The Blairmore Formation
of
Southern Saskatchewan

by

Don Herbert Rousell

B.S.C., University of Manitoba, 1952.

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in the Department of Geology.

We accept this thesis as conforming to the standard required from candidates for the degree of Master of Science.

Members of the
Department of Geology

The University of British Columbia
April, 1956.

Abstract

Rocks of the Lower Cretaceous Blairmore formation extend over the whole of southern Saskatchewan. Along outcrop areas in western Manitoba, the Blairmore has undergone erosional truncation. Equivalent beds are found over almost the entire western interior plains of Canada and the United States.

In southern Saskatchewan and adjacent western Manitoba the formation consists principally of fine to coarse quartzose sandstone, shale, salt and pepper sandstone, lignite, clay ironstone, kaolinite shale, and various mixtures of shaly sandstone and sandy shale.

The Blairmore of the area is divided into five areal units and related to adjacent, more thoroughly studied areas. The divisions are: Mannville, Kootenai, Dakota, Swan River, and Ashville areas. The stratigraphy of each area is described and environment and source areas discussed.

Oil in commercial quantities has been found in the Blairmore formation. The most likely areas of future exploration are suggested.

CONTENTS

List of Illustrations

List of Plates

Chapter I

Introduction

Rocks of Lower Cretaceous Age underlie an extensive area of the interior plains of North America. The western edge reaches, and locally extends into the Rocky Mountains. Their northern limit, fringing the exposed Canadian Shield, is roughly that of the Upper Cretaceous as shown on the Geological Map of North America. The eastern margin outcrops in western Manitoba, extends southward into Minnesota and Iowa, and continues to the Gulf Coast.

Lower Cretaceous outcrops in the United States are located at the eastern erosional edge in North Dakota, Minnesota, Iowa, and Nebraska; along a belt of uplifts in northern Montana; in the Black Hills of South Dakota; and the eastern edge of the Front Range.

Lower Cretaceous outcrops in Canada are found on the erosional fringe; western Manitoba, the edge of the shield and the foothills belt of the Rockies.

Thus the vast majority of Lower Cretaceous rocks of Canada are in the subsurface, buried beneath a thick mantle of Upper Cretaceous and Tertiary sediments. Subsurface studies in the Canadian Plains have been largely hindered by lack of data. Prior to the last decade subsurface information was scanty and limited to a few scattered bore holes or local oil fields. The discovery of the Leduc oilfield in 1947 caused a tremendous increase in drilling and

and now wells are located across the whole of the interior plains. Most published papers on subsurface stratigraphy are limited to rocks of Jurassic and older Age which have so far proved most productive. However, the Lower Cretaceous, essentially the Blairmore formation, has been largely neglected.

Purpose and Scope of Study

This thesis is a continuation of a Blairmore study made during the summer of 1954. During that time samples and cores of over 100 wells were examined. Most of these are recorded on stratigraphic sections included in the thesis. Some 35 additional electric logs were used for control on the maps. Numerous other logs were examined for correlation purposes. Cored wells in conjunction with a good electric log were chosen wherever possible for the stratigraphic sections.

An attempt is made to describe and account for the stratigraphy of the Blairmore formation of southern Saskatchewan. In Chapter II a review of the literature of Blairmore equivalents in Alberta, the northern States, and Manitoba serves as a guide in placing the Saskatchewan Blairmore in the proper perspective.

Wickenden (1932) states -- "The Lower Cretaceous, where it is exposed to the west, in southern Alberta, contains only non-marine deposits. In wells in southwestern Alberta the top of the Lower Cretaceous is generally placed at the first occurrence of deposits that contain coal or are evidently non-marine. Do these non-marine beds extend into Southern Saskatchewan and if so, how far east? In the northwest, in the Athabaska and Peace River valleys, marine Lower Cretaceous deposits occur. Do these extend southeast into southern Saskatchewan?"

The writer hopes that this report will at least partly answer these questions.

Acknowledgements

The Tidewater Associated Oil Co., Regina, Saskatchewan made this study possible. The writer wishes to especially thank the following members of the Tidewater staff who were ever ready to provide technical advice: R. L. Milner, H. A. Gorrell, G. E. Thomas, and W. Myrah. The following oil companies provided data, much of which was confidential at the time: The California Standard Co., Imperial Oil Co., Socony Vacuum Oil Co., Sohio Oil Co.

Mr. J. Ambler, Sohio Oil Co., provided data on the Lloydminister field.

This thesis was prepared under the supervision of Dr. W.H. Mathews of the University of British Columbia. His guidance and constructive criticism are greatly appreciated by the writer. Mr. W. R. Danner provided many helpful suggestions. Mr. J. A. Donnan prepared the thin sections.

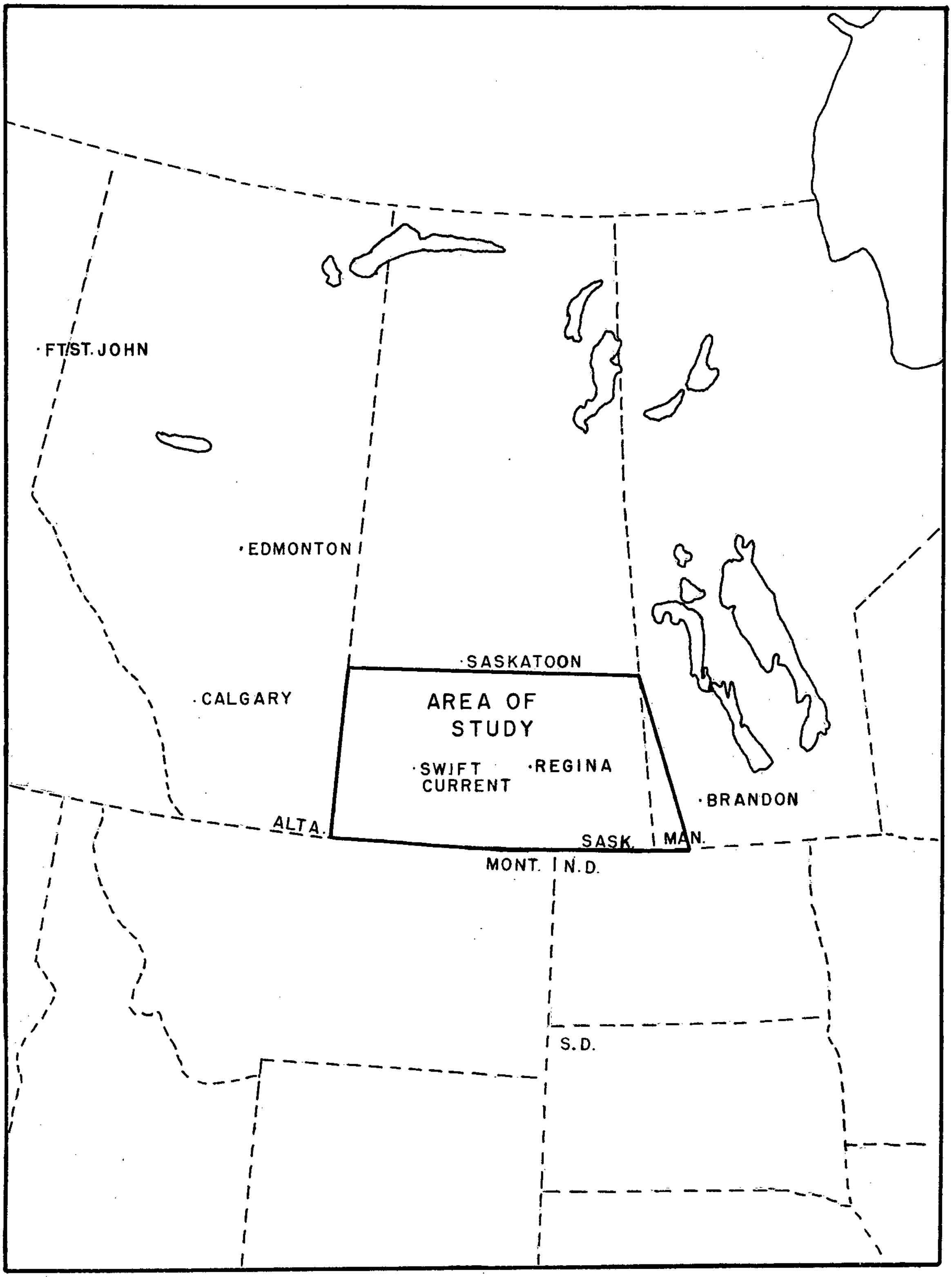

FT. ST. JOHN
EDMONTON
CALGARY
SASKATOON
AREA OF STUDY
SWIFT CURRENT
REGINA
BRANDON
ALTA.
SASK.
MAN.
MONT.
N.D.
S.D.

FIGURE I

Chapter II

REGIONAL STUDY OF THE BLAIRMORE FORMATION AND CORRELATIVES.

General Statement

In order to gain an understanding of the Blairmore of southern Saskatchewan, the writer believes a broad review of Blairmore correlatives elsewhere is essential. A brief summary of the available literature has been made.

Southern Alberta and Foothills

Dawson (1885) first examined the Lower Cretaceous in the foothills and eastern Rockies. He named the lower beds Kootenai (now Kootenay), called the overlying beds Dakota (Blairmore) and assigned them to the Upper Cretaceous. Leach (1911), working in the Blairmore area, named the beds overlying the Kootenay (i.e. Dawson's Kootenai) Blairmore and placed them in the Lower Cretaceous.

Thompson and Axford (1953) provide a detailed Blairmore section near the classical area. Here, the Blairmore consists of 1,800 feet of non-marine greenish and reddish shales, light brown to greenish sandstones, and some conglomerate. A persistent bed of fine conglomerate, about 25 feet thick, exists at the base and lies on the Kootenay. Another conglomerate is present near the top and several beds of greenish limestone are present in the lower part. Plant remains and fresh water shells suggest a non-marine environment.

Further west, in the Rockies proper, the Blairmore reaches a thickness of 6,500 feet. Thinning is rapid toward the east and in the vicinity of Lethbridge, Alberta the Blairmore is 700 feet thick.

Uplift and exposure of crystalline rocks, to the west of the present Rockies, provided the source of both Kootenay and Blairmore sediments.

The Kootenay formation does not extend into the plains. Subsidence of the Alberta Syncline was sufficiently rapid at that time to accommodate all sediments. Apparently sedimentation was continuous between the Jurassic Fernie and the Kootenay.

