THE SOLOMON SANDSTONE
IN THE
FOOTHILLS OF CENTRAL ALBERTA

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A Thesis presented to
The Faculty of Graduate Studies
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In partial fulfillment
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Master of Science

by

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ABSTRACT

The Solomon sandstone extends through Alberta from about the Ghost River in the south to more than one hundred miles north of the Athabasca River. The area described in this dissertation is bounded on the south by the Bow River and on the north by the Athabasca River.

The Solomon sandstone is considered to be a member of the Wapiabi formation. It conformably overlies the Wapiabi shales, and is overlain by shales of the Transition Zone, the uppermost strata of the Wapiabi formation. It is the most recent marine deposit of Cretaceous age in this area.

This sandstone is a resistant-weathering unit with shale above and below it. It outcrops primarily along rivers and forms high ridges as well. At its western extremity it is composed of a medium to thick-bedded fine-grained greenish-grey to rusty-brown sandstone with a one or two-foot bed of chert-pebble conglomerate marking its upper limit. The lower contact is gradational, sometimes being indicated by a very glauconitic zone. The sandstone is composed of angular to

sub-angular grains of quartz and chert with minor amounts of feldspar. The cementing material is predominantly siliceous;but calcareous and argillaceous matrices are not uncommon. Near the eastern edge of the area the sandstone grades into a thin-bedded coarse-grained siltstone which becomes very impure and dark grey to black in color.

The Solomon was derived from previously-existing rocks exposed in the Cordilleran Geanticline to the west. The detritus was deposited under neritic to shallow bathyal conditions on a mildly unstable to unstable shelf area. The rate of subsidence of the area of deposition was not sufficient to offset the effect of the rapid influx of sediments from the rising landmass to the west, and the transition from marine to non-marine conditions took place at the close of Solomon time.

ERRATA:

Page 6. History of Previous Work

G. S. Malloch (Geol. Survey Canada, Mem. 9, 1911) Named the Blackstone, Bighorn and Wapiabi Formations.

Page 9. First Paragraph Should Read

The boundary between the sediments of Upper and Lower Cretaceous age in the Alberta foothills is placed at the base of the Fish Scale zone in the lowermost part of the Blackstone formations. The contact between the Blackstone formations and the underlying Mountain Park formation is marked by a chert pebble conglomerate bed, which has also been considered to be the Upper-Lower Cretaceous contact.

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INTRODUCTION

Nature of Problem

During the summer field season of 1955, the author acted as a geological assistant on a surface stratigraphic party for Canadian Gulf Oil Company. The area covered during the season included the foothills belt of central Alberta, bounded on the north by the Athabasca River and on the south by the Bow River (Fig. 1).

Early in the season the author expressed his desire for a thesis subject related to a phase of the field work. It was suggested by John Patton, Party Chief, that a regional stratigraphic and petrological examination of the Solomon sandstone would constitute an interesting and challenging problem for a Master of Science Thesis. Permission to use this subject was granted by Dr. A. D. Baillie of Canadian Gulf Oil Company.

At each outcrop of the Solomon sandstone examined by the author, samples were collected for the company and for this study. From Solomon outcrops measured by other members of the surface party, representative hand specimens were taken at regular intervals for the author. In addition to this, many of the samples collected from these outcrops

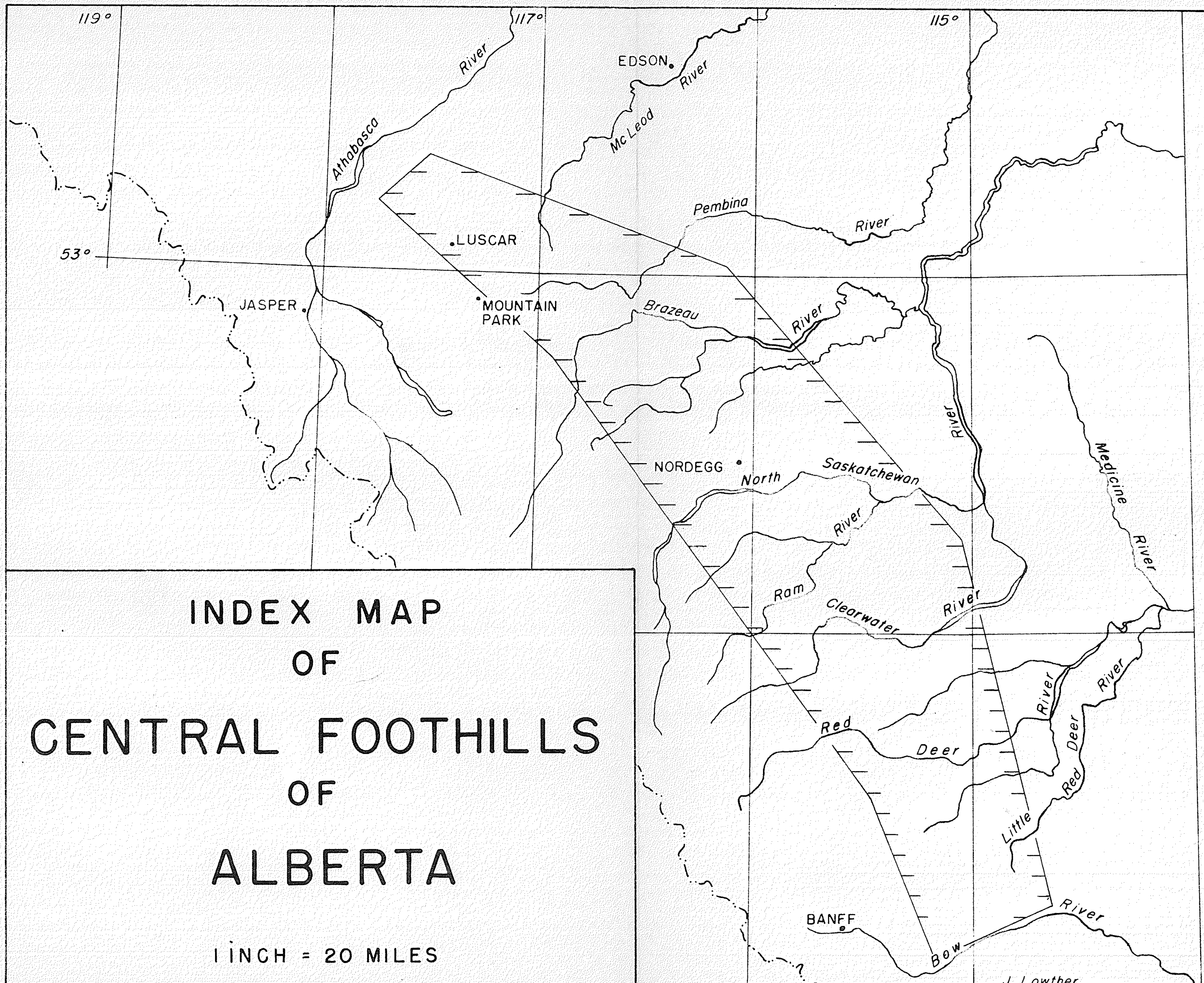

119°
117°
115°
53°
EDSON
McLeod River
Athabasca River
Pembina River
LUSCAR
JASPER
MOUNTAIN PARK
Brazeau River
NORDEGG
North Saskatchewan River
River
Medicine River
Ram River
Clearwater River
Red Deer River
Red Deer River
Little Red Deer River
BANFF
Bow River
J. Lowther
INDEX MAP
OF
CENTRAL FOOTHILLS
OF
ALBERTA
1 INCH = 20 MILES

FIGURE 1

for company purposes were loaned to the author for examination during the latter part of the 1955 - 1956 academic term, and all field data compiled were made available for his study.

The purpose of the study is to attempt to determine the source, depositional environment, areal distribution and lithologic variations of the Solomon, and to outline briefly its economic possibilities as a producer or reservoir of petroleum and natural gas.

Several different laboratory techniques were employed in the investigation of the different properties and characteristics of this sandstone; physical disaggregation; mechanical sieving; grain analysis; heavy mineral separation and identification; preparation, staining and examination of thin sections; and an extensive search of the literature, constitute the work, the results and concomitant interpretations of which are presented in this paper. Maps, figures and photographs are included to illustrate salient features.

The research and analysis was carried out at the Department of Geology of The University of Manitoba during the 1955 - 1956 academic term.

Method of Field Operation

The investigation of this large area during only one field season was made possible by use of a Bell 47-G helicopter. This machine moved men and equipment effectively to elevations ranging up to 7200 feet above sea level. Its range is restricted to approximately 40 miles and for this reason three base camps were established; one at Cadomin, one south of Nordegg on the North Saskatchewan River, and one at the Red Deer Ranger Station, equally spaced to allow the most economical coverage of the area.

As the operation began from each base camp, reconnaissance was flown over the surrounding area to locate the best exposures of the different Mesozoic formations. When a suitable rock exposure was discovered, two men and supplies were landed as nearby as possible to make camp, measure, sample and describe the rock. By this means three parties of two men each were at work at all times. In the southern part of the area, outcrops are less common and of smaller stratigraphic range. This allowed the two-man parties to be flown daily to and from the outcrop. Also in the southern part of the area there are more roads and some outcrops are readily accessible by vehicle.

History of Previous Work

The study of the regional geology of this large area was first attempted in the early 1920's. R. B. MacKay (1925) of the Geological Survey of Canada and R. L. Rutherford (1925, 1926, 1927, 1928) of the Research Council of Alberta conducted extensive mapping projects in the area about this time. Later contributors were Sanderson (1939) for the Brazeau Area, Erdman (1946) for the Cripple Creek Area, and Hume (1936) for the West Half of Wildcat Hills.

At the time of the early exploration the Solomon sandstone had not been named or described as a separate rock unit. Rutherford included the beds now known as the Solomon in the Saunders (Brazeau) formation. MacKay, on the other hand, divided the Wapiabi formation into a lower unit (black marine shale, sandy shale and ironstone) and an upper unit (black marine shale, sandstone, ironstone, and chert-pebble conglomerate). The latter unit includes the strata now known as the Solomon sandstone.

The name "Solomon" was first used in private reports by geologists working in the foothills of the Athabasca River area. It did not appear in published literature until 1945 when it was introduced by A. H. Lang in his report on the Brule and Entrance Map Areas of Alberta.

Acknowledgements

The author wishes to thank J. W. Patton, Party Chief for Canadian Gulf Oil Company, for suggesting the problem and enabling him to examine many of the Solomon outcrops of the area; and Dr. A. D. Baillie, also of

Canadian Gulf Oil Company, for permission to use the Solomon sandstone as a thesis subject and for making available the many samples and field notes for the author's examination.

To Professor E. I. Leith of the Department of Geology of The University of Manitoba, under whose supervision and guidance the research and analysis of the problem were carried out, the author expresses his sincere gratitude for much helpful advice and constructive criticism, especially that rendered during the final preparation of this paper.

Many thanks are also extended to the members of the staff of the Department of Geology of The University of Manitoba for their co-operation and suggestions.

CHAPTER II

UPPER CRETACEOUS STRATIGRAPHY OF CENTRAL ALBERTA FOOTHILLS

General Statement

The boundary between the sediments of Upper and Lower Cretaceous age in the Alberta foothills is placed just above the top of the Mountain Park formation which is the youngest formation of the Blairmore group of Lower Cretaceous age. It is often marked by a thin (6") bed of chert-pebble conglomerate which immediately overlies the uppermost beds of the Mountain Park formation.

The sediments of the early Upper Cretaceous in this area are marine shales with the Bighorn sandstone in the middle of the sequence. The lower shale unit is the Lower Alberta shale (Blackstone formation) and the upper shale unit is the Upper Alberta shale (Wapiabi formation). Above the Wapiabi formation is 5000 feet of sandstone with minor shale and conglomerate. This is the Brazeau formation and is, for the most part, non-marine. Correlation of the Upper Cretaceous formations of the area with the Upper Cretaceous of nearby areas is illustrated in Table 1.

Blackstone Formation

The base of the Blackstone formation is usually marked by a bed of chert-pebble conglomerate. Above this is almost entirely black fissile to thin-bedded somewhat silty and sandy dark grey to brown-weathering marine shale with scattered interbedded hard grey, yellow-weathering concretionary beds of ironstone up to one and one-half feet thick. In the upper part of the formation there are a few thin beds of hard grey, fine-grained sandstone. The uppermost 20 feet are composed of regularly interbedded sandstone and shale. The upper and lower contacts of the formation are well defined. The Blackstone is approximately 1500 feet thick.

Bighorn Formation

The Bighorn formation conformably overlies the Blackstone formation. It consists of hard, slabby, light grey quartzitic sandstone, softer grey sandstone and silty shale, and minor amounts of grey and black shale and conglomerate. There may be two or possibly three bands of sandstone separated by intervals of silty shale. The uppermost sandstone member is almost always capped by a bed of red-weathering chert-pebble conglomerate. The sandstone is light brownish-grey, fine to medium-grained, non-calcareous quartzitic and non-porous. There are several fossil zones within the formation. The most prominent is usually within five feet of the upper contact and contains fairly well preserved specimens of *Cardium* sp. The Bighorn formation is very resistant to weathering and is a prominent ridge-former.

The upper contact with the overlying Wapiabi shales is clear-cut and abrupt. The thickness of the Bighorn formation ranges from 250 to 325 feet in this area.

Wapiabi Formation

The Wapiabi formation is conformable with the underlying Bighorn formation. It consists essentially of soft friable black silty marine shale and thin (1") siltstone beds. The shale weathers dark grey to rusty brown. Beds of concretions and concretionary beds of rusty-weathering, dark grey ironstone are common. The formation is approximately 1800 feet thick. Fossil remains found in the Wapiabi are: Scaphites ventricosus, Inoceramus sp., Oxytoma nebrascensis, and Baculites sp.

Solomon Sandstone

The Solomon sandstone conformably overlies the Wapiabi shales and often the contact between the two is gradational (Plage I, Fig. 2; Plate II, Fig. 2). It is included by some workers in the Wapiabi formation, but others regard it as the basal phase of the Brazeau (Belly River) formation. It is composed of a fine-grained, light greenish-grey, calcareous in part, hard, compact sandstone which weathers greyish-green to yellowish-brown. The sandstone grades laterally into a siltstone to the east and to the south. The lower contact is commonly marked by a prominent glauconitic zone, and the upper contact is traceable by a resistant-weathering one-to two-foot bed of conglomerate containing chert pebbles ranging in diameter from one-quarter to one and one-half inches (Plate III, No's. 1 and 2; Plate IV, No's. 1 and 2) surrounded by a sandy matrix. The sandstone is marine and yields well preserved fossils in certain localities. The most common of these is Oxytoma sp.

The Solomon ranges in thickness from less than 100 feet to more than 250 feet within the study area. North of the Athabasca River the average thickness is 100 feet. To the south and east the sandstone becomes very argillaceous and shaly and is more difficult to recognize as a unit. In most outcrops examined, the upper contact with the overlying Transition Zone is quite abrupt (Plate I, No. 3; Plate II, No. 1).

Transition Zone

The Transition Zone has been regarded by several workers to be part of the Brazeau formation. It is currently considered to be part of the Wapiabi formation (Stott, 1956). It conformably overlies the Solomon sandstone and indicates the change from marine to non-marine conditions of sedimentation. The lower portion is dark grey shale, probably marine, but this grades upward into soft, medium to coarse-grained, dark green sandstone with interbedded grey shale and silty shale which often contains plant fragments. Some beds near the base of this zone are so poorly indurated that they appear to be almost a loose sand. The Transition Zone ranges in thickness from 60 to 120 feet. The upper contact is gradational over 10 to 20 feet.

Brazeau Formation

The Brazeau formation conformably overlies the Transition Zone. It consists of medium to coarse-grained light greenish-grey thick-bedded sandstones interbedded with shale and chert-pebble conglomerate. The diameter of pebbles in the Brazeau conglomerates ranges from one-half inch to four inches, but is one inch on the average. The conglomerates are more common near the base of the formation. The shales are dark grey to greenish-grey and commonly silty. Plant remains are visible throughout the entire formation. The Brazeau formation is approximately 5000 feet thick.

Period		Southern Foothills	Southern Plains	Central & Northern Foothills	Western Peace River Plain
Cretaceous	Upper Cretaceous				
		Bearpaw		Brazeau	Wapiti
		Belly River			
			Pakowki	Transition Zone	Transition Zone
		Highwood Ss.	Milk River Ss.	Solomon Ss.	Chinook Ss.
		Cardium	Cardium	Bighorn	Cardium
		Blackstone	Colorado Group	Blackstone	
					Dunvegan
					Upper Shaftsbury
		Fish Scales	Fish Scales		
	Lower Cretaceous	Mountain Park		Mountain Park	Lower Shaftsbury
			Blairmore Group		

TABLE I

UPPER CRETACEOUS CORRELATION CHART

CHAPTER III

CORRELATION OF THE SOLOMON SANDSTONE

Gleddie (1949) suggests that the Solomon is correlative with each of the following units: Chinook sandstone of the western Peace River Plains area, the Highwood sandstone of the southern foothills of Alberta, and the upper member of the Milk River formation of the plains region of southern Alberta.

Correlation of the Solomon with sandstone members in adjacent areas is based entirely upon lithologic character and stratigraphic position. No conclusive palaeontologic evidence supports the correlation. To explain this correlation, a general lithologic description of each correlative unit will be given along with the relation of the unit to the overlying and underlying strata of the area.

Western Peace River Plains

Chinook sandstone: The Chinook sandstone is a member of the Wapiabi formation. The name was introduced by Gleddie (1949) for a sequence of sandstone and sandy shale containing glauconite, which outcrops in the western Peace River plains area. At the type section, located along Fish Creek, one-half mile above the junction with Wapiti River, the Chinook sandstone is 75 feet thick. However, it thins considerably to the east and only 10 feet ~~are~~ is present on the Smoky River.

The top of the Chinook member is 90 to 100 feet below the basal sandstone beds of the Wapiti formation which overlies the Wapiabi in this area. The interval of the Wapiabi which overlies the Chinook is transitional in nature to the overlying Wapiti formation.

Southern Alberta Foothills

Highwood sandstone: The Highwood sandstone is a member of the Upper Alberta shale of Upper Cretaceous age. The type section outcrops along Highwood River in Sec. 30, Tp. 18, R. 2, W 5thM. The Highwood is described in the Lexicon of Geologic Names in Alberta as "... buff weathering, fine, hard sandstone and sandy shales containing ironstone concretions and generally overlain by a thin band of conglomerate composed of vari-colored chert and quartzite pebbles". It ranges in thickness from zero to 100 feet and is developed more or less locally in the south-central Alberta foothills area. It is most common in the area of Turner Valley.

The Highwood lies conformably on the lower part of the Upper Alberta shale. It is in turn overlain by marine shales and soft sandstones of the upper part of the Upper Alberta shale.

Southern Alberta Plains

Upper member of Milk River formation: The Milk River formation was formally described in published literature by G. M. Dawson (1875) in his "Report of the Geology and Resources of the Region in the Vicinity of the Forty-ninth Parallel from the Lake of the Woods to the Rocky Mountains". The type section is located along the Milk River near Deadhorse Coulee in Sec. 32, Tp. 1, R. 11, W4thM.

The Lexicon of Geologic Names in Alberta states,

> "The top of the Upper Milk River is marked by a concentration of chert pebbles at the base of the overlying Pakowki formation. The upper member consists chiefly of fine-grained, grey, argillaceous sandstones with some interbedding of sandy clays and grey micro-micaceous shales. Thin streaks of impure lignite and bands or inclusions of ironstone are common".

The upper Milk River is best developed near its western edge, attaining a thickness of approximately 200 feet. It thins progressively to the east. It overlies the medium-grained cherty sandstones of the lower Milk River and is conformably overlain by grey micro-micaceous shales of the Pakowki formation.

These descriptions of the Chinook sandstone, Highwood sandstone and upper member of the Milk River formation, show marked lithologic similarities to the Solomon sandstone in the study area. Also, the stratigraphic position of these members is apparently equivalent to that of the Solomon (Table 1).

CHAPTER IV

PHYSIOGRAPHY AND STRUCTURAL GEOLOGY

The structural geology of the foothills of Alberta is complicated and far from being completely understood. The first interpretations, published in early maps and reports of the Geological Survey of Canada, were concerned only with small restricted areas and were based entirely upon surface information. During the past few years, however, much exploration work has been done in the foothills by major oil companies. This exploration has included detailed surface geological mapping, geophysical recording and test-hole drilling. The compilation and study of the data obtained by these methods make it possible to predict with more reasonable certainty the structure beneath the surface. However, as no two foothills structures are the same, correct interpretations are not possible at present.

Topography and Relief

The maximum relief throughout the area is approximately 3500 feet ranging from altitudes of 3500 feet along the courses of the major rivers such as the Athabasca and North Saskatchewan, to more than 7000 feet on top of the Palaeozoic outliers. Locally the relief is only a few hundred feet.

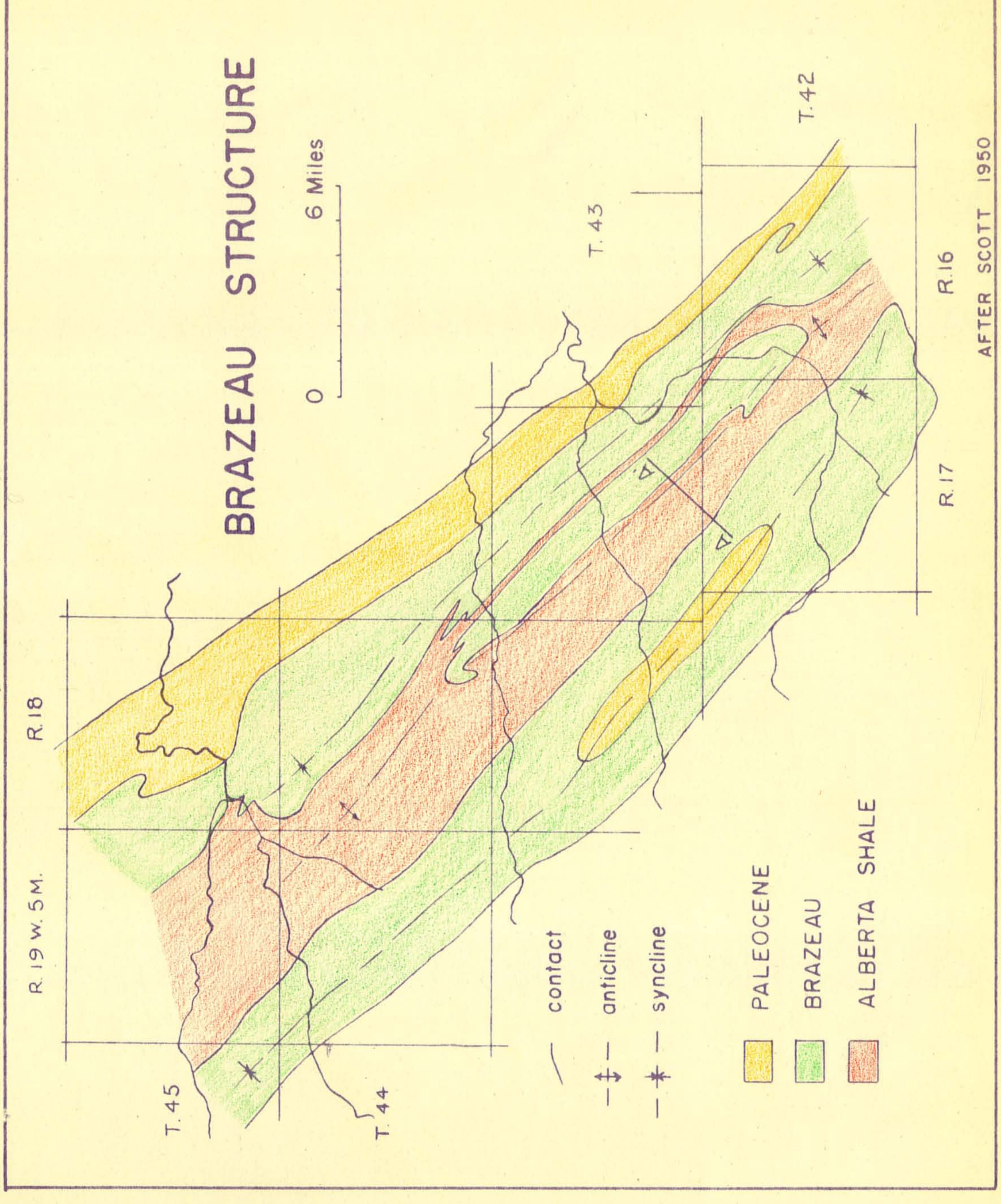

BRAZEAU STRUCTURE
0
6 Miles
R. 19 W. 5 M.
R. 18
R. 17
R. 16
T. 45
T. 44
T. 43
T. 42
contact
anticline
syncline
PALEOCENE
BRAZEAU
ALBERTA SHALE
AFTER SCOTT 1950

