PROVINCE OF ALBERTA

RESEARCH COUNCIL OF ALBERTA
BULLETIN 5

AIR PHOTOGRAPHS OF ALBERTA

by

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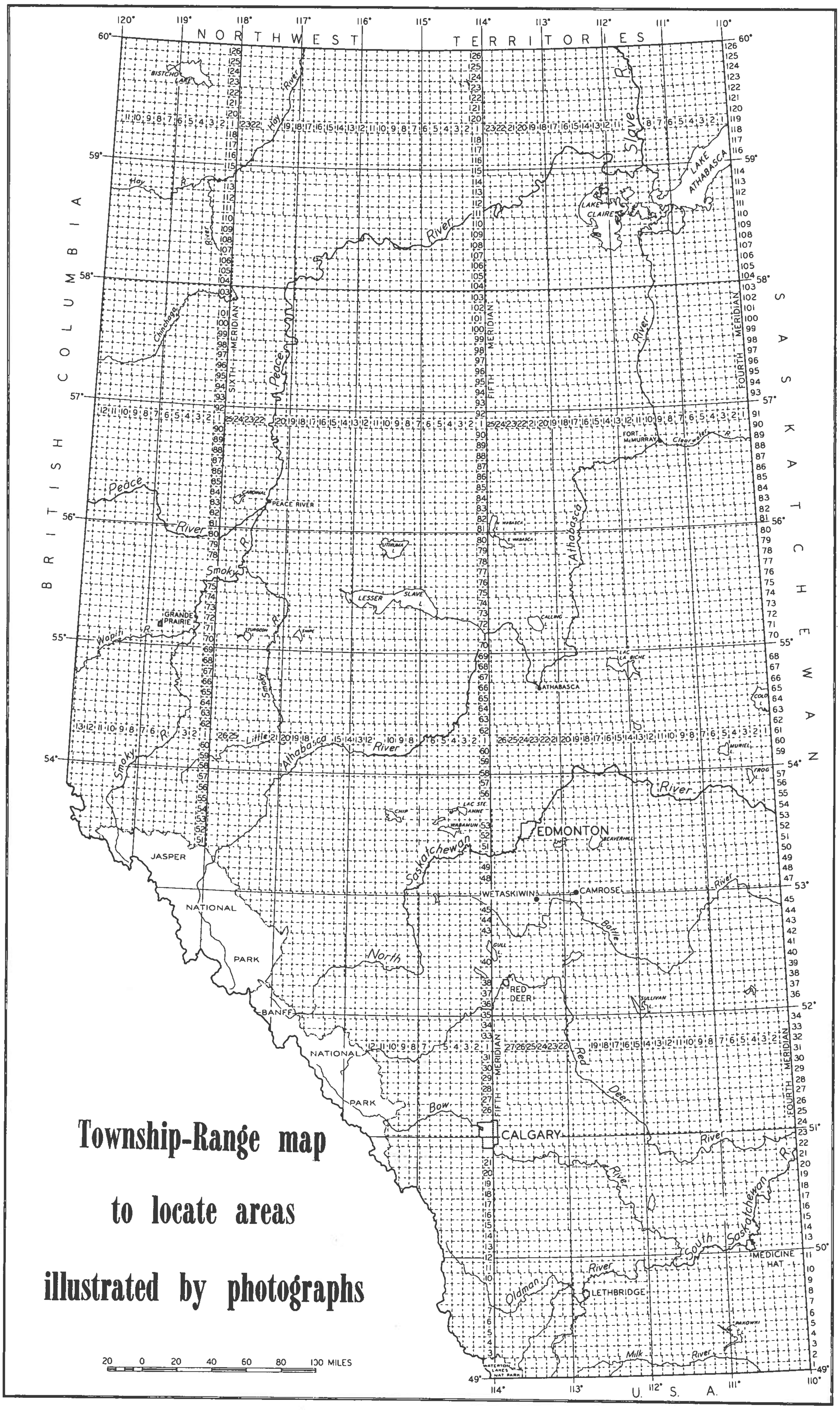


Township-Range map to locate areas illustrated by photographs

INTRODUCTION

In 1956 the Research Council published a report entitled "Air photographs of the Plains region of Alberta". At the time of publication it was realized that a more comprehensive report was required and hence the first report was published in preliminary form. The present report gives a more complete coverage of the Plains region and is strengthened by the addition of photographs from the Mountains and Precambrian Shield. The work on the Plains photographs was done by C. P. Gravenor, the Mountains and Foothills photographs by R. Green and the Shield photographs by J. D. Godfrey.

Over the past 20 years air photographs have been used extensively by geologists, soil scientists, foresters, geographers, topographers and engineers. While air photographs have been used by the different disciplines for a wide variety of purposes, basically they have two main uses: (1) to provide accurate topographic and planimetric maps, and (2) to provide information on landforms, structure and materials on the surface and subsurface of the earth. The main purpose of this report is to describe, by means of selected photographs, some of the major landforms and structural features found in Alberta. It is anticipated that a knowledge of the morphology and origin of these landforms will aid the geologist and other professionals in their exploration and development of Alberta's natural resources.

The photographs have been mounted as stereo-pairs or stereo-triplets for use with a hand stereoscope. In the mountainous areas—because of the great relief—some difficulty may be experienced in obtaining stereo vision. In general the stereoscope should be closed for higher elevations and opened for points of lower elevation. In some cases it is also necessary to rotate the stereoscope slightly in order to stay in stereo vision from one part of the photograph to another.

On most Mountain and Foothills photographs the rock units are numbered, and where numbering has been carried out the oldest units have the lowest numbers. The same rock units are not necessarily recognized on all photographs.

Certain of the glacial features found on the Plains are now being or have been recently formed by glaciers in the Mountains, and photographs of the Mountains should be referred to when examining the Plains photographs.

In some cases it is anticipated that the reader will not be fully familiar with the terminology used and the origin and significance of the various landforms. Where possible the origins are given and new terms are explained but the reader should make use of the list of general references found at the end of each discussion.

With the exception of the photographs of the Precambrian Shield and Mount Assiniboine all of the photographs may be obtained from the Technical Division, Department of Lands and Forests, Edmonton. The Precambrian Shield and Mount Assiniboine photographs may be obtained from the National Air Photographic Library, Topographical Survey, Ottawa. Orders for contact prints should be accompanied by the photograph numbers which are given on the discussion page for each set of photographs. Except for the photographs of Mount Assiniboine the scale is 1:40,000 (1 inch=3,330 feet). Unless indicated otherwise each plate is oriented so that north is at the top of the page.

Mr. C. Van Waas aided in the selection of photographs from the Plains region of northern Alberta and his help is gratefully acknowledged.

Acknowledgment is made to the Technical Division, Department of Lands and Forests, Government of Alberta and to the Royal Canadian Air Force for permission to reproduce the photographs.

Precambrian Shield: Disappointment Lake

Location: Tp. 120, R. 5, W. 4th Mer.

Photograph Nos. A15154-55, 56, 57

Bedrock Geology

Bedrock of principally one type underlies most of the area shown. In the vicinity of Disappointment Lake the rocks have considerable relief above the lake and show large-scale folding (dashed line). The general strong resistance to weathering indicates that these rocks are predominantly granite gneiss. Softer layers of schist and metasedimentary rock have been etched out by weathering and glaciation and form the depressions and valleys of the area. These depressions and valleys parallel the rock strike and provide a means of determining the structural configuration. The core of isoclinal fold (A) is eroded relatively deeply and must be composed of schistose or metasedimentary rocks.

Structure

Clearly-defined large isoclinal to open folds dominate the structural features. To the south the folds die out and give way to more massive granite or granite gneiss terrain. Close to the south shore of Disappointment Lake the foliation dips steeply to the northeast. Two sets of fractures, which in some cases constitute faults, have easterly (B) and northerly or NNE (C) orientations. An en échelon arrangement of some fractures with a steep northerly dip can be noted (D). Little or no horizontal separation is evident in the area around D where the foliation is continuous across the fractures. A major easterly fault exists along the main axis of Disappointment Lake. A significant horizontal separation along this fault is apparent from the lack of fit of the fold pattern on the north and south sides of the lake. This becomes more obvious from the examination of greater photographic coverage of the area around Disappointment Lake.

Glaciation

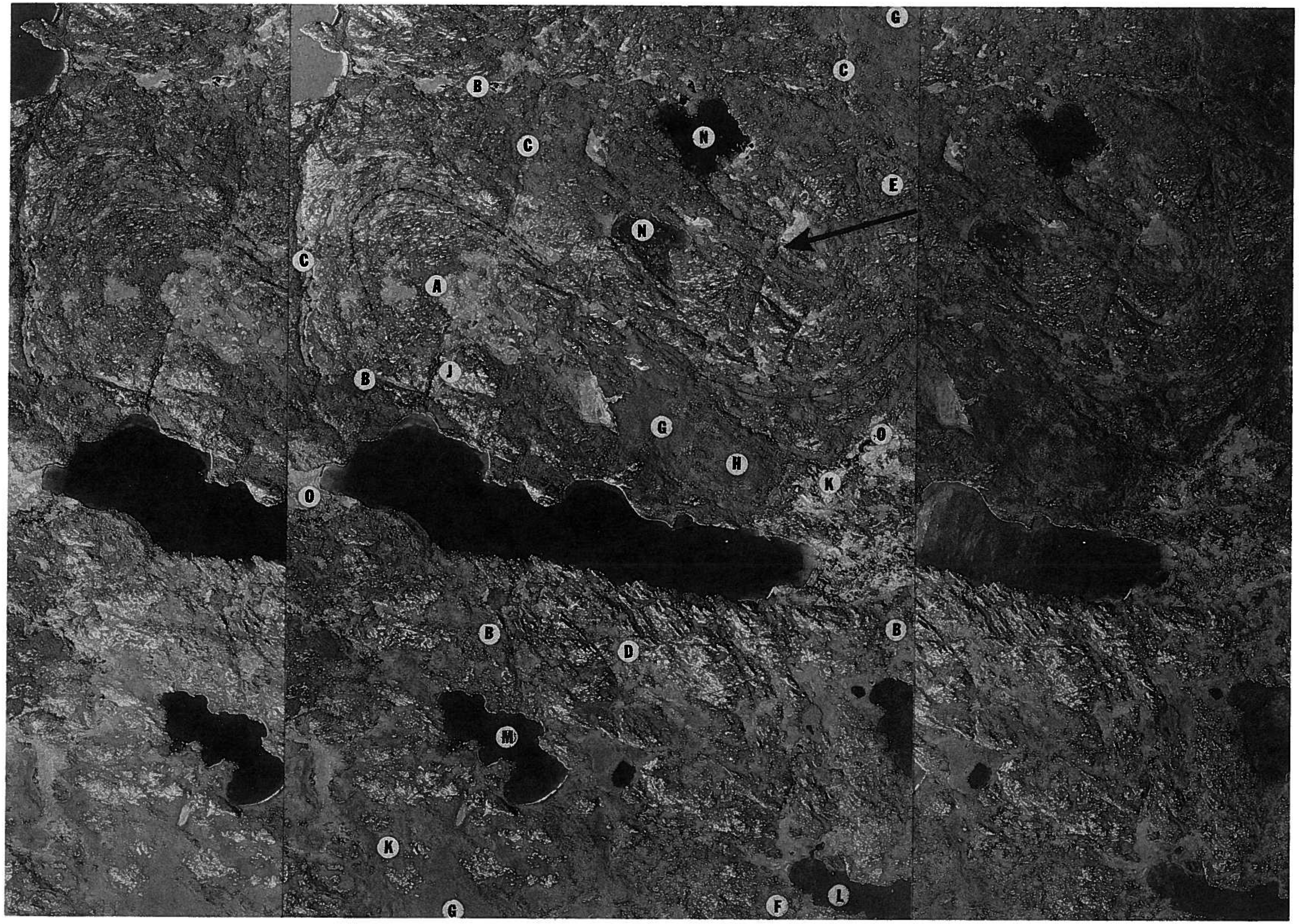
Glacial erosion has left a high proportion of outcrop (light tone) in areas of highest relief and the commonly-formed giant grooves are restricted to the northeast (E) and southeast (F) corners, oriented at north 72 degrees east and north 77 degrees east, respectively. Glacial erosion has developed grooves (E) (arrow) to such an extent that the erosional lineaments (north 72 degrees east) have almost obscured the folded bedrock lineaments (oriented east of north). Sand plains (G), mainly flat-lying, occupy large areas and are covered by a typically uniform growth of large trees. The prominent hill (H) represents a glacial sand-covered bedrock topographic high on which scattered bedrock outcrops can be expected. A small esker or crevasse filling (J) occupies a valley lineament of northerly orientation entering Disappointment Lake. Small outcrops (K) protruding through the glacial sand cover — or through areas of muskeg — have a light tone and slight relief.

Lakes

The position and general shape of Disappointment Lake and lakes L and M are related to WNW-trending fault or fracture features. The lake outlines have been partly modified by subsequent re-shaping in areas of sandy beaches and muskegs. A series of headlands and smooth embayments have thus been developed on the north shore of Disappointment Lake, and are prominent on other lake shorelines. Shallow lakes (N) are characterized by abundant plant life on the water surface. Areas of muskeg (O) are flat, light-toned, and commonly low-lying; they may or may not be associated with a lake.

Reference

Godfrey, J. D. (1958): Aerial photographic interpretation of Precambrian structures north of Lake Athabasca; Res. Coun. Alberta, Bull. 1, 19 pages.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Precambrian Shield: Swinnerton Lake

Location: Tp. 126, R. 2. W. 4th Mer.

Photograph Nos. A15151-79, 80, 81

Bedrock Geology

The rocks which strike NNE (dashed lines) consist of granite gneiss forming well-defined, elongate uplands (A) with intervening less resistant bands of schist or metasedimentary rocks (B) in the valleys. Note that most of the outcrop (light tone) is over the granite gneiss uplands, and only scattered small ridges and knobs of outcrop (C) are found in the muskeg- and lake-filled valleys. Much of the high ground shows a lightly-lined appearance parallel to the northerly rock strike. This must be a consequence of etched metamorphic foliation.

Structure

A major structural feature is the gross delineation of the northerly rock strike by parallel valleys.

The subdivided lineament (DE) represents a major fault which transects the rock strike in a NNW to northwest direction. Fault scarps (E) are prominent at several localities along the fault. Many of the eroded soft lithologic bands referred to above do not extend across the northern branch of this northwest-trending fault, and a similar arrangement of valleys is not found on the southwest side of the fault system. A horizontal separation of several miles along the fault system is indicated. Strike faults within the soft, eroded bands (B) — mechanically weak — are not evident except where erosion-resistant rocks are adjacent to the zone of movement and give rise to scarps (F).

Glaciation

Glacial advance from the ENE has effectively scoured the bedrock providing a high proportion of outcrop on the high ground. This photograph shows excellent examples of giant grooves (flutings) oriented north 63 to 65 degrees east, several miles in length (arrows) (see plate on flutings). Glacial deposits consist largely of small areas of sand (G), either flat-lying or covering gentle slopes. Discontinuous ridges of sand (H) lie north 63 degrees east and parallel the giant grooves. Other unconsolidated glacial debris has been deposited in discontinuous, patchy bands on bedrock, resulting in a mottled-striped vegetation cover parallel to the direction of ice movement. A small esker (crevasse filling?) (J) is contained in a valley between two lakes.

Lakes

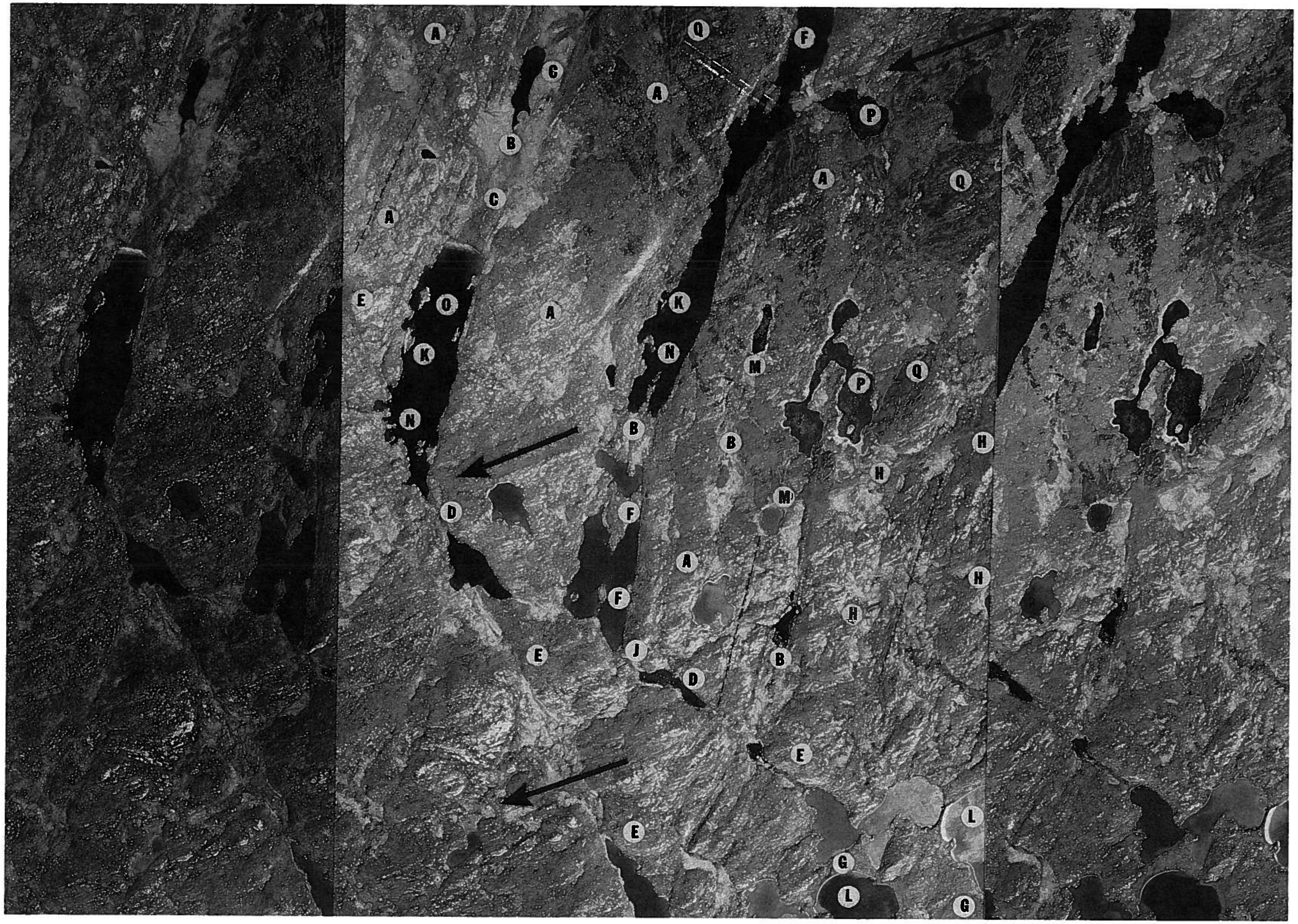
The shapes and distribution of lakes are related to structure, lithology and glacial erosion. The majority of lakes are elongated and are parallel either to the general rock strike or to fault structures. The nature of a lake shoreline is determined by the bedrock, surficial deposits, and direction of ice advance. A rocky shoreline tends to be irregular in outline (K), whereas those adjacent to sand (L) or muskeg (M) have a smoothly curving outline. Plucking by ice action has resulted in highly irregular and embayed shorelines on the west and southwest margins of some lakes (N). A tone gradation through a series of steps from the white sandy shore to the black of the deeps (O) occurs in lakes with shallow, sandy margins. Shallow lakes with possible rocky or bouldery bottoms may have plant-life such as water lilies on the surface which are evident as fine-scale mottled pattern (P).

Burn-out

Recent burn-out areas can be seen as dark-grey patches (Q) elongated in a northerly direction in the northeastern part of the plate. It is likely that the winds blew from the south at the time of the fire. Small "strings" of trees (light tone) represent unburnt remnants, many of which also have a northerly alignment; some of these remnants may have been protected as a result of their occupying open rock fractures. The true percentage of outcrop can be best judged in the burnt areas where it is much higher than it appears to be on the vegetation-covered highland. Also, in areas of recent burn, such as those illustrated, outcrops tend to be free of lichen thus permitting ready examination and evaluation of the bedrock geology.

Reference

Godfrey, J. D. (1960): Geology of Andrew Lake North; Res. Coun. Alberta Prelim. Rept. 58-3 (in press).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Precambrian Shield: Andrew Lake

Location: Tp. 125, R. 1, W. 4th Mer.

Photograph Nos. A15096-3, 4, 5

Bedrock Geology

The major part of the area is underlain by an essentially homogeneous granite. The granite is fairly resistant to weathering, giving rise to rolling upland topography, and is massive compared to the banded and etched granite gneiss terrain shown in "Precambrian Shield: Swinnerton Lake". A boss (A) of granitic rock rises above the general ground elevation and lies within a band of metasedimentary rocks (B) which in part have low resistance to weathering. These rocks which strike NNE occupy the low ground in the east part of the plate and are covered by glacial deposits and muskeg on the northern margin. The interprovincial Alberta-Saskatchewan boundary, surveyed in 1939, crosses the granitic boss (A) in a north direction.

Structure

Bedrock structures of the major part of the area tend to be obscured by the glacial features and the vegetation cover. Granite boss (A) and the metasedimentary band (B) are notable exceptions. Minor faults (C) transect the area in various directions and have associated scarps (D). Fine lineation and a north-trending scarp on the east side of the lake (E) indicate the presence of either steeply-dipping shears in the weak rocks of band B, or a series of almost vertical, thinly-bedded sedimentary rocks.

Glaciation

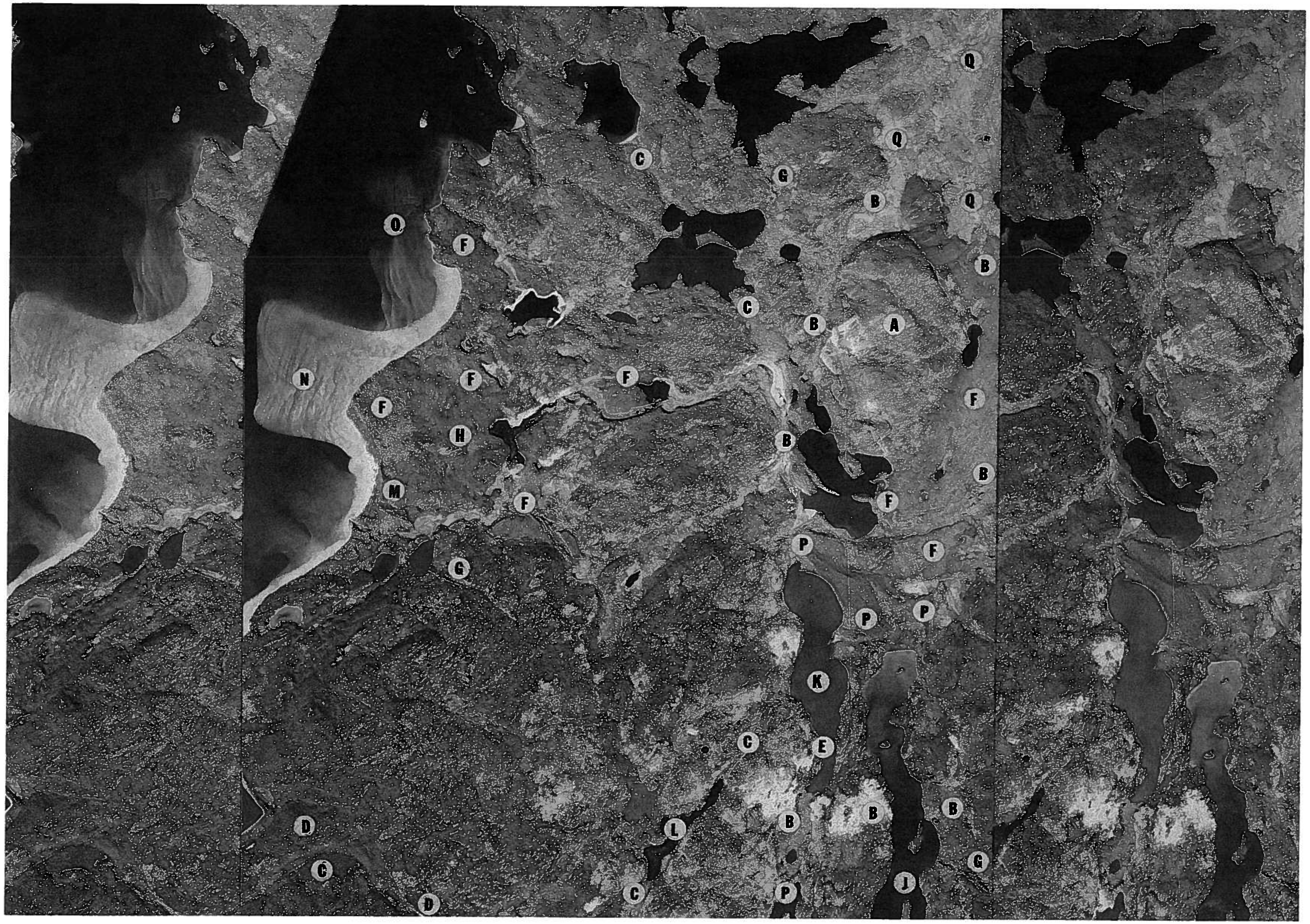
Glacial advance was from the northeast as illustrated by the crag and and tail and ice-plucked features on boss A. The main erosional expressions of continental glaciation are shown as a striped outcrop pattern, giant grooves (trending north 53 degrees east), and the crag and tail effect produced on the granitic boss (A). Glacial deposits are principally made up of flat-lying sand plains (F), with other minor features such as eskers (crevasse fillings?)(G) which commonly occupy small valleys upon entering lakes. Vegetation on the sandy plains is distinctive as a relatively uniform growth of trees except where influenced by other moisture conditions introduced by creeks and muskeg areas. Pinnacles of bedrock (H) project through the glacial sand cover. A mottled-striped pattern of outcrop and vegetation parallels the direction of glaciation on the upland regions.

Lakes

In the absence of major bedrock structures over most of the area, many lake shapes trend to be irregular. Elongated lakes J, K and L are located as a consequence of ice-erosion of a fault and of softer layers in the band of metasedimentary rocks B. Where surficial factors (sandy shores, wind conditions) become significant in reconstructing lake shorelines the latter develop simple, smooth, curving contours as on the east shore of Andrew Lake. A series of raised beaches, marking former shorelines, have been formed at M. The sandy shoal (N) forming a continuity with the extensive sand plain to the east is well defined. Above the shoal the water is only a few feet deep but the sides of the shoal plunge sharply to considerable depth. East-trending gullies in the lake-bottom sand (O) can be related to submarine erosive action of a creek entering Andrew Lake. Old shorelines (P) to the north and south of lakes J and K also indicate a recent lowering of the lake levels. An extensive area of sandy muskeg (Q) is located just north of the boss (A).

Reference

Godfrey, J. D. (1960): Geology of Andrew Lake North; Res. Coun. Alberta, Prelim. Rept. 58-3 (in press).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Preglacial Valley

Location: Tp. 38, R. 8, W. 4th Mer.

Photograph Nos. 160-5205: 1501-31, 32, 33

The main feature shown on the accompanying plate is a broad bedrock lowland. The northern edge of the lowland is marked A and the southern edge B. The lowland area is now occupied by proglacial lake deposits, outwash and ice-contact stratified drift.

It is believed that the bedrock low marks the location of a preglacial river valley which was cut under arid to semi-arid conditions. The age of cutting of the valley is not known and could have been either late Tertiary or Pleistocene. Hence the term preglacial is used rather loosely and in fact means before the first glaciation in this area. That the valley was cut under dry conditions is suggested by the extreme variability in valley width (from 1 to 4 miles) and by the shape of tributary valleys. The variation in valley width is best explained by valley widening through slope retreat and the development of minor pediments (an example of this type of erosion is shown in this report under the title badland development). The tributary valleys are short and armchair-shaped (C and D) which would suggest that they too were formed under conditions of arid erosion. The tributary at point C is filled with moraine (E) and is drift blocked at point F.

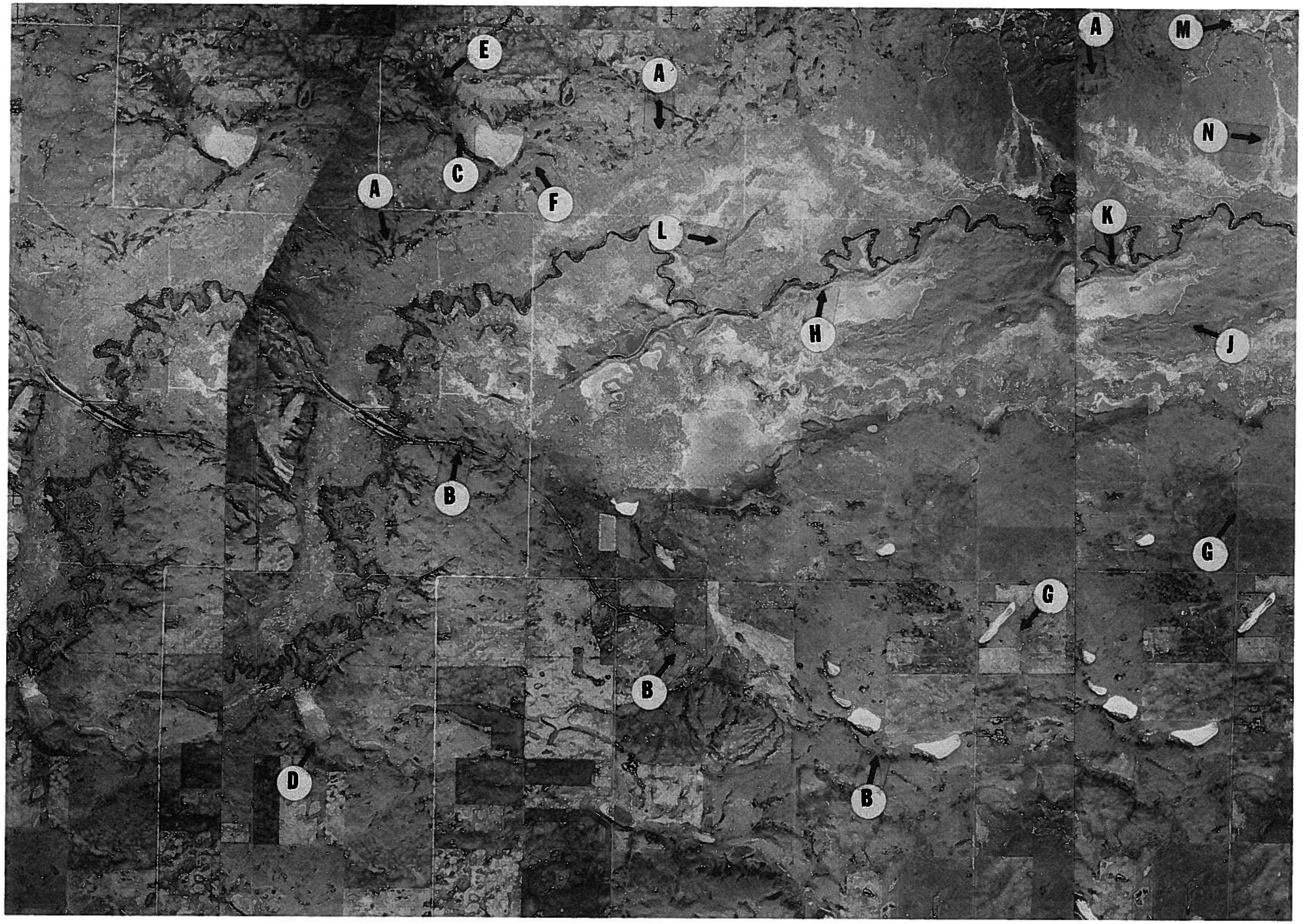
Deglaciation in this area was accomplished largely through downwasting and the uplands were cleared of ice first. Thus it is visualized that the preglacial valley was filled with debris-choked stagnant ice and the neighboring uplands to the north and south were ice free. Meltwaters from this stagnant ice mass deposited pitted outwash flats (G) between the receding ice and the valley wall (B). At the same time and in the same way on the northern side of the valley the drift at point F was deposited.

