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Aerial Photographic Interpretation of Precambrian Structures North of Lake Athabasca

by

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INTRODUCTION

GENERAL STATEMENT

The objective of this study has been to determine the type and pattern of structures found on the Precambrian Shield of northeastern Alberta.

The work was undertaken in order to make available more geological information on this part of the Canadian Shield which, on the basis of proven mineralization under similar geological conditions, should be of some interest with regard to its mineral potential. As mineralization in Shield materials is quite commonly associated with faulted structures, it is hoped that this study—which shows lineal and structural features of northeastern Alberta—will be an aid to prospecting. The study was made from some 700 aerial photographs on a scale of 1:40,000, obtained from the Technical Division, Alberta Department of Lands and Forests, Edmonton.

As a consequence of the large area studied, approximately 3,600 sq. miles, much of the finer structural detail has been omitted on the final map presentation. Generally, only the coarse physiographic features have been selected for inclusion except where it was thought that the smaller features were of significance in the interpretation and understanding of the larger structures.

Unfortunately, interpretations are not always clear and decisive. For example, the topographic expressions of faults of similar magnitude in massive granite,* granite interlensed with softer metasediments, and metasediments alone, are completely different. In general, massive granite exhibits a relatively high relief due to its weather-resisting qualities, and faults within the granite are evident as prominent fractures and scarps. On the other hand, faults in a belt of metasediments may have little or no topographic expression, and may be covered entirely by muskeg.

Some evaluation of this and other problems has been possible by means of a quick reconnaissance and spot check over the area, and some detailed geological mapping has been carried out in the Andrew Lake district.

ACKNOWLEDGMENTS

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TOPOGRAPHY AND VEGETATION

On the mosaic (plate I, in pocket) the distinctive topographic expressions of the Precambrian rocks to the east of the Slave River can be compared to those of the overlying Paleozoic strata on the west. Topo-

*Throughout this paper "granite" is used in the widest petrologic sense of the word and thus includes porphyritic granites, granitic porphyries, etc. It is mainly the structural significance of granites and granitic-type rocks that is under examination, rather than their petrologic or genetic relationships.

graphically the Precambrian is, in general, a gently undulating surface composed of low rounded hills. Locally the topography becomes quite rugged and is broken by deep ice-scoured valleys and fault scarps up to 200 feet high. The Precambrian is represented mainly by outcrop with a large number of glacially-scoured rock-basin lakes and small areas of muskeg. The outline of these lakes is largely controlled by a combination of structure and glacial erosion. Where structure is important in defining the shape of a lake and where granite gneiss is the lithologic rock type, the lakes will very often be bordered by steep slopes and cliffs.

The localization of rock-basin lakes, deep valleys, etc. has been dependent upon the erosion of shear zones and softer metasediments as contrasted with the more resistant granites and granite gneisses which form higher ground. Local relief is probably not greater than 300 feet, though there is a general increase of elevation from 699 feet above sea level at Lake Athabasca, to 1,367 feet in the northeast corner of the map area.

The Paleozoic rock surface is flat and consists almost entirely of a wide expanse of muskeg dotted with countless small open stretches of water. There are no large clearly defined lakes, but occasional navigable creeks can be found. Very slightly elevated rounded ridges are expressions of the underlying Paleozoic rocks, and broad glacial deposits are also present. Large portions of this area are covered by glacio-lacustrine deposits as evidenced by the numerous beach ridges found west of the Slave River.

The valleys on the Shield tend to be more heavily wooded than the intervening high ground, the latter often being completely bare of vegetation. The trees are predominantly evergreens (spruce and fir), but are commonly mixed with deciduous types (mainly poplar).

Scrubby muskeg occupies parts of the lower ground and also isolated patches on the undulating higher ground. Open, watery muskeg is not uncommon but is largely confined to the lower sections of land. Muskeg is often developed behind high sand ridges such as those on the north shore of Lake Athabasca.

ACCESSIBILITY

Alternative routes are available which give direct access to different points in this area. Fort McMurray, some 350 miles north of Edmonton, may be reached either by Canadian Pacific Air Lines commercial flight, or by the Northern Alberta Railways. From Fort McMurray tugs and barges of Northern Transportation operate downstream on the Athabasca River to Fort Chipewyan, across Lake Athabasca to Uranium City, and also down the Slave River to Fort Fitzgerald. McMurray Air Service Ltd. can be chartered out of Fort McMurray to any point within the area.

Canadian Pacific Air Lines have a regular commercial flight from Edmonton to Fort Smith where charter flights may be made.

A daily commercial Canadian Pacific Air Lines flight operates between Edmonton and Uranium City, Saskatchewan, and again charter flights can be made with either McMurray Air Service Ltd. or Saskatchewan Government Airways.

Travel within the area is rather difficult since few of the creeks are sufficiently large to be used as canoe routes, and a number of portages would be necessary on any traverse through this region. Traverse in an east-west direction is particularly arduous as the "grain" of the country is north-south.

GENERAL GEOLOGICAL CONSIDERATIONS

It has long been recognized by geologists that metalliferous vein deposits usually bear some genetic and spatial relationships to faults. Faults and fault zones are generally more easily eroded than the neighboring bedrock. Hence, their topographic expressions are represented by elongated depressions. Such depressions or "linears" can be readily recognized on air photographs. One disadvantage of using topographic depressions as a means of identifying faults, however, is that all linears are not the direct expression of bedrock faulting. On the other hand, some regional fault systems, that occupy depressions as much as several miles wide and a hundred miles or more in length with little outcrop, are quite difficult to recognize on the ground but can be readily identified on air photographs by their linear pattern. One further advantage of aerial photographic analysis is that it affords a method of obtaining an over-all picture of the major structures for a large area in a short space of time and at little expense.

