EDMONTON GEOLOGICAL SOCIETY
EDMONTON SECTION OF THE GEOLOGICAL ASSOCIATION OF CANADA
c/o Department of Earth and Atmospheric Sciences
University of Alberta
Edmonton, Alberta T6G 2E3

2000 FIELD TRIP

GEOLOGY OF THE ALBERTA CYPRESS HILLS (including the Eagle Butte Impact Structure)

September 29 to October 01, 2000

Field Trip Leaders:

Dr. Jack Leberkmo (University of Alberta)
Dr. Nat Rutter (University of Alberta)
With contributions by
Dr. Art Sweet (Geological Survey of Canada, Calgary)
Dr. Octavian Catuneanu (University of Alberta)
Dr. C. Willem Langenberg (Alberta Geological Survey/EUB)

Logistics: Dr. Matthias Grobe (Business Manager, EGS)

EDMONTON GEOLOGICAL SOCIETY

2000 Fall Field Trip,

September 29 - October 1.

Geology of the Alberta Cypress Hills

Field Guide

J. F. Lerbekmo

List of Participants

Nat Rutter	U of A
Mrs. Rutter	
Jack Lebeckmo	U of A
Matthias Grobe	AGS
Jaron Sander	
Caroline Nixon	Alberta College
Dan Nixon	
Doug Vick	U of A
Robert Hardy	Earthworks Consulting
Jason French	U of A
Solveigh Balzer	Caithness Consultants
Tanner Balzer	
Don Peet	AEnvP
Willem Langenberg	AGS
Jack Campbell	Jaycon
Hans Machel	U of A
Reg Olson	AGS
Jill Weiss	AGS
Joan Waters	AGS
Sheila Stewart	AGS
Richard Wong	AEC
Mika Madunicky	EUB
Alan Hildebrand	U of C
Wayne Edwards	U of C
Shahin Dashtgard	Fletcher Canada
John Pawlowize	AGS
Dina Pawlowize	U of A
Keith Bocking	AEnvP
James van Leewen	
Art Sweet	U of C

INTRODUCTION

The Cypress Hills are a highland extending from southeastern Alberta into southwestern Saskatchewan. The top is a relatively flat surface named the Cypress Hills Plain which slopes eastward in Alberta at about 20 feet per mile from 4800 feet at its western extremity to 4500 feet near the Alberta-Saskatchewan boundary. The hills are an erosional remnant of a more widespread surface whose top has been held up by 20 to 50 m of boulder to pebble conglomerate named the Cypress Hills Formation.

The preservation of the unglaciated top of the Cypress Hills some 600 m above the surrounding plains has provided intermittent exposure of about 550 m of Campanian to Paleocene strata from the marine Bearpaw Shale to the continental Ravenscrag Formation as well as the Upper Eocene? Cypress Hills Conglomerate.

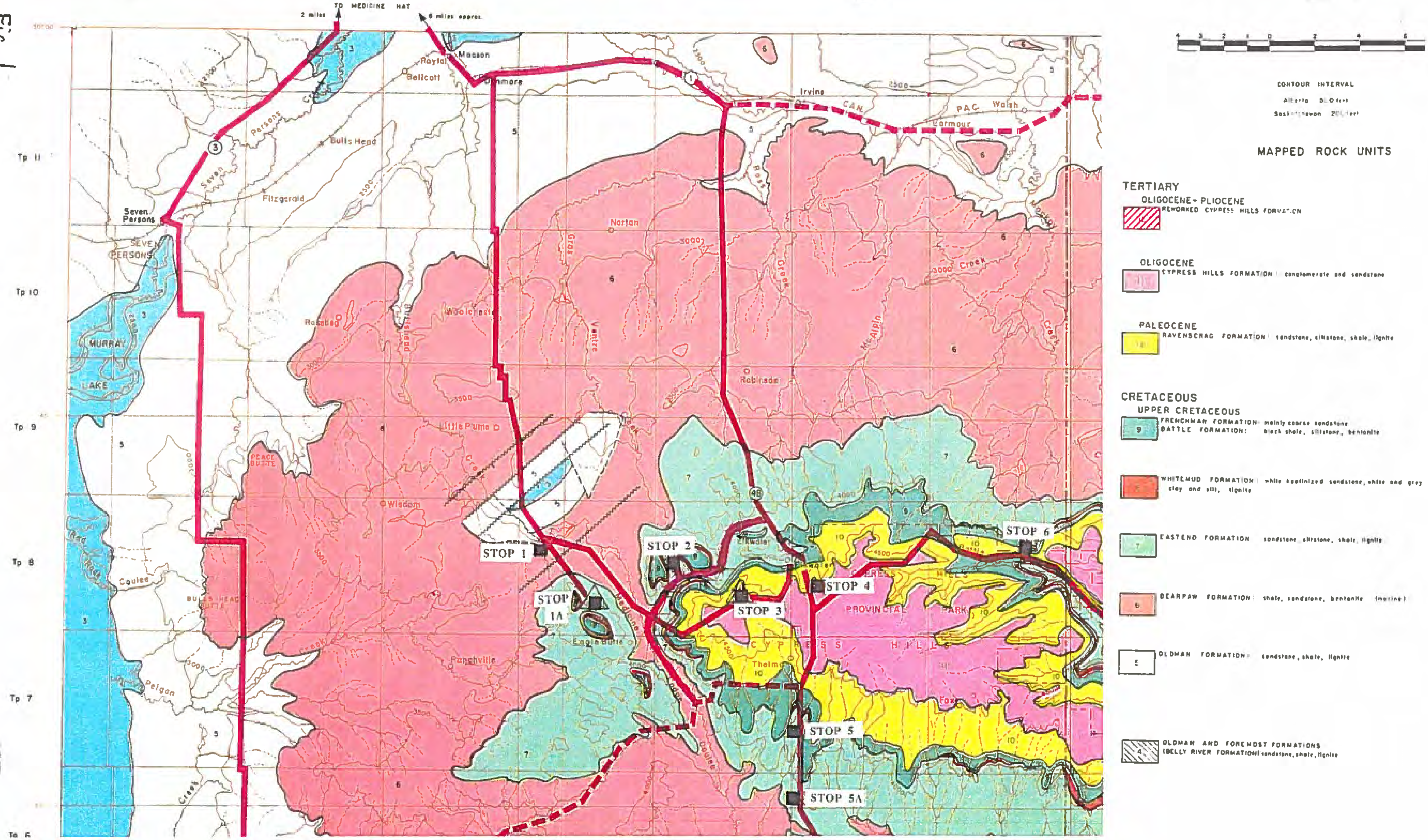
The field trip will make six or more stops to examine outcrops of the formations, as well as to view the locality and effects of the Eagle Butte Extraterrestrial Impact just off the northwest corner of the Hills (Fig. 1).

STOP 1 (IXL Quarry 39)

Quarry 39 is in lower Paleocene strata of the Ravenscrag Formation. Palynological samples studied by Art Sweet of the G.S.C., Calgary, indicate early but not earliest Paleocene (Sweet, pers. comm.), i.e., not older than the Ardley coal zone of the Red Deer Valley area. According to Luke Lindoe (pers. comm.), the K-T boundary and upper Frenchman dinosaur bone-bearing sediments occur about 200 m to the south. The Ravenscrag mudstones were mixed with Whitemud clays from Quarry 45 for ceramic use.

The tilting of the strata in Quarry 39 is believed due to the disturbance caused by the Eagle Butte impact, whose central uplift area containing shatter cones is 5 km to the north northwest (see Fig. 2). The 'Eagle Butte Structure' was produced by the impact of an extraterrestrial body. The time of the impact is not well constrained. No evidence of the impact ejecta could be confirmed in the Ravenscrag sediments of the Elkwater corehole (see Stop 3). An isolated 25 cm-thick peculiar red breccia was encountered at a depth of 75 m but no iridium anomaly was associated with it. Similarly, no evidence of the ejecta occurs in the overlying Cypress Hills Conglomerate, which is probably Upper Eocene in age (see Stop 4). Thus the age of the impact is probably late Paleocene or Eocene. I would favour early Eocene.

Fig. 1


TO MEDICINE HAT
2 miles
6 miles approx.
CONTOUR INTERVAL
Alberta 50.0 feet
Saskatchewan 20.0 feet
MAPPED ROCK UNITS
TERTIARY
OLIGOCENE - PLIOCENE
REWORKED CYPRESS HILLS FORMATION
OLIGOCENE
CYPRESS HILLS FORMATION : conglomerate and sandstone
PALEOCENE
RAVENSCRAG FORMATION : sandstone, siltstone, shale, lignite
CRETACEOUS
UPPER CRETACEOUS
FRENCHMAN FORMATION: mainly coarse sandstone
BATTLE FORMATION: black shale, siltstone, bentonite
WHITEMUD FORMATION : white kaolinized sandstone, white and grey clay and silt, lignite
EASTEND FORMATION sandstone, siltstone, shale, lignite
BEARPAW FORMATION : shale, sandstone, bentonite (marine)
OLDMAN FORMATION : sandstone, shale, lignite
OLDMAN AND FOREMOST FORMATIONS
(BELLY RIVER FORMATION) sandstone, shale, lignite
Tp 11
Tp 10
Tp 9
Tp 8
Tp 7
Tp 6
Seven Persons
SEVEN PERSONS
MURRAY
LAKE
Maxson
Royal
Bellcott
Dunmore
Irvine
Walsh
Carmour
CAN. PAC.
Bulls Head
Fitzgerald
Norton
Robinson
Little Plume
Wisdom
PEACE BUTTE
Eagle Butte
Ranchville
Thelma
Elkwater
PROVINCIAL PARK
CYPRESS HILLS
Pelgon
Coulee
STOP 1
STOP 1A
STOP 2
STOP 3
STOP 4
STOP 5
STOP 5A
STOP 6

A number of seismic lines have been run, and a fairly large number of wells have been drilled within the deformed area by oil companies during oil and gas exploration. A N-S well cross-section shown by Sawatzky (1976, Fig. 7) (Fig. 3) illustrates the structure, showing the central uplift, ring syncline and outer rim common to many larger impact structures. In addition, core taken from the Corexcal - PCP well (14-32-8-4W4) in the central uplift area shows extremely disrupted and contorted Pakowki Shale , as well as shock-induced deformation in quartz grains (Ezeji - Okoye, 1985).

In addition, shatter cones have been recovered from a small area in the central uplift area shown in Fig. 2. Shatter cones are commonly found at confirmed impact sites (Dietz, 1972). The impact crater is roughly circular in outline, about 10 km in diameter and a kilometre deep. The impactor is believed to have been about 200 m in diameter (Lambert, 1988).

STOP 1A (Quarries 45, 92)

In Quarry 45 the upper part of the Eastend Formation as well as the Whitemud were mined for ceramic use. It has now been largely back-filled. The upper wall is in the Frenchman Formation, which disconformably overlies the Battle Formation containing the Kneehills Tuff. The quarry here displayed an interesting case of injection of the Battle Formation upward into the Frenchman. This shows that the Battle was unconsolidated enough to be fluidized by the Eagle Butte impact, indicating relatively shallow burial at the time. The Kneehills Tuff is also folded and faulted.

Quarry 92, the newest in the area, is utilizing upper Eastend and Whitemud sediments, and like Quarry 45 shows a gradation from Eastend into Whitemud, if the formation boundary is based upon colour of the sediment. That is, the Whitemud Formation is the result of deep leaching of feldspathic sediments, producing kaolinite, during a period of lower water table. Upper Whitemud clays may be, in part at least, winnowed and re-deposited sediments.