The esker (H) noted in the centre of the valley was deposited during the final stages of ice melting. This sinuous sand and gravel ridge is flat-topped and is flanked by a series of minor sand and gravel ridges (J). Note the kettle (K) in the top of the ridge. The flat-topped nature of the ridge would suggest that it was deposited in an ice channel which was open to the atmosphere. Such a ridge might be classified as a crevasse filling but the sinuous nature of the ridge suggests a lack of rigid control and hence it is called an esker.

After this portion of the preglacial valley was finally cleared of ice a proglacial lake formed in the lowland as a result of an ice dam farther to the northeast. Sands and silts which were deposited in the lake (L) lap up on the sides of the esker, clearly demonstrating the age relationships of the deposits.

The drift on the northern preglacial valley wall has been breached at point M and underlying bedrock exposed. As a result of this erosion a minor alluvial fan is being constructed at point N.

Preglacial valleys of the type shown are commonly prolific groundwater producers and hence their location is important to the expanding economy of Western Canada.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Drift-Filled Valley

Location: Tp. 40, R. 5, W. 5th Mer.

Photograph Nos. 160-5208: 1552-38, 39

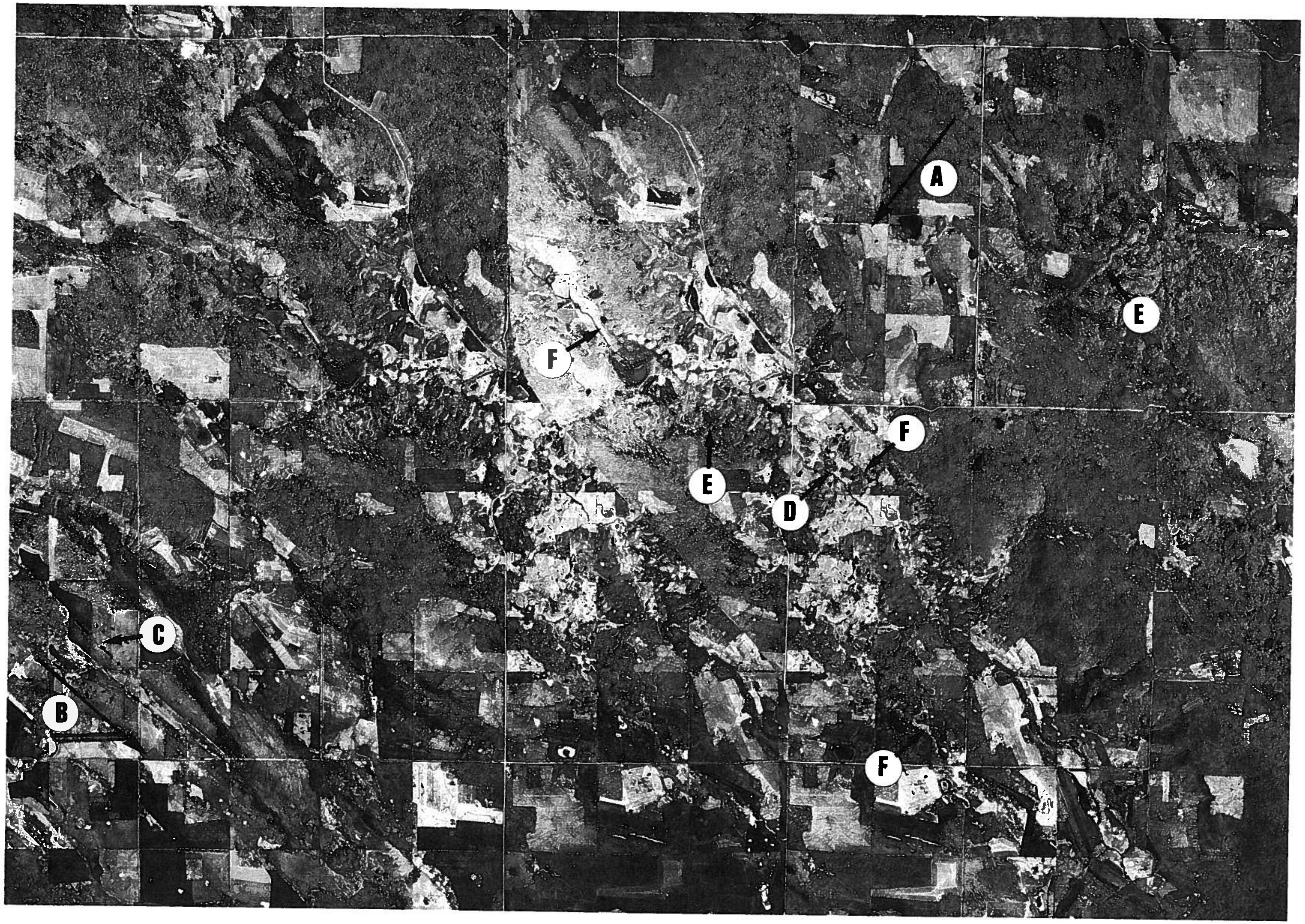
Arrows A and B on the adjoining plate indicate the ice-movement directions which prevailed in the area. The southeasterly direction, illustrated by a fluting at point C, was developed by a major glacier which flowed out of the mountains down the Athabasca River Valley and was deflected to the southeast by southwesterly-moving Keewatin ice (see diagram of ice-flow directions in Alberta under the title of flutings). It is believed that the Keewatin and Cordilleran ice masses coalesced at this location and together moved in a southeasterly direction.

During glacier retreat the two ice masses separated and the front of the Keewatin ice sheet wasted back in a downslope northeasterly direction. As the Keewatin ice retreated a series of parallel southeasterly-trending meltwater channels was developed along the ice margin. The drift-filled valley shown on the adjoining plate is one of these ice-marginal meltwater channels.

At a later date the Keewatin ice readvanced in a southwesterly direction as indicated by the arrow A. Evidence for the direction of this readvance is not shown on this plate but is marked by flutings and washboard moraines immediately to the southeast of the district under consideration (see plate on washboard moraines). Meltwaters from this readvancing glacier were ponded between the ice and the higher ground to the west and a mantle of lacustrine and glacio-fluvial materials was deposited over much of the area. Thus the flutings shown at point C are somewhat subdued due to the fact that there is a layer of lacustrine silt overlying the flutings. The limit of ice advance of the Keewatin ice sheet at this location is marked approximately by the hummocky disintegration moraine found on the floor and on the western slopes of the valley.

The hummocky disintegration moraine is composed of isolated knobs (D)—most of which have an enclosed depression in the top of the knob—and short linear disintegration ridges (E and F). The origin of these morainic features is discussed under hummocky disintegration moraine but it is interesting to note the two directions of linear disintegration ridges. Most of the ridges (E) lie roughly parallel to the direction of ice advance and a small number (F) at right angles. The significance of these directions is discussed under the title linear disintegration ridges.

Drift-filled valleys commonly contain some sand and gravel under the till cover and where such conditions exist groundwater can be developed from the sand and gravel fill. In this area the drift cover in the base of the valley is well below the upland surface and wells are commonly artesian.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Ice-Walled Channels

Location: Tp. 45, R. 10, W. 4th Mer.

Photograph Nos. 160-5215: 1368-12B, 13B, 14B

Drift-filled meltwater channels are among the more spectacular glacial features of the Plains region of Western Canada.

In plan view, the channels present a complex pattern composed of parallel and intersecting elements. In some places the major channels are roughly parallel to the ice-movement direction and the intersecting ones are at right angles. In other places the pattern is more confused and apparently the sub-glacier topography played an important role in determining the position of the channels. That the two directions were not everywhere used at the same time is indicated by the fact that the floor of one channel commonly truncates the deposits of another.

The channels probably originated from meltwaters moving through tunnels in the ice or through open ice-walled trenches. The fact that the pattern shows some control would suggest that the tunnels and ice-walled trenches were developed along crevasses or lines of weakness in the stagnant ice. The origin of the channels is, therefore, analogous to the formation of eskers with the exception that in the case of ice-walled channels the action of the meltwater was one of downcutting. Indeed in some areas it has been noted that the ice-walled channels form a continuous network with eskers. After the channels were cut they were infilled with drift—primarily in the form of hummocky disintegration moraine. It is believed that the infilling took place largely through the slumping of the debris-filled walls into the main channel. This method of infilling explains why one channel was suddenly abandoned in favor of another and also why in some cases there is a greater thickness of drift in the valleys than on the neighboring uplands.

In places where there was little drift in the ice walls there is little drift in the valleys and in some places there is only a thin cover of alluvium on the floors of the channels. In areas of thick drift it is common to find a layer of sand and gravel underlying the moraine fill and in such cases the buried sand and gravel forms an excellent aquifer.

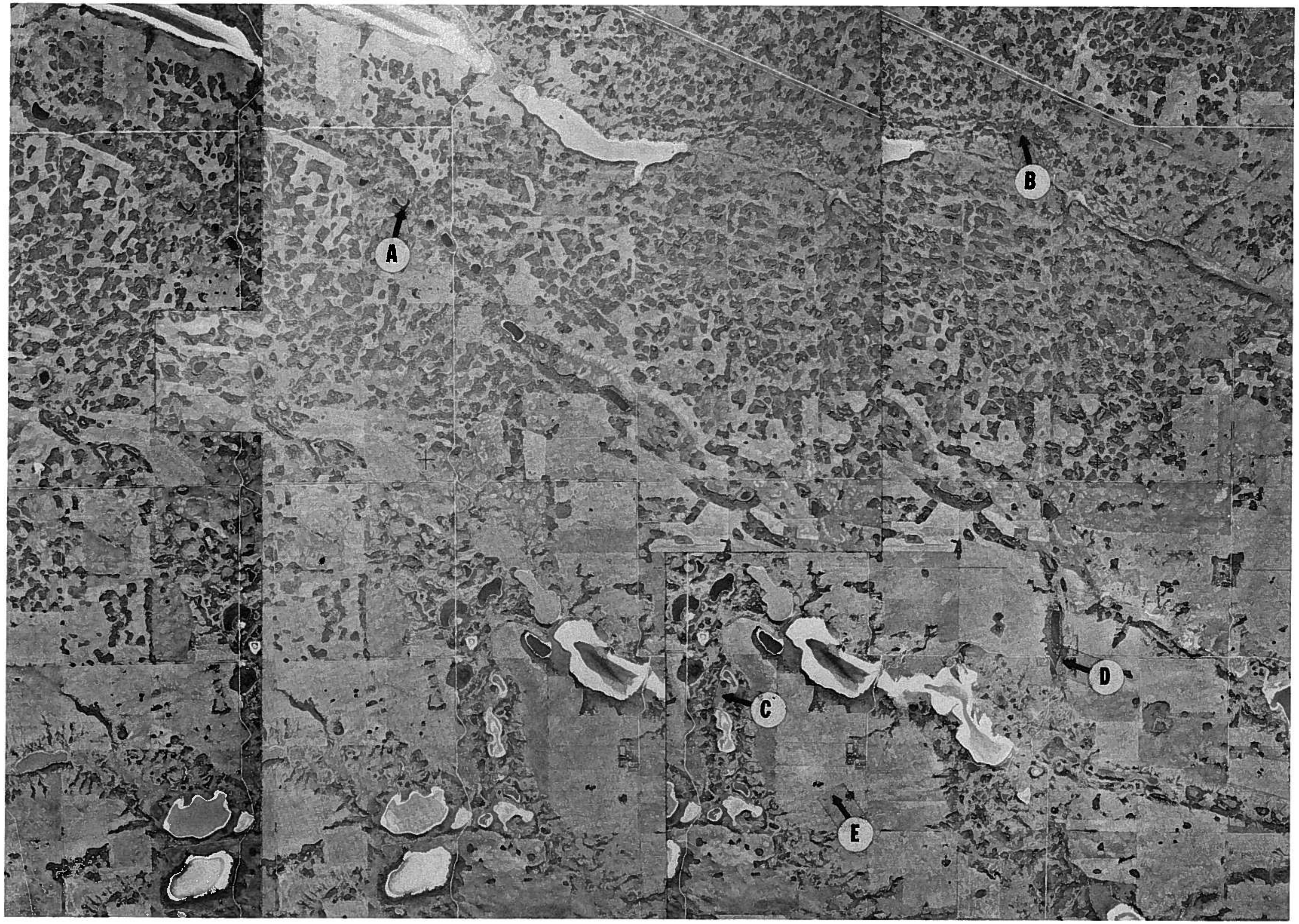
Commonly in areas of thick moraine the channels are almost completely infilled and their location can only be recognized by a chain of water-filled kettles (A). Point B marks a bedrock terrace formed during the cutting of the channel and later covered with hummocky disintegration moraine. Points C and D show the interconnected nature of the channels.

Poorly-developed flutings are evident at point E which indicate a southwesterly ice-movement direction. It is believed that these flutings were developed prior to the last ice movement in the area which was probably towards the south and southeast, roughly parallel to the long dimension of the channels.

Channels of the type described have been called stream-trenches, tunneldale (tunnel valleys) and rinnentäler (channel valleys). As not all the channels were formed in tunnels (some are over a mile in width) the term ice-walled channel has been applied.

Reference

Gravenor, C. P. and Kupsch, W. O. (1959): Ice-disintegration features in Western Canada; Jour. Geol., Vol. 67, p. 55-56.


A
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Ice-Marginal Channel

Location: Tp. 46, R. 20, W. 4th Mer.

Photograph Nos. 160-5216: 1543-22, 23, 24

As the last glacier to inhabit central Alberta retreated to the north and northeast, lakes were ponded between the retreating ice margin and high ground to the west. One such lake was ponded along the North Saskatchewan River Valley in the Edmonton area. The outlet for this lake was along the southern edge of a broad ice lobe in central Alberta. The channel shown on the accompanying plate is a portion of this outlet—which has been named the Gwynne outlet. Although the over-all configuration of this outlet is that of an ice-marginal channel there were places along its course where stagnant ice was probably present on both sides of the channel and other places where the ice margin lay well to the north and the channel merely followed areas of low ground.

The Gwynne outlet—as well as many other similar outlet channels in Alberta—is now occupied by a misfit river. In this case the river—the Battle River—is flowing on a very thin cover of fine-grained alluvium over Upper Cretaceous bedrock. The channel is dotted with a number of shallow lakes which have formed as a result of the low gradient and variation in thickness of the alluvial fill. Driedmeat Lake (A) is an example of one of these lakes.

The Battle River has built an extension of its channel into Driedmeat Lake at point B. In some respects this extension is similar to extensions of mouths of distributaries on deltas and at point C it has closed off the northern part of the lake. The resulting stagnant pond is beginning to fill in with organic material (D).

During the early phases of downcutting of the channel there was a brief period of aggradation followed by further downcutting which has resulted in a high level terrace. At point E the terrace gravels are being used for railway construction purposes. At point F the gravels are being used to purify water for the Town of Camrose. Water is pumped up from Driedmeat Lake into infiltration pits on the surface of the terrace. Wells have been placed in the gravel about 2,000 feet away from the infiltration pits and the well water is transmitted some 10 miles via pipeline to Camrose. Thus the terrace is being used as a large treatment plant for the purification of surface water.

One other point of interest on the photograph is the disappearance of tributary waters into the alluvial fill in the base of the channel (G). This indicates that the channel fill is permeable and is transmitting water to the Battle River from neighboring uplands.


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Flutings

Location: Tp. 96, R. 17, W. 4th Mer.

Location: Tp. 57, R. 7, W. 4th Mer.

Photograph Nos. 160-5705/06A: 2120-136, 137

Photograph Nos. 160-5316: 1443-2, 3, 4

As noted by several geologists there are all gradations between flutings and drumlins and in some places the two coexist (see point A on lower plate for example of a drumlin with flutings on either side). Although flutings might be considered as extremely long narrow drumlins—and are probably genetically related to drumlins—there is generally a fundamental difference in the longitudinal profile. The ideal drumlin has a streamlined shape which resembles an inverted teaspoon, whereas flutings are composed of parallel ridges which may or may not have a stoss end which is steep and a tapering lee end. The long axis of both flutings and drumlins is a measure of the direction of ice movement.

It is commonly noted that the flutings start at a point where the glacier moved over a slight topographic rise. Apparently a pre-existing bedrock or drift obstruction is sometimes sufficient to "trigger" the mechanism whereby flutings are created. An example of this is shown on the top plate where the flutings are observed to start at a slight rise in ground level. In cases where there is no obvious "triggering" topographic break it is quite possible that such a break existed during the initial overriding of the ice but has since been destroyed by the erosive action of the ice or buried under fairly thick drift.

In Alberta flutings are developed on highlands, on the sides of valleys, in lowlands and on uphill positions. From these observations it is believed that gross topography has little effect on the occurrence of flutings.

Flutings and drumlins in Alberta are composed of a wide variety of materials, the most common being till. In extreme northeastern Alberta flutings have been carved out of granite and metasediments (see Swinnerton Lake plate); in the area northwest of McMurray they are composed of sand and in central Alberta most are composed of till but a few have been developed on Cretaceous shales.

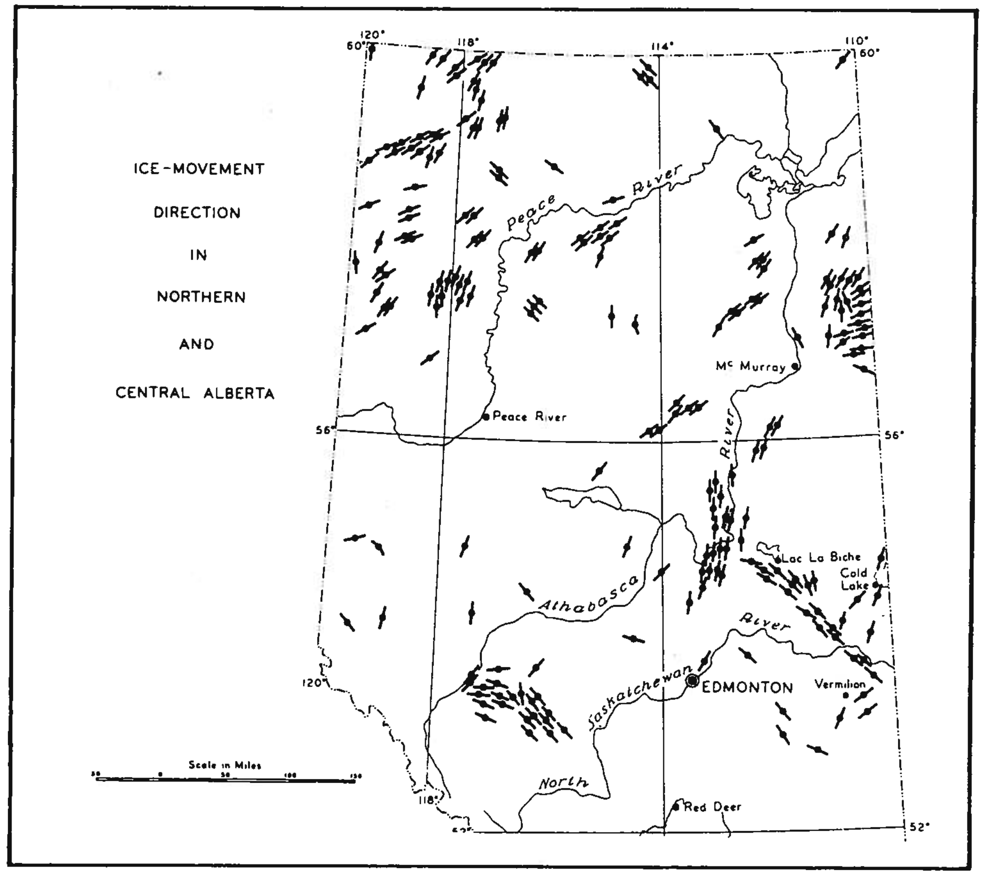
The flutings shown on the adjacent plates are several miles in length and range in height from a few feet to about 30 feet. Measurements on the distance between crests or troughs—fluting wavelength—have been made on several fields of flutings and it is found that there is a preferred wavelength of from 300 to 400 feet and a secondary preferred wavelength of 600 to 700 feet. These preferred wavelengths are apparently independent of topography or lithology.

In the case where flutings are formed from pre-existing drift or bedrock it is obvious that glacial erosion has been the dominant factor in their origin. Where they are made of till, however, it has been suggested that they were created by "plastering-on" of debris from the base of the ice. Another possibility is that till flutings and drumlins have been formed by the erosion and moulding of till which was deposited prior to the drumlin-making process.

An additional point of interest is a pitted valley train noted on the bottom plate at point B.

Reference

Gravenor, C. P. and Meneley, W. A. (1958): Glacial flutings in central and northern Alberta; Am. Jour. Sci., Vol. 256, p. 715-728.

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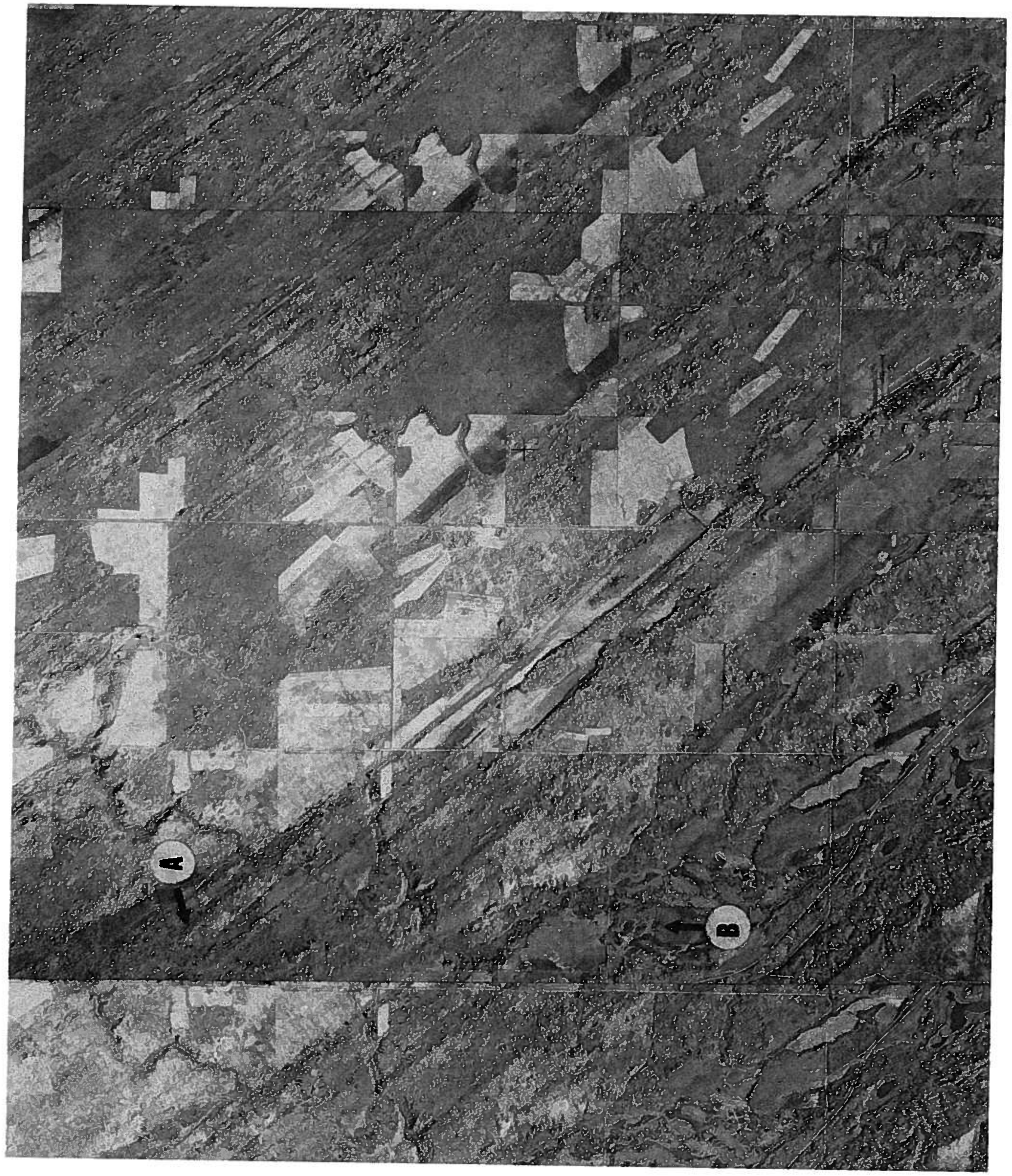

A
B

Ground Moraine

Location: Tp. 44, R. 14, W. 4th Mer.

Photograph Nos. 160-5214: 1368-6, 7, 8

The term moraine has been defined by Flint (1955, p. 111), as "an accumulation of drift having a constructional topographic expression in detail that is independent of the surface of the ground underneath it, and having been built by the direct action of glacier ice". And of ground moraine Flint states, "In accordance with current general usage, ground moraine can be thought of as moraine with low relief devoid of transverse lineal elements". It is noted that this definition excludes those areas where the drift is thin and the surface expression is controlled by underlying features.

Thwaites (1948, p. 45) has attempted to take this factor into account by subdividing the definition into three categories, the first of which deals with thin drift over bedrock which Thwaites terms veneered hills or rock-controlled hills.

The area shown on the adjoining plate is typical of much of the ground moraine in Western Canada. It answers the above definition in that it is an area of low relief and was deposited directly from glacier ice. The relatively thick drift cover—from 40 to 70 feet—suggests that the surface expression is independent of any underlying bedrock control.

There are, however, some features on the ground moraine of Western Canada which are not normally found on ground moraine described elsewhere and which do not fit in with the generally-accepted definition. For example, the ground moraine in Alberta is commonly gradational to hummocky disintegration moraine and such moraine in many places shows transverse elements (see plate on hummocky disintegration moraine). At point A the ground moraine is more hummocky and displays some of the knob and kettle characteristics of dead-ice moraine. The ice-movement direction (B) is indicated by some very faint flutings on the northeast part of the plate. One transverse element is noted—at point C in the form of a linear disintegration ridge. This ridge is composed largely of poorly-sorted sand and gravel and till and was probably formed in a crevasse developed normal to the glacier movement.

The area is dotted with small sloughs which mark depressions in the ground moraine. The steep-sided nature of some of these depressions (D) suggests that they were formed from buried ice blocks and hence are kettles. It is also noted that many of these kettles show elongation parallel to or normal to the direction of ice advance.

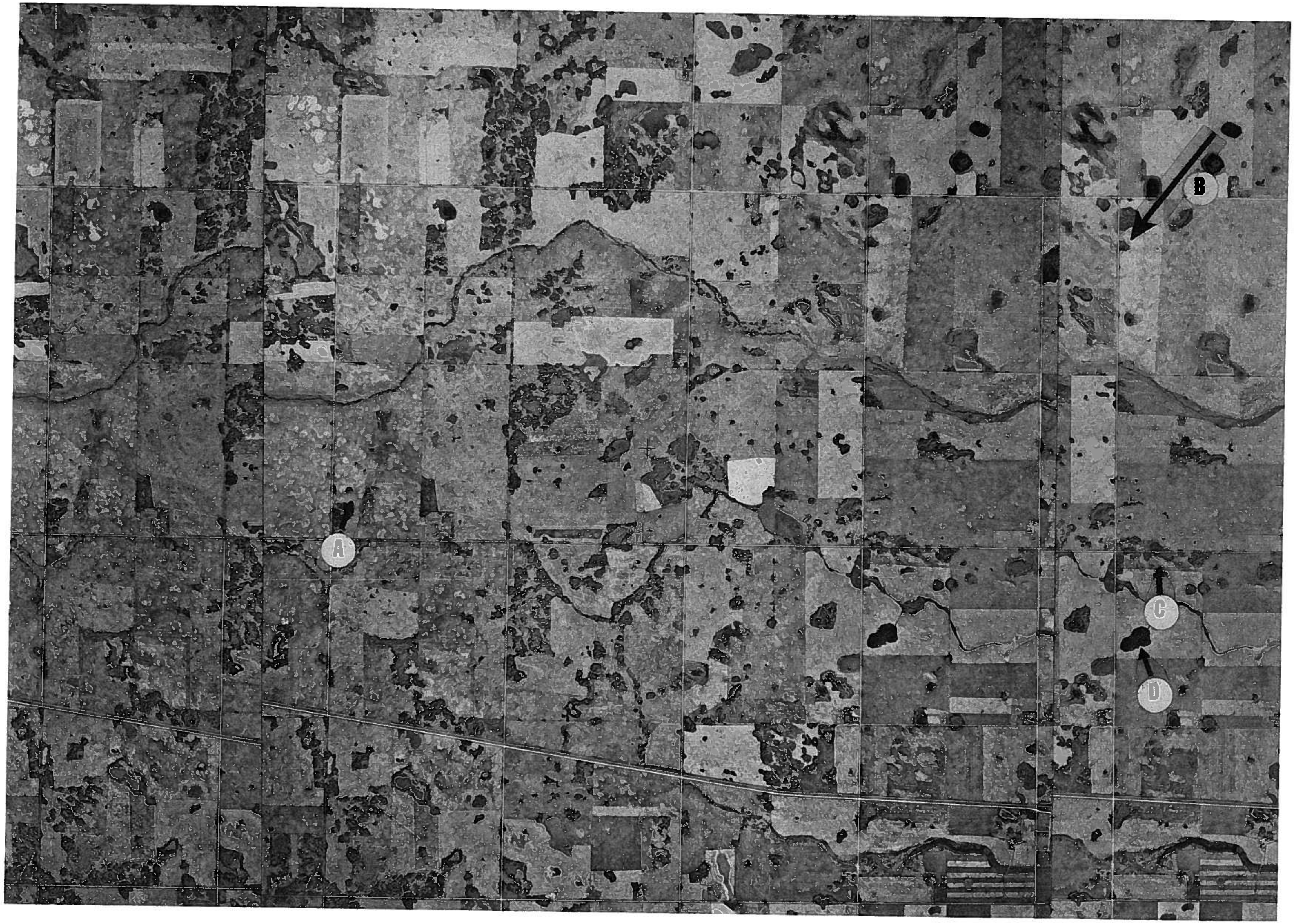
Taking all these factors into account—the transverse elements, gradation to hummocky disintegration moraine, subdued nature of flutings, kettles, and general pebble-grained nature of topography — it is suggested that the entire area is covered by a blanket of debris which was let down from the surface of the ice (see plate on hummocky disintegration moraine) and hence might better be called ablation moraine rather than ground moraine.

Drilling in this area shows that the moraine is composed largely of brown clayey till with included pockets of sand and gravel. It is of some interest to note that the gullies developed on clayey till are of considerable length and are broadly U-shaped in cross section. This type of gully is very useful in photo interpretation since it is indicative of poor internal drainage and hence impermeable and clayey nature of the surface deposits. The many shallow water-filled kettles (sloughs) also give an indication of the impermeable nature of the underlying material.

References

Flint, R. F. (1955): Pleistocene geology of Eastern South Dakota; U.S. Geol. Surv. Prof. Paper 262, 173 pages.

