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# Hydrogeology of the Mount Robson-Wapiti area, Alberta

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HYDROGEOLOGY OF THE MOUNT ROBSON - WAPITI AREA, ALBERTA


ABSTRACT

Within the Rocky Mountains and Foothills, bedrock aquifers are characterized by fracture permeability, and have structural rather than lithological boundaries. Flow systems are thought to be generally shallow and are bounded by major thrust fault zones which form highly permeable conduits for groundwater movement in both horizontal and vertical planes. Discharge from shallow bedrock aquifers is most abundant along these fault zones and flow rates increase with decreasing elevation from about 10 igpm to more than 1500 igpm (0.75 to 110 l/s). The direction of groundwater movement and residence time is determined mainly by relief, regional geological strike and dip, faulting, and fracture permeability. The presence of thermal springs discharging groundwater with total dissolved solids content in the 1000 to 2000 ppm range and high sulfate content and releasing hydrogen sulfide gas suggests locally high thermal gradients. The more promising, and also more readily accessible aquifers are surficial deposits.

Northeast of the Rocky Mountains, the dissected Western Alberta High Plains are underlain by fractured sandstone and shale of the Paskapoo Formation. Fracture permeability leads to rapid transmission of groundwater and water quality is excellent. The water table is often deep below the surface and calcium-magnesium ion ratios range between 3 and 4. The Paskapoo Formation outcrop is thought to be the major recharge area in the map area.

Northeast of the High Plain natural discharge features are rare. Total dissolved solids contents of groundwater from shallow bedrock aquifers increase from less than 500 ppm on the northeast edge of the High Plains to highs of 2000 to 2500 ppm on the Wapiti Plain, and sodium and potassium gradually become the dominant cations. Infiltration of precipitation and surface runoff is minimal due to the presence of surficial deposits containing high proportions of impermeable silt and clay. The groundwater of the Wapiti Plain is thought to be derived from a deep flow system originating in the High Plains to the southwest or farther west in British Columbia. Local recharge occurs in areas devoid of surficial deposits.

Yields range from 100 to 500 igpm (7.6 to 38 l/s) in alluvial outwash gravels of the Rocky Mountain Foothills and High Plains, and 1 to 25 igpm (0.076 to 1.9 l/s) in sandstone, shale, and coal aquifers of the Upper Cretaceous Wapiti Formation. Yields from bedrock aquifers of the Rocky Mountains are generally unpredictable, but carbonate rock types are probably the most highly yielding. Fractured sandstones and shales of the Paskapoo Formation are the most productive bedrock aquifers in the plains area, with yields ranging from 25 to 100 igpm (1.9 to 7.6 l/s), although the probability of intersecting fractured rock is difficult to assess.

## INTRODUCTION

The Mount Robson and Wapiti map areas (NTS 83E and L) are located between longitudes 118° and 120° west and latitudes 53° and 55° north. Under the Canadian land survey system, the area includes Tps 46 to 69, and Rs 1 to 14 W6 Mer; the area covers approximately 8900 sq mi (23,000 $km^2$).

About 75 percent of the Mount Robson map area lies within Willmore Wilderness Provincial Park and Jasper National Park. The remainder of the Mount Robson area and all of the Wapiti area is heavily timbered and essentially undeveloped.

The mining town of Grande Cache is the only permanent residential center within the map area and has a population of 3460 (1975). Small Indian and Métis communities are located along the Muskeg River valley northeast of Grande Cache, and a transient population involved in oil, gas, coal, and lumber exploration and production occupies seasonal camps. Throughout the map area water supplies, including that of Grande Cache, are generally obtained from the surface drainage system.

Access to the area is somewhat limited. From the southeast Highway 40 links Hinton with Grande Cache, and the Forestry Trunk Road continues north from Grande Cache to Grande Prairie. From the north, a number of private gravel and dirt roads extend into the country west of the Smoky and Kakwa Rivers, facilitating access to a number of forestry lookout towers and logging camps. All roads except Highway 40 are virtually impassable in wet weather.

Apart from the lumber and pulp industries based respectively at Grande Prairie and Hinton, commercial activities within the map area are restricted to the Gold Creek sour gas field and processing plant located in Tp 67, R 5, west of the Smoky River, and coal mining at Grande Cache.

Work on the reconnaissance hydrogeological map of the Mount Robson and Wapiti map areas commenced in January, 1975 and was completed in February, 1976. Hydrogeological data are sparse, so the main map is based primarily on field observation and interpretation of surface hydrogeological features, test drilling, and a well inventory compiled during the summer of 1975.

Water wells within the study area are concentrated within a strip of cultivated land along the northern edge of the Wapiti map area. A number of shallow wells completed in alluvial gravels are scattered around the mining town of Grande Cache in the Mount Robson map area. Elsewhere, occasional wells have been drilled to supply oil and gas exploration camps, logging camps, and recreational areas.

Without the control of data from a network of water wells, hydrogeological mapping becomes highly interpretive; thus, it must be stressed that the accompanying map represents a broad, regional interpretation of the hydrogeological regime.

## Previous Work

The earliest geological work in the area was carried out by G. M. Dawson (1880) of The Geological Survey of Canada, who examined geological sections along the lower part of the Wapiti River and Big Mountain Creek. Since then, sporadic forays into the northern parts of the Wapiti area were made by J. A. Allan and J. L. Carr, of the Alberta Research Council who searched for economic coal deposits. More recently, an exploratory soil survey of the Wapiti area was carried out by Lindsay, Wynnyk, and Odynsky (1964). In 1966-67 J. D. Campbell of the Alberta Research Council conducted further coal exploration in the area north of Tp 62. During this program, 177 exploratory holes were drilled to an average depth of 150 ft (45 m) in the Wapiti map area. The surficial geology of parts of the Mount Robson map area and all of the Wapiti map area was mapped by Bayrock (1973) and Bayrock and Reimchen (1975).

R. O. van Everdingen (1972) described the cold sulfur springs on Highway 16 in Tp 47, R 1 and Alberta Environment, Groundwater Development Branch, carried out test drilling along the Muskeg River valley northeast of Grande Cache in 1972 and 1975.

D. A. Hackbarth of Alberta Research Council has been monitoring springs in the Grande Cache area since 1972 in order to evaluate the effects of stripmining on groundwater quality.

## Acknowledgments

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## TOPOGRAPHY AND DRAINAGE

The study area can be divided into five topographic regions, with boundaries trending northwest parallel to the continental divide. From southwest to northeast these regions are:

1) the Main Ranges of the Rocky Mountains;
2) the Front Ranges of the Rocky Mountains;
3) the Rocky Mountain Foothills;
4) the Western Alberta High Plains;
5) the Wapiti Plain.

Topographic highs of the study area lie within the Main Ranges and Front Ranges of the Rocky Mountains. Mount Chown at 10,930 ft (3331 m) AMSL (above mean sea level) and The Rajah at 9903 ft (3018 m) AMSL are the highest points. Local relief within this belt averages 5000 ft (1500 m).

Northeast of the Persimmon Ranges, the Rocky Mountain Foothills extend out to the southwest boundary of the Western Alberta High Plains. Geologically, this boundary is marked by the Muskeg and Wildhay Thrust Faults. Relief within the Foothills belt is 2500 to 3000 ft (760 to 910 m).

The High Plains slope gently northeast from 5000 ft (1500 m) AMSL, adjacent to the Muskeg and Wildhay Faults, to 3500 ft (1100 m) AMSL above the north-facing scarp which drops steeply onto the Wapiti Plain. The High Plains are highly dissected west of the Smoky River where local relief is about 1500 ft (466 m). Nose Mountain is the highest point at 5050 ft (1540 m) AMSL. East of the Smoky River the true physiography of the High Plains is preserved: the Tertiary erosion surface or pediment is capped with quartzite and chert fluvial gravels. Air photographs reveal that relict drainage channels meander across the gravel pediment which slopes from 5000 ft (1500 m) AMSL to 4500 ft (1400 m) AMSL southwest to northeast. The High Plains are underlain by the Paleocene Paskapoo Formation which outcrops in the north-facing scarp slope above the Wapiti Plain.

The area is well drained except for the northern edge of the Wapiti Plain (Tps 68 and 69), where muskeg is common in areas underlain by glacial drift, and swamps develop in hollows between linear sand dune ridges. Lakes are rare and generally small. Drainage patterns within the Rocky Mountains and Foothills are trellised, indicating basic geological control, and rivers flow within broad, U-shaped valleys. On the High Plains and Wapiti Plain the Smoky, Wapiti, and Kakwa Rivers are deeply incised; tributaries are generally small and display dendritic drainage patterns.

Buried preglacial valleys exert minimal control on present-day drainage patterns in the map area, with the exception of the Bezanson buried valley which causes a zig-zag in the course of the Lattornell River (Tp 65, R 2).

Observations in the northeast corner of the Wapiti area indicate that some tributaries of the Smoky and Simonette Rivers are subject to intermittent periods of flow, and in late summer may become dry. These tributaries flow over drift deposits for their entire length. The drift deposits consist mainly of lacustrine clays which prevent groundwater discharge from bedrock aquifers, so stream flow is maintained by precipitation and surface runoff. This is insufficient to produce perennial flow even in areas where infiltration is probably minimal because of the impermeable nature of the underlying drift deposits.

## CLIMATE

According to the Koeppen system of classification the climate of the map area is microthermal and is characterized by a short cool summer with the mean temperature of the warmest month below 22°C and less than four months with mean temperatures of 10°C or more. Climatic data necessary for detailed classification of the Rocky Mountains are lacking; however, those parts of the Main Ranges where permanent icefields are found must have an arctic type climate in which the mean temprature of the warmest month is below 10°C and about 90 percent of the annual precipitation is in the form of snow.

The only meteorological station within the map area which collects year-round data is the Willow Creek Ranger Station in Tp 51, R 3. Outside the map area, Grande Prairie to the north and Jasper to the south also collect year-round data. Partial records, generally from May to September, are available from the following forestry lookout towers: Bald Mountain, Economy, Kakwa, Nose Mountain, Pinto Creek, Simonette, and Huckleberry.

The mean annual temperatures of the area range from 0°C to 3.3°C. The mean daily temperature at Grande Prairie is 1.2°C, at Willow Creek 2.2°C, and at Jasper 2.8°C.

Mean annual precipitation varies from 16.0 in (406 mm) at Jasper, to 26.3 in (668 mm) at Willow Creek, to 18.0 in (457 mm) at Grande Prairie. Within the Rocky Mountains mean annual precipitation is probably more than 30 in (760 mm) and highly variable.

Potential evapotranspiration is generally greater than precipitation during the months May to September in low-lying areas such as at Grande Prairie and Jasper, and at Bald Mountain and Economy Lake lookout towers. At higher altitudes the reverse is true. Potential evapotranspiration calculated by the Thornthwaite method at Jasper, Willow Creek, and Grande Prairie is 18.7 in (475 mm), 16.0 in (406 mm), and 19.5 in (495 mm), respectively. Evapotranspiration occurs during the months of April to October. Isohyets of mean annual precipitation shown on the meteorological side map are modified from Longley (1968).

Topography has significant effects on the climate of the area. North of Jasper the Rocky Mountains decrease in altitude as they pass into British Columbia. This permits rain-bearing winds from the Pacific to enter the Peace River District, allowing the area to receive more moisture than it otherwise would. The Yellowhead Pass near Jasper also provides a channel for air from British Columbia to flow into western Alberta and is responsible for Jasper's mild climate.

# GEOLOGY

## Bedrock Geology

Bedrock units ranging in age from Proterozoic to Tertiary are exposed within the map area in two distinct geological environments:

1) *The Rocky Mountain orogenic belt*, sometimes called the disturbed belt, which consists essentially of sedimentary rocks displayed in a series of homoclinal southwest-dipping imbricate thrust sheets. In general, Proterozoic rocks outcrop within the Main Ranges, Cambrian within the Front Ranges, and Upper Paleozoic to Lower Mesozoic within the Foothills. Price and Mountjoy (1970) argue that deformation of the Rocky Mountains progressed from southwest to northeast during the interval from late Jurassic to Eocene.
2) *The Western Alberta High Plains and Wapiti Plain* where Upper Cretaceous to Lower Tertiary rocks form a broad northwest-trending asymetric syncline. Dips on the north-east limb are shallow while dips on the southwest limb adjacent to the disturbed belt are steeper (20 to 60°).

