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# COAL OCCURRENCES OF THE VULCAN-GLEICHEN AREA, ALBERTA

by

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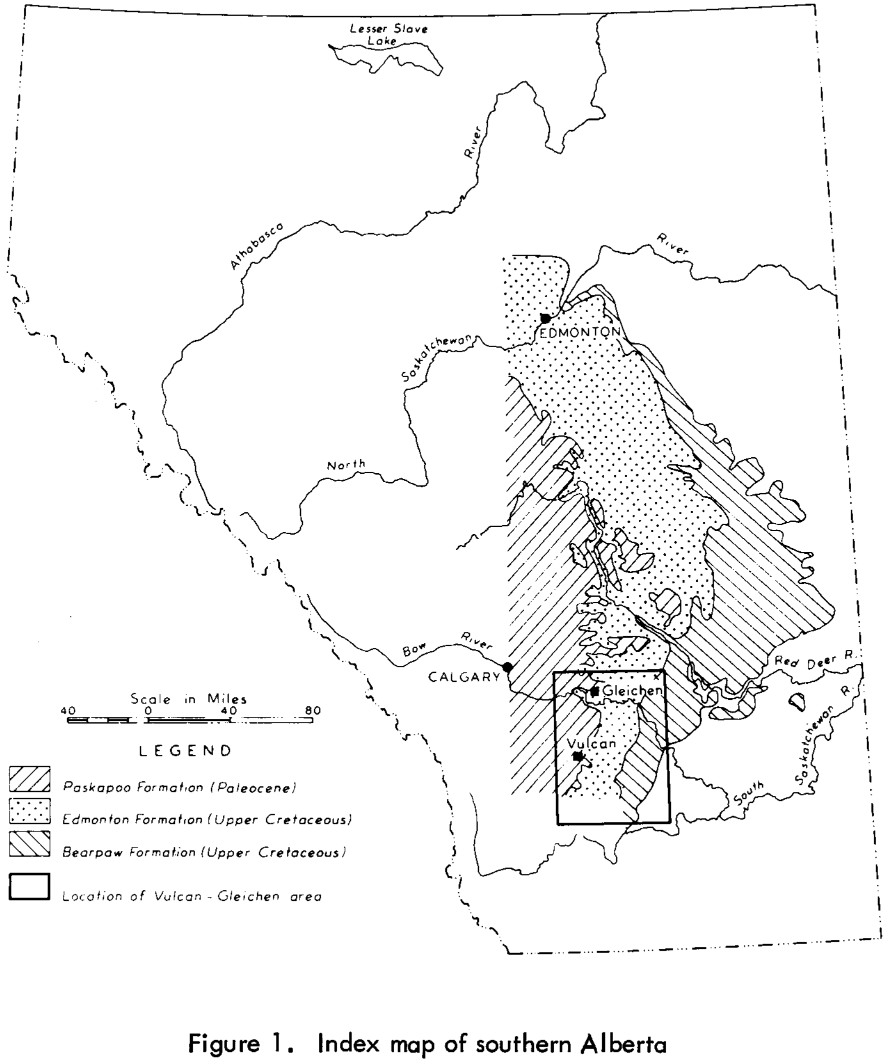


Figure 1. Index map of southern Alberta

# COAL OCCURRENCES OF THE VULCAN-GLEICHEN AREA, ALBERTA


## Abstract

The Vulcan-Gleichen area lies between longitudes 112°15' and 113°30' west and latitudes 49°50' and 51°00 north. As part of a continuing survey aimed at re-assessing the coal energy resources of Alberta, especially those recoverable by stripping methods, this area was examined in 1961 chiefly by means of boreholes spaced at 2-mile intervals. Only three small localities hold any reserves of strippable coal, and in none of these are the recoverable volumes as much as 10 million tons. From the experience gained in this typical area, it appears that few considerable bodies of strip-coal remain to be discovered in the prairie regions of Alberta. Some details were added to positions of the upper and lower boundaries of the Edmonton Formation, both of which are considered gradational and possibly diachronous; on the Bow River the lowest strata of the Paskapoo Formation may be latest Cretaceous in age. In a small region about 113°10' west and 50°20' north the upper part of the Edmonton Formation is deformed by a swarm of small faults related to the Sweetgrass Arch. On the evidence of observed gravel beds and valley conformation, a sequence of stream-courses, relating both to the modern Bow River Valley and to McGregor Valley, is postulated, extending from late Tertiary time to the present.


## INTRODUCTION

The Province of Alberta possesses very large energy reserves in the form of fossil fuels of which coal was the first to attract attention, but in the last 20 years the tremendous development of the oil and natural gas industry has tended to obscure the fact that coal still constitutes a major resource. However, recent developments, such as new large-scale strip-mining methods, improved coal-utilizing electric generating equipment and the ever-increasing price of gas, are conspiring to focus attention once again on coal as a source of cheap electrical power. In fact, almost 20 per cent of present power capacity in Alberta is concentrated in two new coal-fired thermal stations, and consideration is being given to increasing this proportion.

The renascent importance of coal in the economy of the province prompted the Research Council of Alberta to begin in 1958 to re-assess coal energy resources, especially those suitable for recovery by strip-mining methods.

The subsequent project, aimed at estimating reserves in certain selected localities believed potentially attractive to industry, was carried out chiefly by a study of coal-mine exposures and mine-records, supplemented as necessary by boreholes and electric logs, and was published as three reports (Pearson 1959, 1960, 1961).

However, early in 1961 it became apparent, in the light of further developments such as solid-in-liquid pipelining and an even more rapidly changing price structure in the oil and gas industry, that the province stood in need of a new inventory of the strippable coal resources of the whole plains region regardless of location or present economic suitability. For this reason a new co-operative steering committee was constituted comprising representatives from both the Research Council of Alberta and interested industries; and an enlarged Survey was organized, of which this publication is the first product, being a report of the 1961 summer field activities in the Vulcan-Gleichen area (Fig. 1).

Field investigations were limited to a search for coal deposits within 100 feet of the ground surface and containing 50 million tons or more of coal. The 100-foot depth was chosen as a limit since it is somewhat greater than the operating depth of any strip mines on the Western Canada plains; 50 million tons is generally agreed by representatives of the electric power industry to be the minimum tonnage necessary for setting up an economical coal-fired thermal-electric plant.

As Alberta prairie coals may be assumed to have an average in-seam specific gravity of 1.4, then, allowing for some losses in strip-mining, a good estimate of the recoverable coal contained in a seam 1 foot thick and 1 square mile in area is 1 million tons. And as the greatest reasonably persistent thickness of mineable coal that has been found in the prairies is about 12 feet, then the minimum area that a 50-million-ton coal body can occupy is 4 square miles. Accordingly, all such bodies will be intersected by boreholes drilled on a staggered 2-mile grid such as was laid out within the Vulcan-Gleichen area (Fig. 2).

## Previous Work

Study of the geology of Southern Alberta plains, of which the Vulcan-Gleichen area is part, began in the last quarter of the 19th century and became intensive in the 1930's and 1940's. It is summarized in the work of Clark (1931), Dowling (1917), Gallup (1955), Russell (1950, 1962), Russell and Landes (1940), Stewart (1943), Tozer (1953, 1956), and Williams and Dyer (1930).

Few publications, however, deal with coal occurrences, and none deals specifically with coal in the Vulcan-Gleichen area. Allan (1924, 1943) divided Alberta into a series of "Coal Areas" chiefly on the basis of mine distribution, and these have since been used for administrative purposes. Following this usage, a geological map of each "Coal Area" is included in the

"Coal Atlas of Alberta ..." (MacKay, 1949) - a compendium of knowledge on coal occurrences in mines, outcrops and boreholes that remains the major reference work up to the present time. The major part of the Vulcan-Gleichen area lies within the "Champion Coal Area", but that part of it lying north of township 19 falls within the "Gleichen Coal Area".

Only one comprehensive review of the classification of Alberta coals has been published, by Stansfield and Lang (1944), who supplemented Allan's geological treatment of the coal deposits with a catalogue of representative coal analyses from all possible "Coal Areas".

## Acknowledgments

The 1961 coal-exploration drill program represents a doubling of previous years efforts and was possible only through financial support of Calgary Power Limited and Canadian Pacific Railway Natural Resources Division, whose aid and encouragement is gratefully acknowledged. The courtesy of the Blackfoot Indian Band at Gleichen, Alberta, and of their chief, Mr. Clarence McHugh, is also acknowledged; without their permission to examine outcrops and to drill, the Reservation lands would have remained a critical gap in the survey. Dr. Arthur Irwin, chief geologist of the Indian Affairs Branch, Canada Department of Citizenship and Immigration, helped greatly in the survey of the Reserve by his knowledge of outcrops and former Indian mining properties, and by the loan of his own field notes and maps. Elsewhere throughout the area, local informants too numerous to mention offered valuable data on former mining operations and coal discoveries. Finally, most of the information on mine properties was obtained through the co-operation of the Mines Branch, Alberta Department of Mines and Minerals. The senior author wishes to thank Dr. L.A. Bayrock and Dr. A. MacS. Stalker for constructive discussions regarding Appendix E.

## Geography

The Vulcan-Gleichen area (Fig. 1) lies between longitudes 112°15' and 113°30' west and latitudes 49°50' and 51°00' north, and covers approximately 112 townships - an area of about 4,000 square miles.

Eight prominent uplands lie in the Vulcan-Gleichen area (Fig. 2), the highest being Buffalo Hill (Tp. 19, R. 23*) northwest of Milo, which rises to an elevation greater than 3,800 feet. The lowest point in the area is on the Bow River east of Lomond in Tp. 17, R. 17, with an elevation of 2,440 feet. The topography may be generalized as a flat prairie level to the east at roughly 2800 feet elevation, and a more rolling prairie level to the west roughly 600 feet higher; these regions, usually only thinly

* All locations given in this report are west of the Fourth Meridian.

mantled by glacial deposits, are separated by a belt of rolling or rough moraine-covered, bedrock-cored hills 10 to 15 miles wide, extending across the map-area from Bassano to Keho Lake.

The area is traversed by two major stream-trench systems: that of the Bow River cutting from west to east across the northern part of the area; and the McGregor Lake - Little Bow River system cutting a broad "Y" across the central and southern parts. Each system is now deeply entrenched and each has a complicated life history (see Appendix E and Figs. 7 to 9).

Bedrock outcrops in the area are restricted to the walls of the major valleys and to the crests of the major hills. Most exposures, especially in the hill locations, are simply ledges of sandstone projecting through the till mantle, or at best, small slump-crescents or tiny badlands at springs or heads of minor water-courses, never exceeding one-quarter mile in length.

Only along the major stream courses are there extensive outcrops. The valley of the Little Bow River is sufficiently stabilized that its walls are largely grassed over, but the contained reservoir lakes, McGregor and Travers, especially the latter which was formed in 1954, have re-established a regime of bank erosion and it was possible to trace strata continuously for as much as 12 miles.

Outcrops along the Bow River are fairly extensive, though perhaps more difficult to trace laterally because of the winding river. Where the river is cutting into the east face of Jumping Buffalo Hill, an extensive badlands has developed westward almost to the summit, exposing the best and most continuous stratigraphic section in the Vulcan-Gleichen area.

The distribution of the coal-mines in the area (Fig. 2) resembles in general that of the outcrops. There are several concentrations of former pits in the lower levels of the major valley systems (Tp. 14, Rs. 21 and 22; Tps. 15 and 16, R. 21; Tps. 20 and 21, R. 19; Tp. 21, R. 21), but on the crests of the major hills, usually only a scatter of short-lived mines. The group of mines, containing the only two mines still operating, high on the southeast shoulder of the Thigh Hill is the one exception to this generality.

The climate and natural biota of the Vulcan-Gleichen area are those typical of the short-grass prairie. Precipitation is very low and insolation heavy so that moisture-deficiency conditions prevail at most seasons almost every year. Arborescent vegetation is present only in exceptional circumstances.

Upstream from Bassano, the valley of the Bow River lies within the Blackfoot Indian Reserve (number 146) with agency headquarters at Gleichen. The reserve (Fig. 2) covers about eight townships and encompasses two concentrations of former coal mines, that at Cluny Bridge, collectively called the Blackfoot Mines and that around the foot of Jumping Buffalo Hill.

A quite complete system of highways and secondary roads provides access in the Vulcan-Gleichen area. Also, four lines of the Canadian Pacific Railway, the main transcontinental line, and the Hussar, Vauxhall and Vulcan branches, cross the area; the villages and small towns are all situated along these.

Local economy is based almost entirely upon agriculture. In the moraine belt and on the lower prairie to the east, the sparse population tends to depend largely on ranching; but in the higher prairie to the west grain farming predominates so that a somewhat denser population is possible, and towns such as Carmangay, Champion, Vulcan and Gleichen have developed.

About twenty townships of the map-area are irrigated, in the northwest by the Western Irrigation District, east of Bassano by the Eastern Irrigation District, and east of Lomond by the Bow River Project. The main feeder canal for the Bow River Project crosses the area by way of the McGregor-Little Bow valley system; Lake McGregor and Lake Travers are both artificial reservoirs along this canal; the former has been stocked with fish and yields an annual harvest in the order of one-half million pounds of whitefish alone.

## Methods of Study

Two phases of field work were maintained concurrently throughout the field season, a study of bedrock outcrops and mine properties, and a borehole program. In both phases, levels were carried by aneroid altimeter, corrected by barograph and checked, where possible, by reference to topographic maps.

The first phase, the outcrop study, served as a control for the second, delineating those areas worth drilling and clarifying drill data.

The borehole program, the major phase of field operations, followed a "staggered 2-mile grid" (Fig. 2) in which the grid points were all located at road allowance corners. The holes, all located within 100 yards of road allowance crossings, were drilled to a depth usually of 105 feet, but occasionally of 150 or 225 feet; all locations of holes are shown on figure 2.

Equipment used in the borehole program included a "1000-foot" shot-hole rig which drilled 4 3/4-inch diameter holes, using mostly natural mud; three-bladed insert-bits which produced large cuttings; and a large-capacity mud-pump which ensured quick returns to the surface. Cutting samples, dipped from the mud-return stream every 5 feet of hole depth, formed the basis of a lithologic log. Each hole was electric-logged for spontaneous potential and single-point resistivity using a truck-mounted, photo-recording logger. A more complete discussion of the application of electric logging to coal exploration is given by Pearson (1959).

In all, 200 holes were drilled, logged, and electric-logged in 48 working days of 10 hours each, with a total footage of 23,374 feet - an average of 485 feet per day. The working method thus proved to be quite speedy; its precision was tested and found satisfactory by comparing data from a borehole at NE. corner Sec. 33, Tp. 15, R. 23 with information from an operating mine less than 600 feet to the east.

## COAL OCCURRENCES

The findings expressed in this report amplify and to some extent modify the conclusions of MacKay(1949) on the coal resources of the Vulcan-Gleichen area. These findings are summarized in figure 2, where outcrops, coal mines and all 1961 boreholes are plotted, and in figures 4 and 5. Borehole logs are given in Appendix A.

Some aspects of the bedrock geology of the area are discussed in Appendix D and summarized in figure 6. Six rock units outcrop in the area: the Oldman, Bearpaw, Edmonton, St. Mary River, Willow Creek and Paskapoo Formations. A comparison of figure 6 with figure 2 shows that all coal in the Vulcan-Gleichen area, except for a few seams in the Oldman Formation, is contained in the Edmonton Formation.

The Edmonton Formation with its contained coal is thus the major concern of this report. This rock unit is a complex interlensed succession of lithologically indistinguishable fine-grained argillaceous and clastic lenses. No stratum could be correlated with certainty for more than 9 miles, and no fossil zones were recognized. The Kneehills Member, a reliable, extensive marker horizon in central Alberta, is restricted to three townships in the northwest corner of the area.

In the absence of dependable marker horizons, strata of the Edmonton Formation have been assumed to dip regionally in a similar manner to those of other rock units: i.e. to have a very low regional dip to the west and northwest (see Appendix D).

Of the 200 boreholes, the first 58 were drilled to a depth of 150 feet or more and are arranged in three lines designated (Fig. 2) $A-A_1$, $B-B_1$, and $C-C_1$. These three sections are illustrated on figure 4. It may be noted that in these holes no markers correlatable across 2-mile intervals could be recognized within the Edmonton Formation.

