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COAL RESERVES FOR STRIP-MINING, WABAMUN LAKE DISTRICT ALBERTA

by

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ABSTRACT

Strippable coal reserves in the Wabamun Lake district, Alberta are estimated from geological examination and drill-hole data at over 200 million tons. Detailed drill-hole logs are given; the holes were electrologged, and the value of this method in coal exploration is indicated. Study of subsurface water conditions suggests that serious flooding is likely in mining operations in the Gainford area, but that pumps could probably control water influx in the Seba Beach - Highvale area. Proximate coal analyses and brief petrographic descriptions of seams are given, indicating the coal to have a subbituminous B classification and to be bright and banded in nature.

CHAPTER I

INTRODUCTION

The availability of suitable energy reserves is an important factor in selecting plant locations for large industrial enterprises. In Alberta, coal is and will continue to be one of the cheapest sources of energy. Consequently the Research Council of Alberta has initiated a program to estimate the coal reserves in some places potentially attractive to industry. This report covers the first project in the program, an investigation of the strippable coal reserves of the Wabamun Lake district, Alberta.

Calgary Power Limited, according to their publication "The Wabamun Power Plant", have outlined reserves of more than 80 million tons of coal suitable for strip-mining in the area lying north of Wabamun village. This has been accomplished by extensive closely spaced drilling. Calgary Power Limited are planning to convert their 132,000 kilowatt steam generating power plant at Wabamun village from natural gas to coal in 1962, when an expansion to 232,000 kilowatts is complete. This plant utilizes lake-water for cooling purposes.

The purpose of the investigations described in this report was to outline additional areas underlain by coal which can be economically recovered by strip-mining. This has been carried out by tracing the extent of the Wabamun coal seams, and studying the relationship of these seams to thick seams along the Pembina River to the west, and at Coal Arch * and Goose Encampment * on the North Saskatchewan River to the southeast.

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* Local name used in this report for convenience.

Location and Access

The Wabamun Lake district is west of Edmonton in Tps. 50 - 54, Rs. 3 - 7, W. 5th Mer., and is centred about Wabamun Lake (Fig. 1). The map accompanying this report (Fig. 2) covers about 720 square miles. The village of Wabamun, on the north shore of Wabamun Lake, lies about 45 miles west of Edmonton, and is 1 mile south of Highway 16 which traverses the Wabamun Lake district in an east-west direction. Wabamun Lake is skirted on the north shore by the main line of the Canadian National Railways.

Topography and Drainage

The Wabamun Lake district is an area of low relief, and belongs physiographically to the plains area of central and eastern Alberta (Rutherford, 1928, p. 5). Elevations are mainly in the range of 2,400 to 2,600 feet, but exceed 2,700 feet in the south and west of the district where the Tertiary Paskapoo sandstones form a more resistant bedrock than do the Upper Cretaceous Edmonton shales to the north and east. The Paskapoo sandstones form a line of cliffs along the north shore of Wabamun Lake and a gentle scarp slope to the south of the lake. North of Isle and Wabamun Lakes, a capping of brown glacial tills and fluvial gravels, generally more than 50 feet thick, gives a rolling or undulating topography.

Except where cleared, most of the district is covered with deciduous trees, but spruce grows in some of the muskegs, and scattered pines exist on the sandy hills.

Two main drainage systems are present in the Wabamun Lake district. In the western part, the Pembina River flows in a northerly direction towards the Athabasca River and the Mackenzie River drainage system to the Arctic. The

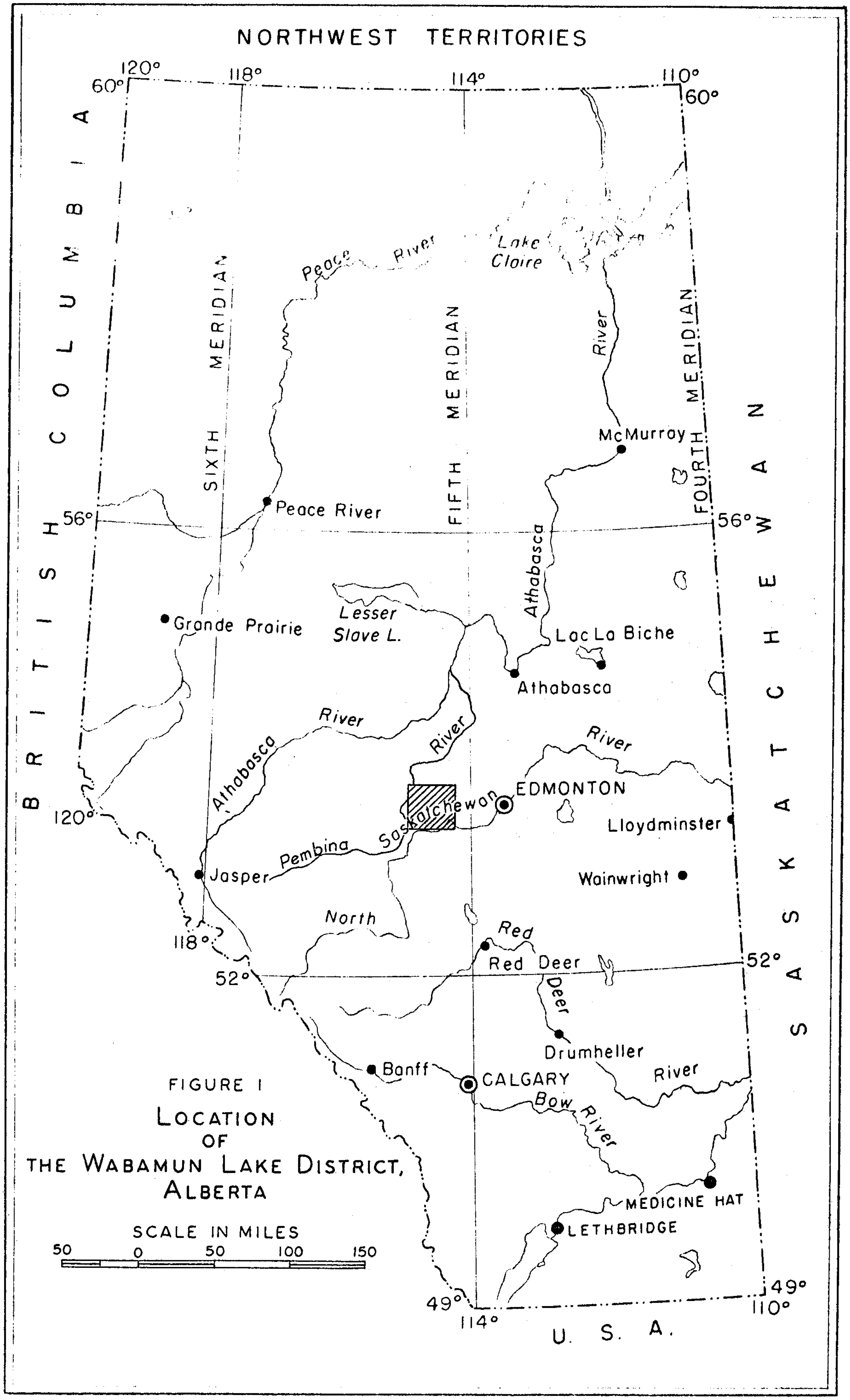

FIGURE I

LOCATION OF THE WABAMUN LAKE DISTRICT, ALBERTA

North Saskatchewan River flows through the southeast corner of the Wabamun Lake district, and thence easterly towards Lake Winnipeg, whose waters flow north via the Nelson River to Hudson Bay. Both the Pembina and North Saskatchewan Rivers flow in valleys which are from 100 to 200 feet deep. The former flows in a narrow valley with steep sides, the latter in a broad, flat valley. It is probable that these river valleys were eroded in post-glacial times, for glacial drainage patterns do not appear to be related to the present river courses. Chip Lake (10 miles west of Entwistle), Isle Lake, Lac Ste. Anne, Wabamun Lake and Low Water Lake are suggested by Rutherford (1928, p. 7) to be the remnants of a "long, narrow, continuous body of water with an east-west trend". The Pembina River appears to have transected a former drainage pattern, for Chip Lake drains east into the Pembina, whilst Isle Lake, whose drainage area extends west almost as far as the Pembina River, drains east into Lac Ste. Anne via Sturgeon River. Wabamun Lake drains to the southeast via Wabamun Creek which flows into the North Saskatchewan River.

Previous Geological Work

Selwyn (1874) and Tyrrell (1887) were the first to report on the geology of the region, each travelling the North Saskatchewan River during the course of exploratory geological surveys for the Federal Government. The geology of the area was more recently described in some detail by Rutherford (1928), and Collins and Swan (1955) have reported on the glacial geology of the St. Ann map area which includes the Wabamun Lake district.

The Wabamun Lake district has received some attention from a number of oil companies during the past decade, interest no doubt being increased by the discovery in 1953 of the large Pembina oil and gas field some 30 miles to the southwest. Eleven wildcat wells have been drilled within the district, and considerable structure test-hole drilling and seismic exploration have been carried out. So far, however, no oil or gas discoveries have been made.

History of Coal Mining

The Wabamun Lake district forms part of the Pembina coal area *, and accounts for much of the coal which has been mined there. Until 1910, only small-scale mining operations were carried out, and probably amounted to no more than a farmer providing coal for himself and for a few neighbors. The Province of Alberta began issuing coal-mining licenses in 1905, and the records show the following number of mining licenses to have been held at various times in the Pembina area:

Year	Number of Licenses
1905	1
1910	2
1915	4
1920	4
1925	4
1930	7
1935	8
1940	4
1945	7
1950	14
1955	6
1958	5

Fifty-nine coal-mining licenses have so far been issued for the Pembina area, but many of these were allowed to lapse after one or two years, and probably no coal at all was mined under a number of them. The Alberta Coal Limited property at Wabamun has the longest record of operation; mining has been carried on there continuously since 1913. A license was held continuously for the underground

* The term "coal area", where used in this report, refers to the areas as defined by Allan (1924, p. 55 - 58; 1925, p. 44 - 45; 1943, p. 161 - 165).

operation at Evansburg from 1910 to 1936. However, of the 59 licenses issued for the Pembina area, only 17 have been held for periods of five years or more.

Until 1935 almost all mining was by underground methods, but since that time coal production has come largely from strip-mining, and no underground operations have been carried out for the past 10 years.

Several underground mining operations were started near Gainford in the years prior to 1925, but none of these lasted for more than two years. They are believed to have closed mainly because of the unfavorable water conditions.

Coal production in the Pembina area reached its peak in 1953, when 270,732 short tons were mined. In the same year Alberta produced 2,399,924 short tons of subbituminous coal and a total of 5,917,423 short tons of all coals. In 1957, the Pembina area produced 115,682 short tons of coal, whilst 1,889,510 short tons of subbituminous coal and 3,155,534 short tons of all coals were produced in the province. Thus the Pembina area at present accounts for between 3 and 4 percent of the total Alberta coal production.

Methods of Study

The area selected for examination was the district around Wabamun Lake in which coal might be present within 100 feet of the surface. A geological field survey was made, and present strip-mine operations and former workings were visited. Because of the very limited number of exposures, drilling was necessary in order to trace the coal seams and hence delineate the coal reserves. In order to find the most suitable locations for the drill holes, structure contours were plotted on a map from information obtained from examination of all outcrops, workings and abandoned strip-mines in the area, from oil and gas well logs and samples on file at the Oil and Gas Conservation Board, and from records on file at the Mines Division of the Alberta Department of Mines and Minerals. Approximate thicknesses of the overburden were thus obtained and areas not underlain by coal were outlined; Figure 2 is a revision of this map incorporating information obtained by drilling. The area, lying between the Pembina River to the west and Lac Ste. Anne and Coal Arch to the east, which was to be examined by exploratory drilling was thus reduced from a possible 800 square miles to approximately 110 square miles.

Thirty-one uncased 5-inch holes were drilled by a truck-mounted rotary Mayhew rig during four weeks in September and October 1958. The depths of the holes varied from 50 to 210 feet; a total of 3,834 feet was drilled. Where coal was encountered at shallow depths, holes were spaced at one-half to one-mile intervals, but elsewhere were up to 6 miles apart.

