Report 75-2

Hydrogeology of the Medicine Hat area, Alberta

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HYDROGEOLOGY OF THE MEDICINE HAT AREA, ALBERTA

ABSTRACT

The Medicine Hat map area is predominantly flat, with rolling hills in the central, eastern and northern parts of the region; the South Saskatchewan, Red Deer and Bow Rivers cut deeply incised valleys into the plains surface.

The great majority of wells produce water from the Oldman Formation. However, a wide and deep bedrock valley which runs from the south central part of the map area to the northeast corner could possibly provide yields of 1 to 500 igpm (0.1 to 38 l/sec) from gravels resting on the bedrock.

Total dissolved solids contents of groundwater over the map area vary from 1,000 to 3,000 mg/l. Water types are sodium bicarbonate in the channels, sodium sulfate in lowland surficial aquifers, calcium bicarbonate in uplands; deep Foremost Formation aquifers are of sodium sulfate type and brackish.

INTRODUCTION

This report is a brief elaboration of the hydrogeological information presented on the accompanying map of the Medicine Hat area (NTS 72L), Alberta.

The map area covers 6,180 sq mi (nearly 16,000 km^2) and lies in the southeast corner of the province between latitudes 50° and 51° north and longitudes 110° and 112° west. In the Alberta land survey system the area covers Tps 12 to 23 and Rs 1 to 15 W 4th Mer.

The Red Deer River flows through the northern half of the map area, and the South Saskatchewan River through the northeast corner of the map area. Road access is limited in the center of the map area, due to a large tract of land being under exclusive lease to the Federal Government.

The City of Medicine Hat has a population of approximately 26,000 and is the industrial center of the southeastern part of the province. The main industries of Medicine Hat and Redcliff (population approximately 2,300) are natural gas production and pottery, fertilizer and tire manufacturing. Water supplies for Medicine Hat, Redcliff, and Suffield are from either the South Saskatchewan River or from wells completed in adjacent river gravels. Brooks (population about 3,750) is another town in the area. The remaining two dozen municipalities (average population about 200) are small villages which occur along branch lines of the Canadian Pacific Railway. Most of these villages get their water supplies from wells or springs.

ACKNOWLEDGMENTS

Test drilling was ably carried out by Hi-rate Drilling Company of Stettler. Mr. K. W. Campbell, technical assistant, constructed the hydrogeological atlas. G. Ozoray, D. Hackbarth, and R. Bibby edited the manuscript.

TOPOGRAPHY AND DRAINAGE

The most notable topographic features in the map area are the deeply incised valleys of the Red Deer, South Saskatchewan, and Bow Rivers. Where these valleys cut into the alluvial flood plains of underlying buried valleys they are broad and shallow with stream meanders occurring on the valley floors. Where they cut into the bedrock, the valleys are narrower and have incised meanders up to 500 ft (150 m) deep. Tributary drainage channels cut into the bedrock to form a typical badland topography, with interconnecting gullies ranging up to 300 ft (90 m) in depth. A good example of this can be observed in the Dinosaur Provincial Park located in the northwestern corner of the map area.

Broad rolling hills cover the central parts of the eastern and northern portions of the map area. They reach a maximum elevation of 2,800 ft (850 m) and have a local relief of 300 ft (90 m). Deep coulees with southeast-northwest trends cut into these hills. Lower ranges of scattered hills exist in the west-central part of the map area.

Another important topographic feature in the map area is the broad valley which runs from Suffield in the southwest-central part of the area to Empress into the northeast corner of the map area, and which is a surface expression of the Lethbridge Buried Valley (Carlson, 1970).

CLIMATE AND VEGETATION

CLIMATE

According to Koeppen's climate classification, the Medicine Hat map area has the climate of a middle latitudes steppe. It is semi-arid and cold with a mean annual temperature less than 64.4°F (18°C) and a mean temperature in the warmest month of over 64.4°F (18°C) (Atlas of Canada, 1957).

Isohyets of mean annual precipitation are shown on the meteorological side map. They are modified from Longley (1968), using climatic data from weather stations in the area. The estimated annual runoff from the area is low and equal to 0.2 to 0.5 in (5 to 13 mm) (Neill *et al.*, 1970). Calculated potential evaporation using the Thornthwaite method (Thornthwaite and Mather, 1957) is 22.3 in (567 mm) which indicates that most of the precipitation is used in evapotranspiration.

Table 1 gives rainfall, potential evapotranspiration, and mean annual temperature for six weather stations in the area.

VEGETATION

The main vegetation types in the ranchlands are short prairie grasses, forbs, and sage brush. Willows, poplars, and meadow grasses are found along the banks and valley bottoms of rivers and coulees. Tree groves are present near farm houses and in fields in the irrigated districts in the western part of the map area.

GEOLOGY

The Geological Survey of Canada published in 1940 a report on the geology of southern Alberta plains by L. S. Russell and R. W. Landes, and, in 1968, published the bedrock geology map for the Medicine Hat area by E. J. W. Irish. In 1972, Alberta Research Council published a geological map of Alberta by R. Green and also a surficial geology map of the Medicine Hat area by Berg and McPherson.

