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HYDROGEOLOGY
OF THE
GRIMSHAW-CHINOOK VALLEY AREA, ALBERTA

by

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HYDROGEOLOGY OF THE GRIMSHAW-CHINOOK VALLEY AREA, ALBERTA

Abstract

The hydrogeological map of the Grimshaw-Chinook Valley area is the prototype for a forthcoming hydrogeological reconnaissance map series, although it is constructed at a larger scale and covers a smaller area than will subsequent maps in the series. It presents on one map the most important hydrogeological aspects of the area: topography, geology, meteorology, groundwater probability, water levels, hydrochemistry, springs, major artificial works, etc.

The main aquifers in the area are near-surface gravels, herein termed the Grimshaw gravels, which are capable of yields in excess of 100 imperial gallons per minute (igpm); and sandstone lenses within the Upper Cretaceous Dunvegan Formation, the cumulative yield of which at any one point may range from 25 to 100 igpm. Water quality is generally good within the Grimshaw gravels, the total dissolved solids content averaging about 500 milligrams per liter (mg/l); and is variable within the Dunvegan Formation ranging from less than 500 mg/l in recharge areas to over 4000 mg/l in discharge areas. Other more locally used aquifers include sand and sand and gravel lenses within the drift. Sands and gravels at and near the base of a buried channel lying at depths of from 500 to 800 feet below ground level constitute a potential aquifer which has not yet been tested for yield.

Calculations of approximate rate of natural recharge to the groundwater reservoir indicate that this may amount to 1.2 to 1.9 inches per year or from 7.5 to 12% of the annual precipitation.

INTRODUCTION

The map of the Grimshaw-Chinook Valley area is the first of a hydrogeological map series to be published by the Research Council of Alberta. The legend follows as closely as possible that suggested by the International Association of Scientific Hydrology (1962), although changes and additions have been found necessary. This map differs from subsequent maps in the series in that it is published at twice the scale and covers only one eighth of the area. This is because it is a prototype map, used in planning the hydrogeological reconnaissance map series, and because of the detail in which the area has been mapped, on a

1:125000 scale (Tokarsky, 1966).

Rutherford (1930) and Jones (1966) conducted previous hydrogeological surveys within the area. Their data is incorporated into the present report.

Agriculture is the principal industry. The two largest towns, Grimshaw and Berwyn, had populations of 1,668 and 446, respectively, in 1968.

Acknowledgments

Field operations were financed jointly by the provincial and federal governments under the terms of the federal Agricultural and Rural Development Act (ARDA). Additional funds for test-drilling operations were received from the Northern Alberta Development Council. This financial support is gratefully acknowledged.

Several other organizations contributed significantly to the project: the Water Resources Division, Alberta Department of Agriculture, who loaned a drilling rig and crew, and who also supplied logs of test holes; McAuley Drilling Company Limited, Edmonton, who supplied water well logs and data; the staff of the Peace River Health Unit, who supplied much hydrochemical data for the area.

Shot hole logs and structure test-hole information were supplied by a number of oil companies and the Alberta Oil and Gas Conservation Board.

Test drilling was ably carried out by R. Forrester Drilling of Red Deer. Field assistance was provided by W. Wolodko and A. Beerwald.

PHYSIOGRAPHY AND DRAINAGE

Three principal physiographic features exist in the map-area.

1) The Whitemud Hills, in the northwest, rising to nearly 2,700 feet above sea level, are underlain by poorly permeable till and shale, and stream density is consequently quite high.

2) A level to rolling northeast-southwest trending plain, on which Cardinal Lake is situated, lies at about 2,100 feet elevation. Extensive near-surface gravels are present on this plain, and because of their permeable nature few streams exist in this area. Springs and seepages, however, are common at and beyond the southeast (downslope) edge of the gravels. The strongest of these

flow at rates in excess of 100 imperial gallons per minute (igpm). The level of Cardinal Lake is continuous with the water table within the gravels, which are only partially saturated over most of their extent.

3) The Peace River valley, 700 to 800 feet deep, cuts across the southeast corner of the map-area.

CLIMATE

According to the Köeppen climatic zone classification (Longley, 1968), the southern portion of the area near the Peace River has long, cool summers, while the northern portion is characterized by short, cool summers. The mean annual temperature at Berwyn is 32.5°F (17 years of record).

Isohyets for the province of Alberta for the 30-year period 1931-1960 have been compiled by Longley (1968). Longley's contours, somewhat modified to conform to topographic features, are shown on the meteorological map.

The mean annual precipitation shown consists of the sum of the mean annual rainfall plus one tenth of the mean annual snowfall (the depth of water resulting from melting newly fallen snow is estimated as one tenth of the depth of snow). Measurements of snowfall are limited to meteorological stations. Rainfall only is recorded at fire lookout towers, which are manned during the period April or May to September or October. One such station, the Whitemud Tower, is shown on the meteorological map. Rainfall amounts to 12.8 inches. If this is considered to form two thirds of the total precipitation, the amount of snowfall would be 64 inches, and total precipitation would be 19.2 inches. This is the value used in the contouring, which illustrates that rainfall, and probably total precipitation also, is heaviest over the area of the Whitemud Hills and decreases away from them.

Sixty to seventy-five per cent of the total precipitation falls as rain; as most of this falls when the soil is unfrozen, it is available for infiltration, although the main replenishment of groundwater supplies occurs during spring snowmelt in April and May. Precipitation is heaviest during the summer months, June, July and August, as is evapotranspiration.

Monthly rates of potential evapotranspiration have been approximated from maps prepared by Bruce and Weisman (1967) who assume that potential evapotranspiration is approximately equal to "free-water" evaporation from small lakes and reservoirs. Values have been calculated for the months May to October only, and are approximately double the amount of rainfall for each of these months. Potential evapotranspiration for the months of snowfall, November to April, is considered to be negligible due to ice formation over open bodies of water. However, a large difference may exist between the values shown and the actual rate of free-water evaporation as the nearest control points are at Beaverlodge and Grande Prairie, some 80 miles southwest of the map-area.

GEOLOGY

Geological reports which cover this map-area include those of the Alberta Study Group (1954), Gleddie (1954), Henderson (1959), Green and Mellon (1962), Burk (1963), and Jones (1966).

The rock units that underlie the poorly consolidated surficial materials are Cretaceous in age. These are shown on the geological map and cross sections. The surficial materials consist mainly of preglacial and interglacial sand, gravel, clay and silt, Pleistocene till and lacustrine clay, and Recent alluvium. The thickness of surficial material reaches a maximum of about 800 feet within the Shaftesbury Channel, a major buried valley within the area (see hydrogeological profiles A-A' and B-B'). This channel lies just to the northwest of the Peace River, runs parallel to it, and represents a preglacial phase of the ancestral Peace system.

The regional dip of the Cretaceous rocks, as indicated by the structure contours, is in a southwesterly direction, at 8 feet per mile in the northern part of the area, steepening to about 25 feet per mile in the southwestern corner.

Shown on the main map is the subsurface extent of the main body of the Grimshaw gravels (Tokarsky, 1966) which form the most extensively utilized aquifer within the area. These shallowly buried gravels lie on a high-level terrace of the more deeply buried Shaftesbury Channel, and constitute much of the northeast-southwest plain referred to under "Physiography."

HYDROGEOLOGY

Due to the density of boreholes within the area, only selected wells are shown on the hydrogeological map. Nearly all are farm wells and over half are hand dug. The towns within the area all utilize well supplies, except for Grimshaw where a horizontal gallery and spring catchment is used.

Water-table contours are shown for the Grimshaw gravels and adjacent areas, as determined during the summer and fall of 1965. They generally reflect the land surface. In the vicinity of Cardinal Lake, groundwater flow, as shown by more detailed contouring (Tokarsky, 1966), is mainly toward the lake. The lake, however, probably feeds the adjacent Grimshaw gravels along part of its southeast shore, as appeared to be the case in the fall of 1965, when water levels were measured.