Each hole was logged by the driller, who was particularly careful with his logging whilst the bit was passing through coal seams. He obtained a high degree of accuracy in his logging by collecting rock fragments from the bit in a large soup-strainer type sieve at closely spaced intervals, and the hole was washed out each time to remove chips from the higher part of the hole. Samples of rock fragments were collected at 5-foot intervals and retained for checking the driller's logs and as a record of the holes. Two holes were partially core-drilled to test the applicability of this method, but it met with only moderate success. Electrologging of the holes for resistance and self-potential characteristics, immediately after they were drilled, was found to be very useful in the recognition and correlation of coal seams.

Most holes were drilled close to the corners of quarter sections and were located with respect to them by pacing. Holes over 500 feet from such corners were located on vertical aerial photographs. Surface elevations at the drill holes were measured with a Paulin survey altimeter, claimed by the makers to be accurate to within 5 feet under suitable weather conditions. Grade elevations along the main line of the Canadian National Railways were used as base stations.

Most of the land adjacent to the south side of Wabamun Lake is low-lying and is underlain by coal; the coal lies at about lake level. The possibility of severe flooding during mining operations therefore exists. In order to estimate the rate of flow of subsurface water which might be encountered during strip-mining operations, bailing tests were carried out in nine holes.

Acknowledgments

The writer is indebted to the coal operators of the Wabamun Lake district for permission to visit and examine their properties, and to the driller, Ray McAuley, for his conscientious work and full co-operation. Calgary Power Limited and Canadian Utilities Limited kindly placed the results of their own work in the area at the writer's disposal.

CHAPTER II

GENERAL GEOLOGY

Rocks of late Cretaceous and early Tertiary ages constitute the bedrock of the Wabamun Lake district, and consist of sandstones, shales and coal seams deposited in a fresh-water environment. The upper Cretaceous is represented by strata of the upper part of the Edmonton formation, first named by Selwyn (1874) as the coal-bearing formation in the neighborhood of the present City of Edmonton. The lower Tertiary is represented by beds of the Paskapoo formation, a name first used by Tyrrell (1887) to describe a sandstone and shale sequence along the lower part of the Blindman River, about 10 miles north of the present City of Red Deer.

The Edmonton Formation

Rutherford (1928, p. 11) gave a general description of the Edmonton:

> "The Edmonton formation in its eastern development is characterized both vertically and laterally by the presence of light-colored bentonitic clays. The greater part of the formation is composed of clays or shales, while sandstones constitute only a minor part, and these also are in most cases bentonitic. Thus any exposed section of the Edmonton formation is usually very light grey in color, due principally to the bentonitic clay material distributed throughout the whole formation. Where the beds are predominantly clays they are often characterized by the presence of clay-ironstone nodules which weather to a reddish brown color. These nodules vary from one inch to about ten inches in diameter, and frequently occur in rows or bands. In addition the Edmonton formation is characterized by coal seams varying in thickness from a few inches up to as much as 25 feet. The thickest seams occur in the upper part of the formation and are present in this area.... On the whole, the Edmonton formation is remarkably free from beds of coarse clastic material. The above description of the Edmonton applies to its development in the eastern part of the area and is general to the Edmonton formation throughout its distribution in Alberta along the eastern side of the general synclinal basin. These beds apparently were deposited as near-shore deposits in shallow water. This deposition followed the retreat of the Bearpaw sea from eastern Alberta and practically the same type of beds was laid down all through Edmonton time."

The Edmonton formation in the Anglo-Canadian Wabamun Lake well (Lsd. 5, Sec. 10, Tp. 51, R. 4, W. 5th Mer.) is about 1,700 feet thick, but only the upper few hundred feet of the formation are exposed in the Wabamun Lake district. These consist largely of light-grey to greenish- or bluish-grey, slightly bentonitic shales with scattered zones of clay-ironstone nodules. Interbedded with the shales are thinner siltstone beds and grey, buff-weathering salt-and-pepper textured sandstones, the latter commonly containing abundant small coal fragments. A thick coal-bearing zone has been found near the top of the Edmonton formation at numerous points throughout the Pembina coal area: it outcrops along the Pembina River 4 miles north of Entwistle, at several places along the north and south shores of Wabamun Lake, and along the North Saskatchewan River at Coal Arch and Goose Encampment. Coal has been mined from this zone at the Evansburg (1 mile west of Entwistle), Gainford, Keystone (Lake Isle) and Lakeside (Wabamun) collieries by underground methods, and by strip-mining along the Pembina River, at several localities around Isle and Wabamun Lakes, and near Coal Arch. This coal-bearing zone has been variously termed the Big seam, Pembina seam, and Wabamun seam. In this report the complete coal unit is referred to as the Pembina coal-bearing zone, and is subdivided into several seams in the vicinity of Wabamun Lake. Elsewhere in Alberta, an important coal-bearing zone near the top of the Edmonton formation has been mined in the Ardley, Big Valley, and Wetaskiwin coal areas. Most coal seams are discontinuous laterally; two seams only a few miles apart may appear to be at the same stratigraphic level, but in places they are found to lens out and others appear at slightly different levels. Electrolog records, principally self-potential and resistivity curves, from numerous oil and gas wells drilled in Alberta between the Bow and Athabasca Rivers, indicate that the coal-bearing unit near the top of the Edmonton formation is continuous between the Ardley and Pembina coal areas (M. Fuglem, oral communication).

In most places throughout the Pembina coal area the coal-bearing unit can be divided into two main seams with a few thinner seams below. The two main seams are generally about 10 feet thick and are separated by an interval of from a few inches to 30 feet of shale and sandstone. The thick seams have been termed the Upper Main and Lower Main seams in this report, and the thinner seams below have been termed the First Lower, Second Lower, Third Lower, and Fourth Lower seams, in descending order. Sections of the Pembina coal-bearing zone are given in figure 3 for Coal Arch, Mount Royal Collieries pit on the south shore of Wabamun Lake, the Wabamun pit of Alberta Coal Limited, and for the Pembina River section at the Pembina Peerless Coal Company pit. The lower parts of sections 2 and 3 have been plotted from drill-hole data supplied by Calgary Power Limited and Canadian Utilities Limited, as this information is not available in present pit operations. The most compact coal section which was observed is at Coal Arch on the North Saskatchewan River (Lsd.1, Sec. 32, Tp. 50, R. 3, W. 5th Mer.), where a 24-foot section of coal includes only 3 feet of shale and bone.

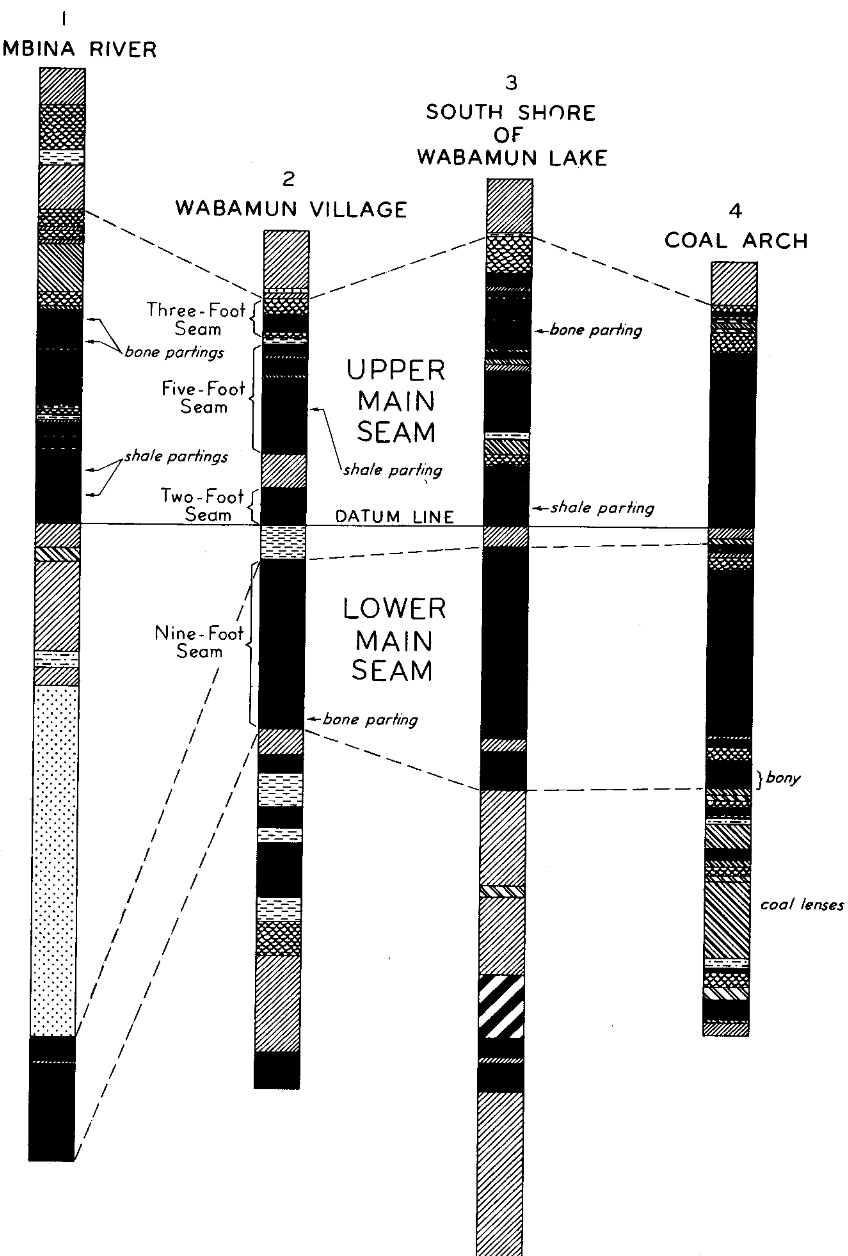

FIGURE 3

Sections Through The Pembina Coal-Bearing Zone, Wabamun Lake District, Alberta

1. Pembina Peerless Coal Company pit and nearby outcrops, NW$\frac{1}{4}$ Sec. 2, Tp. 54, R. 7, W. 5th.
2. Alberta Coal Limited 1957-58 pit, Lsds. 2 and 3, Sec. 15, Tp. 53, R. 4, W. 5th.
3. Mount Royal Collieries Limited pit, Lsds. 4 and 5, Sec. 29, Tp. 52, R. 4, W. 5th.
4. Coal Arch, North Saskatchewan River, Lsd. 1, Sec. 32, Tp. 50, R. 3, W. 5th.

The following section was measured at Coal Arch:

		Feet
	Till, brown Shale and ironstone, brown-weathering Shale, light-grey	10 - 15
Upper Main seam	Coal, soft and bony	0.3
	Coal	0.1
	Coal, soft and bony	0.3
	Clay, brown, bentonitic	0.1
	Shale, black, carbonaceous, with small lenses of bright coal	0.3
	Clay, brownish-grey, bentonitic	0.2
	Coal, bony	0.3
	Coal, banded, bony in top 0.8 feet	1.3
	Coal, bright	0.3
	Coal, dull, soft	0.3
	Coal, bright and massive	4.0
	Coal, banded	4.8
	Shale, dark-chocolate-brown	0.7
	Shale, black, carbonaceous	0.3
Lower Main seam	Coal, bright, massive	0.5
	Shale, grey-brown	0.1
	Coal, hard and bony with small lenses of bright coal	0.8
	Coal, banded	9.3
	Shale, medium-grey	0.4
	Coal, bright and massive	0.3
	Coal, hard and bony with bright lenses	0.8
	Coal, banded	0.7
	Coal, mainly banded, some interlayered bone	0.8
	Shale, black, carbonaceous	0.4
	Clay, bentonitic	0.3
	Shale, black, and bone	0.4
	Coal, dull and banded	0.3
	Coal, soft and bony	0.1
	Siltstone, hard, dark-grey to black, specks and lenses of bright coal	0.3
	Clay, light-grey, silty	0.1
	Bone and black carbonaceous shale with siltstone layers, specks and lenses of bright coal in the shale	1.4
	Coal	0.5
	Shale, black, soft	0.4
	Shale, black, with coal layers	0.5
	Clay, bentonitic	0.3
	Shale, black, hard	0.3

Shale, black and carbonaceous, bright coal layers and lenses	1.7
Shale, black	2.3
Siltstone, light-grey, micaceous	0.6
Shale, black, hard	0.2
Coal, bony	0.8
Clay, bentonitic	0.8
Coal, banded, good quality	0.9
Shale, black, soft	0.2
Shale, light-grey	0.7
(River level)	

Along strike to the northwest, shale partings become more numerous in the Upper Main seam. The following section was measured in the Mount Royal Collieries Limited pit, on the south shore of Wabamun Lake:

