Report 74-1

HYDROGEOLOGY OF THE LETHBRIDGE-FERNIE AREA, ALBERTA

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OF THE LETHBRIDGE-FERNIE AREA,
ALBERTA

Abstract.

Clastic rocks, largely non-marine, of Upper Cretaceous age and some of Tertiary age underlie the plains in the Lethbridge-Fernie map area. The regional dip is westward, ranging from 20 to 200 feet per mile. Closely spaced, high-angle thrust faulting has deformed the Upper and Lower Cretaceous clastics of the foothills belt. Mesozoic clastics, Paleozoic carbonates, and Precambrian clastic and carbonate rocks in the mountain areas have been affected by low- to moderate-angle thrusting.

The interpretation of the hydrogeology has certain limitations due to the low reliability of data over large areas, thus yield values are based on a number of assumptions related to geology and topography. The highest expected well yields are to be found in present-day alluvial gravels and in sands and gravels of buried river valleys. Bedrock formations are expected to give generally very low to moderate yields, although there are some major exceptions.

Groundwater of over 1 000 ppm in total dissolved solids of either sodium sulfate or mixed cation sulfate-bicarbonate type is common over much of the plains part of the area, while better quality potable water of the calcium-magnesium bicarbonate type predominates in the foothills and mountain areas.

INTRODUCTION

This report is written as a supplement to the maps, to direct attention to points of interest, to bring out significant details, and to provide brief explanations of some of the features shown.

The total map area covers approximately 7 665 square miles, approximately 6 105 square miles in the Lethbridge map area (NTS 82H), and 1 560 square miles in the Alberta part of the Fernie map area (NTS 82G). The area is bounded by latitudes 49° and 50° north, longitude 112° west on the east and the Continental Divide on the west. Under the Alberta Land Survey system it includes most of townships 1 to 12, ranges 1 to 6, west of the fifth meridian.

The hydrogeological survey on which the accompanying maps are based was carried out in 1970. Previous hydrogeological studies covering various parts of the area were conducted by Dowling (1923), Meyboom (1960), Scott (1963), Beckie (1964), Geiger ***et al.*** (1966, 1968), Geiger (unpublished), Nielsen (1965, 1969a and b), Kerr (1968), Ford (1969), Clissold (1970), and Vanden Berg and Geiger (1973). This list does not include studies of shallow groundwaters in irrigated areas. Hydrogeological surveys in adjoining areas in the state of Montana have been carried out by Zimmerman (1967) and Swanson (undated).

The area was one of the first settled in Alberta and thus many existing wells have been in service 50 years or more. Lethbridge, with a population of 41 217 in 1971, is the only city in the map area. Incorporated towns, with 1971 populations bracketed, are: Taber (4 765), Pincher Creek (3 227), Coaldale (2 798), Fort MacLeod (2 715), Cardston (2 685), Raymond (2 156), Blairmore (2 037), Coleman (1 534), Magrath (1 215), Picture Butte (1 008), Milk River (775), and Granum (324). The largest villages are: Bellevue (1 242), Stirling (436), Warner (408), Nobleford (401) and Barons (237). In 1971 only Magrath was using a groundwater source of water supply. The annual total usage there amounted to approximately 18 500 000 imperial gallons or approximately 35 imperial gallons per minute (igpm).

Acknowledgments

The program was financed by Alberta Research[1]. The Earth Sciences and Licensing Division, Alberta Environment[2] supplied a drilling rig and crew for part of the program. The exploratory testholes put down by this rig aided greatly in final site selection for detailed test drilling, and in overall evaluation of the area.

Lousana Water Wells of Lousana, Alberta, carried out detailed test drilling and pump testing.

Others whose help is gratefully acknowledged include: K. W. Geiger for seismic shothole data and other information; various district health units for chemical analyses of water wells; the Department of Indian Affairs and Northern Development, National and Historic Parks Branch, for permission to work within the confines of Waterton Lakes National Park; Mr. Gordon Morcom of the Indian Affairs Branch of the same department, for access to water well records for the Blood and Peigan Indian Reserves; the Provincial Analyst of the Alberta Department of Agriculture for chemical analysis of water samples; and the Geochemical Laboratory of Alberta Research.

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[1] Formerly Research Council of Alberta

[2] Formerly Water Resources Division, Alberta Department of Agriculture

I would also like to thank residents of the area for their cooperation on this project, and the water-well drillers who submitted reports on wells drilled.

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TOPOGRAPHY AND DRAINAGE

The physiographic features of the area are named as in the Atlas of Alberta (Government and University of Alberta, 1969, p. 9).

Most of the area of map sheet 82H lies within the Alberta High Plains, which consists of the Eastern Alberta Plains, Western Alberta Plains, Milk River Ridge and Porcupine Hills. The division between the Eastern Alberta Plains and the Western Alberta Plains approximately follows, in a north-south direction, the 3 000-foot contour near Lethbridge, south to the base of the Milk River Ridge. Elevations in the Eastern Alberta Plains range from about 2 500 feet above sea level in the northeastern corner of the area to about 3 500 feet at the base of the Milk River Ridge. The Oldman River cuts down through the plain to below 2 400 feet in the northeastern corner of the area. The Western Alberta Plains start at an elevation of about 3 000 feet at their eastern edge and rise to about 4 000 feet at their southwestern limit. The Milk River Ridge rises from 3 500 feet to a maximum elevation of over 4 600 feet. The Porcupine Hills rise from about 3 300 feet at their base to almost 5 900 feet at their highest point within the map area.

The Western Cordillera extends across the western part of the area. It consists of the Rocky Mountains on the west and the Rocky Mountain Foothills on the east. Elevations in the foothills range from less than 3 700 feet to over 5 800 feet. The Rocky Mountains rise to a maximum elevation of 10 167 feet at Tornado Mountain, in the northwestern corner of the area.

The principal rivers draining the area are the Oldman, Belly and St. Mary Rivers which form part of the South Saskatchewan River system, and the Milk and North Milk Rivers which form part of the Missouri River drainage system.

Mean annual runoff (Neill ***et al.***, 1970) is low in the plains part of the area, ranging from less than 20 acre feet per square mile (i.e. 0.028 cubic feet per second) near Taber to 200 acre feet per square mile near Cardston. The rate of runoff increases rapidly westwards until, near the Continental Divide, it may exceed 3 000 acre feet per square mile (i.e. 4.15 cfs).

CLIMATE

The climate of the area according to the Koeppen climatic zone classification is humid continental; characterized by long, cool summers in the plains and most of the foothills, and by short, cool summers in the remainder of the foothills and in the mountains (Longley, 1968).

The mean temperature in January, the coldest month, averages about 18°F over most of the area. The mean temperature in July, the hottest month, ranges from 62° or 63°F in the mountain areas to about 67°F to the east of Lethbridge (Longley, 1968). The mean annual temperature at Lethbridge Airport is 41.8°F.

The mean annual precipitation based on the 30-year period 1931-60 ranges from less than 14 inches in the northeastern part of the area to over 40 inches in the high mountain area in and near Waterton Lakes National Park.

Annual lake evaporation, which closely approximates potential evapotranspiration (Bruce and Weisman, 1967), ranges from less than 25 inches in the mountain areas (where total precipitation is highest) to more than 40 inches in the northeastern corner of the area (where precipitation is lowest). This provides a total water surplus in the mountain areas and a deficit in the plains areas. Lake evaporation was determined only for the months of May to October inclusive; it is considered to be negligible during the other months of the year because the lake surfaces are frozen. However, during winter, chinook winds do ablate some snow cover, illustrating that winter evaporation is still significant.

GEOLOGY

In the disturbed belt (the Western Cordillera), bedrock formations of Precambrian to Tertiary age are exposed, and in the plains, exposures of Upper Cretaceous to Tertiary age occur. Numerous geological maps and reports are available for the area. Among the most useful are those by: Dawson (1885), Dowling (1917), Williams and Dyer (1930), Russell (1940), Russell and Landes (1940), Williams (1949), Douglas (1951, 1952), Price (1962), and Irish (1967, 1968).

The formations of the foothills and mountains (the disturbed belt) have been deformed by folding and thrust faulting. The formations underlying the plains dip in a general westerly direction towards the Alberta syncline axis, west of which the dip direction reverses.

For the purposes of the hydrogeological map, the bedrock formations of the disturbed belt which show similarities in permeability have been grouped together to form single units.

Belly River Formation: sandstone or sandstone-shale units exhibiting generally moderate permeability.

Alberta Group: shale or shale-hard sandstone units exhibiting generally poor permeability.

Lower Cretaceous, Jurassic, Triassic: shale-fine grained sandstone units exhibiting generally poor to fair permeability.

Paleozoic: mainly carbonate (largely limestone) units exhibiting generally very low permeability except where fractured or containing solution cavities.

Precambrian formations in the mountains: mixed clastic and carbonate units which are generally impermeable except where fractured.

The formations in the plains part of the area are outlined below (after Irish, 1967 and 1968, with hydrogeological comments added).

Tertiary

Paleocene

Porcupine Hills Formation: thick, cross bedded, medium- to coarse-grained buff-weathering, grey sandstone; friable, grey, silty shale (nonmarine). Over 2 500 feet thick. Sandstone beds constitute aquifers; numerous springs.

Tertiary and Cretaceous

Paleocene and Upper Cretaceous

Willow Creek Formation: soft, medium-grained, grey argillaceous sandstone; clayey, grey, green and pink shales; abundant white-weathering, calcareous concretions in shale; grey fossiliferous limestone; massive, crossbedded, buff weathering, grey sandstone in upper part (nonmarine). 1 000-1 300 feet thick on Oldman River. Generally low yields of poor quality water from thin sandstone beds.

Cretaceous

Upper Cretaceous

Kneehills tuff zone: light green to grey, white-weathering, clayey sandstone (Whitemud equivalent); overlain by mauve-weathering, dark purplish grey, bentonitic shale; siliceous tuff (Battle equivalent) (nonmarine). About 20 feet thick on Oldman River. Not known to be an aquifer.

St. Mary River Formation: hard, green, grey, and buff-weathering, grey, fine-grained, calcareous lenticular sandstone; friable, green and grey silty shale; fissile, grey shale, coal and coquinoid limestone occurs in basal part (nonmarine). About 500 feet thick on Oldman River. Sandstone beds constitute aquifers, generally of low yield.

