Earth Sciences Report 79-3

Hydrogeology of the Winagami Area, Alberta

D. Borneuf

Alberta Research Council
1980

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ILLUSTRATION

Hydrogeological map, Winagami area, NTS 83N, Alberta. . . . . in pocket

ABSTRACT

The Winagami map area is underlain by the sediments of the Shaftesbury, Dunvegan, Kaskapau, Bad Heart, Puskwaskau, and Wapiti Formations of Lower and Upper Cretaceous age. The groundwater yields of the area vary from less 0.07 L/s (<1 igpm) to 7 L/s (100 igpm). The presence of the Puskwaskau and Kaskapau sediments and lacustrine clays near Falher and in the northern half of the map area produce poor yields. The Wapiti sediments in the south yield from 0.07 to 0.35 L/s (1 to 5 igpm) and the sediments of the High Prairie and Valleyview channel yield 2 to 8 L/s (25 to 100 igpm) and sporadically reach 30 L/s (400 igpm) and sometimes more in the immediate vicinity of High Prairie.

Groundwater quality is variable: total dissolved solids range from 200 to 3000 mg/L. Groundwater types are calcium-magnesium sulfate or calcium-magnesium bicarbonate; however, sodium-chloride and sodium-sulfate types of water are found in the High Prairie channel.

INTRODUCTION

The Winagami area, mapped in conjuction with the Peace River area during the summer of 1973, covers about 13 000 km^2 (5000 sq mi). Located between latitudes 55^0 and 56^0 north and between longitudes 116^0 and 118^0 west, with respect to the Alberta land survey system the area contains all or parts of townships 69 to 81, and ranges 14 to 27, west of the fifth meridian.

The area is sparsely populated except immediately around the towns of Valleyview (pop. 1708), High Prairie (pop. 2698), and Falher (pop. 942) (Alberta Travel Bureau, 1975). The main villages are McLennan, Donnelly, and Girouxville.

Access to the various parts of the area is limited. With the exception of main and secondary highways that cross the map area from north to south and east to west, few roads allow a detailed survey of the area.

Two-thirds of the area is covered by boreal forest and muskeg. A few forest zones in the area were recently selectively cut or clear cut, but the cuts are not extensive. Farming centers are found around Eaglesham, Tangent, Donnelly, Falher, Girouxville, Valleyview, and High Prairie. Barley, rape seed, and wheat are the main crops of the area.

Of the several Indian reserves within the area, the largest are the Sturgeon Creek and Sucker Creek Reservations. Two large Métis colonies that lie southeast and north of High Prairie, cover 325 km^2 (126 sq mi) and 880 km^2 (340 sq mi).

The two provincial parks in the map area are Winagami Lake Provincial Park [15 km^2 (6 sq mi)] and Williamson Provincial Park [0.6 km^2 (one-quarter sq mi)].

ACKNOWLEDGMENTS

The Government of Alberta financed this program.

G. Snyders of Warnke Drilling, Wetaskiwin carried out the test drilling program. M. Brulotte spent long hours in the field and did preparatory work in the office.

Others whose help is gratefully acknowledged include J. Matthie who drafted the maps, and R. Stein and E. Wallick whose comments and useful discussions are greatly appreciated. F. Tuck edited the report.

Many thanks go also to the various residents of the area who provided helpful information.

TOPOGRAPHY AND DRAINAGE

The map area for the most part is fairly level with an average elevation of approximately 600 m (2000 ft). A group of hills superimposed on the generally flat area north of Sturgeon Lake reach an elevation slightly over 890 m (2900 ft). Other hills, northwest of Sturgeon Lake, reach an elevation of 850 m (2800 ft). These two series of hills are bedrock highs and are separated by the Puskwaskau River, which flows towards the northwest portion of the map area. The northern reaches of the Swan Hills [980 m (3200 ft)] are found in the southeastern corner of the map area.

Streams, rivers, and lakes are numerous over the map area. The most important river is the Peace, which flows across the extreme northwest corner of the map area for approximately 16 km (10 mi). The Smoky River valley is generally 400 m (one-quarter mile) wide and about 180 m (600 ft) deep. The Little Smoky River, which traverses most of the central part of the map area, is a meandering river whose valley varies in depth from less than 30 m (100 ft) east of the town of Valleyview to over 150 m (500 ft) at the point where it joins the Smoky River. The South Heart, West Prairie, and East Prairie Rivers and smaller creeks empty into Buffalo Bay at the western end of Lesser Slave Lake.

The Sturgeon, Snipe, Kimiwan, and Winagami Lakes are the major surface water bodies in the area. The western portion of Lesser Slave Lake is located at the eastern boundary of the map area.

CLIMATE

According to Koeppen's climate classification (Longley, 1972), the map area may be subdivided as follows: the northwest portion of the area is microthermal, with the average temperature of the warmest month above $10^{o}C$ ($50^{o}F$) and the coldest month below $-3^{o}C$ ($27^{o}F$). This northwest area has warm summers with the mean temperature of the warmest month below $22^{o}C$ ($72^{o}F$) and at least four months with mean temperatures of $10^{o}C$ ($50^{o}F$) or more. The remainder of the map area is microthermal with the average temperature of the warmest month above $10^{o}C$ ($50^{o}F$) and the coldest month below $-3^{o}C$ ($27^{o}F$). This area has cool summers with the mean temperature of the warmest month below $22^{o}C$ ($72^{o}F$) and less than four months with mean temperatures of $10^{o}C$ ($50^{o}F$) or more.

Average precipitation in High Prairie is nearly 450 mm (18 in). In Falher, to the northwest, the average precipitation is nearly 420 mm (17 in). The summer of 1973 had an above average rainfall, and temperatures were low.

GEOLOGY

BEDROCK GEOLOGY

Previous work on the bedrock geology was done by Kidd (1946), the Alberta Study Group (1954), Gleddie (1954), Jones (1966), and Green (1972).

Green (1972) described the geology as follows:

> The *Shaftesbury Formation* of Upper and Lower Cretaceous age: dark grey, fish-scale bearing; silty in upper part; numerous nodules and thin beds of concretionary ironstone, bentonite partings; lower part with thin silty and sandy intervals; marine.
>
> The *Dunvegan Formation* of Upper Cretaceous age: grey, fine-grained, feldspathic sandstone with hard calcareous beds; laminated siltstone and grey silty shale; deltaic to marine.
>
> The *Kaskapau Formation* of Upper Cretaceous age: dark grey silty shale, thin concretionary ironstone beds; interbedded in lower part with fine-grained quartzose sandstone and thin beds of ferruginous oolithic mudstone; marine.
>
> The *Bad Heart Formation* of Upper Cretaceous age: fine-grained quartzose sandstone, ferruginous oolithic sandstone and mudstone; marine.

The *Puskwaskau Formation* of Upper Cretaceous age: dark grey fossiliferous shale, silty in upper part; marine.

The *Wapiti Formation* of Upper Cretaceous age: grey, feldspathic; clayey sandstone; grey bentonite; mudstone and bentonite; scattered coal beds; non-marine.

SURFICIAL GEOLOGY

Henderson (1959) mapped and described the surficial geology of the western half of the map area. In this area, ground moraine extends from the northern edge of Sturgeon Lake to the Smoky River and to the north and the northeast. Glacial Lake Falher deposits (Henderson, 1959) are well developed in the Falher area. Dune sands are extensive on both sides of the Smoky, Little Smoky, and Peace Rivers. Small areas of outwash gravels can also be found. Sands and peat moss are present mostly in the southern half of the map area. Many mounds and doughnut-shaped features can be seen north of Valleyview. Slides and slumps are common along the Peace, Smoky, and Little Smoky River valleys.