The boundary between the disturbed belt and Western Alberta High Plains is marked by the Muskeg Thrust Fault to the northwest, and the Wildhay Thrust Fault to the southeast.

Rock unit boundaries shown on the geological side map are taken from the Geological map of Alberta (Green, 1972). The complex geology of the disturbed belt is highly simplified, and many of the boundaries shown are fault contacts even though the faults could not be represented on such a small-scale map.

On the main map and hydrogeological profiles, a more detailed lithological subdivision is presented, but the subdivision is based primarily on the interpretive hydraulic conductivity and gross lithology of the various bedrock units. Thus, the Proterozoic Miette Group is represented as mainly shale though dolomite and limestone are also present within the group. The Lower Cambrian Gog Group is represented as mainly quartzite with well-developed joint systems. The Triassic White Horse Formation, the Mississippian Rundle Group and Banff Formation, and the Devonian Fairholme Group, Alexo Formation and Palliser Formation are shown as carbonates. The Lower Cretaceous Luscar Formation is singled out due to the relative abundance of coal seams, even though about 60 percent of the Luscar succession consists of shale.

The remaining Upper Cambrian and Ordovician formations, the Jurassic Nikanassin Formation, Fernie Group and Kootenay Formation, the Lower Cretaceous Cadomin and Blairmore Formations, and the Upper Cretaceous Alberta Group are represented as mainly shale.

Sandstones are present in many of the previously mentioned bedrock units, but are not singled out because it is thought that a marked reduction in intergranular porosity of sandstones occurs within the disturbed belt and High Plains due to the presence of low-grade metamorphic cementing minerals. Thus the hydraulic conductivity and storage capacity of these sandstones is reduced to a level similar to that of shale; the main facility for storage and transmission of groundwater becomes intraformational fracture systems.

Major thrust faults are represented on the hydrogeological profiles but, due to vertical exaggeration (1:21), the physical disposition of these features is purely schematic, as are geological structures within each thrust sheet.

To the north, in the High Plains and Wapiti Plain, the major unit is the Upper Cretaceous Wapiti Formation which increases in thickness from about 2000 ft (600 m) in the northeast to 7000 ft (2100 m) adjacent to the disturbed belt. Structure contours on the base of the Wapiti Formation are shown on the geological side map and outline the broad Alberta Syncline closing to the northwest. The middle and upper parts of the Wapiti Formation are roughly correlative with the Edmonton Group of south-central Alberta (Irish, 1970). However, within the map area, these stratigraphic rock units are impossible to trace as mappable units. The Battle Formation (Kneehills Tuff) marker bed cannot be traced west of the Smoky River, though the Ardley "coal zone" of the Scollard member has been noted as far west as the headwaters of the Cutbank River near Nose Mountain (Tp 64, R 11) (Kramers and Mellon, 1972).

The Wapiti Formation consists of thinly bedded, nonmarine, bentonitic sandstones and shales. In its upper part, coal seams become relatively abundant. It is overlain by the Paleocene Paskapoo Formation consisting of thicker, cliff-forming calcareous sandstones interbedded with siltstone, shale, and minor coal seams. The Paskapoo Formation is thickest adjacent to the disturbed belt and the outcrop pattern delineates a shallow synclinal structure plunging to the southeast. To the east this structural control becomes less evident and the outcrop is truncated in a northeast direction by a post-Paleocene erosion surface.

Adjacent to the Muskeg and Wildhay Thrust Faults, the Wapiti and Paskapoo Formations are undifferentiated and are grouped under the name Brazeau Formation.

For more detailed stratigraphy and structure of parts of the disturbed belt the reader should refer to Geological Survey of Canada map sheets 1140 A and 1139 A (Irish, 1965) and sheet 47-1963 (Mountjoy, 1963).

## Surficial Geology

The surficial geology of the Wapiti area and part of the Mount Robson area is described by Bayrock (1973) and Bayrock and Reimchen (1975).

Surficial deposits within the map area have an irregular, patchy distribution due to post-glacial erosion. Deposits are generally less than 50 ft (15 m) thick and are most abundant in the northeast half of the Wapiti area where till (ground moraine) and glaciolacustrine silt and clay are the dominant lithologies. Glacial deposits of continental (Laurentide) origin generally occur below 3500 ft (1100 m). Above 3500 ft (1100 m), glacial deposits originated from the Rocky Mountains and extend up to about 5000 ft (1500 m). Above 4000 ft, (1200 m) in areas not covered by local or Rocky Mountain tills, recent colluvial deposits occur.

Remnants of preglacial alluvial sand and gravel deposits are preserved within the Bezanson buried valley in the northeast corner of the map area. These sand and gravel deposits were intersected in Alberta Research Council testhole 11 (Appendix A) at a depth of 184 to 196 ft (56 to 60 m) and consist mainly of quartzite and chert cobbles. The headwaters of the Bezanson buried valley are coincident with the headwaters of the present-day Lattornell River. The preglacial drainage was, and the Lattornell River is, cutting back into Tertiary uplands to the south which are a former erosion surface capped with quartzite and chert gravels up to 20 ft (6 m) thick. These gravels were the major source material of the preglacial alluvium of the Bezanson buried channel. The Tertiary uplands were not glaciated during the classical Wisconsin glacial advance.

Continental ground moraine generally forms a thin veneer (less than 50 ft or 15 m thick). In low-lying areas to the north, within the Bezanson buried valley, and in Tp 69, Rs 6 and 7, this moraine is overlain by glaciolacustrine silt and clay up to 250 ft (76 m) thick. Within the Rocky Mountains and Foothills, some 90 percent of the tills are pre-Wisconsin in age; ground moraine is the most prevalent deposit. Wisconsin tills are present only in the larger valley drainages where lateral moraine is the most prevalent deposit (Bayrock, 1973).

Well-defined glacial outwash channels containing thick gravel deposits exist near the edge of the disturbed belt and extend northeast through the Western Alberta High Plains. The most extensive outwash channel within the area trends northeast from Victor Lake near Grande Cache through Muskeg River and Pierre Greys Lakes and is presently occupied by the Muskeg and Little Smoky Rivers. A second outwash channel extends from the Snake Indian River (Tp 51, R 3) through Rock Lake in a northeast direction, and also southeast down the

Snake Indian River valley. Gravel deposits within the Snake Indian and Rock Lake channels are highly dissected by the present-day drainage and often occur as well-defined terraces. The Athabasca River valley also contains extensive alluvial outwash sands and gravels up to 1000 ft (300 m) thick.

Generally alluvial outwash gravels are very coarse-grained due to their closeness to the source area and range in thickness from 30 ft (9 m) to several hundred feet. The surface of the deposits is generally flat or gently undulating, but is often pitted with ice disintegration features which usually accommodate numerous small lakes and swampy areas such as Pierre Greys Lakes and Joachim Lakes in the Grande Cache-Muskeg River channel.

Recent deposits worthy of note include alluvium, which is generally less than 20 ft (6 m) thick. Extensive alluvial gravels exist along the Smoky River downstream from Grande Cache to the junction with Sheep Creek and also in the lower reaches of the Smoky River within Tps 68 and 69. The Berland River, Jackpine River, and Sheep Creek also contain thick alluvial gravels. Within the Foothills and High Plains of the northern parts of the map area, the major rivers flow in deeply incised gorges. In these gorges, alluvial deposits are dissected and occur as high terraces of limited extent no longer in hydraulic connection with the river.

Within the disturbed belt alluvial fans develop around the larger lakes (for example at Twintree Lake). On the steep valley sides Recent colluvium or talus accumulates, ranging in thickness from 0 to 2 ft (0 to 60 cm) at the top of the talus slope to more than 100 ft (30 m) at the bottom.

Eolian dune sands of limited extent are present along the shores of Jasper Lake on the Athabasca River (reworked alluvial sand); to the east of the Wapiti River in Tp 68, Rs 9, 10, and 11; to the east of the Smoky River in Tps 68 and 69, Rs 2, 3, and 4; and within Tp 64, Rs 1 and 2 (reworked glaciolacustrine sand and silt). The maximum thickness of dune sands is about 40 ft (12 m), but generally is less than 20 ft (6 m).

## HYDROGEOLOGY

### Groundwater Levels and Gradients

Nonpumping water levels from wells situated along the northern boundary of the map area are contoured on the main map. Wells in this area are shallow (100 to 200 ft or 30 to 60 m) and tap sandstone and fissile shale aquifers of the Upper Cretaceous Wapiti Formation.

Occasionally coal seams are intersected but yield poor quality groundwater. A coal seam intersected in Alberta Research Council testhole 2 at 103 to 105 ft (31 to 32 m) bns (beneath natural surface) contained very soft water with high sodium sulfate content.

Generally, static water levels in wells situated on the Wapiti Plain are near surface and decrease with increasing well depth. Near the Smoky River valley in Tps 67 to 69, R 4, static water levels are unusually deep (200 to 300 ft or 60 to 90 m) and several dry wells have been drilled. Limited water well data indicate that groundwater quality in this area is above average. No natural groundwater discharge occurs within the Smoky River valley which suggests that water from the Smoky River and associated alluvial aquifers may be recharging deeper bedrock aquifers in the Cretaceous Wapiti Formation.

In the deeply dissected High Plains west of the Smoky River, highly permeable, fractured sandstones and shales of the Paskapoo Formation combine with rugged topography, steep slopes, and limited upland areas to produce deep static water levels in the more accessible areas. Wells located on the tops and flanks of hills have been drilled to depths of more than 500 ft (150 m) without intersecting fully saturated aquifers. East of the Smoky River the Tertiary pediment is extensive. Relief is less rugged and a thin veneer of fluvial gravels enhances infiltration rates. As a result, static water levels from shallow wells range from a few feet to 50 ft (15 m) bns and the water table surface is closely related to topography.

Flowing seismic shotholes, usually less than 80 ft (24 m) deep, are reported within a narrow belt which trends southeast from the Wapiti River roughly parallel to the disturbed belt and is coincident with the southwest edge of continental drift deposits on the Wapiti Plain. The necessary hydraulic pressure is probably derived from shallow, bedrock flow systems confined by drift deposits, because deeper wells do not flow. Flowing conditions are also encountered along the base of the north-facing Paskapoo Formation scarp slope, where local flow systems are confined by slumped material and flow is usually only a temporary, highly localized condition.

## Test Drilling

During the summer of 1975, the Alberta Research Council drilled 14 test wells within the map area. Three of these were pump tested open hole; the remaining 11 wells were tested with an air-compressor at various depths during drilling. When possible, resistivity, self-potential, and gamma-ray wire-line logs were run. Test wells 1 to 11 inclusive were drilled in an east-west line along the southern edge of the agricultural areas in Tps 68 and 69 and then in a north-south line along the Forestry Trunk Road. Total depth of these wells ranged from 200 ft (61 m) to 500 ft (150 m), but all were bottomed in Wapiti Formation sediments. Test wells 12, 13, and 14 were drilled on the High Plains in Paskapoo Formation sediments to depths ranging from 160 ft (49 m) to 300 ft (91 m). Results of the test drilling program are summarized in Appendix A.

The average expected 20-year safe yields of individual wells and the coefficients of transmissivity of the aquifers were calculated from bail and pump test data. Some 90 percent of these data included only the initial or static water level and final water level at the end of the test. Therefore parameter values obtained are in most cases approximations. In Table 1, average values of apparent transmissivity and 20-year safe yield are presented for the major geological formations. As only 31 wells provided relevant data, this table of values should be viewed qualitatively rather than quantitatively.

## Aquifer Permeability

Intergranular porosity of sandstones decreases in a southwest direction due to low grade metamorphism related to the Rocky Mountain orogenesis. Southwest of a line trending through Grande Prairie parallel to the disturbed belt, sandstone cements include kaolinite, montmorillonite, and calcite, and form up to 20 percent by volume of the whole rock. Farther west towards the Foothills, chlorite cements are found in sandstones of both Wapiti and Paskapoo Formations. East of this line, with the exception of hard carbonate-cemented lenses, sandstones are largely uncemented and intergranular porosity increases (Kramers and Mellon, 1972).

In bedrock formations of the High Plains and Foothills, aquifer permeability and storage capacity is enhanced by the presence of well-developed fracture systems. Provided that a well intersects such fractures, yields are not unduly affected by the southwest decrease in sandstone porosity. However, whether fracture systems are present at any given locality is unpredictable; consequently, yields in this area are highly variable and wells are drilled on a hit-or-miss basis. Alberta Research Council testhole 14 did not intersect a fracture system, but testhole 13 did. Respective 20-year safe yields, calculated from 6-hr pump test data, are 7 igpm (0.5 l/s) and 135 igpm (10 l/s) (Appendix A).

