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THE MISSISSIPPIAN SYSTEM OF SOUTHERN ALBERTA, CANADA

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THE MISSISSIPPIAN SYSTEM
OF
SOUTHERN ALBERTA, CANADA

A Thesis
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In Partial Fulfillment of the Requirements
for the Degree of
Master of Science

by
Howard S. Rhodes

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C O N T E N T S

LIST OF ILLUSTRATIONS

A C K N O W L E D G M E N T S

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A B S T R A C T

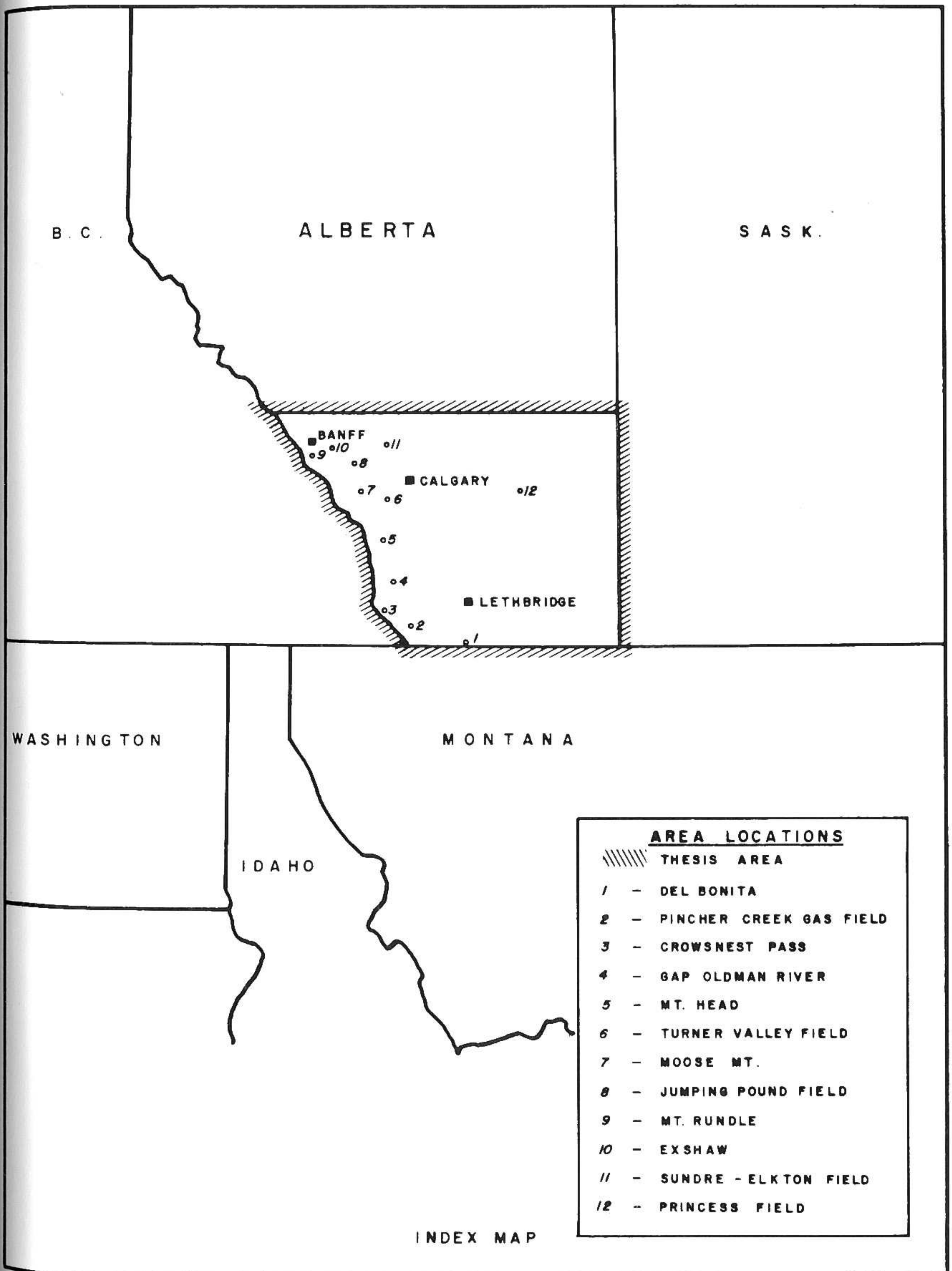
The thesis area covers Southern Alberta from township 34 south to the International Boundary.

The Mississippian system of Southern Alberta consists of rocks of the Kinderhookian, Osagean, Meramecian and Chesterian series.

The Mississippian system thins from west to east, in part due to depositional factors and in part to post-Mississippian erosion. On the western side of the thesis area the rocks aggregate 4150 feet in thickness, thinning to a feather edge toward the northeast corner of the area.

The type of sedimentation responsible for the Mississippian rocks suggests they were deposited in the neritic zone of the Cordilleran miogeosyncline.

Economically, the Mississippian rocks are important producers of oil and gas, most of which is found in the Turner Valley formation and is associated with dolomite.


B.C.
ALBERTA
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BANFF
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WASHINGTON
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AREA LOCATIONS
THESIS AREA
1 - DEL BONITA
2 - PINCHER CREEK GAS FIELD
3 - CROWSNEST PASS
4 - GAP OLDMAN RIVER
5 - MT. HEAD
6 - TURNER VALLEY FIELD
7 - MOOSE MT.
8 - JUMPING POUND FIELD
9 - MT. RUNDLE
10 - EXSHAW
11 - SUNDRE - ELKTON FIELD
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INTRODUCTION

GENERAL STATEMENT

The Mississippian system in Southern Alberta ranges in thickness from zero at its truncated edge to 4150 feet. Kinderhookian to Chesterian series are represented. The thickest sequence of rocks is located on the extreme western side of the thesis area. Eastward the system becomes progressively thinner, part of which is due to depositional factors, and part to post-Mississippian erosion.

The rocks are chiefly carbonate, but clastic and evaporite rocks are also found. The clastic rocks are confined to the upper and lowermost beds, whereas the evaporites are found only in the upper beds.

Oil and natural gas are of prime importance economically in the Mississippian rocks of Southern Alberta. These are produced from the Banff, Pekisko, Turner Valley, and Mount Head formations. However, the Turner Valley formation is by far the largest producer of both oil and natural gas in the area. Production from this formation accounts for perhaps 98% of all oil and natural gas either being produced or capable of being produced from reservoirs in Mississippian rocks in Southern Alberta at the present time.

LOCATION

The area covered by this study includes the southern end of the Province of Alberta. It is bounded on the south by the United States - Canadian International Boundary, on the east by the Alberta - Saskatchewan Provincial Border, and on the west by the Alberta - British Columbia Provincial Border. The northern boundary is at township 34.

PREVIOUS WORK

The first work by a geologist in Southern Alberta was done in 1858 by James Hector, geologist under Captain John Palliser. Captain Palliser had been commissioned by the British Government to conduct surveys of the Bow Valley and adjacent areas. Included in these surveys was the first geological data concerning the general structure of the mountains and reports on the major rock systems.

G. M. Dawson and his assistant R. C. McConnell conducated a geological survey of the Southern Alberta plains between 1881 and 1882.

Dawson (1886) was the first to construct a regional geologic map of the Southern Canadian Rockies.

McConnell (1886, 1887) made a comprehensive study of the stratigraphy and structure of the southern portion of the Canadian Rockies. It was he who first proposed the term Banff formation which included rocks that range in age from Upper Devonian to Triassic.

Dowling (1907) in reporting on the Cascade coal basin discussed the Mississippian stratigraphy.

Kindle (1924) divided the Mississippian system into two formations, the upper being called the Rundle limestone, and the lower the Banff shale.

Shimer (1926) was the first to attempt a detailed faunal and stratigraphic study on the Mississippian system in the Canadian Rockies. His study was made near Lake Minnewanka seven miles northeast of the town of Banff.

Warren (1927) reporting on the Geology of the Banff area gives a detailed description of the stratigraphy and paleontology of the Mississippian system. Later he (1933) discussed the Geology of the Crowsnest pass, and gave an account of the Mississippian rocks, mentioning their likeness to the rocks of the Banff area.

Warren (1937) subdivided the Banff formation, as proposed by Kindle (1924), into two formations: the lower division was termed the Exshaw formation, and the upper the Banff formation.

Link and Moore (1934) discussed the Mississippian stratigraphy in the subsurface at Turner Valley gas and oil field in their paper on the structure of this field.

Hume (1938 and 1939) described the subsurface stratigraphy and structure of the Mississippian rocks in Turner Valley gas and oil field.

Mackenzie (1940) gave a detailed account of the physical and chemical properties of the Mississippian reservoir rocks in the Turner Valley gas and oil field. He also presented a clear account of the sub-division and distribution of these rocks within the field.

Goodman (1945) made a study of the nature and cause of porosity in the reservoir rocks at the Turner Valley gas and oil field.

H. H. Beach delivered a talk before the Society of Petroleum Geologists of Alberta in 1947. In this talk he proposed that the Rundle formation be subdivided into three members: in descending order they are Tunnel Mountain member, Shunda member, and the Dyson member.

Douglas (1953) proposed the Rundle be raised to group status and subdivided into two formations. He named the upper the Mount Head formation and the lower, Livingstone formation. The Mount Head formation is further divided into six members and the Livingstone formation into two.

Raasch (1954) made a study of the Carboniferous section at Highwood Pass and correlated it with the type sections at Banff and Mount Head. This study is of value because of the comparison made between the fossils collected here with those from the Mississippian type section in the Upper Mississippi Valley.

Crickmay (1955) made a re-study of the Lake Minnewanka area (previously studied by Shimer) and gave supplementary descriptions to the original paleontology. He also named three new species of corals.

Penner, before a group of the Alberta Society of Petroleum Geologists in 1955, proposed the name Elkton member for the "Crystalline Zone" and "Lower Porous Zone" of the Turner Valley formation.

Other geologists contributing to the present knowledge of the Mississippian system in Southern Alberta include Moore (1931), Beal (1950), Gallup (1951), and Erdman, et. al. (1953).

With the exception of the oil and gas fields producing, or capable of producing, from rocks of Mississippian age, the above reports and articles are almost exclusively devoted to the study of the rocks and fossils in outcrop sections. Very little has been written about subcrops of the Mississippian system of Southern Alberta.

PRESENT WORK

The present work is an attempt to give a broad, general picture of the Mississippian system in Southern Alberta. A discussion of the lithology, distribution and economic possibilities of each formation is presented.

The field work was started in the spring of 1956 and completed a year later.

The study was divided into five parts:

(1) field work

(2) subsurface investigation

(3) laboratory investigation

(4) interpretation and illustration of acquired data

(5) economic geology

Field Work

Field work consisted of a study of various stratigraphic sections throughout the foothills and mountains of Southern Alberta. The type section for the Rundle group, Banff formation, and Exshaw formation were studied and used as a key to correlation. The formations were identified by their relative stratigraphic positions and a comparison of the lithologic characteristics with those of the type sections. All stratigraphic measurements were made with a steel tape and Brunton compass.

Field studies were conducted in the following areas:

Mount Rundle, Tunnel Mountain, Exshaw,
Mount Rae (Storm Creek) Moose Mountain,
and Crowsnest Pass. (Index map p. vii).

Subsurface Investigation

Subsurface investigation consisted of the study of 472 electrical and radioactive logs. The electrical and radioactive logs were checked against key stratigraphic logs that were prepared from oil well cuttings chosen from wells that were strategically placed because of the completeness of sectional and geographical position. This supplementary material was most useful in helping with problems of correlation and facies change.

Laboratory Investigation

Work in the laboratory involved the making and examining of thin sections, insoluble residue studies and rock staining.

Interpretation and Illustration

From the information obtained from the above studies an isopachous map of the Mississippian system was made. Super-imposed over the isopachous map is a map showing the position of the truncated edges and distribution of the various Mississippian formations. (plate V inside back cover)

Photographs illustrating the various formations, their relative thickness and contacts are included.

Other illustrations included are a stratigraphic cross section of the Mississippian system, from west to east, a plate showing the facies change in the Livingstone formation, and a typical subsurface electrical log and stratigraphic section.

The data obtained from the field and laboratory studies was also used to determine the paleotectonics, and the depositional environments under which the sediments were deposited.

Economic Geology

A study was made of the history, stratigraphy, structure, and reservoir characteristics of each of the major Mississippian oil and gas fields within the thesis area. The minor Mississippian oil and gas fields are discussed in more general terms.

FORMATION	LITHOLOGY	THICKNESS
TUNNEL MOUNTAIN	SILTSTONE, SANDSTONE DOLOMITE	0-600
MOUNT HEAD	DOLOMITE SANDSTONE SILTSTONE ANHYDRITE LIMESTONE SHALE	0-700'
LIVINGSTONE	LIMESTONE DOLOMITE	790'-1650'
TURNER VALLEY	DOLOMITE LIMESTONE	0'-380'
SHUNDA	DOLOMITE LIMESTONE SILTSTONE SHALE ANHYDRITE	0'-270'
PEKISKO	LIMESTONE DOLOMITE (FRAGMENTAL ARGILLACEOUS OOLITIC)	0'-495'(?)
BANFF	LIMESTONE DOLOMITE SILTSTONE SHALE SANDSTONE	0'-1400'
EXSHAW	SHALE	0'-45'

PLATE 1. FORMATION THICKNESS CHART

S T R A T I G R A P H Y

GENERAL STATEMENT

Rocks of the Mississippian system are found throughout the area with the exception of the northeast corner. They crop out in the Rocky Mountains and in part of the foothills belt east of the mountains. In the plains they are present in the subsurface and can be studied from well cutting samples, cores and electrical logs.

The Mississippian system is everywhere unconformably in contact with rocks of the Devonian system below, and unconformably overlain by rocks of the Permian, Triassic, Jurassic, and Cretaceous systems.

After the final emergence of the land mass following the withdrawal of the Chesterian seas the Mississippian rocks laid exposed until Permian times when the western part of the area was once more inundated. The eastern part of the thesis area remained positive until the Cretaceous period. During the interval of time when the area was positive, the surface was subjected to erosion that cut deep channels and removed enormous quantities of rock. Inasmuch as the eastern half of the area remained positive longer than the western half, it is characterized by a much thinner section.

Throughout the thesis, the writer has used the term post-Mississippian erosion in referring to the erosion that took place between the time the Mississippian rocks emerged from the sea until they were once again inundated.

At the present time there is some question about the exact age of the Exshaw and Tunnel Mountain formations. These problems will be discussed with the respective formations.

EXSHAW FORMATION

General Description

The Exshaw formation was named by Warren (1937, p. 456) for an outcrop of black shale between the base of the Banff formation and the top of the Palliser formation.

The type section is on Jura Creek approximately two miles northeast of the town of Exshaw on the Calgary-Banff highway.

The formation is composed of black fissile, non-calcareous pyritic shale. Hard black concretions are found in the shale and are more abundant near the base of the formation.

In most areas throughout the mountains the outcrops of the Exshaw formation are poorly exposed. However, wherever it was observed, both in outcrops and well cuttings, it was found to be remarkably homogeneous.

The contact between the Exshaw shale and the underlying Palliser limestone can be described as a knige-edge contact, (see Figure number 1). In the past a great deal of discussion has taken place as to whether this contact is conformable or not. The writer believes it to be unconformable for the following reasons:

(1) the uppermost surface of the Palliser limestone is highly silicified, (2) a thin deposit of sand is present at the base of the Exshaw shale, (3) the surface of the Palliser is somewhat pitted, and (4) the abrupt change in lithology.

The upper contact appears to be conformable with the Banff formation.

Clark (1954, p. 40) suggests including the basal 30 feet of the Banff formation with the Exshaw formation thus giving the latter a shale and a limestone member. His reason for doing so is based on paleontology. He collected <u>Tornoceras cf. T. (T.) uniangular</u> Conrad in a limestone band two feet above the shale.