BEDROCK TOPOGRAPHY

The bedrock topography was completed only for the southern half of the area due to the inadequacy of information on the northern half. The main features of the bedrock topography follow.

The High Prairie bedrock channel trends approximately west to east and is a continuation of the bedrock channel present to the east in the Lesser Slave Lake map area, which has been outlined by Vogwill (1978). This channel varies in depth from 85 m (280 ft) west of Triangle to slightly over 180 m (600 ft) in the High Prairie area. West of Triangle, gravels were found between 74 and 85 m (242 and 280 ft) resting on the bedrock surface. In the High Prairie area, gravels and sands were found between 167 and 178 m (545 and 584 ft). These gravels comprise an aquifer used by the town of High Prairie even though the water contains up to 112 mg/L of chloride.

The Valleyview channel, in the south-central part of the map area, runs along the present-day valley of the Little Smoky River from south-southwest to north-northwest, and possibly coalesces with the High Prairie channel in the area where the Little Smoky River course changes by nearly 90 degrees. The maximum thickness of the drift found in the channel is slightly over 60 m (200 ft). A few water wells are completed in gravels found in the channel along the southern edge of the map area and some flow at rates of between 4 and 6 L/s (50 and 75 igpm).

The Tangent channel, in the northwest corner of the map area, has been outlined by Henderson (1959), who noted gravels up to 25 m (80 ft) thick in its lower portion. The deepest portion of this channel reaches about 230 m (750 ft). Although no water wells are known to have been drilled in it, the groundwater quality in this channel is apt to be poor.

South and southwest of Sturgeon Lake between Sturgeon Lake and the town of Valleyview, surficial sediments up to 100 m (335 ft) thick have been found in testholes. Along the Puskwaskau River valley the surficial sediments are about 30 m (100 ft) thick.

TEST DRILLING

During the summer of 1973, the Groundwater Division of the Alberta Research Council drilled 22 testholes totalling 2760 m (9060 ft). These testholes varied from 30 to 245 m (105 to 810 ft) deep.

The primary objective of this test drilling program was to define the bedrock surface configuration, to determine whether sands and gravels were present, and to find permeable horizons in the bedrock. The main drilling areas were High Prairie, McLennan-Lac Magloire, and Watino-Culp-Tangent. All testholes, except one, were E-logged with the Alberta Research Council Widco electric logger.

Two testholes had to be abandoned before drilling was completed; one (Lsd 4, Sec 5, Tp 79, R 20, W5th Mer) hit crude oil at a depth of 160 m (533 ft) at the contact between a medium-grained, grey sandstone and a shale succession. The second one (Lsd 12, Sec 21, Tp 77, R 24, W5th Mer) found a strong flow of natural gas at 30 m (105 ft). In this testhole, lost circulation between 24 and 33 m (80 and 100 ft) suggests a relatively high permeability in a sandstone horizon.

When they were abandoned, all testholes were cemented from top to bottom to avoid possible pollution of groundwater and intermixing of groundwaters from different aquifers.

Gravel horizons were rare in the High Prairie area; till and lacustrine clays were the dominant surficial sediments. One exception was a testhole west of Triangle where 11 m (38 ft) of gravel were found resting on shale (possibly of the Puskwaskau Formation) at a depth of 85 m (280 ft).

HYDROGEOLOGY

Previous groundwater studies were done in the general area by Jones in 1962 and 1966.

WATER LEVELS

The water level contours, presented on the main map at 100-ft intervals, were drawn only in the southern portion of the map area where data were adequate. The contours follow the land surface topography quite closely.

FLOWING WELLS

There are few flowing wells in the map area, but some exist in the Métis colony south and southeast of the town of High Prairie. Flows of several litres per second were encountered in testholes drilled by Alberta Environment at depths between 73 and 76 m (240 and 250 ft). In these testholes, in the East Prairie River valley, the water flows from basal sands of a small bedrock channel adjacent to the High Prairie bedrock channel. Flowing wells have also been completed in basal sands and gravels of the Valleyview bedrock channel in the south-central part of the map area. The other flowing wells are shallow flowing seismic shot-holes and are indicated on the main map. These wells are believed to show the presence of shallow flow systems (local) because deeper water wells do not flow.

YIELDS FROM BEDROCK SEDIMENTS

The yield areas shown on the main map were outlined using the few pump tests that were available in different formations. The transmissivities and the 20-year safe yields calculated from these pump tests were applied to similar lithologies observed and reported in water wells and in testholes.

The sediments of the Wapiti Formation, composed of a succession of sandstones, mudstones, and coal beds, which are found in the southern portion of the map area, have been assigned the yield range of 0.07 to 0.4 L/s (1 to 5 igpm) for the shallower portion and 0.4 to 2 L/s (5 to 25 igpm) at greater depths due to a better development of sandstones. Most bedrock water wells in this area are completed in sandstones, although a few coal beds west of Valleyview are water bearing.

The sediments of the Kaskapau and Puskwaskau Formations are mainly composed of shales and have been assigned a yield value of less than 0.07 L/s (1 igpm). The sediments of the Dunvegan Formation, found along the northern edge of the map area, vary in depth from subcrops in the Peace River and Smoky River valleys to about 210 m (700 ft); along the southern edge of the map area, they are found at depths between approximately 670 and 850 m (2200 and 2800 ft). This formation thins rapidly to the southeast of the map area from a thickness of about 140 m (475 ft) in the northwest to about 15 m (50 ft) and less in the southeastern corner of the map area. Over the area these sediments are fine grained and massive (Jones, 1966). Water wells are not known to have reached the Dunvegan strata along the northwestern border of the map area where the depth of this formation is reasonable.

YIELDS IN THE VALLEYVIEW AND HIGH PRAIRIE CHANNELS AND IN SURFICIAL DEPOSITS

Bedrock channel sands and gravels are the highest yielding aquifers in the map area. The High Prairie channel sediments have been assigned the yield range of 2 to 7 L/s (25 to 100 igpm), but locally, for example, in the town of High Prairie, several wells show a 20-year safe yield of over 45 L/s (600 igpm) (Jones, 1966). Only this small area has sufficiently accurate pump test data to estimate the safe yield of the gravel aquifer. The reason for giving the remainder of the channel aquifer a lower yield value is by analogy to the values obtained for the Lesser Slave Lake map area to the east where the main yield value for the same channel is 2 to 7 L/s (25 to 100 igpm).

During the 1973 field season, testholes were drilled to determine the extent of this bedrock channel aquifer, which is tapped by the wells of High Prairie; only one testhole, 22 km (13.5 mi) west of the town of High Prairie encountered 11 m (38 ft) of sands and gravels. Another testhole, 10 km (6.5 mi) east-northeast of the town, hit a total of 2 m (7 ft) of sands and gravel at an elevation of 510 m (1665 ft). At High Prairie, sands and gravels were found at elevations of about 430 m (1415 ft) and 420 m (1380 ft), respectively. Permeable sediments within this channel have a complex distribution and are of a discontinuous nature. Similarly, sand and gravel deposits have been found in the Valleyview bedrock channel in the south-central part of the map area. Yields appear to be

higher in the southern part of the channel [2 to 7 L/s (25 to 100 igpm)] in contrast to the northern part of the channel [0.4 to 2 L/s (5 to 25 igpm)].

