Report 74-9
HYDROGEOLOGY OF THE GLEICHEN AREA, ALBERTA

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Price $2.00

Alberta Research
Edmonton, Alberta
1974

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Abstract

The hydrogeology of the uppermost 1 000 feet (about 300 m) of strata in the Gleichen 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 Belly River sandstones.

Water quality varies: total dissolved solids range from less than 1 000 to more than 5 000 ppm, and the general chemical character of the water varies from Ca/HCO_3 type to Na/SO_4 type. In the deep Milk River sandstones in the southeast corner of the map area Na/Cl type waters are present.

INTRODUCTION

The Gleichen area (NTS 82I) is located between longitudes 112° and 114° west and latitudes 50° and 51° north, and covers townships 12 to 23 and ranges 15 to 30, west of the fourth meridian. The total area is about 6 020 square miles (15 600 km^2).

In 1969-70 D. V. Currie 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[1] files.

A field survey including helicopter flights, groundwater sampling, drilling operations and aquifer testing was carried out in 1970. The hydrogeological reconnaissance maps and profiles and the report were prepared in the winter of 1970-71. The text and reference list were updated in 1974.

Hydrogeologic phenomena in the area, such as springs, artesian wells, and salt precipitates, were mentioned as early as 1885 (Dawson) and later in 1943 (Allan). Previously, hydrogeological surveys were conducted in the northwest segment of the map area (Carlson *et al.*, 1969) and in adjoining areas (Meyboom, 1960). Some regional hydrogeological (Meyboom, 1967) and hydrochemical (Le Breton and Jones, 1962; van Everdingen, 1968) studies have also overlapped the area. Data regarding surface waters were published by Thomas (1956).

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[1] Formerly Research Council of Alberta

The area has an excellent network of highways and paved and gravelled roads, including the two main thoroughfares of the province, Highways No. 1 (Trans-Canada) and No. 2. Only limited pockets of unpopulated ranchlands and hilly areas are without roads. Many railway lines cross the area and there are also local airfields.

Just outside the area to the northwest lies Calgary with a population of 400 000. Within the area the largest towns and their populations as of 1973 are: Claresholm (3 200), High River (3 024), Vulcan (1 384), and Okotoks (1 254). The communities having waterworks based on groundwater are: High River, Okotoks, Nanton, Stavely, Blackie and Mossleigh. Those using surface water are: Claresholm, Vulcan, Vauxhall, Bassano, Gleichen, Champion, Carmangay, Lomond, Milo and Enchant (Alberta Environment, 1974). The map area also encompasses the Blackfoot Indian Reserve and Willow Creek and Little Bow Provincial Parks.

The original vegetation of most of the map area was grass with poplar groves; but on the rolling landscape of the western part there was aspen forest and on the eastern fringes prairie grass grew. Except for small patches, the vegetation has been changed by cultivation and irrigation (Alberta Government and University, 1969).

In the eastern part of the area there is extensive ranching. In the Porcupine Hills lumber is cut. Also there is production of oil and gas in the area, and some coal mining takes place at Bow City.

Acknowledgments

Structure testhole information was received from the Energy Resources Conservation Board.

Test drilling was carried out by Kinsella Drilling of Innisfail, whose drilling crew was Larry Rankin and Bob Gibbon. Field assistance during pump tests was provided by D. Withers.

Meteorological data were received from the Edmonton Weather Office, Environment Canada. A grateful acknowledgment is due to D. V. Currie and A. Turner.

The water samples collected during field work were analyzed by I. E. Davidson, Alberta Research, and Mrs. K. Strausz, Provincial Analyst.

The manuscript was critically read by R. Bibby, D. Borneuf, R. Green, J. Tóth and E. Wallick, and edited by A. Campbell.

TOPOGRAPHY AND DRAINAGE

The map area lies on the western edge of the Interior Plains and includes parts of the Porcupine Hills and Eastern and Western Alberta Plains physiographic regions (Alberta Government and University, 1969). The highest elevation of the area is slightly more than 5 250 feet (1 600 m) above mean sea level and is found in the southwest corner in the Porcupine Hills. The lowest point, where the Bow River leaves the area to the southeast, is less than 2 400 feet (732 m). Within the area are gently sloping hills such as Buffalo Hill which has a height of about 3 850 feet (1 173 m).

The area has a variety of morphologies: canyon-like river valleys, erosional inselbergs, abandoned or essentially buried river valleys, pitted or smooth ground moraine surfaces combined with eskers, gravel flats and level lacustrine plains. The rivers, even the deeply cut ones, are sharply meandering. The Porcupine Hills, although they are geologically part of the Interior Plains, have hilly morphology.

The connection between the preglacial drainage and the present pattern has not always been completely severed. It was observed by Dawson (1885, p. 27) that "The Little Bow... rises in springs... quite close to the bank of the Highwood River, with no intervening high land." The upper Highwood River used to continue its course through the present Little Bow valley. It is likely that their groundwater systems are connected and the springs of the Little Bow are fed by groundwater and bank-storage of the Highwood valley (O. Tokarsky, pers. comm.).