## Springs

In order to compensate for the sparse water well data distribution, approximately 480 natural groundwater discharge points were observed during the summer of 1975. These included springs, seepages, discharge meadows, and muskegs. About 260 water samples were collected for chemical analysis and conductivity, pH, and temperature were measured in the field where possible. Flow rates were usually estimated or measured with a portable V-notch weir.

Table 1. Average Transmissivity and Safe Yield Values for the Major Aquifers of the Mount Robson-Wapiti Area

| Rock Unit | Apparent transmissivity | | Apparent safe yield | |
|---|---|---|---|---|
| | (gpd/ft) | ($m^3$/d/m) | (igpm) | (l/s) |
| Wapiti Formation sediments: | | | | |
| a) northwest corner of map area | 5000 | 74.5 | 100 | 7.6 |
| b) elsewhere | 100-150 | 1.5-2.2 | <5 | <0.4 |
| Paskapoo Formation: | | | | |
| a) from wells that intersected well-developed fracture systems | 3000-3500 | 44.7-52.2 | 50-100 | 3.8-7.6 |
| b) from wells that did not intersect fracture systems | 30-50 | 0.45-0.75 | <5 | <0.4 |
| Glacial outwash gravels | 600-1000 | 8.9-14.9 | 25-50 | 1.9-3.8 |

Within the Wapiti Plain, discharge features are rare and generally restricted to the northwest corner of the map area where drift cover is minimal. In this region, discharge meadows are found on the flatter plain levels surrounding muskeg swamps, and springs and seepages are present at sandstone-shale contacts in bedrock outcrops within the deeply incised river valleys. Also within the river valleys, in particular the middle reaches of the Smoky River, waters rich in calcium bicarbonate discharge from terraced gravel deposits and cascade down the terrace banks to disappear into river alluvium at the base of the slope. Flow rates from bedrock discharge features are generally in the range 1 to 10 igpm (0.08 to 0.76 l/s) but higher flow rates were noted from bedrock springs along the Wapiti River valley in the northwest corner of the map area. In the northeastern parts of the Wapiti Plain, springs are exceedingly rare.

In the High Plains springs and seepages are very common east of the Smoky River, but become less abundant to the west where high relief results in more localized discharge confined to major river valleys. Springs in this area fall into two groups based on surface characteristics and hydrochemistry:

*Group 1)* Boulder tuft springs discharge calcium-magnesium bicarbonate type waters with total dissolved solids contents of 100 to 300 ppm (parts per million) and calcium and magnesium constituting more than 80 percent of the total cations. These springs appear 50 to 100 ft (15 to 30 m) below the Tertiary pediment on steep slopes and are characterized by a steep boulder-strewn cascade. Due to aeration of the cascading waters, the boulders become encrusted in tufa deposits (calcium carbonate precipitate). Discharge occurs because of a permeability contrast between weathered and nonweathered bedrock of the Paskapoo Formation: water is transmitted in the weathered zone along fracture systems and possibly through intergranular porosity rejuvenated by solution of calcite and chlorite sandstone cements. The weathered zone is well developed in areas where the Tertiary pediment is preserved. As the rim of the Tertiary pediment is constantly being eroded new fracture systems are being opened to the surface, and it is quite common to see an abandoned discharge point with a new spring only 20 ft (6 m) away. Flow rates from boulder tuft springs range between 15 and 30 igpm (1.1 to 2.3 l/s). The groundwater temperature averages 3.2°C.

*Group 2)* In topographic lows, groundwater of a longer residence time discharges in springs and seepages. The water is a calcium-magnesium bicarbonate type but contains 30 to 40 percent sodium and potassium (percent of cations by milliequivalents) with total dissolved solids contents in the range of 300 to 900 ppm. Flow from these discharge points is sluggish, and the water does not become aerated as rapidly as in the boulder tuft springs, so tufa deposits are rare. Flow rates are usually lower than boulder tuft springs, but occasionally, where a large fracture system is exposed, flow rates as high as 150 igpm (11 l/s) are encountered. Ungulates are attracted to these discharge points by the higher sodium and potassium concentrations in the water, and characteristic muddy game licks develop around seepage points.

Figure 1 graphically presents the relationship between elevation and total dissolved solids contents in springs located east of the Smoky River. The springs occurring above 4000 ft (1200 m) AMSL are boulder tuft springs; those below 3500 ft (1070 m) AMSL belong to group 2 described above. The decrease in number, and occasional occurrence of, springs with flow rates greater than 100 igpm (7.6 l/s) below 4000 ft (1200 m) AMSL is indicative of highly localized flow through sinuous intraformational fracture systems. The increase in total dissolved solids with decreasing elevation is linear and occurs at the rate of 40 ppm total dissolved solids every 100 ft (30 m) drop in elevation. This linear relationship suggests hydraulic continuity and is characteristic of groundwater recharge conditions.

Figure 2 is a Piper diagram of chemical analyses of boulder tuft spring water showing the trend from calcium to sodium and potassium bicarbonate type waters as a result of base exchange due to progressively longer periods of groundwater residence time.

Within the Rocky Mountains and Foothills, surficial aquifers are the more productive and easily defined. Flow systems and residence times are short, so water quality is excellent (less than 500 ppm total dissolved solids content). Springs and seepages are common in the valley bottoms, at the base of talus deposits, and on the downstream borders of thick sand and gravel deposits of glacial and alluvial origin. Flow rates are seasonal, reaching a maximum in late spring when snowmelt forms a major contribution to infiltrating surface waters. During late summer and winter these springs may cease to flow. Flow rates in early July 1975 were in the range 10 to 50 igpm (0.75 to 3.8 l/s).

The bedrock aquifers of the Rocky Mountains and Foothills are characterized by fracture permeability and have structural rather than lithological boundaries. Bedding planes and joint systems in carbonate rock types (limestone and dolomite) may be enlarged due to solution, and fracture systems in sandstone, shale, and coal horizons are more developed in the crests of folds. Abundant imbricate fault zones form highly permeable conduits for groundwater movement in both horizontal and vertical planes and may represent major boundaries to narrow strike-oriented flow systems. Discharge from shallow bedrock aquifers is most abundant along these fault zones and flow rates increase with decreasing elevation from about 10 igpm to more than 1500 igpm (0.75 to 110 l/s). Groundwater from surficial aquifers and some bedrock aquifers is of the calcium-magnesium bicarbonate type, while many bedrock aquifers contain calcium and magnesium sulfate type waters. These sulfate type waters are particularly evident in springs of the Front Ranges.

The larger sulfur springs such as one beneath Kvass forestry lookout tower on the east bank of the Smoky River (Tp 55, R 10, Sec 3) are found in the deeper river valleys at the faulted basal contact of thick carbonate rock units. A thrust sheet of Upper Paleozoic carbonates

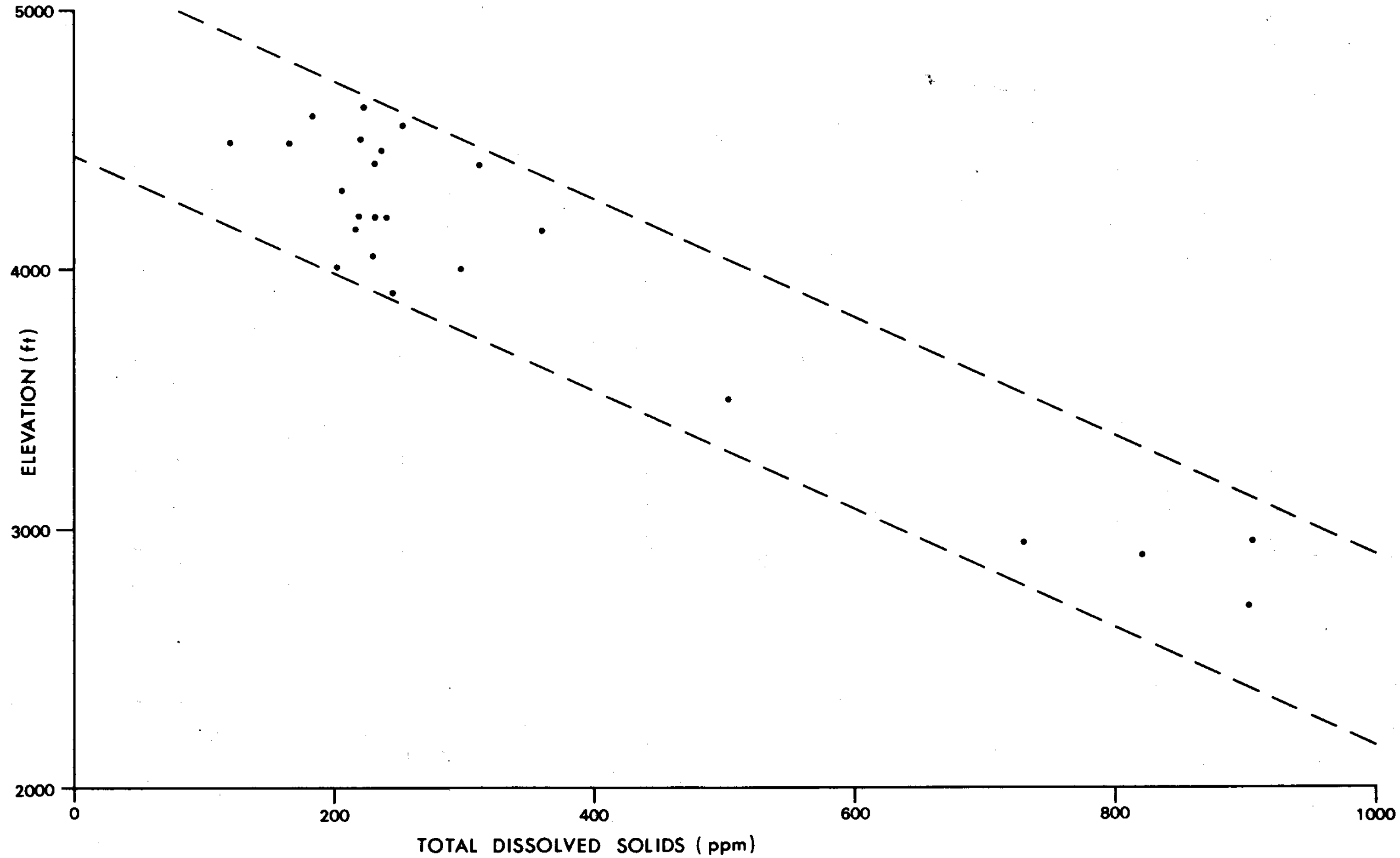



*Figure 1. Graph of total dissolved solids versus elevation from Paskapoo Formation springs located east of the Smoky River, west of the 6th meridian*

overlies Lower Mesozoic shales along the Colin Thrust which extends from the Colin Range in Tp 47, R 1, northwest to Sheep Creek in Tp 56, R 11. A total of 10 sulfur springs were found along this fault system including the well-described cold Sulphur Spring on Highway 16, east of Jasper townsite.

Total dissolved solids contents of sulfur spring waters vary from less than 500 ppm at high elevations to more than 2000 ppm in the deeper river valleys. The temperature ranges from 5°C to 13°C. Figure 3 is a graphical presentation of chemical analyses from 16 sulfur springs located in the Front Ranges of the Mount Robson area. In these waters base exchange takes place between calcium and magnesium and sodium and potassium. In some samples, chloride composes up to 35 percent of total anions expressed as milliequivalents.

## Well Yields

Pump test data and test drilling from the Wapiti Plain and High Plain areas indicate that shallow well yields can be quite closely correlated with spring discharge rates.

In the Wapiti Plain, springs discharge water from confined bedrock aquifers, and flow rates are comparable to the upper limits of expected yields from shallow bedrock wells. In the northwest, around the Wapiti River, this relationship is particularly well displayed.

Within the Paskapoo Formation of the High Plains, springs issue from fracture systems, the aquifers are unconfined, and flow rates may be compared to the lower limits of expected yields from wells intersecting fractured sandstone aquifers.

The color-coded average expected well yields shown on the main map indicate the total quantity of water that may be obtained from a single well tapping all the available aquifers within the upper 1000 ft (300 m) of strata. In most cases yield data are only available from wells developed in bedrock to depths of less than 300 ft (91 m). Therefore boundaries are often poorly established and local anomalies, due to unexplored areas of higher or lower than average permeabilities, are to be expected.