The thickness of the Exshaw formation at the type section is 31 feet. At Mount Rundle it is the same. In the southern end of the area at Crowsnest Pass, DeWit and McLaren (1950, p. 62) reported 44 feet. Just north of the northern end of the area, Stevenson (1950, p. 1846) reports between 120 and 150 feet of Exshaw shale in the Sunwapta Pass. In the subsurface sections under the plains the thickness averages between five and 15 feet.

The Exshaw formation is more widely distributed over the area than any other Mississippian formation. It is present throughout the area with the exception of the northeastern section where it has been removed by post-Mississippian erosion.

Borden (1956, p. 9) states that the name Exshaw formation should be restricted to the Rocky Mountains and the deeper part of the Alberta basin. The black shale referred to as Exshaw shale in the plains he believes to be younger than the Exshaw shale of the mountains, and to be separated from it by an unconformity. His evidence is based on the fact that conodonts are not found in the "true" Exshaw shale, but are found in the "plains" Exshaw shale and in the Exshaw "type" shale overlying the true Exshaw shale.

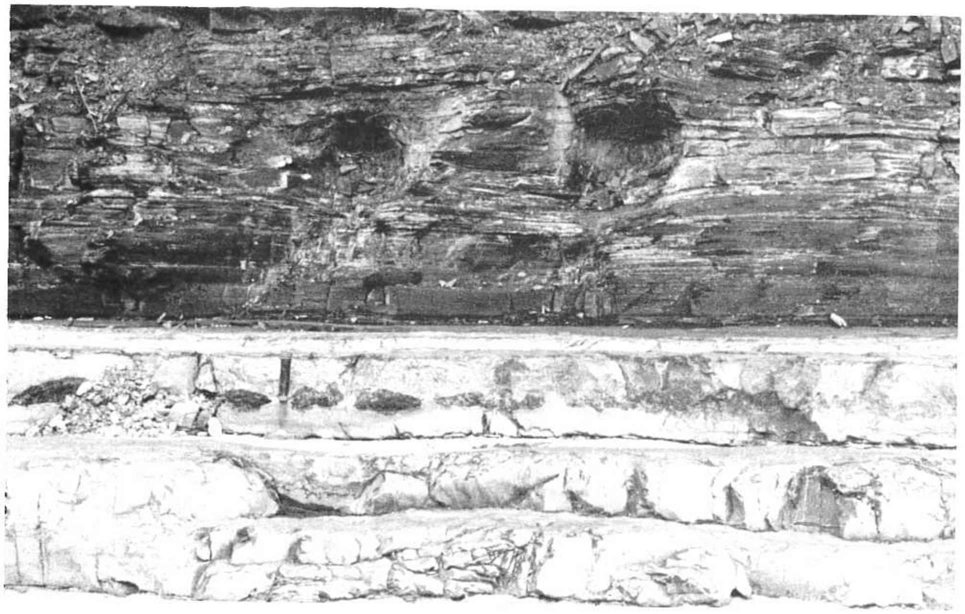


Fig. 1 Exshaw Shale-Palliser Limestone Contact

Fig. 2 Concretion from the Exshaw Formation

Age and Correlation

The Exshaw formation is sparsely fossiliferous, but where fossils have been collected they do not conclusively determine the age. Originally Warren (1937, p. 456) gave it a Devonian age, but the current general census of opinion seems to favor a Mississippian age.

Warren (1937, p. 455) made the following collection:

(Tornoceras) cf. T. (T.) uniangulare (Conrad)

Lingulr cf. melie Hall

Cycloceras sp.

Allorisma ?

Protokionoceras?

DeWit and McLaren (1950, p. 11) made the following collection:

(Tornoceras) cf. T. (T.) uniangulare (Conrad)

Allorisma

Proctid trilobite fragments

In conclusion the fossil evidence for dating the Exshaw formation is not conclusive. However, because of its unconformable contact with rocks of Upper Devonian age below, and conformable contact with the Banff formation above, the writer believes the Exshaw shale to be of Kinderhookian age.

Petrology and Petrography

The Exshaw shale varies in color between jet black and dark brownish-black on fresh surfaces. It weathers a dull black which is in part rusty. The rust colored weathered surface is more pronounced near the base of the formation where the shale has a higher content of pyrite.

The grain size appears to be very uniform throughout the thesis area being made up of clay sized particles. In some sections there is a very minor amount of fine silt sized particles.

The bedding is thin and uniform where observed. In some places the bedding appears to be several inches thick, but closer observation shows it to be thinly bedded laminae of shale weathering more massively than the shale above and below.

The formation is made up of petroliferous fissile shale with nodules of calcareous mudstone (see Figure number 2) and fine pyrite crystals in the lower half. The nodules vary in size between 4 and

18 inches in diameter. Insoluble residues run on the nodules showed them to contain only four per cent calcium carbonate. Field observations would lead one to believe the calcium carbonate content much higher because of the rapid response to acid.

Sedimentation

It is most difficult to visualize the sedimentary agents responsible for the deposition of such a uniformly thin formation covering such a vast area without facies changes. Borden (1956, p. 9) suggests a transgressive sea advancing over an area covered with black soil would rework the soil and re-deposit it over a vast area in a more or less uniform thickness.

Fuller (1956, p. 24) suggests that the Exshaw equivalent shale in Saskatchewan was deposited from the reworked clays, silts, and evaporites of large swamps left behind from the retrogressive Devonian seas.

Economics

No economic value is placed on the Exshaw formation at the present time.

BANFF FORMATION

General Description

The name Banff was first applied to a sequence of rocks from Devonian to Triassic in age by McConnell (1887, p. 17). Kindle (1924, p. 123) restricted the name Banff shale to the lower part of the Mississippian system occupying the stratigraphic position below the Rundle limestone.

The type section is located on the northeast end of Mount Rundle in Banff National Park. Figure number 3 is a photograph of the type section looking southeast.

The Banff formation can be divided into two members on the basis of lithology.

The lower member is more clastic than the upper member. It is composed of shale, siltstone and fine grained sandstone. On the eastern side of the thesis area this member has a well developed porous sandstone which is referred to as the "Banff sand." This sand is best developed in the northeast and east central parts of the thesis area and becomes less well developed toward the west and southwest. It is not present in the north central area. In the mountains it is represented by siltstone.

The upper member is composed of argillaceous, cherty, limestone and calcareous shale which was deposited under cyclic conditions. Clean limestone, siltstone, shale, and dolomite are also found in various amounts. The limestone for the most part is crinoidal.

In some wells limestone and dolomite lentils that closely resembled reefs were observed. These sections were fossiliferous with bryozoa, crinoid plates, and brachiopods. Some of the lentils are porous whereas others are non-porous. The Princess oil and gas field is a good example of a clean porous limestone member that is capable of hydrocarbon production. Here the member is 305 feet thick. The upper 125 feet is composed of light brown to white, coarse crystalline, dolomitic, porous, cherty, fossiliferous limestone. The lower section is 180 feet thick and is composed of dark gray, dense, argillaceous, cherty limestone becoming less cherty and argillaceous in the lower half. The basal 40 feet is slightly silty.

The Banff formation lies with conformity on the Exshaw formation and is conformably overlain by the Livingstone formation in the mountains and by the Pekisko formation in the foothills and plains.

The contact between the Banff and Livingstone formation is gradational over an interval of between twenty and thirty feet. This contact is easily observed in outcrop sections and is placed at a point where the buff to brown weathered silty limestone (or dolomite) of the Banff formation gives way to the gray massive crinoidal limestone of the Livingstone formation.

Beach (1943, p. 20) states that at several places in the Moose Mountain and Mosley areas evidence of a very slight angular discordance between the Banff formation and Rundle group is apparent. He attributes this to local warping of the Banff formation before the deposition of the overlying strata of the Rundle group.

In the subsurface the contact between the Banff and Pekisko formations is not always apparent. In some places there is a thin silt band that is used as a marker to separate the two formations. Where this is absent or not recognized, the top of the Banff formation is placed at the first occurrence of dark gray argillaceous limestone or dark gray calcareous shale.

The Banff formation thins from west to east. At the type section on Mount Rundle it is 1400 feet thick. On the east side of the thesis area it is 380 feet thick.

Hage (1943) reports the Banff formation to be 1000 feet thick in the Dyson Creek Map area. Beals (1950, p. 45) measured 715 feet of Banff formation at Mount Head. Douglas (1950, p. 12) states that the exact thickness of the Banff formation is not exposed in the Gap area on Old Man River. However, he believes the 800 feet that is exposed represents nearly a complete section. Warren (1933, p. 153) measured between 1250 and 1300 feet of Banff rocks on the Crowsnest Pass. The writer believes the section at Crowsnest Pass to be somewhat thinner than reported by Warren. The section is faulted by thrust faulting, consequently the stratigraphic thickness is not as great as it first appears.

The Banff formation is distributed over the entire thesis area with the exception of the northeast corner where it has been removed by post-Mississippian erosion.

Age and Correlation

The Banff formation is Kinderhookian in age.

Beach (1943, p. 22) made the following collection of fossils from the Banff formation at Moose Mountain:

- Fucoids (?)
- *Lophophyllum* sp.
- *Syringopora surcularia* Girty
- *Fenestella* sp. near *F. serratula* Ulrich
- *Fenestella* cf. *rudis* Ulrich
- *Rhombopora* sp.
- *Taeniodictya* sp.
- *Rhipidomella* cf. *missouriensis* (Swallow)
- *Leptaena analoga* (Phillips)
- *Schellwienella planumbona* Weller
- *Productella concentrica* (Hall)
- *Productus fernglenensis* Weller
- *Productus ovatus* Hall
- *Productus gallatinensis* Girty
- *Dielasma chouteauensis* Weller
- *Spirifer centronatus* Winchell
- *Spirifer albapinensis* Hall and Whitfield
- *Spirifer striatiformis* Meek

Crickmay (1955, chart 3) made the following collection from the Lake Minnewanka section:

Tylothyris cf. *clarksvillensis* Winchell

Spirifer cascadensis Warren

Spirifer albertensis Warren

Spiriferella mennewankensis Shimer

Warren (1927, p. 24) lists the following fossils collected from the Banff formation in Banff National Park:

Rhombopora cf. *subannulata* Ulrich

Rhipidomella pulchella Herrick

Leptaena analoga Phillips

Schellwienella planumbona Weller

Chonetes illinoisensis Worthen

Productus arcuatus Hall

Productella pyxidata Hall

Productus blairi Miller

Productus fernglensis Weller

Productus ovatus Hall

Camarotoechia metallica White

Leiorhynchus haguei Girty

Dielasma chouteauensis Weller

Dielasma utah (Hall and Whitfield)

Spirifer centronatus Hall and Whitfield

The Banff formation correlates with the Lodgepole formation of the Williston Basin, the lower Madison formation of Western Montana, and the Gardner formation (lower part) of Utah. The sandstone at the base of the Banff formation, and the black shale directly overlying it, are correlated with the upper two-thirds of the Bakken formation of the Williston Basin. The sand is also correlated with the Coleville sand of Western Saskatchewan.

Petrology and Petrography

The color of the Banff formation varies for the most part between tan and dark brown, with shades of red, yellow and gray. A few sections were noted in the subsurface where the limestone is white. The shale in the basal part of the formation is black or dark bownish black.

The texture of the limestone and argillaceous limestone ranges between fine and coarse grained, with the major amount being fine to medium grained. The coarser clastic sections range in size between fine grained sand and coarse silt.

Thin sections were made of the silty and more calcareous sections in the lower part of the formation and of the limestones in the upper part. The silt stringers are composed of angular quartz grains that range in size between 1/30 mm and 1/16 mm held in an argillaceous matrix and cemented with calcite. Ripple marks and cross-bedding were observed in some thin sections. The carbonates were made of recrystallized calcite and dolomite, the crystals of which range in size between 1/4 mm and 1 mm. Staining revealed between 10% and 14% of the crystals to be dolomite. Argillaceous material in the thin sections had no pattern. It appeared as blotches and fine stringers among the crystals, and made up from 5% to 7% of the rock.

Insoluble residues of the upper limestone member consisted of clay size particles of argillaceous material and euhedral crystals of quartz between 1/16 mm and 1/30 mm long. Insoluble residue made up six per cent or less of this member.

The bedding of the Banff formation ranges in thickness from paper thin in the shale sections to 14 feet in the more massive limestone beds in the upper part of the formation.

The basal section of the Banff formation is always more clastic than the upper part, and goes through several cycles of clastic and carbonate rocks before it finally becomes a relatively clean limestone near the upper contact.

Cross-bedding is found at various places throughout the outcrop sections and is undoubtedly present in the subsurface as well.

Sedimentation

The Banff rocks were deposited on an unstable shelf. Sedimentation appears to have been continuous throughout the entire deposition of the Banff formation. However diastems undoubtedly do exist. The limestone cycles throughout the formation probably represent periods when tectonic activity on the shelf was slower and more advantageous to the growth of lime secreting organisms.

The clastic sediments at the base of the formation are more coarse along the east and southeast perimeters of the thesis area suggesting a closer proximity to the shoreline.

The cross-bedding and ripple marks found associated with the Banff formation would suggest that these rocks were formed in shallow water.

Economics

The Banff sand is porous and oil bearing on the eastern side of the thesis area. The upper carbonate member is found to be porous and oil and gas bearing in the Princess oil field. As a general rule this member is non-porous and is not considered as a prime objective in oil or gas exploration. However, under the right stratigraphic conditions it can contain oil and gas.

LIVINGSTONE FORMATION

General Description

The Livingstone formation was named by Douglas (1955, p. 63) for the lower formation of the Rundle group in the Mount Head Map area.

Inasmuch as the above mentioned publication is a preliminary account of a report in course of preparation the type section was not given. The location of the type section along with an account of the lithology will undoubtedly be presented in the final report.

Throughout the mountains of Southern Alberta the Livingstone formation is easily distinguished wherever it crops out. It is recognised as a light gray to gray cliff forming ribbon of limestone separating the brown shale and argillaceous limestone of the Banff formation from the black to brown dolomite and green, red and black shales of the Mount Head formation. The upper part of the formation is dolomitised and porous in some areas throughout the mountains. In other places it is composed of limestone and is non-porous.

Figure number 4 is a photograph of the Livingstone formation on Tunnell Mountain as seen from the foot of Mount Rundle. The dark beds seen in the photograph represent thin-bedded limestone; the light gray beds are massive bedded limestone.

The Livingstone formation conformably overlies the Banff formation, and appears to be conformably overlain by the Mount Head formation. Laudon (1955, p. 209) states that the contact between the Brazer (Mount Head formation) and the underlying rocks (Livingstone formation) is unconformable in the Crowsnest Pass. The writer has not recognized an unconformable contact between the two above mentioned formations within the thesis area.

At Banff the Livingstone formation is 1050 feet thick and is composed of light-gray to gray, coarse- to fine-grained crinoidal limestone.

In the Dyson Creek Map area, Hague (1943) measured 1000 feet of light gray, coarse to fine grained crinoidal limestone.