A few "groundwater mounds" which appear to be unrelated to topography are probably indications of local perched water-table conditions. An apparent groundwater "sink" on the northwest side of Cardinal Lake appears to be due to well completion in till of very low permeability.

Groundwater flow velocities have been calculated for two areas of the Grimshaw gravels, using the formula:

$$v = \frac{K(dh/dL)}{6.25a} \qquad (1)$$

where v = velocity in feet/day,

K = hydraulic conductivity in gals/day/ft^2,

dh/dL = hydraulic gradient in feet/mile,

a = porosity, expressed as a fraction,

6.25 = number of imperial gallons in a cubic foot.

The hydraulic gradient was obtained from the water-table contours, K from the transmissivity values obtained from pump and bail tests, and the porosity was estimated at 25 per cent.

Areas of artesian flow have been outlined. These occur along the base of the Whitemud Hills near the Whitemud River, and downslope from the southeast subcrop edge of the Grimshaw gravels. Many of the flowing wells are completed in sandstones of the Upper Cretaceous Dunvegan Formation, while others are in surficial materials.

Flowing wells near the Whitemud River owe their origin to natural artesian pressures within a relatively homogeneous medium, the Dunvegan Formation (see Tóth, 1962 and Freeze, 1966 for the theoretical principles). The same principles apply in the case of the other belt of flowing wells. In this case, however, a relatively impermeable downflow boundary or natural dam is involved, where sandstones of the Dunvegan Formation are truncated by the poorly permeable fill of the Shaftesbury Channel (see hydrogeological profiles A-A' and B-B').

The average yield expected from individual wells is indicated on the map and cross sections. This value is based on calculations of 20-year safe yield using the formula (Farvolden, 1959, p. 8; Tóth, 1966, p. 74):

$$Q_{s20} = \frac{TH}{2110} \qquad (2)$$

where Q_{s20} = safe yield supplied from existing storage for 20 years in igpm,

T = coefficient of transmissivity in igpd/ft,

and H = total available drawdown in feet.

The transmissivity has been calculated from bail test data using the formula (Todd, 1959, p. 94):

$$T = \frac{264Q}{s} \qquad (3)$$

where s = drawdown difference in ft/log cycle when data are plotted on semi-log paper.

The only pump test information available is that from one test conducted by the Research Council of Alberta. The Research Council has also conducted numerous bail tests, mostly on wells within the area of the Grimshaw gravels. Apparent transmissivities (Farvolden, 1961, p. 9) can be calculated for a very few wells, in which bail or pump tests have been conducted, but only the initial water level and the water level at the completion of the test have been reported. From these tests an approximation of average expected yield may be obtained. The bail test formula cited above was used in calculating these values.

The average yield indicated is obviously a short-term yield and is not the same as the sustained yield at which a well could be pumped without resulting in aquifer depletion. In other words, recharge may not keep pace with groundwater withdrawal and the aquifers may be almost completely dewatered within the stipulated 20-year period. Practical sustained yields therefore, would be generally less than the yield values indicated. The hydrogeological map shows the average expected (short-term) potential yield supplied by all aquifers within the upper 1,000 feet of geological strata at any single location, regardless of groundwater quality. Well interference and overdraft of supplies in storage are not taken into account. The average expected yield shown on the hydrogeological cross sections refers to the short-term yield that is possible from a properly completed single well that taps all aquifers within the gross stratigraphic unit indicated. The exact depth at which an individual aquifer occurs within each stratigraphic unit is not shown. For example, the yield indicated for the Dunvegan Formation may not be possible from a single aquifer within that formation, but should be possible if a multi-aquifer completion is made that includes all aquifers within that formation.

Three areas have been rated as capable of producing over 500 igpm. These are all near Cardinal Lake within the area of the Grimshaw gravels. A pump or bail test is available from a well within each of these areas. Methods outlined by Cooper and Jacob (1946), Walton (1962), and Prickett (1965) have been used in calculating expected yield from pump tests.

Expected yields of 100 to 500 igpm have been assigned to most of the area covered by the Grimshaw gravels, and to one area outside of it, where a particularly strong spring and flowing wells indicate potentially high yields. Low-lying terraces along the Peace River are probably also capable of such yields. This is indicated by one bail test. Sands and gravels in a buried channel near the Peace River have also been assigned a high yield. These have not been tested.

Relatively low expected yields are postulated for the Peace River Formation and for sandstones within the underlying Spirit River Formation. Neither of these have been tested for yield. A low yield is assumed for lenses of sand and gravel within till and lacustrine sediments.

The lowest expected yields, of less than 1 igpm, have been assigned to shale and clay formations, although locally higher yields may be obtained from sandy lenses or fractured zones. Water from fractured shale has been reported from wells near Brownvale.

In some cases, yields from a certain rock unit can be expected to be higher near the discharge end of the flow system than they would be near the recharge end. This is due in part to a higher head within the formation at the lower end of the flow system. Such a situation is illustrated for the Peace River Formation, although no production tests have been carried out to substantiate this.

Four hydrogeological profiles have been constructed. The profiles give the vertical or third dimension of information shown on the main map and on the geological and hydrochemical side maps.

Profile B-B' has been constructed approximately parallel to regional slope directions. Approximate directions of groundwater flow have been indicated on this profile. Profiles A-A' and C-C' have been drawn obliquely to general slope directions, and profile D-D' almost at right angles to the regional slope. Since actual groundwater flow directions are oblique to the plane of these profiles, only a component of the flow direction is shown.

HYDROCHEMISTRY

Water analyses from more than 300 wells were available for the construction of the hydrochemical map. The 60 per cent values of the various cations and anions have been contoured, based on percentage of equivalents per million. These are the limits of the cation and anion end members as proposed by Davis and De Weist (1966, p. 119). Since existing water wells are completed to depths of generally less than 200 feet, this map represents only the chemistry of waters within this depth interval. Chemical changes in a vertical direction are shown on the hydrogeological profiles.

Groundwater chemistry is dependent, at least in part, on: 1) the chemical composition of the material through which the water moves; 2) the distance the water has moved and the length of time it has taken to negotiate this distance; and 3) possibly residual salinity at greater depths. Thus, waters which move through sandy or gravelly materials do not add appreciably to their content of total dissolved constituents, both because of relatively rapid movement, and because of lack of readily available material to enter into solution. Waters within argillaceous materials, on the other hand, move relatively slowly, and so have longer residence times. In addition, the clay minerals contain constituents readily available for solution and ion exchange. Consequently, rather rapid changes in groundwater chemistry are possible over short distances.

In the near-surface waters, sulfate ions are dominant and occur in both recharge and discharge areas. The bicarbonate-carbonate end member occurs mainly in areas of downward moving waters.

Of the cations, the calcium end member is found mainly in recharge areas, and the sodium end member mainly in discharge areas. The amount of total dissolved solids increases rapidly away from areas of recharge.

Anion end members occur together with cation end members as follows: sodium sulfate waters in discharge areas, calcium bicarbonate waters mainly in recharge areas, and some calcium sulfate waters in either recharge, discharge or indeterminate areas. Intermediate type waters are the commonest types of waters in the Grimshaw gravels.

As potability limits are normally quoted in parts per million, a conversion table is included as an appendix, by which the parts per million content of certain constituents may be approximated if the total dissolved solids content and the percentage value of equivalents per million is known.

The ratio of calcium to magnesium, shown on a separate side map, in general decreases away from recharge areas. High values of this ratio near the edge of the Peace River valley imply local recharge conditions at the top of the bank.