In the Falher area, surficial sediments are composed mainly of clays and silts deposited in glacial Lake Falher (Henderson, 1959). The yields of these sediments are less than 0.07 L/s (<1 igpm) and account for the large number of dugouts in the area. Neither surficial nor bedrock sediments are permeable enough to allow construction of water wells.

To the west of Watino and north of the Smoky River, sand dunes are present over a fairly large area. Local relief exceeds 12 m (40 ft) and the dune area has been stabilized by vegetation. This area is largely unpopulated, so is virtually devoid of water wells. Many springs have been reported to flow into the Smoky River from this sand dune area; however, flow rates are not known. This area was assigned a yield value of 0.07 to 0.4 L/s (1 to 5 igpm).

The Tangent channel in the northwestern part of the map area, which has been outlined by Henderson (1959), has been attributed a yield value of 0.07 to 0.4 L/s (1 to 5 igpm). The depth of this channel and the occurrence of saline groundwater in the deep 260 m (850 ft) Shaftesbury channel to the north, strongly suggest that the groundwater is also saline.

HYDROCHEMISTRY

Various chemical types of groundwaters are found in the area. Few data are available, so the chemistry is discussed in terms of small areas.

The few wells of the Falher area completed in permeable lenses within the surficial sediments produce calcium-magnesium sulfate and calcium-magnesium bicarbonate types of water. Total dissolved solids vary from about 700 mg/L to about 1900 mg/L. A few deep wells [about 430 m (1400 ft) deep] show a sodium-chloride type of water with total solids in the order of 20 000 mg/L.

Groundwaters of the High Prairie area have a total dissolved solids content varying from about 200 mg/L to over 3000 mg/L. Higher values are found in the High Prairie area; lower values are found to the east and west. Near High Prairie, groundwaters of the bedrock channel sediments have total dissolved solids contents varying from 1000 to 1500 mg/L. These waters are acceptable for human consumption. Water is generally of the calcium-magnesium bicarbonate type in shallow drift aquifers, and sodium sulfate and sodium chloride in deeper sediments of the channel. Deeper bedrock waters are of the sodium-bicarbonate and chloride type.

The Valleyview area has two groundwater types: sodium sulfate in shallow drift waters and sodium bicarbonate in deeper bedrock waters. In bedrock waters, total dissolved solids vary from about 400 to 2000 mg/L. Shallower drift wells have total dissolved solids contents varying from 1200 to 3000 mg/L.

CONCLUSIONS

The Winagami map area has good to very poor groundwater in terms of quantity and quality. Both bedrock and surficial sediments contain important aquifers, but the largest yields are produced from sands and gravels of the High Prairie and Valleyview channels. With 12 to 24 m (40 to 80 ft) of gravels and sands resting on the bedrock, the Tangent channel could probably produce several tens of litres per second of groundwater of poor quality.

The most important bedrock aquifer is the Wapiti Formation. Test drilling and pump testing might prove the Dunvegan Formation to be a good aquifer along the northern edge of the map area.

Groundwater quality is highly variable over the map area.

REFERENCES

Alberta Study Group (1954): Lower Cretaceous of the Peace River region; *in* Ralph Leslie Rutherford Memorial Volume, Western Canada Sedimentary Basin Symposium, American Association of Petroleum Geologists, Tulsa, p. 268-278.

Alberta Travel Bureau: (1975), Travel Alberta.

Gleddie, J. (1954): Upper Cretaceous in western Peace River plains, Alberta; *in* Ralph Leslie Rutherford Memorial Volume, Western Canada Sedimentary Basin Symposium, American Association of Petroleum Geologists, Tulsa, p. 486-509.

Green, R. (1972): Geological map of Alberta; Alberta Research Council Map No. 35.

Henderson, E.P. (1959): Surficial geology of Sturgeon Lake map area, Alberta; Geological Survey of Canada, Memoir 303, 108 p.

Jones, J.F. (1962): Reconnaissance groundwater study, Swan Hills and adjacent area, Alberta; Research Council of Alberta, Preliminary Report 62-5, 43 p.

——— (1966): Geology and groundwater resources of the Peace River district, northwestern Alberta; Research Council of Alberta, Bulletin 16, 143 p.

Kidd, S. (1946): Geology and water resources of a part of Peace River area; Research Council of Alberta, internal report.

Longley, R.W. (1972): The climate of the Prairie Provinces; Environment Canada, Atmospheric Environment, Climatological Studies No. 13, Toronto, 79 p.

Vogwill, R.I.J. (1978): Hydrogeology of the Lesser Slave Lake Area, Alberta. Research Council of Alberta Report 77-1, 30 p.

APPENDIX – ALBERTA RESEARCH COUNCIL TESTHOLES

LSD 1-28-72-20-W5

0	5	Clay, light brown, silty
5	10	Clay, light brown, silty, iron stained
10	15	Gravel, fine; sand, coarse
15	35	Siltstone, light grey; sandstone, light brown, fine-grained, iron stained
35	45	Siltstone, clayey, dark grey
45	50	Shale, dark brown, soft
50	60	Sandstone, light grey, fine-grained, hard
60	65	Sandstone, light grey, clayey, silty, soft
65	75	Siltstone, light grey, clayey
75	80	Shales, light grey, soft
80	85	Siltstone, light grey, hard
85	90	Sandstone, clayey, light grey, fine-grained
90	105	Shale, light grey, soft

NE 35-72-21-W5

0	10	Clay, brown, slighty sandy
10	40	Clay, dark grey, sticky, blue-grey, slightly sandy (fine)
40	45	Same as (10-40), but slightly brown, few pebbles, pea size
45	70	Same as (40-45), very soft, iron stained (55-60 ft)
70	95	Same as (45-70), some coal; hard layers at 70-75 ft
95	100	Pebbles, coal
100	145	Clay, sandy, dark grey
145	165	Clay, sandy, dark grey, containing hard layers and pea-sized pebbles
165	250	Clay, hard layers; small quartz chips, red to pale brown; coal
250	260	Same as above, fragments of quartz and fragments of pea-sized gravel; thin, hard layers throughout
260	265	Sandstone, soft, clayey, medium grey
265	270	Coal, blue grey shale, siltstone

LSD 9-35-74-16-W5

0	5	Clay, brown, slightly sandy
5	10	Clay, soft, light brown to reddish brown
10	20	Clay, soft, blue grey
20	45	Clay, soft, blue-green
45	65	Same as above, dark grey, thin small pelecypod shells and fragments of gastropod shells
65	130	Clay, dark grey, very soft; coal fragments
130	215	Clay, dark grey with sandy layers; small gravel and fragments of coal
215	252	Same as above plus shell fragments; gravel pebbles
252	254	Sand, fine
254	260	Clay, sandy; gravel, pea size
260	265	Silt, grey, bright
265	270	Sand and fine gravel
270	275	Sandy, clayey silt
275	325	Clay, light grey, silty; few gravel pebbles
325	480	Clay, light grey, soft, silty
480	485	Same as above plus hard black clay
485	565	Clay, light grey, soft, few pebbles
565	584	No sample
584	595	Shale, light grey, some carbonaceous material
595	584	No sample
584	595	Shale, light grey, some carbonaceous material

LSD 13-23-74-19-W5

0	1	Sand, light brown
1	242	Till; gravel beds, coal fragments at 45, 80, 90, 95, 105 and 150 ft
242	280	Gravel, medium pebble size
280	330	Shale, soft, grey