During Blairmore time subsidence of the Alberta syncline did not keep pace with sedimentation so that fresh and brackish water deposits spread across the plains, possibly as far east as Saskatchewan.

<u>Northern and Central Alberta</u>

Badgley (1952) provides the most comprehensive study of the Lower Cretaceous and central Alberta. Here the Mannville group (Blairmore) is divided into three formations. From oldest to youngest they are McMurray, Clearwater, and Grand Rapids. The marine Joli Fou overlies the Mannville. The underlying detrital Deville formation may be in part Jurassic.

The McMurray formation is predominately non-marine and consists of quartzose sandstone, dark grey shale, much of it pyritic, pelecypods, fish fragments and some coal.

The dominantly marine Clearwater consists of dark marine shales, glauconitic marine greywackes, siltstones, quartzites, and some non-marine shale, greywacke and coal.

The Grand Rapids formation is dominantely non-marine, deltaic. It consists of a complex succession of interbedded greywackes, siltstones, and shales with several thin coal beds.

The Lower Cretaceous of the Peace River-Pouce Coupe' area can be subdivided into a similar succession as the Edmonton-Athabaska-Lloydminister Area.

The Bullhead group is equivalent to the Deville and McMurray. Like the Deville, it may be in part Jurassic. The Bluesky and lower part of the Spirit River formation is equivalent to the Clearwater. The upper part of the Spirit River and the lower part of the Peace River is equivalent to the Grand Rapids formation.

Wickenden (1951) examined Lower Cretaceous sections on Peace River below the mouth of Smoky River. On lithologic basis he suggests environments and source of sediments for the Lower Cretaceous. Seas came in from the north and the land mass supplying most of the sediments lay to the west and southwest. A low lying land mass probably also lay to the east, in the shield area. An offlap-onlap relationship is visulized together with deltaic deposition and shifting shorelines.

The McMurray formation, where it outcrops along the Athabaska river in the vicinity of the town of McMurray, Alberta, is of unique economic importance. The sand is saturated with tar or bitumen. The large scale cross-bedding has been interpreted as forest beds of a delta. To the west drilling indicates sand is being replaced by a shale facies. A shield source is suggested.

McLearn (1945) discusses the northern foothills region. Here, the oldest Cretaceous Bullhead group is divided into the Dunlevy (Kootenay) and Gething (McMurray), both essentially non-marine. Mathews (1946), working in the Carbon Creek-Mount Bickford Map Area divided the Bullhead into a lower marine and upper non-marine section. The Gething, about 1,400 feet thick conformably overlies the Dunlevy. It consists essentially of coarse to fine grained, thick to thin bedded, ripple marked sandstone; siltstones; grey to black shale; clay ironstone; and coal seams.

Northward, in the area of the Sikanni River, important differences are noted and the Bullhead cannot be subdivided. Still further north the group thins out and is absent on the Alaska Highway and on Liard River.

The Fort St. John Group, overlying the Bullhead, is largely marine. Along Pine River the Fort St. John has been subdivided into the Moosebar, Commotion, Hasler, Goodrich and Cruiser in ascending order. These consist of dark marine shale and some sandstone. They are about 4,800 feet thick.

Further north, along Buckinghorse and Sikanni Rivers, the Fort St. John underlies the Buckinghorse and Sikanni formations. The Buckinghorse consists of 3,00 to 3,600 feet of dark shale with marine fossils. The Sikanni is comprised of 980 feet of dark shale with four thick sandstone members in the lower part.

Still further north, on Liard River, the Fort St. John is 4,750 feet thick and consists essentially of dark shale with sandstone toward the centre of the section.

Lloydminister-Vermilion Area

The discovery of oil in the Lower Cretaceous at Vermilion (1940) and Lloydminister (1944) has resulted in intensive drilling and study in the area.

Nauss (1945) proposed the name Mannville formation for beds of Lower Cretaceous age in the Vermilion area. They differ from equivalent beds in the Peace River and McMurray districts in that they are largely non-marine; from the Rocky Mountain Blairmore in containing near shore quartzose sands and a marine shale; from the southern Alberta Lower Cretaceous in that they lack red and green shale.

Because of their local distribution the Mannville has been divided into six members rather than formations. These are, from oldest to youngest:

Diana member -- chiefly rounded unconsolidated quartz sand interbedded with silt and shale; grains coarsest near the base and attain a size of 1 m.m., variable thickness, 0 to 150 feet, due to filling of Paleozoic depressions; the Diana is similar to the McMurray formation; well rounded, well sorted, frosted sand grains suggest a beach deposit.

Cummings member -- largely dark grey to black shale containing abundant pyrite and foraminifera; coal seam near the base; some salt and pepper sandstone; thickness 0 to 90 feet; thins toward the south and is absent near Wainwright; thickens toward the north; Nauss suggests it is the wedge edge of the clearwater shale.

Islay member -- 0 to 60 feet of well sorted, rounded frosted quartz sand; thin coal seams in the upper part.

Tovell member -- largely massive, coarse salt and pepper sandstone, and grey shale with abundant plant remains and some thin coal seams; sand grains are dark smoky quartz and angular quartz and are poorly sorted; thickness ranges from 75 to 116 feet.

Borradaile member -- well rounded quartz sand with an average grain size of 0.15 m.m.; pyrite nodules; grey shale containing woody plant fragments.

O'Sullivan member -- salt and pepper sandstone, grey shale and several prominent coal seams.

Nauss suggests a geologic history for the Lower Cretaceous of the member. Lower Cretaceous seas advanced from the north upon the eroded and irregular Devonian limestone. The beach sands of the Diana accumulated along the shores. The seas readvanced to a point south of Vermilion. The marine muds of the Cummings were deposited in quiet waters. The beach sands of the Islay mark the retreat of the sea. The Tovell member suggests a deltaic deposit of a northward flowing river. A shift of the river mouth allowed the reworking of the upper part of the Tovell and the formation of the Borradaile. Another shift of the river brought the mouth back to the Vermilion area and deposited the deltaic O'Sullivan. Coal was deposited in nearby swamps.

The Lloydminister area, lying to the east of Vermilion and straddling the Saskatchewan-Alberta boundry has been described by Wickenden (1948). The six fold subdivision of Nauss can be traced into Lloydminister area. The Mannville is divided into three parts which represent changes in conditions and source of sediments. They resemble in part the McMurray, Clearwater and Grand Rapids on Athabaska River.

> Lower Division (Diana) -- clean, finegrained quartz sand, with partings of carbon and dark grey shale; lack of glauconite and marine fossils and numerous inclusions of carbonized plant fossils suggests a continental environment; thickness - 97 to 160 feet.
>
> Middle Division (Cummings, Islay, Tovell, Borradaile, plus shale and coal above them) -- during this time the area was likely the site of a delta with the deposition of silt, sand, and shale of marine-brackish water origin; such conditions would lead to considerable local variations; marine beds are more common inthe east and north than in the west and southwest part of the area; the base is a sand containing a little glauconite; overlain by a dark grey, fossiliferous marine shale; Wickenden suggests the latter occupies an extensive area in the plains of Alberta and western Saskatchewan; salt and pepper sandstone, shale and fine, clean quartz sandstone overlies the marine shale; a quartz sand bed called the Lloydminister sand and is probably equivalent to the Islay;

the top of the middle division placed at the top of a coal or carbonaceous shale and medium grey marine shale; the latter shale seems to mark the upper limit of marine conditions.

Upper Division (O'Sullivan) -- non-marine salt and pepper sandstone with some fine grained quartz sandstone, silt, clay, and coal; deltaic conditions may have prevailed, although the sea was likely more remote than during deposition of the middle member; the upper boundry of the Mannville is placed at the contact between the predominately non-marine shale; the latter contains *Haplophragmoides gigas* microfauna.

In summary, deposition conditions in the Lloydminister-Vermilion area were largely deltaic. They were controlled by a shifting shore line with complex interfingering of marine, brackish, and continental sediments. The fine grained, basal quartz sand may have had an eastern or Pre-Cambrian source. Wickenden (1948) suggests that salt and pepper sands were derived from the west. They are characteristic of the Lower Cretaceous of the west, but do not appear in the east (Manitoba).

Manitoba

The presence of Mesozoic strata in western Manitoba account for the physiographic feature referred to as the first prairie step. These strata dip gently to the west and southwest.

Kirk (1930) related "Basal Beds" underlying the Ashville to the Dakota sandstone and placed them in the Upper Cretaceous. Wickenden (1945) suggests a Lower Cretaceous age for the Swan River Group (Blairmore). In south-central Manitoba they lie between marine Jurassic and marine Ashville. North of Swan River, where no marine Jurassic has been recognized, the Swan River Group rests on Devonian rocks. The most southerly exposure of the Swan River formation is along Wilson River, near the town of Dauphin.

In general the sequence consists of interbedded fine grained sands and sandstone, shales, silt, and coal. Thickness varies from a few feet to over 400 feet in the north. Possibly the area around Swan River and extending westward to Hudson Bay Junction in Saskatchewan was a local basin during Swan River Time. Toward the north the presence of coal suggests the section is dominately non-marine. Towards the south glauconitic and fragments of marine molluscs suggest the group is at least partly marine.

Ower (1953) does not recognize Swan River equivalents in southwestern Manitoba. He divides the Ashville into two units, correlates the lower unit (D-2) with the Pelican shale (Joli Fou) and suggested a Lower Cretaceous Age.

Northern States

Rocks of Blairmore age in the Williston basin area are from oldest to youngest Lakota, Minnewaste, Fuson, and Fall River (sometimes called Dakota formation). They have been described by Gries (1952).

Lakota -- non-marine, thick, massive sandstones interbedded with shale or clay and occasional coal seams and conglomerate streaks; in outcrops in the Black Hills, thickness varies from 75 to 485 feet; sandstones are largely fine to medium quartz sand; in channel fillings and heavily cross bedded members, the sand is coarser, and locally conglomeritic; sands in the upper part are finer than basal sands.

Minnewaste formation -- maximum thickness 35 feet; limestone withrminor shale; a local calcareous phase of Fuson-Lakota deposition, and according to Gries should not be considered a formation.

Fuson formation -- grey or variegated shales and sandstone; Gries is of the opinion the Fuson should not be considered a formation, but a closing shaly phase of the Lakota.

Fall River sandstone -- in the Black Hills area consists of a coarse basal sandstone and upper grey to variegated clays, with thin slabby sandstones.