FIGURE II

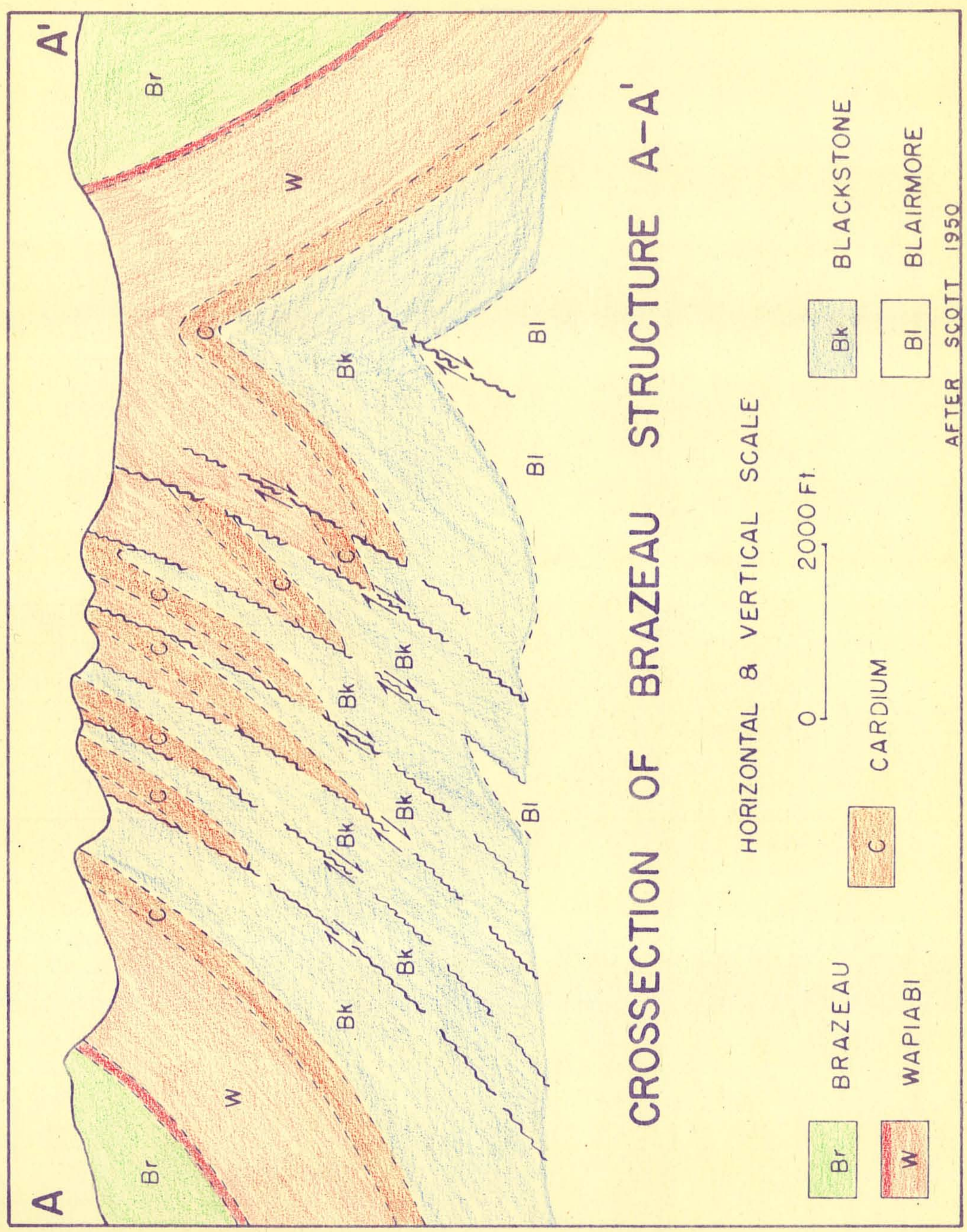

A
A'
CROSSECTION OF BRAZEAU STRUCTURE A–A'
HORIZONTAL & VERTICAL SCALE
0
2000 Ft.
Br
W
C
Bk
Bl
Br BRAZEAU
W WAPIABI
C CARDIUM
Bk BLACKSTONE
Bl BLAIRMORE
AFTER SCOTT 1950

FIGURE III

The topography is controlled by the geologic structure of the underlying strata. The more resistant sandstones form strike ridges which trend approximately 45°west of north. These ridges are parallelled by broad valleys carved from the softer shales. The area is well wooded. Only the upper few hundred feet of the Palaeozoic outliers extend above tree-line.

There are many rivers in the area and the most important ones are transverse to the structure. Rivers which flow parallel to the structure are relatively short. The major rivers which drain the area are, from north to south: Athabasca, McLeod, Pembina, Cardinal, Brazeau, Blackstone, North Saskatchewan, Ram, Clearwater, Red Deer, Waiparous, Ghost and Bow. The best outcrops are found along the banks of these rivers (Plate 1, No. 3). A few outcrops occur along the higher ridges (Plate 1, No. 1) but as a rule these exposures are poor. In the southern part of the area where the relief is considerably less, the strata are exposed only along the rivers.

Structural Geology

Examination of a few geologic cross-sections prepared by previous workers readily illustrates the basic structure of the foothills. A series of these cross-sections is given in Figure VI, and their locations are marked on the map (Fig. IV). An additional cross-section (Fig. III) is given, the location of which is marked on the map (Fig. II). These cross-sections are restricted to the northern part of the area of study. They have been reproduced on an enlarged scale to allow for more detail.

Broad anticlines and synclines so typical of the foothills are illustrated in Cross-section I of Figure VI. Repetition of the Solomon sandstone caused Lang to postulate a series of two underthrust faults from the west, or possibly overthrust faults from the east. A discussion of these faults is given later.

The relationship between the Palaeozoic and Mesozoic formations is shown on Cross-section II. The Palaeozoic formations are thrust over the Mesozoic strata. Overthrust faulting from the west is common within the Mesozoics alone, and is not restricted to the eastern face of the Front Ranges only.

The structure further south is illustrated in Cross-sections III, IV and V. Underthrusting from the west is suggested by McKay in Cross-section V, by two faults east of the Stolberg anticline.

Informative papers on interpretation of foothills structure have been written by Link (1949), Scott (1951), and Hake, Willis and Addison (1942). From field evidence in the Brazeau area, Scott suggests, "... the existence of several thrust faults, folded as a group into a series of anticlines and synclines of considerable amplitude". He suggests also, two tectonic phases. First, low angle thrust faulting from the southwest involving rocks at least as old as Devonian. Underthrusting toward the northeast at the eastern margin of the foothills is part of this movement. Second, folding on a regional scale, accompanied in its more intense phases by adjustment faulting commonly taking the form of steep southwestward dipping thrusts.

Link states that underthrusting from the west or apparent overthrusting from the east is a near-surface phenomenon only, possibly formed during incipient stages of development of folds or as an adjustment feature. Hake, Willis and Addison concur with the folded thrust fault concept and suggest further that the entire foothills structure is vitally dependent on the existence of an incompetent sequence of strata overlying a competent sequence.

Because of variation of stress intensity, direction and mode of operations, and facies changes within the sedimentary sections, no two structures in the foothills are alike.

CHAPTER V

PHYSICAL AND COMPOSITIONAL FEATURES OF THE SOLOMON SANDSTONE

General Statement

The Solomon sandstone is a recognizable unit almost everywhere within the area of study, and also is well developed north of the Athabasca River. In the southern and eastern parts of the area it becomes more difficult to determine its stratigraphic limits. This is especially so of its contact with the underlying black sandy shales of the Wapiabi formation. If glauconite is not present there is no accurate way to determine the lower contact of the Solomon. Usually the upper contact is more obvious as it is often indicated by a resistant bed of chert-pebble conglomerate. Even if the conglomerate bed is not present the dark greenish-grey sandy shale lithology of the Transition Zone is in contrast with the dark grey to black, medium-grained, argillaceous sandstone of the upper part of the Solomon.

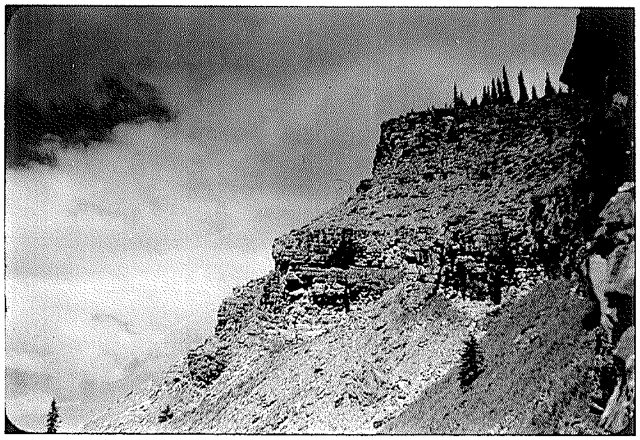
In this chapter the writer proposes to describe, illustrate and discuss the more outstanding features of the Solomon sandstone which may be observed in the field, by thin-section study and by binocular examination.

Description of Plate I

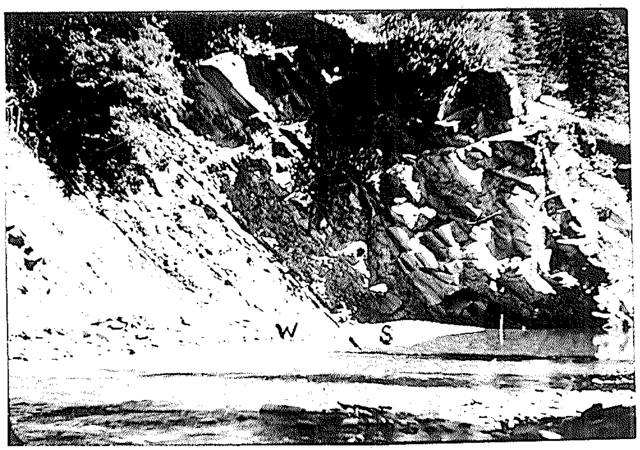
No. 1 Photograph of Littlehorn Creek No. 2 section showing Solomon sandstone as a resistant ridge-forming unit.

No. 2 Photograph of gradational lower contact of Solomon sandstone with underlying Wapiabi shales at Chungo Creek No. 5 section.

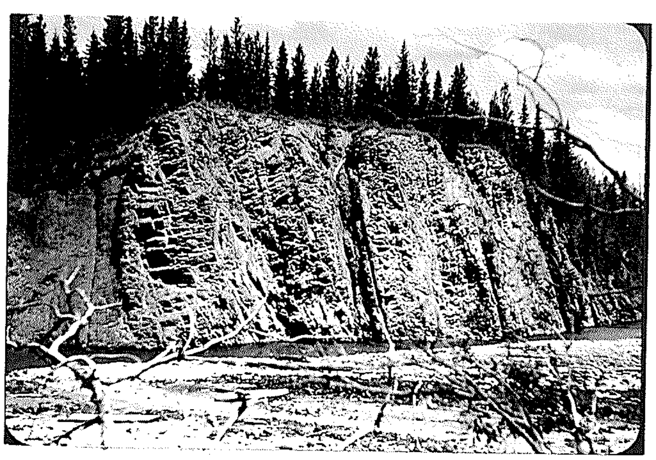
No. 3 Photograph of Solomon sandstone at McLeod River No. 1 section showing beds overturned. Note sharp upper contact at left of photograph.



1



2



PICTURE PRINTED BACKWARDS

3

Plate I

Description of Plate II

1. Photograph of upper part of Solomon sandstone at Thistle Creek No. 1 section. Overlying Transition Zone is covered by vegetation.

No. 2 Photograph of lower part of Solomon at Thistle Creek No. 1 section. Note gradational lower contact with Wapiabi shales.

1

2

Plate II

Physical Features

Bedding: The bedding of the Solomon sandstone varies throughout the area. In the west and north the individual beds are thicker but they become progressively thinner to the south and east. In the northern and western outcrops the beds are often as much as two feet and sometimes two and one-half feet thick. One of the stratigraphic sections measured along Thistle Creek (TLC-1) displays well developed thick bedding (Plate II, No's. 1 and 2). To the south and east where the lithology changes to a very argillaceous sandstone, the Solomon is thin bedded and the individual beds are about one inch thick.

Thickness: The Solomon sandstone has a thickness of 120 to 255 feet in the area of study. North of the Athabasca River it is much thinner, ranging from 80 to 100 feet. The greatest thicknesses are found in the central part of the area and a gradual thinning from north to south is evident. This is illustrated in Figure VII, Lithologic Sections of Solomon Sandstone. The greatest thickness was measured at an outcrop along Cripple Creek (CPL-1) where 255 feet of strata were assigned to the Solomon. The most northerly outcrop (MTC-1) was examined on a ridge, east of Maskuta Creek where a thickness of 120 feet was recorded. At this outcrop, however, the lower contact is not exposed and the true thickness is likely slightly greater. An outcrop of Solomon along the Ghost River (GHR-2) is the most southerly exposure. The thickness recorded here is not accurate as the lower contact of the Solomon is placed arbitrarily due to its gradational nature. Other thicknesses of the Solomon are given in Chapter VIII with the lithologic descriptions.

Contacts: The upper contact of the Solomon sandstone is with the overlying Transition Zone (Plate I, No. 3). In the western and northern parts of the area this contact is very sharply defined by the abrupt lithologic change from conglomerate to dark greenish-grey silty and sandy shale. The shale of the Transition Zone weathers easily and is often at least partially covered by vegetation. To the south and east the upper contact is less well marked but is still quite apparent. The lithologic change is from medium to coarse-grained dark grey sandstone, or in some places an ironstone concretionary bed, to the dark grey to black silty shale of the Transition Zone.

The lower contact of the Solomon is with the underlying shales of the Wapiabi formation. This contact is also evinced by a marked change in lithology from sandstone to shale, and by the presence of a well developed glauconite zone. The change in lithology from shale to sandstone is gradational over 20 to 30 feet, and the base of the Solomon is placed at the lowermost thick bedded sandstone above the Wapiabi shales, or at the lowermost glauconitic sandstone. In the northern and western parts of the area the base is determined on the former criterion, but in the south and east the glauconite zone is the most useful criterion as the underlying Wapiabi shales tend to become more sandy.

Cross-bedding: In several of the Solomon outcrops cross-bedding is a fairly prominent feature. It was noticed in seven of the measured stratigraphic sections, only one of which is south of the North Saskatchewan River. The cross-bedding is at a low angle and rarely exceeds thirty degrees. It may appear as a gross feature of the rock involving several beds, or it may be discernable only by banding of an individual bed. In both types it is made obvious by the presence of dark mineral or rock fragments along the bedding planes. Some specimens show a definite lineation of the long axes of both these dark grains and quartz grains. In the following stratigraphic sections cross-bedding is well developed: Maskuta Creek No. 1, South Pembina River No. 1, Thistle Creek No's. 1 and 2, Whitewater Creek No. 1, Littlehorn Creek No. 1 and Cripple Creek No. 1.

Resistant Beds: The entire Solomon sandstone is a resistant unit in the western part of the area. In the eastern part of the area, where the Solomon is very argillaceous, some beds weather more slowly than others. These slow-weathering beds are somewhat coarser grained and contain a greater percentage of quartz grains than do the surrounding beds. The cementing agent is silica. These beds weather more slowly because of their increased silica content, both as cement and as detrital quartz grains, and are actually fairly clean sandstones, whereas the surrounding beds are more argillaceous and approach the composition of a subgreywacke.

Concretions: A few concretions are found within the limits of the Solomon sandstone. They are not so common here as they are in the underlying Wapiabi shales, and occur only where the Solomon is a dark grey, fine-grained, thin-bedded sandstone or siltstone. These concretions are composed of medium grey, very fine-grained, rusty-weathering ironstone. They are spheroidal in shape, the axis perpendicular to the bedding being slightly shorter than either of the two horizontal axes.

The concretions may occur fairly uniformly along a single bedding plane or may be scattered haphazardly. They may be formed so close together that they have the appearance of a concretionary bed rather than a bed of concretions.

In one outcrop measured along the Ghost River, the concretions are calcareous. One of these calcareous concretions contains pelecypod valves on which the mother of pearl coating of aragonite has been preserved. These calcareous concretions have fractures filled with coarsely-crystalline brown calcite. The fractures are not apparent on the outer surface of the concretions.

Stott (1956) has divided the upper part of the Wapiabi formation into an "Upper Concretionary Shale Zone" and an "Upper Concretionary Siltstone Zone". He regards the latter as an easterly facies of the Solomon sandstone.

The origin of these concretions is difficult to determine. Properties which they exhibit may be used to support both a syngenetic and an epigenetic mode of origin. The thin shaly beds surrounding the concretions appear to be concentric with them for approximately one-quarter inch. In certain stratigraphic sections the concretions contain clastic sand grains and glauconite and at one outcrop along the Red Deer River (RDR-3) an entire conglomerate bed was enclosed in ironstone concretionary material.

In support of a syngenetic origin the relative shortening of the axis of the concretion perpendicular to the bedding is explained by the pressure of accumulating sediments. The clastic material may have been introduced into the growing concretion by slightly turbulent conditions or minor wave action sufficient to agitate the most recently deposited sediments on the sea floor.

For an epigenetic origin the relative shortening of the axis of the concretion perpendicular to the bedding is explained by differential ease of concretion growth. The direction of least resistance to growth would be any direction in the plane of the bedding. The quartz grains and glauconite may have been included in the concretion rather than having been removed by solution.

One theory of origin offered for concretions suggests that they develop fractures from inner dehydration which results in a hollow centre lined with crystalline material. Because the concretions in the Solomon do not have hollow centres, it is more likely that fractures resulted from the force of exterior expansion, and that the calcite mineralization is of a later origin.

Porosity: Porosity is not a prominent feature of the Solomon. Megascopic examination in the field revealed only one porous bed which could be traced from outcrop to outcrop and even it was not sufficiently well developed to be traced to more than three outcrops. This porous zone occurs in the upper two or three feet of sandstone underlying the chert-pebble conglomerate bed. Thin section examination reveals the grains to be quite tightly packed together in the medium to coarse-grained sandstones. Usually, where the cement is siliceous the porosity reaches a minimum. Where it is calcareous the porosity increases noticeably.

In the finer grained sandstones and siltstones found in the eastern and southern parts of the area, the grains are not so tightly packed together. However, the cement is both siliceous and argillaceous and reduces porosity to a minimum. The low porosity here is also due to very poor sorting of the component grains of the sandstones and siltstones.

The sorting and cementing material are the controlling factors of the porosity in the Solomon. The calcareous cement does not completely fill the interstitial spaces in the sandstone, and the induration of these sandstones is not so complete.

Grain Size: The size of the component grains of the Solomon sandstone, exclusive of the conglomerate, ranges from 0.04 millimeters to 1.0 millimeters in diameter. The largest grains are found in the outcrops in the western and northern parts of the area. To the south and east the grain size decreases considerably. Sieve analyses of some of the argillaceous sandstones and siltstones revealed that isolated grains from physically disaggregated sandstone specimens were not too common even in the -200 Tyler mesh (0.074 millimeters). The particles retained on this screen were mostly aggregates of two or more grains, or of two or more fragments of grains. It is very likely that the extreme adhesive properties of the cement have caused fracturing to take place through the grains rather than around the grains, during the processes of physical disaggregation.

The pebbles of the conglomerate range in size from ~~less than~~ 4.0 millimeters to more than 40 millimeters in diameter. The majority of these pebbles are less than 20 millimeters in diameter.

<u>Texture</u>: The coarser-grained sandstones have a very tightly interlocking texture with a relatively small amount of cement. Where the sorting is locally poor, the finer grains fill the interstices. The finer-grained sandstones and siltstones also have this same interlocking texture but not so tightly developed. The argillaceous and siliceous cementing materials are present in increasing percentages and in some thin sections the quartz, chert and other grains may scarcely touch one another.

<u>Sphericity and Roundness</u>: A thorough analysis of the sphericity and roundness properties of the individual grains of the Solomon was made difficult by the strongly binding cement, and by the relatively fine-grained nature of many of the beds. Several attempts were made to disaggregate the sandstone by chemical decomposition of the cement, but none were successful. Mechanical disaggregation by crushing was effective, but even the particles retained on the finest type sieve (-200 mesh) were mostly aggregates of two or more fragments of grains. Attempts were made to analyze a few of these -200 mesh size grains, but it was found that the magnification required for

this caused the edges of the grains shadows to become blurred and rounded. This did not yield accurate data of sphericity and roundness and the attempts were not continued.

Compositional Features

Quartz: The most common mineral present in the Solomon sandstone is quartz. It occurs as sub-angular to sub-rounded grains which range from 0.04 to 1.0 millimeters in diameter and which may comprise as much as 80 percent of the rock. Some euhedra are present. The long axes of the grains parallel the bedding. The grains are both clear and frosted, the relative amounts of each being nearly equal in the coarse sands from the western outcrops. Where the Solomon is more argillaceous and fine-grained, there is a predominance of frosted quartz grains. However, in the slow weathering re-resistant beds almost all of the quartz grains present show little or no frosting. Strain shadows may be observed on many of the quartz grains. In the eastern outcrops where the color of the rock is darker the component quartz grains are darker in color as well.

Chert: Both light greyish-white and dark grey to black chert occur in the Solomon. The conglomerate which marks the top of the unit is composed largely of well rounded chert pebbles which range up to one inch in diameter. When present as sand or silt size grains, white chert is the more common type. As seen in thin sections, these chert grains are sub-rounded and of the same size as the quartz. Exclusive of the conglomerate, chert may make up as much as four to five percent of the rock in some beds. It is most common where the sandstone is medium to coarse-grained.

Potash Feldspar: Potash feldspar may make up as much as seven to 10 percent of some beds. It occurs as sub-angular to sub-rounded grains of the same size (0.04 mm to 1.0 mm) as the quartz grains. It is most common in sands from the western outcrops which are medium to coarse-grained. The feldspar is recognized in some specimens by thin section examination, but a staining technique was found very useful in estimating approximate percentages. An attempt to stain loose grains of -200 Tyler mesh size was found impractical. Potash feldspar is present in the argillaceous facies of the Solomon but in decreasing amounts.

Plagioclase Feldspar: This mineral occurs only in insignificant amounts in the Solomon. A few grains which showed well developed twinning were noted in thin sections but no accurate sodium-calcium ratio could be determined. It was identified only in the medium to coarse-grained sandstones from the western and northern parts of the area of study.

Mica: Muscovite and biotite both occur in the Solomon in amounts ranging up to about one percent. They are equally common and occur as tiny flakes up to 0.5 mm long which lie parallel to the bedding. The grains may be seen in thin section (Plate VII, No. 2) but are easily noticed megascopically along the bedding planes of the fine-grained argillaceous siltstones and sandstones of the Solomon in the eastern part of the area.

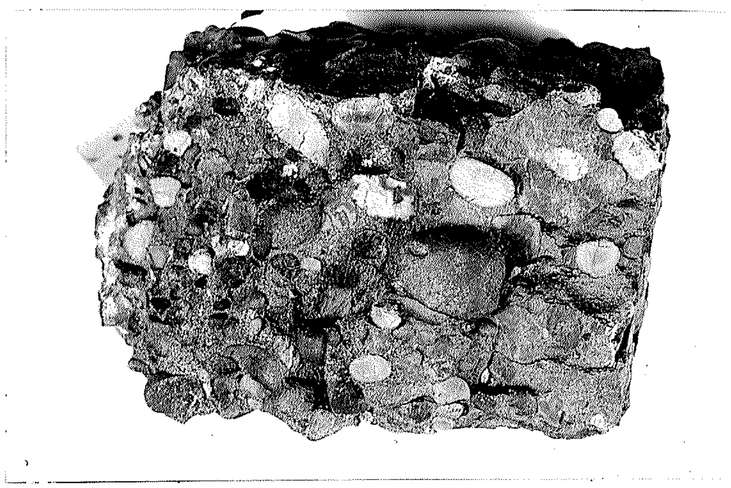
Pyrite: Pyrite is present as thinly disseminated crystalline aggregates. It comprises less than one percent of the rock when it is present. It is more common in the argillaceous sandstones and siltstones, but was also identified in a few of the cleaner medium to coarse-grained sandstones.

Magnetite: A small amount of magnetite, less than 0.1 percent, is found in some sandstones of the western part of the area. It is present as irregular grains which are considerably smaller than the associated quartz grains. A few grains of magnetite were obtained from a heavy mineral analysis of a sample from one of the fine-grained, argillaceous sandstone beds. It is possible that magnetite is present in larger quantities in the argillaceous sandstones and siltstones, but it is very fine-grained and the rock does not lend itself readily to disaggregation. Therefore, small particles of magnetite may adhere to quartz grains or other detrital fragments and resist any effort to isolate them by bromoform separation.

