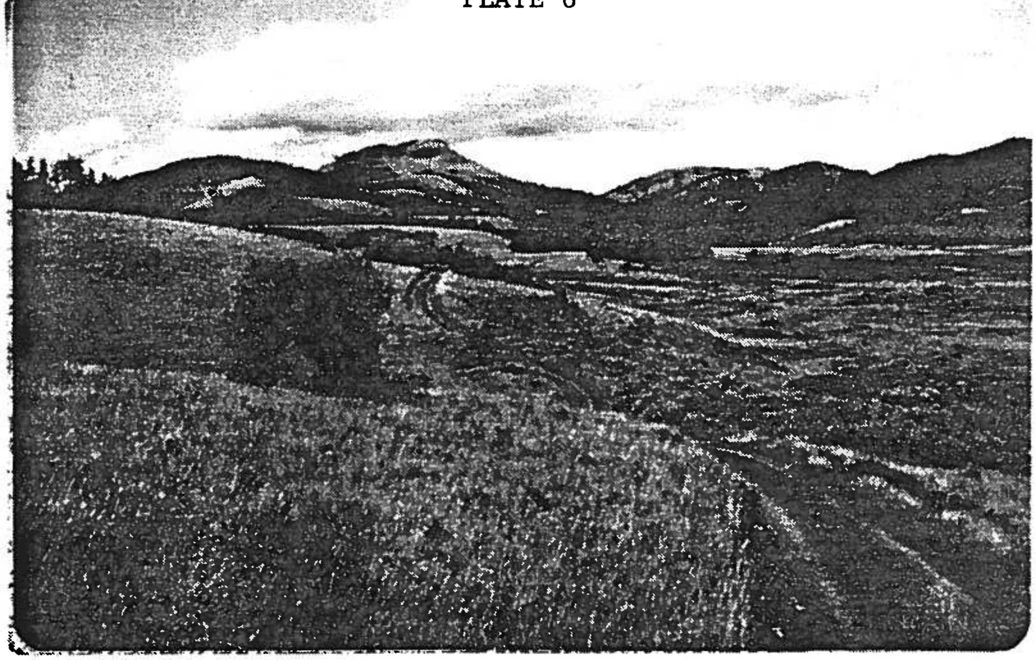
PLATE 5



LAB

Old till (3) and (4) near headwaters of Oldman River. Glacial sediments near the tops of the ridges, colluvium (24) on the slopes and bottom. Twp. 13, Rge. 5, W5M.

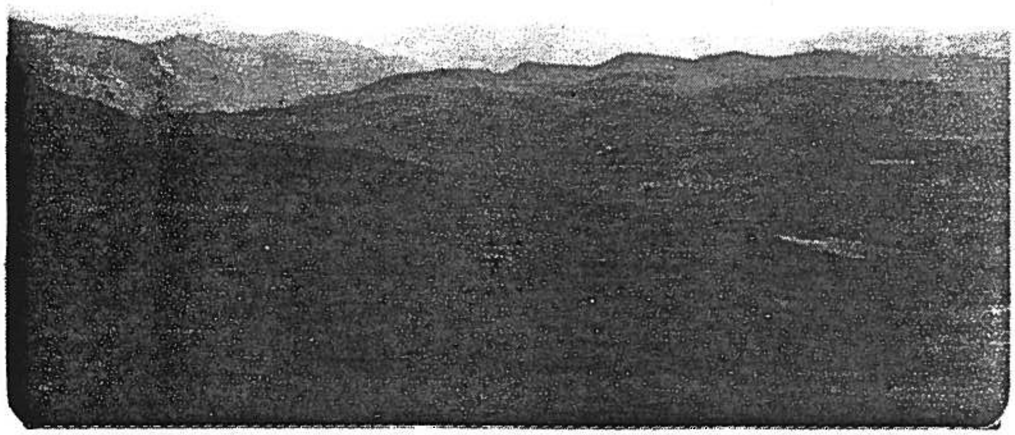
PLATE 6



LAB

View of "unglaciated area", material on hills is colluvium (24) over shale bedrock. About one foot of silty alluvium (22) in stream to right, west of Whaleback Ridge in Twp. 12, Rge. 2, W5M.

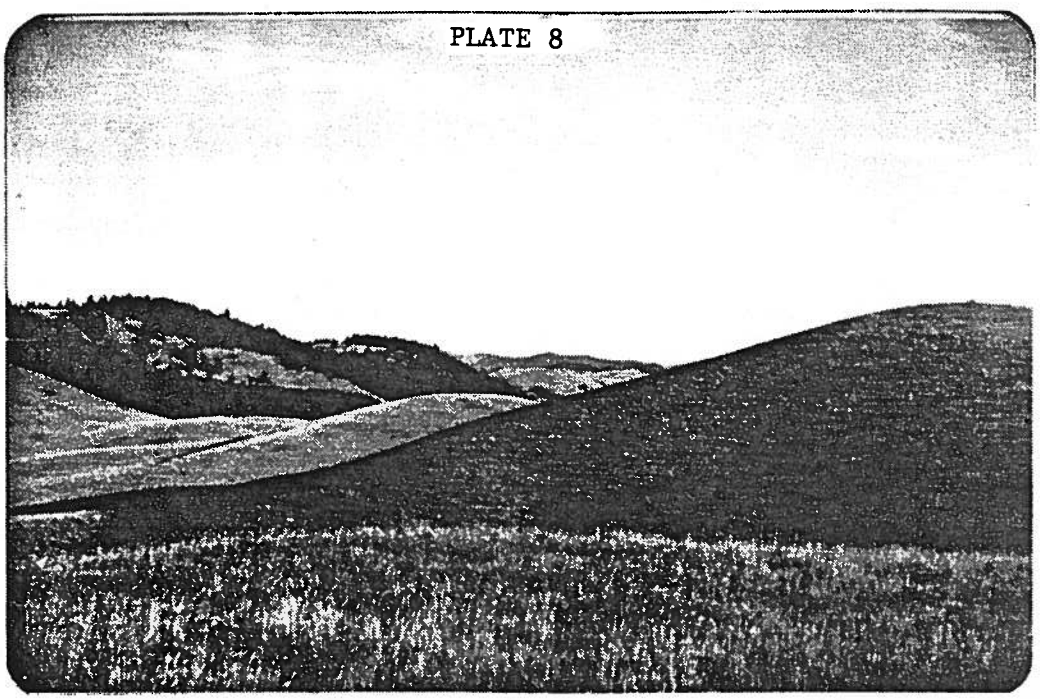
PLATE 7



THFR

Intermediate Till (4) on surface near Elbow River in Twp. 20, Rge. 6, W5M. Till is less than 5 feet in thickness and overlies bedrock.

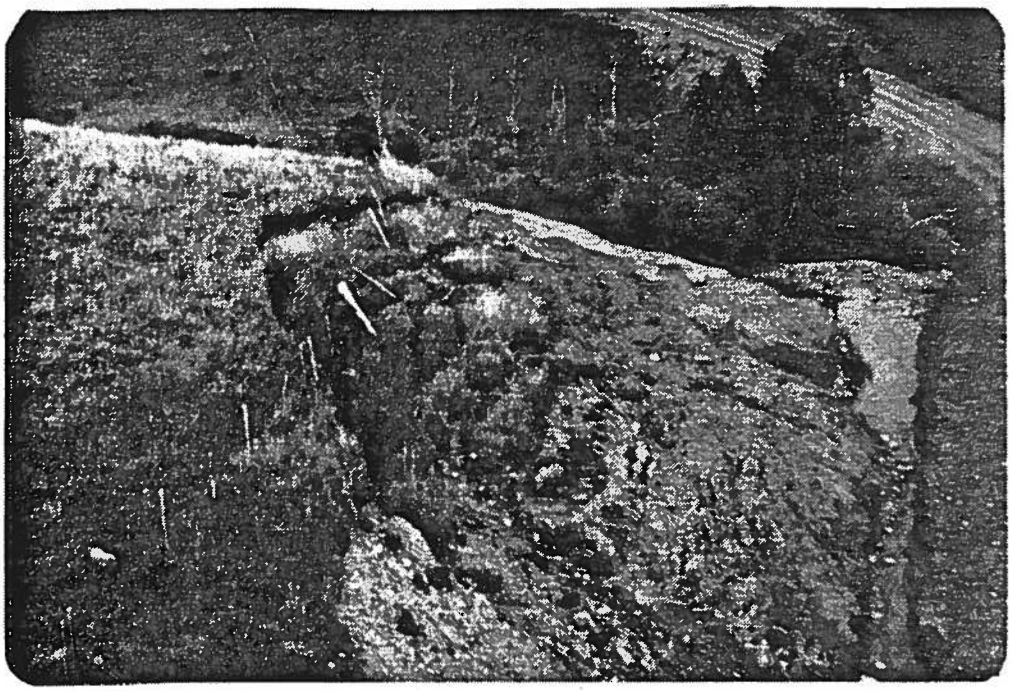
PLATE 8



THFR

Intermediate till (4) west of Whaleback ridge, Twp. 11 Rge. 2, W5M. Till is less than 5' thick and overlies bedrock.