		Feet
	Till, brown	10.0
	Shale, medium-grey	2.5
	Shale, dark-grey	0.5
	Shale, chocolate-brown	0.3
Upper Main seam	Coal, bony	2.3
	Coal	0.8
	Shale, light-grey, silty	0.2
	Coal, friable	0.2
	Coal and grey shale, interbedded	0.2
	Coal, slightly bony	1.0
	Siltstone, grey	0.1
	Shale, light-grey	0.2
	Coal	0.7
	Shale, light-grey	0.1
	Coal	0.5
	Bone	0.1
	Coal	0.3
	Shale, black	0.2
	Shale, black, rusty-weathering	0.1
	Coal	0.3
	Shale, black, coal lenses	0.3
	Coal	3.5
	Shale, dark-grey	0.3
	Siltstone, grey	0.2
	Shale, black	0.7
	Siltstone, dark-grey	0.2
	Coal and black shale	0.5
	Shale, dark-grey	0.2
	Coal, discontinuous shale partings in upper 1 foot	3.1
	Sandstone, grey, silty	0.1
	(Pit floor level)	

In the Alberta Coal Limited pit near the village of Wabamun, this Upper Main seam is divided by the operators into three seams which are 3, 5 and 2 feet thick, in descending order, and the Lower Main seam is here termed the Nine-Foot seam. The Nine-Foot and Two-Foot seams are mined in entirety, and about 2 feet of coal are at present recovered from the Five-Foot seam for sale on the domestic market. The following section was measured at the eastern end of the 1957-58 pit:

		Feet
	Clay, brown-weathering, with scattered clay-ironstone nodules	2.0
	Shale, grey	3.0
	Clay, grey	0.3
	Sandstone, buff to grey, soft, salt-and-pepper texture	0. to 3.0
	Shale, greyish-brown	0.3
Three-Foot seam	Bone	1.0
	Coal, poor quality	1.0
	Shale, brown	0.1
	Shale, black, coal lenses	0.3
	Shale, light-brown	0. to 0.5
	Shale, light-grey	0.1 to 0.2
Five-Foot seam	Coal, poor quality	0.5
	Shale, light-grey	0.1
	Coal, poor quality	0.8
	Shale, black	0.2 to 0.3
	Coal, poor quality	1.5
	Shale, light-grey	0.1
	Coal, bright and banded, good quality	2.6
	Clay, grey	2.0
Two-Foot seam	Coal, good quality	2.0
	Shale, dark-brown	1.5
	Shale, greyish-brown	1.0
Nine-Foot seam	Coal, banded, good quality	9.0 (approx.)
	(Pit floor level)	

Farther west on the Pembina River, 25 to 30 feet of shale and hard, grey sandstone separate the Upper and Lower Main seams. Both seams have been mined by the Pembina Peerless Coal Company (C. Ostertag, operator) in Lsd. 12, Sec. 34, Tp. 53, R. 7, W. 5th Mer. and in the NW. 1/4 of Sec. 3, Tp. 54, R. 7, W. 5th Mer. Only the Upper Main seam is exposed in the present pit operation. The following section was measured:

	Feet
Shale, black, and bone	2.5
Shale, dark-brown	1.0
Shale, greyish-brown	2.4
Shale, black, and coal (bone)	0.9
Shale, brownish-grey	0.3
Shale, black, and coal (bone)	0.5
Shale, black	0.1
Clay, grey, with shaly partings	0.3
Shale, black	2.8
Bone, soft	0.8
Shale, black, and coal	0.3
Clay, grey	0.1
Coal, bony	2.0
Bone, soft	0.3
Coal, good quality	3.0
Shale, brown	0.2
Bone, soft	0.3
Shale, brown	0.3
Coal and dark-grey shale	0.2
Coal	0.7
Shale, brown, and coal	0.1
Coal	0.5
Shale, brown	0.1
Coal, good quality	1.2
Shale, brown	0.1
Coal, good quality, with thin shale partings near the middle	3.0
(Pit floor level)	

Operations in the Gainford and Evansburg collieries were believed (Rutherford, 1928) to be in a seam below the Wabamun seam, but are more likely in the lower part of the Pembina coal-bearing zone. At Gainford and Evansburg, however, the Lower Main seam is separated from the Upper Main seam by a sandstone and shale wedge which thickens to the west. Thus in the eastern part of the Pembina area, the coal probably accumulated in a swamp environment receiving very little transported sediment, whilst farther west the environment was more that of a flood-plain type, with rapid sedimentation sometimes taking place.

The Paskapoo Formation

Massive grey, buff-weathering sandstones with a few, thin shale bands overlie the Edmonton shales in the Pembina coal area, indicating a change from quiet fresh-water sedimentation to deltaic or flood-plain conditions. The sandstones are very similar to the sandstone beds of the Edmonton formation, as both have a salt-and-pepper texture, and contain numerous small disseminated coal fragments. Similar sandstones overlie the Edmonton formation along the Red Deer River valley between Drumheller and Red Deer. These sandstones were termed Paskapoo by Allan and Sanderson (1945), following Tyrrell's original term for similar rocks exposed along the Blindman River near its confluence with the Red Deer River about 6 miles north of Red Deer. Allan and Sanderson (1945, p. 27) described the Paskapoo as consisting,

> "chiefly of soft, grey, clayey sandstones, soft shales and clays slightly indurated. In the lower part of the formation there is a coarse, more or less uncemented sandstone weathering to buff colour and of uniform character over a large area. The formation is of freshwater deposition and contains freshwater fossil shells, chiefly mollusks."

The sandstones in the Pembina coal area fit this description except that they contain less clay and shale. Following Rutherford (1928), they are placed in the Paskapoo formation.

Dinosaur remains are abundant in the Edmonton formation along the Red Deer valley above Drumheller (Allan and Sanderson, 1945; Sternberg, 1947). The upper part of the Edmonton formation contains a ceratopsian fauna, dating it as Lance or latest Cretaceous in age. No dinosaur remains have been reported from the Paskapoo formation, which is therefore considered to be of lower Tertiary age. Allan and Sanderson consider that the Paskapoo formation lies unconformably on the Edmonton formation in the Drumheller area; they believe that in places the upper and middle members of the Edmonton formation are absent.

At Fallis, on the north shore of Wabamun Lake, massive Paskapoo sandstone lies on a thick coal seam in the upper part of the Edmonton formation, although the section examined is probably part of a block which has slumped. The contact is apparently disconformable for it is irregular, and the basal sandstone contains pebbles of quartzite and shale. This bed is overlain by sandstone containing pebbles of grey siltstone and shale, coal and quartzite, pebbles and boulders of clay ironstone, and scattered coal lenses. The following section was measured:

	Feet
Sandstone, buff, medium- to coarse-grained, with small coal fragments	50.0
Sandstone with pebbles of grey siltstone, shale and quartzite, scattered coal lenses, pebbles and boulders of clay-ironstone	1.0 to 2.0
Sandstone or grit, massive and coarse grained, with pebbles of quartzite and shale up to 0.25 inches across	0 to 0.7
(Disconformable surface)	
Bone and black shale	0.1 to 0.3
Siltstone, black, massive	0.3
Coal, weathered and soft	0.3

Shale, dark-brown to black	0.5
Coal	1.0
Shale, black, with white fibrous gypsum stringers	0.3
Coal	1.0
Coal, bony, with white gypsum stringers	0.3
Coal	0.7
Shale, grey and bentonitic	0.1
Coal	2.0
(Lake level)	

Along the Pembina River 14 miles to the west of Fallis, there are at least 100 feet of shales above the thick Pembina coal-bearing zone and beneath 50 to 75 feet of massive Paskapoo sandstone which forms the upper half of the gorge cliffs at Entwistle and Evansburg. The Paskapoo strata apparently change facies rapidly, for Rutherford (1928, p. 18) states that 5 miles south of Evansburg the massive sandstone "lenses out rapidly to the south into alternating beds of shales and argillaceous sandstones."

Recently some doubt has been cast on whether the Paskapoo-Edmonton contact actually is disconformable (W. M. Merrill, oral communication). It may represent only local erosion along early Tertiary river courses, a type of large-scale "wash-out", later filled in by sands and gravels brought down by the rivers.

<u>Pleistocene and Recent Deposits</u>

A thick mantle of glacial tills, sands and gravels overlies most of the Edmonton and Paskapoo strata around Wabamun Lake. The glacial geology of the region has been recently described by Collins and Swan (1955), and so will not be discussed at length in this report.

Unconsolidated sands and gravels, known as the Saskatchewan gravels, overlie the bedrock and underlie glacial deposits in certain parts of the Wabamun Lake district. The gravels are widely distributed between Wabamun and Isle Lakes at points of relatively high relief, but do not occur along the lower parts of old drainage channels. They lie a few feet above the upper coal seam at Wabamun, where they reach a maximum of 15 feet in thickness, and are recovered during the coal-stripping operation. The Saskatchewan gravels are generally believed to be of Upper Tertiary age, but may be of early Pleistocene age. They are considered to be preglacial deposits because they contain arkosic and quartzitic sandstone pebbles derived from the west, rather than pebbles of Precambrian granite and gneiss from the north and northeast.

Glacial tills and associated sands and gravels cover the Wabamun Lake district, except for a belt a few miles wide along the south shore of Wabamun Lake. They are generally less than 50 feet in thickness, except along the courses of buried channels where they exceed 150 feet in places. The tills are largely clayey to sandy in texture, and vary from grey to brown in color.

Where Paskapoo sandstones are at or close to the surface, they appear to have been reworked, possibly by water from melting ice. An extensive mantle of buff-colored sands, resembling those of the Paskapoo formation, and generally only a few feet thick, is spread over the land south and west of Wabamun Lake.

Structure

The Cretaceous and Tertiary strata in the Wabamun Lake district have a dip of between 20 and 50 feet per mile to the southwest. The dip is modified by small anticlines and synclines (termed "rolls" by the local mine operators), with dimensions of a few hundred feet from crest to trough. A syncline is well exposed along the pit face at Wabamun. These "rolls" are probably near-surface features only, produced by ice movement during Pleistocene times (C. P. Gravenor, oral communication). Their axes are commonly found to be at right angles to the direction of ice movement.

Considerable slumping has occurred along the North Saskatchewan River in the vicinity of Coal Arch. The arch itself is a slump structure, probably having dropped almost 100 feet from its original position. A small pit, located in Lsd. 13, Sec. 22, Tp. 50, R. 3, W. 5th Mer., in the Upper Main seam of the Pembina coal-bearing zone about 2 miles southeast of Coal Arch, shows the top of the Upper Main seam to be almost at the surface, and at an elevation of over 2,400 feet or at least 150 feet higher than the seam at Coal Arch. The coal seam at this pit has a dip of several degrees to the west, probably the result of ice action. The coal seams along this section of the North Saskatchewan River are discontinuous, as they have been disturbed by both glacial action and slumping along the sides of the river valley.

CHAPTER III

COAL RESERVES

Distribution of Coal

The coal seams in the Wabamun Lake district have a regional dip averaging about 35 feet per mile to the southwest. Thus the coal seams are cut off at the pre-Pleistocene erosion surface to the north and northeast of the Wabamun field. To the southwest of Wabamun Lake they are too deeply buried to be economically recoverable by open-pit mining at present. Drilling results indicate that the same coal-bearing strata extend from Wabamun to the Pembina River north of Entwistle, where coal outcrops along the sides of the river valley. Between the Pembina River and Wabamun Lake, however, all the coal is too deeply buried to be recovered by stripping methods, except for a small amount near Gainford (see Fig. 2). Coal is absent along most of the northwest side of Isle Lake, where it was eroded in preglacial times and a till and gravel deposit occupies a preglacial drainage channel. Coal is present near the surface along all of the south shore of Wabamun Lake between the villages of Seba Beach and Highvale, as shown in figure 2. It was anticipated that to the east of Highvale, near-surface coal would trend in a southeasterly direction towards Coal Arch on the North Saskatchewan River. However, drill holes in this area went through up to 180 feet of glacial till, but no coal. It appears that, in pre- or early-glacial times, a drainage channel connected the sites of the present lake and river, and was subsequently filled with till. One drill hole (No. 30), on the western margin of the buried channel, intersected a 16-foot section of coal and bone. This intersection suggests that the Wabamun or Pembina seam is, in fact, continuous with the seam at Coal Arch, except where removed by preglacial erosion.