Thwaites, F. T. (1948): Outline of glacial geology; published privately by the author, 129 pages.


A
B
C
D

Hummocky Disintegration Moraine

Location: Tp. 46, R. 12, W. 4th Mer. — Photograph Nos. 160-5216: 1368-10, 11

Location: Tp. 32, R. 6, W. 4th Mer. — Photograph Nos. 160-5113; 1565-22, 23

The term hummocky disintegration moraine is used to describe knob and kettle topography which was deposited from stagnant ice. Other terms such as hummocky dead-ice moraine and hummocky ground moraine have also been used but the writer prefers to include the term disintegration to describe the process whereby the stagnant ice broke up into numerous blocks during the end phase of stagnation. In some places the ice broke up along inherent lines of weakness in the ice and is called "controlled" disintegration whereas in other places no obvious control is present.

There are all gradations between controlled and uncontrolled disintegration. Strong control is noted in the case of linear disintegration ridges which are described elsewhere in this report, whereas there is little evidence of any control in the distribution of the isolated hummocks on the adjoining lower photograph. On the upper photograph there is faint evidence of control as displayed by linear ridges (A) aligned in a northeast direction.

An analysis of hummocky disintegration moraine reveals the presence of several distinct elements, (1) linear ridges (A), (2) knobs (B) (with or without enclosed depressions in the tops of the knobs) and kettles (C), (3) moraine plateaus (D), (4) rim ridges (E), and (5) ice-walled channels (F). Linear ridges and ice-walled channels are not discussed here as they are treated elsewhere in this report. It might be mentioned, however, that the linear ridges (A) shown on the upper plate appear as a coalescence of knobs rather than continuous ridges.

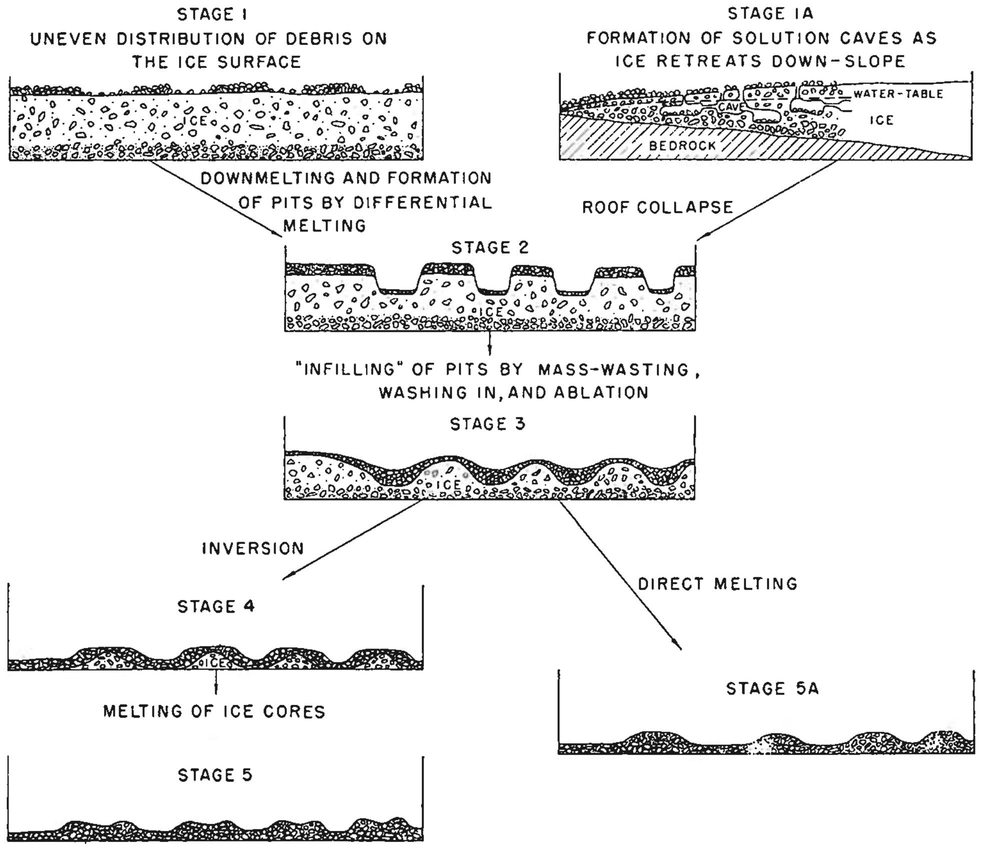
Isolated knobs (B) have a doughnut shape when viewed from the air. Such knobs have been called "prairie mounds" by the writer but this term should probably be dropped and the term moraine knob or moraine hummock used in its place. It is believed that moraine knobs have been formed from superglacial debris which slumped into pits on the stagnant ice surface—see accompanying diagram.

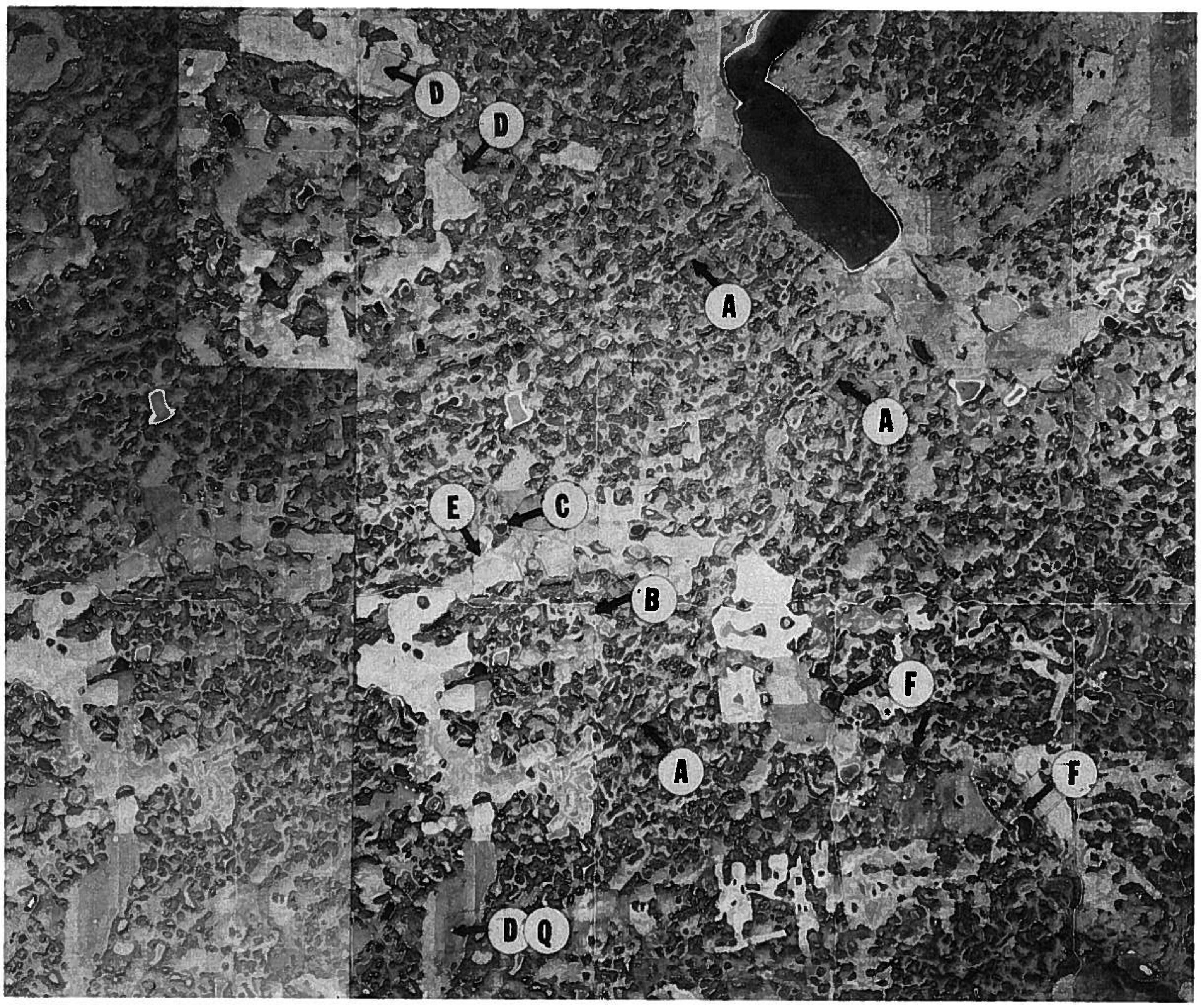
As can be seen on the upper plate there are all gradations between moraine knobs and moraine plateaus (D). A limited amount of drilling done on moraine plateaus indicates that they—like the other components of the moraine—are composed largely of till. Some of the plateaus have a thin veneer (2 to 7 feet) of lacustrine clay at the surface. The plateau shown as DQ at the bottom of the upper plate forms the headwater area of an ice-walled channel which drained to the south. It is believed that moraine plateaus are similar in origin to moraine knobs in that they mark the sites of large open pits on the surface of the dead ice. These pits were water-filled and a thin layer of lacustrine material on the water itself acted as a homogeneous insulating blanket which allowed for uniform melting under the lake. Kettles in the plateaus were formed from buried ice blocks and rim ridges (E) mark points where superglacial debris slumped into the sides of the lakes from the adjacent ice walls.

References

Gravenor, C. P. (1955): The origin and significance of prairie mounds; Am. Jour. Sci., Vol. 253, p. 475-481.

Gravenor, C. P. and Kupsch, W. O. (1959): Ice-disintegration features in Western Canada; Jour. Geol., Vol. 67, p. 50-52.

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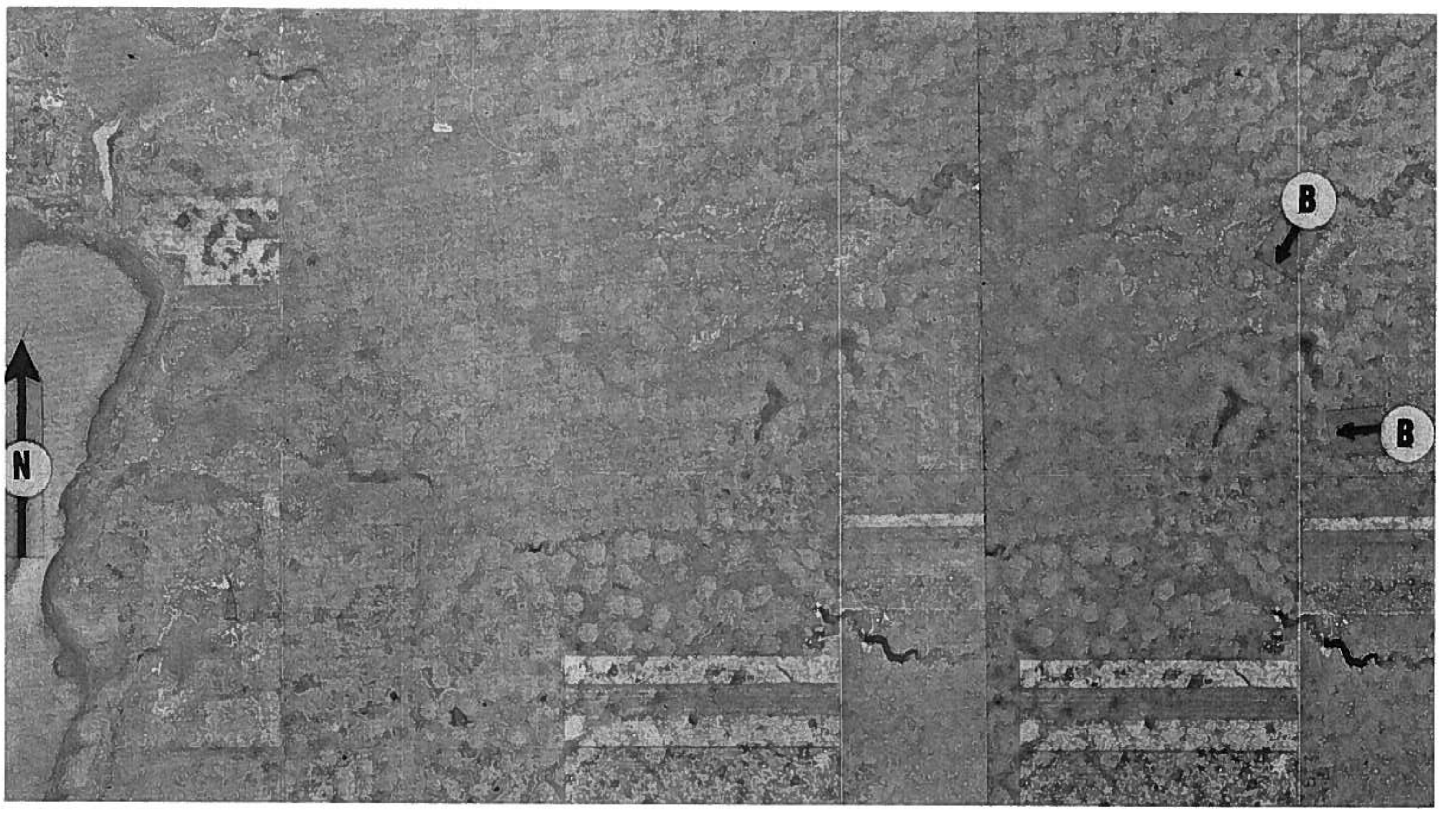
B
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B

Washboard Moraine and Contorted Bedrock

Location: Tp. 38, R. 2, W. 5th Mer. Photograph Nos. 160-5205: 1555-14, 15

Location: Tp. 15, R. 27, W. 4th Mer. Photograph Nos. 160-5005: 1981-3, 4

Location: Tp. 37, R. 9, W. 4th Mer. Photograph Nos. 160-5203: 1501-37, 38, 39

The following three plates illustrate features which were developed along an active ice front. In each case the ice movement direction is indicated by an arrow and the letter A. The first two plates show a series of transverse till ridges which are generally referred to as washboard moraine and the third plate shows a series of bedrock ridges.

The first plate is rather remarkable in that the surface microfeatures have been etched out by snow. The photographs were taken in the late spring of the year after most of the snow had melted except for that which lay in base of furrows (e.g. ploughed field D) and between minor morainic ridges. The next flight line north was taken after all snow had melted and a small stereo inset at the upper left-hand corner shows that the minor morainal ridges are scarcely visible under ordinary conditions. The majority of the ridges (B) are oriented normal to the direction of ice movement except for a few (C) which are parallel to the direction of ice advance. The individual till ridges are from 1 to 5 feet in height, from 300 to 2,000 feet in length and are 100 to 150 feet apart.

In the second plate the ridges are up to 10 feet in height, a mile or more in length and are separated by distances of 100 to 300 feet. The lobate pattern of the ridges on these photographs is typical of much of Southern Alberta and at this location there is evidence of two ice lobes with a reentrant which was occupied by a meltwater channel (B). Farther south this reentrant is marked by a jumble of till ridges (C) and a minor meltwater channel (D). The ice direction is marked by flutings (E). Note that the washboard moraine ridges are developed on the top of the flutings which clearly demonstrates the age relationships. As in the area shown by the first plate the ridges are composed of till and are developed on a till plain. The origin of washboard moraines is uncertain but they are probably related to thrust plane development near the ice margin (see debris-filled thrust planes under title Alpine glaciers), and the ridges parallel to ice-movement are related to longitudinal crevasses or lines of stress in the ice.

The most prominent feature on the third plate is bedrock high—Nose Hill—which forms a part of an extensive series of bedrock erosion remnants in east-central Alberta collectively known as the Neutral Hills. The ridges are composed of soft bentonitic shales and sandstones of late Cretaceous age. In some places bedrock extends to the surface and in other places there is a thin layer of till—5 to 10 feet thick—overlying the bedrock.

Sections through similar terrain in the Monitor district (Slater, 1927) show that the ridges have been produced by severe folding and faulting of the underlying bedrock. In extreme cases the disturbance may extend to depths of 300 feet below which the strata become horizontal.

While it is clear that bedrock ridges of the type illustrated have been produced by glacial action, the mechanism of deformation is not entirely clear. The lobate pattern would suggest that it is an ice-marginal phenomenon and one possibility is that the bedrock under the glacier was water-saturated and frozen and actually acted as part of glacier. The plane of movement would then be below the frozen zone and in underlying plastic bentonitic shales. That is to say that the friction would be less in the unfrozen bedrock than between the ice-bedrock contact. By this explanation the faults and folds in the bedrock are the result of thrust faults and folds developed in the brittle snout of the ice and hence analogous to the formation of washboard moraines. Another possibility is that the ridges were created by a "bulldozing" effect of the glacier and hence somewhat similar to "ice-push" moraines.

Erosion on the southwest side of Nose Hill has produced a thin mantle of fine gravel, sand, silt and clay over the ground moraine (B). This alluvial fan slopes gently away from the foot of the hill and drilling indicates that the alluvium is about 5 feet thick and is underlain by till. Other points of interest on the plate are: (C) hummocky disintegration moraine, (D) springs which are marked by a heavier growth of vegetation and a small stream leading to the north, (E) the disappearance of surface run-off into porous portions of the alluvial fan and (F) accumulation on the fan of salt brought to the surface by internal drainage.

References

Elson, J. A. (1953): Periodicity of deglaciation in North America, Part II Late Wisconsin recession; Geografiska Annaler, Vol. 35, p. 95-104.

Slater, G. (1927): Structure of the Mud Buttes and Tit Hills in Alberta; Bull. Geol. Soc. Am., Vol. 38, p. 721-730.


A
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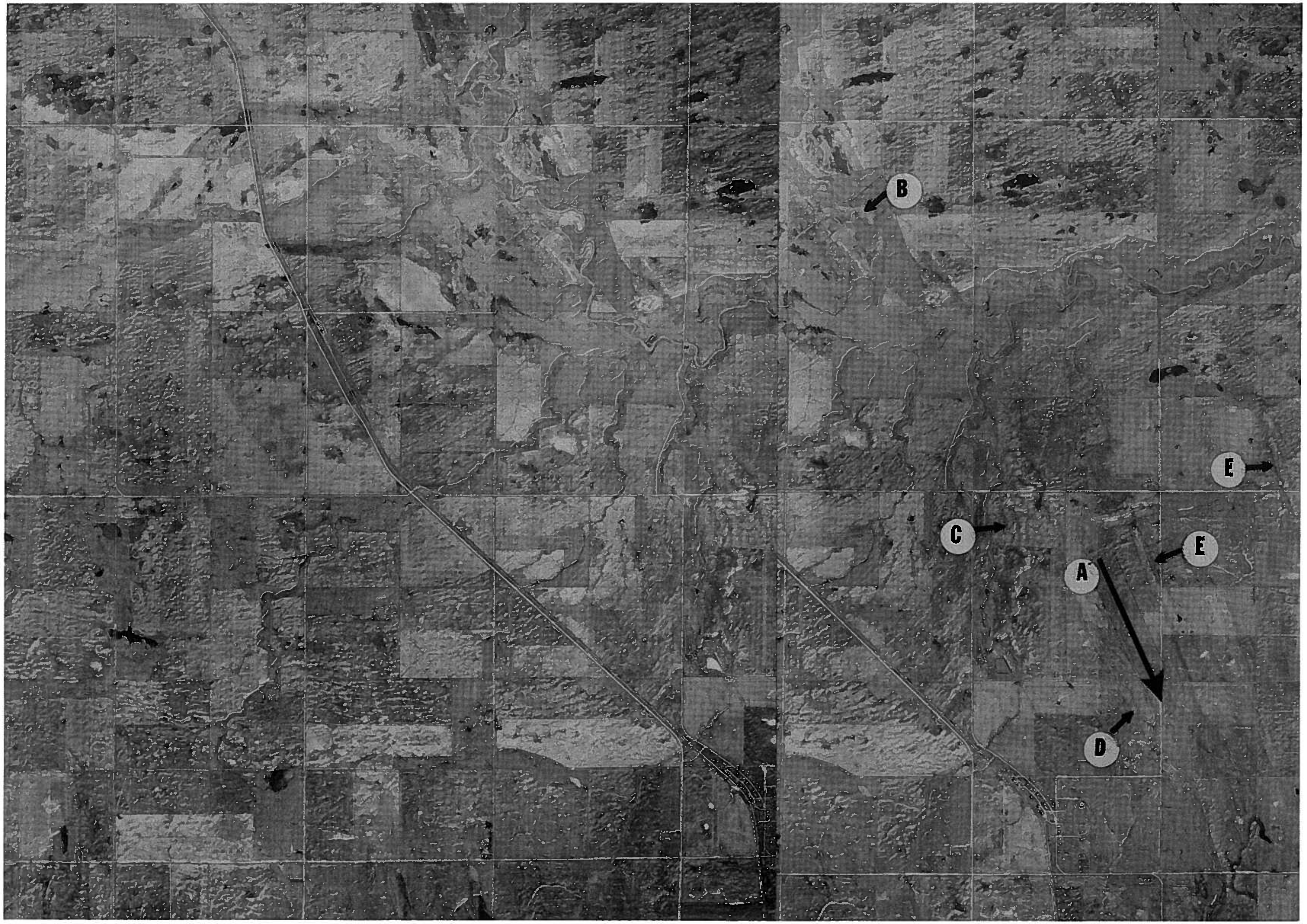
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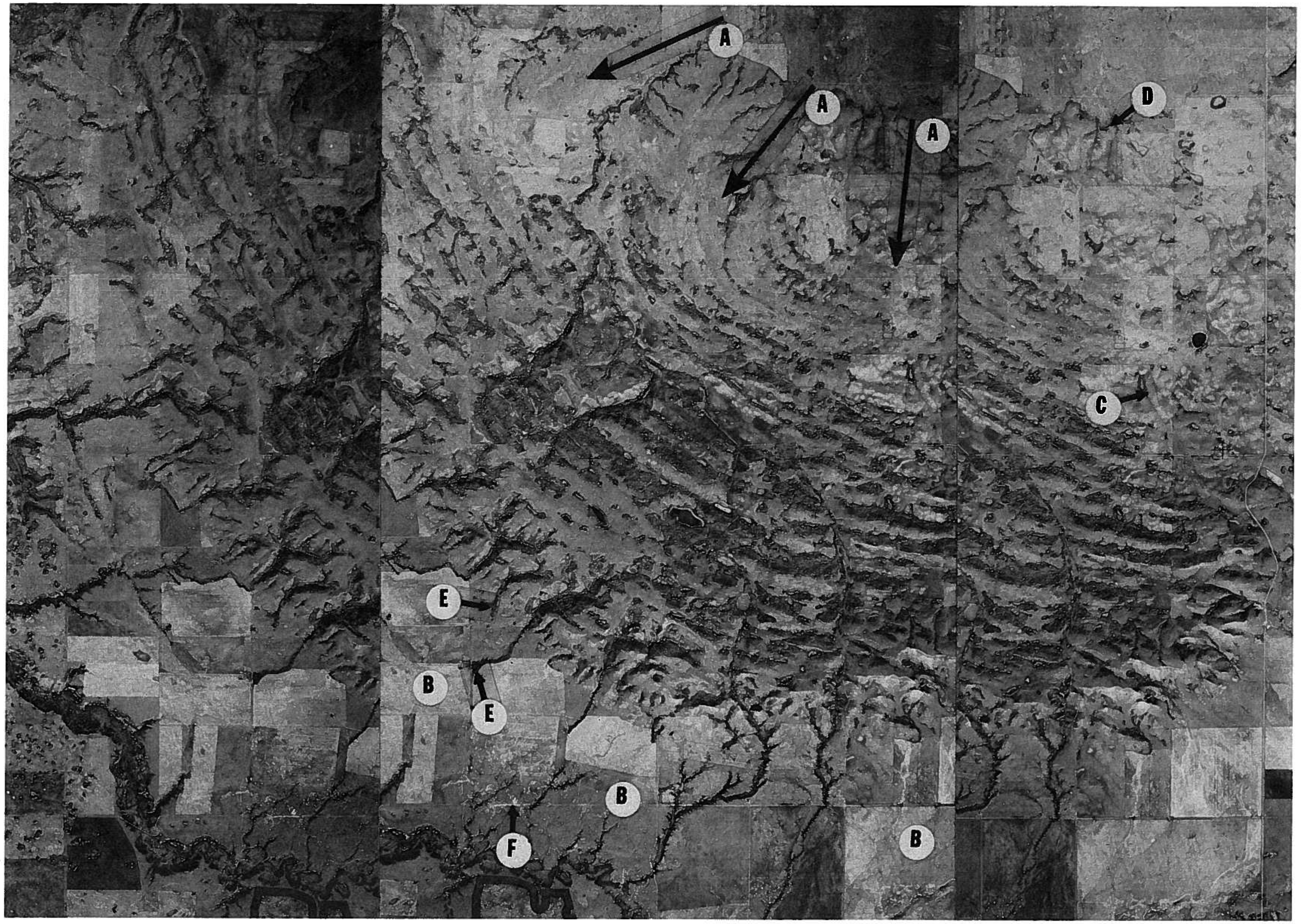
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Linear Disintegration Ridges

Location: Tp. 48, R. 1, W. 4th Mer.

Photograph Nos. 160-5303: 1333-36, 37

Linear ridges which have resulted from ice-stagnation are a common feature over much of the Western Plains. The ridges are composed largely of till and may or may not have included pockets of stratified materials. Where such stratified materials are present they show evidence of collapse (see accompanying diagram—location A) and commonly have included masses of till (see photograph below). The till generally displays evidence of shear and a strong pebble fabric which dip towards the flanks of the ridges.

The ridges vary in height from 5 to 25 feet, in width from 25 to 300 feet and in length from a few yards to several miles. They may be straight (B) or arcuate (C). An important characteristic is that, in general, two sets of ridges intersect at acute (D) or right angles (E). Such intersection of ridges forms a "waffle", diamond or box pattern (F). These intersection patterns indicate controlled deposition which was inherited from the flow characteristics of active ice. The arcuate nature of the ridges is strongly suggestive that these ridges were developed from an ice lobe.

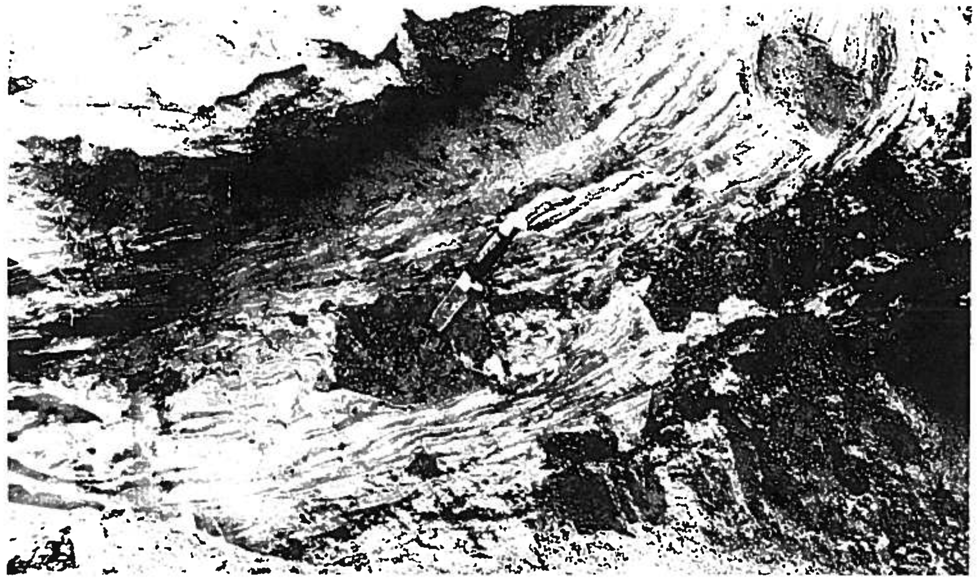
It is believed that the ridges resulted from deposition in crevasses during the late stages of ice stagnation or disintegration. Hence they have been called crevasse fillings or till crevasse fillings; a more general term is linear disintegration ridge.

In some places the ridges become closely spaced and almost imperceptibly grade to areas of hummocky disintegration moraine (G). Thus the two features — ridges and closed depressions — are closely related genetically and the explanation for one must fit the other. The explanation most favored by the writer is that open crevasses were infilled by mass-wasting and washing-in of superglacial debris. When the impounding ice walls melted the debris in the base of the crevasses was let down and at this stage collapse structure and fabric were developed. Another explanation is that the ridges are the result of the squeezing up of water-saturated till into subglacial crevasses by the weight of the ice adjoining the crevasse. Both hypotheses embody the concept of "dead ice" in which crevasses were developed during the active ice stage.

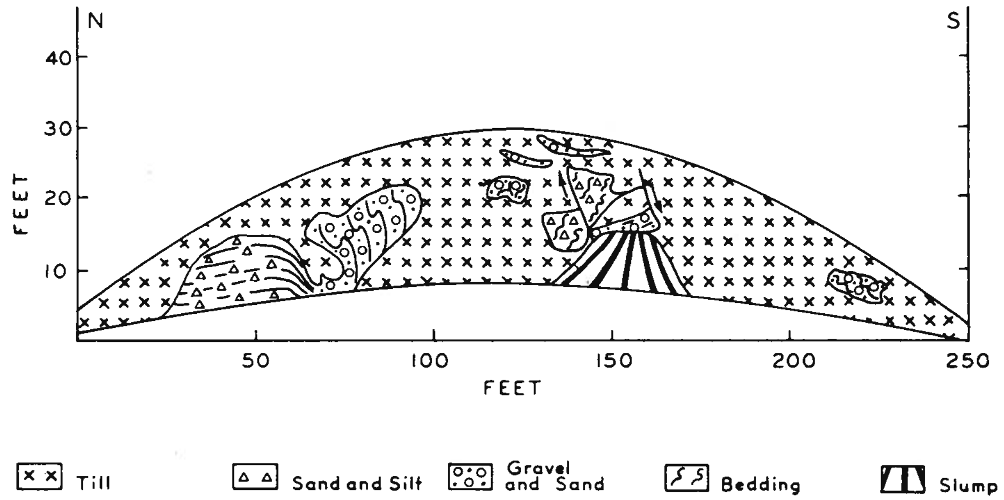
The direction of ice-movement in the area under consideration was towards the southeast and the most prominent of the ridges is developed at right angles to this direction. In some areas of the Western Plains it is noted that the most prominent ridge direction is parallel to or at 45° to the direction of ice-movement. Therefore, although the ridges are not of themselves reliable indicators of ice-movement direction it is significant that the most prominent lie normal, parallel, or at 45° to the direction of flow and hence show flow control.