LSD 9-14-75-14-W5

0	5	Clay, light brown, silty
5	15	Clay, dark grey, soft, black carbonaceous streaks
15	20	Clay, brownish grey, very soft
20	28	Till, grey to brown sand and silt, iron stained and gravel pebbles
28	34	Sand, very coarse, light brown
34	39	Till, sandy, clayey, gravel pebbles, grey
39	43	Gravel, angular
43	55	Till, sand, silt, clay, gravel pebbles, grey
55	58	Sand
58	59	Gravel stringer
59	69	Sand
69	105	Shale, sandy and silty, grey, soft to hard; coal fragments
105	186	Shale, hard, dark grey
186	187	Sandstone, fine, hard, dark grey to black
187	200	Shale, dark grey, hard

LSD 3-29-75-18-W5

0	- 25	Clay, dark brown, sandy, soft
25	- 165	Till, grey, gravel pebbles, clay
165	- 180	Sand, light brown, fine, loose
180	- 210	Till
210	- 300	Shale, dark grey, carbonaceous zones; stringers of sandstone
300	- 407	Shale, dark grey, soft; hard stringers at 391, 398, 401 and 403 ft
407	- 409	Sandstone, hard, light brown, rusty, fine-grained
409	- 413	Shale, dark grey, soft
413	- 414	Sandstone ledge, dark grey, hard, fine-grained
414	- 420	Shale, dark grey, soft

LSD 16-15-76-14-W5

0	- 15	Till, light brown, clayey, silty sandy, iron stained
10	- 15	Same as above, darker color, some gravel pebbles
15	- 25	Same as above, medium brown and medium grey, silt, gravel pebbles, iron stained
25	- 55	Till, clayey, silty, gravel pebbles
55	- 57	Sand, very fine, brownish grey
57	- 75	Till, silty, sand, gravel pebbles, dark grey
75	- 95	Same as above and fine grey sand, gravel pebbles, silty at 90-95 ft
95	- 130	Silt, grey, clayey and some sand
130	- 185	Same as above, harder
185	- 190	Gravel chips in same matrix as above, more clay
190	- 205	Clay, grey, silty, fairly hard
205	- 810	Clay, grey, silty to sandy with occasional gravel pebbles and boulders, soft to medium hard

LSD 13-9-76-14-W5

0	- 5	Clay, light brown, silty
5	- 10	Clay, grey, soft
10	- 45	Shale, alternating hard to soft layers, grey to black, carbonaceous streaks
45	- 116	Shale, dark grey to black, medium soft
116	- 119	Sandstone stringers, dark grey
119	- 135	Shale, silty, soft to hard layers
135	- 155	Sandstone, fine-grained, soft to hard, clayey layers
155	- 230	Shale, dary grey, silty, soft to hard
230	- 235	Sandstone (or siltstone), very hard fine-grained, dark grey
235	- 260	Shale, dark grey, medium hard to hard, silty
260	- 270	Sandstone, very fine-grained, dark grey to light brown, very hard, losing some circulation (265-270 ft); pyritic
270	- 285	Sandstone, soft, clayey, dark grey

LSD 12-20-76-17-W5

0	- 15	Clay, light brown, sandy and silty, iron stained
15	- 35	Till, with gravel pebbles, grey, medium soft
35	- 195	Shale, soft to hard in some layers, dark grey

LSD 2-2-77-14-W5

0	- 5	Clay, sandy, silty, light brown
5	- 15	Silt, light brown to light grey, few gravel pebbles
15	- 30	Clay, soft, grey
30	- 150	Clay, sandy, greyish brown, gravel stringers
150	- 218	Clay, silty to sandy, some carbonaceous material, pebble stringers, light to dark grey
218	- 519	Clay, light grey; silt, light grey; pebble layers
519	- 615	Sandstone, fine-grained, hard, light grey
615	- 700	Shale, medium hard, dark grey to black

LSD 4-5-77-16-W5

0	- 15	Sand, silty and clayey, gravel pebbles, rusty brown
15	- 40	Clay, sandy and silty, medium grey
40	- 80	Till, sandy, clayey, hard, light yellowish brown, iron stained
80	- 105	Till, sandy, silty, brown yellow to pale grey
105	- 140	Shale, sandy, carbonaceous, medium grey
140	- 180	Sandstone, fine-grained, medium grey
180	- 220	Shale, medium hard, medium to dark grey
220	- 250	Sandstone, fine-grained, dark grey, losing circulation
250	- 505	Shale, medium to dark grey, sandstone ledges, carbonaceous

LSD 5-20-77-17-W5

0	- 1	Clay, sand, silty, light brown
1	- 2	Gravel, medium size
2	- 90	Till, gravel pebbles to 30 and at 50 to 70 ft; more clayey (grey to brown) from 20 to 90 ft
90	- 125	Sand, light grey, fine
125	- 130	Clay, dark grey, soft
130	- 135	Sand, light grey, fine to medium
135	- 150	Shale, dark grey, soft and coal fragments
150	- 160	Shale and sandstone, shale is soft and sandy, dark grey; sandstone is hard and grey
160	- 170	Sandstone, grey, soft, clayey, fine-grained
170	- 195	Shale, medium grey, soft

LSD 11-18-77-18-W5

0	- 15	Clay, light brown, silty, sticky
15	- 20	Clay, light brown, sandy
20	- 128	Till, grey, sandy, silty, plus gravel pebbles
128	- 165	Clay, dark grey, hard to medium hard, silty
165	- 180	Clay, dark grey, soft
180	- 205	Sand, fine-grained, grey
205	- 235	Clay, dark grey, sandy to silty, soft
235	- 315	Shale, dark grey, sandy to silty, hard ledges of light brown, fine-grained hard sandstone at 254 and 263 ft
315	- 320	Sandstone, grey, fine-grained, medium hard
320	- 325	Shale, grey, silty, medium soft
325	- 330	Siltstone, grey, medium hard
330	- 345	Shale, grey, medium hard

LSD 2-33-77-19-W5

0	- 5	Clay, light brown to brownish grey, soft
5	- 110	Till, brownish grey to grey, sandy and pebbly; gravel at 35, 45, 57, 65, 70 and 75 ft
110	- 125	Clay, very dark grey, sandy, fine to coarse sand
125	- 133	Sand, fine to coarse plus dark grey clay
133	- 135	Sandstone, greenish grey, very hard to soft, fine-grained
135	- 145	Sandstone, soft, plus clay, dark grey
145	- 160	Shale, dark grey, soft, silty
160	- 170	Claystone, dark grey, soft; at 100-150 ft belemnites; sandstone, light greenish grey
170	- 180	Claystone, dark grey, soft
180	- 185	Siltstone, dark grey
185	- 205	Claystone, dark grey, soft
205	- 210	Same as above, with layers of dark grey shale
210	- 485	Same as above, hard layers at 260, 274 and 290 ft; coal fragments at 280 ft
485	- 500	Sandstone, dark grey, hard, very fine
500	- 505	Shale, dark grey and hard ledges of sandstone, fine dark grey to greenish
505	- 510	Same as above, pyrite fragments
510	- 555	Same as above, some layers of dark carbonaceous shale; hard layers at 535 ft; at 535-540 ft, white specks
555	- 560	Shale, black and sandstone, dark grey, fine-grained
560	- 639	Shale, dark grey, silty, carbonaceous streaks; coal at 595 ft
639	- 646	Sandstone, dark grey, very hard; mother-of-pearl in large quantity
646	- 670	Claystone, soft grey, hard layer at 655 ft
670	- 675	Sandstone, grey, soft, clayey
675	- 705	Claystone and dark grey shale; bentonite