The amount of iron present in well waters, shown on a separate side map, generally increases along lines of groundwater flow. Thus it is lowest in recharge areas and highest in discharge areas. Waters high in iron also tend to be high in total dissolved solids, and in sulfate content.

Sodium chloride waters occur at depth, within the Peace River Formation and older formations. Water types within the Shaftesbury Formation are not known. Sodium chloride waters may predominate, although high sulfate waters may occur in the upper parts of the formation. Regardless of type, it is most probable that the water will be highly mineralized. The upper contact of this formation is taken as the lower limit of potable waters, even though highly mineralized, non-potable waters are present also in many places in overlying materials.

Water within the Grimshaw gravels is of good quality, as is water within the Dunvegan Formation beneath the gravels and near the Whitemud Hills. Water quality within surficial materials is generally poor because of low permeabilities and slow movement of water through them, or due to positions in low-lying areas (areas of upward moving groundwater near the end of a flow system). Similarly, water quality within the Dunvegan Formation deteriorates with increasing distance from areas of recharge.

Groundwater Budget

Calculations of groundwater budget were attempted using three methods, none of which is particularly precise because of the assumptions that had to be made. The first two methods are applicable to the area or region as a whole; the third applies more specifically to the areas underlain by Grimshaw gravels.

Method No. 1

This method (Freeze, 1964, p. 7) involves the calculation of the percentage of a stream's discharge that is due to groundwater inflow. If it is assumed that the mean minimum discharge represents baseflow, and that 70 per cent of this is due to bank storage (Meyboom, 1967a, p. 154), then 30 per cent of the baseflow represents the groundwater contribution from any particular drainage area, provided that all groundwater discharges at the stream. This is not usually the case, as discharge typically takes place over a zone (Tóth, 1962), so that not all of the groundwater reaches the stream. The value for groundwater contribution to the streamflow obtained by this method should therefore be somewhat lower than the actual amount of groundwater discharge.

Streamflow data obtained from the three gauging stations in the region (Table 1) were used to make an estimate of stream discharge for a 3,300 square mile region between Dunvegan and Peace River town. Roughly half of the Grimshaw-Chinook Valley area lies within this region, and thus applicability of the results is considered a reasonable approximation.

The minimum monthly discharge of a stream usually occurs during winter, when much of the flowing water freezes, or during late summer when evapotranspiration in the area greatly exceeds rainfall. The monthly discharge at these times may thus be less than the actual amount of baseflow contribution. For the Peace River district, therefore, stream discharge is considered to approximate most closely to baseflow additions during the month of October, when rainfall and evapotranspiration are both low, and when temperatures are still generally above freezing. Fluctuations in discharge rates are less than for other months of the year (excluding winter months) and flow rates are generally low.

Four years of streamflow records were used in the calculations that follow (Table 1).

Table 1. Discharge of Peace River at Selected Stations for Month of October, 1960 to 1963

Gauging station	Drainage area (sq mi)	Discharge in thousands of cfs Oct. 1960	Oct. 1961	Oct. 1962	Oct. 1963	Mean Oct. discharge 1960 to 1963, inclusive (thousands of cfs)
Peace River at Dunvegan	50,200	48.4	43.1	41.3	44.5	44.3
Peace River at Peace River	72,000	51.7	52.9	51.8	50.2	51.65
Smoky River at Watino	18,500	4.9	10.1	6.4	6.0	6.85

Drainage area under consideration
= (72,000 - 50,200) - 18,500 = 3,300 square miles

Mean baseflow (month of October, 1960 to 1963, inclusive)
= (51,650 - 44,300) - 6,850 = 500 cfs

"Cubic feet per second" may be converted into "inches depth on the drainage area per year" by using the following formula derived by Freeze (1964, p. 7):

$$Di = \frac{Q}{A} \times 13.5$$

$$= \frac{500}{3300} \times 13.5$$

$$= 2.05 \text{ inches}$$

where Di = depth in inches on the drainage area per year;

Q = discharge in cfs;

A = drainage area in square miles.

If 30 per cent of the discharge represents the groundwater contribution, then this amount is: 2.05 x 0.3 = 0.615 inches/year on the drainage area, or 3.8 per cent of the mean annual precipitation of 16 inches. If it is assumed, following Tóth (1962), that the area is fairly equally divisible into recharge and discharge areas, then recharge to the groundwater system will take place over roughly half of the total area. Thus recharge can be estimated at 1.23 inches or 7.6 per cent of the precipitation over the recharge areas. Recharge is assumed to be essentially nil in discharge areas.

Method No. 2

The method of Thornthwaite (1948) was used to calculate potential evapotranspiration and amounts of soil water replenishment and water surplus. The method is too lengthy to show the detailed calculations. Using records from the meteorological station at Berwyn, an annual potential evapotranspiration of 19.2 inches was obtained. This compares with a value of approximately 22 inches obtained from maps prepared by Bruce and Weisman (1967) for which accuracy to within 10 to 15 per cent is claimed.

Assuming that the records from the Berwyn station are representative of conditions for farmland sown to cereal crops, and assuming an annual utilization of 4 inches of soil moisture by cereals (MacIver, 1965), then using the Thornthwaite method of calculation, 1.43 inches of moisture, or 8.7 per cent of the total annual precipitation remains available for runoff or for groundwater recharge. The volume of surface runoff is not known, nor can it be satisfactorily estimated, as streamflow records for Dunvegan are kept only from May to October. However, as permeabilities of materials underlying the soils are quite high in the Berwyn area, it can be assumed that runoff will be fairly low. The amount of annual groundwater recharge is thus probably somewhat less than 8 per cent of the total annual precipitation over recharge areas.

A similar calculation was made using data from the meteorological station at the Peace River Airport. Replenishment of soil moisture reserves at this location was calculated to be less than the 4 inches needed by cereal crops, and infiltration to recharge groundwater reserves could not take place.

The Thornthwaite method of calculating recharge to the groundwater reservoir has a number of shortcomings. Among these are:

1) difficulty of determining consumptive use over large areas by plants accurately,
2) strict applicability of results only to a small area near the meteorological station,
3) general paucity of meteorological stations on a year-round basis in topographically high areas where most recharge occurs.

Method No. 3

Tóth (1968, p. 35-37) has used monthly water level records during periods of ground frost to calculate a groundwater balance.

In the Grimshaw area, automatic water-level recorders were installed at three locations in the fall of 1965 in wells completed in the Grimshaw gravels. The records for two of these are not suitable for a water balance calculation. In the third well an average drop of 0.32 feet over a six-month period of ground frost is indicated over three winters (1965-66, 1966-67, and 1967-68) (i.e. when no recharge was being received). This is equivalent to 3.8 inches for a six-month period or 7.6 inches over one year. Assuming a specific yield of 0.25 for the Grimshaw gravels, a net fluid change of 7.6 x .25 = 1.9 inches/year is indicated. Thus, the amount of annual recharge is 1.9 inches or 12 per cent of the mean annual precipitation.

Comparison of Results

The results of the methods discussed above are summarized in table 2. It will be noticed that the highest value of recharge rate, obtained by use of method 3, was obtained by consideration only of the area underlain by near-surface gravels of high permeability. The rate of recharge over this rather limited area is probably indeed greater than it would be over a more extensive area including subsurface materials of lower permeability.

Table 2. Comparison of Results

	Amount of recharge		Probable reliability of results	
Method	in inches	as per cent of annual precipitation	good	poor
Baseflow method	1.23	7.6		x
Thornthwaite method	1.4	<8		x
Water-level records method	1.9	12	x	

Other Methods

Other methods of determining a groundwater balance are available. Chief among these is the quantitative flow net across a groundwater basin (Freeze, 1968). Calculations of recharge from piezometer installations over small areas have been made (Meyboom, 1967b), as well as calculations of groundwater discharge, using steady-state drainage equations (Meyboom, 1967b). For various reasons, these methods have not been applied in the Grimshaw area.