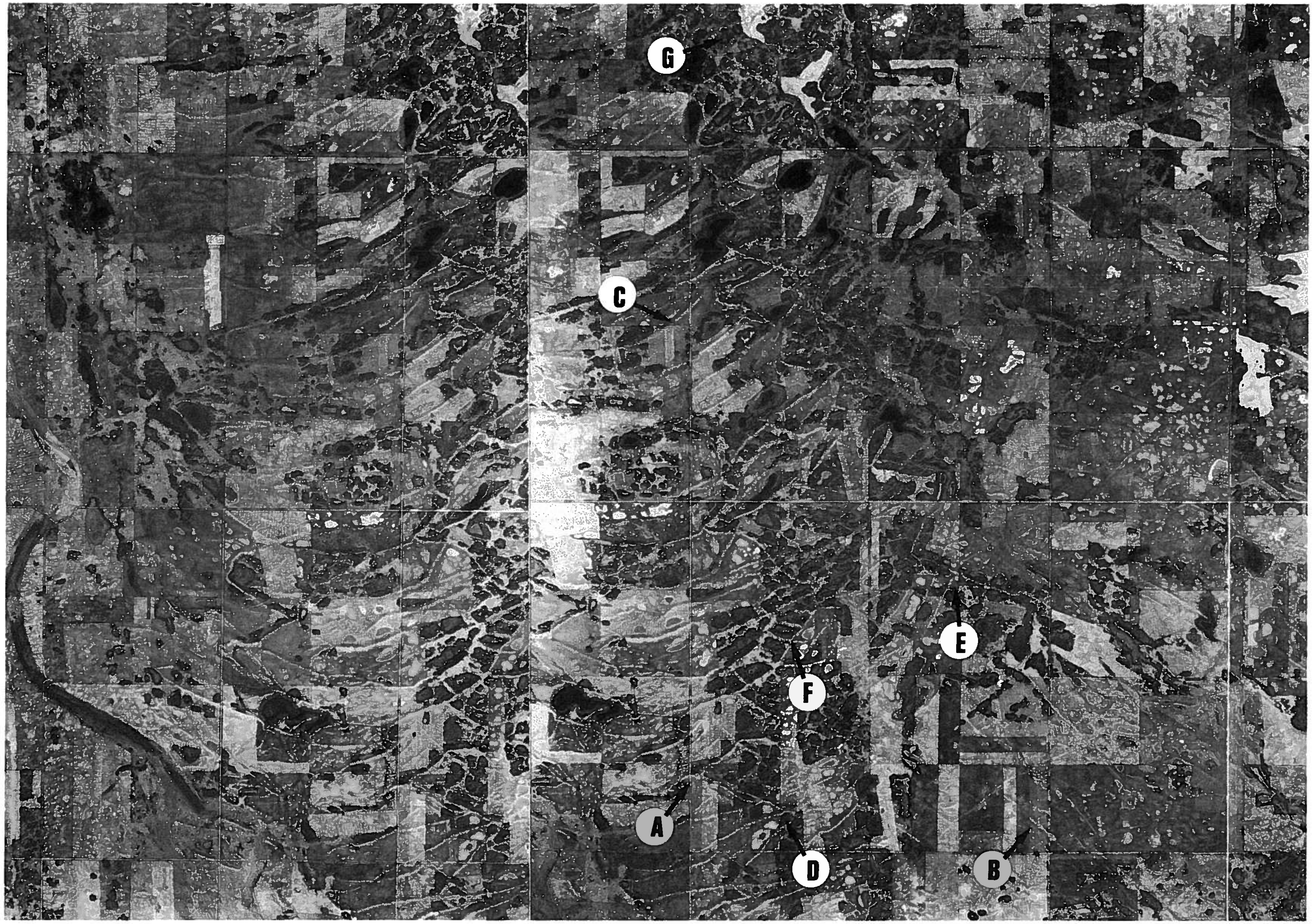
Reference

Gravenor, C. P. and Kupsch, W. O. (1959): Ice-disintegration features in Western Canada; Jour. Geol., Vol. 67, p. 53.



Included masses of till in stratified sediments (knife is in till)

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Outwash and Crevasse Fillings

Location: Tp. 44, R. 9, W. 4th Mer.

Photograph Nos. 160-5213: 1367-16, 17, 18

The area shown on the accompanying photographs lies immediately to the southeast of a series of southeasterly-trending ice-walled channels (see photographs entitled ice-walled channels). At the time that these ice-walled channels were being cut the ice margin was located just to the southeast of the illustrated area and the trend of the ice margin was roughly parallel to the river shown on the east side of the photographs. Meltwaters from the ice-walled channels were concentrated at this location and created a reentrant in the stagnant-ice margin in which were deposited vast quantities of outwash in the form of crevasse fillings (or eskers?) and outwash plains.

The reentrant—or discharge area—is located in a broad northwest-trending preglacial (?) valley which was also used as an ice-marginal channel during glacial retreat and which in turn is now occupied by the postglacial Battle River. The preglacial bedrock valley wall is shown at points A and the edges of the ice-marginal channel are marked B. To the southwest of the line marked by A's the preglacial valley wall disappears under a thick mantle (up to 250 feet) of glacial drift. The stubby U-shaped valleys at point C suggest that the ice-marginal channel walls as well as the hummocky disintegration moraine at point D are underlain by sand. This sand probably belongs to the preglacial valley although it should be kept in mind that this valley may have been used more than once and some of the sand fill may belong to earlier glaciations.

Point E marks the location of a portion of an ice-walled channel which was cut prior to the development of the crevasse fillings and outwash. At the time of cutting of this ice-walled channel the ice margin was several miles to the southeast of the Battle River. Several other ice-walled channels exist to the southeast of the Battle River and the channel at E probably belongs to this earlier system. That the channel at E belongs to an earlier system is indicated by the fact that it is buried under outwash at point F.

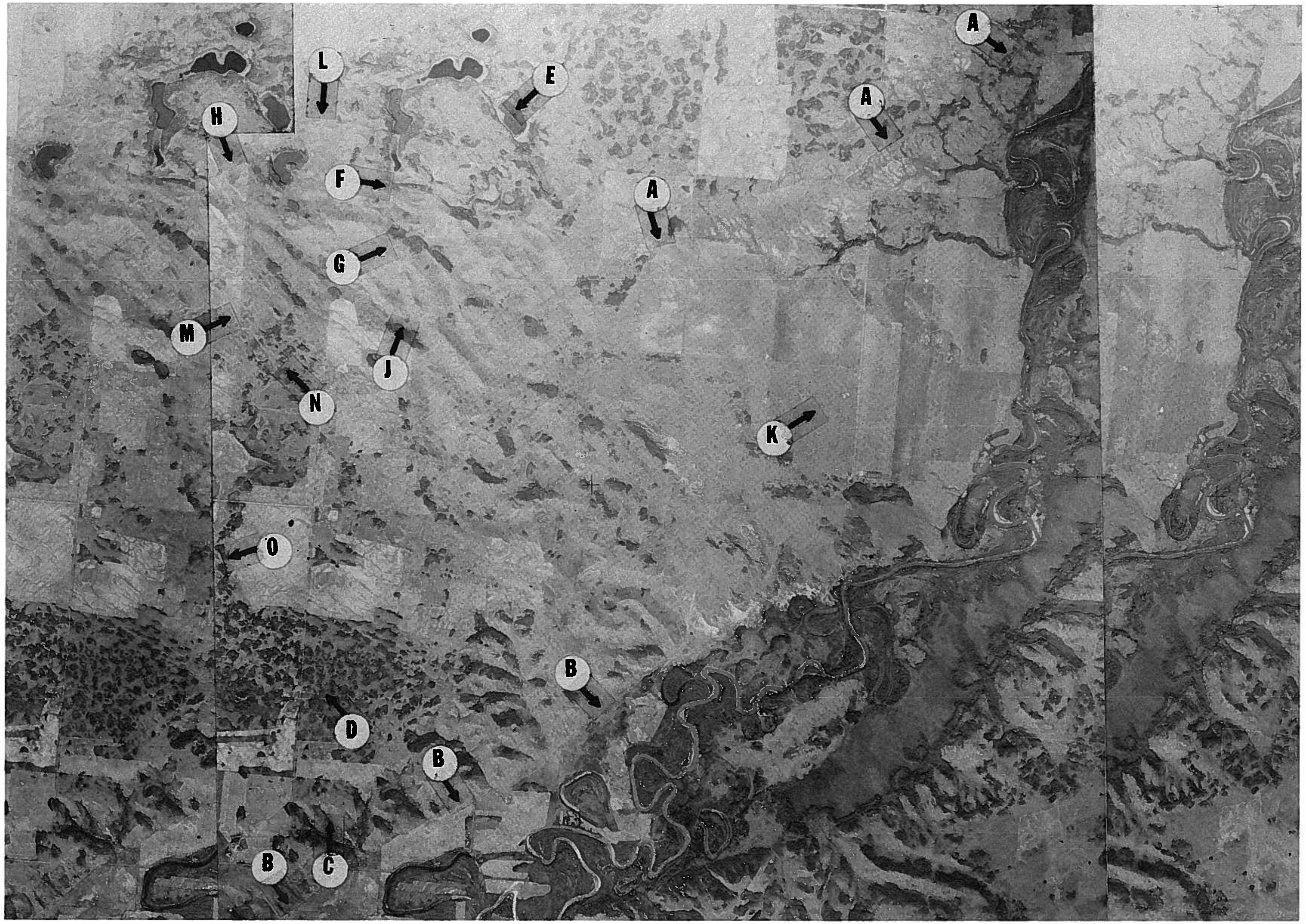
The ridges developed at point G are the result of meltwaters spilling between and over stagnant ice blocks which occupied the reentrant in the ice margin. Note the flat-topped nature of portions of the ridges (G), the kettles in the ridges (H) and the large kettles on the sides of the ridges (J). The ridges and outwash plain (K) are composed largely of sand with some gravel.

One other point of interest is the enclosed sand and gravel ridges at points L and M and their relationship to the hummocky disintegration moraine (D) through the hummocky moraine at point N and the extension of the moraine at point O. It is suggested that part of the outwash was developed on top of the stagnant ice and that the enclosed sand and gravel ridges were formed in ice pits in much the same way as the enclosed till ridges or knobs are formed in hummocky moraine (see photographs entitled hummocky disintegration moraine). Further, the relationships suggest that the sand and gravel ridges and the hummocky moraine were deposited at approximately the same time, as would be expected from the suggested mode of origin. Note that the hummocky moraine at N and D supports a considerable tree growth whereas the adjacent sandy materials do not. This is probably due to the lack of moisture and poor growing conditions in the sand.

References

Gravenor, C. P. and Kupsch, W. O. (1959): Ice-disintegration features in Western Canada; Jour. Geol., Vol. 67, p. 55-56.

Gravenor, C. P. and Bayrock, L. A. (1956): Stream-trench systems in east-central Alberta; Res. Coun. Alberta Prelim. Rept. 56-5, 11 pages.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Pitted Outwash and Organic Terrain

Location: Tp. 40, R. 7, W. 5th Mer.

Location: Tp. 99, R. 1, W. 4th Mer.

Photograph Nos. 160-5207: 1552-30, 31

Photograph Nos. 160-5710: 1786-68, 69

The top stereo-pair shows an area of dissected lacustrine sediments (A) in west-central Alberta. The lacustrine silts and clays were deposited in an ice-dammed lake which existed between the retreating Keewatin ice in the east and highlands to the west. After the lake had drained to the south, meltwaters from the retreating mountain glaciers to the west spilled down the North Saskatchewan River Valley and were deflected by the Keewatin ice front. These meltwaters scoured the lake plain and left a series of southeasterly-trending shallow troughs (B) which are now filled with organic material.

The underlying silts and clays are impermeable and hence surface run-off gathers and remains in surface depressions. The resultant ponds gradually become filled with organic material and muck, commonly referred to as muskeg. In some places the organic growth has taken place over material which is still fluid. Movement of the underlying fluid in a downslope direction creates a frictional drag on the surface organic mat which results in tension cracks in the surface organic layer (C).

In general where movement is noted it is indicative of fairly deep water conditions. In some channels the organic growth of the edge of the channel is apparently thin and anchored to the base of the channel (D) whereas at the centre and deeper parts of the channel the muskeg is moving (E). Thus from photo analysis it is sometimes possible to give an indication of depth or variability in depth of organic terrain.

The lower plate illustrates a dissected pitted outwash plain in northeastern Alberta. That the underlying material is composed of permeable sands is indicated by the disappearance of streams into enclosed depressions on the upland (A) and also the stubby V-shaped gullies (B) which are diagnostic of sandy materials.

The sandy outwash was deposited from meltwater streams which issued from the snout of the retreating glacier. The pits (kettles) (C) mark the location of ice blocks which were buried in the outwash — hence the term pitted outwash plain.

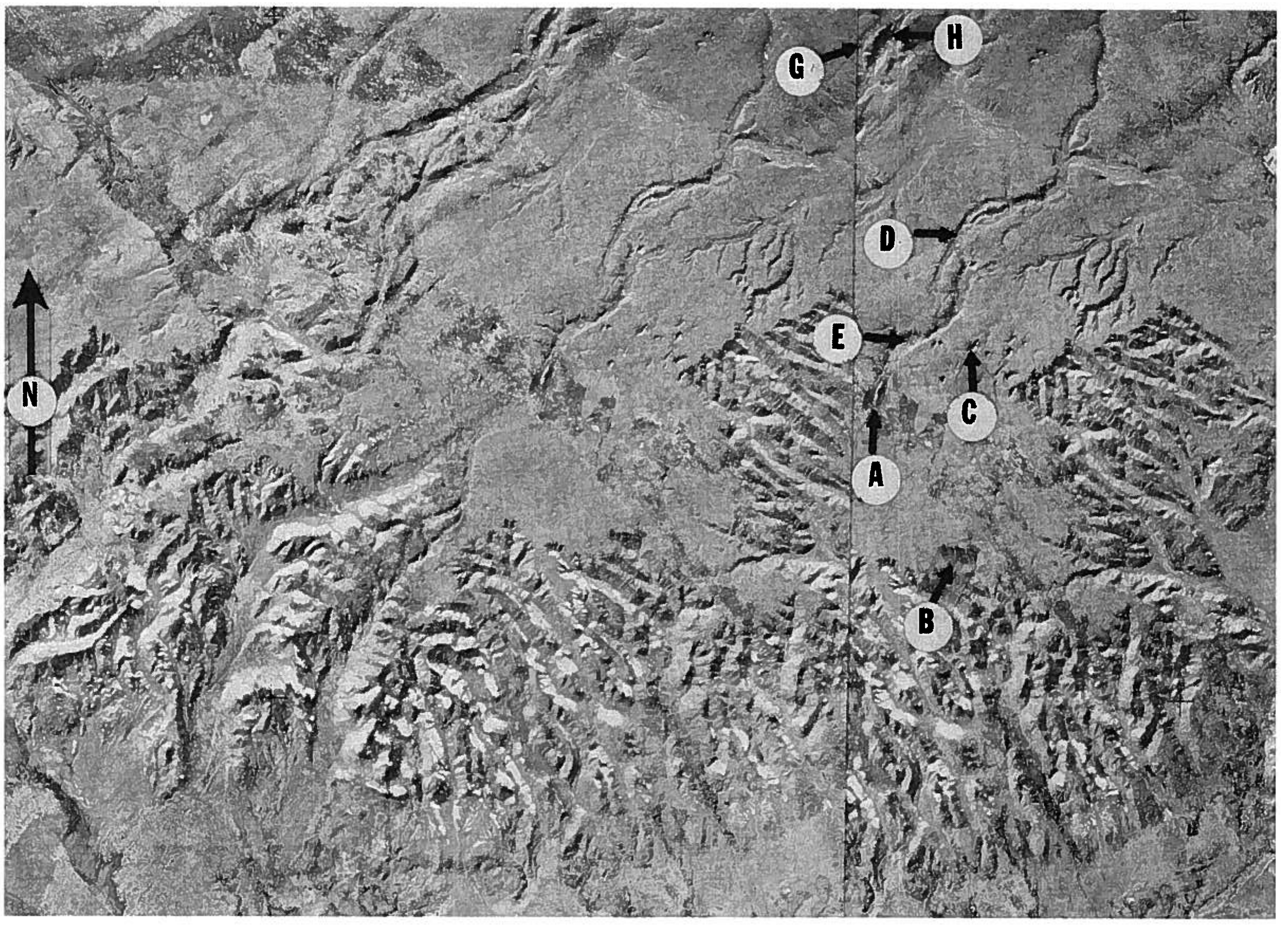
The channels (D) which cut across the outwash plain were developed from glacial meltwaters as is indicated by the kettles found along the channels (E, A and H). Note at point G that one of these channels appears to climb over a small rise. This phenomenon is probably due to the sinking of the land surface at point H through the melting of ice blocks buried in the base of the channel.

It is possible that without any prior knowledge of the geology of an area pitted outwash could be confused with karst topography. In some cases the two types of topography can be differentiated on the basis of the shape of the pits. Pits which have been created through collapse of competent rock — such as dolomite or limestone — commonly have steep sides whereas pits in sand are cone-shaped with the angle of slope equal to the angle of repose of the sand. In the area under discussion it is noted that the pits are confined to the outwash and associated features and are not found in the recently-dissected areas as would be expected if the pits had resulted from solution of underlying rock. Furthermore, the shape of the gullies mentioned above is typical of sand and suggests that the land is underlain by sand to a considerable depth.

Reference

Thwaites, F. T., (1926): The origin and significance of pitted outwash; Jour. Geol., Vol. 34, p. 308-319.

C
E
D
A
B



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Esker

Location: Tp. 95, R. 1, W. 4th Mer.

Photograph Nos. 160-5704: 1818-78, 79, 80

An esker is a sinuous ridge of stratified drift which was deposited by a meltwater stream flowing between walls of ice. Most eskers follow areas of low ground but a few climb over divides and their courses are apparently unaffected by the underlying topography. It is generally agreed that most eskers were developed in subglacial tunnels and it is believed that where eskers climb over highlands that the water in the tunnel was under hydrostatic pressure. It has also been suggested that eskers have formed from streams in englacial tunnels or as superglacial streams and the deposits let down as the ice melted. Inasmuch as many eskers have abundant fine external as well as internal detail it is unlikely that many of them originated very high up in the stagnant ice.

On the accompanying plate note that the main ridge A is flanked on either side by an apron of ice-contact stratified drift (B). This apron was probably deposited during the last phases of esker formation when the ice walls had receded. Another feature common to many eskers is the reticulate channel pattern noted on the apron and also on the main ridges (C). The depression (kettle) at point D was created by the melting out of a buried ice block.

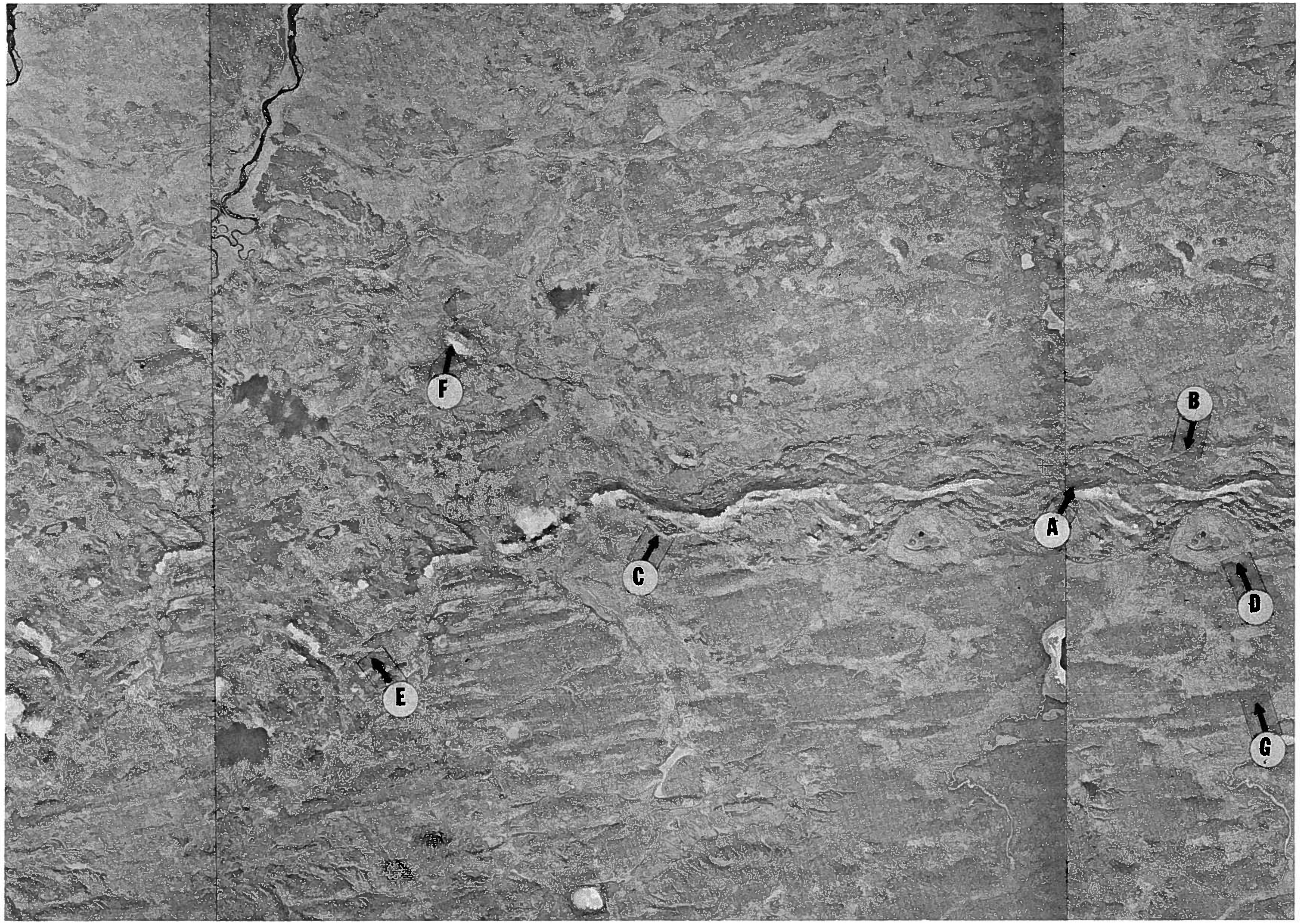
The water which deposited the esker was flowing from east to west — right to left on the photograph. At point E the esker ridge widens into a jumble of knobs and hollows which probably mark the location where the water in the esker tunnel discharged into a reentrant in the ice front. This jumble of ice-contact stratified drift could be termed an ice-contact fan or kame. Another much smaller cone-shaped kame is located at point F. This kame was probably deposited in a pothole or moulin in the ice and hence is termed a moulin kame.

That the ice moved in an east to west direction is evident from the shape of the sandy drumlins found on the southern part of the plate. Note that the stoss end of the drumlin (G) faces the east. As is often the case the esker roughly parallels the direction of ice movement.

Eskers and other ice-contact stratified deposits are important sources of sand and gravel. Therefore, although eskers are not common on the Plains region, their location is important to the construction industry.

Reference

Flint, R. F. (1957): Glacial and Pleistocene geology; John Wiley and Sons Inc., New York, p. 152-159.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Lacustrine Plain and Beach Ridges

Location: Tp. 55, R. 24, W. 4th Mer.
Location: Tp. 112, R. 15, W. 4th Mer.

Photograph Nos. 160-5312: 1826-56, 57, 58
Photograph Nos. 160-5812: 1665-108, 109

Studies made on the glacial lake deposits of central Alberta suggest that in general the lakes were short-lived, shallow, and glacier ice commonly acted as the shores. As a result there are few well-developed shoreline features such as wave-cut cliffs, beaches and offshore bars. The deposits are generally silty to clayey in nature and stratification varies from excellent varving to rude bedding.

Lake plains are usually recognized on air photographs by their flatness, evenness of tone across the photograph, the pattern of development of agricultural lands and lack of kettles. That the materials underlying the plain are impermeable is indicated by the long U-shaped gullies. Although lake plains may be confused with relatively flat areas of ground moraine the presence of two or more of the above factors is usually sufficient to differentiate the two landforms in Western Canada.

In the upper plate the lake deposits form a thin blanket over the underlying till plain and flutings which were developed on the till are quite visible (A) through the clay mantle. A southwesterly ice-movement direction is indicated. Deposition of lake materials across a preglacial (?) valley is indicated at point B. The valley is about one mile in width and that it was developed prior to the advance of the last ice is indicated by a broad drumlin at point C. The pockmarks on the right-hand side of the plate (D) are probably a reflection of a hummocky portion of the underlying moraine and fluting development.

The lower stereo-pair show beach ridges developed on very flat ground around the shores of Lake Claire in northern Alberta. The present shoreline of the lake is noted in the extreme southeast portion of the plate at point A. The ridges are evidently swash marks which were probably developed by strong on-shore waves during storm periods.

The fact that vegetation has not yet taken over on the ridges close to the present lake shore (B) would suggest that the land surface is still rising and eventually Lake Claire will drain completely. It is interesting to note the similarity to contour lines of the ridges where they intersect drainageways (C). This curvature of the ridges is probably a result of the swash ridges being developed along the valleys of minor streams which entered the lake.

Aside from the actual ridges the entire area is covered with muskeg.


A
D
B
C
N


B
A
C

Badland Topography

Location: Tp. 37, R. 14, W. 4th Mer.

Photograph Nos. 160-5204: 1501-14, 15, 16

This set of photographs shows two major features, one, variation in drift thickness over bedrock, and two, erosion of the underlying bedrock.

In the southwest corner of the photographs there are two areas — marked A and B — divided by a dashed line — which show variation in drift thickness. Throughout the area marked A the drift thickness varies from 12 to 20 feet and in the area marked by B the drift thickness varies from zero to 6 feet. The area of thin drift (B) is almost featureless and in some places the thin till cover has been stripped by erosion exposing the underlying bedrock (C). Bedrock is also exposed in stream valley walls and ditches.

In the area of thicker drift (A) the surface is hummocky and supports numerous enclosed depressions (kettles). Note the similarity between the thick drift area shown on this plate and the plate depicting an area of ground moraine.

The remarkable variation in drift thickness found in eastern Alberta indicates that there were wide variations in the amount of in-transport debris in the last glacier to cover the area. Areas of very thin drift also indicate that any drift deposited prior to the last glaciation was removed by the last glacier.

In the northeast part of this district, stream erosion has breached the thin till cover and badlands have developed on the underlying bedrock. The streams head on a northwest-trending escarpment and discharge towards the northeast. At the present rate of erosion it will not be long before the entire escarpment will be exposed.

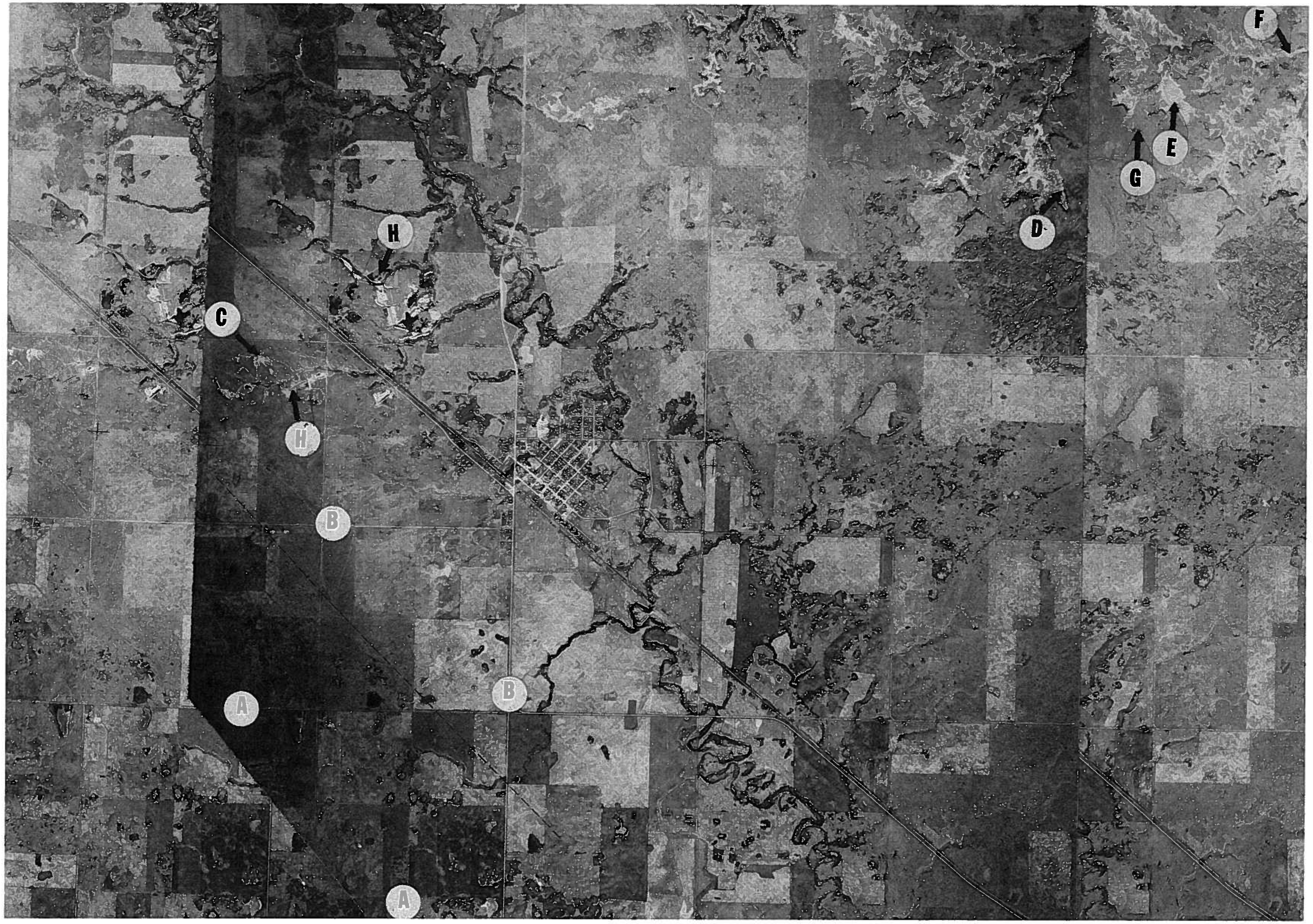
The erosion area is capped by about 5 feet of clayey till which supports a fairly heavy turf. The underlying bedrock is composed of soft bentonitic shales and sandstones of late Cretaceous age. Once the till cover has been breached, erosion progresses largely by slope retreat on the bedrock valley walls which eventually develop into broad erosion pits.

Although there are several elements involved in this type of erosion, for purposes of description these may be divided into 3 main categories, (1) free or active face (D), (2) pediment surface (E), and (3) stream or gathering system (F). The free face consists of a steep wall of exposed bedrock composed of horizontal strata of bentonitic sandstones and shales. This bedrock wall is being actively eroded by runoff spilling over from the upland surface and coursing down the free face in an intricate rill system. The erosion of the free face is facilitated by the alternate swelling and shrinking of the bentonitic bedrock which results in the spalling-off of fragments which fall to the base of the free face and are eventually removed by running water.

At the base of the free face the rills join into larger systems which flow across the pediment surface (E). Thus the debris from the free face is transported across the pediment, and the pediment surface is composed of a thin layer (1 to 2 feet thick) of sandy alluvium over bedrock. At the base of the pediment the rills join stream tributaries (F) and the debris is moved into larger drainage systems.

The entire erosion system is dependent upon maintaining the free face devoid of vegetation. As vegetation takes over the process gradually comes to a halt as is noted at point G.

One other point of interest on the plate is the strip and underground coal mining operation (H).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B
A

Slump

Location: Tp. 39, R. 11, W. 4th Mer.

Photograph Nos. 160-5206: 1551-29, 30

The term slump has been used by Sharpe to describe the intermittent downward slipping of masses of rock with a backward rotation with respect to the slope over which movement takes place. This type of movement commonly produces a series of steps which slope into the bank. Such steps are quite evident in the adjoining plate (A) and it is on this basis that the type of movement shown is called slump.

Undoubtedly, however, the movement is much more complex than simple slump and in some places — especially near the base of the slopes — the slump gives way to a jumble of knobs which is probably representative of an earth-flow type of movement. In this area the slump is developed on soft bentonitic sandstones and shales of late Cretaceous age. On this type of bedrock slump develops on very low slopes — with gradients in the order of 1 in 12 to 1 in 15.

Slump is caused by several factors which can be summarized as follows:

(1) a limited amount of water must be present in order to lubricate the slipping surfaces;

(2) the material at the base of the slope must be removed in order to create the unstable conditions for slumping to continue;

(3) it is best developed in soft bedrock or unconsolidated drift which has a high clay content — preferably of the montmorillonite variety.