From a mineral prospecting point of view aerial photographic studies provide a means of eliminating a great deal of uninteresting ground and at the same time indicate the most promising areas. It should be kept in mind, however, that direct observation of specific cases of shearing, brecciation, mylonization, etc. can only be achieved by field examination.

On the accompanying structural map, it has been possible to subdivide the topographic linears with some degree of certainty on the following basis:

1. Fault, major—regional
2. Fault, minor
3. Fault or strong fracture
4. Fracture, minor—mainly tensional
5. Fracture, minor—irregularly oriented
6. Fracture, minor—closely spaced
7. Shear zone
8. Folded sedimentary or metamorphic structure
9. Surficial features, sand dunes and glacial fluting

In certain areas where linear features of complex and varying orientation have been found, it has been necessary to simplify the interpretation by presenting only those features which have the greatest structural significance.

Structural features can be gradational in character and a certain amount of overlapping of symbols has been used to convey this possibility. As far as possible the more prominent fault scarps within a major shear zone have been delineated by a wavy line. However, in cases where a shear zone passes from an area of high relief to one of low (e.g. muskeg), the fault scarp demarcation has been discontinued. The implication, of course, is not that the particular fault structure is discontinued but that the topographic expression is discontinued at the point where the line of delineation terminates.

As is very often observed in the field, two geological features may parallel each other, one being influenced by the other. In this map area it is common to find metamorphic rock "grain" (shown largely as long and often curved lines), paralleling a fracture system (usually shown by short dashes).

Minor fractures of differing types and origins have been grouped together for simplicity and convenience. They are represented by short dashes and, as there is some uncertainty regarding their geological interpretation, an attempt has been made to subdivide them into three broad classes (Nos. 5, 6 and 7) based on their physical expressions. Many of these minor fractures are related to the major stresses, possibly as tension features. The radial system of fractures on the large central fold to the east of Leland Lake is one example. A great number of the minor fractures are controlled also by the metamorphic and sedimentary foliation which supplied a ready plane of weakness for the relief of shearing stress.

STRUCTURAL FEATURES OF THE MAP AREA

The Precambrian of the northeast corner of Alberta forms the westerly margin of the Athabasca province of the Canadian Shield (Wilson, 1949). In Alberta there is a complexity of structural directions oriented about a general northerly strike, as contrasted to a regional northeast trend over the major part of the Athabasca province. To the north, the Alberta northerly trend gradually swings into the recognized northeast regional structure of the Athabasca province.

The major fault structure in this area is the Allan fault,* a fault of regional dimensions (more than 100 miles in length), and of a northerly orientation. This fault system has been traced for sixty miles within the map area and can be extended northwards into the Northwest Territories for at least an additional one hundred and fifty miles.

The Allan fault system is expressed as a shear zone varying in width from one to five miles, in which the more prominent planes of movement have given rise to fault scarps. In Alberta from the Northwest Territories boundary to the north shore of Lake Athabasca it is clearly marked by a discontinuous series of linear lakes and creeks. Charles Lake, which extends for some thirty miles along the fault zone and which is never more than two miles wide throughout its entire length, is an outstanding example of a structurally controlled lake. Where the Allan fault meets the northern shoreline of Lake Athabasca at Fidler and Lapworth Points, one of the most highly embayed sections of the whole shoreline is to be found. This irregular shoreline is a natural consequence of the erosion of an extensively crushed and sheared belt of rock.

In the northern section of the area the Allan fault consists of a number of fairly well-defined individual parallel fault lines with intervening fault blocks. South of Woodman Lake this characteristic gradually changes to that of a wider shear zone containing a great number of smaller shears. This could imply a change of lithology along the strike of the fault. In the northern section, belts of metasediments within granite and granite gneiss provide the structurally weak zones along which the major planes of movement are confined, whereas in the southern section a more physically uniform granite or granite gneiss rock is present.

The series of strong northeasterly faults (thick dashes) on the north shore of Lake Athabasca northeast of Fort Chipewyan (the Lake Athabasca tectonic trend) may be regarded at least in part as a horsetail or

*This fault has been so named in recognition of the untiring efforts of the late Dr. John A. Allan in establishing the groundwork of our present-day understanding of the geology in Western Canada, and especially within this Province. Two other faults mentioned later in this paper are likewise named in honor of two Western Canadian pioneer geologists, Dr. Percival S. Warren and the late Dr. Ralph L. Rutherford.

drag effect of the Allan fault. There is a distinct braiding as these two fault zones approach each other. To the east of the Allan fault the north shore of Lake Athabasca has been recessed farther to the north, and it is difficult to assess whether or not there is continuation of the northeast-trending faults. They may or may not have been truncated and offset by later movement of the Allan fault.

Considering the structure of the north shore of Lake Athabasca in Saskatchewan, it would seem that the major Lake Athabasca tectonic trend is farther south and offshore in Alberta. Projected to the southwest, the tectonic trend passes through the combined deltas of the Peace and Athabasca Rivers.