Blood Reserve Formation: massive, buff- to yellow-weathering, grey or greenish grey sandstone (marine and nonmarine). About 100 feet thick near U.S. border; pinches out to north. Constitutes a good aquifer near Del Bonita.

Bearpaw Formation: dark grey and brownish grey, rubbly and flaky shale; silty shale; grey, argillaceous sandstone; ironstone concretionary bands; bentonite layers (marine). 720 feet thick on St. Mary River. Does not constitute an aquifer.

Oldman Formation: massive, crossbedded, medium- to coarse-grained, light grey-weathering sandstone; green and grey shale; dark grey and brown carbonaceous shale; ironstone concretionary beds (nonmarine). Characterized by low yields of poor quality water from sandstone beds.

Foremost Formation: green and grey shale; dark carbonaceous shale; grey and green siltstone; grey and pale brown lenticular sandstone; ironstone; coal seams (nonmarine). Foremost and Oldman Formations are generally undivided in the subsurface. Total about 1 200 feet thick. Characterized by low yields of poor quality water from coal and sandstone beds. A local basal sandstone unit (the Verdigris member) forms a locally good aquifer, e.g. near Warner.

Pakowki Formation: dark grey shale and sandy shale; thin interbeds of grey sandstone; thin chert pebble conglomerate at base (marine). About 100 feet thick. Thin sandstone beds may form local low-yield aquifers.

Milk River Formation (Upper Member): soft, grey-weathering, grey, argillaceous sandstone; lenses of massive, light buff-weathering, grey sandstone; soft, grey shale and silty shale; dark grey carbonaceous shale; ironstone (nonmarine). About 120 feet thick. Characterized by low yields from sandstone beds south of the town of Milk River.

Milk River Formation (Lower Member): massive, light grey- to white-weathering, grey, soft and hard sandstone; ironstone concretions; grey and light grey shale, and sandy shale (marine). About 100 feet thick. Constitutes an important aquifer in eastern part of area, to depths ranging from 600 to 1 000 feet. Termed the lower Milk River sandstone in the remainder of this report.

Alberta Group: dark grey, friable and fissle shale, and sandy shale; brown-weathering, grey sandstone (marine). Not known to be an aquifer.

Structure contours have been drawn on the tops of three of the most important water-bearing formations in the plains: the Milk River Formation (Lower Member), the Belly River Formation, and the St. Mary River Formation. The contours on the first two formations are drawn only to an elevation of 1 000 feet above sea level. These formations continue to dip westward to increasing depths but structure contours are not drawn any further because the formations are beyond the present depth of investigation and further contouring would only tend to clutter the map.

The dips of the bedrock formations are generally quite steep across most of the map area when compared to other parts of the Alberta plains. Dips are northerly across the eastern edge of the area averaging about 60 feet per mile in the southeastern corner and decreasing to a low of 15 to 20 feet per mile in the northeastern corner. To the west, however, dips are in a westerly direction; they quickly steepen from 60 to 70 feet per mile near Lethbridge, to about 150 feet per mile near Fort MacLeod and to almost 200 feet per mile farther west. On the eastern edge of the foothills, dips are steeper yet – from 250 to 500 feet per mile in a general northeasterly direction.

Surficial geology within the area has been mapped by Stalker (1959, 1966, 1962, and 1963). Earlier work includes that carried out by Dawson (1885) and Horberg (1952, 1954). Bedrock topography has been mapped by Geiger (1965). More generalized maps showing bedrock channels within the area were prepared by Stalker (1961) and Farvolden (1963). A bedrock topography map for the Blood Indian Reserve was prepared by Scott (1963). Geiger (1965) lists earlier work that had been done on bedrock topography, dating from the observations of Dawson (1885).

Surficial geology and bedrock topography are not shown on the geological side map. Thalwegs of buried valleys, however, are shown on the main hydrogeological map because of the importance of buried valley aquifers for groundwater supplies. Deposits of sand or gravel, where constituting important aquifers and where sufficiently delineated, are also indicated. These deposits (which have not been classified as to age) may be of Recent, Wisconsin (glacial) or early or pre-Wisconsin (preglacial) age. Their water-yielding characteristics are influenced by topographic position, thickness, saturated thickness, lateral extent, degree of sorting and permeability, and by recharge characteristics.

HYDROGEOLOGY

Average water levels have been contoured over the plains part of the area, excluding the Porcupine Hills and Milk River Ridge, in order to indicate the direction of groundwater movement. For the purposes of contouring, only wells between 100 and 400 feet in depth were selected, except near the Porcupine Hills where wells deeper than 100 feet are scarce.

The water levels shown can only be very approximate for the following reasons:

1) water levels will vary from aquifer to aquifer in a single well within the depth range selected;

2) various aquifers are represented;

3) in most cases the water levels have been reported by drillers and farmers (direct measurement by the author or assistants was usually not possible), and do not always represent static water levels;

4) water levels were determined at different intervals of time, whereas seasonal and yearly fluctuations occur;

5) permeabilities are low over much of the area, therefore stabilized static levels are often not obtainable (i.e., reported water levels in these cases will generally be too low).

The resulting contours represent a composite water level that can be considered to be representative of local flow systems in a relatively homogeneous medium.

In the extreme eastern part of the area, only water levels from wells completed in the lower Milk River sandstone aquifer were considered. These contours represent the piezometric surface of the lower Milk River sandstone. Unfortunately, points of control are limited, especially in the area of flowing wells. Reasons 3 and 4 as mentioned above are also applicable over this region. Nevertheless, a general northeasterly flow direction changing to northerly is apparent. The influence of local topography is not readily noticeable, except along some of the coulees, where depression of the piezometric surface may be due not so much to the effect of topography as to a lowering of water levels by strong flowing wells located in the coulees (Meyboom, 1960, p. 43).

Larger areas of flowing wells have been delineated on the map. Smaller, more localized areas which are not shown occur in places along streams, at the bases of hills, and at local breaks in slope. Areas outlined are generalized and may include smaller areas in which wells will not flow. Many, possibly most, of the flowing well areas obtain their flow from semiconfined sands and gravels at depths of 100 to 200 feet. Flows from some of these aquifers are quite strong, up to 100 igpm (or more when initially struck). Flowing wells in bedrock formations are not as common, except in the area of the Milk River sandstone.

In the eastern part of the map area, wells drilled into the lower Milk River sandstone from township 8 northwards, and along Etzikom Coulee (Tp. 6, R. 16) commonly flow. Some of these wells have been flowing continuously for over 50 years. An area of potential flowing wells along Verdigris Coulee (Tp. 4, R. 16) has been outlined on the basis of a well drilled into the Verdigris sandstone member of the Foremost Formation.

Areas where salts have been precipitated on the land surface (alkali patches, etc.) have been delineated. These occur in and on edges of alkali lakes, along and near creek and coulee bottoms, and at prominent breaks in slope. They can be an indication of upward moving groundwater, nearly always through low permeability materials. They can also result from downward- and outward-moving groundwater, where the water has moved relatively long distances or had relatively long residence time in low permeability siltstone, shale, coal, or bentonitic or argillaceous sandstone. Examples may be found on the lower slopes of the Milk River Ridge near Milk River and on some bedrock outcrops along river valleys. In many places, the problem of salt accumulation is aggravated by irrigation practices. Most of the salts are predominantly sodium sulfate, with minor amounts of magnesium and carbonate.

The average expected well yields shown on the map indicate the total quantity of water that can be obtained by a single properly constructed and developed well that taps all water-bearing intervals within the upper 1 000 feet of strata, regardless of quality. In the majority of cases, most of the yield will be from a single zone and generally, except in the case of the lower Milk River sandstone, from depths of less than 300 feet.

The yield values are 20-year estimates based largely on apparent transmissivity and available drawdown.

It should be stressed that this is an interpretative map based on limited control. The probability of obtaining the yield indicated for a given location is less for areas indicated as high yield areas than for low yield areas. Areas in which a yield range is fairly well established, based on long-term pump tests, production tests, or on numerous short-term bail and pump tests, are shown by a dark color. Where the yield range is less well established, where test data are lacking, scarce or judged to be of low reliability, a light color has been used.

Even in areas where the expected yield is shown to be established, local areas of higher or lower expected yield can be found. This can be due to the presence or absence of local, relatively more permeable, lenses of sandstone, sand or gravel; to weathered zones at the drift-bedrock contact, or to other unsuspected conditions. A good understanding of the subsurface geology is essential when interpreting probable well yield.

Where data are scarce the following assumptions have had to be made:

1) geology largely determines rock permeability;

2) topography and to a lesser extent geology, largely determine saturation and hydraulic head conditions;

3) areas of similar geology and topography will have similar yields;

4) the amount of precipitation has little effect on short-term well tests (on which this evaluation is largely based) in which water is drawn almost entirely from existing storage;

5) in earth materials containing good aquifers expected yields are markedly lower in topographically high areas than in low areas due to large differences in available head of water, unless the high areas have a wide lateral extent (Todd, 1959, p. 53);

6) in earth materials containing poor aquifers (e.g. thick shale sequences and some sandstone-shale sequences) the yield range is not noticeably different under differing topographic situations;

7) carbonate and indurated clastic sediments in the Cordillera are almost impermeable, unless they are cavernous or fractured, in which case, in topographically low areas, high yields can be obtained;

8) talus slopes locally form low- to moderate-yield aquifers, provided sufficient precipitation or glacial meltwater is available;

9) alluvial gravels normally form good aquifers.

Detailed water level measurements for eight pump tests of 24 hours or more in duration were available at the time this study was made; six of these were tests conducted by government agencies and two by private consultants. Most of the yield values are based on calculations of apparent transmissivity supplemented by well performance records as determined from drillers, farmers, and town officials from which specific capacity or apparent transmissivity could sometimes be obtained.

The two most important factors which determine the yield are the geologic situation and the topographic position of favorable formations. Yield values and lithology should, therefore, often be correlative. For various reasons, this coincidence appears to be less than might be expected. The apparent lack of coincidence may be due to shortcomings of test interpretation, and different well completion and development techniques, as well as to changes in facies and permeability within a single stratigraphic unit, and to lack of knowledge of stratigraphic details. Delineation of permeable beds and lenses by stratigraphic studies, along with some pump testing, is necessary to further evaluate yield areas. Due to time limitations a comprehensive evaluation of geologic control on the groundwater of the whole map area has not been possible. Generally, however, the highest yield areas reflect more permeable zones, largely sand and gravel within the drift, and permeable sandstone within the bedrock formations. Thus, a detailed knowledge of the geology of the area is valuable in prediction of potential yields.