At this location the removal of material at the base of the slope is being accomplished by two methods: (1) by the undercutting action of the river itself, and, (2) by slope retreat of vegetation-free faces at the base of the valley walls (B).

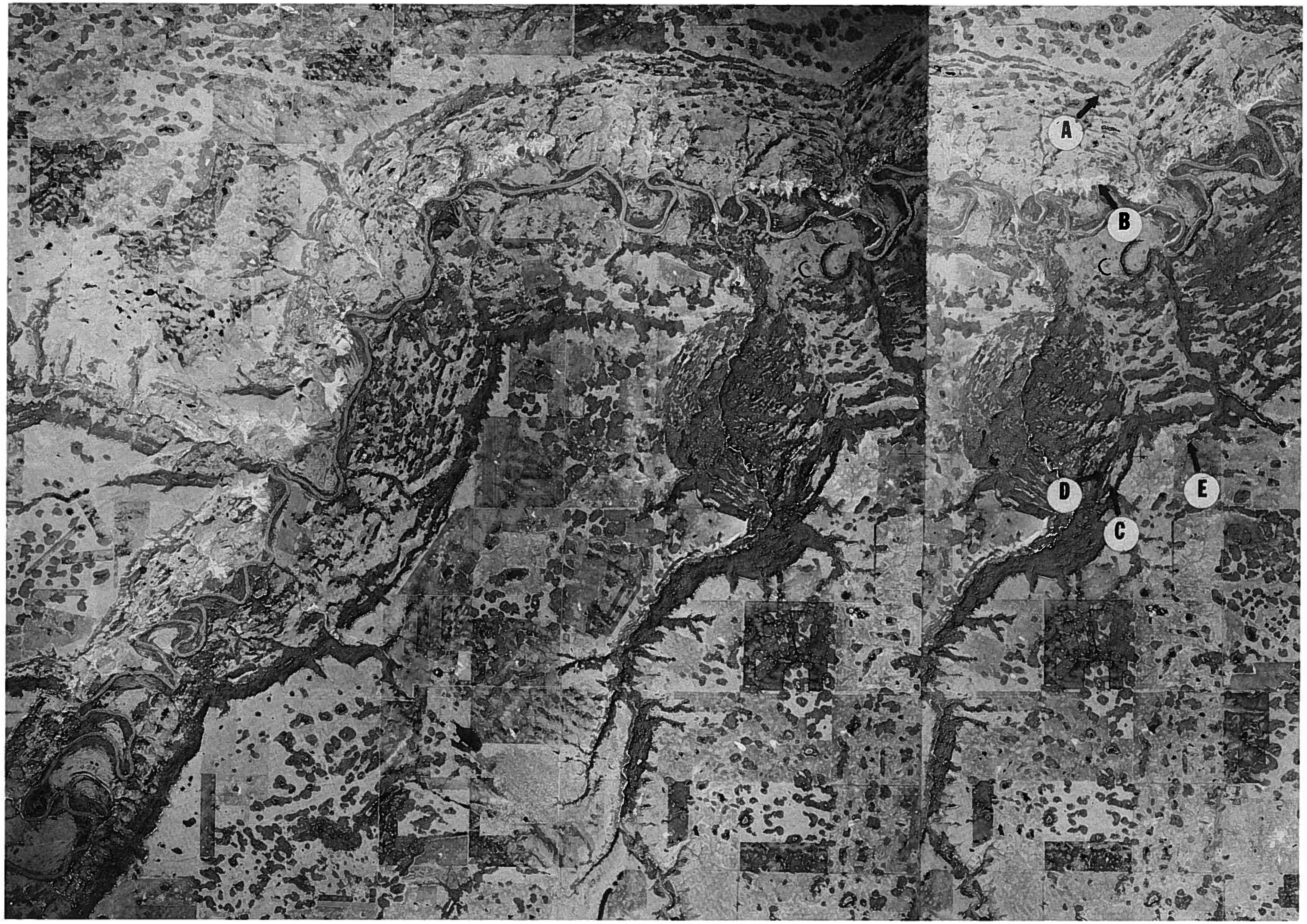
In some places the slump terraces are U-shaped and it is possible that such shapes are representative of two slide blocks with the inner block (C) (at the base of the U) being the larger and because of its greater weight, and hence momentum, moving downslope farther than the outside thinner block (D).

Note that the slump is better developed on the south slope of the valley and on slopes which have the heaviest vegetation cover. Such slopes are probably wetter because of the lack of sunshine.

The thin white line (E) at the break between the upland and the slump area is snow. The valley itself originated as a glacial spillway which is now occupied by the Battle River.

Reference

Sharpe, C. F. S. (1938): Landslides and related phenomena; Columbia University Press, 137 pages.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C
E

Dunes

Location: Tp. 104, R. 7, W. 4th Mer.
Location: Tp. 106, R. 6, W. 4th Mer.
Location: Tp. 70, R. 4, W. 6th Mer.

Photograph Nos. 160-5801: 1780-75, 76
Photograph Nos 160-5803A: 1839-82, 83, 84
Photograph Nos. 160-5502: 1571-149, 150, 151

Generally dunes may be divided into two classes; one, those developed on bare, loose sand and two, those developed in conflict with surface vegetation. The first class includes the desert varieties: barchans (**convex** side toward the wind), transverse, longitudinal and wind-shadow dunes. The second class includes the parabolic, U-shaped, hairpin-shaped dunes, etc., all of which are basically similar in that the **concave** side faces the wind. Some varieties of the U-shaped dune closely resemble barchans and the two have been confused. It is important to realize, therefore, that except for the longitudinal varieties dunes of both classes display an asymmetric cross section with the steeper side in the lee position.

Almost all of the dunes in Alberta belong to the second class, that is, those which have been developed in conflict with vegetation under semi-arid to humid conditions. In central and northern Alberta almost all the dunes have been formed through the action of westerly to northwesterly winds which resulted from a series of low pressure systems flowing in from the Gulf of Alaska.

The first plate is from an area in extreme northeastern Alberta and shows a group of northwesterly-trending sand ridges separated by muskeg. The dune forms are of the U-shaped variety (A) and the wind which created them was from the southeast (B). Note that the steep (lee) side of dune A is on the northwest end of the dune and is shown as a shadow (C). Upon close examination it is noted that the ridges are composed of a series of U-shaped dunes which impart a fishhook appearance to the ridges (D and E).

As previously noted most dunes in Alberta record a westerly to northwesterly wind direction. In extreme northeastern Alberta, however, the dunes are formed by a southeasterly wind. This is possibly due to the fact that these dunes were formed on the northern side of the path of the low pressure systems which cross the province from the Gulf of Alaska. The compound ridge shapes are also peculiar to this part of the province and a possible explanation of their origin will be given in the discussion on the next photograph.

The second plate is from an area a few miles north and east of the first plate and shows one of the few areas in the province where free-blowing sand exists. Two types of dunes are shown, one, U-shaped dunes (A) developed by a southeasterly wind (B) and two, transverse dunes (C) developed by westerly to southwesterly winds (D). The transverse dunes show asymmetric cross profiles with the steep sides facing the east and northeast (E). The area now covered by free-blowing sand was fixed by vegetation not long ago and probably supported U-shaped dunes. In the presently vegetation-fixed area the growth is light and incipient formation of transverse dunes can be seen at F. At other locations the heavier vegetation is being overrun and buried by the oncoming sand. It is noted that the ridges of the transverse dunes are aligned in a north to northwest direction and roughly parallel the fixed ridges of the U-shaped dune area (A). It is suggested that in this area and in the area of the first plate the initial dunes were of the true desert transverse type which were developed from southwesterly winds and were later fixed by vegetation and modified into U-shaped dunes by the action of southeasterly winds. Thus there may well be three cycles of dune formation evident in the second plate. The dunes on both the first and second plates are developed on a sandy glacial lake plain.

The third plate shows a group of U-shaped dunes which are typical of the dunes found over much of the province. In this area — Grande Prairie — the dune-forming winds blew from the west (A). The dune morphology is quite complex varying from isolated U-shapes (B) to compound Z-shapes (C). The dunes are developed on sandy to silty outwash and lacustrine materials. The dunes are stabilized by a cover of coarse grass, aspen, pine and occasional spruce. Sphagnum moss bog fills the spaces between dunes.

Points D, E and F show three terraces of the Wapiti River upon which there is dune development. At point G on the floodplain the dunes have been eroded thus dating the age of dune formation between the development of the number three terrace and the floodplain.

References

Odynsky, Wm. (1985): U-shaped dunes and effective wind directions in Alberta; Can. Jour. Soil Sci., Vol. 38, p. 56-62.

Smith, H. T. U. (1949): Physical effects of Pleistocene climatic changes in non-glaciated areas: Aeolian phenomena, frost action, and stream terracing; Bull. Geol. Soc. Am., Vol. 60, p. 1485-1516.


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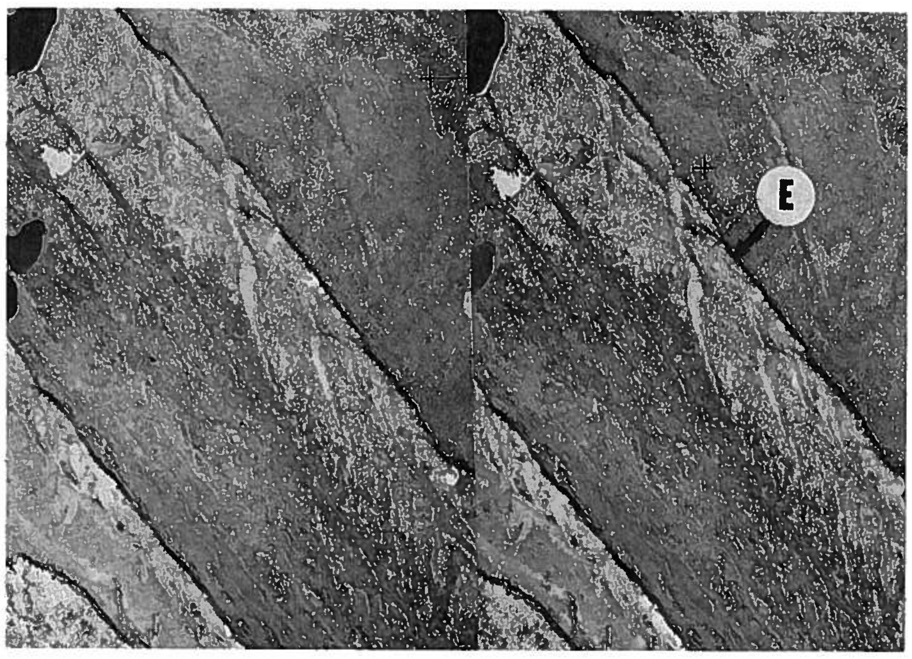
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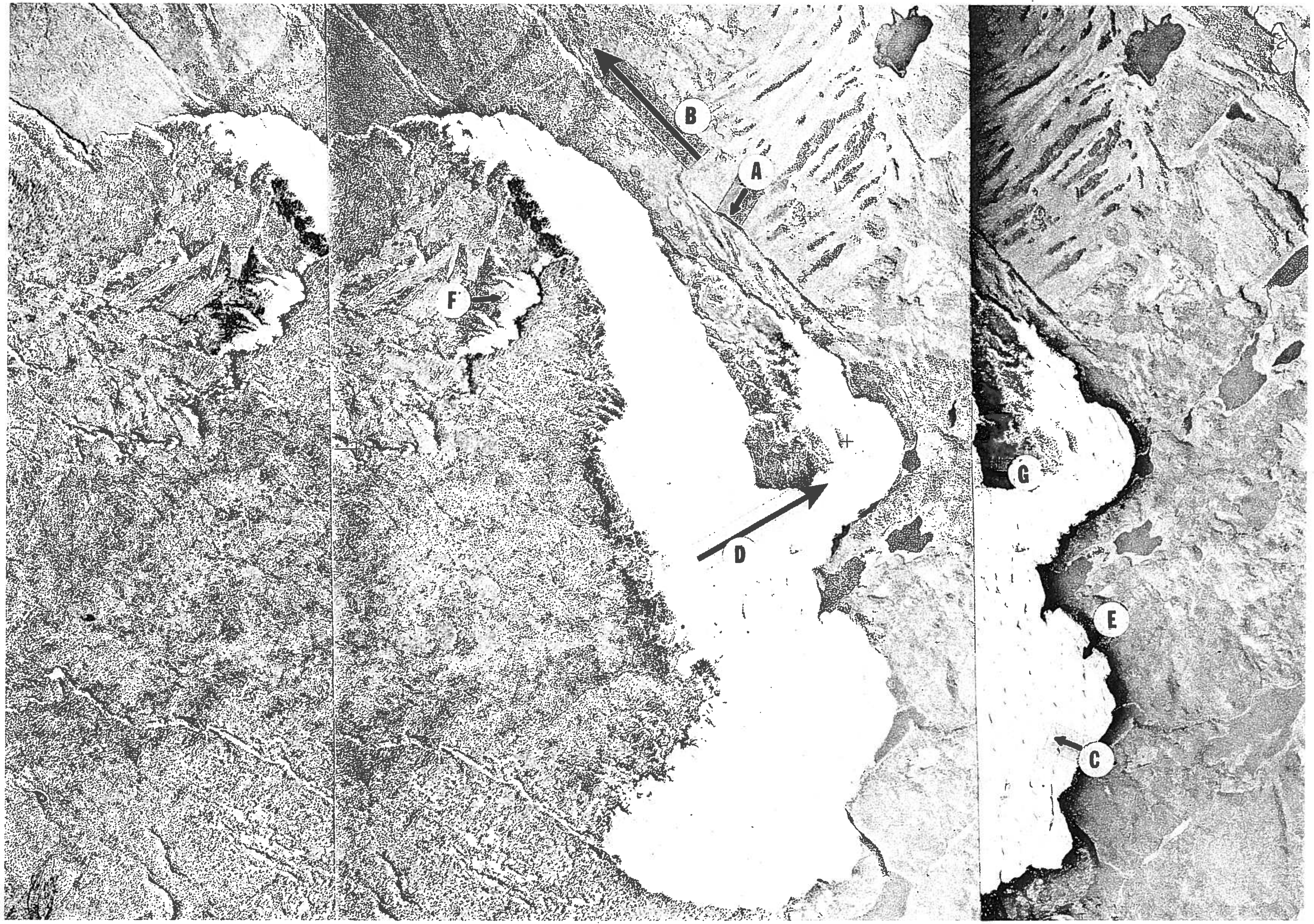
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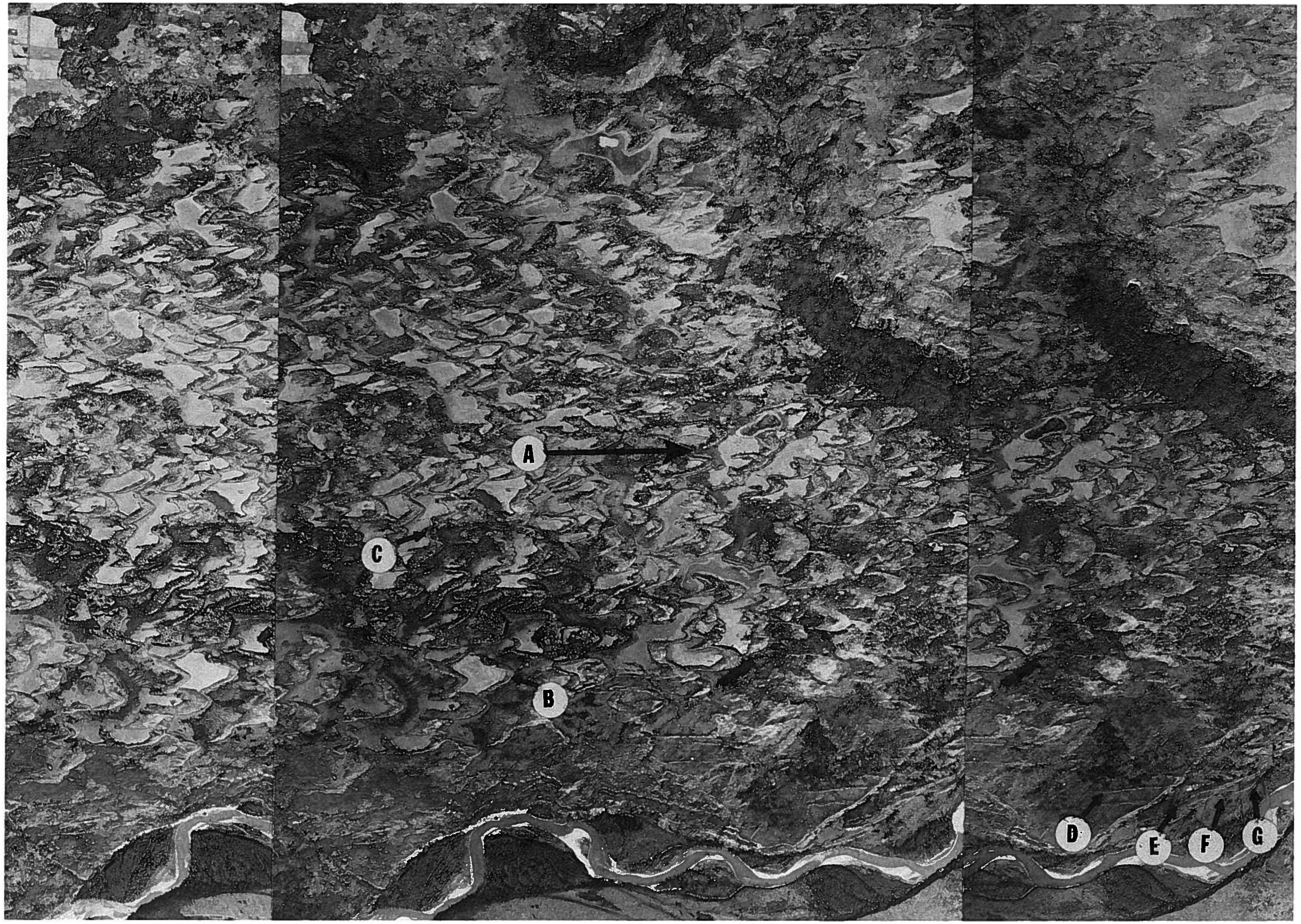
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Karst Topography

Location: Tp. 125, R. 14, W. 4th Mer.

Photograph Nos. 160-5915: 1759-68, 69, 70

According to Thornbury (1954) there are four conditions necessary to the formation of solution topography. These are: (1) soluble rock—preferably limestone—at or near the surface, (2) the soluble rock should be dense, highly jointed and preferably thin bedded, (3) there must exist entrenched major valleys below uplands underlain by soluble well-jointed rock, and (4) moderate to abundant rainfall.

The karst area shown in the accompanying plate is located in extreme northern Alberta and is underlain in turn by dolomite, gypsum and salt, all of Middle Devonian age. Similar to other karst areas south and west of the one under consideration, the underground solution has taken place in the gypsum below the caprock of dolomite. The escarpment noted at point A takes the place of the entrenched river system suggested by Thornbury as one of the essentials to the development of karst topography. The mean annual precipitation in northern Alberta is quite low—12 to 14 inches—but the materials involved are highly soluble and perhaps not so much water is required for solution.

The precipitation which does fall in this area either immediately sinks into the ground or enters small streams which disappear into the subsurface (A). This meteoric water passes through the surface layer of sand (note sand dunes B), through the caprock of dolomite and finally into the gypsum and salt where the solution takes place. The groundwater then moves along joints and solution channels towards the northeast where it emerges in the form of springs at the base of the escarpment (C). Evaporation of this spring water has resulted in salt flats (D) north of the escarpment.

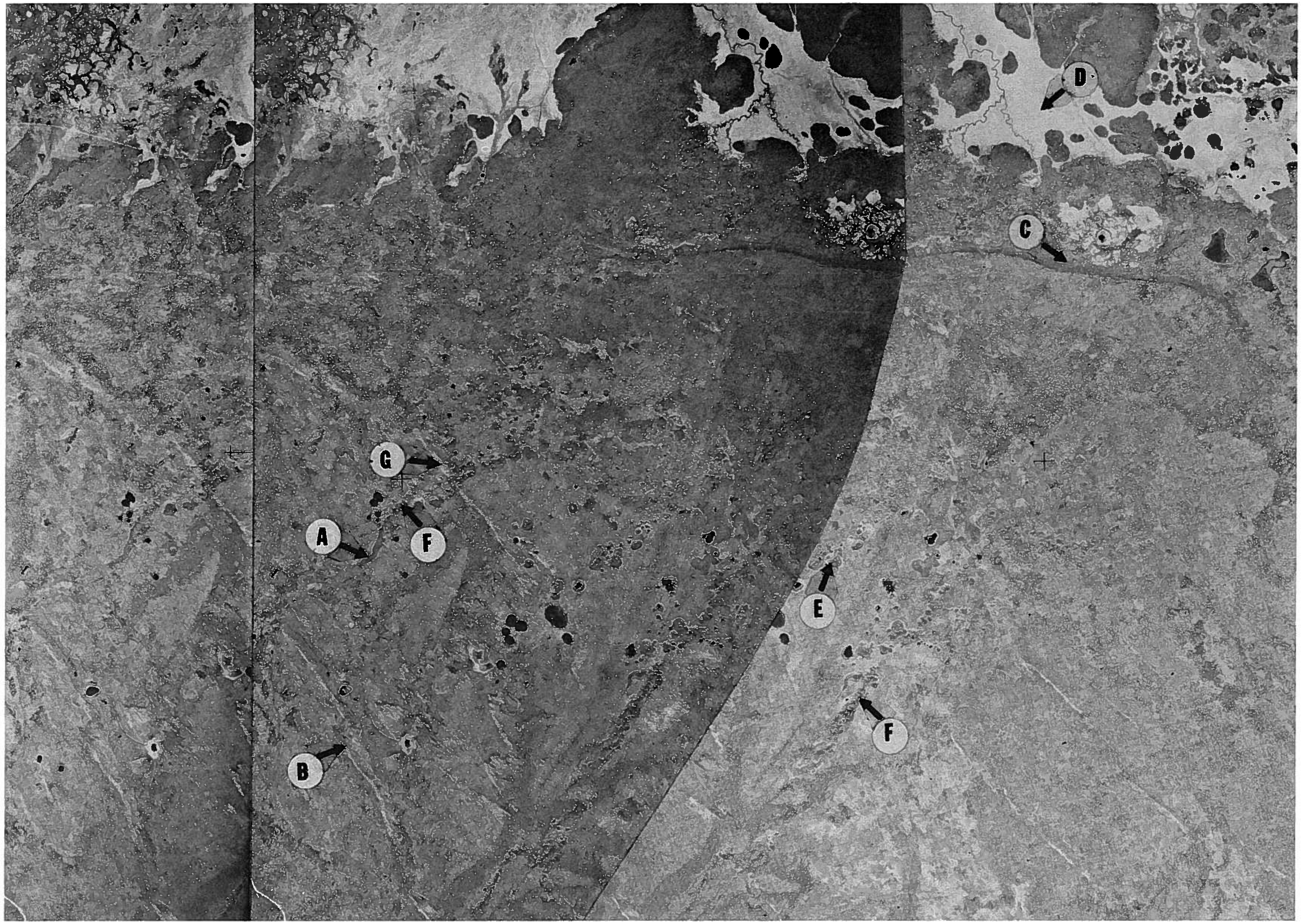
The numerous sinks (E) found on the upland plain have resulted from the formation of underground solution cavities and roof collapse. In places there has been extensive roof collapse over underground river courses (F) and such depressions are termed uvalas. It is noted that these uvalas are aligned in a northeast direction and roughly parallel known structures on the Precambrian Shield northeast of the area under consideration. This would suggest that the underground movement of water is controlled by fractures in the Devonian rocks which in turn are controlled by deep-seated Precambrian structures.

Some of the solution is fairly recent as is indicated by the fact that the sand dunes (which are postglacial) have been cut by roof collapse (G).

References

Camsell, C. (1917): Salt and gypsum deposits of the region between Peace and Slave Rivers, northern Alberta; Geol. Surv. Can., Summ. Rept. 1916, p. 134-141.

Thornbury, W. D. (1954): Principles of geomorphology; John Wiley and Sons Inc., New York, p. 317-340.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Eastern Front of the Foothills

Location: Tp. 14, R. 2, W. 5th Mer.

Photograph Nos. 160-5005x: 1891-53, 54, 55

The Foothills belt of the Rocky Mountains is a physiographic region characterized in large part by elongate north- to northwest-trending valleys and rounded ridges. The eastern front of the Foothills, according to Bostock (1948), coincides with the first zone of faulting and folding west of the rocks of the Plains region. East of the front of the Foothills in much of Alberta the rocks of the Plains lie in a broad synclinal structure, in places over 50 miles across, which is generally known as the Alberta syncline.

In the illustration the front of the Foothills lies along Chain Lakes which extend across the photographs. To the east of the lakes part of the west limb of the Alberta syncline is shown. The stratigraphic succession rises from west to east and is broken by two thrust faults (A, B) and an anticlinal fold, the structure of which is visible at C and D.

Lower Cretaceous Blairmore beds (1) appear in the core of the anticline in the north. The fold axis plunges south, and thus higher Cretaceous beds—the Alberta shale (2), the Wapiabi shale (3) and the Belly River sandstones (4)—form part of this structure towards the south (D).

Grey and green sandstones and silty shales form the Upper Cretaceous St. Mary River formation (5) which grades upward into the Willow Creek formation (not differentiated)—maroon, green and grey shales with soft sandstones. The Willow Creek beds are relatively thin and form the east side of the Chain Lakes Valley; they are overlain disconformably by coarse-grained sandstones and grey and brown shales of the Tertiary Porcupine Hills formation (6) which are several thousand feet thick. Dips in these beds decrease towards the east.

Glacier ice which moved from north to south strongly modified the bedrock and produced drumlinoid features west of Chain Lakes and imparted to the valleys a U-shape. Pitted morainic material (E) remains in one of the valleys.

In the late stages of deglaciation the valley now occupied by Chain Lakes carried meltwater from the north into Willow Creek, and Willow Creek itself carried meltwater from the west. Both meltwater channels are now silted up by glacial outwash material, and misfit streams flow in the channels. The four lakes forming the Chain Lakes are separated by alluvial fans laid down by resequent streams draining into the channel from the east.

References

Douglas, R. J. W. (1950): Callum Creek, Langford Creek and Gap map-areas, Alberta; Geol. Surv. Can. Mem. 255, 124 pages.

Bostock, H. S. (1948): Physiography of the Canadian Cordillera, with special reference to the area north of the Fifty-fifth Parallel; Geol. Surv. Can. Mem. 247, 106 pages.


1
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Imbricate Thrust Faulting

Location: Tp. 6, R. 1, W. 5th Mer.

Photograph Nos. 160-4908: 2069-7, 8

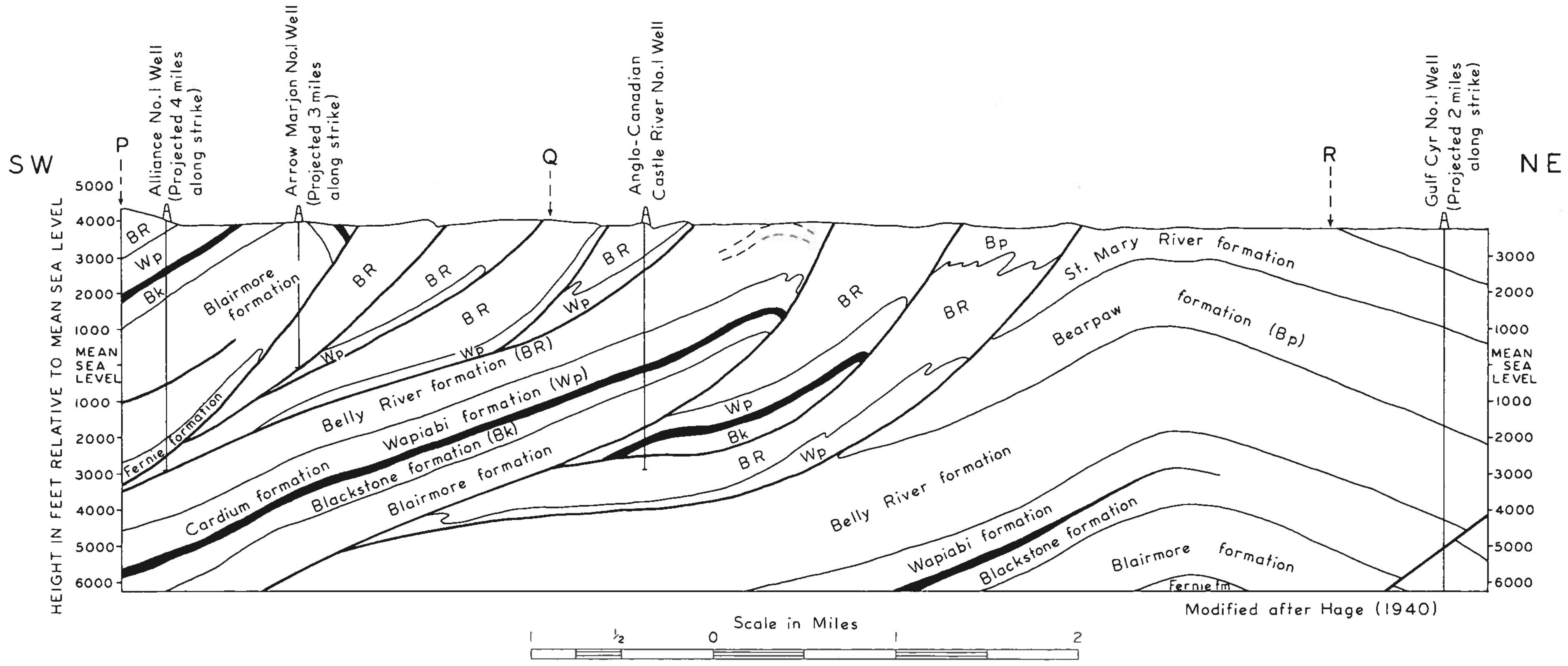
In southwestern Alberta the Foothills of the Rocky Mountains consist of a complex folded and faulted sequence of Mesozoic strata. At the surface in the Foothills a series of closely-spaced, essentially parallel faults can be mapped. The displacement of an individual fault is generally small, and such faults are commonly steeply inclined. Below the surface, however, as proved by drilling records of deep wells, the dips of many of these faults decrease and it can be shown that they are imbricate developments from a sole thrust or thrusts (see cross section PQR). The thrust faults lie roughly parallel to bedding planes for long distances, particularly in incompetent strata, and then may break sharply across competent beds to another incompetent bed. Thus the same unit may be repeated several times by these imbricate thrust faults, as in the illustration where the basal massive sandstone beds (B) of the Belly River formation are repeated four times by thrust faults (F).

The basal member of the Belly River formation consists of approximately 800 feet of coarse-grained sandstone, in beds 30 to 80 feet thick separated by grey shales. The lowermost beds consist of 200 feet of platy sandstone and dark grey shale transitional to the underlying Wapiabi formation (see eastern front of the Foothills photographs).

The Castle River anticline (C), in Belly River strata, lies to the northeast of the main imbricate zone, but to the east of it are at least three additional thrust faults with no topographic expression (see cross section).

