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DEEP CRETACEOUS COAL RESOURCES OF THE ALBERTA PLAINS

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CONTENTS

Page

ILLUSTRATIONS

TABLES

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Abstract

Coal-bearing strata are extensive throughout most of Alberta between the 49th and 57th parallels. Three major coal-bearing stratigraphic zones exist in the Plains region: the Edmonton Group and equivalents, the Belly River (Judith River) Group and the Mannville Group. These zones dip westward, with coal being found from outcrop exposures to depths of over 6,000 feet.

The deep coal zones of the Alberta Plains were investigated through the use of borehole well logs. Most coal seams 2 feet or greater in thickness were recorded and mapped to produce data on distribution and reserve estimates.

The total tonnage of deep coal in the Cretaceous system of the Alberta Plains has been calculated to be in excess of one trillion tons. Mannville Group strata contain the largest reserves, with 628,000 million tons or 60 percent of the total; Edmonton Group strata contain 327,450 million tons or 31 percent of the total; and the remainder of the coal is found in the Belly River Group strata with 89,400 million tons or 9 percent of the total.

The greatest concentration of deep coal seams was found in central Alberta between townships 30 and 50. Coal was found at depths ranging from near surface (Edmonton Group) to 6,000 feet (Mannville Group). Belly River coal was found exclusively in southeastern Alberta, usually at depths of less than 2,000 feet.

These deep coal resources offer Alberta a major potential source of fossil fuel for the future.

INTRODUCTION

Recent emphasis directed toward the development of new sources of energy has renewed interest in the major coal deposits of western Canada and particularly Alberta. Considerable work has been and is being done on the near-surface mineable coal deposits of the Upper Cretaceous strata of the Alberta Plains. However, few investigations have been made of the distribution and magnitude of the deep coal deposits of the Alberta Plains.

Deep coal seams have generally been considered uneconomic for exploitation due to the great cost of mining at depth; however, research now being carried out may find methods of tapping this unused energy source. The United States Government has sponsored a research program into the in situ gasification of deep coal and is successfully operating a pilot plant at Hanna, Wyoming, which has produced up to 2 million cubic feet per day of 50 to 450 BTU synthetic gas. The project is still in its infancy and further work is being carried out.

The Alberta Research Council is also actively pursuing research programs in the field of in situ coal gasification. This study is part of that effort, and is designed to give a reconnaissance geological assessment of the distribution and thickness of the deep coal zones of Alberta. It encompasses the three major coal-bearing zones of Alberta, namely the Upper Cretaceous Edmonton and Belly River Groups and the Lower Cretaceous Mannville Group. Mapping of coal seams was accomplished through the interpretation of borehole well logs, with one representative well per township examined over most of the Alberta Plains. The coal noted in each well log was regarded as being indicative of that entire township. The resultant data was used to compile regional coal geology maps and to calculate approximate reserves.

Acknowledgments

The author wishes to express appreciation to the diligent efforts of Brian Krausert, whose work in well log interpretation contributed directly to this report.

DATA COLLECTION

Coal-bearing horizons were determined from geophysical well logs. One well log per township was investigated for townships 1 to 90; that is, one well log was selected as representative of coal distribution throughout each township. Coal horizons were selected (picked) directly from the logs and tabulated with other data such as well location, name, date, formation tops and reliability of the picks. Cores and chip samples were checked in selected wells to confirm coal picks.

The methods used in data collection give rise to several possible sources of error in the subsequent analysis. These include the following:

Well control: Along the western margin of the Plains and in northern Alberta wells are relatively few, resulting in areas on the maps without subsurface information.

Quality, quantity and type of logs available: A log suite containing a gamma ray log, a porosity log (sonic, neutron, density) and a resistivity log is needed for accurate identification of coal. For some townships, particularly in southern Alberta, only older resistivity logs are available, which by themselves are not useful for picking coal zones, as other rock types show similar responses on these logs. Unreliable picks from these logs were not used for mapping purposes except where other information was available to validate the pick, such as a nearby well with a full suite of logs or documented proof that a large seam existed in that area. The quality of the logs also varied with the operating company, resulting in difficulties in recognizing coal in some areas.

Variation in log depths: The differing depths at which logs started and ended caused problems in mapping the near-surface seams and the deeper seams under established oil and gas fields. Minimum starting depths ranged from 500 to 1,500 feet below surface, thus causing difficulty in mapping shallow seams. In some wells parts of the coal-bearing section were not logged, or logging terminated above the sub-Cretaceous unconformity, as, for example, in the larger oil and gas fields of Pembina and Viking.

Scale of mapping: Since the one well investigated was regarded as being indicative of coal distribution in the entire township, only one value for thickness of each seam was obtained. Coal varies laterally in thickness and often tends to lens; therefore, the individual thickness value obtained could conceivably be high or low, giving a distorted picture of the coal present in that particular township.

Approximate value of coal thicknesses as determined from logs: Coal may exist as a solid seam with good boundary definition or as a zone of coal interspersed with other sediments such as shales, sandstones and siltstones. These latter zones are usually represented on logs by one large log deflection (kick) which defines the entire zone and not the particular individual members. Thus, the thickness values which were taken may well represent a zone rather than a seam of coal, resulting in overestimation of total coal in some areas.

Despite these drawbacks, the maps and estimates described later are probably regionally representative of the deep coal resources of the Alberta Plains.

IDENTIFICATION OF COAL ZONES

Geophysical logs have been used for identification of coal zones since the early 1920s, when logging techniques were in their infancy. High resistivity kicks on the earlier electric logs were indicative of many lithologies, one of which was coal.

Today, coal identification is much more reliable due to the numerous types of logs generally run in a borehole. This section describes the more distinctive properties of coal and how these properties are reflected by the different well logging techniques.

Coal Properties

Coal has a number of diagnostic properties; those mentioned below are most important to borehole interpretation.

Density

Coal densities range from 1.4 to 1.8 gm/cc for anthracite, 1.2 to 1.5 gm/cc for bituminous and 0.7 to 1.5 gm/cc for lignite. Most subsurface Prairie coals have densities around 1.4 gm/cc, indicating a bituminous to subbituminous rank. On a regional basis, coal rank increases from east to west across Alberta with some anthracite coals found in the Foothills region. When a density log is available, coal is easily recognized by a very low density response.

Porosity

Coal seams contain capillaries and minute pores of differing size, thus exhibiting a high microscopic porosity. This high porosity makes coal particularly evident on the porosity logs such as the sonic, neutron and density logs.

The sonic log records interval transit time (ΔT) in microseconds that an acoustic compressional wave takes to travel across 1 foot of formation. This log is useful for differentiating between coal and shales since the ΔT value recorded for coal is usually greater than that for shales. Also, the ΔT value varies inversely with degree of compaction; thus deeper coal horizons have a lower ΔT value than those nearer to the surface.

The lignite coals of southeastern Alberta and Saskatchewan exhibit ΔT values between 140-170 sec/ft while the more common bituminous and subbituminous Alberta coals have ΔT values between 100-150 sec/ft.

The neutron log also gives an indication of porosity and is useful in coal identification. Neutron logs measure the reaction of rocks and contained fluids to neutron bombardment at a given distance. Essentially, the neutron log measures the concentration of hydrogen or free protons. In the case of coal, the porosity values determined from such logs thus indicate the presence of fluids and also the carbon content of the zone.

Carbon Content

Generally, the higher the coal rank, the higher the carbon content and the lower the amount of moisture and ash in the coal. The ash content is an expression of the quantity of mineral impurities a coal contains and, therefore, is an indicator of its economic value. Ash content can be measured on a density log since all mineral impurities are of a significantly higher density than hydrocarbon coal.

Coal Identification

Subsurface coal seams are generally quite distinctive on most well logs. Bond, Alger and Schmidt (1969) give the following summary of responses for coal.

Gamma ray log: Very low radioactivity is recorded, equal to or less than that seen in other low-radioactivity formations. The radiation is related primarily to the amount of potassium, uranium and thorium in a formation.

Density log: Bulk density (ρ_b) is very low, generally less than 1.6 gm/cc. Such densities are much lower than those of adjacent formations, and require a second scale for proper presentation of log data.

Sonic log: The interval transit time (ΔT) is higher than that of surrounding formations. Its actual value is related to the coal rank and quality.

Neutron log: The porosity index (ϕN) is very high. Since carbon is a good moderating material for neutrons, a low count rate and thus a high porosity index results opposite a coal bed.

Laterolog conductivity log: In high ranking coals, the conductivity is close to zero. In lower ranking coals, the variations in conductivity reflect changes in ash content.

Induction electric log: Coal beds cause high lateral curve readings opposite the beds and very low readings in the blind zones immediately below the coal. The long normal curve generally gives sharp reversal readings opposite coal beds thinner than the electrode spacing.

Spontaneous potential log: Occasionally a spontaneous potential response develops opposite a coal seam, but normally no appreciable response is registered against a coal bed.

Caliper log: Generally coal is indicated by sharp kicks on a caliper log, which indicates weak intervals. Caliper logs can sometimes be used for defining tops of coal seams.

Positive identification of coal seams can be accomplished by well log interpretation if certain logs are available. Ideally, the logs should include an induction electric log or laterolog, one or all of the three porosity-sensitive logs (i.e., sonic, neutron and density) and a gamma log. A three-log combination of resistivity, density, and gamma ray is unique for coal because it produces the only combination of low gamma ray, low density, high resistivity measurements. Where a full suite of logs has not been run, coal picks can often be mistakenly made.

The large coal zones such as the Ardley coal zone of the Upper Edmonton Group are quite distinctive and laterally persistent enough to be picked on electric logs only, but picking of minor or local seams is difficult due to the similar responses of coal and calcareously-cemented or fresh-water sandstones on the resistivity log.

Figure 1 shows a log suite from a well drilled through the Grand Rapids and Clearwater Formations in the Wabiskaw Lake area of Alberta. If only a resistivity log is used, many intervals can be considered to be possible coal seams. However, if a porosity log such as a sonic or density log is available, then greater accuracy is assured for coal picks. Of the many high resistivity intervals that resemble coal, only one actually is coal, that from 1,406-1,420 feet, the rest probably being calcareously-cemented or freshwater sandstone zones.

Figure 2 is a suite of logs from a well (Shell Westlock 10-33-61-27 W.4) which show the characteristic responses of coal to five different tools. The suite includes a spontaneous potential log, induction electric log, dual induction laterolog, microlog-caliper, gamma ray-sonic log, and a gamma ray-formation density log. The responses for coal of each tool are discussed below.

Spontaneous Potential Log

The spontaneous potential curve indicates that coal (black markers) is characterized by a nominal "in-kick" or a neutral response. Sometimes a spontaneous potential anomaly similar to that characteristic of a hydrocarbon-producing sand is indicated and positive identification would depend on sidewall sampling techniques.

Induction Electric Log

The resistivity and induction curves show the typical response for coal in intervals 2,328-2,332, 2,526-2,538 and 2,560-2,570 feet. Although not as distinctive as in some logs, the resistivity curve shows a prominent positive "kick" for both the normal and the induction curves.

Sometimes a prominent in-kick or reversal is shown on the resistivity curve (e.g., at 2,400 ft). This interval could be ignored as a possible coal seam if only an induction electric log were available. However, further evidence from sonic and density log responses often indicates coal presence. The negative resistivity response also could be due to the fact that the interval suffered considerable crumbling (often indicated by the caliper log) and that an abnormally thick mud cake had developed. A freshwater mud was probably used and the responses of the mud cake, not those of the coal seam, were recorded.

Dual Induction Laterolog

This log has spontaneous potential responses in the left hand column which are similar to those described above. The laterolog curve, shown on the right, gives a shallow investigation, medium investigation, and deep investigation response. This log measures conductivity and, as illustrated in intervals 2,328-2,332 and 2,470-2,475 feet, the conductivity of coal is quite low. Ideally, high rank coals should show a conductivity close to zero while poorer quality coals show variations which reflect a greater ash content. This log is also good for defining seam boundaries.

Microlog-Caliper Log

This log has limited value for coal identification. The microlog gives some indication of mud cake thickness and can be used when situations occur as described earlier where mud invasion is prominent. The caliper log is often useful in defining the top of a coal seam, such as that seen at depth 2,526 feet, because coal crumbles along borehole walls giving sharp deflections on caliper curves.

Gamma Ray-Sonic Log

This log is probably the most useful, along with an induction electric log, for determining coal zones. In Alberta, the sonic log has been run much more frequently than the density log, thus also making it the most convenient to use.

In the left hand column the gamma ray curve gives a distinctive low response opposite a coal seam. A negative kick can be seen opposite the coals of intervals 2,526-2,540 and 2,560-2,570 feet in figure 2. In some instances a coal seam may have a high concentration of potassium, uranium or thorium and so may be mistaken for a shale interval.

In the right hand column a sonic log which measures interval travel time is present. Coals of intervals 2,526-2,540 and 2,560-2,570 feet show the characteristic high positive kicks indicating high porosity opposite the seams.

Gamma Ray-Density Log

Like the sonic log, a gamma ray curve is present in the left hand column and shows similar responses to those described above. In the right hand column a bulk density curve is present. The density log is excellent for coal identification because of the low density values recorded opposite seams. All the coal seams in figure 2 show density values of around 1.5 gm/cc. Fluctuations in density values are due mostly to the rank of the coal (carbon content) and the cleanliness of the seam (shale content). When shale is interbedded with coal, higher density values are obtained opposite the interval. It is somewhat unfortunate that very few density logs have been run in the nonmarine, coal-bearing sediments of Alberta.

Determinations of Seam Thickness

If good quality logs are available, an experienced person can pick seam boundaries to within 2 inches of core measurements. If the hole is not caved and the coal is surrounded by shale, the laterolog, density or neutron logs are capable of defining boundaries with great accuracy. Generally, seam boundaries are located at the midpoint of the curve deflection or where a definite break of curvature occurs. Table 1 can be used as a guide for boundary picks.

Table 1. Summary of recommended methods for coal thickness determination (from Bond *et al.*, 1969)

Summary of Recommended Methods for Coal Thickness Determination		
Log Signal	Boundary Location	Not Valid When:
Laterolog	Mid-point of Conductivity Deflection	Limestone adjacent to coal (use Density or Neutron)
Formation Density		Caved shale adjacent to coal (use Laterolog)
Thick Seams	Mid-point of Density Deflection	
Thin Seams	Inflection point of Density curve	
Sidewall Neutron		Caved shale or high-moisture clay adjacent to coal (use Laterolog)
Thick Seams	Mid-point of Porosity Index Deflection	
Thin Seams	Inflection point of Porosity Index curve	

Coal Seam Reliability Classification

Given an adequate suite of logs, picking of coal seams from well logs is a comparatively simple process. Logs of the three porosity tools (i.e., sonic, density and neutron) in conjunction with a resistivity log, are an ideal suite for coal identification; however, the combination of tools is not always available. Also, the quality of coal picks depends on log type, number and clarity. For this study, therefore, a five-point reliability classification was drawn up of the probability of coal zones identified from geophysical logs actually being present, as follows:

(1) In order for the probability of coal actually being present to be greater than 90 percent, the geophysical tools used should combine the following characteristics: at least one electric log (spontaneous potential plus various resistivity curves) and other logs with a minimum of two of the specific curves for

Natural gamma
Acoustic velocity (sonic)
Density, and
Sidewall neutron or compensated neutron.

Curve characteristics should be well-defined and coal indicated strongly on all curves.

(2) In order for the probability of coal actually present to be estimated as between 75 and 90 percent, the geophysical logs used should be as in (1) with most criteria indicating coal, but curve characteristics not as well-defined.

(3) For the probability of coal actually present to be 50 to 75 percent, geophysical tools should include an electrical log as in (1) and at least one additional log with reasonably well-defined curve characteristics indicative of coal. Or, alternatively, tools should include one log with good characteristics plus a seam in correlative position with a reliability as in (1) or (2), in three or more adjacent wells.

(4) For the probability of coal actually present to be estimated at 25 to 50 percent, logs should be as in (3) but poorer in quality (old logs, poorly defined characteristics, etc.) with less strong indication of coal; or, alternatively, one log with poorer indication than in class (3), but with a seam in correlative position with a reliability as in (1), (2) or (3) in three or more adjacent wells.

(5) Probability of coal actually present is estimated as less than 25 percent if tools include only one log, or all logs available are of poor quality.

This classification for selecting coal seams from geophysical logs for a large region like Alberta encompasses most types of problems encountered with subsurface picks.

REGIONAL STRATIGRAPHY OF COAL-BEARING STRATA

The Cretaceous System in the Alberta Plains can be divided into two distinct divisions, the Lower and Upper Cretaceous, each of which contains significant coal-bearing strata.

Lower Cretaceous Strata

The Lower Cretaceous strata are limited by the sub-Cretaceous unconformity below and the base of the Fish Scale marker zone above. They show a gradual regional westward increase in thickness from 600 feet at the Alberta-Saskatchewan border to more than 2,500 feet at the Foothills margin. The succession consists of nonmarine and marine sandstone, shales and siltstones.

The Lower Cretaceous strata can be divided into three mappable units, each of which represents a distinct phase of sedimentation. The Lower Mannville Group is essentially a basal fill deposit representing the first sedimentation after a long period of erosion. Sediments are clean nonmarine sandstones with minor shales and minor coal stringers. The Upper Mannville Group comprises a mixture of marine and nonmarine strata representing a time of marine transgression and regression over nonmarine beds. The beds are mostly nonmarine sandstones and shales with numerous coal horizons. The Lower Colorado Group is a marine sequence of shales and sandstones, including the Fish Scale zone sandstones, Colorado shales, Joli Fou Formation shales and Viking Formation sandstones.

Mannville Group

The Mannville Group is found over most of the Alberta Plains, with varying formation names for sections in the southern, central, northwestern and northeastern Plains (Table 2). The most significant of the three units, to this study, is the Upper Mannville Group because of the number and thickness of coal seams occurring throughout it.