The geological control on well yields is most noticeable in the mountain and foothills areas, especially where the drift cover is thin, because then yield areas usually coincide with geological formations, the stratigraphy and lithology of which are quite well known. The detailed stratigraphy of surficial materials on the other hand is not as well known, and is not as predictable. The more permeable materials are generally river-sorted and deposited and, where buried beneath later deposits, can be very difficult to locate. Size sorting and thickness of different units can be quite variable over very short distances which makes accurate predictions of long-term yields difficult.

The plains part of the Lethbridge-Fernie map area differs from that of most areas within central and southern Alberta in that two widespread thick sandstone units, the lower Milk River Formation and the Blood Reserve Formation, and a third unit of more local distribution, the Verdigris sandstone, are present and constitute important aquifers. The groundwater yield, the chemistry, the depth, and the location of these aquifers are more readily predictable than in most other aquifers throughout the province.

Yields greater than 500 igpm are probable in the following places:

1) Buried channel sands and gravels in which a high head exists, and wells often flow. One such channel is near Waterton Dam, (Tp. 4, Rs. 27 and 28, W. 4th Mer.). The damming of Waterton River has resulted in large flows from pre-existing wells. Relief wells drilled near Cochrane Lake to keep farmers' wells from overflowing, flow at rates of up to 1 000 igpm. A pump test indicates that transmissivity is approximately 120 000 igpd/ft (Vanden Berg and Geiger, 1973). Wells near Spring Coulee (Tp. 4, R. 23, W. 4th Mer.) flowing at rates of up to 25 igpm even after many years, are an indication of a high-yield aquifer at that location. A well in Spring Coulee is reported to have flowed at over 100 igpm from a depth of 200 feet; yields of over 500 igpm are considered possible.

2) Cavernous, jointed or fractured limestone, usually with some solutional enlargement. There are no known wells drilled into these limestones. Karst springs, however, with flow rates of as much as 7 500 igpm are present, e.g. at Crowsnest Lake (Tp. 8, R. 5, W. 5th Mer.).

3) Alluvium of mountain rivers, e.g. Crowsnest and Oldman Rivers. Yields of over 500 igpm can be obtained where there is sufficient saturated thickness. A transmissivity value of 400 000 igpd/ft was obtained for gravels at Coleman (Nielsen, 1965).

4) Recent or older alluvium near present-day river courses in which recharge by river water through the gravels may be possible. Several locations within the area appear favorable. Detailed test drilling and lithologic data, however, are necessary before these can be delineated with certainty; therefore, they are not shown on the map. One such location where high yield wells may be possible is the alluvial flat on the west side of the Oldman River at Lethbridge where one well encountered 30 feet of sand and gravel at an elevation below that of river level. This well had 63 feet of available head and was pumped for several hours at 15 igpm with negligible drawdown. Very much higher pumping rates are undoubtedly possible.

5) Abandoned coal mine workings, e.g. near Lethbridge in Sec. 24, Tp. 8, R. 22, W. 4th Mer. In a pump test at this location, a transmissivity of 150 000 igpd/ft and a probable 20-year yield of over I 000 igpm was obtained (Beckie, 1964). However, another test near Hardieville, (Sec. 18, Tp. 9, R. 21, W. 4th Mer.), indicated that a yield of over 20 igpm was not possible.

Yields of 100 to 500 igpm are possible in peripheral areas of the above-mentioned localities, as well as in similar, but less extensive or less permeable materials elsewhere. Some of these are: a small area near Magrath (buried valley aquifer); an area near Fort MacLeod (buried valley aquifer); thick alluvium of mountain rivers in the southwest corner of the map area.

Yields of 25 to 100 igpm may be obtained in peripheral areas to those already mentioned, as well as in:

1) buried sands and gravels near: Mountain View, North Milk River, Twin Butte, Stand Off, Pearce, Woodhouse, Meadow Creek, Burmis, and Todd Creek;

2) alluvial sands and gravels of present-day rivers, where there is sufficient saturated thickness;

3) lower Milk River sandstone near Milk River, Etzikom and Chin Coulees. Zimmerman (1967, p. 9) states that in parts of Glacier and Toole Counties, Montana, which adjoin Alberta, yields as high as 200 igpm can be obtained from this rock unit. It is called the Virgelle sandstone in Montana;

4) Verdigris sandstone near Warner;

5) Blood Reserve sandstone near Del Bonita;

6) basal Belly River sandstone near Leavitt.

Other smaller areas for which such yields may be possible have not been mentioned here but can be located on the hydrogeological map.

Possible yields of 5 to 25 igpm are common from wells completed in the lower Milk River sandstone, in the Porcupine Hills Formation, and in various other bedrock formations and drift deposits. This is also the yield range assigned to low-lying sandstone-shale sequences in the mountains and foothills, e.g. the Belly River Formation, and the Lower Cretaceous, Jurassic and Triassic sequences. These formations are generally well indurated, and water will usually be obtained only where the rocks are fractured. Yields are expected to average closer to 5 igpm than to 25 igpm, and will often be less than 5 igpm in topographically higher areas, and where fractured or weathered rocks are not present.

Yields of 1 to 5 igpm are the highest possible over much of the area. Often it is a matter of chance whether a well will produce less or slightly more than one gallon per minute, and will depend on such factors as the nature of the surficial deposits, presence of fractures or of weathered bedrock, etc.

Yields of less than 1 igpm are common in the well-indurated rocks of the mountains, in thick shale sequences of the Alberta Group, in the Willow Creek Formation, in the Bearpaw shales, in preglacial gravels near Lethbridge drained by the Oldman River, in the Oldman Formation, and less commonly in parts of the St. Mary River and Foremost Formations.

Springs are an indication of near-surface aquifers, and their rate of flow can provide an indication of possible rates of production from wells tapping that aquifer. Selected springs and their rate of flow as measured or calculated at the time of mapping are shown on the map. Side maps indicate groundwater temperatures determined from springs and shallow wells, and the temperature of water within the lower Milk River sandstone.

HYDROCHEMISTRY

The hydrochemistry of the most commonly utilized aquifers is shown on the hydrochemical side map. In the plains, only the chemistry of wells 50 to 400 feet deep has been considered. As calcium and magnesium were not determined separately in many of the analyses these cations were grouped together in the percentage calculations. The same is true of sodium and potassium. Calcium-magnesium bicarbonate waters low in total dissolved solids are commonly present in the mountain belt and throughout most of the foothills, the Porcupine Hills, and the Milk River Ridge. In the area of the Milk River Ridge and in the foothills, total dissolved solids are generally between 500 and 1 000 ppm, and in the other areas mentioned above generally less than 500 ppm. These are areas of largely recharging groundwater, and of short, active flow systems. Sulfate-type water, generally somewhat higher in total dissolved solids than the bicarbonate waters is found only in areas of thick shale sequences and in springs of presumably relatively deep circulation in limestone.

Sodium-potassium waters are present over the remainder of the map area (i.e. over the plains and some adjoining highlands), with sodium the predominant anion. Both bicarbonate- and sulfate-type waters, as well as mixed anion waters, are represented. Sodium-chloride waters occur at greater depth as indicated on the hydrogeological profiles. The bicarbonate-type waters appear to occur closer to areas of recharge and along sand- and gravel-filled buried valleys than do the sulfate-type waters, the valley through Spring Coulee being an exception. Sulfate-type waters are common in areas of groundwater discharge, areas of low permeability, and areas of slow groundwater movement. They are found typically in areas of extensive, relatively flat topography and on the lower slopes of hilly regions. The sulfate and the total dissolved solids content can be extremely high and can vary greatly from place to place, especially in shallow wells. For this reason, over the plains part of the area, only wells over 50 feet deep have been used in compiling the hydrochemical map. A few local areas of shallow waters high in both sulfate and total dissolved solids can not be shown on the hydrogeological profiles because of scale limitations.

The hydrochemistry of the lower Milk River sandstone aquifer down to a depth of 1 000 feet is shown across the eastern part of the map area. A change in quality from southeast to northwest is evident: from a sodium bicarbonate-type water through a belt of mixed sulfate-bicarbonate-chloride waters and finally to sodium chloride waters. This chemical progression appears to accompany a lessening of permeability in this direction as indicated by decreasing probable well yields and may also reflect the supposed direction of groundwater movement from southeast to northwest.

A map showing fluoride and iron content in parts per million in wells over 50 feet deep is presented. Fluoride content in shallower wells is nearly always quite low (much less than 1 ppm). The accuracy of contouring is not great because fluoride determinations were available only for a small number of wells. The highest concentrations are reported from the lower Milk River sandstone. In the area outlined on the map, fluoride concentrations within the lower Milk River sandstone aquifer are highest near Warner, decreasing to the southeast and the northwest. If groundwater movement within this aquifer is assumed to be in a northwesterly direction, this indicates an initial increase in fluoride concentrations along the groundwater flow paths, followed by a decrease. This decrease may possibly be due to the filtering out of fluoride ions with the passage of water through low-permeability earth materials, the same process as proposed for chloride ions (Bredehoeft *et al.,* 1963). In formations closer to the surface, fluoride concentrations in excess of 1 ppm are relatively common in wells completed in the Willow Creek, St. Mary River, Oldman and Foremost Formations, and are less common in the Porcupine Hills and Bearpaw Formations, and in buried valley sands and gravels. Concentrations exceeding 3 parts per million are rare.

Iron concentrations are low in water from the lower Milk River sandstones. The highest concentrations are found in areas of thick drift and in bedrock formations on the Blood Indian Reserve and east and southeast of Lethbridge, as well as in local smaller areas.

Unusually high concentrations of nitrate in the soil and in groundwater within the area have been reported (Wyatt and Newton, 1925). Investigations and test drilling done by the Earth Sciences and Licensing Division, Alberta Department of the Environment, in 1970-71 (David Graveland and Grant Nielsen, pers. comm.) has shown that concentrations of over 1 000 and ranging as high as 6 500 parts per million of nitrate, occur in groundwater at shallow depths in Secs. 5 and 6, Tp. 8, R. 18, W. 4th Mer. A reason for the presence of such high concentrations has not been determined although contamination from the activities of man does not seem to be the cause. Other wells with nitrate concentrations exceeding 100 parts per million occur in the area. In locations other than the one referred to above, concentrations reach a maximum of 936 parts per million. In wells over 50 feet deep, a maximum concentration of 625 parts per million is reported. Contamination of the water supply from seepage of surface effluent may be the cause of the high nitrate content in some of these wells. For others, it is difficult to see how such contamination could occur.