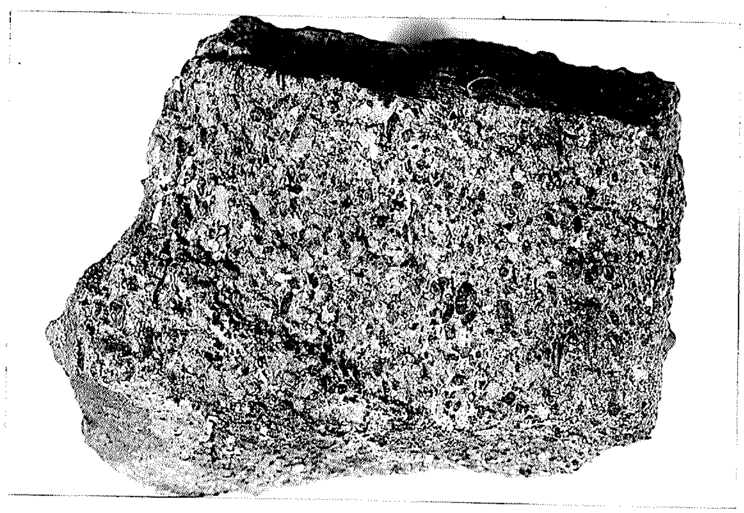
Description of Plate III

No. 1 Photograph of hand specimen of conglomerate from upper part of Solomon sandstone at Littlehorn Creek No. 2 section. Pebbles are of light grey to black chert. x 1

No. 2 Photograph of hand specimen of conglomerate from the top of Solomon sandstone at Cardinal River No. 1 section. Pebbles are mostly grey to black chert. x 1



1



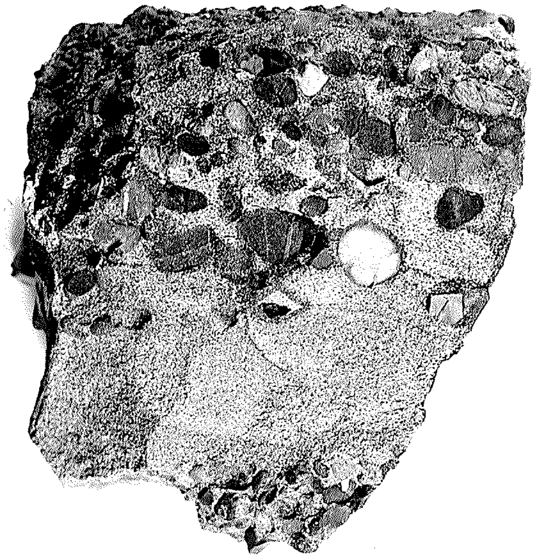
2

Plate III

Description of Plate IV

No. 1 Photograph of hand specimen of conglomerate from Solomon sandstone at Littlehorn Creek No. 2 section. Pebbles are mostly dark grey to black chert. x 1

No. 2 Photomicrograph of conglomerate from Solomon sandstone at Littlehorn Creek No. 2 section showing chert pebbles banded and cut by fine-grained quartz stringers. Note fine grain size of sandy matrix. Crossed Nicol. Diameter of field = 5.7 mm.



1

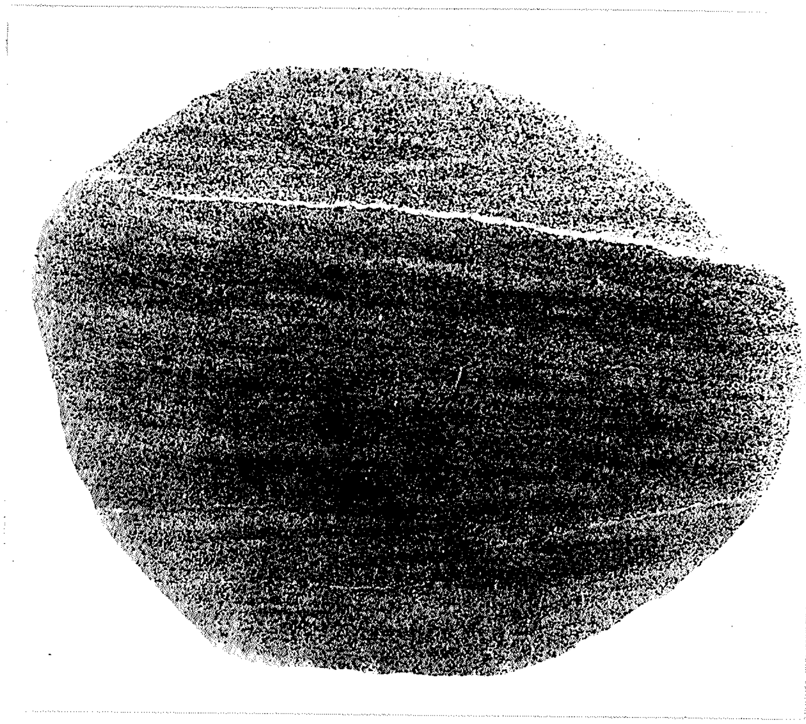
2

Plate IV

Description of Plate V

No. 1 Photograph of a thin section of Solomon sandstone from Whitewater Creek No. 1 section showing low-angle cross-bedding. x 6

No. 2 Photomicrograph of Solomon sandstone from Chungo Creek No. 5 section showing coarse grain size and interlocking texture. Crossed Nicols. 1 millimeter equals 31 units on scale.



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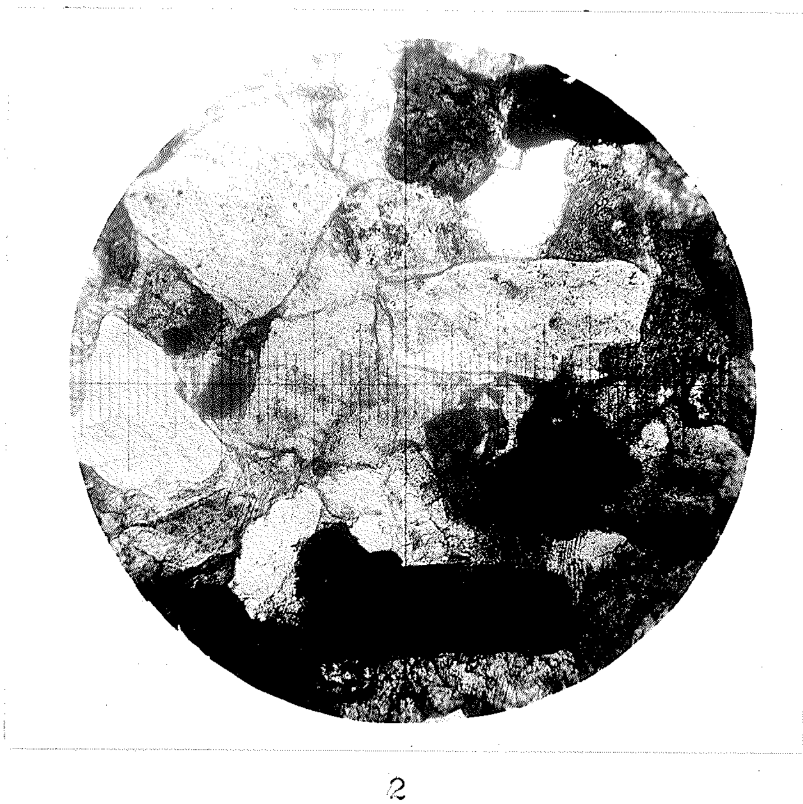


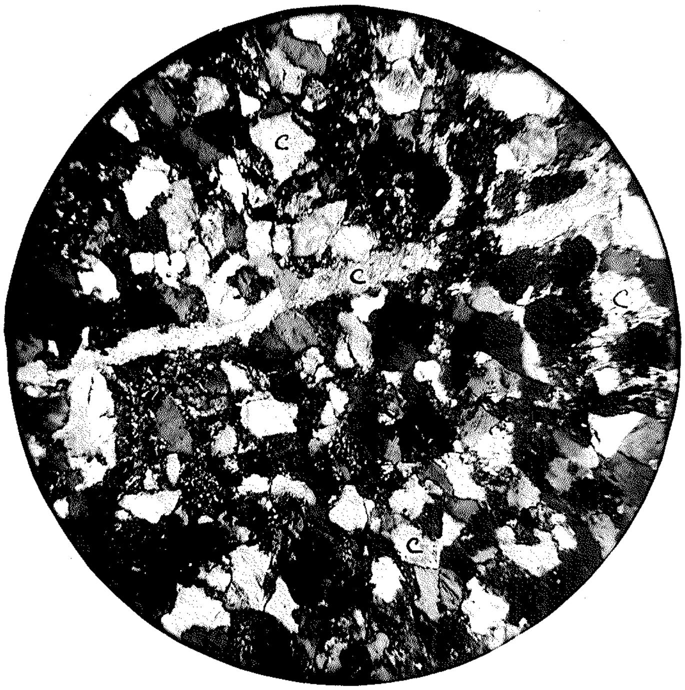
2

Plate V

Description of Plate VI

No. 1 Photomicrograph of Solomon sandstone from McLeod River No. 1 section showing calcite veinlet and calcite grains (c) throughout the rock. Crossed Nicols. Diameter of field = 1.5 mm.

No. 2 Photomicrograph of Solomon sandstone from Littlehorn Creek No. 2 section showing euhedral rhomb of calcite (c) isolated in rock. Crossed Nicols. Diameter of field = 1.5 mm.



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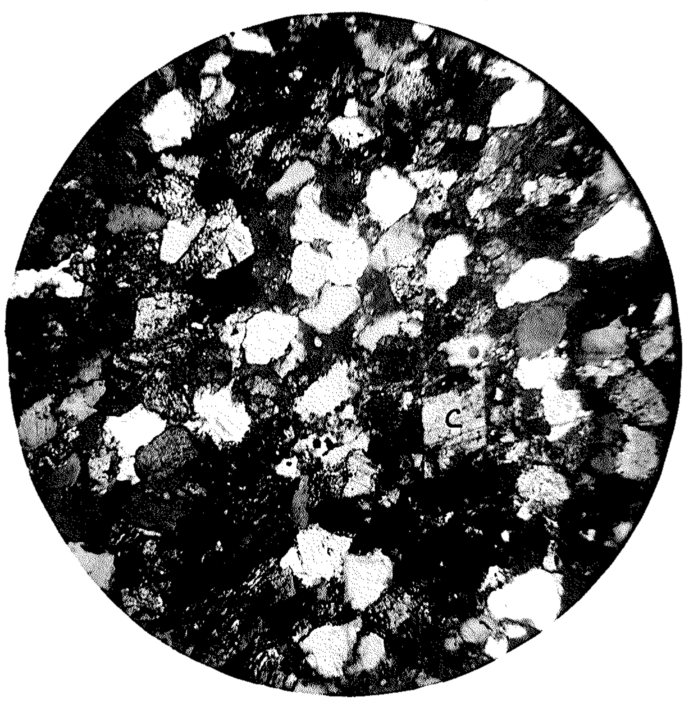


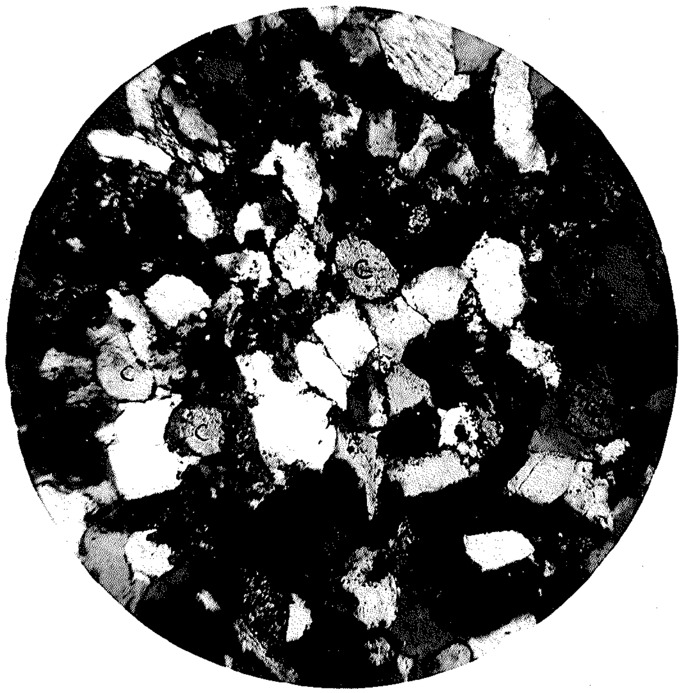
2

Plate VI

Description of Plate VII

No. 1 Photomicrograph of Solomon sandstone from Littlehorn Creek No. 2 section showing well-rounded clastic (?) calcite grains (c). Crossed Nicols. Diameter of field = 1.5 mm.

No. 2 Photomicrograph of Solomon sandstone from Littlehorn Creek No. 2 section showing muscovite (m) to be present. Mottled dark grains are chert. Crossed Nicols. Diameter of field = 1.5 mm.



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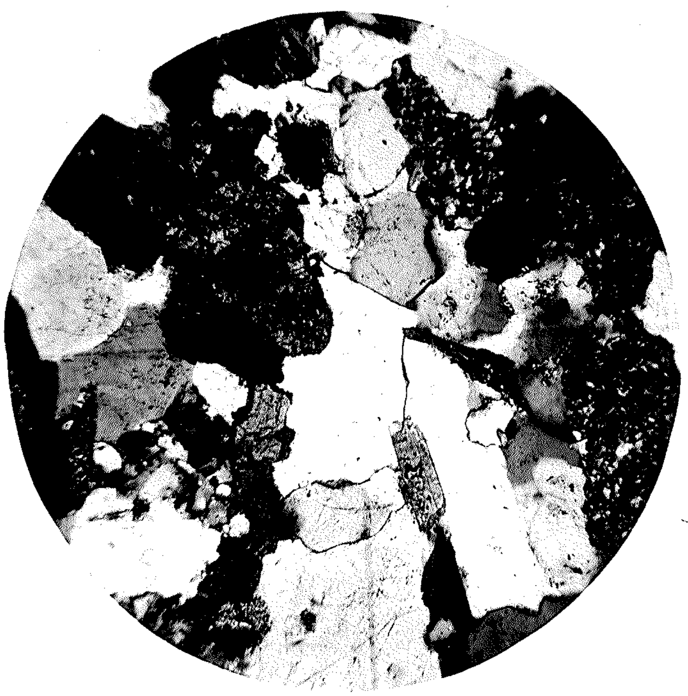


2

Plate VII

<u>Tourmaline and Zircon</u>: These two minerals ~~are~~ WERE found in every bromoform heavy mineral separation which ~~is~~ WAS carried out. They occur as well rounded grains, the tourmaline usually being more elongate. The zircon grains are mostly clear and colorless whereas a few grains of tourmaline are very pale pink in color. Identification of these minerals from thin sections is difficult because of their small grain size and of the masking effect of the argillaceous matrix of the sandstone and ~~stilstone.~~ SILTSTONE.

<u>Calcite</u>: Calcite is the only carbonate mineral found in the Solomon. It is present as euhedra (Plate VI, No. 2), as irregular clastic grains (Plate VII, No. 1) and as crystalline aggregates in the form of veinlets (Plate VI, No. 1). The euhedral and crystalline nature of the calcite present attest to a secondary emplacement from solutions, but the irregular grains examined in thin section by a petrographic microscope appear to be clastic.

In some of the coarser-grained sandstone beds to the west, calcite is the major cementing material and occurs interstitially with the detrital grains. These sandstones always have a dull brown to brownish-green weathering color. This color relationship is also apparent in the strata of the overlying Brazeau formation.

Iron Oxide: Reddish-brown oxides of iron, hematite, and possibly some limonite, are common in certain beds of some of the outcrops examined in the western part of the area. The stratigraphic sections measured along Littlehorn Creek (LHS-2) and McLeod River (MLD-1) contain several beds of this nature. The oxides are present as cementing material, and in thin section appear to surround completely the individual grains of quartz and other minerals. Isolated quartz grains from these beds retain the coating of the rusty oxides. In all sandstone beds with appreciable amounts of iron oxide cement, the quartz grains are medium to coarse in size and compose a greater percentage of the rock than they do in other beds. These beds of sandstone have a characteristic deep rusty-brown weathering color.

It is thought that the iron oxide was introduced at the time of deposition of the sandstone. Krumbein and Garrells (1952) state that iron oxide in the form of hematite may be precipitated from sea-water of pH (hydrogen ion concentration) value ranging from seven to nine and Eh (oxidation-reduction potential) value ranging from -0.2 to +0.2. However, it is most common where the pH ranges from seven to eight and the Eh from 0.0 to +0.2.

<u>Rock fragments</u>: Minor amounts of rock fragments are contained in the Solomon. They are dark green to black in color, angular and may be derived from an andesite or related volcanic deposit. The fragments show alignment parallel to the bedding in the coarser-grained sands. In the very fine-grained sandstones and siltstones and rock fragments are more common and very small. They may compose as much as three to five percent of the rock.

<u>Glauconite</u>: Glauconite is a micaceous mineral and is known to be present in rocks of every geologic age from Cambrian to Recent. It is a common accessory mineral in the Solomon sandstone where it occurs as ellipsoidal or fairly well-rounded grains approximately 0.5 mm in diameter.

The base of the Solomon is marked by the lowest good development of glauconite above the Wapiabi shales. In most outcrops there is a concentration of glauconite grains along one or more bedding planes to mark this contact. To the south and east where the sandstone becomes thin-bedded and argillaceous, and grades into a siltstone, glauconite is dispersed over several bedding planes. It occurs also in the sandstone or siltstone immediately surrounding the ironstone concretions. This was noticed especially in the outcrops along Red Deer River (RDR-3) and Ghost River (GHR-2). Binocular and microscopic examination reveal that glauconite is present not only at the base of the Solomon, but also occurs irregularly throughout the middle and upper parts.

The presence of glauconite in the Solomon is a very significant feature and gives a definite clue to the depositional environment of this sandstone unit. For this reason presently accepted theories on the origin of glauconite are discussed here.

Glauconite is thought to be a product of submarine diagensis. It is reported to originate from biotite (Galliher, 1935); from illite (Light, 1952); from clay fillings of foraminifera, fecal pellets, fragments of volcanic glass, organic opaline silica, feldspars, mica and pyroxenes (Takahashi, 1939). It is known that micaceous minerals and bottom muds of high iron content are commonly associated with glauconite forming in present day deposits.

Cloud Jr. (1953) states:

> "From the work of Yagi, Takahashi concluded that hydration of the parent mineral is the first step; then formation of gelatinous silicates with the loss of alumina, silica and alkalies except potash, and finally absorption of ferric iron, potassium and magnesium."

The physical conditions necessary for the formation of glauconite are as follows:

Salinity: Salinity is an important factor in the formation of glauconite. Glauconite is known to form under marine conditions only, but it is possible that it could be formed from lake water of comparable salinity.

Its formation is apparently facilitated by the presence of decaying organic matter and by related slightly reducing conditions. Factors which support this theory are: (1) all recent sediments which contain glauconite smell of hydrogen sulphide when dredged, (2) there is no fossil evidence in glauconitic deposits of life requiring oxygenated water.

Depth: The depth at which glauconite forms may be indicated by the depths at which it is formed in recent deposits. Cloud Jr. (1955) states that glauconite

> "... 1) occurs as traces from just off-shore to a depth of 2400 fathoms, 2) is probably rare above five and below 1000 fathoms, 3) is commonest at depths of 10 to 400 fathoms, and 4) may originate mainly in the upper part of the 10 to 400 fathom interval."

Temperature and geographical limits: Hadding (1932) suggested that cold water was more favourable for glauconite deposition than warm water, as glauconite is not known to occur with reefs. Lochman (1949) concluded that favourable water temperatures range from eight degrees centigrade to slightly over 20 degrees centigrade with the average around 14 to 15 degrees centigrade. This is typical of a temperate to warm temperate climate. Galliher (1935) states that glauconite is forming in sediments today between the latitudes of 65° south and 80° north.

Turbulence: No special conditions of turbulence are required for the formation of glauconite. Some evidence of turbulence is found in associated sediments but continued marked turbulence does not agree with slightly reducing anaerobic conditions already suggested as favourable for glauconite deposition.

CHAPTER VI

PALAEONTOLOGY

Few well preserved fossils were collected from the outcrops of the Solomon examined by the author. In only four of the stratigraphic sections were any fossil remains recognized. These sections are: McLeod River No. 1 (MLD-1), Thistle Creek No. 1 (TLC-1), Whitewater Creek No. 1 (WWC-1), and Ghost River No. 2 (GHR-2).

Well preserved pelecypods were found 23 feet below the conglomerate bed which marks the upper stratigraphic limit of the Solomon on the McLeod River. These pelecypods were tentatively identified as *Oxytoma* sp.

A much larger, fairly well preserved pelecypod specimen was found 100 feet below the upper contact in Thistle Creek No. 1 section. However, no accurate description or identification of this specimen is available.

In the stratigraphic section measured along Whitewater Creek, poorly preserved pelecypods were found three feet above the base of the Solomon.

At Ghost River No. 2 section a pelecypod (?) fragment was found in the centre of a rusty-weathering ironstone concretion 55 feet below the top of the Solomon.

These are the only occurrences of fossil remains in the Solomon sandstone found by the author.

Several occurrences of fossils in the uppermost beds of the Wapiabi formation, which may ~~of~~ or may not include or be correlative with the Solomon, are listed by Rutherford (1925). He reports the occurrence of the following fossils from the area between the McLeod and Athabasca Rivers:

Oxytoma nebrascana (Evans and Shumard)
Pholodomya papyracea (Meek and Hayden)
Baculites ovatus Say
Ostrea sp. undet.
Liopistha undata (Meek and Hayden)
Tancredia americana (Meek and Hayden)

He reports (1927) the following fauna from the "uppermost Upper Benton beds" on Jumping Pound Creek in Tp. 25, R. 5, W 5thM. The "uppermost Benton beds" are apparently stratigraphically equivalent to the uppermost beds of the Wapiabi formation.

Baculites ovatus Say
Oxytoma nebrascana E & S
Pteria sp. nov.

Hume (1936) states that *Baculites ovatus* occurs in a sandy shale zone 120 to 135 feet below "hard Belly River sandstone" along the Ghost River. He also mentions the occurrence of an oyster bed 36 feet below "Belly River cross-bedded sandstones" along Harold Creek in Tp. 29, R. 7, W 5thM. This is about 200 feet above a glauconitic zone which may bear some relation to the glauconitic zone which marks the base of the Solomon.

Lang (1946) noted the following fossils in the Solomon in the Brule and Entrance Map Areas:

Tellina (?) sp.
Oxytoma nebrascensis
Cardium sp.
Liopistha montanensis

Erdman (1950) reported that Baculites occurs in the upper three hundred feet of the Wapiabi formation.

Irish (1951) found no marine fossils in the Solomon sandstone in the Pierre Greys Lakes Map Area, comprising Townships 55 to 58, Rges. 4 to 7, W 6thM, approximately 60 miles northwest along foothills strike from the northern extremity of the area discussed in this paper.

CHAPTER VII

SOURCE AND DEPOSITION OF THE SOLOMON SANDSTONE

Source

The varying lithology of the Solomon suggests a multiple rather than a singular source for its component constituents. The area from which the detritus was derived was to the west of the area of deposition. At the time these strata were laid down the Cordilleran Geanticline was a positive epeirogenic uplift area extending laterally from just west of that part of the Alberta - British Columbia border which trends northwest to almost as far west as the present Pacific Coast. It extended northward intersecting the 60th parallel on the east at approximately 128° longitude, and on the west at approximately 146° longitude. The Cretaceous seas at this time extended from Central America to the Arctic Ocean covering a broad expanse of the central United States and western plains of Canada.

The nature of the Solomon indicates that the source rocks were both sedimentary and igneous, and possibly metamorphic. The large amount of quartz present was likely derived from a sandstone or a granitic-type intrusive rock. The prominence of strain shadows in the quartz grains suggests that the source rock was subjected to stress metamorphism.

The considerable amount of chert as sand-size grains was derived either from bedded cherts, precipitated chert beds, or from a sandstone containing detrital chert. Rock fragments present resemble andesitic volcanics. The necessary source rocks, therefore, could include sandstone, shale, chemically precipitated chert beds, granitic-type intrusive rocks and andesitic-type volcanics.

Rocks of the types listed above are present in abundance in the Precambrian, Palaeozoic and Mesozoic outcrops in the west-central part of British Columbia. This area was part of the Cordilleran Geanticline during Solomon time. Strata ranging in age from Ordovician to Permian include minor carbonates and abundant orthoquartzites, bedded cherts and volcanics. The theoretical cross-section across southeastern Alaska and British Columbia (Eardley, 1951, Fig. 21, p. 68) indicates the presence of volcanics and greywackes which could have been a source of the Solomon. Also, throughout central British Columbia there are numerous batholithic intrusions of Mesozoic age which are suitable as source rocks for the Solomon.

There are few geologic reports available on the north-central part of British Columbia. However, some general information is available on western areas which may have been source areas for detritus deposited during Solomon time.

Western Rockies in Southern British Columbia: Late Precambrian rocks of the western Rockies of southern British Columbia would have been a suitable source of the detritus which now constitutes the Solomon sandstone. The Hamil series, Badshot formation and Lardeau series of rocks, which underlie the Palaeozoic strata, are mainly schists, phyllites, quartzites and siliceous limestones. These rocks could have readily supplied quartz, mica, chert and rock fragments to the Solomon.