Table 2. Terminology of Lower Cretaceous rock units in the central and northern Alberta Plains (from Mellon, 1967)

L. PEACE R.	L. ATHA. R.	CENTRAL ALBERTA PLAINS				
Badgley (1952)	McLearn (1917) Wickenden (1949)	Nauss (1945)	Hunt (1950)	Badgley (1952)	Glaister (1959)	Williams (1963)
SHAFTESBURY FORMATION	PELICAN SS	LLOYDMINSTER SHALE	Viking Mbr	PELICAN FM	VIKING FM	VIKING FM
	JOLI FOU SH		COLORADO SH	JOLI FOU FM	JOLI FOU FM	JOLI FOU FM
PEACE R. FM: Paddy Mbr Cadotte Mbr Harmon Mbr	GRAND RAPIDS FORMATION	MANNVILLE FORMATION: O'Sullivan Member Borradaile Member	BLAIRMORE FORMATION: upper member	MANNVILLE GROUP: GRAND RAPIDS FORMATION Looma Mbr	MANNVILLE GROUP: UPPER MANNVILLE	MANNVILLE GROUP: GRAND RAPIDS FM
SPIRIT RIVER FM: Notikewin Mbr Falher Mbr Wilrich Mbr	CLEARWATER FORMATION	Tovell Mbr Islay Mbr Cummings Mbr		CLEARWATER FM WabiskawMbr	glauconitic sandstone	CLEARWATER FM WabiskawMbr
BLUESKY FM			ostracod zone		L. MANNVILLE: calc. mbr	McMURRAY FM: calc. mbr
BULLHEAD (?) GROUP	McMURRAY FORMATION	Dina Member	Ellerslie Member	McMURRAY FORMATION	Ellerslie Sandstone	Ellerslie Member
				DEVILLE FM		Deville Member

Southern Plains area

In the southern Plains, the Mannville Group is divided into lower and upper units. The lower Mannville Group is a series of from 50 to 370 feet of nonmarine, buff, fine-grained orthoquartzites and protoquartzites, dark grey silty shales, and carbonaceous grey siltstones. The unit lies between the sub-Cretaceous unconformity at the base and the prominent "calcareous zone" characterized by abundant fossils above.

The upper Mannville is a series of nonmarine sandstones, siltstones and shales consisting of dominantly argillaceous, salt and pepper sandstones with tongues of marine sediments characterized by dark grey shale and glauconitic sandstones occurring in the lower part. Coal stringers are very minor and the unit ranges from 100 to 500 feet thick.

Central Plains area

The Mannville Group again is divided into upper and lower units. The lower Mannville Group consists of a series of orthoquartzites and protoquartzites with minor shales and siltstones. It contains the ostracod zone, a calcareous shale with a rich ostracod, pelecypod and gastropod fauna, and the Ellerslie Formation, a basal nonmarine sequence of grey and white quartzitic sandstones with minor shale and siltstone intercalations.

The upper Mannville Group, also referred to as the Fort Augustus Formation (Mellon, 1967), consists of a sequence of nonmarine grey shales, siltstones, argillaceous sandstones and thick coal seams, with interfingering marine shales and sandstones. The base of the unit is characterized by a prominent glauconitic sandstone member.

Northwest Plains area

The lower Mannville Group is represented by the Bullhead Group which contains two formations. The basal, Cadomin Formation is a basal fill conglomerate zone, and the upper, Gething Formation consists of porous nonmarine quartzose sandstones, greywackes, shales, siltstones and coals.

The upper Mannville Group is represented by the Bluesky and Spirit River Formations. The contact between the Bluesky Formation and the underlying Bullshead Group is characterized by porous glauconitic sandstones which rest conformably upon the underlying predominantly nonmarine units. The major part of the Bluesky Formation consists of well sorted, winnowed greywackes and quartzose sandstones with minor greywackes, shales and siltstones.

The Spirit River Formation is a series of interbedded siltstones, greywackes, shales and several coal seams. It contains three members: the lower Wilrich Member, a series of dark marine and brackish-water shales with interbeds of glauconitic winnowed greywackes; the middle Falher Member, a variable succession of nonmarine sandstones, shales and siltstones with some coal seams; and the uppermost Notikewin Member, a series of greywackes with interbeds of shale, siltstone and coal.

Northeast Plains area

In this area, the lower Mannville Group is represented by the Deville and McMurray Formations. The Deville Formation consists of detrital waxy green and grey shales, siltstones and minor quartzose sandstones. The overlying McMurray Formation is a predominantly nonmarine sequence of quartz sandstones, dark grey shales, greywackes, argillaceous siltstones and minor stringers of bituminous coal.

The upper Mannville unit is represented by two units, the Clearwater and Grand Rapids Formations.

The Clearwater Formation is a marine succession of shales, glauconitic marine greywackes, siltstones, sandstones and minor coal laminae. It includes, in ascending order: the Wabiskaw Member, a massive sandstone unit composed mostly of highly glauconitic winnowed greywacke; the Islay Member, a succession of quartzose sandstones with minor shale, siltstone and coal interbeds; and the ostracod zone (*Metacypris angularis* zone) (Badgley, 1952), a sequence of dark grey shale containing marine and brackish water faunas.

The Grand Rapids Formation interfingers with and overlies the Clearwater Formation, resulting in a transitional contact in most areas. Badgley (1952) places the contact at the top of a fossiliferous shale of a highly glauconitic sandstone bed. The contact thus separates beds representative of two different lithofacies, namely the lagoonal Clearwater suite and the overlying deltaic Grand Rapids suite.

The Grand Rapids Formation is a complex succession of interbedded greywackes, siltstones and shales with several coal seams. It is dominantly nonmarine and includes several members including the St. Edouard Member, a quartzose sandstone with minor shale and siltstone interbeds; the Borradaile Member, a thin quartzose sandstone; and the Looma Member (Badgley, 1952), a laterally persistent unit of interbedded soft, dirty coal, carbonaceous shale and occasional greywacke.

Figure 3 shows a representative section of the Mannville Group from a well in each of the four areas mentioned. Figures 4 a, b, c, d show a detailed cross section through township 40 for the Mannville Group. It can be seen that the major coal seams all occur in the upper Mannville Group.

Upper Cretaceous Strata

The Upper Cretaceous succession of western Canada is characterized by large-scale intertonguing of marine and nonmarine strata. The nonmarine tongues are thicker in the west and thin toward the east, whereas the marine tongues thin toward the west. The sequence is mainly marine at the base but becomes sandier and more continental toward the top. The beds were deposited in a broad, slowly subsiding epeiric seaway flanked on the west by the ancestral cordillera and on the east by the Precambrian Shield. Maximum thickness is about 19,000 feet near the Foothills with minimum thicknesses of a few hundred feet found near the eastern edge. The lower boundary is placed at the base of the Fish Scale marker zone, with the upper boundary occurring at the base of the massive Paskapoo-type sandstones.

Within this sequence, two major nonmarine, coal-bearing units occur: the Edmonton Group and equivalents, and the Belly River (Judith River) Group.

Belly River Group

The other important coal-bearing formation in the Upper Cretaceous is the Belly River *Group,* also known as the Judith River *Formation.* It is an eastward-thinning sedimentary wedge, whose strata are composed predominantly of clays, silts and sands deposited in a nonmarine environment. It is underlain by the Lea Park Formation and overlain by the Bearpaw Formation, both westward and northward thinning wedges of marine silts and clays. The Belly River Group is typical of a deltaic depositional environment -- a composite group of sediments encompassing alluvial, lacustrine, aeolian, lagoonal, swamp, beach and shallow marine environments. In the upper part of the group the sediments are those of an alluvial plain, the inland extension of the delta deposits.

A twofold division of the Belly River Group exists in southern Alberta: the Foremost Formation overlain by the Oldman Formation.

The Foremost Formation consists of a series of shale, siltstone and sandstone beds with abundant carbonaceous material, concretions and coal seams. The abundance of brackish-water faunas indicates sedimentation in a deltaic environment. The dominant color of beds in the Foremost Formation is brown to brownish yellow.

The Oldman Formation consists of shale, siltstone and sandstone in varying proportions, with great lateral and vertical variability. Except for the uppermost 80 to 100 feet where the Lethbridge coal zone occurs, the Oldman beds are sandier than those of the Foremost, with more cross-bedded channel sandstone units. The Oldman beds are an inland facies-equivalent of the Foremost beds, characterized by floodplain deposits rather than deltaic and shoreline deposits, except where the Lethbridge coal zone occurs, indicating return to conditions similar to those prevailing during deposition of the Foremost beds. The dominant colors of the Oldman beds are dark grey to grey to white.

Table 3. Characteristics of the Oldman and Foremost beds in southern Alberta (from McLean, 1971)

AUTHOR	OLDMAN (PALE) BEDS	FOREMOST BEDS
Dawson, 1884	(1) Usually bluish or greenish gray tint (2) Beds rather massive on whole (3) Molluscs rare except at top (4) Freshwater sediments (5) Dinosaurian remains abundant in places	(1) Yellowish and brownish colours (2) More evenly bedded, relatively thin-bedded (3) Molluscs abundant and well preserved (4) Brackish-water sediments (5) Few dinosaurian remains
Dowling, 1917	Similar to Dawson (1) Few carbonaceous beds except at top	Similar to Dawson (1) Many coal seams and carbonaceous beds throughout
Williams and Dyer, 1930	(1) Light colours – light gray to greenish-gray (2) Many massive sandstone beds (3) Coal common only at top (4) Fossils rare – mostly freshwater (5) Large-scale cross-bedding	(1) Darker colours – brown, black, gray, yellow (2) More rapid alternation of strata (3) Coal and carbonaceous shales typical (4) Fossils common – fresh and brackish (5) No foreset delta beds
Slipper and Hunter, 1931	(1) Light grays, greens and yellows (2) Thick beds of sandstone common (3) Few coals and carbonaceous beds (4) Few ferruginous ironstone beds (5) Long cross-bedding typical	(1) Dark colours predominant (2) Mostly thin-bedded (3) Many coals and carbonaceous beds (4) Ferruginous limestone beds typical (5) Mostly non-cross-bedded
Powers, 1931	(1) Gray and greenish-gray with subordinate darker colours (2) Chiefly sandstone and shaly sandstone (3) Light gray, rather massive poorly consolidated sands are typical (4) Reptilian remains common in a few localities (5) Few oyster shells (6) Cross-bedding extremely common (7) Few coals and carbonaceous beds	(1) Light to dark grays and browns (2) Shale and shaly silt with subordinate sand (3) Lensing is a prominent feature (4) Few reptilian remains (5) Oyster shells plentiful (6) Minor cross-bedding (7) Many coals and carbonaceous beds
Hake and Addison, 1931	(1) Light colours (2) Little carbonaceous material (3) Limestone lentils and nodules common	(1) Darker colours (2) Abundant carbonaceous material (3) Few limestones
Yarwood, 1931	(1) Few coal and carbonaceous beds (2) Fossils rare, scattered (3) Primarily green shale with less than 20 percent sandstone	(1) Many coal and carbonaceous beds (2) Fossils common in certain beds (3) Dark shales predominant
Russell and Landes, 1941	(1) Dominant colour – light greenish-gray (2) Shales and clays probably dominant (3) Coal seams confined to top (4) Predominantly freshwater and terrestrial fossils (5) Coarse-grained beds commonly cross-bedded	(1) Fine colour banding (2) Arenaceous rocks probably predominant (3) Numerous coal seams (4) Numerous beds of brackish-water fossils (5) Cross-bedding uncommon
Crockford, 1949	(1) Lighter colours predominant (2) Predominantly freshwater origin (3) Greater proportion of sand (4) Sporadic distribution of freshwater fauna (5) Coal common only at top	(1) Darker colours predominant (2) Predominantly brackish-water origin (3) Smaller proportion of sand (4) Many beds of concentrated brackish-water fauna (5) Coal and carbonaceous beds throughout

Table 3 (from McLean, 1971) lists the characteristics for differentiation of the Foremost and Oldman Formations. The most consistent differences are that Oldman strata are generally lighter in color; coal and carbonaceous beds are more prevalent through the Foremost beds, whereas coal is common only in the uppermost portion of the Oldman Formation; cross-bedding is more common in the Oldman Formation; and fossils, mainly brackish-water types, are common in the Foremost Formation.

Coal seams are generally thin in the Belly River Group, except for the Taber coal seam in the upper Foremost Formation and the Lethbridge coal zone in the upper Oldman Formation. Both seams are prominent deep coal zones and are mined in southern Alberta.

The distribution of coal in the Belly River Group is indicated in table 4.

A second outcrop area of the Belly River Group is in east-central Alberta, described by Shaw and Harding (1954) as containing ten members of alternating deltaic and marine origin with a continental sequence at the top. This section of the Belly River Group is essentially barren of any significant deep coal seams, rendering it unimportant to this study.

Edmonton Group

The Edmonton Group (and its equivalents, the St. Mary River and Wapiti Formations) is an Upper Cretaceous deltaic and fluvial sequence which overlies the marine Bearpaw Formation shale and underlies the nonmarine Paskapoo Formation. It consists of a wedge-shaped sequence of complex interfingering lenses of fresh- and brackish-water sandstones, siltstones, shales and coal beds. The areal extent of the Edmonton Group is shown in figure 5, which also shows equivalent strata to the north and south, the upper part of the Wapiti Formation and the St. Mary River Formation, respectively.

Cross sections B and C (Figs. 6 and 7), which are drawn from a datum at the base of the Fish Scale marker zone, show the generally east to west thickening of the Edmonton Group.

Table 4. Informal divisions of the Judith River Formation (from McLean, 1971)

AUTHOR	LOCATION	STRATIGRAPHIC INTERVAL	INFORMAL DIVISIONS
Johnson and Smith, 1964	Central Montana Winnet-Mosby area	Judith River Formation	(3) Nonmarine, mainly sandstone – 55 feet (2) Nonresistant, nonmarine sandstone, siltstone, mudstone – 140 feet (1) Shallow water, marine sandstone – 78 feet
Hearn et al., 1964	Bearpaw Mountains	Judith River Formation	(4) Clayey sandstone, numerous siltstone concretions – 50 feet (3) Prominent carbonaceous shale, coal, oyster-rich sandstone – 100 feet (2) Lenticular sandstone, clayey sandstone, siltstone, shale, and minor carbonaceous shale – 300-350 feet (1) Predominantly sandstone – 100-150 feet
Slipper and Hunter, 1931	Southern Alberta Plains	Foremost 'beds'	(5) Taber coal horizon – 100 feet (4) Thick, cross-bedded, lenticular sandstone – 120 feet (3) Middle Foremost – extremely heterogeneous – 100 feet (2) McKay coal horizon – variable number of seams – 60 feet (1) Verdigris sandstone – thins to north and east – 60 feet
Hake and Addison, 1931	Milk River Ridge-southwestern Alberta	Pale (Oldman) 'beds'	(4) More sandstone than shale, few limestone beds – 280 feet (3) Predominantly shale with many limestone beds – 175 feet (2) Alternating sandstone, shale, thin limestone beds, with massive sandstone beds. No coal beds – 220 feet (1) Shaly zone – many thin limestone beds, few sandstone or carbonaceous beds – 200 feet
Crockford, 1949	Southern Alberta Plains	Oldman 'beds'	(6) Lethbridge member – coal, carbonaceous shale 80-0 feet (5) Undivided-sandstone, shale, and all gradations between – 80-220 feet
		Foremost 'beds'	(4) Taber coal – 80-220 feet (3) Sandstone, shale, **Ostrea** and **Corbula** beds, 100-150 feet, minor carbonaceous shale (2) McKay coal, not present east of Sweetgrass Arch – 30 feet (1) Verdigris sandstone, not always present – 60 feet