Fig. 3 Mount Rundle showing Formation on Tunnel Mountain

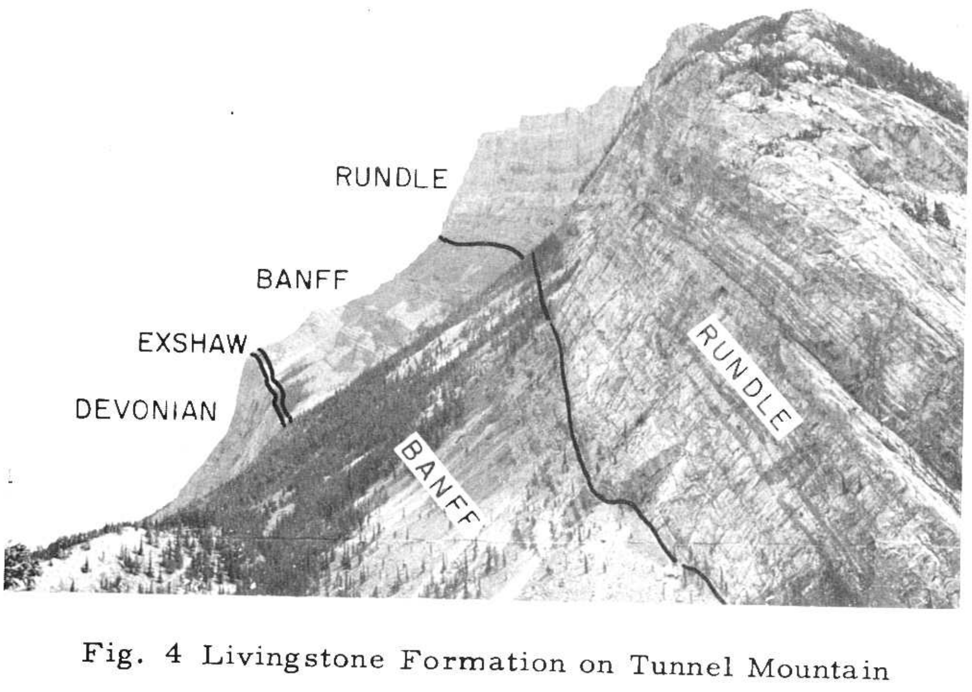


Fig. 4 Livingstone Formation on Tunnel Mountain

Beals (1950, pp. 49-59) made a detailed log of the Mississippian rocks in the Mount Head area and reports the Livingstone formation to be 1173 feet thick. Lithologically it is composed of gray crinoidal limestone and dolomitic limestone with porous zones common in the upper and middle beds.

At the Gap on Old Man River, Douglas (1950, p. 13) describes the Livingstone formation as being 790 feet thick, lithologically composed of massively bedded gray dolomite and buff to gray coarsely crystalline limestone.

In the Crowsnest Pass the Livingstone formation is composed of thick massive beds of light gray to gray, coarse to medium grained crinoidal limestone. The thickness of this section of this section is in question due to faulting.

At Exshaw the formation is 1050 feet thick and is composed of light gray to gray, medium to coarse grained crinoidal limestone which grades into fine crystalline dolomite.

The Livingstone formation is restricted to the mountains and is present from Crowsnest Pass on the south to beyond the northern limits of the thesis area.

Age and Correlation

The Livingstone formation correlates with the Mission Canyon formation of Montana and the Williston Basin and the lower half of the DeBolt formation in Northeastern British Columbia and Northwestern Alberta. To the east in the foothills and plains of Southern Alberta the Livingstone formation grades laterally into the Turner Valley formation at the top of the section, the Shunda formation in the middle, and the Pekisko formation at the base of this section (see plate 2).

Warren (1927, pp. 29-30) reports the following fossils at Banff National Park:

- _Productus burlingtonsis_ (Hall)
- _Spirifer centronatus_ Wenchell
- _Spirifer logani_ (Hall)
- _Spirifer rundlensis_ Warren
- _Reticulasia pseudolineata_ (Hall)
- _Aclinocrinus_ sp. indet.
- _Spirifer banffensis_ Warren
- _Deltodus_ sp. indet.

Psammodus sp. indet.

Syringapora surcularia Girty

Fenestella sp. indet.

Evactinopora ? *tenuiradiate* sp. nov.

Evactinopora ? *stellara* sp. nov.

Pustula punctata (Martin) ?

Beach (1943, p. 28) reports the following fossils collected from the Moose Mountain area.

Triplophyllum dolii (Edwards & Harmes) ?

Fenestella sp.

Productus ovatus Hall

near *Productus fernglenensis* Weller

Spirifier centronatus Winchell

Spirifier sp.

near *Spirifier albapinensis* Hall and Whitfield

Spirifier rundlensis Warren

cf. *Pseudosyrinx gigas* Weller

Martinia sp.

cf. *Reticularea pseudolineata* (Hall)

Petrology and Petrography

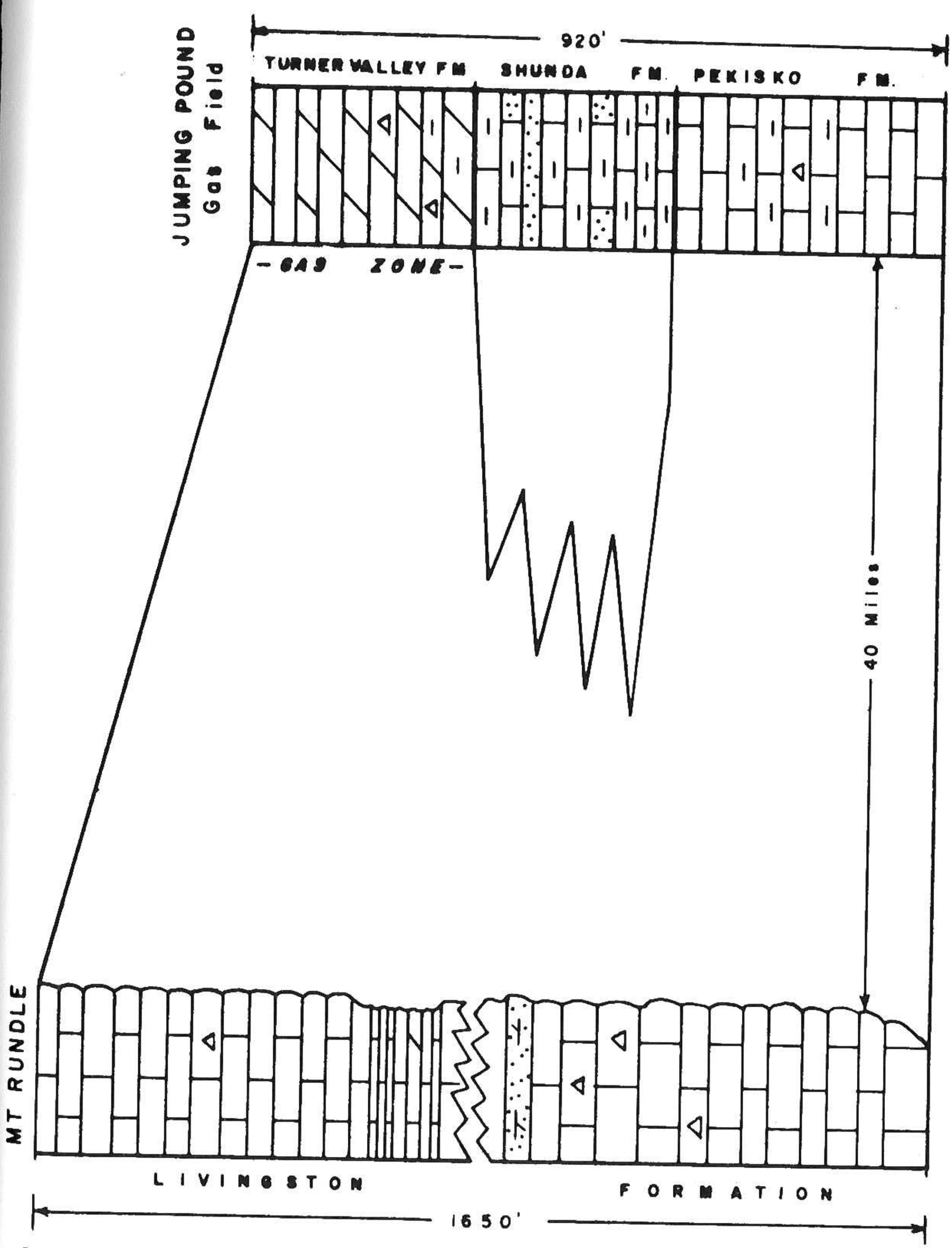
The Livingstone formation ranges in color between light and dark gray with beds of brownish gray to light brown. The rocks weather from light gray to brown. The chert varies in color between gray and black, black being more predominant.

The texture of the rocks is from fine to coarsely crystalline. Thin sections show three ranges in texture. The coarse crystalline rocks were made up of crystals between 1 mm and 3 mm long; the medium crystalline rocks had crystals between 1/10 mm and 1 mm long; the finely crystalline rocks had particles less than 1 mm long.

Staining revealed the presence of dolomite crystals in the coarse and medium grained rocks. They ranged in size between 1/20 mm and 1/2 mm.

Bedding within the Livingstone formation for the most part is massive. However within the darker beds the bedding is only a few inches thick.

PLATE II



Facies Changes Between Livingstone Fm. and Pekisko, Shunda and Turner Valley Fms.

The Livingstone formation is chiefly composed of limestone and dolomitic limestone. The upper one-third of the formation is more dolomitic than the lower two-thirds. It is this part of the formation that correlates with the Turner Valley formation to the east.

The formation as a whole is bioclastic. At Tunnel Mountain, the crinoidal beds make up 74.6% of the rocks, Syringopora, Tetracoralla, Lithostrotion, bryozoa, and bracheapods are also present in minor amounts.

Chert is found as nodules and stringers throughout the Livingstone formation.

Insoluble residues of the pure carbonate rocks revealed less than 0.5% clay sized argillaceous material and doubly terminated euhedral crystals of quartz 1/16 mm long or shorter.

Sedimentation

The Livingstone formation was deposited on a stable shelf that was sinking at a uniform rate. The shelf appears to have been opened to the sea on the western side of the thesis area, thus allowing free circulation over the entire shelf.

The combination of clean water, free circulating currents, and a shallow shelf were advantageous in fostering the prolific fauna from which the Livingstone formation is composed.

Economics

Where the Livingstone formation is dolomatized it is usually porous and would make an excellent reservoir. However the structure within the mountains, with some exceptions, are not advantageous for the trapping and accumulation of hydrocarbons.

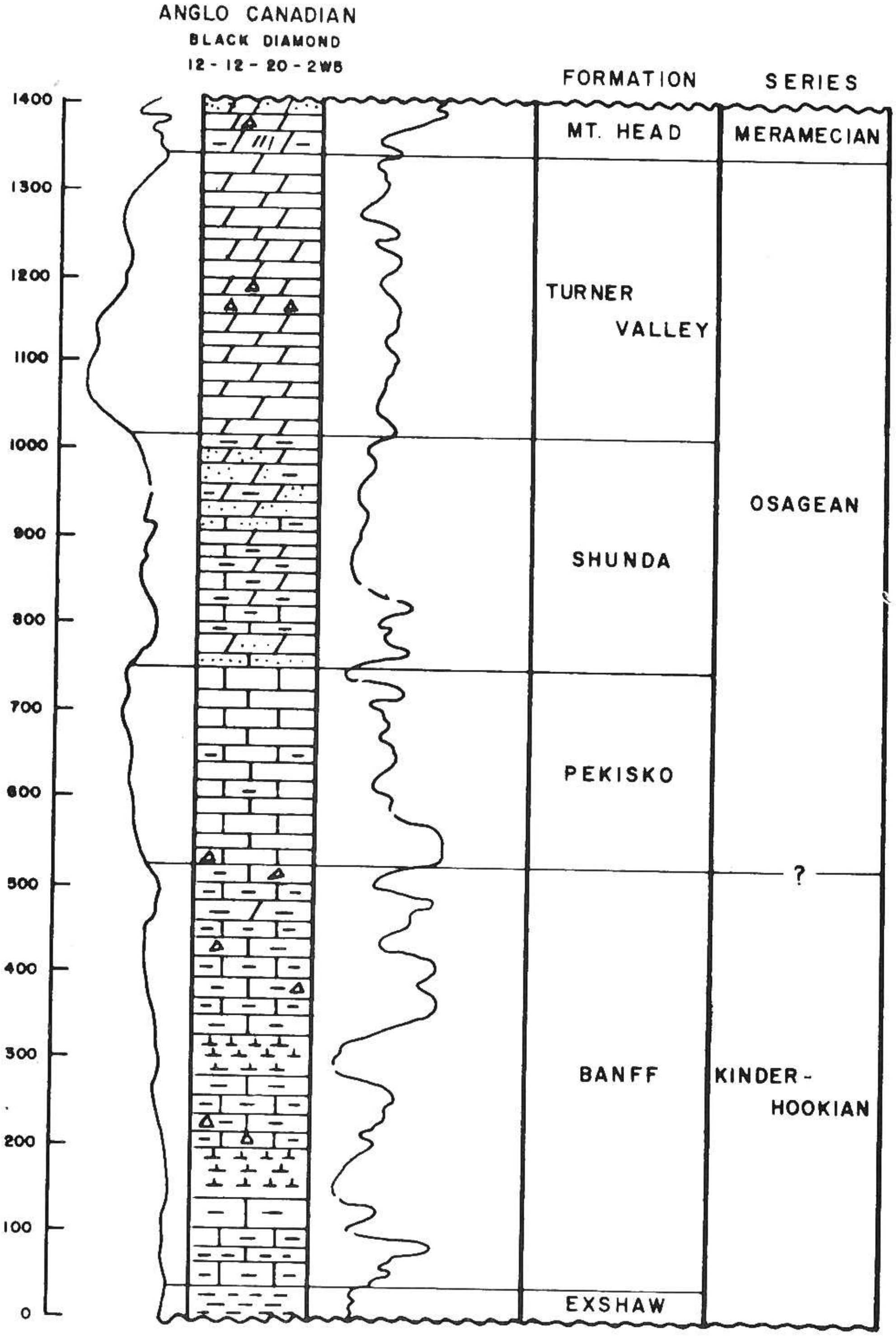
PEKISKO FORMATION

General Description

The name Pekisko was first proposed by Douglas (1953, p. 68) for the lower member of the Livingstone formation. In 1955 the Carboniferous Committee of the Alberta Society of Petroleum Geologists raised the Pekisko to formation status.

Douglas did not specify a type section when he proposed the name. However, on pages 84 and 85 he published a log of the Green

PLATE III



Electric Log - Colomnar Section of Mississippian Subsurface Section in Southern Alberta.

Valley No. 1 well located in Lsd. 6, section 34, township 17, range 3, west of the 5th meridian. This well is located on the Pekisko uplift in the township south of the Turner Valley gas and oil field.

The Pekisko formation is conformably overlain by the Shunda formation on the western side of the area. In the center it is unconformably overlain by Cretaceous rocks north of township 14, and Jurassic rocks south. On the eastern side of the area it is unconformably overlain by Jurassic rocks south of township 18, and Cretaceous rocks north to the eroded edge. Throughout the area the Pekisko formation lies with conformity on top of the Banff formation.

On the western side of the thesis area the Pekisko formation is well developed as illustrated from the geology of the various oil and gas fields.

At Sundre oil field the Pekisko is approximately 150 feet thick and is composed of light tan, brown and gray, fine grained to dense, argillaceous, chalky in part, fragmental, fossiliferous, tight limestone.

At Turner Valley gas and oil field the Pekisko formation is approximately 325 feet thick and is composed of light brown, brown, buff and dark gray, fine to medium grained, argillaceous, silty and oolitic, fossiliferous (crinoids abundant), limestone becoming cherty near the base.

At the Del Bonita oil field the Pekisko is 350 feet thick as reported by Humphreys (1955, p. 131) and is composed of light brown, dense to fine grained, cherty, argillaceous limestone that is fragmental near the top of the section.

Through the center of the area the Pekisko formation ranges in thickness from zero at the truncated edge in township 25, to approximately 500 feet thick. Lithologically it is composed of white, pale pink to light buff, fine to coarse grained, silty, argillaceous, chalky and cherty in part, fossiliferous (crinoidal), dolomitic limestone.

On the eastern side of the area the Pekisko formation varies in thickness from zero at the truncated edge to 495 (?) feet near the Alberta, Montana, Saskatchewan borders. Lithologically it is composed of white to pink, dense to coarse granular, chalky and dolomitic limestone, becoming cherty in the lower part.

The thickness of the Pekisko formation varies from zero at its truncated edge to 495 (?) feet in the southeastern part of the area. In some sections the Pekisko and Banff formation cannot be differentiated. In such cases it is most difficult to determine the true thickness of the separate formations. One well, Fina Triad Lake McGregor No. 10-16 located in Lsd. 10, section 16, township 15, range 21, west of the 4th meridian has a carbonate section of 595 feet thick.