CONCLUSIONS

The highest expected well yields within the map area are to be found in present-day alluvial gravels and in sands and gravels of buried river valleys. Bedrock formations are expected to give generally very low to moderate yields. Exceptions are the local cavernous or fractured limestone areas in the mountainous western part of the area; relatively thick sandstone formations such as the lower Milk River Formation and, more locally, the Verdigris sandstone, the Blood Reserve Formation, the lower Belly River sandstones, and probably local sandstones within the Porcupine Hills Formation. Yields of less than 5 igpm can be expected from shaly bentonitic sandstone sequences over much of the plains part of the area; from thick shale sequences in the foothills and mountains; and from Paleozoic carbonates and Precambrian clastics and carbonates in the mountain ranges.

Groundwater of over 1 000 ppm total dissolved solids of either sodium sulfate or mixed sulfate-bicarbonate type is common over much of the plains part of the area, while better quality potable water of the calcium-magnesium bicarbonate type predominates in the foothills and mountains.

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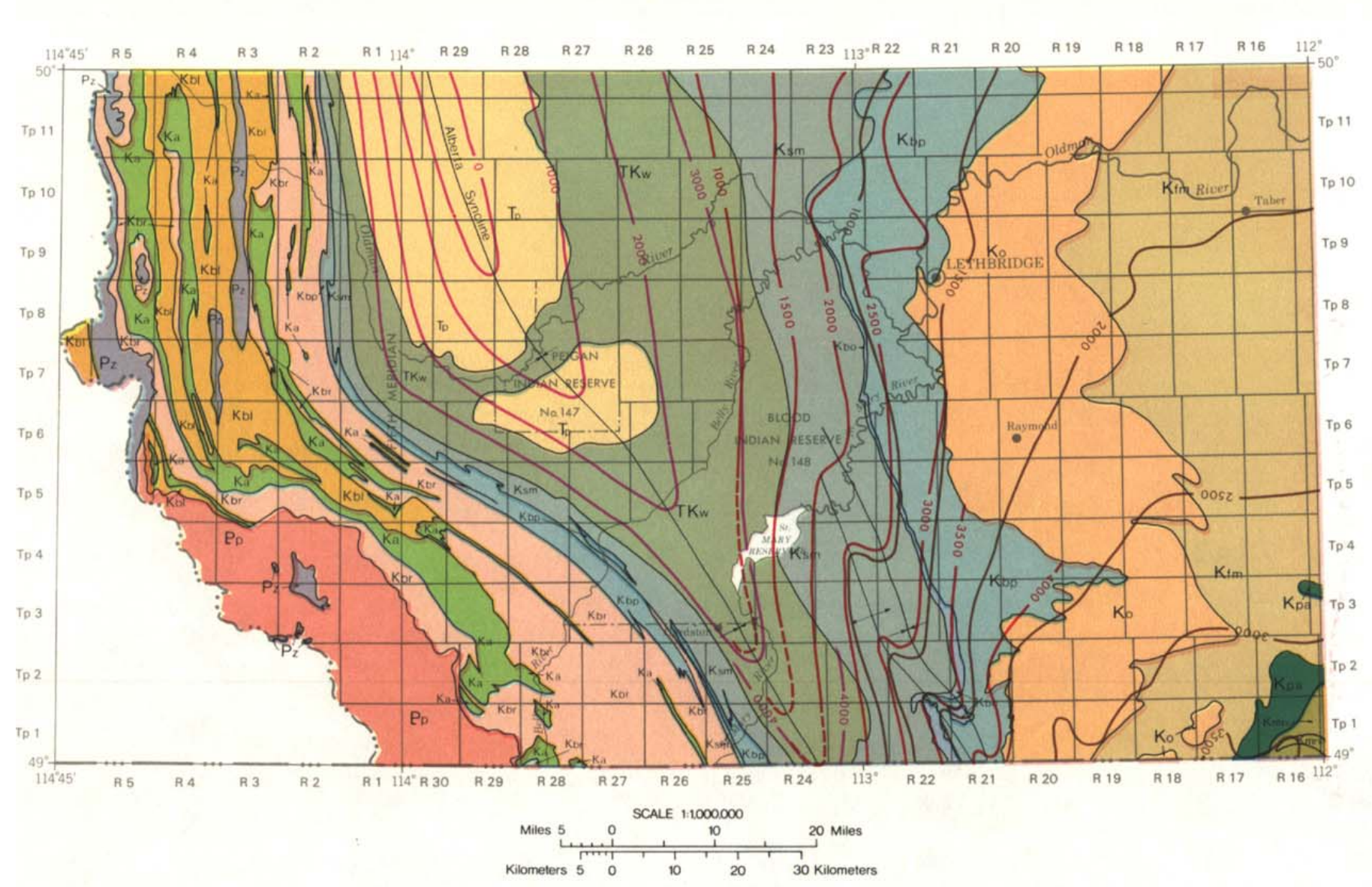
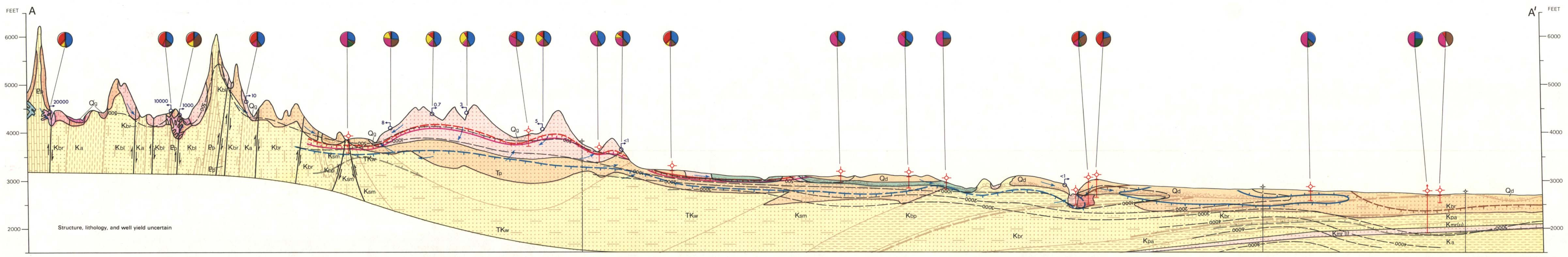
Alberta
RESEARCH

GEOLOGY





LEGEND

- Tp Porcupine Hills Formation: *sandstone, shale*
- TKw Willow Creek Formation: *shale, sandstone*
- Ksm St. Mary River Formation: *sandstone, shale*
- Kbo Blood Reserve Formation: *sandstone*
- Kbp Bearpaw Formation: *shale*
- Ko Oldman Formation: *sandstone, shale*
- Kfm Foremost Formation: *sandstone, shale*
- Kbr Belly River Formation: *sandstone, shale*
- Kpa Pakowki Formation: *shale*
- Kmr(u) Milk River Formation (upper member): *shale, sandstone*
- Kmr(l) Milk River Formation (lower member): *sandstone*
- Ka Alberta Group: *shale*
- Kbl Blairmore Formation and older Mesozoic Formations: *sandstone, shale*
- Pz Paleozoic: *limestone, dolomite, shale*
- Pp Purcell Group: *limestone, dolomite, argillite, siltstone, quartzite*

ock unit boundary

tructure contour in feet above sea level on top of:

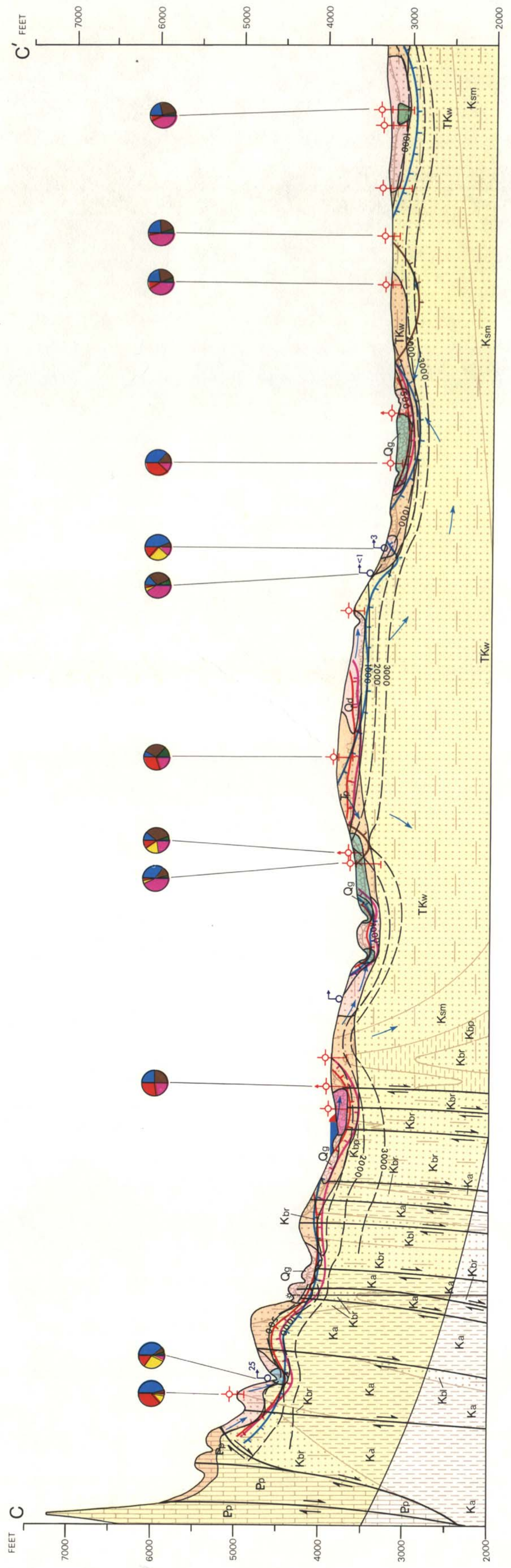
St. Mary River Formation — 3000

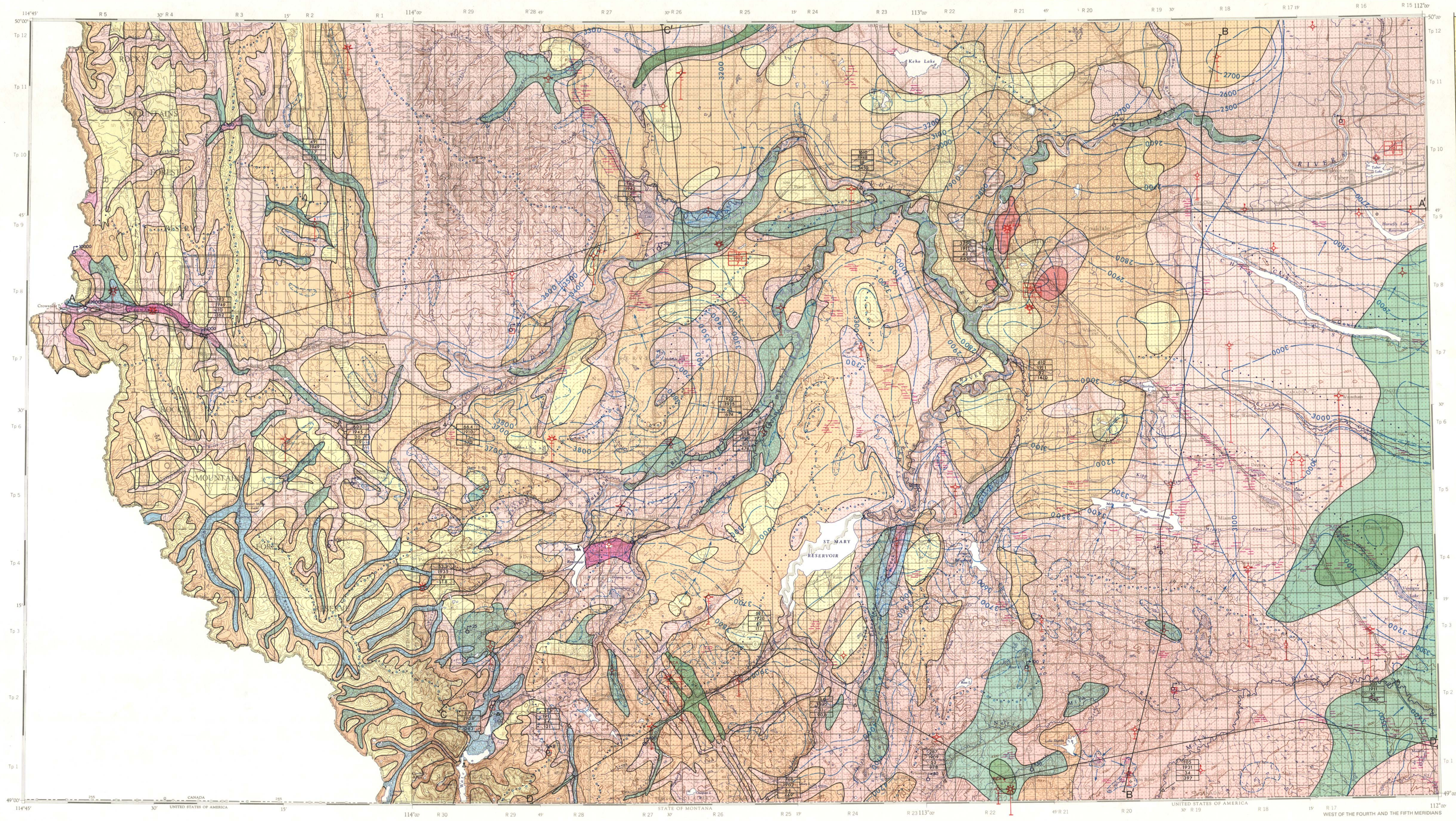
Oldman Formation (to depth of 1000 feet, approximately) — 1500

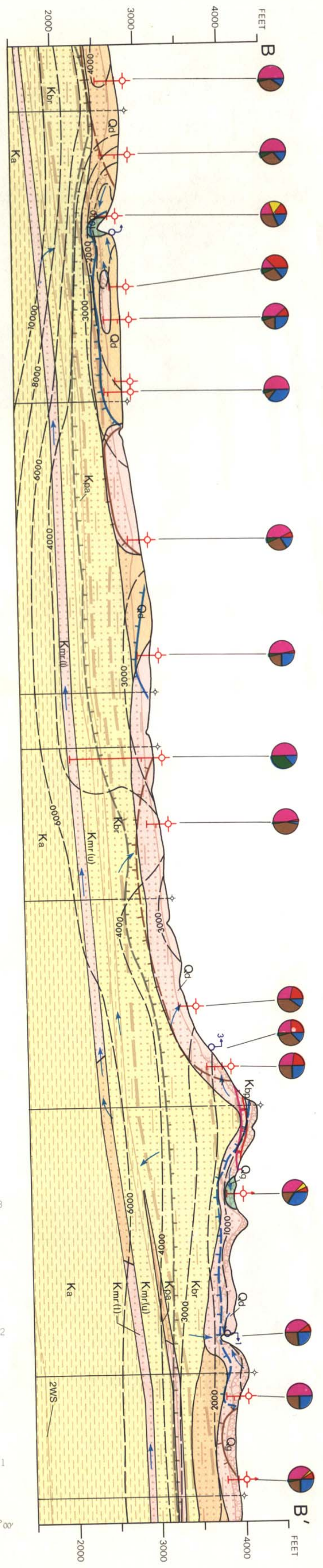
Milk River Formation (lower Member), (to depth of 1000 feet, approximately) — 1000

xis of anticline

xis of syncline

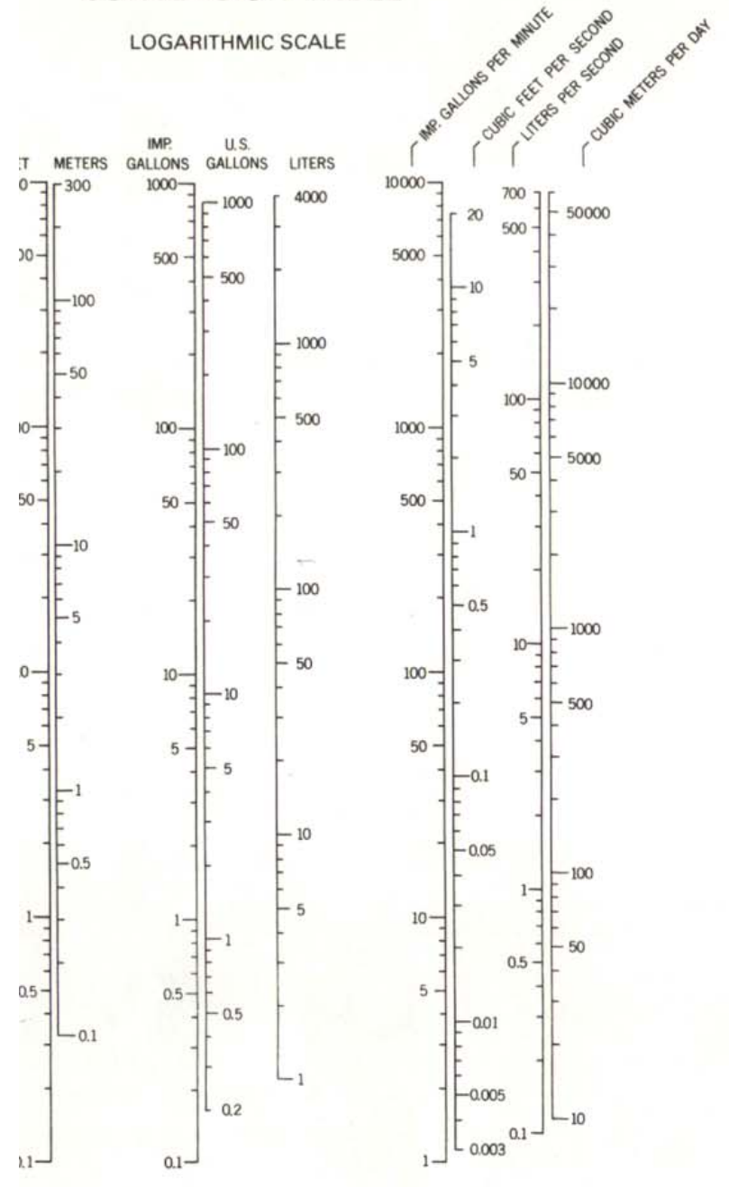






CONVERSION TABLE

LOGARITHMIC SCALE



MAIN MAP LEGEND

Topography

Surface contours (interval 100 feet below 5000 feet east of fifth meridian
interval 200 feet above 5000 feet east of fifth meridian
interval 500 feet west of fifth meridian):

elevation — 3000

depression — 2500

Geology

Geological boundary

Thalweg of buried valley:

defined

approximate

Fault (on profiles only)

QUATERNARY

- Qd Unconsolidated deposits
- Qg Gravel

TERTIARY

- Tp Porcupine Hills Formation

TERTIARY AND CRETACEOUS

- TKw Willow Creek Formation

CRETACEOUS

- Ksm St. Mary River Formation
- Kbo Blood Reserve Formation
- Kbp Bearpaw Formation
- Kbr Belly River Formation
- Kpa Pakowki Formation
- Kmr(u) Milk River Formation (upper member)
- Kmr(l) Milk River Formation (lower member)
- Ka Alberta Group
- Kbl Blairmore Formation and older Mesozoic Formations

PRECAMBRIAN

- Pp Purcell Group

White Specks marker (2WS)

Lithology

- Gravel
- Sand
- Sand and gravel
- Sandstone
- ss Sandstone and argillite
- sh Shale
- Sandstone and shale
- Coal
- ls Carbonate rocks

Hydrography

Lake or slough, perennial

Lake or slough, seasonal

Marsh, muskeg

Stream, perennial

Stream, intermittent

Natural pond or water hole

Surface water divide

Area of noticeable salt precipitates

Hydrometry

Stream gauging station

Average annual discharge in cubic feet per second — 333

Year of commencement of observations — 1935

Number of years averaged for average annual discharge figure — 28

Drainage area in square miles — 11.8

Lake level recording station

Source of Data:

Surface Water Data Alberta
(Inland Waters Branch, Department of Energy, Mines and Resources)

Hydrogeology

Spring, flow rate unknown

Spring, flow rate known

Nonpumping water level contour — 2800

Direction of groundwater flow

Groundwater divide

Boundary of area of artesian flow

Line east of which water level contours are based on Milk River sandstone

Groundwater Probability†

Range of average expected yield of wells (in imperial gallons per minute)

Probable: estimated from quantitative information (pump tests, bail tests, etc.)