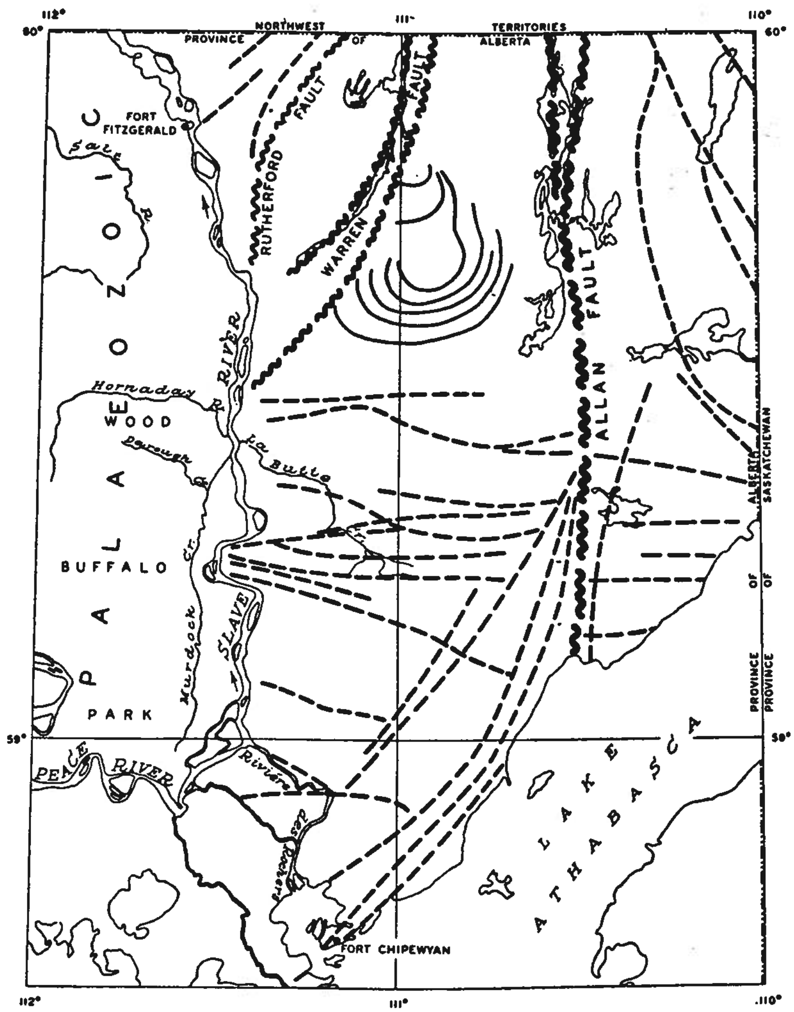
The second major fault structure of the map area is the Warren fault. Clearly delineated by the Leland Lakes system, this fault can be followed for thirty miles in Alberta. To the north, it can be further traced for tens of miles. This fault is probably a part of the general north-trending Allan fault system which is associated with the wide belt of Nonacho and post-Nonacho sediments, passing through the Taltson and Nonacho Lakes area in the Northwest Territories.

To the south, the Warren fault swings southwesterly and passes under the Paleozoic strata on the west side of the Slave River. The fault zone has two fairly distinct planes of maximum shearing as represented in the schematic diagram, figure 1. These individual shear planes are not more than two miles wide at any point. The fault separates a large folded structure to the east from a less definite isoclinal fold on the west. As in the case of the Allan fault, the Warren fault is also more clearly defined in the northern, rather than the southern section. Examination of the air photographs on the marginal Paleozoic beds indicates that this structure may be reflected in these overlying beds. Both post-Paleozoic movement and differential compaction on an irregular basement topography are possible factors in establishing this feature.

The series of northeasterly-trending faults on the west side of the Warren fault is in all probability related to the same movement which formed the Warren fault and should be regarded as branching from this fault. The most prominent of these, the Rutherford fault, swings to a southerly orientation when followed to the south, and passes along strike into the course of the Slave River.

The most westerly of the two shears of the Warren fault zone crosses the Slave River in the vicinity of Stony Islands. This is the probable point of intersection of the Warren and Rutherford faults. On the larger island to the west of Stony Islands the Paleozoic-Precambrian unconformity was observed. Here the Precambrian rocks are highly altered and faulted. Closely spaced sheeting is developed in a north 0 to 25 degrees east direction, which is in accordance with the Warren and Rutherford fault lineations. Weathering has resulted in a gossan in this fault zone. A reverse fault at north 40 degrees east was also noted, and this feature is aligned with the southwest extension of the Warren fault. A short distance to the south on the southern tip of the large island opposite Hay Camp, Precambrian outcrop was observed. Very strong steep shears at north 0 to 6 degrees east cross the outcrop and indicate a continuation of the Rutherford fault.

Belts of folded rocks exist between the three named fault zones, though the one to the west is not too clearly defined. These folded structures are considered to be metamorphic and/or sedimentary in origin. The one to the east appears to be a metamorphic feature within a granite gneiss lithology.



PRINCIPAL STRUCTURAL ELEMENTS OF THE PRECAMBRIAN NORTH OF LAKE ATHABASCA

SCALE IN MILES
4 0 4 8 12 16

LEGEND

Faults, major
Faults, minor
Sedimentary and Metamorphic Structures

DRAWN BY THE RESEARCH COUNCIL OF ALBERTA EDMONTON, ALTA.

FIG. 1

Considering these major fault and fold features together, it seems possible that the faults are shears which have replaced the limbs of the folds under excessive shearing stress. Relative movement has brought south the two folds mentioned, whilst the intervening complementary fold has been moved north and out of the map area.

A system of north-northwest-trending faults can be traced through the eastern portion of the map area. They form part of a regional system of faults extending for at least sixty miles north of the Alberta-Northwest Territories boundary.

Ground examination of two of these faults in the Andrew Lake district shows that upon division and horsetailing they develop into a multi-branched fault zone up to two and one-half miles in width.

Mylonization, brecciation and quartz veins are abundant on individual shears, and in one case a quartz-filled breccia was found to be continuous over a width of five hundred feet.

A concentration of strong east-trending faults is found in the central part of the map area which presents a distinctly different pattern from any other in the region. The principal topographic expression of these faults is found on the west side of the Allan fault, and though less marked, they can be traced in a more subdued topography on the east side.

The general linear shapes of the lakes in the Wylie-Bryant Lakes area are reflections of the east-trending faults, and the intersections of the latter with the Lake Athabasca shoreline have produced a characteristic indented outline.