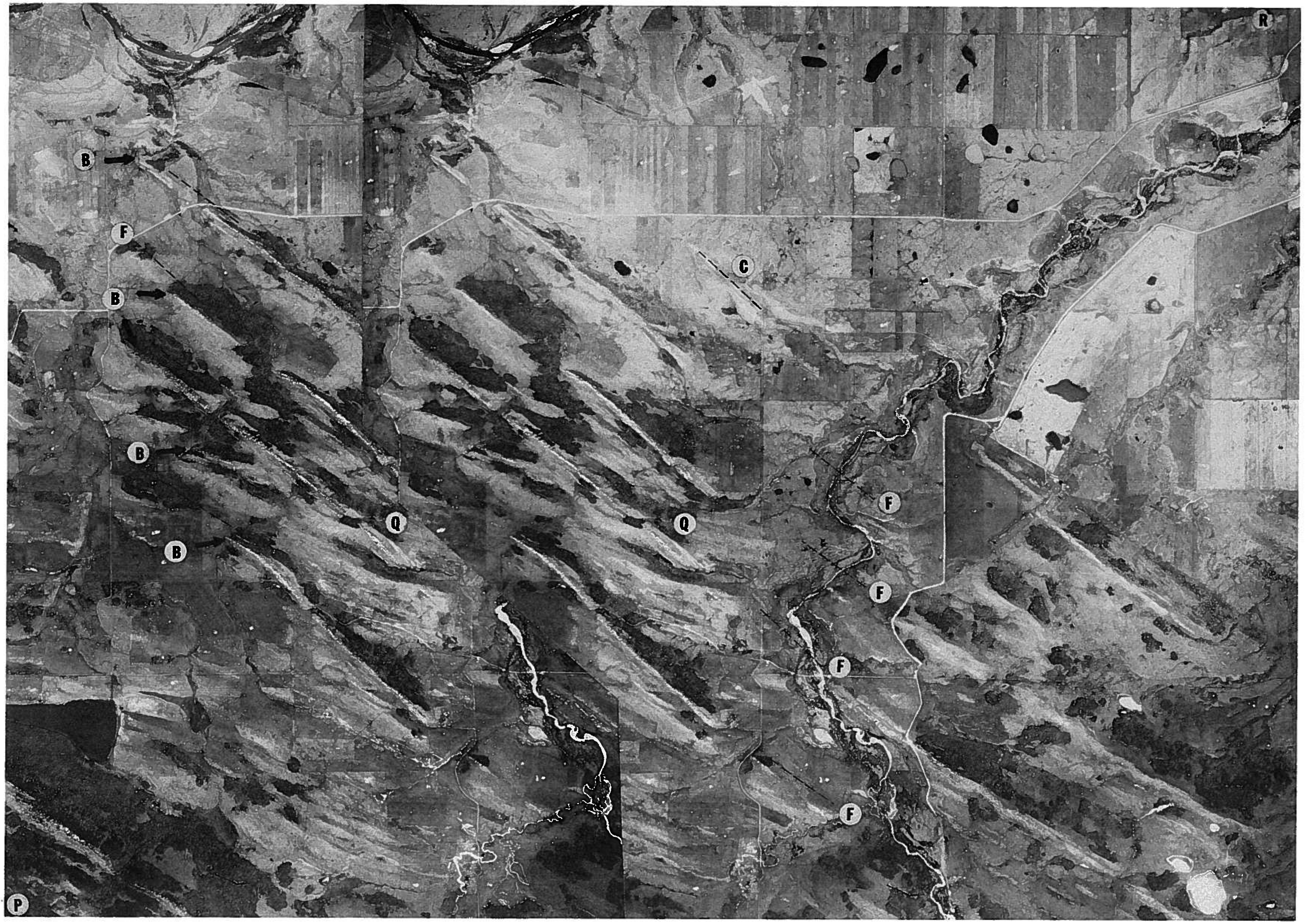
Reference

Hage, C. O. (1940): Beaver Mines, Alberta; Geol. Surv. Can. Map 739A.



Modified after Hage (1940)

STRUCTURE SECTION ALONG LINE P-Q-R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Topographic Expression of Mesozoic Strata

Imbricate Thrust Faulting

Location: Tp. 46, R. 23, W. 5th Mer.

Photograph Nos. 160-5222X: 1861-87, 88, 89

The Town of Mountain Park, a Foothills mining community, lies in the southeast part of the illustration. Railway and road routes from the town follow the McLeod River Valley to the northwest.

A. The crest of the main ridge which is formed by Cadomin conglomerate. North of the ridge this unit is repeated four times by minor thrust faults. The traces of the faults are not visible, and their positions must be inferred (see dashed lines).

A-B. Between these points the Cadomin conglomerate is repeated by three low-angle faults.

C. Axis of a shallow syncline into which the Cadomin is folded between two thrust faults. The conglomerate is exposed on both sides of the fold axis. To the east this syncline pitches out rapidly.

D. West of this point the Cadomin forms the north wall of the valley, and to the north it is repeated higher up the slope by another fault (dashed line).

E. In the vicinity of the Town of Mountain Park, the Cadomin formation is absent due to faulting. The easternmost outcrops of conglomerate are close to the letter E.

F. The rib of Cadomin conglomerate which is repeated on the ridge north of D extends eastward and is folded into an anticline (axis indicated by dashed line). A small flatiron of conglomerate forms the east slope of the ridge on the north flank of the anticline.

G-H. The north limb of the anticline is cut off by a thrust fault (G-H) which repeats Cadomin and lower Luscar beds on its north side. The Cadomin forms the ridge crests north of G and H.

J. On the northern edge of the photograph Fernie and Whitehorse strata are repeated by another thrust fault (J), which cannot be recognized to the southeast where it repeats Fernie against Fernie.

1. Spray River formation. Triassic. Thickness: 700 feet where complete. Siltstone and fine-grained sandstone, overlain by approximately 200 feet of fine-grained dolomite and silty dolomite—the Whitehorse member. This member forms the steep slopes in the northeast part of the illustration.

2. Fernie formation. Jurassic. Thickness: 1,000 feet. Dark shales with limestone and sandstone beds. Grades up into overlying Nikanassin formation.

3. Nikanassin formation. Upper Jurassic, Lower Cretaceous. Thickness: 1,500 feet. Sandstones and shales. Bedding well developed. Medium tone.

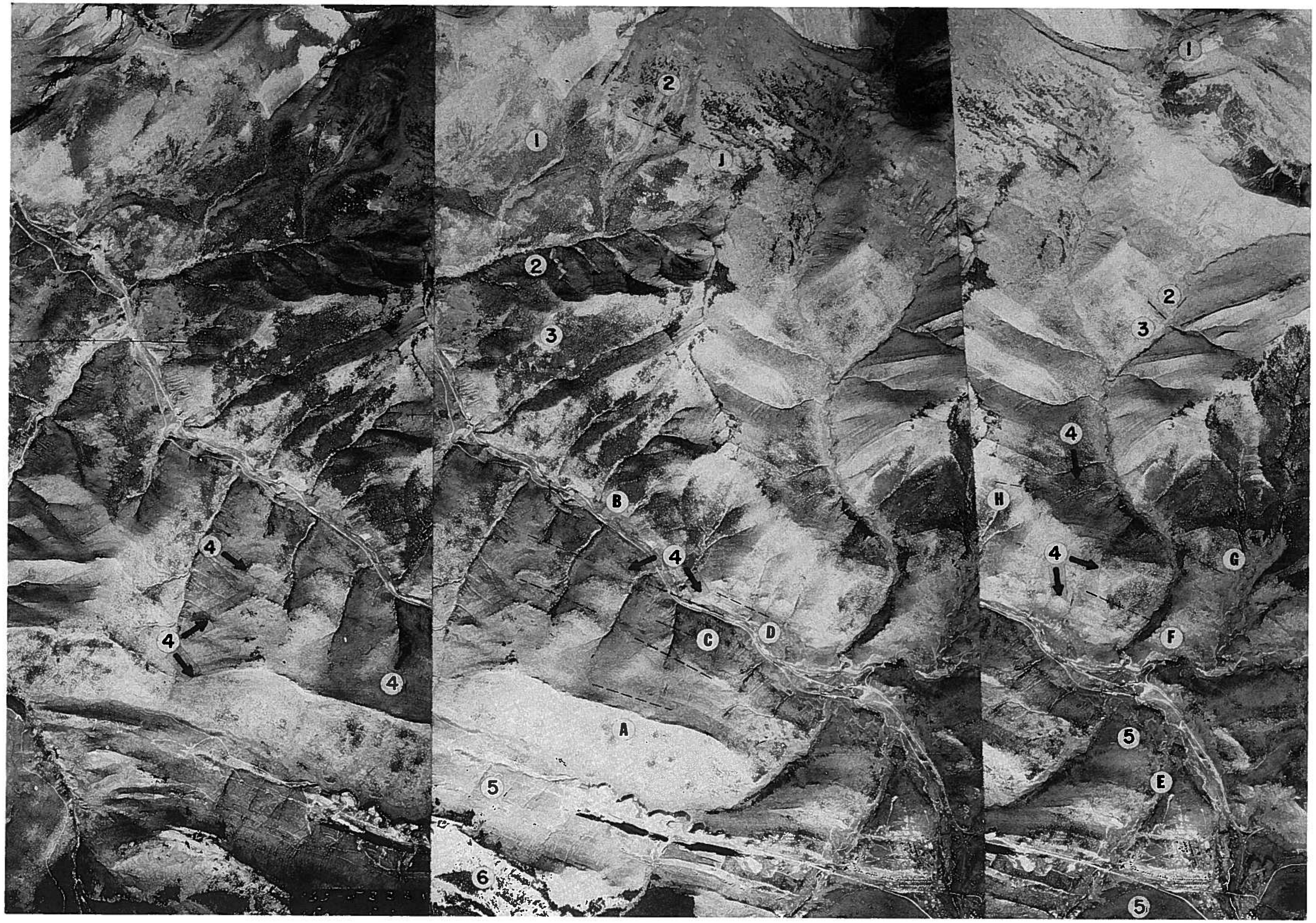
4. Cadomin formation. Cretaceous. Thickness: 15-50 feet. Chert conglomerate. This is a distinctive marker unit in Mesozoic sections, and forms crests of ridges and distinctive ribs on slopes. Light tone.

5. Luscar formation. Cretaceous. Thickness: 1,700 feet. Shale, sandstone and coal. Bedding well developed; non-resistant to erosion; medium to dark tone.

6. Mountain Park formation. Cretaceous. Thickness: 400 feet. Sandstones and shales. Forms the dip slope of the ridge in southwest corner of the illustration.

Reference

Mackay, B. R. (1929): Mountain Park sheet; Geol. Surv. Can. Map 208A.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Synclinal Fold

Topographic Expression of Cretaceous Strata

Location: Tp. 46, Rs. 22, 23, W. 5th Mer.

Photograph Nos. 160-5300XA: 1861-25, 26, 27

The close-spaced imbricate thrust faults and associated tight folds of the southern Foothills are replaced in the central Foothills by broad open folds with more widely-spaced thrust faults. The open syncline illustrated is bounded by faults to the southwest (A) and to the northeast (B). The larger thrust (A) carries Rundle carbonate beds (1) over steeply-dipping Mountain Park (4) or Blackstone strata (5). Below this thrust the beds of the southwest limb of the syncline are more steeply-dipping than those of the northeast limb, and in places they are overturned, as is the Cardium sandstone (6) on the crest of the ridge north of C.

The drainage of the area is superposed or antecedent, as four streams cut across the fold with little deflection of their courses. Studies of the drainage systems of the Mountains and Foothills indicate that superposition is the more likely explanation. Tributary subsequent streams are common and flow in the homoclinal valleys in the northwest of the photograph. Stream capture has been limited, but a few wind gaps are present, as at D.

1. Rundle group. Mississippian. Thickness: 900 feet where complete. Cliff-forming, light-weathering limestones and dolomites.

2. Spray River formation. Triassic. Thickness: 900 feet. The lower part comprises siltstones and dolomites of the Sulphur Mountain member. The upper Whitehorse member, consisting of light-weathering dolomite and dolomitic sandstone, forms the castellated cliffs on the crest of the mountain.

3. Fernie formation. Jurassic. Thickness: 1,300 feet. Black marine shales, fine-grained sandstone and a basal chert conglomerate bed. Forms subdued rounded topography.

4. Mountain Park formation. Cretaceous. Thickness: 400 feet. Hard, coarse-grained sandstones and green sandy shales; local conglomerate lenses.

5. Blackstone formation. Cretaceous. Thickness: 1,500 feet. Black marine shales with limestone lenses and concretions and a grit bed at the base. Forms areas of low relief.

6. Cardium formation. Cretaceous. Thickness: 300 feet. Fine-grained sandstones and dark shales. Forms a distinctive continuous ridge between the low-lying area of Blackstone and Wapiabi shales.

7. Wapiabi formation. Cretaceous. Thickness: 1,700 feet. Black marine shale with local calcareous beds. Bedding seldom visible; forms areas of low relief. Upper part more sandy and resistant—grades into Brazeau formation.

8. Brazeau formation. Cretaceous. Thickness: up to 10,000 feet. Green and grey sandstones and shales with conglomerate bands. The basal coarse sandstone and conglomeratic bands form homoclinal ridges above the Wapiabi beds. Local sandstone beds form minor ridges.

Reference

Mackay, B. R. (1929): Mountain Park sheet; Geol. Surv. Can. Map 208A.


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Anticlinal Fold
Superposed Drainage

Location: Tp. 22, R. 6, W. 5th Mer.

Photograph Nos. 160-5021X: 2278-83, 84, 85

The Moose Mountain "dome" is a broad anticlinal structure in the Foothills belt. The fold is 16 miles long by 7 miles wide, and its axis strikes northwest. The photographs illustrate the southern edge of the anticline where it plunges out to the southeast.

Canyon Creek flows from west to east across the structure and in the centre (A) beds low in the Mississippian Banff formation (1) are exposed. The higher ground in the centre of the fold, including Prairie Mountain (B) are composed of Pekisko, Shunda and Rundle strata (2). The contact between the Banff and Pekisko formations is well exposed on Canyon Creek (C, D). Dips on the east and west flanks of the fold may be as high as 50 degrees, but to the south along the fold as dips are little more than 10 degrees, as at E, where a flatiron is developed in upper Rundle beds.

The Mississippian strata are overlain by Jurassic Fernie beds, and the paraconformable contact is exposed at F. South of the Elbow River the Fernie strata are synclinally folded (G), and a complementary anticline west of the fold replaces to the south the Moose Mountain structure.

A thin development of the Kootenay formation (4) lies above the Fernie shales, and this in turn is overlain by the Blairmore formation (5), with its characteristic ridge-forming conglomerate unit at the base.

Canyon Creek, which has cut its valley across the fold axis, is a superposed stream typical of Rocky Mountain drainage systems. The lower part of the stream follows the east flank of the Moose Mountain dome in a homoclinal valley cut mainly in the easily eroded Fernie shales. The Elbow River, into which Canyon Creek flows, receives several east-flowing tributaries which are superposed streams. Below the confluence of these tributaries the river cuts through extensive valley train deposits, which are in part pitted (H). Remnants of similar deposits are present on the lower part of Canyon Creek, and unconsolidated glacial materials extend well up the slopes of the valley.

1. Banff formation. Mississippian. Thickness: 400 feet exposed. Argillaceous limestones, calcareous and silty shales; less resistant to erosion than overlying beds.

2. Pekisko, Shunda and Rundle formations. Mississippian. Thickness: 1,100 feet. Pekisko (300 feet): light-weathering, coarse-grained calcarenites, forming the distinctive resistant unit above the Banff formation at C and D. Shunda (200 feet): fine-grained dolomites and dolomitic limestones; poorly-exposed, easily eroded unit above the Pekisko. Rundle (600 feet): the lower part consists of light-weathering, resistant, calcarenites and dolomites. Less resistant fine-grained dolomitic and evaporitic beds appear in the upper part.

3. Fernie formation. Jurassic. Thickness: 250 feet. Soft black shales with dark sandstone interbeds. Forms narrow homoclinal valleys; poorly exposed, easily eroded.

4. Kootenay formation. Cretaceous. Thickness: 220 feet. Dark shaly sandstone and sandy shale with local coal seams. A massive 30-foot sandstone at the base commonly forms a distinctive light-weathering rib.

5. Blairmore formation. Cretaceous. Thickness: 2,000 feet. The basal conglomerate, 30 to 40 feet thick, is overlain by dark grey shales and by dark sandstones which locally may form extensive minor ridges.

References

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Rocky Mountain Front Range Development

Location: Tps. 25, 26, R. 12, W. 5th Mer.

Photograph Nos. 160-5104X: 1892-15, 16, 17

The Front Ranges of the Rocky Mountains consist of fault blocks composed predominantly of Upper Paleozoic carbonates and Lower Mesozoic clastic strata. The Paleozoic beds tend to form the mountain ranges and the Mesozoic strata the intervening valleys.

In the vicinity of Banff, Tunnel Mountain (A) and Mount Rundle (B) form part of the Rundle thrust block. Sulphur Mountain (C) to the west belongs to the overlying fault block. North of the Bow River Stoney Squaw Mountain (D) and Cascade Mountain (south end at E) are part of the Rundle fault block. The Mount Rundle thrust lies beneath the foot of Mount Rundle, probably in the vicinity of F, and according to Usher (1959) this fault is exposed near J where Devonian Palliser limestone (1) lies on Cretaceous Kootenay beds (7). On the south end of Cascade Mountain (E) a massive anticlinal fold above the thrust is apparent.

The position of the Sulphur Mountain thrust (dashed lines, G) lies close to the thermal springs on the lower slopes of the mountain; this thrust carries Devonian carbonates over Permian (5) or Triassic beds (6). North of the Bow River a synclinal fold in Rocky Mountain (5) and Spray River beds (6) lies below this fault.

The Bow River at present flows through a gap in the Mount Rundle massif on the south side of Tunnel Mountain (A). A broader preglacial valley of the river (H-J) lies on the north side of Tunnel Mountain; when this first was occupied the Bow River flowed to the northeast. East of Tunnel Mountain the present direction of flow of the river is to the southeast. River capture was effected by headward erosion of a subsequent stream flowing in the softer Mesozoic strata in front of the Rundle Range; this capture took place in preglacial time. Subsequent glaciation has deepened the valley considerably, and the Bow River west of Banff now meanders over extensive valley fill deposits. This valley fill or lake deposits lie on the upstream side of Tunnel Mountain and the till ridge (K). Presumably blockage of the Bow Valley by glacial deposits forced the Bow River to spill southwards into the preglacial valley of the Spray River (A), by which route it returned to its southeast-trending preglacial valley. The Cascade River (at J) in post-glacial time probably flowed down the broad valley north of Tunnel Mountain (J-H), before it cut through the ridge of glacial deposits (at J).

Pitted kame terrace deposits (L) are visible on the southern edge of the present Bow Valley.

1. Fairholme group and Palliser formation. Devonian. Thickness: up to 3,000 feet exposed. Beds of the Fairholme group—grey limestones and dolomites—are present on the lower slopes of the Sulphur Mountain; Warren (1927) measured a thickness of 2,000 feet. Massive, dark-grey, light-weathering dolomites and limestones of the Palliser formation are 1,000 feet thick in the Banff area; they form a distinct scarp (near L) and high cliffs on the lower slopes of Mount Rundle, and are in general poorly exposed on Sulphur Mountain.
2. Banff formation. Mississippian. Thickness: 1,400 feet. Dark-weathering, calcareous siltstones and impure limestones and dolomites, which form scree slopes and local low cliffs. This formation forms a distinctive unit on the middle slopes of Mount Rundle. Exposures on Sulphur Mountain are generally poor; the contact with the underlying Palliser beds is exposed (at M).
3. Livingstone formation. Mississippian. Thickness: 1,200 feet. Massive light-weathering, cliff-forming limestones with dolomite beds. This unit forms massive cliffs of the upper part of Mount Rundle.
4. Mount Head and Tunnel Mountain formations. Mississippian. Thickness: 900 feet. Impure limestone, dolomite, and sandy dolomite; thinner-bedded and less resistant to erosion than the Livingstone strata.
5. Rocky Mountain formation. Pennsylvanian and Permian. Thickness: 600 feet. Light-weathering dolomite, sandy dolomite, sandstone and massive chert.
6. Spray River formation. Triassic. Thickness: approximately 1,500 feet. Dark calcareous and dolomitic shales and siltstones, with impure limestone and dolomite.
7. Kootenay formation. Cretaceous. Thickness: at least 1,000 feet. Thin sandstone and silty shale bands; local coal seams.

References

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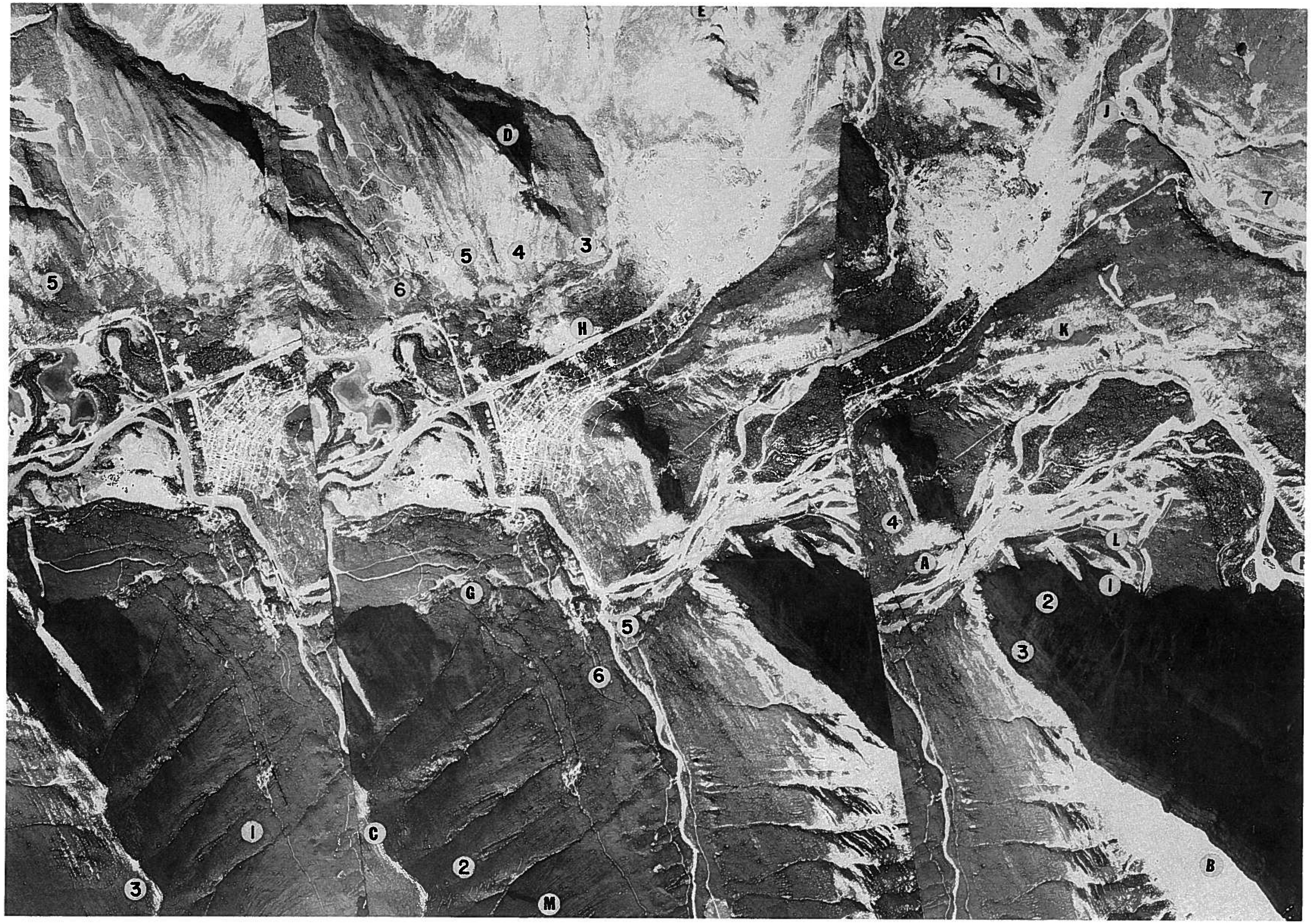
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Topographic Expression of Paleozoic and Lower Mesozoic Strata

Location: Tp. 35, R. 16, W. 5th Mer.

Photograph Nos. 160-5201X: 2431-68, 69

Different rock types within a stratigraphic succession can, if conditions are suitable, be differentiated on the basis of their topographic expressions. In the area illustrated, because of the general lack of vegetation and of the products of mass wasting most of the rock types show distinctive topographic forms and tonal differences. In these two Front Range fault blocks strata ranging in age from late Cambrian to Jurassic are present. The trace of the more northeasterly thrust fault (1) is particularly distinct, but that of the other (2) is less easily distinguished as talus covers much of the fault trace. The Turner Valley formation (H), however, forms a distinctive cliff above the fault.

A. Upper Cambrian strata and possibly Ghost River formation (Middle Devonian). Thickness: approximately 500 feet. Light-weathering, relatively thin-bedded grey and buff dolomites and silty dolomites, green and red shales. Light tone.

B. Flume and Perdrix formations. Upper Devonian. Thickness: 600 feet. Dark-grey and black limestones, shales, dolomites. The Perdrix strata above are more thin-bedded and are less resistant to erosion than are those of the Flume formation. Dark tone.

C. Mount Hawk formation. Upper Devonian. Thickness: 500 feet. Grey and dark-grey limestones and dolomites with some shale. In part massive-bedded, cliff-forming. Light to medium tone.

D. Alexo formation. Upper Devonian. Thickness: 200 feet. Grey and brown dolomite, silty dolomite and siltstone. In general non-resistant to erosion.

E. Palliser formation. Upper Devonian. Thickness: 950 feet. Dark-grey, light-weathering massive limestone; upper part more thin-bedded and argillaceous. Light tone.

F. Banff formation. Mississippian. Thickness: 700 feet. Dark-grey and black argillaceous limestone and shale; thin-bedded, non-resistant to erosion. Dark tone.

G. Pekisko and Shunda formations. Mississippian. Thickness: 350 and 120 feet, respectively. Pekisko: light-grey, massive, crinoidal, cliff-forming limestone (150 feet), light tone, overlain by 200 feet of fine-grained, dark-grey limestone, dark tone. Shunda: brown and grey, fine-grained limestone and dolomite, medium tone.

H. Turner Valley and Mount Head formations. Mississippian. Thickness: 150 and 300 feet, respectively. Turner Valley: massive, cliff-forming, light- and medium-grey limestone, light to medium tone. Mount Head: light- to dark-grey, thin-bedded to massive dolomite with some limestone; alternating resistant and non-resistant bands; light to medium tone.

J. Etherington and Rocky Mountain formations. Mississippian and (?) Permian. Thickness: 250 feet. These beds cannot always be distinguished from the underlying strata. Etherington: thin- to medium-bedded argillacious and arenaceous dolomites; lower part non-resistant to erosion; light to medium tone. Rocky Mountain: 50 feet of grey sandstone with some chert.

K. Spray River formation. Triassic. Thickness: 1,300 feet. Sulphur Mountain member (lower): approximately 800 feet; grey, fine-grained sandstones and siltstones, rusty-weathering, thin-bedded, in general non-resistant to erosion; dark tone; may include a more dolomitic middle unit, more resistant, locally cliff-forming. Whitehorse member (upper): approximately 500 feet; fine-grained dolomite and silty dolomite, thin-bedded, light-weathering, locally cliff-forming; light to medium tone.

L. Fernie formation. Jurassic. Thickness: not known. Dark-grey shales, silty shales and sandstones; dark limestone and dolomite near the base. Non-resistant to erosion, forms areas of low relief. Dark tone.

References

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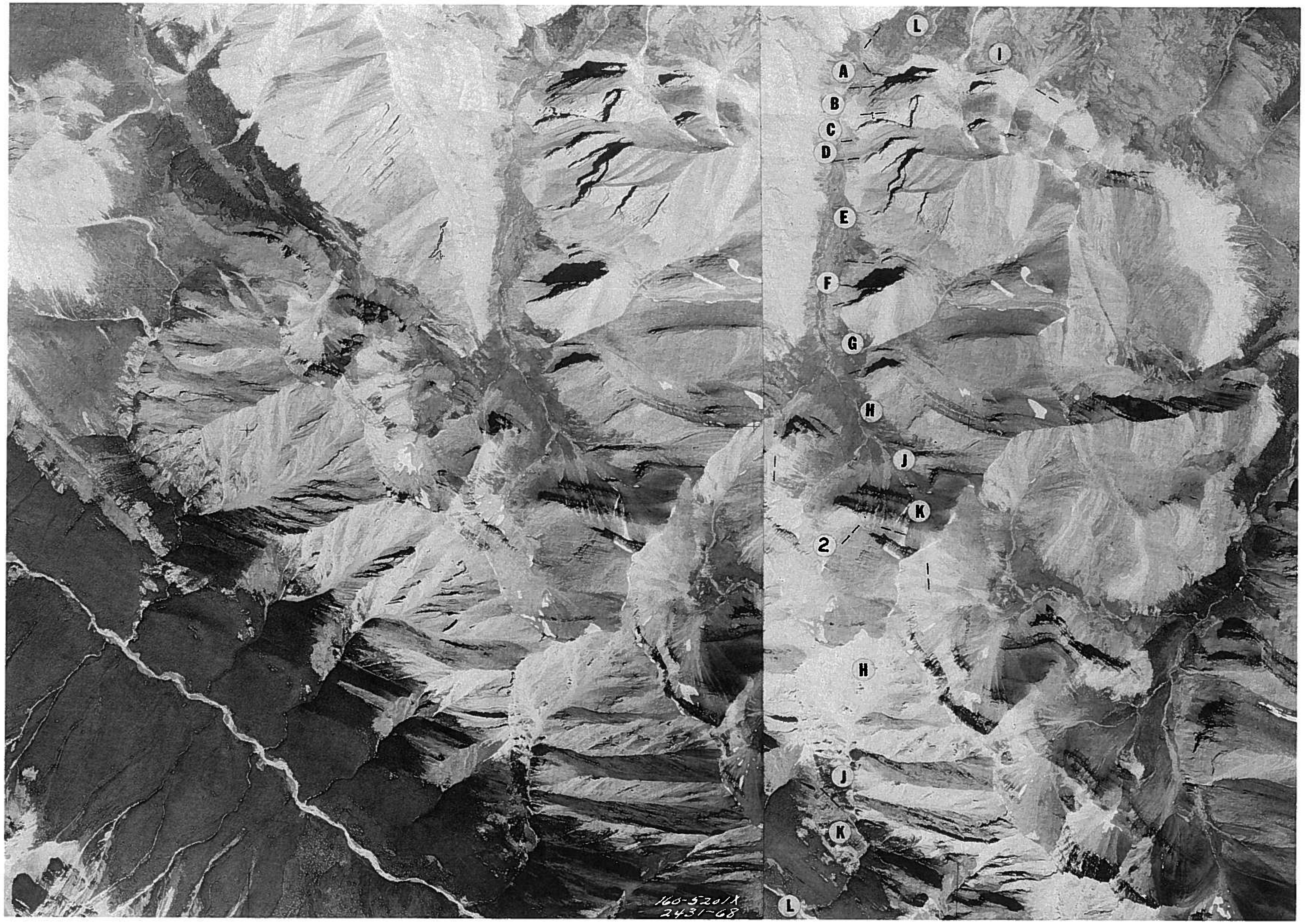
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Plunging Anticline

Stripmining Operations

Location: Tps. 6, 7, R. 4, W. 5th Mer.

Photograph Nos. 160-14912X: 2423-112, 113, 114

South of the Bow River a number of the Front Ranges of the Rocky Mountains plunge gently southward; thus higher beds in the succession appear and constitute successively greater parts of the structures. Many of these beds are less resistant to erosion than are the Paleozoic carbonates, and thus several ranges decrease in elevation towards the south, and eventually disappear.

