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THE SEDIMENTARY PETROGRAPHY AND STRATIGRAPHY OF THE MISSISSIPPIAN WHITEWATER LAKE MEMBER OF SOUTHWESTERN MANITOBA

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ABSTRACT

The Whitewater Lake Member of the Mississippian Lodgepole Formation is a subsurface unit which can be correlated over an area of about 1400 square miles in southwestern Manitoba. The member is divided into an upper and a lower unit, the lower unit being typically more argillaceous than the upper unit.

The Whitewater Lake Member represents a well developed cycle of calcareous sedimentation similar to the underlying Virden Member. Whitewater Lake sedimentation began with and was ended by an influx of clay size terrigenous sediment. These argillaceous zones allow the member to be correlated but, however, they thin and are difficult to recognize to the west and correlations become unreliable in that direction.

During Whitewater Lake times, a large, shallow, coastal shoal occurred in the Whitewater-Lulu Lake area. To the west and in the Virden area, deeper water, open marine shoal margin and shallow shelf conditions prevailed. The coastal shoal area is characterized by lump, oolitic, and argillaceous limestones; the shelf and shoal margin area by micritic, skeletal, and argillaceous limestones.

It is believed that the Whitewater Lake limestones were formed under conditions very similar to those under which calcareous sediments are forming on the present day Bahama Banks.

The Whitewater Lake Member is in close proximity to the Mississippian-Jurassic unconformity and has undergone extensive dolomitization and anhydritization related to this unconformity particularly where the overlying Jurassic Amaranth Red Bed cover is less than twenty feet thick.

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CHAPTER ONE

INTRODUCTION

General Statement

The Whitewater Lake Member occurs within the Lodgepole Formation[1] of early Mississippian (Kinderhookian) age on the northeast flank of the Williston Basin in the southwest corner of the province of Manitoba (Figure 1). The upper part of the Lodgepole in this area consists of cyclically deposited limestones of which the Whitewater Lake Member appears to represent one complete cycle.

Although the unit is of limited areal extent (1400 square miles in the Canadian area of study), the Whitewater Lake Member occurs in an area of significant, economic importance as it includes the North Virden Scallion, Virden-Roselea, Maples, Routledge, West Routledge, Souris-Hartney, Whitewater, and Lulu Lake (abandoned) oil fields (Figure 2). It is the producing interval for the Whitewater and Lulu Lake fields, and in part for the Maples field.

It is the purpose of this thesis to establish the limits of Whitewater Lake correlation, to describe in detail the sedimentary petrography, and from available information from studies of recent calcareous sediments, to reconstruct

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1. Souris Valley Beds of the Saskatchewan Geological Society (1956).