The Pekisko formation is distributed over the entire area with the exception of the northeast corner, where it has been removed by post-Mississippian erosion, and the extreme western edge, where the Pekisko formation has undergone a facies change.

Age and Correlation

The Pekisko formation correlates with the base of the Livingstone formation on the western edge of the area. It also correlates with the Mission Canyon formation in the Williston Basin.

Because of its stratigraphic position and correlation with the above mentioned formations the Pekisko formation is considered to be Osagean in age.

Petrology and Petrography

The colors of the Pekisko rocks are tan, buff, brown, gray, and dark gray on the west side and center of the area. On the east and south sides they are light buff, tan, white and pink.

The texture varies between fine and medium grained on the west and in the center of the area. On the east and south the texture varies between fine and coarse. The coarser textured rocks are re-crystallized limestone.

The rocks on the west side and in the center are fragmental and oolitic; on the east and south sides they are more crystalline.

The Pekisko rocks are composed of limestone, dolomitic limestone, argillaceous limestone, silty limestone, chalk, argillaceous chalk and chert.

For the most part the Pekisko formation lacks porosity; however on the east and south sides of the area porosity is locally developed.

Sedimentation

The Pekisko formation was deposited over a platform that divided the Alberta Basin from the Williston Basin. Over the central part of the platform the water was shallow, which resulted in the deposition of oolites, fragmental limestone, argillaceous and silty limestone and chert. On the Williston Basin side of the platform (east) and the south end, the water was deeper and cleaner which resulted in the deposition of clean crystalline limestone. The clean crinoidal limestone of the Livingstone formation was deposited in the deeper waters west of the Pekisko platform.

Economics

Within the thesis area the Pekisko formation has no commercial oil or gas production. However, shows of oil and gas have been encountered. North of the area oil and gas have been found in commercial quantities.

The rocks on the east and south sides of the area have better oil and gas reservoir properties than those of the center and western side.

SHUNDA FORMATION

General Description

The name Shunda was proposed by H. H. Beach in 1947 before a group of geologists of the Alberta Society of Petroleum Geologists. He used the term for the middel member of three members into which he had divided the Rundle limestone. However, it is not clear to the writer how much of the Rundle limestone this covered.

Gallup (1956, p. 89) used the term Shunda for the middle member of the Rundle limestone in the Turner Valley field. Inasmuch as there is some question as to where in the section Beach's member lies, the writer has used the name Shunda in this thesis in the way it was proposed and used by Gallup.

The Shunda was raised from member to formation status by the Carboniferous Committee of the Alberta Society of Petroleum Geologists in 1955.

The Shunda formation is composed of dark gray to brown, fine grained, argillaceous, silty, in part fragmental, and dolomitic limestone; dark gray to dark greenish gray and brown dense argillaceous, silty anhydritic, fragmental (in part) dolomite; tan to brown anhydrite; dark gray to greenish gray shale; and light green to white interbeds of calcareous silt and fine grained sandstone.

The composition of the Shunda formation changes greatly in the percentage of the above mentioned rock types from area to area.

Within the Sundre oil field the Shunda formation is approximately 112 feet thick and is composed of: light gray to dark gray and buff to tan, fine crystalline, fine grained, dense, argillaceous, chalky, anhydritic and silty limestone and dolomite; and light green, calcareous siltstone.

At Jumping Pound gas field the Shunda formation is approximately 220 feet thick and is lithologically composed of brown to dark gray, dense, argillaceous, and silty interbedded dolomite with hard greenish gray shale and stringers of siltstone. Some anhydrite is present.

In Turner Valley oil and gas field the Shunda formation is approximately 250 feet thick and is made up of dark brown to dark gray, dense to very fine crystalline, argillaceous, anhydritic, cherty, silty and argillaceous limestone and dolomite with bands of dolomitic siltstone.

At the Pincher Creek gas field the full section of the Shunda formation has not been penetrated, however the upper part is composed of gray to brown, fine to coarse grained, fragmental, anhydrite, cherty limestone and dolomite with thin interbeds of black shale.

In the extreme southern part of the area, at Del Bonita, the Shunda is approximately 200 feet thick. Humphries (1955, p. 191) states that this zone is composed of light gray to cream, coarse crystalline, silty dolomite; and light gray to cream, dense to fine crystalline limestone, fragmental in part, becoming argillaceous and cherty near the base.

The Shunda formation conformably overlies the Pekisko formation, and is conformably overlain by the Turner Valley formation. Near the eastern limits of the Shunda formation the Turner Valley formation has been removed by post-Mississippian erosion. In such areas the Shunda formation is unconformably overlain by Jurassic rocks in the southern half of the area (south of township 17) and Cretaceous rocks in the northern half.

The Shunda formation ranges in thickness from zero at its eroded edge to 270 feet thick. In most wells where the Shunda formation has not been eroded the thickness is between 150 and 200 feet. The thinnest interval recognized was 45 feet and the thickest 270 feet.

A true Shunda section has not been observed in the mountains by the writer, however at the type section of the Rundle group on Tunnel Mountain there is a thin bed of siltstone in the center of the Livingstone formation. Another section within the mountains that might represent the Shunda formation was observed in the drill cuttings of the well, Phillips Husky Savanna Creek No. 1 located in Lsd. 12, section 20, township 14, range 4, west of the 5th meridian, between the interval of 7640 feet and 7910 feet. Generally speaking however, the Shunda formation is restricted to the western half of the area east of the mountains. Shunda rocks were removed from the eastern half of the thesis area by post-Mississippian erosion.

The Shunda formation is well developed in the eastern foothills and adjacent plains in the northern part of the area becoming less well developed to obscure in the southern part.

Age and Correlation

The 1955 Carboniferous Committee of the Alberta Society of Petroleum Geologists proposed an Osagean age for the Shunda formation.

The Shunda formation correlates with the center section of the Livingstone formation in the mountains to the west, and with the center section of the Mission Canyon formation of the Williston Basin.

Petrology and Petrography

The colors of the carbonate rocks are brown, tan, cream, gray, and greenish gray. The shale is black, dark brown, dark gray, and greenish gray. The siltstone and sandstone are white, pale green to greenish gray. The chert is brown, gray to dark gray. The anhydrite is buff.

The texture of the rocks ranges from clay sized particles in the shale to coarse grained limestones and dolomites. The texture of the carbonate rocks is from fine to coarse grained; however most of the rocks have textures between fine and medium grained, which for the most part are dense. The coarser clastic rocks have testures of silt and fine grained sand. The anhydrite is very fine grained and dense.

The sedimentary structure as observed in well samples is not too clearly outlined. However it can be said that the carbonate rocks are interbedded with thin interbeds of shale and siltstone, the amount of which changes from well to well. The rock is also brecciated and fragmental in places.

Lithologically, the formation is composed of limestone, argillaceous limestone, dolomite, argillaceous dolomite, calcareous sandstone, anhydrite and chert. Dolomite and limestone are by far the most abundant rocks in the Shunda formation.

No thin sections or insoluble residues were made of this formation because of the lack of chips of suitable size. All information was obtained from electrical logs and oil well drilling chips.

Sedimentation

The Shunda formation appears to have been deposited during a retrogressive movement of the Osagean sea which affected the landward side of the shelf to a more marked extent than the basinward side. During the regressive movement the previously deposited carbonate rocks were broken and re-deposited as fragmental limestones and dolomites. Anhydrite was formed in isolated bodies of water that had restricted circulation. The siltstones and sandstones probably represent deposition close to the strand line which fluctuated from time to time.

The Shunda formation becomes more clastic near its truncated edge. This would suggest a strand line not too far east of the present eastern limits of the formation.

Economics

The Shunda formation as a whole does not have good oil or gas reservoir characteristics. However it is fractured in some wells within the Sundre-Elkton oil and gas field chain and has produced oil after being acidized.

TURNER VALLEY FORMATION

General Description

H. H. Beach was the first to propose the name Turner Valley member in an unpublished address before the Alberta Society of Petroleum Geologists in 1947.[1] The type section was designated as the Mississippian reservoir rocks in the Turner Valley gas and oil field.

The Turner Valley member was raised to formation status by the Carboniferous Committee of the Alberta Society of Petroleum Geologists in 1953.

The Turner Valley formation is divided into three members; in descending order they are: the Upper Porous member, Middle Dense member, and Elkton member. The Upper Porous and Middle Dense members are names handed down from the drillers in Turner Valley gas and oil field and are accepted as formal names.

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1 Personal communication to the writer from D. F. Penner.

Raasch (1956, pp. 17-18) registers a protest to the formal use of the names Upper Porous and Middle Dense members.' He proposed the names be changed to the Mount Rae member for the Upper Porous member, and Misty member for the Middle Dense member. These terms as yet have not received official recognition.

The name Elkton member was proposed by D. F. Penner in an unpublished address before the Alberta Society of Petroleum Geologists in 1955.

In the Sundre-Elkton chain of oil and gas fields the Upper Porous and Middle Dense members have been removed by post-Mississippian erosion. The Elkton member for the most part is well intact, but in some places erosional channels have removed it completely.

The Elkton member has a maximum thickness of 152 feet and is composed of light tan to light brown, coarse crystalline, vuggy, in part cherty dolomite with thin stringers of greenish gray shale.

In the Westward Ho oil field, second field from the north end of the chain, dolomite as described above grades into light tan to light gray, coarse crystalline, non-porous limestone.

At the Jumping Pound gas field the Turner Valley formation is between 239 and 290 feet thick. The Upper Porous member has an average thickness of 43 feet and is composed of buff to light brown, fine to medium crystalline, vuggy dolomite. The thickness of the Middle Dense member averages 64 feet. Its composition is buff to light brown, fine to medium crystalline, argillaceous, anhydritic and calcareous, porous dolomite. The Elkton member has an average thickness of 130 feet and is composed of buff to light brown, fine to medium crystalline, dolomite with intercrystalline and vuggy porosity.

East of Jumping Pound gas field in the well, Western Bearspaw No. 22-9, located in Lsd. 9, section 22, township 25, range 2, west of the 5th meridian, the Upper Porous member and the upper part of the Middle Dense member have been removed by post-Mississippian erosion. Here the Middle Dense member is 30 feet thick and is composed of light gray to buff, fine crystalline to dense, cherty, dolomite. The Elkton member is 145 feet thick and is composed of light gray to buff with a trace of cream and pink, dense to medium crystalline, granular in part, brecciated, silty, arenaceous, calcareous, and chalky dolomite with thin stringers of silt and very fine grained sandstone.

Still further east near the erosional edge of the Turner Valley formation, in Lsd. 10, section 36, township 24, range 29, west of the 4th meridian, post-Mississippian erosion has removed all but 60 feet of the Elkton member. Lithologically it is composed of cream to light buff, dense to coarse crystalline, silty dolomitic, cherty and chalky, non-porous limestone, with stringers of greenish gray waxy glauconitic shale.

From the foregoing east-west section from Jumping Pound to Mobil Calgary No. 36-10 the lateral variation of change from dolomite to limestone within the Elkton member is evident, also the change in grain size and quantity of clastic sediments was noticeable indicating the approach of a shore line to the east.

At Turner Valley the Turner Valley formation is approximately 300 feet thick. The Upper Porous member is between 80 and 100 feet thick, lithologically composed of white to brown, dense to medium crystalline, slightly argillaceous in part, vuggy dolomite. The Middle Dense member is 60 feet thick and is made up of dense, cherty, calcareous dolomite. The Elkton member is 120 feet thick and grades between white, fine to coarse crystalline, non-porous limestone and white to brown, fine to medium crystalline, vuggy dolomite. Within the Turner Valley gas and oil field the Elkton member changes vertically and horizontally from dolomite to limestone.

In the well Barnsdale Willson No. 1, located in Lsd. 14, section 6, township 17, range 25, west of the 4th meridian, (36 miles east of the south end of Turner Valley oil and gas field) the Turner Valley formation is 300 feet thick. In this well at least part of the Upper Porous member has been removed by post-Mississippian erosion. The rest of the Turner Valley formation is composed of light gray, tan, white and light brown, cherty, sucrosic to coarse crystalline dolomite with traces of vuggy porosity near the top. This section cannot be divided into members on the basis of lithology.

In the Pincher Creek gas field the Turner Valley formation is 380 feet thick. The Upper Porous member is 120 feet thick and is composed of tan to light brown, fine to medium crystalline limestone, with thin stringers of dense dolomite. Intergranular pososity is present in the coarser crystalline dolomite. The Middle Dense member is less than 50 feet thick and is composed of fine crystalline, calcareous, silty, argillaceous and cherty dolomite. The Elkton member is between 235 feet and 165 feet thick, lithologically composed of tan to brown, coarse crystalline, fragmental limestone interbedded with fine to medium crystalline, calcareous dolomite. Porosity is developed in the dolomite.

At the well Western Blood No. 17-9 located in Lsd. 9, section 17, township 5, range 25, west of the 4th meridian (23 miles east of the Pincher Creek gas field) the Turner Valley formation is 200 feet thick. The Upper Porous member has in part been removed by post-Mississippian erosion and cannot be differentiated from the Middle Dense member. These members together are 125 feet thick. They are composed of buff to gray buff, dense to very fine crystalline, cherty, slightly argillaceous and silty dolomite. The Elkton member is 135 feet thick and is composed of light gray to buff, fine to medium crystalline dolomite grading to dolomitic limestone.

In the south end of the thesis area the well, Mobil Oil Willson No. 32-12 located in Lsd. 12, section 32, township 7, range 20, west of the 4th meridian, is producing oil from the Elkton member. At this location the Turner Valley formation has been eroded removing all but 75 feet of the Elkton member which is composed of light gray to light tan, coarse crystalline vuggy dolomite.

The Turner Valley formation is restricted to the eastern foothills and the western third of the plains. It conformably overlies the Shunda formation and is conformably overlain by the Mount Head formation in the west, and unconformably overlain by Jurassic rocks south of township 21 and Cretaceous rocks north of township 21.

Age and Correlation

The Turner Valley formation is Osagean in age and correlates with the upper third of the Livingstone formation in the mountains to the west. It also correlates with the lower half of the DeBolt formation of Northeastern British Columbia and Northwestern Alberta, with the Upper Mission Canyon formation of Montana and the Williston Basin.

The Turner Valley formation occupies the same stratigraphic position as the Keokirk limestone in the Mid-Continent area and the Mississippian type section in the Upper Mississippi Valley.

Petrology and Petrography

The colors of the rocks are white, light buff, buff, tan, light brown, brown, cream and light gray.

The texture ranges from aphanitic in the Middle Dense member to coarse crystalline in the Upper Porous and Elkton members. However, the texture within the Upper Porous and Elkton members for the most part ranges in size between fine and medium crystalline.

Lithologically the Turner Valley formation is composed of limestone, dolomite, and silty, argillaceous, anhydritic, cherty limestone and dolomite. In the Elkton member the entire section might be composed of either limestone or dolomite, or a combination of the two. When both are present the limestone is always found overlying the dolomite. Exceptions to this are found only in thin beds of dolomite within the limestone. Within the Elkton member the limestone thickens at the expense of the dolomite.

Insoluble residues show the composition of silt within the Elkton member varies from none to as high as 31%. The highest percentage of silt was found within the Westward Ho oil field. The silt is composed of angular quartz grains and euhedral crystals of quartz ranging in size between 1/8 mm and 1/16 mm.

The porosity within the Turner Valley formation is associated with dolomitization. With the exception of fractures the writer has not observed porosity in the limestone. The porosity is both intergranular and vuggy. Porosity observed in thin sections ranged between 7% and 10%. MacKenzie (1940, p. 1634) states that the porosity within the Turner Valley oil and gas field ranges between 1% and 20% with an average of 10%.

The vugs measured in thin sections varied between 1/8 mm and 1 mm in diameter and were almost without exception lined with a black dead-oil residue.