In southern Alberta the Front Ranges are represented by several large, locally faulted, anticlinal structures which bring Paleozoic strata to the surface. The Livingstone Range (see plunging folds and landslide photographs) and the Blairmore Range are two such structures.

The southern end of the Blairmore Range lies in the centre of the plate. Paleozoic strata (1, 2) form Hillcrest Mountain (A) and extend southward along Hastings Ridge (B) as far as the southernmost hairpin turn on the road. South of the road the Paleozoic strata plunge out, and the anticlinal ridge is replaced by anticlinal valley (C) cut in Fernie shales (3). The fold axis, indicated by dashed lines, lies on the east flank of Hastings Ridge and exposes Rundle strata (1) in the core. The densely tree-covered higher slopes are formed by Rocky Mountain beds (2).

On the west flank of Hastings Ridge extensive stripmining operations were in progress when these photographs were taken (1949). A 15-foot coal seam in the Kootenay formation (4) was worked at the Adanac Strip Mine (D), where the Cadomin conglomerate (5) was stripped off to obtain the coal. Other coal seams in this formation have been prospected and in places worked, as on the east side of the valley of Byron Creek (E) and on the east flank of Hillcrest Mountain (A). Some prospecting has also been carried out west of the Adanac Mine where Kootenay strata are repeated by a fault (F-F).

On the east side of the anticline there is no repetition of strata, only local folding: two minor synclines and an anticline at G and contortion in the vicinity of H.

1. Rundle group. Mississippian. Thickness: up to 1,000 feet exposed. Grey and dark-grey limestone and dolomite.

2. Rocky Mountain formation. Pennsylvanian and Permian. Thickness: 350 feet. Light-grey dolomite, limestone, chert breccia and sandstone; dark-grey siltstone, green and maroon shales.

3. Fernie formation. Jurassic. Thickness: 1,200 feet. Dark-grey and black shales, silty shales and limestones. Poorly exposed, easily eroded.

4. Kootenay formation. Cretaceous. Thickness: 500 feet. Basal dark sandstone, overlain by shale, sandstone and coal.

5, 6. Blairmore formation. Cretaceous. Thickness: 2,000 feet. Greenish and grey sandstones and mudstones, with local conglomerate bands. 5. Cadomin formation. Thickness: 10 to 35 feet. Basal chert- and quartzite-conglomerate of Blairmore formation. Distinctive ridge-forming unit.

7. Crowsnest formation. Cretaceous. Thickness: 450 feet. Agglomerate, variously-coloured tuffaceous shales.

8. Blackstone formation. Cretaceous. Thickness: up to 200 feet exposed. Dark-grey shales and silty shales; easily eroded.

References

Clow, W. H. A. and M. B. B. Crockford (1951): Geology of Carbondale River area; Res. Coun. Alberta Rept. 59, 70 pages.

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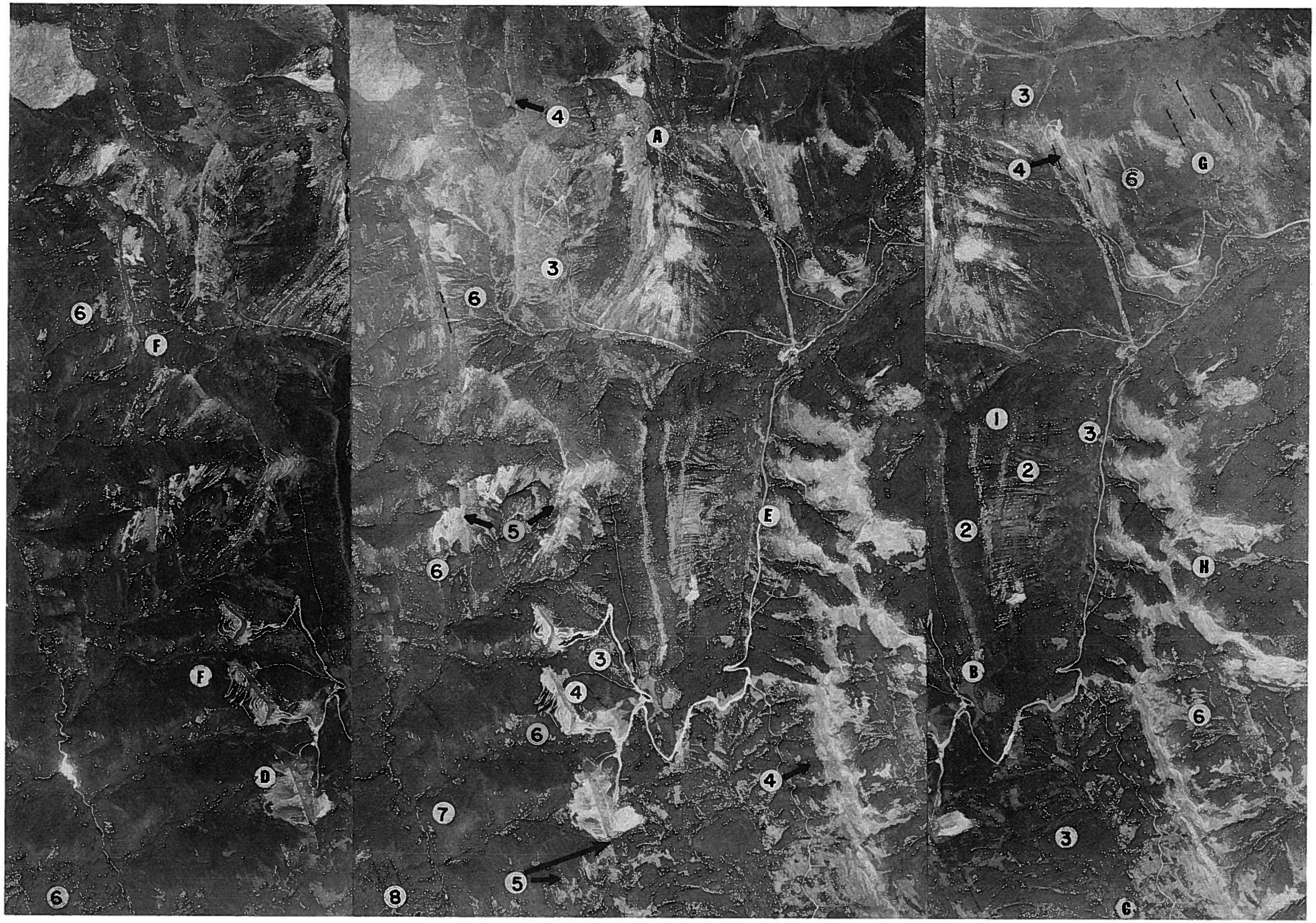
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Fold Structures

Location: Tp. 13, R. 3, W. 5th Mer.

Photograph Nos. 160-5001: 1952A-46, 47, 48

The Livingstone Range, a complex anticlinal structure with associated folds and faults, is in southern Alberta the representative of the First Front Range in the Bow River Valley. The Range consists predominantly of Upper Paleozoic strata (1, 2), which are well exposed where west-flowing streams cut through the major folds.

Small anticlinal folds (A, B), bounded on the east by faults, lie on the west flank of the major anticline of the Livingstone Range (C-C-C). Another minor anticline (D) lies against the east flank of the main fold, separated from it by an acute synclinal fold (E). Farther to the east two additional anticlinal folds (F, G) have an intervening broader syncline (H). A third syncline (J) lies between the Livingstone Range (C-C-C) and anticline F.

A minor thrust fault (K) lies on the west flank of the Livingstone Range, separating minor folds A and B from the major anticlinal structure.

The Livingstone fault, a major folded sole thrust, is present only in the northeast of the area, where its trace underlies slumped material on the slopes at L.

In this area geologic structure and varying resistance to erosion of rock units have exerted almost complete control on the development of topography. Practically all primary tributaries of the two main superposed streams flow in homoclinal valleys, twelve of which have been cut in Jurassic Fernie shales (3). The lower beds of the Blairmore formation (5) are also recessive and four valleys are cut in these strata. Two tributary stream valleys are synclinal, the streams flowing along the axes of synclines E and J.

Wherever Paleozoic beds (1, 2) are brought to the surface in folds, anticlinal ridges are developed (A, B, C, D, F). The other anticlinal ridge (G) is supported by the basal conglomerate of the Blairmore formation (5). Anticlinal valleys are not present in the area, but the development of such a feature is in progress on the southern part of anticline F, where Fernie shales (3) are being eroded in the centre of the fold.

Remnants of a synclinal ridge are present along fold H, where upper Blairmore beds along the synclinal axis form some of the highest ground in the area.

1. Rundle Group. Mississippian. Thickness: up to 1,000 feet exposed. Light- and dark-grey dolomite and limestone with some shale. Varying resistance to erosion. In addition to where indicated, these beds are exposed in the cores of anticlines A, B and F.

2. Rocky Mountain formation. Pennsylvanian (?) and Permian. Thickness: 50 feet. Light-weathering, fine-grained quartz sandstones, massive grey chert and chert breccias. In proportion to their thickness, beds of this unit have very extensive areas of outcrop because of their erosion-resistant character and because the overlying Fernie beds are rapidly stripped off by erosion.

3. Fernie formation. Jurassic. Thickness: 900 feet. Dark-grey and black shale with local black sandstones and limestones. In general poorly exposed; on photographs bedding is normally indistinct except where more resistant sandstone or limestone bands outcrop.

4. Kootenay formation. Cretaceous. Thickness: 350 feet. Dark-grey and black shales and sandstone; local coal seams. Sandstone units are present at base and top of the formation.

5. Blairmore formation. Cretaceous. Thickness: 1,500 feet. Grey and greenish sandstone and green and maroon silty shales, conglomerates. The basal conglomerate, as always, is a distinctive ridge-forming unit and marker. In this area resistant conglomeratic bands higher in the formation also support local ridges.

Reference

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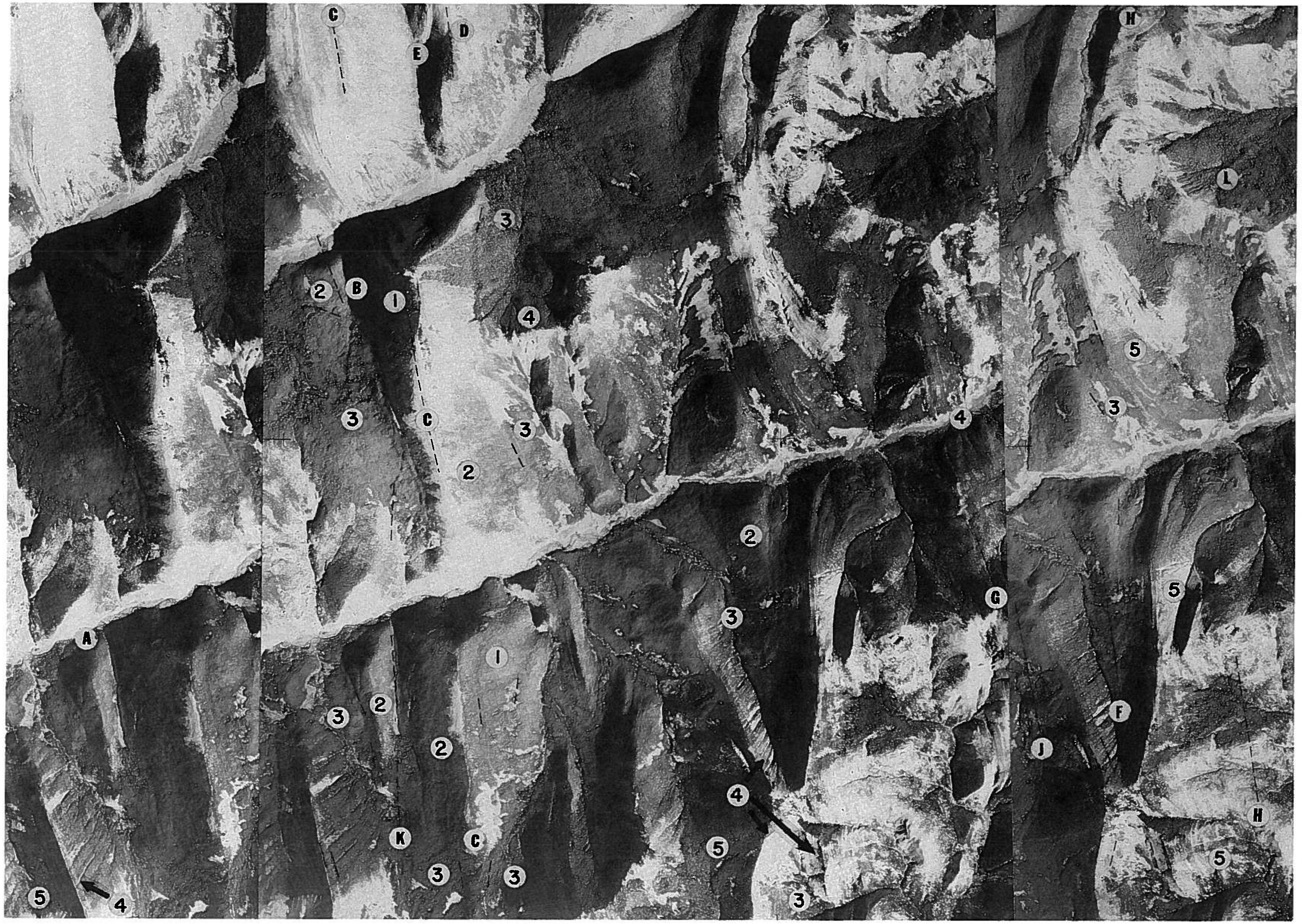
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Plunging Folds

Landslide

Location: Tps. 7, 8, Rs. 3, 4, W. 5th Mer.

Photograph Nos. 160-4913: 2425-51, 52
Photograph Nos. 160-4914X: 2218-89, 90, 91

The Frank slide took place on April 29, 1903, when a mass of limestone forming the east face of Turtle Mountain fell into the valley below. The slide destroyed part of the town of Frank and took some 66 lives. The main portion of the slipped mass swept across the valley floor and buried it to a depth of approximately 50 feet. Part of the debris was carried up slopes on the north side of the valley where it splayed out into a number of lobes.

The site of the old town of Frank lies east of J. The present town lies north of the railway, the site to which it was moved following the slide.

The limestone which formed the slide material is predominantly Mississippian Rundle beds (1) which have been thrust by the Turtle Mountain fault (K) over Jurassic Fernie (2) and Cretaceous Kootenay (3) and Blairmore strata (4). A coal seam in the Kootenay beds was mined at Frank; the original mine entrance was at the south end of the old town, and mine workings extended up the lower slopes of Turtle Mountain as indicated by dayholes (L) on the south edge of the talus slope. The seam mined has a near vertical dip, and it was considered (Daly et al, 1912) that settling in the workings following removal of the coal was a contributing factor to the cause of the landslide.

The steeply-dipping Kootenay strata, in places overturned, form part of the west limb of an asymmetrical syncline below the Turtle Mountain fault; a portion of the fold axis is indicated by a dashed line (M).

The major structure on the east side of the photographs is the southern end of the Livingstone Range. Mississippian beds forming the major part of this range plunge out in the vicinity of N and O. At N an anticline in Rundle and Rocky Mountain strata (1) plunges out steeply to the south; the fold axis is indicated by a dashed line. To the east of the adjacent syncline this anticline is replaced en échelon by a similar fold with Paleozoic beds in the core. These strata plunge out at O and farther south an anticlinal valley is cut in Fernie shales (2). The hogbacks east of this valley form the west limb of a broad synclinal structure (P) in Kootenay (3) and Blairmore beds (4).

In the vicinity of O, P, and the town of Bellevue, abundant dayholes indicate the presence of extensive workings in a coal seam near the top of the Kootenay formation (3).

A kame terrace (Q) flanks the foot of Turtle Mountain south of the slide area. Other terraces of possibly the same nature lie on the valley sides west and north of Frank (J).

1. Banff, Rundle, and Rocky Mountain formations. Mississippian, Pennsylvanian and Permian. Thickness: 2,000 feet approximately. An incomplete section of the Banff formation—grey limestones and dolomites—lies on the Turtle Mountain fault north of the slide area (Norris, 1955). The major part of Turtle Mountain, however, consists of medium- to dark-grey limestone and dolomites which weather to a light colour. The carbonates in the core of the anticline north of O also belong to the Rundle formation, as do most of the strata of that part of the Livingstone Range illustrated. The Rocky Mountain formation, 300 feet thick, consists of grey dolomites, limestones, chert breccias and maroon and green shales; this unit forms the steeply-inclined flatirons on the west flank of anticline O.
2. Fernie formation. Jurassic. Thickness: 700 feet.
   Dark-grey and black shales and silty shales with sandstones.
3. Kootenay formation. Cretaceous. Thickness: 500 feet. Dark shales, grey sandstones, coal seams.
4. Blairmore formation. Cretaceous. Thickness: 200 feet. Basal chert- and quartzite-conglomerate (Cadomin member); greenish and grey sandstones and mudstones with local conglomerate bands.

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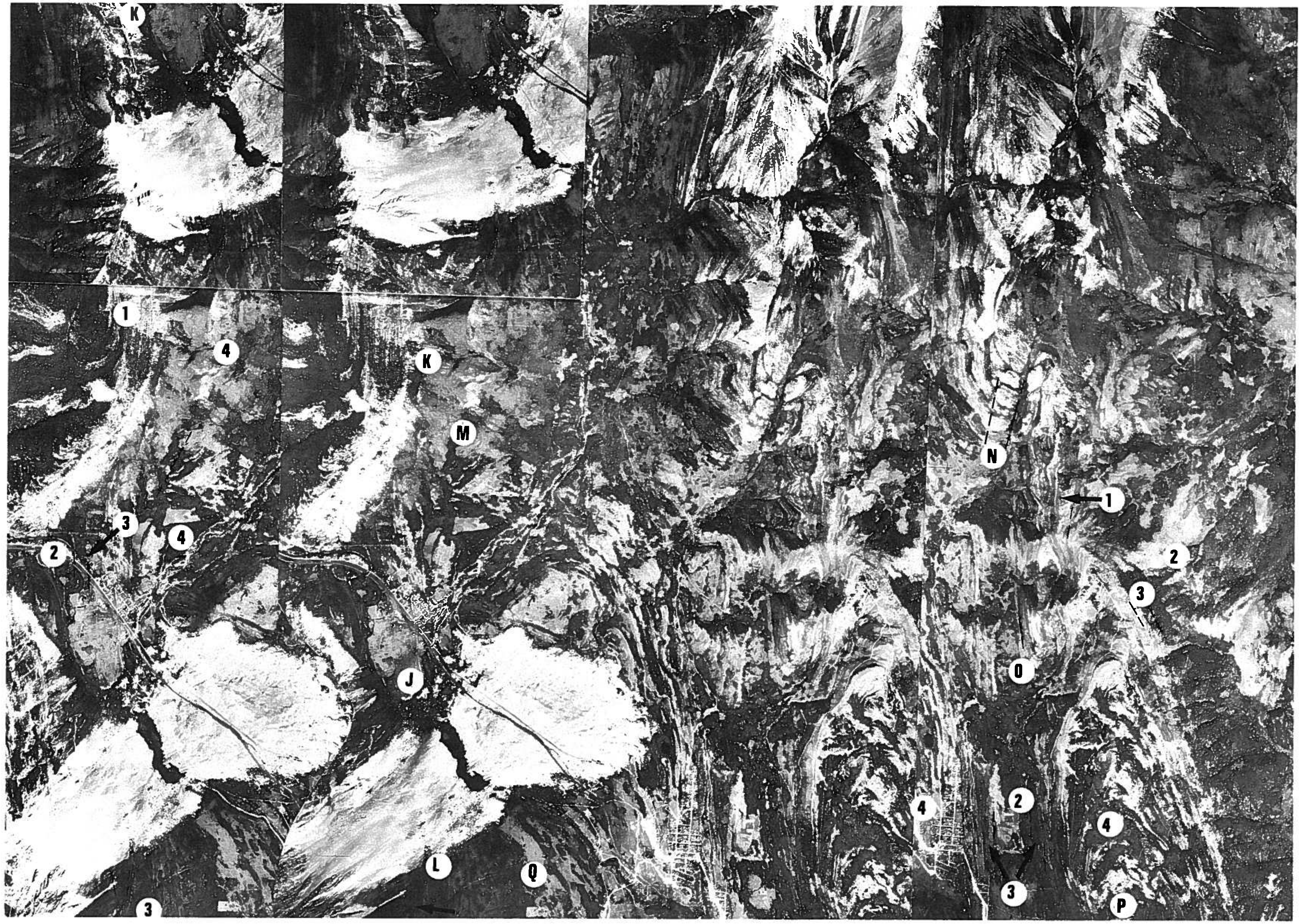
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Topographic Expression of Precambrian Strata

Lewis Thrust Fault

Location: Tps. 3, 4, R. 1, W. 5th Mer.

Photograph Nos. 160-4906X: 2423-43, 44, 45

In southwestern Alberta and northwestern Montana, the Clarke Range consists of a broad synclinal structure in Precambrian sedimentary strata which have been carried over younger Paleozoic and Mesozoic beds by the Lewis thrust (Clark, 1954). A well drilled in the Flathead Valley on the western edge of the Clarke Range proved the presence of Paleozoic and Mesozoic beds below the Lewis thrust. Thus it can be inferred that the strata forming the Clarke Range have been carried a minimum distance of 20 miles over younger strata, and override part of the Foothills belt in southwestern Alberta.

Part of the northern edge of the Clarke Range is illustrated in these photographs, where Precambrian strata (1 to 6) lie on relatively undisturbed Upper Cretaceous Belly River beds (7) of the Foothills belt.

The plane of the Lewis thrust (A) dips gently to the southwest and thus its trace is to some extent influenced by topography. In front of the thrust the lower ground with rounded subdued topography is formed by Cretaceous rocks, and the mountainous area above the thrust consists of Precambrian strata.

Apart from the Lewis thrust there are few structural features illustrated: minor flexures and a small thrust fault (B) are present in the southwest ridge of Drywood Mountain, and minor folding in Precambrian beds is visible in a few other places.

Arête ridges and poorly-defined cirques flank the main peaks, which are separated by deep valleys with U-shaped profiles. In one glaciated valley a stream (C) has incised a distinctive V-shaped notch in the valley floor.

The lack of vegetation at higher elevations permits distinctive topographic and photographic expression of certain Precambrian rock units: the basaltic lava (4) and the Sheppard (5) and Kintla formations (6).

1. Appekunny formation. Precambrian. Thickness: up to 1,600 feet. Grey and green argillite; brown-weathering limestone, sandstone and quartzite. Medium tone.
2. Grinnell formation. Precambrian. Thickness: 750 feet. Red argillite, red and white quartzite. In places a slight change in topographic expression, and to a darker tone, is apparent at the contact with the underlying Appekunny formation. In general this unit forms rounded features.
3. Siyeh formation. Precambrian. Thickness: 3,000 feet. Grey, brown-weathering argillite limestone, quartzite. Lighter tone than underlying Grinnell formation. These beds form more angular features than Grinnell strata.
4. Basaltic lava. Precambrian. Thickness: 350 feet. Dark vesicular and amygdaloidal basalt; distinctive dark tone and strong jagged features.
5. Sheppard formation. Precambrian. Thickness: 470 feet. Brown-weathering argillite, limestone and sandstone; light tone; less resistant to erosion than underlying lava.
6. Kintla formation. Precambrian. Thickness: up to 700 feet. Red argillite, buff-weathering quartzite and limestone. The argillite has a dark tone and forms rounded topography; the quartzite and limestone have light to medium tones and have a sharper topographic expression.
7. Belly River formation. Cretaceous. Thickness: up to 4,500 feet. Grey sandstones and shales with carbonaceous beds.

References

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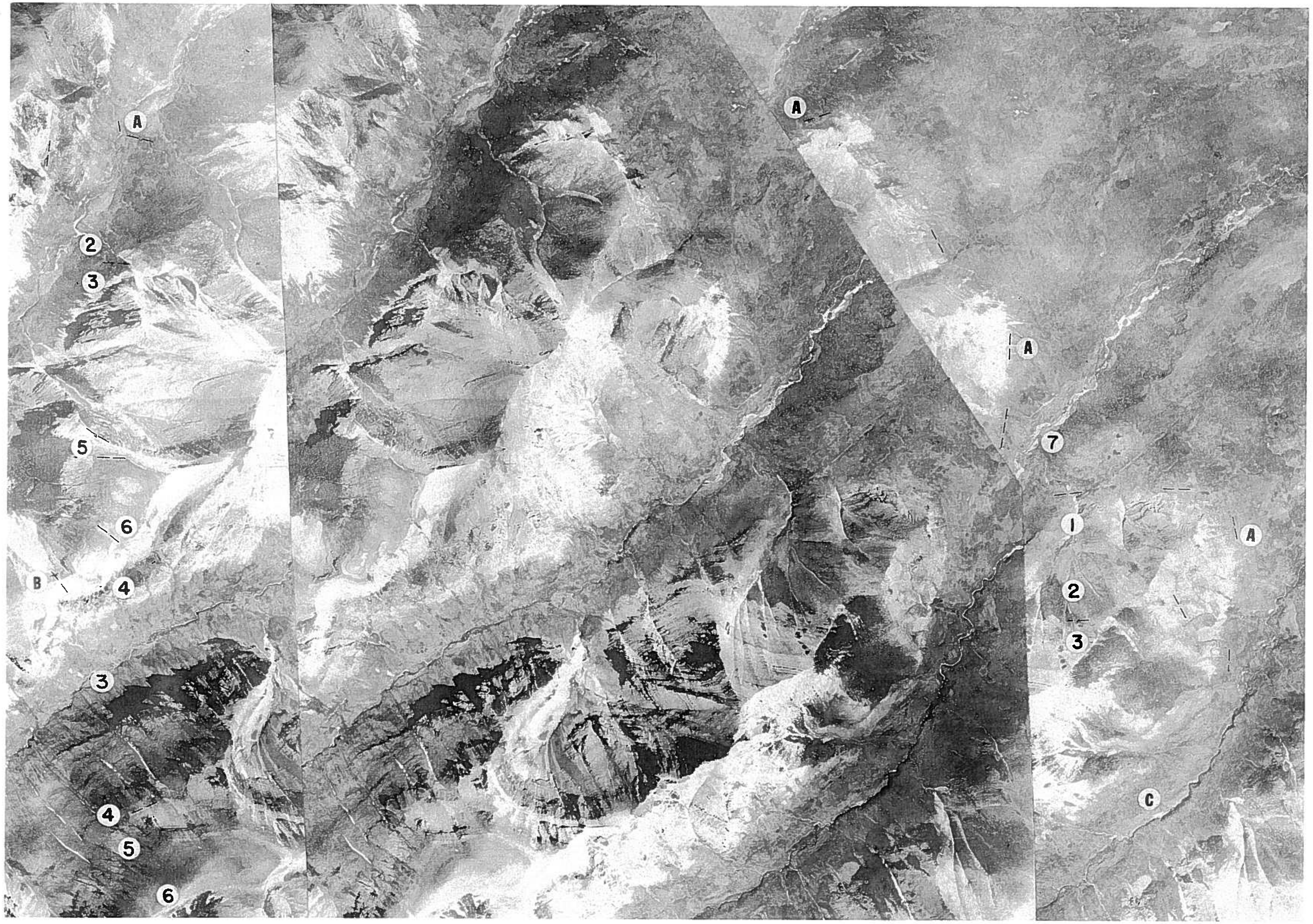
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Folded Thrust Fault, Fenster and Klippe

Location: Tp. 12, R. 6, W. 5th Mer.

Photograph Nos. 160-5001X: 2277A-29, 30, 31

The Lewis fault is one of the major faults in the southern Rocky Mountains. It is a low-angle thrust which in the area illustrated carries Upper Paleozoic Devonian and Mississippian rocks (1, 2, 3) over Upper Cretaceous Belly River beds (4). The trace of this thrust fault (A) is sinuous, and follows the base of the cliffs of Beehive Mountain (M) and its southern extension, and a part of the fault underlies a small klippe (B) lying a half mile east of the main thrust mass. Characteristically light-weathering Paleozoic carbonates lie above the fault and form the klippe.

The plane of the thrust appears to follow closely the bedding planes of the Paleozoic beds. Thus the fault is folded anticlinally along the axis C-D: at D a cross section of the folded thrust is visible. This fold axis runs northward through the col west of Beehive Mountain. The east side of the crest of the fold at D is broken by a subsidiary thrust fault which extends northward along the ridge: it is traceable as far as E and probably extends onto the upper ridges of Beehive Mountain.

A synclinal fold (F), complementary to the anticline C-D, lies to the east of the fault D-E, and in the core of the fold resistant Rundle strata are present.

Minor folds in Mississippian strata are well exposed in the arête ridges on the east side of the photograph.

In the vicinity of G erosion of the Paleozoic strata has produced a fenster and Cretaceous strata outcrop on the lower slopes and on the valley floor.

Glacial influence on land forms of the area has been considerable. Extensive headwall erosion of cirques on both the east and west flanks has led to development of a sinuous arête ridge extending southward from Beehive Mountain.

Varying amounts of talus have accumulated in the cirques, sufficient in one (H) to permit development of a rock glacier. Talus creep is evident in the lower parts of several cirques.

1. Palliser formation. Devonian. Thickness: 1,000 feet. Light-weathering, cliff-forming limestone. Approximately 200 feet of beds are present above the Lewis thrust.

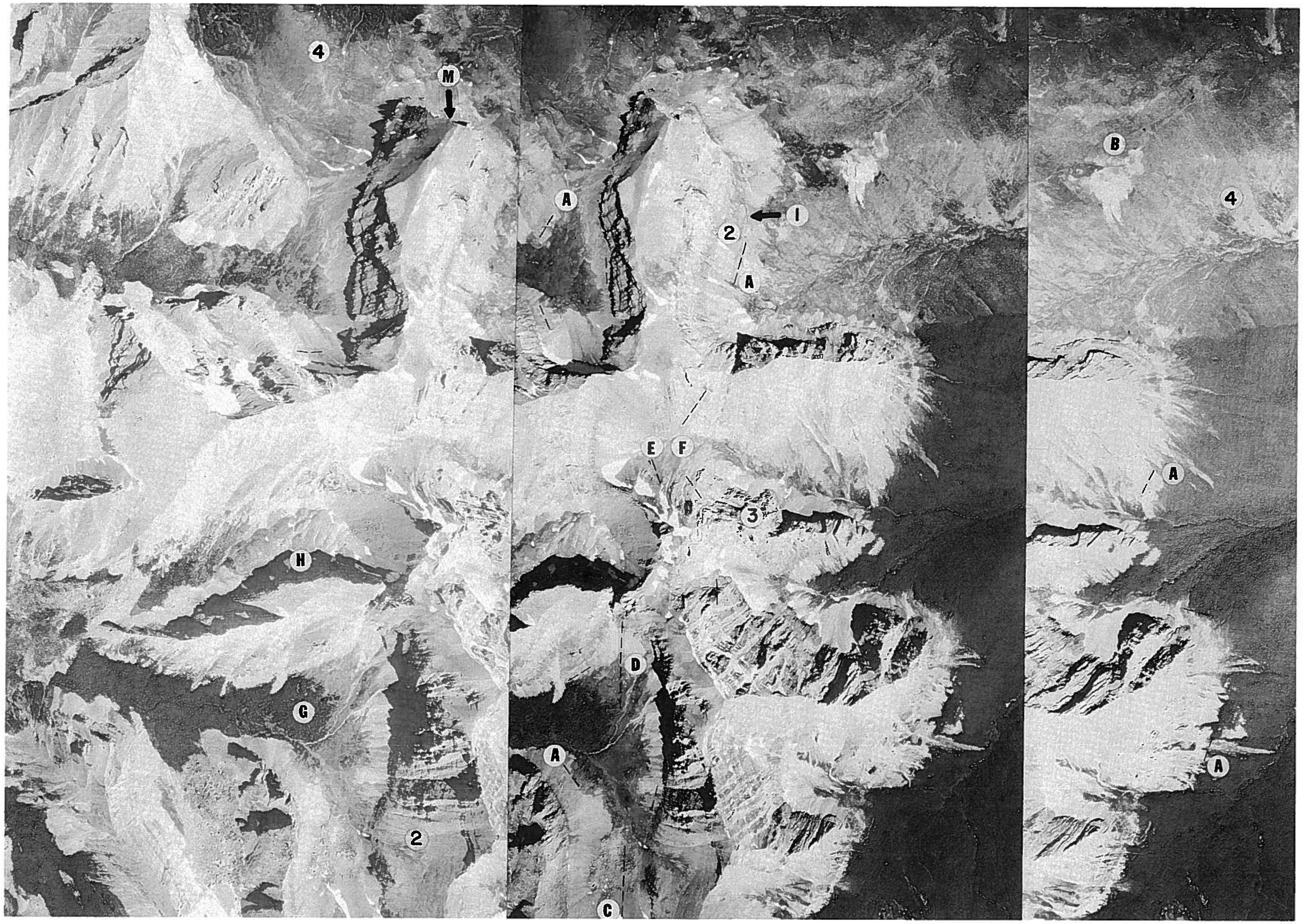
2. Banff formation. Mississippian. Thickness: 900 feet. Dark, calcareous siltstone and shales with interbedded limestone and dolomite bands. A non-resistant unit, poorly exposed on many mountain slopes.