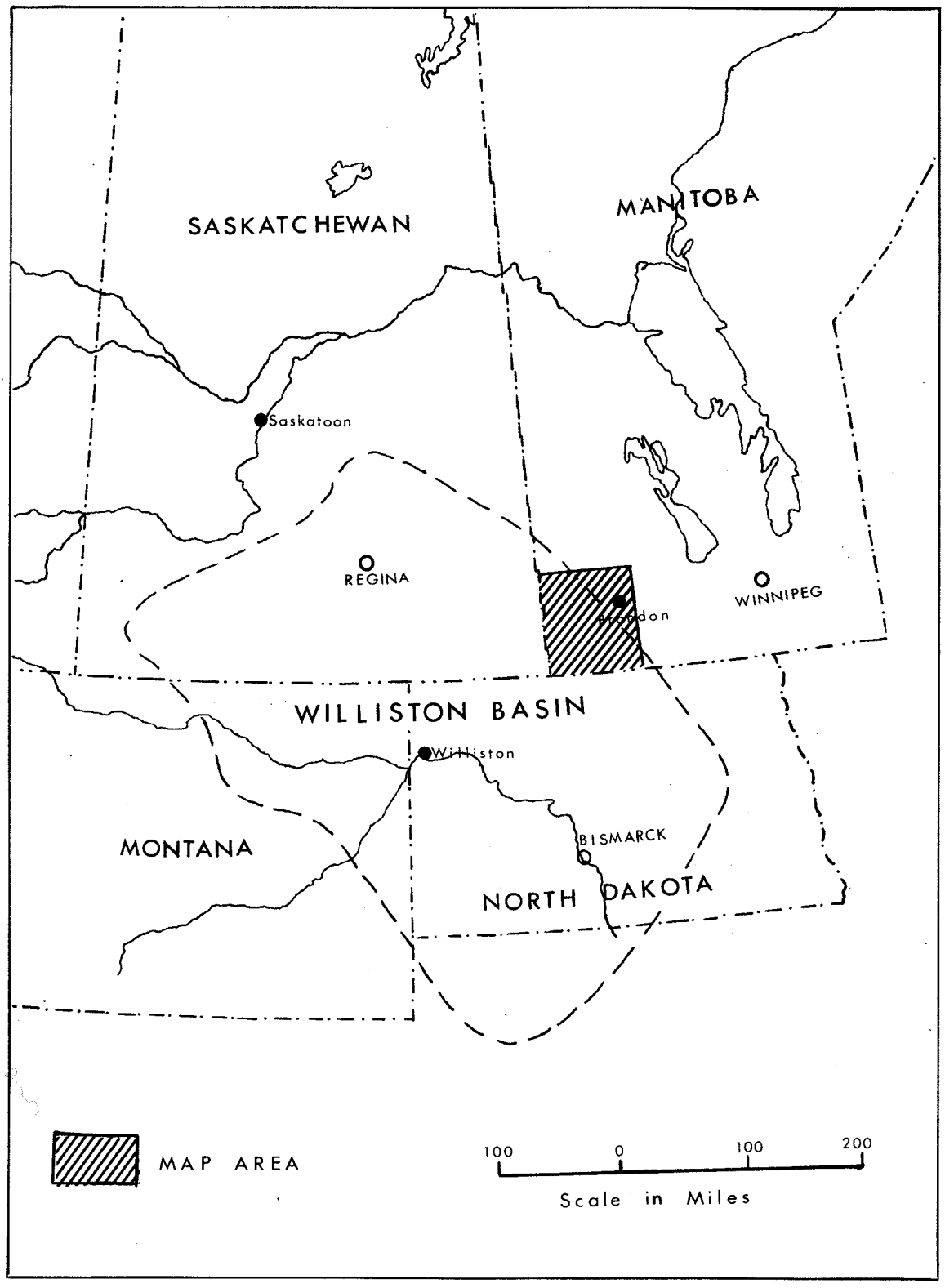

Figure 1 Location Map

the depositional environment of the member.

Previous Work

Early work on the Mississippian of Manitoba consisted of general stratigraphic papers dealing with the grosser aspects of the major units. With the discovery and development of petroleum, a number of local subdivisions of the Lodgepole were proposed for the various oil fields particularly in the Virden and Daly field areas. Among these local subdivisions, were papers by Milne and Nickoloff (1955), Atkinson and Hegion (1956), and Organ and Russin (1956).

Stanton (1956) proposed a more regional stratigraphic breakdown of the Lodgepole Formation into units of member rank in the Virden-Whitewater area. In ascending order they are the Scallion, Virden, and Whitewater Lake Members and an upper unnamed unit. He pointed out, however, that due to lithologic variations resultant from changes in the depositional environment, the subdivision of the Lodgepole into these units is applicable only over a relatively limited area roughly parallel to the eastern erosional edge of the Mississippian subcrop in Manitoba and northern North Dakota.

McCabe (1959) presented an excellent regional stratigraphic study of the entire Mississippian sequence found in Manitoba, integrating the previous local stratigraphic studies. Later McCabe (1963) proposed the term Flossie Lake

Member for the unnamed part of the Lodgepole overlying the Whitewater Lake Member in a report on the Mississippian oil fields of Manitoba.

No papers have been written which deal explicitly with the Whitewater Lake Member as such.

Method of Study

Mississippian strata do not outcrop anywhere within the northeastern portion of the Williston Basin and thus the study was based entirely on the examination of subsurface information restricted to the province of Manitoba.

Mechanical logs (electric and radiation) and cores, where available, were examined from 96 wells in southwestern Manitoba (Figure 2). Nine selected cores were described in detail (Appendix II).

To study the sedimentary petrography, polished and etched sections cut parallel and perpendicular to the bedding were examined with a binocular microscope, and 19 thin sections were made to obtain detailed information. Dolomite, calcite, and anhydrite, where intermixed, were identified by staining with alizarine red S solutions as described by Friedman (1959).

Acknowledgements

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CHAPTER TWO

DESCRIPTIVE STRATIGRAPHY

Regional Stratigraphy

The following outline of the regional stratigraphy of the area has been gathered in part from previous published works, mainly those by Stanton (1958) and McCabe (1959 and 1963).

The area under consideration is situated, geologically, on the northeastern edge of the Williston Basin, a negative structural feature whose centre lies in northwestern North Dakota, which has influenced sedimentation in this area during much of the Paleozoic and Mesozoic Eras. Paleozoic sediments dip to the southwest at an average of 30 feet per mile and they are overlain unconformably by Mesozoic sediments which dip to the southwest at about 12 feet per mile.

Mississippian strata form the youngest carbonate sequence of the Paleozoic sedimentary rocks in Manitoba. They are underlain by an older Paleozoic sequence of limestone and dolomite with minor sandstone and shale, and are overlain by an upper, Mesozoic and Cenozoic sequence of shale and sandstone. The Mississippian strata of Manitoba were subjected to intense erosion during post-Mississippian, pre-Jurassic time. Jurassic red beds and evaporites were deposited on the

erosion surface and show angular unconformity with respect to the underlying Mississippian strata.

Mississippian strata in Manitoba have been divided into four well defined lithologic units named from bottom to top: the Bakken, Lodgepole, Mission Canyon, and Charles Formations (Figure 3). These formations form a somewhat irregular series of northwest trending subcrop belts beneath the younger Jurassic strata.