Within the Rocky Mountains and Foothills, yield categories are based on the interpretation of natural discharge features, topography, geological structure, and lithological characteristics of the various rock units. Topography influenced the initial allocation of a yield category of less than 1 igpm (0.076 l/s) for areas lying above 7000 ft (2100 m) AMSL. At such elevations, surficial deposits are very thin or absent, relief is very steep, and bedrock is probably unsaturated to depths greater than 1000 ft (300 m). These areas are thought to be important groundwater recharge zones for the deeper bedrock flow systems of the Rocky Mountains.

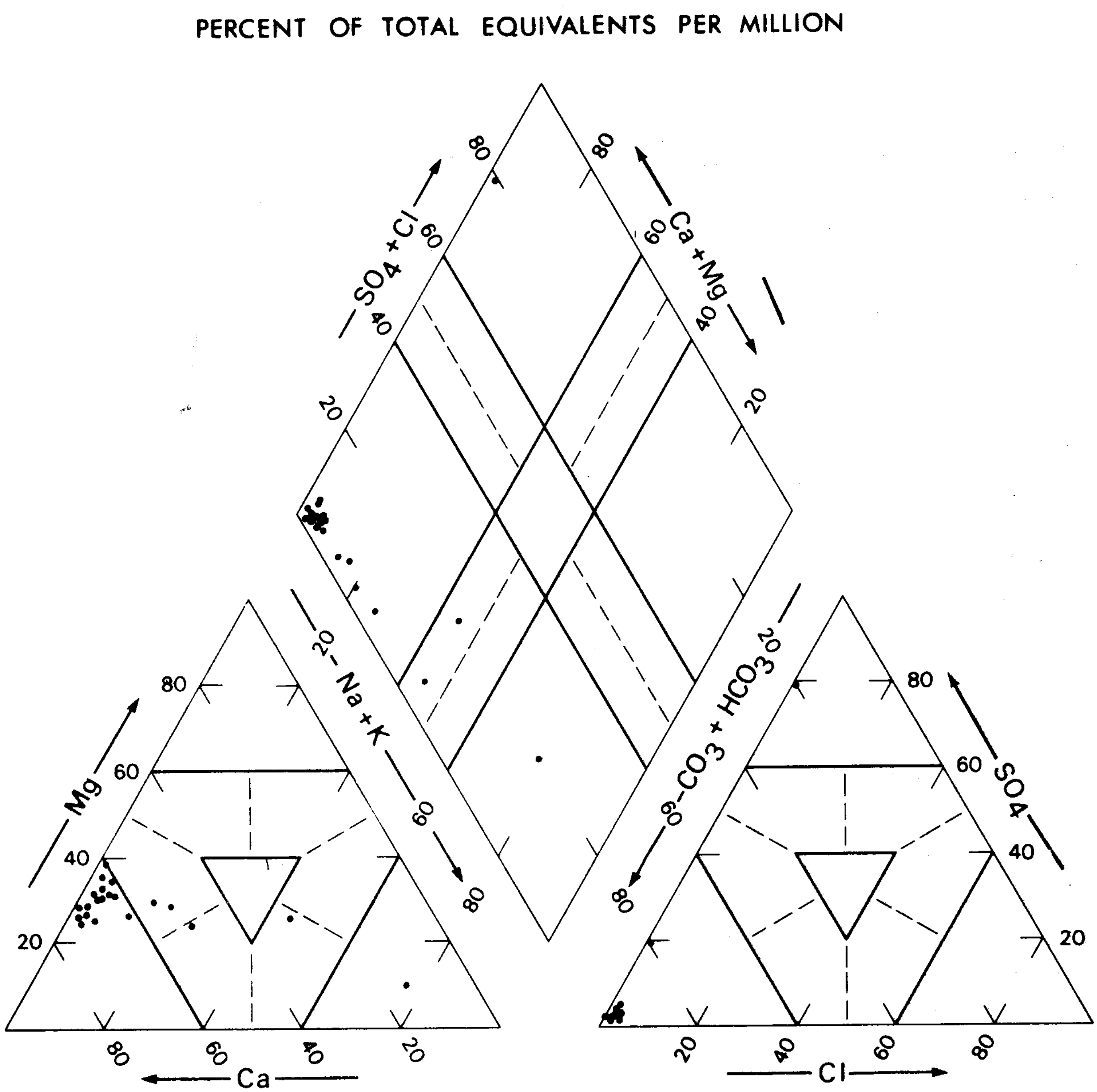



*Figure 2. Piper diagram showing the hydrochemistry of boulder tuft springs of the eastern part of the High Plains*

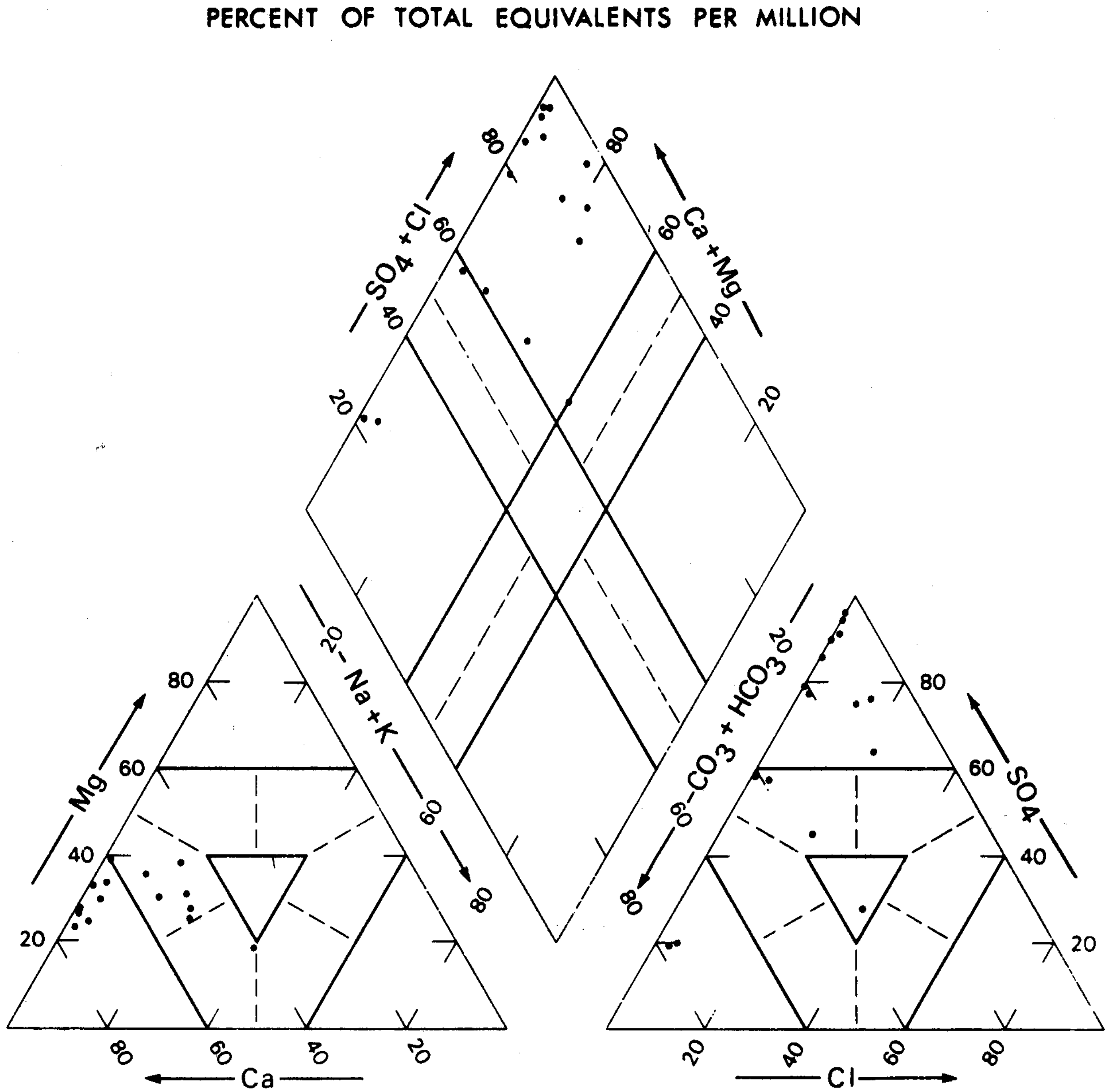



*Figure 3. Piper diagram showing the hydrochemistry of sulfur springs from the Front Ranges of the Rocky Mountains*

Geological structure accounts for the downward projection of yield areas along southwest-plunging fault zones on the hydrogeological profiles. Bedrock permeabilities are probably above average due to the cataclastic effects of thrust faulting.

Karstified Paleozoic limestones and dolomites are considered the most important and most potentially productive bedrock aquifers within the Rocky Mountains, though no borehole data are available. Proterozoic and Cambrian Quartzites of the Main Ranges, along with coal seams of the Upper Cretaceous Luscar Formation of the Foothills, are also considered potentially productive but to a lesser degree.

Several dry wells have been drilled in Upper Cretaceous Alberta Group shales in the Rocky Mountain Foothills (around Grande Cache).

## HYDROCHEMISTRY

The majority of hydrochemical data used in the construction of the hydrochemical side map is from shallow wells (200 to 300 ft or 61 to 91 m) and surface discharge features. Thus, the hydrochemical patterns presented relate to shallow bedrock aquifers. Hydrochemical facies changes with depth are indicated on the hydrogeological profiles.

Three hydrochemically distinct groundwater types are present in the shallow bedrock aquifers of the map area:

1) *Calcium and magnesium bicarbonate type groundwater* is the most widespread and is found in all the surficial aquifers.
2) *Calcium and magnesium sulfate type groundwaters* with up to 35 percent chloride (percent milliequivalents of anions) are restricted to the Front Ranges of the Rocky Mountains, but may occur at depth over a much wider area. No sulfate type groundwaters were noted outside the disturbed belt.
3) *Sodium and potassium bicarbonate type groundwaters* occur in the extreme northern parts of the map area. In the northeast these soft groundwaters extend as far south as Tp 59, R 1.

Total dissolved solids contents of groundwaters are usually less than 1000 ppm and show a general increase from southwest to northeast outside of the disturbed belt. Within the Paskapoo Formation of the High Plains, groundwater in shallow aquifers contains less than 300 ppm total dissolved solids, and total dissolved solids content increases with depth to probably not more than 500 ppm. In the upper parts of the Wapiti Formation immediately north of the Paskapoo outcrop, shallow wells tap groundwater in the 300 to 500 ppm range.

Deeper wells, or wells located in topographic lows tap groundwater with total dissolved solids contents between 500 and 1000 ppm. Calcium and magnesium ions are dominant in shallow groundwaters but give way to sodium and potassium at depth. To the northeast, total dissolved solids contents slowly increase to highs greater than 2000 ppm but not exceeding 2500 ppm. The more saline groundwaters correspond to the sodium and potassium bicarbonate hydrochemical facies described previously.

Within the Rocky Mountains, the sulfate type groundwaters have total dissolved solids contents ranging from 500 to 2500 ppm, the high values occurring in topographic lows. Bicarbonate type groundwater collected from springs and seepages generally contains less than 300 ppm total dissolved solids.

The hydrochemistry of groundwater in the Bezanson buried valley gravels is not known. However, most surficial aquifers within the map area contain groundwater with less than 300 ppm total dissolved solids.

Contamination of surficial aquifers by discharging bedrock groundwaters sometimes results in higher total dissolved solids values in surficial aquifers of the Rocky Mountains and Foothills. Three wells completed in alluvial gravels of the Smoky River valley at Daniels Flats north of Grande Cache showed dramatic increase in total dissolved solids contents with depth: from 460 ppm at 30 ft (9 m) bns to 630 ppm at 70 ft (21 m) bns, to 980 ppm at 120 ft (37 m) bns.

At Rock Lake, outwash gravels overlie Lower Cretaceous and Jurassic siltstone, shale, and coal. Chemical analysis of spring and pond water from the area underlain by outwash gravels indicates that total dissolved solids contents range from 200 to 300 ppm and that between 30 and 60 percent of the total anions are sulfate. The sulfates are thought to be derived from discharging bedrock groundwaters.