Considering the whole area, these contrasting fracture patterns of the north and south sections are most probably the consequence of a change of lithologic character. To the north are alternating major belts of metasediments and associated granite gneisses, whilst in the southern section massive granites and granite gneisses are generally prevalent.

SPECIFIC AREAS

Slave River

The course of the Slave River is largely controlled by the bedrock structures of the Precambrian Shield. It is no coincidence that the Slave River generally follows the line of overlap of the Paleozoic rocks onto the Precambrian basement* which is believed to be a structurally controlled contact.

The sixteen-mile section of rapids which extends to the northwest from Fort Fitzgerald and involves a drop of one hundred and nine feet is related to the northeastern-trending faults which cross the river.

The general northerly trend of the upper part of the Slave River coincides with a major structural break of the same orientation, the Rutherford fault.

At Caribou Islands, where the Paleozoic unconformity is very well displayed at a number of points, the principal shear direction in the Precambrian is north-trending, parallel to the Slave River. From a consideration of the position of the unconformities and the attitude of the shears, it seems that at least the two eastern channels of the Slave River occupy north-trending faults.

Two other shear directions are present in the Precambrian at Caribou Islands, one at north 40 degrees east and another at north 35 degrees west. The former is probably related to the northeast fault system more prominently developed a short distance to the north, and it has no effect on the course of the river here. The north 35 degrees west shear is more important, however, for the Slave River is diverted along this northwesterly path from the north-trending Rutherford fault. With

*In detail there are a number of local exceptions and it can be seen from the aerial photographs that the river has deviated from its present course in recent times. These changes, however, are minor adjustments to surface condition variations and the over-all picture is consistent with the general statement made above.

only a few deviations, this northerly trend controls the course of the Slave River along the remainder of the upstream section.

Farther to the south, a continuation of the north-trending Rutherford shear can be seen in the Precambrian exposed on the southwestern tip of the large island to the west of Stony Islands. Again, strong north-trending shears cross the Precambrian exposed on the southern tip of the large island opposite Hay Camp.

Just south of Hay Camp the Slave River widens as the west bank swings abruptly to the west. A cliff section of Paleozoic strata is exposed here with a well-developed breccia on the east end. The swing of the river is no doubt related to its intersection with the Warren fault, but the breccia could have been developed either in connection with the Rutherford or Warren faults, or as a collapse feature resulting from solution of underlying evaporites.

At the mouth of La Butte Creek the Slave River swings to a direction of north 30 degrees west. At this point the river is split into two channels by an elongated island which parallels the banks and is composed of Precambrian rock. Shears in the Precambrian parallel the general alignment of the island and have an orientation of north 30 to 35 degrees west; these are minor shears related to the major east-trending faults to the south. A system of northwest-trending shears branches from the east-trending faults and generally parallels the lower course of La Butte Creek. These shears tend to swing more northwesterly (north 30 degrees west) as they are traced farther to the northwest and parallel the course of the river as described above.

The spectacular U-shaped course of the Slave River to the south is a particularly good demonstration of the structural control of its channel. The abrupt displacement of the river channel four miles to the west follows as a consequence of its intersection with the prominent east-trending faults. Not only is there a structural reason for the disruption of an orderly north-trending channel, but erosion-resistant granites are also brought in along these faults.

From the commencement of the Slave River (the junction of the Peace River and the Rivière des Rochers) to Lake Athabasca there is a departure from the general northerly trend of the channel. The channel divides and becomes controlled by a west-northwest and a northeast fault system. Along with the lower part of the Peace River, these various channels form a rectangular drainage pattern.

Considering the Slave River as a whole, there is evidence in the map area to indicate that it follows a major, though interrupted, north-trending fault system, the Rutherford fault. It is further suggested that this same fault system has a westerly down-faulted side which has preserved the overlying Paleozoic rocks. The present extent of Paleozoic cover has been largely controlled by this fault contact, and is roughly coincident with the Slave River channel.

It should be noted that to the south of Lake Athabasca the lower course of the Athabasca River for 120 miles downstream from Fort McMurray is aligned with the Slave River. Perhaps some significance is associated with this feature in terms of the suggested Slave River structure.

North Shore of Lake Athabasca

The general northeast orientation of the shoreline is parallel to the Lake Athabasca tectonic trend. The principal expression of this structure on shore can be seen in the section from Fidler Point to Fort Chipewyan. Here a wide zone of strong northeast faults has sliced up an area predominantly underlain by granites and granite gneisses. As the Allan fault is approached, there is a tendency for some of the northeast faults to swing more northerly and into the Allan fault. Considering a possible change of lithology and a northward recession of the shoreline on the east side of the Allan fault, there still does not appear to be a continuation of these northeast structures to the east. However, as previously mentioned, the principal expression of the Lake Athabasca tectonic trend lies farther south offshore.

Extensive embayments have been made into the shoreline at Fidler Point as the wide shear zone of the Allan fault enters the lake. Smaller, though still marked, embayments have been made in the vicinity of Greywillow Point, at the Saskatchewan boundary, as principally east-trending fault structures intersect the shoreline.

Secondary features have been superimposed on the shoreline, such as the building up of a sand spit at Sand Point, the silting up of bays as at Greywillow Point, and the building up of long sections of sand ridges which smooth out the smaller irregularities of the shoreline.

Goldschmidt Lake

Goldschmidt Lake, situated to the southwest of Mercredi Lake, is in the midst of an area of tight folds presumed to be an expression of the lithology of the Tazin metasediment type, i.e., biotite schists with lenses of feldspathic pegmatites, granites and amphibolites, grading to porphyritic biotite schists and porphyritic biotite granites. The arcuate structure of Goldschmidt Lake is a folded, sheared and mylonized porphyritic granite, with siliceous feldspathized mylonite and minor chloritic schist. This is believed to be a typical expression of a highly folded and sheared belt of Tazin metasediments, the softer biotite schist components having been scooped out to leave a rock-basin lake. Only the more resistant associated granitic and siliceous materials remain as directly observable topographic features, providing information on the structure and lithology.