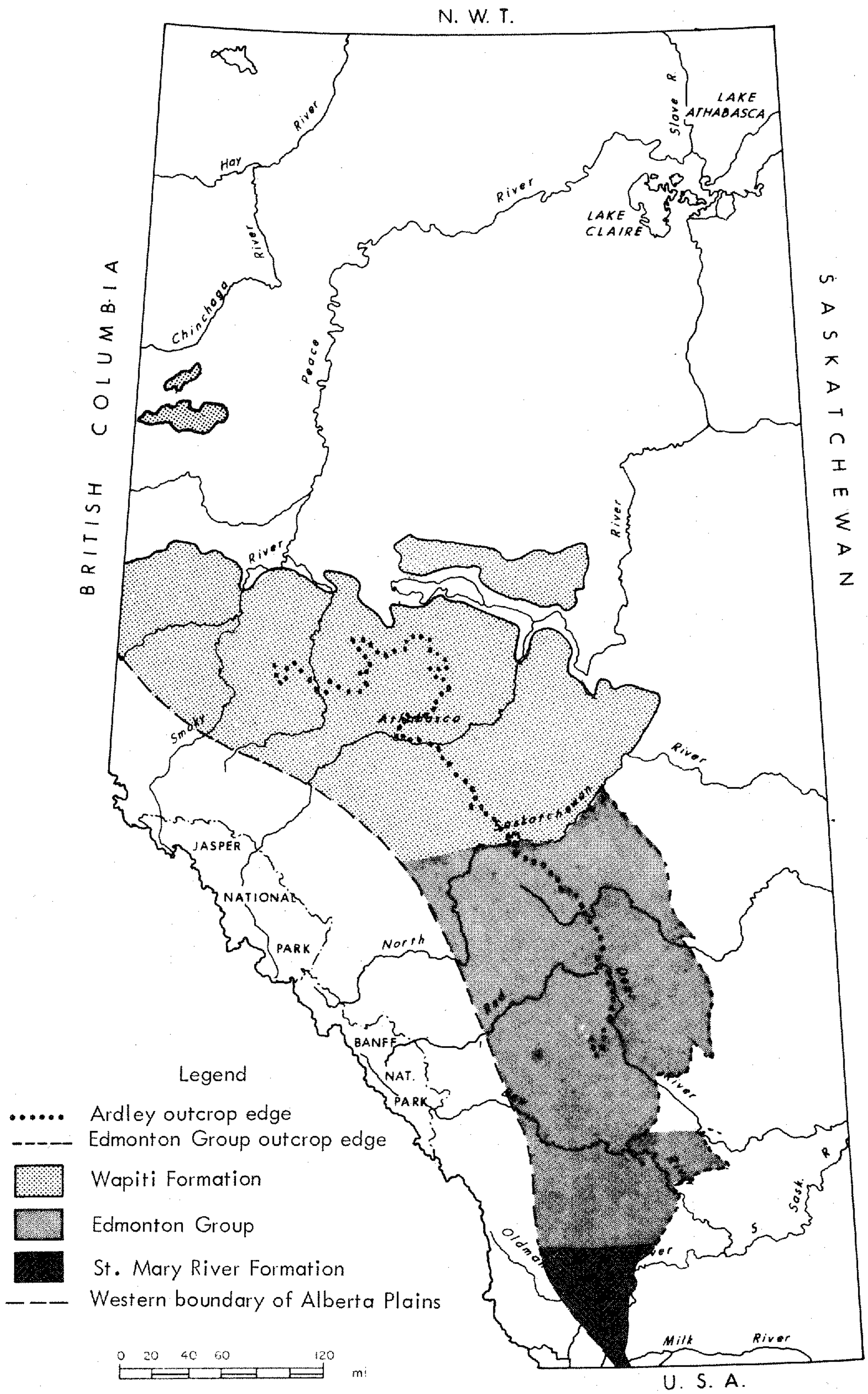

FIGURE 5. *Distribution of Edmonton Group and equivalent strata.*

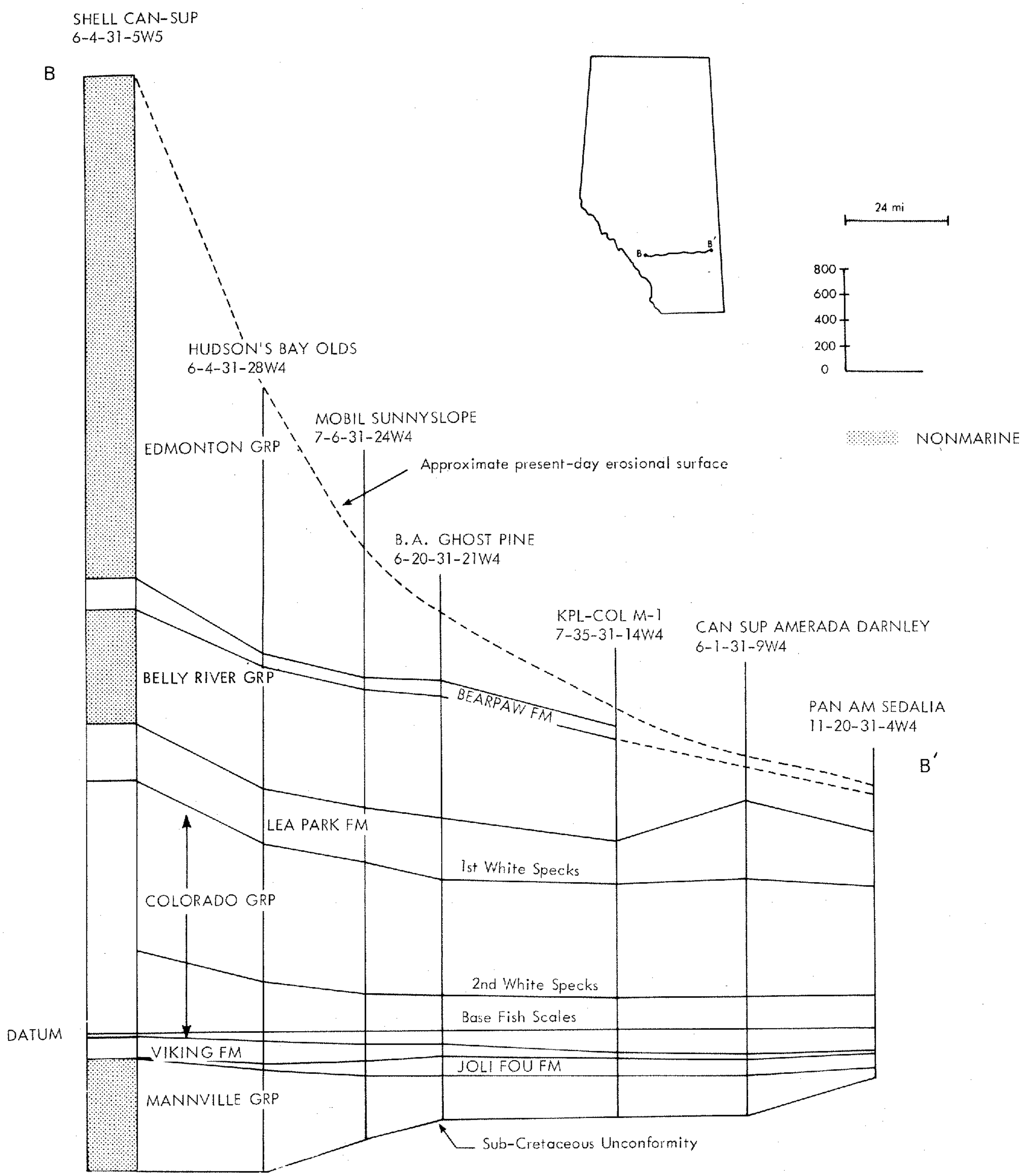

FIGURE 6. Schematic cross section of wells through south-central Alberta.

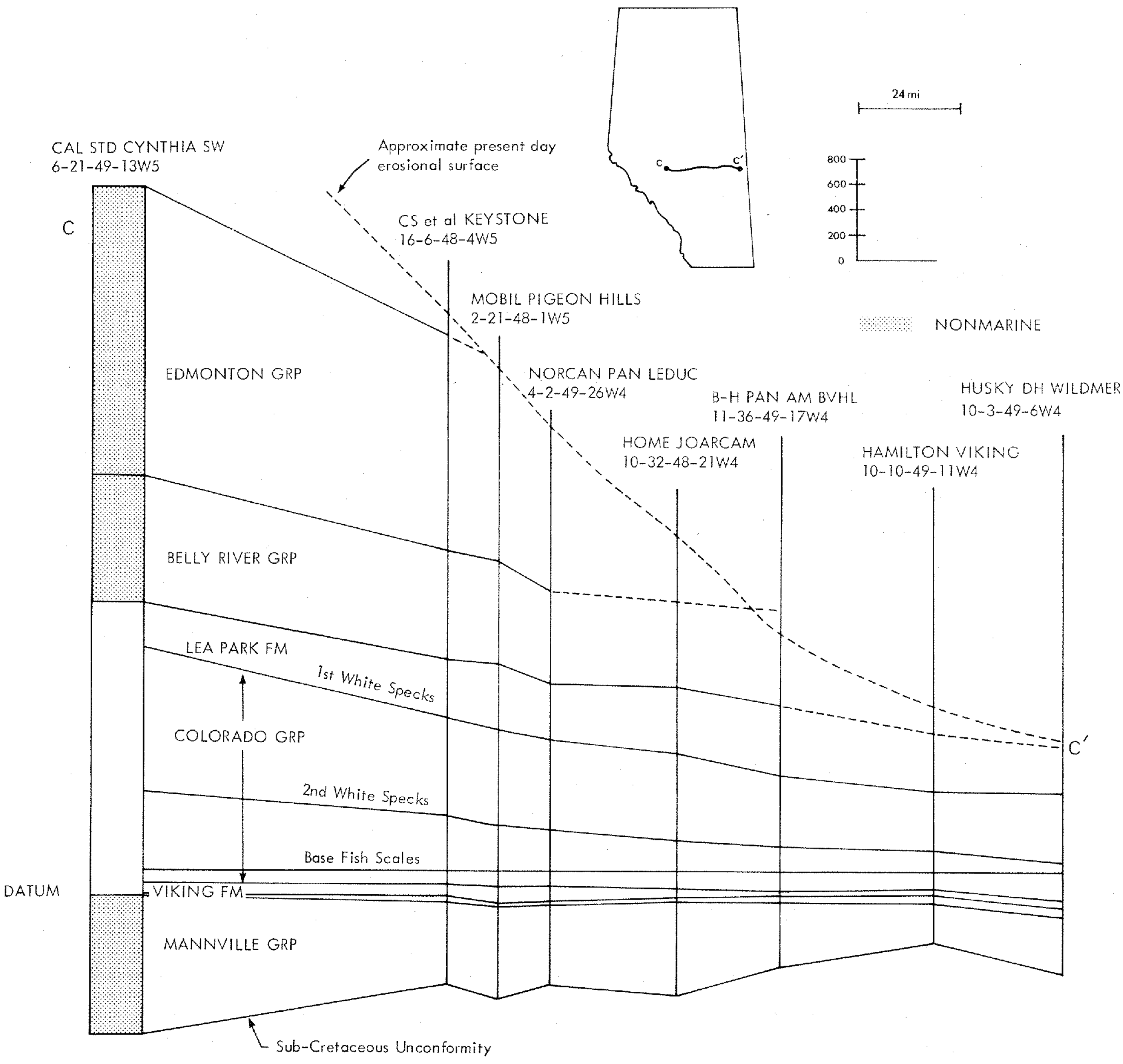

FIGURE 7. Schematic cross section of wells through central Alberta.

The Edmonton Group of south-central and central Alberta ranges from approximately 50° N latitude northward to the North Saskatchewan River. The formation has been extensively studied. Table 5 gives a comparison of classifications by four different authors. The classification by Ower (1960) gives the following descriptions of Edmonton Group strata between the Red Deer and North Saskatchewan Rivers:

Member A - Grey and brown bentonitic shales containing considerable carbonaceous matter; white and light grey salt and pepper feldspathic sandstone; ironstone bands and concretions are common; numerous coal seams and beds of coaly and carbonaceous shale; thickens rapidly to north replacing the underlying Bearpaw shale; thickness approximately 450 feet.

Member B - Light green, somewhat bentonitic shales with lenses and beds of salt and pepper sandstone; the Red Deer River area contains the Drumheller marine tongue, consisting of thin bands of fossiliferous limestone containing *Arrhinoceratops* dinosaurian fauna; thickness varies from 200 to 300 feet.

Member C - Bentonitic grey shales and salt and pepper sandstones containing several coal horizons; massive sandstone lenses up to 50 feet thick in some localities; member approximately 90 feet thick.

Member D - Kneehills Tuff Zone: black to brown bentonitic shale, containing purplish tuffaceous shale and thin tuff bands near top, often white clay shale and bentonitic clayey white sand at base; thickness varies from 20 to 25 feet.

Member E - Northern Facies: dull green to grey, slightly bentonitic shales; fine to coarse salt and pepper sandstones; heavy coal seams.

Southern Facies: lower part, pale green bentonitic shale with heavy lenses of salt and pepper, often quartzose, sandstones; overlain by beds similar to the northern facies; contains coal seams and *Triceratops* dinosaurian faunas; thickness varies from 185 to 400 feet.

Table 5. Upper Cretaceous rock-units and coal seams of the Alberta Plains (from Steiner *et al.*, 1972)

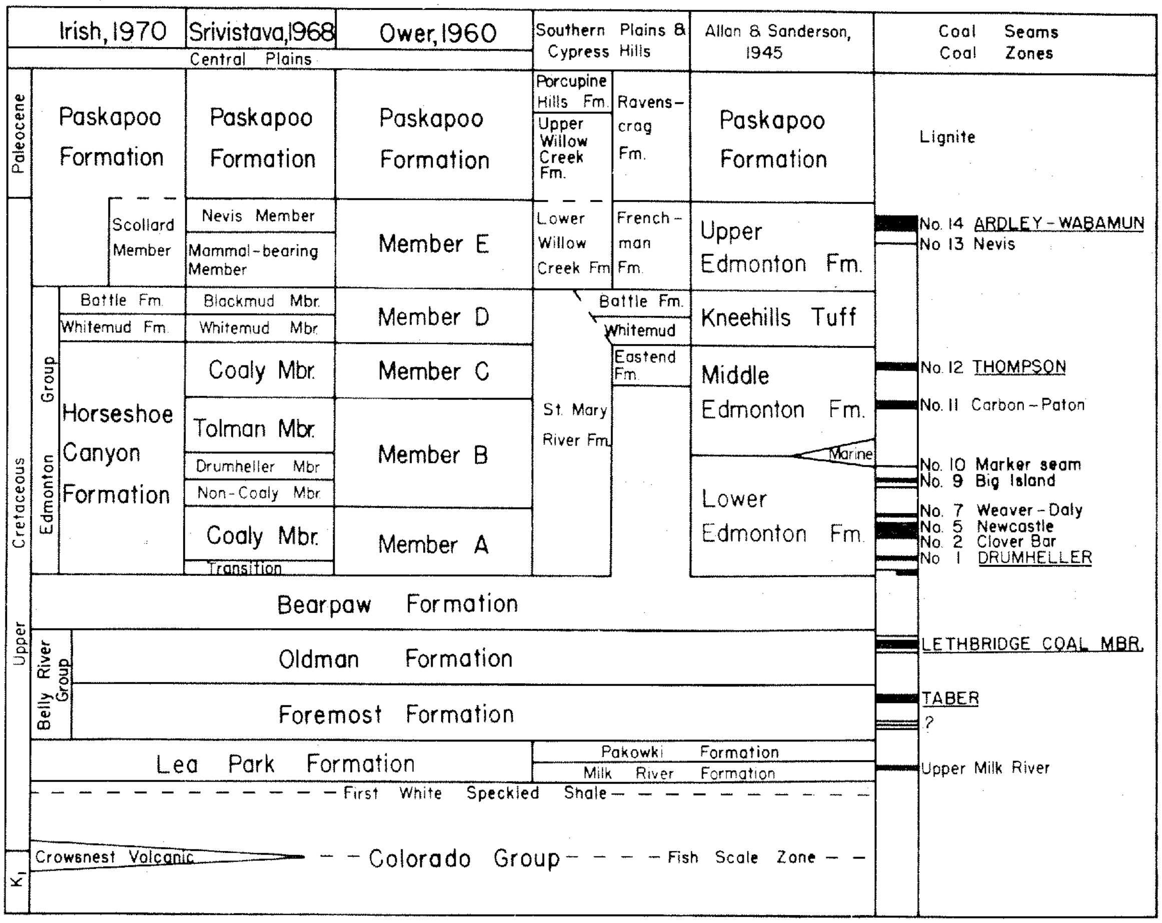

Table 5 also indicates Ower's classification and the relationship of the major coal seams to the members. Members A, C and E are most significant because coal zones are found within them.

Member A contains numerous coal seams (Table 5) including the Big Island, Weaver-Daly and Drumheller seams. These seams generally occur as a close-knit collection of seams which are not always present in their entirety in the subsurface; however, they indicate a concentration of coal seams in the basal Edmonton Group. These seams are extensively mined in southwestern and central Alberta.

Member C contains the Thompson and Carbon coal seams, two horizons which are particularly important in central Alberta.

Member D is significant because it contains the Kneehills Tuff marker bed. This 20- to 40-foot tuff bed represents a period of volcanic activity; it is, therefore, a significant time marker zone over most of western Alberta and is useful in subsurface location of the Ardley zone from logs.

Member E contains the important Ardley coal zone which is the thickest and most widespread coal zone of the formation. It is found at the top of the member, adjacent to the massive Paskapoo channel sandstones, and may be related to them. The Ardley zone outcrops over most of central Alberta (Fig. 5) and is closely associated with the Kneehills Tuff outcrop edge. Coal of this zone is mined in many areas, and the westerly dip of the Edmonton Group (approximately 15 to 20 ft/mi) results in the subsurface Ardley west of the outcrop margin becoming a most prominent deep coal horizon in the western Plains.

St. Mary River Formation

The southern equivalent of the Edmonton Group is known as the St. Mary River Formation. This sequence of strata extends from the Canadian border to approximately 50°N. The St. Mary River Formation consists of resistant grey, calcareous, lenticular sandstones alternating with soft grey-brown and greenish sandstones, shales and sandy shales. The formation varies in thickness from 1,500 to 1,600 feet and is overlain by the Willow Creek Formation, which is a series of nonresistant shales and greenish grey, soft sandstones. North of latitude 50°N the subdivision of the St. Mary River and Willow Creek Formations is not recognized and all Cretaceous post-Bearpaw strata are known collectively as the Edmonton Group.

Wapiti Formation

The northern equivalent of the Edmonton Group is the Wapiti Formation, a thick succession of nonmarine sandstones, siltstones and coal beds. The formation is equivalent to the nonmarine Edmonton and Belly River Groups of central Alberta. The intervening Bearpaw Formation thins out near the North Saskatchewan River, thus making the nonmarine Edmonton and Belly River Groups indistinguishable north of the river.

Kramers and Mellon (1972) have indicated that the Wapiti Formation varies in thickness from zero feet at its eastern outcrop edge to 4,500 feet at depth near the Foothills. The lower Wapiti Formation contains more sandstones than the upper portion and has numerous thin coal seams. The middle Wapiti Formation has more shales than the lower and also fewer coal seams, with bentonite beds believed to be equivalents of the Kneehills Tuff zone becoming prominent near the top.

The upper Wapiti Formation is similar to Ower's Member E and contains the Ardley coal zone in subsurface. It consists of interfingering sandstones and mudstones which grade upward into more massive Paskapoo strata. Figure 8 and table 6 show the correlation of the Wapiti Formation with the Upper Cretaceous strata of central Alberta.