## Iron Concentrations

Iron concentrations in the groundwaters of the Rocky Mountains are generally less than 0.5 ppm. However, occasional values in excess of 2 ppm were noted in springs discharging groundwater from ironstone-containing Alberta Group shales, and also from glacial gravel aquifers in the outwash channels near Grande Cache-Muskeg River valley and at Rock Lake. Terraced alluvial gravel deposits in the middle reaches of the Smoky River valley contain groundwater with iron concentrations of 1 to 3 ppm. To the north, on the Wapiti Plain, values greater than 2 ppm iron were noted from shallow bedrock aquifers of the Wapiti Formation. In this area, iron concentrations increase with depth and can be as high as 10 to 20 ppm.

## Fluoride Concentrations

Generally, fluoride occurs in concentrations of less than 0.4 ppm throughout the map area with highs of 1 to 3 ppm occurring in shallow bedrock aquifers to the northwest around the Wapiti River valley.

## Calcium - Magnesium Ion Ratio

The ratio of calcium to magnesium ions in groundwaters was calculated from milliequivalent values.

A general spatial relationship with bedrock lithology is evident within the Rocky Mountains. In the Main Ranges calcium-magnesium ratios range from 2.5 to 4 and the dominant bedrock lithology is quartzite. In the Front Ranges, magnesium carbonates abound in dolomite formations and calcium-magnesium ratios are accordingly low (1 to 2).

Farther north in the High Plains and Wapiti Plain, the effects of increased groundwater residence times and topography become more evident. In general calcium-magnesium ratios decrease in a northeast direction as total dissolved solids increase and sodium and potassium gradually replace calcium and magnesium as the dominant cations.

High values are especially common adjacent to major surface water divides in the High Plains where fracture permeability in the Paskapoo Formation enhances rapid infiltration of precipitation and snowmelt which initially has a high calcium-magnesium ratio. Thus, high calcium-magnesium ratios are characteristic of groundwater recharge areas. Magnesium is available from Paskapoo Formation sandstones which have chlorite (hydrous silicate of aluminium, iron and magnesium) cements in outcrops close to the disturbed belt. However, magnesium is more soluble at low temperatures than calcium and as a result of rapid groundwater flow through fracture systems is probably flushed out of the system.

# CONCLUSIONS

Existing water well data within the map area are scarce and data from depths greater than 200 ft (61 m) are very rare. Consequently, the construction of the hydrogeological map and profiles was based, to a large extent, on the author's interpretation of the prevailing geological conditions and surface hydrogeological features.

Groundwater quality is highly variable but generally it is potable (less than 1000 ppm total dissolved solids). Locally within the Rocky Mountains and in the developing agricultural area to the north, total dissolved solids contents exceed 1000 ppm in shallow bedrock aquifers. High sulfate concentrations in some bedrock aquifers of the Rocky Mountains could make development for potable purposes unacceptable.

The most promising surficial aquifer is glacial outwash sand and gravel which, with good well construction, could give yields in the range of 100 to 500 igpm (7.6 to 38 l/s). Generally, in areas north of the Rocky Mountains and Foothills, surficial deposits are thin, of limited areal extent, and relatively impermeable; they consist mainly of lacustrine silts and clay and clayey till. Alluvial gravel deposits of the major river valleys are generally highly dissected, occur on narrow terraces, and are not in hydraulic connection with river waters. Yields are not enhanced by induced infiltration and may decrease rapidly under heavy abstraction. Preglacial gravels of the Bezanson buried valley may be of a discontinuous nature due to their close proximity to the headwaters of the preglacial drainage system. Further investigation of these deposits would be required to enable accurate assessment of their production potential.

Fractured Paskapoo Formation sandstone and shale of the Western Alberta High Plains are the most productive bedrock aquifers, with yields in the range of 25 to 100 igpm (1.9 to 7.6 l/s). However, the hardness of the rock and presence of fracture permeability sometimes leads to insurmountable drilling problems. Drilling is often tediously slow, and loss of circulation is a common problem in rotary drilling. As a general rule, groundwater supplies are more easily obtainable from Paskapoo Formation aquifers east of the Smoky River.

High yields in the range 100 to 500 igpm (7.6 to 37.9 l/s) might be obtainable from carbonate rocks of the Rocky Mountains where karstic features are well developed in topographically low outcrops.

Groundwater recharge conditions prevail within the Western Alberta High Plains where highly permeable fracture systems and a hill capping of coarse fluvial gravels enhance infiltration rates. Hydrochemistry and topography suggest a northeast direction of groundwater movement.

Complex geological structure and rugged topography, together with variable hydrochemistry due to the mixing of groundwater from deep and shallow flow systems, result in poor hydrogeological definition and detail in bedrock formations of the Rocky Mountains and Foothills. The major factors affecting direction of groundwater movement and residence time in the Rocky Mountains are relief, regional geological strike and dip, folding, and thrust fault zones. Rugged relief results in steep groundwater gradients and consequent rapid groundwater movement. Discharge occurs when the permeability of the medium (rock) can no longer accommodate such rapid transmission of groundwater or when the aquifer becomes fully saturated. Steep groundwater gradients also provide sufficient hydraulic pressure or head to induce deep penetration of groundwaters. Such conditions are further evidenced by the presence of highly saline (more than 2000 ppm total dissolved solids) calcium-magnesium sulfate type groundwater, often with above average temperatures.

Essentially horizontal and upward directions of groundwater movement are thought to occur within fault zones which act as conduits transmitting groundwater towards narrow discharge zones in topographically low areas. As it is difficult to assess bedrock permeabilities at any given location and the more accessible areas are usually underlain by surficial deposits in one form or another, the more usable and more easily defined aquifers of the Rocky Mountains and Foothills must be the surficial deposits. These generally occur in the valley bottoms and, owing to their closeness to the source area, are invariably of a coarse-grained, highly permeable nature.

## REFERENCES

Atlas of Alberta (1969): Univ. Alberta Press in association with Univ. Toronto Press.

Allan, J. A. and Carr, J. L. (1948): Geology and coal occurrences of the Wapiti-Cutbank area, Res. Coun. Alberta Rept. 48, 43 pages.

Bayrock, L. A.: Surficial geology Wapiti sheet, NTS 83L, Res. Coun. Alberta unpublished map.

Bayrock, L. A. and Reimchen, T. H. F. (1975): Surficial geology and erosion potential, foothills of Alberta north of 52° latitude; prepared for Alberta Environment, Govt. of Alberta. Unpublished.

Carrigy, M. A. (1971): Lithostratigraphy of the Uppermost Cretaceous (Lance) and Paleocene strata of the Alberta plains; Res. Coun. Alberta Bull. 27, 153 pages.

Charlesworth, H. A. K., Weiner, J. L., Akehurst, A. J., Bielenstein, H. U., Evans, C. R., Griffiths, R. E., Remington, D. B., Staufer, M. R., Steiner, J. (1967): Precambrian geology of the Jasper region, Alberta; Res. Coun. Alberta Bull. 23, 74 pages.

Cherry, J. A., van Everdingen, R. O., Meneley, W. A. and Tóth, J. (1972): Hydrogeology of the Rocky Mountains and interior plains; 24th Int. Geol. Congr. Field Excursion Guidebook A26, 42 pages.

Dawson, G. M. (1880): Report on an exploration from Port Simpson on the Pacific Coast to Edmonton on the Saskatchewan, embracing a portion of the northern part of British Columbia and the Peace river country; Geol. Surv. Canada Rept. of Progress 1879-80, Part B.

Drake, J. J. and Ford, D. C. (1974): Hydrochemistry of the Athabasca and North Saskatchewan Rivers in the Rocky Mountains of Canada; Water Resources Res., Vol. 10, No. 6, p. 1192-1198.

Green, R. (1972): Geological map of Alberta; Res. Coun. Alberta map.

Irish, E. J. W. (1965): Geology of the Rocky Mountain foothills; Geol. Surv. Canada Mem. 334, 241 pages.

--------------- (1970): The Edmonton Group of south-central Alberta; Bull. Can. Petroleum Geol., Vol. 18, p. 125-155.

Kramers, J. W. and Mellon, G. B. (1972): Upper Cretaceous-Paleocene coal-bearing strata, northwest-central Alberta plains; Proc. 1st Geol. Conf. on Western Canadian Coal; Res. Coun. Alberta Info. Ser. 60, p. 109-124.

Lindsay, J. D., Wynnyk, A. and Odynsky, W. (1964): Exploratory soil survey of Alberta map sheets 83L, 83K, 83F, and 83J; Res. Coun. Alberta Prelim. Soil Surv. Rept. 64-2.

Longley, R. W. (1972): The climate of the Prairie Provinces; Environ. Canada Climatol. Studies No. 13, 79 pages.

Meinzer, O. E. (1923): Outline of groundwater hydrology, with definitions; U.S. Geol. Surv. Water Supply Paper 494, 71 pages.

Mountjoy, E. W. (1963): Geology, Mount Robson, southeast quarter; Geol. Surv. Canada Map 47-1963.

Neilson, G. L. (1972): Drilling program - Grande Cache area; Alberta Environment, Soils, Geology and Groundwater Branch, 20 pages.

Owen, J. R. (1960): The Edmonton Formation; Jour. Alberta Soc. Petr. Geol., Vol. 8, p. 309-323.

Price, R. A. and Mountjoy, E. W. (1970): Geological structure of the Canadian Rocky Mountains between Bow and Athabasca Rivers - a Progress Report; Geol. Assoc. Canada, Spec. Paper No. 6, p. 7-26.

Souther, J. G. and Halstead, E. C. (1969): Mineral and thermal waters of Canada; 23rd Int. Geol. Congress, Vol. 19, p. 225-256.

Twardy, A. G. (in preparation): Soil survey, Wapiti sheet, NTS 83L, Alberta Res. Coun.

van Everdingen, R. O. (1972): Thermal and mineral springs in the southern Rocky Mountains of Canada; Environment Canada, 151 pages.

# APPENDIX A. ALBERTA RESEARCH COUNCIL TESTHOLES

1. Location: Lsd 14, Sec 22, Tp 68, R 9, W 6th Mer
   Total depth: 200 ft (61 m)
   Static water level: 5.4 ft (1.7 m) bns (beneath natural surface)

| Depth (feet) | Lithology |
|---|---|
| 0-45 | dark grey lacustrine clay |
| | *Wapiti Formation* |
| 45-200 | light grey bentonitic sandstone interbedded with dark grey shale and occasional thin coal seams |

Tests: Compressor test 0-100 ft = 3 igpm for 3/4 hr
0-200 ft = 8 igpm for 3/4 hr

Status: Abandoned

2. Location: Lsd 2, Sec 13, Tp 69, R 8, W 6th Mer
   Total depth: 200 ft (61 m)
   Static water level: 57 ft (17 m) bns

| Depth (feet) | Lithology |
|---|---|
| 0-53 | grey-brown till |
| | *Wapiti Formation* |
| 53-103 | brown and grey, fine-grained bentonitic sandstone and clayey silt |
| 103-105 | coal |
| 105-200 | dark brown and grey, silty bentonitic sandstone and shale |

Tests: Compressor test 0-100 ft = 0-1 igpm
0-200 ft = 2 igpm for 1/2 hr

Status: Abandoned

3. Location: NW, Sec 30, Tp 68, R5, W 6th Mer
Total depth: 200 ft (61 m)
Static water level: 38 ft (12 m) bns

| Depth (feet) | Lithology |
|---|---|
| 0-44 | dark brown, silty lacustrine clay |
| | *Wapiti Formation* |
| 44-200 | light grey to dark grey calcareous sandstone, bentonitic sandstone and siltstone interbedded with blue-grey shale, occasional thin coal seams and bentonite beds |

Tests: Compressor test 0-100 = 0-1 igpm
0-200 = 3 igpm for 1 hr

Status: Abandoned

4. Location: Lsd 12, Sec 15, Tp 68, R 5, W 6th Mer
Total depth: 240 ft (73 m)

| Depth (feet) | Lithology |
|---|---|
| 0-150 | grey lacustrine clay and silt with occasional thin coal seams (placer in origin) |
| | *Wapiti Formation* |
| 150-240 | fine-grained, light grey, silty sandstone |