The coal seams rarely lie within 30 feet of the surface north of Wabamun Lake because of the blanket of surficial Pleistocene deposits. The lower seams extend farther northeast beneath the drift cover because of the southwesterly dip of the formations. The surficial deposits are very thin south of Wabamun Lake, and so here the coal seams approach very close to the surface.

About 50 feet east of the Mount Royal Collieries pit, on the south shore of Wabamun Lake, boulders of burnt coal and shale are present in the bank. Two holes drilled by Canadian Utilities Limited in Lsds. 2 and 3, Sec. 29, Tp. 52, R. 4, W. 5th Mer., intersected burnt coal and shale near the surface (written communication). About 6 feet of burnt coal and shale were encountered at the top of hole No. 27, drilled at Highvale. The burnt rock is probably an erratic transported from a nearby locality by ice. Thus the upper coal seam in the area around the southeast end of Wabamun Lake apparently has been burnt out, but the eastern limits of burning are not known.

Structure contours on the top of the Upper Main seam throughout most of the Wabamun Lake district are presented in figure 2. These contours have been constructed from drill-hole data, field observations, mine records, and oil company records supplied by the Oil and Gas Conservation Board. The structure contours are accurate only in those areas which were drilled in some detail. Examination of figure 2 indicates that the coal seams do not have a uniform dip to the southwest, but vary between 20 and 50 feet per mile in amount and between south and west in direction. About 1 mile south of Seba Beach, however, on the eastern flank of a large syncline, dips as great as 100 feet per mile occur for distances of up to half a mile. Local steep dips are indicated in drill-hole data supplied by Calgary Power Limited for their work north of Wabamun Lake. There, two holes which are 230 feet apart cut the Upper Main seam at elevations which imply an average dip of 18 degrees between the holes. A syncline which is at present exposed in the working face of the Alberta Coal Limited pit at Wabamun has dips of 5 degrees on each flank. The larger fold-like structures have northeast trending axes, but some of the smaller rolls appear to be oriented at random. The large synclinal structure between Wabamun and Isle Lakes, as shown in figure 2, has smaller associated anticlines on each flank.

Thicknesses of overburden above the Upper Main seam are shown in figure 2 by isopachs. The isopachs are considered to be precise only in those areas in which drilling was done by the Research Council of Alberta, and in the area north of Wabamun which was drilled by Calgary Power Limited. Three areas, each underlain at depths of less than 75 feet by 10 million tons or more of strippable coal, are indicated in figure 2. The coal north of the village of Wabamun was outlined by Calgary Power Limited, and that near Gainford and between Seba Beach and Highvale has been outlined as a result of the work described in this report. Strippable coal occurs along the Pembina River valley north of Entwistle, but detailed work would be required to determine the reserves, as the coal is deeply buried both east and west of the valley. Available information did not warrant the plotting of isopachs along the river valley. Coal is present near the surface along the north shore of Wabamun Lake, but only in a very narrow belt. Near-surface coal probably also occurs in the southeastern part of the Wabamun Lake district, in the vicinity of Coal Arch. As previously mentioned, the bedrock has been much disturbed by slumping along the sides of the North Saskatchewan River valley and by ice action. In the absence of drill-hole data, it is impossible to make any reliable estimate of the coal reserves there or to plot isopachs.

The hatched areas in figure 2 indicate where coal might be expected if the seams had not been eroded away prior to Pleistocene times. These areas should be considered as interpretive rather than as defined. Calgary Power Limited (written communication) found that:

> "In all knolls and hills drilled, depth to the coal measures is less than in the flats and swamps nearby. The bedrock erosion surface and the surface topography generally rise and fall together."

The bedrock surface probably rises beneath knolls and hills because of the presence of "rolls" in such places. If these "rolls" are due to squeezing during ice movement, then the present topographic surface was controlled by the mechanics of glacier flow rather than by the distribution of till by the glacier.

Description of Coal Seams

Only coal seams in the two areas underlain by considerable reserves of strippable coal which was outlined by drilling are described here.

(1) Near Gainford, at the southwest end of Isle Lake, drill holes Nos. 1, 2, 6, and 7 intersected coal, as shown in the logs (Appendix 1) and sections (Fig. 4). The Upper Main seam was encountered only in hole No. 7, where it is 8 feet thick and contains a bone or shale parting, one-half foot thick, in the middle. This seam is missing in hole No. 6, probably because the coal-bearing strata are near to the pre-Pleistocene erosion surface. Only one thick coal seam, overlain by thick sandstones of Paskapoo type, is present in holes Nos. 1 and 2. It is

probable that this seam represents the Lower Main seam of the Pembina coal-bearing strata, the Upper Main seam having been removed during a period of erosion in pre-Paskapoo time, prior to the deposition of the sandstones. However, the coal seam in hole No. 2 is about 75 feet higher in elevation than the seam in hole No. 1, half a mile to the north, and so could be a seam higher than the Pembina coal-bearing zone; if not, then it must be on the crest of a "roll". In hole No. 7, the Upper Main seam is separated from the Lower Main seam by 22.5 feet of grey shales and silty shales. The thickness of the intervening strata is in accordance with the trend shown in figure 3, where the sediments between the two main seams thicken markedly westwards from Wabamun to the Pembina River.

The Lower Main seam consists of interlayered coal and grey shale, with almost as much shale as coal in most of the holes. Hence the seam is generally unsuitable for mining, although it was this seam which was mined by underground methods at Gainford during the years 1912 to 1914. The thin lower seams beneath the Lower Main seam, which are present both north and south of Wabamun Lake, were intersected in only one of the holes (No. 1) drilled near Gainford.

(2) Between Seba Beach and Highvale on the south shore of Wabamun Lake, a thick coal sequence which appears to be at the same stratigraphic level as the coal at Wabamun Village and at Gainford, lies near the surface. The two main seams, each about 10 feet thick, are separated by only 1 to 4 feet of brown shale. In each deep drill hole which encountered the main seams south of the lake, four or five lower seams, varying in thickness from 1 to 3 feet, were also found. They lie in a 25-foot section of grey shales beneath the Lower Main seam, and are remarkably constant in thickness and relative position for 13 miles between

Seba Beach and Highvale. This similarity is illustrated by the electrolog resistivity curves shown in figure 5.

The Lower Main seam is likewise very persistent throughout the area. It varies from 8 to 11 feet in thickness and always contains two or three narrow bone or shale partings in its upper part. It appears to be a good quality coal throughout. The bone and shale partings vary from less than 1 inch to 1 foot in thickness, and the coal layers are generally 1 to 6 feet thick, although up to 9 feet of massive coal were intersected in some holes.

The Upper Main seam is the least persistent between Seba Beach and Highvale. It varies from 6 to 13 feet in thickness and contains several bone and shale layers (Appendix I, and Figs. 4 and 5). In places these layers are narrow partings, and the seam contains as much as 8 feet of massive coal. More commonly, however, the shale and bone partings vary from less than 1 inch up to 3 feet in thickness, and the coal layers vary from 1 to 5 feet in thickness. The seam tends to be more massive in the east, and tends to have thicker shale partings westward. Apparently conditions were not ideal for coal deposition at the time that this upper seam was accumulating, as several periods of inorganic sedimentation interrupted peat accumulation. These changes may have been precursors of the earth movements which influenced the deposition of the massive Paskapoo sandstones a short time later. Brown shales are commonly associated with the coal in the Upper and Lower Main seams, rather than the grey shales which lie above and below the coal-bearing strata. This brown color probably results from a small content of carbonaceous material. A very persistent brown shale zone above the Lower Main seam (or Nine-Foot seam) north of Wabamun was noted in drill logs provided by Calgary Power Limited.

Subsurface Water Conditions

Near Gainford and between Seba Beach and Highvale the strippable coal deposits are both low-lying and adjacent to lakes. In both places, therefore, water would probably be a serious problem in any mining operations.

Holes drilled near Gainford encountered large quantities of water at shallow depth. Gainford Colliery and a number of small nearby strip mines have remained open for only short periods, due largely to severe flooding. In view of the low tonnage of strippable coal, and the large quantities of near-surface groundwater, no further study of groundwater conditions in the Gainford area was attempted.

Along the south shore of Wabamun Lake, coal outcrops at lake level (2,378 feet) in the western part, and a few feet above lake level in the eastern part. At the Mount Royal Collieries property (Lsds. 4 and 5, Sec. 29, Tp. 52, R. 4, W. 5th Mer.) the Upper Main seam is above water level, but the Lower Main seam is below. As the regional dip is to the southwest, at about 50 feet per mile south of the lake, all the coal seams are below lake level about half a mile to the south. The rate of flow of water in the coal seams depends upon (a) their permeability which in turn depends upon the distribution of fractures in the coal, and (b) whether the coal is actually in contact with the lake, or separated from it by impervious glacial till.

In order to estimate the volume of water which would have to be pumped from a pit during its operation, bailing tests were carried out in nine of the drill holes south of Wabamun Lake. Details of the bailing-test technique and a summary of the method of estimating the rate of flow of groundwater are given in Appendix II. Values for the transmissibility (T) in gallons per day per foot and the discharge flow (Q) in gallons per day have been calculated for groundwater in each of the nine holes (Table 1).

TABLE 1

Results of Bailing Tests for Holes Along the South Shore of Wabamun Lake

Hole No.	Elevation of top of Upper Main seam (feet)	Elevation of water table (feet)	Transmissibility (gallons per day per foot)	Discharge flow (gallons per day)
14	2,348	2,348	446	162,000
15	2,400	2,395	130	15,600
18	2,390	2,389	43	7,100
20	2,393	2,388	4,800	more than 250,000
21	2,394	2,384	84	7,900
22	2,377	2,395	34	9,600
24	2,394	2,424	54	17,100
26	only lower seams present	2,424	64	16,000
27	2,418	2,436	1,065	25,400

The values for transmissibility and discharge flow hold only at the exact site of the drill hole, because groundwater flow is very sensitive to the distribution of small fractures within the aquifer. Similarly, there are liable to be major fracture zones within the coal seams which would act as conduits, and create zones of anomalously high groundwater flow (R. N. Farvolden, oral communication). However, apart from holes Nos. 14 and 20, the determined rates of discharge flow are surprisingly uniform, and indicate that water would not create too great a problem in any mining operation along the south shore of

Wabamun Lake. A discharge flow of 100,000 gallons per day means that water would have to be pumped out at that rate, which is about 70 gallons per minute. Since the water would not have to be raised more than about 100 feet, a 5-horsepower pump should be adequate for this work. Zones with a high discharge flow, such as near hole No. 20, would, however, have to be avoided.

Estimation of Coal Reserves

(i) The Gainford Field

On the basis of four drill holes, coal is believed to be present within 75 feet of the surface under 1,600 acres (2.50 square miles). It is estimated that there is a thickness of at least 6 feet of mineable coal, and if the coal has a specific gravity of 1.29, then reserves total 16 million short tons. Owing to the proximity to Isle Lake, serious flooding will probably be encountered in any mining operation.

(ii) The Seba Beach - Highvale Field

Drill-hole data indicate that between Seba Beach and Highvale approximately 6,750 acres (10.54 square miles) are underlain by coal having 75 feet or less of cover. If it is assumed that there is a total thickness of 12 feet of mineable coal, with a specific gravity of 1.29, the reserves are 140 million short tons. It is possible that as much as 15 feet of coal could be mined throughout the field; then the reserves would amount to 180 million short tons. These figures are maximum values for the coal potential of the area. Detailed drilling may show that the coal is unexpectedly absent or burned out in certain places. However, a conservative estimate is more than 100 million tons of strippable coal. An overburden ratio of about 6/1 has been used as the economic limit for strip-mining. A large operation should be able to work economically at a ratio of up to 10/1, thereby increasing the estimated coal reserves by approximately 50 per cent.

CHAPTER IV

COMPOSITION OF THE COAL

Chemical Data

The coal in the Pembina coal area is subbituminous B according to the Canadian classification (Stansfield and Lang, 1944). It is an Alberta domestic coal, and is free burning and smokeless. In their report, Stansfield and Lang divide the Pembina area into three districts, and give the typical analyses shown in table 2, compiled from analyses made in the Coal Analytical Laboratory of the Research Council of Alberta.