BEDROCK GEOLOGY

The units underlying the map area to a depth of 1,000 ft (300 m), are the Upper Cretaceous Bearpaw, Oldman, Foremost, and Pakowki Formations. Sections of the Bearpaw, Oldman, and Foremost Formations outcrop along the banks of the Red Deer and South Saskatchewan Rivers and in tributary channels; detailed descriptions of river sections are given by Russell and Landes (1940). The bedrock subcrops are shown on the geology side map together with the structure of the base of the Oldman Formation which is the most important bedrock unit for groundwater. The geological map presented here was drawn from formation contact elevations (above mean sea level) determined from electric logs of structure testholes and from oil and gas wells (ERCB, 1964-70).

The Bearpaw Formation, uppermost in the subcrop, has been almost completely removed by erosion in the southern and western parts of the map area. However, almost 300 ft (90 m) remain in the north central and eastern highlands. This formation consists mainly of dark shales with some thin sandstone lenses which thicken and have a larger areal extent in the north central part of the map area and farther north in the Oyen map area.

The upper contact of the Oldman Formation was selected at the top of the first good sandstone and shale sequence, the lower contact was selected at the base of the major sandstone.

The Foremost and Pakowki Formations underlie the Oldman, and have a thickness ranging from 560 ft (170 m) to 820 ft (250 m). The base of the Foremost Formation was picked at the base of the lowermost consistent sandstone member. In outcrop the unit appears to consist of dark grey claystones with some thin sandstone and coal beds. Two or three sandstone layers of local extent are present in the lower part of the formation in the south central part of the map area. A consistent basal sandstone bed is present only to the north and east but this bed may correlate with the middle sandstone bed in the south (cross section C-C') with the result that the Foremost section to the east and the north may actually be thicker than shown on the cross section. The base of the Pakowki was picked at the top of the uppermost Milk River sandstone member, which is a consistent marker bed across the map area. This sandstone bed dips to the north and northeast and appears to reflect a northern extension of the Bow Island Arch, shown by Meyboom (1960).

SURFICIAL SEDIMENTS

Unconsolidated materials overlying the bedrock include:

1) up to 360 ft (110 m) of preglacial flood-plain deposits and overlying tills and gravels in the buried valleys of the old drainage system;
2) up to 100 ft (30 m) of till present in the low-lying areas of the western half of the map area;
3) approximately 200 ft (60 m) of thick hummocky moraine found in the north and east central part of the map area.

Recent flood plain deposits are found along the existing river channels.

HYDROGEOLOGY

For most of the area, the pump-test data available are composed of water levels, depths to the top of aquifers, bailing or pumping rates, durations, and maximum drawdowns. These values can be used to calculate an apparent transmissivity by plotting initial and final drawdown against the log of the time, and then using the slope of this straight line in Jacob's modified formula. The apparent transmissivity value is then substituted in another

Table 1. Rainfall, Potential Evapotranspiration and Mean Annual Temperature Data for Meteorological Stations in the Study Area

	Rainfall		Potential Evapotranspiration		Mean Annual Temperature	
Stations	mm	in	mm	in	°C	°F
Brooks	344.2	13.55	535.9	21.1	11.1	52
Empress	240.5	9.47	581.7	22.9	3.4	38.1
Hays	328.4	12.93	563.9	22.2	4.8	40.7
Jenner	317.2	12.49	553.7	21.8	10.6	51
Medicine Hat	362.9	14.29	596.9	23.5	11.7	53.1
Suffield	320.5	12.62	574.0	22.6	10.7	51.2
AVERAGE	318.8	12.55	567.7	22.35	8.7	47.6

Table 2. Data from Testholes Drilled in the Study Area

Testhole Number	Location Lsd	Sec	Tp	R (W4)	Depth (ft)	Aquifer Intervals (ft)	Lithology	Number of Pump Tests	Transmissivity (igpd/ft)
1	1	33	14	10	365	338-353	gravel	2 at 135 igpm	726 (average)
2	1	4	18	9	600	165-175	sandstone	1 at 22 igpm	pump well: 400 obs well: 3100
3	9	28	14	9	500	350-358	gravel	5 step-down	168 (average)
4	16	35	14	13	560	none	-	none	very low
5	16	36	22	11	560	open hole	sand and gravel zone	step-down	347

formula for calculating the "20-year safe yield, Q_{s20}." The formula used is as follows (Farvolden, 1961):

$$Q_{s20} = \frac{TH}{2110}$$

where,

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

T = coefficient of transmissivity in igpd/ft,

H = total available drawdown in feet for confined aquifers, H = depth to top of aquifer minus depth to static water level; for unconfined aquifers, H is taken arbitrarily at two thirds of the difference between static water level and the base of the aquifer.

The coefficient of transmissivity was calculated from bail and pump test data using the formula (Todd, 1959, p. 94):

$$T = \frac{264Q}{S}$$

where,

Q = pumping rate in igpm,

S = drawdown in ft/log cycle.

BEDROCK AQUIFERS

The erosional remnants of the Bearpaw Formation consist mainly of shales. However, in the north central part of the map area, a few wells yielding 0 to 5 igpm (0 to 0.4 l/sec) have been developed in a basal sandstone of the Bearpaw Formation.

The majority of wells that are producing water from bedrock aquifers are developed in the Oldman Formation. Interbedded sandstone lenses can be correlated over large areas. Yield estimates for those wells that have been pump- or bail-tested range from 5 to 40 igpm (0.4 to 3 l/sec).

Where the Oldman Formation has been nearly or completely eroded by the preglacial drainage system, the bedrock wells are completed in the Foremost Formation. Wells completed in Foremost aquifers are concentrated in the northwest corner and in the central parts of the southeastern and eastern quarters of the map area. In this aquifer yields range from 10 to 40 igpm (0.7 to 3 l/sec).