Purcell Range: Precambrian rocks in the Purcell range include some suitable source beds for the Solomon. The Lower Purcell series of Proterozoic age is the most likely of these. It is composed of argillaceous quartzite, argillite and minor magnesian limestone. The overlying strata here are largely carbonates with only minor clastic units.

The detrital material composing the Solomon apparent was derived from pre-existing rocks to the north and west, as the Solomon becomes more argillaceous and more difficult to recognize to the south and east. It is possible that some detritus was derived from rocks further south. If this is so, then it is plausible that the Cretaceous seas of Solomon time may have extended further west in present south-central Alberta, than is shown in previously accepted palaeogeographic maps. The equivalent near-shore sand deposits which should be present in this area may have been removed and concealed by later faulting. The exact western limit of Cretaceous seas is unknown. It must be kept in mind also that the Highwood sandstone is similar lithologically to the Solomon and likely has a similar history. However, the two sandstones are not laterally continuous but are separated by a shale facies. This fact would support the proposed westward embayment in the shoreline of the sea during Solomon time.

Deposition

The Solomon has lithologic characteristics of a sandstone deposited under infraneritic, epineritic or shallow bathyal environments on a mildly unstable to unstable shelf area. It might be described in some localities as a subgreywacke, being poorly sorted in part, fine-grained, impure, angular and greenish-grey in color.

Krumbein and Sloss (1951) describe the rocks formed under epineritic conditions on an unstable shelf as "... greenish-grey, ...dark grey to black, ...quartzose to subgreywacke sandstone, cross-bedded, ripple marked. Shales commonly siltstones... carbonaceous, calcareous, ..."; and the rocks formed under infraneritic conditions on an unstable shelf as "...greenish-grey, ... Sheet sands mainly fine-grained; ...fine-grained to subgreywacke sandstones, evenly bedded...".

The presence of glauconite in the Solomon suggests a fairly shallow water site of deposition (Cloud Jr., 1955) with no specific conditions of turbulence. Also, interlensing of conglomerate and cross-bedding observed in western exposures suggest shallow water conditions of deposition. For these reasons the above mentioned environmental conditions are thought to have existed at the time the Solomon was deposited.

The relatively consistent conglomerate bed which denotes the top of the Solomon may well indicate an eastward regression of the sea and the transition from marine to non-marine conditions of sedimentation throughout the area. This regression may have been an initial effect of the Laramide Revolution. That the particle size of the conglomerate decreases from a coarse pebble conglomerate in the west to a coarse grit sandstone in the east is a definite indication of a western source area. The western exposures of the sandstone are near-shore deposits, and it is not likely that the western shore of the sea during Solomon time was much further west of these outcrops.

The area of deposition subsided at a rate which was not great enough to offset the shoaling effect caused by the rapid influx of detrital material and by the rising landmass to the west. This is evident from the transition of Wapiabi shales to Solomon sandstone and to the overlying marine and non-marine shales of the Transition Zone.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Summary

The Solomon sandstone member of the Wapiabi formation has a maximum thickness of 255 feet in that part of the foothills belt bounded on the north by the Athabasca River and on the south by the Bow River. It occurs throughout most of the area designated but is indeterminable in the extreme southern part. It is known to occur for a considerable distance northwest of this area along the strike of the foothills.

The Solomon consists of a fine to medium-grained sandstone which is overlain by a one to two-foot bed of conglomerate which marks the top of the member. The sandstone is coarser-grained and lighter in color to the west and north and becomes darker in color, finer-grained and more impure as it "shales out" to the south and east. At some of the southern outcrops the Solomon may be described as a subgreywacke containing lenses of clear, coarse-grained quartzose sandstone. The pebbles of the conglomerate bed vary laterally in size as does the grain size of the sandstone. The conglomerate bed is absent in several of the southern exposures, being represented in some by a similar thickness of coarser-grained sandstone or grit. In some localities fossil pelecypods are recovered from a thin zone in the upper part of the Solomon.

Overlying the Solomon member is the Transition Zone, which consists of dark grey to greenish-grey sandy shale. This unit represents the change from marine to non-marine conditions. It is included in the Wapiabi formation. The upper contact of the Solomon is quite sharp. Underlying the Solomon are shales of the Wapiabi formation. These are dark grey to black, sandy, thin to platy bedded, fissile shales with abundant rusty-weathering ironstone concretions. The lower contact of the Solomon with these shales, is usually gradational over a 20 to 30-foot interval of inter-bedded sandstone and shale. The contact is picked at the base of the lowermost massive sandstone bed overlying the shale or by the presence of a prominent glauconitic zone.

The Solomon is, for the most part, a very fine-grained sandstone. It is a fairly poorly sorted, impure, sub-angular sandstone with a tight interlocking texture. It contains only a minor amount of heavy accessory minerals such as tourmaline, zircon, and magnetite.

Conclusions

From this study of the Solomon sandstone, the following conclusions were reached:

1. The Solomon was deposited under conditions ranging from neritic to shallow bathyal on a mildly unstable shelf area.

2. Poor sorting of the sandstone indicates rapid deposition while frosted grains indicate extensive transport. It is likely that much of the quartz present in the Solomon is re-worked from a previously-existing clastic sediment.

3. The source of the material which composes the Solomon sandstone was from the north and west of the area of deposition and possibly from the western part of the Cordilleran Geanticline. The age of the source rocks may range from Precambrian to Cretaceous.

4. The Solomon and Highwood sandstones may be one continuous deposit. The shale interval separating them laterally could be due to a western embayment of the sea during Solomon time, masked at present by faulting and by the doubtful accuracy of the accepted western shoreline of the Late Cretaceous seas.

5. The Solomon has no well developed porous zones as seen in outcrop. However, it may be a potential reservoir of hydrocarbons in the eastern silt facies in the subsurface. The Cardium formation is not porous in outcrop or in subsurface, but yields petroleum prolifically at the Pembina field when subjected to a sand-fracturing process.

6. The Solomon is correlated with (a) the Chinook sandstone of the Peace River area, (b) the Highwood sandstone of the southern foothills, and (c) the upper member of the Milk River sandstone of the southern plains of Alberta. It is the youngest wholly marine deposit of Cretaceous age in the area of study.

CHAPTER IX

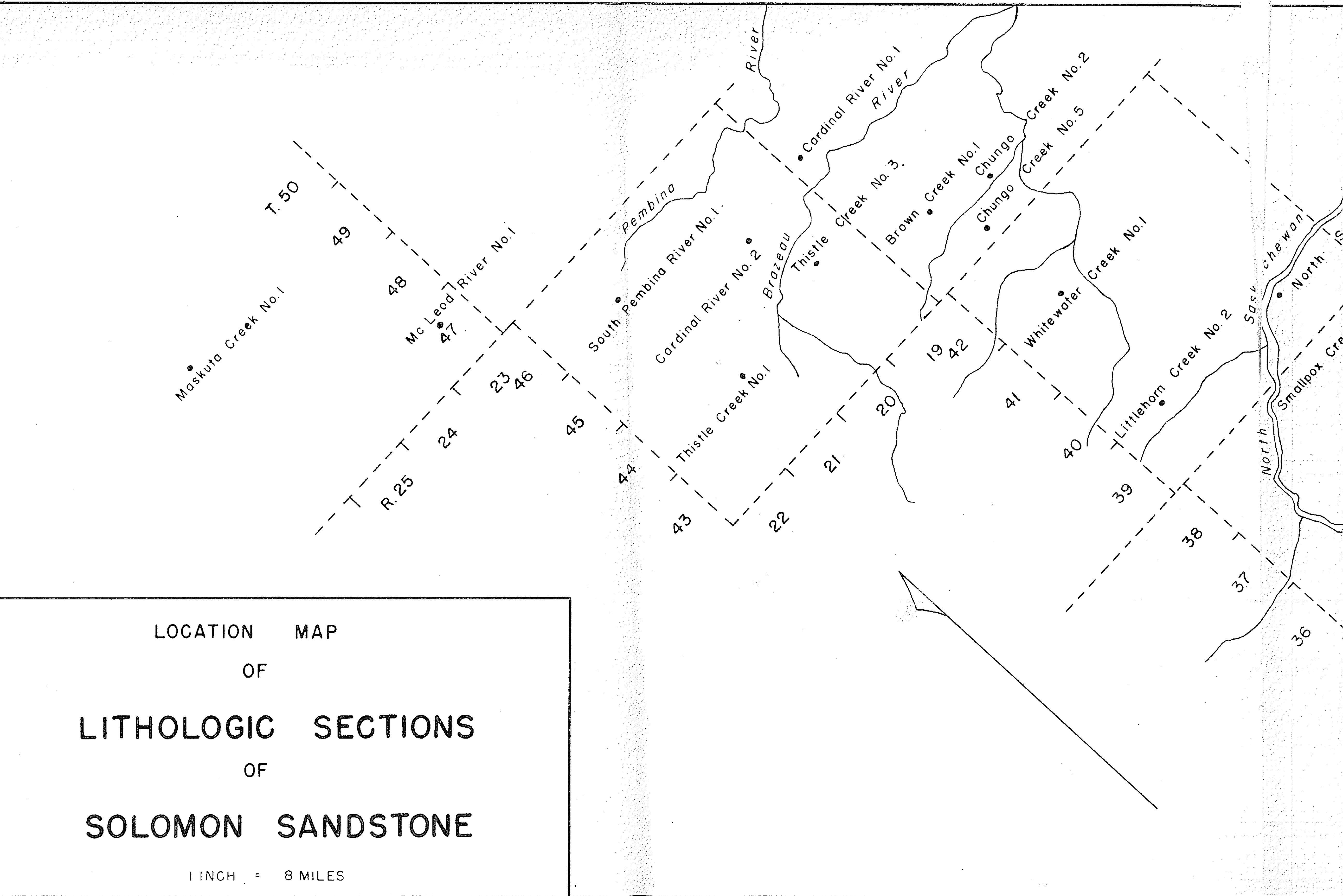
LITHOLOGIC DESCRIPTION OF SECTIONS

In this section are given the names and locations of all outcrops of Solomon sandstone measured, together with a detailed description of the lithology of most of the outcrops. The lithologic descriptions omitted are of those sections for which detailed examination of the samples was impossible, or which have poor, indeterminable contacts, or which are located very near and are similar to other sections described. Information obtained from these outcrops is nevertheless considered in the text of this report.

List of Measured Sections

Brown Creek No. 1	Tp. 43	R. 18, W5M.	Section 35
* Burnt Timber Creek No. 1	Tp. 29	R. 9, W5M.	
Burnt Timber Creek No. 2	Tp. 29	R. 9, W5M.	
* Cardinal River No. 1	Tp. 45	R. 18, W5M.	Sections 18 and 7
Cardinal River No. 2	Tp. 45	R. 20, W5M.	Section 13
* Chungo Creek No. 2	Tp. 43	R. 17, W5M.	Section 22
Chungo Creek No. 5	Tp. 43	R. 17, W5M.	Section 7
Cripple Creek No. 1	Tp. 37	R. 14, W5M.	Section 20
Ghost River No. w	Tp. 27	R. 6, W5M.	Section 6
Littlehorn Creek No. 2	Tp. 39	R. 18, W5M.	Section 35
Maskuta Creek No. 1	Tp. 49	R. 26, W5M.	Section 26
McLeod River No. 1	Tp. 47	R. 23, W5M.	Section 22
North Saskatchewan No. 1	Tp. 39	R.16, W5M.	Section 25
Red Deer River No. 3	Tp. 31	R. 8, W5M.	Section 11
Smallpox Creek No. 1	Tp. 38	R. 15, W5M.	Section 34
South Pembina River No. 1	Tp. 46	R. 21, W5M.	Section 7
Thistle Creek No. 1	Tp. 44	R. 21, W5M.	Section 10
Thistle Creek No. 3	Tp. 44	R. 19, W5M.	Section 21
Whitewater Creek No. 1	Tp. 41	R. 18, W5M.	Section 36

* Not described



LOCATION MAP

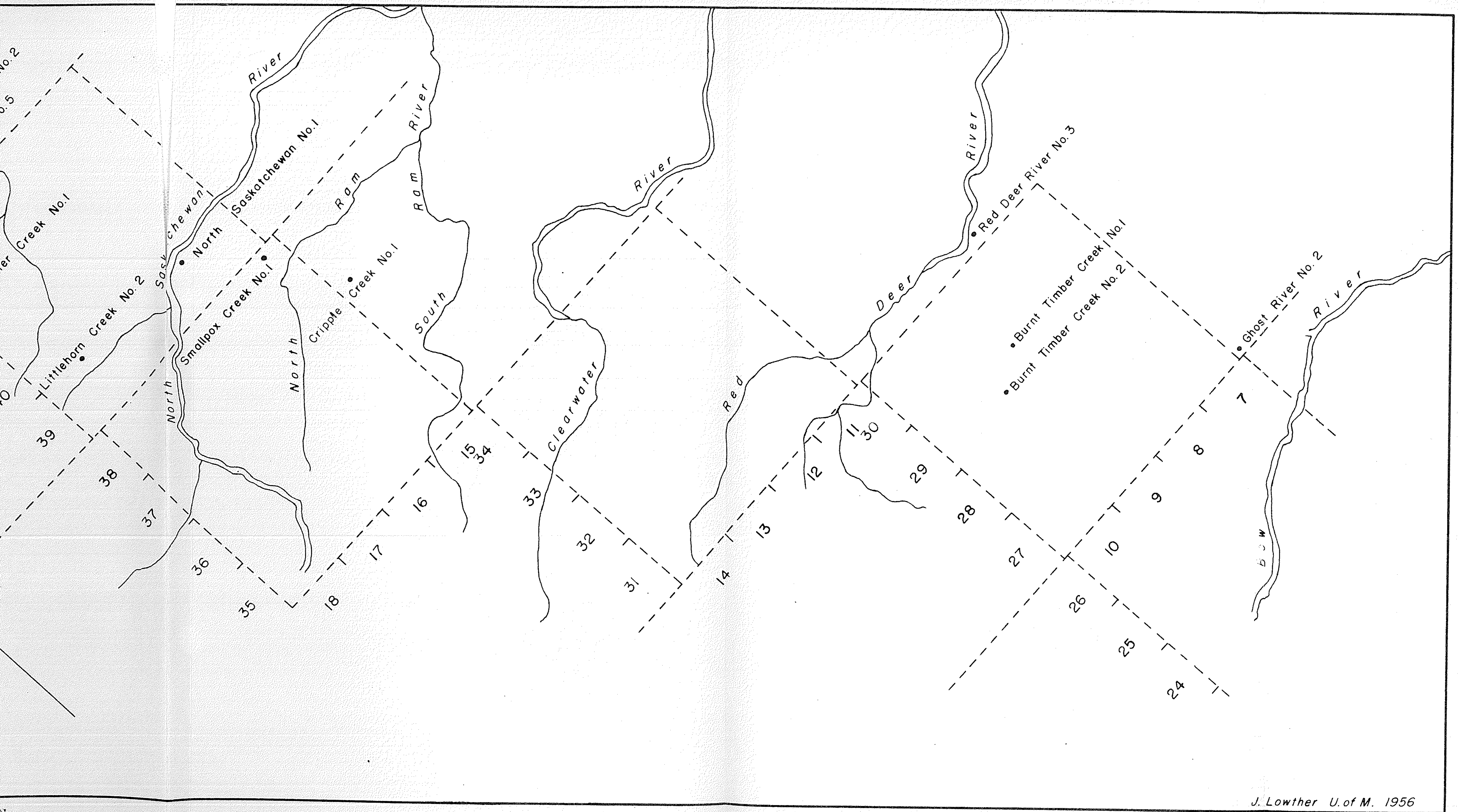
OF

LITHOLOGIC SECTIONS

OF

SOLOMON SANDSTONE

1 INCH = 8 MILES


North Saskatchewan River
Saskatchewan No.1
North
Smallpox Creek No.1
Littlehorn Creek No.2
Creek No.1
Ram River
South Ram
North Cripple Creek No.1
Clearwater River
Red Deer River
Red Deer River No.3
Burnt Timber Creek No.1
Burnt Timber Creek No.2
Ghost River No.2
Bow River
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J. Lowther U. of M. 1956

FIGURE V

BROWN CREEK NO. 1

Township 43, Range 18, W5M, Section 35

	Overlain by shale; fine-grained, dark grey, non-calcareous, slightly sandy, thin-bedded (¼").
0 - 6'	Conglomerate: coarse-grained sandy matrix, medium grey, non-calcareous, slightly argillaceous, containing abundant well-rounded pebbles to ½" diameter of black and brown chert, medium-bedded. From 2 - 6 feet pebbles are not too common.
6 - 44'	Sandstone: medium to coarse-grained, medium grey, argillaceous, non-calcareous, more argillaceous sand interlensed, thin-bedded (½" - 4"). Lower 20 feet of unit becomes less argillaceous.
44 - 54'	Sandstone: fine-grained, dark grey, non-calcareous, very argillaceous, almost sandy shale, thin-bedded (½" - 1"). Has lenses and thin interbeds of less argillaceous, cleaner sand.
54 - 83'	Covered.
83 - 99'	Shale: fine to very fine-grained, dark grey, non-calcareous, very sandy and silty, thin to platy bedded (to 1"). Has a few irregular lenses of sandstone down to 99'.
99 - 128'	Interbedded shale as in unit (83' - 99') and sandstone: dark grey, medium-grained, argillaceous, non-calcareous, thin-bedded (2"). To 109' the sandstone is the predominant lithology. From 109' the lithologies are the same with the shale comprising 60 to 65 percent of the thickness.
128 - 163'	Covered.
163 - 174'	Sandstone: medium to coarse-grained, dark grey, very argillaceous, non-calcareous, thin irregular bedding (2"), friable, soft.

174 - 203' Interbedded sandstone as in unit 163 - 174' and shale: dark grey, very fine-grained, sandy and silty, non-calcareous. Sand and shale are in about equal amounts.

203 - 214' Shale: as in interbedded unit 174 - 203' above.

214 - 219' Sandstone: medium to coarse-grained, dark grey, very argillaceous, non-calcareous, thin-bedded (3").

219 - 234' Shale: as in interbedded unit 174 - 203' above.

BURNT TIMBER CREEK NO. 2
Township 29, Range 9, W5M

Overlain by shale: fine-grained, dark grey, silty and sandy in places, calcareous in part, white mica flakes present, weathers brown to rusty brown.

0 - 8' Sandstone: fine to medium-grained, dark grey to black, argillaceous, non-calcareous, thin-bedded, both frosted and clear quartz grains, dark grains common, trace of glauconite.

8 - 35' Sandstone-Siltstone: very fine-grained, medium to dark grey, very argillaceous, non-calcareous, thin-bedded (2"), some larger quartz grains, both clear and frosted.
By 12 feet this sand is interlensed and/or interbedded with fine to medium-grained type of sand which is very glauconitic and has scattered white mica flakes present.
By 20 feet a few beds of rusty-weathering concretions of grey calcareous siltstone with coarse-crystalline calcite along fractures.

35 - 130' Sandstone: fine-grained, medium to dark grey, argillaceous, non-calcareous, thin-bedded, glauconitic, white mica flakes common. Ironstone concretions also contain glauconite. By 60 feet sand is becoming cleaner and has fewer dark grains present. By 70 feet glauconite is rare to absent, but white mica flakes consistently present. From 100 feet becoming very fine-grained.

130 - 165'	Sandstone: very fine to fine-grained, dark grey, fairly argillaceous, non-calcareous, thin-bedded (2") very glauconitic. By 160 - 165 feet the glauconite is not evident.
165'	Likely base of Solomon - similar lithology but becoming much more argillaceous.

CARDINAL RIVER NO. 2
Township 45, Range 20, W5M, Section 13

0 - 4'	Sandstone: fine-grained, greenish-grey, argillaceous, non-calcareous, conglomeratic, contains small scattered, well-rounded pebbles of black chert.
5 - 9'	Covered.
9 - 15'	Sandstone: fine to medium-grained, grey-green, conglomeratic with small scattered pebbles of black chert. Lower 2 feet is coarser-grained and contains rusty-weathering concretions of medium grey, micro-crystalline ironstone.
15 - 17'	Shale: very fine-grained, sandy-silty, medium grey, platy-bedded to 1/8".
17 - 28'	Sandstone: fine-grained, medium to dark grey, argillaceous, non-calcareous, platy to thin-bedded (2"), white mica flakes present but not too abundant, some carbon films. Interlensed with sandstone of similar lithology but very fine-grained almost to a siltstone.
28 - 66'	Covered.
66 - 92'	Sandstone: fine to very fine-grained, medium grey, non-calcareous, argillaceous, hard, medium to thick-bedded, contains yellowish-brown flecks throughout. From 70 feet glauconite grains present. Contains rusty-weathering concretions of medium grey, non-calcareous ironstone material which also contains glauconite. Lower 10 feet becomes darker grey with tiny flakes and minute books of white mica visible.

92 - 163'	Gradational contact to
	Sandstone-Siltstone: very fine-grained, medium grey, very argillaceous, thin-bedded, contains angular shale fragments near base. Rusty-weathering concretions of dark grey, calcareous in part, ironstone-siltstone material. From 98' - 109' the argillaceous content increases. Concretions common in intervals from 117 - 122' and 134 - 143'.
163'	Base of Solomon sandstone. Gradational to and underlain by shale: dark grey, non-calcareous, silty, yellow-weathering, grading into typical Wapiabi lithology.

CHUNGO CREEK NO. 5
Township 43, Range 17, W5M, Section 7

	Overlain by platy-bedded (¼") medium green, fine-grained, non-calcareous sandstone of Transition Zone.
0 - 2'	Sandstone: medium-grained, medium grey-green in color, non-calcareous, medium bedded (1'), cross-bedding visible, dark grains common, contains few well-rounded small pebbles (3/16") of black chert, quartz grains are frosted, high percentage of chert grains in sand (10%).
2 - 22'	Covered.
22 - 23'	Sandstone: fine-grained, medium-greenish-grey, non-calcareous, medium-bedded, abundant dark grains.
23 - 27'	Sandstone: similar to sand in unit 22 - 23' but is coarse-grained and calcareous. Long axes of grains are notably parallel to the bedding; trace of glauconite.
27 - 77'	Covered.

77 - 82'	Sandstone: fine-grained, medium greenish-grey, slightly calcareous, quartz grains clear and frosted, poorly sorted, minor flakes of biotite and grains of glauconite.
82 - 87'	Covered.
87 - 92'	Sandstone: very similar to unit 77 - 82' above.
92 - 112'	Covered.
112 - 117'	Sandstone: medium-grained, medium greyish-green, abundant dark grains which are smaller than the quartz grains, slightly calcareous, quartz grains are quite angular and frosted; rock has a tight, interlocking texture.
117 - 123'	Covered.
123 - 130'	Sandstone: very similar to sandstone unit 112 - 117' above.
130 - 152'	Covered.
152 - 172'	Sandstone: medium-grained, medium to dark greenish-grey, slightly argillaceous, slightly calcareous, discontinuous shaly banding, dark grains appear more angular than quartz grains; concentration of dark grains causes parting planes parallel to the bedding, very well-cemented almost quartzitic in places.
172 - 179'	Covered.
179 - 189'	Sandstone: medium-grained, medium greenish-grey, calcareous, quartz grains mostly angular, thick-bedded (1' - 2'), abundant fine-grained and interstitial chert, some kaolin in the siliceous cement, plagioclase grains present (3%), poorly sorted, abundant dark grains present in the sand.
189 - 194'	Covered.
194 - 199'	Sandstone: very similar to unit 179 - 189'.
199 - 202'	Covered.

202 - 213'	Sandstone: fine-grained, medium greyish-green, non-calcareous, very argillaceous, thin-bedded, (1"), poor to negligible porosity, weathers recessively medium greenish-grey.
213 - 220'	Sandstone: fine to medium-grained, light greenish-grey, thick-bedded (2'), non-calcareous, weathers same color, twinned plagioclase grains present (2%), grains very angular, some sign of secondary growth on quartz grains, minor mica flakes.
220 - 232'	Covered.
232 - 237'	Sandstone: similar to unit 213 - 227' above, dark grains show bedding well, abundant chert grains.
237 - 245'	Covered.
245 - 260'	Sandstone: as in unit 213 - 220' above.
	Base of Solomon.

CRIPPLE CREEK NO. 1

Township 37, Range 14, W5M, Section 20

Overlain by a covered interval of approximately 50 feet which is in turn overlain by sandstone: light greenish-grey, coarse-grained, typical of Brazeau formation.

0 - 1'	Conglomerate: coarse-grained, sandy matrix, rusty-brown, argillaceous, non-calcareous, containing abundant pebbles ($\frac{1}{4}$" - $\frac{1}{2}$") of grey and black chert which are well-rounded.
1 - 40'	Sandstone: coarse-grained, dark greyish-brown to dark brown in color, thin-bedded, bedded poorly, with knobby appearance, argillaceous, non-calcareous, weathers medium grey. The sand becomes more resistant and harder near the base of the unit.

