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Hydrogeology of the Sand River Area, Alberta

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ABSTRACT

The hydrogeology of the aquifers in the uppermost 1,000 feet (about 300 m) of the Sand River area is described. Maps and profiles were constructed from existing data and from data collected by a field survey and drilling and testing operations. The 20-year safe yields range from 1 igpm (about 5 L/min) to more than 100 igpm (about 450 L/min). The best aquifers are Quaternary sands and gravels and Upper Cretaceous Wapiti sandstones.

Water quality is typically calcium-magnesium bicarbonate type with local occurrence of calcium-sulfate, sodium-sulfate, and sodium-bicarbonate type water. Total dissolved solids average 1,000 ± 600 ppm. High iron and nitrate concentrations are the main water quality problems in the area.

INTRODUCTION

The Sand River area (NTS 73L) is located between longitudes 110° (the Alberta-Saskatchewan provincial boundary and the 4th Meridian of the Canadian land survey system) and 112° west and latitudes 54° and 55° north, and covers wholly or partly Tp 58 to 69 and R 1 to 14, west of the fourth meridian. The total area is about 5,524 square miles (14,300 km^2).

The southern and western parts of the area have a satisfactory network of paved and gravelled roads, including highways 28 and 28A to Cold Lake. Two main railways provide service to the area and there are also local airfields. The northeastern and north-central parts are practically roadless. An extensive part of the roadless tracts belongs to the Department of National Defense Primrose Lake Air Weapons Range. The map area also encompasses Garner Lake, Sir Winston Churchill, and Moose Lake Provincial Parks; Beaver Lake, Cold Lake, Saddle Lake, Whitefish Lake, Heart Lake, Kehiwin, and Puskiakiwenin Indian Reserves; Nos. 7, 9, and 10 Metis Colonies; and the Cold Lake RCAF Station.

Within the area, the towns and their populations as of 1978 are: Grand Centre (2751), Bonnyville (2873), Lac La Biche (1948), Cold Lake (1303), and Vilna (335) (Travel Alberta, 1978). All these communities have waterworks based on groundwater supplies (Alberta Environment, 1976).

The primary vegetation of most of the map area is aspen poplar. Treed muskeg of *Sphagnum* mosses and black spruce and tracts of jackpine - white spruce forests are found in smaller areas (Alberta Government and University, 1969, p. 9). Farming is concentrated along the highways and scattered over the remainder of the area except in the northeast and north-central parts. Lumbering is an important industry. There is extensive natural gas production, and the heavy oil deposits of the Cold Lake area constitute a potential energy resource.

Some regional hydrogeological (Le Breton, 1963) and hydrochemical (Le Breton and Jones, 1962; van Everdingen, 1968) studies overlapped the area. Several detailed investigations were carried out by the Alberta Department of the Environment: water supply studies at Elizabeth Metis Colony (Prosser, 1973) and Elinor Lake (Hardick, 1974) and a study of buried channels in the major part of the Sand River area (Yoon and Vander Pluym, 1974). Data regarding surface waters were published by Inland Water Directorate (1976). The neighbouring map areas have already been mapped hydrogeologically (Christiansen and Whitaker, 1974; various Alberta Research Council maps).

In 1971 R. Stein prepared a Hydrogeological Information Map Atlas at a scale of 1:50,000 covering the map area and incorporating all hydrogeological data available in published literature and in the Alberta Research Council files. In 1974, this Atlas was updated.

A field survey including helicopter flights, groundwater sampling, drilling operations and aquifer testing was carried out in 1974. In 1974-75 a detailed hydrogeochemical study was carried out by E. Wallick, along a profile line. The hydrogeological reconnaissance maps and profiles and the report were prepared in the winter of 1974-75. The maps and profiles follow the Alberta Research Council standard legend (Badry, 1972).

In addition to the usual airphoto interpretation, ERTS-1 satellite images also were studied and interpreted (Ozoray, 1975a, 1975b).

ACKNOWLEDGMENTS

Test drilling was carried out by Universal Drilling Contractors of Three Hills, whose driller was W.B. Hansen, assisted by L. Mudryk. Aquifer tests were carried out by L.L. Chorney, Sugden.

The water samples collected during field work were analyzed in the Chemical Laboratory of the Research Council of Alberta, headed by J.R. Nelson.

Advice regarding the bedrock topography side map was received from V. Carlson, R. Green, and J. Kramers. The manuscript was critically read by G. Gabert and D. Hackbarth.

TOPOGRAPHY AND DRAINAGE

The map area lies within the Alberta High Plains portion of the Interior Plains and includes parts of the Mostoos Hills Upland and Eastern Alberta Plains physiographic regions (Alberta Government and University, 1969, p. 9). The highest elevation of the area is about 2,830 feet (863 m) above mean sea level and is found in the north-central part of the area, near Heart Lake lookout. The lowest point, where the Beaver River leaves the area to the southeast is about 1,620 feet (494 m). This corresponds to about 1,210 feet (369 m) variation in elevation within the area.

The topography is rolling hills and undulating plains. The morphology is mostly glacial: ground moraine (in some areas hummocky), fluted surfaces, eskers. There are also glaciofluvial and glaciolacustrine surfaces. Ice-disintegration surfaces (Gravenor and Kupsch, 1959) are widespread. The Beaver and Sand Rivers have alluvial terraces.

A subcontinental divide cuts through the Sand River map area. Most of the area (the watershed of the Beaver River, together with its tributary, the Sand River) drains into Hudson Bay via the Churchill River system; the southwestern corner of the area also drains into the Hudson Bay but via the Saskatchewan River - Nelson River system. The northwestern corner (the watershed of the La Biche) drains into the Arctic Ocean by the Athabasca River - Mackenzie River system.

There are a number of lakes, the largest (Cold Lake, Primrose Lake, Lac La Biche) lying only partially within the map area. Muriel, Beaver, Moose, Pinehurst, Seibert, Wolf, Touchwood, Marie, Whitefish, and Spencer Lakes (and a number of other, smaller ones) exceed several square miles in area. Most of the lakes are of glacial origin. Their shapes are often controlled by glacial phenomena: Wolf Lake was carved by eskers; Fork Lake occupies the fork of two arched glacial scars. ERTS-1 satellite images show excellently the systems of elongated glacial depressions with chains of lakes situated in them (Ozoray, 1975b). Some deep valleys, occupied by narrow, long, curved lakes or small misfit watercourses (such as the Kehiwin Lake - Thin Lake - Mooselake River valley) are clearly carved-up, unburied remnants of an older drainage system, likely spillways of the melting icesheet.

CLIMATE

The entire area is in the "short, cool summer" (Dc) Koeppen zone (Longley, 1972, Fig. 53). The northeast corner of the area is within the climafrost zone (Lindsay and Odynsky, 1965) where the frozen condition in organic soils is temporary but frequently lasts for more than a year.

There are continuous long-term meteorological observations available for three stations [the mean January, July, and annual temperatures in °C are given in brackets (Environment Canada, Atmospheric Environment, undated)] Lac La Biche in the northwest (-17.9, 17.1, 1.2), Iron River in the center (-18.4, 16.7, 0.8), and Cold Lake in the east (-19.2, 17.1, 1.1).