The Pakowki Formation is composed of shale and has no known aquifers.

Continuous records of water-level fluctuations are not available for existing wells. During the well survey however, discussion with farmers indicated that water levels in bedrock wells seem to stabilize one to two years after completion. This indicates that transmissivity is great enough to sustain pumping and that the recharge of the aquifers is balancing present-day withdrawals. This also shows that two years are enough for the wells to reach equilibrium, and this means that apparent safe yields can be considered as practical sustained yields.

SURFICIAL AQUIFERS

For water-table aquifers, where they are composed of outwash sands and gravels near the ground surface, the yield range assigned is 5 to 25 igpm (0.4 to 2 l/sec). In the western part of the area where bedrock aquifers are overlain by thin tills and glacial sands and gravels, and where the main source of infiltration is from irrigation waters, the assigned probable range can be considered as the sustained yield and is from 1 to 5 igpm (0.07 to 0.4 l/sec).

A small number of wells are completed in sand and gravel deposits that are present at the bottom of the preglacial Lethbridge, Medicine Hat and Calgary Buried Valleys; their yields range possibly from 100 to 500 igpm (7 to 38 l/sec). Most of these wells are exploratory Alberta Research Council testholes. A large part of the Lethbridge Buried Valley occurs within the Suffield Military Reserve, so very little is known about it.

North of the city of Medicine Hat the South Saskatchewan River flows over the preglacial Medicine Hat Buried Valley. Test wells completed in the Recent and preglacial valley deposits at Police Point have been pump tested at several hundred gallons per minute (Meyboom, 1963). Other high-yield wells are completed in preglacial valley deposits which receive their recharge from the present river system, for instance, west of Sandy Point crossing on Highway 41 and at Empress.

Wells in glacial sands and gravels lying within or on till deposits yield 5 to 25 igpm (0.4 to 2 l/sec). This type of deposit is found south and southwest of Schuler and Jenner and along the west side of the South Saskatchewan River north of the city of Medicine Hat, where several springs have been developed for farm water supplies. The largest of this type of spring in the map area, in the city of Medicine Hat, has a discharge of over 100 igpm (>7.5 l/sec).

There are also a number of springs issuing from surficial materials such as glacial sands and gravels; they are found along coulees tributary to the Red Deer River north of Brooks; these springs are believed to be due to irrigation returns; the yield category assigned to these glacial sands and gravels is 5 to 25 igpm (0.4 to 2 l/sec).

TEST DRILLING

Test drilling was carried out at five sites to locate aquifers and to determine aquifer yields. Table 2 gives location, depth of the testhole, the aquifer intervals, the lithology, and the aquifer parameters.

Site 1 - This site was chosen in order to investigate aquifer conditions in the buried valley north of the present-day Red Deer River valley, and also aquifer conditions in the underlying bedrock.

Site 2 - This second site was chosen to locate the buried valley aquifers and to test bedrock aquifers in the Oldman and Foremost Formations.

Site 3 - This site was chosen to determine aquifer conditions in the Lethbridge Buried Valley deposits.

Site 4 - Investigations at this site were designed to locate and test buried valley and bedrock aquifers.

Site 5 - An additional observation well was installed adjacent to a farm well at this location in order to test gravels of the Lethbridge Buried Valley. Due to development problems, there was limited water level response during the pump test and calculated yield values are considered unreliable.

HYDROCHEMISTRY

Travel time, the nature of the flow system, the position of the sampling point, and the lithology of the aquifer are the important parameters that control groundwater quality in the map area. In the case of a surficial aquifer located in an upland area, water enters the flow system through infiltration and flows to areas of discharge in a relatively short time. These waters have generally less than 1,000 mg/l total dissolved solids; the main water type is calcium bicarbonate. Spring waters of this type are used in the hamlets of Schuler and Jenner.

Where a surficial aquifer is located in a regional low, groundwaters may have moved slowly through a regional flow system before entering the aquifer. In these waters total dissolved solids are over 3,000 mg/l; the main water type is sodium sulfate.

An aquifer of this type may also have calcium bicarbonate waters in the upper part and mixed waters where local and regional flow systems are contiguous. The total dissolved solids of the mixed waters range from 1,500 to 3,000 mg/l and they are of sodium bicarbonate or calcium sulfate types. Waters of these types are present in shallow wells northeast of Brooks.

Where the major component of mixed waters originates from surface infiltration, as in the irrigated areas, the sulfate waters of the regional flow systems are largely diluted. This type of water is encountered in springs discharging along Metzhiwin Coulee.

In the same fashion, waters moving in the buried valley deposits have three main sources:

1) direct infiltration from the surface,
2) natural recharge from present-day river systems,
3) natural discharge from regional flow systems.

In each case the quality of the water will reflect its source and may be of calcium sulfate, or calcium bicarbonate, or sodium sulfate type, or a mixture of these. In the regionally high areas and along steep river banks, the direction of groundwater flow is downwards into bedrock aquifers. These conditions are present in the central parts of the eastern and southern quarters of the map area, where in general, wells are developed in sandstones of the Oldman and Foremost Formations. The total dissolved solids of waters from both areas range from 1,000 to 2,000 mg/l and the main water type is sodium bicarbonate.