STOP 2 (Quarry 34)

This quarry is in an isolated fault block with the Whitemud Formation about 30 m lower than its elevation in the Cypress Hills a kilometre to the south. Differences between quarries 45 and 34 demonstrate the variability in Whitemud stratigraphy over short distances. According to Lindoe (1965), the Whitemud Formation consists of three cycles, in addition to a more variable basal unit. Where a transition from the Eastend into the

Whitemud, marked only by increased kaolinization of Eastend, is not present, a basal partly kaolinzed Whitemud sandstone may rest disconformably on Eastend sands or clays. However, this basal unit is often missing and too variable to be recognised as a time of cyclic deposition. After this, however, there were three periods of cyclic deposition, recognized by Lindoe as cycles #1 - #3. The cycles begin with a kaolinitic sandstone with an erosive base and fine upward, ending with a poorly drained carbonaceous horizon. As a consequence, cycle #1 may also be missing, having been removed by erosion before cycle #2 deposition. This is the case at Quarry 34, where even though an average of 13 m of Whitemud occurs beneath the Battle, only cycles #2 and #3 are preserved, and cycle #2 cuts into the Eastend Formation. In addition, the top of cycle #2 has been removed by northward bedding plane faulting. Cycle #2 is dominated by kaolinized sandstone, whereas cycle #3 is finer, and the Whitemud - Battle contact is gradational. The lower part of the Battle Formation is essentially the final phase of cycle #3, and was considered to be part of the Whitemud Formation by early workers (e.g., Russell and Landes, 1940). The Battle becomes increasingly montmorillonitic (smectitic) upward, but the basal part is kaolinitic enough to be used for ceramic clay. Thus from a mining standpoint the Whitemud - Battle contact occurs in the dark-coloured Battle where the smectite - kaolinite ratio becomes uneconomic.

Although the Whitemud Formation stretches for more than 150 km through the Cypress Hills of Alberta and Saskatchewan, only over 10 to 15% of this distance is the kaolinite to smectite ratio high enough for it to be considered for ceramic use, and only a small percentage of this bulk volume is actually used (Lindoe, 1965).

STOP 2A (Shark Tooth Locality)

Highway 941 along Medicine Lodge Coulee in the vicinity of STOP 2A provides glimpses of the stratigraphy from the upper Bearpaw Formation to the basal Frenchman beds (Fig. 3). The resistant sandstone unit at the base of the exposed section is the marine Oxarart Member of the Bearpaw, and the softer sands in the road ditch have yielded shark teeth. The Bearpaw shale above the Oxarart, and the overlying Eastend strata, are mostly covered, but the upper Eastend and Whitemud Formations are exposed near the top of the coulee just at the Cypress Hills Park south boundary. The coloured route map (Fig. 1) has been taken from the A.S.P.G. 15th Field Conference Guidebook Part II (1965). This map shows the Eastend Formation as mapped by Russell and Landes (1940), who placed the base of the Eastend Formation at the base of what is now called the Oxarart Member of the

Bearpaw Formation. The Eastend Formation is now considered to begin with the first major local seam above the Thelma Sandstone Member of the Bearpaw (see Fig. 3).

STOP 3 (Elkwater Corehole Site)

This is the site of the Elkwater Corehole of the Canadian Continental Drilling Program (CCDP) Cretaceous - Tertiary (K-T) Boundary Drilling Project (see Braman *et al.*, 1999; Lerbekmo, 1999; Braman and Sweet, 1999) (Fig. 4 this guide.) The corehole was spudded in the base of the Cypress Hills Formation and was terminated high in the Eastend Formation. A minor disconformity accounts for the missing K-T boundary claystone at the top of the Frenchman. A larger disconformity is believed to be present near the top of the Ravenscrag, accounting for a missing polarity zone.

STOP 3A (Viewpoint)

This viewpoint on the Cypress Hills Plateau pern ... ift area of the Eagle Butte Impact.

The Cypress Hills Plateau surface is about 600 m ... It is called the Cypress Hills Plain and is an erosional remna ... of depositional surfaces which are believed to have been areally much more extensive at one time. The next lower surface is the well known Flaxville Plain of Montana (see Alden, 1924; Broscoe, 1965). The Cypress Plain is an unglaciated surface and has developed a rather impervious soil-covered surface in the time since deposition of the underlying Cypress Hills Conglomerate, believed to be of Upper Eocene age here.

There are no cypress on the Cypress Hills, but the name is believed to have come from some French voyageurs at Chesterfield House at the junction of the Red Deer and South Saskatchewan rivers who felt that the distant hills reminded them of the cypress-covered hills of France. The Blackfoot properly called them the 'Pine Hills' for the dominance of lodgepole pine and spruce (Gallup, 1965). However, because of their elevation and consequent micro-environment, they do host some fauna and flora that are isolated in these hills from their counterparts elsewhere (see McCorquedale, 1965).

STOP 4 (Cypress Hills Conglomerate)

The Cypress Hills Formation in Alberta consists of 10 to 30 m of pebble-to-boulder size quartzite and chert conglomerate resting disconformably on mudrocks of the Ravenscrag Formation. The maximum clast size is around 30 cm. Metaquartzite dominates the coarser sizes and chert the finer; together making up more than 90 % of the clasts. The other principal rock types are orthoquartzite and vein quartz. A miscellaneous group constituting less than 1% consists of argillites, conglomerate pebbles and porphyries (Vonhoff, 1965). Transport direction as indicated by cross-bedding and pebble imbrication was to the northeast (Vonhoff, 1965; Leckie and Cheel, 1989). Fossils have been found in the formation only near the eastern end of the Cypress Hills and Swift Current Plateau, in Saskatchewan. Fossil vertebrates leave been collected there since the late part of the 19th century and is still continuing. The oldest fossils are the Swift Current Fauna (Uintan, Middle Eocene) from the Swift Current Plateau north of the Cypress Hills.

The Cypress Hills Formation in the eastern Cypress Hills of Saskatchewan is up to about 75 m thick, dominated by sands, silts and clays in the upper 60 m. The fauna of the eastern Cypress Hills which occupies the largest stratigraphic interval (lowest 45 m) is the Cypress Hills Fauna of Chadronian (Upper Eocene) Age (which includes Titanotheres and Brontotheres). These occur in the coarsest part of the formation and have thus been considered equivalent in age to the Alberta conglomerate, though without fossil proof. The upper 30 m of the formation in Saskatchewan represents the Lower, Middle and Upper Oligocene as well as the Middle Miocene (Hemingfordian) (McDouglas, 1997, fig. 2; Storer and Bryant, 1997, table 1). This is a total time span of about 25 million years (43-18 Ma) (Woodburne and Swisher, 1995).

The source of the Cypress Hills Formation is indicated to be to the southwest according to transportation direction. The only possible source for some of the metasediments (coloured argillites, etc.) is believed to be the Belt Superseries, the closest outcrops of which are at least 300 km away. Vonhoff (1965) believed the only source for the range of lithologies in the formation was western Montana, but these rock types are also present in extreme southwestern Alberta and southeastern B.C.

Leckie and Cheel (1989) have offered an interpretation of the depositional history of the Cypress Hills Formation that involves a sequence of moves following two or more uplifts. The first one or two were related to the tectonic uplift of the Laramide Orogeny in the Rocky Mountains, and the last to the intrusive uplift of the Sweetgrass Hills. However, Alden (1924) concluded that the gradient from the Rocky Mountains would have been capable of transporting the gravels to their present location. Also, the Cypress Hills are believed to be only a small remnant of a much more widespread Plain. The Sweetgrass Hills are not large enough areally to have supplied gravel to such a Plain. One also wonders about the implications of the large range in age of the gravels. I believe the history of the Cypress Hills Formation is much more complicated than has hitherto been perceived.

STOP 5 (Whitemud - Battle, Kneehills Tuff)

A small exposure of the Whitemud Formation occurs in a pit just to the east of Highway 41. The Battle Formation including the Kneehills Tuff is exposed to the west of the road on the property of Denis Reese.

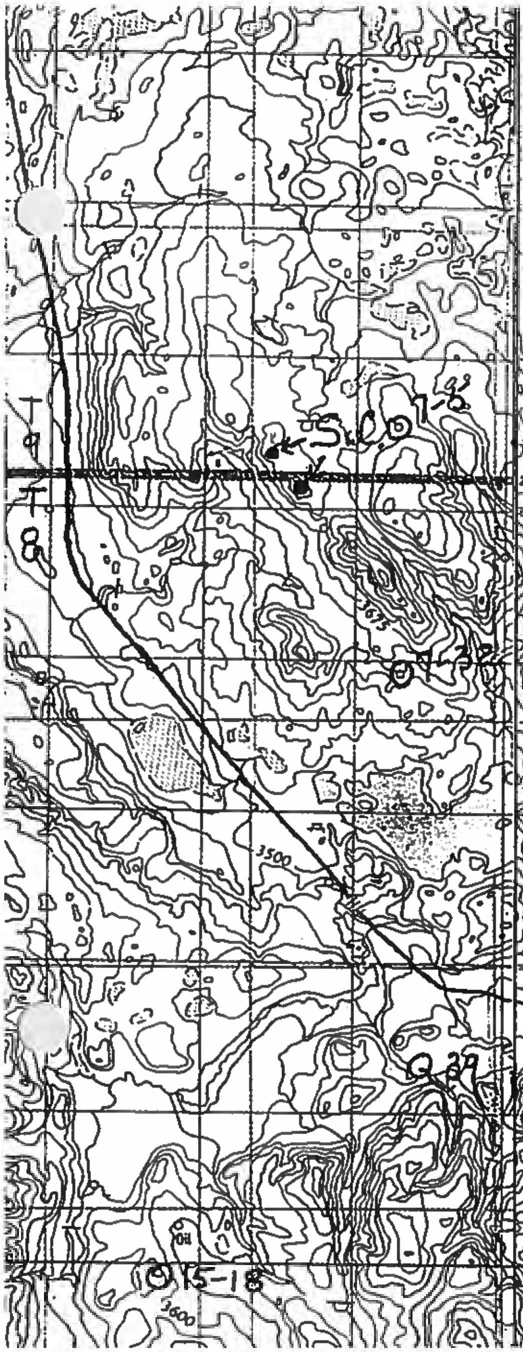
STOP 5A (Oxarart Member)

The road to the west from Highway 41 cuts down through the Oxarart Member, providing an exposure of the basal contact with the Medicine Lodge Member of the Bearpaw Formation. Northward along Thelma Creek, the entire Oxarart Member is exposed on the Yeast and Bierback properties.

STOP 6 (Police Point Slide and Viewpoint)

A large recent landslide has provided a good exposure of the contact between the Cypress Hills Formation and the underlying Ravenscrag Formation. A shell hash and mammal site carrying the 'Police Point local fauna' occurs 0.3 m below the top of the Ravenscrag. A 10 cm coal seam occurs 3 m below the top (Fig. 5). The exact age of the top of the Ravenscrag here is still in doubt. Krause (1978) believed the primates at Police Point indicated a middle Tiffanian age. Fox (1990) considered them to be middle or late Tiffanian (Ti 3 or Ti 4). The palynomorphs from the coal seam provide an equal degree of age uncertainty, middle or upper Paleocene (P3 - P4) (A. R. Sweet, pers. comm.). In the Red Deer Valley, palynological zones P3 and P4 both occur within magnetozone 26 r as do the Ti 3 mammal sites. The upper 14m of the Ravenscrag at Police Point are in a reversed polarity zone which is therefore considered to be 26 r. As this would be near the base of 26 r and therefore older than the mammal and palynological sites in 26 r in the Red Deer Valley, the top of the Ravenscrag at Police Point is likely to be no younger than middle Paleocene Ti 3 and P3. Zircon separated from a bentonite just below the mammal site shell hash has given a U-Pb age of 62.8 ± 0.2 Ma (Baadsgaard and Lerbekmo, in progress). This may be a little too old for this horizon.