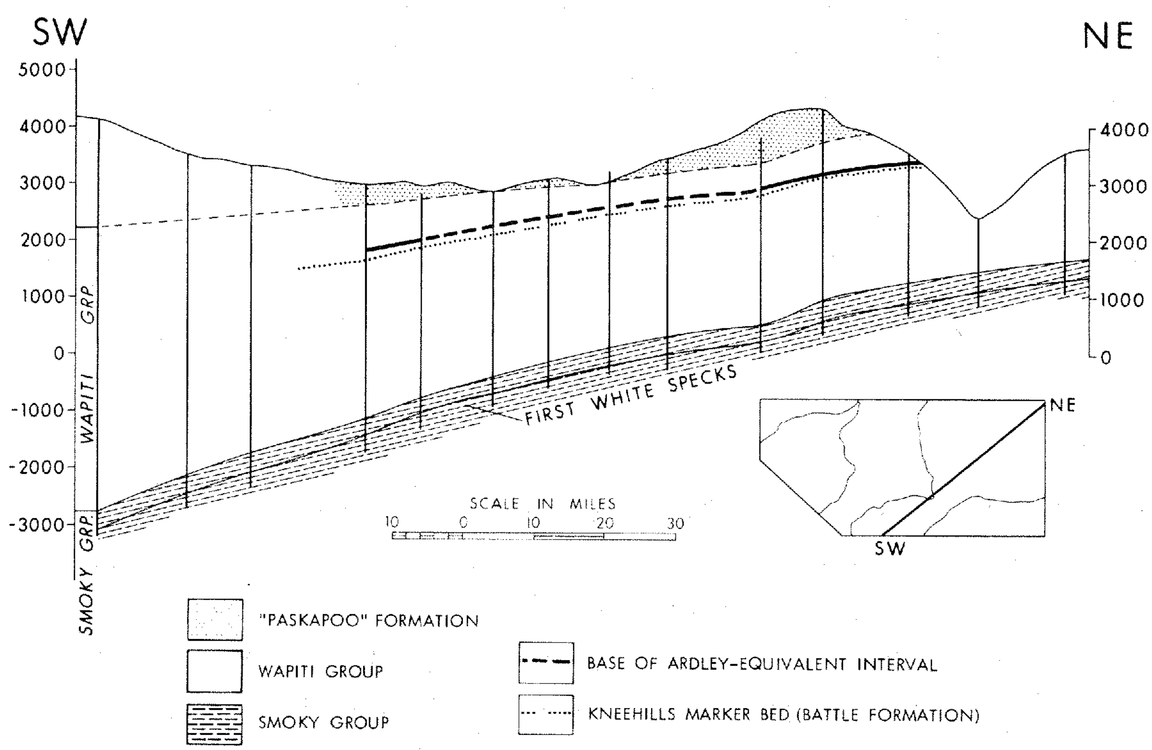

FIGURE 8. Schematic cross section through Upper Cretaceous and Paleocene rock units, northwest-central Alberta Plains (from Kramers and Mellon, 1972).

Table 6. Correlation of Upper Cretaceous and Paleocene formations in central Alberta (from Kramers and Mellon, 1972)

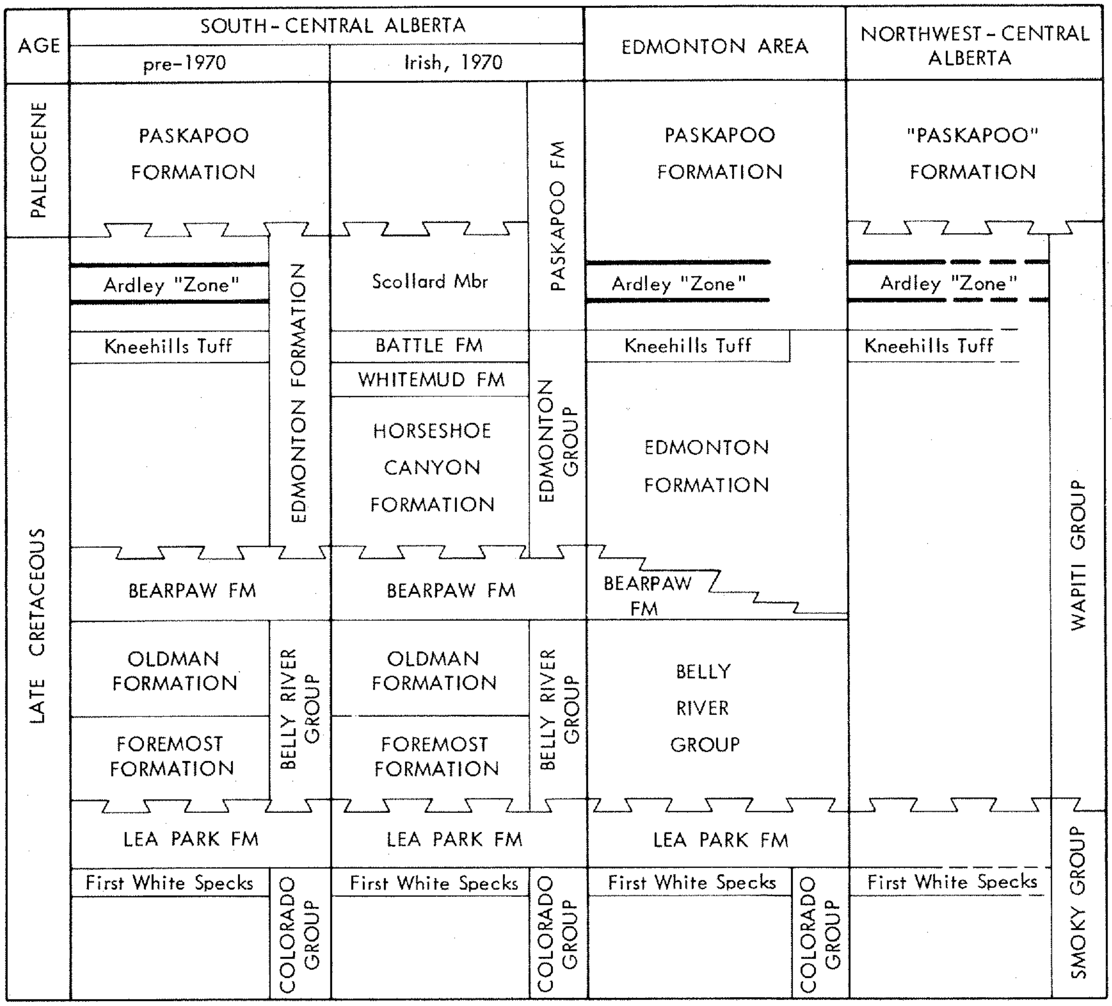

Figure 9 is a cross section from northwest to southeast Alberta, and indicates the erosional disappearance of the Wapiti Formation to the north and the position of the Edmonton Group and equivalents in the south. More detailed cross sections of these groups and formations have been prepared by other authors, for example, Ower (1960), Irish (1970), Elliot (1960) and Allan and Sanderson (1945).

COAL GEOLOGY

In this section, each of the three major coal-bearing formations or groups in Alberta is discussed separately in terms of its coal deposits. For each zone, maps were prepared outlining the distribution and thickness of coal seams 5 feet or greater in thickness, the number of seams 5 feet or greater in thickness found in each township, and an isopach of the top of the interval to the present-day erosional surface.

Each unit was mapped separately to allow reserve estimates to be calculated for each unit, as well as providing a basis for the discussion of coal geology.

Mannville Group

Distribution and Correlation

The areal extent of coal-bearing Mannville Group strata is shown on figure 10: a large deltaic sequence of sediments deposited in late Mannville time occur from approximately township 17 in the south to township 70 in the northwest of the province. Within this area the major coal zones of the group are found. Figure 10 also shows the differences in total cumulative thicknesses of seams 5 feet or greater. Figure 11 is an isopach map of the top of the Mannville Group to the present-day erosional surface, indicating the relative depths at which Mannville strata are found with respect to the surface. The most shallow Mannville coal seams are located at depths of approximately 1,500 feet in the northeast, while the deepest coals occur at depths greater than 8,000 feet along the Foothills margin.

The area of greatest accumulation of coal is in central Alberta between townships 32 and 45, from range 17 west of the 4th meridian to the western Plains margin. These coal measures are at depths of 3,500 feet at range 17 west of the 4th meridian, increasing in depth to over 8,000 feet at the Foothills margin.

The coal is found almost exclusively in the upper Mannville Group with seams being thick, clean and with well-defined boundaries.

The distribution of coal north of township 45 is not as uniform as in the central Alberta area. Seams tend to become thinner, resulting in several areas where little or no coal was detected. The coals were found mostly in the upper Mannville Group, except for a small region in the northwestern corner (townships 60 to 70) where coal was found in the lower Mannville Gething Formation. This coal is similar to that found in the major Gething delta strata which outcrop in the mountains of northeastern British Columbia.

Figure 10 indicates general areas of deposition and accumulation of organic matter. In central Alberta, conditions were such that great accumulation took place, resulting in numerous and thick coal seams. Figure 12 indicates the generalized distribution of the depositional facies during late Mannville time. The area south of township 17 is barren of coal measures, indicating a probable inland floodplain environment. Mellon (1967) recognized a redbed sequence in this area, deposited from a source of clastics to the southwest. Central Alberta between townships 17 and 70 is dominated by deltaic environments resulting in prominent coal and carbonaceous materials. The coal reaches maximum thickness in an area north of Red Deer, and thicknesses subsequently decrease toward the north. North of township 70 little coal is found. This northern area represents a marine facies characterized by deposits of marine shales, siltstones and greywackes. Correlation of coal seams is difficult due to the great lateral variability and lenticularity of coal seams; however, in central Alberta some thick, laterally persistent coal seams do occur. A major seam, often referred to as the "Medicine River Seam," appears to be correlative across much of the area shown in table 4. The seam is a thick, tight, high-rank seam with good lateral continuity and boundary definition. It is well-defined on subsurface logs and is often used as a marker horizon in the area. This seam could possibly correlate with Badgley's (1952) Looma Member of the Grand Rapids Formation.

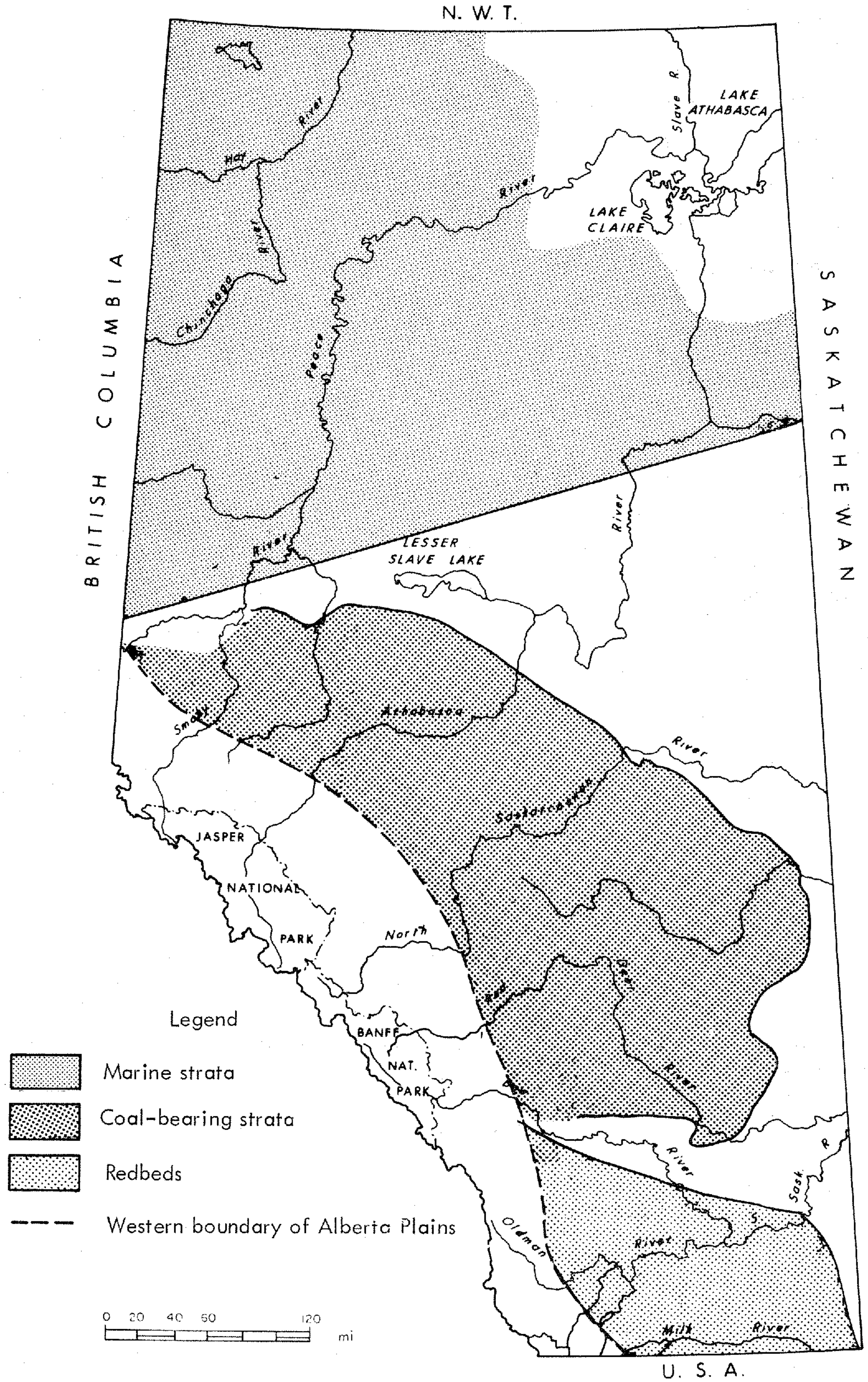

FIGURE 12. Distribution of depositional environments during Late Mannville time.

Number and Thickness of Seams

Mannville Group strata thicken from east to west across Alberta, with a concomitant increase in total cumulative coal. Figure 13, which represents the number of coal seams of 5 feet or greater in thickness, indicates that there is an average of two to three thick seams per township, with the number generally increasing toward the Foothills margin. Smaller seams (less than 5 feet thick) are generally found in greater numbers toward the western margin and also in the northwestern region of the mapped area.

The most extensive coal measures were observed in a central area bounded by township 32, township 45, range 17 west of the 4th meridian and the Foothills margin. In this area, zones over 40 feet thick (accumulative) occurred in some townships, with at least one seam greater than 15 feet thick found in most townships west of range 20 west of the 4th meridian. North and south of this central area seam thicknesses decrease, with maximum thicknesses being from 10 to 15 feet; coal seams in these areas tend to be less well defined on the subsurface logs and also appear to contain more non-coaly materials (silts, shales) within the seam limits.

Coal Rank

Mannville Group coal can generally be said to vary in rank with depth. Generally, coal increases in rank from east to west, with high volatile C bituminous coals found in eastern Alberta, high volatile A bituminous coals at a 5,000-foot depth in the Red Deer area (Tp. 40, R. 23 W. 4th Mer.) and medium volatile bituminous coals found near the Foothills. Some selected determinations of rank and calorific value are shown in table 7 for coals sampled from cores taken in the Mannville Group.

Table 7. Fixed carbon, gross calorific value and rank of some coal samples from the Mannville Group (courtesy of J. F. Fryer and J. D. Campbell)

			Mineral Matter Free		
Location	Region	Depth	Dry Fixed Carbon %	Moist Gross BTU	Rank
6-34-30-8 W4	Youngstown	3188	61.0	11,720	High volatile C bituminous
11-9-35-23 W4	Ghostpine	5165	61.3	14,340	High volatile A bituminous
10-12-36-5 W5	Raven	8009	74.4	14,830	Medium volatile bituminous

Belly River Group

Distribution and Correlation

The Belly River Group is a relatively minor coal-bearing unit compared to the Edmonton and Mannville Groups. However, the amount of near-surface coal (at less than 2,000 feet depth) makes this group the most important in southeastern Alberta.

Figure 14 indicates that in the Belly River Group coal seams 5 feet or greater in thickness are found exclusively between the 49th parallel and township 32. North of township 32, coal does exist in Belly River strata but the amount is minimal.

The scattered distribution pattern in figure 14 shows that Belly River deep coals are quite thin and stringy. Rarely does a township exhibit a cumulative thickness of greater than 10 feet, with the exceptions probably being areas where lensing occurs. Seams less than 5 feet thick are found throughout most townships within southeastern Alberta. These seams are concentrated in the lower Foremost Formation, the Oldman Formation being barren of coal except for the major Lethbridge seams found near the top.

This seam and the Taber coal zone near the top of the Foremost Formation account for most of the mapped areas with seams 5 feet or greater in thickness.

The isopach map (Fig. 15) of the top of the Belly River Group to the present-day erosional surface indicates most of the deep coal is found at depths of 1,500 feet or less. Thus, this region is suitable for possible exploitation.

Figure 14, showing the distribution of Belly River Group coal, is probably the least accurate of the three distribution maps compiled, since in southern Alberta many well logs are old and frequently without porosity logs; consequently coal picks are often inaccurate.

Correlation of seams is particularly difficult in the Belly River Group as a result of the thin and stringy nature of the coal. However, some correlation of the Lethbridge and Taber coal zones can be accomplished if actively pursued.

Number and Thickness of Seams

Seam numbers are relatively few within the deeper Belly River strata, and the thicknesses are small except in a few townships where up to 10 feet of cumulative coal is found. Figure 16 shows that more than one seam 5 feet or greater in thickness occurring at any point is unusual.

Coal Rank

Belly River Group coals vary in rank from lignite to high volatile C bituminous in the map area. The coals of the Oldman and Foremost Formations vary from subbituminous B to high volatile C bituminous in near-surface mines (Table 8). At depth slightly higher ranks are to be expected (see Fig. 22). Again, rank increases toward the west as the depth of burial increases.