TABLE 2

Typical Coal Analyses for the Pembina Coal Area
(After Stansfield & Lang, 1944)

Proximate and ultimate analyses in weight per cent

	District		
	A	B	C
Proximate			
Moisture	19.3	21.4	20.5
Ash	10.3	8.0	6.3
Volatile matter	26.7	28.3	28.7
Fixed carbon	43.7	42.3	44.5
Ultimate			
Carbon	53.8	53.0	--
Hydrogen	5.4	5.7	--
Sulfur	0.2	0.8	--
Nitrogen	0.8	0.7	--
Oxygen	29.5	31.8	--
Ash	10.3	8.0	--
Fuel ratio	1.65	1.50	1.55
Gross B.t.u. per lb.	9,070	8,920	9,500
Net B.t.u. per lb.	8,580	8,400	--

District A	Evansburg (Tp. 53, R. 6, W. 5th Mer.)
District B	Wabamun (Tp. 53, R. 4, W. 5th Mer.)
District C	Genesee (Tps. 50-51, R. 3, W. 5th Mer.) (mean of two samples only)

Analyses are also available in the Research Council of Alberta files for coal from a former strip mine on the southeast shore of Isle Lake (table 3, No. 1) and from a former small strip mine near Coal Arch (table 3, No. 2), both of which worked the Upper Main seam of the Pembina coal-bearing zone.

TABLE 3

Coal Analyses, Pembina Area (on a capacity moisture basis)

Proximate and ultimate analyses in weight per cent

	1	2
Proximate		
Moisture	28.4	20.7
Ash	7.0	6.6
Volatile matter	27.4	27.1
Fixed carbon	37.2	45.6
Ultimate		
Carbon	45.80	55.5
Hydrogen	5.60	5.6
Sulfur	0.20	--
Nitrogen	0.70	--
Oxygen	40.7	--
Ash	7.0	6.6
Fuel ratio	1.36	1.68
Gross B.t.u. per lb.	7,250	9,280

1. Gainford Collieries, mine No. 1409, located in the SE. 1/4 of Sec. 36, Tp. 53, R. 6, W. 5th Mer. (sampled and analysed in 1938).

2. H. H. Wright mine, mine No. 1606, located in Sec. 31, Tp. 50, R. 3, W. 5th Mer. (sampled and analysed in 1943).

The very high moisture and low fixed carbon contents of the Isle Lake sample suggests that the coal was highly oxidized (J. F. Fryer, oral communication).

Analyses for the Wabamun open-pit coals have been provided by Calgary Power Limited (written communication). One sample of each of the Five-Foot and Two-Foot seams (equivalent to the Upper Main seam), and the Nine-Foot seam (equivalent to the Lower Main seam) are given in Table 4.

TABLE 4

Coal Analyses, Alberta Coal Limited Pit, Wabamun

Proximate analyses in weight per cent

	Five-Foot seam	Two-Foot seam	Nine-Foot seam
Proximate			
Moisture	19.6	21.4	20.5
Ash	11.3	4.9	8.07
Volatiles	27.0	28.9	27.92
Fixed carbon	42.1	44.8	43.51
Fuel ratio	1.56	1.55	1.56
Gross B.t.u. per lb.	8,580	9,210	8,971

These values are similar to the typical analyses given by Stansfield and Lang (Table 2), except for the low ash content of the Two-Foot seam.

Four analyses (Table 5) have been made in the Coal Analytical Laboratory of the Research Council of Alberta on samples collected from holes drilled along the south shore of Wabamun Lake.

TABLE 5

Analyses of Coal from South of Wabamun Lake
(a - on capacity moisture basis)
(b - on dry basis)

Proximate analyses in weight per cent

	1		2		3		4	
	a	b	a	b	a	b	a	b
Proximate								
Moisture	21.2	0.0	21.8	0.0	23.2	0.0	18.4	0.0
Ash	9.4	11.9	14.9	19.0	9.9	12.8	11.9	14.6
Volatile matter	27.4	34.8	24.4	31.3	26.5	34.5	27.4	33.6
Fixed carbon	42.0	53.3	38.9	49.7	40.4	52.7	42.3	51.8
Fuel ratio	1.53	1.53	1.59	1.59	1.52	1.53	1.54	1.54
Gross B.t.u. per lb.	8,700	11,050	8,000	10,230	8,340	10,860	8,720	10,690

1. Chip sample collected across Lower Main seam in hole No. 13, interval 72.5 to 82.0 feet.

2. Chip sample collected across Upper Main seam in hole No. 17, interval 63.5 to 70.5 feet.

3. Chip sample collected across Lower Main seam in hole No. 17, interval 71.5 to 81.5 feet.

4. Sample of drill core across Lower Main seam in hole No. 23, interval 17.3 to 28.0 feet. Core quartered for sample.

Analyses made in the Coal Analytical Laboratory, Research Council of Alberta.

Collecting drill chips is not a very satisfactory method of obtaining samples for analysis, but, in the absence of cores, it was the only method available. The results obtained are similar to the various other Pembina coal area analyses, although analysis No. 2 suggests that the Upper Main seam has a rather high ash content. This is probably due to the incorporation of several thin bone and shale partings in the sample even though any visible shale fragments were hand-picked from the samples. Analysis No. 4 was made on the most representative sample, obtained from an almost complete drill core across 10.7 feet of Lower Main seam.

When the gross calorific values given for the analyses in tables 2 to 5 are converted to a mineral-matter-free basis, they almost all fall within the range 9,500 - 10,000 B.t.u. per pound. Hence, the Wabamun coals are at the lower end of the subbituminous B coal group, according to the Canadian classification. Subbituminous B coals are those which are both weathering and non-agglomerating, and have gross calorific values within the range 9,500 to 11,000 B.t.u. per pound on a moist mineral-matter-free basis.

Petrographic Data

A brief examination has been made of coal samples collected from the drill holes in order to identify the coal rock types in the seams. The classification suggested by Hacquebard (1951), which is a compromise between the German (Stach, 1935) and the United States (Park and O'Donnell, 1948) classifications, has been adopted. Four rock types are used, as shown in table 6.

TABLE 6

Petrographic Classification of Coal (After P. A. Hacquebard, 1951)

Rock Type	Percentage of vitrinite	Appearance	Percentage of opaque matter
Vitrain	100 - 96	bright coal	less than 20
Clarain	95 - 51		
Claro-Durain	50 - 21	dull coal	20 - 30
Durain	20 - 0		more than 30

Samples of coal cuttings from the drill holes were examined by means of a stereoscopic microscope at magnifications up to 40, and qualitatively classified according to the widths and frequencies of bright and dull bands. Vitrain has been taken to include that bright material in bands of 1 mm. or more in width. Precise results can be obtained by using counting techniques on thin or polished sections.

All seams in the Wabamun Lake district are thinly layered, and the four rock types - vitrain, clarain, claro-durain, and durain - are intimately mixed in the heterogeneous coal mass. Clarain generally predominates, but vitrain is present in lenses up to 5 mm. thick in some samples; the coals are essentially bright, with lenses and layers of dull coal. Examination of samples from drill holes south of Wabamun Lake indicates that the major parts of the two main seams are bright coals consisting largely of vitrain and clarain. The lower parts of these seams contain more dull coal and consist largely of clarain, claro-durain and durain. The coal in the First Lower seam is intermediate (clarain and claro-durain); the Second Lower seam contains dull coal (clarain, claro-durain and durain); the Third Lower seam contains generally bright coal (vitrain, clarain and claro-durain); and the coal in the Fourth Lower seam is intermediate (clarain and claro-durain).

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APPENDIX I

DRILL - HOLE LOGS

The following logs are based on the driller's logs, samples collected at 5-foot intervals, and electrolog interpretations. Sections across coal seams where coal, bone, and shale are interlayered are based largely on electrolog interpretations. It is not possible to distinguish with certainty between bone and shale, but the rock type given first is considered the most probable. All depths are expressed in feet. Hole locations are shown in figure 2.

No. 1

Location: 40 feet west of NE. corner of
Sec. 14, Tp. 53, R. 6, W. 5th Mer.
Surface elevation: 2,436 feet.

0	- 4.0	clay, grey
4.0	- 15.0	muskeg
15.0	- 45.0	sandstone, buff, soft
45.0	- 60.0	sandstone, grey, soft
60.0	- 63.0	sandstone, grey, hard
63.0	- 100.0	sandstone, grey, soft
100.0	- 102.0	coal
102.0	- 102.5	bone or shale
102.5	- 108.0	coal
108.0	- 108.5	bone or shale
108.5	- 110.0	coal
110.0	- 127.0	shale, grey
127.0	- 129.0	shale, brown
129.0	- 130.0	shale, grey
130.0	- 131.8	coal
131.8	- 134.0	shale, grey
134.0	- 136.2	coal
136.2	- 138.0	shale, grey
138.0	- 139.0	bone
139.0	- 141.0	shale, grey
141.0	- 142.2	coal
142.2	- 142.5	bone or shale
142.5	- 143.9	coal
143.9	- 160.0	shale, grey

No. 2

Location: 2,360 feet south of NE. corner
of Sec. 14, Tp. 53, R. 6, W. 5th Mer.
Surface elevation: 2,450 feet.

0	- 1.5	till, brown, clay
1.5	- 30.5	sandstone, buff, soft
30.5	- 31.0	bone
31.0	- 38.7	sandstone, grey, soft
38.7	- 41.5	coal
41.5	- 42.3	shale, brown
42.3	- 44.5	coal
44.5	- 75.0	shale, grey
75.0		sandstone, grey, hard

No. 3

Location: At NE. corner of
Sec. 19, Tp. 53, R. 5, W. 5th Mer.
Surface elevation: 2,590 feet.

0	- 21.0	till, brown, clay
21.0	- 73.5	sandstone, buff, soft
73.5	- 74.0	coal
74.0	- 76.0	sandstone, soft
76.0	- 77.3	sandstone, hard
77.3	- 101.0	shale, grey
101.0	- 144.0	shale, grey
144.0	- 150.0	sandstone, buff

No. 4

Location: 2,650 feet south of NE. corner
of Sec. 28, Tp. 53, R. 5, W. 5th Mer.
Surface elevation: 2,611 feet.

0	- 5.0	till, brown, sandy-clay
5.0	- 11.0	sand, buff
11.0	- 25.5	gravel
25.5	- 68.0	sandstone, buff, soft
68.0	- 200.0	sandstone, grey, soft

No. 5

Location: 100 feet west of NE. corner of Sec. 13, Tp. 53, R. 5, W. 5th Mer.
Surface elevation: 2,600 feet.

0	- 13.0	sand, buff
13.0	- 17.5	gravel
17.5	- 93.0	sandstone, buff, soft
93.0	- 139.0	sandstone, grey, soft
139.0	- 142.3	coal
142.3	- 144.2	shale
144.2	- 144.8	coal
144.8	- 145.1	bone
145.1	- 146.2	coal
146.2	- 146.7	bone
146.7	- 149.0	coal
149.0	- 156.0	shale
156.0	- 157.2	coal
157.2	- 158.7	shale, brown
158.7	- 168.7	coal
168.7	- 173.2	shale, grey
173.2	- 175.8	shale, grey
175.8	- 176.8	coal
176.8	- 178.0	shale, grey
178.0	- 180.0	coal
180.0	- 182.2	shale, brown
182.2	- 183.8	coal
183.8	- 189.3	shale, brown
189.3	- 191.2	coal
191.2	- 191.8	shale, brown
191.8	- 192.9	coal
192.9	- 197.0	shale, brown
197.0	- 200.0	shale, grey

No. 6

Location: 490 feet south of NE. corner of Sec. 16, Tp. 53, R. 6, W. 5th Mer.
Surface elevation: 2,440 feet.

0	- 24.0	till, brown, sandy-clay
24.0	- 28.0	shale, grey, silty
28.0	- 30.0	siltstone, grey
30.0	- 32.5	shale, brown
32.5	- 40.7	coal
40.7	- 40.9	bone
40.9	- 41.2	coal
41.2	- 49.8	shale, grey and brown
49.8	- 50.5	coal
50.5	- 60.0	shale, grey
60.0	- 80.0	siltstone, grey
80.0	- 100.0	sandstone, grey

No. 7

Location: 2,885 feet south and 264 feet east of NW. corner of Sec. 20, Tp. 53, R. 6, W. 5th Mer.
Surface elevation: 2,408 feet.