The Whitewater Lake Member occurs in the Lodgepole Formation which is predominantly a shaly limestone that shows marked lateral changes in lithology from coarse-grained calcarenite limestone to fine-grained limestone, shaly limestone, calcareous shale, and black shale (McCabe, 1963, p.2). These thin interbeds of argillaceous limestone enable the succession to be subdivided. The Lodgepole Formation is equivalent to the Souris Valley Beds of Saskatchewan (Saskatchewan Geological Society, 1956) and to the Bottineau interval of North Dakota. In the area of study the Lodgepole Formation has been subdivided into units of member rank. In ascending order these are the Scallion Member (including the Routledge Shale facies), the Virden Member, the Whitewater Lake Member, and the Flossie Lake Member. This subdivision along with the characteristic lithology and maximum thickness of each member is illustrated in Table 1. However, due to lithologic variations resultant from changes in the depositional environment, these units are applicable only to a relatively

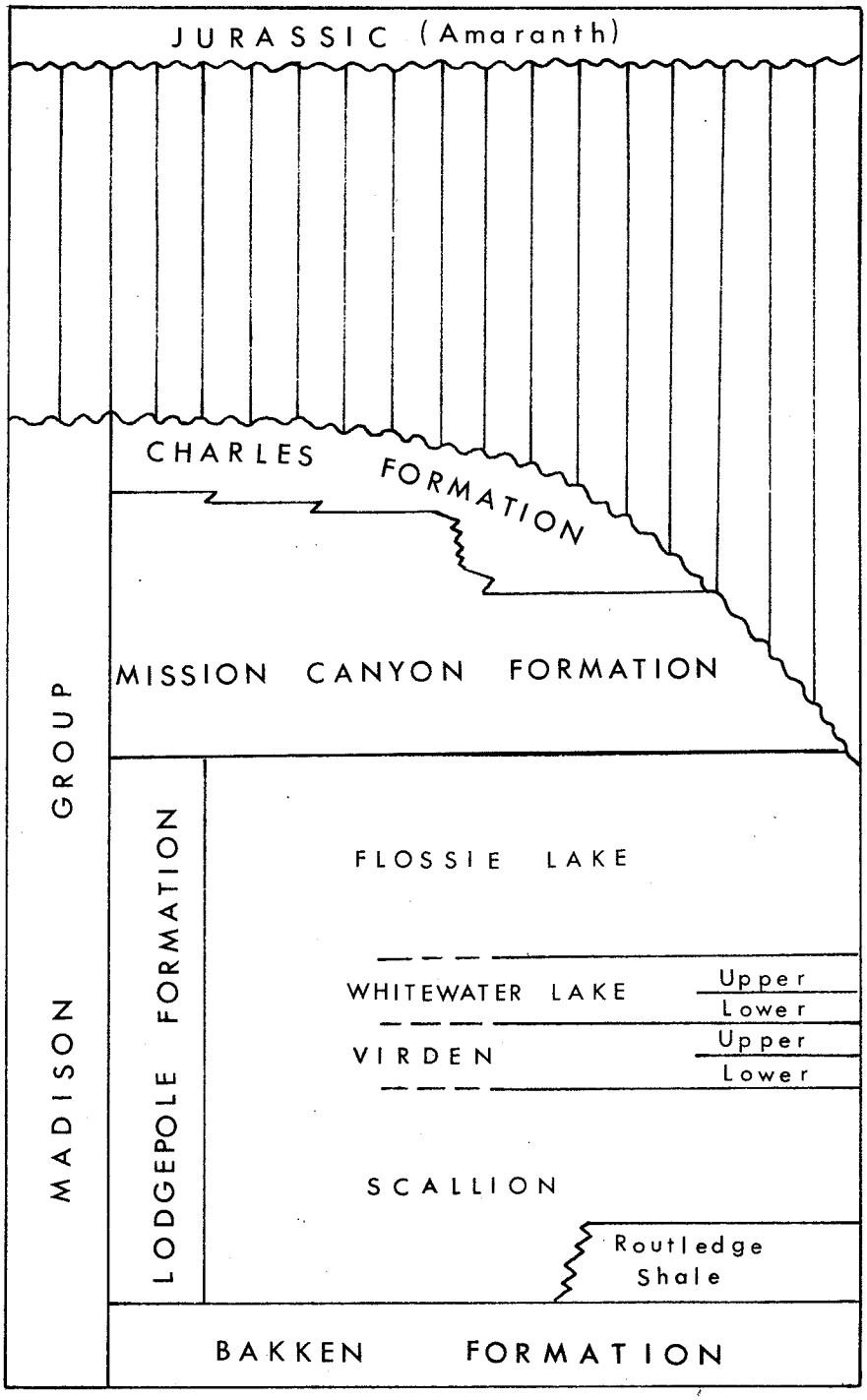

Figure 3 Subdivision And Nomenclature Of Mississippian Strata In Southwestern Manitoba

TABLE 1

SUBDIVISION OF THE LODGEPOLE FORMATION IN SOUTHWESTERN MANITOBA

Member		Lithology	Maximum Thickness (Feet)
Flossie Lake		Micritic, skeletal, and argillaceous limestones.	210
Whitewater Lake	Upper Unit	Non-argillaceous lump, oolitic, skeletal, and micritic limestones.	40
	Lower Unit	Interbedded argillaceous limestones with oolitic, micritic, and skeletal limestones.	40
Virden	Upper Unit	Non-argillaceous skeletal, lump, and oolitic limestones.	45
	Lower Unit	Interbedded argillaceous limestones and calcareous shale with oolitic and skeletal limestones.	45
Scallion		Micritic, cherty, and skeletal limestones. Routledge facies is a black shale.	245

narrow belt paralleling the eastern erosional edge of the Mississippian in Manitoba and northern North Dakota.

Both Stanton (1958) and McCabe (1959 and 1963) give type sections, lithologic descriptions, and stratigraphic maps and crossections of the Lodgepole Formation in Manitoba.