Table 8. Gross calorific value and rank of some coal mine samples, Belly River Group (from Campbell, 1964)

Location	Area	Formation	Moist, mineral matter free, gross BTU	Rank
7-10-3-11 W4	Milk River	Foremost	10,280	Subbituminous A
8-7-7-21 W4	Lethbridge (Pothole)	Oldman	11,840	High volatile C bituminous
2-11-8-22 W4	Lethbridge	Oldman	12,130	High volatile C bituminous
5-24-9-22 W4	Lethbridge	Oldman	12,300	High volatile C bituminous
5-22-12-10 W4	Taber	Foremost	9,840	Subbituminous B
8-16-17-17 W4	Brooks	Oldman	10,560	Subbituminous A

Edmonton Group and Equivalents

Distribution and Correlation

The Edmonton Group and equivalents contain most of the known coal deposits found to date in the Alberta Plains. Edmonton Group coals are currently used for generation of electric power in localities such as Wabamun and Forestburg, with coals in other areas being considered for exploitation.

The area of greatest accumulation of Edmonton Group coal is in central Alberta between townships 20 and 65. South of township 20 coal is minimal, the St. Mary Formation lacking any known exploitable coal seams. Within the central Alberta area, the deep Edmonton Group coals are found essentially in three members: A, C, and E. The line of the outcrop margin of the Ardley coal zone (Fig. 5) is significant to coal exploitation in this area. The cumulative thickness values for townships east of this line are indicative of coals found in the lower Edmonton Group Members A and C. These members contain substantial coal seams including those shown in figure 17 which can be correlated over most of central Alberta. The cumulative totals of deep coal west of the present Ardley outcrop line are representative of all coal-bearing members of the Edmonton Group (i.e., Members A, C, and E) including the major Ardley coal zone. Thickness values west of the outcrop line are thus generally much greater than those east of it due to the inclusion of the Ardley zone (Fig. 24).

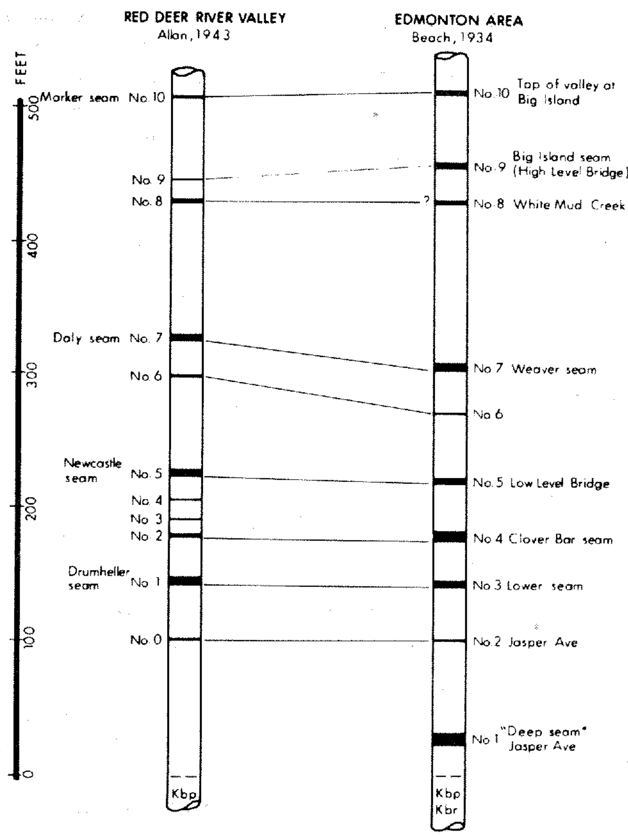

FIGURE 17. Correlation of coal seams in lower part of Horseshoe Canyon Formation (lower Edmonton Formation). Kbp = Bearpaw Formation, Kbr = Belly River Group (from Steiner et al., 1972).

Figure 18 indicates that the area of greatest coal accumulation is bounded by townships 42 and 52, between ranges 3 and 15 west of the 5th meridian. This region contains the greatest thicknesses of coal, with some cumulative thicknesses of seams 5 feet or greater reaching over 60 feet, and some individual coal zones (e.g., the Ardley coal zone) being up to 40 feet thick. Near the eastern margin of this area the Ardley coal zone is between 600 and 800 feet below surface. The westerly dipping nature of the strata results in the Ardley zone becoming increasingly deeper to the west, and is found at a depth of 3,000 feet at the western Plains margin. The lower Edmonton Group seams in this area are thick near the eastern margin but the number and size of seams decreases to the west, the seams becoming insignificant at the western edge of the area.

Regionally, figure 18 indicates uniform coal deposition, and at least one major seam 5 feet or greater in thickness is found in essentially every township (Fig. 19). Seam depths vary from outcrop exposures to depths of over 4,000 feet for lower Edmonton Group seams near the western margin of the area.

Difficulties in obtaining data for mapping and reserve estimate purposes occurred in several townships where log control and quality was lacking. Many townships where the subsurface Ardley coal zone is known to occur could not be evaluated because the Ardley zone was above the starting point of the logs. Thus, significant coal areas are omitted from the distribution map and also from the reserve estimates.

Correlation of seams in the Edmonton Group has been attempted by many people with only modest results. The most widely correlated zone is the Ardley zone which occurs extensively in west-central Alberta. The Carbon and Thompson seams (Member C) have been correlated over an area of central Alberta and also have been observed to be correlative in the subsurface logs of this area, but disappear toward the north and west margins of the mapped area. Correlation of lower Edmonton Member A seams has been done between the Red Deer River and the North Saskatchewan River (Fig. 17); however, these seams tend to be numerous and not particularly thick and thus subsurface correlation between townships is tedious.

Number and Thickness of Seams

The Ardley zone extends from about township 35 north to approximately township 60 where it thins and eventually grades out toward the surface. Between these points the Ardley zone represents the greatest commercial coal-bearing zone in the Alberta Plains. The area between townships 42 and 52, west of the 5th meridian, contains the thickest and greatest number of coal seams 5 feet thick or greater (Fig. 19). The Ardley coal zone in this area occurs as two distinct units, each zone being well defined on subsurface logs. The total cumulative thickness of the zones reaches 40 feet or greater in some townships.

North of township 52 the amount of deep Edmonton Group coal decreases, with seams becoming thinner and fewer in number. North of the Athabasca River, deep coal seams are relatively few and occur in the middle and lower Wapiti Formation. These seams probably represent the farthest northern extension of the seams of Member A in central Alberta. Most coals mined in the central Alberta Plains are either from the upper or lower Edmonton Group. The lower Edmonton Group seams are mined extensively in south-central Alberta (Drumheller), while upper Edmonton Group coals are mined in many areas and extensively in the Lake Wabamun area.

Coal Rank

The coals of the Edmonton Group vary in rank across the province, from lignites in the east to high volatile C bituminous near the Foothills margin (Fig. 21).

Figure 20 indicates variation in coal rank geographically, and also refers primarily to Edmonton Group coals. Decrease in rank away from the Foothills margin is apparent again.

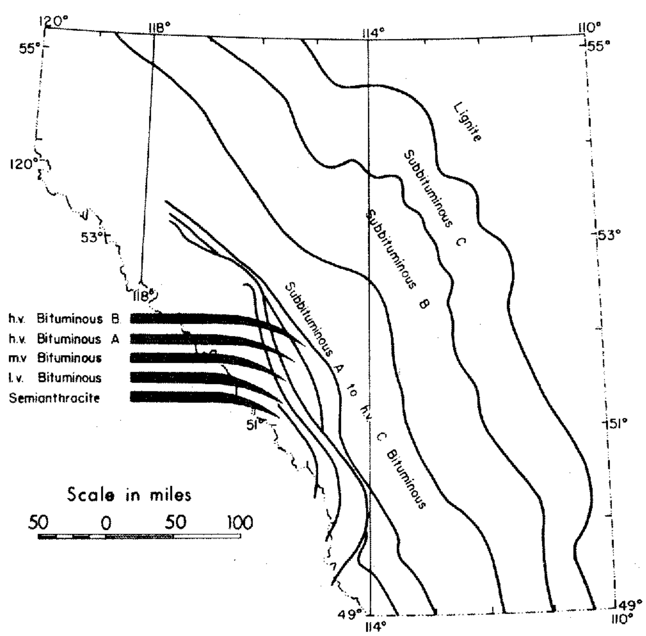

FIGURE 20.

Regional rank distribution of near-surface Alberta Coal according to ASTM classification, but independent of weathering characteristics (from Steiner et al., 1972).

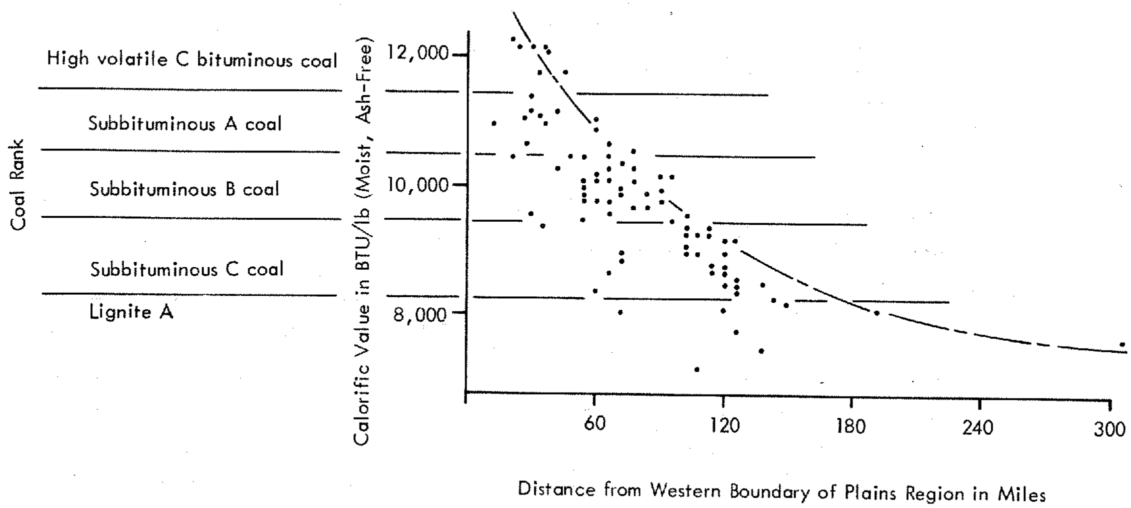

FIGURE 21. Rank versus distance from the western boundary of the Plains region for Edmonton Formation coals (from Campbell, 1972).

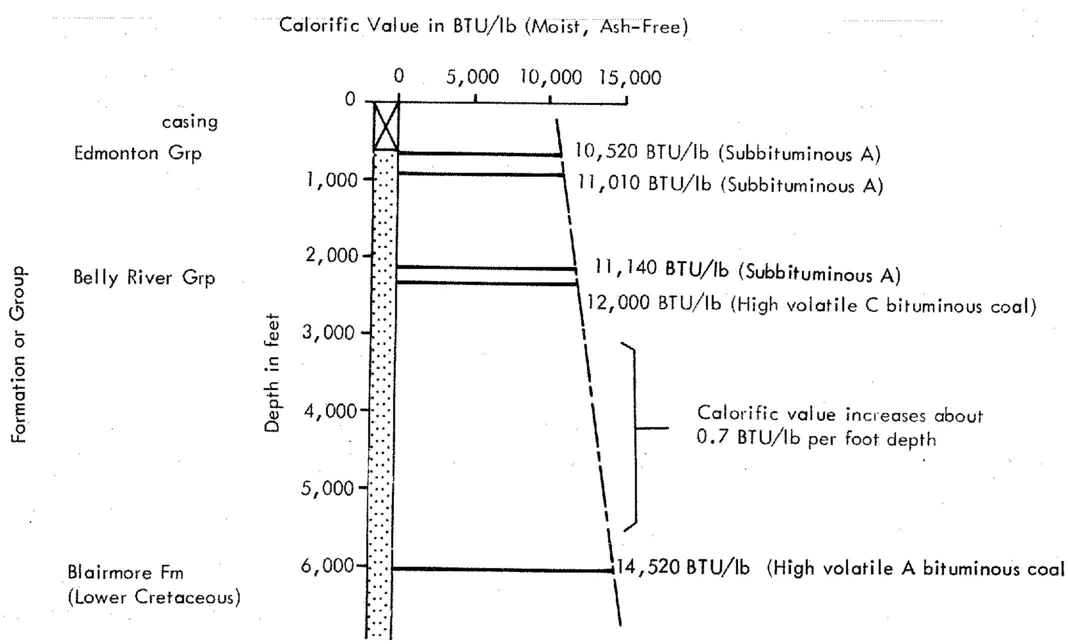

FIGURE 22. Relation between coal rank and depth for Cretaceous coal seams (from Campbell, 1972).

Table 9 shows some gross calorific values and ranks of some mined coal seams in the Edmonton and Wapiti Groups.

Table 9. Gross calorific value and rank of some coal mine samples, Edmonton and Wapiti Groups (from Campbell, 1964)

Location	Area	Group	Member	Moist, mineral matter free, gross BTU	Rank
5-11-25-22 W4	Gleichen	Edmonton	A	10,660	Subbituminous A
4-19-27-18 W4	Drumheller	Edmonton	A	10,290	Subbituminous B
3-13-29-13 W4	Sheerness	Edmonton	A	8,790	Subbituminous C
10-21-30-17 W4	Sheerness	Edmonton	E	9,540	Subbituminous B
1-9-35-20 W4	Big Valley	Edmonton	C	9,860	Subbituminous B
5-17-38-23 W4	Ardley	Edmonton	E	10,210	Subbituminous B
16-26-40-16 W4	Castor	Edmonton	A	9,270	Subbituminous C
2-20-46-19 W4	Camrose	Edmonton	A	9,350	Subbituminous C
6-26-50-19 W4	Tofield	Edmonton	A	9,100	Subbituminous C
9-15-50-4 W4	Pembina	Edmonton	E	10,110	Subbituminous B
3-13-52-25 W4	Edmonton	Edmonton	A	9,930	Subbituminous B
12-34-53-7 W5	Pembina	Edmonton	E	10,030	Subbituminous B
4-36-54-25 W4	Edmonton	Edmonton	A	9,400	Subbituminous C
1-31-59-10 W5	Whitecourt	Edmonton	C	10,310	Subbituminous B
NE 2-68-10 W6	(Pinto Ck.)	Wapiti		12,480	High volatile C bituminous
3-21-70-10 W6	Halcourt	Wapiti		12,320	High volatile C bituminous

ESTIMATION OF RESOURCES

The resource estimates obtained in this study indicate the approximate coal tonnages for each coal interval. The estimates for each particular township depend on the amount of coal found in the one particular well examined. However, the average total value should be reasonably correct, and the estimates derived give a general idea of the total amount of deep subsurface coal occurring in the Alberta Plains.

Calculations were made using a value of 36×10^6 tons of coal for a 1-foot interval throughout one township. This value was obtained by the following formula:

$$36 \frac{cwp}{2{,}000} = \text{tons per township}$$

where c = value in cubic feet of 1 foot of coal throughout one section (one square mile), that is, 1 ft x $(5{,}280 \text{ ft})^2 = 2.788 \times 10^7$ cu ft

w = number of lbs in 1 cu ft of water

p = density of coal (an average density of 1.35 was selected for Alberta coals, representative of a subbituminous A coal.)

Substituting values into the formula, the following estimate of tons per township was obtained:

$$\frac{(5{,}280)^2(\text{cu ft}) \times 62(\text{lbs/cu ft}) \times 1.35}{2000} = 1.167 \times 10^6 \text{ tons/section}$$

Assuming that an average of 15 percent of the picked interval contained non coaly material (sand, silt, clays, etc.), a value of 1×10^6 tons of coal was obtained for a 1-foot seam throughout one section of land. Since there are 36 sections per township, the standard value of 36×10^6 tons for a 1-foot interval over a township was obtained.

Several factors related to the data collection methods directly affect the final estimates; these have been discussed in a previous section, but are summarized here because of their significance in the understanding of the results.

In several townships either no well control existed or insufficient quantity or quality of logs were available to allow accurate coal picks. This was especially so in the western part of the map area. New well data could increase the coal resource estimates in these areas.

In many townships, electric logs were not run for the entire Cretaceous System; thus, in some areas no estimates are shown for a particular formation. In many townships near-surface coal seams (at less than 1,000 feet depth) were not picked owing to differences in starting depths of the logs; this often excluded near-surface Ardley zone tonnages in these townships.

Tables 10 and 11 show the estimated resources for each coal-bearing zone in Alberta. Table 12 shows estimates of coal tonnages in terms of depths below surface, to give an indication of the amounts of exploitable coal.

Table 10. Resource estimates of Cretaceous coal-bearing rock units (millions of tons)

Group	Seams 2-5 ft thick	Seams >5 ft thick	Total Coal
Edmonton	128,700	198,751	327,451
Belly River	30,996	58,392	89,388
Mannville	226,254	401,724	627,978
Total	385,950	658,867	1,044,817

Table 11. Coal tonnages by rock unit (values in percent)

Group	Seams 2-5 ft thick	Seams >5 ft thick	Total Coal
Edmonton	33.35	30.14	31.34
Belly River	8.03	8.86	8.56
Mannville	58.62	60.10	60.10

Table 12. Resources *versus* depth for seams more than 5 feet thick in the Alberta Plains

Depth (ft below surface)	Total Coal (percent)	Reserves (10^6 tons)
700 - 2,000	33	218,350
2,000 - 4,000	26	173,150
4,000 - 6,000	30	195,680
>6,000	11	71,680

An estimated value of 1.045 trillion tons of coal was obtained for the Cretaceous System of the Alberta Plains. This estimate includes all coal seams 2 feet or greater in thickness. Table 10 illustrates that 63 percent or 659 billion tons of coal occurs in seams 5 feet or greater in thickness.