Andrew Lake

This lake, typical of many in the area, owes its origin to the glacial erosion of soft Tazin metasediments. Its shape and size are closely related to the structure and lithology of the local rocks. The lithology and rock foliation have a general northerly trend in this region. With the exception of the recent surficial features, the lake outline is paralleled by structure, even in some of the unexpected finer details. Arcuate shorelines and wide open bays commonly have a structural parallelism in the adjacent rocks on shore. In many instances a few feet of biotite schist on the foreshore provide evidence for the origin of the lake before giving way to a sequence of granite gneisses or porphyries farther inland. Peninsulas, headlands, promontories and islands are invariably largely composed of the more resistant lithologic rock types, commonly associated with the Tazin metasediments; these are pegmatites, biotite granites and granite gneisses (locally garnetiferous), and porphyritic siliceous biotite schists. Narrow fingered bays and abrupt straight-line terminations as at the northeast end of the lake, which are not related to the normal changes of lithology, can be attributed to fault zones. Two such prominent north-northwest faults are indicated on the map in the Andrew Lake area.

Tulip Lake

On first examination of its intricate shape one is tempted to assume that Tulip Lake is situated on the crest of a tight isoclinal fold. This interpretation is further enhanced by the location of Tulip Lake between the inward curving Rutherford and Warren faults. Further, it is believed that a fold does exist at the meeting of the "inside" components of these two structures in the hook of Dog River as it leaves Myers Lake.

However, it is believed that the intriguing shape of this lake (which suggests the crest of a fold) is a consequence of the combination of a north-northeast foliation and an east-trending system of fractures. The north-northeast foliation represents the limbs of an isoclinal fold, the crest of which is developed several miles to the southwest. Rock types are porphyritic biotite granite, partly chloritized, and silicified garnetiferous biotite granite. Considerable shearing and mylonization are evident in detail, and fracture cleavage is associated locally with these features.

Arch Lake

An apparent isoclinal fold within the U-shape of Arch Lake is more probably an open S-shaped structure. Approximately north-trending foliation from the north meets the northwest edge of the lake, curves eastward around the lake, and continues on its northerly trend along the east limb of the lake. Most likely low-angle cross fractures are responsible for the development of the west limb of Arch Lake. The bedrock lithology is porphyritic granite with chlorite and blue quartz, and metasediments of siliceous chloritic schist with amphibolite.

Barrow Lake

In the massive granites and granite gneisses of this area, there is almost complete outcrop. Consequently, the expression of fault and fracture patterns is such that aerial photographic interpretation of structure is considerably facilitated. A prominent northeast-trending fault scarp lies on the east shore of Barrow Lake. It is apparently offset about one-third of a mile to the east, against a strong east-trending fault at the south end of the lake. After continuation for a mile farther to the southwest, another strong east-trending fault truncates the fault. There is no obvious similar feature with which to correlate on the opposite side of this fault to suggest what the offset might be.

Disappointment Lake

In the vicinity of Disappointment Lake a series of isoclinal folds is developed which on the basis of experience in this area might be expected to be a belt of Tazin-type metasediments, having the association, at least in part, of a biotite schist lithology. However, examination of this feature revealed a granite gneiss which tends to grade to a porphyritic granite. Chlorite is developed locally and is especially apparent in chloritized amphibolite. A little mylonite and chloritized-feldspathized rock is associated in shear zones within the granite gneiss.

One of the series of strong east-trending faults trends through Disappointment Lake. The disrupted pattern of folded granite gneiss on each side of this fault clearly indicates a significant fault displacement. In order to accommodate the geometry of these folds, a minimum displacement of the southern block about half of a mile to the east is required. Alternative displacements could arrive at the same configuration. However, consideration of the shape of the isoclinal folds involved and the structural information on a similar feature at Barrow Lake suggests the above as a likely solution.

SPECIAL FEATURES

Dark Belt between Ryan Lake and Fishery Bay

An area of about seventeen by four miles extending in an easterly direction between Ryan Lake and Fishery Bay shows up as a dense black mass on the aerial photographs. It is a low watery muskeg with a dense vegetation cover. Misleading lines of trees and vegetation patterns commonly developed in these areas should be disregarded as their geological significance is doubtful.

Topographic Features on a Large Glaciated Fold

A large fold some fifteen miles across in an easterly direction occupies the centre of the northern section of the map area. In examining the topographic character along this fold, it is apparent that there are some variations which might be attributed to such factors as lithologic changes, different types of minor structure, or a gradational change in the intensity of a shear. Ice has traversed this fold in a general direction from the northeast. As a consequence of the varying angles of the fold ridges presented to the ice advance, differing erosional forms have been produced. Where the angle between ridge and ice flow has been large, the ridges have been rounded and flattened. The resultant topography has been smoothed and "softened" as the relief has been reduced. On the other hand, where the ridges have been parallel or sub-parallel to the direction of ice flow, erosion has scoured the valleys and the ridges have been rounded. Relief has been accentuated through a greater contrast between valley bottoms and ridge tops, and the topography considerably "sharpened" and made irregular. (A similar effect has been produced on a larger scale in the northeast-trending features to the northeast of Fort Chipewyan.) These characteristics are very well exhibited as a gradational change along the fold as one follows the fold from the east to the south side.