Whitewater Lake Member

The Whitewater Lake Member represents a well developed cycle of calcareous sedimentation very similar to the underlying Virden Member. A calcareous cycle consists of a basal section of argillaceous limestones interbedded with oolitic and skeletal or lump limestones which grade upward into massive non-argillaceous limestones at the top. The upper limit is defined by the occurrence of argillaceous beds apparently marking the initiation of a third more poorly defined cycle. It is this apparent cyclical nature of this portion of the Lodgepole which has influenced the selection of the member subdivision points. The Whitewater Lake Member has been divided into an upper and a lower unit (Stanton, 1958), the lower being typically more argillaceous than the upper. For descriptive purposes, these units are termed the Upper Whitewater Lake unit and the Lower Whitewater Lake unit of the Whitewater Lake Member and are not considered to be formal stratigraphic units.

The argillaceous marker beds which define the upper

and lower limits of the member thin to the west where they merge and interfinger with the thinly interbedded argillaceous and non-argillaceous limestones of the western Whitewater Lake stratigraphic equivalent. These marker beds are very difficult to recognize or distinguish from the other argillaceous zones and correlations become unreliable and interpretational in that direction.

Throughout much of the area of study the Whitewater Lake Member is in close proximity to the Mississippian-Jurassic unconformity, and the resultant dolomitization and anhydritization effects have in many instances altered the original lithologic and mechanical log characteristics especially in the northern part of the area. Type sections (Stanton, 1958) are taken from a composite of two wells in the Whitewater field area in Tp. 3, Rge. 21 W.P.M. where the member is fully developed and has escaped most of the above secondary effects.

The Whitewater Lake subcrop belt along with the area of satisfactory correlation is illustrated in Figure 4. This area of satisfactory or practical correlation comprises a region of about 1400 square miles adjacent to the subcrop belt in the Canadian area of study. Although the Whitewater Lake Member appears to extend into northern North Dakota the area of study was arbitrarily cut off at the U.S. border. Well control is poor and cores are rare in the western area of

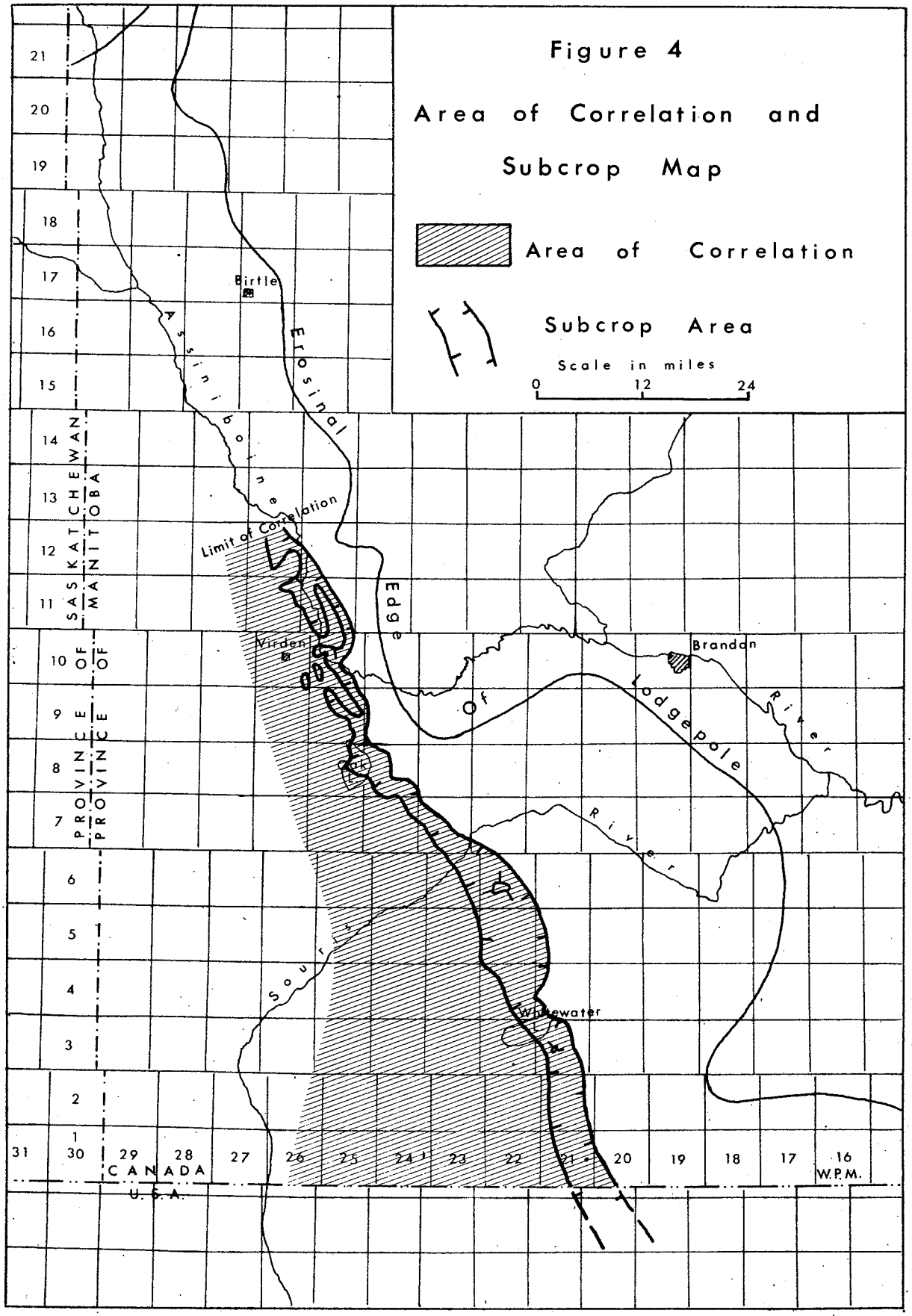
Figure 4
Area of Correlation and Subcrop Map
Area of Correlation
Subcrop Area
Scale in miles
0 12 24
Birtle
Assiniboine
Erosional
Edge
Limit of Correlation
Virden
Oak
Brandon
Lodgepole
River
Of
Whitewater
Lake
SASKATCHEWAN
MANITOBA
PROVINCE OF
PROVINCE OF
CANADA
U.S.A.
W.P.M.