Total dissolved solids of waters belonging to regional flow that passes through bedrock material are over 3,000 mg/l. The main water type in this case is sodium sulfate. Waters of this type are found in aquifers of the Oldman Formation in the Brooks area and to the south and to the east, and in deep Foremost aquifers underlying the central and the eastern parts of the area.

Contours of total dissolved solids and water types shown on the hydrochemical side map represent the waters in the main aquifers and as a result are not continuous. In the central part of the map these contours are hypothetical, because of the paucity of the data.

CONCLUSION

Surficial sands and gravels, buried valley deposits, and sandstones and coal lenses of the Oldman and Foremost Formations form the main aquifers in particular parts of the map area. The yields of the buried valley deposits range from 25 to 500 igpm (2 to 38 l/sec). The main source of recharge is from surface infiltration. The dominant water type is sodium bicarbonate. However, in the buried valley deposits in the northwest corner of the map area mixed waters are present, as a significant portion of them are derived from regional flow.

Yields from surficial sands and gravels range from 5 to 25 igpm (0.4 to 2 l/sec). Upland waters are of calcium bicarbonate type whereas waters from lowland surficial aquifers are of sodium sulfate or mixed types. Yields from bedrock aquifers range from 5 to 25 igpm (0.4 to 2 l/sec). Waters in upland areas are of sodium bicarbonate type and good for human consumption whereas waters of regional lows or of deep Foremost aquifers are of sodium sulfate type and brackish.

REFERENCES

Atlas of Canada (1957): Dept. Mines and Tech. Surveys, Geog. Branch, Ottawa, 110 plates.

Berg, T. E., and R. A. McPherson (1972): Surficial geology map of the Medicine Hat area, Alberta, NTS 72L; Res. Coun. Alberta map.

Carlson, V. A. (1970): Bedrock topography of the Medicine Hat map area, Alberta, NTS 72L; Res. Coun. Alberta map.

Christiansen, E. A. (1965): Geology and groundwater resources of the Kindersley area, Saskatchewan, 72N; Saskatchewan Res. Coun., Geol. Div., Rept. 7, 25 pages.

-------------------- (1967): Collapse structures near Saskatoon, Saskatchewan, Canada; Can. J. Earth Sci., Vol. 4, P. 757-767.

Energy Resources Conservation Board (1964-1970): Schedule of wells.

Farvolden, R. N. (1961): Groundwater resources of the Pembina area, Alberta; Res. Coun. Alberta Rept. 61-4, 26 pages.

--------------- (1963): Bedrock channels of southern Alberta; *in* Early contributions to groundwater hydrogeology of Alberta; Res. Coun. Alberta Bull. 12, p. 63-75.

Green, R. (1972): Geological map of Alberta; Res. Coun. Alberta map.

Irish, E. J. W. (1968): Geology map of Medicine Hat area, NTS 72L; Geol. Surv. Canada Map 22-1967.

Jacob, C. E. (1946): Radial flow in a leaky artesian aquifer; Trans. Amer. Geophys. Union. Vol. 27, p. 198-205.

------------ (1950): Flow of groundwater; *in* Engineering Hydraulics, H. Rouse, ed., John Wiley and Sons Inc., New York, p. 321-386.

Longley, R. W. (1968): Climatic maps for Alberta; Univ. Alberta, 8 pages.

Meyboom, P. (1960): Geology and groundwater resources of the Milk River sandstone in southern Alberta; Res. Coun. Alberta Mem. 2, 89 pages.

----------- (1963): Induced infiltration, Medicine Hat, Alberta; *in* Early contributions to the groundwater hydrogeology of Alberta, Res. Coun. Alberta Bull. 12, p. 88-94.

Neill, C. R., D. I. Bray, Maria F. Schouten, and J. R. Card (1970): Selected characteristics of streamflow in Alberta; Res. Coun. Alberta Rept. 70-1, 55 pages.

Ozoray, G. and A. T. Lytviak (1974): Hydrogeology of the Gleichen map area, NTS 82I, Alberta; Res. Coun. Alberta Rept. 74-9, 16 pages.

Russell, L. S. and R. W. Landes (1940): Geology of the southern Alberta Plains; Geol. Surv. Canada Mem. 222, 223 pages.

Thornthwaite, C. W., and J. R. Mather (1957): Introductions and tables for computing potential evapotranspiration and the water table balance; Drexel Institute of Technology, Laboratory of Climatology Publications in Climatology, Vol. 10, No. 3, Centerton, New Jersey, p. 185-243.

Todd, D. K. (1959): Groundwater Hydrology; John Wiley and Sons Inc., New York, 366 pages.

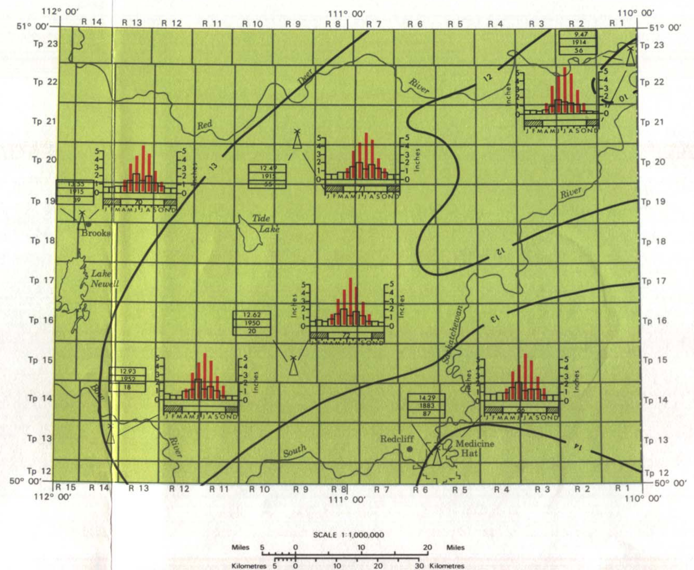
Vanden Berg, A. (1966): Pump test of an alluvial aquifer at Redcliff, Alberta; Res. Coun. Alberta, Groundwater Div. Int. Rept., 24 pages.