CONCLUSIONS

The hydrogeological map, together with side maps and cross sections, is an interpretative representation of information relevant to a hydrogeological study of a region. This series of maps will enable quick determination of many aspects of hydrogeology, including delineation of areas of differing groundwater yield, hydrochemistry, the nature and extent of aquifer materials, and information on water levels, drilling depths, and drilling conditions.

The maps are largely self-explanatory, requiring a minimum of accompanying text.

Calculations of the groundwater budget indicate that from 7.5 to 12 per cent of annual precipitation or 1.2 to 1.9 inches of rain on the drainage area per year serve to provide recharge to the groundwater body.

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APPENDIX A.

TABLE FOR CONVERSION OF TOTAL DISSOLVED SOLIDS IN PARTS PER MILLION TO PARTS PER MILLION OF VARIOUS ANIONS AND CATIONS

(E. G. Le Breton and O. Tokarsky)

APPENDIX A. TABLE FOR CONVERSION OF TOTAL DISSOLVED SOLIDS IN PARTS PER MILLION TO PARTS PER MILLION OF VARIOUS ANIONS AND CATIONS

(E. G. Le Breton and O. Tokarsky)

Total dissolved solids	Water in which CO_3 makes up 100% of the anions						Water in which SO_4 makes up 100% of the anions						Water in which Cl makes up 100% of the anions					
	100% $NaCO_3$		100% $CaCO_3$		100% $MgCO_3$		100% $NaSO_4$		100% $CaSO_4$		100% $MgSO_4$		100% NaCl		100% CaCl		100% MgCl	
	CO_3:Na 1.3:1		CO_3:Ca 1.5:1		CO_3:Mg 2.47:1		SO_4:Na 2.09:1		SO_4:Ca 2.4:1		SO_4:Mg 3.95:1		Cl:Na 1.54:1		Cl:Ca 1.77:1		Cl:Mg 2.92:1	
ppm	ppm		ppm		ppm		ppm		ppm		ppm		ppm		ppm		ppm	
	CO_3	Na	CO_3	Ca	CO_3	Mg	SO_4	Na	SO_4	Ca	SO_4	Mg	Cl	Na	Cl	Ca	Cl	Mg
500	283	217	300	200	356	144	338	162	353	147	399	101	303	197	320	180	372	128
750	424	326	450	300	534	216	507	243	528	222	598	152	454	296	480	270	558	192
1000	565	435	600	400	712	288	676	324	706	294	798	202	606	394	640	360	744	256
1250	707	543	750	500	890	360	845	405	882	368	999	251	758	492	800	450	930	320
1500	849	651	900	600	1068	432	1014	486	1059	441	1197	303	909	591	960	540	1116	384
1750	990	760	1050	700	1246	504	1183	567	1236	514	1397	353	1061	689	1120	630	1302	448
2000	1133	867	1200	800	1424	576	1352	648	1412	588	1596	404	1212	788	1280	720	1488	512
2500	1415	1085	1500	1000	1780	720	1690	810	1765	735	1995	505	1515	985	1600	900	1860	640
3000	1700	1300	1800	1200	2136	864	2028	972	2117	883	2494	606	1818	1182	1920	1080	2232	768

Use of the Table

By the use of the table, together with a few simple calculations, a conversion can be approximated from percentage of equivalents per million to parts per million for the various ions listed.

For example, at a point on the map in section 25, township 83, range 25, west fifth meridian, dissolved solids equal approximately 1000 ppm, sulfates exceed 60% of the total anions, and no one constituent exceeds 60% of the total cations. At this point, we can estimate that Ca, Mg and Na percentages are almost equal. Using the table for 100% SO_4 waters, which is a close approximation of the actual case, we can determine that the parts per million of sulfate will be more than 436 and less than 727 (60% and 100%, respectively, values of the average of 676, 706, and 798). Assuming that 500 ppm of sulfate is the upper limit of potability (a figure often used in Alberta), then the water is probably non-potable, but may be of marginal quality. The values obtained are not absolutely correct because of the probable presence of other anions, but they do give an approximation of the sulfate content.

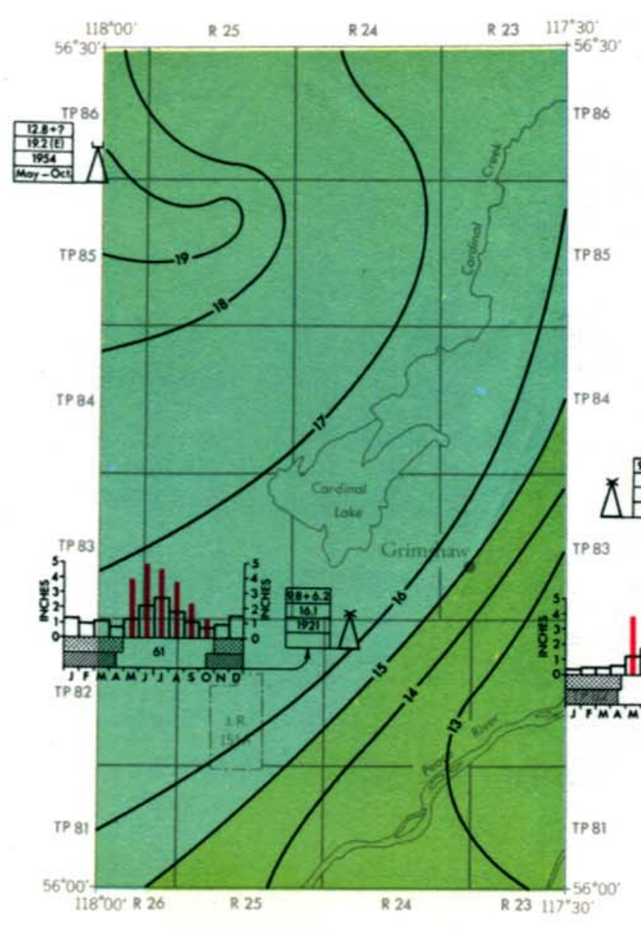
METEOROLOGY

LEGEND

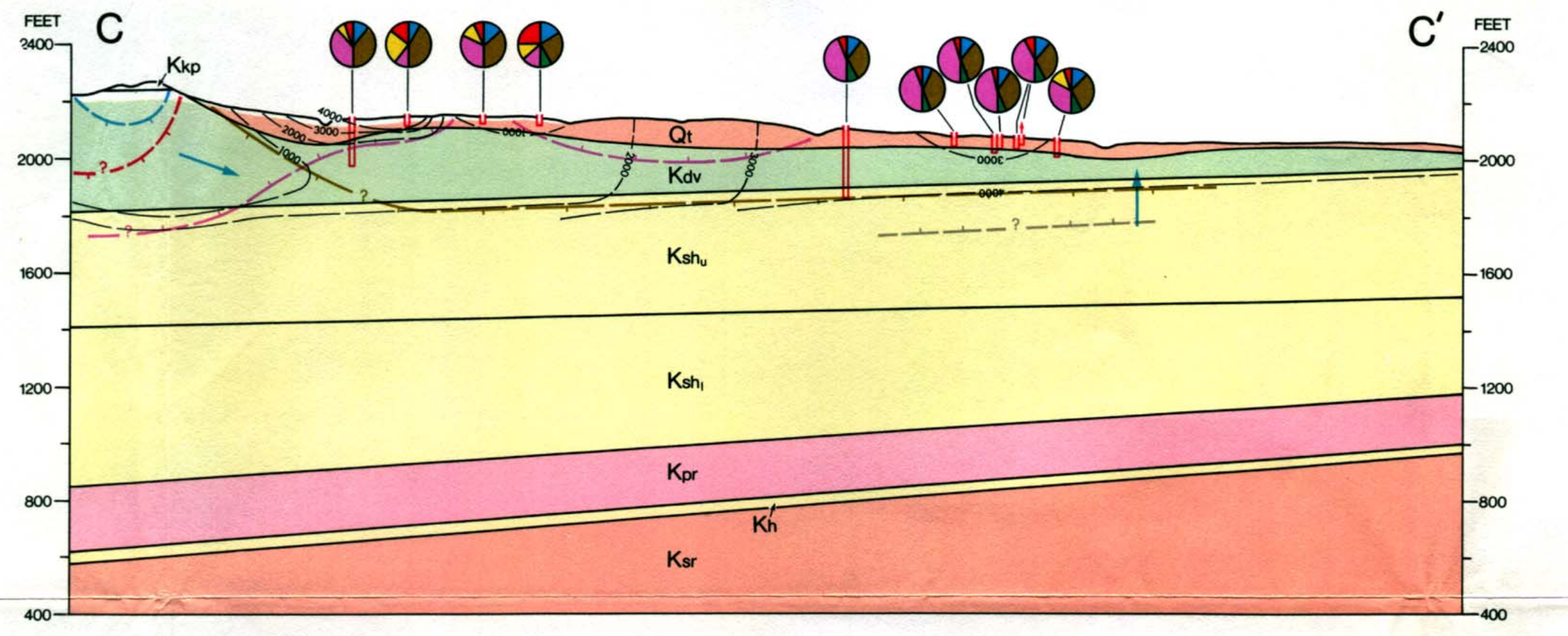
Mean annual precipitation:
- 🟩 less than 15 inches
- 🟩 15 to 20 inches
- Isohyet, mean annual precipitation in inches
- Meteorological station
- Rain gauge only