Possible: estimated from qualitative information (flow regime, lithology, etc.)

- >500
- 100-500
- 25-100
- 5-25
- 1-5
- <1

Yield area boundary

†The indicated average expected yields to wells are predictions based on the best data available at the time of map compilation; due to data shortcomings and special conditions, local discrepancies between predicted and actual yields are inevitable. Multiaquifer completion may be necessary to obtain the yield indicated.

Wells and Other Artificial Works

Water well, nonflowing

Water well, flowing

Water well, nonproducing

Well, shallow depth

Water well, 20-year safe yield calculated from apparent transmissivity

Water well, 20-year safe yield calculated from a good bail test or a short pump test

Water well, 20-year safe yield calculated from a pump test of sufficient length to reflect regional hydraulic conditions

Adjacent wells

Test well with more than one piezometer in a single borehole or with groundwater data collected from several depths during drilling

Observation well with automatic recorder

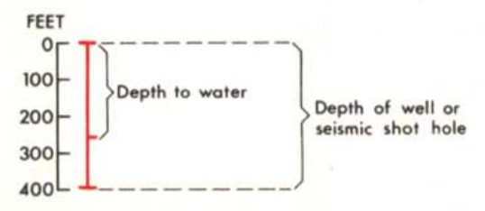
Mean annual water level fluctuation in feet — 25

Year of commencement of observations — 1963

Years of record averaged for mean annual water level fluctuation figure — 11

Seismic shothole reported to have flowed

Depth scale



Location of Research Council of Alberta test well — RCA

Gas well*

Abandoned well, drilled for oil or gas*

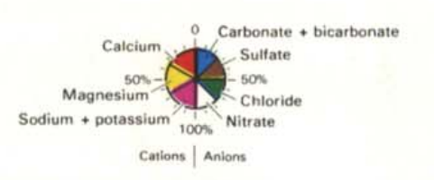
Structure testhole*

Spring catchment

Line of hydrogeological profile — A A'

*Vertical line portion of oil, gas or other exploratory test well symbols used on hydrogeological profiles indicates well depth; dashed portion indicates surface casing interval.

Hydrochemistry



Note: When the yellow Mg pie sector is absent, Ca + Mg are represented as a unit by the red pie sector.

Total dissolved solids in parts per million:

defined — 500

approximate — 500

Isogram along which calcium and magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium and magnesium content:

defined

approximate

Isogram along which sodium and potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium and potassium content:

defined

approximate

Isogram along which carbonate and bicarbonate constitute 60 percent of total anions*; teeth indicate direction of lesser carbonate and bicarbonate content:

defined

approximate

Isogram along which sulfate constitutes 60 percent of total anions*; teeth indicate direction of lesser sulfate content:

defined

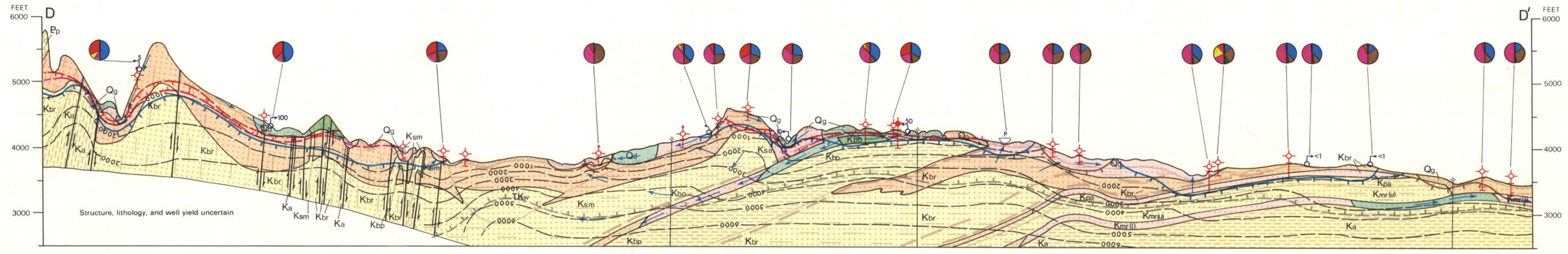
approximate

Isogram along which chloride constitutes 60 percent of total anions*; teeth indicate direction of lesser chloride content:

defined

approximate

*Determined on equivalents per million basis.



SCALE 1:250,000
Miles 5 0 5 10 15 20 Miles
Kilometers 5 0 5 10 15 20 25 30 Kilometers

HYDROGEOLOGICAL MAP
LETHBRIDGE - FERNIE
ALBERTA

NTS 82G-H

All elevations in feet above mean sea level

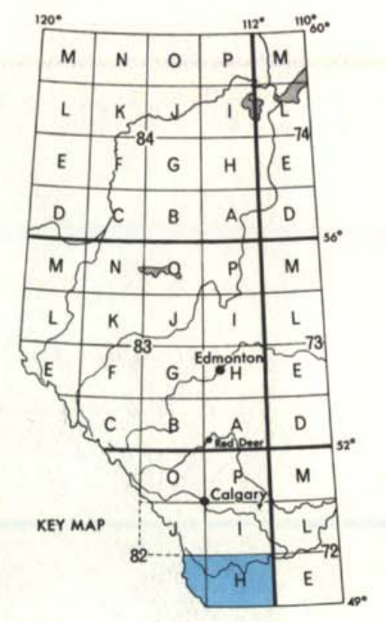
Vertical exaggeration of the hydrogeological profiles is approximately 20X

Hydrogeology by O. Tokarsky 1973, based on data collected in 1970 and 1971

Cartographic editing by A. Badry, A. Gill and F. Smith

An expanded legend and explanatory notes for use with this hydrogeological map series is available from Alberta Research, Edmonton, Canada