Correlations between the Dakota formation, where it was first described in Nebraska, with subsurface and outcrop beds further west have been subject to much controversy. Gries (1954) has clarified this somewhat. In the type are, the Dakota rests on Pre-Cambrian and is in part Upper Cretaceous. What has been called the Dakota formation in North Dakota is simply a western tongue of the Dakota of the type area. The name Fall River sandstone is suggested for this tongue.

In Montana equivalent Lower Cretaceous rocks are Kootenai formation (not the Kootenai of Dawson or the Kootenay) and the overlying "Basal Colorado Sandy Zone" or First Cat Creek Member.

Kootenai formation -- interbedded varicolored to mottled shale or claystone and poorly sorted, often tuffaceous to andesitic sandstone; an upper sandstone often greenish and flaked with biotite; the basal sandstone (Lakota or Third Cat Creek) often coarse grained to conglomerate.

First Cat Creek -- marine; interbedded black or grey shale, sandstone, and siltstone; a local well developed sandstone often found at the base.

Saskatchewan

Fraser et al (1935) discuss the Blairmore from data obtained from a few scattered deep wells. They suggest a possible three fold subdivision of non-marine (?), marine (on the basis of Haplophragmoides gigas microfauna) and non-marine.

A tentative correlation may be made with Lower Cretaceous of northern Alberta. The marine section may be equivalent to Clearwater or Loon River and the overlying coal bearing zone with the upper parts of the Grand Rapids and Peace River sandstone.

They recognize that across the plains from east to west the Blairmore coarsens and thickens and that the entirely non-marine beds of the west pass into partly non-marine, partly marine in the middle or eastern parts of the plains. To explain this they envisage a rise of a great land mass, Zephyria, on the site of the Selkirk, Purcell, and other ranges west of the Rockies. Erosion of Zephyria built out alluvial plains and deltas to the east. Maximum deltaic expansion supposedly took place during Inoceramus Cadottensis, Upper Peace River, or Albian time. The delta extended across southern Saskatchewan into Manitoba.

Hadley and Milner (1953) attempt to relate Lower Cretaceous beds of southwestern Saskatchewan to equivalent beds in northern Montana. They feel the use of the term Blairmore to cover both marine and non-marine beds in Saskatchewan is not entirely acceptable. They suggest the marine Upper Blairmore is more closely related to the overlying marine Colorado formation than the underlying non-marine Blairmore. The Montana term "Basal Colorado Sandy Zone" (Dakota or First Cat Creek) should be adopted instead of Upper Blairmore. The Montana Kootenai should be applied to the lagoonal lower Blairmore of Saskatchewan.

Chapter III

DESCRIPTIVE STRATIGRAPHY

General Statement

Variations in thickness, lithology, and source areas provide a logical basis for dividing the Blairmore formation of Saskatchewan into five distinctive Areal Units. Although boundaries have been drawn on the map (Fig. 3) as solid lines, they are actually gradational. The writer proposes adoption of stratigraphic nomeclature of surrounding, more thoroughly studied areas. The application of the name Blairmore to the interval in question, across the whole of southern Saskatchewan, should be used only in a general sense.

Mannville Area

Definition

This forms a broad southeast tongue-like projection in the northwestern part of the area and is related to the Mannville formation of Vermilion-Lloydminister area. The name Mannville formation is proposed to cover the Blairmore formation of this area.

Thickness

The average thickness of the tongue is 400 feet, although thicknesses of 550 feet are reached in local depressions. The latter may be accounted for by filling of uneven topography.

CORRELATION CHART OF SASKATCHEWAN BLAIRMORE

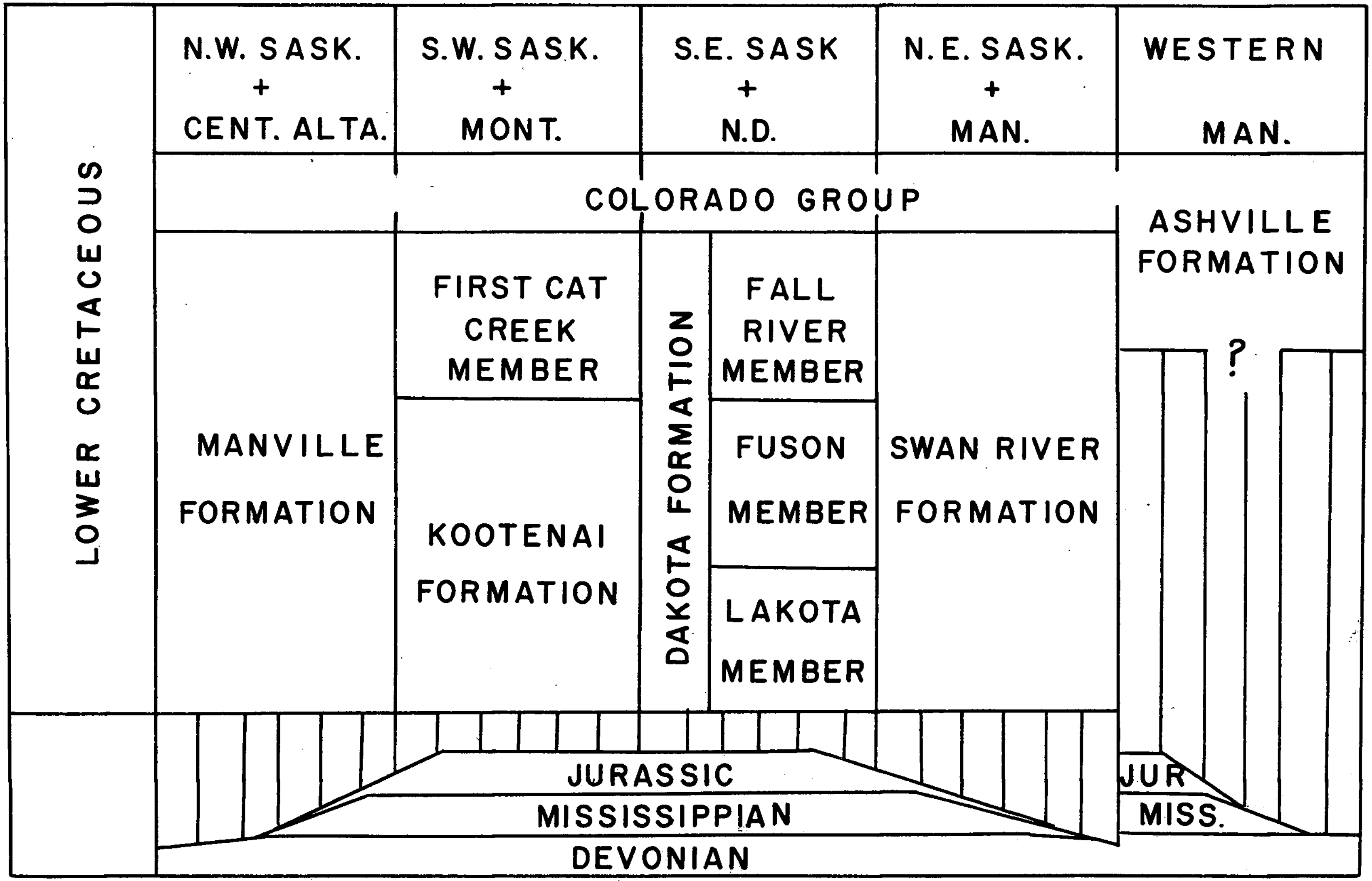
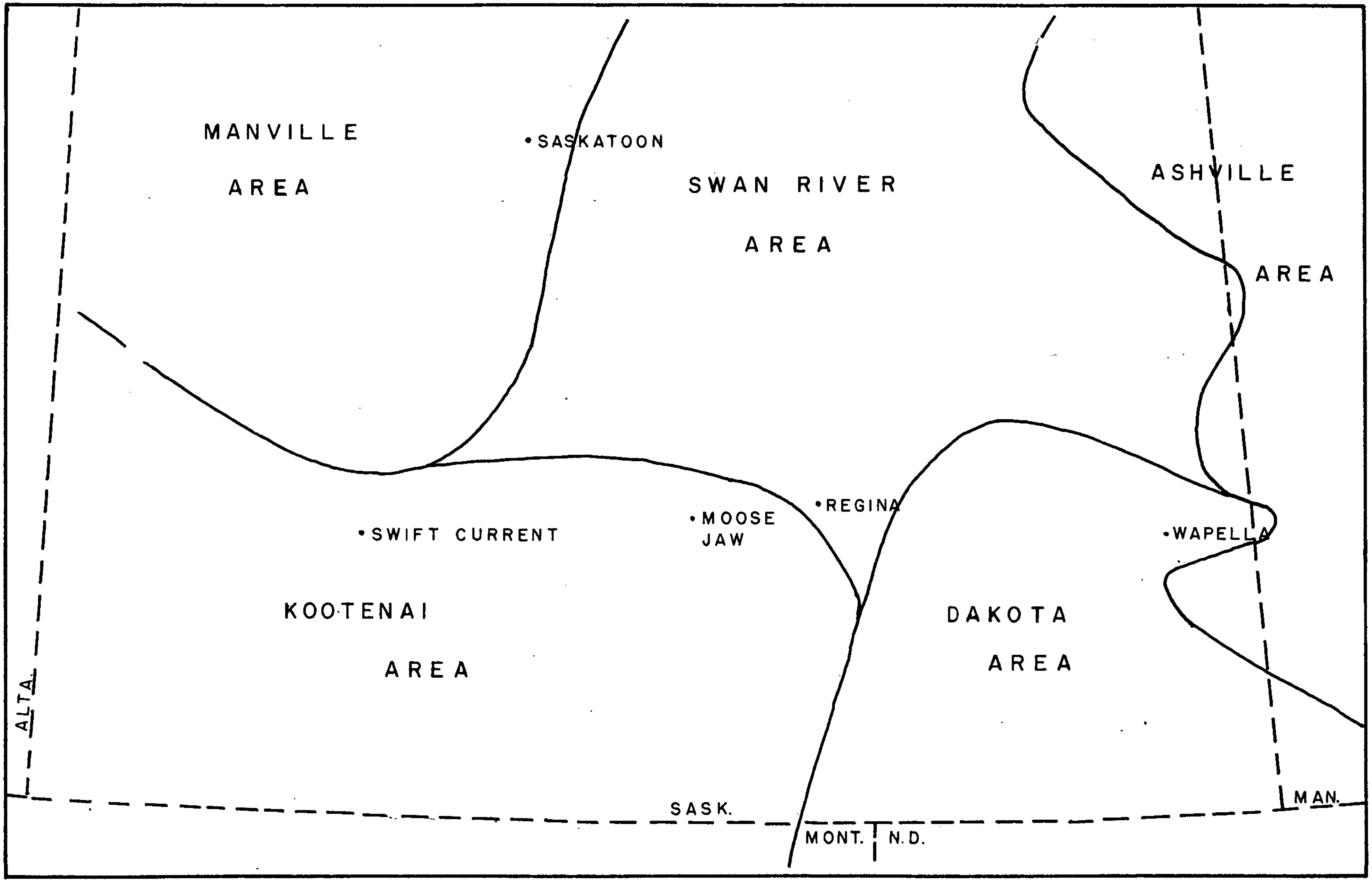


FIGURE 2



AREAL SUBDIVISIONS OF SASK. BLAIRMORE

FIGURE 3

Relation to underlying beds

The northern portion is underlain by dolomitic green and red silty shales of the Devonian Qu'Apelle Group. Toward the south and southwest the Lodgepole limestone (Mississippian) overlaps the Devonian and underlies the Mannville. The southern edge of the Mannville is underlain by the Shaunavon and Vanguard formations of Jurassic Age.