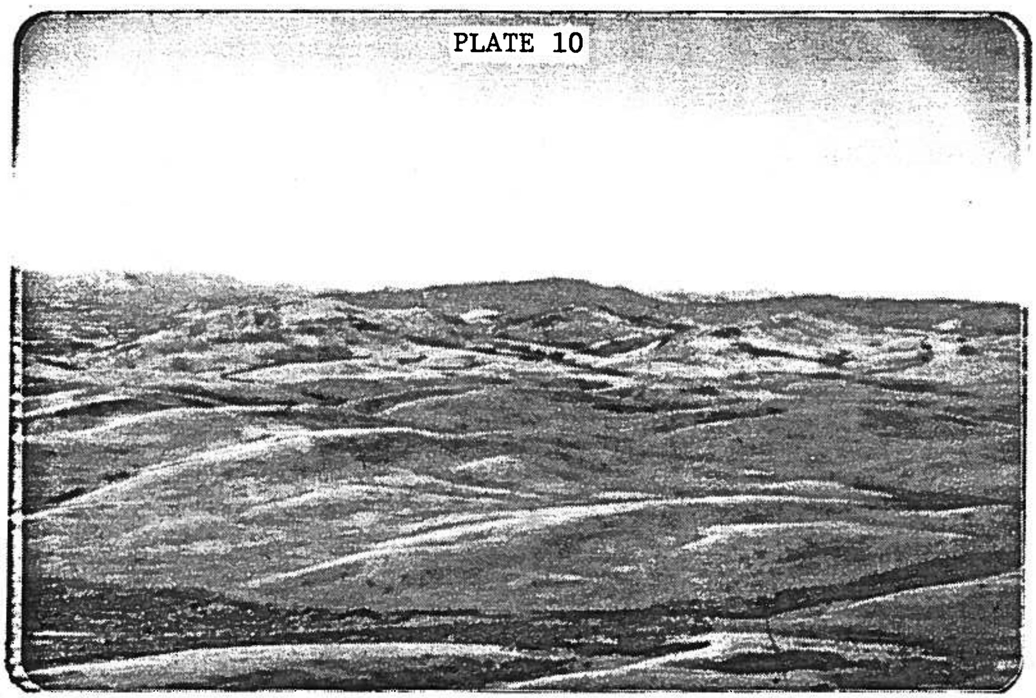
PLATE 9



THFR

Slumping (29) of Intermediate Continental till in the Oldman River near Cowley.

PLATE 10



LAB

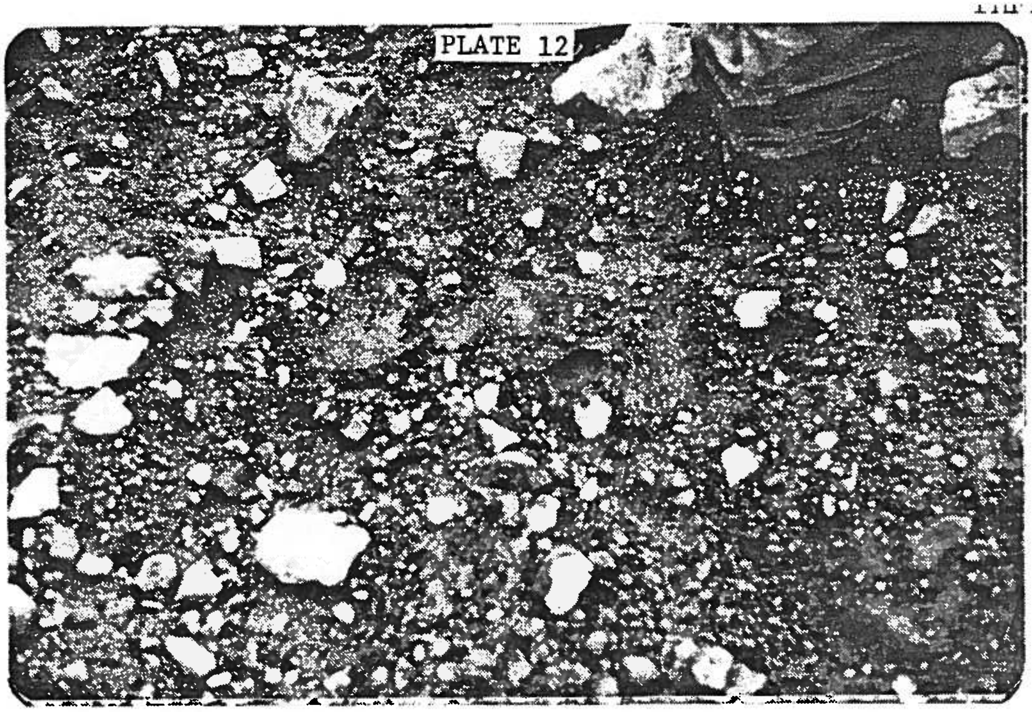
Young till (7) on grassy Foothills in Twp. 16, Rge. 3, W5M. Glaciolacustrine (15) in valleys. Foothills in the distance are thin colluvium over bedrock.

PLATE 11

THFR

Young till (7). Rill and gully erosion proceeds rapidly through the leached profile to the unleached part. At this point downward erosion stops due to the stone content and recrystallization of carbonates. Erosion now will be lateral and the road will be eroded. Twp. 27, Rge. 5, W5M, West of Cochrane.

PLATE 12



THFR

Close up of stony mountain till (7) showing striated limestones, south of Spray Lakes in Twp. 22, Rge. 10, W5M.

PLATE 13

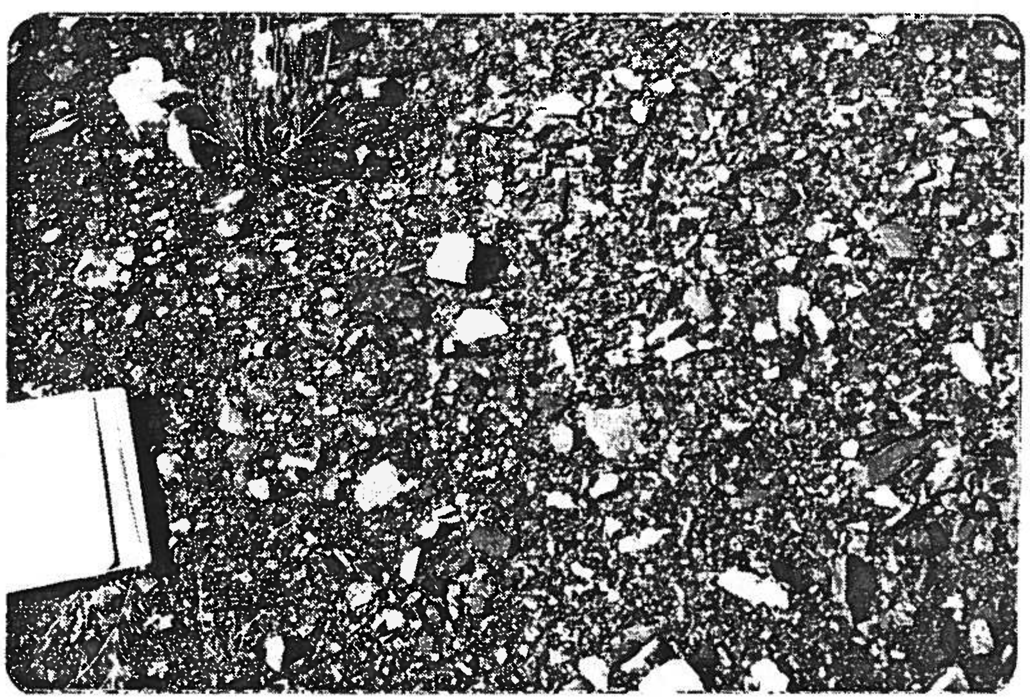
Rills in young till (7) freshly exposed surface less than one year old. On new road west of Priddis in Twp. 22, Rge. 3, W5M

IDT

PLATE 14 below

Young mountain till (7) showing numerous red shales green volcanics, white to pink quartzites and rare limestones in Twp. 4, Rge. 3, W5M. South of Beaver Mines.