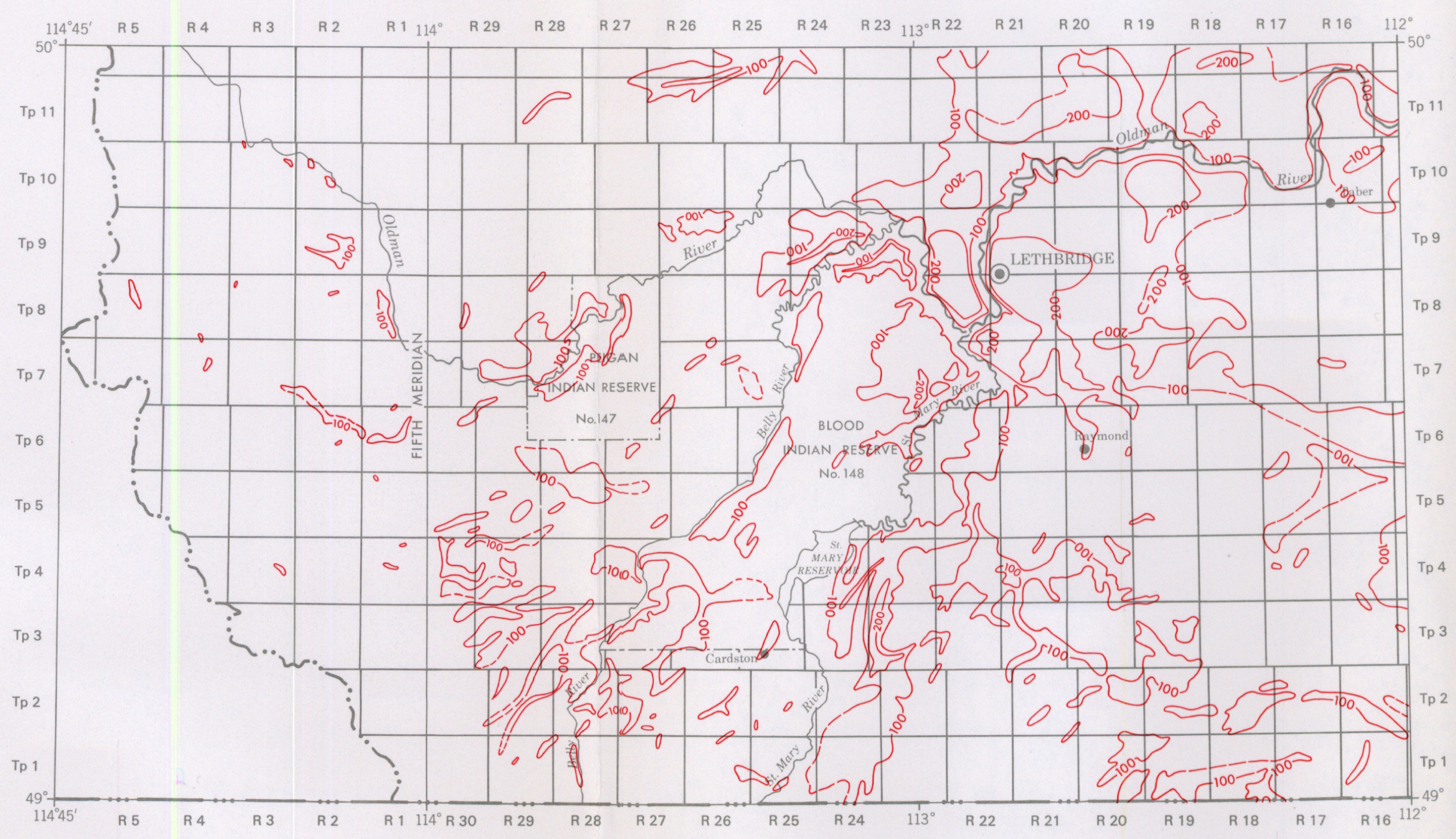
Map to accompany Report 74-1



Sheet 1 of 2

Published 1974

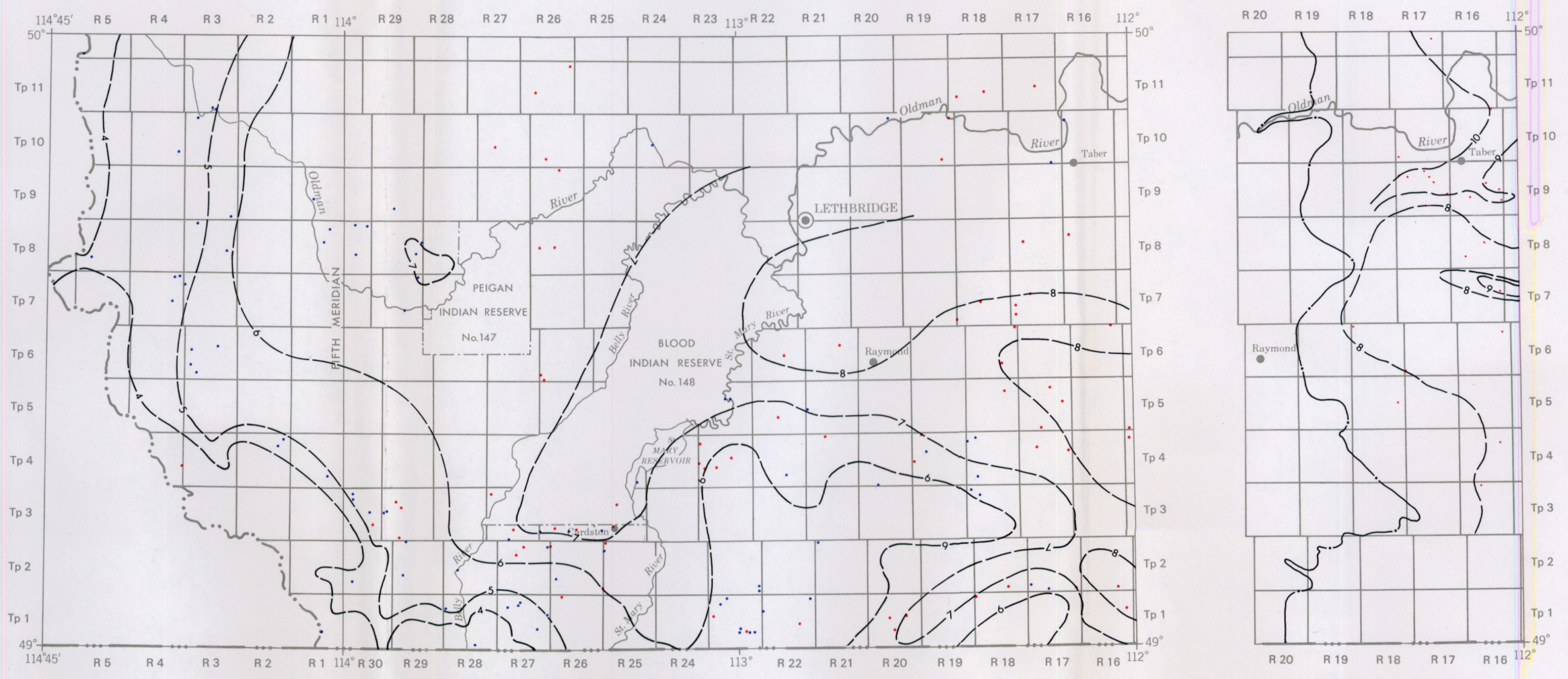
DRIFT THICKNESS



LEGEND

Isopach of drift, in feet:
defined .... —200—
approximate .... – – –

GROUNDWATER TEMPERATURE



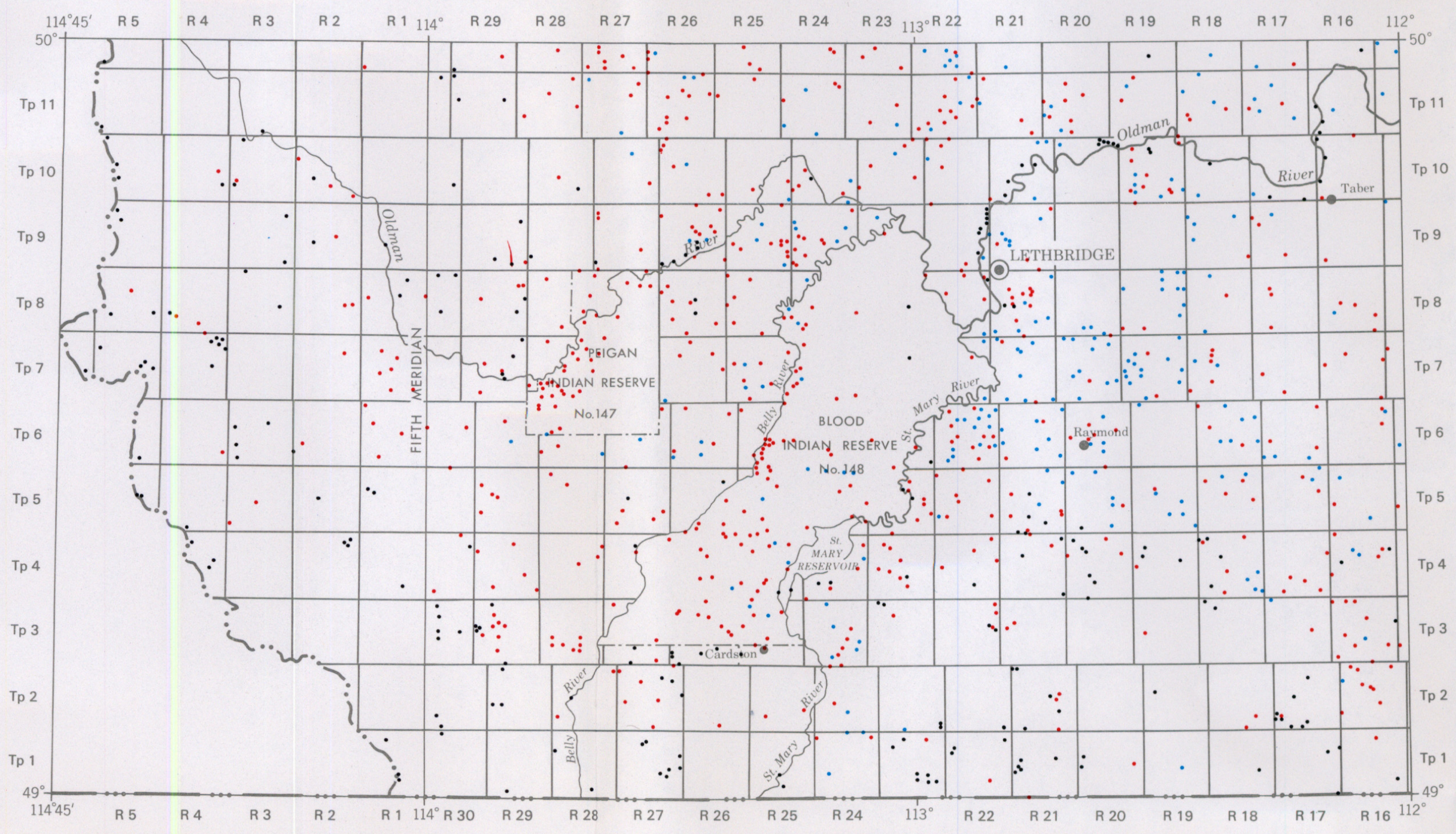
Springs and Wells 50 to 400 Feet Deep

Lower Milk River Sandstone

LEGEND

Data control point marking the location of a well .... •
Data control point marking the location of a spring .... •
Isotherm (°C) .... – – 9 – –
Line west of which lower Milk River sandstone is deeper than 1000 feet below surface .... —·—

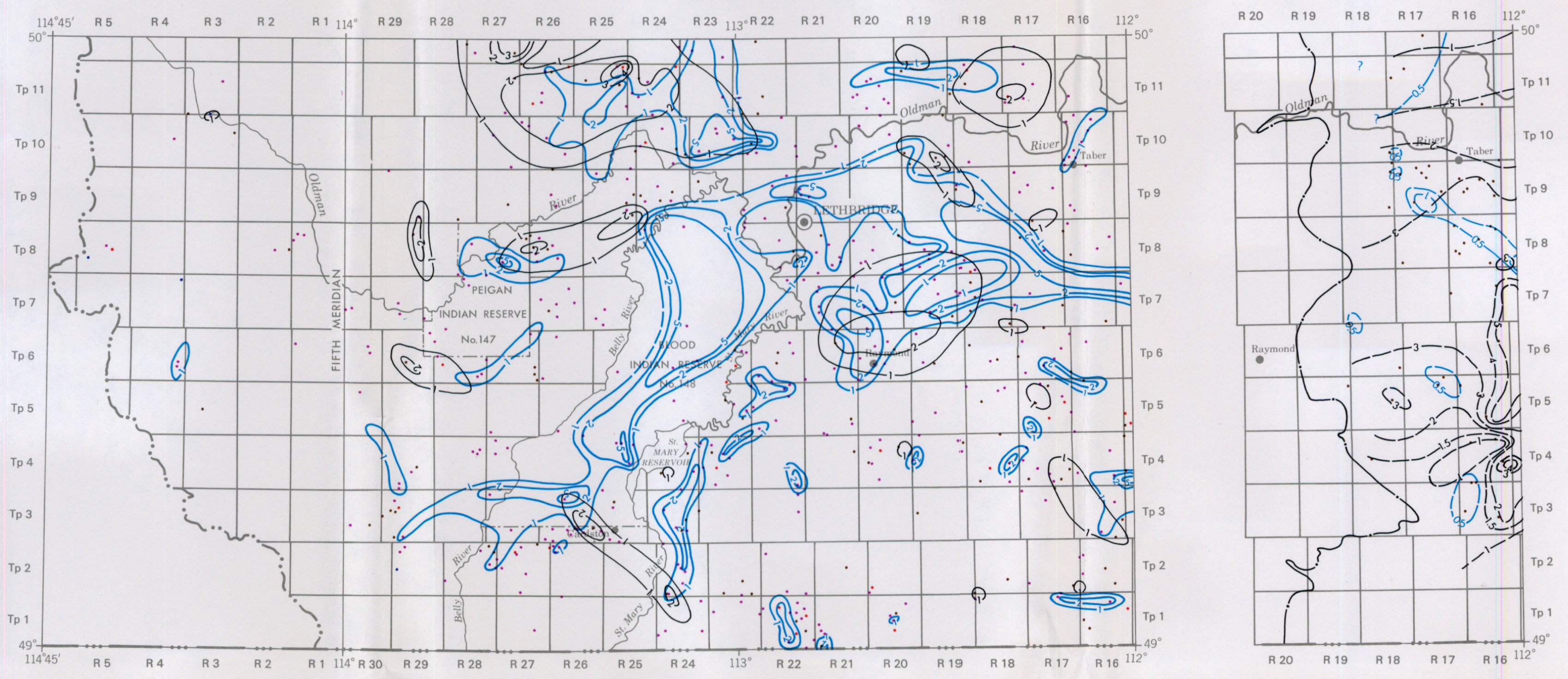
DATA DENSITY



LEGEND

Data control point marking the location of a well with water level information only .... •
Data control point marking the location of a well with yield information (i.e. production test) .... •
Data control point marking the location of a spring .... •