All boreholes are plotted and classified on figure 2 into those that intercepted coal seams more than 1 foot thick, those that intercepted traces of coal, and those barren of coal. At each hole location are noted thicknesses in feet of overburden and of coal seams, respectively, written as a ratio (e.g. 72:2); where several seams were recorded, the overburden indicated for each lower seam is the thickness of the interval between it and the seam next above. All holes are catalogued in Appendix A in order of their land-survey locations, together with their elevations, depths drilled and coal and gravel occurrences if any. Appendix B is a catalogue of the 40 boreholes that intercepted coal seams 1 foot or more in thickness, and contains the lithologic log of each hole with the elevations of all coal seams.

In the Vulcan-Gleichen area, only two coal mines are now working, both small underground operations along the north boundary of Tp. 15, R. 23. The actual number of mines that have been opened in the area is not known since all have been small and often so ephemeral as to be difficult to find now. In some cases only slight black and grey discolorations on a grassy hillside indicate where coal was once worked. From the records of the Mines Branch, Alberta Department of Mines and Minerals, from the "Coal Atlas of Alberta" (MacKay,1949), and from local information, mines were traced and as many as possible were visited. All mines that could be located are listed in Appendix C together with their survey-locations, their Mines Branch registration number, seam elevations, cover thickness, and seam logs where available. Each quarter-section where a mine is known to have been opened is marked by symbol on figure 2, except those areas designated "Area 1" and "Area 2" where coal occurrences were sufficiently numerous to warrant special attention. "Area 1", around the Thigh Hill northeast of Champion, and "Area 2" centered on Jumping Buffalo Hill in the east end of the Blackfoot Indian Reserve, are shown on a larger scale and in greater detail in figures 4 and 5, respectively.

Coal outcrops are uncommon in the Vulcan-Gleichen area except along the lower slopes of the major valley systems. All those examined are marked on figures 2, 4 and 5; their distribution, together with that of the mines and of boreholes intersecting coal, roughly indicates the near-surface pattern of coal occurrence.

## Southern Region

In distribution, the coal mines of the area appear in figure 2 to fall into eight groups, and in Appendix C, they are classified accordingly. However, borehole and outcrop data indicate that the southern four of these groups may be considered as one, the underlying continuity being obscured by a series of surficial features including gravel-filled valleys on the east side of Tp. 14, R. 22, a thick bed of lake deposits in Tp. 14, R. 23, a range of rough, till-covered hills in the northeastern part of Tp. 15, R. 22, and an ubiquitous drift mantle. Also, the trench of the Little Bow River divides the region into two major parts - a southern part which includes the south Travers mines and also Blackspring Ridge (Tp. 13, R. 22) where no mines were recorded, and a northern part including Carmangay, Thigh Hill and the Lake McGregor mines.

South of Travers Reservoir, coal has been mined only around Wolf Coulee (Sec. 30, Tp. 14, R. 21) where the seam exploited, about 4 feet thick and traceable for about 5 miles, dips to the west across the face of the reservoir cliffs from 100 feet above the water in Sec. 31, Tp. 14, R. 21 to water-level in Lsd. 16, Sec. 33, Tp. 14, R. 22. Numerous small coal seams occur somewhat erratically throughout the bedrock in Blackspring Ridge southward through township 13; on the assumption that they have approximately the same dip as the Wolf Coulee seam, these appear to belong to three coaly zones separated from each other by 100 to 160 feet of barren strata (Fig. 2).

The lower limit of the lowest of the three zones, which is believed to be as much as 270 feet thick, is taken to be the Wolf Coulee coal seam; in Sec. 31, Tp. 14, R. 21, this seam lies about 30 feet above the base of the Edmonton Formation, the coal-bearing formation of this region (see Appendix D). The middle zone, believed to be 70 to 120 feet thick, is probably separated from the lowest by a barren interval about 100 feet thick; its upper limit is probably exposed in the spring-outcrops in Sec. 7, Tp. 13, R. 22 at an elevation of 3280 feet. In the uppermost coal zone on Blackspring Ridge, only one seam is known, whose presence is inferred from weathered coal in soil in SW. 1/4 Sec. 17, Tp. 13, R. 22 at an elevation of 3440 feet.

The Wolf Coulee seam also outcrops in the cliff on the north side of Travers Reservoir at Little Bow Provincial Park (Sec. 2, Tp. 15, R. 22). From this location it may be traced eastward to the North Travers cluster of mines (Sec. 17, Tp. 15, R. 21) and northward along both sides of Lake McGregor to the limits of bedrock outcrop in Sec. 32, Tp. 16, R. 21. In the region north of Travers Reservoir this is the lowest coal seam, and in an outcrop in Lsd. 13, Sec. 4, Tp. 16, R. 21 it lies about 15 feet above the base of the Edmonton Formation.

Above the Wolf Coulee seam, however, strata cannot be correlated from the south side of Travers Reservoir to the north side with certainty. Above an almost completely barren zone overlying the Wolf Coulee seam with a thickness of up to 300 feet there appears to be a coaly zone in the southwestern part of Tp. 15, R. 22 and the southeastern part of Tp. 15, R. 23, consisting of two distinct seams or groups of seams (Fig. 4a; sections D-$D_2$, D-$D_3$, Fig. 4b). It is believed that the lower of these seams (which is split where intersected by the borehole at NE. corner Sec. 24, Tp. 15, R. 23) is the one exploited at Rhodes Mine in NE. 1/4 Sec. 8, Tp. 15, R. 22; it may also be equivalent to the seam exploited at the Carmangay mine in Sec. 9, Tp. 14, R. 23.

In the northwestern part of Tp. 16, R. 21 and the northeastern part of Tp. 16, R. 22 there is evidence of a coaly zone consisting of two distinct seams separated from the Wolf Coulee coal seam by a barren zone about 200 feet thick. It is assumed that the same coaly zone occurs in the two regions, and that it dips, like the underlying Wolf Coulee seam, at about 20 feet per mile to the west near Sec. 2, Tp. 15, R. 22 and about 15 feet per mile near Sec. 17, Tp. 15, R. 21. This coaly zone, on the basis of elevation, may be a correlative of the uppermost part of the lowest coaly zone recognized south of Travers Reservoir.

In the regions discussed above, strata are believed to be almost flat-lying and undisturbed, but the coal seam or seams south of Thigh Hill are not. There are two distinct clusters of mines here: an upper one mostly in E. 1/2 Sec. 8, Tp. 16, R. 23 (the Thigh Hill mines) and a lower one, mostly along the south boundary of Sec. 4, Tp. 16, R. 23 (the Champion mines); annual surveys of these mines, reported to the Mines Branch, supply sufficient data to allow the drawing of structure contours and isopachs of the coal seams (see section $D-D_2$, Fig. 4b; Fig. 4c).

In the Thigh Hill mines (Fig. 4c), the seam exhibits a distinct domal structure with a dip of about 200 feet to the mile on the west side over a distance of nearly 3500 feet - an extremely steep and persistent dip for a prairie coal seam. At the Champion mines the seam dips even more steeply over short distances and has the attitude of a somewhat irregular monocline dipping south and south-southwest.

The Reid Hill mine occupies an isolated position in Lsds. 14 and 15, Sec. 24, Tp. 16, R. 23, where a 1.8-foot seam outcropping along the east face of a sharp hogback ridge was continuously exploited as an underground operation for 31 years. The mine entry was located directly in the coal outcrop on the east face of the ridge (Fig. 4b, section $D-D_1$), and the mine survey records indicate that the coal seam dips one to two degrees south of west at a slope of 211 feet per mile for at least 1000 feet.

The relationship amongst seams at the Thigh Hill mines, the Champion mines and the Reid Hill mine is unknown since no information is available from the areas between. If it be assumed that the same seam was mined at the two Thigh Hill clusters (section $D-D_2$, Fig. 4b), then the disposition of the anticlinal structures indicates that the seam is probably not continuous between the clusters. In fact, the mine workings in Lsd. 13, Sec. 34, Tp. 15, R. 23 are terminated on the east by a fault which displaces the coal at least 4 feet (pers. comm. Mr. E. Fontana, manager, Champion Mine). The attitude and throw of this fault are not known, but its strike appears to be 10 to 15 degrees west of north, very much the same direction as the long axes of the swarm of ovoid hills making up Thigh Hill.

Because the coal seams exhibit unusually steep dips, and because they may be discontinuous, it is concluded that the area south and east of Thigh Hill, and including the Thigh Hill mine clusters and the Reid Hill mine has been disturbed by faulting (see Appendix D).

Only one strip-pit is known to have been operated in this southern region, exploiting a 2.5-foot seam in Lsds. 9 and 16, Sec. 20, Tp. 16 R. 21 - a very unsuitable spot on the west wall of the Lake McGregor trench, with cover thickness of 120 feet everywhere except closely adjacent to the outcrop. Probably no more than a few hundred tons of coal could be mined. Elsewhere only the small area between Champion mines and the assumed seam outcrop 1.5 miles to the south has any possibility for stripping, and the rolling nature of the surface makes this very unlikely. Throughout the region, thicknesses of seams intersected in the boreholes were small; the only mineable seams are known from mines that have been opened up, and these, as can be seen from the maps (Figs. 2, 4) are restricted to very small areas. It is concluded that while seams or at least coaly zones may be widespread and fairly continuous, only locally do they thicken enough to become mineable.

### Northeast of Vulcan

Two isolated coal mines lie north of Snake Creek and northeast of the town of Vulcan (Fig. 2; Appendix C). One of these, recorded by MacKay (1949) in Sec. 17, Tp. 18, R. 23, could not be found, nor was it known to long-time residents. Immediately to the southeast a roadcut along the north boundary of Sec. 8, Tp. 18, R. 23 shows a 40-foot section of Paskapoo-type sandstone, siltstone and minor shale whose top is about level with the surface at the supposed mine; holes bored at the NE. corners of Secs. 8 and 19, Tp. 18, R. 23 showed no coal or coaly strata.

The other mine, in Lsd. 5, Sec. 34, Tp. 18, R. 23, certainly operated for a little time although no records of it exist. A straight entry went into the coal outcrop on the east wall of a dry "wind-gap" valley that cuts across an upland spur. The outcrop is marked only by a dark streak at the edge of a tilled field, and the seam's thickness is unknown; above it, to the surface of the upland spur, lie about 45 feet of sandstone. On the basis of altitude as well as of context, this seam appears to occupy a stratigraphic position roughly the same as that at the Thigh Hill mines.

### North and East of Milo

North and east of Milo is a well-marked assemblage of coal occurrences including both mines and borehole intercepts (Fig. 2; section $B-B_1$, Fig. 3a). Coal outcrops are rare and all coal seams are thin, usually about 1 foot, although the borehole at the NE. corner Sec. 34, Tp. 18, R. 20 intercepted 2.5 feet of coal at the 109-foot depth, and a thickness of 3 feet was reported for a seam in the isolated mine on the peak of Milo Ridge in the SW. 1/4 Sec. 26, Tp. 18, R. 21.

It appears that four coal-zones may be recognizable on the west side of Milo Ridge (Fig. 3), the lowermost represented by the mine and questionable outcrop in Sec. 5, Tp. 19, R. 21, at Milo, and the uppermost by the mine on the peak of the ridge (Sec. 26, Tp. 18, R. 21). On the east side of the ridge, five zones probably can be discerned, of which the upper four appear to correlate with the four on the west side. The lowermost on the east side is represented by the many thin coaly stringers intercepted in the borehole at NE. corner Sec. 34, Tp. 18, R. 20; the symbols in Sec. 3, Tp. 19, R. 19 indicate its subcrop position against post-glacial deposits (see section $B-B_1$, Fig. 3a). Minor coal zones intercepted by the boreholes at NE. corner Sec. 10, Tp. 18, R. 20 and NE. corner Sec. 7, Tp. 17, R. 20 are believed to lie at approximately the same stratigraphic position.

In the Milo region, only one strip-mine is known to have been operated - a pit measuring less than 150 feet by 40 feet in Sec. 10, Tp. 19, R. 21. The whole region, as mentioned previously, is part of the band of rough, till-covered hills extending across the Vulcan-Gleichen area from southwest to northeast; the irregular nature of the ground would make large-scale strip-mining extremely difficult. All coal seams observed are thinner than 3 feet, and most are mere coaly streaks.

## East Blackfoot Reserve

The largest masses of coal known in the Vulcan-Gleichen area are contained in a well-marked region in and around the easternmost one third of the Blackfoot Indian Reserve adjacent to the town of Bassano. In this region are many river-cliff outcrops, and a number of mines have been opened; consequently, because of the amount of information available, this district is considered in more detail as Area 2 (Figs. 2, 5).

Columns 2, 3 and 4 of the cross section $E-E_1$ (Fig. 5b) represent sections measured from continuous outcrop around the Blackfoot mines about Sec. 1, Tp. 21, R. 21, where there is clear evidence of a certain amount of local seam undulation or "rolling" with amplitudes in the order of 10 or 20 feet. The regional structure is nevertheless a relatively simple monocline with dips to the west of about 10 feet per mile.

Probably three more or less distinct coaly zones are recognizable in the area (section $E-E_1$, Fig. 5b). The lowermost, recorded in columns 18, 19 and 20, outcrops in the cliffs and badlands on either side of the Bow River about 7 miles southwest of Bassano (Secs. 22 and 23, Tp. 20, R. 19); it appears to contain one dominant seam of coal 4 to 6 feet thick lying immediately on top of Bearpaw-type strata (silty Bassano Member; see Appendix D) and in a few places underlying similar Bearpaw-type strata. A small underground mine in Lsd. 6, Sec. 26, Tp. 20, R. 19 exploited this seam, and the pit in Lsd. 14, Sec. 30, Tp. 20, R. 18, worked a probable correlative coal stringer; also there may have been a mine on the Blackfoot Reserve in Lsd. 16, Sec. 33, Tp. 20, R. 19 that extracted coal from this lower zone.

The two major occurrences of coal-bearing strata in Area 2 lie about 8 miles apart, on the Blackfoot Reserve, the one at the Blackfoot mines on the Bow river south of Cluny (Sec. 1, Tp. 21, R. 21), and the other at the Jumping Buffalo Hill or Jerry mines (Sec. 33, Tp. 20, R. 19). On the basis of assumed regional dip and structure, these are believed to be correlative strata and are indicated as such on figure 5. They constitute the Blackfoot coal zone, the middle of the three assumed coaly zones in the area.

Exploitation in this Blackfoot coal zone has been discontinuous, but often extensive. Probably the largest mining operations undertaken in the Vulcan-Gleichen area have been at the Blackfoot Mines (Lsds. 15, 16, Sec. 1, Tp. 21, R. 21 and Lsd. 1, Sec. 12, Tp. 21, R. 21). Here, and also at the adjacent Many Shot mines (Lsd. 13, Sec. 6, Tp. 21, R. 20) and the new Blackfoot strip pit (Lsd. 6, Sec. 12, Tp. 21, R. 21), coal - over half of it bright coal - was taken from a coaly zone about 24 feet thick that can be traced for more than one mile along the river-cliff outcrops (Fig. 5c).

In Lsd. 13, Sec. 6, Tp. 21, R. 20 and Lsd. 16, Sec. 1, Tp. 21, R. 21, the Blackfoot zone outcrops near the foot of a steep 150-foot river cliff, but northwestward from Lsd. 2, Sec. 12, Tp. 21, R. 21 it extends along the rim of a low 25-foot river terrace, and the upper coal-benches have been eroded, the lower ones now being overlain by fluvial silts and gravels. Consequently, at the strip mine and probably through much of the area to the northwest shown to be potentially strippable (Fig. 5a), only 5 to 6 feet of coal may be assumed to be present. Furthermore, some of the coal under the river bench may be below water-level.

At the Jumping Buffalo Hill or Jerry mines, exploitation has been discontinuous, though often extensive, and most operations have been concentrated on the large 14-foot seam (Fig. 5c). In Lsds. 5, 6 and 12, Sec. 33, Tp. 20, R. 19, mining has been carried on mostly by driving short underground entries directly into the seam from outcrops in the floor of badlands basins or at the foot of the basin walls; some evidence of strip mining is apparent in Lsd. 5. In Lsd. 14, where the same seam is largely burned out in outcrop, a mine was apparently operated through a slope or shaft.

The 14-foot "Jerry Seam" where exploited, lies beneath an old dissected river-terrace. Probably it extends to the southwest beneath Jumping Buffalo Hill itself, but here it lies at such a depth that the borehole at the NE. corner Sec. 20, Tp. 20, R. 19 failed to intercept it even though drilled to 225 feet. Thus this seam is to be considered strippable only where it underlies the river terrace; any reserves under the hill lie so deep that they can be exploited only by underground mining. The 4-foot coal seam that was extracted in the underground mine in Lsd. 16, Sec. 31, Tp. 20, R. 19, probably represents a northwestward extension of the same seam, but as a borehole immediately to the east of this mine (NE. corner Sec. 31, Tp. 20, R. 19) found no coal, in this region most of the seam has apparently been removed by erosion.