Localization of Lakes and Valleys

These features are largely dependent on the preferential erosion of planes of structural weakness or softer bands of rock. There has been little influence on the distribution or development of the general topographic features by glacial activity in this area. The topography has been developed in accordance with the underlying bedrock structures. The main function of ice action has been to modify the already established features, such as deepening or widening a valley or rounding a hill or ridge. There has been little change in the pre- and post-glacial topographic features of this part of the Shield. Ice erosion has generally lowered the land surface by the removal of a probable thick layer of soil and has also deepened linears where conditions were suitable. Local over-deepening of a depression and morainic damming have been the major factors in the formation of the glacial lakes.

Groups of lakes can commonly be seen to form geometric patterns which are in harmony with the structure in different areas. In the absence of geological information, the reverse procedure can be applied where the analysis of the distribution of lakes and creeks can yield some very useful structural data. The significance of the Charles-Alexander-Woodman series of lakes serves to emphasize the importance of the Allan fault structure. In a similar manner, the Leland-Myers Lakes position the Warren fault structure. Lakes in these two major features are primarily structural in origin, though there is added lithologic significance. The linears through Ryan Lake, represented as projecting arms and valleys, are taken to be indicative of fracture systems, without any lithological implications.

Within the distance of six miles between Andrew and Bayonet Lakes there is a series of at least seven parallel north-northeast trending lake- and creek-occupied linears. These linears are basically controlled by alternating bands of resistant and less-resistant rocks. The same less-resistant rocks which have been readily eroded have also provided the planes of weakness along which relief of stress has taken place. In this case then, there has also been some structural assistance to an already favorable lithology in establishing a belt of rock suitable for valley development. This orderly series of linears comes to an abrupt end as they are cut off to the south by a strong north-northwest fault which passes through the south end of Andrew Lake. To the south of this fault, between Andrew Lake and Bayonet Lake, in contrast to the north side, the lakes show no orderly pattern but appear disorganized and irregularly shaped. This leads to the suggestion that there is an important movement on the north-northwest fault which is responsible for a change of lithology from the north to the south side. In attempting to determine the movement of this fault the most likely solution seems to be a lateral displacement of the south side, at least four miles to the northwest. Here, a similar series of linears, though not so perfectly developed, trends south-southwest in the area to the west of Bayonet Lake. The linears pass through Ashton Lake to the south and become involved in a major north-trending shear system. Bayonet Lake itself is a combination of lithologic control on the southern north-northeast trending section, but on meeting the north-northwest fault the northern extension of the lake bends around so as to conform and occupy the fault depression. Thus, this lake owes its origin to both lithology and structure, each being a controlling influence in different parts of the lake.

The Development of Lake Shapes

The two factors primarily responsible for the determination of the shapes of lakes are structure and glaciation. Included with structure is lithology, as the latter's influence alone is difficult to evaluate and is often inseparable from structural factors.

Analysis of the shapes of lakes reveals that a large percentage are structurally controlled features, both in general outline and in minor detail. Some striking examples amongst the larger lakes are Charles, Leland, Ryan, Ashton, Tulip and Andrew Lakes.

The development of an irregular and highly embayed shoreline due to glaciation has been confined to points where suitably spaced and oriented weak zones in the bedrock are evident. This particular erosive effect of ice is largely expressed on the south and west lake shores, as the ice advance in this area was generally from the northeast though it swung to an easterly direction in some sections and locally even trended east-southeast. In any locality the predominant alignment of embayments tends to be parallel or sub-parallel to the direction of glaciation. Examples are in the Roderick, Peters, Wylie, Burstall, and Cockscomb Lakes.

Though by no means a general rule, the east shoreline of the rock-basin lakes tends to be bevelled down while the west one is steep, as pointed out by Hicks (1932). The ice advancing from the east or northeast has gouged out the softer metasediment bands, but has left a smoothed cliff or prominence on meeting a resistant band which has formed the west shore. Protected behind this resistant bluff, the surface dips gently away. A steeply dipping contact would promote the development of an abrupt westerly shoreline, and it might also be expected that glacial erosion would result in a deeper gouging out of the lake depression along the westerly margins.

Amongst the larger lakes Colin Lake has an atypical general outline. It forms a broad 'V', to which little but the broadest geological significance can be attached. The lake, lying in a broad, flat, lowland area, is somewhat unique for this region. Due to the relative paucity of outcrop in this locality and to a certain amount of recent infilling, there is little detailed structural or topographic control of most of the present lake outline. However, some of the shoreline features, particularly on the east and south sides, can be related to adjacent structural characters in the bedrock.

On many of the larger lakes which have a broad east-trending expanse, sandy shores and shoals are commonly developed on the easterly margins. These features can be attributed to predominant westerly or northwesterly winds which have developed currents in the lakes and carried sand which has been piled up on those shores. Outstanding examples are Cornwall, Colin, Burstall, and Andrew Lakes.

Pseudo-fold Feature

In the area two and one-half to five miles north of Greywillow Point a feature is developed which could be mistaken for a large-scale fold. It appears, on first examination, that there are fold limbs oriented north-northwest and east-northeast with a concave curvature to the southwest. However, it is reasonably clear that this apparent fold is actually a combination of two independent features: one, a north-northwest "grain" or foliation of the rocks, and two, east-northeast glacial fluting. Other examples of this type of feature can be found in the map area, but the one described above is particularly deceptive due to the irregular and spotty nature of the outcrop pattern.

STRUCTURE AND TOPOGRAPHY AS A CLUE TO LITHOLOGY

Structural and topographic features can be utilized to provide some information on the lithologic types of rock to be found in the map area. Broad groups of rocks can be distinguished on the basis of their differing physical properties, namely, their various structural expressions in response to applied stress and their varying abilities to resist weathering.