Isohyets, modified from Longley (1972) are shown on the meteorological side map. Data from four summer raingauges measuring precipitation only from May to September were also taken into account (Stashko, 1971). October-April precipitation was calculated using the same rate as was observed at the nearest meteorological station: that is 35.1 percent of the May to September one for Sand River Lookout and La Corey Ranger Station (as observed at Iron River); 44.5 percent for Primrose Lookout (as at Cold Lake), and 58.4 percent for Heart Lake Lookout (as at Lac La Biche). Unfortunately, these raingauge observations are available only for the last few (usually eight) years. Although the precipitation of these observation years appears to diverge from the long term average, the data were not adjusted to conform to the usual 30-year period.

The station with the greatest calculated annual precipitation is Heart Lake Lookout with 24.4 inches (620 mm); the smallest one is La Corey Ranger Station with 14.3 inches (363 mm) precipitation annually. The potential evaporation, estimated from the maps of Bruce and Weisman (1967) exceeds precipitation as an annual mean and also during each month from May to October for all three meteorological stations.

Information on snow cover and climatological stations as presented in Potter (1965a, 1965b) was used in construction of the meteorological side map.

GEOLOGY

Geological maps which include the Sand River area have been constructed by Lang (1965) and Green (1972). The geology of the Cold Lake oil sands deposits has been studied by the Energy Resources Conservation Board (1973).

Bedrock topography is shown on the geological side map. This map is partly based on work by Yoon and Vander Pluym (1974, Fig. 6), as well as on unpublished comments by V. Carlson (Alberta Environment) and R. Green and J. Kramers of Alberta Research Council.

Contour lines of the top of the Mannville Formation and the boundary of the Wapiti Formation subcrop are shown on the geological side map.

There are virtually no bedrock outcrops in the area. There are only two subcropping bedrock formations: the Wapiti and Lea Park Formations of Upper Cretaceous age.

The profiles show the geology down to mean sea level. The following bedrock units were distinguished mainly on the basis of lithology as interpreted from electric logs.

Devonian hardrocks: mostly limestone although it also contains dolomite, shale, and evaporites. This unit is separated from the overlying Mannville Group by the basal Cretaceous unconformity (erosional surface, modified by tectonic and collapse processes).

Mannville Group (Lower Cretaceous): salt-and-pepper sands, non-marine gray shale, quartz sand, coal seams and a marine shale member (Alberta Society of Petroleum Geologists, 1960). It also includes the Cold Lake oil sands deposits.

Joli Fou Formation (Lower Cretaceous): marine shale.

Viking Formation (Lower Cretaceous): primarily marine sandstone.

La Biche Formation (Upper and Lower Cretaceous): marine shale.

A narrow band of *interbedded sandstone and shale* lying immediately below the Second White Specks marker.

Upper Colorado Group and Lea Park Formation (Upper Cretaceous): marine shales.

Wapiti Formation (Upper Cretaceous): non-marine sandstone and mudstone.

Over most of the area, the drift cover is quite thick - up to several hundred feet in the northern part. Where drill hole information is scarce, drift lithologies are not differentiated on the map. Where some data are available, a distinction is made between "sand and gravel" and "sand and silt" lithology.

HYDROGEOLOGY

DATA USED IN MAP PREPARATION

The accompanying maps were constructed using 1,870 data points consisting of 320 groundwater level data, 550 lithologs or electric logs without groundwater references, 780 water chemistry analyses including 180 analyses of deep formation waters, and 220 20-year safe or apparent 20-year safe yield calculations based on transmissivities obtained from short term aquifer tests. The distribution of points is shown on the data density side map.

GROUNDWATER LEVELS

On the main hydrogeological map, contours of groundwater levels above mean sea level have been drawn for areas where sufficient data were available. The contour interval is 100 feet (about 30 m). In any area, the water levels of the most used aquifer or most common well depth were contoured.

Groundwater flow directions are shown on the main map and on the profiles.

AQUIFER LITHOLOGY

The only important bedrock aquifer in the area is the Wapiti Formation which subcrops in the southwest corner. Its lithology (sandstone or sandstone and shale) is shown on the map only where it is not overlain by sand and gravel of the Beverly Buried Valley or thick drift deposits. Elsewhere drift lithology is shown. Where enough data are available to make such a distinction the lithology is shown as sand, sand and silt, or sand and gravel. At other places, drift lithology is generalized as sand, silt, and gravel.

On the hydrogeological profiles each formation is shown by a generalized lithology: Devonian as limestone (other facies are not distinguished); Viking Formation as sandstone; Wapiti Formation as sandstone and shale; Mannville Group and the beds under the Second White Specks marker as shale and sandstone; and Joli Fou, La Biche Formation, and the Lea Park Formation - Upper Colorado Group as shale.

The actual groundwater yields depend on several factors, such as silt content, thickness, and rechargeability. Therefore, different yield ranges can be present within any given aquifer.

GROUNDWATER PROBABILITY

The average available 20-year yield from the upper 1,000 feet (about 300 m) of strata is shown on the main map by means of color-coded areas.

For the calculation of transmissivity from pump test data, Jacob's modified non-equilibrium formula is used:

$$T = 264\ Q/\Delta s$$

where T = transmissivity in imperial gallons/day/foot (igpd/ft), Q = pumping rate in imperial gallons/minute (igpm), and Δs = drawdown in feet/log cycle of minutes.

Few proper pump tests were available, but in some instances the duration and rate of bailing or pumping and the total drawdown during development of a well were reported by drillers. In the absence of any better data, an apparent transmissivity can be calculated from this information. Experience shows that apparent transmissivity values can give an acceptable picture of the regional variation in relevant rock properties.

For the calculation of the 20-year safe yield of a well, the following formula was used:

$$Q_{20} = TH/2110$$

where Q_{20} = 20-year safe yield in igpm and is defined as the constant rate at which the well can be continuously pumped so that at the end of 20 years the water level will be drawn down to the top of the producing aquifer; T = transmissivity in igpd/ft; H = total available drawdown in feet, which is the difference between the static water level and the top of the producing aquifer; and 2110 = constant for 8 log. cycles, about 20 years.

Where *apparent* transmissivity is used in this formula, the result is naturally an *apparent* 20-year yield.

There were certain difficulties involved in defining the yield areas because:

(a) mostly, only Q_{20} values based on short aquifer tests or apparent Q_{20} values were available;

(b) the data available were usually only for the shallowest aquifer satisfying the local water demand;

(c) Q_{20} data differed due to varied drilling and well development techniques and because of individual testing methods, even for the same locality and aquifer.

The more accurate measurements were given greater consideration; extrapolations based on geological conditions, electric and lithologic logs, and topography were used; and a drilling and testing program was carried out to overcome these shortcomings. Because for the most part only estimations were available, mostly light shades of color are used on the map and the profiles.

Reliable data for yields over 500 igpm (about 2,250 L/min) were not found. Mapped yield ranges are:

(a) 100-500 igpm (about 450-2,250 L/min) — some sand and gravel patches;

(b) 25-100 igpm (about 100-450 L/min) — some sand and gravel deposits, part of the Wapiti sandstone, and the Devonian limestone;

(c) 5-25 igpm (about 25-100 L/min) — most of the remaining part of the drift and of the Wapiti Formation, and the Mannville Group;

(d) 1-5 igpm (about 5-25 L/min) — some drift depositions of low transmissivity (silt, till) and/or unfavorable topography, the beds below the Second White Specks marker and the Viking Formation.

The yield range of less than 1 igpm (about 5 L/min) is shown only on the profiles and includes the Lea Park - Upper Colorado, La Biche, and Joli Fou shales. Although there are wells yielding less than 1 igpm (about 5 L/min), they either do not characterize the entire 1,000-foot column of rocks considered during the construction of the map or they do not characterize areas big enough to appear on the main map. The least favorable areas are those where Lea Park shales are overlain by silt or till.