The Gleichen map area is part of the South Saskatchewan drainage basin (South Saskatchewan River-Saskatchewan River-Nelson River-Hudson Bay system). The Bow River flows through the area and collects a number of tributaries: the Highwood River, the West and East Arrowwood Creeks and the Crowfoot Creek. The Little Bow River originates within the area and receives Mosquito Creek. Both the Little Bow River and Willow Creek flow into the Oldman River outside the map area.

The divides are uncertain for some distances: for example, between the Little Bow (Oldman subbasin) and West Arrowwood Creek (Bow subbasin) or between the Bow and the Red Deer subbasins in the northeast corner. Artificial projects such as reservoirs, flood-storage, canals and irrigation ditches further complicate the situation.

There are a number of lakes. Some, such as McGregor Lake (the largest), Travers Reservoir and Little Bow Lake are artificial. Most of the other lakes and sloughs are of glacial origin. The shallow basin of Frank Lake may be partly tectonic. The strange shape of the Clear Lake group is influenced by parallel esker ridges.

The lakes and sloughs are shallow. They seasonally change their size and shorelines and are usually salty. In late summer, salt-crust covered sloughs and lakeshores are common and alkaline patches dot the plains. Predominant salts are soda and Na-sulfates (Grossman, 1968).

CLIMATE

The greater part of the area is in the "long, cool summer" zone as defined by Koeppen; a little patch in the east is in the "savannah" zone (Longley, 1968).

The mean January, July and annual temperatures at Gleichen in the north are 10.0°F (-12.2°C), 64.3°F (17.9°C) and 38.3°F (3.5°C) and at Vauxhall in the south are 12.8°F (-10.7°C), 66°F (18.9°C) and 39.7°F (4.3°C), respectively (Canada Department of Transport, Meteorological Branch, 1967).

Isohyets, modified from Longley (1968), are shown on the meteorological side map. The mean annual precipitation is less than 13 inches (330 mm) in the east and more than 20 inches (508 mm) in the southwest. The annual potential evaporation, estimated from the maps of Bruce and Weisman (1967), is about 40 inches (1 016 mm) at Vauxhall in the southeast and about 30 inches (762 mm) at both Okotoks in the northwest and Lyndon in the southwest. All over the area potential evaporation exceeds precipitation by one and a half to three times.

For the construction of the meteorological side map, the publication of Potter (1965) and the observations of different stations have been considered.

GEOLOGY

The bedrock geology of the map area and relevant stratigraphic questions are discussed in publications by Dawson (1885), Williams and Dyer (1930), Russell and Landes (1940), Allan (1943), Stewart (1943), Crockford (1949), Webb (1954), Glaister (1959), Mellon (1967), Irish (1968, 1970), Irish and Havard (1968) and Carrigy (1970). The geological map of Alberta (Green, 1972) has also been considered in the construction of the various maps attached to this report. Published data regarding oil and gas (Alberta Oil and Gas Conservation Board, 1964-1970), coal (Campbell and Almadi, 1964; Campbell, 1967), other minerals (Govett and Byrne, 1958) and water (Geiger ***et al.***, 1968) also have been used. Formations deeper than 1 000 feet (about 300 m) and literature regarding them were not usually considered.

A bedrock topography map was published by Geiger (1968). The bedrock structure and its influence on surface morphology was discussed by Robinson ***et al.*** (1969) and by Ozoray (1972a). Some relevant discussions of glacial geology are by Stalker (1956), Gravenor and Kupsch (1959) and Westgate and Bayrock (1964).

The surficial geology and geomorphology of the Gleichen map area were discussed by Bayrock and Jones (1963), Stalker (1957, 1965) and Alley (1973), and the network of buried valleys by Stalker (1961) and Farvolden (1963).

On the geology side map, four hydrogeologically important geological surfaces are shown by contour lines:

1. the top of the Whitemud and Battle Formations, based on Irish and Havard (1968);

2. the top of the Bearpaw Formation which delineates the base of the St. Mary River (Horseshoe Canyon) Formation or the lowest sandstone stratum of it;

3. the base of the Bearpaw Formation indicating the top of the Belly River Group (Oldman Formation) (i.e. first sandstone below the Bearpaw Formation);

4. the top of the Lower Milk River Formation or the first well developed sandstone in the Milk River Formation.

Away from the Porcupine Hills, there are only scattered bedrock outcrops in canyons, valley flanks and the like. The Upper Cretaceous Milk River (fine-grained sandstones interbedded with clay and shale) and Pakowki (mostly shale) Formations do not outcrop. The subcropping near-surface bedrock formations from southeast to northwest are:

(a) Upper Cretaceous Belly River Group (Foremost and Oldman Formations): bentonitic sandstones, grey or greenish grey shales and coal.

(b) Upper Cretaceous Bearpaw Formation: predominantly black and grey shale, some clayey sandstone.

(c) Upper Cretaceous St. Mary River (Horseshoe Canyon) Formation: grey, argillaceous shales and sandstones.

(d) Upper Cretaceous Whitemud and Battle Formations (including the Kneehills Tuff Zone).