study away from the subcrop belt.

1. Lower Whitewater Lake Unit

The type section for the Lower Whitewater Lake unit is the interval 2545'-2585' in the California Standard Whitewater 10-17-3-21 WPM well (Figure 5 and core description in Appendix II, Page 77).

The unit consists of two to five foot thick beds of oolitic, and skeletal or lump limestones interbedded with mottled reddish to greenish gray argillaceous limestones and calcareous shales. However, to the west of the type area and in the Virden area, the oolitic limestone beds disappear and the lower unit consists mainly of a single argillaceous unit 10 to 20 feet thick (Figure 6). In the Virden area, the basal shaly part of the lower unit is called the Roselea Shale (Stanton, 1958).

The lower unit is characterized by low resistivity and high spontaneous potential electric log curves (Figure 5). Negative deflections on the spontaneous potential curve and positive deflections on the resistivity curve correspond to the "clean" oolitic, skeletal, and lump limestones.

The base of the unit is taken at a fairly abrupt contact between the underlying non-argillaceous, skeletal, oolitic and lump limestones of the Upper Virden Member and the interbedded argillaceous limestones of the Lower Whitewater Lake

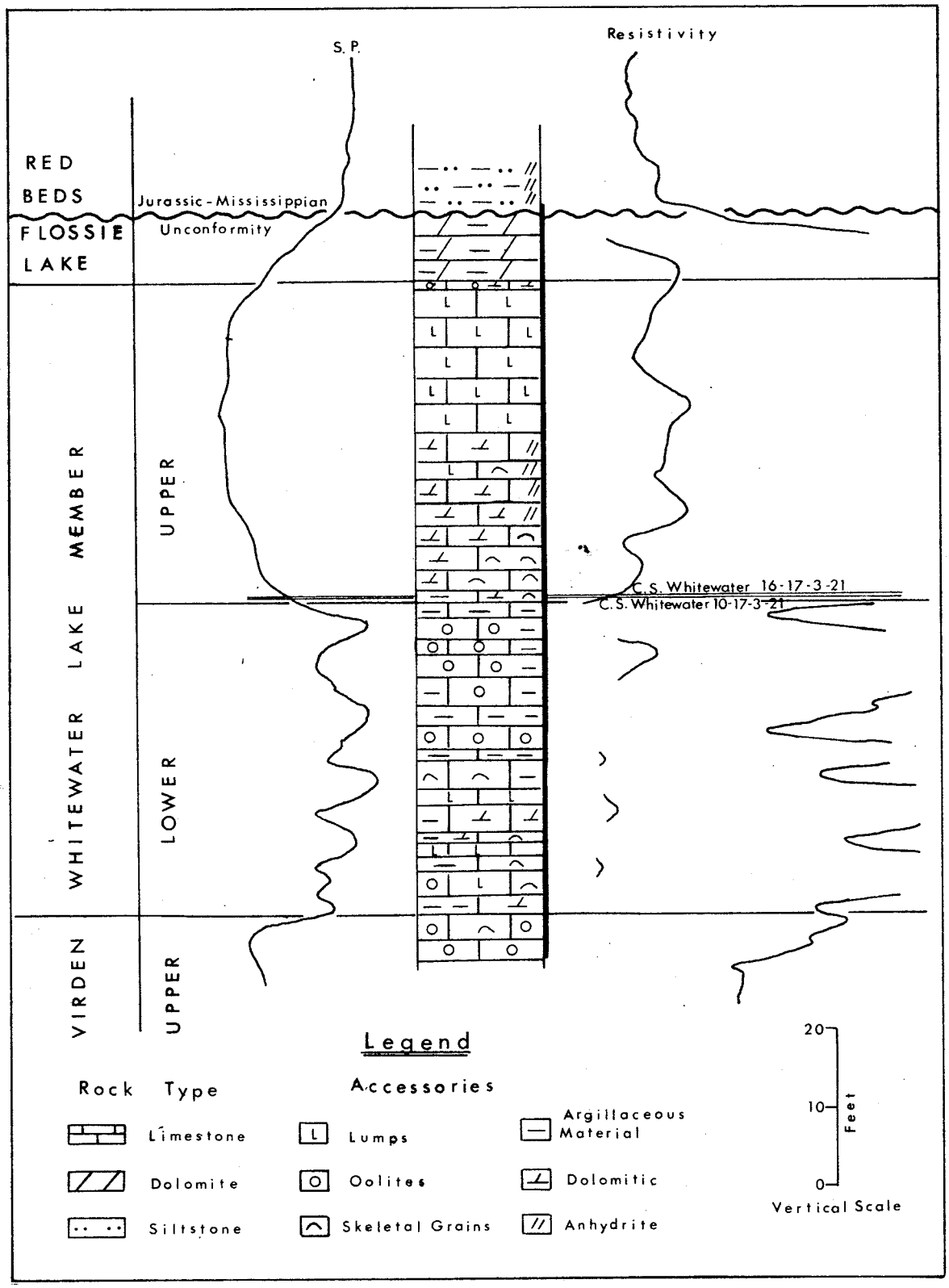

Figure 5 Type Section Of The Whitewater Lake Member

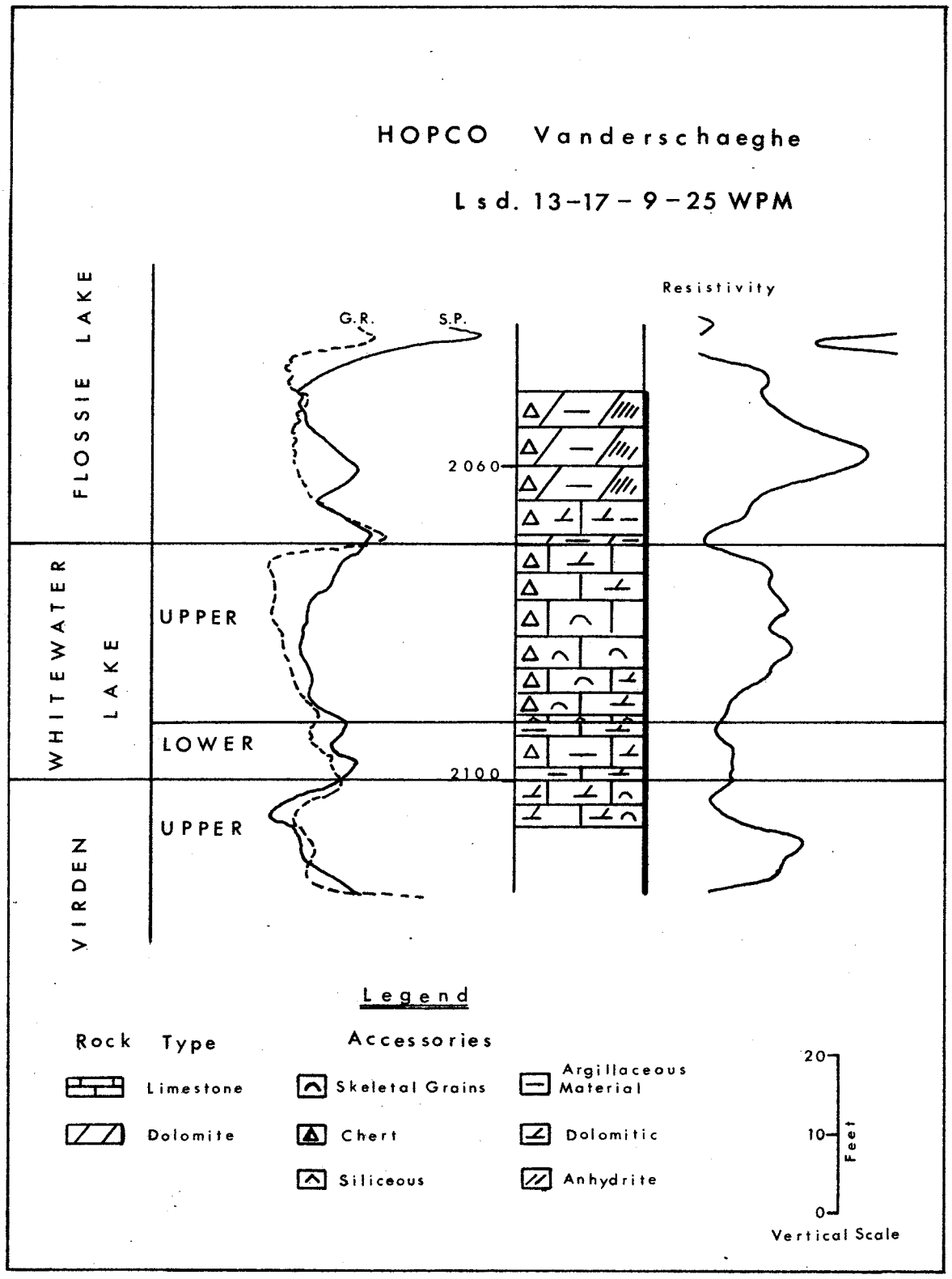

Figure 6 Typical Section Of The Whitewater Lake Member In The Western Area Of Study

unit. The top is taken at the base of the non-argillaceous limestone of the Upper Whitewater Lake unit. Both contacts are readily picked on the basis of the mechanical log character (Figures 7 and 8).

The Lower Whitewater Lake unit has a maximum thickness of about 40 feet in the Whitewater area, (Figure 9). To the west and in the Virden area it thins to about 10 to 20 feet. The limit of correlation corresponds approximately with the 10 foot isopach contour line. However, the Lower Whitewater Lake unit in general can be correlated over a larger area than the upper unit.

2. Upper Whitewater Lake Unit

The type section for the Upper Whitewater Lake unit is the interval 2502'-2542' in the California Standard Whitewater 16-17-3-21 WPM well (Figure 5 and core description in Appendix II, Page 80).