THFR



THFR

PLATE 15 right

Slumping young glacial till (7) on Banff-Calgary highway near Three Sisters. Twp. 24, Rge. 10, W5M

LAB

PLATE 16 left

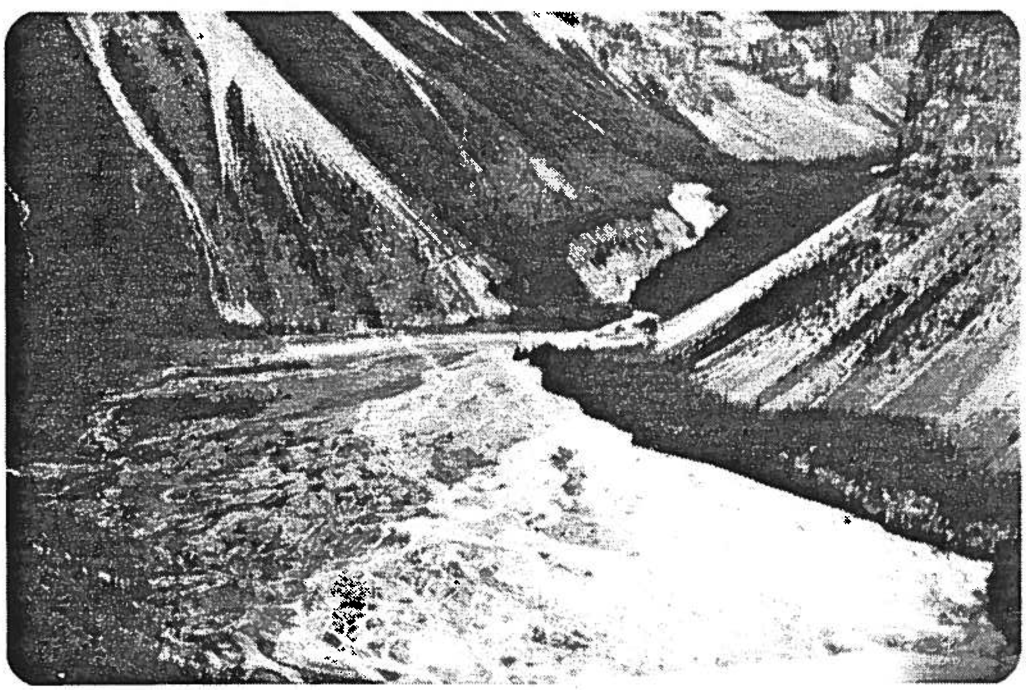
Young till (7). Note abundant angular lime-stone clasts.

PLATE 17

THFR

Paved glaciofluvial terraces on Oldman River (9). Glacial till in foreground. Twp. 10, Rge. 2, W5M.

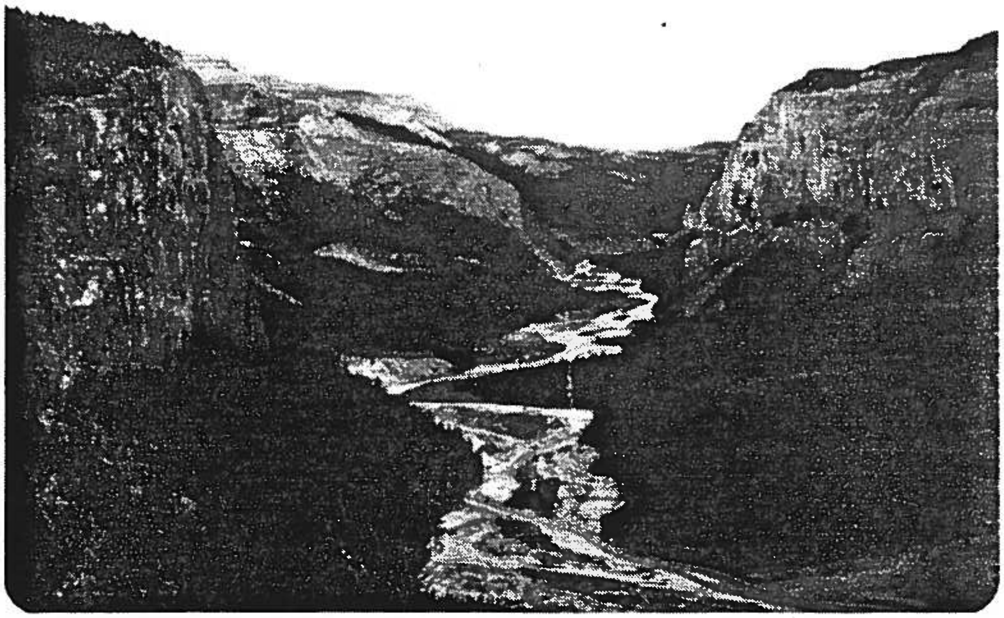
PLATE 18



THFR

Valley train (13) with talus slopes (27) on tributary to Smoky River. Twp. 52, Rge. 5, W6M. Note hanging valley in right background.

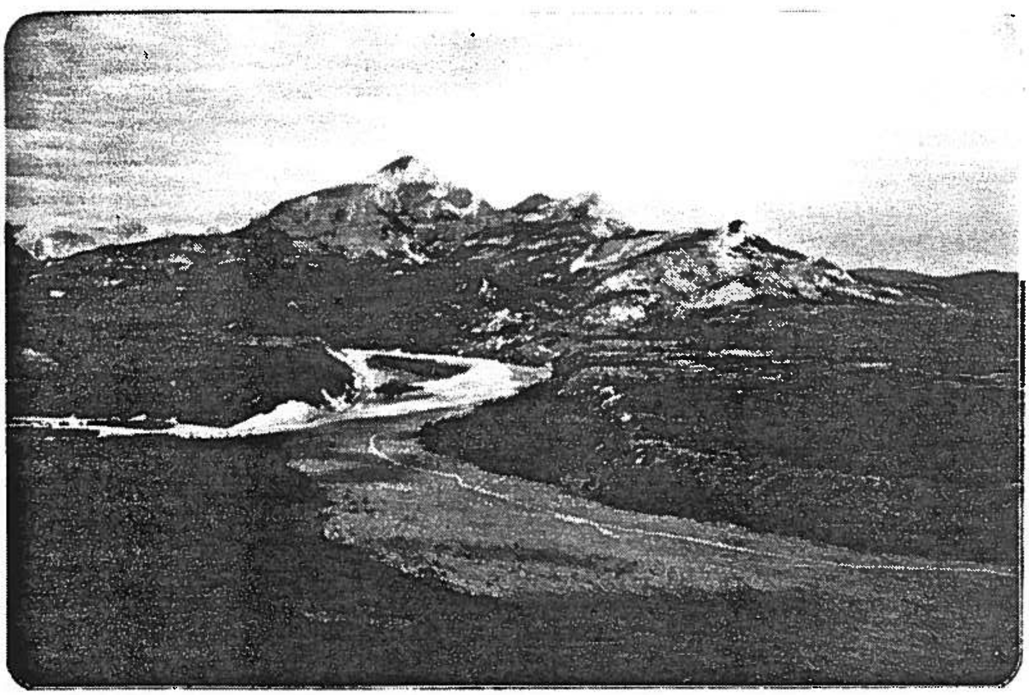
PLATE 19



THFR

Tributary to Lake Minnewanka, near the Ghost River in Twp. 27, Rge. 9, W5M. Note dissected alluvial fans (23), bare rock (1) with colluvium (24) on top. Photo looking west into Banff National Park.

PLATE 20



THFR

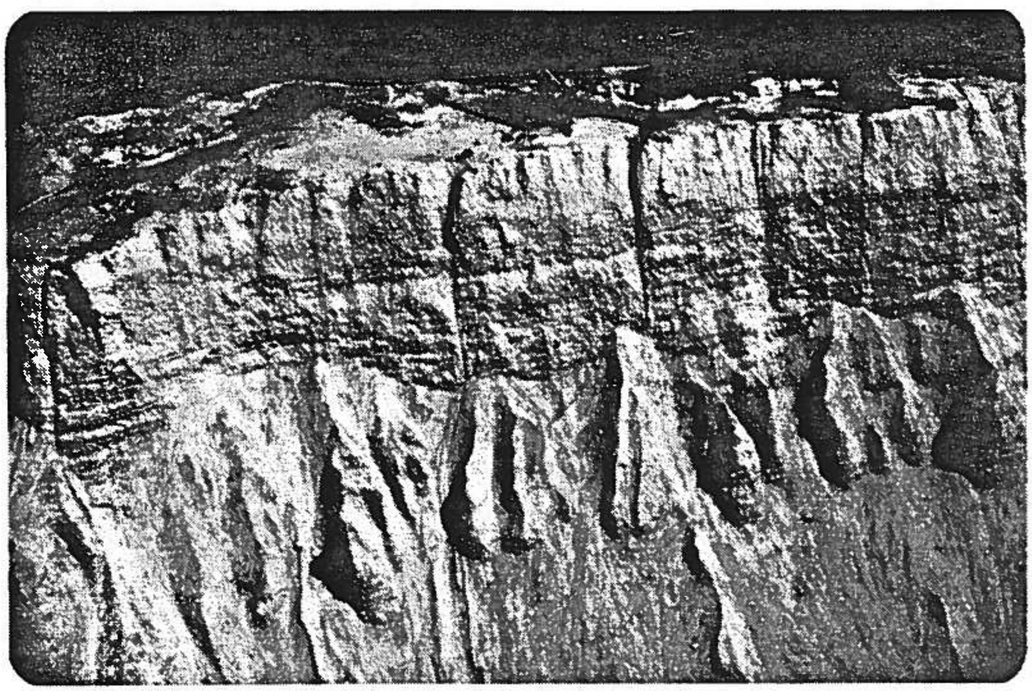
Valley train (13) on Ghost River, West of Calgary in Twp. 27, Rge. 9, W5M. Black Rock Mountain on right with numerous rock slides (28) and Devil's Head Mountain in left centre.

PLATE 21

THFR

Kame complex (11) north and west of Lundbreck.
Crowsnest Pass in rear background.