(e) Upper Cretaceous – Paleocene Willow Creek (Paskapoo) Formation: grey fine to medium-grained sandstones, variably argillaceous; and grey or green shales.

(f) Paleocene Porcupine Hills Formation: predominantly sandstones.

The surficial geology of the area was mapped by Stalker (1957, 1965). Thickness of the drift cover is usually 50 to 100 feet (15-30 m), but in some places is as thick as 200 feet (about 60 m).

The northeast corner of the area is covered by preglacial sandy to silty gravels (Bassano-Gem gravel area, Carlson ***et al.***, 1969), overlain by younger deposits within

Pleistocene and Recent river and creek deposits; thin sheets of postglacial lake deposits (sometimes modified by wind), sands and gravelly sands are widespread. If they are massive enough the map shows them. However, they are often insignificant local pockets. The buried or dry glacial valleys are shown on the main (hydrogeological) map.

Till deposits are extensive and sometimes contain sand pockets. Lacustrine clays and silts and silty alkaline soils are also common. The deposits of Recent and Pleistocene rivers are hydrogeologically important.

HYDROGEOLOGY

Data Used in Map Preparation

The attached maps were constructed using 3 445 data points comprised of 1 521 groundwater level data, 662 lithologs or electric logs without groundwater references, 111 hydrogeologic surface features, 989 water chemistry analyses and 162, mostly apparent, 20-year safe yield and spring yield data. Their distribution, which is uneven unfortunately, is shown on the data density side map. The bedrock topography map by Geiger (1968) was often utilized during the construction of the maps so his numerous stratigraphic and lithologic data have also influenced the results.

Groundwater Levels

On the main (hydrogeological) map, contours of groundwater levels above mean sea level have been drawn. The contour interval is 200 feet (60 m). In any area, the water levels from the most used aquifer and well depth were contoured. Thus, in the Porcupine Hills, springs were contoured; on the eastern and southeastern fringes and over the alluvial strips and shallow buried valleys wells less than 50 feet (15 m) deep in drift were contoured; in the major part of the area wells 50 to 150 feet (15-45 m) deep in drift or bedrock were contoured. Wells deeper than 150 feet (45 m) usually were not considered in constructing groundwater level contours because such wells are not generally used in the map area. However, they were used to evaluate flow systems. Groundwater flow directions are shown on the main map and on the profiles.

Aquifer Lithology

The lithology of drift is shown wherever the drift contains a large quantity of sand and gravel and is the better and more used aquifer. This is the case with the Bassano-Gem preglacial sand and gravel sheet, the Pleistocene and Recent river deposits, and the sandy lacustrine facies. The actual yields, of course, depend on several factors, such as silt content, thickness and rechargeability, so there may be different yield ranges within any given aquifer.

In other areas bedrock lithology is shown because it is lithologically more uniform and, except for Bearpaw shales, can supply an equal or higher yield than the drift.

Groundwater Probability

The average available 20-year safe 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 based on a pump test, Jacob's modified nonequilibrium formula is used:

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

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

Few pump tests were available but, in some instances, the duration and rate of bailing or pumping and the total drawdown were given. Such data are often reported by the drillers during development of a well; in the absence of any better data, an apparent transmissivity can be calculated (Ozoray, 1970). Experience shows that apparent transmissivity values can give a statistically acceptable picture of the regional variation of local transmissivities.

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.

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

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

(a) mostly, only apparent Q_{20} values were available (213 out of the total 307 Q_{20} data);

(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 developing techniques and to individual testing methods, even for the same locality and aquifer.

To overcome these shortcomings, the more accurate measurements were given greater consideration, extrapolation based on geological and topographical considerations was used, and a drilling and testing program was carried out.

As had been found in other areas (Ozoray, 1972c), the 20-year safe yield of carefully established testholes was usually higher than the apparent Q_{20} values of the neighbouring farm wells. This is probably due to the use of shallow-well data and the technology employed for completing farm wells.

Data are regrettably scarce over the eastern part of the area, so that yield estimation is based on geologic conditions, electric and lithologic logs and topography; on the map light shades of colors distinguish such areas.

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 gravel and sand patches;

(b) 25-100 igpm (about 100-450 l/min): preglacial and alluvial sands and gravels; the near-surface Belly River sandstones near Enchant;

(c) 5-25 igpm (about 25-100 l/min): about half of the drift facies, such as fine lacustrine sands and silty alluvium; the Porcupine Hills, St. Mary River and Milk River Formations and parts of the Willow Creek Formation and the Belly River Group;

(d) 1-5 igpm (about 5-25 l/min): most tills and lacustrine deposits; most of the Willow Creek Formation and the Belly River Group.

The yield range of less than 1 igpm (about 5 l/min) is shown only on the profiles and includes the Bearpaw and Pakowki Formations. Although there are wells yielding less than 1 igpm (about 5 l/min), they do not characterize areas large enough to appear on the main map. Down to 1 000 feet (300 m) some water is available either from drift or from bedrock. The least favorable areas occur where the Bearpaw shales are overlain by till.

Areas of Flowing Wells

Shallow flowing wells, resulting from local flow-systems, are quite common over the whole area. Their areal distribution is shown on the hydrogeological map.