The uppermost of the three coaly zones recognized in Area 2 is illustrated in columns 7, 8, 9 and 10, section E-$E_1$ (Fig. 5b), all of which lie on the crest of the western spur of Jumping Buffalo Hill. Coal seams in this zone appear to be lensy and impersistent, though one seam (column 7) reaches 4 feet in thickness and the lowest coal in column 9 may be as thick. The thick overburden and irregular surface configuration make strip-mining impractical.

## North of Bow River

Few coal occurrences are known north of the Bow River, and only 1 of 34 boreholes encountered any coal (NE. corner Sec. 10, Tp. 21, R. 19) - a few chips at a depth of 90 feet. The SW. quarter Sec. 30, Tp. 21, R. 20 was registered many years ago as a coal mine but local informants state that only an initial prospect shaft was sunk. There is a record of a mine in Lsd. 1, Sec. 7, Tp. 22, R. 21, but no evidence of mining activity or coal occurrence was found. Two coaly stringers, both less than 6 inches thick, are exposed in a river-cliff in the SW. quarter Sec. 10, Tp. 21, R. 23, but no coal of commercial interest is present.

The only mine north of the Bow River that is known to have produced coal lies in the SE. quarter Sec. 7, Tp. 22, R. 20; the seam exploited is no more than 2 feet thick, but several small slack-heaps indicate past activity and, on the authority of local informants, coal may have been shipped to Calgary immediately after the Canadian Pacific Railway line was constructed in 1885. The elevation of the seam, 2705 feet, suggests that it may represent the Blackfoot coal zone. Work in the summer of 1962 indicates that this mine lies at the southern end of a series of thin, probably discontinuous and certainly uneconomical coal occurrences stretching northward for more than 20 miles towards Hussar.

## COAL PRODUCTION AND ANALYSES

Past production of coal in the Vulcan-Gleichen area is not readily determinable; tonnages are reported by the Alberta Mines Branch only for each Coal Area, and the Vulcan-Gleichen area encompasses the "Champion Coal Area", but not all of the "Gleichen Coal Area". Tonnages, however, have never been high, the combined annual output from the two Coal Areas varying over the years 1930 to 1960 from a high of 41,381 tons in 1938 to a low of 9,106 in 1960.

The coal is all sub-bituminous in rank; six analyses of samples from the area are available - four from the work of Stansfield and Lang (1944) (Table 1) and two from drill-cutting samples collected in 1961 (Table 2).

Though the Vulcan-Gleichen area has never been searched systematically for coal waxes and resins, a part of it appears to be one of the richer regions of Alberta in this respect*. Blebs of resin have been discovered up to several inches in diameter. In the course of the 1961 Survey, resin was observed occurring abundantly in the following locations:

-Champion Mine, Lsd. 13, Sec. 34, Tp. 15, R. 23 - yellow blebs

* Further information on coal waxes and resins is contained in an internal report, available at the Research Council of Alberta.

Table 1. "As Received" Proximate Analyses of Coals of Vulcan-Gleichen Area (from Stansfield and Lang, 1944)

| Parameter | South Travers Reservoir Region | Thigh Hill Region | McGregor Lake Region | Gleichen Coal Area (locality not specified) |
|---|---|---|---|---|
| moisture (%) | 14.9 | 12.7 | 17.3 | 17.6 |
| ash (%) | 7.1 | 7.4 | 8.3 | 9.5 |
| volatile matter (%) | 31.9 | 34.9 | 32.1 | 31.0 |
| fixed Carbon (%) | 46.1 | 45.0 | 42.3 | 41.9 |
| gross calorific value (B.t.u. per lb.) | 10,320 | 10,690 | 9,830 | 9,570 |
| rank | Sub-bituminous A | Sub-bituminous A | Sub-bituminous A | Sub-bituminous A |

Table 2. "As Received" Proximate Analyses of Drill-cutting Coal Samples, 1961 (analyst, J.F. Fryer)

| Parameter | Sample 1* | Sample 2* |
|---|---|---|
| moisture (%) | 15.9 | 14.5 |
| ash (%) | 5.6 | 8.4 |
| volatile matter (%) | 31.7 | 32.2 |
| fixed Carbon (%) | 46.8 | 44.9 |
| gross calorific value (B.t.u. per lb.) | 10,060 | 9,760 |
| rank | Sub-bituminous B | Sub-bituminous B |

* Provenance of Sample 1; NE. cor. Sec. 19, Tp. 18, R. 20; depth 87 feet.
Provenance of Sample 2; NE. cor. Sec. 20, Tp. 20, R. 19; depth 80 feet.

to 1/8 in.; abundant in bottom 6 inches.

- Reid Hill Mine, Lsd. 15, Sec. 24, Tp. 16, R. 23, blebs to 1/8 in. in dirty coal in slack heap.

- Abandoned mine east of Lake McGregor, NE. quarter Sec. 28, Tp. 15, R. 21, blebs to 1/8 in. in base of 2-foot seam.

These locations are all in a relatively restricted area between Thigh Hill and Lake McGregor; it seems that, should coal resins and waxes be considered economically important, this is a logical place to search for them.

## CONCLUSIONS AND ESTIMATES

Thin seams of coal were found widely disseminated through the Edmonton Formation in the Vulcan-Gleichen area, but the drilling program only slightly amplified previous knowledge of their distribution. From this it is inferred that the location of most near-surface coal bodies in the Vulcan-Gleichen area has long been known.

This conclusion is not surprising if the most urgent needs of the early settlers on the Alberta short-grass prairies - water and warmth - be considered. Great numbers of wells were drilled for water so that most of the near-surface coal seams must have been intersected and noted; and whenever these were even marginally suitable, they were exploited. Thus, a shallow-drilling program is certain to be a repetition of the haphazard but nonetheless effective program of the original settlers and can probably do little more than supply details of thickness, depth and continuity of already recognized coal occurrences.

However, in areas mantled by extensive sheets of gravel, such as the northeast flank of Blackspring Ridge (Tp. 14, R. 21) and the north end of McGregor Valley (Tp. 20, R. 21) (see Fig. 7), the search for water would most likely be successful without wells having to penetrate into bedrock; and gravel beds are difficult and expensive to drill through. Thus there may remain, under these gravel sheets, coal resources which are as yet unknown.

The near-surface coal found in the Vulcan-Gleichen area, all sub-bituminous A or B in rank, occurs in the following regions:

(1) Blackspring Ridge, Thigh Hill, and the shores of Lake McGregor,

(2) on hill crests northeast of Vulcan,

(3) east of Milo,

(4) the east end of the Blackfoot Indian Reserve,

(5) north of the Bow River.

In all five regions, the terrain is rolling and usually drift-covered, especially along the central belt of moraine-covered hills, so that variable and commonly thick overburden covers the coal. This, plus the fact that seams are generally thin, precludes economic recovery in most places. However, at Thigh Hill and in the eastern part of the Blackfoot Reserve, thicker seams are present, and where these lie under level prairie or river flats, some small prospects for strip-mining of coal exist.

At the Thigh Hill mines (Fig. 4a) the 4-foot seam rolls erratically and is covered by heavy overburden almost everywhere except south of the presently operating Champion Mine (Sec. 34, Tp. 15, R. 23). In the gentle depression that extends downhill from the mine to the outcrop in Sec. 27, Tp. 15, R. 23, a narrow area of about 10 legal subdivisions (Fig. 4c) may be underlain by strippable coal. The seam, however, is buried deeply on either side under upward rolling hills and may be cut and deformed by faulting, and also there is no assurance that it maintains its thickness. Thus no estimate of strippable tonnages can be given.

At the Blackfoot mines (Fig. 5a) a strippable coal seam may extend northwestward from the recently operated strip pit (Lsd. 6, Sec. 12, Tp. 21, R. 21) under the river terrace as far as the SW. quarter Sec. 14, Tp. 21, R. 21. All but the lower 5-foot bench of the coaly zone probably has been eroded and part of this remaining seam may lie below the level of the Bow River toward the west. Nevertheless, a maximum of five legal subdivisions are underlain by 5 feet of strippable coal - a maximum strippable reserve of about 1.5 million tons.

At the Jumping Buffalo Hill mines (Fig. 5a) the full thickness of the Jerry seam may be strippable under several erosional remnants in the northwestern part of the badlands area east and northeast of the hill, and under a larger area at the foot of the hill towards the north. It is estimated that 12 feet of coal are strippable under nine legal subdivisions - a total reserve of about 6.5 million tons. It should be noted that a substantially larger but unknown tonnage lies in the same seam under Jumping Buffalo Hill at a depth exceeding 225 feet. Recovery of this coal would require underground methods which, in view of the great thickness of the seam might be economically attractive.

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## APPENDIX A. LOCATIONS OF 1961 BOREHOLES

| Location (west of 4th Meridian) | Ground Elevation (feet) | Total Depth (feet) | Occurrence: Coal, Total Thickness (feet) | Occurrence: Gravel Present |
|---|---|---|---|---|
| NE 32-11-22 | 3179 | 75 | | O |
| NE 34-11-22 | 3239 | 45 | | * |
| NE 9-12-22 | 3305 | 230 | | B |
| NE 20-12-22 | 3377 | 122 | | |
| NE 33-12-22 | 3355 | 150 | 3 | |
| NE 33-12-23 | 3113 | 105 | | |
| NE 35-12-23 | 3190 | 120 | .5 | |
| NE 21-13-20 | 2895 | 150 | | |
| NE 23-13-21 | 3000 | 150 | | |
| NE 34-13-21 | 3120 | 150 | | |
| NE 36-13-21 | 3003 | 150 | | |
| NE 8-13-22 | 3362 | 150 | 1.25 | |
| NE 10-13-22 | 3262 | 20 | | O |
| NE 19-13-22 | 3272 | 105 | 1.5 | |
| NE 21-13-22 | 3327 | 150 | 2 | |
| NE 23-13-22 | 3172 | 150 | 2 | |
| NE 34-13-22 | 3215 | 150 | | |
| NE 8-13-23 | 3125 | 105 | | |
| NE 10-13-23 | 3110 | 105 | | |
| NE 19-13-23 | 3105 | 105 | | |
| NE 21-13-23 | 3097 | 105 | | * |
| NE 23-13-23 | 3125 | 120 | .75 | |
| NE 32-13-23 | 3088 | 105 | | |
| NE 36-13-23 | 3091 | 105 | 1 | |
| NE 12-13-24 | 3137 | 105 | | |
| NE 7-14-21 | 3125 | 90 | | O |
| NE 9-14-21 | 3124 | 150 | | |
| NE 11-14-21 | 3060 | 150 | | |

1. Legend for types of gravel occurrences:
   B -- gravel bed resting directly on bedrock, overlain directly by glacial deposit.
   O-- thick gravel bed, not drilled through; overlain directly by glacial deposit.
   * -- thin gravel bed, underlain by glacial deposits; kame type, etc.

| Location (west of 4th Meridian) | Ground Elevation (feet) | Total Depth (feet) | Occurrence Coal, Total Thickness (feet) | Occurrence Gravel Present |
|---|---|---|---|---|
| NE 20-14-21 | 3100 | 150 | | |
| NE 33-14-21 | 2904 | 150 | | B |
| NE 11-14-22 | 3125 | 40 | | O |
| NE 22-14-22 | 3112 | 120 | 3 | |
| NE 24-14-22 | 3110 | 150 | 4.5 | |
| NE 7-14-23 | 3148 | 105 | | |
| NE 9-14-23 | 3085 | 105 | | |
| NE 20-14-23 | 3165 | 105 | | |
| NE 22-14-23 | 3109 | 105 | | * |
| NE 31-14-23 | 3140 | 105 | | |
| NE 33-14-23 | 3077 | 105 | 1.5 | |
| NE 35-14-23 | 3058 | 105 | | |
| NE 11-14-24 | 3116 | 105 | | |
| NE 22-14-24 | 3209 | 105 | | |
| NE 24-14-24 | 3200 | 115 | | |
| NE 33-14-24 | 3185 | 105 | | |
| NE 9-15-21 | 2805 | 150 | | |
| NE 12-15-21 | 2936 | 150 | | |
| NE 22-15-21 | 3110 | 150 | | * |
| NE 35-15-21 | 3078 | 122 | | O |
| NE 7-15-22 | 3089 | 105 | | |
| NE 9-15-22 | 3225 | 150 | 3.5 | |
| NE 20-15-22 | 3250 | 150 | 2 | |
| NE 31-15-22 | 3225 | 105 | | |
| NE 7-15-23 | 3150 | 105 | | |
| NE 9-15-23 | 3075 | 105 | | |
| NE 11-15-23 | 3089 | 105 | 1 | |
| NE 20-15-23 | 3075 | 105 | | |
| NE 24-15-23 | 3150 | 150 | 5.25 | |
| NE 31-15-23 | 3151 | 105 | | |
| NE 33-15-23 | 3280 | 150 | 4 | |
| NE 35-15-23 | 3272 | 150 | | |
| NE 9-15-24 | 3175 | 105 | | |
| NE 11-15-24 | 3174 | 105 | | |
| NE 20-15-24 | 3175 | 105 | | * |
| NE 24-15-24 | 3155 | 105 | | |
| NE 35-15-24 | 3274 | 105 | | |

| Location (west of 4th Meridian) | Ground Elevation (feet) | Total Depth (feet) | Occurrence: Coal, Total Thickness (feet) | Occurrence: Gravel Present |
|---|---|---|---|---|
| NE 12-16-21 | 2985 | 150 | | B |
| NE 19-16-21 | 2976 | 105 | 3 | B |
| NE 23-16-21 | 3000 | 150 | | |
| NE 36-16-21 | 3030 | 150 | | |
| NE 8-16-22 | 3232 | 105 | | |
| NE 10-16-22 | 3300 | 105 | | B |
| NE 12-16-22 | 3135 | 105 | | B |
| NE 19-16-22 | 3175 | 105 | 1 | |
| NE 21-16-22 | 3148 | 105 | | B |
| NE 23-16-22 | 3120 | 105 | 1 | |
| NE 32-16-22 | 3291 | 105 | | |
| NE 34-16-22 | 3172 | 120 | 1.5 | B |
| NE 36-16-22 | 2994 | 105 | 1 | B |
| NE 8-16-23 | 2295 | 150 | 1 | |
| NE 10-16-23 | 3192 | 105 | | |
| NE 12-16-23 | 3210 | 105 | | |
| NE 19-16-23 | 3305 | 100 | | |
| NE 21-16-23 | 3112 | 105 | | |
| NE 23-16-23 | 3192 | 105 | 1 | * |
| NE 32-16-23 | 3289 | 105 | | |
| NE 34-16-23 | 3213 | 60 | | O |
| NE 36-16-23 | 3138 | 105 | 1 | |
| NE 10-16-24 | 3270 | 233 | 1 | |
| NE 12-16-24 | 3310 | 150 | | |
| NE 34-16-24 | 3297 | 105 | | |
| NE 36-16-24 | 3216 | 105 | | |
| NE 7-17-20 | 3025 | 150 | 1 | |
| NE 20-17-20 | 3175 | 150 | 1 | * |
| NE 33-17-20 | 3055 | 150 | | |
| NE 7-17-22 | 3058 | 105 | | |
| NE 9-17-22 | 3080 | 105 | | |
| NE 11-17-22 | 3064 | 105 | | |
| NE 31-17-22 | 3210 | 105 | | |
| NE 33-17-22 | 2995 | 60 | | O |
| NE 35-17-22 | 2915 | 45 | | O |
| NE 7-17-23 | 3175 | 80 | | |
| NE 20-17-23 | 3216 | 105 | | * |