The map shows a conservative, low-yield estimation in some areas such as south of Cold Lake because the available test data from shallow wells represent low yields.

It must be kept in mind that the groundwater yield color code signifies only groundwater quantity not quality (see the discussion of hydrochemistry). Some units such as the Mannville Group contain aquifers with high yields but unpotable water.

FLOWING WELLS

Flowing wells are few in number and are usually found in topographic lows such as deep river valleys or lake shores. Selected wells are shown by symbols on the main map.

TEST DRILLING AND AQUIFER TESTS

A 191 foot (58 m) deep testhole was drilled on a gravel terrace of the Beaver River (Lsd 5, Sec 30, Tp 62, R 5, W 4th Mer) by Universal Drilling Contractors. The drilling encountered Quaternary sand or sand and gravel. Water flowed from the testhole but because of quicksand conditions the yield test was inconclusive.

A 271 foot (83 m) deep well (SE quarter of Sec 35, Tp 60, R 12, W 4th Mer) was aquifer tested by L. L. Chorney. Drillers encountered Quaternary till and reached sand at the boundary of the Quaternary and the Upper Cretaceous Wapiti Formation at the 225 foot (69 m) depth. The static water level in the well is 60 feet (18 m) below surface. A 20-year safe yield value of 25 igpm (114 L/min) was calculated, on the basis of a 2-hour bail and 2-hour recovery test.

A 70 foot (21 m) deep well (Lsd 5, Sec 9, Tp 60, R 6, W 4th Mer) was aquifer tested by L. L. Chorney. The aquifer is Quaternary till with sand pockets; the hole was drilled to a depth of 260 feet (79 m) and reaches Upper Cretaceous Lea Park shales at a depth of 120 feet (37 m). The static water level in the well is 27 feet (8 m). A 6 igpm (27 L/m) 20-year safe yield value was calculated, based on only a 1-hour bail and a 1-hour recovery test.

HYDROGEOLOGICAL PROFILES

Four hydrogeological profiles were constructed to show the 20-year safe yield of the important formations without showing the individual aquifers. The color-coded main map shows the sum of yield of the formations in the upper 1,000 feet (about 300 m), but because of the logarithmic yield scale chosen, they in practice agree with the highest ranked formation. Topography, stratigraphy, generalized lithology of the formations, flow systems, groundwater chemistry, and important observation points (wells, testholes) are shown on the profiles.

HYDROCHEMISTRY

SOURCES OF DATA

Most of the information presented here pertains only to groundwaters in the glacial surficial sediments due to the scarcity of wells completed in the bedrock. Hydrochemical data were obtained from several sources: Provincial Analyst (prior to 1973), District Health Units, Pollution Control Laboratory of Alberta Environment, and Alberta Research Council Geology Division (now Geological Survey) chemistry laboratory. In addition to these analyses, some 90 samples of drift groundwater were collected and analyzed by E.I. Wallick in the field and by the ARC Geology Division (now Geological Survey) chemistry laboratory during August 1974 and March 1975. These analyses include measurements of field pH, alkalinity, conductivity, temperature, and total iron content.

AREAL WATER QUALITY IN THE DRIFT AQUIFERS

As indicated on the hydrochemical sidemaps, data are available for the southern half of the map area and the Lac La Biche Reserve area. The broad areal picture suggests that aquifers in the southwest and west portions of the eastern part of the map area yield substantially fresher waters. Total solids are greater than 2,000 mg/L in groundwater of the Grandin and Owlseye areas, while exceptionally fresh (less than 500 mg/L) groundwaters are found in the Helina, Franchere, Stry, and Cold Lake areas. It is believed that the area of high total dissolved solids is correlated to the subcrop of the Belly River Formation, while low total solids areas tend to be present in association with preglacial channels developed on the Lea Park Formation.

The regional picture of the distribution of hydrochemical types is as follows:

(a) Ca^{++} - $SO_4^{=}$ and Na^{+} - $SO_4^{=}$ groundwaters are found primarily in the southwest;

(b) HCO_3^{-} is the dominant anion in all areas except Lac La Biche Settlement, Whitefish Lake, Hoselaw, and St. Vincent;

(c) $SO_4^{=}$ - type districts include the area northwest of Grandin, the Rich Lake-Fork Lake area, the area southeast of Owlseye, and the area northwest of Bonnyville;

(d) Na^{+} - type groundwaters are found primarily in the Lac La Biche, Spedden, Boscombe, and St. Vincent-Flat Lake areas;