Test Drilling and Aquifer Tests

Four testholes were drilled with a cable-tool rig, and several bail tests were run. A 4-day pump test was carried out on the Bassano testhole. Hydrological characteristics were then calculated. Details are tabulated in Appendix A.

Hydrogeological Profiles

Four hydrogeological profiles were constructed. Their crosspoints are the four testholes. The profiles show the 20-year safe yield of the important formations without showing the individual aquifers. The color-coded main map shows the sum of yields of the formations in the upper 1 000 feet (about 300 m). However, because of the logarithmically chosen yield scale, 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, springs, testholes) are shown on the profiles.

HYDROCHEMISTRY

A groundwater chemistry map was constructed based on 980 analyses of groundwater (including springs) and on nine analyses of surface waters as reference. About 400 of the samples were collected during fieldwork. During the evaluation of the data, the works of Piper (1944), Back (1966), Rozkowski (1967) and Hem (1970) were taken into consideration.

The area shows great chemical variety. Total dissolved solids can vary from less than 1 000 to more than 5 000 ppm (mg/l). Patches of Ca+Mg or Na+K, CO_3+HCO_3 or SO_4 give to the map a mosaic-like appearance. Na_2SO_4 is often present in groundwater and in the lakes. In the southeast corner of the map area the deep Milk River sandstone aquifer contains saline water (NaCl) of over 10 000 ppm. However, the locally used near-surface aquifer is shown on the map, as the Milk River sandstone is at the limit of representable depth.

CONCLUSIONS

Well yields vary greatly within the map area. The best aquifers are the Quaternary sands and gravels, which at places yield over 100 igpm (about 450 l/min), and at other places yield 25 to 100 igpm (about 100-450 l/min). Some Belly River sandstones also yield 25 to 100 igpm. The fine lacustrine sands, silty alluvium, and the Porcupine Hills, St. Mary River and parts of the Willow Creek and Belly River sediments yield 5 to 25 igpm (about 25-100 l/min). In over a quarter of the area, the estimated 20-year safe yield is less than 5 igpm (about 25 l/min). Most of the tills, lacustrine deposits, and Willow Creek and Belly River sediments belong to this category. The yield of the Bearpaw and Pakowki Formations is estimated to be less than 1 igpm (about 5 l/min). However, due to the lack of data and to the use of apparent values the yield rank of many parts of the area may be underestimated. Three out of four testholes proved to have higher rank of yield value than the previous estimates for their areas.

The highly variable and often low quality groundwater chemistry represents a major practical problem in use of groundwater in the map area.

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

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APPENDIX A. ALBERTA RESEARCH TESTHOLES

1) Location: SW corner, Lsd. 5, Sec. 11, Tp. 14, R. 19, W. 4th Mer.

Elevation: 2 720 feet

Contractor: Kinsella Drilling Ltd.

0- 20	silty sand
20- 25	sand and minor coal
25-160	sand, gravel and silt
160-175	shale, black to green
175-220	shale and sandstone, coal seams
220-250	interbedded shales, black to grey to green, and sandstones

Tests: 2-hour bail test at 372 feet at 10 igpm; available drawdown of 190 feet.

2) Location: Lsd. 16, Sec. 12, Tp. 15, R. 26, W. 4th Mer.

Elevation: 3 120 feet

Contractor: Kinsella Drilling Ltd.

0- 35	sand and gravel interbedded with clay
35-140	shale, black to grey to green, with minor sandstone beds and coal seams
140-170	sandstone, grey-green, fine- to medium fine-grained
170-435	interbedded shales, grey to black, and sandstones, medium fine to very fine, grey to tan

Tests: 2-hour bail test at 133 feet at 10 igpm. Total drawdown of 100 feet. Bail test in 35 feet indicated induced infiltration from the Little Bow River.

3) Location: Lsd. 1, Sec. 25, Tp. 20, R. 26, W. 4th Mer.

Elevation: 3 440 feet

Contractor: Kinsella Drilling Ltd.

0- 35	sand, clay and gravel
35-500	shale, dark grey and calcareous, interbedded with sandstone, light to medium grey, fine- to medium fine-grained

Tests: Bail tests at 187, 417 and 500 feet had insignificant yields.

2-hour bail test at 63 feet yielded 10 igpm.
40-minute bail test at 337 feet at a rate of 10 igpm with a drawdown of 300 feet.

4) Location: Lsd. 3, Sec. 15, Tp. 21, R. 18, W. 4th Mer.

Elevation: 2 550 feet

Contractor: Kinsella Drilling Ltd.