Due to the bedded character of sediments and foliated or banded character of metamorphic rocks, these are the most likely rock types to be associated with a contorted or folded area. These characters serve to differentiate between the typically banded and layered metamorphic granite gneiss and biotite schist terrain, and the more massive granitic areas. On this part of the Precambrian Shield metasediments (metamorphic rocks still retaining some sedimentary features) largely consist of biotite siliceous schists with some impure quartzite which grade into porphyritic biotite schist. Compared to the granite gneiss type of metamorphic rock, these metasediments are generally far softer and have been readily eroded glacially to form a great number of the rock-basin lakes. Many examples of folded granite gneiss terrain can be seen in the Mercredi-Arch-Leland Lakes area, and an outstanding illustration is to be found in the vicinity of Disappointment Lake. These areas have an outcrop expression which is characteristic of a granite gneiss lithology. Little remains of the biotite schist type lithology in outcrop, due to its relative ease of erosion. As a result, only small portions of larger bands can be noted close to lake basins. Examples can be seen on the margins of the northern section of Charles Lake.

A positive and clear separation of the biotite schist and granite gneiss rocks may not always be possible, due to gradations and interlensing relationships. However, there is usually sufficient predominance of one or other of the rock types to permit a reasonable generalization.

Resistance to weathering and especially to glacial erosion has proved to be an important factor in distinguishing some rock types. "Etching" of the landscape by glacial activity is unfortunately controlled by both structural and lithological factors, though the latter may be by far the most important. A separation and evaluation of these two interplaying factors cannot always be satisfactorily resolved. As mentioned in the earlier section on "The development of lake shapes", not only are the biotite schist belts most susceptible to glacial erosion, but they have also provided the structurally weak zones along which fault movements have been localized.

Lithologic control in the development of the lake and valley pattern, especially in the northern part of the map area, is very evident. Even in the detail of lake shapes the close resemblance between shore outline and adjacent lithologic structure is quite apparent. Parts of the shoreline features of Andrew Lake are notable in this respect.

As remarked under "Localization of lakes and valleys", the north-northeast-trending system of lakes and valleys on the northwest side of Andrew Lake is an excellent example of lithologic control of lake and valley development. The valleys terminate abruptly to the south where they meet the prominent northwest fault. The valley development pattern on the south side of the fault is completely different, reflecting a change in lithology, and strongly suggests a significant displacement along this fault.

Positive topographic features are provided by the relatively resistant weathering rock types, the granite gneisses and granites in particular. A wide area of granite gneiss is enclosed within the broad fold structure located in the north central part of the map area. A notable block of massive granite is present in the general area of Ryan, Barrow and Darwin Lakes, and it projects to the west where the Slave River makes a large U-detour around it. Typical of a granitic bedrock, almost complete outcrop is attained in an "upland" region where every detail in a fault-fracture system is plainly evident.

The fault-scarp deep-valley features so characteristically developed in the northern part of the Allan fault are typical of fault zones where interlensed granites, pegmatites and porphyries occur in biotite schist. As would be anticipated, the rock contacts are highly sheared, and the more resistant rock types form the ridges and hills while the softer schists have been scooped out.

GLACIATION

During the Pleistocene epoch this whole area was subjected to the effects of continental glaciation. Though glacial deposits are locally important, they represent only a minor phase of the glacial activity, the main expression of which has been through extensive and commonly intensive erosion. The main effect has been to remove any soils which have developed and to scour off the bedrock surfaces, leaving the surfaces almost as they are found at the present time.

Glacial characteristics have been superimposed on the bedrock geology with varying effects and results. In areas where the bedrock structures were more or less parallel to the direction of ice advance, the glacial erosion has served to emphasize the topographic expression of those features. However, where the structure of the bedrock lies at a high angle to the direction of ice advance, modification has resulted in the opposite effect of diminution of the appropriate topographic features. In some areas this glacial modification has progressed to the point where the bedrock structures have been completely or at least effectively obliterated.* Such areas are generally flat, consisting of a uniform rock type, and are commonly low-lying. They can be found in the northeast and east margins of the area where the bedrock features are subdued amongst the superimposed glacial lakes, valleys and grooves.

The lakes owe their origin to the activities of glacial erosion and damming. The direct relationships between lake development, lake shape, bedrock structure, and glaciation have received detailed treatment previously in this paper and warrant no further mention.

The regions of relatively high relief show the effects of glacial erosion and present either a fresh, clean rock surface or one that is lichen-covered. Evidence of glaciation is present as highly polished and striated surfaces, common erratics, and small and giant grooves. On the majority of outcrops it is possible to find several of these characteristic features.

In the lowland regions highly polished, striated, and grooved rock surfaces are commonly found bordering the rock-basin lakes. Other signs of glaciation are expressed as irregular sandy eskers and as expanses of sandy plains up to several square miles in area. Examples of these features can be found in the Andrew Lake area and in the general vicinity of Colin Lake.

The orientation of glacial fluting† measured from aerial photographs compares closely with that of glacial striae measured in the field.‡ The pattern of one is duplicated by the other. On the east margin the flutings strike north 60 degrees east conforming to a general direction of ice advance from the northeast. Along the northern section of the map area the flutings remain in a general east-northeast direction. In the south, however, the flutings swing in an almost symmetrical arch which is concave to the north. Towards the west, the east-northeast orientation of the striae on the east margin becomes east and finally east-southeast in the neighborhood of the Slave River.

SAND DUNES

The development of sand dunes is mainly confined to the central and east-central parts of the map area. They represent a mixture of complex and simple forms, and it is rather difficult to assign them to definite dune types. The most common variety is a longitudinal sand ridge which is

*One example is that of the pseudo-fold previously mentioned in the text.