| Location (west of 4th Meridian) | Ground Elevation (feet) | Total Depth (feet) | Occurrence Coal, Total Thickness (feet) | Gravel Present |
|---|---|---|---|---|
| NE 33-17-23 | 3256 | 105 | | |
| NE 35-17-23 | 3205 | 105 | | |
| NE 32-18-18 | 2923 | 210 | | |
| NE 32-18-19 | 3057 | 150 | .75 | B |
| NE 34-18-19 | 2440 | 150 | | |
| NE 36-18-19 | 2923 | 150 | | |
| NE 10-18-20 | 3008 | 150 | 3.25 | |
| NE 19-18-20 | 3179 | 105 | 2 | |
| NE 21-18-20 | 3090 | 145 | | |
| NE 32-18-20 | 3040 | 150 | 2 | |
| NE 34-18-20 | 2955 | 150 | 6.5 | |
| NE 36-18-20 | 2960 | 150 | 1 | * |
| NE 8-18-21 | 2901 | 105 | | |
| NE 21-18-21 | 3039 | 100 | | |
| NE 32-18-21 | 3033 | 150 | 2 | |
| NE 34-18-21 | 3125 | 150 | | |
| NE 36-18-21 | 3167 | 150 | 1 | |
| NE 10-18-22 | 2950 | 45 | | O |
| NE 32-18-22 | 3055 | 155 | | O |
| NE 34-18-22 | 2859 | 150 | B | |
| NE 36-18-22 | 2876 | 180 | | |
| NE 8-18-23 | 3292 | 105 | | * |
| NE 19-18-23 | 3456 | 105 | | |
| NE 36-18-24 | 3443 | 105 | | |
| NE 19-19-19 | 3112 | 150 | 1.75 | |
| NE 32-19-19 | 2904 | 150 | | |
| NE 8-19-20 | 3094 | 105 | 1 | |
| NE 10-19-20 | 3039 | 60 | | |
| NE 12-19-20 | 2975 | 150 | | |
| NE 19-19-20 | 2956 | 105 | | |
| NE 21-19-20 | 2937 | 120 | | |
| NE 34-19-20 | 2949 | 105 | | |
| NE 36-19-20 | 3076 | 105 | | |
| NE 10-19-21 | 3017 | 105 | | |
| NE 12-19-21 | 3225 | 105 | 3.25 | |
| NE 21-19-21 | 2906 | 105 | 1.5 | |
| NE 23-19-21 | 3092 | 105 | 4.5 | |
| NE 34-19-21 | 2883 | 105 | | |

| Location (west of 4th Meridian) | Ground Elevation (feet) | Total Depth (feet) | Occurrence | |
|---|---|---|---|---|
| | | | Coal, Total Thickness (feet) | Gravel Present |
| NE 36-19-21 | 2965 | 105 | | |
| NE 21-19-22 | 3051 | 105 | | |
| NE 34-19-22 | 2947 | 90 | | O |
| NE 36-19-22 | 2883 | 105 | | B |
| NE 8-19-23 | 3774 | 105 | | |
| NE 7-20-18 | 2791 | 105 | | |
| NE 9-20-19 | 2841 | 150 | | |
| NE 20-20-19 | 2987 | 225 | 4 | * |
| NE 24-20-19 | 2795 | 105 | | |
| NE 31-20-19 | 2812 | 150 | | B |
| NE 33-20-19 | 2704 | 105 | 5 | * |
| NE 9-20-20 | 3032 | 105 | | |
| NE 11-20-20 | 3125 | 105 | 2.5 | |
| NE 20-20-20 | 2893 | 105 | | |
| NE 22-20-20 | 3006 | 105 | | |
| NE 24-20-20 | 2937 | 90 | | * |
| NE 31-20-20 | 2671 | 60 | | * |
| NE 35-20-20 | 2854 | 120 | 2.75 | |
| NE 9-20-21 | 2852 | 105 | | |
| NE 20-20-21 | 2825 | 75 | | O |
| NE 31-20-21 | 2852 | 75 | | O |
| NE 33-20-21 | 2841 | 80 | | O |
| NE 35-20-21 | 2805 | 105 | | O |
| NE 24-20-22 | 2878 | 55 | | O |
| NE 35-20-22 | 2892 | 65 | | O |
| NE 10-21-19 | 2726 | 120 | | |
| NE 21-21-19 | 2707 | 105 | | |
| NE 23-21-19 | 2664 | 105 | | |
| NE 32-21-19 | 2727 | 105 | | |
| NE 8-21-20 | 2640 | 15 | | * |
| NE 21-21-20 | 2683 | 15 | | |
| NE 32-21-20 | 2789 | 105 | | |
| NE 34-21-20 | 2766 | 105 | | |
| NE 36-21-20 | 2779 | 75 | | |
| NE 34-21-21 | 2917 | 80 | | O |
| NE 36-21-21 | 2779 | 65 | | O |
| NE 8-21-22 | 2879 | 105 | | |

| Location (west of 4th Meridian) | Ground Elevation (feet) | Total Depth (feet) | Occurrence Coal, Total Thickness (feet) | Gravel Present |
|---|---|---|---|---|
| NE 12-21-22 | 2865 | 105 | | |
| NE 19-21-22 | 2868 | 105 | | |
| NE 21-21-22 | 2894 | 105 | | |
| NE 34-21-22 | 2842 | 105 | | |
| NE 23-21-23 | 2893 | 105 | | |
| NE 23-21-24 | 2926 | 105 | | O |
| NE 9-22-20 | 2807 | 105 | | |
| NE 7-22-21 | 2991 | 105 | | |
| NE 11-22-21 | 2943 | 25 | | O |
| NE 9-22-22 | 2898 | 105 | | |
| NE 11-22-22 | 2956 | 105 | | |
| NE 22-22-22 | 2957 | 120 | | |
| NE 24-22-22 | 3044 | 105 | | |
| NE 31-22-22 | 2933 | 105 | | |
| NE 33-22-22 | 2933 | 105 | | |
| NE 9-22-23 | 2872 | 105 | | |
| NE 11-22-23 | 2870 | 105 | | |
| NE 20-22-23 | 2970 | 105 | | |
| NE 22-22-23 | 2928 | 105 | | |
| NE 24-22-23 | 2968 | 105 | | |
| NE 7-22-24 | 3038 | 105 | | |
| NE 11-22-24 | 2984 | 105 | | |
| NE 22-22-24 | 3053 | 150 | | |

## APPENDIX B. LOGS OF 1961 BOREHOLES INTERSECTING COAL

(Lithologic logs corrected with the aid of electric logs.
All depths in feet; locations west of 4th Meridian.)

NE 33-12-22 surface elevation: 3355'

| | | |
|---|---|---|
| 0 - | 41.5 | buff till |
| 41.5 - | 61 | dark brown weathered coaly shale (bedrock: 3313.5') |
| 61 - | 110 | light grey and dark brown bentonitic silty shale |
| 110 - | 123 | dark brown shale |
| 123 - | 125 | coal (top: 3232') |
| 125 - | 134 | light grey bentonitic shale |
| 134 - | 135 | coal (top: 3221') |
| 135 - | 150 | dark grey hard shale. |

NE 19-13-22 surface elevation: 3272'

| | | |
|---|---|---|
| 0 - | 15 | buff salt & pepper siltstone (bedrock at surface) |
| 15 - | 35 | brown shale |
| 35 - | 39 | brown coaly shale |
| 39 - | 73 | light grey to brown bentonitic shale |
| 73 - | 74 | coal (top: 3199') |
| 74 - | 94 | light to dark grey bentonitic shale |
| 94 - | 94.5 | coal (top: 3178') |
| 94.5 - | 99 | light grey salt & pepper bentonitic siltstone |
| 99 - | 105 | light grey shale. |

NE 21-13-22 surface elevation: 2237'

| | | |
|---|---|---|
| 0 - | 10 | buff till |
| 10 - | 32 | buff shale (bedrock: 3317') |
| 32 - | 37 | light grey salt & pepper bentonitic well cemented sandstone |
| 37 - | 47 | light grey to light green very bentonitic shale |
| 47 - | 52 | light grey salt & pepper bentonitic siltstone |
| 52 - | 56 | light grey bentonitic shale |
| 56 - | 61.5 | light grey salt & pepper well cemented siltstone |
| 61.5 - | 62.5 | coal (top: 3265.5') |
| 62.5 - | 77 | dark grey shale |
| 77 - | 82 | light grey salt & pepper sandstone |
| 82 - | 85 | black shale |
| 85 - | 87 | light grey salt & pepper bentonitic sandstone |
| 87 - | 91.5 | black shale |
| 91.5 - | 94.5 | light grey salt & pepper siltstone |
| 94.5 - | 112 | black to dark brown coaly shale |
| 112 - | 122 | dark grey shalley siltstone |
| 122 - | 131.5 | light brown bentonitic shale |
| 131.5 - | 132.5 | coal (top: 3195.5') |
| 132.5 - | 150 | light grey bentonitic shale. |

NE 23-13-22 surface elevation: 3172'

| | | |
|---|---|---|
| 0 - | 35 | buff till |
| 35 - | 77 | light brown shale with coal stringers (bedrock: 3137') |
| 77 - | 85 | light grey salt & pepper siltstone |
| 85 - | 89 | light brown shale |
| 89 - | 90 | coal (top: 3083') |
| 90 - | 102 | light brown shale |
| 102 - | 137 | light grey salt & pepper siltstone |
| 137 - | 138 | coal (top: 3035') |
| 138 - | 142 | shale |
| 142 - | 147 | weathered coal & shale |
| 147 - | 150 | shale. |

NE 36-13-23 surface elevation: 3091'

| | | | |
|---|---|---|---|
| 0 | - | 45 | buff till |
| 45 | - | 69 | dark grey glacial lake deposit |
| 69 | - | 72 | brown coaly shale (bedrock: 2922') |
| 72 | - | 73 | coal (top: 2919') |
| 73 | - | 90 | light grey bentonitic shale |
| 90 | - | 105 | light grey salt & pepper sandstone. |

NE 22-14-22 surface elevation: 3112'

| | | | |
|---|---|---|---|
| 0 | - | 35 | till |
| 35 | - | 45 | buff silty clay |
| 45 | - | 50 | light grey silty clay |
| 50 | - | 60 | light grey salt & pepper siltstone (bedrock: 3062') |
| 60 | - | 65 | dark brown silty shale |
| 65 | - | 70 | dark grey salt & pepper siltstone |
| 70 | - | 80 | no samples - lost circulation |
| 80 | - | 85 | dark grey siltstone |
| 85 | - | 90 | coal (3') & dark brown shale (top: 3027') |
| 90 | - | 95 | light grey salt & pepper siltstone |
| 95 | - | 105 | dark brown silty shale |
| 105 | - | 120 | no samples - lost circulation. |

NE 24-14-22 surface elevation: 3110'

| | | | |
|---|---|---|---|
| 0 | - | 45 | buff till |
| 45 | - | 110 | dark grey glacial lake deposit |
| 110 | - | 112 | dark grey silty shale (bedrock: 3000') |
| 112 | - | 115 | coal (top: 2998') |
| 115 | - | 126 | light grey silty shale |
| 126 | - | 132 | light grey salt & pepper bentonitic siltstone |
| 132 | - | 138 | light grey bentonitic shale |
| 138 | - | 139.5 | coal (top: 2972') |
| 139.5 | - | 150 | brown silty coaly shale with thin coal stringers. |

NE 33-14-23 surface elevation: 3077'

| | | | |
|---|---|---|---|
| 0 | - | 40 | till |
| 40 | - | 48 | brown coaly shale (bedrock: 3037') |
| 48 | - | 54 | grey siltstone |
| 54 | - | 66.5 | light grey bentonitic shale |
| 66.5 | - | 68 | shaley coal (top: 3010.5') |
| 68 | - | 105 | light grey to brown shale. |

NE 9-15-22 surface elevation: 3225'

| | | | |
|---|---|---|---|
| 0 | - | 55 | till |
| 55 | - | 100 | dark grey glacial lake deposit |

| | | | |
|---|---|---|---|
| 100 | - | 110 | dark grey salt & pepper bentonitic siltstone (bedrock: 3125') |
| 110 | - | 120 | brown shale |
| 120 | - | 123.5 | coal (top: 3105') |
| 123.5 | - | 129.5 | bentonitic siltstone |
| 129.5 | - | 135 | silty shale |
| 135 | - | 141 | salt & pepper siltstone |
| 141 | - | 144 | shale |
| 144 | - | 146 | light grey salt & pepper siltstone with coal stringers |
| 146 | - | 150 | brown silty shale. |

NE 20-15-22 surface elevation: 3250'

| | | | |
|---|---|---|---|
| 0 | - | 55 | till |
| 55 | - | 65 | dark grey siltstone (bedrock: 3195') |
| 65 | - | 81 | shale |
| 81 | - | 98 | shaley siltstone |
| 98 | - | 100 | coal & shale (top: 3152') |
| 100 | - | 110 | dark brown silty shale |
| 110 | - | 115 | light grey salt & pepper siltstone |
| 115 | - | 120 | shale |
| 120 | - | 123 | light grey salt & pepper siltstone |
| 123 | - | 128 | shale |
| 128 | - | 131 | light brown siltstone |
| 131 | - | 137 | light brown silty shale |
| 137 | - | 144 | light brown siltstone |
| 144 | - | 150 | dark brown silty shale. |

NE 11-15-23 surface elevation: 3089'

| | | | |
|---|---|---|---|
| 0 | - | 30 | buff till and brown clay with coal chips |
| 30 | - | 40 | dark grey glacial lake deposit |
| 40 | - | 48 | light grey salt & pepper bentonitic siltstone (bedrock: 3049') |
| 48 | - | 53.5 | dark grey silty shale |
| 53.5 | - | 54.5 | sandstone |
| 54.5 | - | 71.5 | dark grey silty bentonitic shale |
| 71.5 | - | 72.5 | coal (top: 3017.5') |
| 72.5 | - | 78 | light grey bentonitic coaly shale |
| 78 | - | 81 | light grey shale |
| 81 | - | 85 | siltstone |
| 85 | - | 98 | light grey shale |
| 98 | - | 101.5 | brown silty shaley coal |
| 101.5 | - | 105 | shale. |

NE 24-15-23 surface elevation: 3150'

| | | | |
|---|---|---|---|
| 0 | - | 38 | till |
| 38 | - | 50 | salt & pepper very bentonitic siltstone (bedrock: 3112') |
| 50 | - | 52.5 | coal (top: 3100') |
| 52.5 | - | 70 | dark grey silty bentonitic shale |

| | | |
|---|---|---|
| 70 - 79 | dark grey bentonitic siltstone |
| 79 - 86 | silty shale |
| 86 - 91 | dark grey siltstone |
| 91 - 100 | dark brown silty shale |
| 100 - 102 | light grey salt & pepper bentonitic siltstone |
| 102 - 126 | shale and siltstone |
| 126 - 126.75 | coal (top: 3024') |
| 126.75- 144 | dark brown silty shale |
| 144 - 146 | coal (top: 3006') |
| 146 - 150 | dark brown shale. |

NE 33-15-23 surface elevation: 3280'

| | |
|---|---|
| 0 - 10 | dark grey salt & pepper sandstone (bedrock at surface) |
| 10 - 20 | dark grey shale, black shale, coal |
| 20 - 44 | grey sandstone and shale |
| 44 - 46 | sandstone |
| 46 - 63 | silty grey shale |
| 63 - 67 | coal (top: 3217') |
| 67 - 100 | grey siltstone |
| 100 - 104 | salt & pepper sandstone |
| 104 - 150 | grey shale. |

NE 19-16-21 surface elevation: 2976'

| | |
|---|---|
| 0 - 49 | buff till |
| 49 - 61.5 | gravel |
| 61.5 - 70 | light grey salt & pepper siltstone (bedrock: 2914.5') |
| 70 - 73 | coal (top: 2906') |
| 73 - 86 | brown bentonitic coaly shale |
| 86 - 87 | coaly shale? |
| 87 - 89 | light grey bentonite |
| 89 - 92 | coaly shale? |
| 92 - 105 | dark grey bentonitic shale. |

NE 19-16-22 surface elevation: 3175'

| | |
|---|---|
| 0 - 33 | buff till |
| 33 - 78 | dark grey glacial lake deposit |
| 78 - 79 | coal (bedrock: 3097') |
| 79 - 92 | dark brown coaly shale |
| 92 - 105 | dark silty shale. |

NE 23-16-22 surface elevation: 3120'

| | |
|---|---|
| 0 - 46 | buff till |
| 46 - 47 | coal (bedrock: 3074') |
| 47 - 52 | brown coaly shale |
| 52 - 75 | light brown bentonitic shale |

| | | | |
|---|---|---|---|
| 75 | - | 79 | light grey salt & pepper bentonitic siltstone |
| 79 | - | 95 | light brown bentonitic shale |
| 95 | - | 100 | light brown bentonitic coaly shale |
| 100 | - | 105 | light grey salt & pepper siltstone. |

NE 34-16-22 surface elevation: 3172'

| | | | |
|---|---|---|---|
| 0 | - | 35 | buff till |
| 35 | - | 90 | dark grey glacial lake deposit |
| 90 | - | 96 | gravel |
| 96 | - | 102 | coaly shale (bedrock: 3076') |
| 102 | - | 103 | coal (top: 3070') |
| 103 | - | 107 | brown bentonitic coaly shale |
| 107 | - | 107.5 | coal (top: 3065') |
| 107.5 | - | 120 | dark grey bentonitic shale. |