Figures



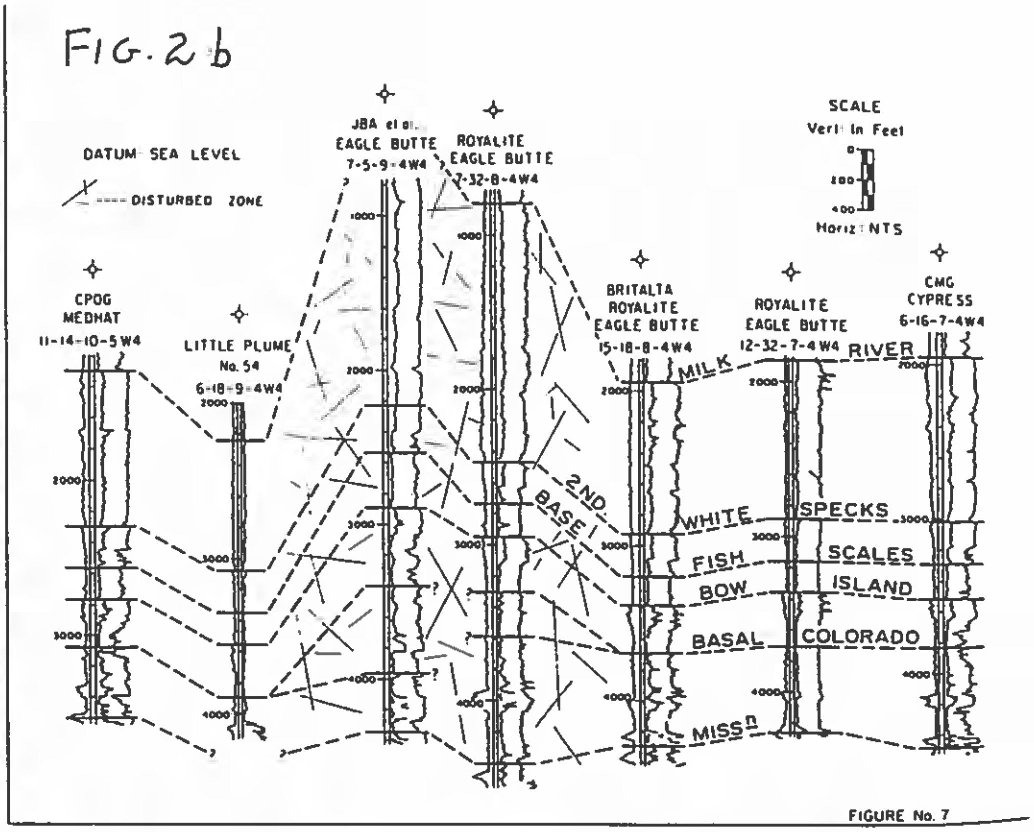
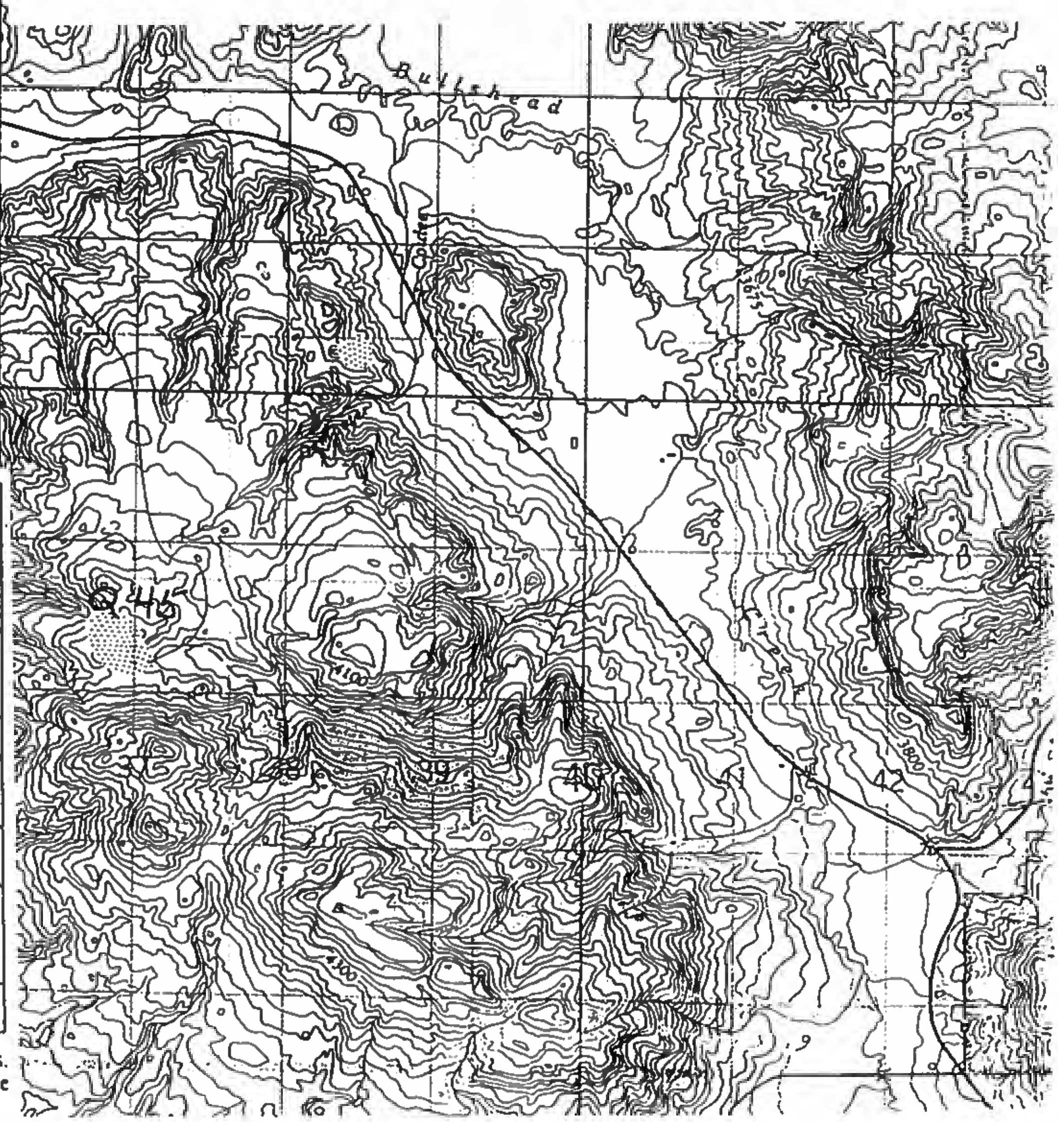


FIG. 7. Log section of wells from Figure 6, Eagle Butte, Alberta.



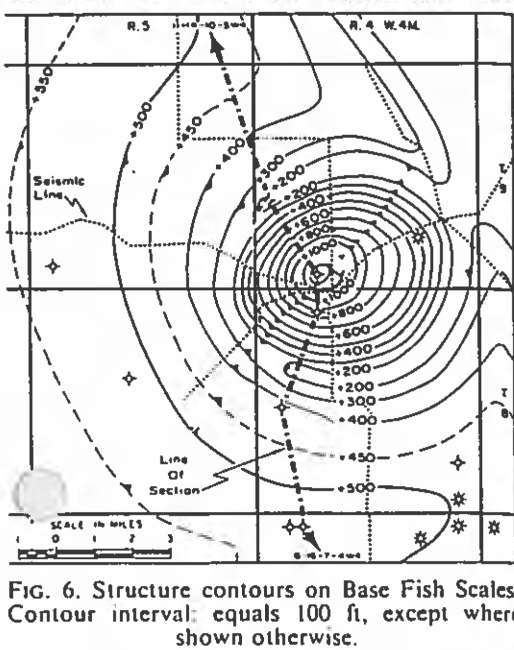


FIG. 6. Structure contours on Base Fish Scales. Contour interval: equals 100 ft, except where shown otherwise.

FIG. 2c

FIG. 2a

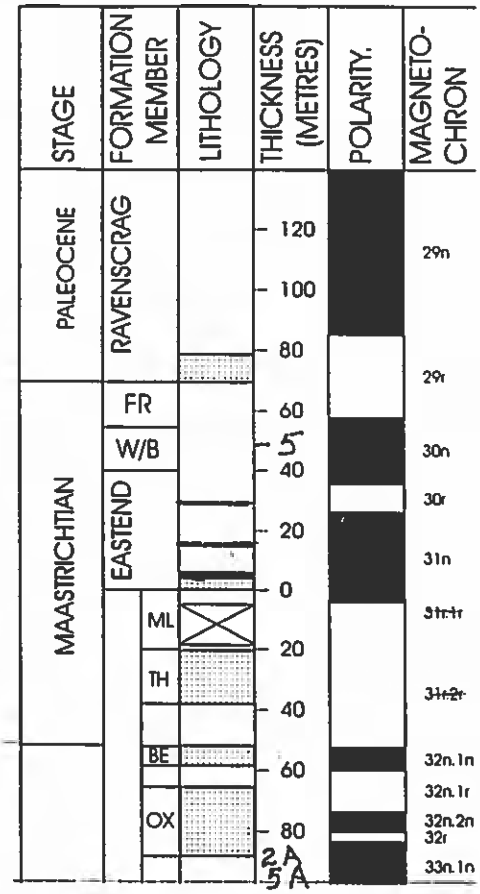


FIG. 3

Fig. 2. Lithology, palynostratigraphy, and magnetostratigraphy of the Elkwater core. EAST., Eastend, W., Whitemud, BAT., Battle, FR., Frenchman, CYP., Cypress Hills; l., late, e., early; P0, P1, P2, *Wodehouseia spinata* Zone – *Aquilapollenites reticulatus* Subzone, *W. fimbriata*, and *Momipites wyomingensis* zones, respectively. Black and white in the polarity column represent normal and reverse polarity, respectively. Numbers to the right are assigned polarity chrons.

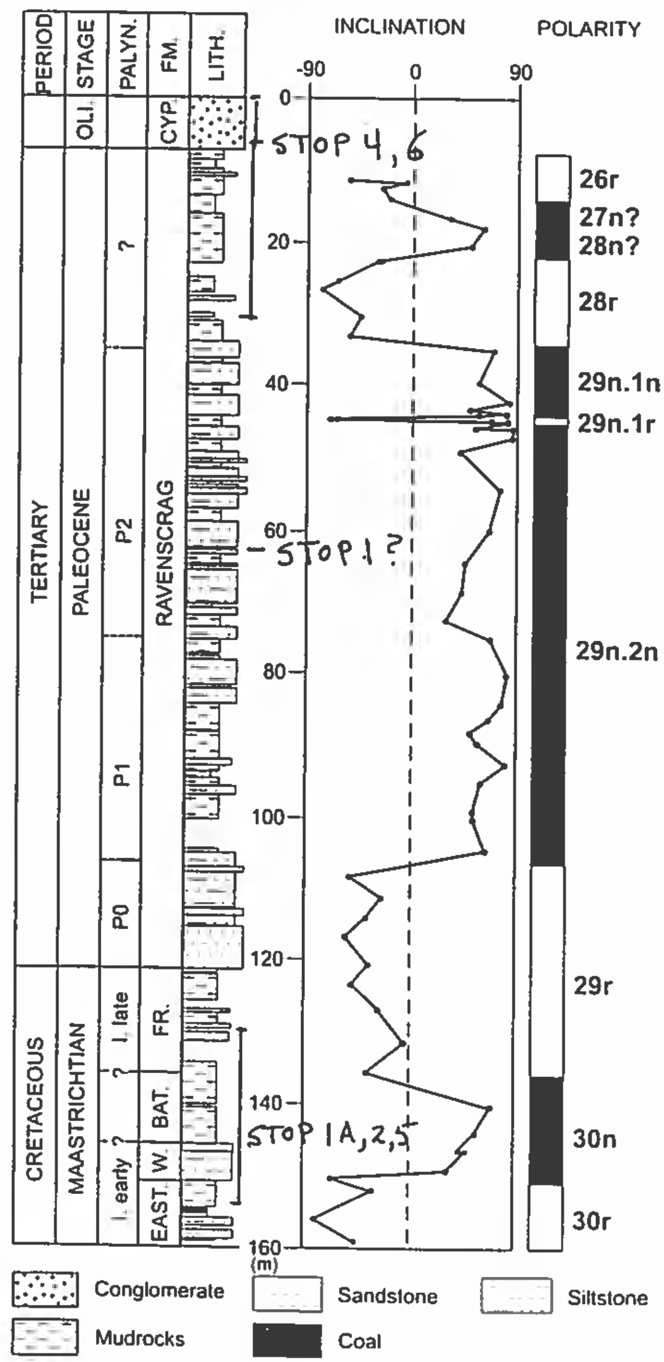


FIG. 4

POLICE PT. (STOP 6)