Description

The Tidewater Duperow Cr. #1 well is fully cored throughout the section and is given in the appendix as a type well. This well is the most northerly of those examined and presumably bears the closest relationship to the Mannville in the Lloydminister-Vermilion area.

The general lithology of the area consists of interbedded fine grained sandstone, silty shale, dark carbonaceous shale, a bed of coarse grained sandstone and calcareous salt and pepper sandstone. The latter consists of quartz grains and carbonaceous fragments cemented in a calcareous matrix. Individual beds seldom exceed 15 or 20 feet. This is well illustrated by the electric log. Dark color indicates lack of oxidation. The above features, together with the poorly sorted nature of the sediments indicates rapid burial under fluctuating conditions.

The basal beds in the north consist of fine brown or green shale, slightly silty, with some carbonaceous material or lignite. Further south, the Mannville thins and sandstone rests on the Devonian.

Overlying the shale is a bed of fine grained sandstone containing heavy oil. Well #66 is the southern limit of the oil. No oil occurs in the basal beds of section D-D', to the east.

A salt and pepper sandstone, over 20 feet thick, persists as far south as well #63. It is best developed in well #64 where it lies on the Devonian and is 75 feet thick. The salt and pepper sandstone is frequently associated with carbonaceous lenses. A thin section of the former is described at the end of the chapter.

A rather heterogeneous sequence, difficult to subdivide, overlies the salt and pepper sandstone. Fine-grained, grey and brown, in part calcareous sandstone is the main type with silty or carbonaceous shale interbeds. Thin limestone beds are occasionally present but are not confined to any particular stratigraphic position. Clay ironstone concretions or siderite pellets are occasionally found. The above section, toward the south, becomes shaly and grades into Kootenai lithology.

An overlying thin black shale may correspond to the black shale at the base of the First Cat Creek in Kootenai area.

This is followed by about 40 feet of coarse to very coarse sandstone. Glauconite is associated with the sand in well #68. The grains are sub-rounded but become angular to the south, in well #65. Further south grain size diminishes and the thickness of the unit decreases to nil.

A dark grey to black shale separates the above from a sandy section which marks the top of the Mannville. The sand is light green, find grained, and slightly glauconitic in the extreme north. Toward the south the sand is poorly sorted, coarse, medium and fine grained, generally calcareous. This sand provides a good electric log break with the overlying marine Colorado Shale.

Kootenai Area

Definition

The area so defined comprises about 1/3 of the area of study and occupies the southwestern portion of the province. Blairmore beds are directly correlated with the Kootenai-First Cat Creek of Montana. The writer proposes that the non-marine section overlying the Jurassic and underlying the black shale bed of the First Cat Creek be called the Lower Kootenai Member. The overlying marine section is to be called First Cat Creek member and included in the Kootenai (Blairmore) formation.

Thickness

The isopach map (Plate 8) shows two tongues of thicker deposition projecting from the southwest into southern Saskatchewan. A maximum thickness of 400 feet is attained in the eastern tongue, slightly west of the third meridian. A saddle separates this from another tongue at the western edge of Saskatchewan. Here thickness reaches 300 feet.

There appears to be a platform in the area of the town of Swift Current. Northeast of here a minimum Blairmore thickness of 100 feet is recorded.

Relation to Underlying Beds

Most of the area is underlain by Upper Vanguard shale. The Jurassic has undergone erosional truncation toward the north. Here the Blairmore is underlain by Middle and Lower Vanguard, and in the extreme northwest perhaps even the Mississippian may underlie the Blairmore.

Description

Lower Kootenai Member --

Tne non-marine Lower Kootenai Member varies considerably from well to well. Thus no single well description fits the entire area. Lithologic descriptions for well #52 is given in the appendix.

In the southeastern part of this area a salt and pepper sandstone, of varying thickness, commonly lies at or near the base of the Kootenai. Occasionally, as in wells #3 and #64, fine to medium sandstone underlies salt and pepper sandstone. This sand contains thin beds of carbonaceous shale and plant remains.

To the west, in wells #11 and #12, dark grey shale and fine grained sandstone occupies the position of salt and pepper sandstone. Carbonaceous material is associated with the sandstone.

In the northwest, in wells #19 and #20, the salt and pepper sandstone dominates the Kootenai section. West and north of these wells salt and pepper sandstone is insignificant or absent until the area of Mannville sedimentation is encountered.

A dominately shaly sequence overlies the basal sandy beds. In the south grey shale predominates with some red, green, yellow and black shales. Toward the east, along section A-A', the sequence becomes sandy, with thin interbeds of carbonaceous material.

South of Swift Current the Kootenai section thins considerably and the shaly section is not represented. Probably this was an area of non-deposition or mild erosion.

In the area of the Fosterton oil field, where the Kootenai rests on the Lower Vanguard, near or on the erosional edge of the Middle Vanguard sand, a fine grained quartzose sand is developed. This sand was likely derived from the Middle Vanguard.

North of here the section above the salt and pepper sandstone consists of green, greenish-grey, and some black and brown shale. Throughout the section siderite pellets or clay ironstone concretions are frequently found interbedded in a cream, kaolinitic matrix. They do not occupy a particular stratigraphic position and cannot be correlated as a distinctive unit between wells.

A thin section of siderite pellets was examined and a description is included at the end of the chapter.

The top of the Kootenai, in the southwest and northwest, consists mainly of fine grained sandstone interbedded with grey, greenish-grey, black and red shale. Toward the southeast fine grained calcareous sandstone becomes prominent with fewer shale breaks. Along section B-B', generalizations are difficult. The trend seems to be to a shalier section toward the east. In wells #57, #58 and #59, in the north, a salt and pepper sandstone is at or near the top of the Kootenai.

First Cat Creek member --

The First Cat Creek marine member is overlain by the Colorado shale and separated from the underlying Lower Kootenai Member by a prominent black shale horizon. This member can be traced over 35,000 square miles of southern Saskatchewan. It is best developed within the Kootenai area, but does extend as a fringe beyond. Locally, it is as thick as the Lower Kootenai Member. As shown on the cross sections, individual beds 10 or 15 feet thick are traceable for over 100 miles.

The base is marked by a black shale of remarkable persistence. In many wells this contains a bed of grey shale near the centre. Thickness is approximately 25 feet, thinning at the depositional edge of the shale. The section overlying the black shale consists of siltstone, silty shale, thin black shale beds and fine grained sandstone, occasionally calcareous. The top is usually a fine grained calcareous sandstone. In a few wells west of Swift Current, coarse, angular quartz grains mark the top of the First Cat Creek.

Dakota Area

Definition

The term Dakota formation is applied to an area of distinctive lithology in southeastern Saskatchewan and southeastern Manitoba. The section is correlated with the so called Dakota Group (Lakota, Fuson, Fall River) of eastern Montana and North Dakota. The writer recognizes that "Dakota" has been applied in several senses. Here, Dakota covers the section between the Jurassic and the overlying Colorado shale.

Some difficulty was encountered in placing the northern boundary of the area. Sediments here have a northern, as well as southern source. The boundary was placed where the course basal sand became shaly. Here, sands derived from the north are replaced by a shaly facies.

Thickness

The maximum thickness is 400 feet. Beds thin comparitively rapidly in the vicinity of the Manitoba-Saskatchewan border. The average thickness is about 350 feet.

Relation to Underlying Beds

The Dakota formation is underlain by Vanguard formation in the south and the Shaunavon formation toward the north. Both are of Jurassic age.

Description

A detailed description of well #79 is included in the appendix and may be considered as a type section for the area. The Dakota formation is divided into three members which are approximately equivalent to similarly named formations in North Dakota. They are, from oldest to youngest, Lakota, Fuson, Fall River.

The basal Lakota member is a heterogeneous sandstone unit, often reaching 125 feet in thickness. The upper part is usually shaly. Grain size is variable but very coarse to granule size are present. Grains are usually angular and broken although sub-rounded grains are not uncommon. Some are frosted and pitted, a few are clear. Rose, and some yellow grains are prominent in addition to clear quartz. The beds have a high porosity. Calcite and cream kaolinite are cementing material.

Where the Jurassic-Cretaceous contact has been cored (wells #39, #40 and #41), the base of the Blairmore is marked by a striking pebble conglomerate. It consists of rounded quartz pebbles, and in one case a dolomite pebble, embedded in a matrix of fine pyritic sand or shale. This conglomerate marks a time of maximum energy conditions in the Blairmore of southern Saskatchewan. The underlying Jurassic shale is brown. This may suggest a period of weathering and an ancient soil horizon.

The Fuson, overlying the coarse basal sands, is a dominately shaly section. The lithology in the southern part of the Dakota area consists of fine grained, locally calcareous shale, interbedded with grey and black carbonaceous shale. Red, yellow, and green shale occurs locally. Occasionally, siderite pellets are found near the top of the section. Toward the north the Fuson becomes sandy. Well #40 contains over 125 feet of brown medium-grained sandstone. Further north, in well #82, the sand becomes coarse and angular. A northern source is apparent.

The upper member in the Dakota area, the Fall River, is a sandy section. Thickness averages 100 feet. The thickest section is near the Swan River boundary and due to the presence of sediments derived from the north.