40 - 50'	Inaccessible - appears similar to sand in unit 1 - 40', but possibly finer-grained.
50 - 60'	Sandstone: medium to fine-grained, dark grey, very argillaceous, non-calcareous, thin irregular bedding, poor porosity.
60 - 105'	Two different lithologies are interlensed and/or interbedded: 1) Sandstone: medium to fine-grained, dark grey, hard, argillaceous, slightly calcareous in part, thin-bedded (6") 2) Sandstone: fine-grained, medium grey, argillaceous, non-calcareous, very glauconitic, medium bedded (1" - 12"), fine banding shows cross-bedding, some sericite in matrix. These two lithologic types are present in about equal amounts.
105 - 145'	Covered.
145 - 190'	Sandstone: medium-grained, dark grey, very argillaceous, non-calcareous, poorly bedded (6"), contains a few platy cross-bedded banded beds which are less argillaceous. At 155 feet a few rusty-weathering calcareous concretions of argillaceous and siliceous material. From 171 to 180 feet sand is slightly calcareous.
190 - 215'	Sandstone: very similar to unit 145 - 190' but is fine-grained and exceedingly argillaceous, almost a sandy shale.
215 - 232'	Sandstone: fine-grained, dark grey, non-calcareous, argillaceous, but much less argillaceous than unit 190 - 215', poorly bedded (6") weathers dark grey.
232 - 255'	Sandstone: very similar to last sandstone unit (215 - 232') but very glauconitic.
255'	Covered and underlain by hard grey shale and thin sandstone beds.

Overlain by a covered interval of approximately 50 feet which is in turn overlain by typical thick-bedded grey-green Belly River sandstone.

0 - 155' Shale: fine-grained, medium to dark grey, very sandy, could almost be described as an argillaceous sandstone, non-calcareous, well-developed thin bedding (¼"), contains a few 1" and 2" beds of tight, slightly cleaner more resistant sandstone which weathers light grey. At 20 feet a bed of concretions of ironstone, micro-granular, dark grey, non-calcareous with 8" diameter, weathering yellow-brown. At 55 feet a similar bed of concretions occurs, but the shale surrounding these concretions is very glauconitic.
Lithology is remarkably constant.
At 85, 90, 110, 112 and 148 feet beds of concretions occur of similar material to those at 20 feet.

155' Base of Section - outcrop was still available but it was inaccessible.

LITTLEHORN CREEK NO. 2
Township 39, Range 18, W5M, Section 35

Overlain by a covered recessive zone of approximately 100 feet stratigraphic, and this in turn overlain by medium to coarse-grained Brazeau sandstone.

0 - 74' Sandstone: fine to medium-grained, medium rusty-brown, non-calcareous, iron oxide coating on grains, thin-bedded (6"), grains sub-angular to sub-rounded, clear and frosted, abundant dark grains. At 15 feet thin conglomerate lens with matrix of sand as described above. Pebbles are of white to black chert and about ½" in diameter. At 25 feet minor potash feldspar noted. At 32 feet more conglomerate interlensing. Cross-bedding common. At 41 feet more conglomerate interlensing.

74 - 87'	Sandstone: fine-grained, medium to light grey, non-calcareous, slightly argillaceous, becoming thinner bedded (2" to 3") and well-banded. By 84 feet sand becomes brownish-grey in color.
87 - 112	Covered.
112 - 133'	Sandstone: coarse-grained, light to medium grey, non-calcareous, medium to thick-bedded (2'), abundant dark grains present, rusty flecks appear throughout the rock, rare grains of glauconite, tightly packed. After 123 feet no glauconite present.
133 - 164'	Sandstone: medium to fine-grained, rusty brown, non-calcareous, slightly argillaceous, medium bedded, white and dark mica flakes visible. By 140 feet bedding is thin to medium (1" - 12").
164 - 172'	Sandstone: fine-grained, dark brownish-grey, non-calcareous, white mica flakes visible, thin-bedded (6") to medium (12").
172 - 192'	Covered.
192 - 196'	Sandstone: fine to very fine-grained, medium grey, non-calcareous, thin to medium bedded (1" - 8"), sand is glauconitic with exceptional development of glauconite along bedding planes, fine banding (1/16").
196'	Covered - Base of outcrop.

MASKUTA CREEK NO. 1

Township 49, Range 26, W5M, Section 26

Overlain by a 22-foot covered interval which in turn is overlain by sandstone: fine-grained, light greenish-grey, very calcareous, platy-bedded (3/4"); weathers recessively greenish-brown.

0 - 5'	Conglomerate: fine to medium-grained, sandy matrix; greyish-green, slightly argillaceous, thin-bedded (3") rare scattered pebbles ½" in diameter of black chert.
5 - 7'	Covered.
7 - 10'	Sandstone: medium to coarse-grained, light greenish-grey, calcareous in part, porous sub-angular to sub-rounded, clear and frosted quartz grains, abundant dark grains present, also some white mica flakes.
10 - 30'	Sandstone: fine to medium-grained, light greenish-grey, non-calcareous, thin to medium-bedded (1" to 1'), white mica flakes becoming quite common, clear and frosted quartz grains, becoming slightly calcareous in part after 20 feet.
30 - 90'	Sandstone: similar to last sandstone above (10 - 30') but becoming medium rusty-brown. Each grain is coated with iron oxide, minor glauconite present. By 50 feet sandstone is dark rusty brown in color. Thin-bedded (3"). Glauconite is abundant at 77 feet. After 80 feet sand is gradually losing deep brown color.
90 - 120'	Sandstone: fine to medium-grained, greyish-green, fairly calcareous, thin to medium-bedded (1" to 1') fine (1/16") banding visible on fresh surface, quartz grains mostly frosted and sub-angular, dark grains common in sand, glauconite very minor, weathers medium brown to a depth of 1/4". Tiny cavities may indicate solution. Becoming light grey by 110 feet.

Base of exposed strata.

MCLEOD RIVER NO. 1
Township 47, Range 23, W5M, Section 22

	Overlain by shale: fine-grained, dark grey to black, non-calcareous, thin-bedded ($\frac{1}{2}$") weathering recessively with respect to underlying sandstone.
0 - 1'	Conglomerate: fine, sandy matrix, quite badly weathered to a rusty-brown color. Abundant pebbles of black chert 1$\frac{1}{2}$" in diameter.
1 - 16'	Sandstone: fine-grained, medium rusty-brown, non-calcareous, minor white mica flakes visible, abundant dark grains, all grains coated with iron oxide. About 75% quartz.
16 - 90'	Sandstone: as in unit 1 - 16' but changing color from brown to greenish-grey. At 23 feet is platy-bedded for 1 foot - good fossil zone. Sand becomes finer-grained and medium-bedded by 50 feet. Grains sub-angular to sub-rounded.
90 - 100'	Sandstone: similar to unit 1 - 16' but has well developed shaly partings.
100 - 105'	Sandstone: fine to very fine-grained, medium greyish-green, argillaceous, fairly calcareous in part; thin to medium-bedded (8"), weathers green-grey.
105 - 128'	Sandstone: similar to unit 100 - 105' but not calcareous.
128 - 150'	Sandstone: as in unit 100 - 105' but becoming mostly thin-bedded with recessive 1-foot intervals of dark greenish-grey, non-calcareous sandy shale.
	Covered below.

NORTH SASKATCHEWAN NO. 1
Township 39, Range 16, W5M, Section 25,
Lsd's. 8 and 9

	Overlain by shale: very fine-grained, dark grey to black, silty, non-calcareous.
0 - 20'	Siltstone: fine to very fine-grained, dark grey to black, argillaceous, non-calcareous, thin-bedded (3") interlensed with a fine to medium-grained sandstone which is cleaner. Glauconite developed locally, most common in the cleaner sand lenses, white mica flakes quite common, minor carbonaceous and coally stringers. Very little glauconite from 15 feet.
20 - 80'	Inaccessible cliff.
80 - 137'	Siltstone: interlensed with sandstone as in unit 0 - 20' above, glauconite is rare to absent. By 110 feet glauconite is absent, white mica flakes still common. By 125 feet unit becomes more argillaceous for about 10 feet.
137 - 160'	Covered.
160 - 190'	Siltstone-Sandstone: very fine-grained, dark grey, argillaceous, non-calcareous, very similar to unit 80 - 137' above, but is more shaly. Glauconite is more common but white mica becoming rare. From 175 feet the rock is less well-indurated. By 180 feet, white mica is common again. By 190 feet glauconite is absent.
190'	Gradational lower contact of Solomon. Underlying lithology is similar but grading into shale after 10 feet; no glauconite.

SOUTH PEMBINA RIVER NO. 1
Township 46, Range 21, W5M, Section 7

	Overlain by a covered interval but chert pebbles ½" to 1½" diameter occur right above outcrop.
0 - 48'	Sandstone: fine to medium-grained, light greyish-brown in color, calcareous in part, slightly argillaceous, thin-bedded (1" to 3") weathers light greenish-grey. After 10 feet no longer calcareous.
48 - 100'	Sandstone: similar to unit 0 - 48' but is finer (fine) grained and banded on weathered surface, calcareous in part and weathers rusty-brown. By 73 feet the sand is greenish-grey in color and thin to platy-bedded (1") and banding is no longer visible on weathered surface. From 85 to 95 feet the sand is medium bedded (1').
100 - 104	Covered.
104 - 106'	Sandstone: as last sandstone above.
106 - 107'	Siltstone: very fine-grained, dark grey, irregular bedding (4" to 6"), argillaceous, non-calcareous.
	Bottom of section.

THISTLE CREEK NO. 1
Township 44, Range 21, W5M, Section 10

Overlain by shale: very fine-grained, dark grey, non-calcareous, sandy-silty, fissile, weathering slightly recessively dark grey.

0 - 1'	Conglomerate: coarse-grained, sandy matrix, rusty-brown, non-calcareous, numerous well-rounded pebbles (1") of black and dark grey chert.
1 - 2'	Sandstone: coarse-grained, medium greyish-green, very slightly calcareous, siliceous, thin-bedded (6") weathers dark grey, contains rare scattered chert pebbles.
2 - 22'	Covered.
22 - 47'	Sandstone: medium to coarse-grained, greenish-grey, non-calcareous, medium-bedded (12") poor porosity, some interbedded rusty-brown bands present with prominent white mica content, weathers greyish-green to rusty-brown. Low angle cross-bedding is apparent on weathered surface. By 27 feet the brown sand is more common lithology.
47 - 52'	Covered.
52 - 85'	Sandstone: fine to medium-grained, mostly medium brown in color but some greenish-grey beds as well, non-calcareous, medium bedded (14") grains are angular and coated with iron oxide. Minor glauconite present.
84 - 119'	Sandstone: medium-grained, brownish-green in color, non-calcareous, medium-bedded (12"), poor porosity, weathers medium greyish-brown. By 95 feet the sand becomes calcareous but calcite present as individual grains, euhedra and subhedra, not as irregular matrix. Minor zircon grains present, very tightly packed. Fine-grained siltstone-ironstone concretions occur intermittently after 100 feet. At 100 feet a bed of fossil pelecypods, no glauconite present.
119 - 135'	Covered.
135 - 155'	Sandstone: fine-grained, medium brown in color, quartz grains angular to sub-angular calcite as grains common, but not as cement, siliceous, quartz grains coated with iron oxide, medium-bedded, rare glauconite.
155 - 157'	Covered.

157 - 162' Sandstone: medium to fine-grained, light greenish-brown, slightly calcareous, siliceous, thin to thick bedding (3" to 2'), fair porosity, slightly more glauconite present than in unit 135 - 155', angular to sub-angular grains, chert grains common, most grains coated with iron oxide.

162' Base of Solomon Sandstone.

Underlain by thin-bedded sandstone and shale.

THISTLE CREEK NO. 3
Township 44, Range 19, W5M, Section 21
Las. 2

Overlain by a covered interval with dark grey shale in minor talus.

0 - 3' Conglomerate: medium-grained sandy matrix greyish-brown, slightly calcareous in part, contains fairly abundant well-rounded pebbles ½" in diameter of grey to black chert, siliceous cement.

3 - 34' Sandstone: fine to medium-grained, medium to rusty-brown, non-calcareous, slightly argillaceous, medium to thick-bedded (10"-2'), weathers rusty-brown. Has minor lenses of pebble conglomerate. After 10 feet sand becomes fine-grained.

34 - 53' Sandstone: fine-grained, becoming light greyish-brown in color, slightly argillaceous, calcareous in part, medium-bedded (1'). Minor glauconite from 45 feet.

53 - 56' Covered.

56 - 76' Sandstone: fine-grained, medium grey, calcareous, thin to medium-bedded (8") weathers grey to black, glauconite trace to absent.

76 - 101' Sandstone: similar to unit 56 - 76', but no longer calcareous, no glauconite, rock seems less well-cemented.

101 - 113' Sandstone: similar to sandstone unit 56 - 76'. At 102' a fossil zone - pelecypods along bedding plane. Banding and cross-bedding visible on weathered surface.

113' Gradation contact to Wapiabi formation and interbedded shale, siltstone and sandstone.

WHITEWATER CREEK NO. 1

Township 41, Range 18, W5M, Section 36

Overlain by shale: fine-grained, dark grey, non-calcareous, silty, thin to platy bedded (1/8") poor porosity, weathers dark grey to reddish-rusty-brown, some thin (½") more silty bands weather more resistantly.

0 - 55' Sandstone: fine to medium-grained, medium to dark grey, argillaceous, slightly calcareous, calcite as subhedra not as interstitial material, chert common as grains and interstitial material to the quartz grains, quartz grains are sub-angular, thin-bedded (3") weathers dark grey. Individual beds show cross-bedding. Minor potash feldspar, quartz grains commonly fractured. By 25 feet shredded sericite flakes visible under microscope. At 35 feet zircon grains seen in thin section. At 43 feet minor disseminated sulphide (pyrrhotite?) present for about 5 feet.

55 - 58'	Siltstone-Limestone: very fine-grained, dark grey, argillaceous, very calcareous, weathers light yellowish-grey, medium bedded (8" - 12"). Three beds separated by about 1" band of shale, fossiliferous mother of pearl preserved on pelecypods.
58'	Dark grey, argillaceous, thin-bedded sandstone.

B I B L I O G R A P H Y

Alberta Society of Petroleum Geologists (1954) Lexicon of Geologic Names in Alberta.

Allan, J.A.: (1914) Geology of Field Map Area, B.C. and Alberta; Geol. Surv. Canada, Mem. 55.

Bailey, E.B.: (1930) New light on Sedimentation and Tectonics; Geological Magazine, Vol. 67, pp. 77-92.

Barrel, J.: (1925) Marine and Terrestrial Conglomerates; Bull. Geological Society America, Vol. 36, pp. 279-342.

Bates, Robert L.: (1938) Occurrence and Origin of Certain Limonite Concretions; Jour. Sed. Petrol., Vol. 8, pp. 91-99.

Cloud, Preston E. Jr.: (1955) Physical Limits of Glauconite Formation; Bull. Amer. Assoc. Petrol. Geol., Vol. 39, No. 4, pp. 484-492.

Daly, R.A.: (1915) A Geological Reconnaissance Between Golden and Kamloops, B.C., along the Canadian Pacific Railway; Geol. Surv. Canada, Mem. 68.

Dapples, E.C.: (1947) Sandstone Types and Their Associated Depositional Environments; Jour. Sed. Petrol., Vol. 17, No. 3, pp. 91-100.

_______, Krumbein, W.C., and Sloss, L.L.: (1953) Petrographic and Lithologic Attributes of Sandstones; Jour. Geol., Vol. 61, No. 4, pp. 291-317.

_______, (1948) Tectonic Control of Lithologic Associations; Bull. Amer. Assoc. Petrol. Geol., Vol. 32, No. 10, pp. 1924-1947.

Dowling, D.B.: (1915) The Cretaceous Sea in Alberta; Trans. Roy. Soc. Can., Sect. IV, pp. 27-42.

Eardley, A.J.: (1951) Structural Geology of North America; Harper and Sons, New York, 624 pages.

Erdman, O.A.: (1946) Cripple Creek, Alberta, Map and Descriptive Notes; Geol. Surv. Canada, Paper 46-22.

_______, (1950) Alexo and Saunders Map-areas, Alberta; Geol. Surv. Canada, Mem. 254.

Fleming, R.H. and Revelle, R.: (1939) Physical Processes in the Ocean; Recent Marine Sediments (Amer. Assoc. Petrol. Geol.,) pp. 48-141.

Folk, Robert L.: (1951) Stages of Textural Maturity in Sedimentary Rocks; Jour. Sed. Petrol., Vol. 21, pp. 127-130.

__________, (1954) The Distinction Between Grain Size and Mineral Composition in Sedimentary Rock Nomenclature; Jour. Geol. Vol. 62, No. 4, pp. 344-359.

Galliher, E. Wayne,: (1935) Glauconite Genesis; Bull. Geol. Soc. Amer., Vol. 46, pp. 1351-1366.

__________, (1935) Geology of Glauconite; Bull. Amer. Assoc. Petrol. Geol., Vol. 19, No. 11, pp. 1569-1607.

Gilbert, C.M.: (1949) Cementation of Some California Tertiary Reservoir Sands; Jour. Geol., Vol. 57, No. 1, pp. 1-17.

Gleddie, Joseph,: (1949) Upper Cretaceous in Western Peace River Plains, Alberta; Bull. Amer. Assoc. Petrol. Geol., Vol. 33, No. 4, pp. 511-532.

Goldstein, A. Jr.: (1950) Mineralogy of Some Cretaceous Sands of Colorado Front Range; Jour. Sed. Petrol. Vol. 20, No. 2, pp. 85-97.

Goodman, A.J.: (1951) Tectonics of East Side of Cordillera in Western Canada; Bull. Amer. Assoc. Petrol. Geol., Vol. 35, No. 4, pp. 783-796.

Graham, William, A.P.: (1930) A Textural and Petrographic Study of the Cambrian Sandstones of Minnesota; Jour. Geol., Vol. 38, pp. 696-716.

Hake, B.F., Willis, Robin, and Addison, C.C.: (1942) Folded Thrust Faults in the Foothills of Alberta; Bull. Geol. Soc. Amer., Vol. 53, No. 2, pp. 291-334.

Hatch, F.H., Rastall, R.H., and Black, Maurice,: (1938) The Petrology of the Sedimentary rocks; Third edition. Thomas Murby and Company, 382 pages.

Hendricks, Sterling B., and Ross, Clarence S.: (1941) Chemical Composition and Genesis of Glauconite and Celadonite; Amer. Mineralogist, Vol. 26, No. 12, pp. 683-708.

Hume, G.S.: (1936) The West half of Wildcat Hills Map Area, Alberta; Can. Dept. Mines, Mem. 188.

__________, (1940) The Structure and Oil Prospects of the Foothills of Alberta Between Highwood and Bow Rivers; Geol. Surv. Canada, Paper 40-8.

Irish, E.J.W.: (1951) Pierre Greys Lakes Map Area, Alberta; Geol. Surv. Canada, Mem. 258, pp. 30-31.

King, C.A.M.: (1951) Depth of Disturbance of Sand on Sea Beaches by Waves; Jour. Sed. Petrol., Vol. 21, No. 3, pp. 131-140.

Krumbein, W.C.: (1932) The Mechanical Analysis of Fine Grained Sediments; Jour. Sed. Petrol., Vol. 2, No. 3, pp. 140-149.

__________, (1941) Measurement and Geological Significance of Shape and Roundness of Sedimentary Rock Particles; Jour. Sed. Petrol., Vol. 11, pp. 64-72.

__________, (1941) The Effects of Abrasion on the Size, Shape and Roundness of Rock Fragments; Jour. Geol., Vol. 49, pp. 482-520.

__________, (1948) Lithofacies Maps and Regional Sedimentary Stratigraphic Analysis; Bull. Amer. Assoc. Petrol. Geol., Vol. 32, No. 10, pp. 1909-1923.

__________, and Sloss, L.L.: (1951) Stratigraphy and Sedimentation; W.H. Freeman and Company, San Francisco, California, 497 pages.

__________, and Garrels (1952) Origin and Classification of Chemical Sediments in Terms of pH and Oxidation-reduction Potentials; Jour. Geol., Vol. 60, No. 1, pp. 1-33.

Krynine, P.D.: (1948) The Megascopic Study and Field Classification of Sedimentary Rocks; Jour. Geol., Vol. 56, No. 2, pp. 130-165.

Lang, A.H.: (1938) Keithley Creek Map Area, Cariboo District, British Columbia. Preliminary Report; Geol. Surv. Canada, Paper 38-16.

__________, (1946) Brule and Entrance Map Areas, Alberta; Geol. Surv. Canada, Mem. 244.

Link, Theodore, A.: (1949) Interpretations of Foothills Structures, Alberta, Canada; Bull. Amer. Assoc. Petrol. Geol., Vol. 33, No. 9, pp. 1475-1501.

MacKay, B.R.: (1925) Mountain Park Sheet; Geol. Surv. Canada, Map 208A.

__________, (1925) Cadomin Sheet; Geol. Surv. Canada, Map 209A.

__________, (1940) Wapiabi Creek, Alberta, Preliminary Map; Geol. Surv. Canada, Paper 40-13.

__________, (1940) Grave Flats, Alberta, Preliminary Map; Geol. Surv. Canada, Paper 40-15.

__________, (1940) Pembina Forks, Alberta, Preliminary Map; Geol. Surv. Canada, Paper 40-16.

__________, (1940) George Creek, Alberta, Preliminary Map; Geol. Surv. Canada, Paper 40-17.

__________, (1941) Brazeau River, Alberta, Preliminary Map; Geol. Surv. Canada, Paper 41-4.

__________, (1941) Bighorn River, Alberta, Preliminary Map; Geol. Surv. Canada, Paper 41-9.

__________, (1943) Foothills Belt of Central Alberta, Preliminary Map; Geol. Surv. Canada, Paper 43-3.

__________, (1943) Wawa Creek, Alberta, Preliminary Map and Descriptive Notes; Geol. Surv. Canada, Paper 43-10.

Mansfield, G.R.: (1907) The Characteristics of Various Types of Conglomerates; Jour. Geol., Vol. 15, pp. 550-555.

McLearn, F.H., and Kindle, E.D.: (1950) Geology of Northeastern British Columbia; Geol. Surv. Canada, Mem. 259.

Packham, G.H.: (1954) Sedimentary Structures as an Important Factor in the Classification of Sandstones; Amer. Jour. Sci., Vol. 252, pp. 466-476.

Payne, Thomas, G.: (1942) Stratigraphic Analysis and Environmental Reconstruction; Bull. Amer. Assoc. Petrol. Geol., Vol. 26, No. 11, pp. 1697-1770.

Pettijohn, F.J.: (1949) Sedimentary Rocks; Harper and Brothers, New York, 526 pages.

_________, (1954) Classification of Sandstones; Jour. Geol. Vol. 62, No. 4, pp. 360-365.

Prather, J.K.: (1905) Glauconite; Jour. Geol., Vol. 13, No. 6, pp. 509-513.

Rice, H.M.A.: (1938) East Half Nelson Map Area, British Columbia, Preliminary Report; Geol. Surv. Canada, Paper 38-17.

Rich, J.L.: (1951) Three Critical Environments of Deposition, and Criteria for Recognition of Rocks Deposited in Each of Them; Bull. Geol. Soc. Amer., Vol. 62, pp. 1-20.

Rodgers, John,: (1950) The Nomenclature and Classification of Sedimentary Rocks; Amer. Jour. Sci., Vol. 248, pp. 297-311.

Russell, R. Dana,: (1949) Effects of Transportation on Sedimentary Particles. Recent Marine Sediments; Amer. Assoc. Petrol. Geol., pp. 32-47.

Rutherford, R.L.: (1925) Geology of the Foothills Belt Between McLeod and Athabasca Rivers, Alberta; Research Council of Alberta, Report No. 11.

_________, (1926) Geology of the Area Between North Saskatchewan and Embarras Rivers, Alberta; Research Council of Alberta, Report No. 15.

_________, (1927) Geology Along the Bow River Between Cochrane and Kananaskis, Alberta; Research Council of Alberta, Report No. 17.

_________, (1928) Geology of the Area Between North Saskatchewan and McLeod Rivers, Alberta; Research Council of Alberta, Report No. 19.

Sanderson, J.D.G.: (1939) Geology of the Brazeau Area; Trans. Can. Ist. Min. Metall., Vol. 42, pp. 429-442.

Schofield, Stuart, J.: (1915) Geology of Cranbrook Map Area, British Columbia; Geol. Surv. Canada, Mem. 76.

Schuchert, Charles,: (1955) Atlas of Palaeogeographic Maps of North America; John Wiley and Sons, New York.

Scott, J.C.: (1951) Folded Faults in Rocky Mountain Foothills of Alberta, Canada; Bull. Amer. Assoc. Petrol. Geol., Vol. 35, No. 11, pp. 2316-2347.

Scruton, P.C.: (1950) Petrography and Environment of Deposition; Amer. Jour. Sci., Vol. 248, No. 66, pp. 408-426.

Smith, Laurence, L.: (1948) Hollow Ferruginous Concretions in South Carolina; Jour. Geol. Vol. 56, pp. 218-225.