Table 12 represents a comparison of calculated tonnages *versus* depth, for seams 5 feet or greater in thickness. Between 700 and 2,000 feet below the surface approximately 33 percent or 218,350 million tons of coal are present. Between 2,000 feet and 4,000 feet, 26 percent or 173,150 million tons of coal exist; 30 percent or 195,680 million tons lie between 4,000 and 6,000 feet; and 11 percent or 71,680 million tons are located at depths greater than 6,000 feet. Most of the shallow coal (at 2,000 ft or less in depth) was found in the Edmonton and Belly River Groups and the coals greater than 2,000 feet in depth occurred for the most part in the Mannville Group.

Mannville Group

The Mannville Group contains the largest tonnages of coal of the three zones investigated. A total of 628,000 million tons was obtained for Mannville Group coal; this represents 60 percent of the total coal found. For seams 5 feet or greater in thickness, 402,000 million tons of coal was estimated, again representing 60 percent of the total of coal found in seams 5 feet or greater in thickness. The Mannville Group and its equivalents also contain additional major coal resources in the Mountains and Foothills areas of Alberta.

Belly River Group

This group contains relatively little coal compared with the other two coal-bearing zones; however, the coal contained represents most of the deep coal in southeastern Alberta. Belly River strata contain 89,999 million tons of coal, or 8.5 percent of the total deep coal of the Alberta Plains. Of this amount, 58,400 million tons occurs in seams 5 feet thick or greater, representing about 9 percent of the total coal in this category. It is significant to note that the majority of this coal occurs at depths less than 2,000 feet.

Edmonton Group and Equivalents

Most of the coal resource figures published to date for the Alberta Plains are indications of the amount of coal found in the Edmonton Group. Most Edmonton Group coal seams are found at depths less than 2,000 feet; therefore, they constitute most of the province's shallow recoverable coal.

The Edmonton Group was found to contain 31 percent of the total calculated coal or 327,450 million tons. For seams 5 feet or greater in thickness, 198,750 million tons was estimated or 30 percent of the total. This large figure is still only one-half that of Mannville Group strata.

CONCLUSIONS

The extensive coal zones of the Alberta Plains are an attractive potential source of energy for the future, should conditions make it economically feasible to exploit them. The most feasible coals to exploit are those of the upper Edmonton Group (Ardley zone) and the Belly River Group, both occurring at relatively shallow depths; however, the size and quality of the deeper Mannville coal seams make them interesting as a possible in situ source of fossil fuel energy.

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SHEET 2 OF 4

FIGURE 4. LOG SUITE FOR A CROSS SECTION THROUGH TOWNSHIP 40.

To accompany Alberta Research Council Report 75-4
by J. R. Yurko

SHEET 1 OF 4

FIGURE 4. LOG SUITE FOR A CROSS SECTION THROUGH TOWNSHIP 40.

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SHEET 3 OF 4

FIGURE 4. LOG SUITE FOR A CROSS SECTION THROUGH TOWNSHIP 40.

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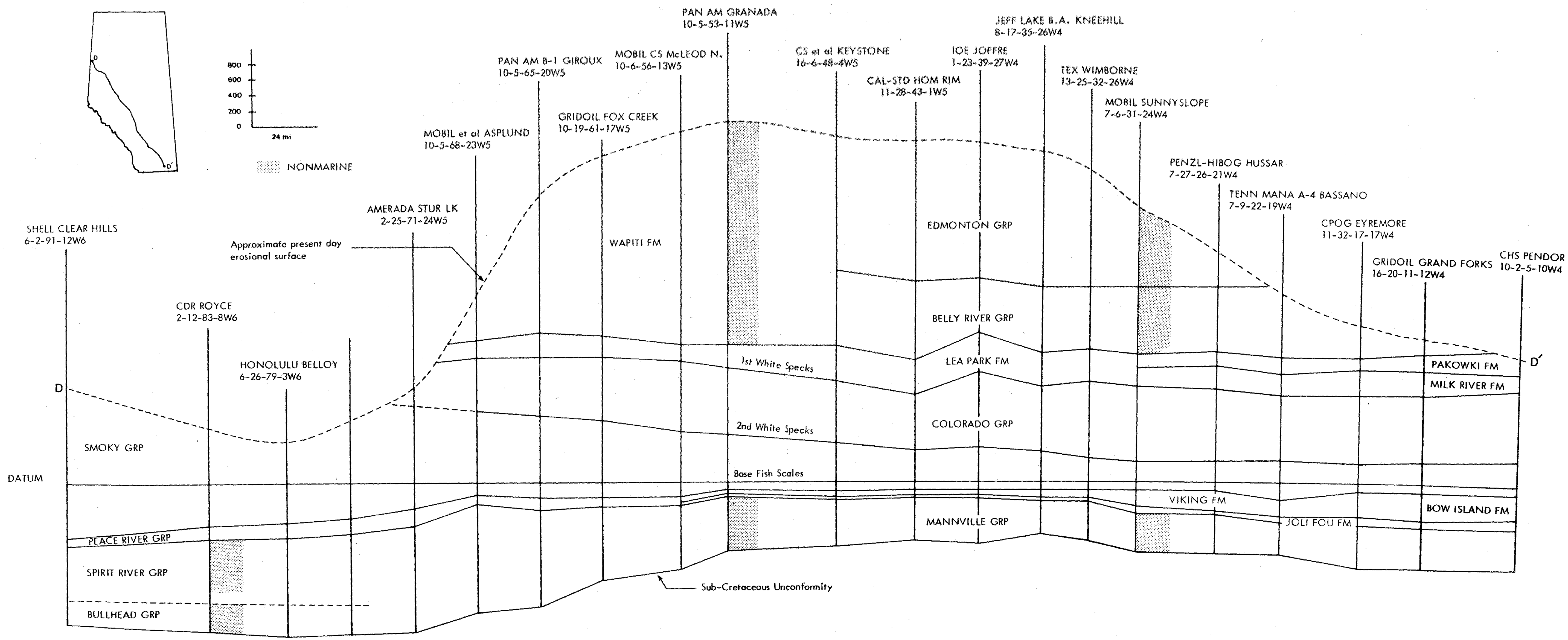

FIGURE 9. SCHEMATIC CROSS SECTION OF WELLS FROM NORTHWEST TO SOUTHEAST ALBERTA.

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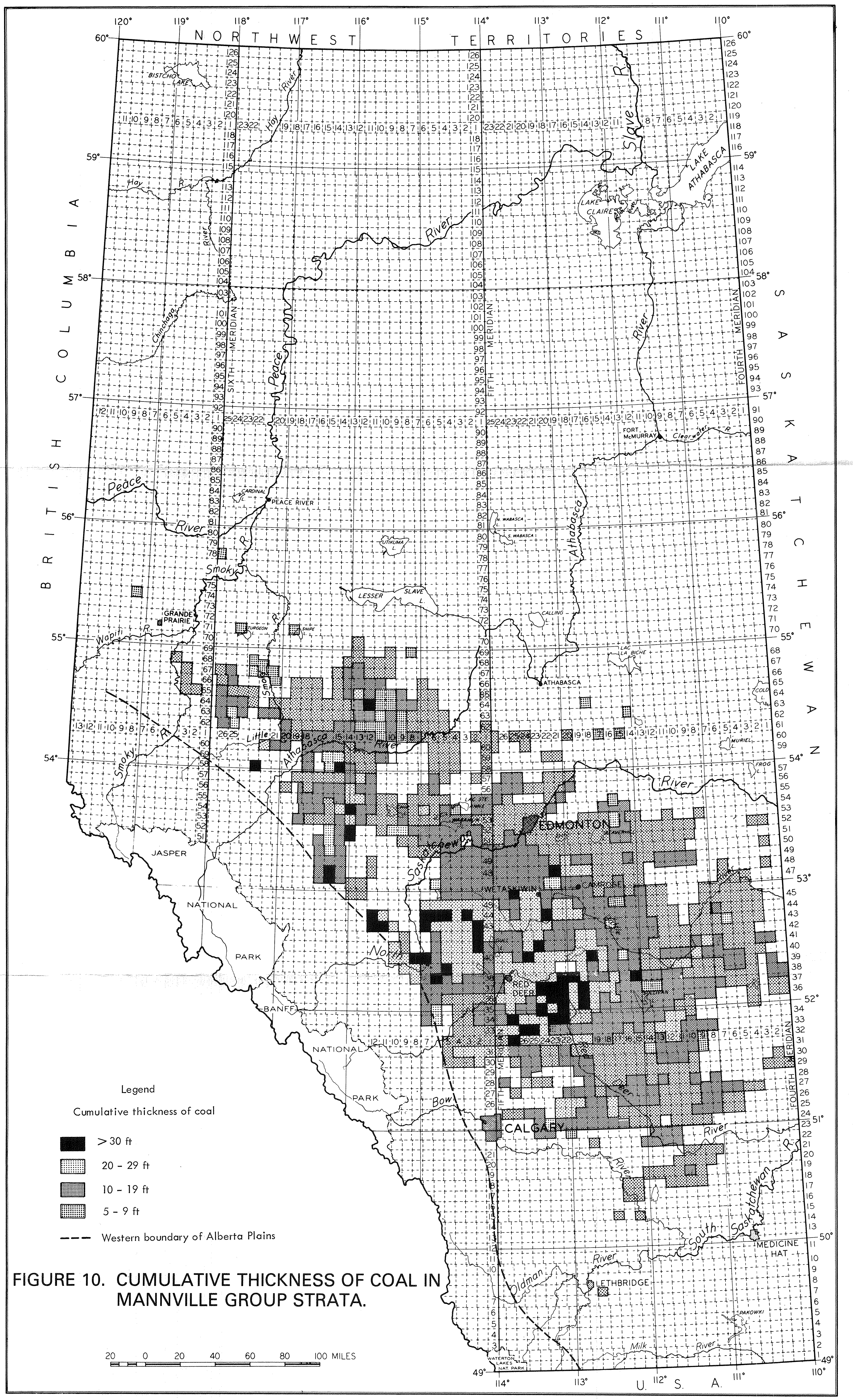

FIGURE 10. CUMULATIVE THICKNESS OF COAL IN MANNVILLE GROUP STRATA.

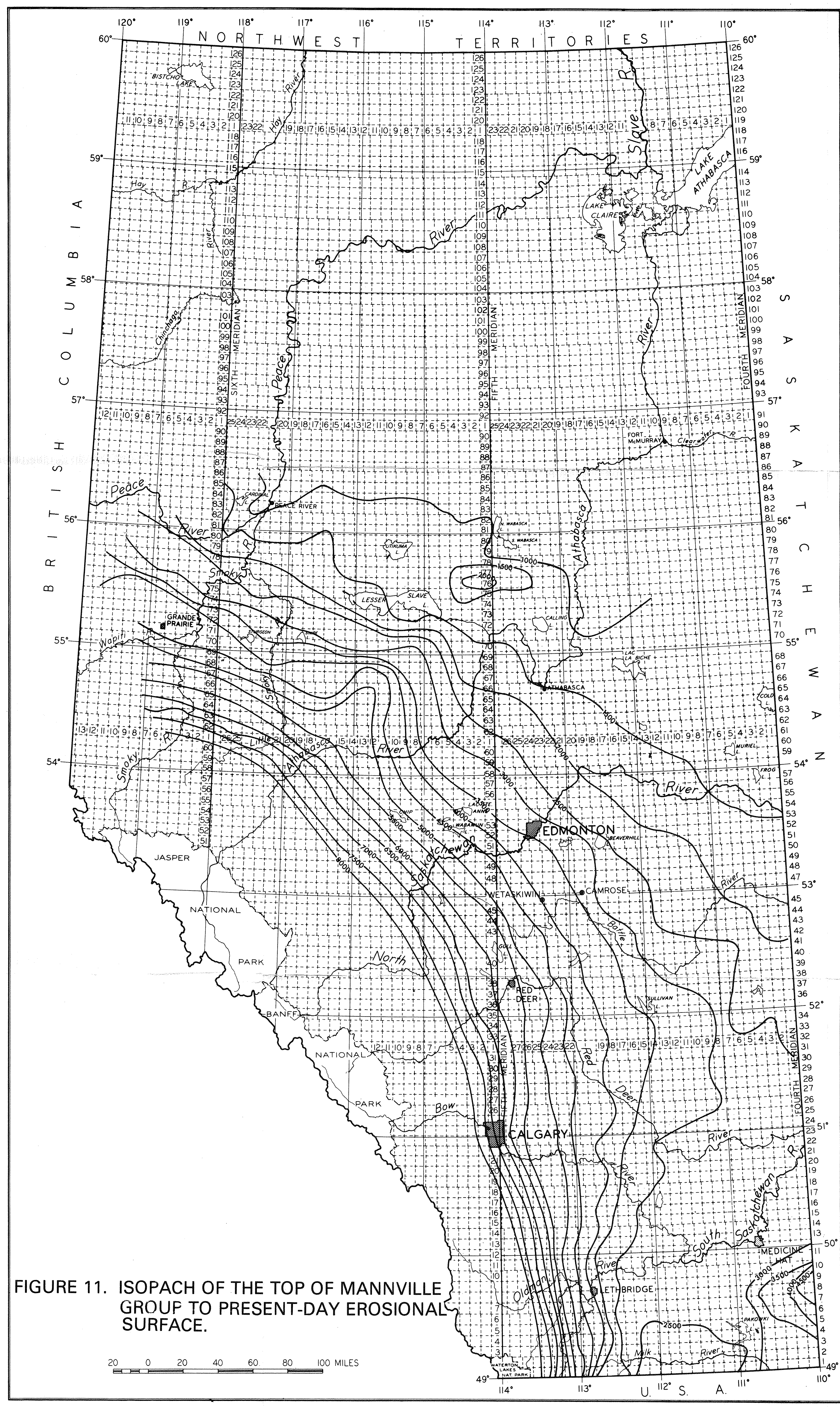

FIGURE 11. ISOPACH OF THE TOP OF MANNVILLE GROUP TO PRESENT-DAY EROSIONAL SURFACE.

FIGURES 10 AND 11

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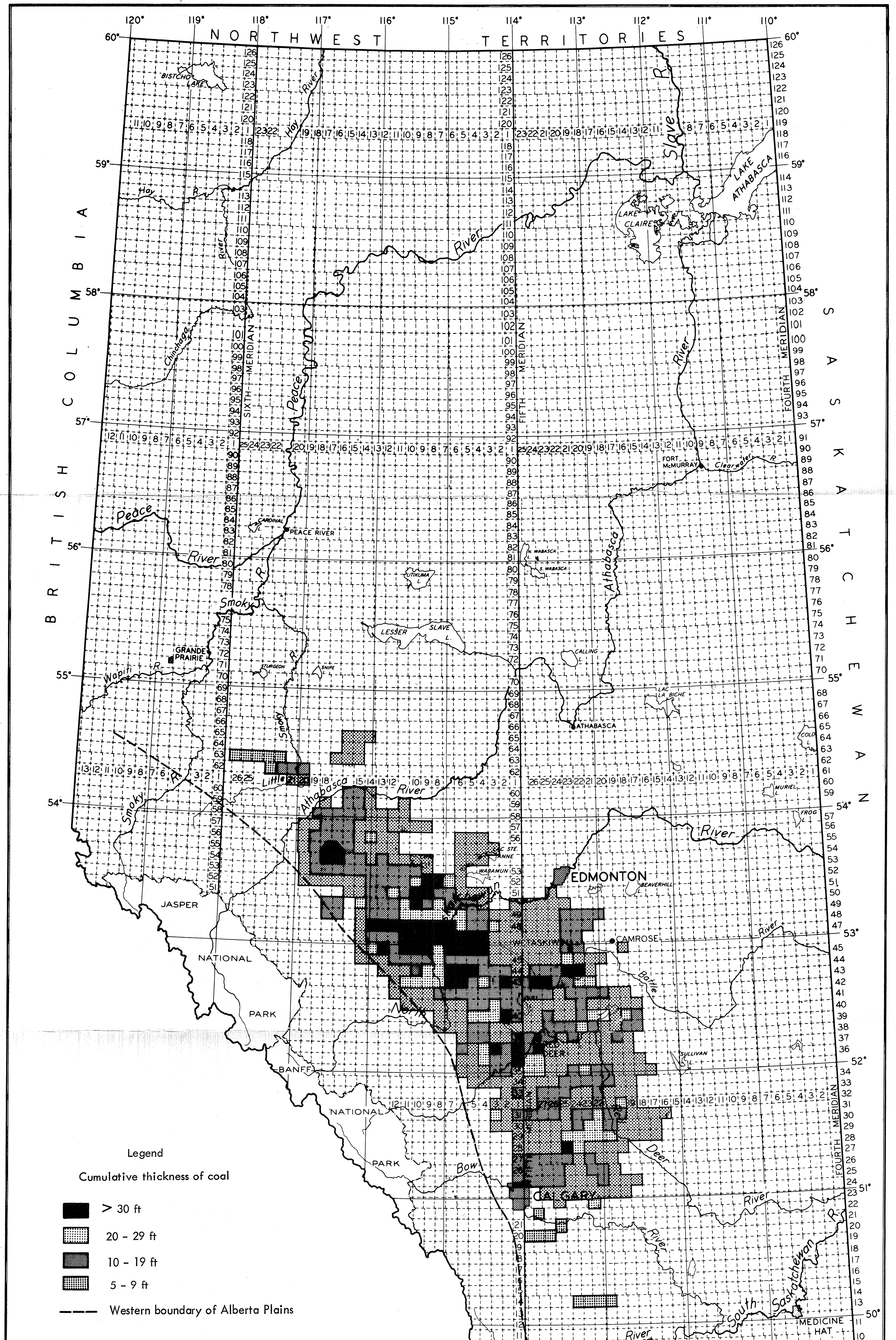

FIGURE 18. CUMULATIVE THICKNESS OF EDMONTON GROUP STRATA.