LSD 15-9-77-20-W5

0	- 15	Clay, dark greyish brown, sandy and silty
15	- 30	Clay, brown, silty and gravel pebbles
30	- 35	Clay, dark grey, sandy and silty
35	- 43	Sand, brown, coarse, fine gravel
43	- 90	Till, with gravel pebbles at 50 ft
90	- 95	Clay, dark grey, sandy
95	- 120	Till, with gravel pebbles at 95 ft
120	- 130	Sand, grey, fine, loose
130	- 202	Claystone, dark grey, medium hard; coal at 170 and 179 ft; siltstone at 175 ft; shell fragments at 180 ft
202	- 207	Sandstone, grey, fine-grained, hard
207	- 215	Claystone, dark grey
215	- 220	Siltstone, dark grey, clayey
220	- 300	Claystone, dark grey; siltstone ledges at 255 and 298 ft

LSD 12-21-77-24-W5

0	- 28	Gravel, boulders
28	- 45	Shale, black carbonaceous to tarry; hard to drill
45	- 60	Shale, dark grey, hard, carbonaceous
60	- 63	Shale, grey, silty, hard
63	- 75	Sandstone, grey, fine-grained, soft, clayey

75	- 80	Shale, grey, sandy, hard
80	- 110	Sandstone, grey, fine-grained, soft, clayey (losing circulation)
110	- 135	Shale, dark grey, silty, hard
135	- 140	Shale, dark grey; shale, dark brown; sandstone, greenish grey, fine-grained
140	- 145	Shale, dark grey, silty; sandstone, greenish grey, fine-grained, soft

Hole abandoned due to the presence of natural gas.

LSD 16-36-77-24-W5

0	- 5	Old road surface; clay, light brown, sandy to silty; gravel pebbles
5	- 20	Sand, light brown, fine; plus clay, dark grey, sandy
20	- 45	Clay, dark grey, medium hard
45	- 65	Sand, fine grey; plus coal and wood pieces
65	- 137	Clay, dark grey, sandy to silty, medium hard to soft
137	- 139	Sandstone, medium-grained, pale grey, very hard
139	- 250	Shale, dark grey, silty and coal fragments at 160 ft; hard layers at 152, 161 (quartz fragments)
250	- 255	Sandstone, light grey, fine-grained, soft; shale, dark greyish green
255	- 265	Shale, dark grey, soft
265	- 270	Same as above; light grey, fine-grained, soft
270	- 295	Shale, light grey, medium soft
295	- 310	Same as above; dark grey carbonaceous shale
310	- 315	Shale, black, containing tar

LSD 3-4-78-23-W5

0	- 3	Old road surface
3	- 30	Sand, light brown, fine; clay
30	- 105	Clay, soft grey
105	- 360	Till; gravel at 115, 150, 165, 190, 210, 230, 245, 265, 275, 295, 305, 335 and 345 ft; coal at 125, 155, 170, 180, 235 and 240 ft
360	- 385	Shale, dark grey
385	- 405	Shale, dark grey, sandy; sandstone, salt and pepper, hard, fine-grained at 385, 390 and 403 ft
405	- 480	Shale, dark grey, medium hard

LSD 4-4-78-24-W5

0	- 3	Sand, fine, rusty brown
3	- 15	Clay, light brown, silty, soft; clay, grey, soft
15	- 135	Clay, dark grey, silty, with: gravel pebbles at 20, 90 and 115 ft, coal at 90 and 120 ft, and sand at 125 ft
135	- 199	Claystone, dark greyish brown to dark grey, silty, soft
199	- 405	Shale, dark grey, medium soft

LSD 4-5-79-20-W5

0	- 5	Clay, brown, silty, soft
5	- 10	Clay, light greyish brown
10	- 15	Clay, light grey, silty, medium soft; gravel pebbles
15	- 106	Till
106	- 115	Sand, dark greenish grey, clayey
115	- 415	Shale, grey, silty, soft
415	- 420	Hard layer (no sample)
420	- 500	Claystone, grey, silty, soft
505	- 521	Shale, dark grey to black (hard ledge at 508 ft)
521	- 533	Sandstone, medium-grained, grey, very hard; after 533 ft crude oil starts to come up
533	- 550	Claystone, dark grey; shale, dark grey to black, soft
550	- 585	Claystone and shale, black in color; more oil
585	- 595	Sandstone, fine-grained, grey, medium hard; shale

LSD 5-5-79-20-W5

0	- 15	Clay, sandy, light brown
15	- 30	Clay, sandy, bluish grey, few pebbles
30	- 125	As above, no pebbles
125	- 190	Shale, soft, bluish grey
190	- 435	Shale, sandy, dark to medium grey sandstone stringers, pale grey, fine
435	- 445	Sandstone and siltstone, dark grey, white specks
445	- 485	Sandstone and shale, dark to medium grey, hard to medium hard, oil streaks
485	- 600	Sandstone, fine, salt and pepper, hard to medium hard; shale, dark grey

LSD 8-36-79-21-W5

0 - 30	Till, light brown, pebbles and sand
39 - 75	Clay, blue grey to dark grey, numerous pebbles, hard to medium hard
75 - 125	Sandstone alternating with shales, soft to hard
125 - 335	Shale, very sandy, medium hard, medium grey, mother-of-pearl at 230-235 ft; sandstone stringers
335 - 375	Sandstone, fine-grained, dark to medium grey, shale stringers
375 - 560	Alternating shale and sandstone beds, hard to very soft, dark grey; oil streaks at 414 ft; white specks at 450-455 ft

