Earth Sciences Report 81-2

Hydrogeology of the Peace River Area, Alberta

D. Borneuf

Alberta
RESEARCH COUNCIL

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Alberta Research Council
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ABSTRACT

The Peace River area, located in northwestern Alberta, has little relief with the exception of the Whitemud Hills in the northwestern quarter of the map area. The Peace River valley cuts deeply into shales and sandstones of Upper Cretaceous age. Total annual precipitation varies from 355 to nearly 480 mm (14 to nearly 19 in) and the lowest amount of precipitation falls in the area immediately surrounding the town of Peace River.

Yields range from 0.4 L/s (5 igpm) in Upper Cretaceous sandstones to possibly 38 L/s (500 igpm) in the Grimshaw gravels to the northwest of the town of Peace River. Coarse alluvial sediments found in the Peace River valley at several locations may prove capable of yields of up to 7.6 L/s (100 igpm), and possibly higher.

Water of better quality is found generally in areas of recharge and in the Grimshaw gravels; however, this is not true of all surficial sediments. No data are available for most of the area east of the Peace River.

The main types of water encountered in the Peace River area are calcium-magnesium sulfate and calcium-magnesium bicarbonate with total dissolved solids ranging from 200 to almost 5000 mg/L. Surficial aquifers of the Manning region are of poor quality with total dissolved solids ranging from 1410 to slightly over 11 000 mg/L. The water is the sodium sulfate type with nitrates present in many of the shallow wells.

INTRODUCTION

The Peace River area, located in the northwestern part of Alberta, lies between longitudes 116° and 118° west and latitudes 56° and 57° north. The area contains all or parts of Tps 81 to 92 and Rs 13 to 26, W 5th Mer (dominion land survey system).

The map area, which covers approximately 13 000 km^2 (5000 sq mi), was mapped in conjunction with the Winagami map area to the south, during the summer of 1973.

Approximately one-third of the area is settled, mostly in the Peace River-Grimshaw, Manning, and Clear Hills areas. The largest community in the area is the town of Peace River, which has a population of 5754 (Canadian Almanac, 1981). Other small towns are Grimshaw (pop. 2209) and Manning (pop. 1166), which are respectively about 19 km (12 mi) west and 80 km (50 mi) north of the town of Peace River (Canadian Almanac, 1981).

Previous hydrogeological and related studies were conducted in the general area by Rutherford (1930), Kidd (1946), Jones (1966), Tokarsky (1967, 1971), and Marciniuk and Kerr (1971). A map of the bedrock topography was prepared by Tokarsky (1967) for the Grimshaw-Cardinal Lake area.

Wyatt (1935) prepared a preliminary soil survey of the Peace River-High Prairie-Sturgeon Lake area.

Geology of the bedrock sediments has been studied by many authors: McLearn (1918, 1919), Warren (1939), Crickmay (1944), Wickenden (1951), Alberta Study Group (1954), Gleddie (1954), Stelck and Wall (1954), Stelck (1955), Stelck and Wetter (1958), MacDonald (1957), Wall (1960), and Energy Resources Conservation Board (1963). Geological maps of the area were prepared by Jones (1966) and Green (1972).

Cultivation takes place in the southwestern part of the map area in the Peace River-Grimshaw area, at the foot of the Whitemud Hills in the west central portion of the map area, and around Manning.

ACKNOWLEDGMENTS

The author wishes to acknowledge the diligent work of M.E. Brulotte, both in the office and in the field. C. Henry and B. Pretula also helped prepare maps in the office.

Others whose help is gratefully acknowledged include the Alberta Research Council geochemical laboratory for running chemical analyses on numerous water samples, and the analytical laboratory of the Department of the Environment for providing groundwater analyses. The

local residents of the area provided much help during the field season and are also thanked for their cooperation.

W. Ceroici, E. Wallick, and A. Lytviak critically read this paper and the author wishes to thank them for their comments and helpful suggestions. F. Tuck edited the report.

TOPOGRAPHY AND DRAINAGE

The eastern part of the area has flat to gently rolling topography; elevations range from 490 m (1600 ft) to slightly over 730 m (2400 ft) above mean sea level. In the western part, the topography is more diverse; elevations range from 490 m (1600 ft) to 817 m (2700 ft) in the Whitemud Hills.