†H. T. U. Smith (1948) in his study of giant grooves in northwest Canada has been able to affirm that these distinctive grooves indicate the true direction of ice flowage. The dimensions of these grooves fall in the size range of those quoted by Smith, which were up to one hundred feet in depth, three hundred feet in width, and could extend for several miles. Smith was able to eliminate the likelihood of either structural or topographic control of the giant grooves, and they were attributed to intensive local erosive capacity of the ice. Further, Smith suggests that "Lithology was a selective factor, making for varying degrees of susceptibility to the erosive process, and thus permitting easy incision in some places while inhibiting effective carving elsewhere."

‡Due to topographic irregularities over an area, a uniform advance of the ice is prevented, and some variation of striae orientation can be expected, and in fact is observed.

oriented in a northwesterly direction. Longitudinal sand ridges are commonly formed behind bedrock obstacles in the face of northwesterly winds. They can be seen to be grouped in pairs; these pairs of ridges are joined at their northwest extremities and diverge at a small angle of two or three degrees. At some distance (on the order of a quarter of a mile) from the apex, they may gently curve so as to form parallel linears. The maximum development observed was a length of two and one-half miles.

Complex forms result when a number of these acute angled V-type longitudinal ridges are overlapped and interfere with each other, as is quite commonly found.

On the Alberta-Saskatchewan boundary, and more particularly in Saskatchewan, a sigmoidal-shaped type of dune is quite common. The distance between the limbs of a dune is up to one-eighth of a mile, and the maximum length of a limb at least half a mile.

The material used in forming these sand dune features is undoubtedly of glacial and recent origin.

SUMMARY

Glacial erosion has effectively scoured the land surface, allowing the topographic features to be greatly influenced by the underlying bedrock structures and lithology. Aerial photographic analysis has thus been facilitated, and a reasonably continuous structural and in part lithological picture has been formulated.

Lithologic character has been a principal factor in determining the type and pattern of structural relief resulting from the imposed stresses.

The structural features displayed in the area under examination are more than likely a consequence of the interplay of several periods of major deformation. Classification and separation of these features as related to a sequence of events is a difficult problem. Further complications are introduced from the belief that several periods of movement have operated along the same planes of weakness.

The principal structures in the area are the northeasterly Lake Athabasca tectonic trend and the north-trending Allan and related faults. Movement on these two fault systems probably both antedate and postdate other fault movements in the area. Major folding in the area was most likely immediately pre-Allan fault movement, and related to the same stress system.

Though no direct evidence can be quoted, it is suggested that the two systems of north-northwest-trending and east faults are later than the time of initiation of the two major fault systems. Movement on the east-trending faults was one of the final stress adjustments. This is demonstrated by offset features in both the Barrow and Disappointment Lakes areas.

Post-Paleozoic movements can be illustrated on some of the faults in the vicinity of the Paleozoic overlap. Shears in the Precambrian basement can be seen to extend into the overlying Paleozoic formation at Caribou Islands. A lineation in the Paleozoic strata to the west of the Slave River is on alignment with the Warren fault. A hint is provided of the probable southwest continuation of this fault in the basement to the west of the Slave River and also into the overlying Paleozoic formations. Post-Paleozoic movement with a westerly downthrow on the suggested general weak zone which contains the Rutherford fault and the Slave

River would conveniently result in the preservation of the Paleozoic formations west of the Slave River.

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Aerial photographs obtained from Technical Division, Department of Lands and Forests, Alberta.

Mosaic assembled by J.D.Godfrey, Research Council of Alberta, 1957. Published, 1958.

AERIAL PHOTOGRAPHIC MOSAIC OF PRECAMBRIAN SHIELD NORTH OF LAKE ATHABASCA, ALBERTA

PLATE I.

Scale 1 Inch to 8 Miles

8 0 8 16 Miles

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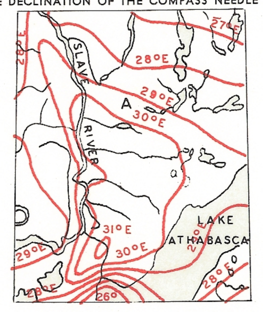
GEOLOGICAL DIVISION.

Map to accompany bulletin. 1

Published in 1958.

THE DECLINATION OF THE COMPASS NEEDLE 1954.



LEGEND

STRUCTURAL FEATURES

Fault, major - regional

Fault, minor

Fault or strong fracture

Fracture, minor - mainly tension

Fracture, minor - irregular orientation

Fracture, minor - closely spaced

Shear zone

Folded sedimentary or metamorphic structures

SURFICIAL FEATURES

Sand dunes

Glacial flutings

Aerial photographic interpretation by J. D. Godfrey.

MAP 25

AERIAL PHOTOGRAPHIC INTERPRETATION OF PRECAMBRIAN STRUCTURES NORTH OF LAKE ATHABASCA

ALBERTA

WEST OF FOURTH MERIDIAN

Scale 1 Inch to 2 Miles.

2 1 0 2 4 6 8 10

REFERENCE

Secondary road

Boundary, provincial

Boundary, park, game preservation

Boundary, township, surveyed

Boundary, township, unsurveyed

Boundary, settlement

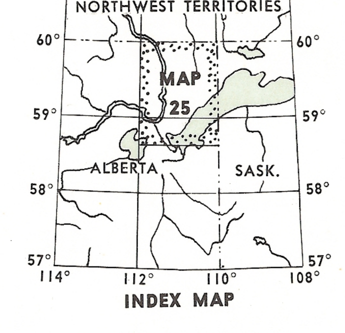
Lake and stream, permanent

Lake and stream, intermittent

Rapids

Cartography taken from Department of Lands and Forests, Alberta, Aerial Survey Sheets No. 74M. and north half of 74L—1951.

Magnetic declination taken from Canada Sheets No. 74M. and north half of 74L, National Topographic Series, Department of Mines and Technical Surveys, Canada—1955.



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