Sedimentation

The Turner Valley formation appears to have been deposited on a stable shelf that was subsiding at a slow even rate.

The relationship between the dolomite and limestone is very interesting, but difficult to explain. The writer has not, as yet, found a satisfactory solution to the problem. Rigby[1] suggests that the dolomitic sections might be the results of wave action and currents winnowing limestone debris. The winnowing would remove the fine grained material and leave a porous deposit that was acted upon by circulating water, bringing about dolomitization thus increasing the porosity. The limestone sections, on the other hand, deposited in areas not acted upon to a marked extent by waves and currents, received the finer grained more impervious materials; consequently they were not dolomitized.

Economics

The Turner Valley formation is by far the most important producer of oil and gas in the Mississippian system of Southern Alberta. Virtually all of the production from the Turner Valley formation comes from the Elkton member. It is productive at the Sundre-Elkton gas and oil fields, Jumping Pound gas field, Turner Valley gas and oil field, and in the Pincher Creek gas field. The Middle Dense member is productive in the north end of Jumping Pound gas field. The Upper Porous member is productive in the Turner Valley gas and oil field and at Pincher Creek gas field.

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1 Personal communication.

MOUNT HEAD FORMATION

General Description

The Mount Head formation was named by Douglas (1953, p. 68). The type section is located in the Mount Head Map area "on ridges north of Flat Creek and Highwood River."

The Mount Head formation is subdivided into six members. In ascending order they are: Wielderman, Baril, Salter, Cummings, Marston and Camavon. Following is Douglas' (1953, pp. 75 and 78) log of the type section:

Rundle group
Mount Head formation
Carnarvon member
Finely crystalline and crypto-crystalline limestone; thin calcareous shale and dolomitic limestone 160

Marston member
Finely crystalline, crypto-crystalline and arenaceous granular dolomites and limestones; anhydrite in Flat Creek well 140

Cummings member
Coarsely crystalline limestone, with interbedded finely crystalline, cherty dolomite and limestone 200

Salter member
Arenaceous granular and finely crystalline dolomite, solution breccias at top; anhydrite in Flat Creek well 100

Baril member
Medium and coarsely crystalline limestone, in part oolitic; arenaceous granular and finely crystalline dolomite 50

Wielderman member
Arenaceous, granular limestone 45

The individual members of the Mount Head formation are hard to identify away from the Mount Head area. It seems that for the most part this formation is more easily divided into two members as Douglas (1950, p. 13) did in the Livingstone Range. Here the upper member is 200 feet thick and is composed of black to dark gray, dense, hard limestone with thin interbeds of black calcareous shale and coarsely crystalline limestone. The lower member is 450 feet thick and is composed of buff to brown, fine grained, thin bedded, argillaceous dolomite, alternating with gray, fine to medium grained, massive, cherty limestone, grading to dolomite.

At Storm Creek on the southwest side of Mount Rae, the Mount Head formation is 557 feet thick as measured by Raasch (1943, p. 6). Here Raasch describes three members in the Mount Head formation. His members are as follows in descending order: Member No. 1 is 188 feet thick. It is composed of black to dark gray, bituminous, argillaceous limestone interbedded with thin beds of black calcareous shale. Member No. 2 is 134 feet thick. It is composed of black, massive, dense, highly argillaceous, cherty, crinoidal limestone. This member stands out as a topographically resistent unit. Member No. 3 is 235 feet thick. It is composed of black to gray, fine to medium grained, argillaceous limestone. This member is highly fossiliferous and reefoidal in part.

Figure number 5 is a photograph of the Mount Head formation at the Head of Storm Creek.

On Exshaw Creek the Mount Head formation as reported by Clark (1954, p. 42) is 600 feet thick. It is composed of dark gray to black, coarse crystalline to dense, crinoidal, argillaceous, fossiliferous limestone with beds of dark gray, red and green shale. The lower limestone beds are arenaceous and silty.

In Canyon Creek at Moose Mountain the Mount Head formation is 300+ feet thick. It is composed of gray to tan, coarse to fine crystalline, crinoidal limestone, grading to dolomite and tan to gray, coarse crystalline, arenaceous and silty porous dolomite.

Figure number 6 is a photograph taken near the top of the Mount Head formation at Moose Mountain showing the porous nature of the dolomite.

Due to the relative ease with which this formation weathers and the steep dip of the beds in most outcrops, this portion of the Mississippian system is rarely well exposed.

The Mount Head formation lies with conformity on the Livingstone formation in the mountains and on the Turner Valley formation of the foothills. It is conformably overlain with the Tunnel Mountain formation in the mountains and unconformably overlain by Jurassic rocks in the foothills and plains.

The Mount Head formation varies in thickness from zero at its truncated edge to 700 feet at its type section.

This portion of the Mississippian system is restricted to the western side of the thesis area. It is present throughout the mountains and foothills and has been observed in the subsurface at Jumping Pound, Turner Valley and Pincher Creek fields.

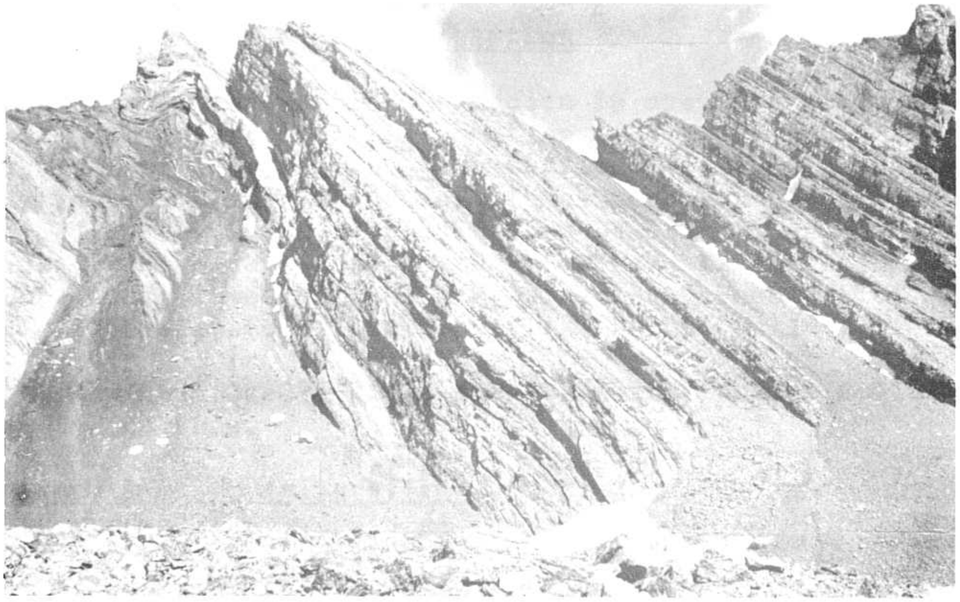


Fig. 5 Mount Head Formation at Head of Storm Creek

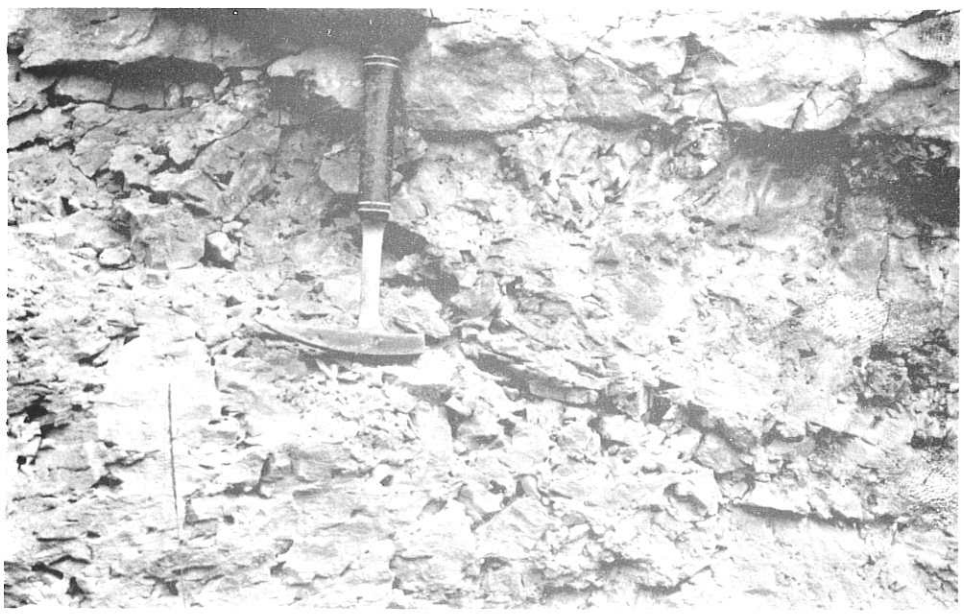


Fig. 6 Porous Dolomite in Mount Head Formation at Moose Mountain

Age and Correlation

The Mount Head formation is Meramecian in age. It correlates with the upper half of the DeBolt formation of Northwestern Alberta and Northeastern British Columbia, the Charles limestone of the Williston Basin, the Brazer formation of Southern Idaho and the Northern Utah, and the Humbug formation and Deseret limestone of Central Utah. It also correlates with the Warsaw limestone, Spergin limestone, St. Louis limestone and Ste. Genevieve limestone of the Mississippian type section of the Upper Mississippi Valley.

Warren (1927, pp. 31-32) lists the following fossils collected from the Banff Park area.

Hapsiphyelum calcareforme (Hall) ?
Triplophyelum minnewankense Shimer
Lophophyelum ? *cascadense* sp. nov.
Cliscophyelum ? *bouffense* sp. nov.
Lithostrotion flexuosum sp. nov.
Syringapora surcularia Gerty
Fenestella serratula Ulrich
Fenestella cf. *tenas* Ulrich
Productus infatus McChesney
Pustula punctata (Martin)
Spirifer cf. *arkansanus* Girty
Spirifer cf. *increbescens* Hall
Eumetria marcyi (Shumard)
Eumetria vera (Hall)
Composita triniechea (Hall)
Composita transversa (Mather)

Petrology and Petrography

The colors of the limestones and dolomites are medium gray, dark gray, black, buff to dark brown. The siltstone is tan and light green. The shale is black, green and red.

The texture of the carbonate rocks ranges from cryptocrystalline to coarse grained. The siltstones were composed of coarse grained silt and very fine grained sand.

Thin sections showed the crystallized limestone to be composed of calcite crystals ranging in size between 1/10 mm and 2 mm.

The bedding in the carbonate rocks ranged from a few inches to 10 feet thick. Thin beds of shale or highly argillaceous limestone was observed on the bedding planes of the carbonate rocks.

Many of the rocks are brecciated and oolites are present in some sections. Cross-bedding, or solution breccia was observed in a siltstone bed at Moose Mountain.

Lithologically the Mount Head formation is composed of limestone, crinoidal limestone, argillaceous limestone, dolomite, argillaceous dolomite, silty dolomite, anhydrite, dolomitic siltstone and shale.

Thin sections of the carbonate rocks showed them to be composed of detrital organic remains of crinoids, foraminifera, brachiopods, bryozoan, corals, and other non-recognizable organic remains. These fragments are so re-crystallized in some slides that it was difficult to recognize anything but the outlines of the various organisms. The fossil fragments are held together by calcite and dolomite cement and an argillaceous matrix which made up from 25% to 60% of the rock. The organic remains as a rule are less recrystallized in the more argillaceous rocks.

Insoluble residues were composed of argillaceous materials, silt sized quartz grains, silicified fossil remains, pyrite and chert. The percentage of insoluble residue ranged from less than 1% in the clean light colored limestones and dolomites (rare) to 97% in a dolomite siltstone.

Sedimentation

The strata of the Mount Head formation was deposited under the environment of an unstable shelf. The cross-bedding (?) brecciation, and oolites would suggest that the water was shallow. The anhydrite was probably deposited in isolated basins caused by a fluctuation in the strand line.

Economics

The Mount Head formation has possibilities of becoming a major producer of oil and gas. It is oil productive at Turner Valley oil and gas field, and is gas bearing close to its truncated edge southeast of the Turner Valley field. In the mountains, outcrop sections in some areas are vuggy and oil stained. At Moose Mountain residual oil is found in vugs. Residual oil was also found in Mount Head rocks at Mount Rae.

TUNNEL MOUNTAIN FORMATION

General Description

The name Tunnel Mountain was first proposed by H. H. Beach in 1947 in an unpublished address before a group of Alberta geologists. He proposed the name as the upper of three members into which he divided the Rundle formation.

The type section for the Tunnel Mountain formation is on the south side of Tunnel Mountain in Banff Park. It is 630± feet thick and can be divided into two members on the basis of lithology. The upper member is 250 feet thick and is composed of gray, gray buff to reddish brown, fine to medium grained, cherty, thin bedded sandstone, grading into quartzite. The sandstone is slightly dolomitic in places, grading into arenaceous dolomite in the upper 50 feet. The lower member is 380 feet thick. It is composed of dark gray, fine to coarse crystalline, crinoidal, argillaceous, arenaceous, dolomitic limestone grading to dolomite; and gray to dark buff, fine to medium crystalline, cherty, arenaceous, calcareous dolomite.

At the head of Storm Creek, the Tunnel Mountain formation is 602 feet thick according to Raasch (1954, p. 4). Lithologically it is composed of gray- to dark-gray, fine- to medium-crystalline, cherty, silty, dolomitic limestone grading to dolomite with interbeds of gray and green calcareous shale. Dark gray crinoidal limestone is present in the center of the section.

At Exshaw the Tunnel Mountain formation is 275 feet thick according to Clark (1954, p. 43). Due to the ease with which the formation weathers, good exposures in this area are rare and rather difficult to measure. The upper part of the formation is composed of gray fine grained, dolomitic sandstone. The lower part is composed of gray, fine to medium crystalline, arenaceous dolomite. The sand content increases progressively from the bottom to the top of the section.

At Mount Head, Douglas (1953, p. 68) refers to the Tunnel Mountain formation as the Ethington member of the Rocky Mountain formation. Here the Tunnel Mountain formation is 290 feet thick and is composed of three parts as described by Douglas (1953, p. 75).

The upper part is 130 feet thick. It is composed of arenaceous, granular dolomite, partly cherty, finely crystalline dolomite.

The middle part is 60 feet thick and is composed of arenaceous, granular limestone, partly cherty; medium crystalline limestone; and medium crystalline porous dolomite.

The lower part is 100 feet thick. It is composed of green shale and finely crystalline limestone and dolomite.

In the Gap on Old Man River, Douglas (1950, p. 13) refers to the Tunnel Mountain formation as Member D of the Rundle formation. He describes it as being 250 feet thick, lithologically composed of gray, fine-grained, blocky limestone, buff, fine-grained dolomite, breccias of limestone and chert, cross-bedded, arenaceous dolomite, and thin stringers of porous limestone and green shale.

In Crowsnest Pass the Tunnel Mountain formation like the other formations within the Mississippian system is faulted. The true thickness of this formation according to Raasch (1955, p. 1) is 576 feet thick. Lithologically it is composed of light gray, fine grained, crinoidal limestone, interbedded with green calcareous slightly arenaceous shale.

The Tunnel Mountain formation thins from west to east. This is in part due to post-Mississippian erosion. In the western most exposures the formation is 600+ feet thick. In the eastern most exposures it is between 250 and 300 feet thick.

The Tunnell Mountain formation is confined to the western edge of the thesis area. It has not been observed east of the mountains by the writer.

Age and Correlation

The Tunnel Mountain formation correlates with the Stoddard formation of the Peace River district of Northwestern Alberta and Northeastern British Columbia, the Great Blue limestone and the lower part of the Manning Canyon shale of Utah, and the Big Snowy Group of Central Montana and the Williston Basin.

The age of the Tunnel Mountain formation has been in question for many years. Early workers place it in the Pennsylvanian and Permian systems. More recent workers place it in the Mississippian system and assign it to the Chesterian series.