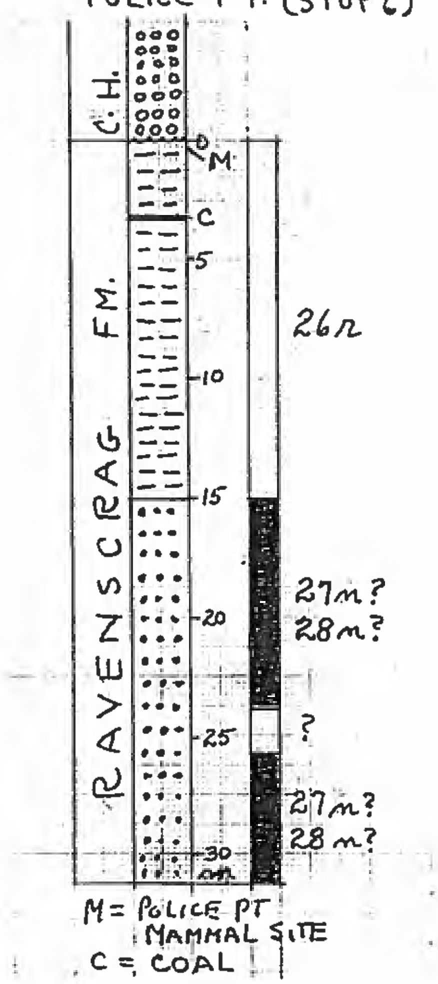


FIG. 5

DEFORMATION IN QUARRY 39

Willem Langenberg and Heather Budney
Alberta Geological Survey/EUB

The Eagle Butte meteorite impact caused down-warping and uplift in the area of Quarry 39 (Sawatzky, 1976). The centre of the impact is straight North of the quarry and consequently impact related structures can be expected to have a South directed sense of movement. Quarry 39 exploits clay and silty clay of the Tertiary Ravenscrag Formation. Quarry 39 is located on the rim of the impact structure.

Structures present in the quarry are inclined beds, folds, faults and joints. In the East part of the exposure the beds are dipping on average 16 degrees to the East. An anticline is exposed on the West side with a western limb dipping 29 degrees to the SSW. These two intersecting limbs define an anticlinal fold axis plunging 12 degrees to the southeast. This fold axis is also indicated by the girdle distribution of all 44 measurements in the pit. The poles to bedding have a fair bit of scatter around this girdle, possibly indicating an older warping of the bedding with an E-W trending axis. The main fold seems to indicate a NE-SW shortening direction (see enclosed sketch from Budney, 2000). A similar shortening direction is indicated by two thrust faults, which are dipping 80 to 85 degrees in direction N50E.

The documented shortening direction does not appear to agree with a South directed sense of movement, as would be expected from the Eagle Butte impact. The direction seems to agree more with glaciotectonism by a SW advancing Pleistocene glacier (Westgate, 1968). A similar conclusion was made by Tsui (1987), who made observations in several quarries in the Eagle Butte region. It is still possible that the glaciotectonism was superimposed on an E-W trending open fold, indicated by the scatter and the variation of the elevation of the Ravenscrag formation in the area. Such folding with possible east trending fold axes on the rim of the impact structure would be a direct result of the impact.

Things to see:

Notice the east dipping beds in the east part of the pit, the steeper SSW dipping beds in the extreme west part of the pit, and the resulting anticline with fold axis plunging southeast. Observe the generally steeply northeast dipping thrust faults. All these structures indicate movement directions to the southwest. Joint sets in a concretionary bed are orthogonal, with one set close to vertical south dipping and the other close to vertical east dipping. The relationship of these joints to the other structural elements is uncertain.

References

Budney, H., 2000, A structural analyses and geologic history of I-X-L Quarry 39, Cypress Hills region, Alberta. Unpublished Honours B.Sc. Thesis, University of Alberta, 30 pages.

Sawatzky, H.B, 1976, Two probable late Cretaceous astroblemes in western Canada-Eagle Butte, Alberta and Dumas, Saskatchewan. Geophysics, v.41, pp.1261-1271.

Tsui, P.C., 1987, Geotechnical investigations of glaciotectonic deformation in central and southern Alberta. Unpublished Ph.D. Thesis, University of Alberta, 452 pages.

Westgate, J.A., 1968, Surficial geology of the Foremost-Cypress Hills area, Alberta, Alberta research Council, Bulletin 22, 121 pages.

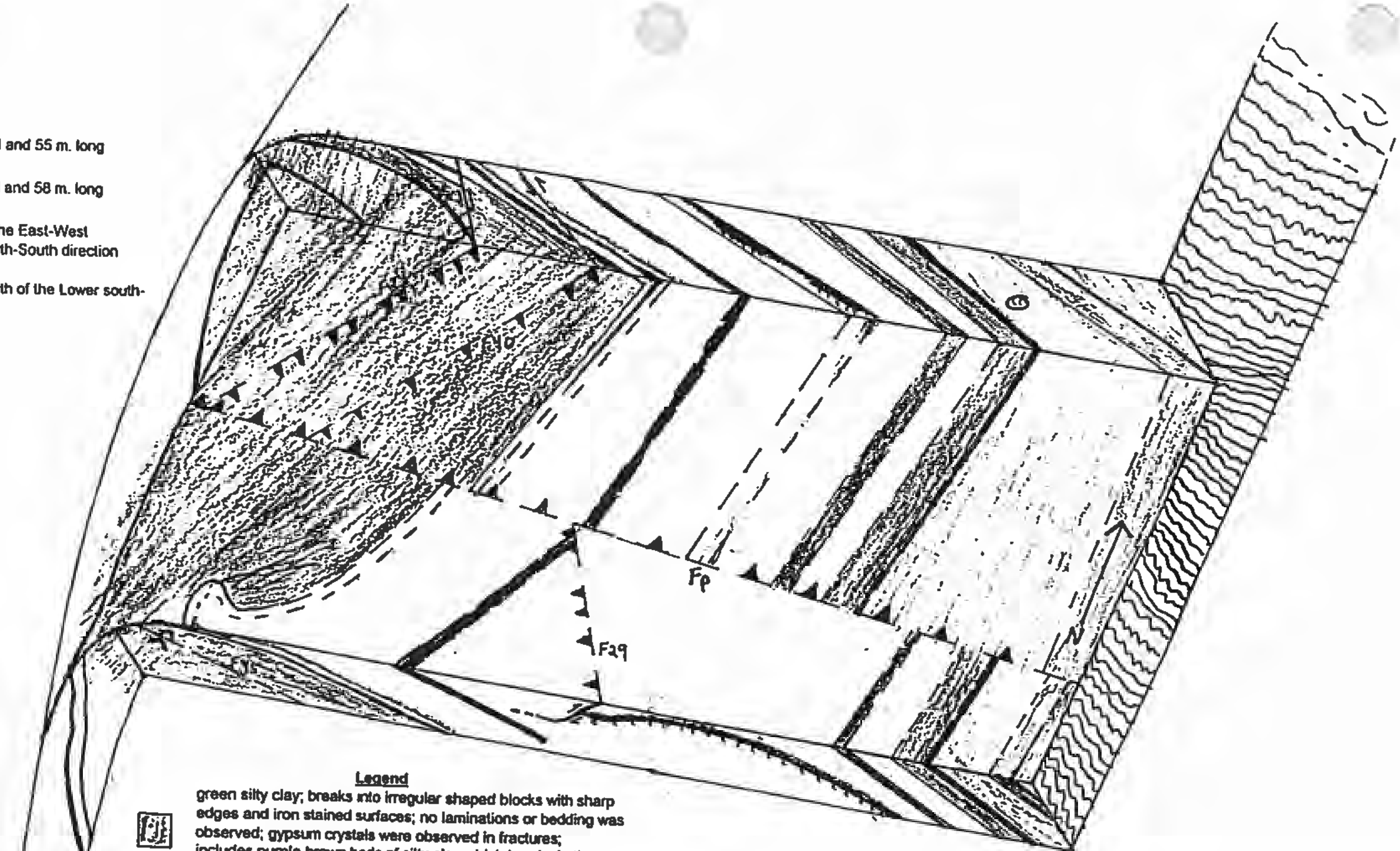
Dimensions

Upper south-facing wall is 4 m. tall and 55 m. long

Lower south-facing wall is 4 m. tall and 58 m. long

Top of the bench is 55 m. long in the East-West direction and 23 m long in the North-South direction

East facing wall extends 18 m. south of the Lower south-facing wall



Legend

- green silty clay; breaks into irregular shaped blocks with sharp edges and iron stained surfaces; no laminations or bedding was observed; gypsum crystals were observed in fractures; includes purple-brown beds of silty clay which breaks in the same fashion as the green silty clays
- black carbonaceous rich poorly consolidated silts; breaks into angular irregular shaped blocks
- white poorly consolidated silty sand
- buff clay rich to sandy poorly consolidated material which locally weathers to white; breaks into larger rhombs; some beds are well laminated; disturbed and cross-bedded laminae were observed; sandier layers are better consolidated and break into irregular shaped chips
- jointed pale green shale
- dark grey clayey silt; breaks into small chips with iron stained surfaces; crumbles when rubbed; no laminae or bedding observed
- grey-brown poorly consolidated fine grained sediment
- thrust fault (triangles are within the hanging wall)
- sense of motion
- Fx name of the fault in the text; (p) refers to the proposed fault in the text
- wall is artificial and is not observable in outcrop

all dashed lines were not observed in outcrop.

Sketch of Geology of I-X-L Quarry 39

EDMONTON GEOLOGICAL SOCIETY

2000 Fall Field Trip,

September 29 - October 1.