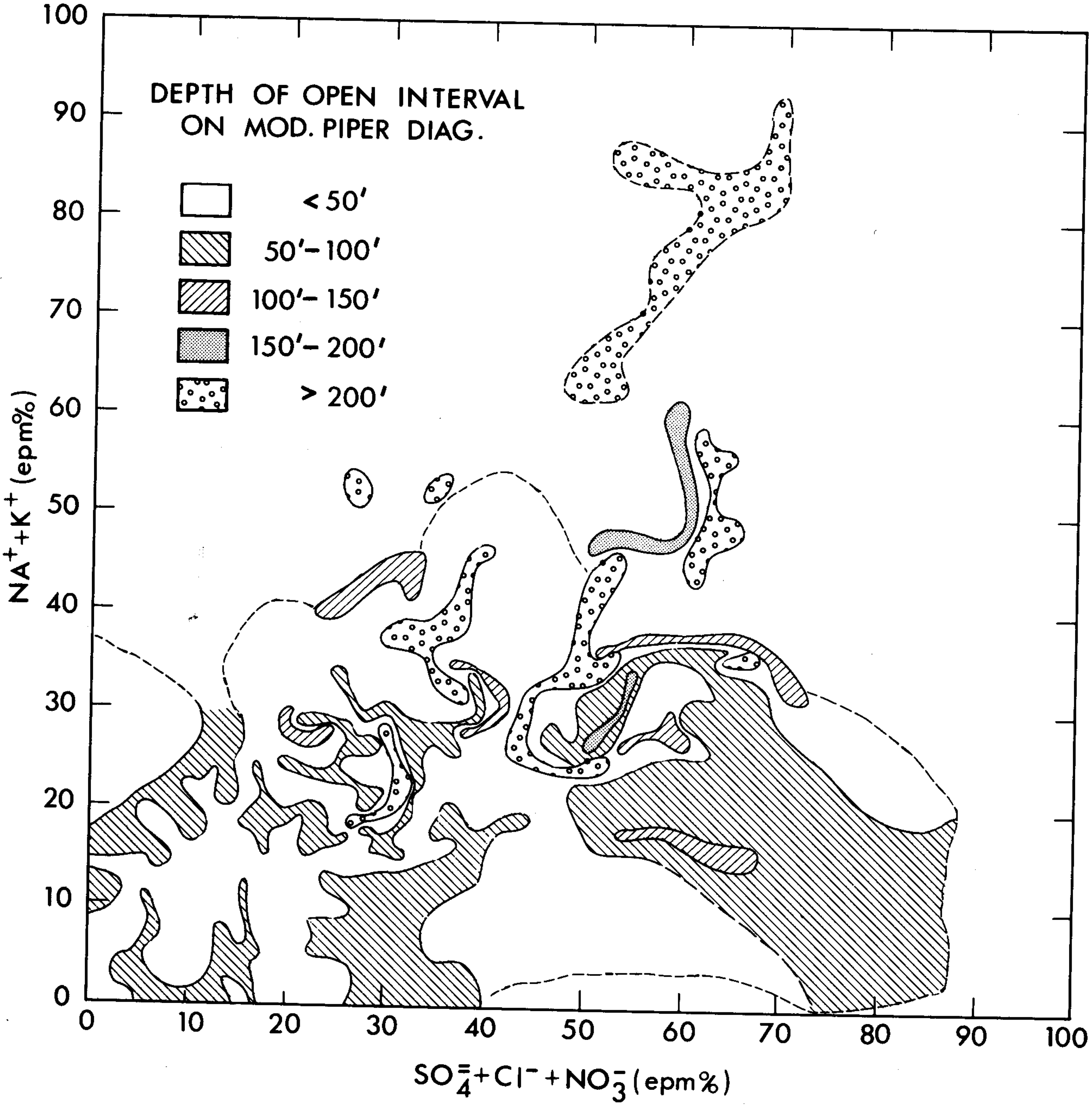

FIGURE 1. Hydrochemical type versus well depth

(e) Highest Cl⁻ waters are found in the northwest corner of the Cold Lake Indian Reserve, reaching 100 mg/L, Cl⁻ at the 70 mg/L level is present near Goodridge. Cl⁻ concentrations are well below 50 mg/L elsewhere in the Sand River area, and tend to be lowest over the Belly River Formation and in the preglacial channels due to more rapid circulation of groundwater.

RELATION OF HYDROCHEMICAL TYPE TO WELL DEPTH

Figure 1 is a modified Piper diagram (Piper, 1944) in the sense that well-depth intervals have been plotted in the water-type field. Ca^{++}/Mg^{++} - HCO_3^- waters are found most frequently in wells less than 100 feet (30 m) deep,

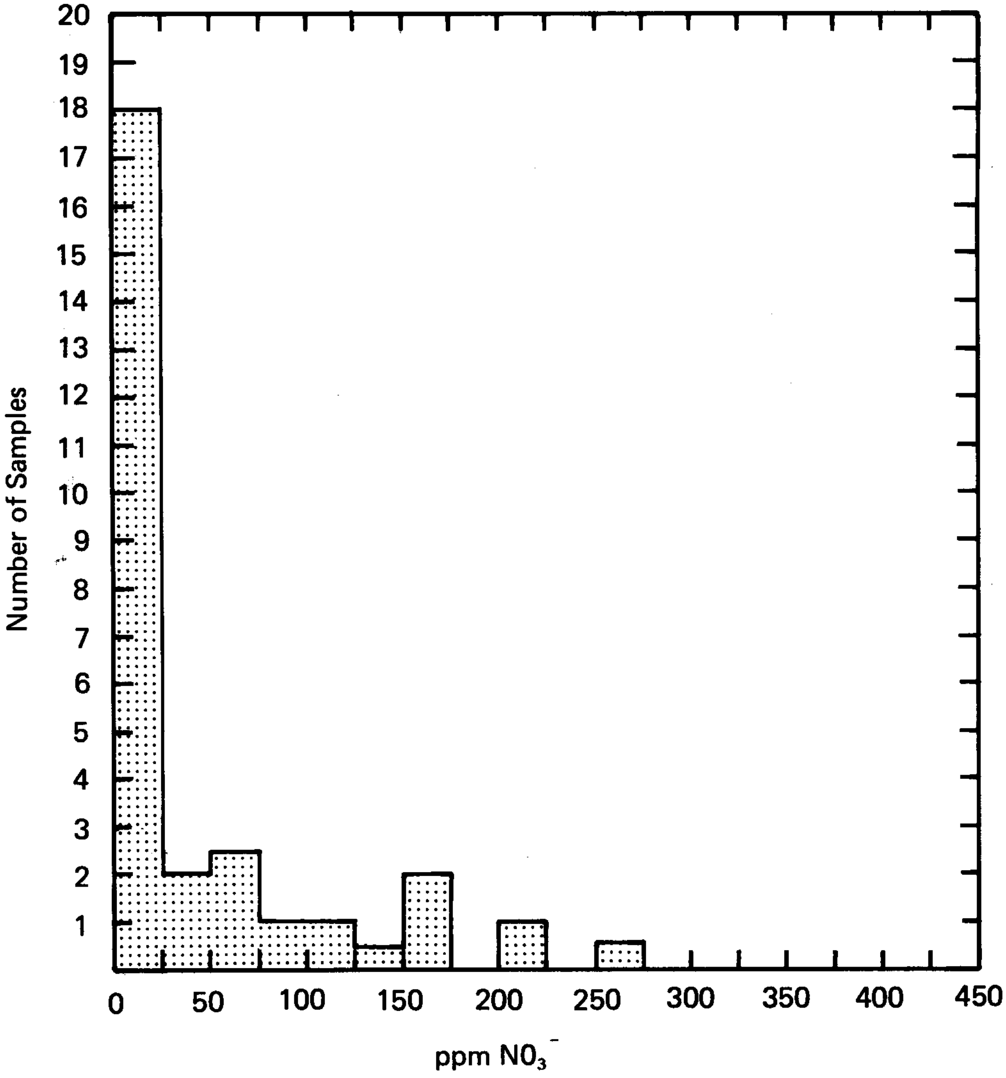

FIGURE 2. Distribution of NO_3^- in traverse samples

although other water types may also be present at shallow depth. Ca^{++}/Mg^{++} - $SO_4^=$ waters occur at depths less than 150 feet (50 m). Na^+ - $SO_4^=$ type waters tend to occur in deeper wells.

A linear trend, indicated by the dashed line envelope, shows that the groundwaters change from Ca^{++}/Mg^{++} - HCO_3^- facies at shallow depths to the Na^+ - SO_4^+ facies at greater depths. This indicates a change from solubility control by calcite to solubility control by gypsum, and then loss of Ca^{++} and gain of Na^+ by exchange with montmorillonite in the drift and shallow bedrock.

MAJOR WATER QUALITY PROBLEMS

Figures 2 and 3 are frequency distributions of nitrate and iron concentrations, respectively, based upon samples collected by the authors on a traverse from Vilna to Cold Lake. Note that mg/L NO_3^- is approximately Poisson-distributed with about 70 percent of the data falling below the recommended limit of 45 mg/L. Dangerously high levels of NO_3^- were found in the remainder of the samples; nitrate in excess of 50 mg/L is known to cause methaglobinemia in young children. Total iron is also approximately Poisson-distributed. About 50 percent of the samples contained