Stott, D.F., (1956) The Alberta Group, Rocky Mountain Foothills, Alberta; Geol. Surv. Canada, Paper 56-1.

Takahashi, Jun-Ichi,: (1939) Synopsis of Glauconitization; Recent Marine Sediments, American Assoc. Petrol. Geol., pp. 503-512.

Tallman, S.L.: (1949) Sandstone Types: Their Abundance and Cementing Agents; Jour. Geol., Vol. 57, pp. 582-591.

Taylor, J.M.: (1950) Pore-Space Reduction in Sands; Bull. Amer. Assoc. Petrol. Geol., Vol. 34, No. 4, pp. 701-716.

Todd, J.E.: (1903) Concretions and Their Geological Effects; Bull. Geol. Soc. Amer., Vol. 14, pp. 353-368.

Twenhofel, W.H.: (1931) Environment in Sedimentation and Stratigraphy; Bull. Geol. Soc. Amer., Vol. 42, pp. 407-424.

________, (1949) Principles of Sedimentation; McGraw-Hill Book Company, New York, 610 pages.

__________, (1947) Environmentsl Significance of Conglomerates; Jour. Sed. Petrol. Vol. 17, pp. 119-128.

Wadell, Hakon,: (1932) Volume, Shape and Roundness of Rock Particles; Jour. Geol., Vol. 40, pp. 443-451.

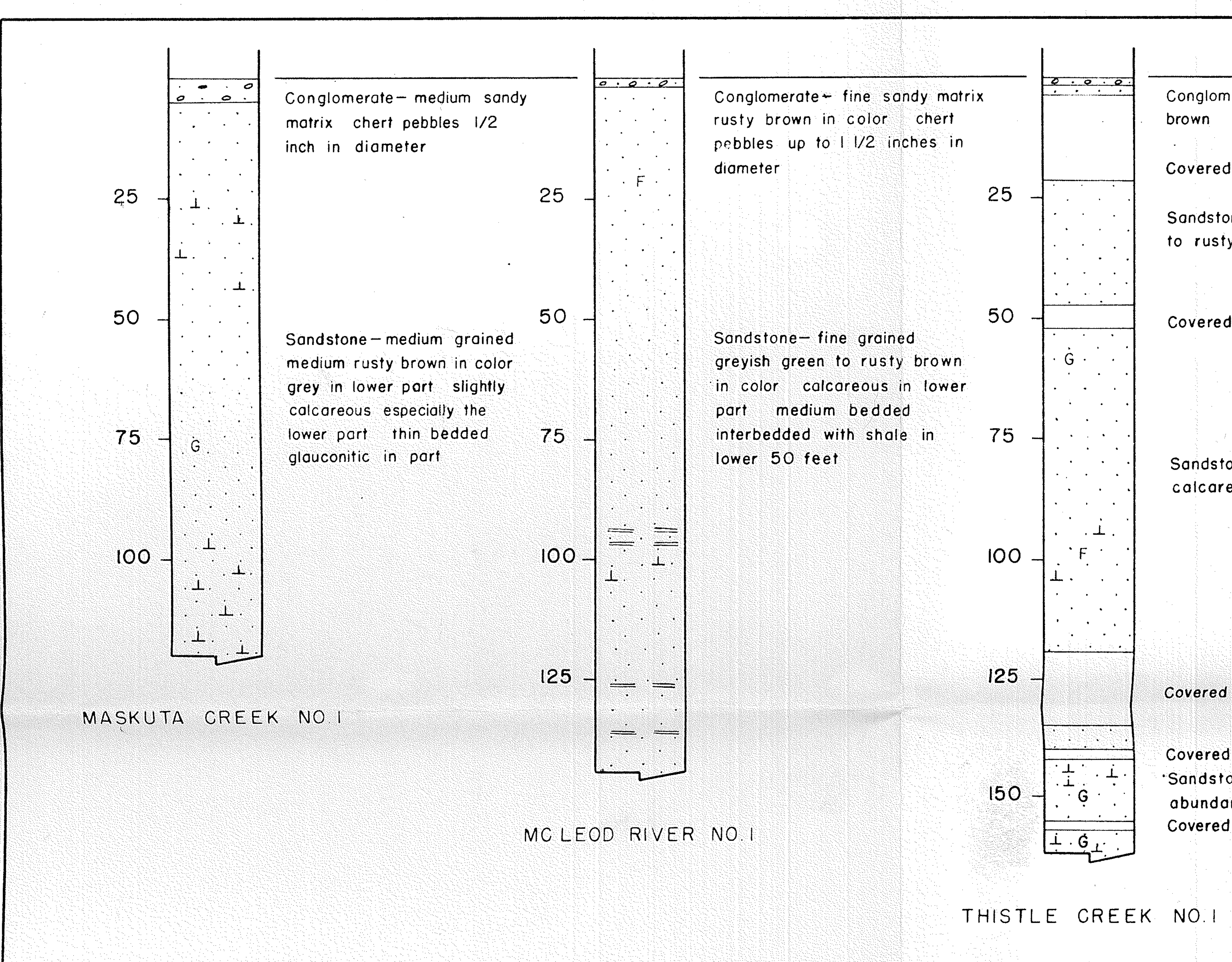
__________, (1933) Sphericity and Roundness of Rock Particles; Jour. Geol., Vol. 41, pp. 310-331.

Waldschmidt, W.A.: (1941) Cementing Materials in Sandstones, and Their Probable Influence on Migration and Accumulation of Oil and Gas; Bull. Amer. Assoc. Petrol. Geol., Vol. 25, pp. 1839-1879.

Walker, J.F., and Bancroft, M.F.: (1929) Lardeau Map Area, British Columbia; Geol. Surv. Canada, Mem. 161.

Webb, J.B., and Hertlein, L.G.: (1934) Zones in Alberta Shale in Foothills of Southwestern Alberta; Bull. Amer. Assoc. Petrol. Geol., Vol. 18, pp. 1387-1415.

Wentworth, Chester, K.: (1922) A Scale of Grade and Class Terms for Clastic Sediments; Jour. Geol., Vol. 30, pp. 377-392.



LITHOLOGIC SECTIONS OF

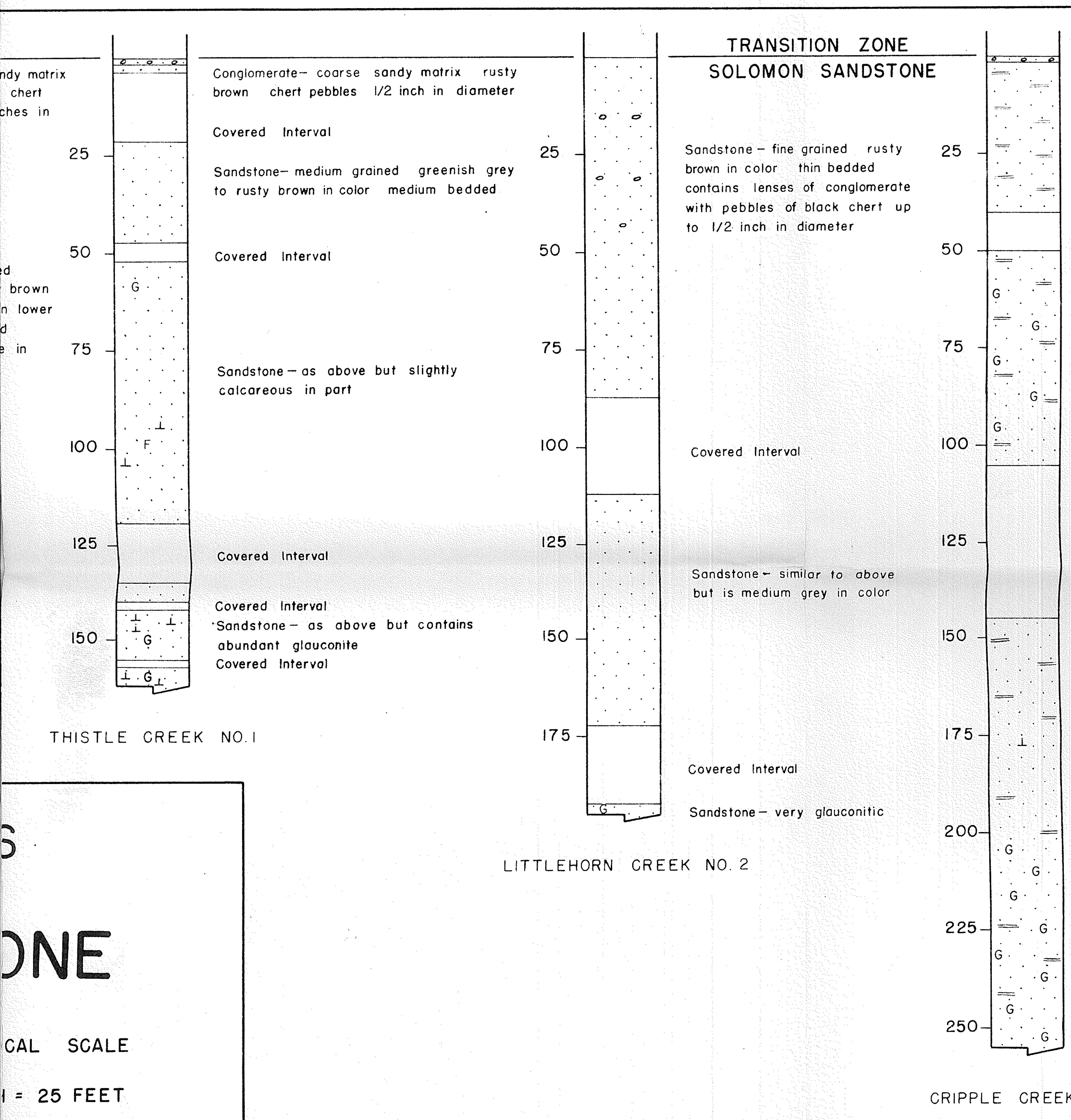
SOLOMON SANDSTONE

HORIZONTAL SCALE

I INCH = 8 MILES

VERTICAL SCALE

I INCH = 25 FEET


ndy matrix
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ches in
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25
50
75
100
125
150
175
200
225
250
Conglomerate– coarse sandy matrix rusty brown chert pebbles 1/2 inch in diameter
Covered Interval
Sandstone– medium grained greenish grey to rusty brown in color medium bedded
Covered Interval
Sandstone – as above but slightly calcareous in part
Covered Interval
Covered Interval
Sandstone – as above but contains abundant glauconite
Covered Interval
THISTLE CREEK NO. 1
TRANSITION ZONE
SOLOMON SANDSTONE
Sandstone – fine grained rusty brown in color thin bedded contains lenses of conglomerate with pebbles of black chert up to 1/2 inch in diameter
Covered Interval
Sandstone – similar to above but is medium grey in color
Covered Interval
Sandstone – very glauconitic
LITTLEHORN CREEK NO. 2
CRIPPLE CREEK
S
ONE
CAL SCALE
1 = 25 FEET

FIGURE VII

ONE
STONE

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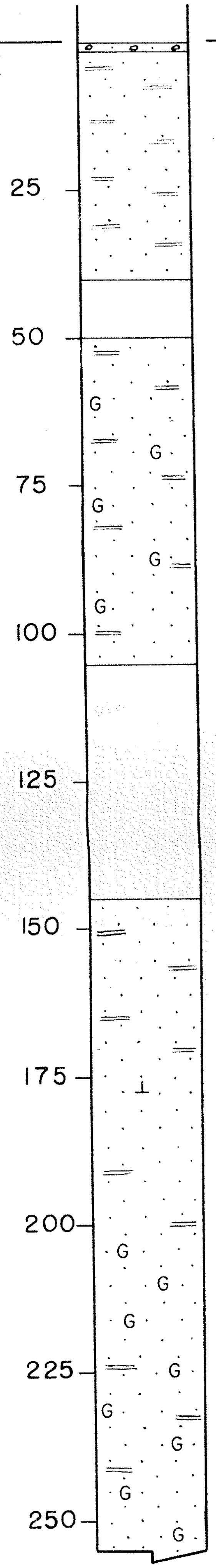


Conglomerate - coarse sandy matrix rusty brown chert pebbles 1/2 inch in diameter

Sandstone - medium grained medium grey to brown in color argillaceous contains lenses and interbeds of finer grained sand thin bedded

Covered Interval

Sandstone - as above but quite glauconitic

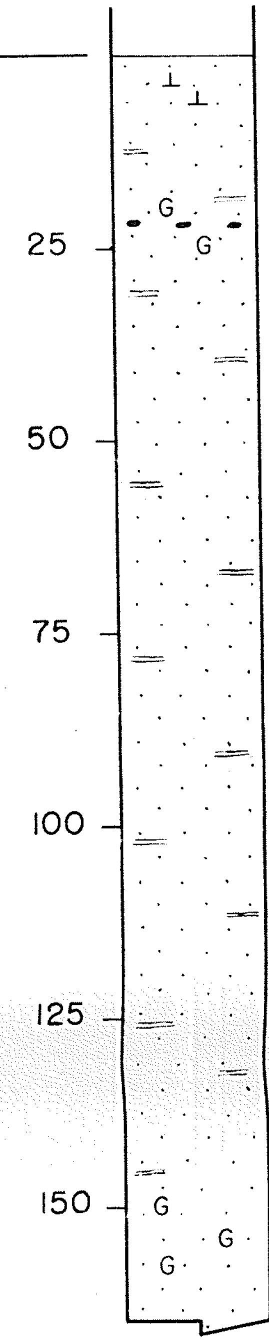
Covered Interval

Sandstone - as above but very glauconitic in lower part

CRIPPLE CREEK NO. I

Sandstone - coarse grained at top otherwise fine to medium grained dark grey to black argillaceous thin bedded Ironstone concretions in upper part

Sandstone - as above but very glauconitic near base



BURNT TIMBER CREEK NO. 2

Shale - fin
to black i
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concretion
some hav
associate

GURE VII

rusty
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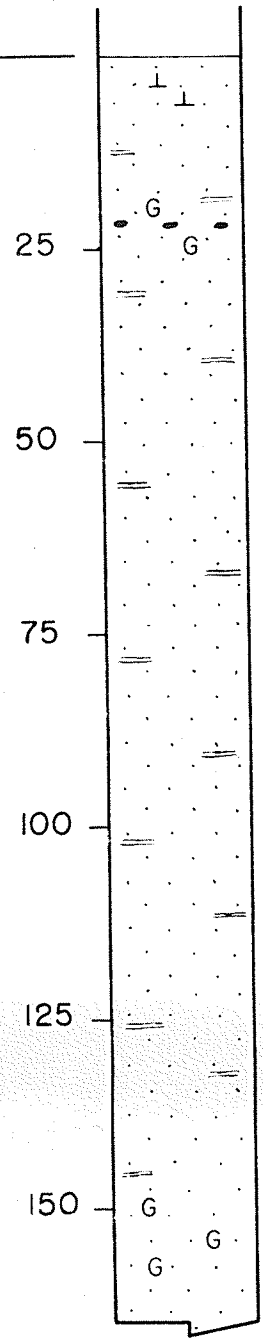
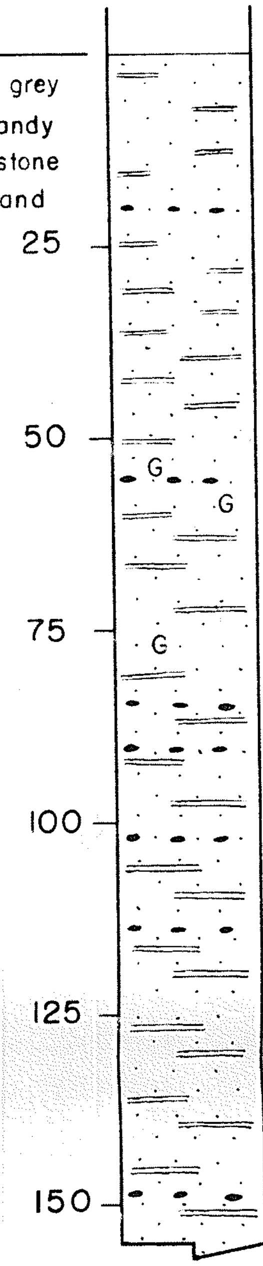
Sandstone – coarse grained at top otherwise fine to medium grained dark grey to black argillaceous thin bedded Ironstone concretions in upper part

Sandstone – as above but very glauconitic near base



BURNT TIMBER CREEK NO. 2

Shale – fine grained dark grey to black in color very sandy thin bedded beds of ironstone concretions are common and some have glauconite associated with them



GHOST RIVER NO. 2

J. Lowther U. of M. 1956

8

NIKANASSIN FORMATION

7 shale and sandstone

JURASSIC

FERNIE FORMATION

6 shale, sandstone, basal limestone

TRIASSIC

SPRAY RIVER FORMATION

5 brown weathering sandstone and shale, not always present

CARBONIFEROUS

PALEOZOIC

ROCKY MOUNTAIN QUARTZITE

4 not always described as separate unit

RUNDLE FORMATION

3 limestone

BANFF FORMATION

2 shale and sandy shale

DEVONIAN

1 limestone

9000

7000

5000

3000

STRUCTURAL SECTIONS ACROSS
CENTRAL FOOTHILLS
ALBERTA

HORIZONTAL SCALE

1 INCH = 1 MILE

VERTICAL SCALE

1 INCH = 1 MILE

LEGEND

PASKAPOO FORMATION

17 — sandstone, shale and conglomerate

UPPER CRETACEOUS

EDMONTON FORMATION

16 — sandstone, shale and conglomerate

BRAZEAU FORMATION

15 — sandstone and shale, conglomerate in lower part

WAPIABI FORMATION

14 — Solomon Sandstone

13 — black marine shale and sandy shale, ironstone concretions

BIGHORN FORMATION

12 — quartzitic sandstone and black marine shale

BLACKSTONE FORMATION

11 — black marine shale, sandy shale and sandstone

LOWER CRETACEOUS

MOUNTAIN PARK FORMATION

10 — sandstone, conglomerate and shale

LUSCAR FORMATION

9 — shale, sandstone, coal seams

CADOMIN CONGLOMERATE

8

NIKANASSIN FORMATION

7 — shale and sandstone

JURASSIC

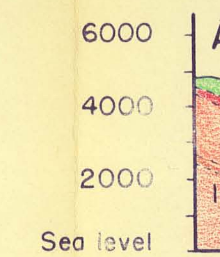
FERNIE FORMATION

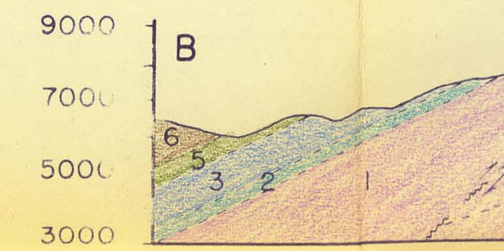
6 — shale, sandstone, basal limestone

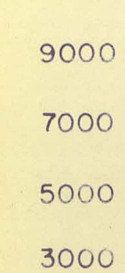
TRIASSIC

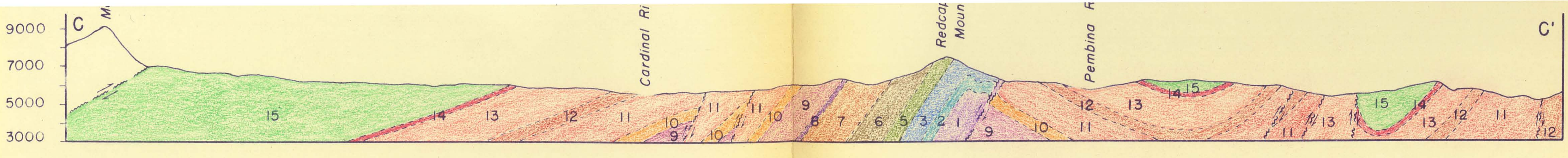
SPRAY RIVER FORMATION

MESOZOIC

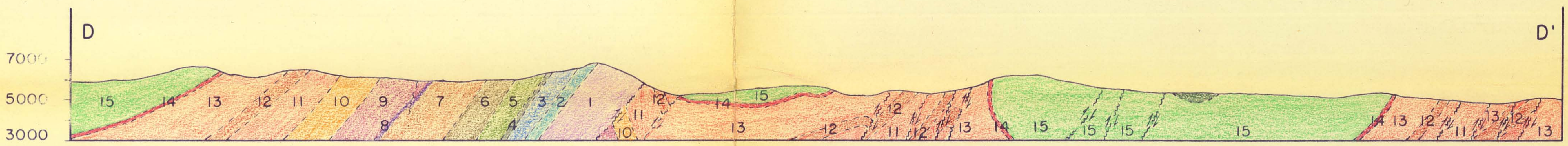




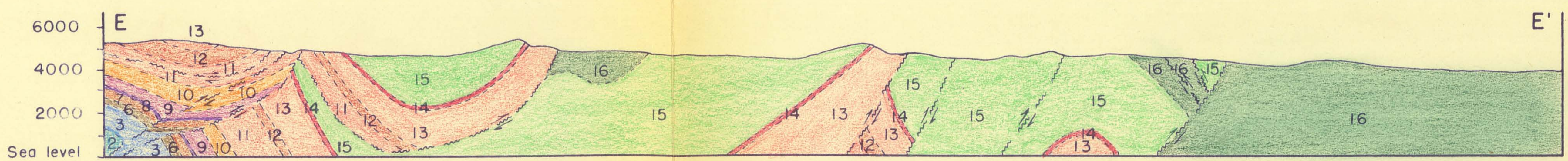




After B.R. MacKay Mountain Park Sheet

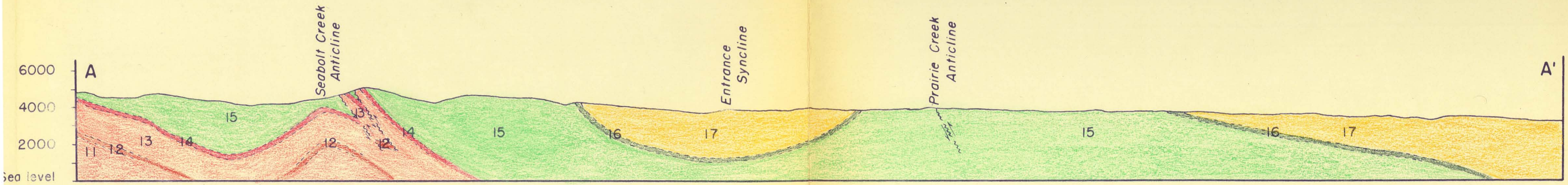


After B.R. MacKay George Creek Preliminary Map



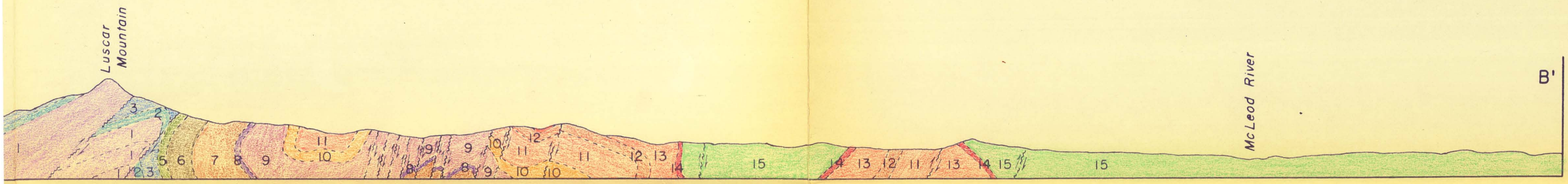
After B.R. MacKay Wawa Creek Preliminary Map