PLATE 22



THFR

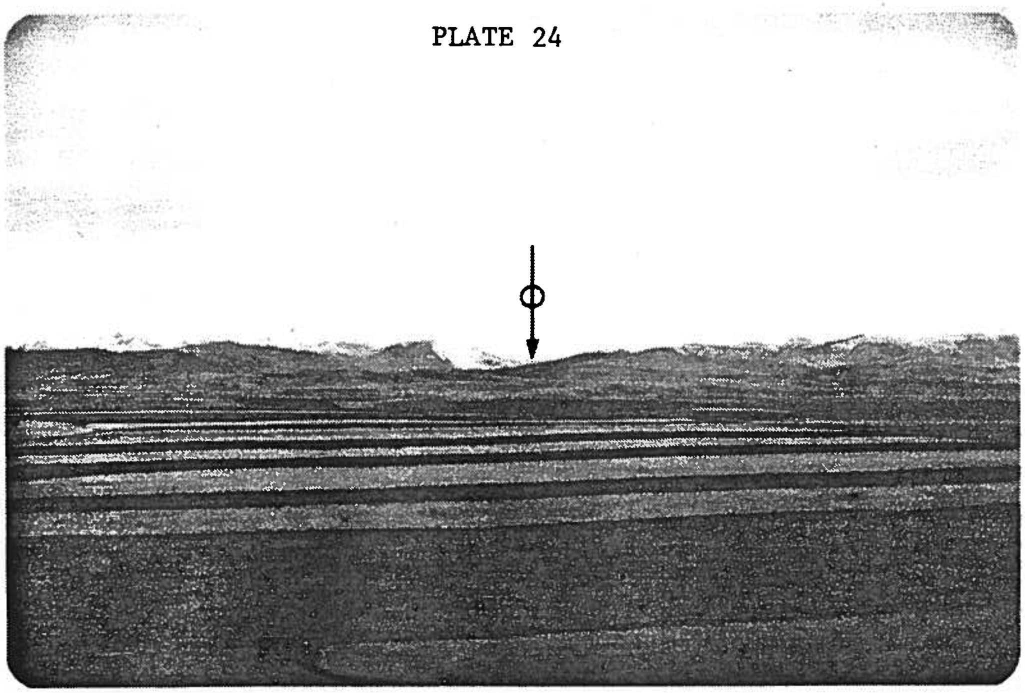
Outwash gravel (9) with wind blown sediments (16)
on top. Near Cline River in Twp. 37, Rge. 17, W5M.

PLATE 23

THFR

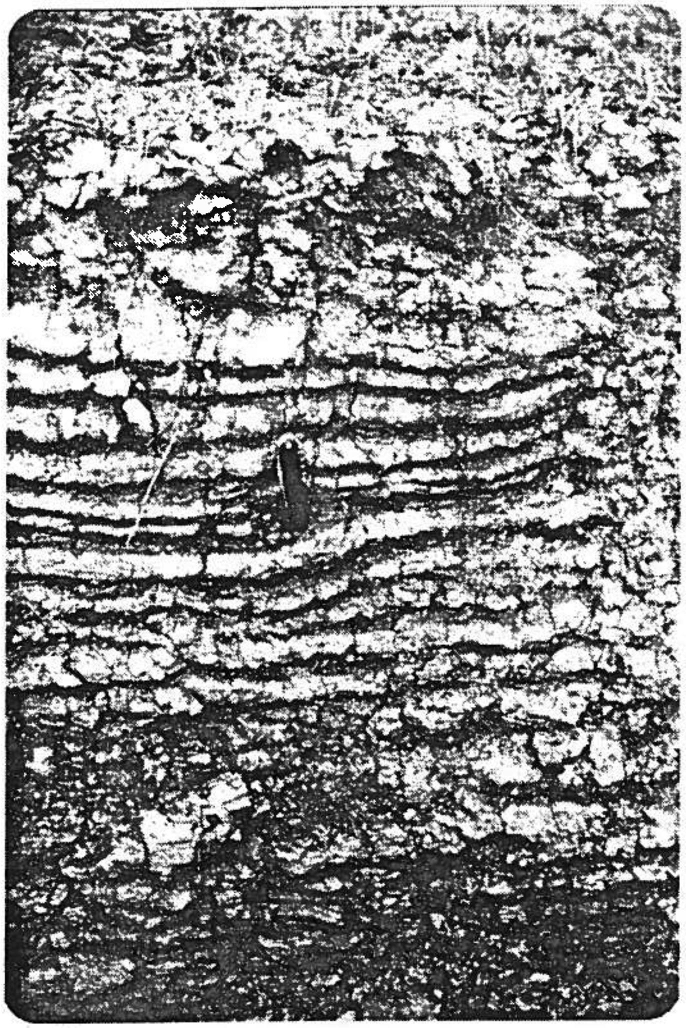
Moulin kames (11) on outwash plain (9) near Panther River Pass in Twp. 31, Rge. 12, W5M. Glacial till on mountain up to break in slope.

PLATE 24



THFR

View of Crowsnest Pass and Frank Slide (west of arrow) from Pincher Creek. Glaciolacustrine in foreground (15), Continental till (4b) of Intermediate age on first hill, and young mountain till (7) higher up. (See crossection on following page)



THFR .

PLATE 25 left

Laminated glaciolacustrine sediments (15), in cross-section.

THFR

PLATE 26 right

Slumping (29) on railroad grade south of Cowley in thick glaciolacustrine sediments in Twp. 7, Rge, 1, W5M

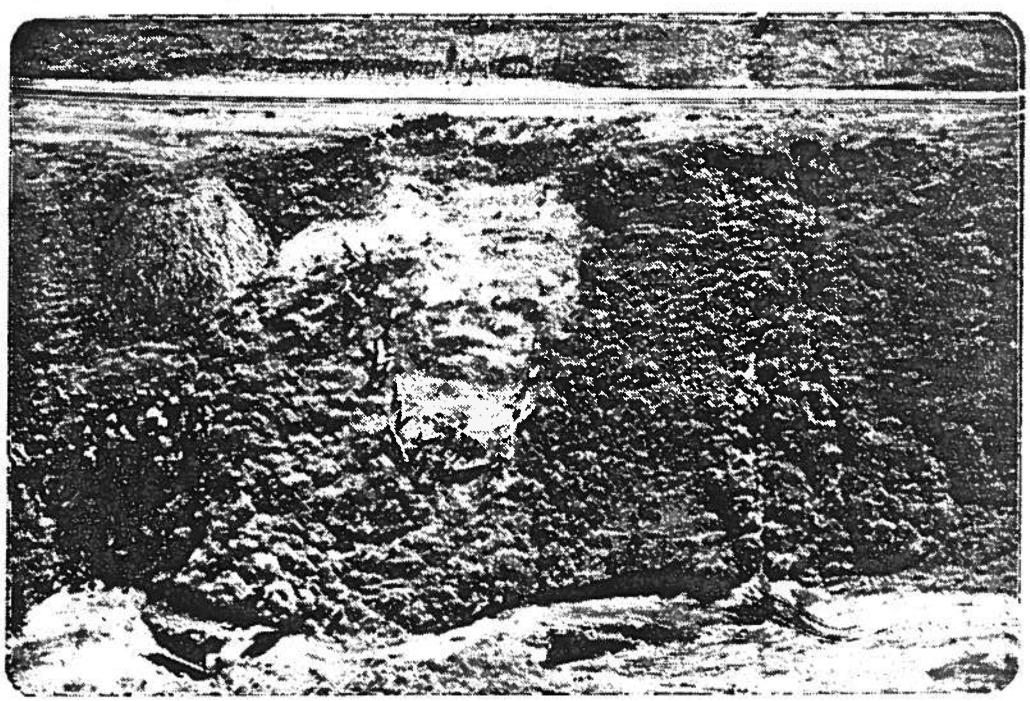
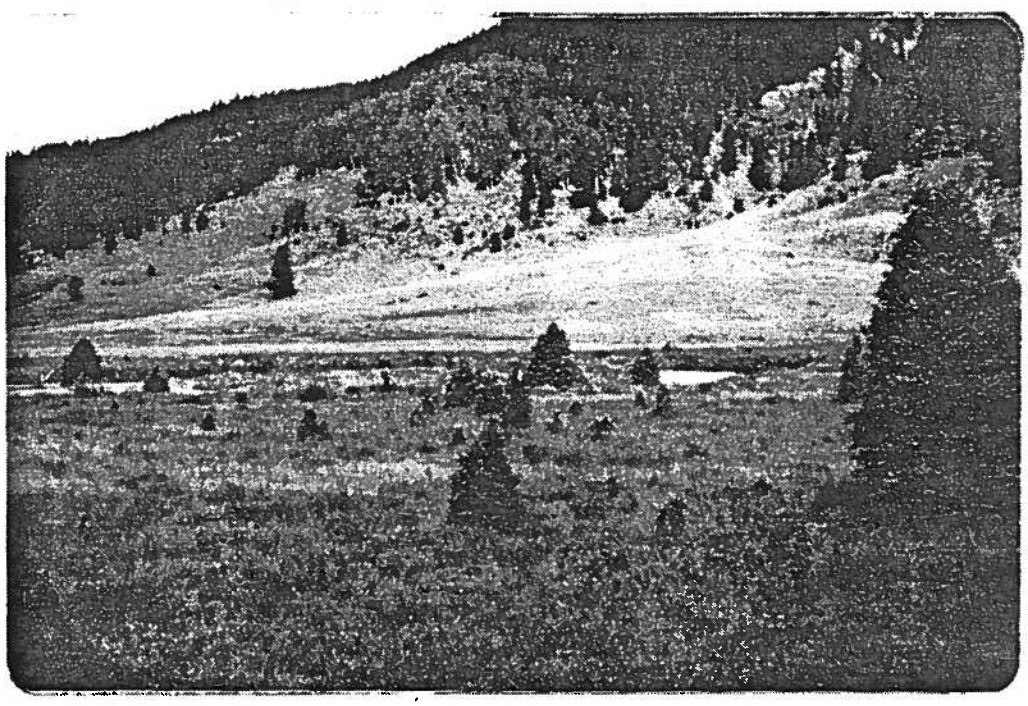


PLATE 27

THFR

Large alluvial fans (23) near Ya Ha Tinda Ranch on Red Deer River (21) Twp. 32, Rge. 12, W5M.