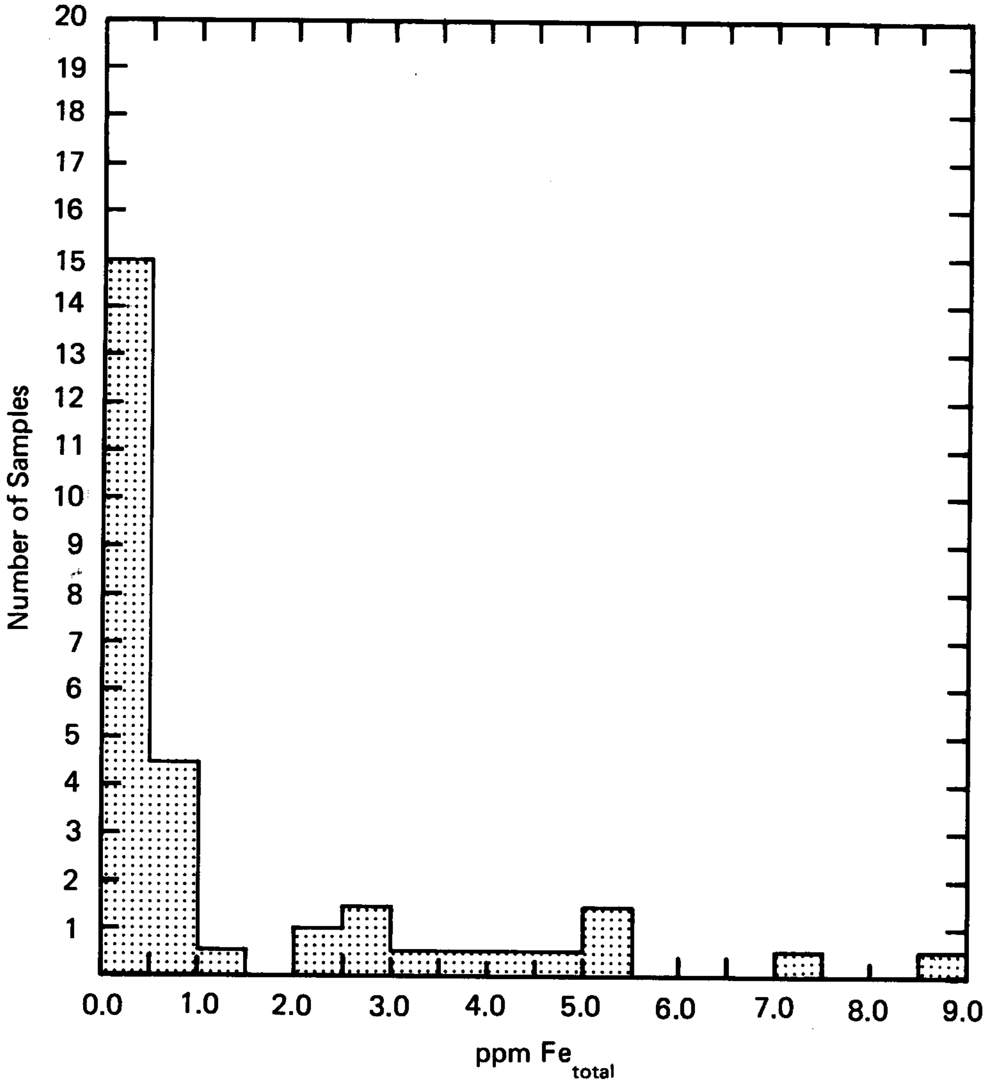

FIGURE 3. Distribution of Fe_{total} in traverse samples

less than the threshold of taste and smell level of 0.3 mg/L while the remainder contained up to 9 mg/L.

SEASONAL VARIABILITY OF WATER QUALITY

Replicate samples were collected and analyzed in August, 1974 and in March, 1975 to assess the degree of seasonal variability of groundwater chemistry. Such information is important because most sampling in the Province is carried out during the summer months and the chemical data are therefore biased toward a time interval of roughly 33 percent of the year.

Table 1 gives the mean and range of the concentration difference between winter and summer for major constituents in 33 pairs of samples collected along the traverse from Vilna to Cold Lake. Generally, the means are included within the large standard deviations as a result of the high scatter of the data. Winter samples were apparently fresher than summer samples by 90 ± 369 mg/L with a large range from 381 to over 1,500 mg/L. Winter minus summer differences were negative for magnesium, bicarbonate, sulfate, chloride, and nitrate, suggesting that lower leaching activity during the winter attenuates the flushing of salts from the soil and unsaturated zone into the groundwater system.

The high seasonal variability of chemical quality of these groundwaters has a significant effect upon the precision of the hydrochemical map contours.

TABLE 1
Seasonal Variation of Water Quality in Drift Aquifers

Constituent	Winter Minus Summer Concentrations (mg/L)	
	Mean*	Range
Ca^{++}	10±35	-105 to 92
Mg^{++}	-22±55	-247 to 15
Na^{+}	1.5±62	-110 to 278
K^{+}	.45±3.6	-17 to 8
HCO_3^-	-8±135	-446 to 247
$SO_4^{=}$	-26±213	-900 to 407
Cl^-	-8±44	-168 to 34
NO_3^-	-18±64	-232 to 139
TDS	-90±369	-1502 to 381

*mean and standard deviation of duplicate analyses of waters from 33 wells

TABLE 2
Saturation Indices

Mineral	Saturation Index (S.I.)*
Calcite	0.25±.16
Dolomite	0.51±.37
Gypsum	-1.46±.49
Ca-Montmorillonite	0.02±0.10
Illite	-0.73±0.20
Kaolinite	0.92±.16
Microcline	-1.49±.27
Albite	-2.74±.60
Anorthite	-10.79±.31

*mean and standard deviation of 54 samples

$\text{S.I.} = \log \frac{Q}{K_{(T)}}$ where Q = activity product; $K_{(T)}$ = temperature corrected equilibrium constant (Paces, 1972)

RELATION OF AQUIFER MINERALS TO HYDROCHEMISTRY

Saturation indices with respect to calcite, dolomite, gypsum, Ca-montmorillonite, illite, kaolinite, albite, anorthite, and microcline were computed for the samples collected during August 1974, and are given in table 2. A slight oversaturation with respect to calcite was indicated. The groundwaters were oversaturated with respect to dolomite, and undersaturated with respect to gypsum. It was particularly interesting to note the equilibrium saturation with respect to Ca-montmorillonite, slight undersaturation with respect to illite, and oversaturation with respect to kaolinite. The groundwaters were markedly undersaturated with respect to the feldspars: albite, anorthite, microcline. The saturation index data suggest that calcite and the clay minerals in the till, in particular Ca-montmorillonite, are the controlling solid phases in development of the groundwater chemistry.

Montmorillonite, illite, and kaolinite are known to constitute about 57, 21, and 22 percent of the clay minerals of the Belly River Formation, respectively (Locker, 1973), and Ca-montmorillonite is known to occur in the drift sediments. The typical mineralogic composition of till includes the silicate minerals such as quartz, plagioclase, micas, and clay minerals with montmorillonite as the predominant clay mineral group with minor hornblende, pyroxene, illite, and kaolinite; the carbonate minerals: calcite and dolomite; and such sulfate and chloride minerals as gypsum, anhydrite, halite, and mirabilite (Grisak, *et al.*, 1976).

CONCLUSIONS

Well yields vary greatly within the area. The best aquifers are the Quaternary sands and gravels, which in places yield over 100 igpm (about 450 L/min). More than 25 igpm (about 100 L/min) is available from drift or from Wapiti sandstones in slightly over one half of the area. About a third part of the area is classified as yielding between 5 to 25 igpm (about 25 to 100 L/min) from drift and Wapiti sandstones and shales. Only small areas are classified as yielding between 1 to 5 igpm (5 to 25 L/min) from drift, mostly from silt or till. Some geological units (Lea Park - Upper Colorado, La Biche and Joli Fou shales), shown only by the profiles, are estimated to yield below 1 igpm (5 L/min). The yield rank of many parts of the area may be underestimated, due to lack of data and to the use of short term tests or apparent transmissivity values.

Groundwater quality represents a major practical problem. Below about 1,000 ft (300 m) the groundwater is saline.

The abandoned and essentially buried glacial and preglacial valleys may contain valuable groundwater resources.