The area has a multitude of lakes. East of the Peace River the largest lakes, from north to south, are Cadotte, Otter, and Haig Lakes. West of the Peace River, they are the Cardinal, St. Germain, Leddy, Flood, Pluvius, and Driftwood Lakes.

The main drainage in the area is provided by the Peace River valley, which is also the area's most striking morphological feature. The valley bottom elevation ranges from 335 m (1100 ft) at the southern boundary of the study area to 300 m (1000 ft) at the northern boundary. The valley is incised to depths of from slightly over 210 m (700 ft) to 150 m (500 ft) over the same range.

The Peace River is 1200 m (¾ mi) wide just north of the town of Peace River and its average width is slightly over 400 m (¼ mi). The northern part of the map area has large meanders with radii up to 2.4 km (1.5 m). Terraces formed by the changing Peace River course are composed of sediments such as sands, gravels, and boulders, and therefore are potentially excellent aquifers.

The main rivers and creeks joining the Peace River on the left bank are, from north to south: Whitemud River, Rousseau and Buchanan Creeks, and the Notikewin River, which joins the Peace River just past the northern boundary of the study area. On the right bank, in downstream order, the Smoky, Heart, Cadotte, and Little Cadotte Rivers join the Peace. The Smoky River, which joins the Peace River about 4.8 km (3 mi) upstream of the town of Peace River, has a 210 m (700 ft) deep valley. The Heart River, which joins the Peace at the south end of town, despite its small size, has a valley ranging from 180 m (600 ft) at the mouth to 120 m (400 ft), 12.8 km (8 mi) upstream of the town of Peace River. The Cadotte and the Little Cadotte Rivers join before their confluence with the Peace River.

ACCESS

Access is fair to good west of the Peace River. This area constitutes about one third of the study area and contains the towns of Peace River, Grimshaw, and Manning, as well as developed land around and between these towns. In the two thirds of the study area that lies east of the Peace River, access is very poor to nonexistent. The landscape is mainly muskeg and boreal forest and development consists of a few, small settlements and some activity related to the Peace River tar sands at Three Creeks and Simon Lakes.

CLIMATE

According to Koeppen's climate classification (Longley, 1972), the map area can be divided into two climatic zones:

1. the southwest corner of the map area is microthermal with an average temperature of the warmest month above 10°C (50°F) and the coldest month below -3°C (27°F); this area has warm summers with a mean temperature of 10°C (50°F) or more;
2. the remainder of the map area is microthermal with the average temperature of the warmest month above 10°C (50°F) and the coldest month below -3°C (27°F); this area has cool summers with the mean temperature of the warmest month below 22°C (72°F) and less than four months with a mean temperature of 10°C (50°F) or more.

Few weather stations exist in the area. The towns of Peace River and Grimshaw, which have the longest records (10 years), have an average annual total precipitation of about 355 mm (14 in). Other settlements such as Berwyn, Clear Hills, and Notikewin have either short (less than 10 years) or interrupted records.

From 355 mm (14 in) in the area immediately surrounding the town of Peace River, the average annual precipitation increases eastward to almost 480 mm (19 in) and westward to slightly above 460 mm (18 in). As a general rule, the lower precipitation values follow the Peace River valley and increase from there to the maxima indicated on the meteorological side map.

Snow accounts for 25 percent of the total precipitation at Peace River and 29 percent at Berwyn southwest of the town.

Potential evapotranspiration (using the Thornthwaite method, 1957) is about 400 mm (16 in) at the town of Peace River and about 380 mm (15 in) at Berwyn.

GEOLOGY

BEDROCK GEOLOGY

The bedrock formations found within the limits of the cross-sections are of Lower and Upper Cretaceous age and, in ascending order, the succeeding formations are the Peace River, Shaftesbury, Dunvegan, Kaskapau and the Smoky Group. The following bedrock geology description is from Green (1972).

The Peace River Formation of Lower Cretaceous age outcrops in the Peace River valley. It is mainly composed of fine-grained quartzose sandstone (Cadotte member), dark gray silty shale (Harmon member), fine-grained glauconitic sandstone, silty interbeds in lower part (Notikewin member); shoreline complex.