NE 36-16-22 surface elevation: 2994'

| | | | |
|---|---|---|---|
| 0 | - | 44 | buff till |
| 44 | - | 69 | dark grey glacial lake deposit |
| 69 | - | 70.5 | gravel |
| 70.5 | - | 79 | dark grey bentonitic shale (bedrock: 2923.5') |
| 79 | - | 80 | coal (top: 2915') |
| 80 | - | 100 | light grey bentonitic shale |
| 100 | - | 105 | light grey salt & pepper siltstone. |

NE 8-16-23 surface elevation: 3295'

| | | | |
|---|---|---|---|
| 0 | - | 23 | buff till |
| 23 | - | 40 | buff to grey salt & pepper bentonitic sandstone (bedrock: 3272') |
| 40 | - | 52 | salt & pepper bentonitic siltstone |
| 52 | - | 62 | salt & pepper sandstone with thin coal stringers |
| 62 | - | 77 | light grey salt & pepper siltstone |
| 77 | - | 78 | coal (top: 3218') |
| 78 | - | 86 | shale |
| 86 | - | 125 | shaley siltstone |
| 125 | - | 128 | shale |
| 128 | - | 150 | light grey salt & pepper siltstone. |

NE 23-16-23 surface elevation: 3192'

| | | | |
|---|---|---|---|
| 0 | - | 5 | till |
| 5 | - | 40 | sand and gravel |
| 40 | - | 65 | light grey bentonitic shale (bedrock: 3152') |
| 65 | - | 67 | coaly shale |
| 67 | - | 68 | coal & shale (top: 3125') |
| 68 | - | 105 | light grey bentonitic shale. |

NE 36-16-23 surface elevation: 3138'

| | | |
|---|---|---|
| 0 | - 50 | buff till |
| 50 | - 72 | buff shale (bedrock: 3088') |
| 72 | - 85.5 | light grey to brown coaly shale |
| 85.5 | - 86 | coal (top: 3053') |
| 86 | - 105 | light grey bentonitic shale. |

NE 10-16-24 surface elevation: 3270'

| | | |
|---|---|---|
| 0 | - 50 | buff till |
| 50 | - 113 | dark grey glacial lake deposit (bedrock: 3220') |
| 113 | - 120 | silty shale |
| 120 | - 130 | silty bentonite |
| 130 | - 135 | salt & pepper bentonitic siltstone |
| 135 | - 136, | coal (top: 3135') |
| 136 | - 154 | salt & pepper bentonitic siltstone |
| 154 | - 159 | light grey salt & pepper bentonitic sandstone |
| 159 | - 169 | bentonitic siltstone |
| 169 | - 171 | light grey salt & pepper coarse sandstone |
| 171 | - 179 | bentonitic siltstone |
| 179 | - 186 | shale |
| 186 | - 199 | light grey salt & pepper bentonitic sandstone - thin coal stringers |
| 199 | - 202 | shale |
| 202 | - 206 | light grey salt & pepper bentonitic sandstone |
| 206 | - 210 | shale |
| 210 | - 220 | bentonitic siltstone |
| 220 | - 224 | shale |
| 224 | - 228 | light grey salt & pepper siltstone |
| 228 | - 233 | light grey shale. |

NE 7-17-20 surface elevation: 3025'

| | | |
|---|---|---|
| 0 | - 57 | buff till |
| 57 | - 110 | dark grey glacial lake deposit |
| 110 | - 118 | shale (bedrock: 2915') |
| 118 | - 119 | coal (top: 2907') |
| 119 | - 126 | silty shale |
| 126 | - 137 | light grey salt & pepper bentonitic siltstone |
| 137 | - 150 | silty shale. |

NE 20-17-20 surface elevation: 3175'

| | | |
|---|---|---|
| 0 | - 40 | buff till |
| 40 | - 85 | gravel and till |
| 85 | - 105 | dark grey glacial lake deposit |
| 105 | - 110 | siltstone (bedrock: 3070') |
| 110 | - 117 | silty shale |

| | | |
|---|---|---|
| 117 - 127 | dark grey shale |
| 127 - 128 | weathered coal (top: 3048') |
| 128 - 141 | dark grey shale |
| 141 - 150 | light grey salt & pepper siltstone. |

NE 10-18-20 surface elevation: 3008'

| | |
|---|---|
| 0 - 15 | buff till |
| 15 - 35 | till - lost circulation - no samples |
| 35 - 121 | dark grey glacial lake deposit |
| 121 - 123 | shale (bedrock: 2887') |
| 123 - 131 | light grey salt & pepper bentonitic siltstone |
| 131 - 132 | coal (top: 2877') |
| 132 - 134 | shale |
| 134 - 135.25 | coal (top: 2874') |
| 135.25- 138 | shale |
| 138 - 139 | coal (top: 2870') |
| 139 - 150 | light grey shale. |

NE 19-18-20 surface elevation: 3179'

| | |
|---|---|
| 0 - 40 | buff till |
| 40 - 65 | light grey bentonitic shale (bedrock: 3139') |
| 65 - 66 | coal (top: 3114') |
| 66 - 71 | light grey silty shale |
| 71 - 75 | silty shale |
| 75 - 81 | light grey salt & pepper sandstone |
| 81 - 87 | light grey siltstone |
| 87 - 89 | coal (top: 3092') |
| 89 - 105 | shale with siltstone and coal stringers. |

NE 32-18-20 surface elevation: 3040'

| | |
|---|---|
| 0 - 43 | buff till |
| 43 - 57 | light grey salt & pepper siltstone (bedrock: 2997') |
| 57 - 64 | dark brown bentonitic shale |
| 64 - 77 | light grey salt & pepper siltstone |
| 77 - 78 | coal (top: 2963') |
| 78 - 83 | dark brown silty shale |
| 83 - 86 | light grey salt & pepper bentonitic siltstone |
| 86 - 121 | dark brown and light grey bentonitic shale |
| 121 - 122 | coal (top: 2919') |
| 122 - 150 | light grey silty bentonitic shale. |

NE 34-18-20 surface elevation: 2955'

| | |
|---|---|
| 0 - 25 | buff till |
| 25 - 86 | dark grey glacial lake deposit |

| | | |
|---|---|---|
| 86 - | 88 | dark brown silty shale (bedrock: 2869') |
| 88 - | 89 | coal (top: 2867') |
| 89 - | 110 | shale |
| 110 - | 112.5 | coal (top: 2845') |
| 112.5 - | 121 | shale |
| 121 - | 128 | coal stringers and brown coaly shale |
| 128 - | 136 | shale |
| 136 - | 137 | coal (top: 2819) |
| 137 - | 138 | shale |
| 138 - | 140 | coal (top: 2817') |
| 140 - | 150 | shale with thin coal stringers. |

NE 36-18-20 surface elevation: 2960'

| | | |
|---|---|---|
| 0 - | 20 | buff till |
| 20 - | 78 | dark grey glacial lake deposit |
| 78 - | 90 | glacial gravel |
| 90 - | 141 | dark grey glacial lake deposit |
| 141 - | 142 | coal (bedrock: 2819') |
| 142 - | 150 | brown silty shale with thin coal stringers. |

NE 32-18-21 surface elevation: 3033'

| | | |
|---|---|---|
| 0 - | 50 | till |
| 50 - | 55 | no samples - lost circulation |
| 55 - | 98 | dark grey glacial lake deposit |
| 98 - | 100 | coal (bedrock: 2934') |
| 100 - | 107 | dark grey bentonitic shale |
| 107 - | 110 | light grey bentonitic siltstone |
| 110 - | 150 | dark grey bentonitic silty shale. |

NE 36-18-21 surface elevation: 3167'

| | | |
|---|---|---|
| 0 - | 25 | buff till |
| 25 - | 66 | light grey silty shale (bedrock: 3142') |
| 66 - | 68 | light grey salt & pepper bentonitic siltstone with coal stringers |
| 68 - | 90 | dark brown silty shale |
| 90 - | 91 | coal (top: 3077') |
| 91 - | 95 | dark brown silty shale |
| 95 - | 98 | light grey salt & pepper siltstone |
| 98 - | 150 | light grey to dark silty shale with siltstone stringers. |

NE 19-19-19 surface elevation: 3112'

| | | |
|---|---|---|
| 0 - | 64 | buff to dark grey till |
| 64 - | 71 | brown bentonitic shale (bedrock: 3047') |
| 71 - | 75 | dark grey silty bentonitic shale |

| | | | |
|---|---|---|---|
| 75 | - | 79 | light grey salt & pepper siltstone |
| 79 | - | 86 | light grey bentonitic shale |
| 86 | - | 89.5 | light grey salt & pepper well cemented siltstone |
| 89.5 | - | 92.5 | brown shale |
| 92.5 | - | 93 | coal (top: 3019.75') |
| 93 | - | 99.5 | brown shale |
| 99.5 | - | 100.5 | coal (top: 3012.5') |
| 100.5 | - | 105 | chocolate brown bentonitic shale |
| 105 | - | 118 | silty shale |
| 118 | - | 150 | dark grey shale. |

NE 8-19-20 surface elevation: 3094'

| | | | |
|---|---|---|---|
| 0 | - | 47 | buff till |
| 47 | - | 52.5 | brown shale (bedrock: 3047') |
| 52.5 | - | 53.5 | weathered coal (top: 3041.5') |
| 53.5 | - | 60 | dark grey shale |
| 60 | - | 69 | light grey salt & pepper sandstone |
| 69 | - | 90 | light grey and brown shale with coal stringer |
| 90 | - | 105 | light grey to dark brown bentonitic shale . |

NE 12-19-21 surface elevation: 3225'

| | | | |
|---|---|---|---|
| 0 | - | 22 | buff till |
| 22 | - | 30 | grey silty shale (bedrock: 3203') |
| 30 | - | 32 | siltstone |
| 32 | - | 34 | brown bentonitic shale |
| 34 | - | 36 | siltstone |
| 36 | - | 44 | brown bentonitic shale |
| 44 | - | 45 | buff salt & pepper sandstone |
| 45 | - | 64 | light buff bentonitic shale |
| 64 | - | 64.75 | weathered coal (top: 3161') |
| 64.75 | - | 73 | brown bentonitic shale |
| 73 | - | 78 | shale |
| 78 | - | 79 | coal (top: 3147') |
| 79 | - | 96 | light grey bentonitic shale |
| 96 | - | 96.75 | coal (top: 3129') |
| 96 | - | 105 | light grey bentonitic shale. |

NE 21-19-21 surface elevation: 2906'

| | | | |
|---|---|---|---|
| 0 | - | 40 | buff till |
| 40 | - | 44 | light grey silty shale (bedrock: 2866') |
| 44 | - | 48 | coaly shale |
| 48 | - | 52 | weathered coal & light grey silty shale |
| 52 | - | 70 | dark brown coaly shale with coal stringers |
| 70 | - | 71.5 | coal (top: 2836') |
| 71.5 | - | 80 | brown coaly shale |
| 80 | - | 95 | lost circulation |
| 95 | - | 105 | light grey bentonitic shale. |

NE 23-19-21 surface elevation: 3092'

| | | | |
|---|---|---|---|
| 0 | - | 30 | buff till |
| 30 | - | 54 | light grey to buff silty bentonitic shale (bedrock: 3062') |
| 54 | - | 57 | coal (2') and coaly shale (top: 3038') |
| 57 | - | 65 | buff shale |
| 65 | - | 67.5 | coal and coaly shale (top: 3027') |
| 67.5 | - | 105 | brown to dark grey shale. |

NE 20-20-19 surface elevation: 2987'

| | | | |
|---|---|---|---|
| 0 | - | 5 | gravel |
| 5 | - | 52 | buff till |
| 52 | - | 78 | dark grey glacial lake deposit |
| 78 | - | 79 | coal (bedrock: 2909') |
| 79 | - | 80 | coaly shale |
| 80 | - | 81 | coal (top: 2907') |
| 81 | - | 83.5 | shale |
| 83.5 | - | 85 | coaly shale |
| 85 | - | 91.5 | dark grey to brown coaly shale |
| 91.5 | - | 95 | coal and coaly shale |
| 95 | - | 130 | dark grey and brown bentonitic shale |
| 130 | - | 138.5 | light grey salt & pepper siltstone |
| 138.5 | - | 152.5 | light grey silty shale |
| 152.5 | - | 154.5 | coaly shale |
| 154.5 | - | 172 | dark grey silty shale |
| 172 | - | 173 | coal (top: 2815') |
| 173 | - | 179 | dark grey silty shale |
| 179 | - | 180 | coal (top: 2808') |
| 180 | - | 191 | light grey silty shale |
| 191 | - | 200 | brown bentonitic shale |
| 200 | - | 225 | light grey salt & pepper sandstone and shale. |

NE 33-20-19 surface elevation: 2704'

| | | | |
|---|---|---|---|
| 0 | - | 25 | buff till with boulders and gravel |
| 25 | - | 36.5 | dark grey bentonitic shale (bedrock: 2679') |
| 36.5 | - | 40 | coal (top: 2667.75') |
| 40 | - | 40.75 | light grey salt & pepper sandstone |
| 40.75 | - | 42 | coal (top: 2663.25') |
| 42 | - | 54 | dark grey sandy shale |
| 54 | - | 59 | dark grey bentonitic shale |
| 59 | - | 62.5 | sandstone |
| 62.5 | - | 94 | light to dark grey silty shale |
| 94 | - | 95.5 | grey well cemented siltstone |
| 95.5 | - | 105 | silty shale. |

NE 11-20-20 surface elevation: 3125'

| | | |
|---|---|---|
| 0 | - 15 | buff till |
| 15 | - 20 | buff and grey till |
| 20 | - 20 | dark grey glacial lake deposit |
| 30 | - 33 | light grey bentonitic shale (bedrock: 3095') |
| 33 | - 35 | sandstone |
| 35 | - 40 | light grey bentonitic shale |
| 40 | - 50 | light grey salt & pepper sandstone |
| 50 | - 80 | light grey to green and brown bentonitic shale |
| 80 | - 82.5 | coal (top: 3045') |
| 82.5 | - 105 | light grey bentonitic shale. |

NE 35-20-20 surface elevation: 2854'

| | | |
|---|---|---|
| 0 | - 30 | buff till |
| 30 | - 51.5 | brown and dark grey bentonitic shale (bedrock: 2824') |
| 51.5 | - 61 | light grey salt & pepper well cemented sandstone |
| 61 | - 79 | light grey to green and brown (coaly) bentonitic shale |
| 79 | - 80 | coal (top: 2775') |
| 80 | - 100 | light grey and brown bentonitic shale |
| 100 | - 102 | brown coaly shale |
| 102 | - 102.75 | coal (top: 2752') |
| 102.75 | - 105 | brown coaly shale |
| 105 | - 106 | coal (top: 2749') |
| 106 | - 111 | brown coaly shale |
| 111 | - 120 | light grey well cemented siltstone. |

## APPENDIX C. LOCATIONS OF COAL MINES REGISTERED OR OPERATED WITHIN THE VULCAN-GLEICHEN AREA

NOTE 1 - A few old mines, discovered in the course of fieldwork, are not listed in the records of the Mines Branch, Alberta Department of Mines and Minerals. It is presumed that these were opened under "Domestic Permits"-annually-renewable licences allowing property-holders to extract up to 50 tons of coal per year for their own use. The Domestic Permit regulation was withdrawn in the year 1949.