Tests: None, due to poor condition of the hole

Status: Abandoned at 240 ft due to lost circulation

5. Location: Lsd 4, Sec 32, Tp 67, R4, W 6th Mer
Total depth: 20 ft (6 m)

| Depth (feet) | Lithology |
|---|---|
| 0-20 | Alluvial sand and gravel |

Tests: None, due to caving

Status: Abandoned

6. Location: Lsd 6, Sec 2, Tp 67, R 4, W 6th Mer
Total depth: 300 ft (91 m)

| Depth (feet) | Lithology |
|---|---|
| 0-200 | light grey, sandy till |
| 200-234 | light grey till interbedded with thin gravel beds |
| | *Wapiti Formation* |
| 234-300 | thinly bedded, light grey bentonitic siltstone and clayey sandstone |

Tests: Compressor test 0-300 ft = 0 to 1 igpm

Status: Abandoned

7. Location: Lsd 1, Sec 29, Tp 65, R 2, W 6th Mer
Total depth: 200 ft (61 m)
Static water level: 24 ft (7.3 m) bns

| Depth (feet) | Lithology |
|---|---|
| 0-80 | grey-brown, gravelly till |
| | *Wapiti Formation* |
| 80-200 | light grey bentonitic siltstone and sandstone with thin coal seams occurring at 80 to 90 ft and 130 ft |

Tests: Compressor test 0-100 = 3 igpm for 1/2 hr
0-200 = 8 igpm for 3/4 hr

Status: Abandoned

8. Location: Lsd 11, Sec 36, Tp 64, R 2, W 6th Mer
Total depth: 200 ft (61 m)
Static water level: 5 ft (2 m) bns

| Depth (feet) | Lithology |
|---|---|
| 0-65 | grey-brown silty till |
| 65-75 | glacial sand and gravel |
| 75-83 | grey-brown silty till |
| 83-91 | glacial sand and gravel |
| | *Wapiti Formation* |
| 91-200 | soft clayey siltstone interbedded with occasional thin coal seams |

Tests: Compressor test 0-100 ft = 10 igpm for 1/2 hr

Status: Abandoned

9. Location: Lsd 11, Sec 10, Tp 67, R 2, W 6th Mer
Total depth: 200 ft (61 m)
Static water level: 59 ft (18 m) bns

| Depth (feet) | Lithology |
|---|---|
| 0-46 | grey silty till |
| | *Wapiti Formation* |
| 46-60 | buff yellow clayey sandstone |
| 60-88 | fine-grained calcareous sandstone |
| 88-200 | grey-brown coal and shale horizons |

Tests: Compressor test 0-100 ft = 3 igpm for 3/4 hr

Status: Abandoned

10. Location: Lsd 16, Sec 32, Tp 68, R 2, W 6th Mer
Total depth: 500 ft (150 m)
Static water level: 63.7 ft (19.4 m) bns

| Depth (feet) | Lithology |
|---|---|
| 0-10 | brown silty clay |
| | *Wapiti Formation* |
| 10-300 | light grey bentonitic siltstone interbedded with bentonitic sandstone, minor shale,(sometimes carbonaceous)and thin coal seams. Major sandstone horizons occur at 257 to 266 ft and 289 to 298 ft. Coal seams occur at 274 to 276 ft and 363 to 364 ft. |
| 300-500 | mainly dark grey and black carbonaceous shales |

Tests: The well was pump tested open hole at 6 igpm for 6 hr. Total drawdown was 80.7 ft (24.6 m). The calculated transmissivity is about 50 igpd/ft. Twenty year safe yield calculated with an available drawdown of 180 ft is about 4 igpm.

Status: Abandoned

11. Location: Lsd 1, Sec 34, Tp 63, R 2, W 6th Mer
Total depth: 210 ft (64 m)

| Depth (feet) | Lithology |
|---|---|
| 0-10 | eolian sand |
| 10-80 | dark grey lacustrine clay |
| 80-150 | till |
| 150-184 | till with thin glacial gravel interbeds |
| 184-196 | sand and gravel. Mainly quartzite and chert boulders (reworked Tertiary gravels) |
| | *Wapiti Formation* |
| 196-210 | dark grey shale with thin coal seams and bentonitic sandstone horizons |

Tests: None, due to poor condition of the hole

Status: Abandoned

12. Location: Lsd 4, Sec 2, Tp 64, R 7, W 6th Mer

Total depth: 160 ft (49 m)

Static water level: 56 ft (17 m) bns

| Depth (feet) | Lithology |
|---|---|
| 0-100 | soft silty clay and boulders (slumped material) |
| | *Scollard Member* |
| 100-113 | grey brown shale |
| 113-160 | medium grained grey sandstone with thin shale interbeds |

Tests: Compressor test 0-100 ft = 3 igpm for 3/4 hr

0-260 ft = 30 igpm for 3/4 hr

Status: Abandoned after caving in

13. Location: Lsd 8, Sec 3, Tp 58, R 2, W 6th Mer

Total depth: 260 ft (79 m)

Static water level: 15.2 ft (4.6 m) bns

| Depth (feet) | Lithology |
|---|---|
| 0-18 | brown, sandy clay with boulders - mainly broken sandstone |
| | *Paskapoo Formation* |
| 18-260 | fine-grained, calcareous, salt and pepper sandstone interbedded with thin green-grey shale, siltstone, clay and coal horizons. Sandstone/shale ratio = 0.8. |

Tests: The well was pump tested open hole at 10 igpm for 6 hr. Total drawdown was 19.2 ft (5.8 m). The calculated transmissivity is about 4400 igpd/ft. Twenty year safe yield calculated with an available drawdown of 65 ft (20 m) is about 135 igpm.

Status: Abandoned

14. Location: Lsd 1, Sec 24, Tp 54, R 1, W 6th Mer

Total depth: 300 ft (91 m)

Static water level: 50.5 ft (15.4 m)

| Depth (feet) | Lithology |
|---|---|
| 0-15 | clay |
| | *Paskapoo Formation* |
| 15-179 | hard, fine-grained calcareous sandstone |
| 179-245 | grey shale interbedded with thin sandstone lenses |
| 245-260 | sandstone, as above |
| 260-265 | coal |
| 265-277 | grey and brown shale |
| 277-280 | coal |
| 280-284 | grey shale |
| 284-295 | sandstone as above |
| 295-300 | grey and brown shale |

Tests: The well was pump tested open hole at 7 igpm for 6 hr. Total drawdown was 39 ft (12 m). The calculated transmissivity is about 58 igpd/ft. The twenty year safe yield, calculated with an available drawdown of 230 ft (70 m) is about 7 igpm.

Status: Abandoned

Alberta
RESEARCH COUNCIL

## METEOROLOGY MAP

### LEGEND

Isohyet, mean annual precipitation in inches (cm)
- defined ........ 18(45)
- approximate ........ 22(56)

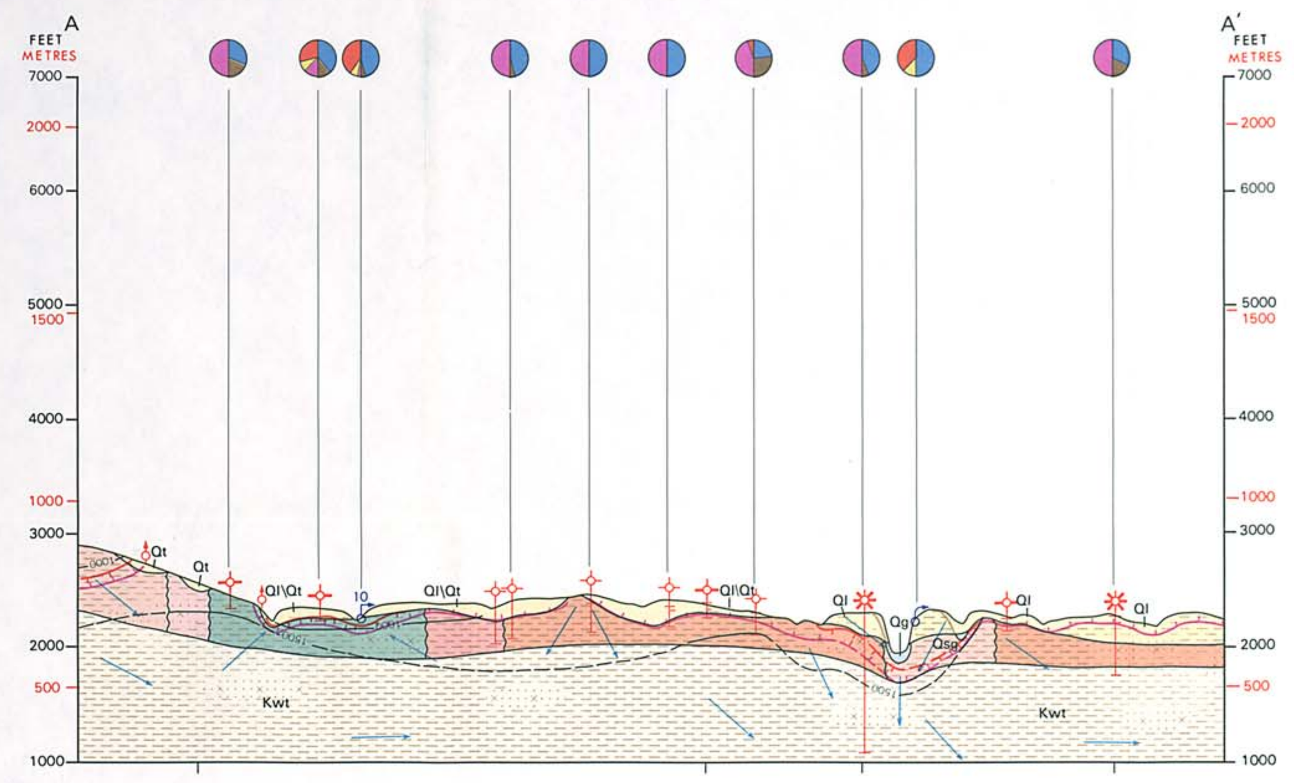
Mean annual precipitation
- 15-20 inches (38-50 cm) ........
- 20-25 inches (50-65 cm) ........

Meteorological station ........

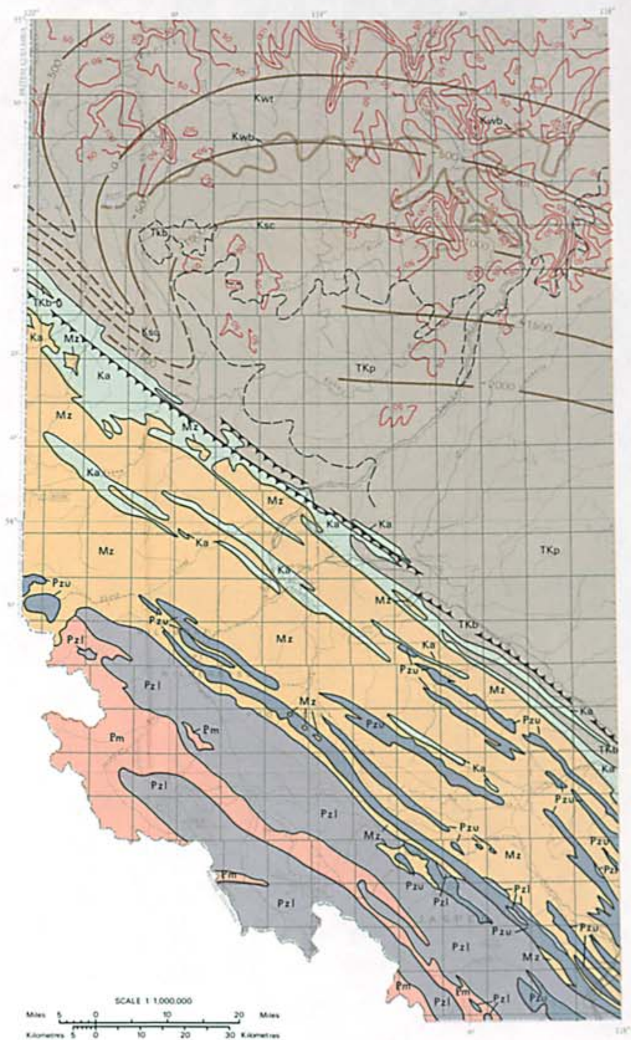
Standard rain gauge only ........

Precipitation data:
- Mean annual precipitation in inches (cm) ........
- 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 Canada (Longley, 1968); Climate of the Prairie Provinces (Longley, 1972); Monthly record of meteorological observations (Meteorological Branch, Canada Department of Transport); Provisional evaporation maps of Canada — Department of Transport Circular 4531 (Bruce and Weisman, 1967).