HYDROGEOLOGICAL MAP WINAGAMI ALBERTA

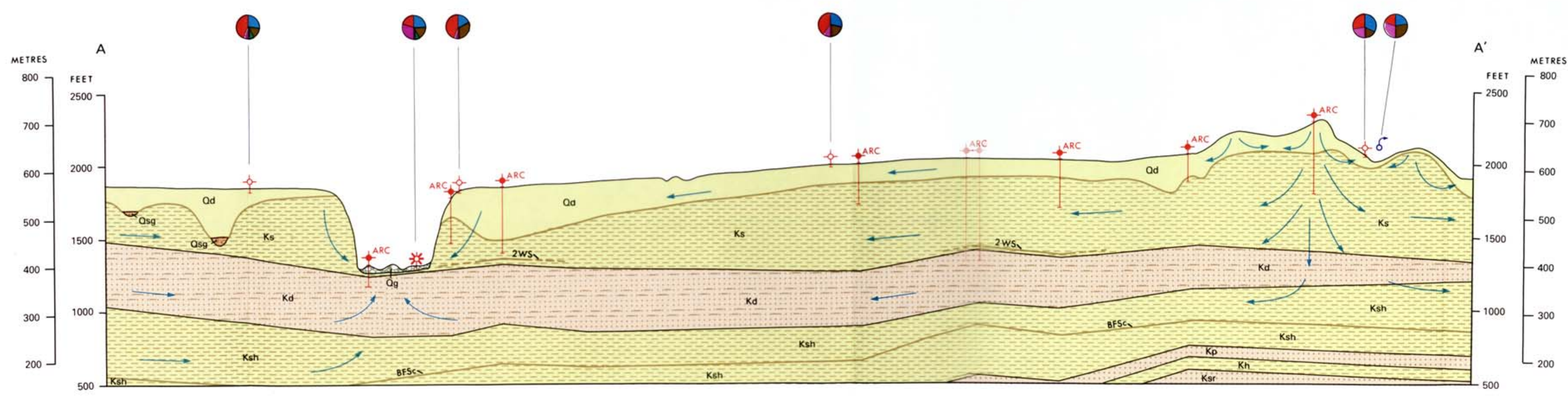
Alberta RESEARCH COUNCIL

LEGEND

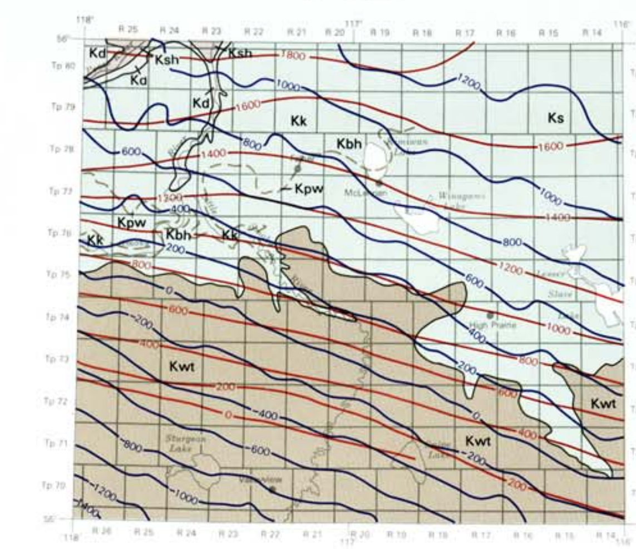
Isohyet, mean annual precipitation in inches (cm) .... 16(40)
Mean annual precipitation in inches (cm):
- 10 to 15 inches (25 to 38 cm)
- 15 to 20 inches (38 to 51 cm)
- 20 to 25 inches (51 to 64 cm)

Meteorological station
Precipitation data:
- Mean annual precipitation in inches (cm) (percent rainfall)
- Year of commencement of observations
- Number of years in average
- Mean monthly precipitation
- Period when surface is usually snow-covered
- Period with mean daily temperatures below freezing (°C)
- Figure indicates percentage of mean annual precipitation falling as rain

METEOROLOGY



GEOLOGY



LEGEND

Wapiti Formation: *feldspathic, clayey sandstone; bentonitic mudstone and bentonite; scattered clay beds; nonmarine*
Kwt

Puskwaskau Formation: *fossiliferous shale; silty in upper part; marine*
Kpw

Bad Heat Formation: *quartzose sandstone, ferruginous oolitic sandstone and mudstone; marine*
Kbh

Kaskapau Formation: *shale, thin concretionary ironstone beds; interbedded in lower part with fine-grained quartzose, sandstone and thin beds of oolitic mudstone; marine*
Kk

Dunvegan Formation: *fish-grained feldspathic sandstone with hard calcareous beds; laminated siltstone and shale; deltaic to marine*
Kd

Shaftesbury Formation: *fish-scale bearing shale; numerous nodules and thin beds of concretionary ironstone; bentonite partings; lower part with thin silty and sandy intervals; marine*
Ksh

Rock unit boundary
Structure contour of base of Fish Scale Zone 600
Structure contour on top of Dunvegan Formation 1800
Geology after R. Green (1970)
Structure contours of base of Fish Scale Zone from Alberta Energy Resources Conservation Board
Structure contours on top of Dunvegan Formation from J. Jones

MAIN MAP LEGEND

Topography

Surface contours and elevation in feet (interval 100 feet)

Geology

Geological boundary
Thalweg of buried valley:
- defined
- approximate

QUATERNARY

Qd	Unconsolidated deposits

CRETACEOUS

Kwt	Wapiti Formation
Ks	Smoky Group
1WS	First White Specks Zone
Kbp	Bad Heart Formation
Kcr	Cardium Formation
2WS	Second White Specks Zone
Kd	Dunvegan Formation
Ksh	Shaftesbury Formation
BFSc	Base of the Fish Scale Zone
Kp	Peace River Formation
Kh	Harmon Member
Ksr	Spirit River Formation

Lithology

Gravel
Sand and gravel
Sand
Sandstone
Shale
Coal

Hydrography

Lake or slough, perennial
Marsh, muskeg
Stream, perennial
Stream, intermittent
Surface water divide

Hydrogeology

Spring, flow rate unknown
Nonpumping water level contour in the bedrock (elevation in feet followed by metres in brackets) and vertical component of groundwater movement — Upward flow 1900 (580) Downward flow
Component of groundwater flow perpendicular to profile:
- out of profile (towards reader)
- into profile (away from reader)

Component of groundwater flow parallel to profile
Groundwater divide
Boundary of area of artesian flow

Groundwater Probability†

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

Probable: estimated from quantitative information (pump tests, bail tests, etc.)
Possible: estimated from qualitative information (flow regime, lithology, etc.)

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 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. Multi-aquifer completion may be necessary to obtain the yield indicated.

Wells and Other Artificial Works

Depth Scale

FEET 0, 100, 200, 300, 400 — Depth to water — Depth of well or seismic shot hole

Water well, flowing
Location of Alberta Research Council test well .... ARC
Water well, 20-year safe yield calculated from apparent transmissivity
Water well, 20-year safe yield calculated from a pump test of sufficient length to reflect regional hydraulic conditions
Seismic shothole reported to have flowed, unknown depth
Oil well
Gas Well
Other exploratory well or core hole
Depth of exploratory well

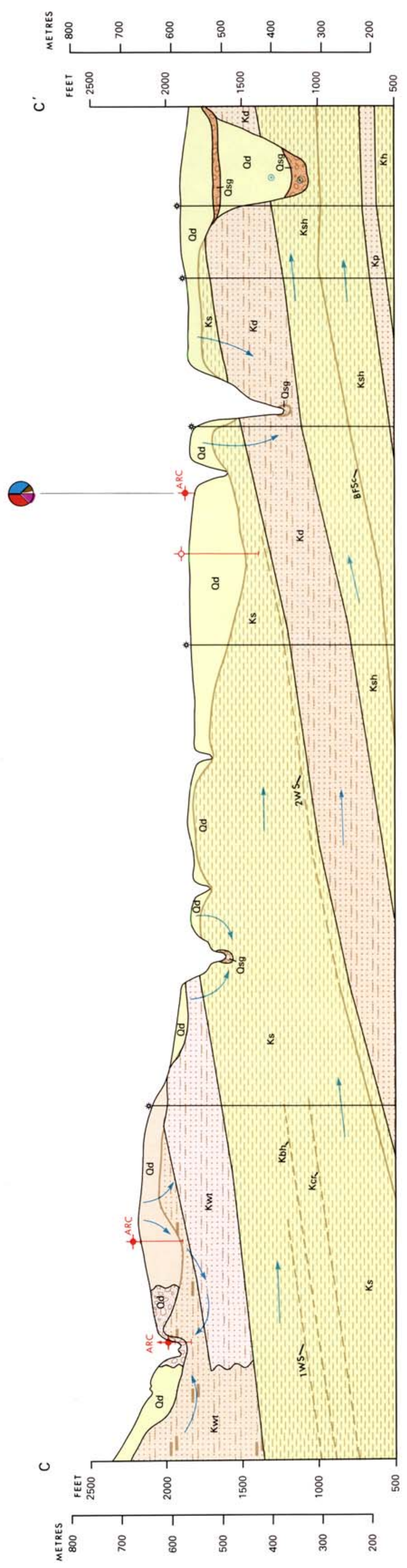
The vertical line portion of oil, gas, or other exploratory test well symbols indicates the well depth; the dashed portion indicates the surface casing interval where applicable or where known (otherwise, a solid line is used).