FIGURE VI



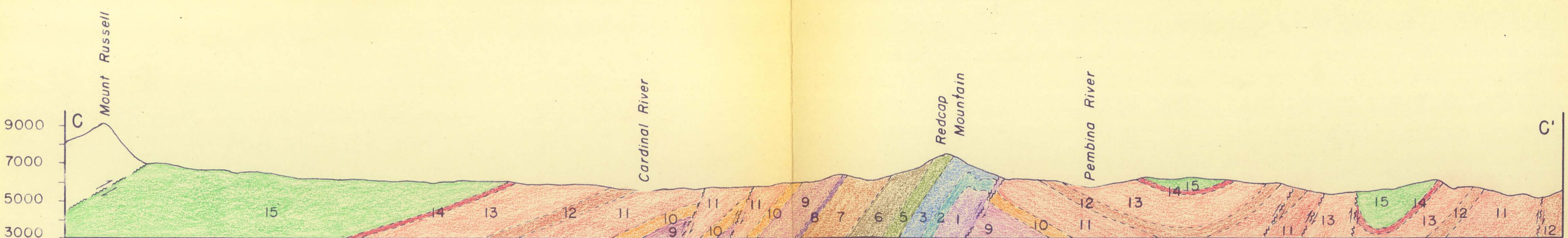
I

After A.H. Lang Brule and Entrance Map Areas



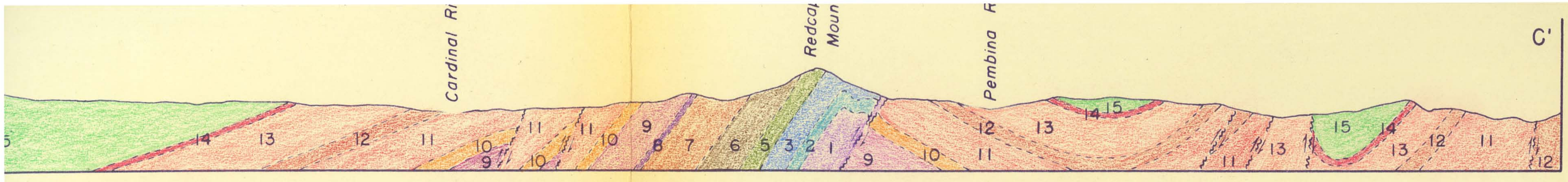
II

After B.R. MacKay Cadomin Sheet



III

After B.R. MacKay Mountain Park Sheet



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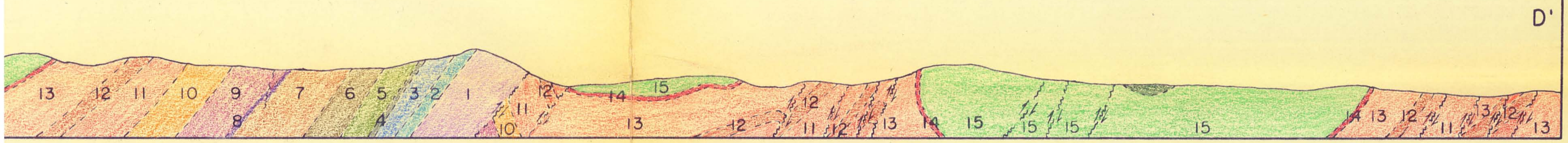
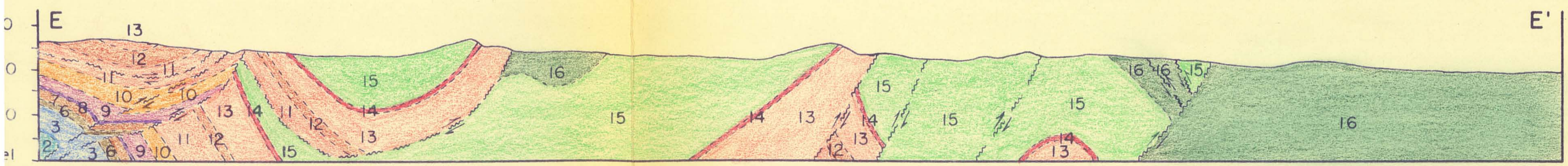


IV

After B.R. MacKay George Creek Preliminary Map

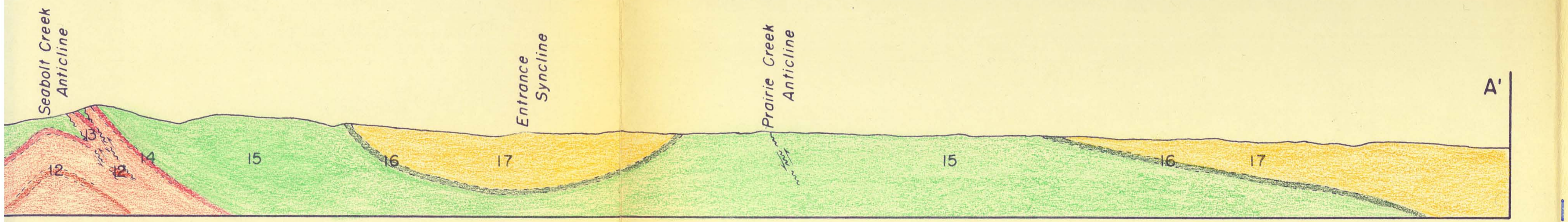


V

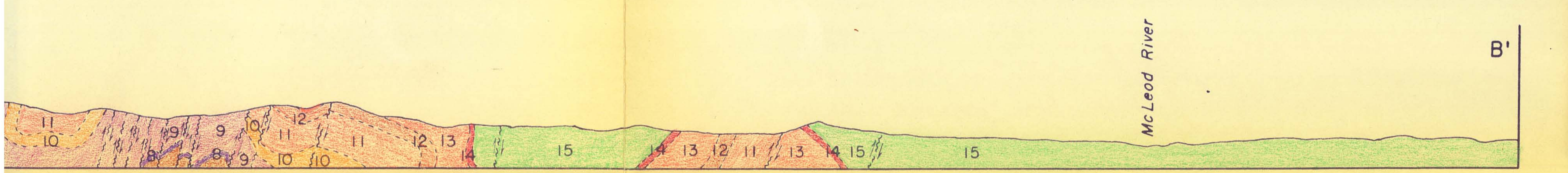
After B.R. MacKay Wawa Creek Preliminary Map

J. Lowther U. of M 1956

E VI

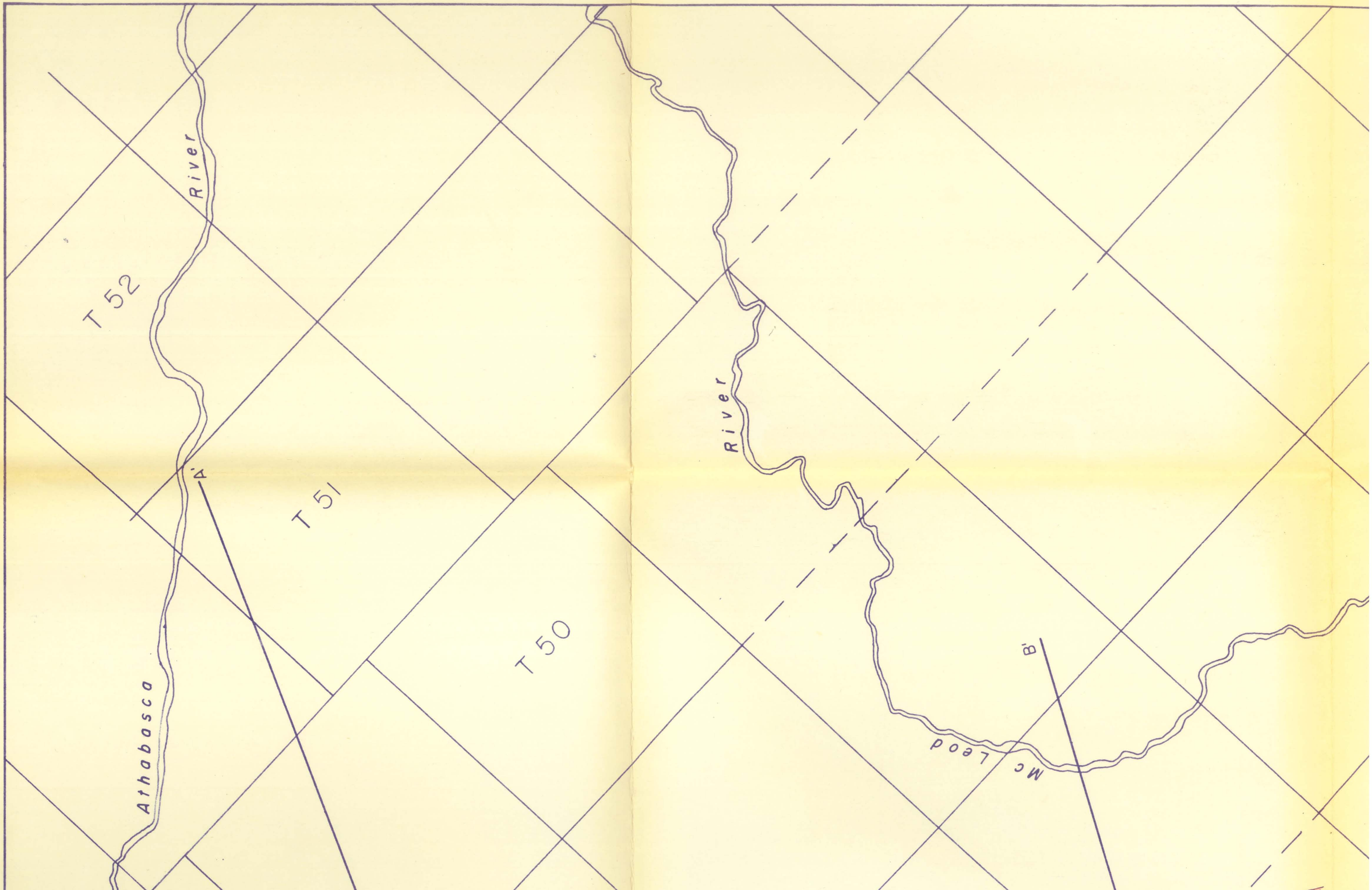


After A.H. Lang Brule and Entrance Map Areas



After B.R. MacKay Cadomin Sheet

After B.R. MacKay Mountain Park Sheet


T 52
River
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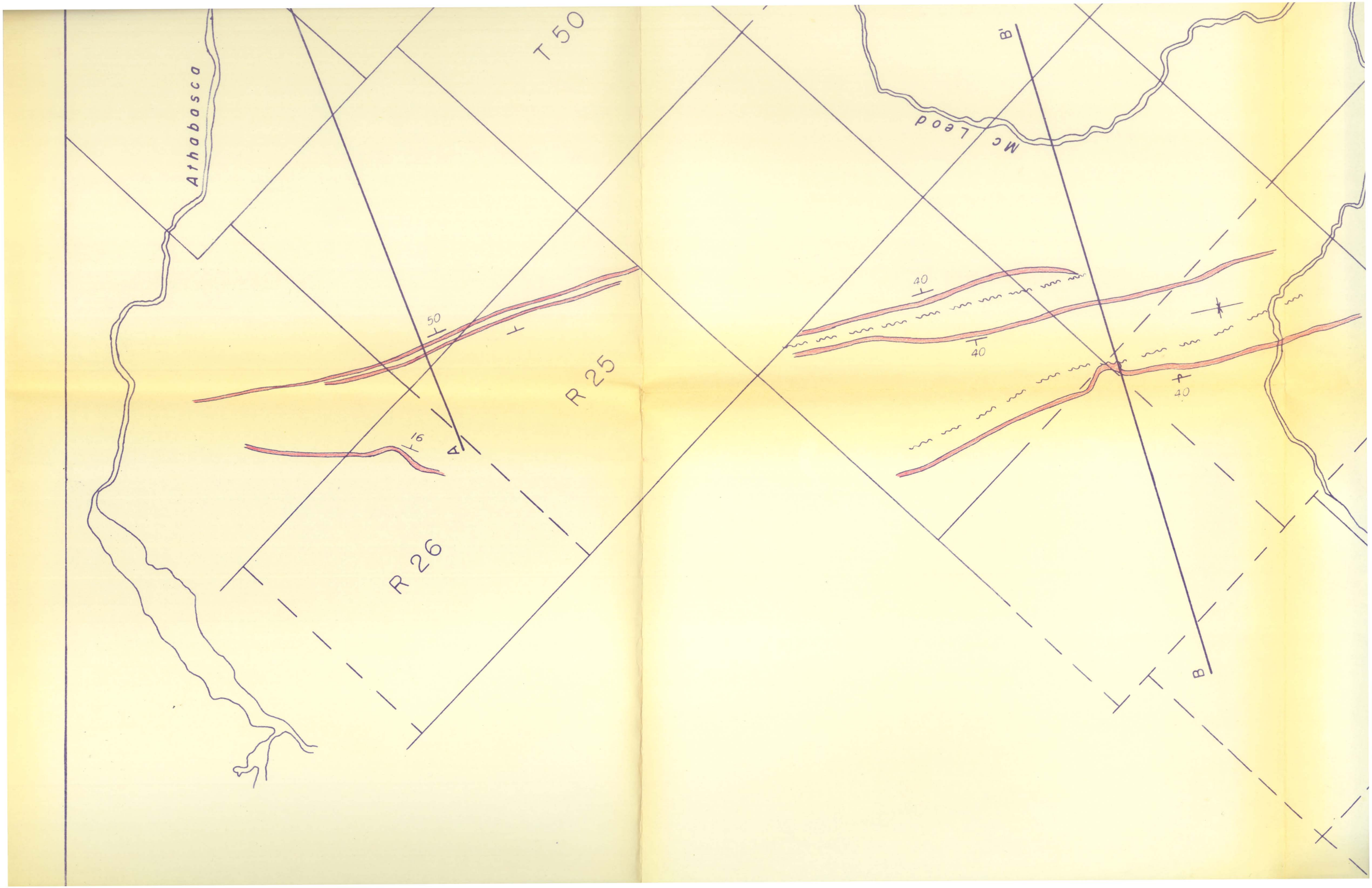
T 51
T 50
Athabasca
River
B'
Mc Leod



T 50
Athabasca
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R 26
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16
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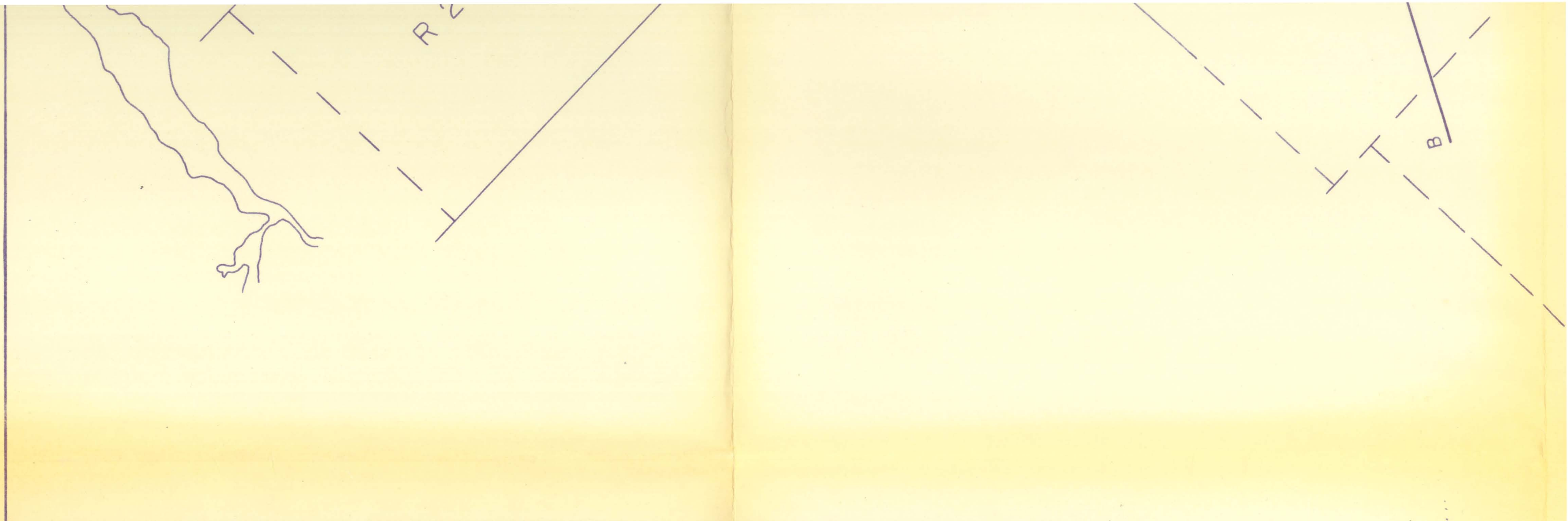
40