Precipitation data
- Mean annual rainfall + estimated (1/10) or measured rainfall equivalent of snowfall (? indicates snowfall not measured)
- Mean annual precipitation, in inches (E indicates estimated)
- Commencement of observations
- Months of record if less than full year
- Mean monthly potential evapotranspiration (estimated)
- 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

Source of data: Climatic Maps for Alberta (Longley, 1968) and Monthly Record of Meteorological Observations (Meteorological Branch, Canada Department of Transport)

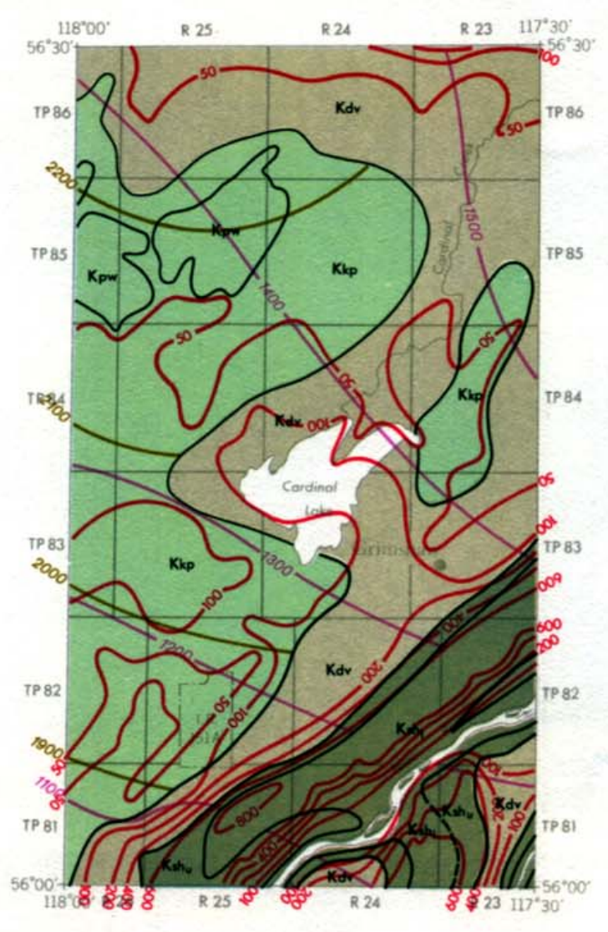


SCALE 1:500,000
Miles 5 0 5 10 Miles
Kilometers 5 0 5 10 15 Kilometers