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Alberta RESEARCH COUNCIL

METEOROLOGY

LEGEND

Isohyet, mean annual precipitation in inches (cm) .... —16(41)—
Boundary of discontinuous permafrost .... ▲▲▲▲▲
Mean annual precipitation in inches (cm):
🟩 less than 15 inches (less than 38 cm)
🟩 15 to 20 inches (38 to 51 cm)
🟦 20 to 25 inches (51 to 64 cm)
Meteorological station ....
Standard rain gauge ....
Precipitation data:
- Mean annual precipitation in inches (cm)
- Year of commencement of observations
- Number of years of record averaged to determine mean annual precipitation figure
- Months of record
- Mean monthly potential evapotranspiration
- Mean monthly precipitation
- Period when surface is usually snow-covered
- Period with mean daily temperatures below freezing
- Figure indicates percentage of mean annual precipitation falling as rain

Source: The Climate of the Prairie Provinces (R.W. Longley, 1972)
Temperature and Precipitation, Prairie Provinces (Environment Canada)
Precipitation Means, Alberta Forestry Stations (Staskko, 1971)
Provisional Evaporation Maps of Canada (Bruce and Weisman, 1971)

MAIN MAP LEGEND

Topography

Surface contours and elevation in feet (interval 100 feet) ....

Geology

Geological boundary ....

QUATERNARY

Qd	Unconsolidated deposits
Qsg	Sands and gravels
Qs	Sands

CRETACEOUS

Kwt	Wapiti Formation
Klp	Lea Park Formation
Kco(u)	Upper Colorado Group
2ws	Second White Specks Zone
Klb	Labiche Formation
Kv	Viking Formation
Kj	Joli Fou Formation
Kmv	Mannville Group

DEVONIAN

D	Undifferentiated

Lithology

- Gravel
- Sand and gravel
- Sand
- Sandstone
- Silt
- Shale
- Limestone

Hydrography

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

Hydrogeology

Water table contours in feet (followed by metres and brackets) and direction of groundwater flow .... Upward flow 1900 (580) Downward flow
Direction of groundwater flow ....
Component of groundwater flow parallel to profile ....

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.)

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

Wells and Other Artificial Works

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

- Water well, nonflowing
- Water well, flowing
- Water well, shallow depth
- Water well, 20-year safe yield calculated from apparent transmissivity
- Water well, 20-year safe yield calculated from a good bail test or a short pump test
- Water well, 20-year safe yield calculated from a pump test of sufficient length to reflect regional hydraulic conditions
- Location of Research Council of Alberta test well .... ARC
- Gas well*
- Suspended well drilled for oil or gas*
- Abandoned well*
- Structure testhole*
- Other exploratory testhole*
- 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 available or where known; otherwise a solid line is used.

Line of hydrogeological profile .... A A′

Hydrochemistry

Calcium, Magnesium, Sodium + potassium (Cations) | Carbonate + bicarbonate, Sulfate, Chloride, Nitrate (Anions); 0, 50%, 100%

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

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

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

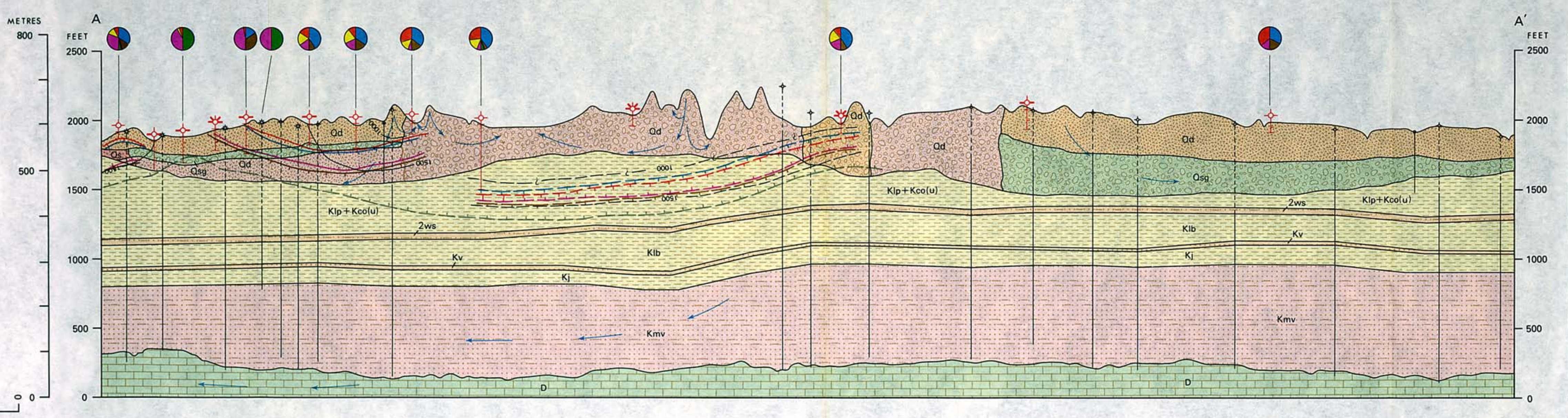
Isogram along which sodium + potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content:
- defined
- approximate

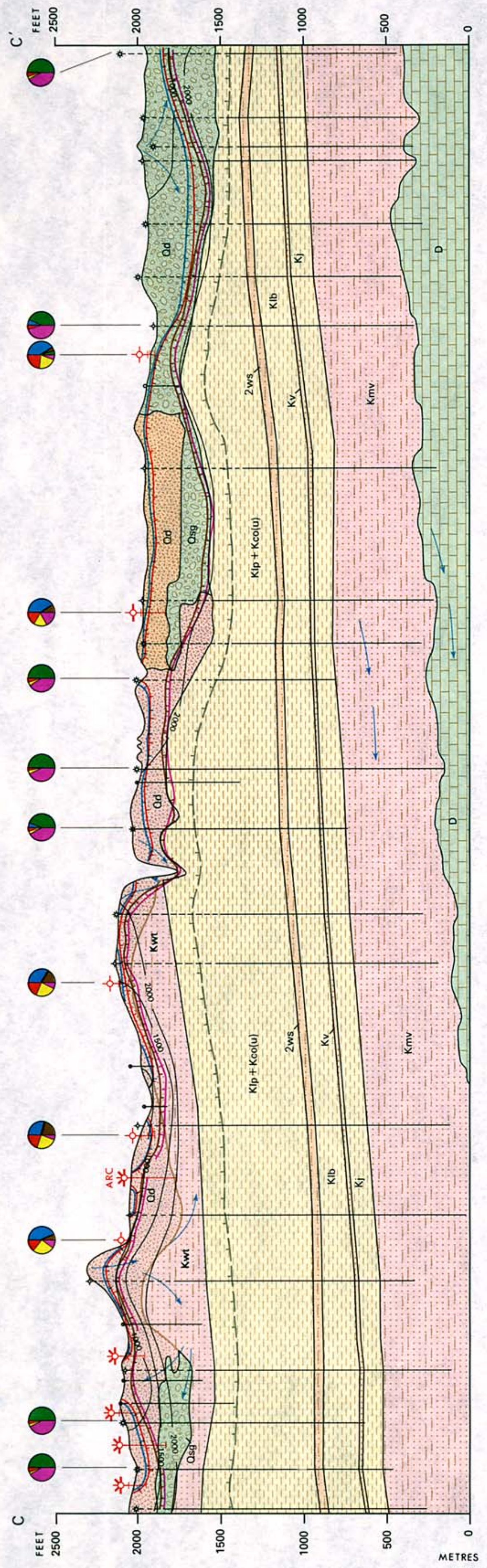
Isogram along which carbonate + bicarbonate constitute 60 percent of total anions*; teeth indicate direction of lesser carbonate + bicarbonate content:
- defined
- approximate