The Shaftesbury Formation of Upper and Lower Cretaceous age is composed of dark gray, fish-scale bearing shale, 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 consists of gray, fine-grained, feldspathic sandstone with hard calcareous beds, laminated siltstone and gray silty shale; deltaic to marine.

The Kaskapau Formation of Upper Cretaceous age consists of dark gray silty shale, thin concretionary ironstone beds, interbedded in lower part with fine-grained quartzose sandstone and thin beds of ferruginous oolithic mudstone; marine.

The Smoky Group of Upper Cretaceous age to the east of the Peace River is composed of dark gray shale and silty shale, nodules and thin beds of concretionary ironstone; marine.

SURFICIAL SEDIMENTS

Relatively permeable shallow surficial sediments such as sands and gravels were outlined for the western portion of the map area on the basis of seismic shotholes and water well lithologs. Fairly large areas of sands or gravels are found west of the Peace River in the general area of Cardinal Lake. As previously indicated by Tokarsky (1967, 1971), the Grimshaw gravels are significant both in areal extent and in thickness. Other types of gravels and sands are also present and have been outlined on the map. These are either surficial or very shallow or present as gravel and sand terraces in the valley of the Peace River.

BEDROCK TOPOGRAPHY AND BEDROCK CHANNELS AQUIFERS

A bedrock topography map was prepared for part of the western portion of the study area by Tokarsky (1967, 1971). This map was extended northward on the basis of additional data obtained during the course of the present study. These data included bedrock elevations obtained from shothole logs, previous Alberta Research Council testholes and a study by Marciniuk and Kerr (1971). The bedrock topography shows three main buried channels which could prove to contain good aquifers. These channels could be important as potential aquifers despite the fact that the water quality is likely to be poor because of high sulfates or chlorides. Such chemistry has been observed in similar channels in other parts of the province.

The main and best known bedrock channel in the map area is the Shaftesbury, which runs north of and parallel to the Peace River in a southwest-northeast direction. This channel is filled with up to 240 m (800 ft) of sediments, including gravels and sands. This channel is believed to cross the Peace River valley towards the east where available data show the presence of a bedrock channel in the Three Creeks area.

Also indicated on the map is a deep (210 to 240 m or 700 to 800 ft) bedrock channel, which has been named l'Hirondelle channel (referring to a small Métis community in the area). This channel runs probably from west to east in the eastern part of the map area, and passes underneath Lubicon Lakes, then continues east and possibly follows the Loon River valley on the Peerless Lake map area to the east. Another branch runs possibly to the west and merges with the Shaftesbury channel. Little information is available on this area, but three oil wells at the eastern boundary of the map area report the presence of 210 to 240 m (700 to 800 ft) of surficial material. Also, the base of the fish scale marker is eroded in that same area at about the same depth.

The Manning channel, first recognized by Tokarsky (pers. comm.), was outlined and described by Marciniuk and Kerr (1971). The Alberta Research Council and the Department of the Environment conducted test drilling to outline its extent. This channel is filled with over 150 m (500 ft) of surficial sediments in the center. Gravel, resting on the bedrock surface, is fairly extensive and can be found over several townships around Manning. The testholes that were

drilled in the channel by the Alberta Research Council and the Department of the Environment yielded large quantities of water that were, unfortunately, of poor quality.

YIELDS OF DRIFT AQUIFERS

The Grimshaw gravels, found in the area surrounding Cardinal Lake, have a probable yield range up to 8 L/s (100 igpm) and possibly exceeding 38 L/s (500 igpm). Other gravel units have a probable yield ranging from 2 to possibly more than 8 L/s (25 to 100 igpm). Other deposits such as surficial and deeper sands and gravels found north of Cardinal Lake were assigned a 20-year safe yield of 0.4 to 2 L/s (5 to 25 igpm).

The Manning bedrock channel sediments were assigned a yield range of 2 to 8 L/s (25 to 100 igpm) due to the presence of gravels and sands found during test drilling and in structure testhole logs.

A few pump tests or bail tests were conducted in the deepest gravels or sands to be found in this channel.

- A testhole (Lsd 15, Sec 11, Tp 91, R 23, W 5th Mer) drilled by the Department of the Environment in 1969, encountered gravels between 161 and 167 m (529 and 548 ft). The well was pump tested for four days at 1.3 L/s (17 igpm) and showed 0.66 m (2 ft) of drawdown. Calculation of the transmissivity yielded a value of 6000 igpd/ft and a 20-year safe yield of about 23 L/s (300 igpm).