PLATE 28



LAB

View of alluvial fan (23) west of Limestone Mountain in Twp. 34, Rge. 11, W5M. Coarse alluvium (21) in foreground.

LDP

PLATE 29 left

Active rock glacier (19) west of Upper Kananaskis Lakes in Twp. 29, Rge. 10, W5M

PLATE 30

Active rock glacier (19) in plane view. In Twp. 34, Rge. 17, W5M near headwaters of Siffleur River.

THFR

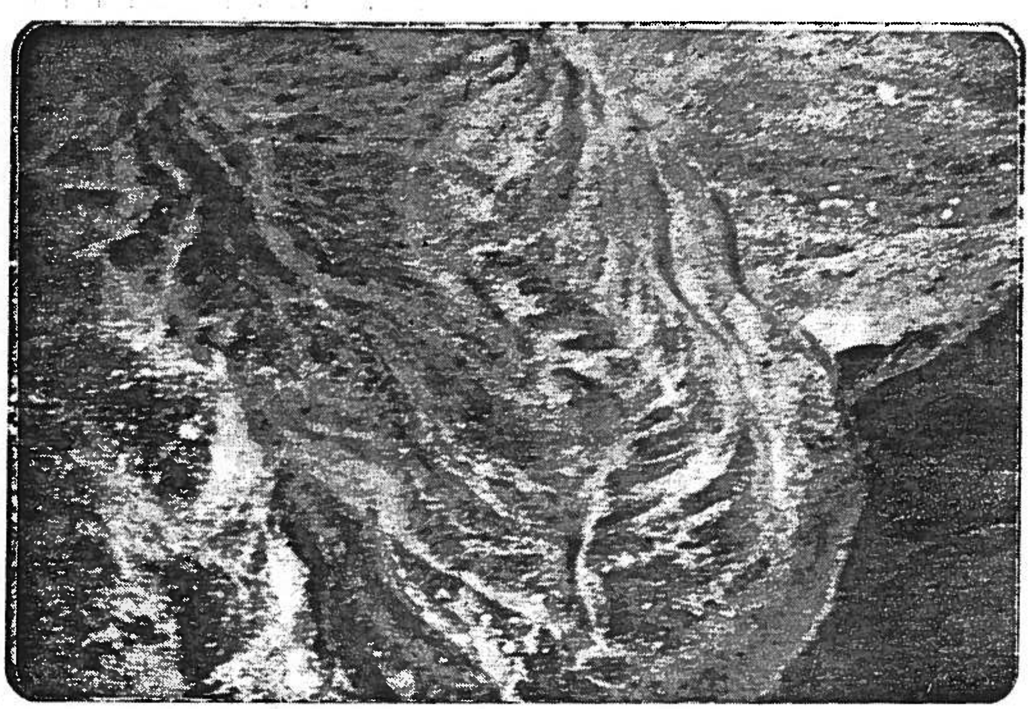
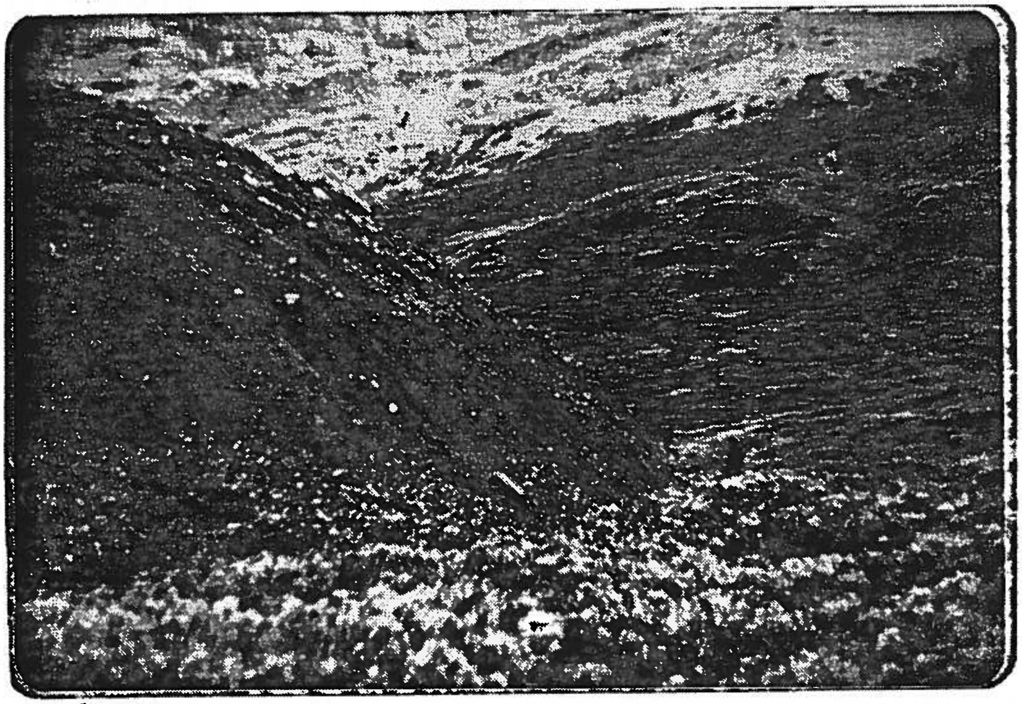


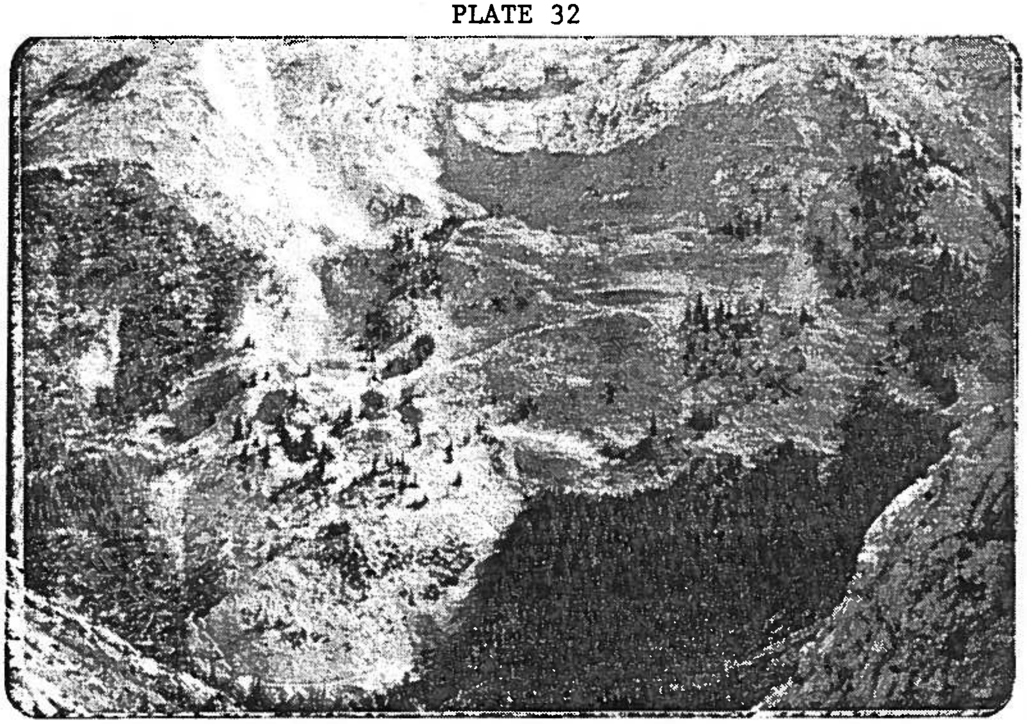
PLATE 31



THFR

Active front of rock glacier (19) advancing down valley covered with young mountain till (7). See former photograph for plan view of this rock glacier.