Notes on the Quaternary Geology

Field Guide

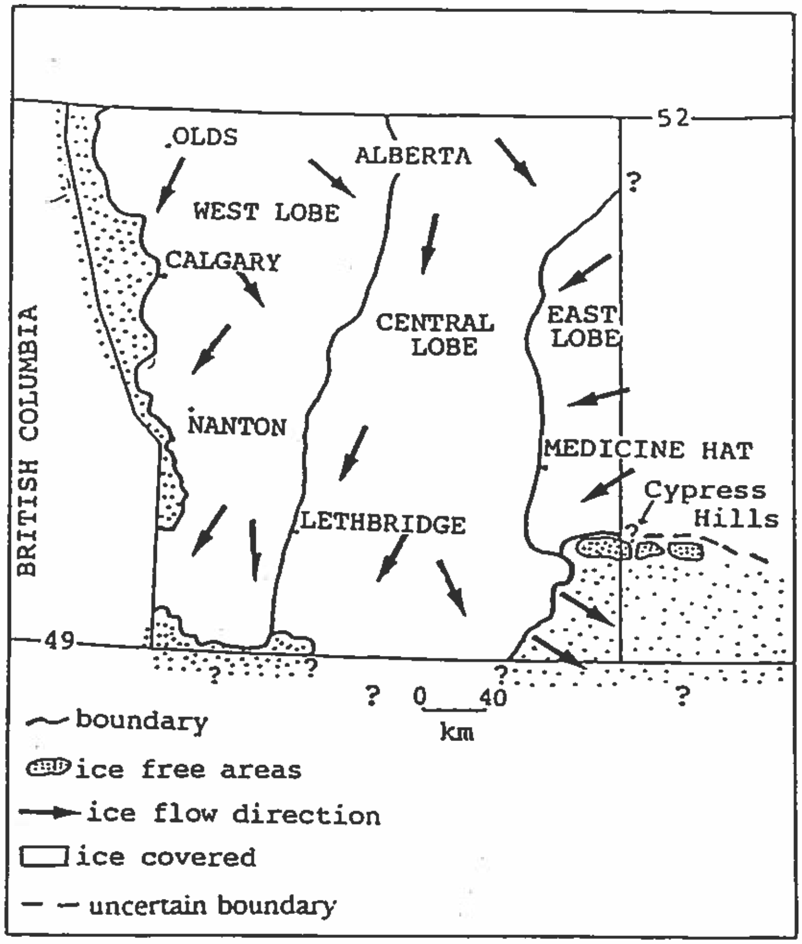
Nat Rutter*

* Most diagrams are from John Kulig's Ph.D. thesis
Quaternary History of the Cypress Hills

BK: The Quaternary history of the Cypress Hills and adjacent areas in Alberta and Saskatchewan.

BA: Kulig-John-Joseph

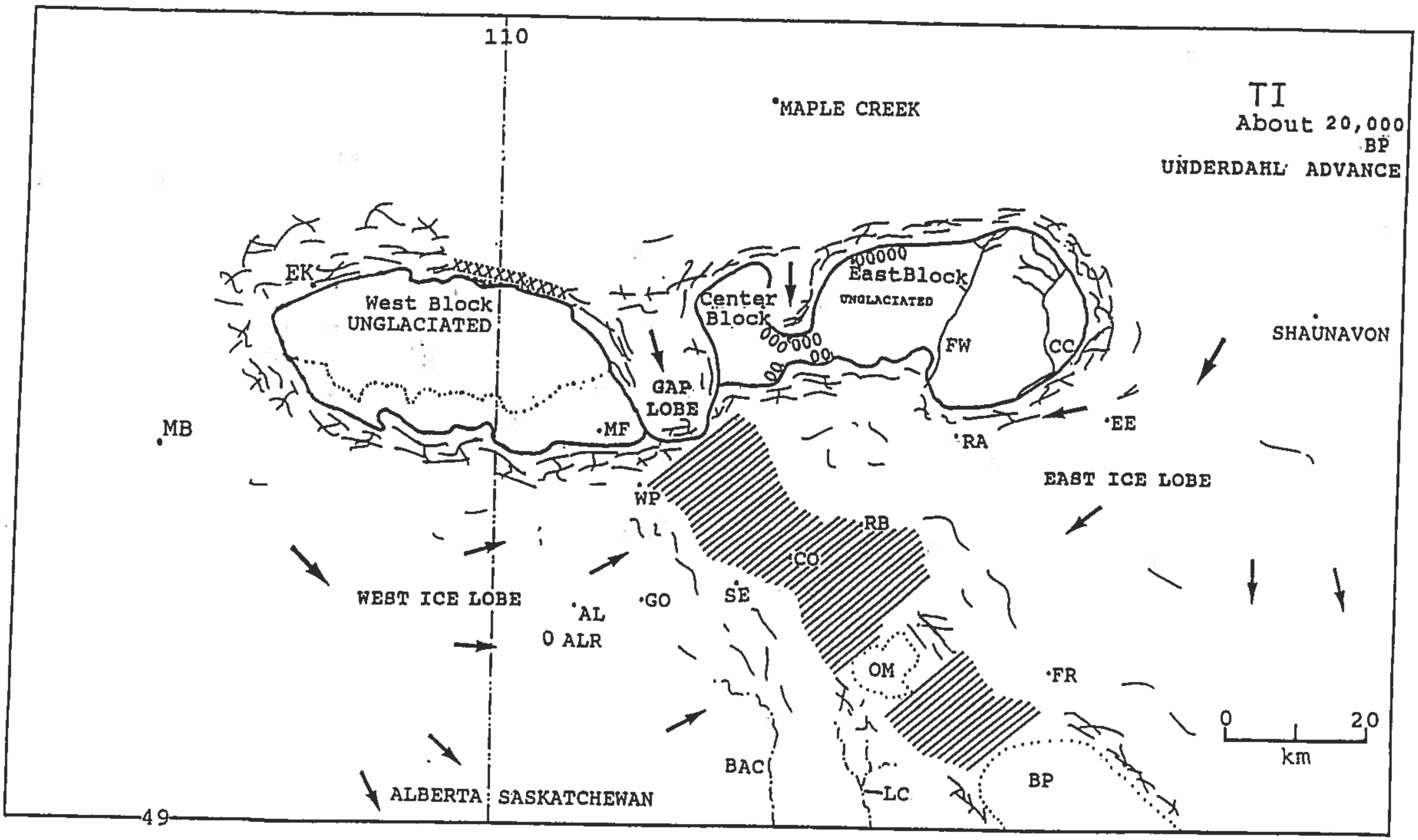
AB: The objectives of this investigation into the surficial deposits covering the Cypress Hills and the adjacent plains in Saskatchewan are, (1) to determine the genesis of the diamicton units in the study area that were described in the field and analyzed in thin-section, (2) to determine the origin of the Frenchman channel, (3) to develop a deglaciation pattern that updates previously published regional chronologies and deglaciation sequences from adjacent areas. Two glacigenic units are present south of the Saskatchewan Cypress Hills along the border between Saskatchewan and Montana, a widespread thick ((super 10) m) subglacial meltout till underlying a subaerial glacigenic debris-flow complex. The meltout till's widespread distribution reflects: (1) a highly concentrated basal debris layer, (2) the overlying subaerial debris-flow unit's role as an insulating mantle that slowed the rate of meltout, and (3) the maintenance of drainage away from the ice front precluding formation of large ice-contact glacial lakes in which glaciolacustrine depositional processes would have predominated. Glacigenic deposits in the Canal, Gilchrist, and Cypress Lake sections, on and near the southern flanks of the hills, consist of diamicton beds containing diamicton pebbles and irregular intraclasts of normally graded silts. The diamicton beds are intercalated with sand, silt, and clay laminae, which are deformed by dropstones. They were deposited in lakes impounded at the Late Wisconsinan Maximum when the ice (West, Gap, and East lobes) surrounding the Cypress Hills coalesced blocking the local drainage. Catastrophic release of these lakes during the initial stages of retreat from the maximum of the Late Wisconsin Glaciation, cut the Frenchman channel in its sidehill position along the Cypress Hills. The outburst began with the release of glacial Lake Graburn near Merry flat, which triggered the subsequent outbursts of glacial lakes Cypress, Belanger, Robsart, and Blacktail. Thin-section analysis of sediments from the study area and central Alberta revealed that the subglacial meltout till had well to strongly developed skelsepic and lattisepic plasma fabrics with clean grain boundaries. Glacially derived debris-flows, whether deposited subaerially or subaquatically, have insepic plasma fabrics and obscured grain boundaries. The ice of the last part of the Wisconsin Glaciation was the most extensive ice. This may reflect formation of a western ice divide not present during earlier glaciations. Erratics scattered over the surface beyond the limits of this ice are not the remnants of older more extensive glaciations but material ice rafted across the lakes impounded at the maximum. Two advances (Middle Creek and Altawan) were newly recognized in the area south of the Cypress Hills. Also the maximum of limit of the Late Wisconsin Glaciation has been redefined and given a new name, the Underdahl Advance. During deglaciation the East Lobe was largely immobile, whereas the West Lobe underwent several extensive advances and retreats and is more similar to a continuously surging margin. The West Lobe was probably derived from a different ice divide from the East Lobe.



The three ice lobes present in Alberta during the early stages of retreat of the Late Wisconsinan ice in Alberta and Saskatchewan. The boundaries of the East Lobe are uncertain in Saskatchewan as are the valleys and plateaus in British Columbia that are ice-free (after Shetsen 1984).

'. TI, the Underdahl Advance, about 20,000 BP. Distribution of the ice at the maximum of the Late Wisconsin Glaciation showing the location of the ice lobes. Ice extended south of the Cypress Hills to the limit of the Late Wisconsin Glaciation in Montana. Letter code in Fig. 6.2.

- ice covered plateaus
- erratics limit
- ice margin
- coalescence area
- ice
- xxxxxx end moraine
- 000000 ice pushed gravels
- ice flow direction
- Battle and Lyons creeks under ice cover at this time.


TI
About 20,000 BP
UNDERDAHL ADVANCE
MAPLE CREEK
SHAUNAVON
West Block
UNGLACIATED
Center Block
EastBlock
UNGLACIATED
GAP LOBE
WEST ICE LOBE
EAST ICE LOBE
ALBERTA
SASKATCHEWAN
110
49
MB
EK
MF
WP
FW
CC
RA
EE
RB
CO
SE
GO
AL
O ALR
OM
FR
BAC
LC
BP
0
20
km

. The five ice advances in the study area, 1 the Underdahl Advance, 2, the Middle Creek Advance, 3, the Altawan Advance, 4, the Pakowki Advance, 5, the Etzikom Advance. Stalker's (1977) Late Wisconsinan margin followed the Etzikom Advance Margin. In Alberta the Pakowki and Etzikom margins reflect the margins drawn in Westgate (1968). The Middle Creek margin in Alberta is equivalent to the Wild Horse margin north of the West Block (Westgate 1968) but south of the West Block the Middle Creek Advance is less extensive than Westgate's Wild Horse Advance (Westgate, 1968). The location of the Middle Creek margin on west flank of the West Block is uncertain as this area may have been part of the coalescence zone between the West Lobe and the East Lobe (see text). The Underdahl Advance is the most extensive advance in the area. Letter code given in Fig. 6.2.

coalescence zone between the East and West Lobes

area not glaciated during the Late Wisconsin glaciation

Westgate's (1968) margins

Westgate (1968) margin uncertain

margins developed in this paper

uncertain margins (this paper)