HYDROGEOLOGICAL MAP MEDICINE HAT ALBERTA

NTS 72L

Alberta Research Council

METEOROLOGY



LEGEND

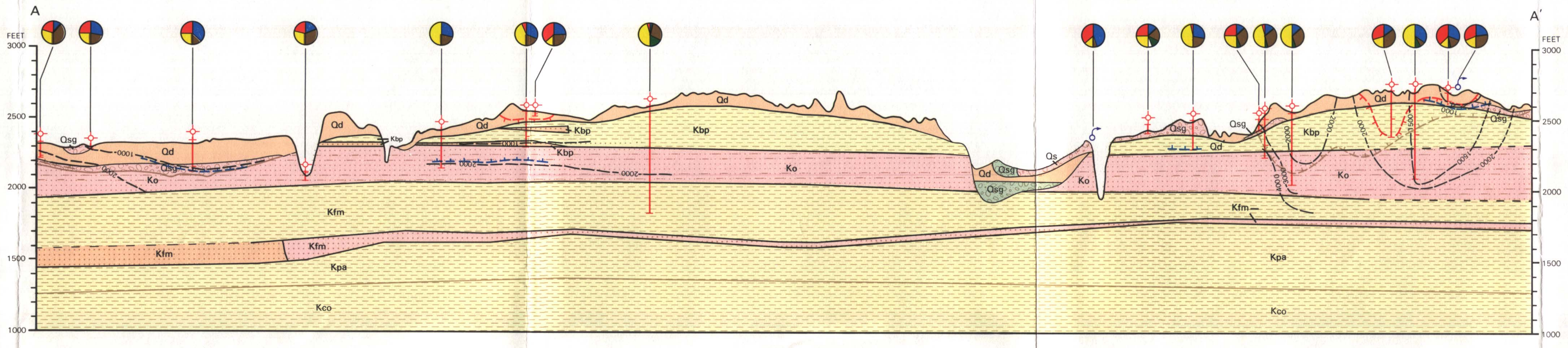
[Is]ohyet, mean annual precipitation in inches 13

[M]ean annual precipitation: less than 15" ....

[M]eteorological station ....

[P]recipitation data:

- Mean annual precipitation in inches 12.62
- Year of commencement of observations 1950
- Number of years of record averaged to determine the mean annual precipitation figure 20
- Mean monthly potential evapotranspiration
- Mean monthly precipitation
- Period when surface is usually snow-covered
- Period with mean daily temperature below freezing (0°C)
- Figure indicates percentage of mean annual precipitation falling as rain