- A second testhole (Lsd 7, Sec 18, Tp 92, R 21, W 5th Mer) drilled by the Department of the Environment in 1970, found boulders, clay, and gravels between 109 and 111 m (358 and 365 ft). An attempt to pump test it showed that no appreciable amount of water was available at that depth.

- A testhole (Lsd 13, Sec 28, Tp 91, R 22, W 5th Mer) drilled by the Alberta Research Council in 1967 found an appreciable amount of saturated sands and gravels at a depth between 104 and 145 m (340 and 475 ft). Caving problems due to the fineness of the sand did not allow a proper pump test.

On the basis of such tests and from the presence of gravels recognized in structure testholes over a large area, this channel has been given a yield range of 2 to 8 L/s (25 to 100 igpm). The water quality in this aquifer is quite poor since total dissolved solids in the three previous testholes were 2941, 11 627, and 1410 mg/L respectively.

Unconsolidated sediments of l'Hirondelle bedrock channel are expected to yield 2 to 8 L/s (25 to 100 igpm). Only when thicknesses and distribution of gravel and sand horizons are defined through drilling and pump tests are conducted, can more accurate yield figures be attributed to the channel.

YIELDS OF BEDROCK AQUIFERS

Yield areas have been defined by Tokarsky (1971) in the Grimshaw-Cardinal Lake areas. Some changes to the yield values were made in that area and yields are not expected to be higher than 8 L/s (100 igpm). In the remainder of the map area where transmissivity control is poor to nonexistent, the assigned yield ranges reflect the lithology of the bedrock sediments. To the east of the Peace River, bedrock yields are expected to be in the range of 0.4 to 2 L/s (1 to 25 igpm).

RECHARGE – DISCHARGE

Water levels closely follow the surface topography. Gradients become steeper closer to streams and river valleys. Some water levels are quite deep (130 m or 420 ft) in the Manning bedrock channel where water level measurements taken during the drilling of one Alberta Research Council testhole (Lsd 13, Sec 28, Tp 91, R 22, W 5th Mer) suggest a downward groundwater movement through the channel sediments.

Recharge occurs in the Whitemud Hills west of the map area. It occurs also in low-lying areas where relatively high permeabilities are encountered at or near the surface, as is the case for that part of the Grimshaw gravels north and west of the town of Peace River.

Flowing conditions were used to define the main discharge areas. These conditions are found south and southwest of Cardinal Lake and also along the base of the northern slopes of the Whitemud Hills. Usually these flowing conditions occur at shallow depths with the exception of flowing wells that are between 45 and 80 m (150 to 250 ft) deep in an area directly south of Cardinal Lake (Tp 82, R 25). These wells are completed in sands, gravels, or even quicksand and flow at discharge rates ranging from less than 0.075 L/s (<1 igpm) to about 3.8 L/s (50 igpm).

HYDROCHEMISTRY

Groundwater chemical data are sparse for the map area and nonexistent for the area east of the Peace River. Most of the data used for the chemistry were found in the area

west of the Peace River, and half of that area was described in detail by Tokarsky (1967, 1971). The portion described was added to the chemical side map in order to give a better picture of the chemistry.

Aquifers in the Manning region contain waters of mixed types. As mentioned in the previous discussion of the Manning channel, the groundwater quality is quite poor and often unfit for human consumption (Manning uses surface water for its water supply). Many shallow wells in the Manning channel area show the presence of nitrates; it is not known why the nitrate content is high. Deeper wells are of the sodium sulfate type with total dissolved solids ranging from 1410 to about 11 000 mg/L.

Groundwater of various chemical types is found in the Whitemud Hills. At higher elevations one can find sodium-calcium magnesium-bicarbonate waters with total dissolved solids ranging from 300 to 2000 mg/L. Downslope, the waters are a calcium-magnesium-sulfate type with total dissolved solids ranging from 700 to more than 7000 mg/L. At the foot of the hills, sodium-sulfate waters are found with total dissolved solids ranging from 700 to 7000 mg/L.