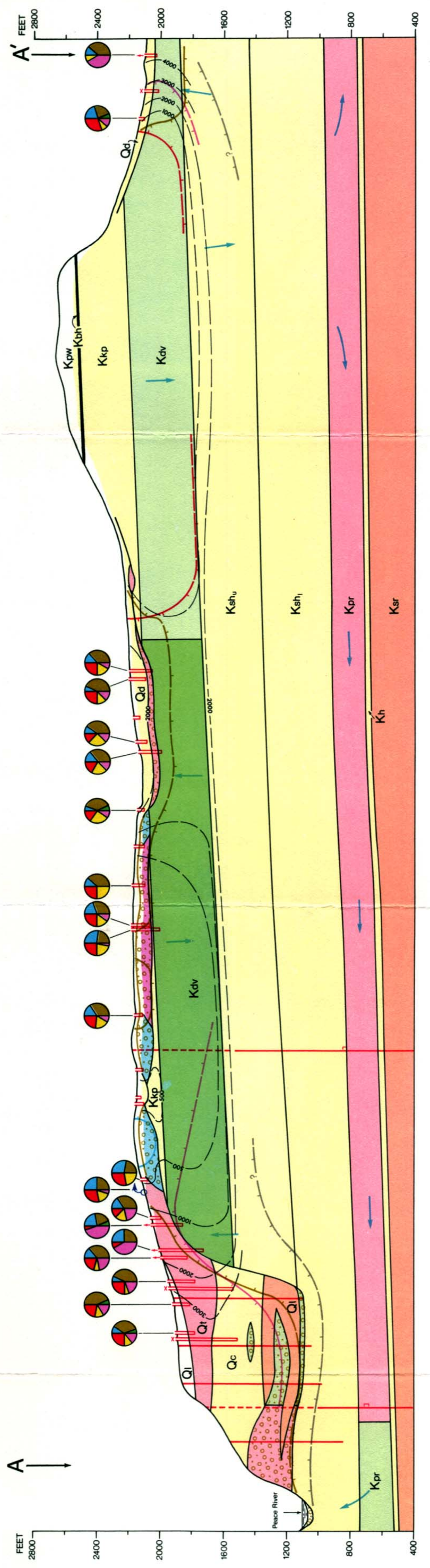
GEOLOGY

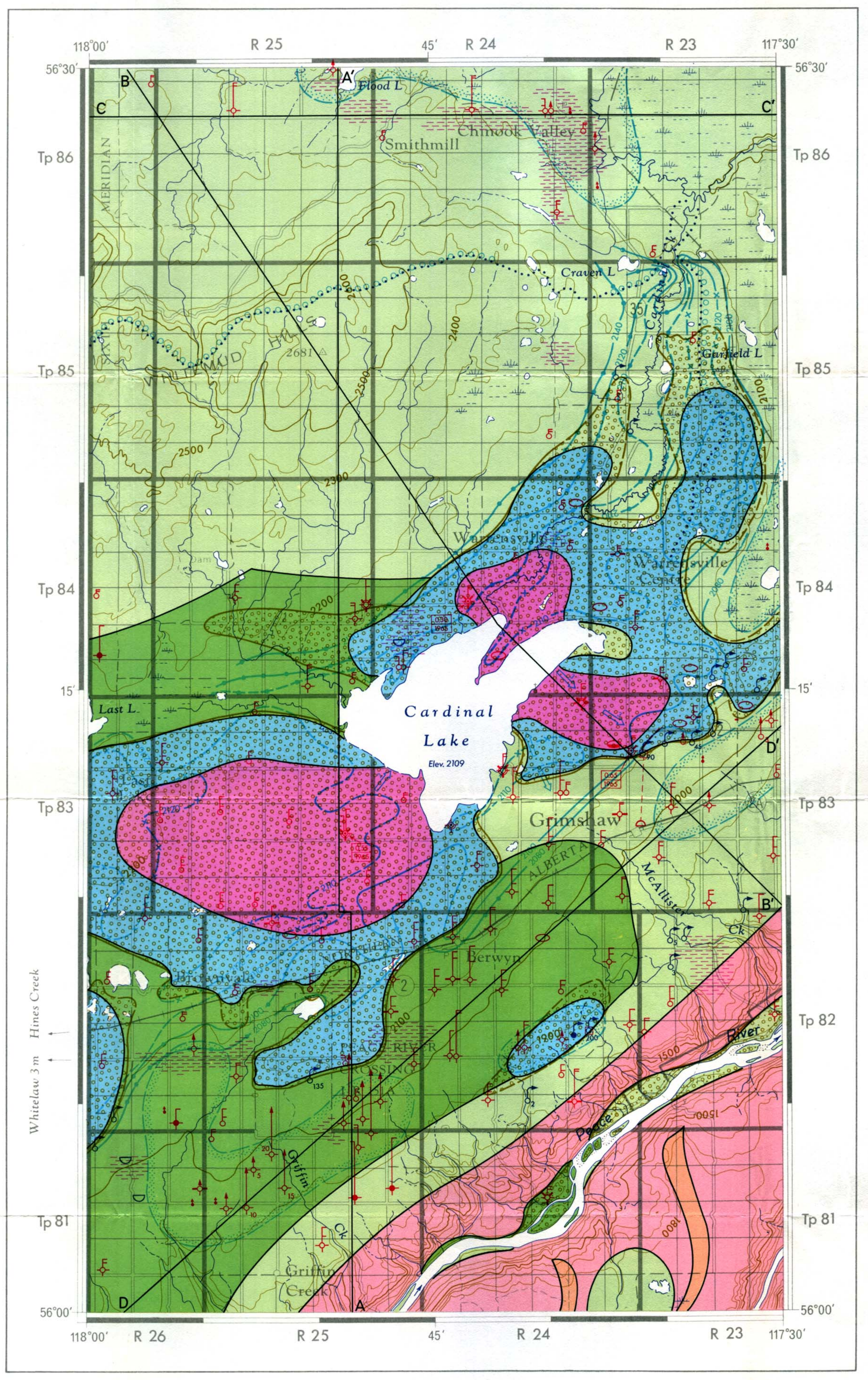
LEGEND



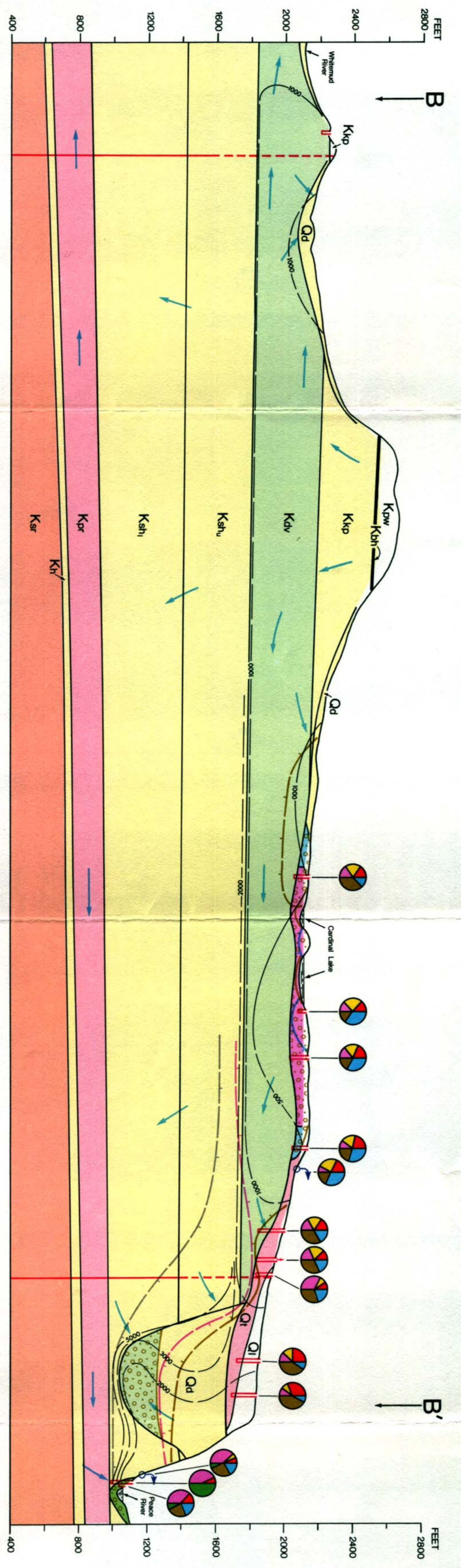
- Kpw Puskwaskau Formation: *shale*
- Kkp Kaskapau Formation: *shale*
- Kdv Dunvegan Formation: *sandstone, siltstone, shale*
- Ksh_u, Ksh_l Shaftesbury Formation, upper (u) and lower (l) members: *shale*
- Rock unit boundary
- Thickness of surficial deposits, in feet
- Structure contour on top of Dunvegan Formation
- Structure contour on top of lower member, Shaftesbury Formation

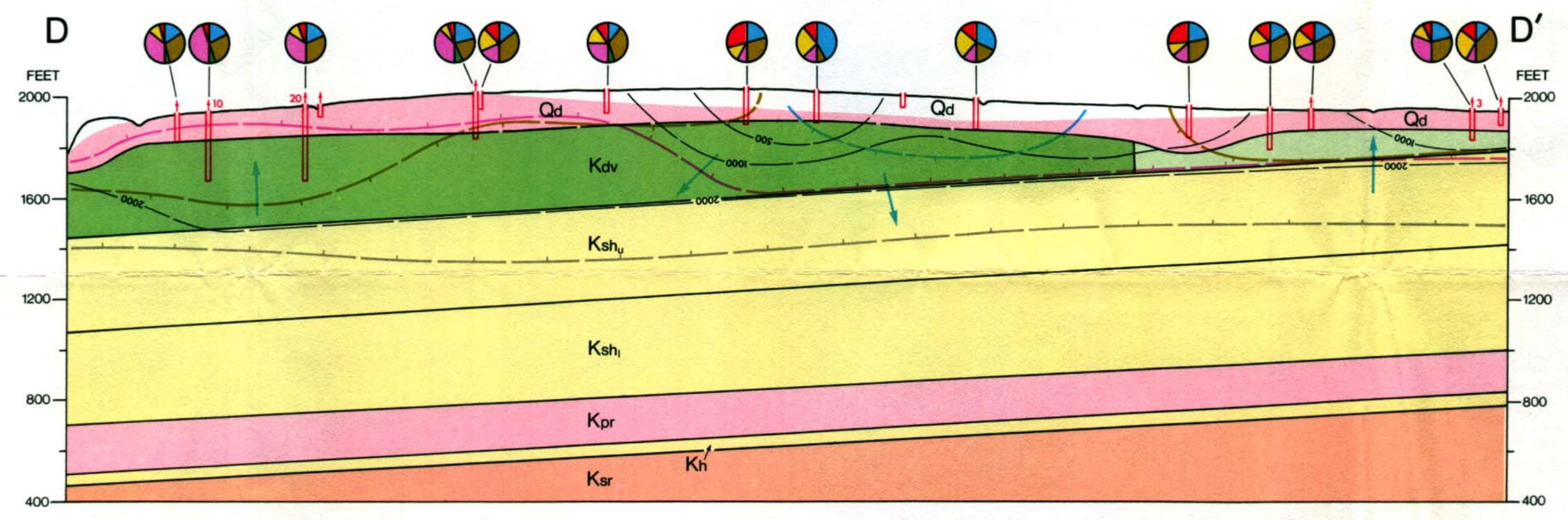
SCALE 1:500,000
Miles 5 0 5 10 Miles
Kilometers 5 0 5 10 15 Kilometers