MAIN MAP LEGEND

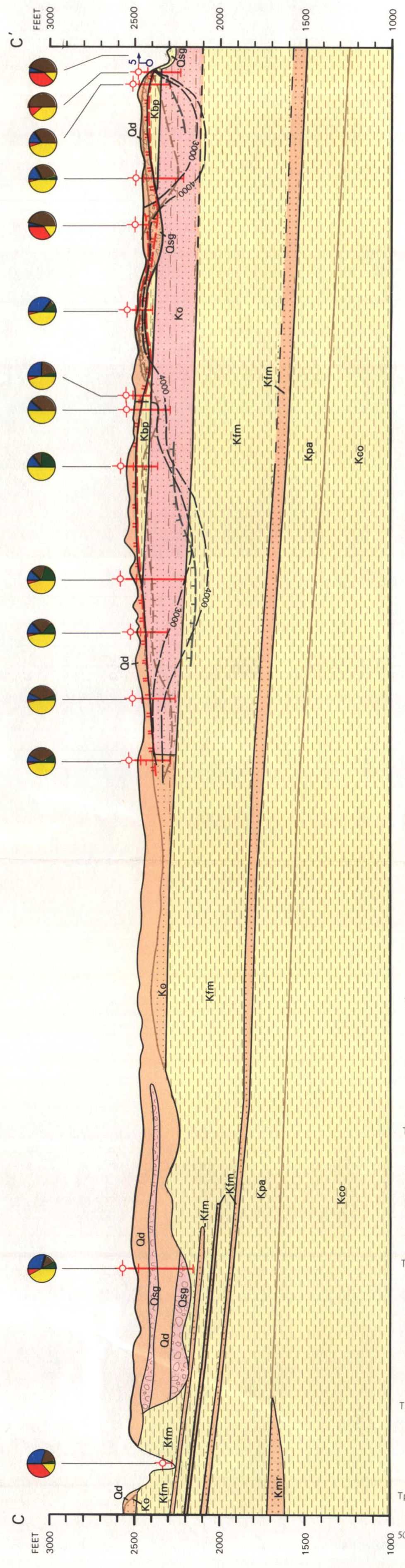
QUATERNARY

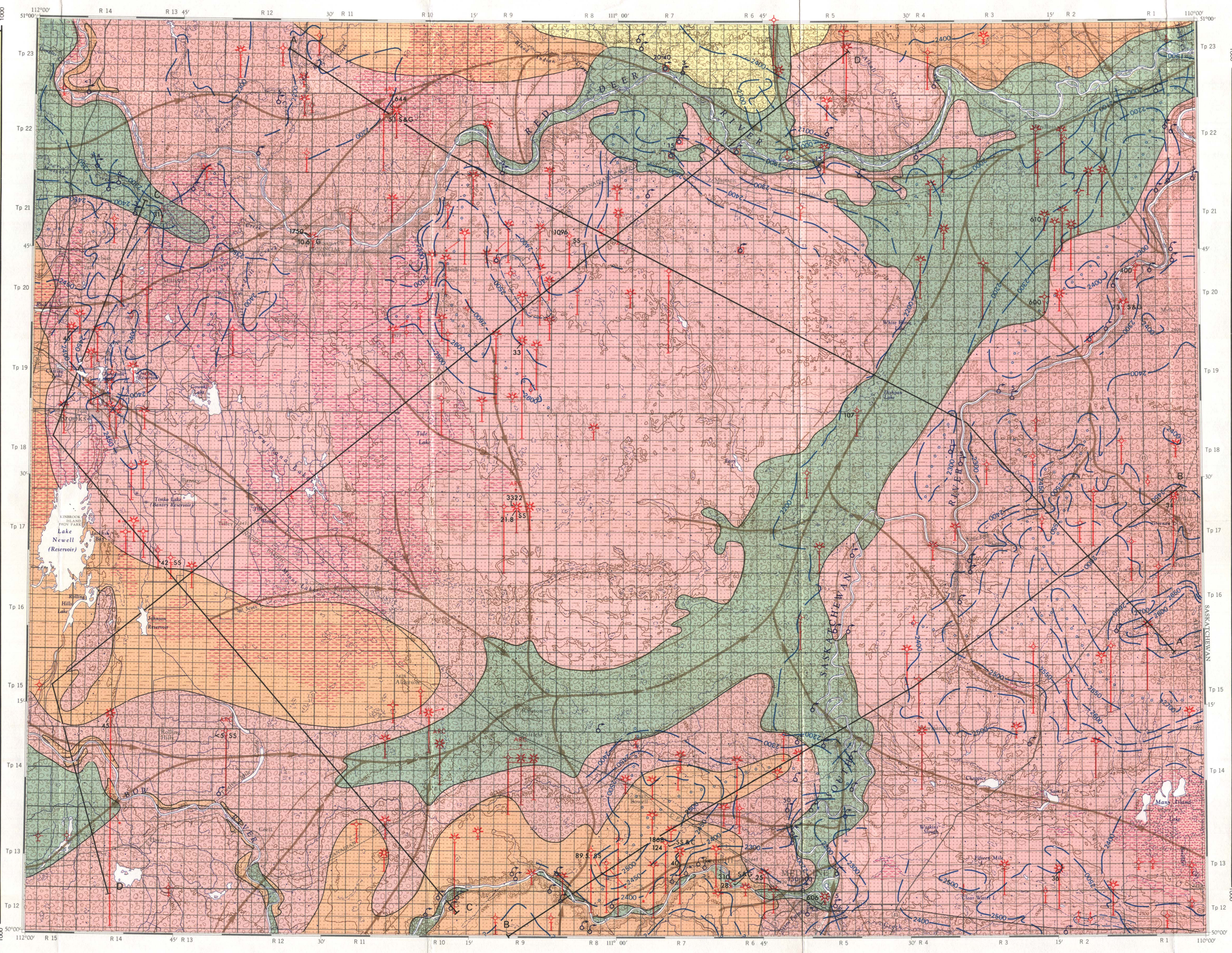
- Qd Unconsolidated deposits
- Qsg Quaternary sands and gravels