The Grimshaw-Peace River area has groundwater of mixed types, calcium-magnesium sodium-sulfate. In groundwaters found near Cardinal Lake, the bicarbonate anion is dominant. Total dissolved solids increase downslope from about 500 mg/L in Cardinal Lake to about 3000 mg/L south and southwest of the lake.

CONCLUSIONS

Aquifers in the Peace River map area are found both in surficial and bedrock sediments. Yields vary greatly from as little as 0.07 L/s (1 igpm) up to a possible high of 38 L/s (500 igpm). Some aquifers, such as the river valley gravels of the Peace River valley, are small in extent. Induced infiltration wells may produce over 7 L/s (100 igpm). Water quality is good in the area of the Grimshaw gravels to poor in the bedrock channels.

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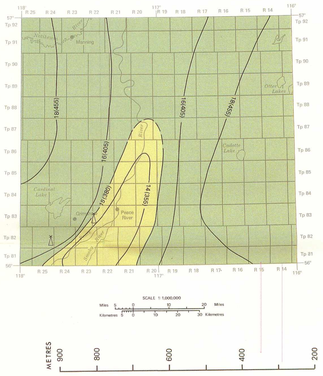
METEOROLOGY

LEGEND

Isohyet, mean annual precipitation in inches (mm)
defined ..... 15(380)
approximate ..... 15(380)
Mean annual precipitation in inches (mm):
less than 15 inches (less than 380 mm)
15 to 20 inches (380 to 510 mm)
Meteorological station
Precipitation data:
Mean annual precipitation estimated in inches
Year of commencement of observations
Number of years in average
Mean monthly precipitation:
Period when surface is usually snow covered
Period when mean daily temperature is below freezing
Figure indicates percentage of mean annual precipitation falling as rain

Source: Climatic maps for Alberta (R.W. Longley)



ERRATA
Section D-D[1] Ks shales should be yellow (pale).

MAIN MAP LEGEND

Topography
Surface contours and elevation in feet (interval 500 feet)
Sides and slumps

Geology
Geological boundary:
defined
approximate
Thalweg of buried valley

QUATERNARY
Od — Unconsolidated deposits
Qsg — Unconsolidated sand and gravel

CRETACEOUS
Ks — Smoky Group
Kd — Dunvegan Formation
Ksh — Shaftesbury Formation
Kp — Peace River Formation
Ksr — Spirit River Formation
Kk — Kaskapau Formation
Kh — Harmon Member
Bfsc — Base of Fish Scale

Lithology
Grimshaw Gravel
Buried Gravel
Surficial Sand and Gravel or River Terrace Gravel
Sand
Sandstone
Shale
Sandstone and Shale
Shale and Sandstone

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

Hydrogeology
Spring flow rate unknown — Upward Flow
Nonpumping water level contour in the bedrock (elevation in feet followed by metres in brackets) and vertical component of groundwater movement — C 2000(610) D — Downward Flow
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)
	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 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 with estimates of safe yield and apparent transmissivity
Flowing shothole
Oil well
Burning gas well
Structure test hole
Depth of exploratory well
Dugout or borrow pit

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 hydrahemia, a solid line is used).
Note: On the main map exploratory wells appear as point symbols only.

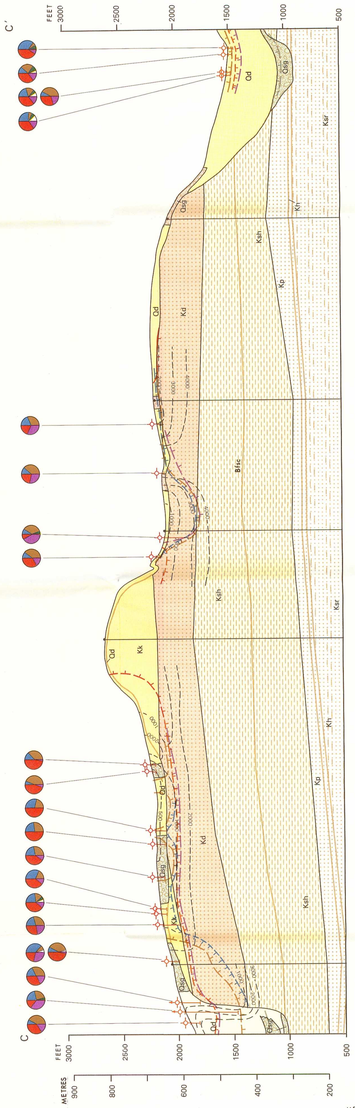
Line of hydrogeological profile — A A'