SCALE 1:125,000
Miles 5 0 5 10 Miles
Kilometers 5 0 5 10 15 Kilometers
WEST OF FIFTH MERIDIAN





MAIN MAP LEGEND

Topography
- Surface contours (interval 100 feet)

Geology
Boundary of significant near-surface water-bearing deposits:
- known
- approximate

Lithology
- Sand and gravel

Hydrography
- Surface water divide
- Spring and flow rate, in imperial gallons per minute
- Spring, inactive
- Natural pond or water hole with no outlet
- Stream
- Stream, intermittent or dry
- Lake
- Lake, intermittent
- Marsh or swamp

Groundwater hydrology
- Upward flow / Downward flow: Water table contour (elevation in feet above mean sea level)
- Direction and calculated velocity of groundwater flow (in feet per day)
- Groundwater divide
- Boundary of area of artesian flow (stipple lies within the boundary)
- Area of salt precipitates
- Nonpumping water level

Boreholes, Wells and other works
- Borehole, seismic shot hole, test hole, etc.
- Location of former flowing seismic shot hole
- Water well, dug or bored
- Water well, dug or bored, flowing, and flow rate in imperial gallons per minute
- Water well, drilled
- Water well, drilled (bar shows well depth and depth to water; scale 1 mm = 20 feet)
- Water well, drilled, flowing, and flow rate in imperial gallons per minute (length of arrow indicates well depth; scale 1 mm = 20 feet)
- Water well, drilled, nonproductive
- Test well
- Drilled well, site of pump test (24 hours or longer), 20-year safe yield calculated
- Drilled well, site of bail test or short pump test, 20-year safe yield calculated
- Drilled well, safe yield estimated from apparent transmissivity
- Observation well, provided with automatic recorder
- Observation well, recording lake level, provided with automatic recorder
- 0.65 Mean annual water level fluctuation, in feet
- 1965 Commencement of observations
- Differing water levels from different depths, in same well or closely adjacent wells
- Cistern, storage tank
- Developed spring
- Infiltration gallery
- Water pipeline
- Gravel pit, dry
- Gravel pit, containing water
- A A' Line of hydrogeological profile

Groundwater Probability*

Average expected yield of wells (in imperial gallons per minute)
established from pump or bail tests, etc.
estimated, from flow regime, lithology, etc.

established	estimated	
🟪		
🟦		500
🟩	🟩	100
	🟥	25
	🟧	5
	🟨	1

White area within hydrogeological profiles indicates the unsaturated zone.

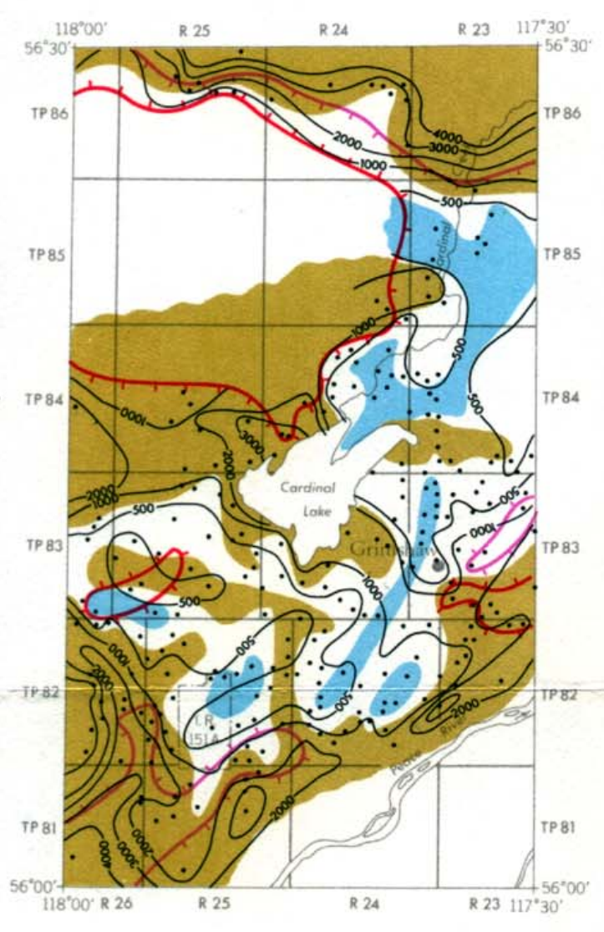
*The expected yields of wells are predictions, based on the best data available at the time of map compilation; due to data shortcomings, local variations in geology, well completion techniques and similar noncontrollable factors, less water may be obtainable from some individual wells than the yield range predicted.

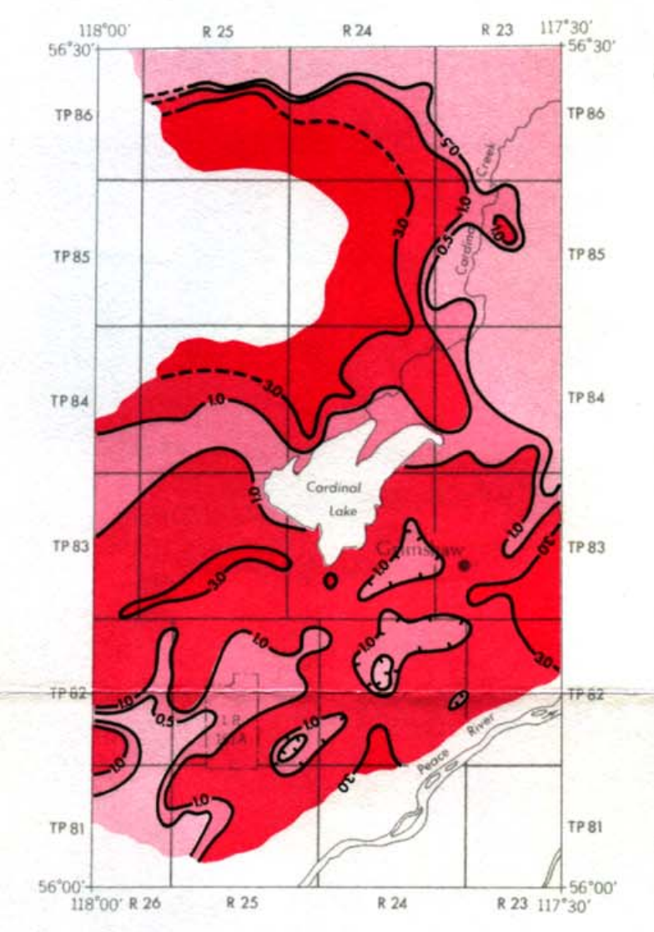
HYDROCHEMISTRY

LEGEND

- Total dissolved solids, in parts per million
- Sulfate constituting over 60 per cent of total anions, on equivalents per million basis
- Bicarbonate + carbonate constituting over 60 per cent of total anions, on equivalents per million basis
- Isogram along which calcium constitutes 60 per cent of total cations; teeth indicate direction of lesser calcium content
- Isogram along which sodium + potassium constitutes 60 per cent of total cations; teeth indicate direction of lesser sodium + potassium content
- · Data point