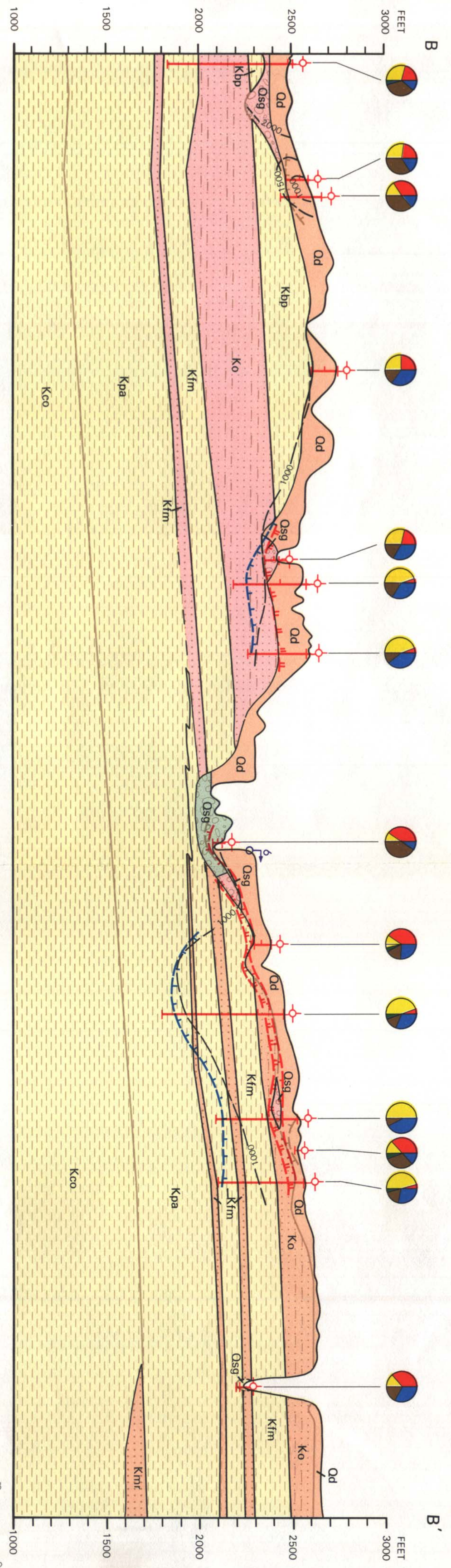
CRETACEOUS

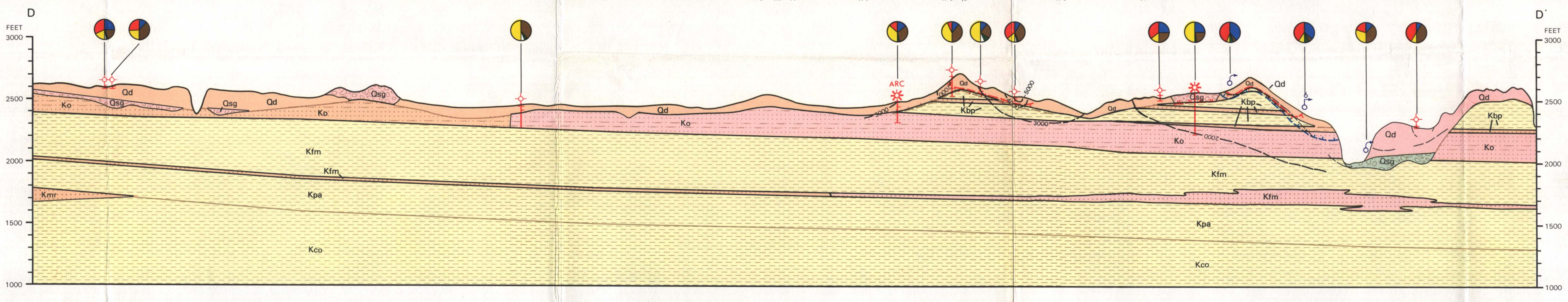
- Kbp Bearpaw Formation
- Ko Oldman Formation
- Kfm Foremost Formation
- Kpa Pakowki Formation
- Kmr Milk River Formation
- Kco Colorado Group

[Li]thology · [H]ydrography · [H]ydrogeology · [G]roundwater Probability · [W]ells and Other Artificial Works · [H]ydrochemistry



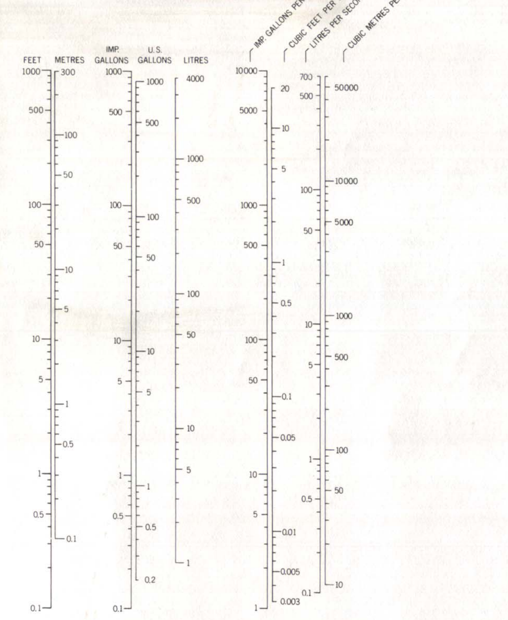






CONVERSION TABLE

LOGARITHMIC SCALE



All elevations in feet above mean sea level.

Vertical exaggeration of the profiles is approximately 40X.

Hydrogeology by D. M. Borneuf and D. R. Stevenson, based on data collected in 1970.

Cartographic editing by A. R. Campbell.

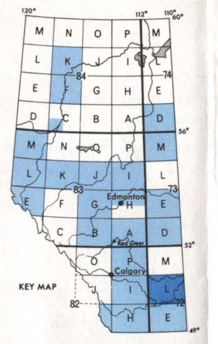
Drafting by R. W. Swenson

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

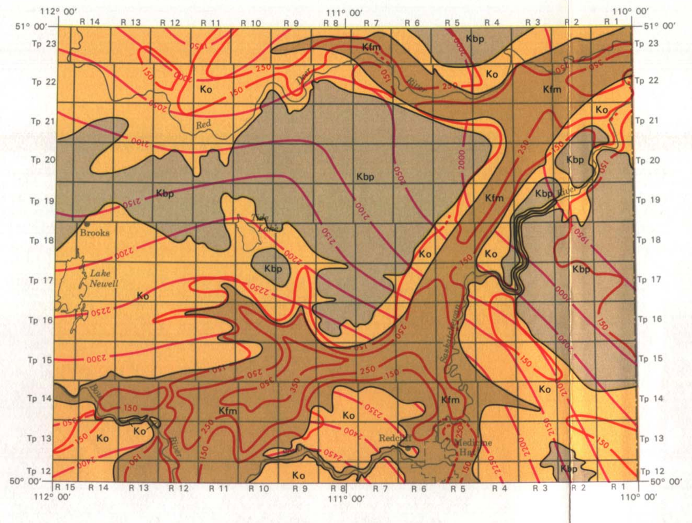
Map is to accompany Report 75-2.