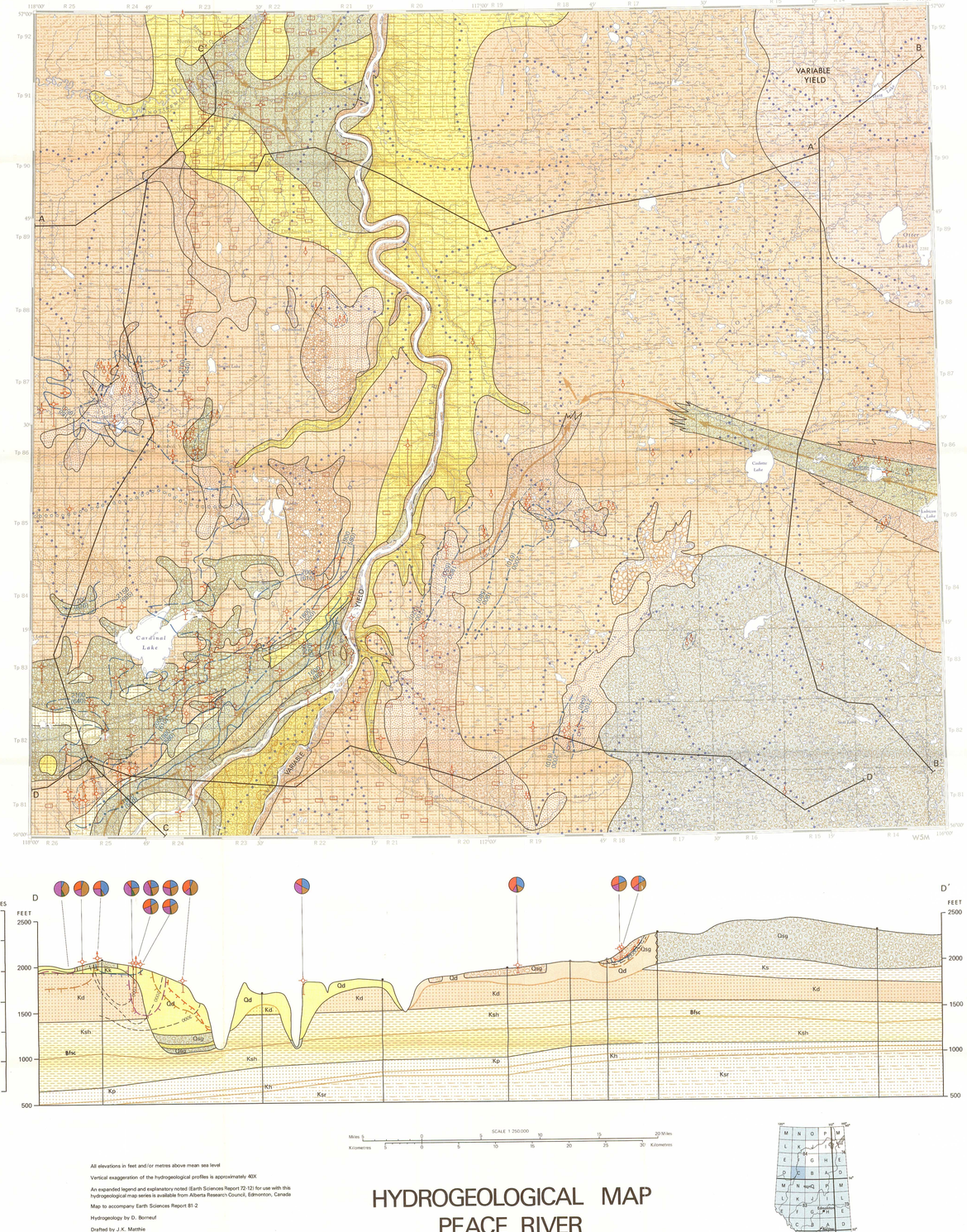
Hydrochemistry
Calcium
Magnesium
Sodium + potassium
Carbonate + bicarbonate
Sulfate
Chloride
Nitrate
CATIONS | ANIONS

note: when the yellow Mg pie sector is absent Ca & Mg are represented as a unit by the red sector