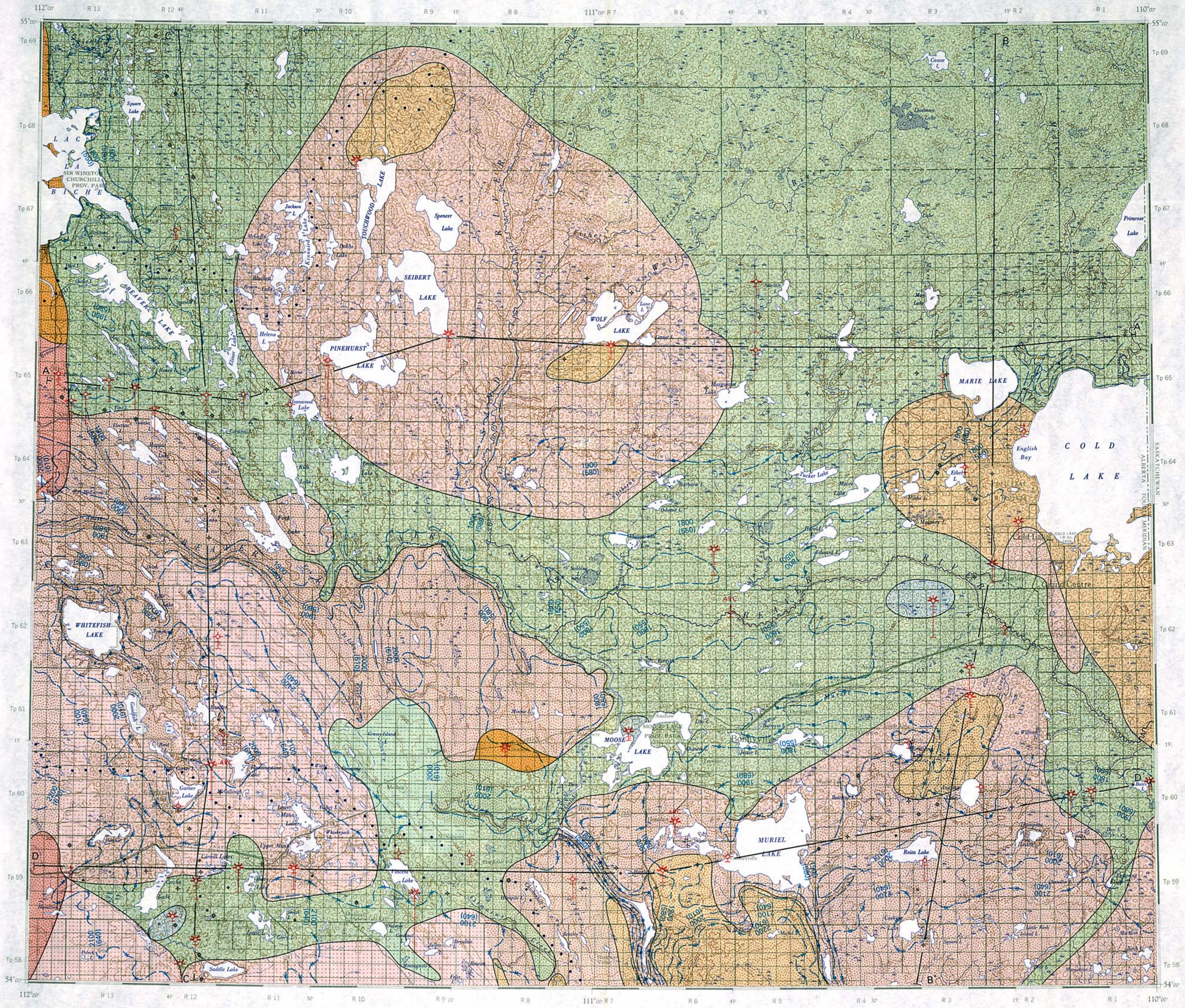
Isogram along which sulfate constitutes 60 percent of total anions*; teeth indicate direction of lesser sulfate content:
- defined
- approximate

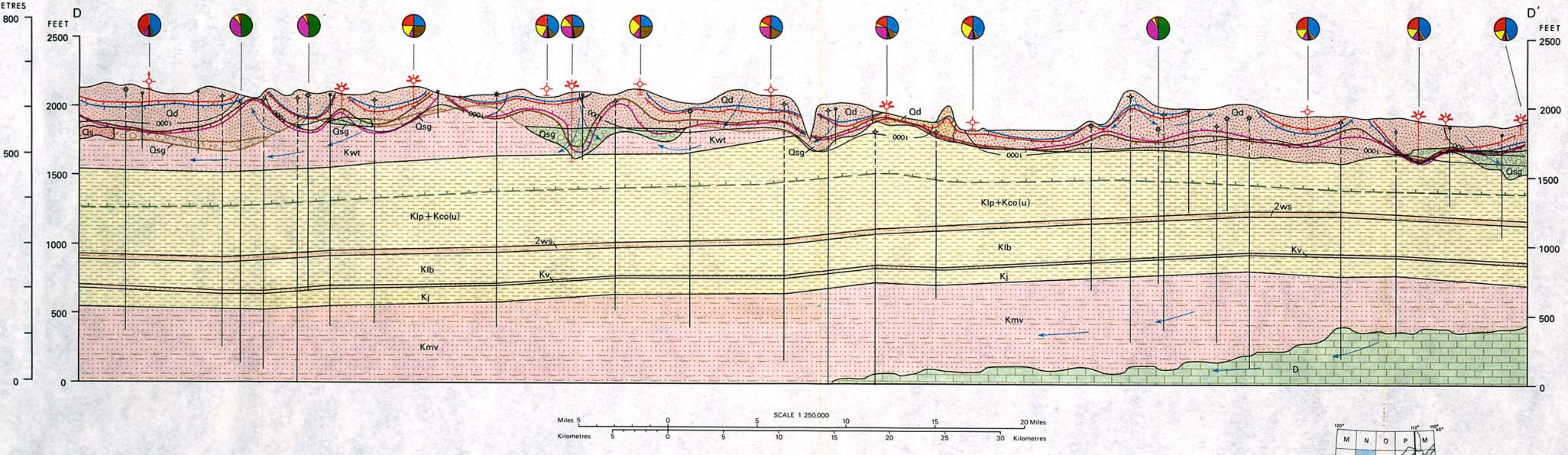
Isogram along which chloride constitutes 60 percent of total anions*; teeth indicate direction of lesser chloride content:
- approximate

*determined on equivalents per million basis









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 79-1.

Hydrogeology by G.F. Ozoray, E.I. Wallick, and A.T. Lytviak.

Drafted by R.W. Swenson.