3. Livingstone formation. Mississippian. Thickness: 1,100 feet. Grey, coarse-grained, crinoidal limestone with dolomite interbeds; light-weathering, cliff-forming.

4. Belly River formation. Cretaceous. Thickness: up to 3,500 feet. Dark, fine-grained sandstones and greenish-grey silty shales. These beds dip west at 20 to 30 degrees, and form a subdued, subrounded topography. Thin thrust slices of Cardium and Wapiabi beds are present in places between the Belly River strata and the Lewis thrust (Norris, 1958). These are not distinguishable on the photographs.

Reference

Norris, D. K. (1958): Beehive Mountain, Alberta and British Columbia; Geol. Surv. Can. Paper 58-5, 22 pages.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Klippe and Major Thrust Fault

Location: Tps. 8, 9, R. 5, W. 5th Mer.

Photograph Nos. 160-4917X: 2113-45, 46, 47

Crowsnest Mountain (A), elevation 9,138 feet, is an erosional remnant of Paleozoic limestone lying in the Crowsnest Pass two and one half miles east of the main Paleozoic mass of the High Rock Range. The High Rock Range and Crowsnest Mountain are both underlain by the Lewis fault (B, C) which thrusts Mississippian beds over Upper Cretaceous Belly River sandstones.

The trace of the thrust beneath Crowsnest Mountain is obscured by scree material, but its position (C, dashed lines) is readily located at the abrupt change in topographic expression of the rock units.

In front of the High Rock Range the Belly River beds dip steeply to the west (D). These strata may be overturned, but this cannot be determined from the photographs alone. To the west of Crowsnest Mountain sandstone ribs of the Belly River formation are visible, dipping to the east (E), and on the east side of the mountain the Belly River strata dip westward (F). On tracing these beds to the north, it is apparent that Crowsnest Mountain lies on the axis of a syncline in Cretaceous strata; the axis of the syncline (G), indicated by a dashed line, plunges to the south. The beds on the west of the synclinal axis (G) are steep-dipping, and are probably folded into an acute anticline, the axis of which lies in the vicinity of the valley at H.

The Belly River strata grade downward through passage beds into the underlying Wapiabi shale. The dendritic, well-incised drainage pattern developed in the northeast corner of the photograph (J) is suggestive of the topographic expression of the Wapiabi beds.

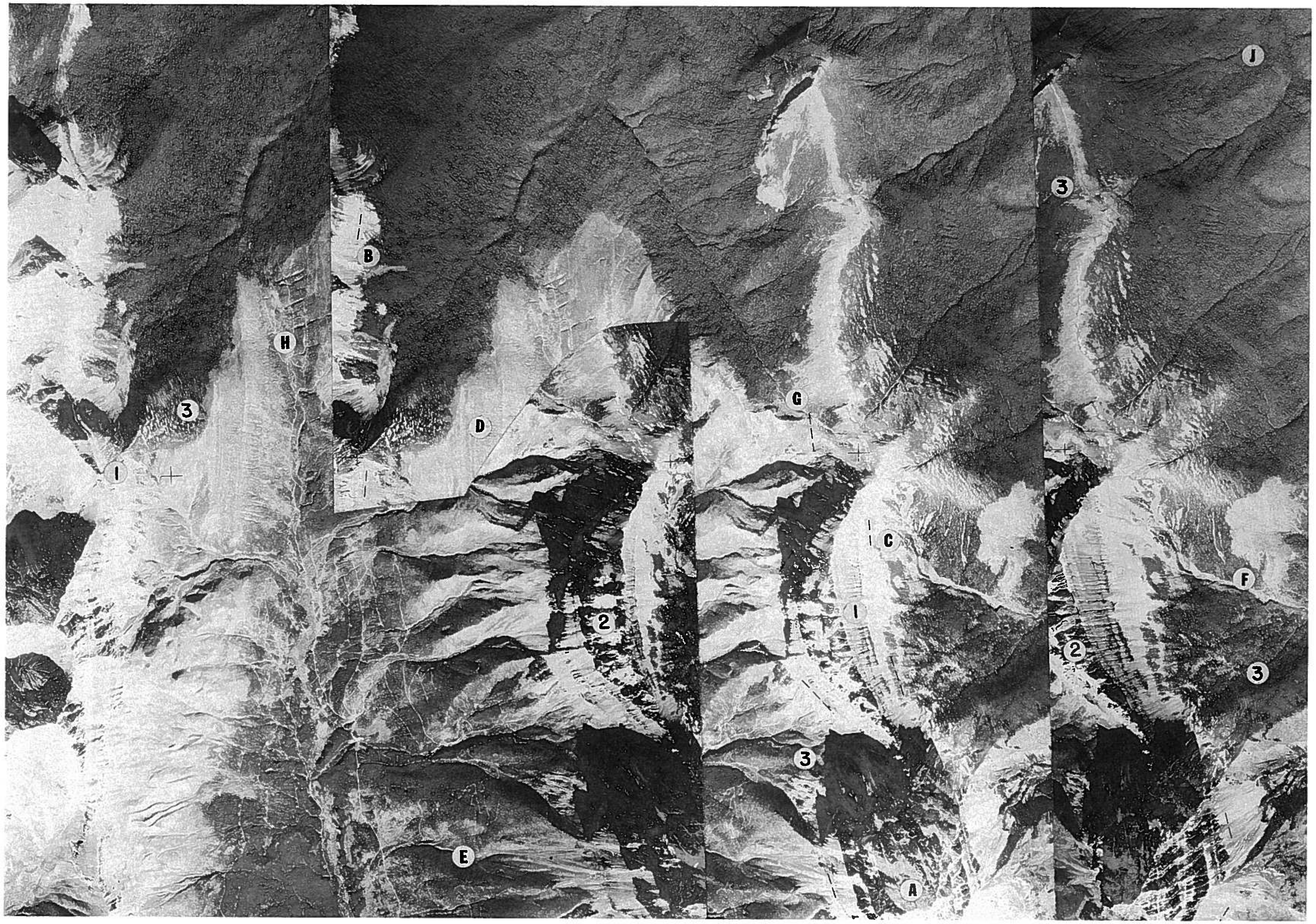
1. Banff formation. Mississippian. Thickness: 1,000 feet. Only the upper part of the Banff formation is present. Dark-grey calcareous siltstones, mudstones, impure limestones; chert nodules and stringers. Dark-weathering, medium tone, in general non-resistant to erosion.

2. Rundle group. Mississippian. Thickness: 2,000 feet. The lower part of the group comprises the Livingstone formation—1,200 feet of crinoidal limestones and dolomitic limestones. These beds form the main peak of Crowsnest Mountain proper, and the upper part of the main ridge of the mountain. The upper beds of the group are absent in the area illustrated.

3. Belly River formation. Upper Cretaceous. Thickness: up to 2,500 feet. Light-grey sandstones and intervening green shales make up this unit, which grades downward through silty and sandy shales into the underlying Wapiabi shale.

Reference

Mackay, B. R. (1949): Atlas, coal areas of Alberta, to accompany estimate of coal reserves prepared for the Royal Commission on Coal, 1949; Geol. Surv. Can., 52 maps, 50 pages.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Topographic Expression of Cambrian Strata

Erosional Land Forms of Mountain Glaciation

Location: Tp. 28, Rs. 14, 15, W. 5th Mer.

Photograph Nos. 160-5109X: 2424-9, 10, 11

The Main Ranges of the Rocky Mountains lie to the west of the Front Ranges, from which they are considered to be separated by the trace of the Castle Mountain thrust. These Ranges consist in large part of Lower Paleozoic strata which are predominantly massive, cliff-forming units.

Pulsatilla Mountain (A) (10,060 feet) is composed of Cambrian strata, and it lies on the east limb of the broad Castle Mountain syncline. The east side of the Mountain drops 2,500 feet to the valley of Johnson Creek, in which lies the Castle Mountain thrust (B). This is a low-angle fault which, where illustrated, thrusts Lower Cambrian strata onto Upper Devonian beds. This structural feature is probably a fault zone rather than a single fault, and the zone may extend from the dashed line at B to the east wall of the valley. Part of the trace of the Castle Mountain thrust is obscured by landslide debris (C) from the east wall of the valley.

Mount Avens (D) (9,700 feet) is an arête ridge and small horn; the west side is a dip slope on Cambrian dolomites, and the east coast of the Mountain is composed of cirque walls. These cirques (E, F, G) are developed in the Middle Cambrian Stephen formation (4). In cirque E two tarns are present; two tarns were present in cirque F, but the lower tarn is now completely filled by talus and the upper tarn partially. In cirque G one tarn is present, and in the lower part of the cirque underground drainage from the floor of the rock basin prohibits lake formation.

In each of cirques E, F, and G headward cirque extension has taken place towards the south. The tendency for snowfields and icefields to develop first on north- and northeast-facing slopes is apparent in these cirques, and also on the north and east flanks of Pulsatilla Mountain (A) where one cirque (H) contains a small glacier. A large lateral moraine is developed at the north end of cirque H. In the adjoining cirque to the west a small snowfield and glacier are present; at the glacier snout a small lake is dammed behind a terminal moraine.

South of Mount Pulsatilla two rock-basin lakes (J) are present on the floors of cirques; the arête dividing the two cirques has been largely removed by erosion. These cirques open to the west into a broad glacial trough, on the floor of which glacial steps (K, L, M) are present. In steps K and L the riegels are poorly developed, thus the rock-basin lake on step L is small, and on step K the riegel has been cut through by stream action and the lake drained. The riser of step L is well developed and a large rock-basin lake is developed on step M.

1. St. Piran quartzite. Lower Cambrian. Thickness: 1,500 feet. Predominantly quartzite, with slate and phyllite beds. In the northwest part of the plate this formation is largely covered. In the northeast part of the plate glacial action has accentuated the quartzite beds and has etched the intervening softer material.
2. Mount Whyte formation. Middle Cambrian. Thickness: 200 - 300 feet. Argillaceous limestone and calcareous shale or slate. This is a non-resistant unit, has a medium to dark tone and has been cut back by glacial action.
3. Cathedral formation. Middle Cambrian. Thickness: 1,000 feet. Light-grey bedded dolomite with some limestone. This unit is massive and cliff-forming. The formation dips steeply towards the west on the east side of the photographs, and is almost flat lying where it forms the floor of glacial step M.
4. Stephen formation. Middle Cambrian. Thickness: 450 feet. A shale-limestone sequence, non-resistant to erosion. Headwall extension of cirques E, F, and G has taken place in Stephen formation beds. A small fault may cut this unit across the floor of cirque G. Stephen strata on the west side of the photograph are covered by the talus at the base of the riser of step L. This well-developed riser is an indication of the lithological control of the glacial erosion.
5. Eldon formation. Middle Cambrian. Thickness: 1,000 feet. Light-colored reefoid dolomite, massive, cliff-forming. Upper part shows more bedding and grades upward into the Pika formation. The Eldon forms the headwalls of cirques E, F, and G, and the floor of the glacial trough and related cirques (J-K-L).
6. Pika formation. Middle Cambrian. Thickness: 500 feet. Medium- to dark-colored bedded dolomite and limestone. These beds are cliff-forming but are somewhat less resistant than the underlying massive Eldon strata.
7. Arctomys formation. Upper Cambrian. Thickness: 300 feet. Variegated thin-bedded shales with limestone and dolomite beds. Medium tone. These strata are present mainly on the west ridge of Pulsatilla Mountain. They may form the crest of the ridge in southwest part of the photgraph.

Reference

Deiss, C. C. (1939): Cambrian formations of southwestern Alberta and southeastern British Columbia; Bull. Geol. Soc. Am., Vol. 50, p. 951-1026.

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Topographic Expression of Cambrian Strata

Glacial Horn and Related Cirques

Location: SW ¼ Tp. 22, R. 12, W. 5th Mer.
SE ¼ Tp. 22, R. 13, W 5th Mer.

Photograph Nos. CA 114-23, 24

The mountains shown in these photographs comprise the Mount Assiniboine massif, on the British Columbia - Alberta boundary. The photographs are oblique aerial photographs taken by the Royal Canadian Air Force in 1924. The main photograph faces north-northeast, and was taken from the British Columbia side of the provincial boundary. This boundary crosses the peak of Mount Assiniboine (elevation 11,870 feet) and extends southwards along the ridge to Mount Aye (elevation 10,640 feet), the flat-topped peak in the right middle ground.

The southwest ridge of Mount Assiniboine leads to Mount Sturdee (A) (elevation 10,300 feet) in the left middle ground, the south arête of which separates Assiniboine Lake in the left foreground and Lunette Lake in the centre foreground. These are rock-basin lakes at the head of a glacial trough which leads towards the south. Extensive cirque development has taken place above this main glacial trough. At a lower level the cirque in the right foreground and that above Lunette Lake are developed. At an upper level several cirques have been developed, the headwalls of which, at least 1,500 feet high, abut against the main peak of Mount Assiniboine. Small glaciers present in these cirques do not reach the lower level cirques. Between the upper cirques are well-developed arête ridges which lead to the main glacial horn of Mount Assiniboine.

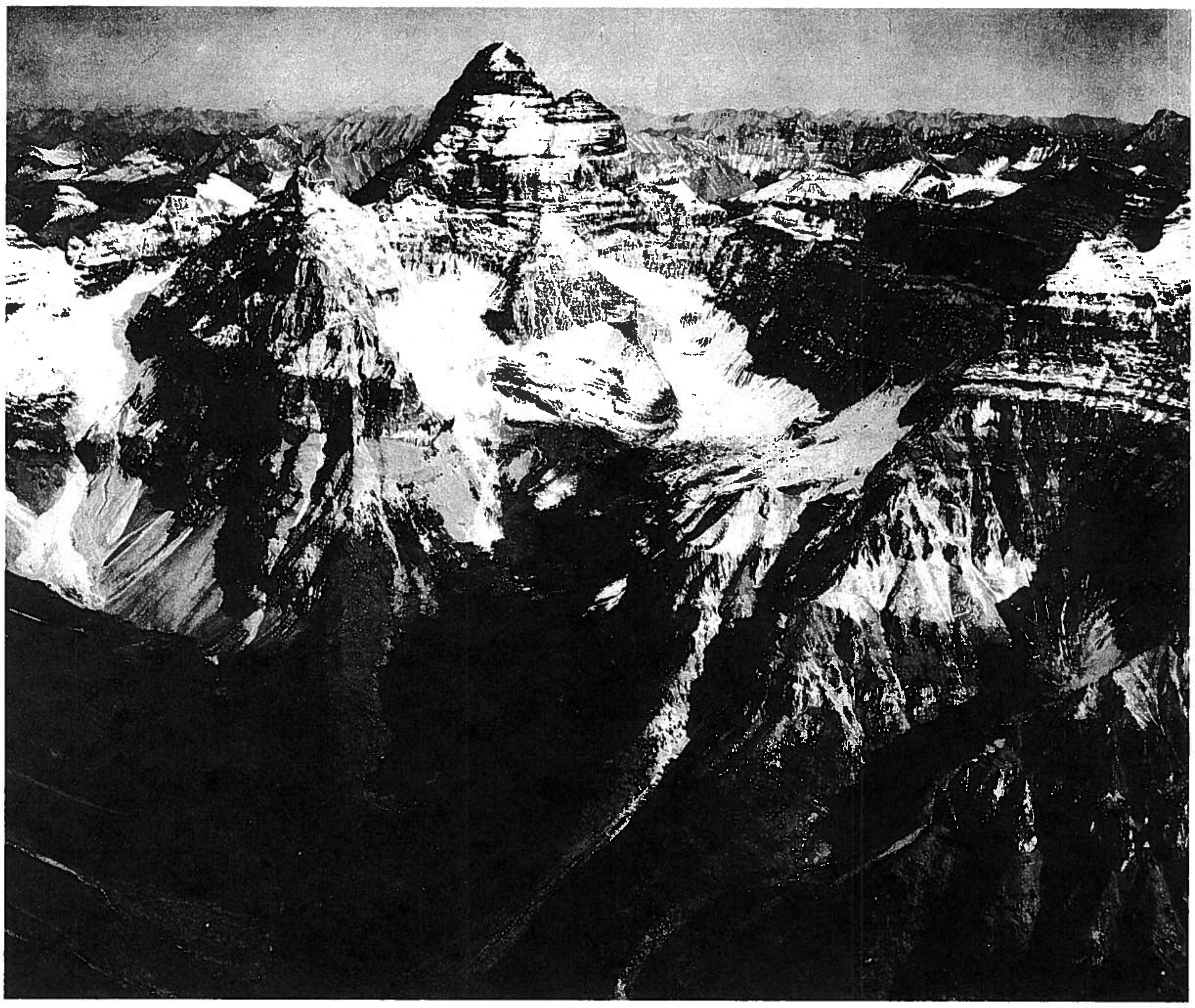
In the background the almost accordant summit line suggests the former presence of a peneplain or pediplain, now strongly dissected. A few mountain peaks stand above this surface as monadnocks or inselbergs—Mounts Assiniboine and Aylmer are two examples; Mount Aylmer (elevation 10,375 feet) is 33 miles away and appears on the horizon behind Mount Sturdee. These erosional remnants have been modified and are now glacial horns.

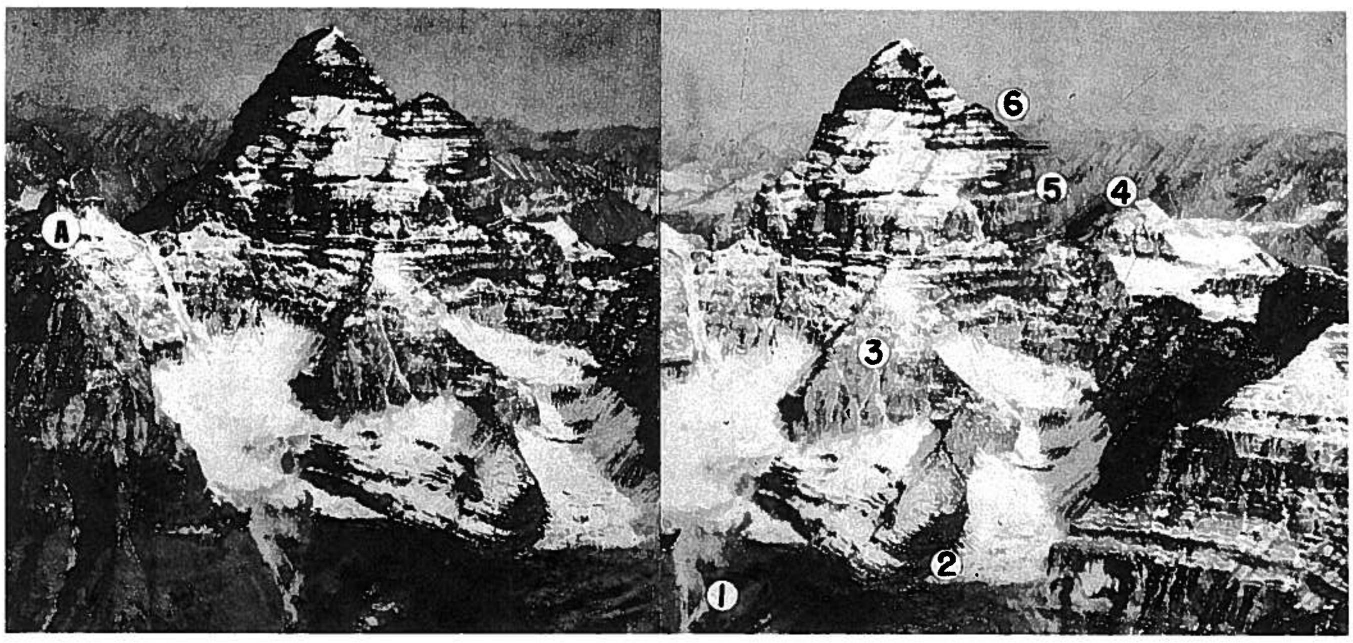
1. St. Piran formation. Lower Cambrian. Thickness: 1,200 feet. This is the Gog formation of Deiss (1940) and it consists of quartzites with shale interbeds. These strata form the lower, partially scree-covered cliffs and the headwalls of the lower cirques. The lower slopes and the valley floor are probably underlain by Precambrian Hector shales.
2. Mount Whyte formation. Middle Cambrian. Thickness: 500 feet. Naiset formation of Deiss (1940). Impure limestones and shales, thin-bedded, non-resistant to erosion. These beds form the first major notch in the mountain slopes, including much of the floors of the upper cirques.
3. Cathedral formation. Middle Cambrian. Thickness: 1,000 feet. Bedded limestone and dolomite. This unit forms the headwalls of the upper cirques and also much of the main arête ridges leading to the main peak.
4. Stephen formation. Middle Cambrian. Thickness: 250 feet. Limestone and shale. A non-resistant unit which forms the notch cut back to the base of the main peak of Mount Assiniboine. Probably also forms much of the peaks of Mounts Aye and Sturdee.
5. Eldon formation. Middle Cambrian. Thickness: 1,200 feet. Massive dolomite with some thin limestone beds. Forms the main cliffs on the lower part of Mount Assiniboine proper.
6. Arctomys and Ottertail formations. Upper Cambrian. Thickness: 1,300 feet. Limestone, dolomite and shale which form the main pyramid of Mount Assiniboine.

References

Deiss, C. C. (1940): Lower and Middle Cambrian stratigraphy of southwestern Alberta and southeastern British Columbia; Bull. Geol. Soc. Am., Vol. 51, p. 731-794.

North, F. K. and G. G. L. Henderson (1954): Summary of the geology of the southern Rocky Mountains of Canada; Alberta Soc. Petroleum Geol., Fourth Ann. Field Conf. Guide Book, p. 15-81.

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Alpine Glaciers

Location: Tps. 32, 33, R. 21, W. 5th Mer.

Photograph Nos. 160-5117X: 2427-5, 6, 7

Along the Continental Divide (the Alberta-British Columbia boundary) a number of small mountain icecaps exist. Most of these icecaps feed valley glaciers, such as the Freshfield Glacier, illustrated in these photographs. A small icecap feeds the Pangman Glacier, which joins the Freshfield Glacier from the west.

A glacial meltwater stream, Freshfield Brook, flows from the snout of the glacier and cuts through a former end-moraine of the glacier (A). The present snout of the glacier (B) has a small lake at its foot, in which a number of bergs are floating. The lack of cliffs at the snout suggests that most of the bergs originated through underwater calving. Between the lake and the tree-covered end moraine extensive outwash deposits cover the valley floor.

Abundant glacial debris covers much of the snout of the glacier, on which shear planes (C) are developed. These dirt-laden shear planes are present only on the lowest one mile of the glacier's surface; the apparent variation in dip on the shear planes is probably a function of downwasting.

Small lateral moraines (D) on the valley sides indicate that the glacier has recently downwasted. Lateral moraines (E), now being formed, are visible at several places.

The oblique gashes in the lateral moraines are due to material slumping into chevron crevasses (F) which are well developed in the middle portions of this glacier. In this part of the glacier the chevron crevasses intersect at approximately 90 degrees, as indicated by the dashed lines. Down valley, the angle between the two sets of crevasses decreases, and on the snout crevasses, etched out by water action, lie parallel to the valley walls.

Extensive crevassing (G) has developed in three parts of the glacier where the ice flows over steep slopes on rock steps (see plate of erosional land forms of mountain glaciation).

Between a glacier and the valley wall a depression—the fosse (H)—is commonly developed. In places the fosse may be filled with morainic material (E).

A series of light and dark bands (J), convex downslope, cross the central part of the Pangman Glacier. These are ogives (Forbes bands), which are formed below ice falls and possibly represent the amount of fall during a particular year.

Other surface features of the glacier are small meltwater streams which may disappear into moulins (K and northwest of C), and medial moraines such as those (L) developing from scree material from the northeast ridge of Mount Freshfield. The medial moraines of the west side of the Freshfield Glacier become lateral moraines (E) downglacier.

The continuity of lateral and end moraines is illustrated by moraines (M) of the Niverville Glacier.

Bergschrunds (N) of small glaciers are developed against cirque headwalls of Mounts Niverville and Garth.

NOTE: Adjustment of stereoscopy on the left side of the illustration is best made by using the avalanche material to the left of the letter J.


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160-5117X

Depositional Features of Valley Glaciers

Location: Tp. 39, R. 24, W. 5th Mer.

Photograph Nos. 160-5208X: 1473-8, 9, 10

In the Rocky Mountains, the meltwater streams fed by the mountain icecaps commonly flow in broad troughs formerly occupied by glaciers and which now contain several types of glacial deposits.

The Sunwapta River, flowing from south to north across the illustration, rises in the Columbia Icefield 10 miles to the south, and receives meltwater from several glaciers in that area.

A. Alluvial fans representing load dumped by tributary streams where they enter the main drainage channel. The two fans developed at the mouths of streams flowing into the Sunwapta River from the west extend over halfway across the valley floor. The sources of both of these western tributaries are in the icefield on the north flank of Diadem Peak.

B. Glacial outwash material being deposited on the valley floor has led to a braided development of Sunwapta River.

D-D. Lateral drainage channels which were developed along the margins of a valley glacier and mark successive positions of downwasting. Parts of the courses of these drainage channels are occupied by present tributary streams. These channels are deeply cut along this northeast side of the valley because the strike of the bedrock is parallel to the length of the valley.

H. Grizzly Creek flows in a hanging valley, tributary to the main glacial trough now occupied by the Sunwapta River.

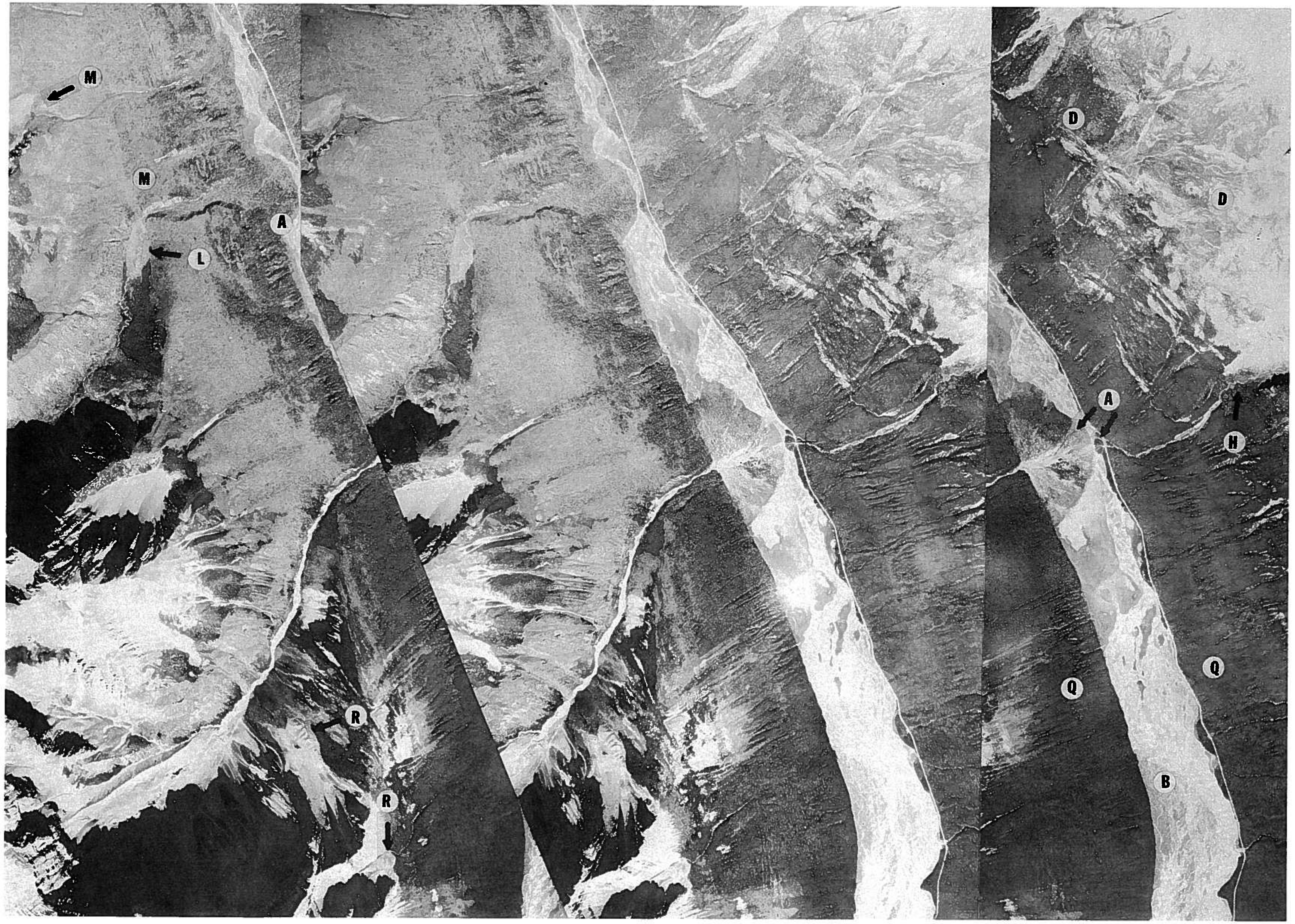
L. Bed of a former lake in a tributary valley. The tributary stream above the lake bed flows in a U-shaped valley, meanders across the lake bed and has cut a channel through a lateral moraine which formerly dammed the lake.

M-M. Lateral moraines extending northward along the valley sides. These were deposited by the main glacier occupying the Sunwapta River Valley. Two lateral moraines of a tributary glacier are present on the slope west of the lake bed (L). Where the lateral moraines cross the mouths of tributary valleys lake deposits are in most places present behind the moraines. These deposits have been eroded to various degrees.

Q. Unconsolidated glacial deposits of the valley train of the glacier. Note that these materials are very susceptible to gullying and to slumping.

R. Rock glaciers developing from the upper walls of small cirques. These features are common at the high elevations in the Rocky Mountains.

The difficulty inherent in roadbuilding in this type of terrain is apparent on this plate. The Banff-Jasper highway following the east bank of the Sunwapta River is susceptible to undercutting in time of flood and to blockage from above by avalanche, landslide and slump.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