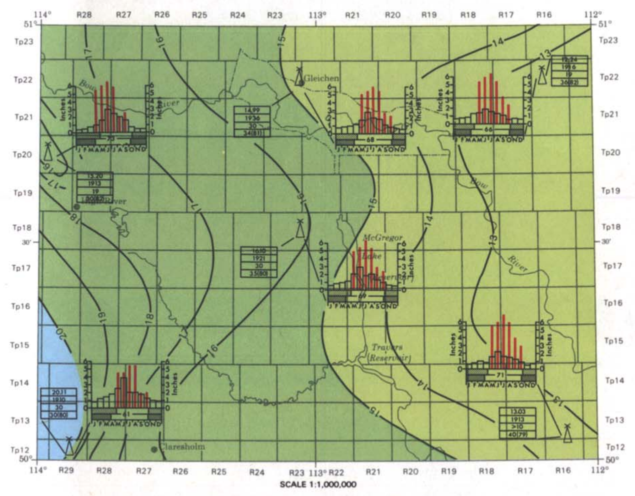
0-105	sand, silt and gravel
105-500	shale, dark to light grey, generally calcareous

Tests: Two bail tests at 87 and 92 feet yielded a rate of 30 igpm.

A pump test at 105 feet for 5 000 minutes yielded 50 igpm; Q_{20} (est.) is 74 igpm from a drawdown of 50 feet.

Alberta RESEARCH

METEOROLOGY



LEGEND

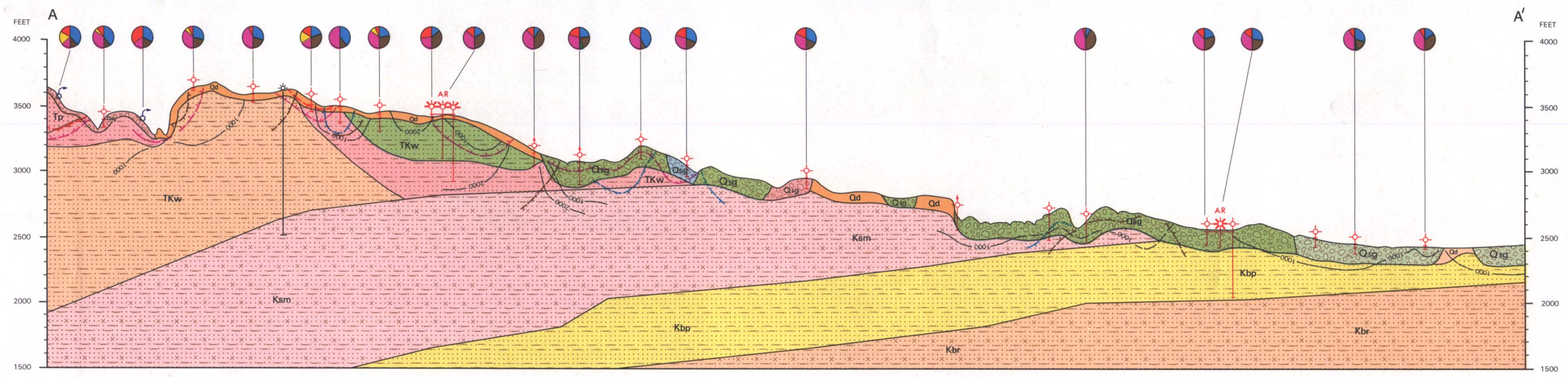
Isohyet, mean annual precipitation in inches