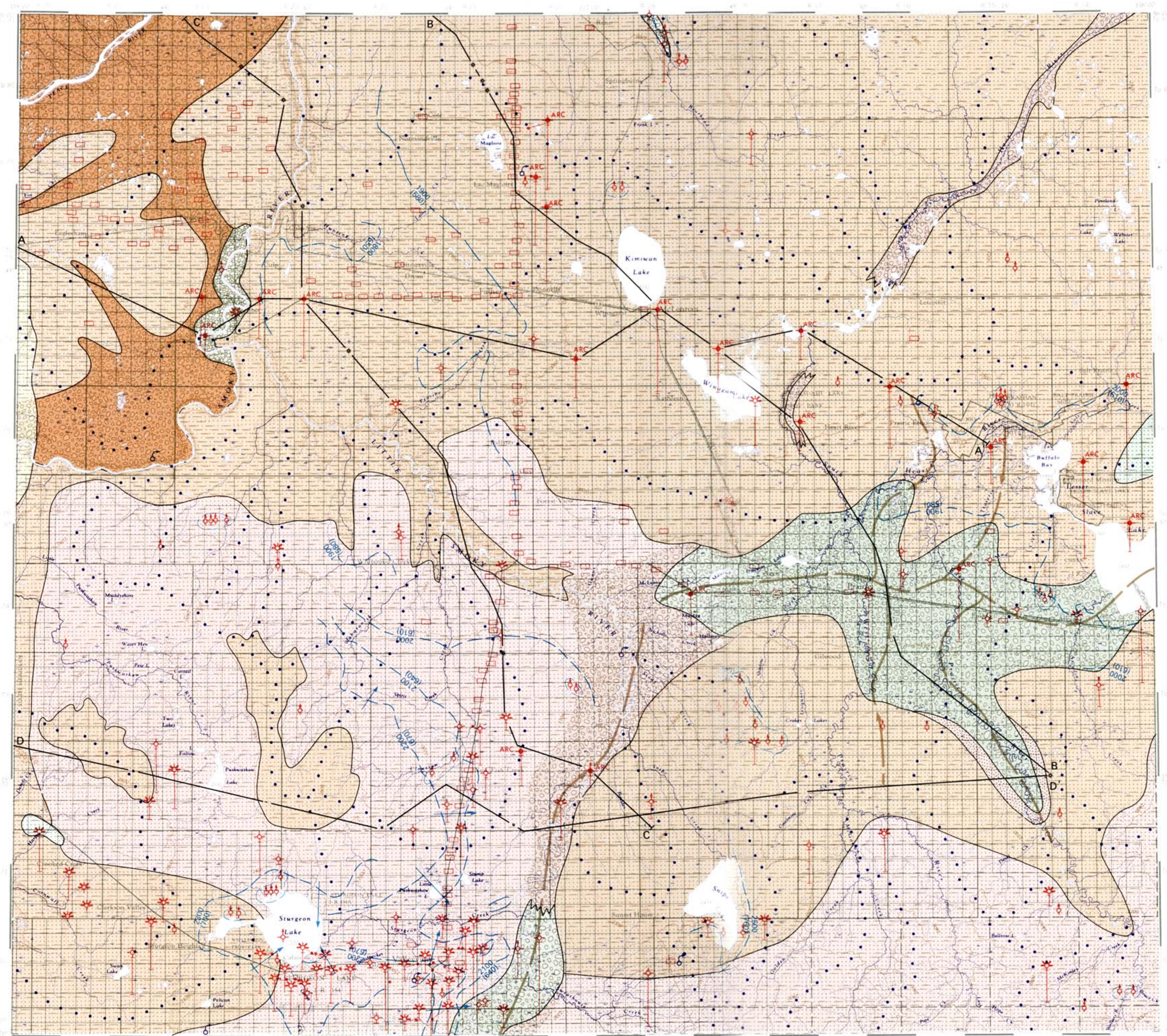
Note: On the main map exploratory wells appear as point symbols only.

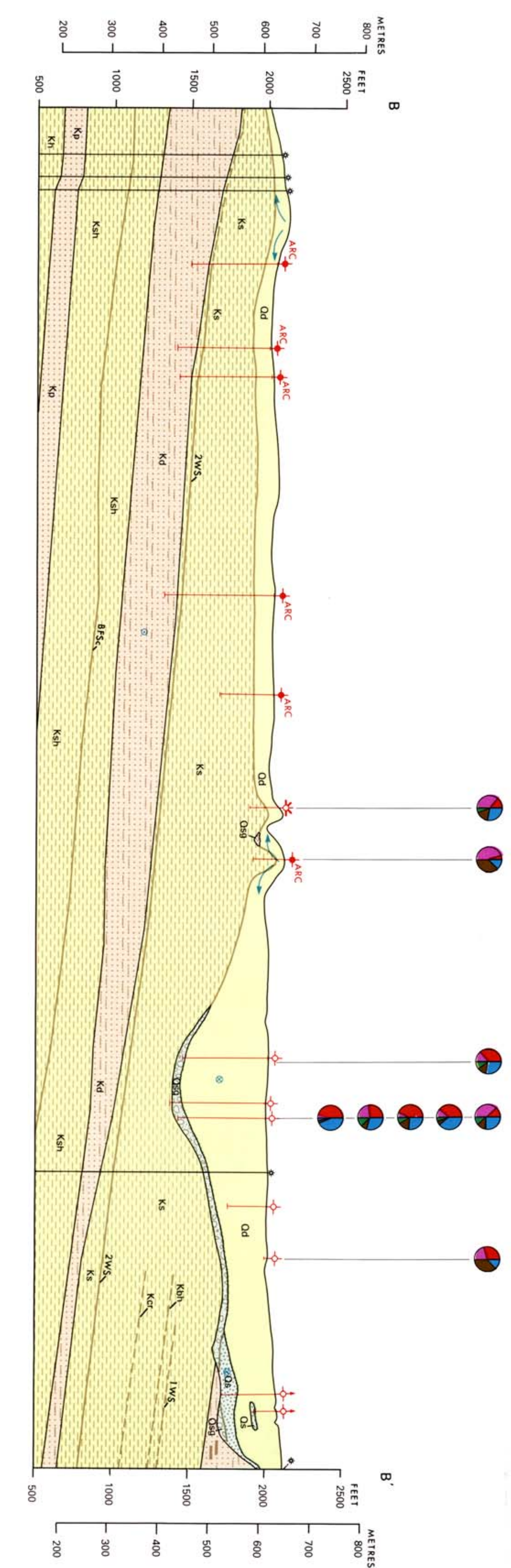
Dugout or borrow pit
Line of hydrogeological profile .... B — B′

Hydrochemistry

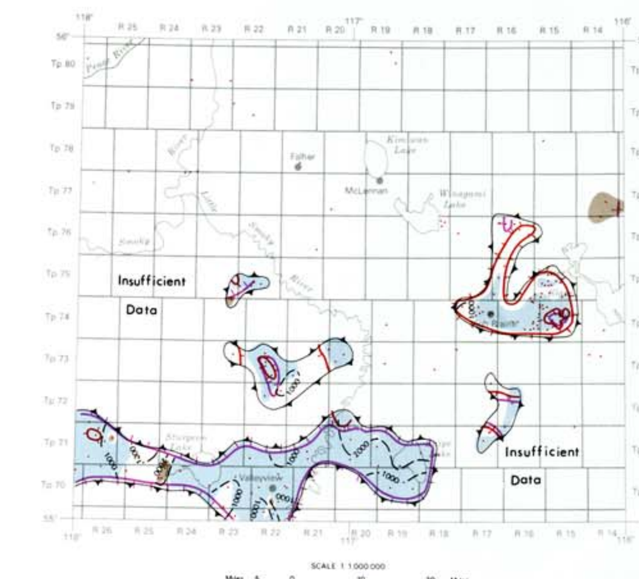
Note: When the yellow Mg pie sector is absent, Ca + Mg are represented as a unit by the red pie sector.