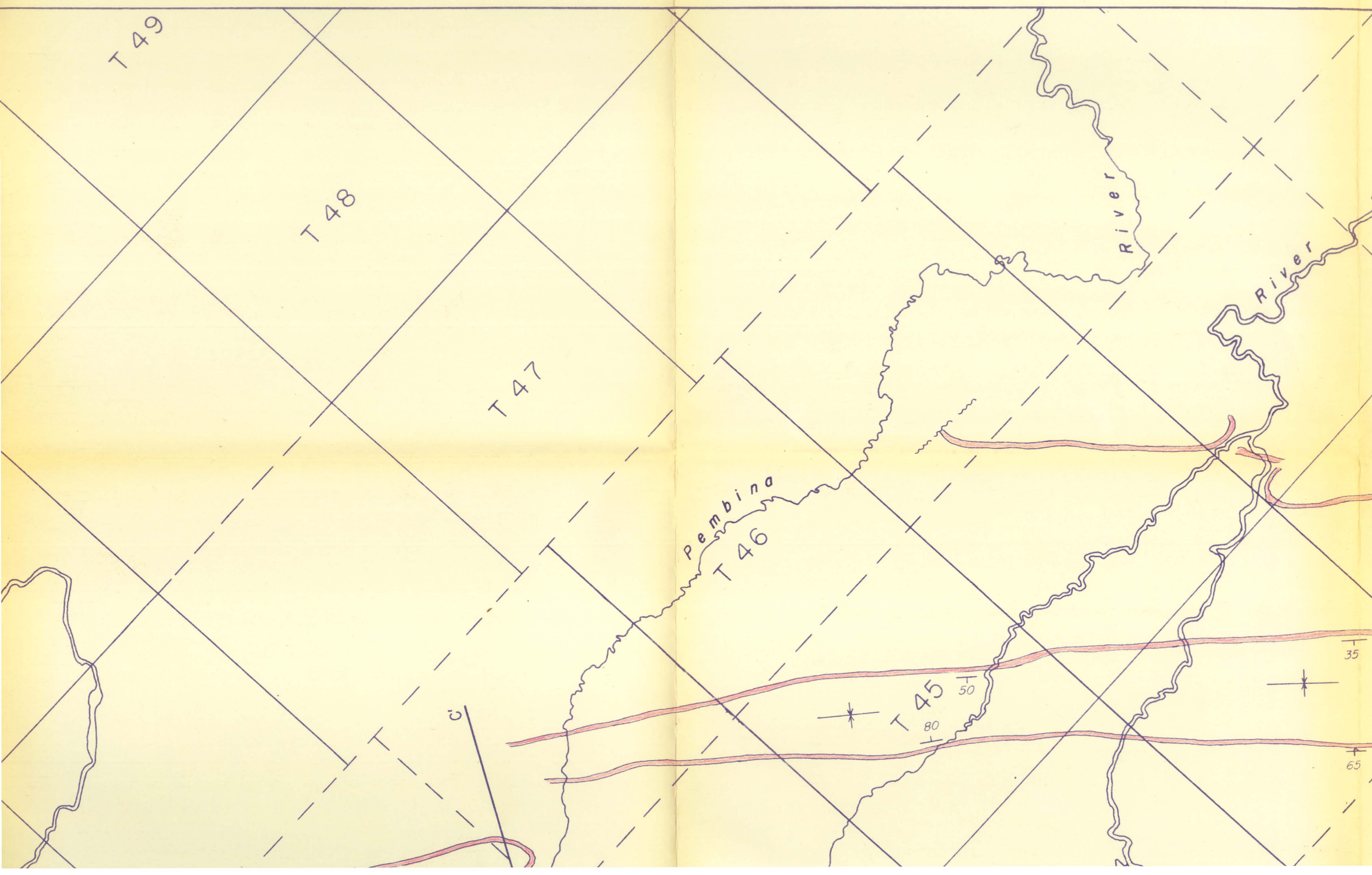
OUTCROP MAP OF

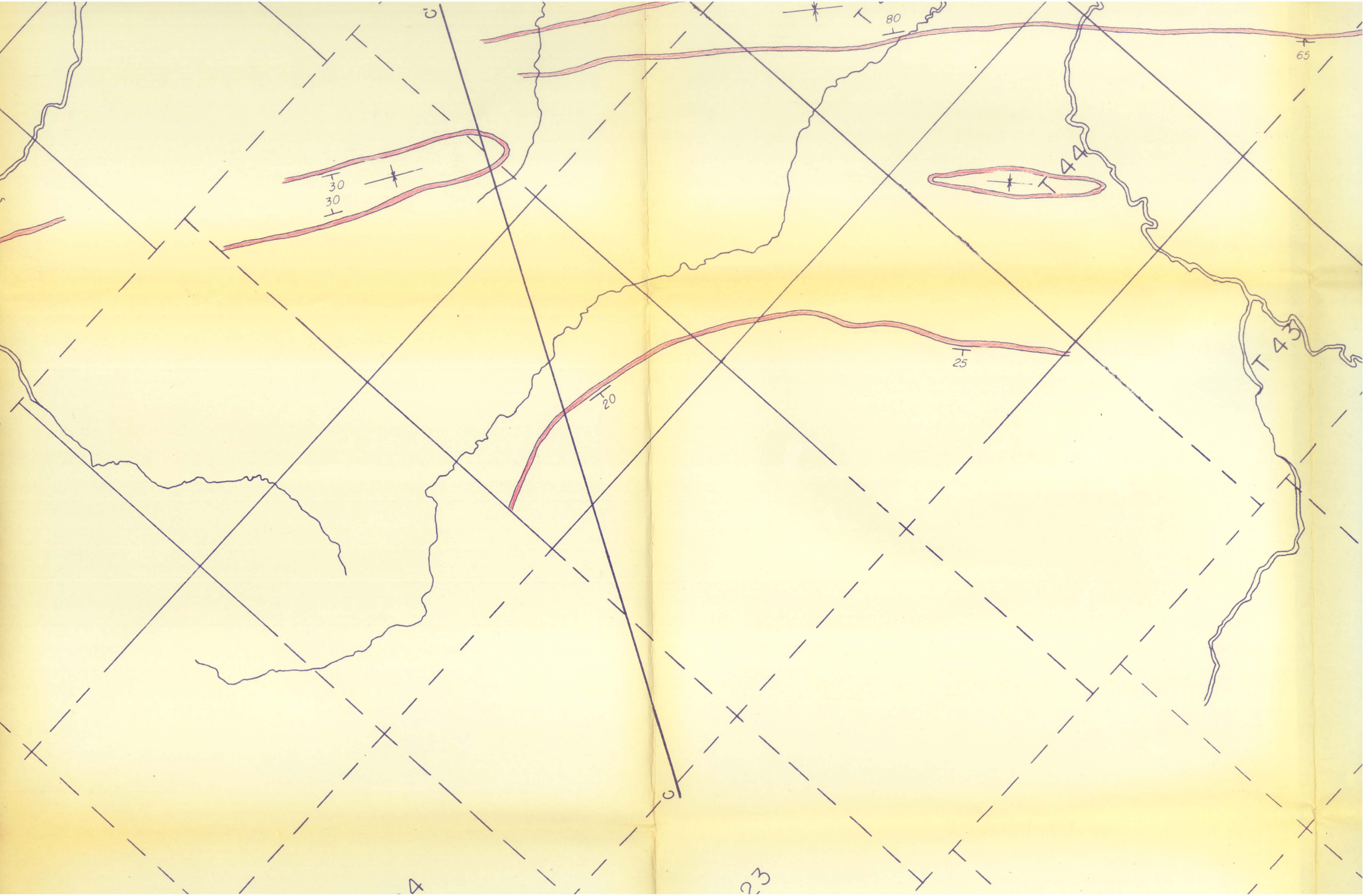
SOLOMON SANDSTONE

SHOWING LOCATION OF

STRUCTURAL SECTIONS

1 INCH = 2 MILES


T 49
T 48
T 47
T 46
T 45
Pembina
River
River
C'
50
80
35
65



C'
80
65
30
30
44
T 43
25
20
C
24
23

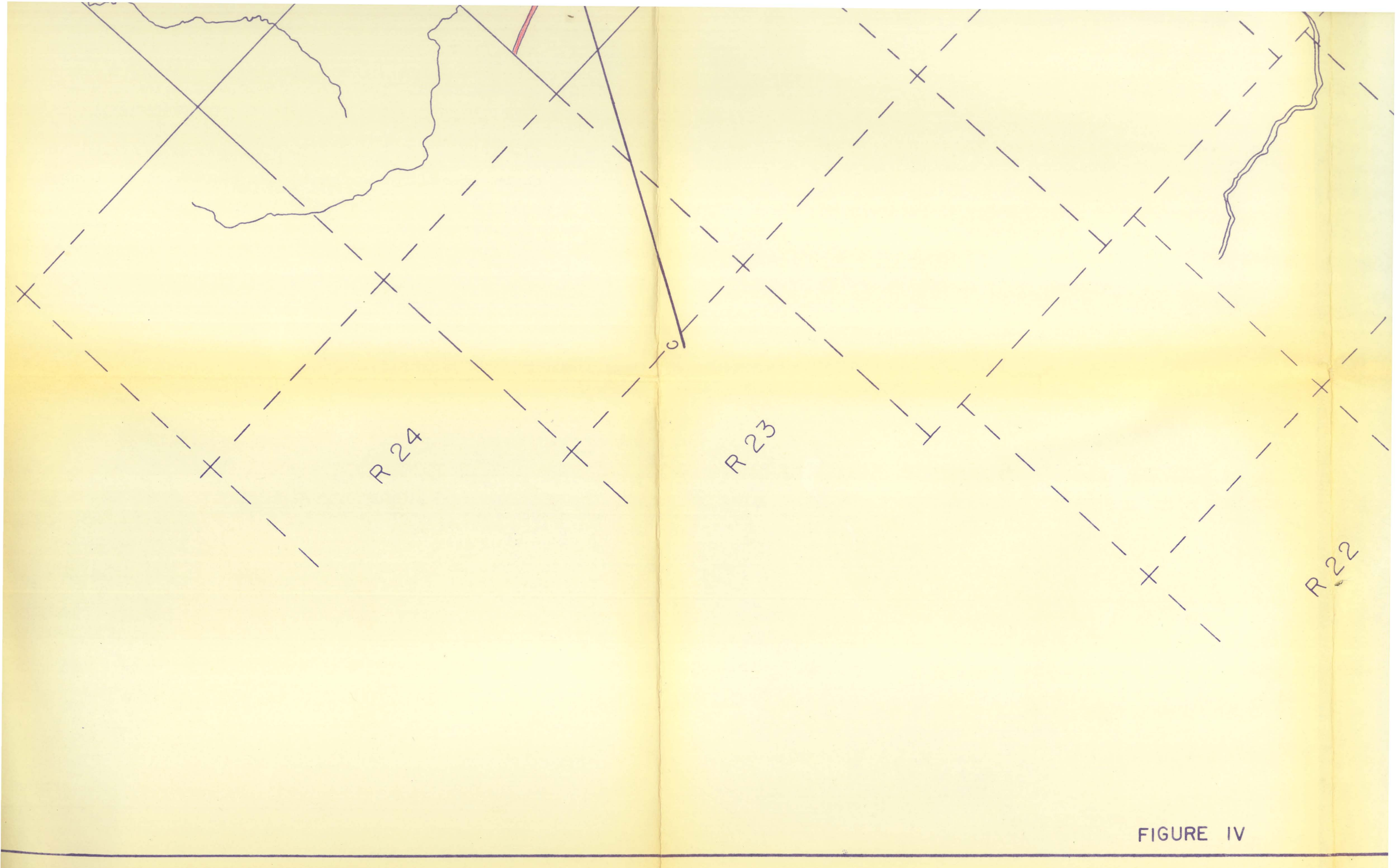
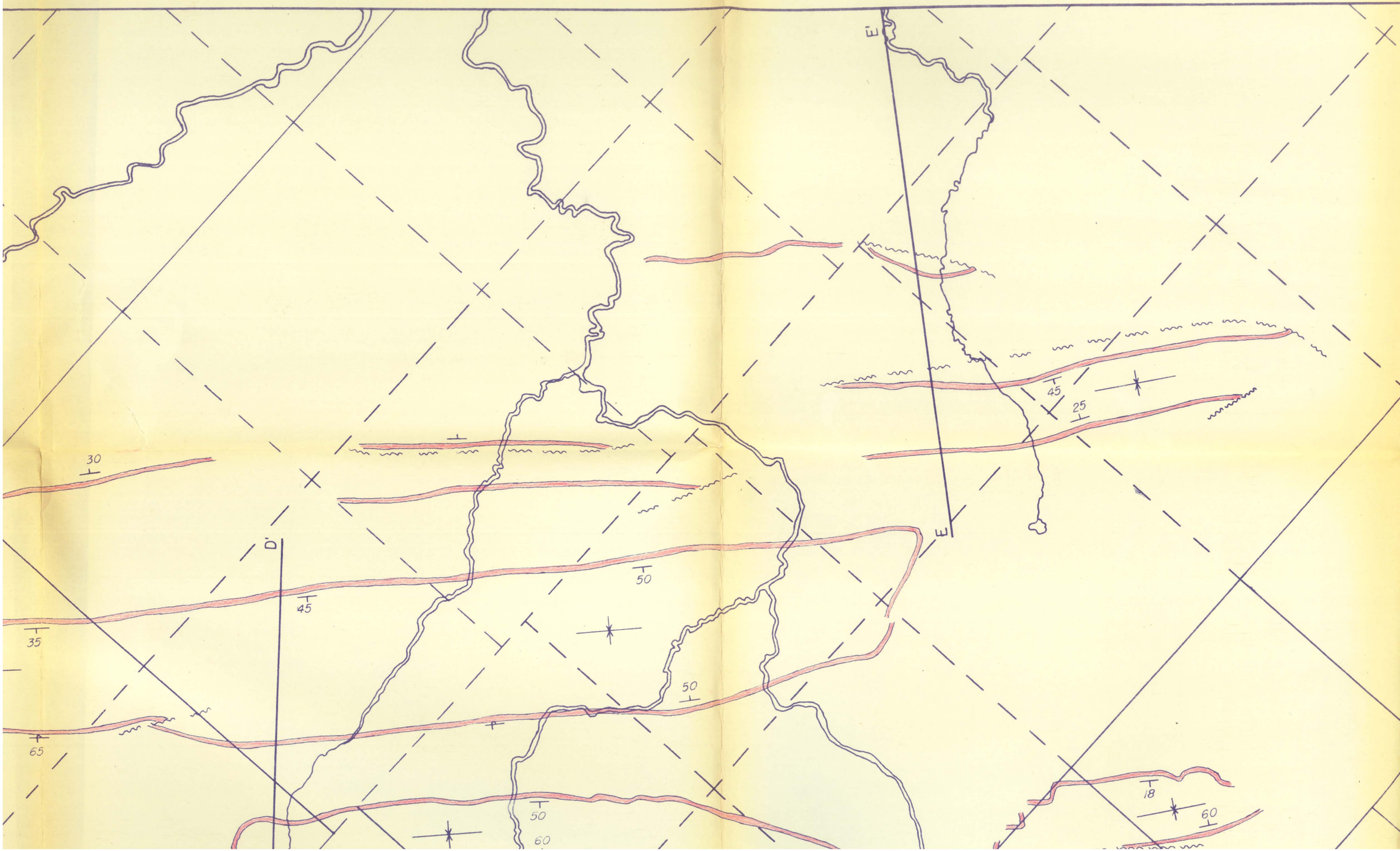
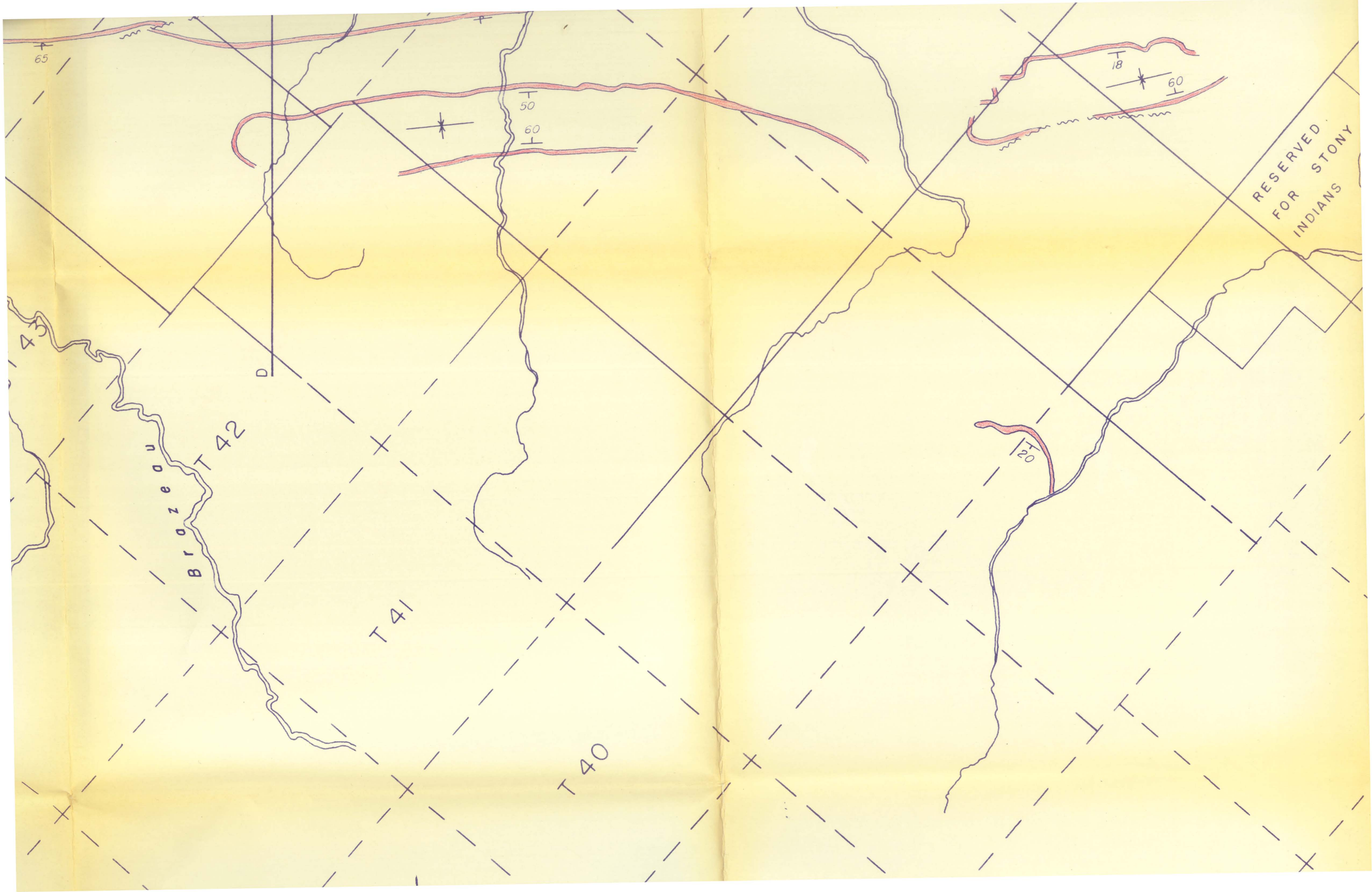


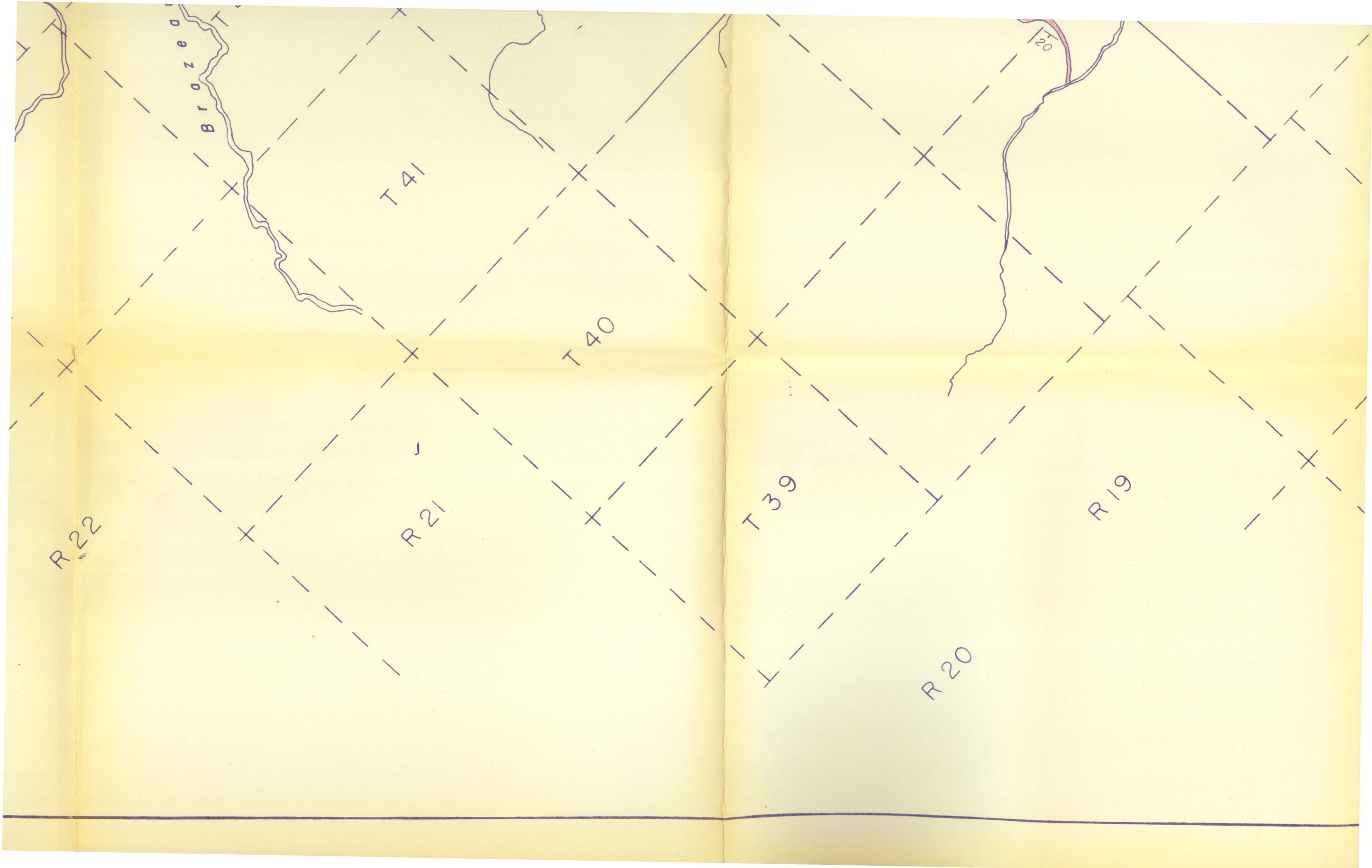
FIGURE IV

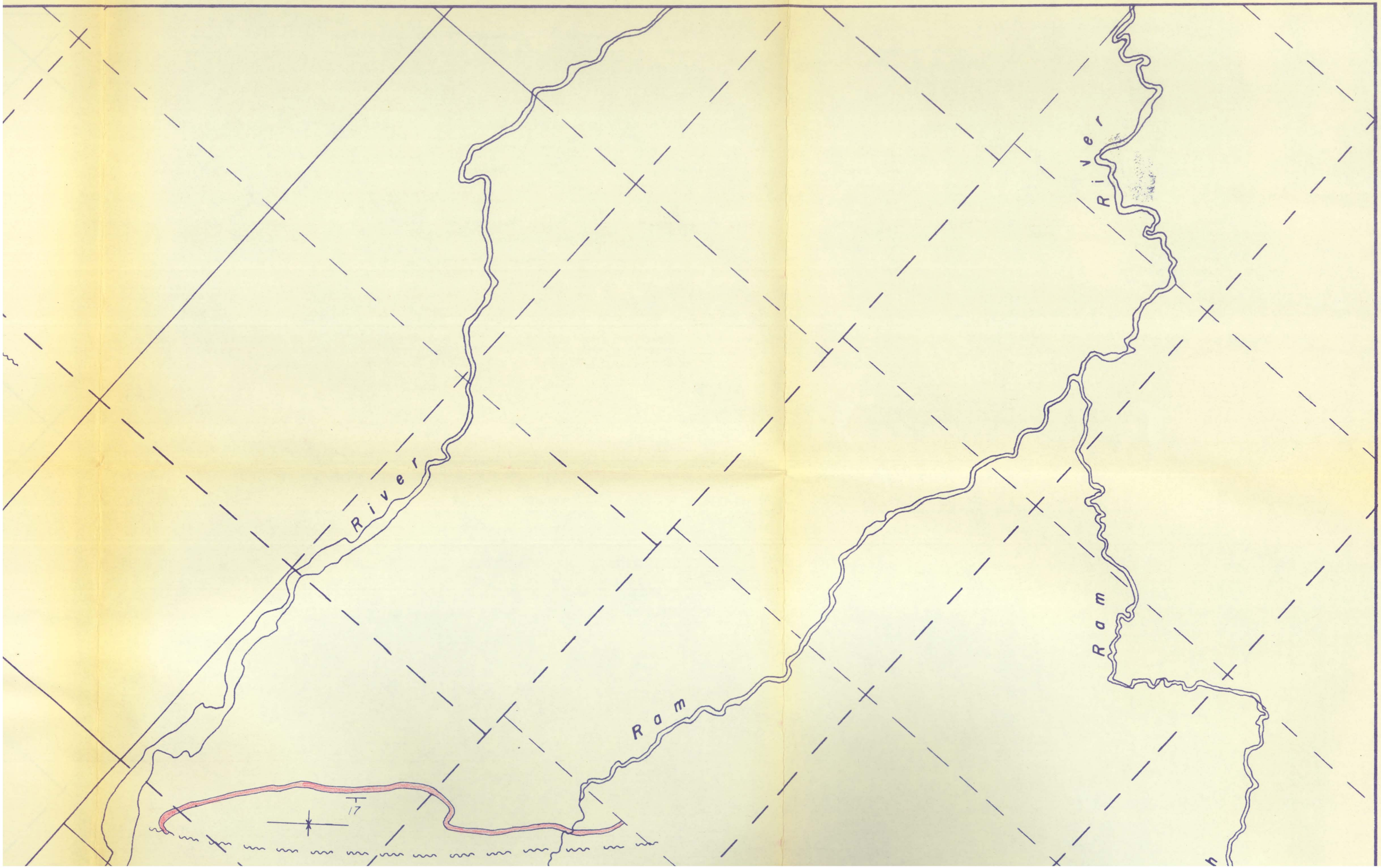


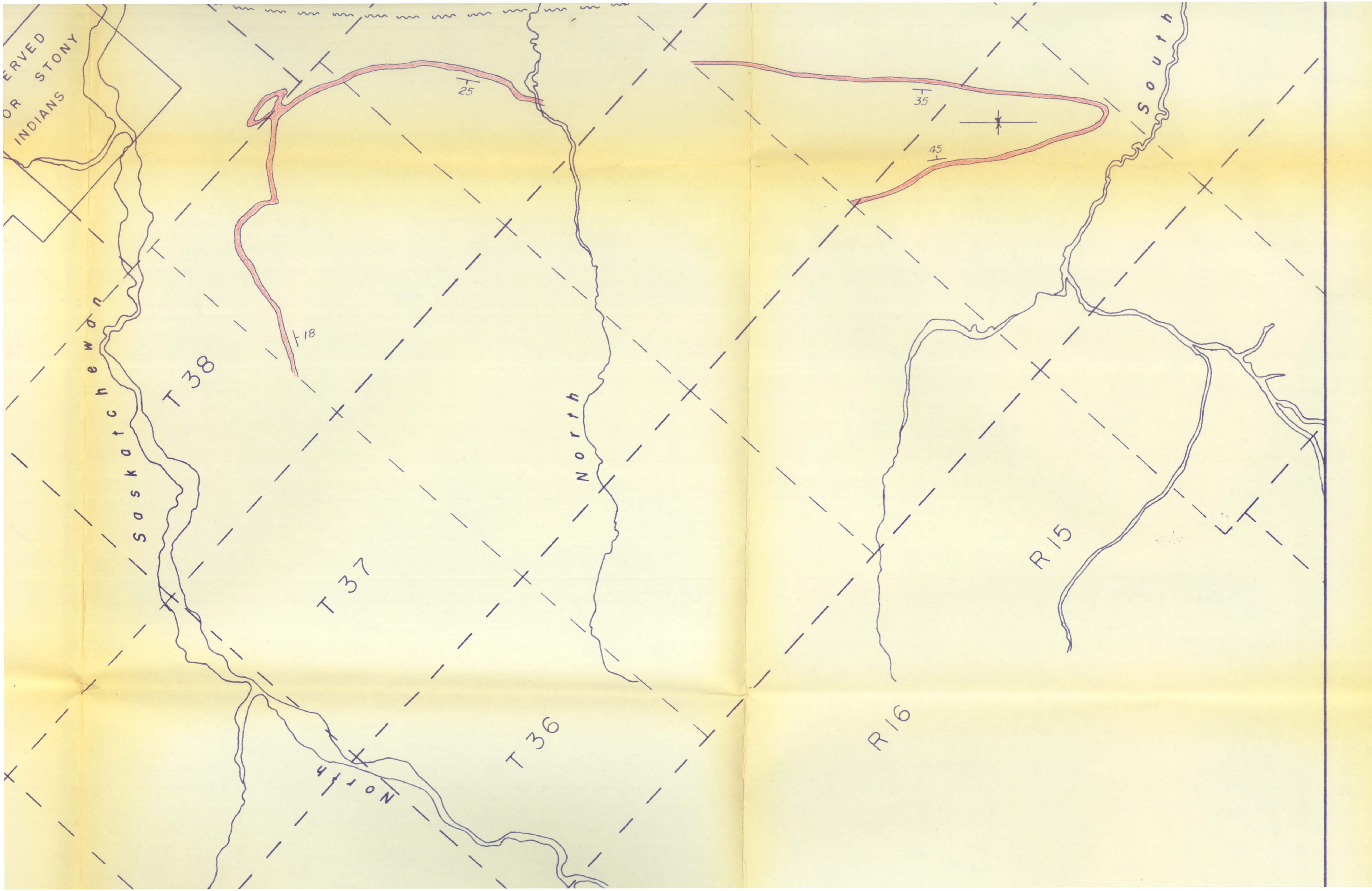
E'
E
D'
30
45
25
50
45
35
50
65
18
60
50
60



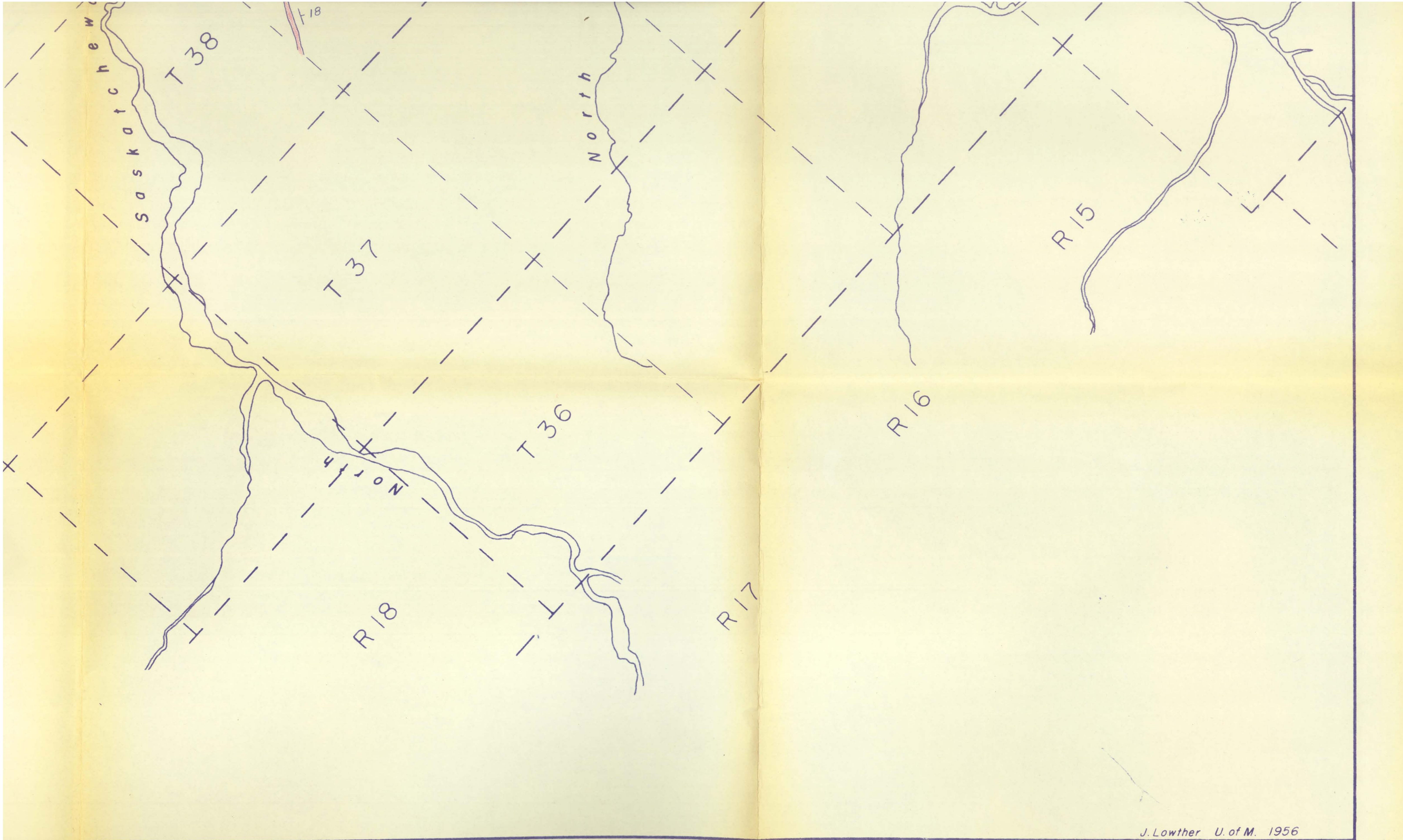
65
50
60
18
60
RESERVED FOR STONY INDIANS
D
43
T 42
Brazeau
T41
T 40
20


Brazeau
T 41
T 40
T 39
R 22
R 21
R 20
R 19


River
River
Ram
Ram
17



ERVED
FOR STONY
INDIANS
Saskatchewan
North
North
South
T 38
T 37
T 36
R 16
R 15
25
35
45
18


Saskatchew
North
North
North
T 38
T 37
T 36
R18
R17
R16
R15
18
J. Lowther U. of M. 1956