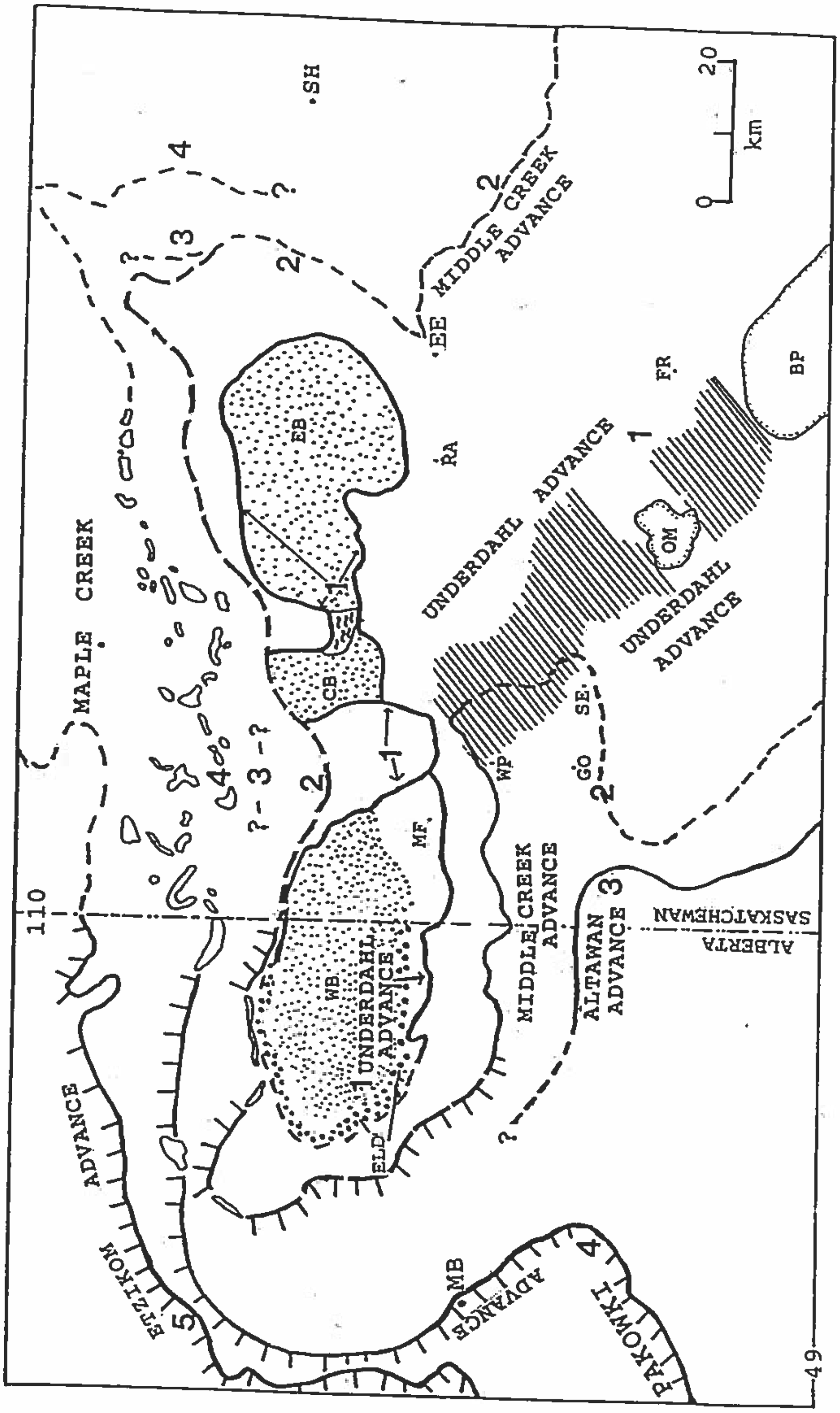
discontinuous hummocky ridge

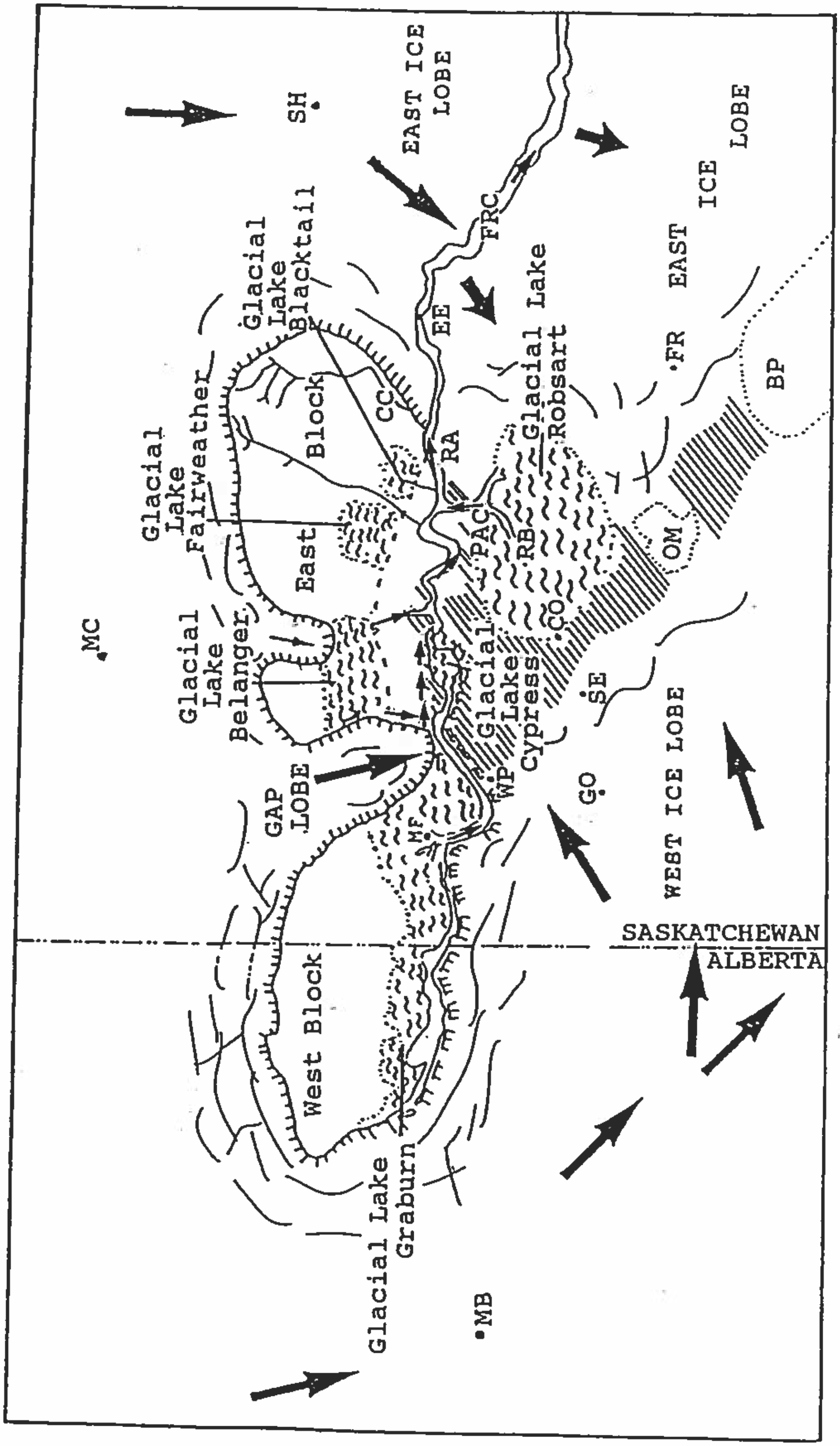
impounded glacial lake

plateau ice-covered during the maximum and then ice free

erratics limit

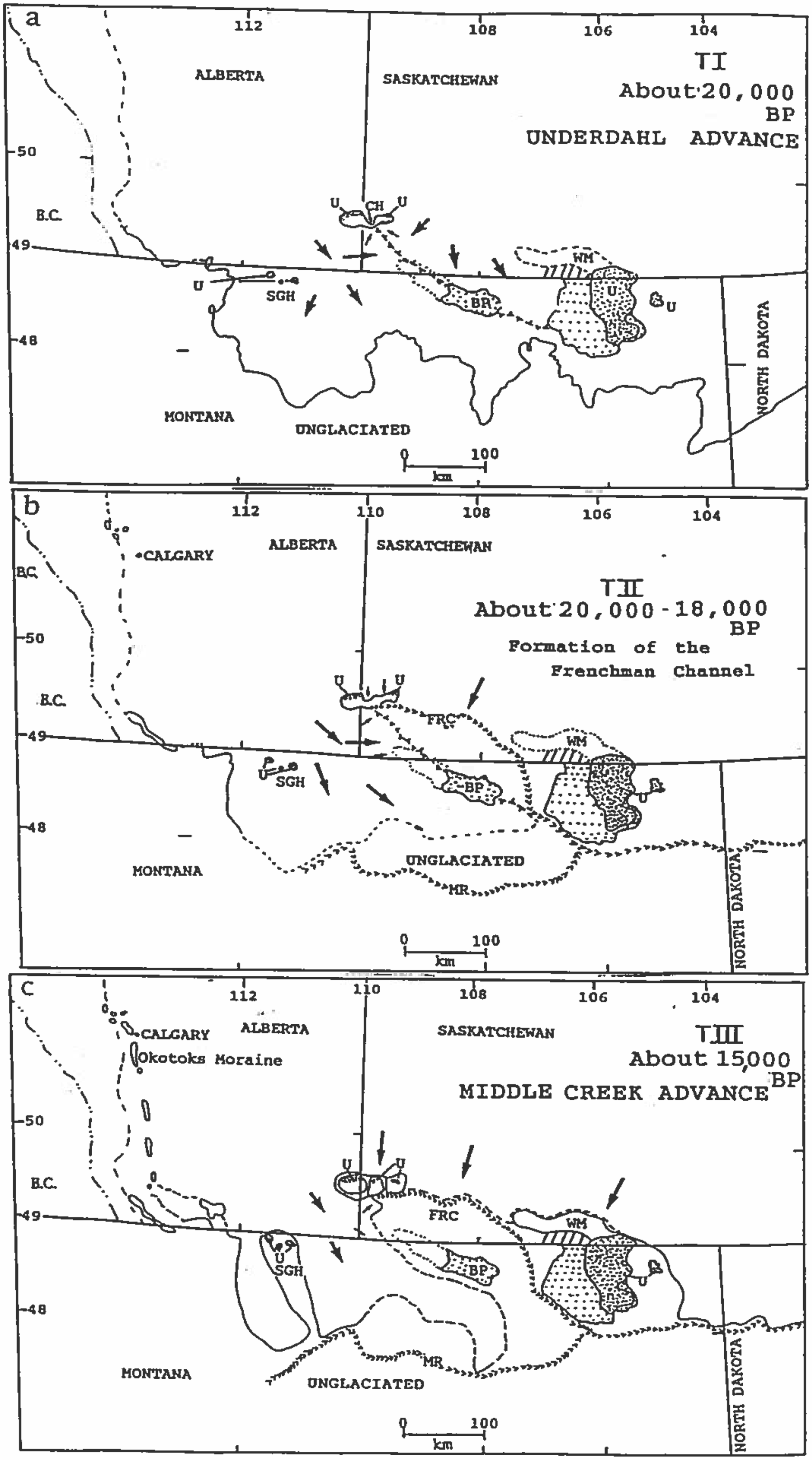
ELKWATER DRIFT ELD

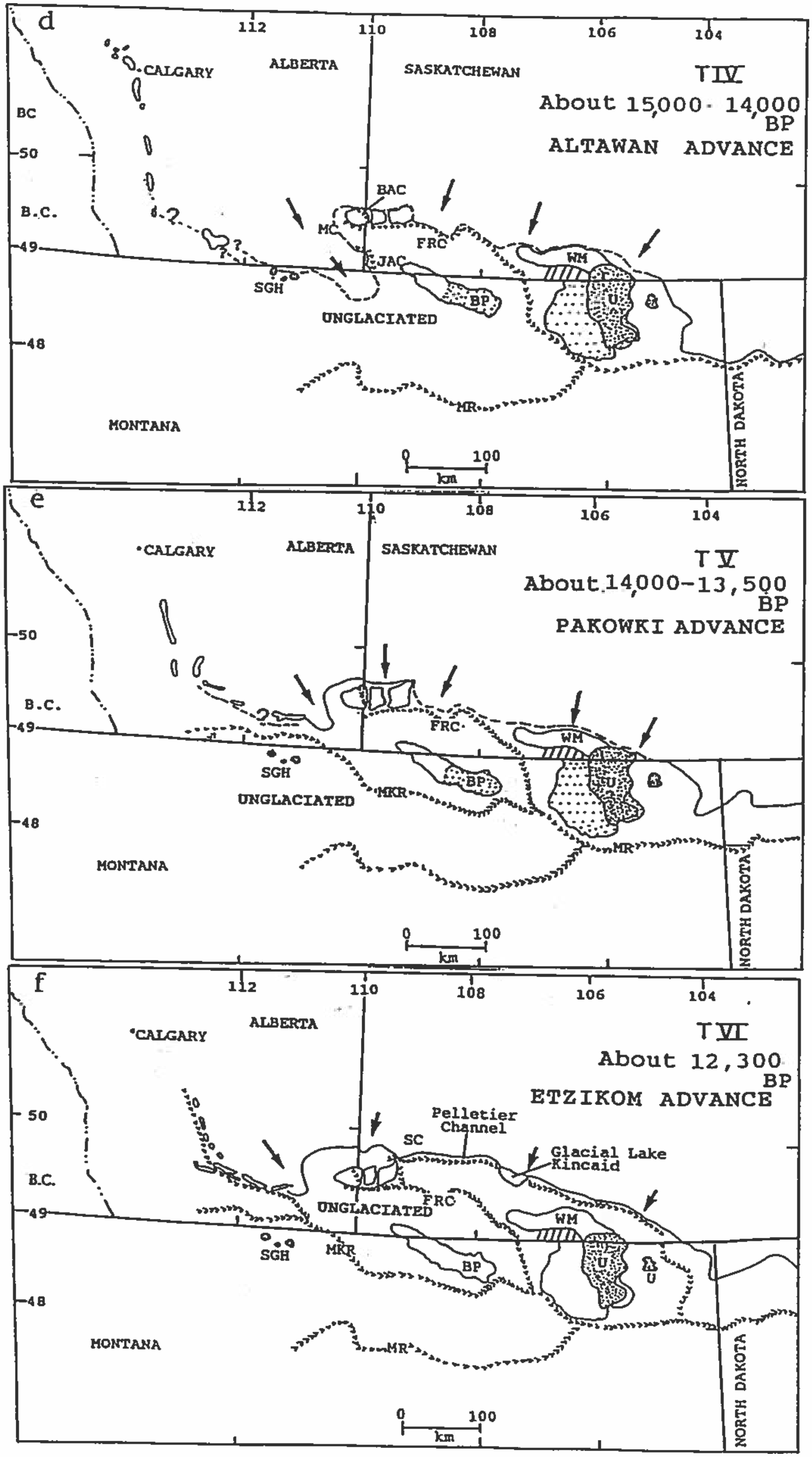

MAPLE CREEK
SH
EE
RA
FR
BP
OM
EB
CB
MF
WB
SE
GO
WP
ELD
MB
MIDDLE CREEK ADVANCE
MIDDLE CREEK ADVANCE
UNDERDAHL ADVANCE
UNDERDAHL ADVANCE
UNDERDAHL ADVANCE
ALTAWAN ADVANCE
ETZIKOM ADVANCE
PAKOWKI ADVANCE
ALBERTA
SASKATCHEWAN
110
49
0 20 km

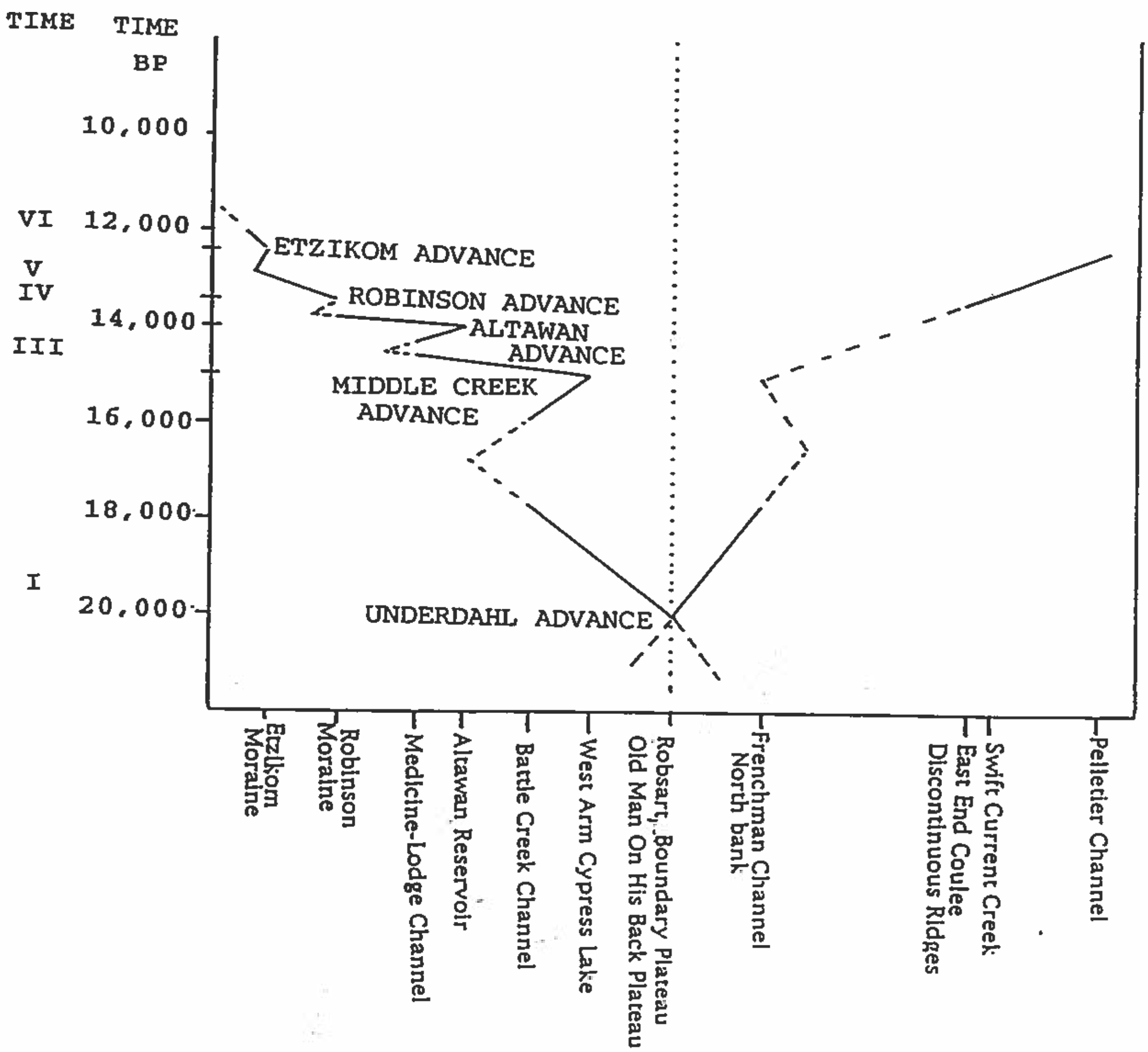

EAST ICE LOBE
SH
EAST ICE LOBE
FRC
EE
Glacial Lake Blacktail
Glacial Lake Robsart
FR
BP
CC
RA
Block
Glacial Lake Fairweather
East
PAC
RB
OM
CO
MC
Glacial Lake Belanger
Glacial Lake Cypress
SE
WP
GO
GAP LOBE
MF
WEST ICE LOBE
SASKATCHEWAN
ALBERTA
West Block
Glacial Lake Graburn
MB

Regional distribution of the ice front at each of the six time slices descri in the text. 6.14a Underdahl Advance. 6.14b Ice margin during incision of the Frenchman Channel. Ice margins out of the main study area are uncertain. 6.14c Mid Creek Advance. 6.14d Altawan Advance. 6.14e Robinson Advance. 6.14f Etzikom Advance showing Pelletier Channel and glacial Lake Kincaid. Letter Code given in Figure 6.1, 6.2. The diagrams are based on work published by Horberg (1952), Westgate (1968), Clayton and Moran (1982), Fullerton and Colton (1986), Klassen (1991, 1992) and the author's fieldwork (1988 - 1991).

SGH	Sweet Grass Hills
U	never glaciated
	ice boundary
	uncertain ice boundary
	coalescence zone
	ice flow direction