HYDROCHEMISTRY

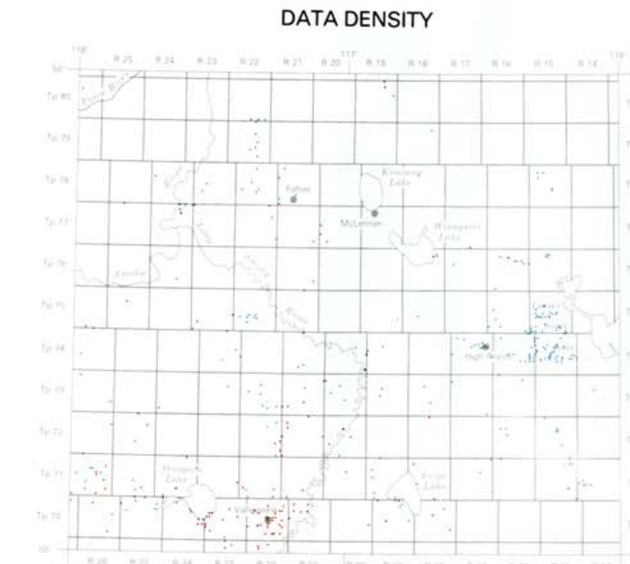


LEGEND

Data control point
Total dissolved solids in mg/L:
- approximate 1000

Carbonate + bicarbonate constituting over 60 percent of total anions*
Sulfate 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, defined:
Isogram along which sodium + potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content, defined:
* determined on equivalents per million basis

DATA DENSITY

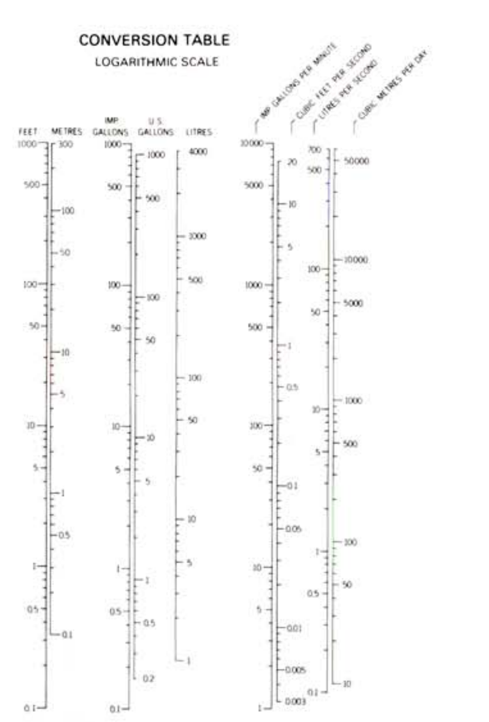


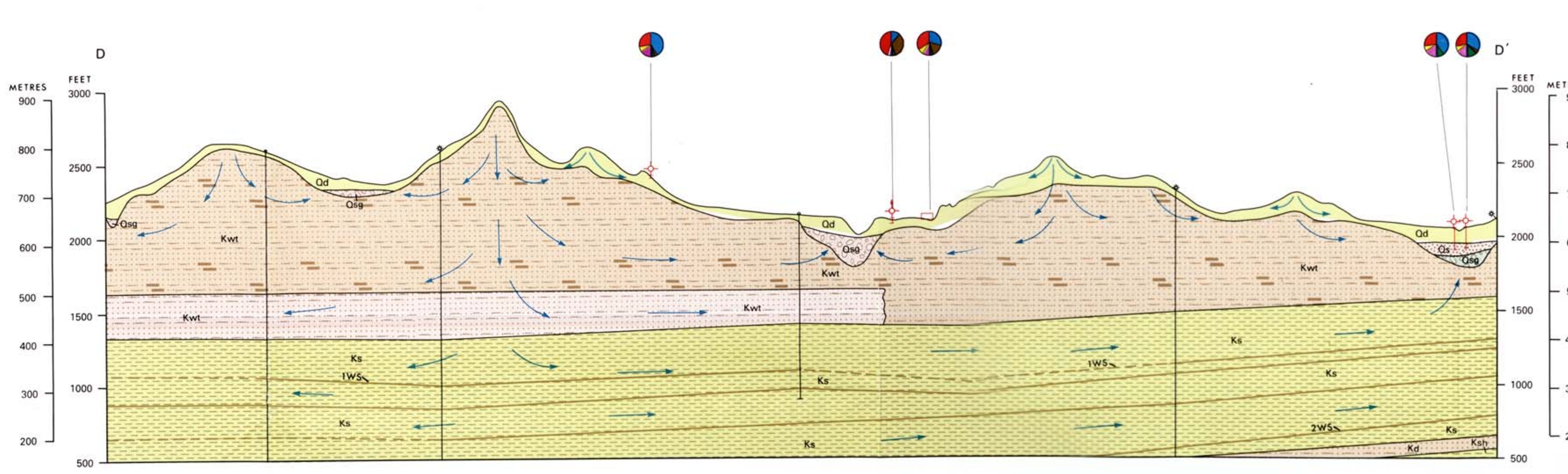
LEGEND

Data control point marking location of a well with water level information only
Data control point marking location of a well with yield information only
Data control point marking location of a well with water level and yield information
Data control point marking location of a surface hydrogeological feature

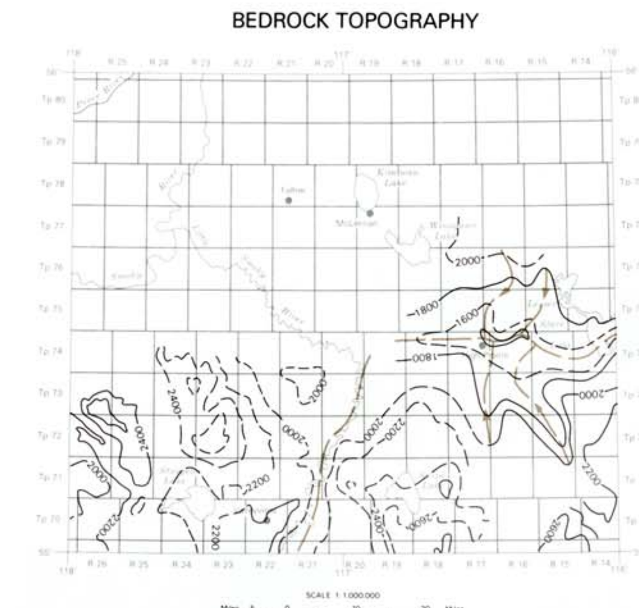
CONVERSION TABLE

LOGARITHMIC SCALE





BEDROCK TOPOGRAPHY



LEGEND

Bedrock contours
- defined 2000
- approximate 1600

Thalweg of buried valley
- defined

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

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 series is available from Publications, Alberta Research Council, 11315 - 87 Avenue, Edmonton, Canada T6G 2C2.

Map to accompany Report 79-3.

Hydrogeology by D. Borneuf.

Drafted by J.K. Matthie.

HYDROGEOLOGICAL MAP
WINAGAMI
ALBERTA

NTS 83N

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