SCALE 1:500,000
Miles 5 0 5 10 Miles
Kilometers 5 0 5 10 15 Kilometers





CALCIUM-MAGNESIUM RATIO

LEGEND

- < 0.5
- 0.5 to 1.0
- 1.0 to 3.0
- > 3.0
- good control
- poor control

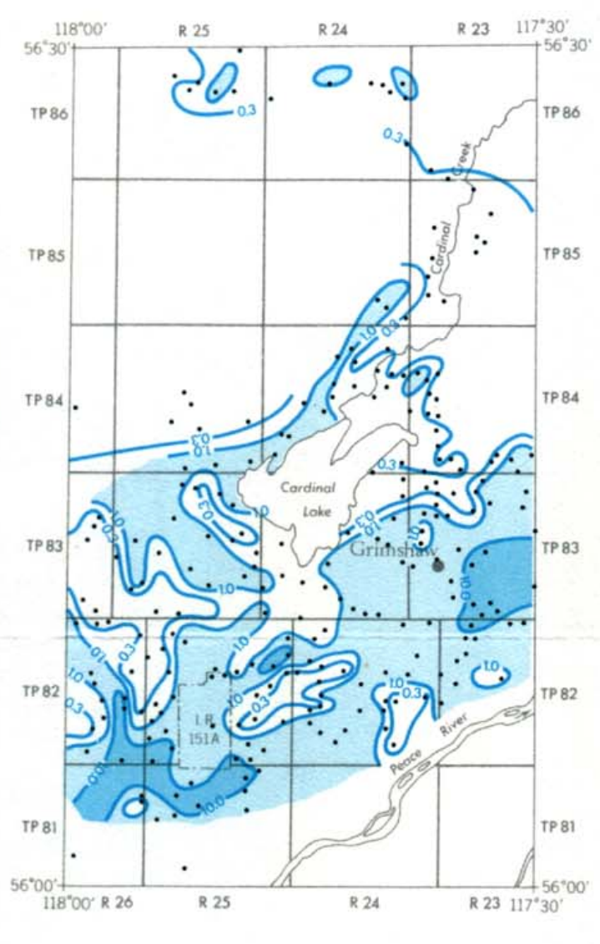
SCALE 1:500,000
Miles 5 0 5 10 Miles
Kilometers 5 0 5 10 15 Kilometers

IRON CONTENT

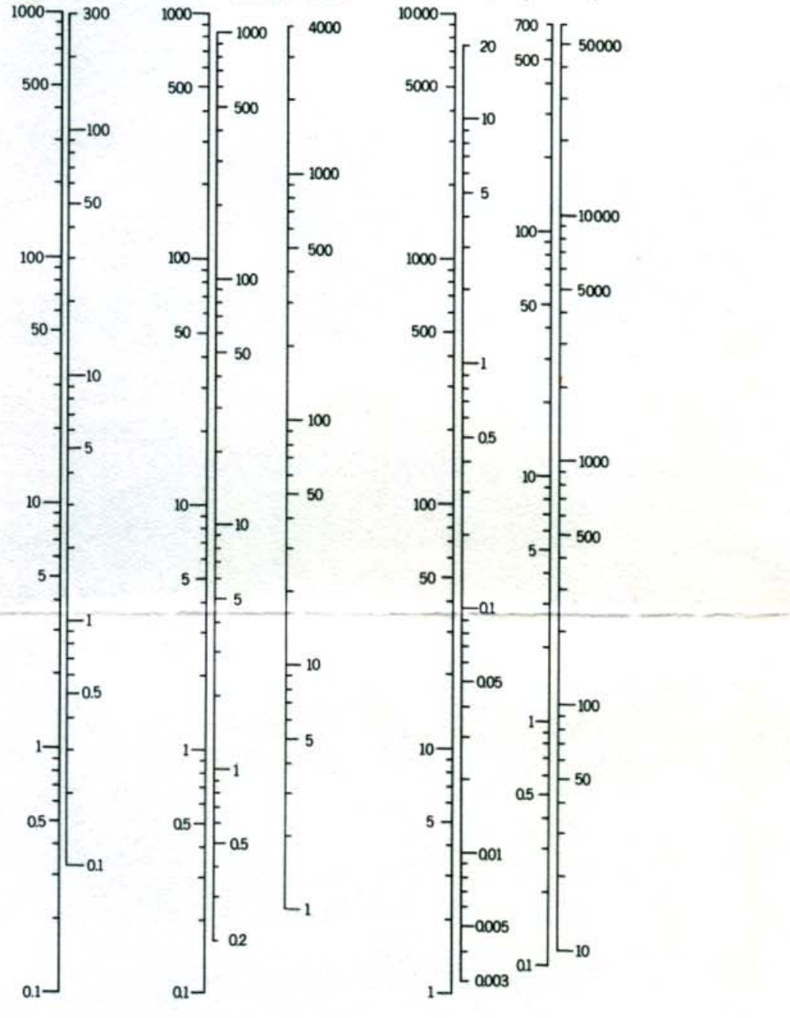
LEGEND

- Iron content in parts per million
- Iron content ranging between 1.0 and 10 parts per million
- Iron content over 10 parts per million
- · Data point

SCALE 1:500,000
Miles 5 0 5 10 Miles
Kilometers 5 0 5 10 15 Kilometers



CONVERSION TABLE
LOGARITHMIC SCALE



HYDROGEOLOGICAL PROFILE LEGEND

(horizontal scale same as main map scale;
vertical scale: 1 cm = 200 ft.;
vertical exaggeration about 20x)

Geology

QUATERNARY

- Qd Drift: *unconsolidated surficial deposits*
- Qt Till, clayey: *local pockets of sand and gravel*
- Qc Clay and silty clay: *lacustrine and slack water deposits*
- Ql Clay, silt: *lacustrine deposits*

UPPER CRETACEOUS

- Kpw Puskwaskau Formation: *dark grey fissile shale: 0 - 130 feet*
- Kbh Bad Heart Formation: *black, orange-weathering, oolitic, iron-rich sandstone*
- Kkp Kaskapau Formation: *dark grey fissile shale, sandy and silty shale, sandstone; 0 - 370 feet*
- Kdv Dunvegan Formation: *grey silty carbonaceous shale, beds and lenses of grey, soft, clay-cemented sandstone; 0 - 405 feet*
- Ksh_u Shaftesbury Formation, upper member: *grey silty shale, siltstone lenses; 0 - 460 feet*

LOWER CRETACEOUS

- Ksh_l Shaftesbury Formation, lower member: *dark grey fissile shale; 270 - 460 feet*
- Kpr Peace River Formation, Paddy and Cadotte Members: *poorly sorted, fine- to medium-grained sandstone, locally shaly; 100 - 165 feet*
- Kh Peace River Formation, Harmon Member: *dark grey shale, minor siltstone, sandstone: 40 - 70 feet*
- Ksr Spirit River Formation: *grey shale, fine-grained sandstone, local coal seams; fine- to medium-grained sandstone in upper part*

Boreholes, wells and other works

- Water well or test well
- Water well, nonproductive
- Water well, flowing, and flow rate in imperial gallons per minute
- Geological test hole
- Exploratory oil or gas well; broken line indicates surface casing interval
- Interval of drill-stem test

Groundwater hydrology and chemistry

- Component of groundwater flow direction

- Total dissolved solids, in parts per million
- Isogram along which calcium constitutes 60 per cent of total cations*
- Isogram along which sodium + potassium constitutes 60 per cent of total cations*
- Isogram along which carbonate + bicarbonate constitutes 60 per cent of total anions*
- Isogram along which sulfate constitutes 60 per cent of total anions*
- Isogram along which chloride constitutes 60 per cent of total anions*

*1) determined on equivalents per million basis.
2) teeth indicate direction of lesser cation content

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Shot hole logs and structure test hole information were supplied by a number of oil companies and the Alberta Oil and Gas Conservation Board.

HYDROGEOLOGICAL MAP
GRIMSHAW - CHINOOK VALLEY
NTS 84C/4 AND 84C/5
ALBERTA

Published 1970

Hydrogeology by O. Tokarsky, 1968, based on data collected in 1965
Cartographic editing by R. Green; drawn by H. Weiss

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