	ice-covered upland
	morainal ridge
	river and meltwater channels
	area in southern Saskatchewan possibly covered by pre-Late Wisconsinan ice.
	pre-Late Wisconsinan affected area in Montana


a
112
108
106
104
ALBERTA
SASKATCHEWAN
TI
About 20,000 BP
UNDERDAHL ADVANCE
50
B.C.
49
U
CH
WM
SGH
BR
48
NORTH DAKOTA
MONTANA
UNGLACIATED
0 100 km
b
112
110
108
106
104
CALGARY
ALBERTA
SASKATCHEWAN
B.C.
TII
About 20,000 - 18,000 BP
Formation of the Frenchman Channel
50
49
FRC
WM
SGH
BP
48
MONTANA
UNGLACIATED
MR
NORTH DAKOTA
0 100 km
c
112
110
108
106
104
CALGARY
ALBERTA
SASKATCHEWAN
Okotoks Moraine
TIII
About 15,000 BP
MIDDLE CREEK ADVANCE
50
B.C.
49
FRC
WM
SGH
BP
48
MONTANA
UNGLACIATED
MR
NORTH DAKOTA
0 100 km

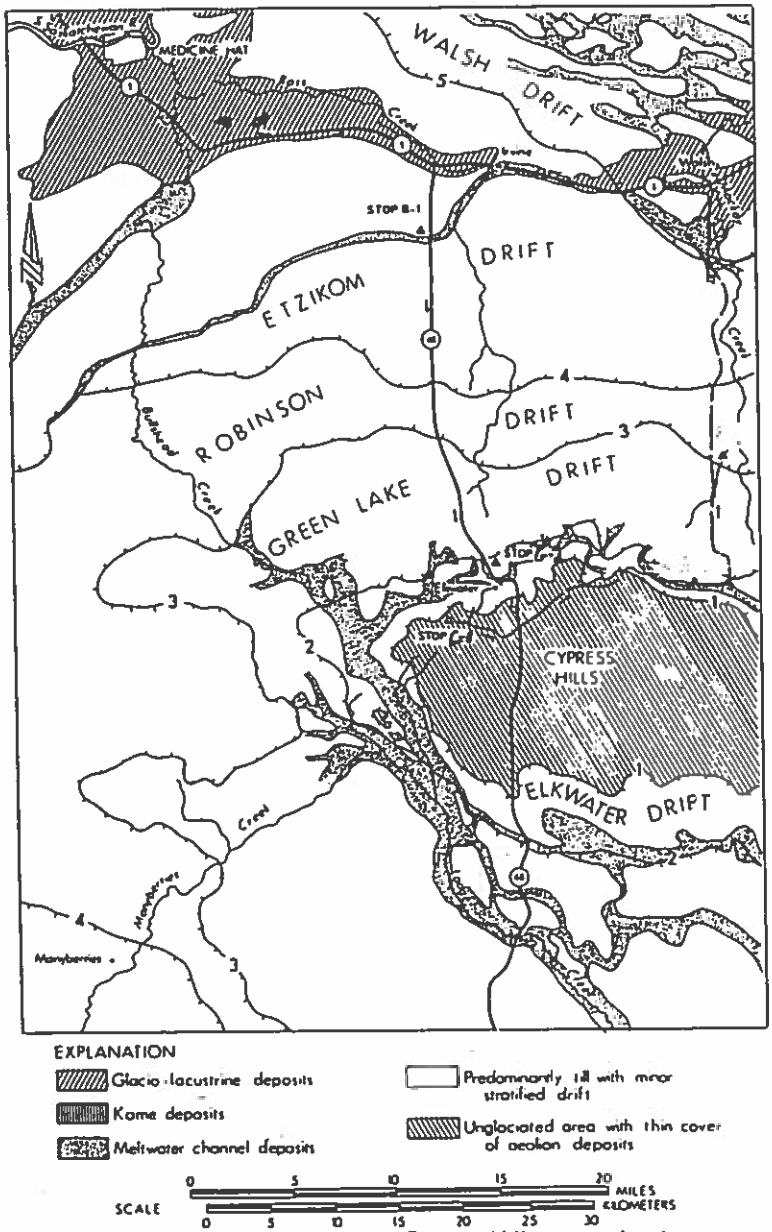

d
112
110
108
106
104
CALGARY
ALBERTA
SASKATCHEWAN
T IV
About 15,000 - 14,000 BP
ALTAWAN ADVANCE
BC
50
B.C.
49
BAC
MC
FRC
WM
JAC
SGH
BP
U
UNGLACIATED
48
MR
MONTANA
NORTH DAKOTA
0
100
km
e
112
110
108
106
104
CALGARY
ALBERTA
SASKATCHEWAN
T V
About 14,000-13,500 BP
PAKOWKI ADVANCE
50
B.C.
49
FRC
WM
SGH
BP
U
UNGLACIATED
MKR
48
MR
MONTANA
NORTH DAKOTA
0
100
km
f
112
110
108
106
104
CALGARY
ALBERTA
T VI
About 12,300 BP
ETZIKOM ADVANCE
50
Pelletier Channel
SC
Glacial Lake Kincaid
B.C.
49
UNGLACIATED
FRC
WM
SGH
MKR
BP
U
48
MR
MONTANA
NORTH DAKOTA
0
100
km



Schematic time-distance diagram of the relationship between the East and West lobes in the study area during the Late Wisconsinan. The Gap Lobe was only present during the Late Wisconsinan maximum when it coalesced with the East and West lobes. After this it has not been recognized with certainty.