## GEOLOGY MAP



### LEGEND

Paskapoo Formation: *sandstone, siltstone, shale, and thin coal seams; Scollard Member (Ksc): sandstone, shale, and major coal seams (including Ardley "coal zone"); nonmarine* — TKp

Brazeau Formation: *grey, fine-grained, feldspathic sandstone with hard calcareous beds; laminated siltstone and grey silty shale; deltaic to marine.* — TKb

Whitemud and Battle Formations: *pale grey, bentonitic sandstone and mudstone (Whitemud Formation); purplish-black bentonitic beds containing siliceous tuff beds (Battle Formation); nonmarine* — Kwb

Wapiti Formation: *bentonitic sandstone and shale; nonmarine* — Kwt

Alberta Group: *mainly shale* — Ka

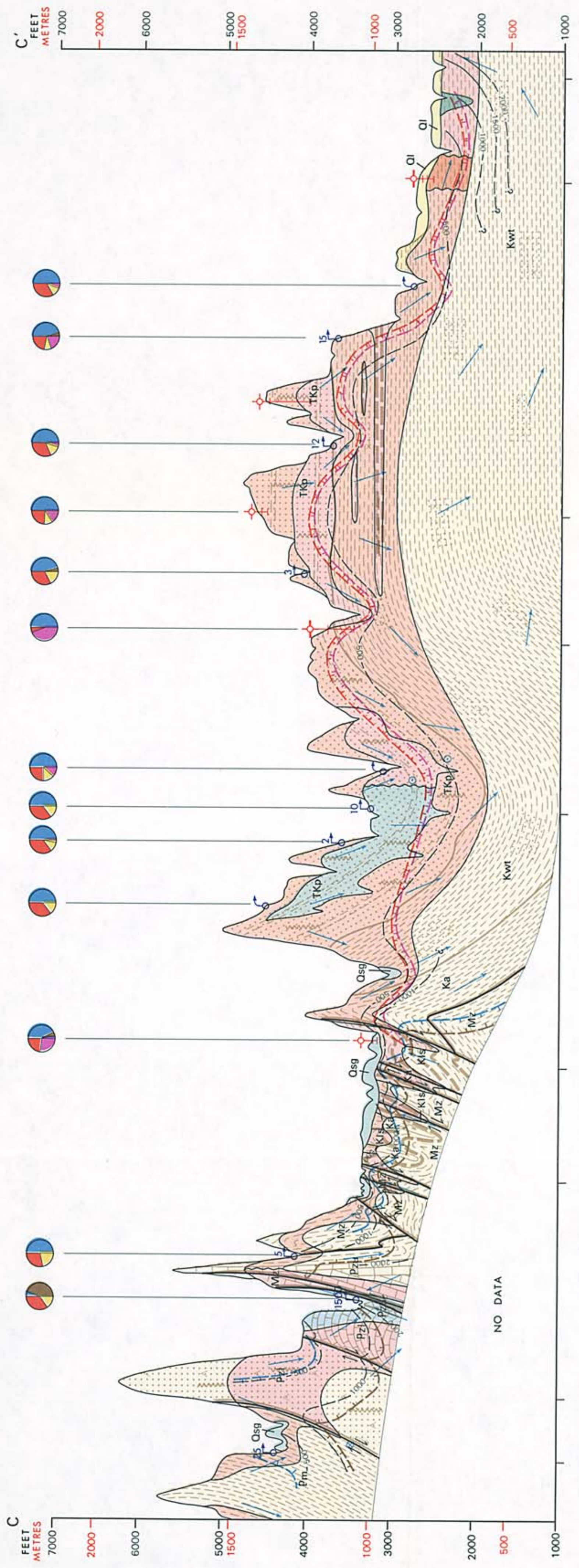
Undifferentiated Mesozoic: *calcareous siltstone, limestone; thick-bedded cherty sandstone, shale, and coal (Luscar Formation)* — Mz

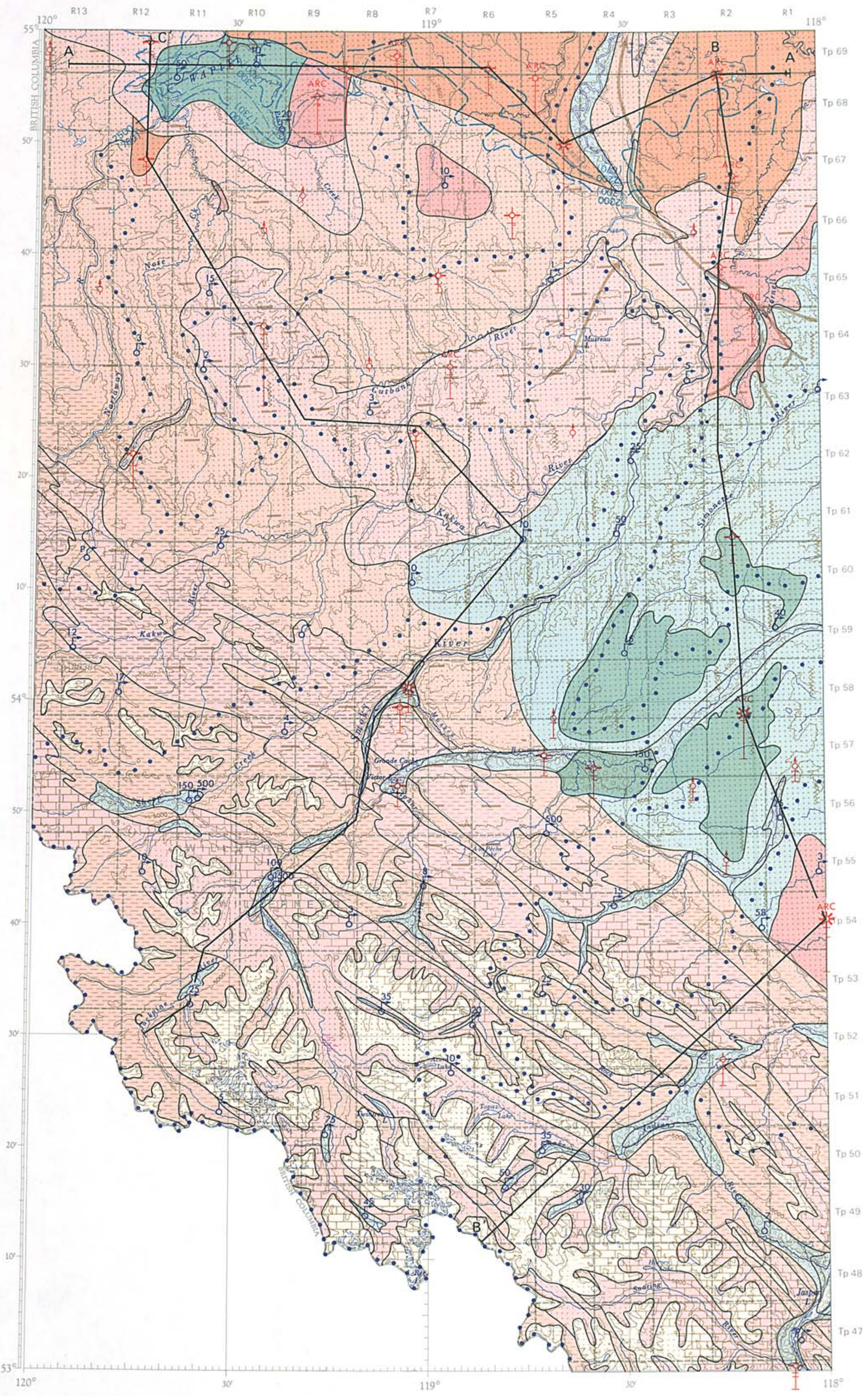
Undifferentiated Upper Paleozoic: *argillaceous limestone and dolomite, calcareous shale, quartzose sandstone and siltstone* — Pzu

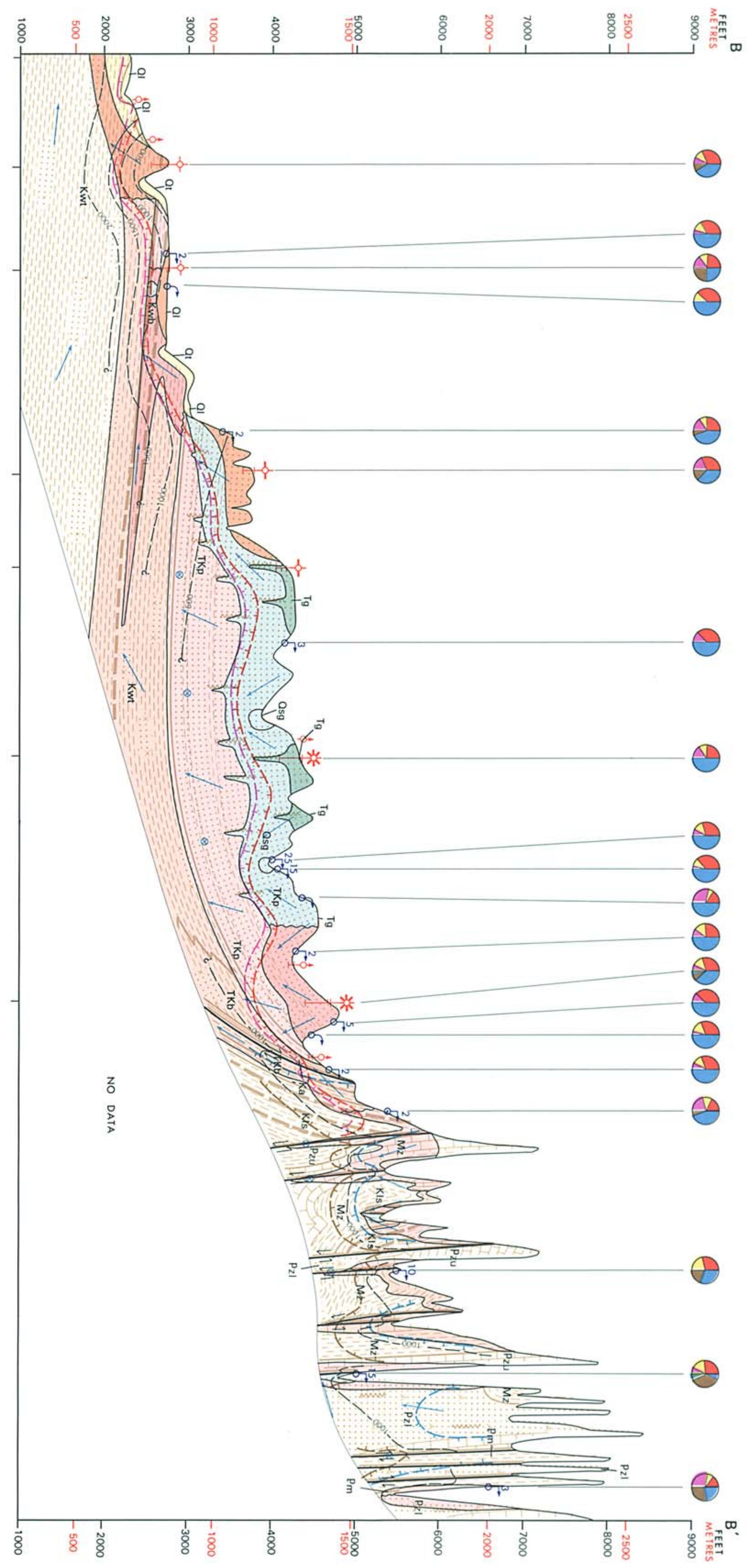
Undifferentiated Lower Paleozoic: *quartzite, dolomite, limestone* — Pzl

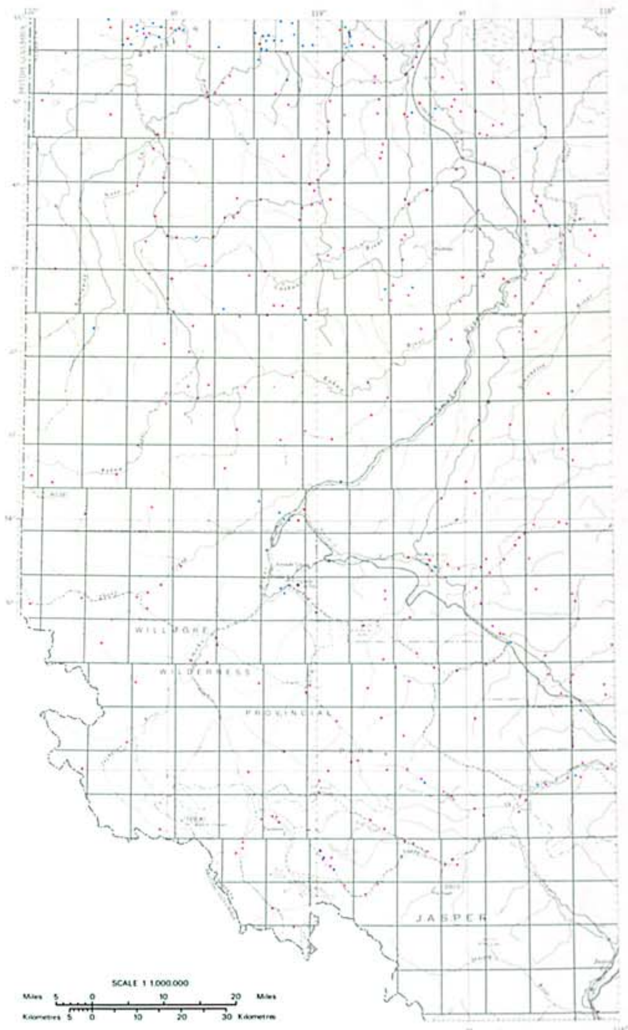
Miette Group: *argillite with minor dolomite and limestone* — Pm

- Rock unit boundary: defined, approximate ........
- Thrust fault (teeth on upper plate) ........
- Structure contour on base of Wapiti Formation (elevation in feet): defined, approximate ........ 500
- Isopach of drift on Wapiti Plains and parts of the Western Alberta High Plains (in feet) ........ 50









## MAIN MAP LEGEND

### Topography

Surface contours and elevation in feet ........ 3000

### Geology

- Geological boundary ........
- Fault, and direction of movement ........
- Fold axis ........
- Thalweg of buried valley ........