NOTE 2 - Registered Coal Mines in Alberta are numbered consecutively without regard to geographical location. Approximate date of a mine's first registration may be determined from its registration number by referring to the following table:

| Registration Number: | Approximate Year: |
|---|---|
| 1 - 100 | 1888 - 1905 (Territorial Government) |
| 100 - 200 | 1905 - 1909 |
| 200 - 300 | 1909 - 1911 |

| | | | |
|---|---|---|---|
| 300 - | 400 | 1911 - | 1913 |
| 400 - | 499 | 1913 - | 1915 |
| 600 - | 700 | 1915 - | 1917 |
| 700 - | 800 | 1917 - | 1919 |
| 800 - | 900 | 1919 - | 1921 |
| 900 - | 1000 | 1921 - | 1922 |
| 1000 - | 1100 | 1922 - | 1923 |
| 1100 - | 1200 | 1923 - | 1925 |
| 1200 - | 1300 | 1925 - | 1929 |
| 1300 - | 1400 | 1929 - | 1932 |
| 1400 - | 1500 | 1932 - | 1936 |
| 1500 - | 1600 | 1936 - | 1943 |
| 1600 - | 1700 | 1943 - | 1949 |
| 1700 - | 1758 | 1949 - | 1964 |

| Region | Location (W.4th Mer.) | Mine Number | Type | Elev. of Seam at Entry | Cover (feet) | Representative Logs: Notes |
|---|---|---|---|---|---|---|
| Carmangay | -Lsd.9 & 16 Sec.9-Tp. 14-R.23 | 1112 | u/g* | 2980' | | Soapstone, clay .25", coal 1.5', bone .5', shale |
| S. of Travers Reservoir | -NE. Sec.29-Tp. 14-R.21 | 264 | | | | |
| | -Lsd.13 Sec.30-Tp. 14-R.21 | 730 | u/g | | | |
| | -NE. Sec.25-Tp. 14-R.22 | | | | | |
| | -Lsd.14 Sec.25-Tp. 14-R.22 | | | | | |
| N. of Travers; Lake McGregor | -Lsd.1,3,4,6 8 Sec.17-Tp. 15-R.21 | 1336 | " | | | |
| | | 663 | | | | |
| | | 685 | " | 2880 | 150 | Coal 2', bone 1', coal .5', bone .5' |
| | | 1350 | " | 2880 | | |
| | -Lsd.2,9,15, 16 Sec.28-Tp. 15-R.21 | 1141 | " | 2900 | 125 | |
| | | 461 | | 2910 | | |
| | | 777 | | | | |

* underground

| Region | Location (W.4th Mer.) | Mine Number | Type | Elev. of Seam at Entry | Cover (feet) | Representative Logs: Notes |
|---|---|---|---|---|---|---|
| N. of Travers; Lake McGregor (cont) | -Lsd.2 Sec.33-Tp. 15-R.21 | | u/g | | | |
| | -Lsd.1 Sec.4-Tp. 16-R.21 | 929 | " | | | |
| | -NW. Sec.4-Tp. 16-R.21 | 137 | " | 2870 | 150 | |
| | -Lsd.13 Sec.9-Tp. 16-R.21 | 1182 | " | | | |
| | -Lsd.9,16 Sec.20-Tp. 16-R.21 | 1434 | strip pit | 2880 | | |
| | -Lsd.15,16 Sec.29-Tp. 16-R.21 | 224 | u/g | 2875 | | |
| | -Lsd.9 Sec.29-Tp. 16-R.21 | 134 | " | | | |
| | -Lsd.2 Sec.32-Tp. 16-R.21 | | " | | | |
| | -NE. Sec.29-Tp. 16-R.21 | 659 | " | | | |
| Thigh Hill | -Lsd.7 Sec.8-Tp. 15-R.22 | 136 | " | 3070 | 100-120 | (Rhodes Mine) |
| | -NW. Sec.8-Tp. 15-R.22 | 307 | " | | | |
| | -Lsd.4 Sec.9-Tp. 15-R.22 | 714 | " | | | |
| | -Lsd.14 Sec.32-Tp. 15-R.23 | 1424 | " | | | |
| | -Lsd.16 Sec.32-Tp. 15-R.23 | 1454 | " | 3145 | | |

| Region | Location (W.4th Mer.) | Mine Number | Type | Elev.of Seam at Entry | Cover (feet) | Representative Logs: Notes |
|---|---|---|---|---|---|---|
| Thigh | -Lsd.9,14,15, | 476 | u/g | 3190 | 33 | |
| Hill | 16 | | | | | |
| (cont) | Sec.33-Tp. | 1273 | " | 3160 | | |
| | 15-R.23 | | | | | |
| | -Lsd.13 | 1509 | " | 3195 | 55 | |
| | Sec.34-Tp. | | | | | |
| | 15-R.23 | 1509A | " | 3210 | 50-60 | (Champion Mine-operating 1961) Sandstone, black bentonitic shale with lenses of bentonite 1-4', platy coal .2', coal 4', shale floor |
| | -Lsd.4,5 | 822 | " | | | |
| | Sec.24-Tp. | 1290 | | | | |
| | 16-R.22 | | | | | |
| | -SE. | | | | | |
| | Sec.24-Tp. | 432 | " | | | |
| | 16-R.22 | | | | | |
| | -Lsd.1,2,3,4, | 910 | " | 3213 | | (Smith Mine-operating 1961) |
| | 13 | | | | | |
| | Sec.4-Tp. | 1137 | " | 3183 | | |
| | 16-R.23 | 198 | " | 3270 | | |
| | -Lsd.1 | 1415 | " | 3165 | 70 | |
| | Sec.5-Tp. | | | | | |
| | 16-R.23 | | | | | |
| | -S.1/2 | 218 | " | | | |
| | Sec.8-Tp. | | | | | |
| | 16-R.23 | | | | | |
| | -Lsd.7,8 | 1418 | " | 3240 | | |
| | Sec.8-Tp. | 1319 | " | 3270 | | |
| | 16-R.23 | | | | | |
| | -Lsd.10 | 1382 | " | | | |
| | Sec.8-Tp. | | | | | |
| | 16-R.23 | | | | | |
| | -Lsd.16 | 296 | " | 3275 | | |
| | Sec.5-Tp. | | | | | |
| | 16-R.23 | | | | | |
| | -Lsd.1,8 | | " | | | |
| | Sec.8-Tp. | | | | | |
| | 16-R.23 | | | | | |

| Region | Location (W.4th Mer.) | Mine Number | Type | Elev.of Seam at Entry | Cover (feet) | Representative Logs: Notes |
|---|---|---|---|---|---|---|
| Thigh Hill (cont) | -Lsd.7,10 Sec.8-Tp. 16-R.23 | 1371 | u/g | 3230 | | |
| | -Lsd.9,10 Sec.8-Tp. 16-R.23 | 1565 | " | 3250 | 95+ | |
| | -Lsd.11 Sec.8-Tp. 16-R.23 | 1466 | " | 3150 | 170+ | |
| | -Lsd.4 Sec.9-Tp. 16-R.23 | 739 | " | 3270 | | |
| | -Lsd.14,15 Sec.24-Tp. 16-R.23 | 151 | " | 3215 | 45 | (Reid Hill Mine) Sandstone, black shale .2', coal .8', sandstone .1', coal 1.0', black shale .2', clay floor |
| NE. of Vulcan | -Lsd.5 Sec.34-Tp. 17-R.23 | | " | 3295 | 45 | |
| | -Lsd.5 Sec.17-Tp. 18-R.23 | 1320 | | | | |
| NE. of Milo | -Lsd.10 Sec.32-Tp. 18-R.20 | | " | 3020 | 30-60 | |
| | -Lsd.4 Sec.26-Tp. 18-R.21 | 437 963 | " | 3325 | 90 | |
| | -Lsd.9,15 Sec.5-Tp. 19-R.20 | 1222 | " | | | |
| | -Lsd.15 Sec.5-Tp. 19-R.21 | | " | 2850 | 50 | |
| | -Lsd.11 Sec.10-Tp. 19-R.21 | 941 | " | 3010 | 5-50 | (may have been a strip pit) |
| | -Lsd.4 Sec.27-Tp. 19-R.21 | 1023 | " | 3010 | 10-50 | |

| Region | Location (W.4th Mer.) | Mine Number | Type | Elev. of Seam at Entry | Cover (feet) | Representative Logs: Notes |
|---|---|---|---|---|---|---|
| E. half of Black-foot Reserve | -Lsd.11,14 Sec.30-Tp.20-R.18 | 1111 | u/g | 2770 | | |
| | -Lsd.6 and/or 7 Sec.26-Tp.20-R.19 | 1249 | " | 2670 | | |
| | -Lsd.16 Sec.31-Tp.20-R.19 | | " | | | |
| | -Lsd.4,5 Sec.33-Tp.20-R.19 | 72b | " | 2780 | 10-35 | (Jerry Mine) Black shale 1', coal 1', bone .5', coal 4', bone and coal1.5', coal 1', bentonite .2', coal 3.8', bentonite .2', coal 2.9' |
| | -Lsd.12 Sec.33-Tp.20-R.19 | 842 | | | | |
| | -Lsd.14 Sec.33-Tp.20-R.19 | | " | | | |
| | -Lsd.16 Sec.33-Tp.20-R.19 | | " | 2690 | 35-55 | |
| | -Lsd.10 Sec.12-Tp.20-R.20 | | | | | |
| | -Lsd.3 Sec.32-Tp.20-R.20 | | | | | |
| | -Lsd.13 Sec.6-Tp.21-R.20 | 72a | " | 2705 | | (Many Shot Mine) |
| | -Lsd.16 Sec.1-Tp.21-R.21 | | " | 2710 | 120 | (Blackfoot Mine) Coal .8', coal 1.2', coal 1.4', covered 4', coal 1', black siltstone 1.5', coal 3.5', covered 4' (probably incl. 2.5' dirty coal), coal 3', bone .5', coal 1' |

| Region | Location (W.4th Mer.) | Mine Number | Type | Elev.of Seam at Entry | Cover (feet) | Representative Logs: Notes |
|---|---|---|---|---|---|---|
| E. half of Black-foot Reserve (cont) | -Lsd.1 Sec.12-Tp. 21-R.21 | | " | 2710 | | |
| | -Lsd.6 Sec.12-Tp. 21-R.21 | | strip pit | 2670 | 18 | |
| | -Lsd.8 Sec.12-Tp. 21-R.21 | | u/g | | | |
| N. of C.P.R. Main Line | -SW. Sec.30-Tp. 21-R.20 | 747 | " | | | |
| | -Lsd.2 Sec.7-Tp. 22-R.20 | 1067 | " | 2705 | 110 | |
| | -SE. Sec.7-Tp. 22-R.20 | 990 | | | | |
| | -Lsd.1 Sec.7-Tp. 22-R.21 | 1103 | " | | | |

## APPENDIX D. BOUNDARIES OF THE EDMONTON FORMATION IN THE VULCAN-GLEICHEN AREA

by

J.D. Campbell

### General

As explained in the text of this report, the Vulcan-Gleichen area lies between the longitudes 112°15' and 113°20' west, and latitudes 49°50' and 51°00' north. Topographically it consists of a flat prairie level to the east at roughly 2800 feet elevation, a more rolling prairie level to the west at about 3400 feet elevation and, separating these, a belt of rough bedrock-cored hills 10 to 15 miles wide extending across the map-area from Keho Lake to Bassano.

Russell and Landes (1940) reviewed the geology of this general region and presented a detailed study of the southernly part of the area. The geological map of the "Bassano Area" (Stewart, 1943) includes roughly the eastern half of the Vulcan-Gleichen area and was used by MacKay (1949) in compiling the "Champion" and "Gleichen" Coal-Area maps. Clark (1931) and Gallup (1955) described outcrop occurrences of the Bearpaw Formation and its relation to the Edmonton Formation in the Vulcan-Gleichen area, and Russell (1950) and Tozer (1952, 1953, 1956) gave general accounts of the Upper Cretaceous and Paleocene strata of the southern part of Alberta.

Previous study of the surface bedrock adjacent to the Vulcan-Gleichen area has been based on outcrops which are mostly restricted to the major stream-trenches; geological boundaries have therefore had to be interpolated for distances as great as 30 miles. The considerable data on bedrock lithology amassed by the 1961 Research Council borehole program in areas between the trenches make it possible to map the boundaries of the Edmonton Formation with somewhat greater precision than heretofore (Fig. 6).

## Rock Units

Six rock units outcrop in the Vulcan-Gleichen area (Fig. 6). The lowermost of these, the continental, coal-bearing Oldman Formation underlies about nine townships in the extreme eastern and southeastern part of the map-area, but is not considered in this report. Nor was consideration given to the thin-bedded cliff-forming grey calcareous sandstones of the St. Mary River Formation or the variegated sandy shales of the Willow Creek Formation which outcrop sparingly in about seven townships south of the Little Bow River and west of Highway 23; their distribution on the map (Fig. 6) is based chiefly on data from Tozer (1956).

The remainder of the map-area is underlain by the Bearpaw, Edmonton and Paskapoo Formations, each of roughly the same areal extent. The Bearpaw Formation, Late Cretaceous in age, consists of thin-bedded marine shales and siltstones overlying the Oldman Formation; the Edmonton Formation, mostly latest Cretaceous in age, consists of nonmarine sandstones, siltstones, shales and coal seams, and lies above the Bearpaw; at the top of the column lies the Paskapoo Formation, mostly Paleocene in age - a sequence of nonmarine sandstones, siltstones and shales.

The upper and lower boundaries of the Edmonton Formation appear to be transitional; no more than local unconformities occur at them. For this reason, somewhat arbitrary criteria (Campbell, 1962) have been adopted to aid in positioning formational boundaries. These criteria are outlined below.

All uniform, thinly bedded, argillaceous strata at the base of the Edmonton Formation, which are dark-grey as cutting samples and grey, brownish or chocolate-colored in outcrop, and which give a uniform, low-resistivity trace on the electric log, are referred to the Bearpaw Formation.

All light-colored, irregularly bedded strata overlying the Bearpaw, containing coal seams or coaly beds, and giving complex or erratic electric log resistivity traces are referred to the Edmonton Formation. This rock unit may be distinguished from the Bearpaw by its irregularly bedded nature, its higher content of carbonaceous and fine-grained arenaceous beds, and its lighter color, both in cutting samples and in weathered outcrop; also, the Bearpaw Formation contains marine fossils and the Edmonton contains dinosaur remains.

The Paskapoo Formation is defined as any massive, light-buff weathering, non-dinosaur-bearing sandstone overlying known Edmonton strata, plus any other associated nonmarine strata lying above the sandstone. It is distinguished from the underlying Edmonton Formation by the greater coarseness of its sand grains, by its lower content of argillaceous, bentonitic and carbonaceous beds, by its darker grey color in unweathered chip samples, and by its buff color when weathered, commonly in outcrop appearing definitely yellow.

Besides resting on the foregoing arbitrary criteria, the following discussion depends on a major assumption that has already been mentioned in the text of this report. Since, in the Vulcan-Gleichen area, no marker horizons were recongnized that have more than the most restricted local importance, it was assumed that regionally, all strata are relatively flat-lying, with only a gentle persistent dip to the west and northwest.

The most workable subdivision of the Edmonton Formation is that of Ower (1960), which is based chiefly on exposures along the Red Deer and North Saskatchewan Rivers; Ower recognized five members, designated A to E, in ascending order. Four of the members - A, B, C and E - consist of complexly interfingered clastic strata with no marker horizons except coal seams and coquina beds, which, while traceable over short distances, are lensy and diachronous in the extreme.

Member D, however, the Kneehills Member, sometimes called the "Kneehills Tuff zone", 15 to 80 feet thick, is remarkably uniform and persistent and is the only reliable marker horizon above the top of the Colorado Group in central and western Alberta. Moreover, since one or more beds of volcanic tuff 1 inch to 2 feet thick are usually present near its top, it is believed to be essentially isochronous. Sternberg (1947) has shown that the Kneehills Member marks the position of a distinct break in the dinosaurian fauna of the Edmonton Formation, and Bell (1949) demonstrated a corresponding break in the macrofloral succession. Campbell (1962) observed that the member as exposed along the Red Deer River Valley exhibits a sharp upper boundary, but that its lower boundary is markedly gradational. Thus any time hiatus indicated by the faunal and floral breaks must lie at the top of the Kneehills Member.

Campbell (1962) concluded that both the upper and the lower boundaries of the Edmonton Formation are conformable in central Alberta.

The lower boundary, with the Bearpaw Formation, is notably diachronous; the upper, with the Paskapoo, is located in a complex of interbedded deltaic sediments with no widespread unconformity and probably little local channel disconformity. Results of the 1961 borehole program suggest that the same conditions obtain at least as far south as township 14.

The thickness of the Edmonton Formation below the Kneehills Member is extremely variable, ranging upward from essentially zero at Sheerness in the Hanna district where the Kneehills rests directly and conformably on the Bearpaw-type sediments (Campbell, 1962) to nearly 2000 feet on the North Saskatchewan River. On the Bow River, where the regional dip is assumed to be 10 to 15 feet per mile westward, the outcrop of the Kneehills Member in Tp. 22, R. 24 (2935 feet elevation) must lie between 500 and 700 feet above the top of the Bearpaw Formation at Jumping Buffalo Hill in Tp. 20, R. 19 (elevation 2700 feet).

## Lower Boundary of the Edmonton Formation

On the basis of both field observation and drillhole data, the lower boundary of the Edmonton Formation in the Vulcan-Gleichen area is positioned differently on Fig. 6 than it was by Stewart (1943). Some of the more significant data are discussed below.