The Fall River member is separated from the underlying Fuson by a dark grey, partly carbonaceous shale. This corresponds to the black shale at the base of the First Cat Creek. Thus the Fall River and First Cat Creek members are directly correlated. The shale is not present in the northern part of the area.

The Fall River consists of fine, medium and sometimes calcareous, sandstone. It may contain coarse well rounded and angular sand grains. The top of the Fall River Member is usually marked by a thin, fine-grained calcareous sandstone. Toward the north the section becomes shaly.

Well #82, near the Swan River Area boundary, contains sands derived from the north. A 50 foot sandstone unit, at the base of the Fall River, is composed of coarse frosted, usually rounded sand grains. These grains become coarser and more angular toward the north, into the Swan River area.

Swan River Area

Definition

This area is bounded on the south by the Dakota area, and on the east by the Mannville area. It is delimited to cover that part of the Blairmore whose sediments were largely derived from the Pre-Cambrian to the north and northeast. Where this area forms a common corner with Mannville and Dakota areas, exact relationships are somewhat obscure because of lack of data.

Correlation between Swan River formation subsurface beds and outcrop sections are not clearly understood. The writer has applied the name Ashville to dominately shaly beds to the east. This subdivision, based on thickness and lithology, appears justified.

Thickness

The Swan River formation reaches a maximum thickness of 450 feet north of Canora, Saskatchewan, in wells #98 and #99. This thick section extends as a broad tongue from the north and may have been a local basin during Blairmore time. West of this local basin, thickness is about 275 feet over a broad platform. In the extreme western part of the area the Swan River is thinnest, less than 100 feet.

Relation to Underlying Beds

In the south and southwest, the Swan River is underlain by the Lower Vanguard, Shaunavon, and Gravelbourg formations of Jurassic Age. In the east the Lodgepole (Mississippian), and in the north the Devonian, underlie the Swan River formation.

Description

The extent of the area, coupled with lithologic variations even between adjacent wells, makes a generalized description difficult.

In the thick northern section, typified by well#99, the basal beds consist of fine grained, in part calcareous sandstone, interbedded with some grey shale and lignite. Toward the south, the Swan River thins and the Basal beds are not represented.

Above these lagoonal beds is a coarse grained sandstone, 50 to 75 feet thick. Sorting is poor, grains are very coarse to granule size, angular, frosted and pitted. Some clear quartz grains are present. How much of the above beds are represented by sectionD-D' to the east, is controversial. The coarse grained basal sandstone is described above seems to be represented in well #74.

In the northwest, a heterogeneous sequence of fine grained sandstone, grey shale, and lignite lies above the coarse sand. A coarse angular sandstone bed is near the top. The top of the Swan River sequence is marked by a fine grained calcareous sandstone which is apparently prevalent over the entire area.

Ashville Area

Definition

This area has been delimited to cover a sequence of beds consisting largely of shale and fine grained sandstone. The Ashville area lies at the eastern margin of the area of study, in the vicinity of the Saskatchewan-Manitoba boundary. The name Ashville was first applied to beds which overlie the Swan River formation in outcrop section (Kirk 1929).

Ower (1953) examined the subsurface stratigraphy of southwestern Manitoba. He suggests the Swan River formation, as defined from outcrop areas, is not represented in the subsurface of southwestern Manitoba. The Ashville formation was divided into two sections. Ower is of the opinion that the lower may be, in part, equivalent to the Swan River.

Thickness

Along the gradational contact with areas to the west, the Ashville averages 200 feet in thickness. Although specific data is lacking, the isopach pattern suggests rapid thinning, probably to a zero edge, toward the east.

Relation to Underlying Beds

The Ashville rests on the Lower Vanguard (Jurassic) in the south and Devonian in the north.

Description

The Ashville formation consists of fine grained sandstone with interbedded black and green shale. There are a few thin beds of medium grained sandstone near the top.

Some of the shale is bentonitic.

In the south, near the international border the section is shalier, whereas in the north fine grained sandstone is more prevalent. Some siderite is found in well #45. A detailed description of this well is included in the appendix.

Thin Section Study

An attempt to make thin sections of a representative suite of specimans was thwarted by the unconsolidated nature of much of the material.

A slab was first impregnated by heating in liquid plastic. This was allowed to cool. The slab was then Glass lapped until all plastic was removed from the surface, leaving the vugs filled. Impregnation and glass lapping were repeated several times and the section completed in the standard manner.

Tidewater Forgan Cr. #1 Well #63

Thin section at 2322 feet.

Thickness of bed -- 10 feet.

Limestone.

The limestone shows spherulitic texture; under crossed nicols individual spherulites show dark crosses resembling a uniaxial interference figure; as the stage is rotated successive grains become extinct and the cross remains parallel to the cross hairs. The limestone was likely precipitated as a semi-solid mud or microcrystalline ooze; shrinkage and consolidation, with expulsion of water produced the spherulitic texture. The section is cut by a thin calcite vein. Pyrite is dessemin-ated throughout the section.

Tidewater Duperow Cr. #2 Well #66

Thin section at 2674 feet. Salt and pepper sandstone.

Quartz comprises the "salt".

Sphericity[1] -- average = 0.5; some grains 0.3; only a few grains are 0.9.

Roundness -- average = 0.5; some are 0.1; a few grains have a roundness of 0.9 and sphericity of 0.9.

Grain size -- ranges from 0.02 m.m. to 1 m.m.; average size = 0.1 m.m.

In general most quartz grains have a fairly sharp extinction; a few grains possess very irregular extinction.

"Pepper" -- In hand speciman the material is black and soft and may be carbonaceous material. In thin section each grain is composed of what are likely tiny quartz or chert fragments enclosed in a black carbonaceous matrix. Under high power these fragments exhibit undulatory extinction in contrast to the larger "salt" quartz grains.

Dark grey or reddish brown altered material is scattered throughout the slide; opaque under crossed nicols; under reflected light the material has a buff or milky appearance suggestive of leucoxene.

A few grains of fresh or slightly altered plagioclase are scattered throughout the slide; for two grains in the zone $\perp$ o:r:o $x' \wedge$ o1ô-12° the composition is at least as calcic as An30 The section contains a few grains of pyrite.

Tidewater Imperial Plato #1 Well#61

Section at 2739 feet.

In hand speciman this is a brick red, argillaceous sandstone; quartz fragments are subrounded and up to 0.6 m.m. in size; enclosed in a limonite stained calcite matrix.

Anglo Canadian Coates #2-13

Depth -- 1959 feet.

---

1 For meaning of figures refer to chart p. 81 of Krumbein and Sloss (1951).

Location -- unknown.

Speciman from the Fuson shale.

Siderite pellets or clay ironstone concretions. The pellets over most of their area appear clouded or stained with either hematite or limonite. Along some of the unstained edges the characteristic high birefringence of carbonate is seen. This, together with the alteration, appears to confirm the suggestion that the concretions are actually siderite.

Tidewater Morse Cr. #1 Well #29

Section at 3340 feet.

Fine-grained sandstone.

Quartz is angular with a low roundness factor; grain size ranges from 0.1 m.m. to particles too small to measure; most of the quartz possesses a slightly undulatory extinction. The clayey matrix contains some muscovite, chlorite, and biotite; some limonite staining is present; a trace of plagioclase and microcline. Calcite is present as fine crystalline grains.

Chapter IV

TECTONIC INTERPRETATION

Pre-Blairmore Tectonic History

The general thickening of all Pre-Blairmore beds to the southeast suggests the Williston basin was an active negative element since Cambrian time. The Paleogeologic Map of the pre-Blairmore (Plate 9) shows that from south to north the Blairmore rests on progressively older beds. This feature is due to erosional truncation rather than a depositional edge. Two periods of tilting and erosion are evident.

A prolonged period of erosion occurred in post-Mississippian time. Upward tilting to the north eroded Mississippian beds and exposed the Devonian in the Northern part of the area. Pennsylvanisn and Permian beds are absent. Jurassic sediments lapped over older rocks. Tilting caused withdrawal of Jurassic Seas. Erosion was not as extensive as in the post-Mississippian period. Basal Jurassic beds rest on Devonian in the northern part of the area.

Tectonic features

The northern extent of the Williston basin is a prominent feature on the structual map with depths of 1600 feet subsea, in the deepest part. A northwestern nose has been called Moose Jaw syncline by various writers. Although Blairmore sediments do thicken toward the basin, the nature of the lithology suggests this is due more to proximity to source areas rather than a negative feature of the basin. Sediments are shallow water. The basin was likely stable during Blairmore time.

A prominent dome extends from the south into the Kootenai area. This is a northern extension of the Bowdoin dome of northern Montana. Blairmore sediments thicken over the dome, especially on the eastern flank. The upwarp was a post Blairmore feature.

In the vicinity of the town of Swift Current and to the northeast, Blairmore sediments are thinnest. This feature is reflected on the structural contour map as a relatively broad area with a flat or gently dipping surface. This, together with the lithology suggests a stable platform between areas to the north and south which were receiving sediments.

Isopach lines, in the northeastern corner of the Swan River area, trend toward closure. This suggests a local basin although the structural contours show a high. This might be conveniently called Swan River Basin.

The broad north-south trending Sweet Grass arch, toward the Alberta Boundary, is not a prominent feature on the structure map. The Blairmore thins over the arch and it was a positive element during Blairmore time.

Pre-Blairmore-Post-Jurassic Surface

Structural contour maps on any prominent horizon from the Cambrian to the Recent all show downward tilting toward the south. This, plus thickening to the south for all formations beginning at the Cambrian, suggest the prolonged activity of the Williston basin.

A simple structural contour map, such as the one prepared (Plate 7), in comparison with the isopach (Plate 8), suggests the former map bears little relationship to the topography of the Blairmore surface at the close of Blairmore time and the initiation of the marine transgression of Colorado time. In fact any structural map is simply a reflection of post-Blairmore warping.

A means of portrayal of the depositional surface at the initiation of Blairmore deposition is suggested. The lower member of the Shaunavon formation is a limestone unit. This is the most persistent Jurassic unit in Saskatchewan even though calcareous shale is developed toward the east. Presumably at the close of Lower Shaunavon time conditions were at an optimum of stability and the top of the Lower Shaunavon would be essentially a planar surface. The writer suggests an isopach map of the Upper Shaunavon and Vanguard formations would provide a guide to the extent of post-Jurassic erosion and the topography at the initiation of Blairmore deposition. This method however, would be dependent on more or less uniform post-Jurassic uplift rather than irregular warping. The Blairmore would fill irregularities of the erosional surface.