QUATERNARY

| | |
|---|---|
| Ql | Lacustrine clay and silt |
| Qt | Till |
| Qg | Gravel |
| Qsg | Sand and gravel |

TERTIARY

| | |
|---|---|
| Tg | Fluvial gravel |

CRETACEOUS — TERTIARY

| | |
|---|---|
| TKp | Paskapoo Formation |
| Ksc | Scollard Member of Paskapoo Formation |
| TKb | Brazeau Formation |

CRETACEOUS

| | |
|---|---|
| Kwb | Whitemud and Battle Formations |
| Kwt | Wapiti Formation |
| Ka | Alberta Group |
| Kls | Luscar Formation |

MESOZOIC

| | |
|---|---|
| Mz | Lower Cretaceous pre-Blairmore Group strata and undifferentiated Jurassic and Triassic strata |

PALEOZOIC

| | |
|---|---|
| Pzu | Undifferentiated Upper Paleozoic (Permian, Pennsylvanian, Mississippian, and Upper Devonian) strata |
| Pzl | Undifferentiated Lower Paleozoic (Lower Devonian, Silurian, Ordovician, and Cambrian) strata |

PROTEROZOIC

| | |
|---|---|
| Pm | Miette Group |

### Lithology

- Sand and gravel ........
- Sandstone; sandstone, bentonitic ........
- Quartzite ........
- Shale and siltstone ........
- Carbonate rocks ........
- Coal ........
- Fractured rocks ........

### Hydrography

- Lake or slough, perennial
- Marsh, muskeg
- Stream, perennial
- Stream, intermittent
- Disappearance point of stream
- Glacier
- Surface water divide
- Area of noticeable salt precipitates

### Hydrogeology

- Spring, permanent, flow rate unknown
- Spring, flow rate known in igpm (l/sec) ........ 25(2)
- Spring, flow rate measured over a period of time
- Nonpumping water level contour; defined ........ 2200 (670)
- Component of groundwater flow parallel to profile
- Component of groundwater flow perpendicular to profile: out of profile (i.e. towards reader); into profile (i.e. away from reader)
- Boundary of area of artesian flow

### Groundwater Probability†

Range of average yield of wells in igpm (l/sec)

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

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

| igpm | (l/sec) |
|---|---|
| 100-500 | (8-38) |
| 25-100 | (2-8) |
| 5-25 | (0.4-2) |
| 1-5 | (0.1-0.4) |
| <1 | (<0.1) |

Yield area boundary

†The indicated average expected yields to wells are based on the best available data at the time of map compilation…

### Wells and Other Artificial Works

Depth Scale — METRES / FEET: 0, 100, 200, 300, 400; Depth to water; Depth of well or seismic shot hole

- Water well, nonflowing
- Water well, 20 year safe yield calculated from apparent transmissivity
- Water well, 20 year safe yield calculated from pump test of sufficient length to reflect regional hydraulic conditions
- Alberta Research Council test well ........ ARC
- Seismic shothole reported to have flowed
- Oil well
- Gas well
- Abandoned well, drilled for oil or gas
- Depth of exploratory well

The vertical line portion of oil, gas, or other exploratory test well symbols indicates the well depth…

Line of hydrogeological profile ........ A A'

### Hydrochemistry

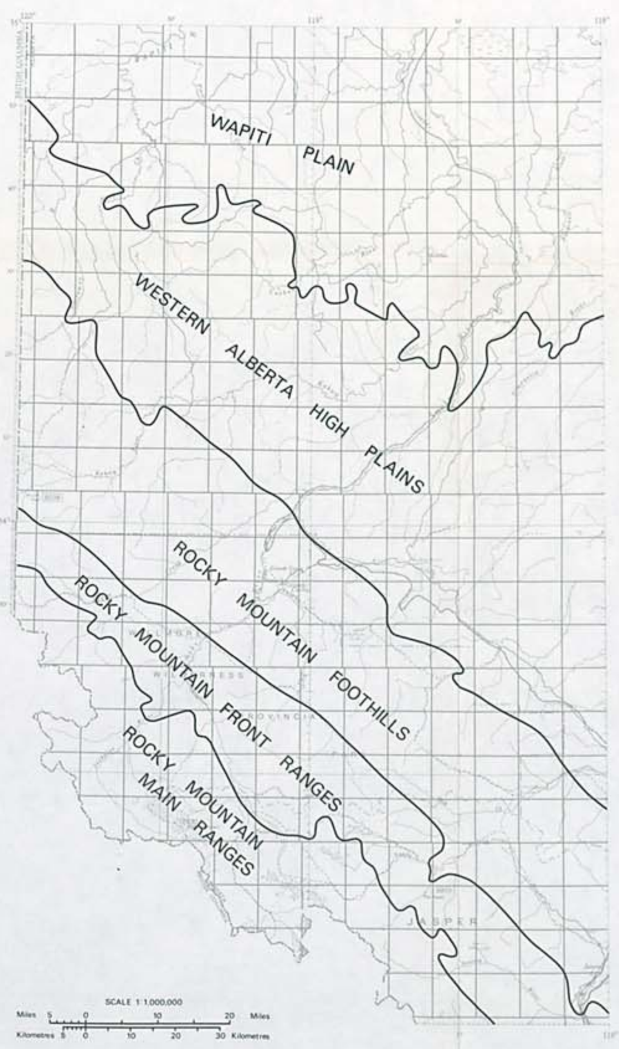
Calcium; Magnesium; Sodium + potassium; Carbonate + bicarbonate; Sulfate; Chloride; Nitrate

Total dissolved solids in parts per million: defined; approximate ........ 500

- Isogram along which calcium + magnesium constitutes 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content: defined; approximate
- Isogram along which sodium + potassium constitutes 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content: defined; approximate
- Isogram along which carbonate + bicarbonate constitutes 60 percent of total anions*; teeth indicate direction of lesser carbonate + bicarbonate content: approximate
- Isogram along which sulfate constitutes 60 percent of total anions*; teeth indicate direction of lesser sulfate content: approximate

*Determined on an equivalents per million basis

## PHYSIOGRAPHY MAP




### LEGEND

Physiographical boundary ........

SCALE 1:500,000 — Miles 10 0 10 20 30 40 Miles; Kilometres 10 0 10 20 30 40 50 60 Kilometres

# HYDROGEOLOGICAL MAP
# MOUNT ROBSON – WAPITI
# ALBERTA

NTS 83E – 83L

All elevations in feet above mean sea level

Vertical exaggeration of the hydrogeological profiles is approximately 40X

An expanded legend and explanatory notes (Report 72-12) for use with this hydrogeological map are available from Alberta Research Council, Edmonton, Canada

Map to accompany Report 76-5

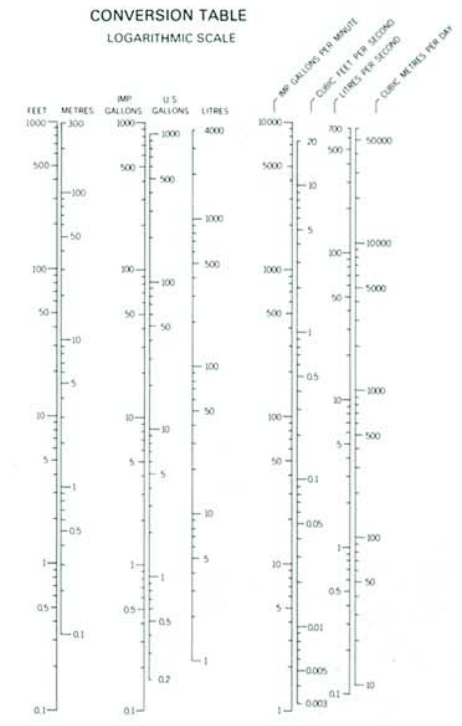
Hydrogeology by R. Barnes, 1976, based on data collected in 1975

Editing by A. Campbell

Drafting by R. Swenson


KEY MAP

CONVERSION TABLE
LOGARITHMIC SCALE

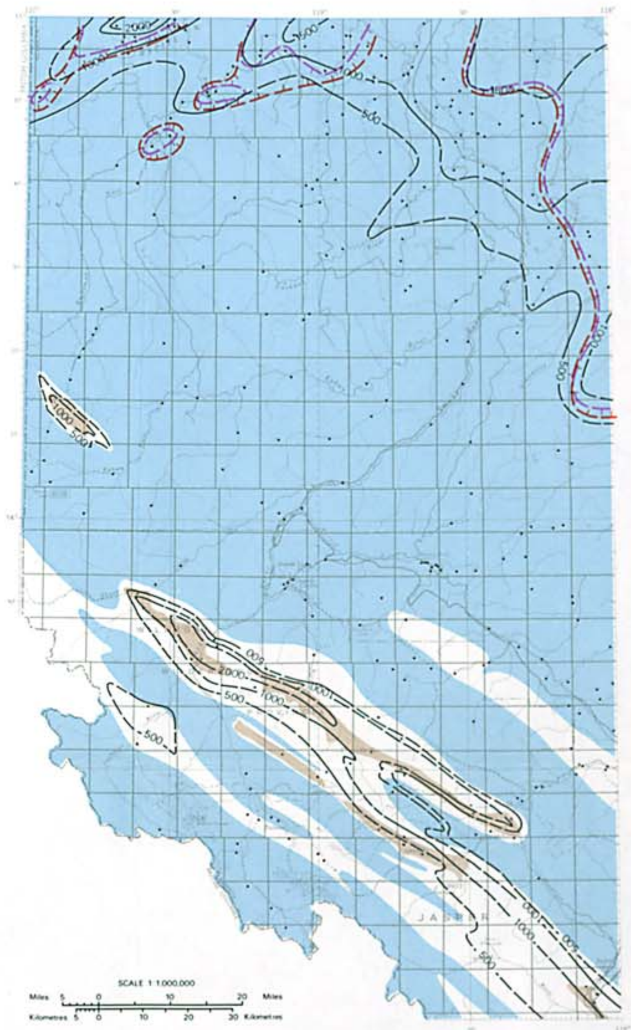


## DATA DENSITY MAP

### 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 hydrogeological surface feature ........

## HYDROCHEMISTRY MAP (of shallow bedrock aquifers)



### LEGEND

Data control point ........

Total dissolved solids in parts per million:
- defined ........ 500
- approximate ........ 500

Isogram along which calcium + magnesium constitutes 60 percent of total cations*; teeth indicate direction of lesser calcium + magnesium content:
- approximate ........

Isogram along which sodium + potassium constitutes 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content:
- approximate ........

Carbonate + bicarbonate constituting over 60 percent of total anions* ........

Sulfate constituting over 60 percent of total anions* ........

*Determined on equivalents per million basis