Raasch (1954, pp. 11, 13) collected the following list of fossils from Storm Creek:

Echinocrinus sp.

Batostomella spinulosa Ulrich

Composita subquadrata (Hall)

Composita trinuclea (Hall

Acanthopecten sp.

Bairdea cestriensis Ulrich

Bythocypris aff. *truncata* Cooper

These fossils support a Chesterian age.

Warren (1956, p. 247) makes the following statement concerning the age of the Tunnel Mountain formation at the type section: "The age determination is not simple, as the formation is usually very sparsely fossiliferous and such fossils as do occur are poorly preserved. They are usually internal molds and a wide latitude must be allowed for error in identification." He assigns the formation to the Pennsylvanian system on the strength of the following fossils:

Caninia torquia (Owen)

Orbiculoidea arenaria Shimer

Schuchertella ? sp.

Dictyoclostus semireticulatus (Martin)

Dictyoclostus coloradoensis (Girty) ?

Juresania nebrascensis (Owen)

Paraphorhynchus obscurum Shimer

Dielasma arkensanum Weller

Phricodothyris perplexa McChesney

Mayalina wyomingensis (Lea)

Petrology and Petrography

The colors of the carbonate rocks are light gray, gray, dark gray and buff. The shale is dark gray, light green and gray green. The siltstones and sandstones are gray, gray buff and reddish brown; the chert is gray to dark gray.

The texture of the carbonate rocks ranges from fine to coarse crystalline. Staining and etching show the calcite crystals to be larger than the dolomite crystals within the same rock samples. The calcite crystals range in sizes up to 2 mm whereas the dolomite crystals range in size from 1/32 to 1/3 mm. The texture of the siltstones and sandstones range from fine silt to medium grained sand.

Lithologically the formation is composed of limestone, argillaceous and silty limestone, dolomite, argillaceous and silty dolomite, siltstone, calcareous and dolomitic siltstone, quartzite, shale, calcareous and dolomitic shale, and chert. The lighter colored carbonate rocks are made up of between 10% and 50% dolomite. The average clean carbonate rock was composed of 75% calcite, 24% dolomite and 1% or less of quartz grains and euhedral crystals of quartz. The darker carbonate rocks contain up to 30% argillaceous material and silt sized quartz grains. The calcite in these rocks is granular (calcilutites).

The dolomitic siltstones give an appearance of quartzite. They are very hard and break with a concoidal fracture. Insoluble residues of these rocks show them to be composed of angular quartz grains of silt and fine grained sand cemented entirely with dolomite and minor amounts of calcite.

Sedimentation

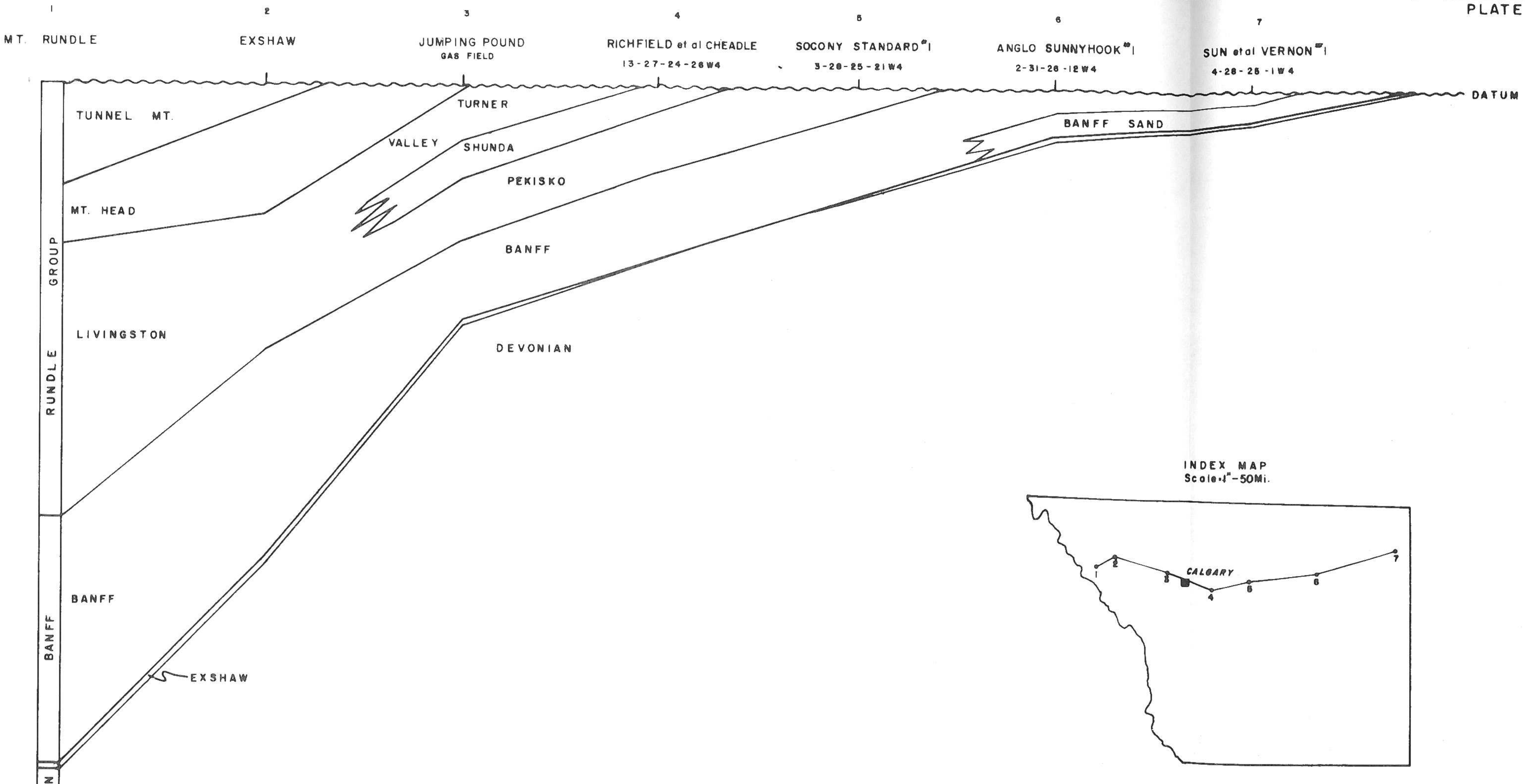
The Tunnel Mountain formation was deposited on a shelf that was slowly emerging from the sea. The water over the shelf was probably never deep.

The northern end of the thesis area was closer shoreward as evident from the coarser clastic rocks in that direction.

The Mississippian Period was brought to a close by the final withdrawal of the Chesterian seas.

Economics

The Tunnel Mountain formation is not considered a good prospect for oil and/or gas accummulation because of its geographical position and the poor reservoir characteristics of its rocks.



Stratigraphic Cross Section of the Mississippian System From Mt. Rundle to Sun et al Vernon No. 1

VERTICAL SCALE: 1" - 500'

E C O N O M I C   G E O L O G Y

GENERAL STATEMENT

Oil, natural gas, sulphur and rock wool are recovered or produced from Mississippian rocks in Southern Alberta.

Four major oil and/or gas fields and several minor fields are located within the geographic boundaries embraced by this thesis. The fields, starting with the southernmost and progressing through to the north are as follows: Pincher Creek gas field, Turner Valley oil and gas field, Jumping Pound gas field, and Sundre - Westward Ho - Harmattan - Elkton oil and gas field. The latter is a series of fields producing from the same zone that have been grouped together for the purpose of discussion.

PINCHER CREEK GAS-CONDENSATE FIELD

Location

The Pincher Creek field is located between eleven and one-half and nineteen miles southeast of the town of Pincher Creek on highway No. 31, which leads to Waterton Park. Calgary is located approximately 100 miles due north of the field.

History

The general Pincher Creek - Waterton area had a very long and disappointing history in regard to oil exploration and drilling until the discovery of gas at the Pincher Creek gas field by Canadian Gulf Oil Company in 1947.

In the early days before the advent of settlers in Southern Alberta the Indians were attracted by oil seepages on Cameron Creek west of Waterton Lakes. This oil was used by the Indians for medical purposes. Through persuasion the settlers found the source of the Indian's oil and used it to great advantage for greasing their wagons and other farm machinery. In 1902 a well, Lincham No. 1, was drilled to a depth of 1900 feet. At 1020 feet oil in uncommercial quantities was found. A second well drilled about the same time west of Waterton Lakes spudded into Precambrian rocks and at 1500 feet faulted into Upper Cretaceous rocks of the Benton formation. This well was the first to penetrate the Lewis overthrust and it indicates that the oil found along Cameron Creek was seeping through the overthrust from the Cretaceous beds below. By the end of 1946, 28 wells had been drilled and abandoned without reaching the Paleozoic limestone or finding oil or gas in commercial quantities.

In April of 1947, after an extensive geophysical program, Canadian Gulf spudded what was to become the discovery well of the Pincher Creek gas-condensate field. Pincher Creek No. 1, located in Lsd. 15, section 24, township 3, range 29, west of the 4th meridian, contacted the top of the Rundle limestone at 11,705 feet and has a final total depth of 12,516 feet. The well was completed June 19, 1948, with an indicated open flow of 45 MMcf/d of gas and 1670 barrels of distillate per day. Pincher Creek is Alberta's largest gas-condensate field.

Stratigraphy

The Mississippian system within the Pincher Creek field is overlain by some 12,000 feet of Recent, Pleistocene, Cretaceous, and Jurassic sediments. Because of the nature of this thesis, these sediments will not be discussed.

Mount Head Formation

The Mount Head formation is approximately 150 feet thick and is composed of slightly silty and argillaceous dense dolomites and recemented breccia. Stringers of crystalline dolomite are found throughout the zone but are more abundant near the base. Some intergranular porosity is present, and fractures are in part lined with calcite, quartz and solid black hydrocarbons.

Turner Valley Formation

Upper Porous Member. There is approximately 120 feet of the Upper Porous member. Lithologically it is composed of fine to medium crystalline dolomite with thin layers of fine to dense dolomite. Fossil voids contribute the major portion of the highly intergranular porosity. Permeability is enhanced by the presence of vertical and diagonal fractures.

Middle Dense Member. This zone has an average thickness of less than 50 feet and is composed of finely crystalline, calcareous, dolomite, interbedded with silty, argillaceous and cherty dolomite. Some intervals of clean dolomite have intergranular porosity. Vertical and horizontal fractures are present throughout.

Elkton Member. The Elkton member has a thickness of between 233 feet and 193 feet. Lithologically it is composed of interbedded crystalline dolomite and coarsely crystalline, fragmental limestone. Well developed porosity is present in part of the dolomite and to a lesser extent in the limestone. Fractures are present.

Shunda Formation

The full thickness of this zone has not been penetrated in any of the wells drilled at Pincher Creek. The Pincher Creek No. 1 well drilled 303 feet of the Shunda formation and found it to be composed of a series of normal marine to coarse fragmental limestones with three intervals of dense to finely crystalline dolomite. The upper thirty feet is predominantly composed of dense limestone and dense dolomite.

Structure

The subsurface structure shows the Pincher Creek production horizon to be a doubly plunging thrust block of Mississippian limestone with a gentle dip of between 4° and 8° to the southwest and a strike of north 30° west. The field limits are as yet not definitely defined. The gas/water interface is taken at a subsea elevation of -8200 feet; this would place the western limits of the field just east of the third well drilled in the field, Fred Schrimpp No. 1 located in Lsd. 4, section 35, township 3, range 29, west of the 4th meridian. This well contacted the top of the Rundle group at a subsea elevation of -8232 feet, or 32 feet below the gas/water interface. The northern limit has been reached and lies slightly south of Rudolf No. 1, located in Lsd. 11, section 31, township 4, range 29, west of the 4th meridian. This well contacted the top of the Rundle group at a subsea elevation of -8118 feet and the Upper Porous member at a subsea elevation of -8267 feet or 67 feet below the gas/water interface. The eastern limit of the field is very abrupt due to the thrust fault. However, this side of the field has not been definitely established although a well, F. M. Huddlestun No. 1, located in Lsd. 6, section 1, township 4, range 29, west of the 4th meridian, contacted the Upper Porous member at 190 feet below the gas/water interface (-8390). The southern limits of the field are not as yet defined.

Production

Ten wells have been drilled in the Pincher Creek field. Of the ten wells, seven are completed gas wells and three have the status of suspended or abandoned wells. These suspended wells contacted the Upper Porous member below the gas/water interface. The eleventh well, Ray Marr No. 1, located in Lsd. 7, section 28, township 4, range 29, west of the 4th meridian, is currently drilling.

Reservoir Factors and Reserve Estimates[1]

Reservoir Rock: Turner Valley Formation

Type Gas: Non-associated

Specific Gravity (AIR = 1): 0.58

Heat Value BTU/CF: 1,042

Average Well Depth: 11,700 feet

Gas/Water Interface: 8200 feet subsea (-8200 feet)

Average Thickness of Pay Zone: 389.1 feet

Porosity: 4.62%

Connate Water: 16%

Original Pressure: 4,945 P.S.I.A.

Reservoir Temperature: 191° Fahrenheit

Original Gas In Place: 3,631.3 billion cubic feet

Gross Absolute Open Flow/Well/Pay: 75 MMcf

CO_2 and H_2S makes up 17% of the gas

Permeability Type: 10% Intergranular - 90% Intermediate

Pincher Creek at the present time has the status of a shut-in gas field and will remain as such until the completion of at least part of the Trans Canada Pipe Line. Trans Canada Pipe Line has a contract with the British American Oil Company (formerly Canadian Gulf Oil Company) whereby they will buy 100 MMcf/d of gas during their first year of operation and 170 MMcf/d in subsequent years. British American Oil Company has just finished building a sulphur plant in the Pincher Creek field in order to prepare the gas for delivery to Trans Canada Pipe Line. This plant will be capable of processing 170 MMcf of crude natural gas per day from which it will recover 780 long tons of sulphur, 1230 barrels of propane, 1300 barrels of butane, 1020 barrels of natural gasoline and 7810 barrels of condensate.

TURNER VALLEY GAS-CONDENSATE AND OIL FIELD

Location

Turner Valley gas and oil field is located within the foothills belt, 35 miles southwest of Calgary.

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1 Figures from the Reservoir Engineering Digest.

History

Turner Valley has had a very colorful and productive history, and although production is on the decline there is still a lot of gas and oil within this field. Gas seeps were detected on the bank of Sheep River by the settlers of the Turner Valley area. One such seep, located near the present site of the Royalite plant, had enough gas flowing from it to interest promoters from Calgary, and in 1913 the first well, Dingman No. 1, was drilled. This well found gas and distillate in the Blairmore sands. After the success of Dingman No. 1, several more Blairmore wells were drilled, and a pipeline was constructed to Okotoks to join the Calgary-Bow Island gas line.

The year 1924 was momentus for Turner Valley because in that year Royalite No. 4 was completed as a gas well in the Rundle limestone at a depth of 3740 feet with an initial potential of 22 MMcf/d of gas and a high condensate content. Between 1924 and 1936, 114 wells were drilled into the Rundle limestone for the purpose of producing the naphtha contained in the gas. Part of the gas was sold and transported to Calgary for domestic and industrical heating. Inasmuch as gas was produced in excess of gas requirements, gas was flared after the removal of naphtha. Hume (1950, p. 320) estimates about one trillion cubic feet of gas was flared between 1924 and 1936.

In April of 1930, Model No. 1 contacted the Rundle limestone at 5801 feet (subsea elevation of 1707). This well was completed 105 feet into the Rundle limestone and had an initial production of 83 barrels per day of discolored naphtha (68.5° gravity). By December of the same year the production had increased to 176 barrels of crude naphtha per day. Link (1953, p. 128) states that this well should receive credit for being the first well in Turner Valley to discover oil, but due to its limited size it received little attention. Oil was "re-discovered" in April of 1936 when Turner Valley Royalties No. 1 found oil in the Rundle limestone at a depth of 6395 feet (subsea elevation of -2155). This well was completed with an initial flow of 860 barrels of 45° API oil per day. From 1936 to 1940 wells were drilled on the west flank of the Turner Valley structure in search of the oil.