PLATE 32



THFR

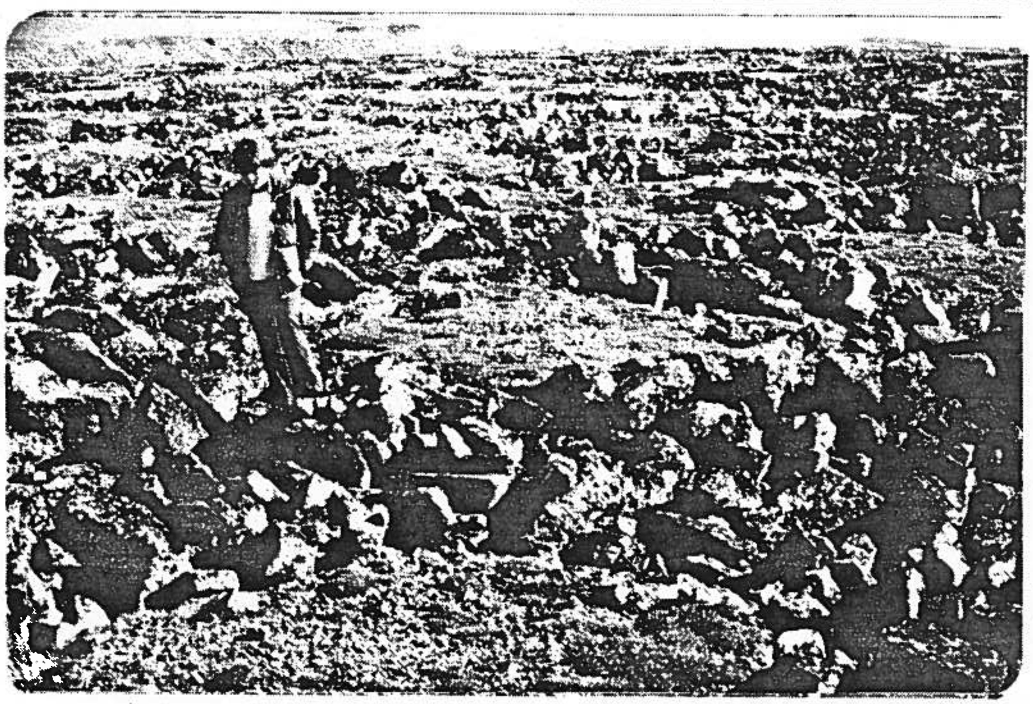
Rock slide (28) on west side of Livingstone Range in Twp 8, Rge. 3, W5M.

PLATE 33

LAB

Overview of Pleatau Mountain showing stone polygons of the patterned terrain (25) in Twp. 15, Rge. 5, W5M.

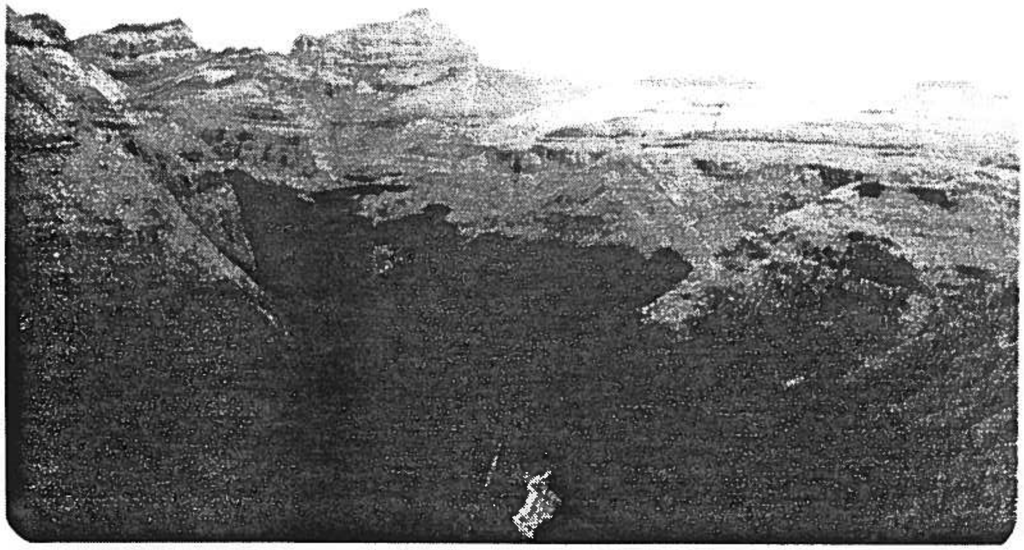
PLATE 34



LAB

Patterned terrain (25) on top of Plateau Mountain west of Longview in Twp. 15, Rge. 5, W5M. Bedrock is 6 feet below surface.

PLATE 35



LAB

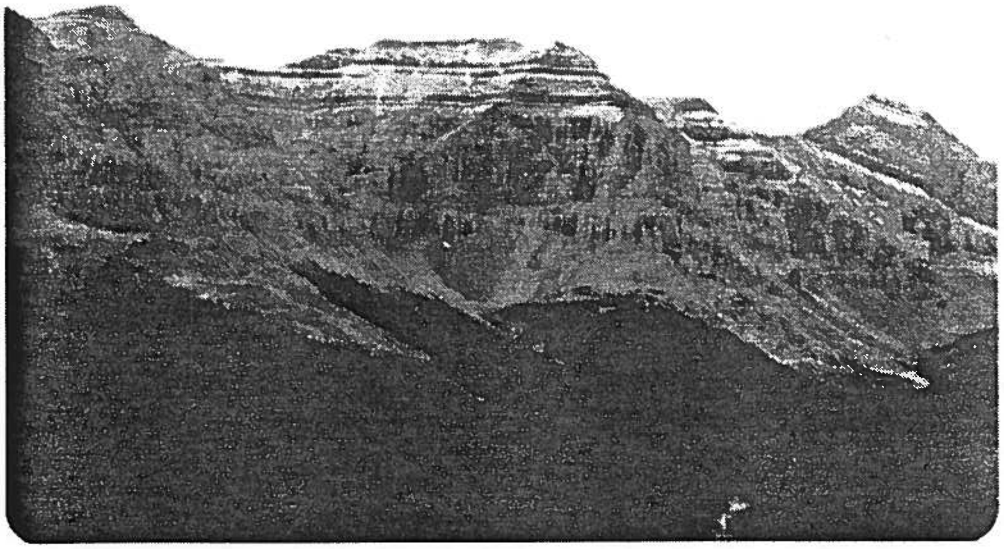
Rockslides (28), talus cones (27) and colluvium (24) to base of valley near headwaters of Elbow River in Twp. 20, Rge. 7, W5M

PLATE 36

THFR

Rock slide (28) in Crowsnest Pass (Frank Slide).

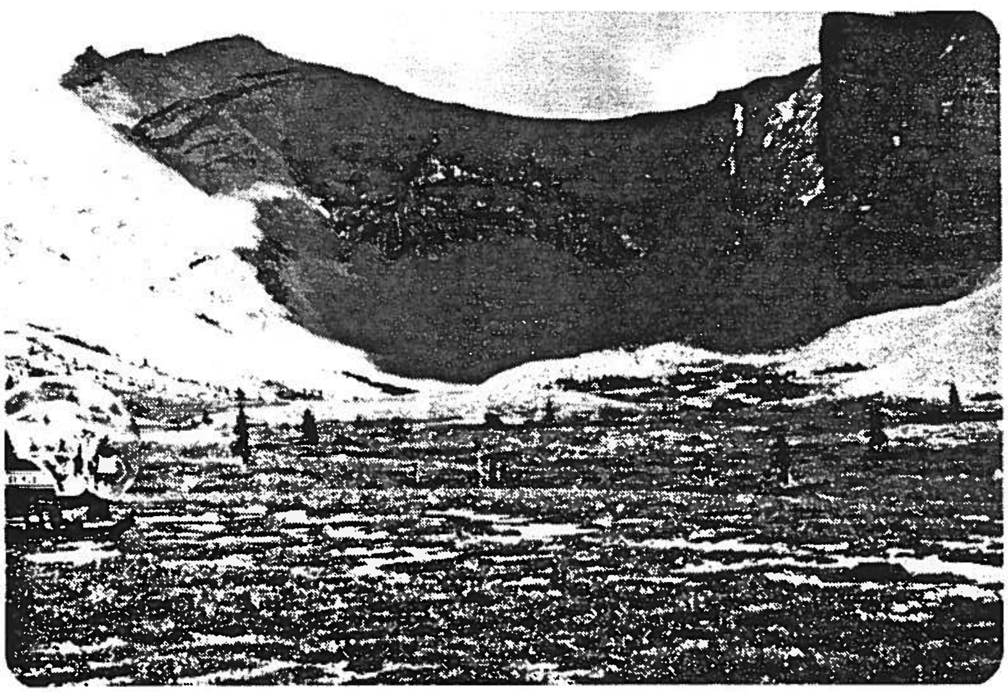
PLATE 37



LAB

Rockslides (28), talus slopes (27), bare rock (1), and colluvium (24) to the stream bottom. Near Waterton Park.