The thick Blairmore sections on the isopach map are not necessarily a reflection of deposition in topographic lows. They are related more to proximity to source areas. The percent sand map generally follows isopach trends. The sections are shalier further from source areas.

Chapter V

INTERPRETATIVE STRATIGRAPHY

General Statement

Blairmore sediments in southern Saskatchewan are controlled by factors such as nature and influence of underlying beds, pre-Blairmore topography, location and tectonic activity of source areas, tectonic elements within the area, and environments. The interplay of such factors has enabled the writer to divide the Blairmore into five stratigraphic areas. The interpretative stratigraphy of each area, for the purpose of organization, will be discussed separately.

Mannville Area

Sediments of the Mannville area are largely of deltaic origin. They represent the southern extremety of a delta whose deposits were concentrated largely in the Lloydminister-Vermilion area.

Source areas lay to the west, in the Cordilleran region. A sea lay to the northeast during most of Mannville time. The dark color of the sediments (lack of oxidation) plus lateral and vertical changes of the section suggest rapid deposition under shifting conditions.

The basal beds are lignite and fine grained sandstone. This suggests sluggish streams meandering over low-lying swampy land.

The overlying salt and pepper sandstones definitely had a western source. They are characteristic of the Alberta Blairmore but are not represented in central and eastern Saskatchewan. Salt and pepper sandstone was derived from Metamorphic crystalline rocks. Here they represent winnowing of greywakes which are represented further west.

The overlying fine grained sandstone and shale represent a lessening of activity in the source area. They indicate alluvial deposits of sluggish streams.

A thin, fresh water limestone bed is of shallow water origin and was deposited when there was little influx from source areas.

The upper coarse grained quartzose sand likely had a shield source. Associated glauconite suggest the sand formed a marine beach. This might be explained by northward tilting, toward the close of Blairmore time. A sea lay toward the south (First Cat Creek). The quartz grains are angular in the south, sub-rounded toward the north. This may be due to a reworking of the beach by a retreating shore line which brought about the widespread marine inundation of Colorado time.

Kootenai Area

Sediments of the Kootenai formation are derived from the west or southwest. The latter is suggested because a tongue which projects into Saskatchewan appears to thicken to the south.

Salt and pepper sandstone, frequently found directly overlying the Jurassic, is one of the dominant lithologic types of this formation. It appears to fill local irregularities of the Pre-Blairmore surface. Poorly sorted, angular, quartz together with a calcareous matrix suggests deltaic deposition by sluggish streams. The suprisingly fresh appearance of feldspar suggests erosion of crystalline rocks rather than reworking of older sediments.

Fine grained sandstone and shale are contemporaneous with salt and pepper sandstone. Interbedded lignite and carbonaceous shale represent local swamp conditions.

Clay ironstone concretions or siderite, embedded in a cream kaolinitic matrix, represent special local environmental conditions. They are not present in any particular stratigraphic position. The iron was probably precipitated when mechanical deposition was in abeyance. Under normal conditions iron is comparitively insoluble. Organic acids and carbon dioxide both increase the solubility of iron. Decaying bacteria could supply these agents and reduce the iron to the ferrous state. Under the petrographic microscope the nodules are definitely siderite. The iron may have precipitated and undergone pene-contemporaneous segregation into nodules, possibly around a decaying organic nucleus. The environment was likely a stagnant fresh water lagoon.

The influence of strata underlying the Kootenai reaches economic importance along the erosional edge of the Middle Vanguard Jurassic sandstone. The overlying basal Kootenai sands are re-worked Middle Vanguard sandstone. The Lower Vanguard shale, underlying the Middle Vanguard, has a fairly even thickness. Where this section is fully represented, some of the overlying sand must be Jurassic. Where the Lower Vanguard is thin (undergone erosion), then the sand is assigned to the Kootenai.

The First Cat Creek member is marine. Thin beds within the member may be easily traced from well to well and many are traceable over the entire Kootenai area.

The basal black shale is present well beyond the boundaries of the Kootenai area. This represents rapid ingress of seas from the west and southwest. Waters were probably stagnant. This black shale, although it thinned considerably, spread across the Dakota area. In the southern part, the shale is overlain by the Fall River sandstone. Thus the First Cat Creek may be directly correlated with the Fall River. The First Cat Creek is of Blairmore age and should not be considered as a sandy phase of the Colorado.

First Cat Creek beds were deposited along a shore line which shifted northward and southward. The failure of the sea to retreat to the southwest and the general downward sinking initiated the widespread marine conditions of Colorado time.

Dakota Area

The isopach-percent sand map shows the Dakota formation thickening and becoming sandier toward the south and southwest. Many of the quartz fragments of the Lakota member are rose in color. The Pre-Cambrian Quartzites of Minnesota also possess a distinctive rose hue. (W. R. Danner -- personal communication). The writer suggests this as the source area of Dakota sediments.

The basal Lakota represnt a beach sand. The material was transported by streams moving northward. The frosted and pitted nature of the grains suggests the sands were shifted by winds. Probably dunes were built up in the vicinity of the beaches. This section becomes finer grained and shalier toward the north, away from the source area. Probably open water lay to the north and to the east, in the Ashville area.

The middle Fuson Shale member represents decreasing erosion in the source area. The occasional red shale bed may indicate local exposure. In one well a shale breccia at the Lakota-Fuson contact indicates definite local erosion. Whether a local diastem was present over the entire area at this time is unknown. Toward the Swan River area coarse sands occur in the Fuson member but these have a northern source. Widespread, although temporary, marine conditions occurred at the end of Fuson deposition as indicated by a thin black shale.

The Fall River sandstone is a beach sand. Sediments were derived from the south and the shoreline shifted toward the north. Toward the Swan River boundary some of the upper sands have a northern source.

Swan River Area

Sediments of the Swan River area were derived from the Pre-Cambrian shield to the north and northeast.

The thick section in the northeastern part of the area may be a local basin. Although data is incomplete, the isopach lines trend toward closure to the north.

The basal beds of lignite and fine grained sandstone represent a swamp or lagoonal environment. Upward tilting to the north initiated increased erosion of the shield. The coarse grained sandstone above the lignite and fine grained sandstone represents a southward moving beach deposit. The shoreline retreated and advanced again near the close of Swan River time. The second advance was not as extensive as the first.

Ashville Area

Sediments of the Ashville formation are fine grained calcareous sandstone and green, black and grey shale. This is in contrast to the coarser sediments of Dakota and Swan River areas to the west.

During Blairmore time this area was covered by a shallow sea. It was probably a site of mild erosion or non-deposition during much of Blairmore time. Sediments are off-shore deposits and were likely received both from Dakota and Swan

River areas. Shallow swampy conditions occasionally prevailed as attested by thin lignite beds. During the deposition of the black shale at the base of the First Cat Creek this sea was probably continuous with the sea which initiated in the Kootenai area (First Cat Creek). A bay of the Ashville sea seems to have been frequently present in the transitional area between Dakota-Swan River areas.

Some of the lower shaly beds may be Jurassic (Stott 1955). This would suggest an even longer post-Jurassic interval of non-deposition.

Chapter VI

PETROLEUM GEOLOGY

Producing Fields

Oil production within the area of study is limited to two areas.

Principal production occurs in the area north west of Swift Current. Here the Kootenai is underlain by Middle Vanguard sandstone. This sandstone underwent local reworking during Blairmore time. Difficulty is frequently experienced in assigning the sand a Jurrasic or Cretaceous age.

The main fields in the area are:

Fosterton -- 30 miles northwest of Swift Current; production from the Lower Cretaceous Jurassic Roseray sand member.
Cantuar -- 19 miles northwest of Swift Current; production from the basal Blairmore Cantuar and Roseray sand as well as the Middle Vanguard.
Battrum -- 10 miles northeast of Fosterton field; Roseray and Upper Shaunavon (Jurassic) production.
Gull Lake -- 25 miles southwest of Fosterton; production from the Cantuar member and Shaunavon formation.
Java -- 10 miles west of Swift Current.
Success -- 8 miles northeast of Cantuar; production from the Cantuar sand.

The Fosterton field, typical of the area, is described by Bowie (1954). It lies at the western end of the Moose Jaw embayment and the northwestern flank of the Coburg syncline. The trap is controlled by both stratigraphy and structure. The field is a shallow dome with approximately 40 feet of closure. The sand is medium to fine grained, rounded and well sorted. The clay or kaolin content is variable. Porosity decreases toward the outer margins of the field.

The Wapella field lies in the Kootenai area of eastern Saskatchewan. Production is from basal Blairmore (Lakota) and Jurassic sandstone. These beds represent a beach sand, near the edge of the Ashville sea.

Petroleum Possibilities

With the exception of local thin limestone beds, all Blairmore sediments are clastic. This, together with the lack of intense tectonic activity suggests future Blairmore oil fields will be simple stratigraphic structural traps.

The Bowdoin dome might seem a favorable structure for oil accumulation. However, the sediments here consist of impervious salt and pepper sandstone and shaly sandstone.

Oil occurs in the upper part of the Lower Kootenai member in Well #52. However, the sand bed is thin and the oil may have migrated toward the Fosterton area.

Within the Mannville area oil occurs in the thin sandy beds at the base of the section. Unfortunately, these members are thin and are frequently interbedded with lignite. The upper coarse grained sandstonemembers are barren. Further exploration in this area, especially toward the north, might prove fruitful. This would necessitate locating areas where the delta was at a still stand. Waves would have sufficient time to rework and sort the sands, thus increasing the porosity.

In the Wapella area exploration might be directed toward finding a further extension of the Wapella sand. Toward the south the Lakota sand possesses excellent porosity, yet is barren of oil. Possibly the oil has migrated up dip to the Wapella area. In this area the sand becomes shaly and impervious. Possibly this prevents the oil from further migration and may be a clue to the oil occurrence in the Wapella field.

Oil has not been observed in the Fall River sand. It becomes shaly toward the north.

Although the Swan River formation contains numerous coarse sandy beds with good porosity, no oil was observed by the writer. The Devonian may have been the source of much of the Blairmore oil. Possibly during Post-Mississippian erosion the oil migrated to the surface of the exposed Devonian and was dissipated. Gussow (1954) suggests that oil contained in the fields of Alberta did not migrate until Post-Blairmore time. If there is oil in the Swan River formation it may have migrated up dip and is now north of the area of study.