Mean annual precipitation in inches:
<15
15-20
20-25

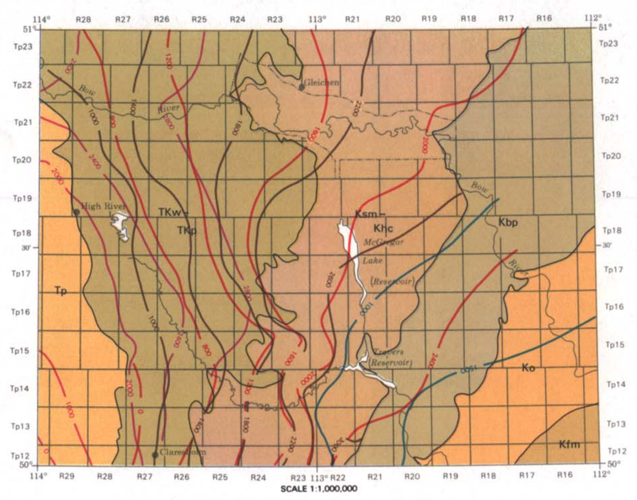
Meteorological station

Precipitation data

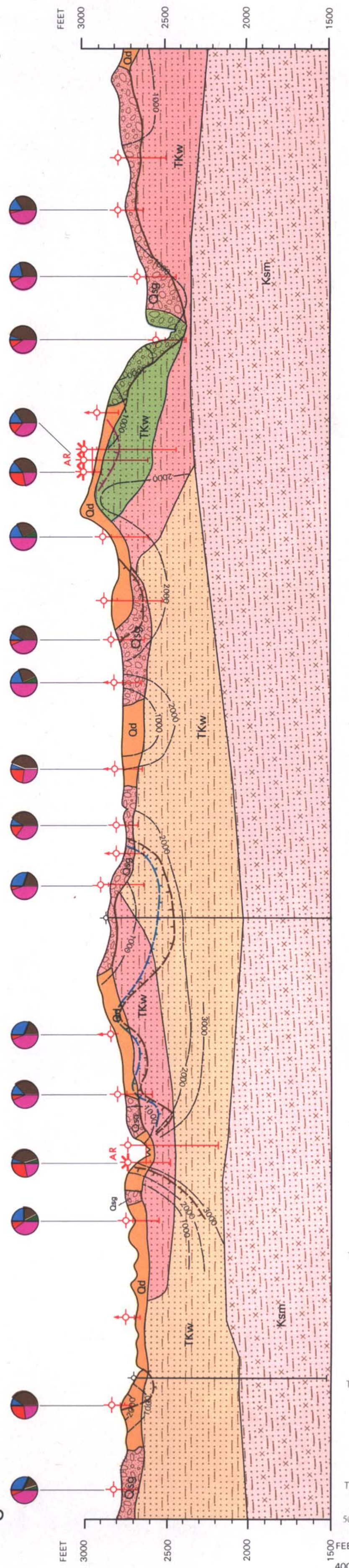
Sources of data

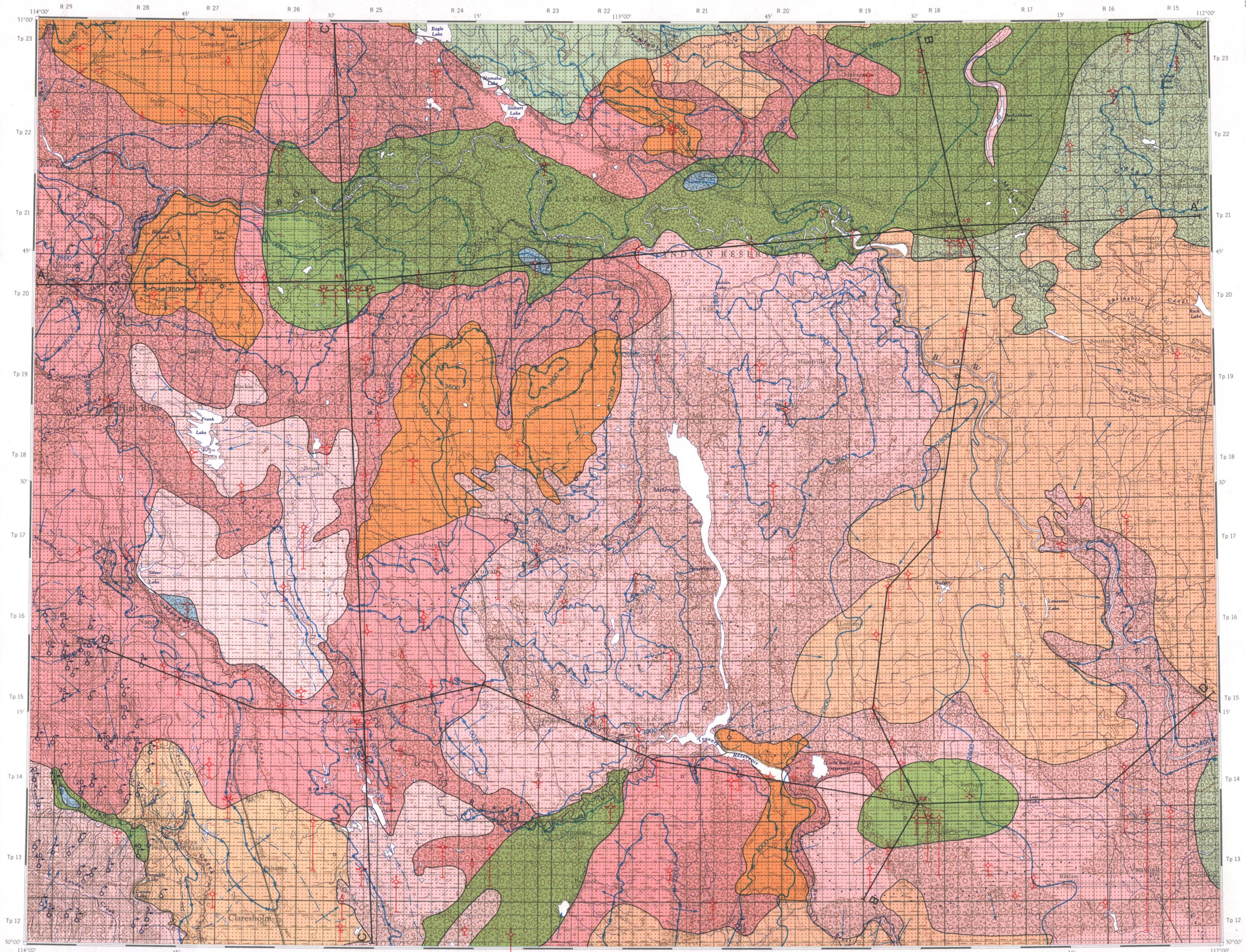


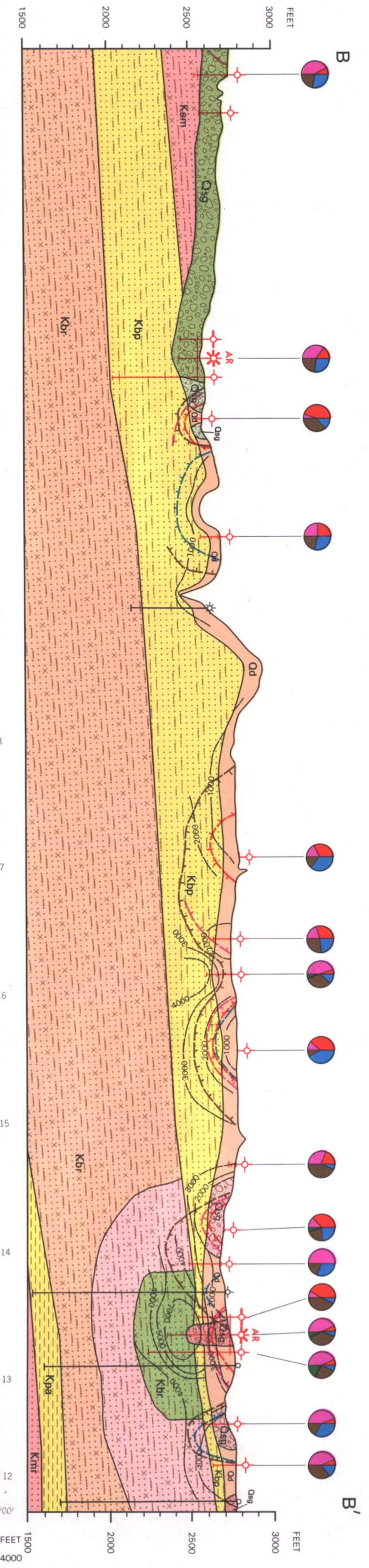
GEOLOGY

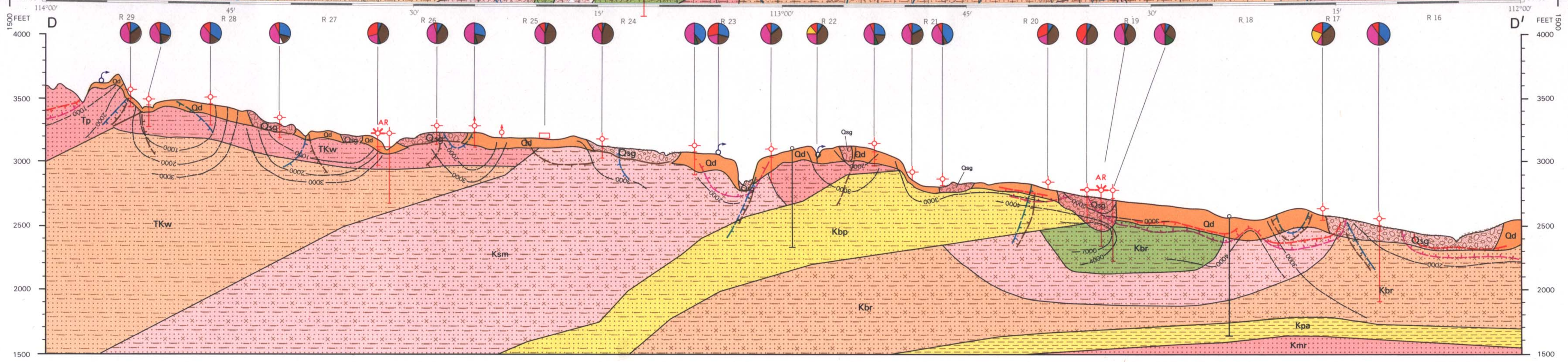


LEGEND









MAIN MAP LEGEND

Topography

Surface contours (interval 100 feet):
- elevation
- depression
- approximate

Geology

Geological boundary

QUATERNARY

Qd — Unconsolidated deposits	Qsg — Sand and gravel

TERTIARY

Tp — Porcupine Hills Formation

TERTIARY-CRETACEOUS

TKw — Willow Creek Formation

CRETACEOUS

Ksm — St. Mary River Formation	Kmr — Milk River Formation
Kbp — Bearpaw Formation	
Kbr — Belly River Formation	
Kpa — Pakowki Formation	

Lithology

Sand and gravel

Sandstone

Shale

Bentonitic sandstone

Hydrography

Lake or slough, perennial

Lake or slough, seasonal

Stream, perennial

Surface water divide

Area of noticeable salt precipitates

Hydrogeology

Spring, flow rate unknown

Spring, flow rate known (imperial gallons per minute)

Nonpumping water level contour (elevation in feet) and vertical component of groundwater movement

Direction of groundwater flow

Boundary of area of artesian flow

Groundwater Probability†

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

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

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

100-500
25-100
5-25
1-5
<1

Yield area boundary

†The indicated average expected yields 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

Water well

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

Test well with more than one piezometer in a single borehole or with groundwater data collected from several depths during drilling

Seismic shothole reported to have flowed, unknown depth

Seismic shothole reported to have flowed, known depth

Depth Scale

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

Location of Alberta Research test well

Gas well*

Abandoned well*

Structure testhole*

Other borehole*

Dugout or borrow pit

Line of hydrogeological profile A — A′

*Vertical line portion of oil, gas or other exploratory test well symbols on hydrogeological profiles indicates well depth; dashed portion indicates surface casing interval.