0	- 5.0	till, brown, clay
5.0	- 7.0	till, grey, sandy-clay
7.0	- 8.0	gravel
8.0	- 20.0	till, grey-brown, sandy-clay
20.0	- 38.0	sand, buff
38.0	- 44.5	gravel
44.5	- 51.5	till, brown, clay
51.5	- 55.5	coal
55.5	- 56.0	bone or shale
56.0	- 60.0	coal
60.0	- 82.5	shale, grey, silty
82.5	- 85.0	coal
85.0	- 87.2	shale, grey
87.2	- 89.0	coal
89.0	- 110.0	shale, grey

No. 8

Location: 3,200 feet south of NE. corner of Sec. 34, Tp. 53, R. 6, W. 5th Mer.
Surface elevation: 2,419 feet.

0	- 27.0	sand, brown, clayey
27.0	- 46.0	sand, blue-grey, clayey
46.0	- 51.0	till, grey, sandy-clay
51.0	- 64.0	gravel

No. 9

Location: 2,900 feet south of NE. corner of Sec. 2, Tp. 54, R. 6, W. 5th Mer.
Surface elevation: 2,435 feet.

0	- 12.0	till, brown, sandy-clay
12.0	- 52.0	till, blue-grey, sandy-clay
52.0	- 56.0	sand and gravel
56.0	- 71.5	till, sandy-clay
71.5	- 82.0	gravel
82.0	- 103.5	till, brown, clay
103.5	- 117.0	shale, grey
117.0	- 160.0	brown shale

No. 10

Location: At NE. corner of Sec. 3, Tp. 54, R. 6, W. 5th Mer.
Surface elevation: 2,536 feet.

0	- 17.0	till, brown, sandy-clay
17.0	- 56.0	till, blue-grey, sandy-clay
56.0	- 75.5	gravel
75.5	- 85.0	shale, grey, silty
85.0	- 97.5	sandstone, grey, silty
97.5	- 103.5	coal
103.5	- 133.0	shale, grey
133.0	- 135.0	coal
135.0	- 137.0	shale, dark-grey
137.0	- 139.0	coal
139.0	- 155.0	shale, grey
155.0	- 170.0	sandstone, light-grey

No. 11

Location: 3,050 feet south of NE. corner of Sec. 19, Tp. 54, R. 7, W. 5th Mer.
Surface elevation: 2,476 feet.

0	- 8.0	till, brown, sandy-clay
8.0	- 40.0	till, grey, sandy-clay
40.0	- 122.0	sand, grey and buff, clayey
122.0	- 127.0	till, brown, clay
127.0	- 139.0	shale, brown with a few narrow coal layers
139.0	- 163.0	shale, brown
163.0	- 200.0	shale, grey, silty

No. 12

Location: 50 feet west and 50 feet north of SE. corner of Sec. 1, Tp. 53, R. 6, W. 5th Mer.
Surface elevation: 2,412 feet.

0	- 13.0	till, brown, clay
13.0	- 22.0	sandstone, grey, soft
22.0	- 28.0	sandstone, grey, hard
28.0	- 56.0	sandstone, grey, soft
56.0	- 65.0	shale, greenish-grey
65.0	- 118.0	shale, grey
118.0	- 120.0	shale, black
120.0	- 130.5	coal with narrow brown shale partings
130.5	- 132.5	shale, brown
132.5	- 133.7	coal
133.7	- 134.0	bone or shale
134.0	- 143.0	coal
143.0	- 148.5	shale, grey
148.5	- 150.0	coal
150.0	- 151.5	shale, brown
151.5	- 152.5	coal
152.5	- 153.0	shale, brown
153.0	- 156.0	coal
156.0	- 157.0	shale, brown
157.0	- 158.0	coal
158.0	- 158.5	shale, brown
158.5	- 162.0	coal
162.0	- 164.0	shale, brown
164.0	- 168.0	coal and brown shale
168.0	- 190.0	shale, grey

No. 13

Location: 250 feet north of SE. corner of Sec. 1, Tp. 53, R. 6, W. 5th Mer.
Surface elevation: 2,410 feet.

0	6.0	sand, buff, soft
6.0	25.0	sandstone, buff, soft
25.0	58.0	sandstone, grey
58.0	60.0	shale, brown
60.0	60.3	coal
60.3	62.0	shale, brown
62.0	63.0	coal
63.0	64.0	shale, brown
64.0	65.0	coal
65.0	66.0	shale, brown
66.0	67.0	coal
67.0	67.5	shale, brown
67.5	70.0	coal
70.0	72.5	shale, brown
72.5	73.5	coal
73.5	73.8	bone or shale
73.8	77.0	coal
77.0	77.7	bone or shale
77.7	82.3	coal
82.3	93.0	shale, grey
93.0	97.0	bentonite and grey shale
97.0	98.0	coal
98.0	98.3	bone or shale
98.3	100.0	coal
100.0	102.0	shale, brown
102.0	103.5	coal
103.5	107.0	shale, brown
107.0	109.0	bentonite and brown shale
109.0	109.3	shale, brown
109.3	111.5	coal
111.5	112.1	shale, brown
112.1	113.0	coal
113.0	140.0	shale, grey

No. 14

Location: 90 feet south of NE. corner of Sec. 31, Tp. 52, R. 5, W. 5th Mer.
Surface elevation: 2,420 feet.

0	12.0	till, brown, sandy-clay
12.0	27.0	shale, grey, silty
27.0	72.0	sandstone, grey, soft
72.0	75.0	coal
75.0	75.8	shale, brown
75.8	77.2	coal
77.2	77.5	bone or shale
77.5	82.5	coal
82.5	83.5	shale, brown
83.5	88.5	coal
88.5	89.5	shale or bone
89.5	94.5	coal
94.5	100.0	shale, grey

No. 15

Location: 1,510 feet south of NE. corner of Sec. 33, Tp. 52, R. 5, W. 5th Mer.
Surface elevation: 2,369 feet.

0	4.5	till, brown clay
4.5	13.0	coal, soft
13.0	14.0	bone
14.0	16.5	coal
16.5	18.5	shale
18.5	19.5	coal
19.5	20.0	shale, brown
20.0	28.0	coal
28.0	32.0	shale, grey
32.0	33.0	coal
33.0	36.5	shale, brown
36.5	39.0	coal
39.0	41.5	shale, grey
41.5	42.5	coal
42.5	43.0	shale, grey
43.0	44.0	bone or shale
44.0	45.0	shale, grey
45.0	46.0	bone or shale
46.0	48.0	shale
48.0	50.0	coal
50.0	50.5	shale, grey, or bone
50.5	51.5	coal
51.5	60.0	shale, grey

No. 16

Location: 30 feet south and 50 feet east of NW. corner of Sec. 27, Tp. 52, R. 5, W. 5th Mer.
Surface elevation: 2,369 feet.

0	- 7.0	till, brown, sandy-clay
7.0	- 38.0	sandstone, buff, soft
38.0	- 68.0	shale, grey
68.0	- 100.0	shale, dark brown

No. 17

Location: 30 feet south and 50 feet east of NW. corner of Sec. 27, Tp. 52, R. 5, W. 5th Mer.
Surface elevation: 2,417 feet.

0	- 6.0	clay, brown, sandy
6.0	- 47.0	sandstone, buff, soft
47.0	- 64.2	sandstone, grey
64.2	- 65.3	coal
65.3	- 65.4	bone
65.4	- 70.7	coal
70.7	- 72.0	shale, brown
72.0	- 73.5	coal
73.5	- 74.0	bone or shale
74.0	- 76.4	coal
76.4	- 77.0	bone or shale
77.0	- 83.2	coal
83.2	- 87.0	shale, grey
87.0	- 88.0	coal
88.0	- 92.0	shale, brown
92.0	- 94.0	coal
94.0	- 96.3	shale, brown
96.3	- 97.2	coal
97.2	- 98.0	shale, brown
98.0	- 100.2	bone
100.2	- 102.7	shale, brown
102.7	- 104.5	coal
104.5	- 104.9	bone or shale
104.9	- 106.3	coal
106.3	- 130.0	shale, grey

No. 18

Location: 50 feet north and 2,505 feet west of SE. corner of Sec. 34, Tp. 52, R. 5, W. 5th Mer.
Surface elevation: 2,404 feet

0	- 13.5	clay, brown, sandy
13.5	- 19.0	coal
19.0	- 20.5	shale, brown
20.5	- 21.5	coal
21.5	- 21.9	bone or shale
21.9	- 23.5	coal
23.5	- 23.9	bone or shale
23.9	- 27.8	coal
27.8	- 29.5	shale, brown
29.5	- 30.2	coal
30.2	- 30.6	bone or shale
30.6	- 38.5	coal
38.5	- 42.0	shale, grey
42.0	- 44.2	coal
44.2	- 46.0	shale, grey
46.0	- 50.0	coal
50.0	- 52.3	shale, grey
52.3	- 53.2	coal
53.2	- 53.5	shale, grey
53.5	- 55.5	bone
55.5	- 58.0	shale, grey
58.0	- 60.0	coal
60.0	- 60.4	shale, grey
60.4	- 61.8	coal
61.8	- 65.0	shale, grey

No. 19

Location: 250 feet east of NW. corner of Sec. 26, Tp. 52, R. 5, W. 5th Mer.
Surface elevation: 2,415 feet.

0 -	28.0	sandstone, buff, soft
28.0 -	43.5	shale, light blue-grey
43.5 -	44.5	shale, brown
44.5 -	46.5	coal
46.5 -	48.0	shale, brown
48.0 -	50.5	coal
50.5 -	53.5	shale
53.5 -	54.5	coal
54.5 -	55.2	bone or shale
55.2 -	57.8	coal
57.8 -	59.0	shale, brown
59.0 -	60.2	coal
60.2 -	60.5	bone or shale
60.5 -	61.5	coal
61.5 -	61.9	bone or shale
61.9 -	70.5	coal
70.5 -	70.8	shale, grey
70.8 -	73.3	coal
73.3 -	73.7	shale, grey
73.7 -	78.8	coal and brown shale
78.8 -	81.2	shale, grey
81.2 -	83.0	coal
83.0 -	84.2	shale, brown
84.2 -	84.6	coal
84.6 -	86.0	bone or brown shale
86.0 -	87.8	shale, brown
87.8 -	89.7	coal
89.7 -	90.0	bone or shale
90.0 -	91.0	coal
91.0 -	130.0	shale, grey

No. 20

Location: 35 feet north and 40 feet east of SW. corner of Sec. 36, Tp. 52, R. 5, W. 5th Mer.
Surface elevation: 2,400 feet.

0 -	5.5	till, brown, sandy-clay
5.5 -	12.5	coal, soft
12.5 -	13.5	shale, brown
13.5 -	17.5	coal
17.5 -	18.6	shale or bone
18.6 -	25.2	coal
25.2 -	27.2	shale, brown
27.2 -	28.2	coal
28.2 -	31.3	shale, brown
31.3 -	35.0	coal and brown shale
35.0 -	36.3	shale, brown
36.3 -	38.0	coal
38.0 -	38.8	shale, brown
38.8 -	41.0	bone
41.0 -	42.0	shale, brown
42.0 -	44.8	coal
44.8 -	45.2	bone or shale
45.2 -	46.5	coal
46.5 -	50.0	shale, grey

No. 21

Location: 50 feet north and 75 feet east of SW. corner of Sec. 29, Tp. 52, R. 4, W. 5th Mer.
Surface elevation: 2,424 feet.

0 - 12.0	till, brown, sandy-clay
12.0 - 18.0	shale, grey
18.0 - 20.5	coal
20.5 - 26.5	shale, grey, and bone
26.5 - 28.5	coal
28.5 - 30.3	shale, brown
30.3 - 34.0	coal
34.0 - 35.0	shale, brown
35.0 - 36.1	coal
36.1 - 36.3	bone or shale
36.3 - 41.8	coal
41.8 - 44.0	shale, brown
44.0 - 48.3	coal
48.3 - 48.8	bone or shale
48.8 - 54.2	coal
54.2 - 56.2	shale, grey
56.2 - 57.8	coal
57.8 - 59.5	shale, brown
59.5 - 63.3	coal and bone
63.3 - 65.7	shale, grey
65.7 - 66.4	coal
66.4 - 68.0	shale
68.0 - 70.0	bone or shale
70.0 - 71.8	shale, brown
71.8 - 75.5	coal
75.5 - 80.0	shale, grey

No. 22

Location: 40 feet west and 650 feet south of NE. corner of Sec. 7, Tp. 52, R. 4, W. 5th Mer.
Surface Elevation: 2,405 feet.