It is highly unlikely that oil in commercial quantities will be found in the Ashville formation. The beds consist largely of marine shales and fine grained shaly sandstones.

Conclusions

Before any conclusions on the origin and environments of Blairmore sediments of southern Saskatchewan could be reached, a detailed stratigraphic description was necessary. This is illustrated by means of the stratigraphic sections.

A great deal of future work remains. Firmer correlations between the Blairmore of southern Saskatchewan and surrounding areas should be made. Little is known about the Blairmore north of the area of study. Even in southern Saskatchewan there remain large areas where knowledge of the Blairmore formation remains obscure.

The writer hopes this thesis will provide at least a framework for future workers.

Bibliography

Badgley, P. C. (1952) -- "Notes on the Subsurface Stratigraphy and Oil and Gas Geology of the Lower Cretaceous Series of Central Alberta" -- Geol. Surv. Can. Paper 52 - 11.

Bowie, A. B. (1954) -- "A report on the Fosterton Field" -- Oil in Canada, Vol. 6, No. 38, pp. 23 - 28.

Brown, R. W. (1946) -- "Fossil Plants and Jurrasic - Cretaceous Boundary in Montana and Alberta" -- Bull. Am. Assoc. Pet. Geol., Vol. 30, No. 2, pp. 238 - 248.

Cobban, W. A. (1951) -- "Colorado shale of Central and Northwestern Montana and Equivalent Rocks of Black Hills". Bull, Am. Assoc. Pet. Geol., Vol. 35, No. 10, pp. 2170 - 2198.

Crowley, A. J. (1951) -- "Possible Lower Cretaceous Ullifting of Black Hills, Wyoming and South Dakota." -- Bull. Am. Assoc. Pet. Geol., Vol. 35, No. 1, pp. 83 - 107.

Douglas, J. W. (1951) -- "Preliminary Map, Pincher Creek Alberta" -- Geol. Surv. Can. Paper 51 - 22.

Francis, D. R. (1954) -- "The Jurassic Sediments ofSaskatchewan." -- report 13, Saskatchewan Department of Mineral Resources.

Fraser, F. J., McLearn, F. H., Russell, L. S., Warren, P. S., and Wickenden, R. T. D. (1935) -- "Geology of Southern Saskatchewan" -- Geol. Surv. Can. Memoir 176.

Gallup, W. B., and Hamilton, G. J. (1953) -- "The Orogenic History of the Williston Basin, Saskatchewan." -- Guidebook, 4th Annual Field Conference, Billings Geological Society. pp. 123 - 136.

Gries, J. P. (1954) -- "Cretaceous Rocks of Williston Basin." -- Bull. Am. Assoc. Pet. Geol. Vol. 38, No. 4, pp. 443 - 453.

Gussow, W. C. (1954) -- "Outline of the Time of Migration of Oil and Gas in Alberta, Canada." -- Oil in Canada, Vol. VI, No. 39, pp. 30 - 42.

Hadley, H. D., andMilner, R. T., (1953) -- "Regional Stratigraphy of the Lower Cretaceous and Jurassic." -- Guidebook, 4th Annual Field Conference, Billings Geological Society, pp. 85 - 86.

Hatch, F. H., Rastall, R. H., and Black, M. (1938) -- "The Petology of the Sedimentary Rocks" -- Thomas Murby & Co., London, England.

Henderson, J. F. (1945) -- "Fall Creek Map Area." -- Geol. Surv. Can Paper 45-19.

Hume, G. S., and Hage, C. O. (1941) -- "The Geology of East Central Alberta." -- Geol. Surv. Can. Memoir 232.

Irwin, J. S. (1931) -- "Stratigraphic Correlations and Nomenclature in Plains of Southern Alberta." -- Bull. Am. Assoc. Pet. Geol., Vol. 15, No. 10, pp. 1129 - 1139.

Kamen-Kaye, M. (1953) -- "The Tectonic Patterns of Southwestern Saskatchewan, Canada." Guidebook, 4th Annual Field Conference, Billings Geological Society. pp. 118 - 122.

Karlstrom, T. N. V. (1948) -- "Geology and Ore Deposits of the Hecla Mining District, Beaverhead Country, Montana." State of Montana Bureau of Mines, Geology Memoir No. 25.

Kirk, S. R. (1929) - "Cretaceous Stratigraphy of the Manitoba Escarpment." -- Geol. Surv. Can. Summ. Rpt., Part B, pp. 112 - 135.

Kline, V. H. (1942) -- "Stratigraphy of North Dakota" -- Bull. Am. Assoc. Pet. Geol., Vol. 26, No. 3, pp. 336 - 379.

Krumbein, W. C. and Sloss, L. L. (1951) -- "Stratigraphy and Sedimentation." -- W. H. Freeman and Co., San Francisco, California.

Krumbein, W. C., Sloss, L.L., and Dapples, E. C. (1949) -- "Sedimentary Tectonics and Sedimentary Environments." -- Bull. Am. Assoc. Pet. Geol., Vol. 33, No. 11, pp. 1859 - 1891.

Leach, W. W. (1911) -- "Geology of the Blairmore Map Area." -- Geol. Surv. Can. Summ. Rpt., pp. 192 - 200.

Lindsey, K. B. (1954) -- "Petroleum in the Williston Basin, Including Parts of Montana, North and South Dakota, and Canada." -- U.S. Bureau of Mines Report of Investigations No. 5055.

Link, T. A. (1931) -- "Alberta Syncline, Canada." -- Bull. Am. Assoc. Pet. Geol., Vol. 15, No. 5, pp. 491 - 507.

Loranger, D. M. (1951) -- "Useful Blairmore Microfossils in Central and Southern Alberta, Canada." -- Bull. Am. Assoc. Pet. Geol., Vol. 35, No. 11, pp. 2348 - 2367.

Mathews, W. H. (1946) -- Geology and Coal Resources of the Carbon Creek-Mount Bickford Map-Area." British Columbia Department of Mines, Bull. No. 24.

McLearn, F. H. (1932) -- "Problems of the Lower Cretaceous of the Canadian Interior." -- Trans. Royal Soc. of Canada, Third Series, Vol. XXVI, Sec. IV, pp. 57 - 175.

McLearn, F. H. (1944) -- "Revision of the Paleogeography of the Lower Cretaceous of the Western Interior of Canada." -- Geol. Surv. Can. Paper 44-32.

Nauss, A. W. (1945) -- "Cretaceous Stratigraphy of the Vermilion Area, Alberta, Canada." -- Bull. Am. Assoc. Pet. Geol., Vol. 29, No. 1, pp. 1605 - 1629.

Ower, J. R. (1953) -- "The Subsurface Stratigraphy of Southwestern Manitoba." Can. Inst. Min. and Met., Vol. 46, pp. 735 - 743.

Perry, E. S. (1937) -- "Natural Gas in Montana" -- State of Mont. Bureau of Mines and Geology Memoir No. 3.

Russell, L. S. and Landes, R. W. (1940) -- Geology of the Southern Alberta Plains." -- Geol Surv. Can. Memoir 221.

Stott, D. F. (1955) -- "Jurassic Stratigraphy of Manitoba." -- Manitoba Department of Mines and Natural Resources. Pub. 54-2.

Taylor, J. H. (1949) -- "Petrology of the Northhampton Sand Ironstone Formation." -- Memoirs Geol. Society of Great Britain, Code No. 62-371.

Thompson, R. S. and Axford, D. W. (1953) -- "Notes on the Cretaceous of Southern Alberta" -- Guidebook, 3rd Annual Field Conference, Alberta Society of Petroleum Geologists, pp. 33-59.

Wickenden, R. T. D. (1931) -- "Variations in Thickness of Cretaceous Formations in Southern Manitoba." -- Geol. Surv. Can. Summ. Rpt.for 1930, Part B., pp. 72 - 103.

- - - - - - - - - - (1932) -- "Notes on Some Deep Wells in Saskatchewan." -- Trans. Royal Soc. Can., Vol. XXVI Sec. IV, pp. 177-196.

- - - - - - - - - - (1945) -- "Mesozoic Stratigraphy of the Eastern Plains, Manitoba and Saskatchewan." Geol. Surv. Can. Memoir 239.

- - - - - - - - - - (1948) -- "The Lower Cretaceous of the Lloydminister Oil and Gas Area, Alberta and Saskatchewan." Geol. Surv. Can. Paper 48-21.

- - - - - - - - - - (1949) -- "Some Cretaceous Sections along Athabaska River from the Mouth of Calling River to Below Grand Rapids, Alberta." -- Geol. Surv. Can. Paper 49-15.

- - - - - - - - - - (1951) -- "Some Lower Cretaceous Sections on Peace River Below the Mouth of Smoky River, Alberta." -- Geol. Surv. Can. Paper 51-16.

Williams, M. Y. (1944) -- "Geological Investigations along the Alaska Highway from Fort Nelson B. C. to Watson Lake, Yukon." Geol. Surv. Can. Paper 44-28.