In 1940, under the direction of J. O. C. Sanderson, Home Millarville No. 1 was drilled and completed. This well resulted in the northward extension of Turner Valley and extended the field approximately eight miles. Almost all the drilling from 1940 to the present has been done in the northern end of the field.

Probably more articles and reports, both private and government, have been written on the geology of Turner Valley than any other oil or gas field in Western Canada.

Stratigraphy

No well within the Turner Valley field has penetrated the full Mississippian section. However, one well, Royalite et al Devonian Test No. 1, located in Lsd. 2, section 25, township 19, range 3, west of the 5th meridian, drilled 1555 feet of Mississippian rock before faulting back into the Blairmore formation. It is believed by the writer that the faulting occurred at the base of the Mississippian system in the Exshaw formation, approximately 30 feet above the top of the Devonian system.

Mount Head Formation

The Mount Head Formation is 120 feet thick.

This horizon is composed of brown, buff to light buff, microcrystalline to dense argillaceous and silty dolomite. Stringers of brown chert are present throughout the zone. A thin zone (5-8 feet) of porosity is found near the top of this formation throughout the field and a thicker zone of porosity (10-15 feet) occurs in the center of the formation in the northern half of the field. Mineralogically (MacKenzie 1940, p. 1627) the Mount Head formation is composed of between 47% and 68% dolomite, 12% and 26% calcite, 15% and 26% SiO_2 (chert and silt) and 5% and 9% oxides of Al. and Fe.

Turner Valley Formation

The Turner Valley Formation is 300 feet thick.

Upper Porous Member. The Upper Porous member is 80 to 100 feet thick. The Upper Porous Zone is quite uniform in thickness and composition throughout the Turner Valley field. However, there is a color change in the dolomite from brown in the north half of the field to white in the south. Lithologically the Upper Porous member is composed of brown to white, dense to medium crystalline, in part slightly argillaceous, porous, fossiliferous (crinoids and bracheopods) dolomite. MacKenzie (1940, p. 1637) points out that the voids within the cores and chips are relatively small with the great majority being less than 1/16 of an inch in diameter and a few 1/4 of an inch in diameter. The mineralogical composition (MacKenzie, 1940, p. 1627) shows a much higher percentage of dolomite than the Mount Head formation with 96% dolomite and 4% limestone.

Middle Dense Member. The Middle Dense Member if 60 feet thick. It is the most persistent marker in the Turner Valley formation and is composed of dark dense siliceous dolomite with thin (1 to 2 feet thick) bands of chert. Mineralogically (MacKenzie, 1940, p. 1627) it is composed of between 46% and 74% dolomite, 15% and 25% limestone, 11% and 25% SiO_2 (mostly chert), oxides of Al. and Fe. 0% and 4%.

<u>Elkton Member</u>. The Elkton member is 60 to 120 feet thick. It is composed of white to light tan, fine to coarse crystalline, non-porous, fossiliferous limestone grading into brown to white, dense to medium crystalline, slightly argillaceous, porous, fossiliferous dolomite. Some wells within the field have as much as 120 feet of limestone with no dolomite whereas others have 120 feet of dolomite and no limestone. In the center and extreme south end of the field the Elkton member is composed of limestone. In wells where both limestone and dolomite are present the limestone is always found above the dolomite.

Shunda Formation

The Shunda Formation is 250 feet thick.

Lithologically the Shunda formation is composed of medium brown to dark brown and dark gray, dense to very fine crystalline, silty and cherty limestone with stringers of light brown to dark gray argillaceous, silty dolomitic and light gray, hard dolomitic siltstone. Crinoid and brachiopod fragments are common throughout.

Pekisko Formation

The Pekisko Formation is 325 feet thick.

Lithologically the Pekisko formation is composed of light brown, brown, buff, and dark gray, fine to medium crystalline, oolitic and fine grained, argillaceous and in part silty, limestone with bands of brownish gray chert near the base. The Pekisko formation is very fossiliferous throughout, containing a preponderance of crinoids. Brachiopods, pelecypods, and ostracods are also abundant.

Banff Formation

The Banff formation is 460 feet thick and is made up of three members.

<u>Upper Member</u>. The upper member is 310 feet thick and is composed of light brown to dark gray, dense to medium crystalline, argillaceous, silty limestone with abundant brownish gray chert in the upper part and dark brown calcareous shale stringers throughout. This member is fossiliferous throughout with crinoid plates and brachiopods.

<u>Middle Member</u>. The middle member is 90 feet thick and is composed of dark gray hard calcareous shale.

<u>Lower Member</u>. The lower member is 60 feet thick and is composed of dark gray, very fine to dense, highly argillaceous, limestone becoming slightly silty near the base.

Exshaw Formation

The Exshaw Formation is 50 feet (?) thick.

The full section of the Exshaw formation has not been penetrated within the Turner Valley field. Royalite et al Devonian Test No. 1 had a trace of blackish brown to medium brown, calcareous shale at the base of the Banff shale just above the fault (Turner Valley sole fault) that faulted back into the Blairmore formation. The writer believes this shale to be the Exshaw shale that acted as a glide plane for the fault.

A few miles east of Turner Valley the Exshaw formation is 50 feet thick as observed in the Shell Anglo-Canadian Pine Creek No. 1 well, located in Lsd. 12, section 12, township 20, range 2, west of the 5th meridian. At this location the Exshaw formation is composed of dark gray to black, calcareous shale with a trace of dark brown chert at the top of the formation.

<u>Structure</u>

The Turner Valley field is one of the most, if not the most, complicated oil and/or gas bearing structures in Canada. Structurally this field is composed of two separate but related features. The south and largest is referred to as the Turner Valley structure whereas the north of Millarville structure is smaller and much more complicated. Both are developed over the Turner Valley sole fault. The Millarville structure represents an imbricated section of Mississippian and younger rocks that have been thrust over the northwest plunging faulted asymmetrical anticline. This structure, the axial plane of which dips west 77°, has been thrust eastward on the Turner Valley sole fault from its original place of deposition. Gallup (1951, p. 809) states that at least 10,000 feet of horizontal override and 5,000 feet of vertical displacement of the Paleozoic rocks in the central section of Turner Valley has taken place.

MacKenzie (1940, p. 1636) recognizes three types of tension fractures in Turner Valley:

1. Longitudinal tension fractures located on the crest and caused during folding of the structure. In cross-sections these fractures converge from the outer surface toward the core of the anticline. In plan they tend to parallel the strike of the anticline.

2. Fractures that are caused by minor folding and faulting on the surface of the Paleozoic limestone (Rundle limestone). Such structures are probably very few in number.

3. Minor tension, or tear faults caused by the eastward movement of the thrust sheet at the time of the major dislocation. These tear faults would have displacements of only a few inches.

Production

Turner Valley is currently producing oil from 302 wells and gas from 78 wells. The accumulated production of oil since the discovery to the end of 1955 is 116,931,570 barrels. The amount of gas produced from this field would only be a guess inasmuch as most of the early gas production was flared after naphtha was taken from it. A conservative estimate was made by Hume (1950, p. 322) of 1.50 trillion cubic feet of gas produced to the end of 1947.

Reservoir Factors and Reserve Estimates[1]

Reservoir Rock: Turner Valley Formation and Mt. Mead Formation

Type of Gas: Gas cap and solution gas

Specific Gravity (AIR = 1)

Gravity of Oil: 40.8° A.P.I.

Original Gas/oil Interface: 2220 feet subsea (-2220 feet)

Average Thickness of Pay Zone: 145 feet

Average Porosity: Upper Porous - 7%, Lower Porous 7.8%

Average Permeability: 6.84 Millidarcys

Reservoir Drive: Gas cap and water

Reservoir Temperature: 148° F. at 8339 feet

Original Oil in Place: 760,000,000 barrels

Original Gas in Place: 1.75 trillion cubic feet (Conservative estimate)

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1 Figures from the Reservoir Engineering Digest.

JUMPING POUND WET GAS FIELD

Location

The Jumping Pound gas field is located 18 miles west of Calgary and 20 miles northwest of the northern end of Turner Valley oil and gas field.

History

Jumping Pound like the two aforementioned fields had considerable activity before the discovery of gas in the Rundle limestone. Drilling started in 1914 shortly after the discovery of gas at the Dingman well in Turner Valley. The prime objective of these wells, nine in number, was to test the folded and faulted Upper Cretaceous sands that were the first to produce in the Turner Valley field. The deepest hole drilled in Jumping Pound prior to Shell's discovery well was Brown Consolidated Babson No. 1, which abandoned hole at 6885 feet after the well faulted from Fernie shale (Jurassic) back into the Belly River formation (Upper Cretaceous).

After an extensive geophysical search a location was picked and drilled by Shell Oil Co. of Canada which resulted in the discovery of the Jumping Pound gas-condensate field in 1944. The discovery well was Jumping Pound Unit No. 1, located in Lsd. 4, section 24, township 25, range 5, west of the 5th meridian. This well contacted the top of the Rundle limestone at 9618 feet (-5598) and had an initial potential of 6.5 MMcf/d of wet gas. Development drilling continued until 1947 and was stopped in that year after completion of Jumping Pound Unit No. 4. In 1950 development was started again after finding an outlet for the gas. At the present time there are 11 wells capable of production and 3 abandoned wells within the limits of the Jumping Pound gas-condensate field.

Jumping Pound like Turner Valley and Pincher Creek is located within the foothills belt; consequently drilling is deep and difficult.

Stratigraphy

There is between 9,600 feet and 10,600 feet of faulted and folded Mesozoic clastic sediments above the Mississippian sequence of rocks.

Mount Head Formation

The Mount Head formation has been eroded from most of the field, but according to Martin (1956, p. 131) there is as much as 13 feet present in some wells.

Turner Valley Formation

The Turner Valley formation is between 239 and 290 feet thick and is made up of three members: the Upper Porous, Middle Dense, and Elkton.

Upper Porous Member. The average thickness of the Upper Porous member is 43 feet.

The Upper Porous member is composed of light brown to buff, fine to medium crystalline, dolomite, with intercrystalline and vuggy porosity. The porosity is streaked and not confined to a main horizon as it is at Turner Valley.

Middle Dense Member. The average thickness of the Middle Dense member is 64 feet.

The Middle Dense member is composed of light brown to buff, fine to medium crystalline, argillaceous, calcareous and anhydritic dolomite. This zone is porous and productive in the north end of the field where porosity in the Middle Dense member makes up about one-third of the total thickness of the pay zone.

Elkton Member. The average thickness of the Elkton member is 136 feet.

The Elkton member is lithologically like that of the Upper Porous member being composed of light brown to tan, fine to medium crystalline, in part vuggy dolomite.

Shunda Formation

The Shunda formation is approximately 220 feet thick.

The top of the Shunda formation is marked by brown, dense, argillaceous dolomite, interbedded with hard greenish gray, dolomitic shale. The remaining section is composed of dark brown to black, microcrystalline to dense, silty, dolomite with stringers of gray, dolomitic, argillaceous, anhydritic siltstone; white fine crystalline anhydrite with thin interbeds of dolomite and shale; and near the base, dark gray, very fine crystalline to lithographic, argillaceous, dolomitic limestone.

Pekisko Formation

The Pekisko formation is approximately 300 feet thick.

The Pekisko formation is composed of gray to brown, very fine crystalline to dense, in part argillaceous and silty, fossiliferous, oolitic limestone. Crinoid plates are very abundant throughout the sections with brachiopods and pelecypods less abundant.

Banff Formation

The Banff formation is between 500 and 600 feet thick.

The Banff formation can be divided into two members within the Jumping Pound field.

Upper Member. The upper member approximately 300 feet thick is composed of dark gray to black dense, argillaceous limestone with stringers of dark gray to black calcareous shale. Stringers, and/or nodules of black chert are prominent throughout this section. Crinoid plates are periodically found.

Lower Member. The lower member is approximately 300 feet thick and is composed of dark gray, micromicaceous, fossiliferous (brachiopods and crinoid plates) calcareous shale. The lower half of this member is somewhat silty.

Exshaw Formation

The Exshaw formation is 30 feet thick.

The Exshaw formation is composed of black bituminous, radioactive calcareous shale.

Structure

The surface structure at Jumping Pound is similar to that of Turner Valley as observed from Hume's (1939) map. The surface is cut by numerous thrust faults, the strike of which varies between N 22° W and N 32° W. The thrust faults parallel each other and are from 1/4 of a mile to 1 mile apart. The first of these thrust sheets is located approximately 1 1/2 miles to 2 miles east of the field and represents the dividing line between the foothills and plains physiographic provinces. The thrusting for the most part has taken place in the Belly River and Colorado formations. Both formations are composed, at least in part, of incompetent shales which act as glide planes.

The thrust faults of most importance in this area are the Jumping Pound fault and the sole fault. The Jumping Pound fault is exposed at the surface and dips west at a gentle angle cutting across Cretaceous rocks until it reaches the top of the Fernie formation (Jurassic) which acts as a glide plane. The second fault is the sole fault. It does not appear to reach the surface. This fault cuts across Cretaceous, Jurassic and Mississippian rocks and probably used the Banff formation as a glide plane.

The overthrust Rundle limestone (Turner Valley formation) is the producing horizon at the Jumping Pound field. The underthrust has been penetrated in two wells both of which found the Rundle limestone water-bearing.

Production

The Jumping Pound gas field is 12 miles long and between 1/2 and 2 miles wide. Fourteen wells have drilled into the Rundle limestone of which eleven are flowing gas wells and two have been abandoned because of the non-commercial quantities of gas and one abandoned after contacting the pay zone below the gas/water interface.

Reservoir Factors and Reserve Estimates[1]

Reservoir Rock: Turner Valley Formation

Type of Gas: Non-associated

Specific Gravity (AIR 2 1): 0.704

Heat Value: 1,064 BTU/CF

Average Well Depth: 9700 to 9800 feet

Gas/Water Interface: 6436 (-6436) feet subsea

Area of Field: 5,853 acres

Average Pay Thickness: 149 feet

Rock Volume: 872,107 acre feet

Average Porosity: 8%

Connate Water: 13%

Virgin Pressure: 3995 P.S.I.A.

Reservoir Temperature: 194° Fahrenheit

Original Gas in Place Per Acre Foot: 838,000 C.F.

Original Gas in Place: 731 Billion Cubic feet

Gross Absolute Open Flow/Well/Day: 23.2 MMcf/d

Composition of the Crude Natural Gas (Mann, 1953, p. 487)

Methane	84.2 Mole per cent
Ethane	3.8 Mole per cent
Propane	1.0 Mole per cent
Butane	0.5 Mole per cent

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1 Figures from the Reservoir Engineering Digest.

Pentane and higher	0.8 Mole per cent
Carbon dioxide	6.2 Mole per cent
Hydrogen sulphide	3.5 Mole per cent

One million cubic feet of crude gas has 9.3 barrels of condensate (50° API) and 3.5 barrels of natural gasoline (68° API).

Shell Oil Company is currently selling gas from Jumping Pound to the Canadian Western Natural Gas Co. at the rate of 160 MMcf/d. This gas is distributed in Calgary and Exshaw. The field is capable of producing 167 MMcf/d.

The sulphur plant operated in connection with the gas scrubbing process at Jumping Pound can produce up to 88 short tons of elemental sulphur per day.

SUNDRE - WESTWARD HO - HARMATTAN - ELKTON FIELDS

Location

The four fields listed in this heading are located from 45 to 65 miles northwest of Calgary. Physiographically they are located on the extreme western side of the plains bordering the foothills.

Sundre, Westward Ho and Harmattan are oil pools all producing from the Elkton member of the Turner Valley formation. These pools appear to be separate reservoirs in spite of their close geographical connection.

The Elkton gas pool located east and south of the Harmattan oil pool is probably continuous with, and the gas cap of, the Harmattan oil pool.