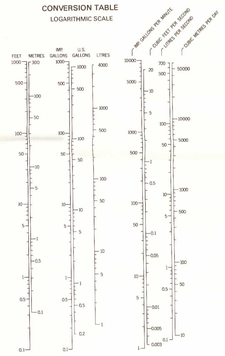
Total dissolved solid in parts per million:
approximate 3000
Isogram along which calcium & magnesium constitute 60 percent of total cations*; teeth indicate direction of lesser calcium & magnesium content
defined
approximate
Isogram along which sodium & potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium & potassium content:
defined
approximate
Isogram along which chloride constitutes 60 percent of total anions*; teeth indicate direction of lesser chloride 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

**Determined on equivalents per million basis.*





CONVERSION TABLE
LOGARITHMIC SCALE



All elevations in feet and/or metres above mean sea level
Vertical exaggeration of the hydrogeological profiles is approximately 40X
An expanded legend and explanatory noted (Earth Sciences Report 72-12) for use with this hydrogeological map series is available from Alberta Research Council, Edmonton, Canada
Map to accompany Earth Sciences Report 81-2
Hydrogeology by D. Borneuf
Drafted by J.K. Matthie

SCALE 1:250,000
Miles
Kilometres

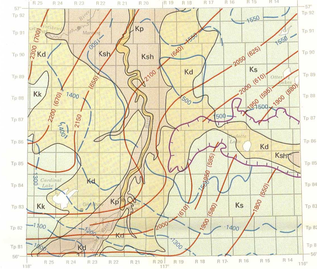
HYDROGEOLOGICAL MAP
PEACE RIVER
ALBERTA
NTS 84C

Base map provided by Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa; modified by Surveys Branch, Alberta Transportation, Edmonton

Alberta RESEARCH COUNCIL

Published in 1983

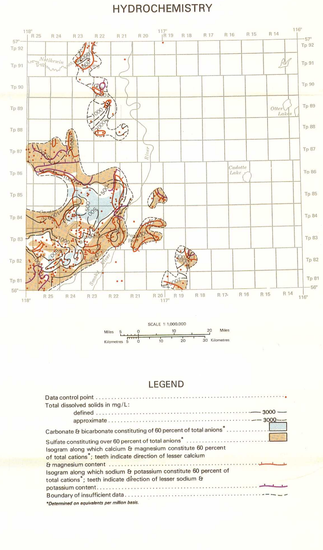
GEOLOGY



LEGEND

Smoky Group: *dark grey shale and silty shale, nodules and thin beds of concretionary ironstone; include unnamed dark grey shale unit on Caribou Mountains and Buffalo Head Hills; marine*
Ks
Kaskapau Formation: *dark grey silty shale, thin concretionary ironstone beds; interbedded in lower part with fine grained quartzose sandstone and thin beds of ferruginous oolitic mudstone; marine*
Kk
Peace River Formation: *fine-grained quartzose sandstone (Cadotte Member); dark grey silty shale (Harmon Member); fine-grained glauconitic sandstone; silty interbeds in lower part (Nookewin Member); shoreline complex*
Kp
Dunvegan Formation: *grey, fine-grained, feldspathic sandstone with hard calcareous beds; laminated siltstone and grey silty shale; deltaic to marine*
Kd
Shaftesbury Formation: *dark grey fish-scale bearing shale, silty in upper part; 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 on top of Dunvegan Formation ..... 2000(610)
Structure contour on Base of Fish Scale Zone 1500
Boundary of area with no Base of Fish Scale

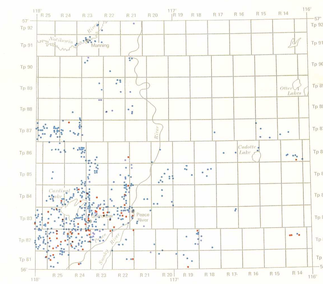
HYDROCHEMISTRY



LEGEND

Data control point
Total dissolved solids in mg/L:
defined 3000
approximate 3000
Carbonate & bicarbonate constituting of 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
Isogram along which sodium & potassium constitute 60 percent of total cations*; teeth indicate direction of lesser sodium & potassium content
Boundary of insufficient data
**Determined on equivalents per million basis.*

DATA DENSITY



LEGEND

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