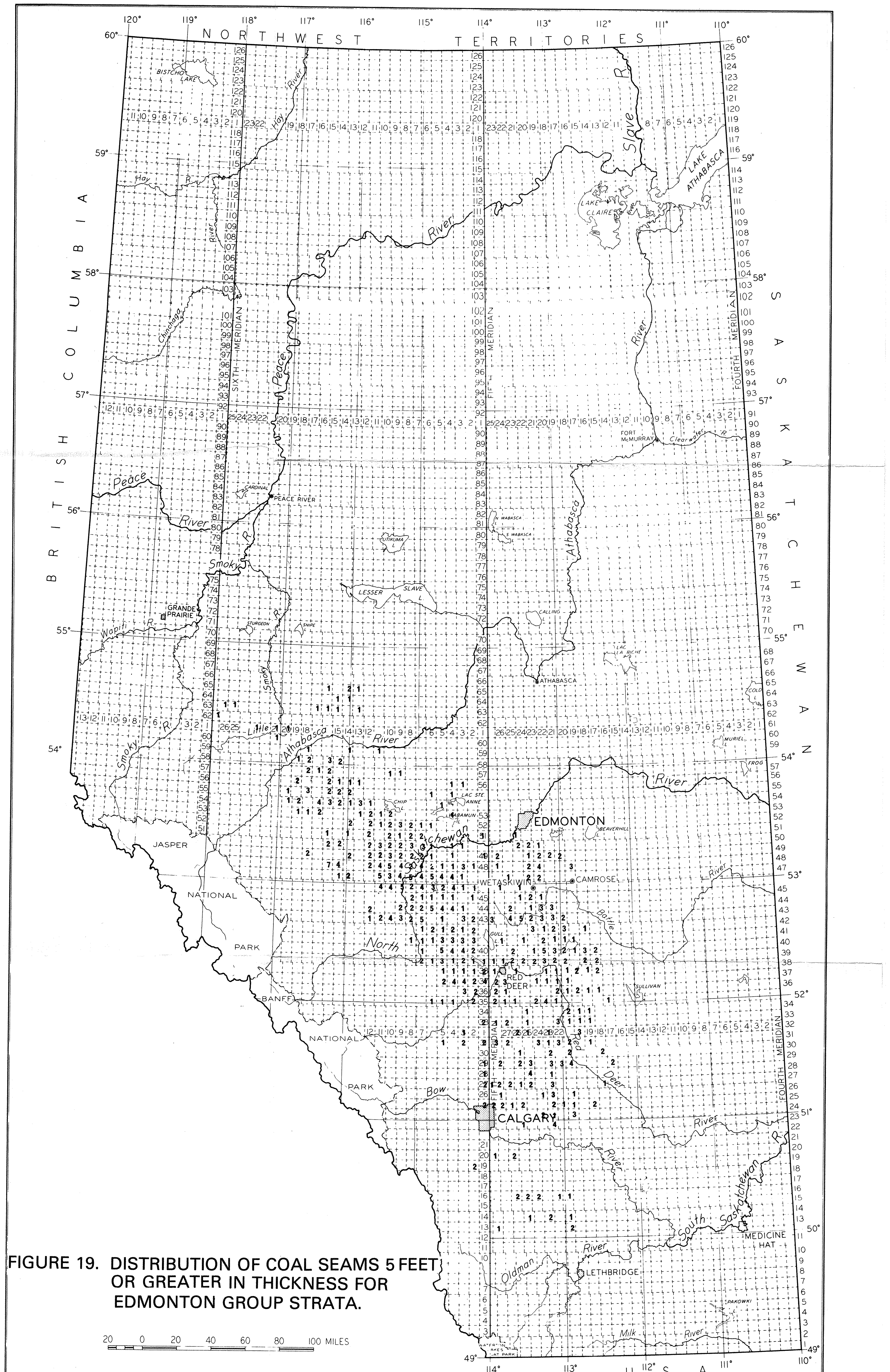

FIGURE 19. DISTRIBUTION OF COAL SEAMS 5 FEET OR GREATER IN THICKNESS FOR EDMONTON GROUP STRATA.

FIGURES 18 AND 19

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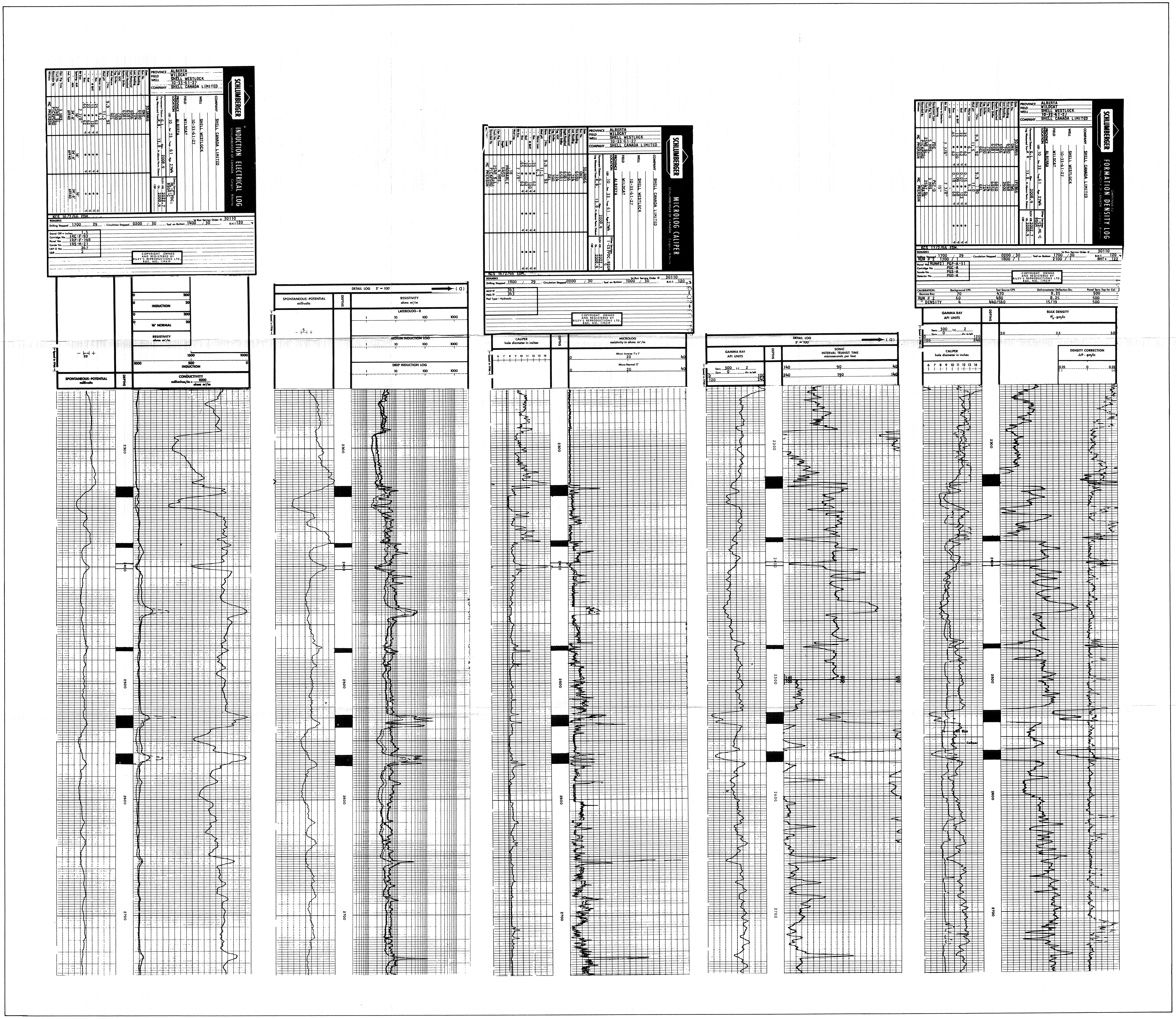

FIGURE 2. LOG SUITE FROM SHELL WESTLOCK WELL INDICATING CHARACTERISTIC RESPONSES OF VARIOUS LOGS TO MANNVILLE GROUP COAL SEAMS.

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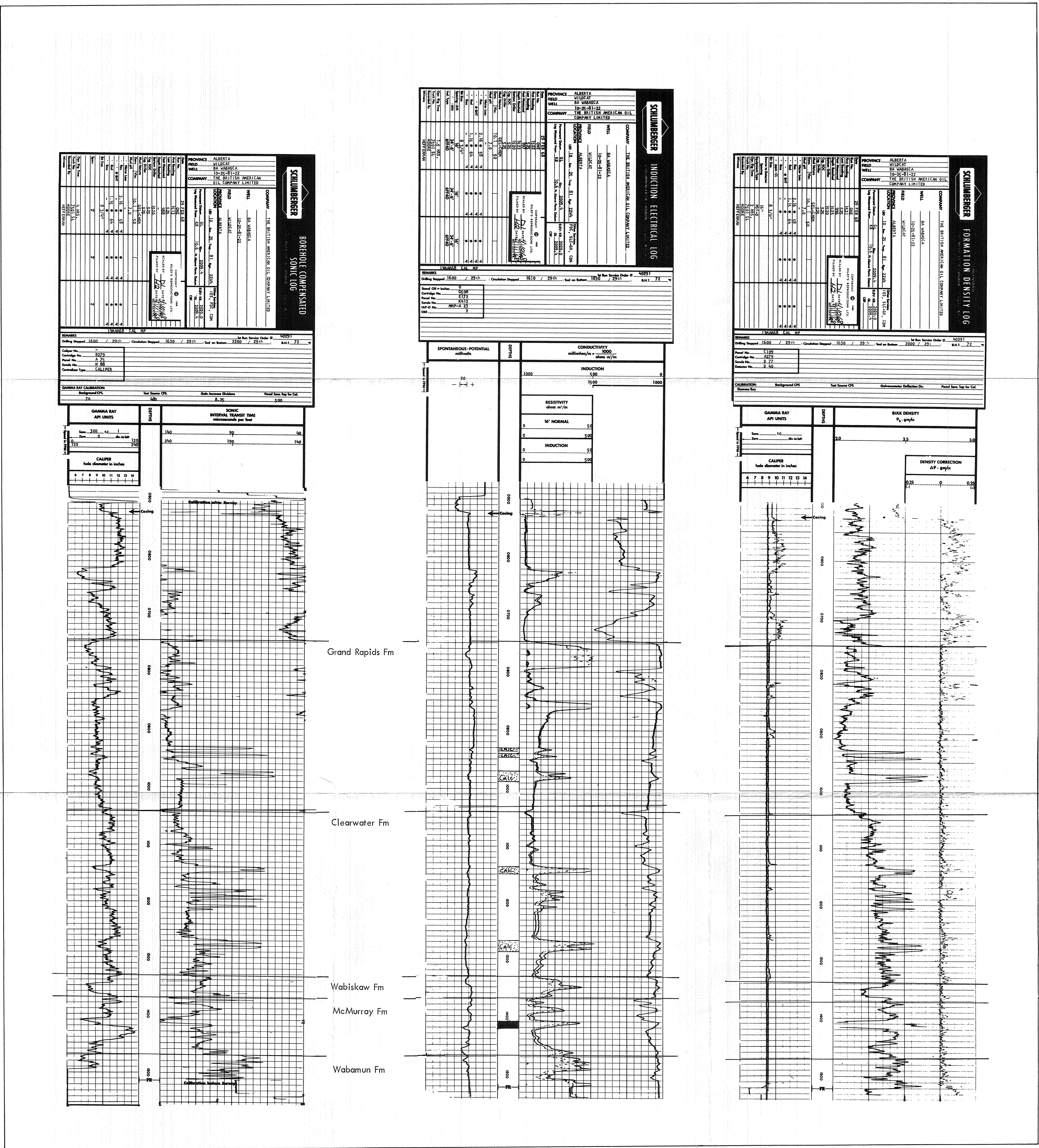

FIGURE 1. LOG SUITE FROM B.A. WABASCA WELL INDICATING SIMILAR RESPONSES OF SANDSTONE AND COAL.

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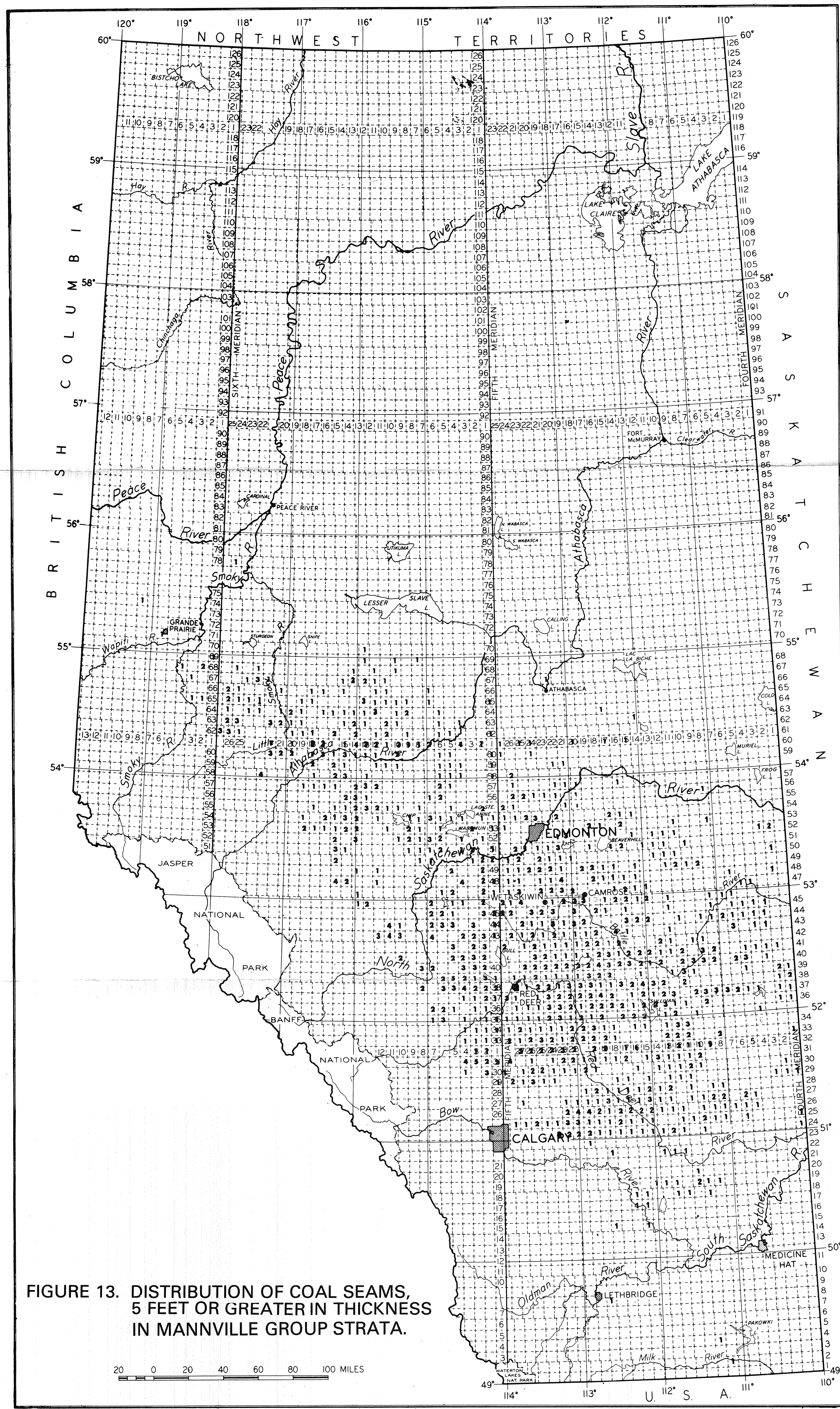

FIGURE 13. DISTRIBUTION OF COAL SEAMS, 5 FEET OR GREATER IN THICKNESS IN MANNVILLE GROUP STRATA.

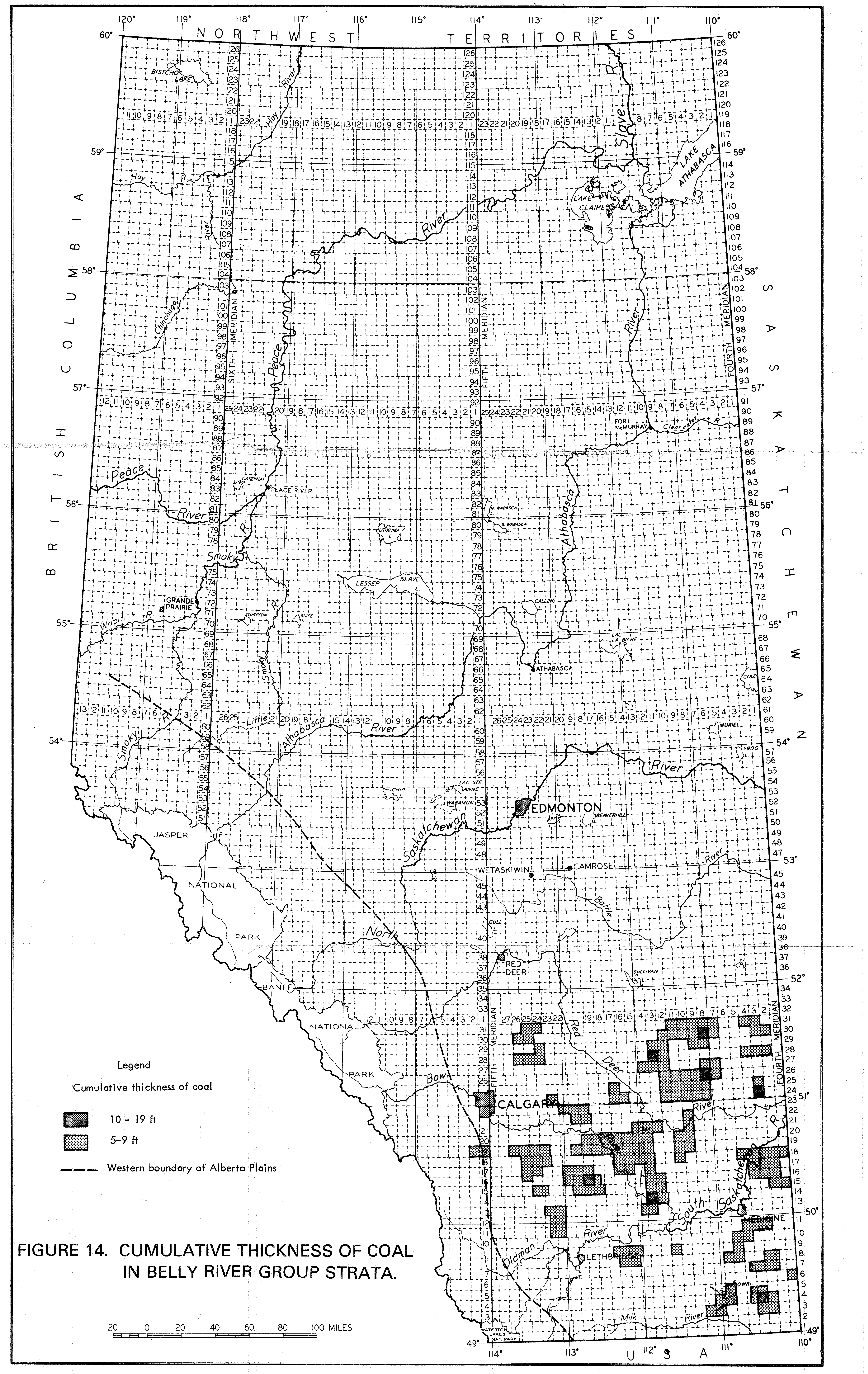

FIGURE 14. CUMULATIVE THICKNESS OF COAL IN BELLY RIVER GROUP STRATA.