History

Unlike the rest of the Mississippian field in Southern Alberta, this chain of pools does not have a long and colorful past. The history starts with the discovery of gas at the Canadian Superior Robertson No. 9-26 well, located in Lsd. 9, section 26, township 30, range 3, west of the 5th meridian. This well was completed as a wet gas well in the Elkton member of the Turner Valley formation in July, 1951. In the spring of 1954, two more wet gas wells were completed in the Elkton member north of the discovery. The wells are Great Plains Canadian Superior et al Elkton No. 16-13, located in Lsd. 16, section 13, township 31, range 4 west of the 5th meridian, and Shell West Olds No. A-16-15, located in Lsd. 16, section 15, township 33, range 4, west of the 5th meridian.

The first well to discover commercial oil was Hudson's Bay Sundre No. 1, located in Lsd. 1, section 4, township 34, range 5, west of the 5th meridian. This well was completed in January of 1955 as an Elkton limestone oil well.

In March of 1955, Westward Ho oil pool was discovered when Hudson's Bay Oilwell Operators Westward Ho. No. 1, located in Lsd. 7, section 8, township 33, range 4, west of the 5th meridian, was completed as an Elkton limestone oil well.

Harmattan oil pool was discovered in December, 1955, when Oilwell Operators C. & E. Harmatton No. 1-7, located in Lsd. 1, section 7, township 33, range 4, west of the 5th meridian, found oil in the Elkton limestone.

Stratigraphy

Post-Mississippian erosion has cut deeply into the Turner Valley formation removing completely the Upper Porous and Middle Dense members and in some places the Elkton member.

Elkton Member. The Elkton member has a maximum thickness of 152 feet.

The contact of the Elkton member with the overlying Cretaceous sands is unconformable. The Elkton surface is very irregular and in some places deep channels have completely removed it. Lithologically the Elkton member is made up of tan to light brown, coarse crystalline, vuggy, porous, dolomite with minor shale stringers of greenish gray shale. Dolomite as described above is found in Elkton, Harmattan and Sundre. At Westward Ho dolomite grades laterally into coarsely crystalline non-porous limestone.

Shunda Formation

The Shunda formation is approximately 112 feet thick.

The Shunda formation is not considered as a reservoir rock, but in some wells it is fractured and has produced oil after being treated with acid. Lithologically the Shunda formation is composed of gray to buff, argillaceous and silty, limestone and dolomite.

Pekisko Formation

The Pekisko formation is approximately 150 feet thick.

The Pekisko formation is composed of light tan, brown, and gray, argillaceous fragmental, fine crystalline to dense, fossiliferous, limestone which is chalky in part.

Banff Formation

The Banff formation is approximately 620 feet thick.

The Banff formation is very calcareous in this area and can be divided into two members.

Upper Member. The upper member, 150 feet thick, is composed of tan to dark gray, very fine grained to dense, argillaceous, fossiliferous limestone, and dark gray, high calcareous shale.

Lower Member. The lower member, 470 feet thick, is made up of limestone and shale like the upper member with shale becoming more abundant. Chert is abundant throughout this member and makes drilling slow.

Exshaw Formation

The Exshaw formation is approximately 15 feet thick.

The Exshaw formation is made up of black, calcareous shale.

Structure

The structure along this trend is not a complicated faulted and folded structure as it has been in the previously discussed fields.

The Elkton member of the Turner Valley formation forms a dip slope with a strike of between N 10° W and N 14° W and dips 70 feet per mile west.

Oil and gas accumulation has been governed by stratigraphic conditions. The Elkton member pinches out up-dip due to erosional truncation. There is also a lithoface change from porous dolomite to non-porous limestone.

The reason for separate pools being formed along this trend has not been absolutely determined as yet. However, the writer can offer two suggestions, the first is that some if not all of the pools are separated by erosional channels and the second, they are separated by lithofacies changes from porous dolomite to tight limestone.

Production

As of January 1, 1957, there were 92 oil wells in the Sundre-Elkton chain of pools. Sundre has 31 oil wells, Westward Ho has 16 oil wells and Harmattan - Elkton have 45 oil wells.

Reservoir Factors and Reserve Estimates[1]

	Sundre	Westward Ho	Harmattan
API Gravity of Oil	32	35.2 - 36.2	35.6
Original Gas/Oil Interface (Subsea)	-5445	-5223	-5370
Original Oil/Water Interface (Subsea)	-5539	-5434	-5414
Average Thickness of Pay Zone in Feet	70 Gross	37.7	52 Gross
Average Porosity in Per Cent	12	6.6	12
Average Permeability in Millidarcies	368	66	114
Reservoir Dirve	Gas & Water	Gas & Water	Gas & Water
Reservoir Temperature Degree Fahrenheit	201 (?)	200	--
Original Oil in Place in barrels	61,324,000	24,731,000	85,000,000
Connate Water in Per Cent	15	15	15-25
Recovery in Per Cent	35-50	35-50	35-50
Estimated Recovery Stock Tank Barrels (Lower Limits)	21,463,500	8,655,700	30,000,000
Recovery Barrels per Acre Foot	205	103	203

MINOR AND/OR UNDEVELOPED MISSISSIPPIAN OIL AND GAS FIELDS IN SOUTHERN ALBERTA

Aside from the major fields previously discussed there are several smaller fields which produce oil from Mississippian rocks and should be mentioned.

Del Bonita Oil Field

Del Bonita is located 45 miles south of Lethbridge in township 1, ranges 21 and 22, west of the 4th meridian. As of October, 1955, there were twelve wells in this field capable of production. These wells produce from the Elkton member of the Turner Valley formation

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1 Figures from the Reservoir Engineering Digest.

at a depth of approximately 5300 feet. Production is about 100 barrels of 34° to 37° API oil per day for the field. This field is structurally located on a northwest plunging nose of the Sweet Grass Arch.

Spring Coulee Oil Field

The Spring Coulee oil field is located 12 miles northwest of Del Bonita. The field is producing from the same zone as Del Bonita and is located on the same structure. There are four wells producing in this field. Production is approximately 20 barrels per day of 37° API oil for the field. The oil, like that at Del Bonita, is of asphalt base.

South Princess Oil Field

The South Princess oil field is located 140 miles east to southeast of Calgary in township 19, range 11, west of the 4th meridian. This field produces oil from three separate horizons, one of which is of Mississippian age. These wells, eleven in number, are currently lying dormant due to production problems. Production is from a carbonate facies within the upper part of the Banff formation or from the Basal section of the Rundle group (Pekisko formation). The oil is 28° API.

Savanna Creek Gas Field

The Savanna Creek gas field is located in the mountains 60 miles southwest of Calgary in township 14, range 4, west of the 5th meridian.

This field at the present time has two capped gas wells and a well that is still being drilled. The first well, Husky Northern Target Savanna Creek No. 1, located in Lsd. 12, section 20, township 14, range 4, west of the 5th meridian, to find production in this area, found gas in three zones. The writer has correlated these zones to the Turner Valley formation and the Pekisko formation. The Turner Valley formation has one zone approximately 410 feet thick which embraces the lower two-thirds of that formation and tested at 18 MMcf/d of gas after perforating and acidizing. The Pekisko formation has two zones of production, one of which tested 15.84 MMcf/d of gas and the other which tested 26 MMcf/d of gas after perforating and acidizing. These wells are located on a very complicated structure under what appears at the surface to be a simple doubly plunging symmetrical anticline.

This field could develop into one of the largest gas fields in Western Canada.

Gas and oil have been found in numerous isolated wells throughout Southern Alberta in rocks of Mississippian age. Many of the gas wells have been completed as potential gas wells awaiting market.

C O N C L U S I O N

The Mississippian system in Southern Alberta is composed of rocks that were formed from sediments deposited on the eastern shelf of the Cordilleran miogeosyncline. At no place within the area were eugeosynclinal rocks observed. Sedimentation took place under stable to slightly unstable tectonic conditions that appear to have been continuous at least on the western side of the area throughout the entire period.

The clastic sediments appear to have come from the northeast. It is assumed by the writer that these sediments were derived from the Precambrian shield inasmuch as there is no evidence to suggest they came from Paleozoic rocks.

The carbonate rocks were in part derived from Devonian rocks and in part from contemporaneous organic remains.

The Mississippian systems thicken from east to west. The thickest section measured was at Banff park where the section is 4100 feet thick. Warren (1933, p. 148) gives figures that add up to an aggregate thickness of 6500 feet in the Crowsnest Pass. This section is badly faulted and the writer believes the true thickness to be somewhat thinner.

In the writer's opinion the Mississippian rocks were deposited under shallow water conditions. Probably at no place did the water exceed the depths beyond the neritic zone. With the exception of the Livingstone and Turner Valley formations, which were deposited in an infraneritic environment, the Mississippian rocks were deposited in an epineritic environment.

The Exshaw formation was deposited from either reworked humus or paludal sediments during the initial transgression of the Mississippian sea. The transgression covered the entire thesis area, and the area was submerged until the end of Pekisko times.

The sea was unstable during the deposition of the Banff formation as is evident from the cyclic sedimentation in the Banff rocks. In some areas the sea was relatively clear and clean limestones were deposited. In other areas the sea was murky which resulted in the deposition of calcareous shale and argillaceous limestone. Follwoing the deposition of the Banff formation the sea became much cleaner.

The Pekisko formation was deposited in a cleaner and more stable sea than the preceding formation.

The writer postulated a platform through the center of the area that had its landward side toward the north. The limestones deposited over the platform are brecciated and argillaceous in part, whereas along the perimeters they are not brecciated and are clean.

The Shunda formation was deposited during a retrogressive movement of the sea that affected the landward sediments to a more marked extent than the sediments that were deposited farther seaward.

After the deposition of the Shunda formation the sea once more transgressed the land mass depositing the Turner Valley formation.

During the deposition of the Turner Valley formation the sea was warm and clean which resulted in a prolific fauna growth. The remains of these organisms make up the major part of the Turner Valley rocks.

Following the deposition of the Turner Valley formation the sea went through several cycles of transgression and regression, which resulted in the deposition of the Mount Head and Tunnel Mountain formations.

The tectonic activity that brought about the fluctuations in sea level from Shunda times to the close of the Mississippian period were probably related to the Antler Peak orogenies of Nevada.

Dolomitization of the limestones appears to have been restricted to the more coarse bioclastics that had been winnowed. Consequently these sediments were porous thus allowing free circulation of seawater which resulted in a magnesium calcium ion exchange.

Economically the Mississippian rocks are important for oil and gas production. Exploration to date has found only small quantities of oil and gas in formations other than the Turner Valley formation. However, there is reason to believe that production in larger quantities will be found in other formations.

Inasmuch as oil and gas accumulation in the Turner Valley formation is controlled by dolomitization, facies studies are of great importance in isolating areas for future drilling.

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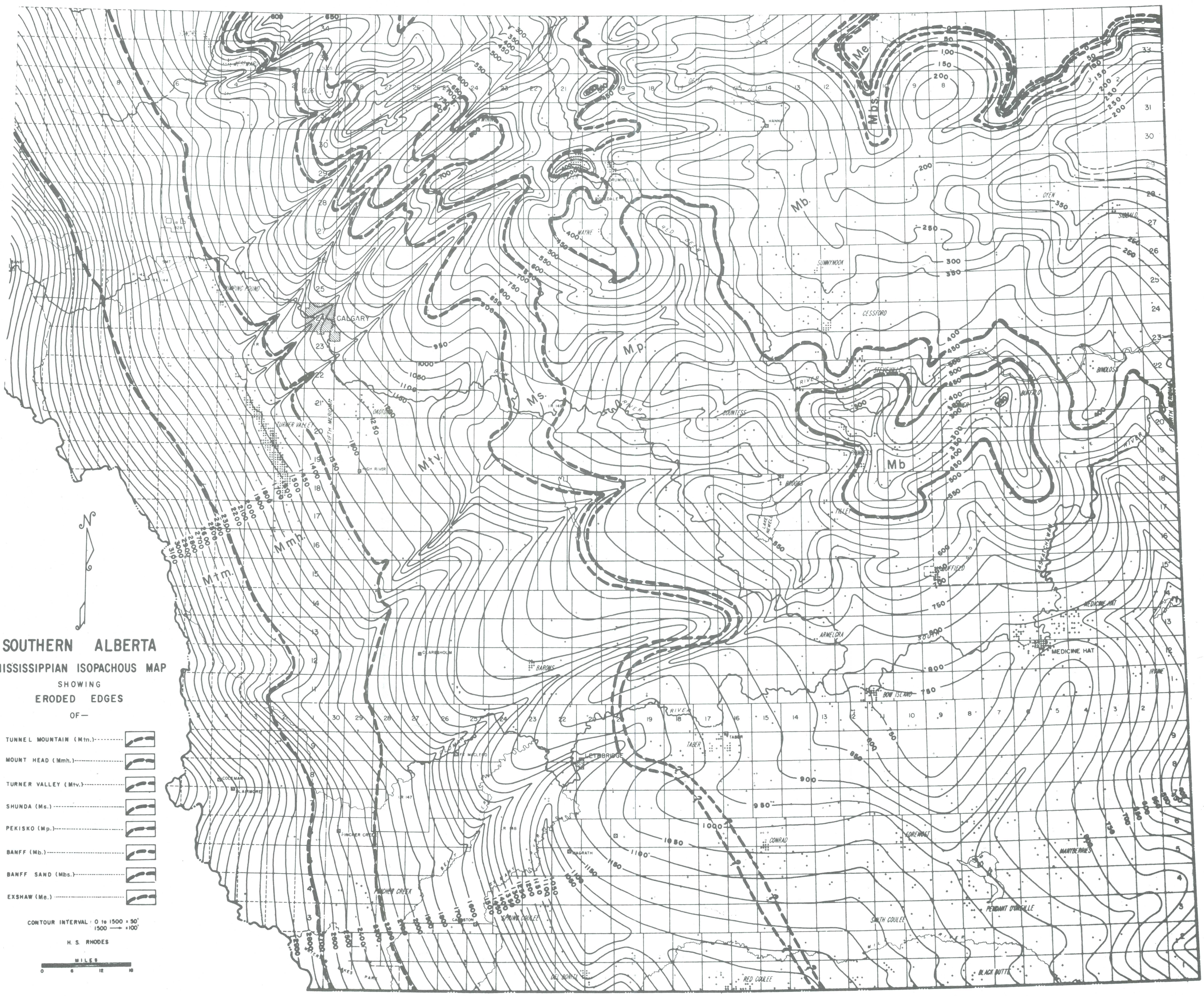
SOUTHERN ALBERTA
MISSISSIPPIAN ISOPACHOUS MAP
SHOWING
ERODED EDGES
OF—
TUNNEL MOUNTAIN (Mtn.)
MOUNT HEAD (Mmh.)
TURNER VALLEY (Mtv.)
SHUNDA (Ms.)
PEKISKO (Mp.)
BANFF (Mb.)
BANFF SAND (Mbs.)
EXSHAW (Me.)
CONTOUR INTERVAL : 0 to 1500 = 50'
1500 → = 100'
H. S. RHODES
MILES
0 6 12 18
CALGARY
TURNER VALLEY
HIGH RIVER
CLARESHOLM
BARONS
LETHBRIDGE
TABER
MAGRATH
CONRAD
FOREMOST
BOW ISLAND
MEDICINE HAT
MANYBERRIES
PENDANT D'OREILLE
SMITH COULEE
BLACK BUTTE
RED COULEE
DEL BONITA
SPRING COULEE
CARDSTON
PINCHER CREEK
COLEMAN
FT. MCLEOD
ARMELGRA
SUFFIELD
TILLEY
BROOKS
COUNTESS
CESSFORD
SUNNYNOOK
HANNA
DRUMHELLER
WAYNE
BINDLOSS
OYEN
JUMPING POUND
Mtm.
Mmh.
Mtv.
Ms.
Mp.
Mb.
Mbs.
Me.