LITHOLOGIC SYMBOLS

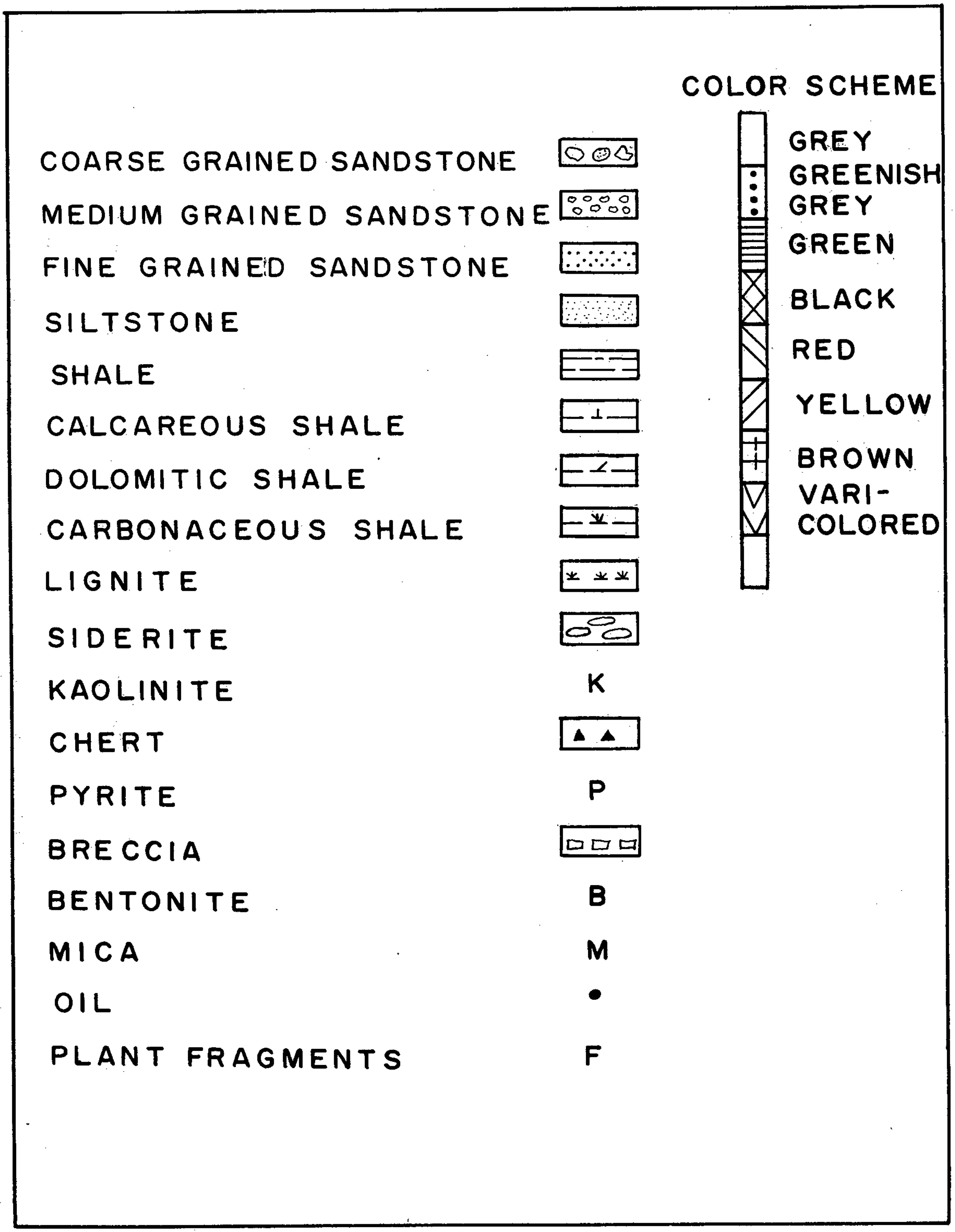


FIGURE 4

Appendix

Well #67 Tidewater Duperow Cr. #1

Depth in feet	Lithology
	Mannville Formation
2210-2215	Silty shale -- light and dark grey; some light green glauconitic shale and siltstone; trace of light greenish grey sandstone.
2215-2220	Shale -- black; trace of light green, fine grained, well sorted glauconitic sandstone.
2220-2245	Sandstone, light greyish green, fine grained, good porosity; parting of black shale at 2270.
2245-2270	Shale -- dark grey, partings of glauconitic sandstone.
2270-2275	Shale - dark grey, silty.
2275-2290	Sandstone -- green to grey, slightly glauconitic, coarse grained, locally shaly, good porosity.
2290-2300	Shale -- black; numerous partings and inclusions of light greenish-grey sandstone.
2300-2310	Sandstone -- light grey, fine grained, calcareous; interbedded black shale.
2310-2330	Shale -- dark grey, silty.
2330-2350	Silty shale -- dark grey, hard.
2350-2360	Sandstone -- light tan-grey, fine grained, calcareous, indurate.
2360-2380	Sandstone -- light grey to white, fine grained, generally soft, good porosity.
2380-2385	Siltstone -- light grey.
2385-2390	Salt and pepper sandstone.

2390-2415	Shale -- light and dark grey, silty, scattered carbonaceous material.
2415-2425	Sandstone -- light grey, fine grained, clayey, soft, carbonaceous fragments.
2425-2430	Silty shale -- light and dark grey, sandy.
2430-2435	Dolomite -- light brown, silty.
2435-2450	Sandstone -- light grey, very fine grained to silty.
2450-2475	Sandstone -- light grey, very fine grained, clayey.
2475-2480	Silty dolomite -- light brown, finely granular.
2480-2490	Sandstone -- light grey to white, fine grained, clayey matrix.
2490-2495	Calcareous sandstone -- light grey, medium grained, hard.
2495-2505	Shaly sandstone and silty shale -- dark grey.
2505-2520	Silty shale, dark grey; trace of black shale.
2520-2535	Salt and pepper sandstone -- calcareous.
2535-2555	Silty shale -- light grey; trace of lignite.
2555-2560	Clayey sandstone -- light brown, fine grained, oil saturated; trace of lignite.
2560-2590	Silty shale -- dark grey, carbonaceous material.
2590-2600	Sandstone -- light brown, fine grained,oil saturated.
2600-2605	Silty shale -- hard, massive.
2605-2610	Lignite.

2610-2620	Shale -- light brown, silty, carbonaceous material.
	Jurassic
2620-2622	Shale -- light green to white; slightly dolomitic shale.
2622-	Dolomitic shale -- light green, soft, waxy.

Well #52 Tidewater Pelletier Cr. #1

Depth in feet	Lithology
	Colorado formation
-3535	Shale -- dark grey to black, slightly silty.
	First Cat Creek member
3535-3550	Sandstone -- medium to coarse grained, well rounded, some broken grains; interbedded with dark grey shale.
3550-3560	Shale -- dark grey; trace of fine grained sandstone.
3560-3575	Sandstone -- grey, fine grained, dense, calcareous.
3575-3590	Shale -- dark grey to black, carbonaceous.
3590-3600	Sandstone; grey fine grained.
3600-3605	Shale -- dark grey.
3605-3615	Siltstone and grey shale.
3615-3635	Shale -- light and dark grey.
3635-3640	Sandstone, -- grey, very fine grained.
3640-3675	Shale -- dark grey to black, carbonaceous; some interbedded siltstone.
	Lower Kootenai member
3675-3695	Sandstone -- grey, fine grained, oil saturated; thin black shale parting.

3695-3700	Salt and pepper sandstone -- locally calcareous, pyritic.
3700-3720	Shale -- green; trace of redshale; sandy toward base.
3720-3725	Salt and pepper sandstone.
3725-3765	Shale -- grey, black, red and green.
3765-3780	Shale -- brown, sandy.
3780-3805	Shaly sandstone -- grey, fine grained, evidence of slumping; some carbonaceous fragments.
3805-3807	Shale -- green; some inclusions of yellow shale fragments.
3807-3815	Shale -- green sandy toward base.
	Jurassic
3815-	Shaly sandstone -- green fine grained, friable.

Well #79 Imperial Tidewater Carlyle #1

Depth in feet	Lithology
	Colorado formation
-2660	Shale -- dark grey to black, carbonaceous.
	Dakota formation
2660-2665	Sandstone -- fine grained, calcareous.
2665-2670	Sandstone -- medium grained, angular.
2670-2685	Sandstone -- grey, very fine grained.
2685-2750	Sandstone -- grey, fine grained, friable, locally calcareous.
2750-2760	Shale -- dark grey.
2760-2780	Sandstone -- medium grained, angular; shale parting at base.

2780-2850	Sandstone -- medium, some coarse grained, angular and sub-rounded, rose colored; black shale parting toward base.
2850-2900	Sandstone -- medium grained; shaly partings.
2900-2902	Breccia; black shale fragments in greenish grey, calcareous shale matrix.
2902-2905	Sandstone -- very fine grained, slightly calcareous.
2905-2910	Shale -- dark greenish grey.
2910-2960	Sandstone -- very fine to medium grained, some pink grains, carbonaceous material; good porosity.
2960-2965	Shale -- yellowish-green.
2965-3015	Sandstone -- grey, poorly sorted, very fine to very coarse grains; some coaly inclusions.
3015-3025	Sandstone -- very coarse to granule size, rose and yellow grains.
3025-3028	Shale -- green, dense, slickenslided, pyritic concretions.
3028-3030	Interbedded green shale and very fine grained sandstone; numerous yellow shale fragments; bedding irregular, dips shallow to steep.

Jurassic

3030-	Shale -- green, dense.

Well #99 Socony Buchanan #1

Depth in feet	Lithology
	Colorado formation
-1085	Shale -- medium grey, slightly calcareous.
	Swan River formation
1085-1100	Sandstone -- grey, some brown, fine grained, dense.

1100-1105	Shale -- grey.
1105-1120	Sandstone -- brown, fine grained, dense.
1120-1125	Shale -- black.
1125-1135	Sandstone -- grey, fine grained.
1135-1190	Sandstone -- medium to coarse grained, angular and broken; grey shale partings.
1190-125	Sandstone -- grey, brown, fine grained, calcareous.
1250-1255	Siderite.
1255-1265	Sandstone -- fine grained, and interbedded grey shale.
1265-1285	Shale -- dark grey and lignite.
1285-1355	Siltstone -- grey and yellow; shale -- yellow and grey; trace of coal.
1355-1435	Sandstone -- medium to coarse grained; coarser toward the base.
1435-1440	Shale -- brown.
1440-1470	Interbedded dark grey shale and fine grained sandstone.
1470-1525	Sandstone -- grey, fine grained.
1525-1540	Lignite.
1540-1560	Siltstone grading into fine grained calcareous sandstone at the base.
1560-1565	Shale -- dark brown and dark grey.
	Devonian
1565-	Limestone -- light grey and cream.

Well #45 Imperial Foxwarren #1

Depth in feet	Lithology
	Colorado formation

-1280	Shale -- dark grey, dense.
	Ashville formation
1280-1325	Sandstone -- grey, fine grained, shaly, carbonaceous fragments.
1325-1335	Shale -- black, carbonaceous.
1335-1345	Sandstone -- grey, fine grained, argillaceous and silty; calcareous and carbonaceous at base; dark grey shale parting at base.
1345-1380	Sandstone -- grey, fine grained; shaly partings; siderite.
1380-1415	Sandstone -- grey, fine grained, argillaceous.
1415-1420	Shale -- dark grey, and siderite.
1420-1430	Sand -- fine grained, carbonaceous fragments.
1430-1460	Interbedded fine grained sandstone and grey shale.
1460-1505	Interbedded light grey, fine grained sandstone, and green shale.
1505-1510	Shale -- green and red; calcareous fine grained sandstone; trace of chert.
1510-1520	Sandstone -- grey, fine grained, calcareous.
1520-1525	Shale -- red and green, bentonitic.
	Mississippian
1525-	Limestone -- buff, finely crystalline, dense.