FIGURES 13 AND 14

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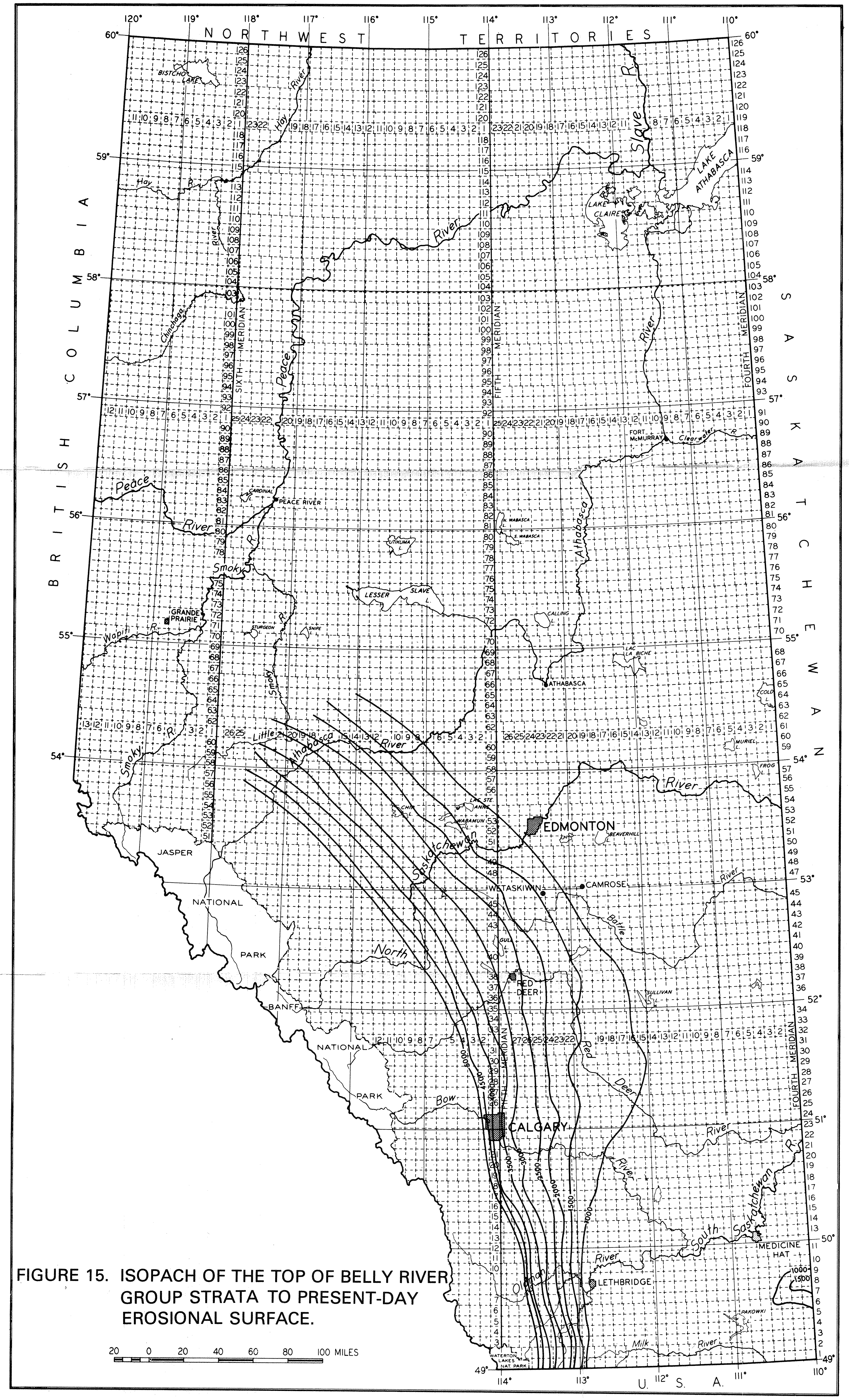

FIGURE 15. ISOPACH OF THE TOP OF BELLY RIVER GROUP STRATA TO PRESENT-DAY EROSIONAL SURFACE.

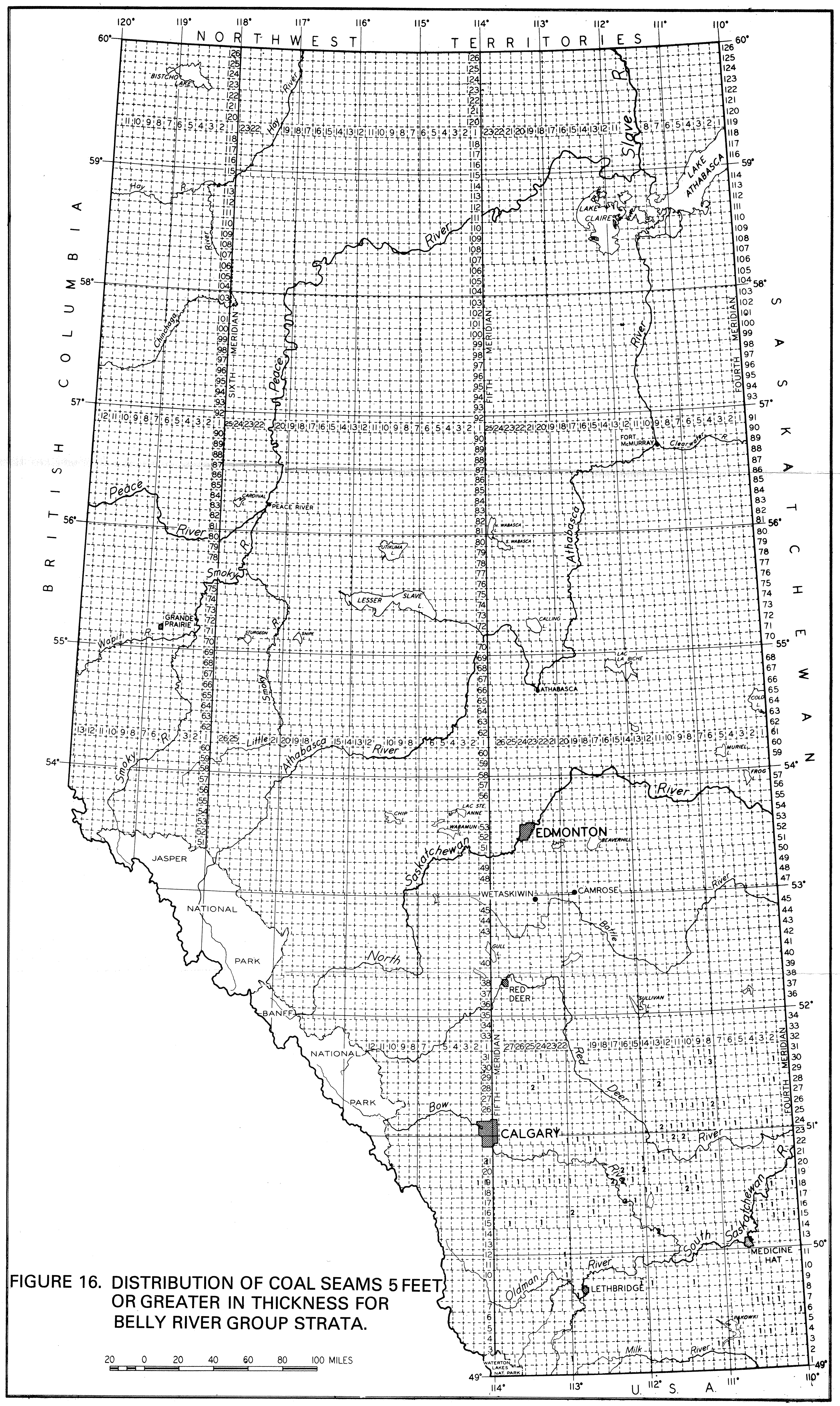

FIGURE 16. DISTRIBUTION OF COAL SEAMS 5 FEET OR GREATER IN THICKNESS FOR BELLY RIVER GROUP STRATA.

FIGURES 15 AND 16

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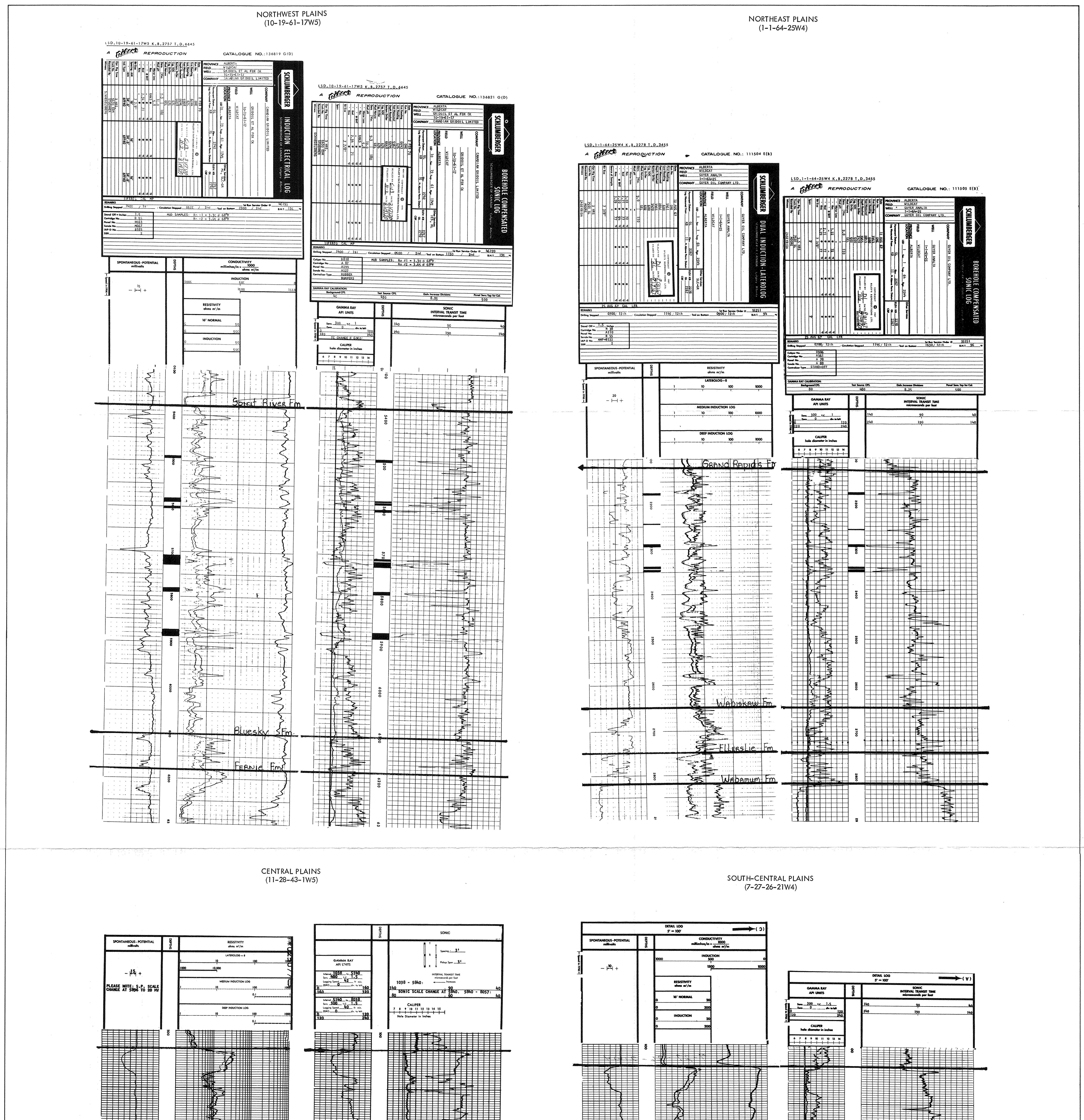

FIGURE 3. WELL LOGS SHOWING TYPICAL MANNVILLE GROUP SECTIONS IN NORTHEAST, NORTHWEST, CENTRAL AND SOUTH-CENTRAL ALBERTA PLAINS.

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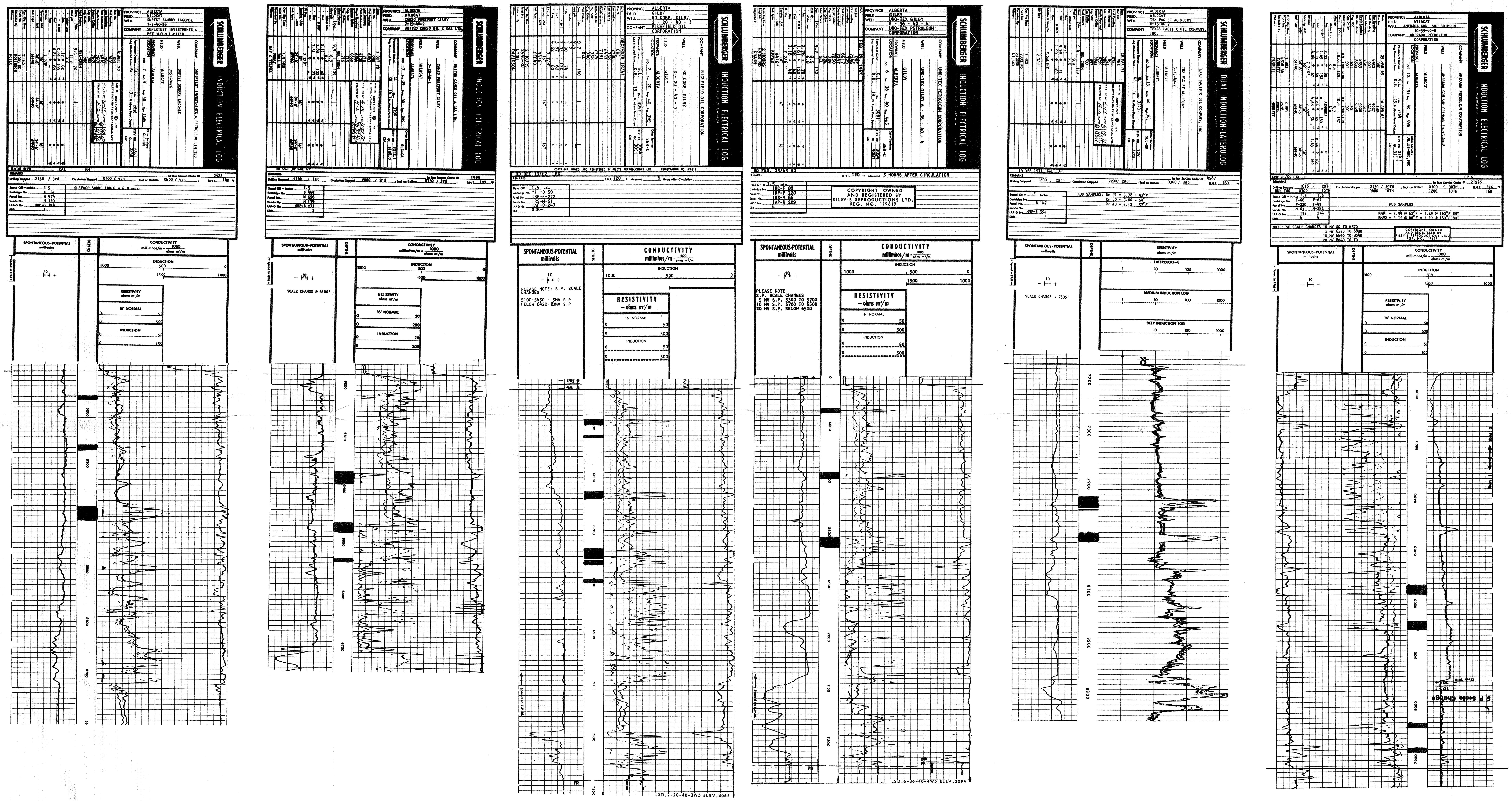

SHEET 4 OF 4

FIGURE 4. LOG SUITE FOR A CROSS SECTION THROUGH TOWNSHIP 40.

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