The best exposures of the Edmonton-Bearpaw boundary are to be seen in the extensive badlands scarring the east face of Jumping Buffalo Hill (Fig. 5a, 5b). The lowermost coaly beds of the Edmonton Formation are underlain by rusty- to chocolate-weathering shaly sandstones and sandy siltstones. Sanderson (1931) considered these to be a northern extension of the Fox Hills Formation; Gallup (1955) referred the strata below the Edmonton Formation partly to the Fox Hills and partly to the Rye Grass Member of the Bearpaw Formation (see Link and Childerhose, 1931). But Russell (1932) showed that the assumed Fox Hills Formation of the Lethbridge region is older than the type Fox Hills of North Dakota and consequently he renamed the rock unit at Lethbridge the Blood Reserve Formation. Russell also examined the Jumping Buffalo Hill outcrop and gave the name Bassano Member to the uppermost 200 feet of Bearpaw Formation - "finely banded brown sandy shale and clayey sandstone" - of nearshore marine and brackish-water origin; this member he recognized as far north as Hanna. If it be assumed that the Kneehills Member of the Edmonton Formation is a time marker, then the Edmonton-Bearpaw boundary must be strongly diachronous between Bassano, where the boundary is 500 or 700 feet below the Kneehills, and Hanna where it lies essentially at the Kneehills horizon (see Campbell, 1962). It then follows that the Bassano Member must be equally diachronous.

The local irregularity of the Bassano (Bearpaw) - Edmonton contact can be seen in a badlands gully leading down to the Bow River in the general region of Gallup's (1955) section. Sections measured at the head and mouth of the gully are given below (see also sections 17, 18, Fig. 5b).

Section at head of gully (Lsd. 15, Sec. 22, Tp. 20, R. 19)

| | Thickness (feet) | |
|---|---|---|
| Top of section (surface) | | (el. 2890 feet) |
| Buff till | 3.0 | |
| White-weathering, argillaceous uniform, cross-bedded sandstone (base rusty colored) | 47.0 | |
| Bright COAL | 1.0 | (el. 2845 feet) |
| Black shale and bone | 4.0 - 4.5 | |
| Carbonaceous black unconsolidated sandstone | 0.2 | |
| Bright white-weathering, argillaceous, uniform, cross-bedded sandstone; basal 6 feet highly bentonitic | 41.0 | |
| Dark reddish-rusty clay-ironstone band | 1.0 - 3.0 | (el. 2800 feet) |
| White-weathering sandstone | 19.0 | |
| Chocolate-brown-weathering interbedded siltstone and sandstone (Bassano-Member-type) | Base covered | |

Section at mouth of gully (Lsd. 16, Sec. 22, Tp. 20, R. 19)

| | Thickness (feet) |
|---|---|
| Top of section (surface) | |
| Buff till | 90 - 100 |
| Grey-weathering siltstone with bright sulphur-yellow band | 0.8 |
| COAL | 5.0 |
| Grey to black shale | 4.0 |
| Grey to white interbedded siltstone and sandstone | 28 |

| | | |
|---|---|---|
| Chocolate-brown-weathering argillaceous sandstone (Bassano-Member-type) | 18 | |
| Chocolate-brown-weathering interbedded siltstone and shale | 22 | |
| Chocolate-brown-weathering argillaceous sandstone | 25 | |
| Chocolate-brown-weathering interbedded siltstone and shale | 45 | |
| Talus | 45 | |
| River level | | (el. 2520 feet) |

A continuous section is exposed along the walls of the badland gully; Bearpaw-type beds are present about 90 feet higher, stratigraphically in the western section than in the eastern. The coal seam of section 18 (Fig. 5b) passes laterally westward into Bearpaw-type strata, and about half way between the two column-locations, a 3-foot bed of chocolate-brown, weathered silty shale strata thickens into a lens, 15 feet thick by 30 feet long and interdigitating with the overlying Edmonton-type white sandstone.

Extremes of interdigitation also characterize the Edmonton-Bearpaw contact east of the Bow River and south of Bassano. Till cover in this region is very thin and the land very flat, and in consequence, land forms closely reflect the variations of bedrock type. In the relatively complete cliff exposures along the east bank of the Bow River between Sec. 34, Tp. 20, R. 19 and Sec. 31, Tp. 19, R. 18, Edmonton-type beds are absent except in Secs. 23, 24, and 26, Tp. 20, R. 19. Consequently the considerable area of the Edmonton Formation shown here in earlier maps (Stewart, 1943; MacKay, 1949) has been reduced to a few isolated outliers.

Other outliers are present in Tp. 19, R. 18, where the Edmonton Formation is represented by an isolated lens of white sandstone exposed on hill shoulders on the west bank of the Bow River, and in Tps. 15 and 16, R. 21, where an upland is underlain by an outlier of Edmonton Formation.

The base of a 25-foot, massive white salt-and-pepper sandstone bed is taken as the base of the Edmonton Formation along the south side of Travers Reservoir, where it can be traced for about 5 miles in an east-west direction. Over this distance it dips westward at approximately 20 feet per mile.

South of township 13, the only evidence available is from a borehole at NE. corner Sec. 9, Tp. 12, R. 22 which penetrated Edmonton-type beds and encountered Bearpaw-type strata at an elevation of 3150 feet. This is consistent with earlier work (Russell and Landes, 1940) but appears to disagree with the known situation at Travers Reservoir. No attempt was therefore made to complete the boundary along the east flank of Blackspring Ridge between Tp. 13, R. 21 and Keho Lake.

Russell (1962) describes prominent badlands on the west side of Scabby Butte in Sec. 19, Tp. 11, R. 22 as the southernmost known occurrence of Edmonton-type beds.

## Upper Boundary of the Edmonton Formation

The upper boundary of the Edmonton Formation is, like the lower boundary, differently depicted on figure 6 than on earlier geological maps (MacKay,1949). This is in part a consequence of more detailed information; but to some extent, also it is a function of the criteria used to differentiate the rock units (see p. 42-43).

As mentioned earlier, the only reliable marker horizon recognized in Alberta above the Colorado Group is the Kneehills Member of the Edmonton Formation; in the Vulcan-Gleichen area, the only region where the relation of the Edmonton-Paskapoo contact to this member is known is west and northwest of Gleichen (Tps. 22 and 23, Rs. 23 and 24). In this region, Paskapoo-type beds lie directly over the Kneehills Member. Earlier writers (e.g. Tozer, 1956) have assumed that the boundary here is profoundly unconformable and that the basal Paskapoo rocks are Paleocene in age.

In the series of outcrops in Tp. 22, R. 24 in which the Kneehills Member appears for some distance along the Bow River with Paskapoo-type sandstones immediately overlying it, the boundary is doubtless unconformable. However, the unconformity probably is not profound. In the first place, there is doubt that the quartz-pebble conglomerates seen in this series of outcrops constitute a basal conglomerate as earlier writers (e.g. Tozer, 1956) assumed; the best current section in the township, the river cliff in Lsd. 3, Sec. 22, Tp. 22, R. 24 is as follows:

| Unit | | Thickness (feet) |
|---|---|---|
| | (top of section obscured) | |
| 10 | Drift, possibly disturbed: buff till with irregular stringers of gravel; base well-marked | 25 |
| 9 | Sandstone, yellow-buff-weathered, thick-bedded, coarsely cross-bedded | 17 |

| | | |
|---|---|---|
| 8 | Brecciated sandstone | 2 |
| 7 | Sandstone, yellow-buff-weathered, thick-bedded | 8 |
| 6 | Quartzite-pebble conglomerate, siltstone matrix | 2 |
| 5 | Sandstone, yellow-buff-weathered, massive | 6 |
| | (covered interval) | 2 |
| 4 | Shale, dark-mauve-weathered, uniform, thinly bedded, highly bentonitic, grades down into unit 3 | 8 |
| 3 | Shale, similar to unit 4 but light-mauve-weathered (probably intergrades with the following) | 11 |
| 2 | Sandstone, white, very bentonitic | 15 |
| 1 | Interbedded soft sandstones and silt-stones, grey- to rusty grey- to grey-buff-weathered | 32 |
| | Water level (high water) (elevation 2870 feet) | |

In the foregoing section, the quartz-pebble conglomerate does not form the base of the Paskapoo Formation but is underlain by at least 6 feet of massive yellow-buff-weathered sandstone. Thus it is not a true basal conglomerate and its regional significance should not be over-emphasized.

That the Edmonton-Paskapoo contact is not profoundly unconformable is further supported by the following variant development of the Kneehills Member which appears in a large northeast-facing badlands crescent in the centre of Sec. 26, Tp. 23, R. 23:

| Unit | | Thickness (feet) |
|---|---|---|
| 10 | Buff-weathered, uniform coarse sand-stone, top obscured by vegetation | |
| 9 | Grey-buff-weathered uniform medium-bedded siltstone; in aspect intermediate between Edmonton and Paskapoo-type strata | 15-20 |

| | | |
|---|---|---|
| | (contact intergradational, at elevation 2935 feet) | |
| 8 | Cream-colored highly bentonitic clay | 2 |
| 7 | Grey-white highly bentonitic clay containing two thick bands of grey-white fissile tuff | 2-3 |
| 6 | Light-mauve-weathered, thin-bedded highly bentonitic shale; uniform except for two bands of similar color that appear to consist of highly fissile tuff | 8 |
| 5 | Grey-white, highly bentonitic clay with irregular stringers of blue-grey fissile tuff and of mauve-weathered, highly bentonitic shale | 7 |
| 4 | Light-mauve-weathered thin-bedded uniform highly bentonitic shale | 12 |
| 3 | Dark blue-grey, thin-bedded tuff | 1 |
| 2 | Dark-mauve-weathered, thin-bedded uniform bentonitic shale | 10 |
| 1 | White highly bentonitic sandstone | 2 |
| | (base covered) | |

The Edmonton-Paskapoo boundary in this section is placed at the base of unit 10, the buff-weathering sandstone bed. But the resemblance of unit 9 to Paskapoo-type strata in general, together with the apparent conformity between units 9 and 10, serves only to underline the arbitrary nature of this boundary. The unconformity on the Bow River appears to be local, not extending as far northeast as the present section.

The assumption that basal Paskapoo rocks west of Gleichen are Paleocene in age is based on their lithologic similarity with rocks of known Paleocene age elsewhere, and on Tozer's (1952) report of early Paleocene Molluscan fossils from the north bank of the Bow River in NW. 1/4 Sec. 27, Tp. 21, R. 26, at least 300 feet higher in the section. But the rocks in the 300-foot interval have not yielded fossils, and, if there be little or no unconformity at their base, they may include equivalents of the upper part of the Edmonton Formation exposed along the Red Deer River (Ower's "member E"). The absence of Cretaceous saurian remains may be a function of environmental conditions (as evidenced by coarse-grained sandstone and conglomerate) unsuitable for their preservation.

On the Red Deer River, there is no assurance that the uppermost part of the Edmonton Formation is Cretaceous in age (Campbell, 1962); on the Bow River there is none that the basal Paskapoo beds are Paleocene.

East and south of Gleichen, many other locations were noted where buff-weathered Paskapoo-type beds overlie coal-bearing Edmonton-type strata, but in none of them was any evidence seen of the Kneehills Member (although Tozer, 1952, reports its presence about 5 miles south of the Vulcan-Gleichen area on the Oldman River in Sec. 25, Tp. 10, R. 25). In these locations the Paskapoo Formation rests directly on the middle part of the Edmonton Formation. Since the Edmonton-Paskapoo contact appears to be only slightly unconformable where the Kneehills Member is present, it may also be nearly conformable elsewhere. If this be the case, then the Kneehills Member is absent probably as a result of nondeposition rather than of pre-Paskapoo erosion, and the bases of the Paskapoo-type rocks lying at the summits of Cluny Hill in Tp. 22, R. 21 and of Thigh Hill in Tp. 16, R. 23 (Fig.6 ) would thus be as old as or older than, the Kneehills.

On the basis of borehole and outcrop data, it is believed that the main ridge of Thigh Hill is capped by Paskapoo-type sandstone over 200 feet thick. Thigh Hill can be seen on air photographs to consist of a series of oval-shaped subparallel ridges trending 20 to 35 degrees west of north. This topographic configuration is not the product of glacial action, since the ridge summits are almost completely free of glacial deposits and since, lateral to the ridges, there are narrow glacial flutings which differ significantly in form and orientation and in consistency of orientation from the ridges.

South and east of the hill and adjacent to the Edmonton-Paskapoo contact are the Thigh Hill coal seam occurrences, and these serve as the only stratigraphic markers in the region. Sections $D\text{-}D_1$, $D\text{-}D_2$ (Fig. 4b), based largely on relatively well-kept mine records, show that the seams exhibit much steeper dips and have a more irregular occurrence than is usual in prairie strata. Whereas the Kneehills Member west of Gleichen dips about 15 feet per mile to the northwest, and the basal Edmonton Formation sandstone beds along the south side of Travers Reservoir dip westward at approximately 20 feet per mile, the coal seam at the Champion mine cluster in Sec. 33, Tp. 15, R. 23, dips southwestward at about 100 feet per mile, that at Thigh Hill mines cluster in Sec. 8, Tp. 16, R. 23, dips west at about 200 feet per mile, and the seam at Reid Hill mine in Sec. 24, Tp. 16, R. 23, dips westward at a slope of 211 feet per mile for at least 1000 feet.

Campbell (1962) considered that the structure at Thigh Hill mine cluster was a function of extreme diachronism of the coal seam, somewhat exaggerated perhaps, by differential compaction. However, it is now thought that the structure evident around Thigh Hill may be the result of post-depositional deformation; the dome-structure and the steep monoclines are more readily explained as parts either of a series of anticlinal folds or, more likely, of a series of fault-blocks. It is suggested that the Thigh Hill is cut by a series of subparallel faults striking 10 to 30 degrees west of north, for the following reasons:

(1) A fault is reported to cut the coal seam in the Champion Mine, striking 10 or 15 degrees west of north (pers. comm., Mr. E. Fontana, manager, Champion Mine);

(2) All strata, where observed, dip towards the west or southwest; major dips towards the east and north are unknown;

(3) Thigh Hill ridges, Reid Hill, and the series of lower hills between (section $D-D_1$, Fig. 4b) all have the appearance of scarps with steep east and northeast faces and gentler, more stable west and southwest slopes.

Bedrock faulting is known to exist elsewhere in the plains region of Alberta; faults are known in the mines at Lethbridge (Williams and Dyer, 1930; and Russell and Landes, 1940), at Bullshead Butte and elsewhere in the Cypress Hills (Williams and Dyer, 1930), and along the South Saskatchewan and Oldman Rivers (pers. comm., J. Westgate). Within the Vulcan-Gleichen area, in Sec. 2, Tp. 18, R. 18, there is a disturbed outlier of Edmonton Formation which is related to a circular topographical feature, about 4 miles in diameter, consisting of a series of low barren arcuate hills with their steeper slopes facing toward the centre. Stewart (1943) interpreted the structure as a series of intersecting linear faults.

All of these prairie faults are located within a broad area dominated structurally by the Sweetgrass Arch. Wells (1957) showed that this feature, <u>or its predecessors</u>, has been fairly continuously active since Paleozoic time, with a slightly increased pace in the Tertiary.

The Edmonton-Paskapoo boundary may be affected by bedrock faulting at other locations in the Vulcan-Gleichen area, such as the series of north-northwest-trending ridges in the northwest part of Tp. 17, R. 23, but the coal seams east and south of Thigh Hill are the only available stratigraphic markers by which such faulting can be recognized.

South of Thigh Hill, it is believed the criteria for distinguishing the Edmonton and Paskapoo Formations hold true as far as the Little Bow River; Tozer (1956) however, has shown that in that region, Edmonton-, St. Mary River-, Willow Creek-, and Paskapoo-type beds interlens in a most complex manner.

# APPENDIX E. NOTES ON ANCESTRAL STREAM COURSES, VULCAN-GLEICHEN AREA

by

J.D. Campbell

Farvolden (1963) showed in regional outline the stream-drainage pattern of southern Alberta as it existed "prior to the last glaciation of the area"; of necessity his maps exhibit a number of anomalies since his data did not allow him to distinguish the historical order of events. Alden (1932) has shown, in eastern Montana, the broad chronology of a series of sands and gravels preserved on multiple river terraces; and he postulated a time-span from late Tertiary to early Pleistocene. This appendix, based in part on bore-hole data, attempts to show the sequence of stream-development in the Vulcan-Gleichen area, over a time-span of unknown duration, prior to glaciation.