Hydrochemistry

Cations: Calcium, Magnesium, Sodium + potassium — Anions: Carbonate + bicarbonate, Sulfate, Chloride, Nitrate (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:
approximate

Isogram along which calcium + magnesium constitute 60 per cent of total cations*; teeth indicate direction of lesser calcium + magnesium content

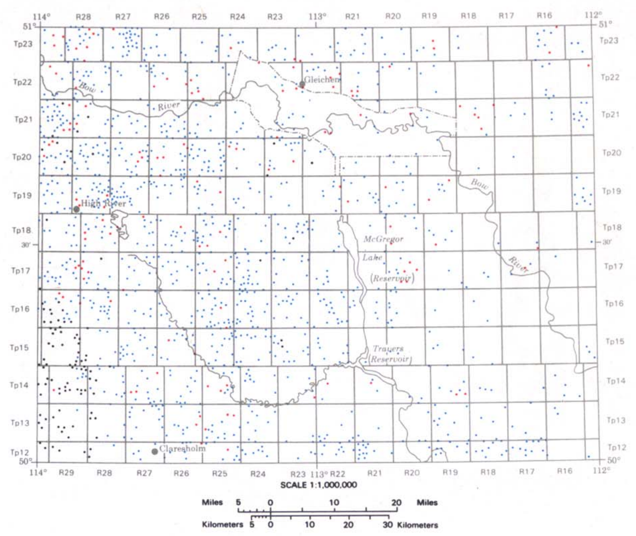
Isogram along which sodium + potassium constitutes 60 percent of total cations*; teeth indicate direction of lesser sodium + potassium content

Isogram along which carbonate + bicarbonate constitutes 60 percent of total anions*; teeth indicate direction of lesser carbonate + bicarbonate content

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

*Determined on equivalents per million basis.

DATA DENSITY



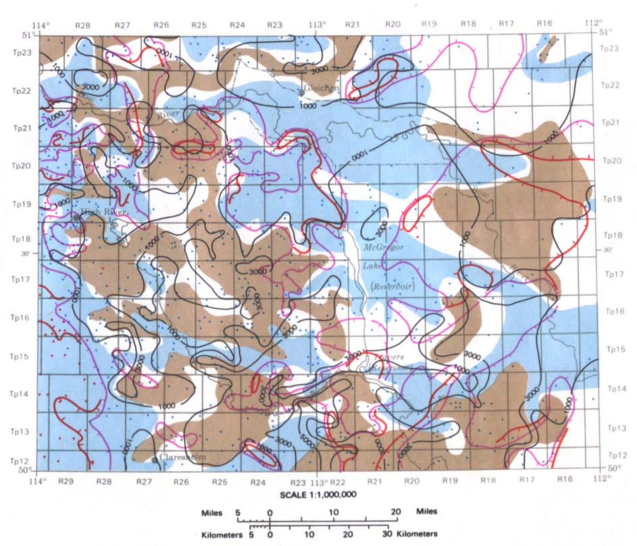
LEGEND

Data control point marking the location of a well with water level information only

Data control point marking the location of a well with yield information (i.e. production tests)

Data control point marking the location of a spring

HYDROCHEMISTRY



LEGEND

Data control point marking the location of a well with a chemical analysis

Data control point marking the location of a spring with a chemical analysis

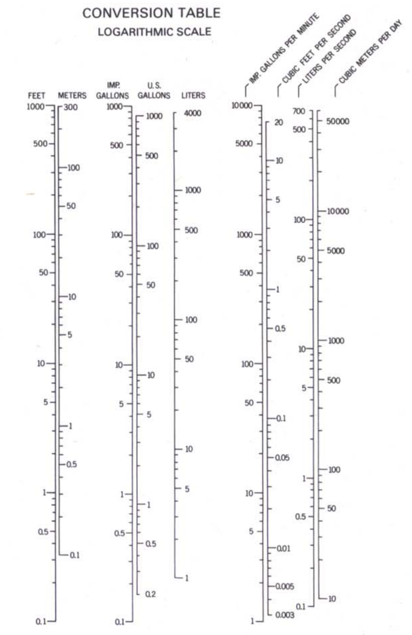
Total dissolved solids in parts per million

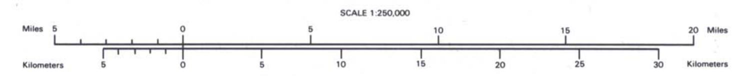
Bicarbonate + carbonate constituting over 60 percent of total anions*

Sulfate constituting over 60 percent of total anions*

*Determined on equivalents per million basis.

CONVERSION TABLE
LOGARITHMIC SCALE





All elevations in feet above mean sea level.

Vertical exaggeration of the hydrogeological profiles is approximately 40 X.

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

Map to accompany Report 74-9.

Hydrogeology by G. Ozoray 1970, 1972, based on data collected in 1970.

Drawn by H. Dey and R. Swenson.

Cartographic editing by F. Smith and A. R. Campbell

HYDROGEOLOGICAL MAP
GLEICHEN
ALBERTA

NTS 82I