The upper unit in the Whitewater-Lulu Lake area consists predominantly of non-argillaceous lump limestones or bahamites which grade into oolitic and skeletal limestones toward the base. To the west and in the Virden area, the upper unit undergoes a facies change to micritic and skeletal limestones (Figure 6). The unit is much thinner in this area than in the type area.

The upper unit is characterized by a blocky, negative

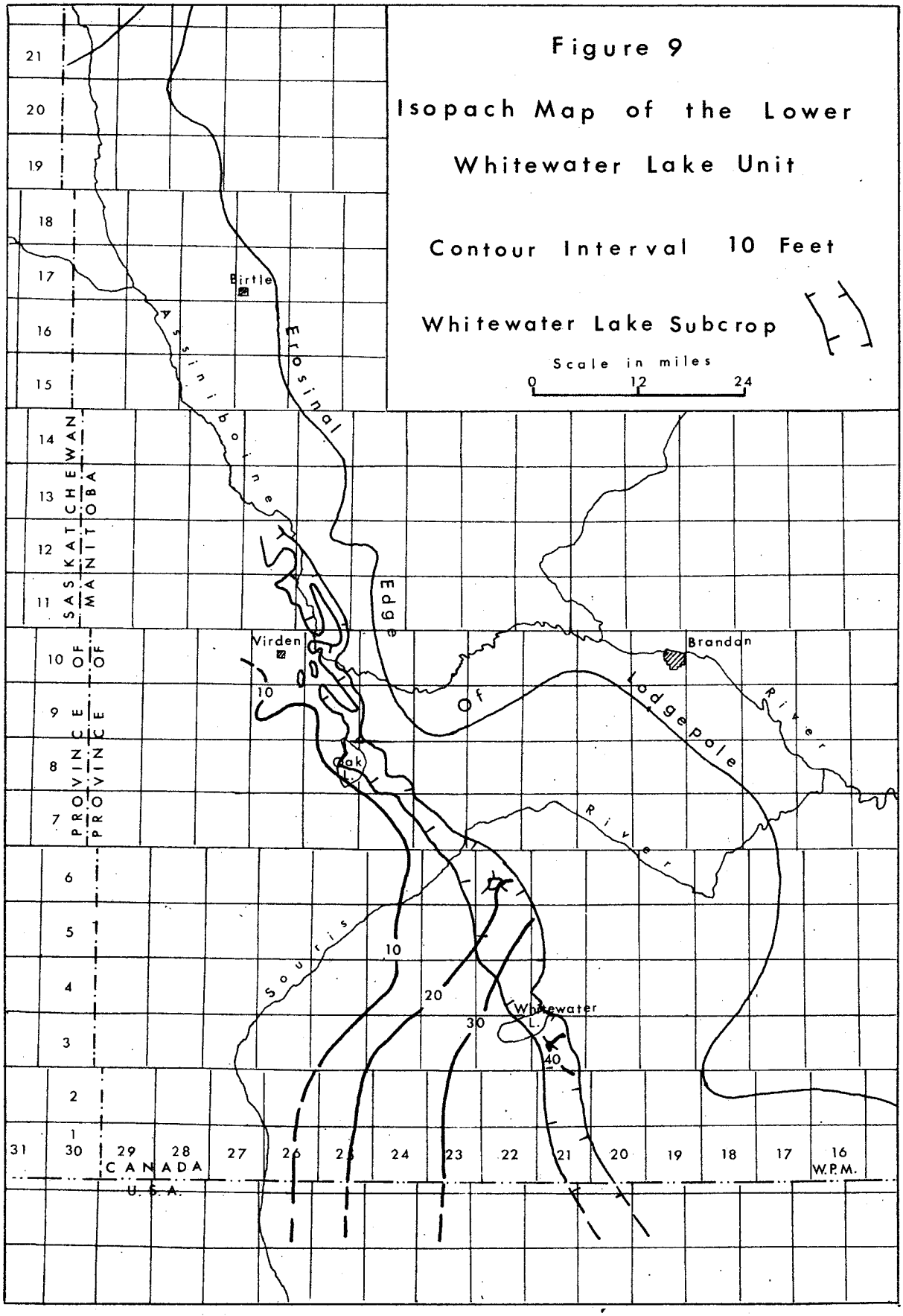
Figure 9
Isopach Map of the Lower
Whitewater Lake Unit
Contour Interval 10 Feet
Whitewater Lake Subcrop
Scale in miles
0 12 24
Birtle
Assiniboine
Erosional
edge
Of
Virden
Brandon
Oak L.
Lodgepole
River
Souris
River
Whitewater L.
10
20
30
40
SASKATCHEWAN
MANITOBA
PROVINCE OF
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spontaneous potential trace and low radioactivity on the gamma ray curve indicating a porous, relatively non-argillaceous unit (Figure 5).

The base of the unit is marked by the fairly sharp contact of non-argillaceous limestones with the inter-bedded argillaceous limestones of the lower unit. The mechanical log character of this transition is quite distinctive (Figure 5). The top of the unit is taken at the base of the argillaceous limestone of the Flossie Lake Member above the cleaner Whitewater Lake limestone. This contact is not as clearly defined as the lower contact as it is reflected only slightly on the mechanical logs making it a difficult and interpretational pick in places (Figures 7 and 8). This is due to the fact that this unit is not as argillaceous or shaly as the underlying lower units of the Virden and Whitewater Lake Members. Also, it appears to thin more rapidly in a westerly direction than the latter units. For these reasons the upper unit cannot be correlated over as large an area as the lower unit.