0 - 30.0	till, grey, clay
30.0 - 31.3	coal
31.3 - 32.5	bone or shale
32.5 - 33.8	coal
33.8 - 33.9	bone
33.9 - 34.8	coal
34.8 - 35.0	bone
35.0 - 39.6	coal
39.6 - 43.0	shale, brown
43.0 - 46.0	coal
46.0 - 46.3	bone or shale
46.3 - 48.7	coal
48.7 - 48.9	bone or shale
48.9 - 52.4	coal
52.4 - 54.2	shale, grey
54.2 - 56.0	coal
56.0 - 59.3	shale, brown
59.3 - 61.5	coal
61.5 - 64.0	shale, grey
64.0 - 67.0	bone or shale
67.0 - 69.6	shale, brown
69.6 - 72.0	coal
72.0 - 72.4	bone or shale
72.4 - 74.0	coal
74.0 - 80.0	shale, grey

No. 23

Location: 2,615 feet south of NE. corner of Sec. 8, Tp. 52, R. 4, W. 5th Mer.
Surface elevation: 2,372 feet.

0	- 7.5	till, grey, clay
7.5	- 9.5	shale, black
9.5	- 10.0	shale, brown
10.0	- 16.3	coal
16.3	- 17.7	shale, brown
17.7	- 22.2	coal
22.2	- 22.5	bone or shale
22.5	- 28.4	coal
28.4	- 30.3	shale, brown
30.3	- 31.8	coal
31.8	- 34.8	shale, brown
34.8	- 37.7	coal
37.7	- 39.2	shale, grey
39.2	- 40.0	coal
40.0	- 41.2	shale, grey
41.2	- 43.3	bentonite
43.3	- 43.7	shale, grey
43.7	- 44.2	bone or shale
44.2	- 45.5	shale, grey
45.5	- 47.8	coal
47.8	- 48.2	bone or shale
48.2	- 49.2	coal
49.2	- 50.0	shale, grey
50.0	- 51.5	siltstone
51.5	- 55.2	shale, grey
55.2	- 57.2	sandstone, grey
57.2	- 60.0	shale, grey
60.0	- 61.0	sandstone, grey, hard
61.0	- 87.0	shale, grey
87.0		sandstone, grey, hard

No. 24

Location: 50 feet north and 365 feet east of SW. corner of Sec. 9, Tp. 52, R. 4, W. 5th Mer.
Surface elevation: 2,453 feet

0	- 14.0	till, grey, sandy-clay
14.0	- 23.0	till, brown, clay
23.0	- 37.0	sandstone, light-grey
37.0	- 60.0	shale, grey
60.0	- 61.0	coal
61.0	- 61.3	bone or shale
61.3	- 63.5	coal
63.5	- 63.6	bone
63.6	- 68.0	coal
68.0	- 70.0	shale, brown
70.0	- 80.0	coal
80.0	- 81.5	shale, grey
81.5	- 83.2	coal
83.2	- 86.7	shale, grey
86.7	- 89.0	coal
89.0	- 90.5	shale, brown
90.5	- 91.0	bone
91.0	- 93.0	shale, brown
93.0	- 95.0	bone
95.0	- 96.5	shale, brown
96.5	- 98.2	coal
98.2	- 98.6	bone or shale
98.6	- 100.5	coal
100.5	- 103.0	shale, light-grey
103.0		sandstone, hard

No. 25

Location: 1,465 feet south of NE. corner of Sec. 4, Tp. 52, R. 4, W. 5th Mer.
Surface elevation: 2,371 feet.

0	- 12.0	till, brown, clay
12.0	- 18.0	till, grey, clay
18.0	- 28.0	till, grey and brown, clay
28.0	- 48.5	sandstone, buff, soft
48.5	- 49.5	sandstone, grey, hard
49.5	- 60.0	sandstone, grey, soft

No. 26

Location: 80 feet west and 2,565 feet south of NE. corner of Sec. 4, Tp. 52, R. 4, W. 5th Mer.
Surface elevation: 2,433 feet.

0	- 25.0	till, brown, soft clay
25.0	- 35.0	till, grey, sticky clay
35.0	- 38.2	coal
38.2	- 39.5	shale
39.5	- 40.0	bone
40.0	- 41.0	shale, brown
41.0	- 43.0	bone
43.0	- 45.2	shale, brown
45.2	- 47.7	coal
47.7	- 60.0	shale, grey

No. 27

Location: 110 feet north of SE. corner of Sec. 3, Tp. 52, R. 4, W. 5th Mer.
Surface elevation: 2,440 feet.

0	- 2.0	clay, brown
2.0	- 8.0	coal, burnt
8.0	- 20.0	till, brown, clay
20.0	- 27.5	shale, grey, silty
27.5	33.5	coal
33.5	- 35.5	shale, brown
35.5	- 36.0	coal
36.0	- 36.2	bone or shale
36.2	- 39.6	coal
39.6	- 40.5	shale or bone
40.5	- 45.5	coal
45.5	- 47.0	shale, grey
47.0	- 48.5	coal
48.5	- 52.5	shale, brown
52.5	- 54.5	coal
54.5	- 62.0	shale, brown, and bone
62.0	- 65.4	coal and bone
65.4	- 100.0	shale, grey

No. 28

Location: 2,640 feet south and 125 feet west of NE. corner of Sec. 12, Tp. 52, R. 4, W. 5th Mer.
Surface elevation: 2,495 feet.

0	- 58.0	till, brown, silty-clay
58.0	- 179.5	till, bluish-grey, clay
179.5	- 190.5	shale, grey and brown
190.5	- 192.0	coal
192.0	- 210.0	shale, grey

No. 29

Location: 4,150 feet west of NE. corner of Sec. 33, Tp. 51, R. 3, W. 5th Mer.
Surface elevation: 2,403 feet.

0	- 12.0	till, brown, clay
12.0	- 50.0	till, blue-grey, clay
50.0	- 159.7	shale, grey
159.7	- 160.0	coal
160.0	- 167.1	shale, grey
167.1	- 167.4	coal
167.4	- 170.0	shale, grey

No. 30

Location: 75 feet north of SE. corner of Sec. 36, Tp. 51, R. 4, W. 5th Mer.
Surface elevation: 2,416 feet.

0	- 10.0	till, brown, clay
10.0	- 133.0	till, bluish-grey, clay
133.0	- 135.5	bone and clay
135.5	- 137.5	shale, brown and black
137.5	- 154.0	coal, bone in part
154.0	- 164.0	shale, brown
164.0	- 180.0	shale, grey

No. 31

Location: 650 feet east of NW. corner of Sec. 17, Tp. 51, R. 3, W. 5th Mer.
Surface elevation: 2,395 feet.

0 -	5.0	clay, brown, sandy
5.0 -	8.0	muskeg
8.0 -	88.0	till, brown, sandy-clay
88.0 -	88.5	coal (?)
88.5 -	98.0	shale, brown
98.0 -	101.0	coal (?)
101.0 -	134.0	shale, brown
134.0 -	135.6	coal
135.6 -	140.0	shale, brown
140.0 -	150.0	shale, grey

APPENDIX II

METHOD OF ESTIMATION OF SUBSURFACE WATER FLOW

The rate of flow of subsurface water was investigated in nine drill holes south of Wabamun Lake, in order to determine whether strip-mining of coal would be feasible. After the holes were drilled and electrically logged, they were washed out and bailed dry or to an equilibrium level at which the rate of water influx equalled the bailing rate. After bailing, the holes were plugged until the following day to allow the water to rise to the water table. The water level in the hole was checked until constant, and then the hole was bailed with a 3-gallon bailer for about 30 minutes. The volume of water bailed and the total bailing time were carefully recorded, in order to calculate the average bailing rate in gallons per minute. Immediately bailing ceased, the water level in the hole was measured with an electric tape, at 1-minute intervals for 5 or 10 minutes, then at 5- and 10-minute intervals until 1 hour after the bailing stopped.

From these measurements, the transmissibility (T) of the column of strata through which water passes into the drill hole can be calculated, by means of the following equation (Theis, 1935):

$$T = \frac{264\ Q}{s'} \log_{10} {}^{t}/_{t'} \qquad (1)$$

where T = coefficient of transmissibility in gallons per day per foot,

Q = discharge in gallons per minute,

t = time since bailing started,

t' = time since bailing stopped,

and s' = residual drawdown in feet (the difference between the observed water level at time t' and the level it would have if there had been no bailing).

By plotting residual drawdown, s', against t/t' on semilogarithmic co-ordinate paper, s' being plotted on the arithmetic scale and t/t' on the logarithmic scale, the points should give a straight line with a slope $\log_{10} (t/t')/_{s'}$. When t/t' is chosen over one log cycle, the above equation reduces to

$$T = \frac{264\ Q}{S'} \qquad (2)$$

where S' = change in residual drawdown in feet, per log cycle of time.

The calculated values of T have been given in table 1.

In order to calculate the rate at which water would flow into a small pit at the location of each bailed hole, it has been assumed that a pit will have a circular zone of influence for groundwater flow. A zone of influence is here defined as the area around a pit from which water will move towards the pit. Its radius depends upon the continuity of porous strata (the aquifer) around the pit, and the depth to which the pit reaches below the water table. After equilibrium conditions have been attained, the rate of groundwater flow into a small pit is virtually independent of the pit's areal dimensions, and is related only to its depth, the zone of influence, and the coefficient of transmissibility of the aquifer

(R. N. Farvolden, oral communication). Hence for purposes of calculation, an open pit can be regarded as a bore hole or well. The discharge of a well is given by:

$$Q_d = TIL \qquad (3)$$

where Q_d = discharge flow in gallons per day,

T = coefficient of transmissibility in gallons per day per foot,

I = hydraulic gradient,

and L = length of cross-section of discharge in feet.

Now $I = s/r$,

and $L = 2\pi r$ for a circular zone of influence,

where s = depth of hole below the water table in feet,

and r = radius of zone of influence in feet;

hence

$$Q_d = 2\pi r\, T.\frac{s}{r} \qquad (4)$$

or

$$Q_d = 2\pi T s \qquad (5)$$

By means of equation (5), the values of Q_d were calculated for each bailed hole (table 1). These values are the amounts of water which would have to be pumped per day from a small pit opened at each well site.

For a large pit with an equal hydraulic gradient in its zone of influence, L will increase slightly, and Q_d proportionately. For example, for a well, bore hole or small pit with a circular zone of influence of radius 1 mile,

$L = 2\pi r$ (where r is the radius)

or L = 33,200 feet.

A large pit with a working face 1 mile long and having a width of 0.5 miles from working face to rear wall would have as a zone of influence an area approximating an ellipse with semiaxes of 1.50 and 1.25 miles. Its circumference is given by

$$L = 2\sqrt{\frac{a^2 + b^2}{2}} \quad \text{(where a and b are the semiaxes)}$$

or $$L = 45,800 \text{ feet.}$$

Thus L and hence Q_d increase by only 38 per cent for this great increase in pit size.

APPENDIX III

VALUE OF ELECTROLOGGING

Electrical logging has been used for over 25 years by oil companies to provide useful information about their drilled wells and structure test holes. Electrolog records have been used for a similar purpose in exploring for coal in the Wabamun Lake district. Each drill hole was logged for resistivity and self-potential characteristics. Interpretation of the electrologs has been largely based upon the resistivity record; the self-potential curves were much less sensitive than the resistivity curves although the two almost always agreed. The electrolog records showed that coal can be readily distinguished from clays, shales, sands and most sandstones, because of its much greater resistance. However, coal may be confused with coarse gravels and with hard, narrow sandstone beds. By comparing one section of core logged visually with the electrolog for that hole, it was found that shale and bone partings within the seam can be detected down to thicknesses of about 2 inches. Table 7 is a comparison of the driller's log with the electrolog interpretation for hole No. 17. The electrolog interpretation provides more information about the coal seam than the driller gave. It was particularly useful in obtaining the precise thicknesses of coal seams in a hole, and in identifying the individual coal seams in an interlayered sequence of coal and shale. An electrolog is particularly useful for a "blind" hole - a hole where there is insufficient recovery of chips or core to provide a record of lithology.

On an exploratory coal drilling program, electrologging should accompany logging by the driller. When drilling to prove the coal reserves in a known field, only electrologging is necessary, once the general rock succession and approximate position of the coal seams are known.