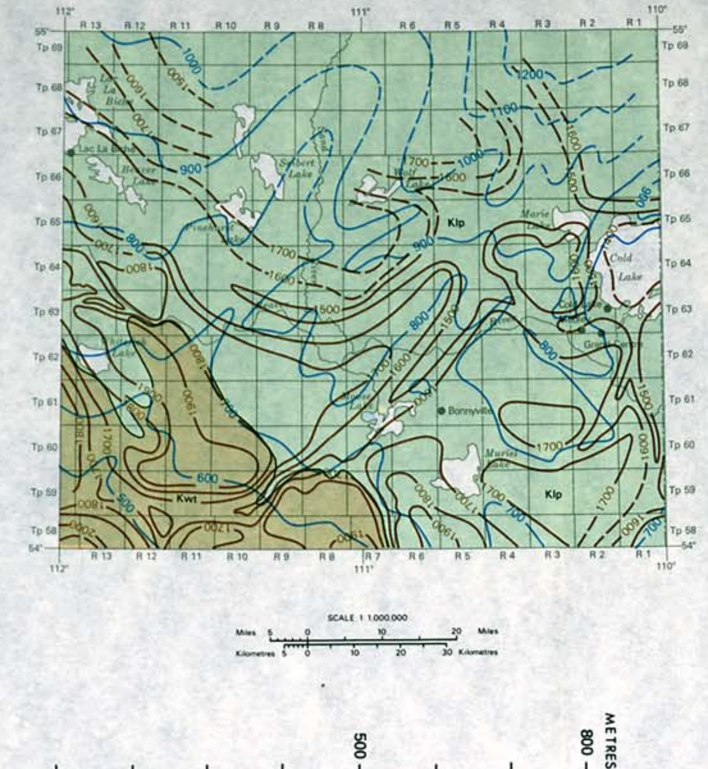
Cartographic editing by A.R. Campbell.

HYDROGEOLOGICAL MAP
SAND RIVER
ALBERTA

NTS 73L

Base map provided by Surveys and Mapping Branch,
Department of Energy, Mines and Resources, Ottawa.

GEOLOGY

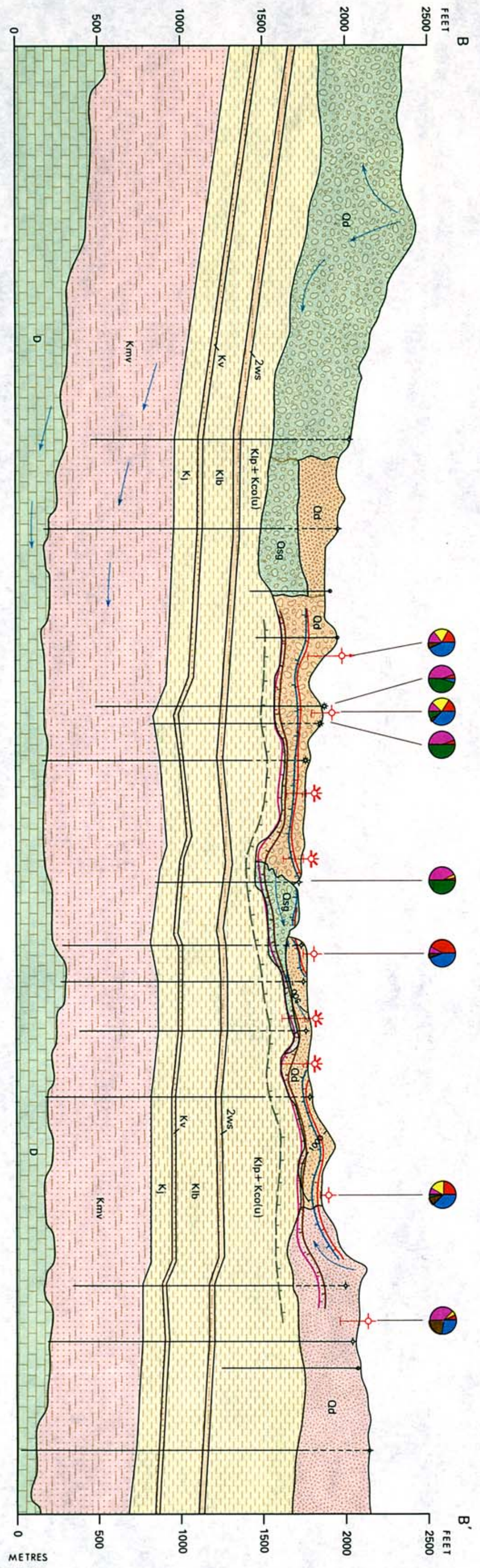


LEGEND

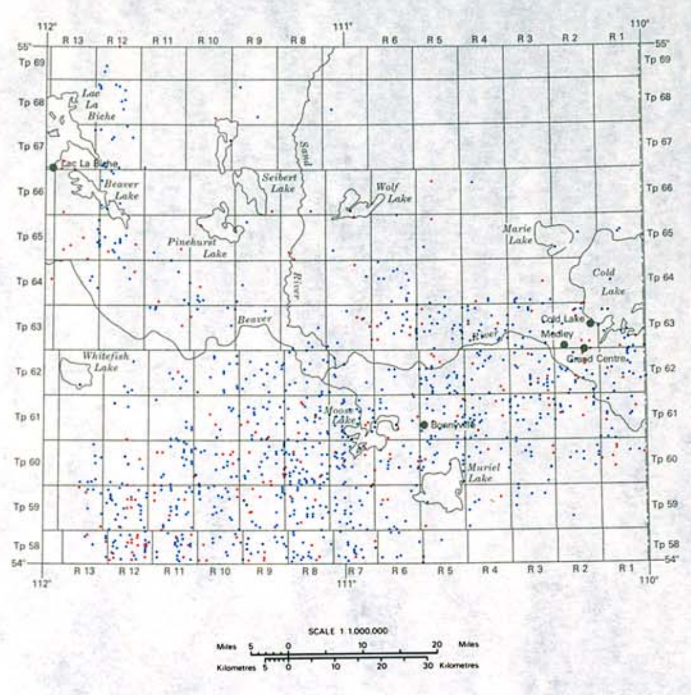
Lea Park Formation: *dark gray shale; pale gray, glauconitic silty shale with ironstone concretions; marine*
Klp

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

Rock unit boundary ....
Bedrock topography contour .... —1700—
Structure contour on top of Mannville Formation .... —1400—



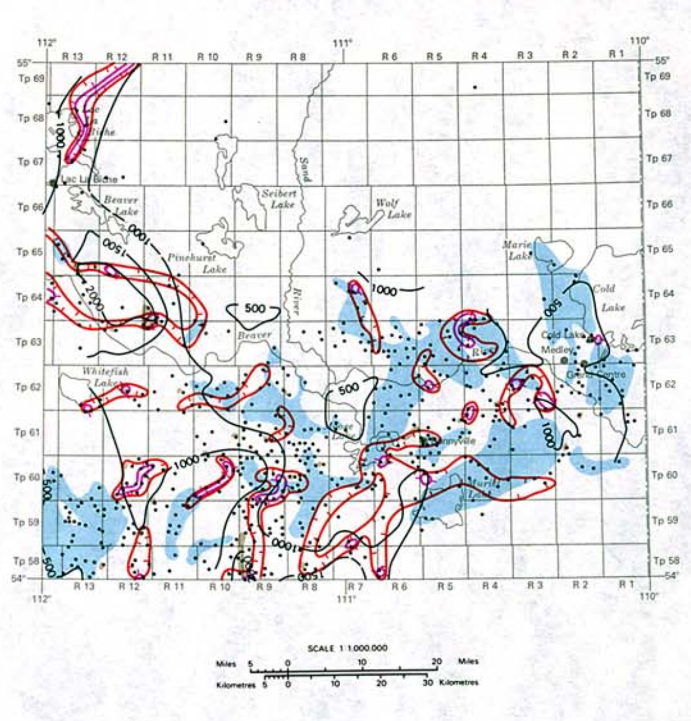
DATA DENSITY



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 ....
Data control point marking location of a hydrogeological surface feature ....

HYDROCHEMISTRY



LEGEND

Data control point ....

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

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

CONVERSION TABLE

LOGARITHMIC SCALE