	Reference							
LATE WISCONSIN GLACIATION UNITS	WESTGATE (1968)*	WESTGATE (1972)*	CHRISTIANSEN (1979)***	CLAYTON AND MORAN (1982)***	FULLERTON AND COLTON (1986, Chart 1)**	CHRISTIANSEN (1992)**	KLASSEN (1992), exact equivalents uncertain	THIS PAPER***
	ETZIKOM DRIFT	ETZIKOM DRIFT	PHASE 2	PHASES F-H, exact correlations uncertain	CRAZY HORSE, LORING AND FORT ASSINIBOINE TILLS, surface tills in Montana, (no Late Wisconsinan Subdivisions)	BATTLEFORD FORMATION, contains numerous local surface till units	Last Advance Drift Interlobate Drift First Advance Drift	ETZIKOM ADVANCE
	PAKOWKI DRIFT	ROBINSON DRIFT						ROBINSON ADVANCE
				PHASE E?				ALTAWAN ADVANCE
				PHASE E?				MIDDLE CREEK ADVANCE
	WILDHORSE DRIFT	GREEN LAKE DRIFT	PHASE 1	PHASE D				UNDERDAHL ADVANCE
PRE-LATE WISCONSIN GLACIATION UNITS	ELKWATER DRIFT	ELKWATER DRIFT	NONE MENTIONED	PHASES A, B, C	HERRON PARK TILL, MARKLES POINT TILL, KISLER BUTTE TILL, (ILLINOIAN)	FLORAL FORMATION upper till Early Wisconsinan, lower till Illinoian	BEDROCK WITH DRIFT LANDSCAPE COMPLEX	NO PRE-LATE WISCONSINAN DRIFT UNITS IDENTIFIED
					2 HAVRE TILLS, 2 PERCH BAY TILLS, ARCHER TILL, (PRE-ILLINOIAN)	SUTHERLAND GROUP pre-Illinoian, Warman, Dundurn and Mennon Formation till(s)	BEDROCK WITH RESIDUAL DRIFT LANDSCAPE COMPLEX	

The chart shows some of the glacial units identified in the study area and adjacent areas. * denotes morphostratigraphic units (now called allostratigraphic units), ** denotes lithostratigraphic units, *** denotes chronostratigraphic event units, Klassen's (1992) landscape complexes have no direct equivalents buy should broadly correlate to the units indicated. Christiansen (1979) and Clayton and Moran (1982) used radiocarbon dates and long distance correlation of glacial landforms and glacial margins to set up their chronology. The use of lithostratigraphic, morphostratigraphic and chronostratigraphic terms in the area has created a complex and confusing glacial chronology for the area.



Surficial geology of the Cypress Hills area, showing route

STOP G-1 Slump scarp along northern escarpment of Cypress Hills; 47 miles (76 km). Elevation, 4,775 feet (1,455.2 m).

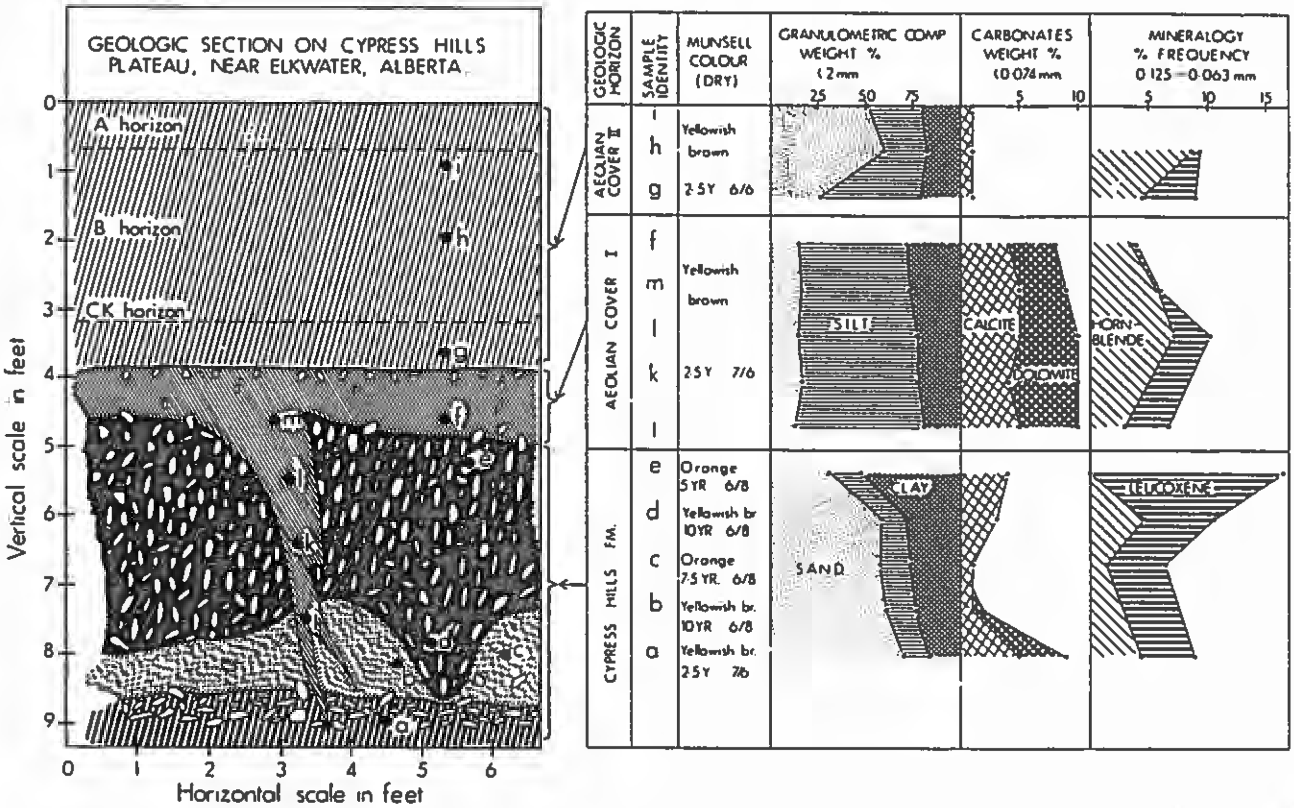
The Cypress Hills paleosol is developed in the uppermost few feet of the Cypress Hills Formation and is commonly covered by Quaternary eolian deposits. It has been preserved at several localities on the plateau and is readily discernible because of its reddish B-horizon. Lithologic data, which are summarized in Figs. 8-20 and 8-21, justify use of the term "paleosol" and demonstrate that sediments in the B-horizon have been relatively strongly weathered. 1) The localized absence of dolomite shows that carbonates were once leached from this zone and that the present calcite is of secondary origin. 2) The concentration of clay-sized material decreases progressively downward and is suggestive of an alluvial origin. 3) Weathering has been most intense at the top of the reddish zone of the Cypress Hills Formation where hornblende is absent and leucoxene reaches its maximum concentration. At slightly lower levels hornblende grains are present but their dentate margins show that they have suffered much corrosion. 4) Clay minerals likewise show a progressive upward increase in degree of weathering. Smectite, mica, and kaolinite are all present in the matrix of the unweathered Cypress Hills gravels, but in the overlying reddish zone they are either absent, altered, or of considerably lower concentration. It is most probable that this soil developed during the long weathering interval that proceeded the Elkwater glaciation.

The section exposed along northern escarpment of Cypress Hills consists of:

Quaternary	
6. Eolian cover II; yellowish-brown loam; topsoil is a black chernozem	4.0 feet (1.2 m)
5. Eolian cover I; yellowish-brown calcareous silt-loam with quartzite pebbles concentrated in uppermost part; fills frost wedge and is 1 foot (0.3 m) thick above Cypress Hills Formation; clay content increases progressively upwards through unit	1.0 feet (0.3 m)
Oligocene	
4. Cypress Hills Formation; loose gravel similar in lithology to lower units with abundant reddish to orange coloured clayey matrix; the truncated B-horizon of Cypress Hills paleosol; pebbles coated with secondary calcite; Quaternary frost action has moved elongated pebbles into vertical or highly inclined positions, produced involutions, and a silt-filled frost wedge, 4 feet (1.2 m) long and 8 inches (20 cm wide that cuts through units 3 and 4	3.0 feet (0.9 m)
3. Cypress Hills Formation; yellowish-brown to orange coloured sandy clay loam with a few quartzite pebbles; manganese oxide patches in sand and as coatings on pebbles; deformation during Quaternary is indicated by periglacial involutions	1.0 feet (0.3 m)
2. Cypress Hills Formation; loose gravel with abundant sandy loam matrix; lithologically similar to underlying unit except that calcareous cement is absent	20.0 feet (6.1 m)
1. Cypress Hills Formation; conglomerate with minor sand lenses; well-rounded cobbles and pebbles of quartzite, argillite, arkose, and chert cemented together with calcium carbonate; a cliff-forming unit whose lower slopes are covered with colluvium	15.0 feet (4.6 m)

Two phases of periglacial activity can be deciphered in the disturbed Cypress Hills paleosol. Elongate pebbles were moved into highly inclined positions and involutions were formed during the earlier phase. These structures, which point to cold, moist soil conditions at the time of their formation, are penetrated by younger frost wedges whose delicate "rootlets", intact margins, and undeformed silt infilling show that they never contained ground ice but instead were filled immediately with eolian sediment. These wedges developed under dry, very cold conditions when permafrost was well established in the area.

The northern escarpment of the Cypress Hills has suffered extensive slumping during post-glacial times. This is particularly well demonstrated at this site where slumped material has partly filled the Elkwater ice-marginal channel, providing the dam which has led to the development of Elkwater Lake.



Geologic section in Cypress Hills Plateau, near Elkwater, with lithologic data on the Cypress Hills paleosol and overlying eolian deposits

STOP G-2 Mitchell Gravel Pit; 41 miles (66 km). Elevation, 4,050 feet (1,234.4 m).

Approximately 10 feet (3 m) of Green Lake outwash gravel and sand is exposed here. Carbonate rocks are conspicuous but Athabasca sandstone is very sparse. Sedimentary structures indicate that the immediate source area was to the north, namely the Green Lake stagnant ice mass whose former extent is now delineated by hummocky disintegration moraine. Elkwater drift lies immediately to the south and its subdued topographic expression is clearly visible to the southwest. This is probably the oldest surficial Laurentide glacial drift sheet in Western Canada.