SCALE 1:250,000

KEY MAP



GEOLOGY



LEGEND

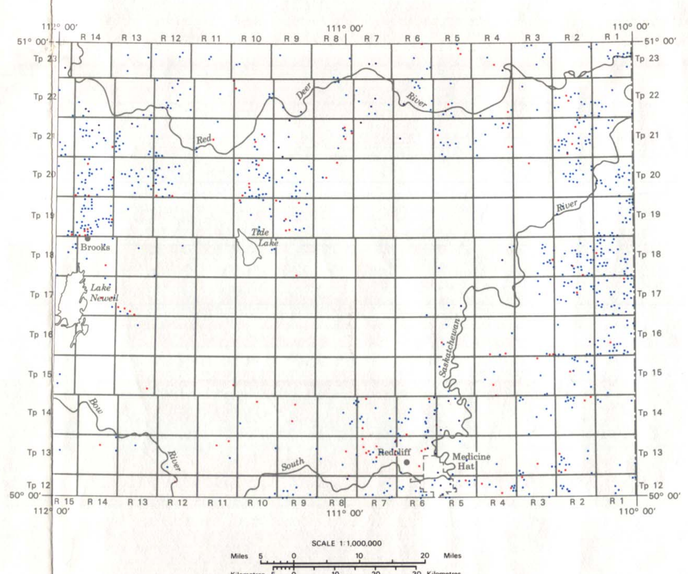
- Kbp — Bearpaw Formation: *shale, glauconitic and clayey sandstone, thin bentonitic and ironstone beds*
- Ko — Oldman Formation: *sandstone, siltstone, mudstone, carbonaceous shale*
- Kfm — Foremost Formation: *sandstone, siltstone, mudstone, carbonaceous shale, ironstone, thin coal beds*

Rock unit boundary ....

Isopach of drift, in feet (defined, approximate:) 150

Structure contour of base of Oldman Formation 2000

DATA DENSITY



SCALE 1:1,000,000

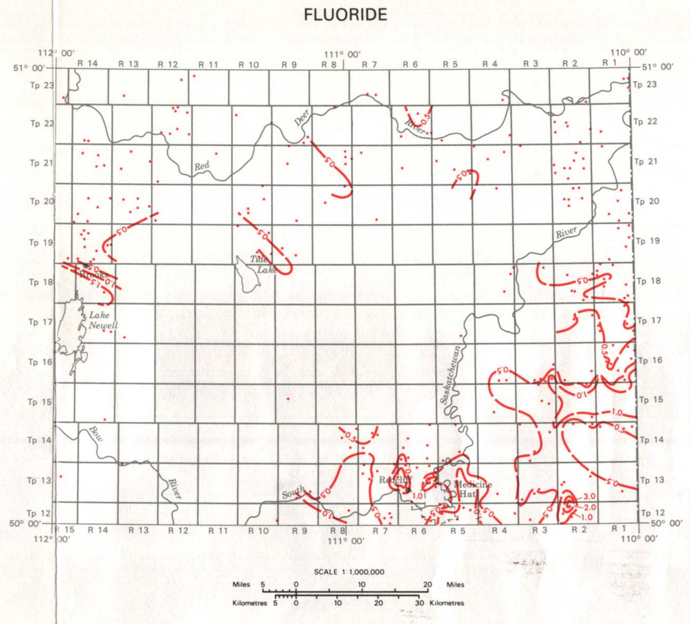
LEGEND

Well with water level information only ....

Well with yield information ....

Spring ....

FLUORIDE



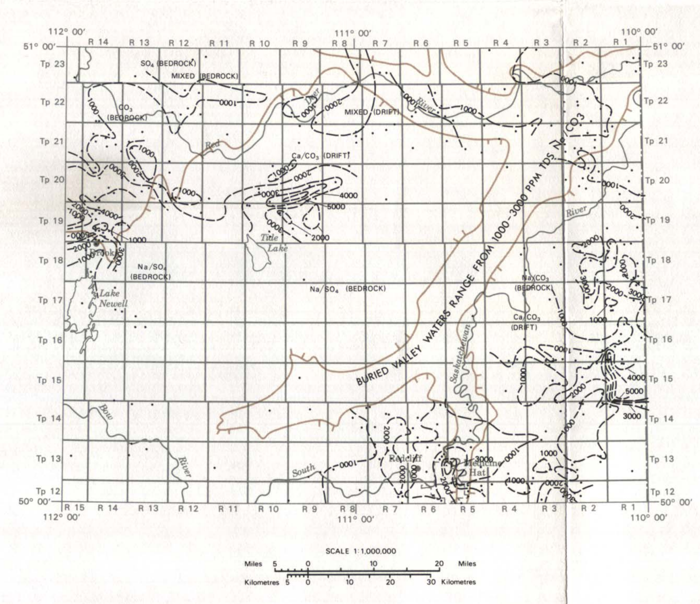
SCALE 1:1,000,000

LEGEND

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

Fluoride content in parts per million (approximate) 1.5

HYDROCHEMISTRY



LEGEND

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

Total dissolved solids in parts per million (approximate) 1000

Hydrochemical facies:

- calcium cation .... Ca
- sodium cation .... Na
- carbonate anion .... CO_3
- sulfate anion .... SO_4

Buried valley boundaries ....