PLATE 38



THFR

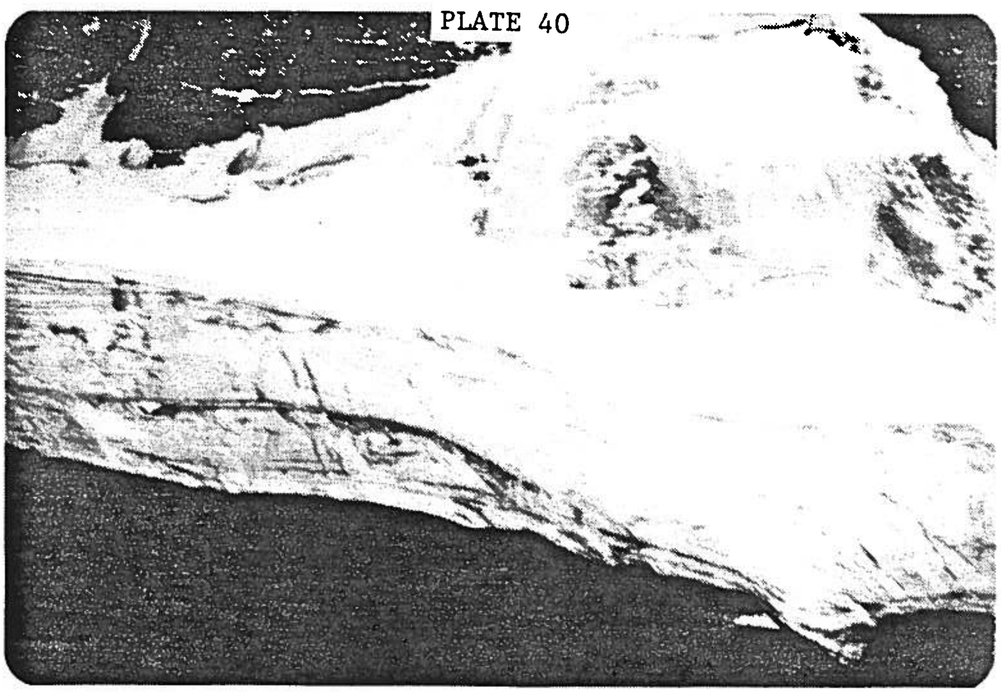
Cirque till (18) in foreground (under helicopter) talus cones (27) at base of mountains. Colluvium (24) and bare rock (1) on slopes. Twp. 54, Rge. 12, W6M.

PLATE 39

LAB

Small cirque glacier (20) with fresh lateral moraines composed of young cirque till (18) covered in places by colluvium (24) in Twp. 13, Rge. 5, W5M near the Oldman River.

PLATE 40



THFR

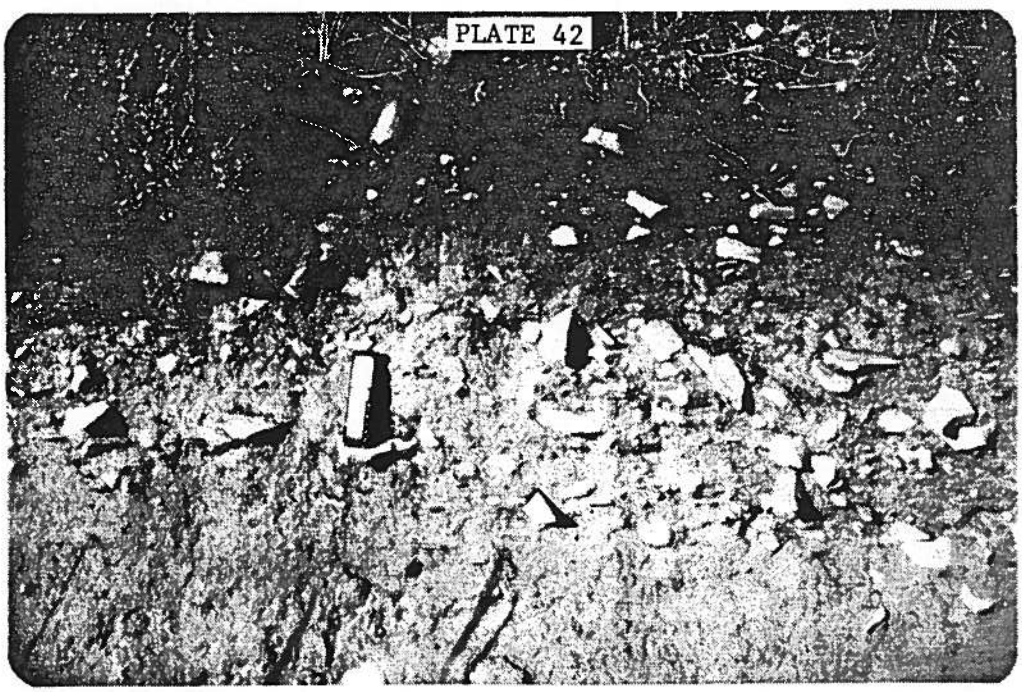
Glacial ice (20) about 200 meters in thickness. In Willmore Wilderness Park.

PLATE 41

IDT

Colluvium (24) on slopes, alluvial fan (23) in middle foreground, outwash gravel (9) in foreground on Highwood River. Twp. 9, Rge. 4, W5M

PLATE 42



THFR

Colluvium (24) over glaciolacustrine sediments (15). Note angularity of clasts with pseudo-bedding planes. Photo taken near Oldman River in southern Alberta.

THFR

PLATE 43 above

Young glacial till (7) over Cretaceous bedrock on new Nordegg-Rocky Mountain House highway near Twp. 41, Rge. 15, W5M. Note coal seams.

THFR

PLATE 44

Thin colluvium (24) over weathered Cretaceous shale near Ram River Falls.

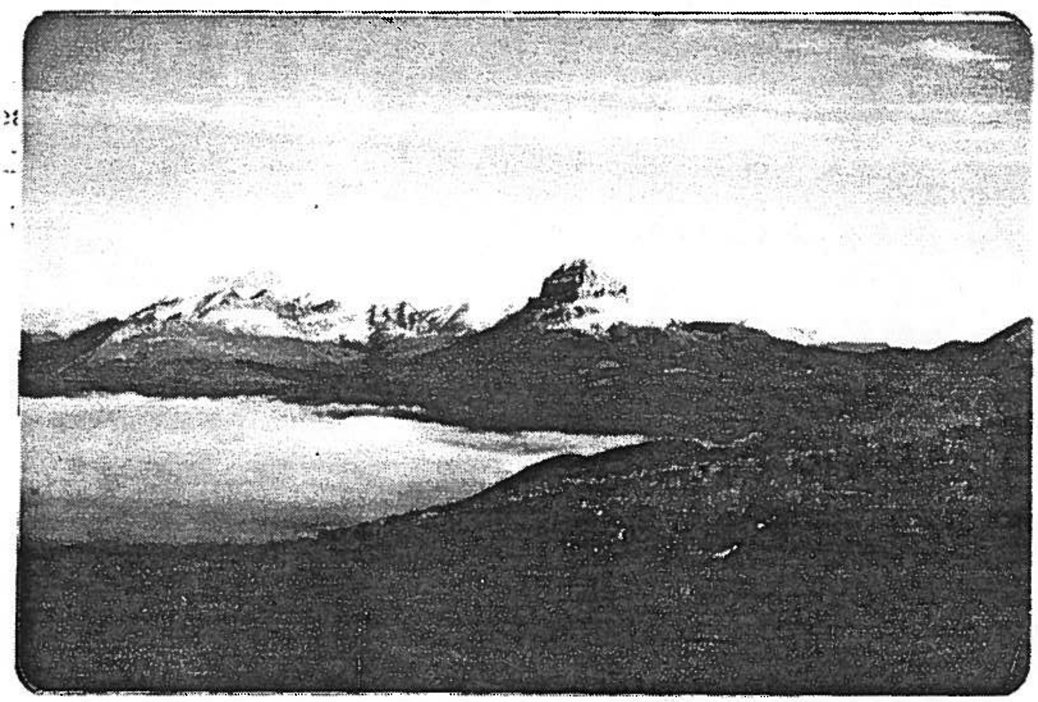
Twp. 36, Rge 13, W5M

PLATE 45

THFR

Active erosion in colluvium (24). No glacial deposits on hill in background. Twp.22, Rge.6, W5M. West of Millarville.