IRON AND FLUORIDE



Springs and Wells 50 to 400 Feet Deep

Lower Milk River Sandstone

LEGEND

Iron content in parts per million
defined .... —5—
approximate .... – –1– –

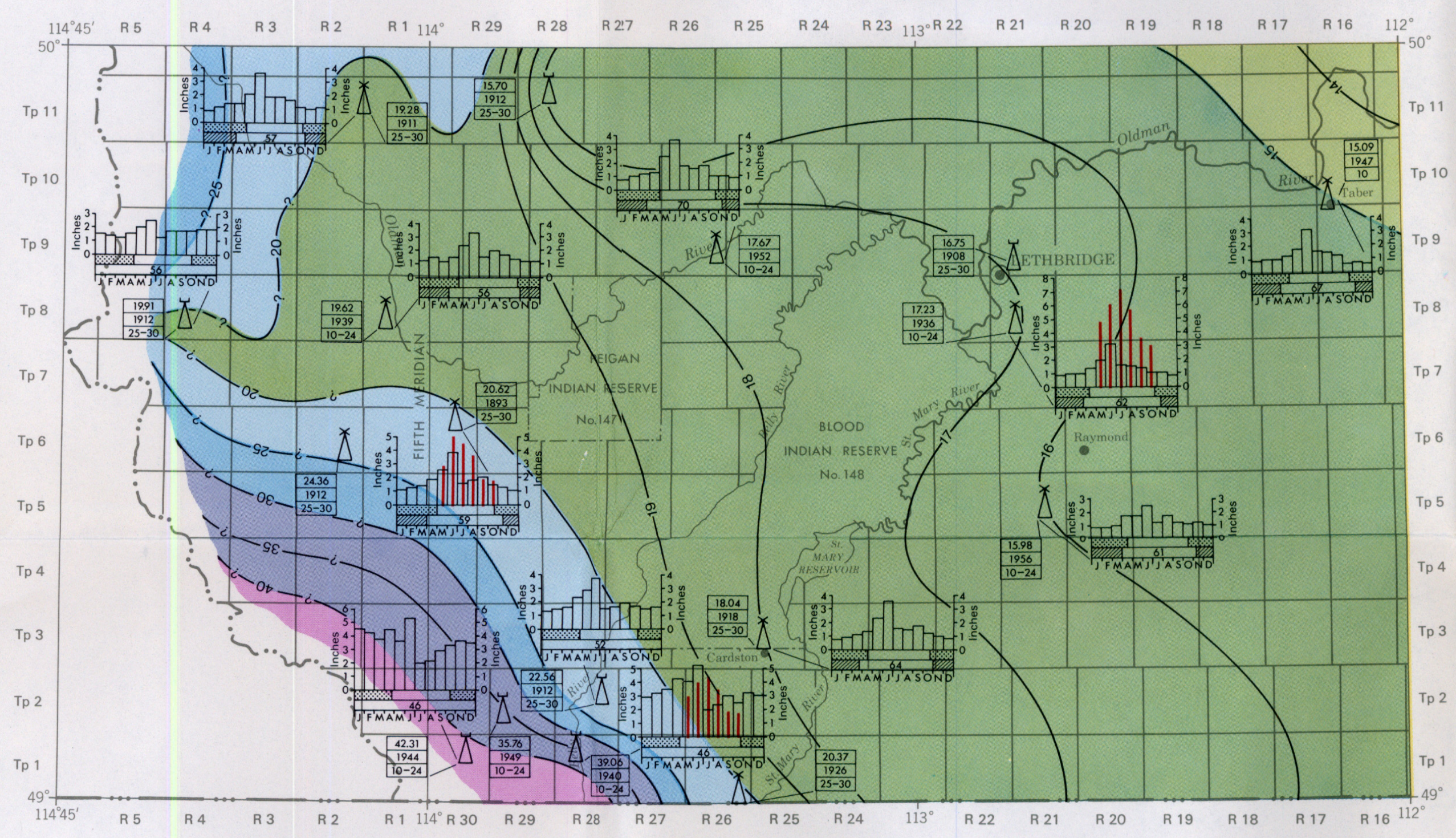
Fluoride content in parts per million
defined .... —4—
approximate .... – –1– –

Data control point marking the location of a well with a chemical analysis:
for iron .... •
for fluoride .... •
for iron and fluoride .... •

Data control point marking the location of a spring with a chemical analysis .... •

Line west of which lower Milk River sandstone is deeper than 1000 feet below surface .... —·—

METEOROLOGY



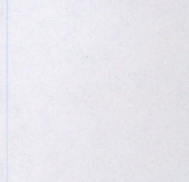
LEGEND

Isohyet, mean annual precipitation in inches .... —15—

Mean annual precipitation in inches:
- 🟨 less than 15
- 🟩 15-20
- 🟦 20-25
- 🟦 25-30
- 🟪 30-40
- 🟪 more than 40

Meteorological station .... △
Standard rain gauge only .... △

Precipitation data:

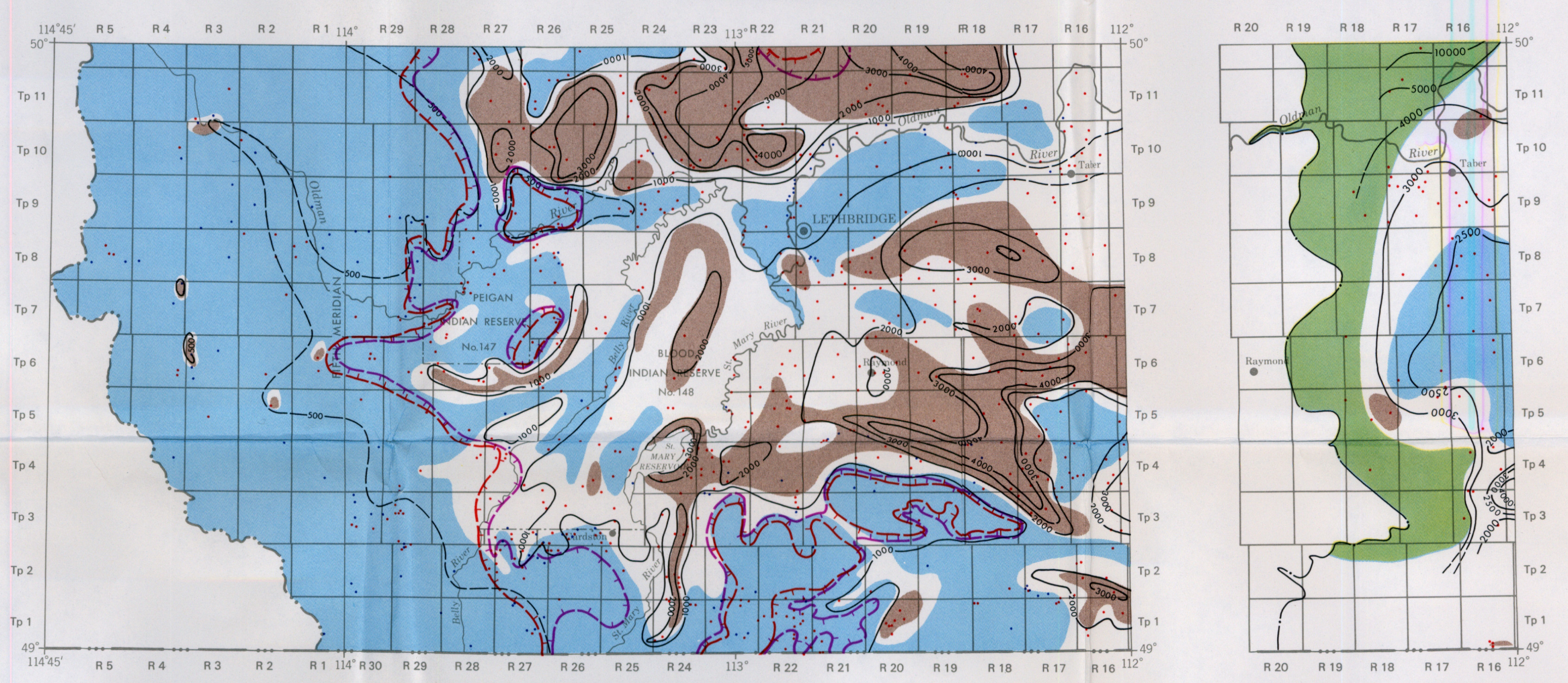


Mean annual precipitation in inches
Year of commencement of observations
Number of years of record averaged to determine the mean annual precipitation figure
Mean monthly potential evapotranspiration*
Mean monthly precipitation
Period when surface is usually snow covered
Period with mean daily temperature below freezing (0°C)
Figure indicates percentage of mean annual precipitation falling as rain

Sources of data:
Climatic Maps of Alberta (Longley, 1968); Monthly Record of Meteorological Observations (Meteorological Branch, Canada Department of Transport); and Provisional Evaporation Maps of Canada, Department of Transport Circular 4531 (Bruce and Weisman, 1967).

*Evapotranspiration estimates are based on the Provisional Evaporation Maps of Canada.

HYDROCHEMISTRY



Springs and Wells 50 to 400 Feet Deep

Lower Milk River Sandstone

LEGEND

Data control point marking the location of a well with a chemical analysis .... •

Data control point marking the location of a spring with a chemical analysis .... •

Total dissolved solids in parts per million:
defined .... —2000—
approximate .... – –1000– –

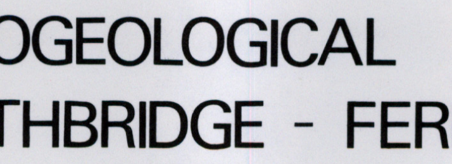
Bicarbonate + carbonate constituting over 60 percent of total anions* .... 🟦
Sulfate constituting over 60 percent of total anions* .... 🟫
Chloride constituting over 60 percent of total anions* .... 🟩

Isogram along which calcium + magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content .... ┴ ┴ ┴

Isogram along which sodium + potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content .... ┴ ┴ ┴

Line west of which lower Milk River sandstone is deeper than 1000 feet below surface .... —·—

*Determined on equivalents per million basis



HYDROGEOLOGICAL MAP
LETHBRIDGE - FERNIE
ALBERTA

NTS 82G-H

Sheet 2 of 2