During the course of the coal survey, a record was kept of drift-bedrock contacts and of all gravel beds encountered (Appendix A). At many locations the latter could not be penetrated, gravel being a considerable obstacle to a rotary drilling rig; also in most cases, no distinction could be made between gravels derived from the Cordillera to the west and those from the Precambrian Shield to the northeast. From the records obtained, however, it has been possible to reconstruct an outline of part of the geomorphological history of the region. This outline is expressed in figures 7, 8 and 9.

In the following discussion, several assumptions are made:

(1) there was only one major glaciation advance across the Vulcan-Gleichen area, from a general northern direction (pers. comm., L. A. Bayrock);

(2) topography around the locations discussed is flat enough that the present locations of gravel beds have not been significantly affected by mass slumping;

(3) any thick gravel bed lying directly on bedrock and overlain by till or other glacial deposits is the product of a preglacial, or at least interstadial, stream;

(4) if such a gravel bed is clearly related to a main channel-valley, then the elevation of its position on the valley wall gives an indication of its relative age; that is, the highest gravel beds are the oldest, and progressively younger gravels beds are found at progressively lower elevations (no evidence was noted upon which estimates of absolute age could be based and no such estimates are given);

(5) characteristics of present valley-gradients are reliable indicators of the magnitude and direction of ancestral valley-gradients.

Although some of the elevations quoted below are of gravel-bed tops, others of bases, errors due to this inconsistency probably are small enough to be ignored since the beds are usually thin.

Of the 200 holes drilled during the survey, 132 penetrated through the drift mantle, thus enabling bedrock elevations to be determined. From these and from outcrops, approximate bedrock contours have been drawn in the region of the McGregor Valley (Fig. 7).

Of the 200 survey boreholes, 50 encountered gravel; these 50 fell into three groups:

(1) Eleven holes in the McGregor Valley and two in the Bow River Valley which encountered well-marked gravel beds lying directly on bedrock and overlain in turn by till or other unmistakable glacial deposits.

(2) Twenty-one holes in the McGregor Valley and one in the Bow River Valley which encountered, but did not penetrate, gravel beds overlain by till or other unmistakable glacial deposits and suspected, from appearance and field relations, to lie directly on bedrock.

(3) The remaining 16 holes which encountered only kame-type or other unmistakably glacial or postglacial gravels and which are not further considered here.

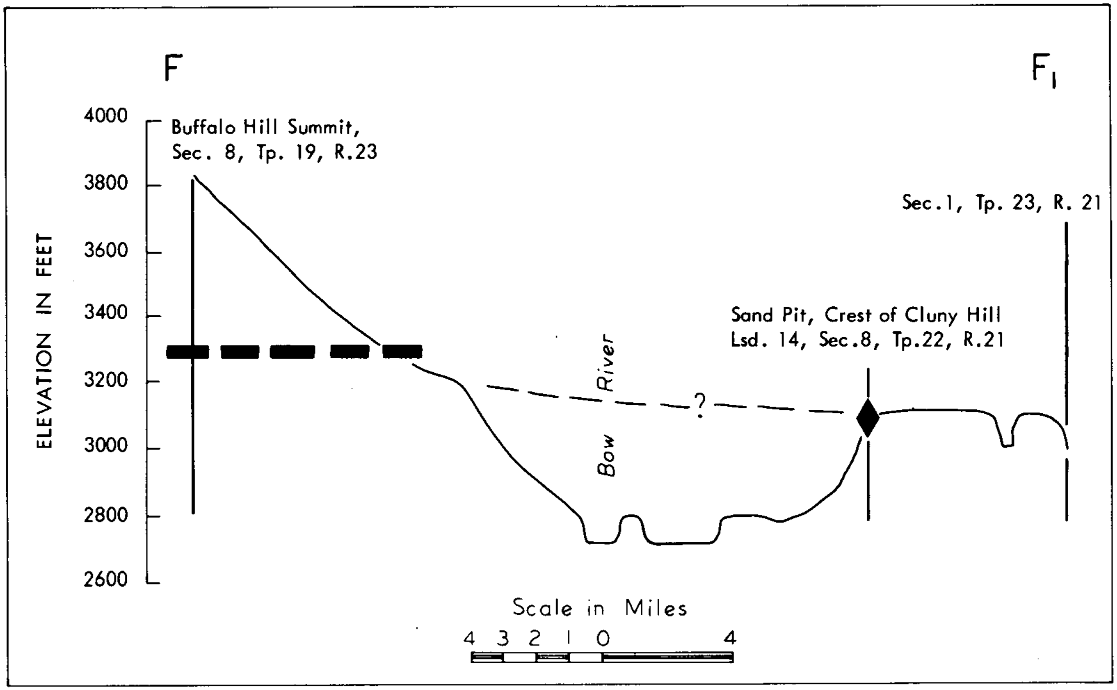
The 35 holes in groups (1) and (2) are plotted on figure 7 along with 10 records of gravel outcrops, 3 of which are based on data from Stalker (1957); to these were added 6 holes drilled by the coal survey in 1962 which encountered gravel under till along the north boundary of township 22. From consideration of these 51 points, especially their relative elevations, from bedrock and topographic contours and from examination of air photographs, the author believes it is possible to arrange the alluvial deposits known in the McGregor Valley and the Bow River Valley in the chronological sequence presented and annotated below. However, only one terrace was recognized - a prominent bench along the south bank of the Bow River. The following sequence of alluvial deposits is therefore believed to be a record of widespread gradual downcutting, erratic but nonetheless mostly continuous, rather than of alternating downcutting and equilibrium.

A. On the flat summits of Buffalo Hill in Secs. 8, 16 and 17, Tp. 19, R. 23, at elevations of 3770 and 3890 feet, thin gravel deposits lie directly over Paskapoo-type bedrock or over thin bedrock-derived soils. These gravels, consisting of more than 99 per cent quartzite pebbles and less than one per cent deeply pitted carbonate pebbles, are believed to be relics of ancient river-channel gravels which, on the basis of elevation, must be the oldest in the Vulcan-Gleichen area. Slightly younger than these are the "pre-glacial gravel deposits" which Stalker (1957) has described from the north flank of the hill in Sec. 4, Tp. 20, R. 23 at about 3500 feet elevation, and in Sec. 14, Tp. 20, R. 24, at about 3380 feet elevation. The summit gravels have yielded no fossils and hence cannot be dated, but they lie at a similar elevation to, and within the same general physiographic region as do the better preserved gravels capping the Hand Hills about 75 miles to the north-northeast, to which Russell (1957, 1958), on the basis of an included horse bone, assigned an early Pliocene age. Possibly the Buffalo Hill gravels, like the Hand Hill gravels, may be assumed to date from late Tertiary time.

B. Section F-$F_1$, figure 8, a topographic profile from Buffalo Hill to Cluny Hill, shows that there have been two distinct ancestral Bow River Valleys, at least in Tp. 21, R. 22, an upper, older one and a lower, newer one distinguished by a sharp shoulder at the 3200 foot level on the north flank of Buffalo Hill. The floor of the older, upper valley appears, on the basis of elevation, to correlate reasonably well with the uppermost elevation at which preglacial gravels were found in the McGregor Valley (about 3250 feet elevation); it also appears to correlate with the extensive, now much disturbed and obscured gravels that cover the flat summit of Cluny Hill at 3100 feet elevation in Tp. 22, R. 21, of which the small sand-pit exposure in Lsd. 14, Sec. 8, Tp. 22, R. 21 is an example. The author believes that, at the time of the older, upper valley, two major rivers, the McGregor Valley River, rising south and possibly southeast of the Vulcan-Gleichen area, and the ancestral Bow River, rising west and southwest of the area, met at the northeast corner of Buffalo Hill and thence flowed northeastward across Cluny Hill. (Strictly speaking, Section F-$F_1$ does not lie across this ancestral valley, but in a bend).

C. The younger ancestral Bow River Valley below the 3200-foot shoulder appears to be the product of stream rejuvenation; it has moderately steep walls and a broad, relatively flat floor that slopes eastward at about 9 feet per mile. On the basis of elevation, it is believed that the earlier stages of this rejuvenated valley correlate with gravel beds intercepted on the east flank of Cluny Hill, and with all gravel intercepts above about 2740 feet elevation in the north end of McGregor Valley and above about 2850 feet in the southern part.

North of township 15, the lowest of the McGregor Valley gravels are related to a well-marked buried channel in which lie both the village of Lomond and the north half of modern Lake McGregor; since the floor of this valley slopes northward at an average gradient of about 3 feet per mile, the stream that carved it is believed to have had its source east of range 19 in a region now well below 2700 feet elevation, and to have flowed west past Lomond at an elevation of about 2890 feet. Headwater piracy by streams flowing into the lower part of the present Bow River Valley must have initiated a process of eastward erosional planation that gives Lomond Channel the appearance of crossing a highland in Tp. 16, R. 20. It is possible that this




LEGEND

Approximate elevation, western and highest limit of gravels in McGregor Valley . . . . . . . . . . . . . ▬ ▬ ▬

Outcrop of gravel resting on bedrock . . . . . . . . . . . . . . . ◆

Figure 8. Cross section F-F1, ancestral Bow River Valley

stream piracy, the marked difference in gradient between the north-trending McGregor Valley and the east-trending Bow River Valley, and the rejuvenation of the Bow River Valley are all evidences of crustal activity centred in the mountains to the west of the area.

The prominent terrace along the south bank of the Bow River, about 160 feet above present water level, marked by gravel beds in Sec. 9, Tp. 21, R. 23 and at NE. corners Sec. 35, Tp. 20, R. 22 and Sec. 31, Tp. 20, R. 19, appears to correlate with the Lomond Channel.

D. The youngest preglacial Bow River appears to have been a considerable stream occupying about the same course, levels, and gradient as the modern river. Stalker (1961 and pers. comm.) postulated that it bypassed the gorge in Tp. 20, R. 19 and passed, at or below 2570 feet elevation, by way of a glacially buried valley eastward beyond Bassano in Tp. 21, R. 18. The 1962 Research Council borehole program disclosed the presence of an extensive sheet of preglacial gravels extending eastward and northeastward from Cluny Hill and at least 30 miles beyond the Vulcan-Gleichen area; in Tp. 22, this sheet slopes to the east with a gradient greater than 16 feet per mile, and no valley-wall can be recognized. Possibly there occurred a gradual lateral southeastward migration or "slip-off" of the ancestral Bow River Valley from Cluny Hill summit at 3100 feet elevation, (paragraph B above) to the east flank of Cluny Hill above 2700 feet and to the Bassano Channel at about 2570 feet. On the basis of elevation, Stalker's channel appears to have turned northward from Bassano to the region east of Crawling Valley in range 17.

In the McGregor Valley, during most recent preglacial times, the Lomond Channel shrank to a minor trench clearly visible in air photographs, though glacially buried, in Tps. 19 and 20, R. 21, while, through the process of stream-capture, the southern part of the valley was being drained eastward or southeastward by way of the ancestral Little Bow River.

In Tps. 14 and 15, R. 20, three ancestral Little Bow channels can be recognized on air photographs and their floor elevations are established respectively by gravel beds at NE. corner Sec. 33, Tp. 14, R. 21 (2800 feet), in Sec. 18, Tp. 14, R. 20 (2760 feet) and on the walls of the present river valley about Sec. 3, Tp. 14, R. 20 (below 2700 feet). These three possibly represent successive proglacial displacements of the Little Bow River. Similarly, bedrock contours indicate several alternative channels of the Little Bow in Tps. 14 and 15, Rs. 23 and 24; however, since no gravel deposits were discovered in these channels, no estimate is made of chronological sequence, although they too may represent successive proglacial displacements. The headwaters of the Little Bow River lie in a relatively flat lowland west of township 24 and drain into the McGregor Valley through a major gap (Tp. 14, R. 22) cutting the more or less continuous bedrock ridge which extends from Buffalo Hill to Scabby Butte. Probably at one time most of the lowland was drained northward by an ancestral West Arrowwood Creek, but, through the process of stream-capture in preglacial time, its middle part came to be drained to the east.

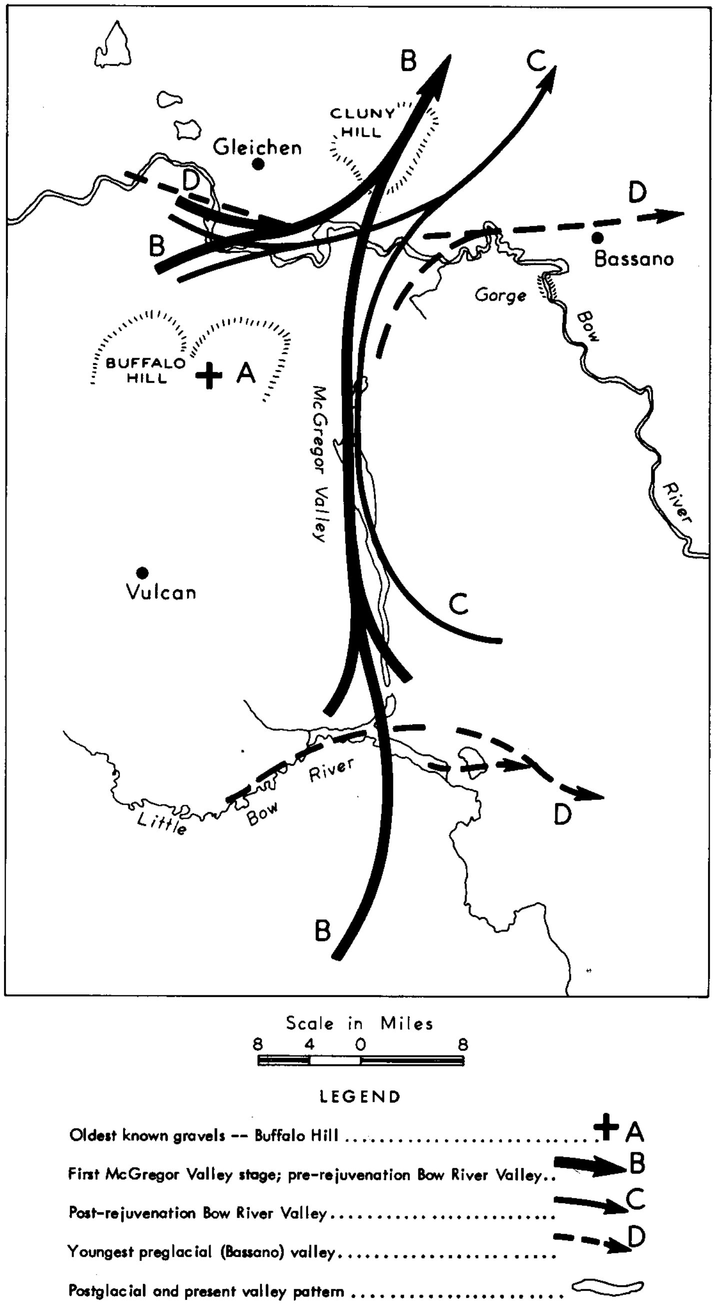



Figure 9. Postulated valley-sequence, Vulcan-Gleichen area

Keho Channel in Tp. 11, R. 22 may have been a spillway for a rising Lake Carmangay (see Stalker, 1957) at a time when the advancing glacier had blocked the gap in Tp. 14, R. 22, and thus may be considered the youngest preglacial course of the Little Bow River.

E. In postglacial time, streams assumed essentially their present configurations. Crowfoot Creek and the south end of Lake McGregor occupy glacier-retreat meltwater spillways cut in bedrock; the Little Bow River is entrenched in the floor of the most recent of its three preglacial displacement channels, while the Bow River abruptly leaves its ancestral valley west of Bassano and turns sharply southward by way of a gorge 150 to 200 feet deep which it carved, Stalker (pers. comm.) believes, when diverted by a retreating glacier.

The foregoing gravel sequence is summarized in Table 3; in addition the sketch-map figure 9 has been drawn to suggest the postulated sequence of streams in the Vulcan-Gleichen area.

Table 3. Correlation Chart of Gravel Beds, Vulcan-Gleichen Area

| | Bow River Valley | McGregor Valley |
|---|---|---|
| E | modern river bed;<br>Gorge in Tp. 20, R. 19 | meltwater spillways |
| D | latest preglacial gravels<br>Bassano-Crawling Valley Channel | relict stream course in north;<br>Little Bow River in south |
| C | rejuvenated Bow River Valley;<br>east flank Cluny Hill gravels | mid-level gravel deposits;<br>Lomond Channel |
| B | 3200-foot shoulder of Buffalo Hill;<br>Cluny Hill summit gravels | uppermost gravels |
| A | Buffalo Hill gravels<br>(late Tertiary?) | - |