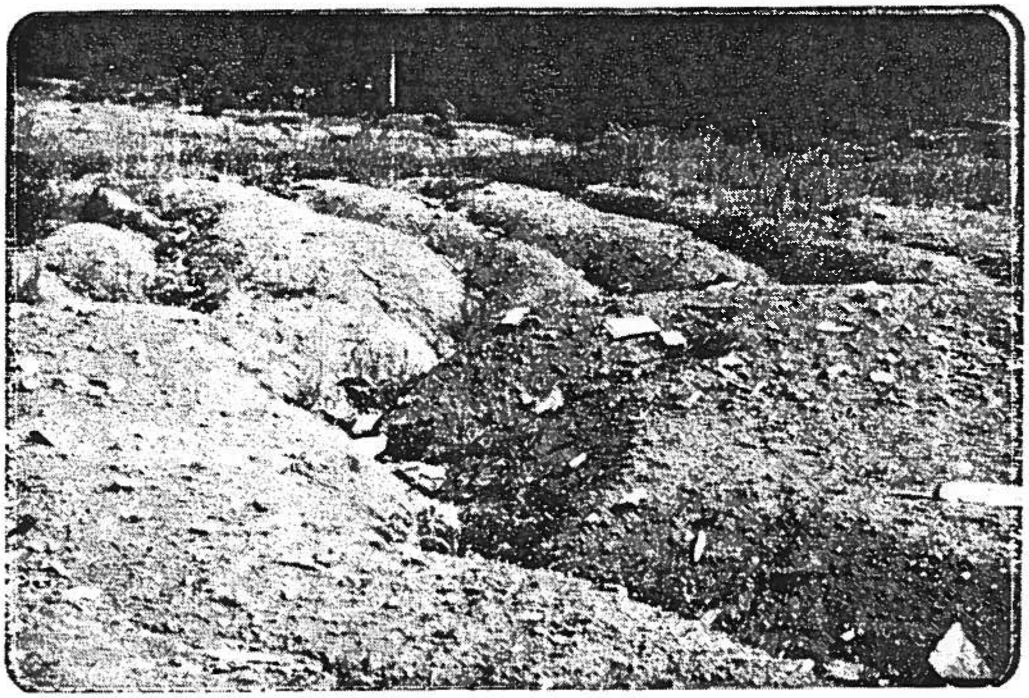
PLATE 46



THFR

Crowsnest mountain in Crowsnest Pass. Thin colluvium (24) over bedrock in foreground. Twp. 9, Rge. 5, W5M.

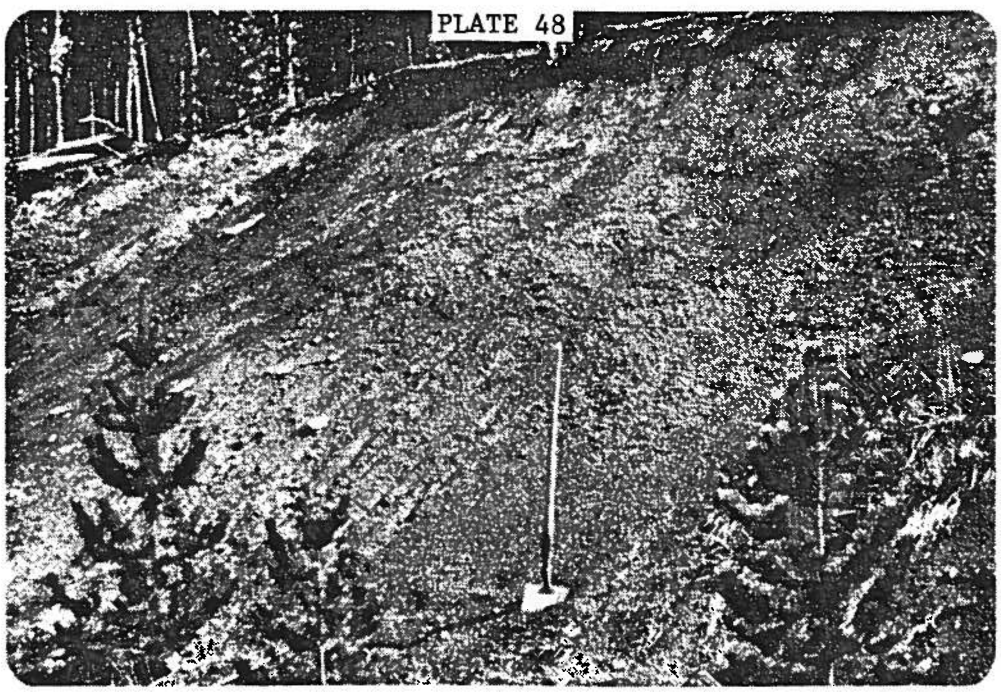
PLATE 47



LAB

Weathered bedrock (24) showing extensive erosion by rills and gullies. Surficial material exposed about 5 years ago in Twp. 28, Rge. 7, W5M, west of Water Valley.

PLATE 48



THFR

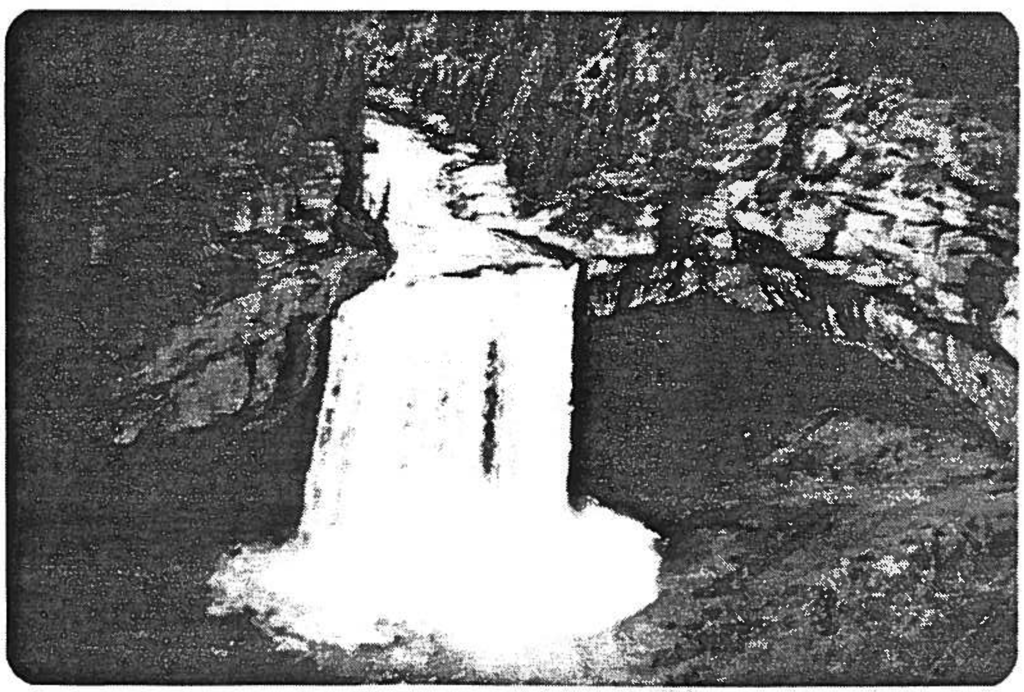
Weathered rock (Cretaceous shale) capped by thin colluvial (24) cover with limestone erratics. Near Clearwater River, North of Sundre. Twp. 34, Rge. 12, W5M.

PLATE 49

THFR

Weathered rock (Cretaceous siltstone) capped by colluvium (24) in Twp. 27, Rge. 6, W5M west of Calgary on forestry trunk road.

PLATE 50



THFR

Kakwa Falls with underlying Cretaceous coal seam, Twp. 59, Rge. 13, W6M.

TABLE 3

SUGGESTED CORRELATION CHART OF ROCKY MOUNTAIN AND FOOTHILL STRATIGRAPHY, CANADA

		CORDILLERAN ORIGIN										LAURENTIDE ORIGIN				
AUTHOR		Rutter (1974) (in Roed)	Rutter and Reimchen (1972)	Roed (1975)	Reimchen (1969)	Boydell, Bayrock and Reimchen (1974)	Rutter (1972)	Alley (1973)	Stalker (1958)	Horberg (1952, 1954)	Bayrock and Reimchen (This Report)		Roed (1975)	Boydell, Bayrock and Reimchen (1974)	Alley (1973)	Stalker (1958)
AREA		Peace River B.C.	Pine Pass B.C.	Athabasca Valley	N. Saskatchewan River	Rocky Mountain House	Banff	Crowsnest	Crowsnest	Waterton	Alberta Rocky Mountains and Foothills		Athabasca Valley	Rocky Mountain House	Crowsnest	
RECENT		Deserter's Canyon		Drystone Creek			Eisenhower				Neoglacial II Neoglacial I Cirque Till (18) Schist Till (6)					
PLEISTOCENE – Wisconsin Glaciation	Late	Late Portage Mountain	Young	Obed Marlboro	Upper	Jackfish Creek Lamoral	Canmore Bow Valley	Hidden Creek Ernst		Late Wisconsin	Young Till (7) Young Till (7b)	Young Till (5)	Edson - Mayberne	Sylvan Lake	Buffalo Lake	
	Early	Early Portage Mountain	Intermediate	Valley Glacier	Middle	Baseline	pre-Bow Valley ?	Maycroft	Map Unit 6,8	Early Wisconsin	Intermediate Till (4)	Intermediate Till (4b)	Marsh Creek		Maunsell	Map Units 5,7
PLEISTOCENE – Sangamon Interglacial																
PLEISTOCENE – Illinoisan Glaciation			Old	Early Cordilleran	Lower	Hummingbird	"Erratics"	Albertan	Map Unit 3,4	Kennedy	Old Till (3)	"Canadian Shield Erratics"			Labuma	