In the type area, the upper unit has a depositional thickness of about 40 feet (Figure 10). These maximum thicknesses are present along remnant topographic highs within the subcrop belt in the Lulu Lake, Whitewater, and Souris-Hartney oil fields. However, to the west away from the subcrop area and in the Virden region, the unit thins in

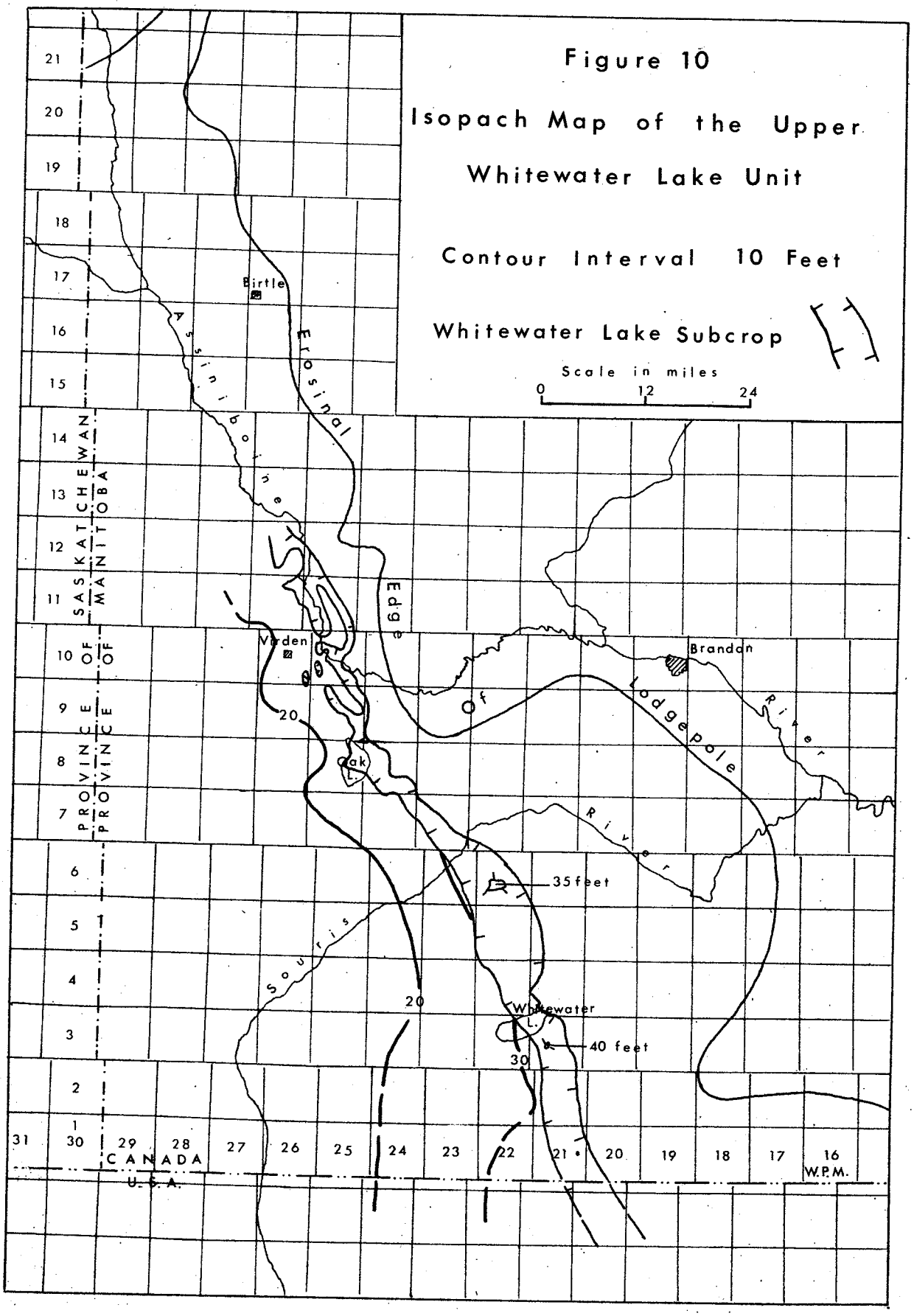
Figure 10
Isopach Map of the Upper
Whitewater Lake Unit
Contour Interval 10 Feet
Whitewater Lake Subcrop
Scale in miles
0 12 24
Birtle
Assiniboine
Erosional
Edge
of
Virden
Brandon
Lodgepole
River
Oak L.
20
35 feet
Souris
River
Whitewater L.
40 feet
30
SASKATCHEWAN
MANITOBA
PROVINCE OF
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W.P.M.

about 10 or 20 miles to 20 or 25 feet. The limit of satisfactory correlation corresponds approximately with the 20 foot isopach contour line.

It is possible that the fully developed Whitewater Lake lithology (upper and lower units) of the Whitewater-Lulu Lake area was deposited east of the Virden area but has subsequently been removed during the Mississippian-Jurassic erosion period. The subcrop area strikes or trends about 35^{o} west of north cutting off the isopach contour lines of both units which have a northerly trend.