TABLE 7

Comparison of Driller's Log and Electrolog Interpretation
for Hole No. 17

Feet	Driller's Log	Feet	Electrolog Interpretation
0 - 6.0	shale, brown	0 - 7.5	not logged
6.0 - 47.0	sand	7.5 - 61.0	sand
47.0 - 63.5	clay, grey, sandy	61.0 - 64.2	clay or shale
63.5 - 70.5	coal	64.2 - 65.3	coal
		65.3 - 65.4	bone
		65.4 - 70.7	coal
70.5 - 71.5	shale, brown	70.7 - 72.0	shale
		72.0 - 73.5	coal
		73.5 - 74.0	bone or shale
71.5 - 81.5	coal	74.0 - 76.4	coal
		76.4 - 77.0	bone or shale
		77.0 - 83.2	coal
81.5 - 85.7	shale, grey	83.2 - 87.0	shale
85.7 - 87.0	coal	87.0 - 88.0	coal
87.0 - 88.5	shale, brown	88.0 - 92.0	shale
88.5 - 91.0	coal and brown shale	92.0 - 94.0	coal
91.0 - 93.5	coal	94.0 - 96.3	shale
93.5 - 95.0	shale, grey	96.3 - 97.2	coal
95.0 - 96.5	coal	97.2 - 98.0	shale
96.5 - 97.5	coal and brown shale	98.0 - 100.2	bone
97.5 - 99.5	coal, bony	100.2 - 102.7	shale
99.5 - 101.5	shale, brown	102.7 - 104.5	coal
101.5 - 105.0	bone and coal	104.5 - 104.9	bone or shale
		104.9 - 106.3	coal
105.0 - 130.0	shale, grey	106.3 - 125.0	shale
		125.0 - 130.0	not logged

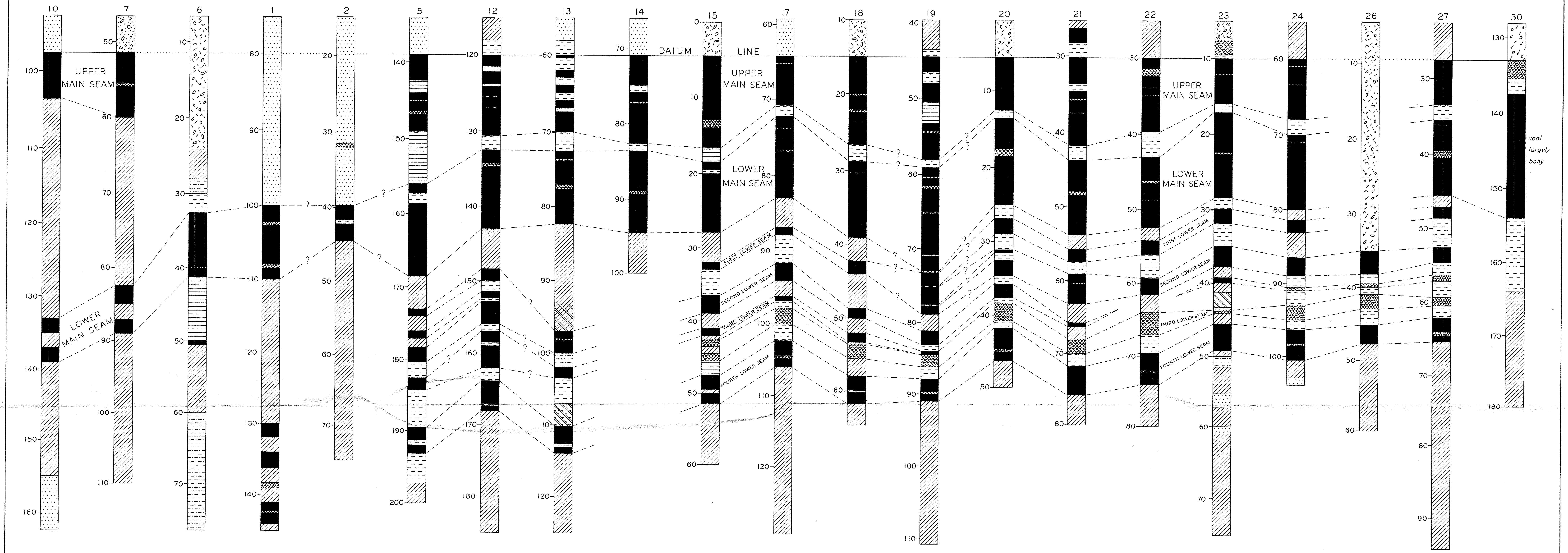


FIGURE 4

Detailed Sections Through Coal Seams, Wabamun Lake District, Alberta

COMPILED FROM DRILL-HOLE LOGS AND ELECTROLOGS

Vertical Scale in Feet
5 0 5 10 15

Depth in feet shown alongside sections
Hole locations are shown on Figure 2

LEGEND

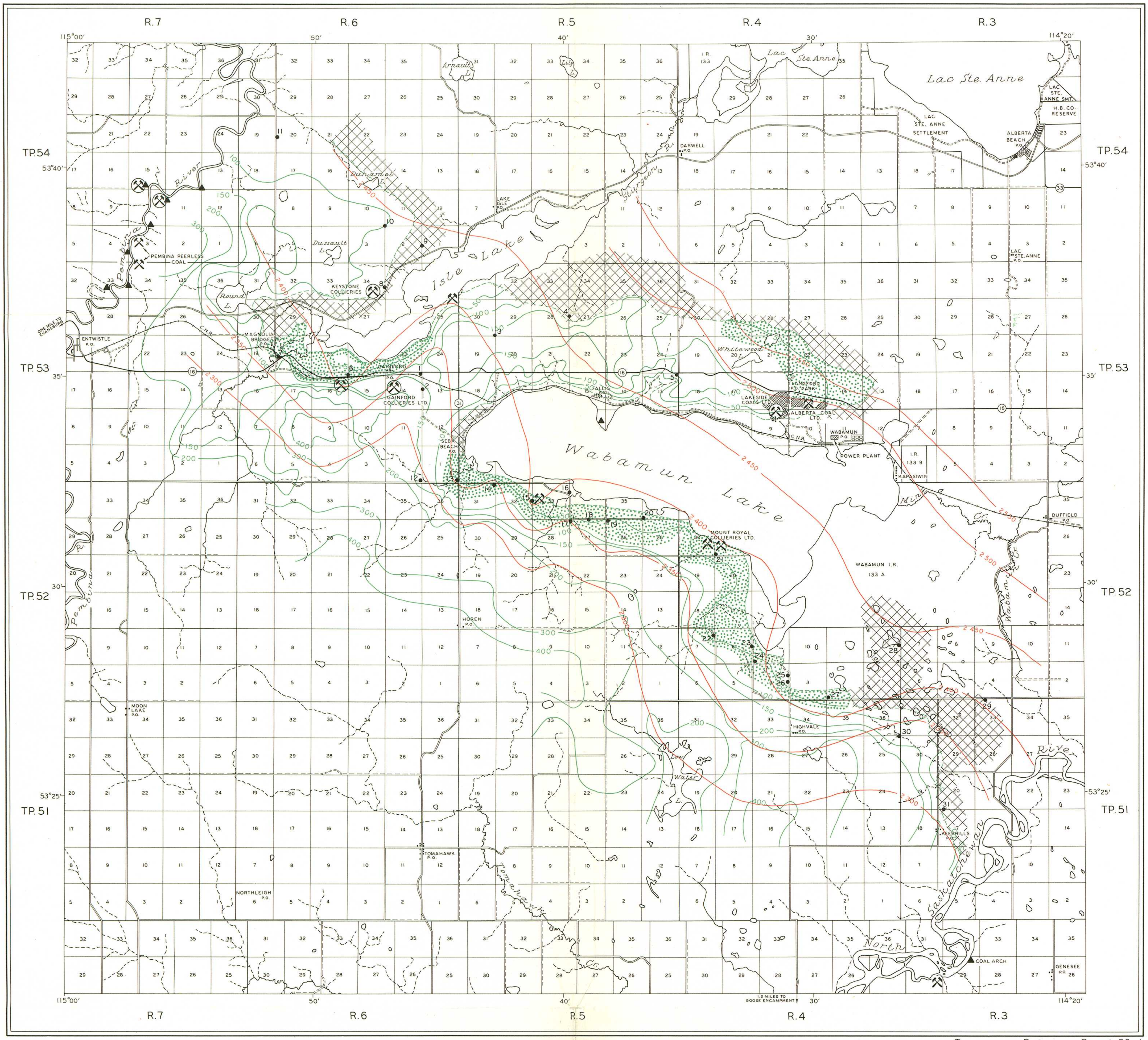
SUPERFICIAL DEPOSITS

- *Till, brown, clay and sandy clay*
- *Till, grey, clay and sandy clay*
- *Gravel*

BEDROCK (EDMONTON AND PASKAPOO FORMATIONS)

- *Coal*
- *Bone and carbonaceous shale*
- *Bentonite*
- *Shale, brown*
- *Shale, grey*
- *Shale (colour unknown)*
- *Siltstone*
- *Sandstone*

To accompany Preliminary Report 59-1.



To accompany Preliminary Report 59-1

LEGEND

- Extensive areas underlain by coal at depths of 75 feet or less
- Structure contours (*interval 50 feet*) on top of Upper Main coal seam. (*Elevations in feet above Mean Sea Level*) — 2300
- Depth to top of Upper Main coal seam; determined largely by extrapolation. Isopach interval {50 feet below 200 foot isopach; 100 feet above 200 foot isopach} — 100
- Limit of coal
- Areas under which main coal seams are believed absent, due to pre-glacial erosion
- Coal mined out
- Coal mines, underground (*all abandoned*)
- Coal strip-mines
- Drill holes
- Outcrop of Pembina coal seam

FIGURE 2

COAL RESERVES OF THE WABAMUN LAKE DISTRICT, ALBERTA

WEST OF FIFTH MERIDIAN

Scale in Miles

1 ½ 0 1 2 3 4

REFERENCE

- Town or Village
- Buildings
- Post Office — P.O.
- Provincial Highway — 16
- Main Road
- Secondary Road
- Railway
- River and Lake
- Stream, intermittent
- Township Boundary
- Section Line

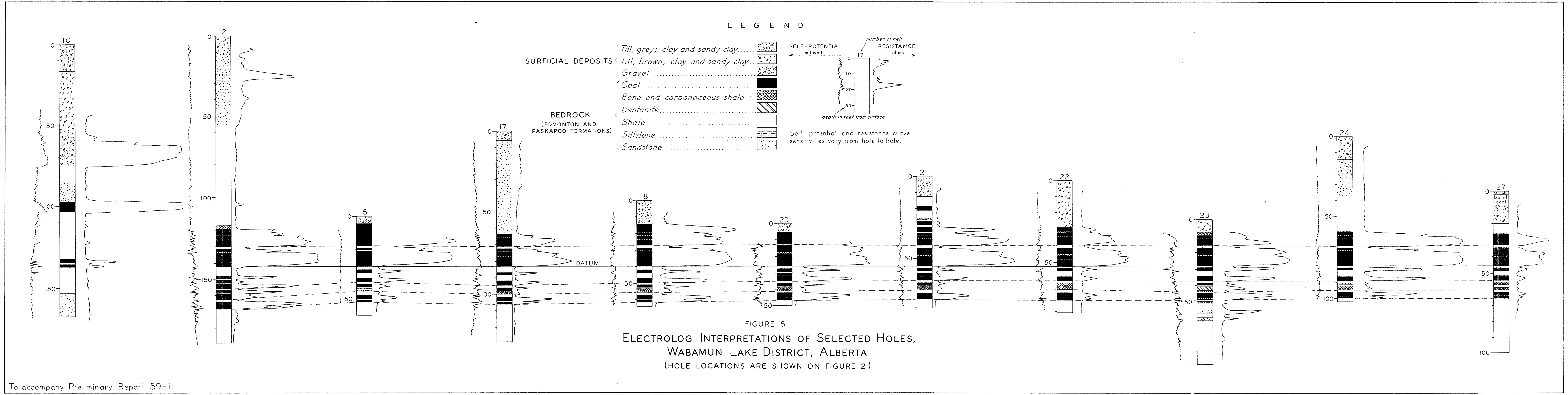


FIGURE 5

ELECTROLOG INTERPRETATIONS OF SELECTED HOLES, WABAMUN LAKE DISTRICT, ALBERTA

(HOLE LOCATIONS ARE SHOWN ON FIGURE 2)

To accompany Preliminary Report 59-1.