Report 75-5

Hydrogeology of the Vermilion area, Alberta

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Alberta Research Council
1976

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HYDROGEOLOGY OF THE VERMILION AREA, ALBERTA

Abstract

The Vermilion map area lies in the plains-parkland transition zone of east-central Alberta and covers approximately 5660 square miles (14,660 km^2). Average annual precipitation is 16 inches (41 cm) and potential evaporation exceeds precipitation from April to October.

Both bedrock and surficial deposits are possible groundwater sources. The bedrock interval supplying groundwater in the region is a complex interfingering of sandstones and shales in the lower Belly River Formation. There is difficulty in correlating the various sandstones over even small distances but two units, the Ribstone Creek and the Birch Lake members, are fairly widespread and form the major aquifers in the region with yields of 25-100 igpm (100-450 l/min). Sediments in preglacial and meltwater channels are a secondary source of groundwater and yield 5-25 igpm (25-100 l/min) or more depending on aquifer lithology.

Groundwater quality is generally good with total dissolved solids within the limits of human consumption although in regions of discharge total dissolved solids and sulfate values can be very high.

In addition to the groundwater availability map at 1:250,000 scale, the related maps at 1:1,000,000 and the hydrogeological sections, three detailed geological sections of the northeast portion of the map area are included.

INTRODUCTION

The purpose of this report, in addition to providing basic information pertinent to the map, is to supply supplementary data gathered during field work and test drilling operations.

The map area covers approximately 5660 square miles (14,660 km^2). The groundwater survey upon which the maps are based was conducted from May to December 1971. Previous investigations into the area were conducted by the Geological Survey of Canada in the 1930's, but the most comprehensive work is that of Le Breton (1963).

The Vermilion map area lies in the plains-parkland transition zone of east-central Alberta. The area is largely agricultural and water wells are numerous. The only major center of population which draws heavily on the groundwater resource is the city of Lloydminster (population of 8691 based on 1971 census). The largest towns within the map area are St. Paul (4161), Vermilion (2915), Viking (1178), Two Hills (979) and Elk Point (729).

The data from individual wells and testholes together with interpretive geological cross sections is included with this report in the hope that drillers operating in the area will find this detailed information useful.

Acknowledgments

Testhole drilling in the northeast part of the map area was conducted by the drilling crew of the Groundwater Branch, Earth Sciences and Licensing Division, Alberta Environment. This cooperative venture led to the use of the department's side-hole sample rig on a contract basis in conjunction with further testhole drilling performed by Stan Byrt and Sons, Lloydminster. The authors worked closely with Stan Byrt and Sons and as a result were able to collect water samples and conduct many pump tests on domestically drilled wells.

The authors also with to acknowledge the help of V. A. Carlson, former staff member of the Alberta Research Council. Discussions with him were of great benefit in the evaluation of the area and resulted in the establishment of Carlson's law: The width of any preglacial valley is directly related to the distance between testholes. O. Tokarsky completed the hydrochemical study and the structure contouring on the geological side map and thanks are extended to him and to other staff members who edited the manuscript.

TOPOGRAPHY AND DRAINAGE

The Vermilion area is a rolling plain, for the most part morainic in origin, but with some bedrock uplands and some glacial meltwater channels incised into the surface. Elevations range from 1650 to 2500 feet (500 to 760 m) above mean sea level with the regional slope to the east (Ellwood, 1960).

The North Saskatchewan River enters the area in township 56, range 12, west of the 4th meridian just under 1800 feet (550 m) and leaves the area in Tp. 53, R. 1 at just under 1650 feet

(500 m). The Vermilion River has its source near Torlea in Tp. 48, R. 13 at an elevation of 1970 feet (600 m). It joins the North Saskatchewan in Tp. 54, R. 3 at an elevation of about 1700 feet (520 m). The Battle River enters the map area from the south in Tp. 46, R. 6 at just under 2000 feet (610 m) elevation, and leaves the area near the eastern edge of R. 4 in the same township.

The major river is the North Saskatchewan which flows through the northern one third of the map area in a general east-southeast direction. This river has fairly steep banks — between 200 and 300 feet (60 to 90 m) high — with generally very little river floodplain. The major tributaries to the river within the borders of the map area are Slawa Creek, Silver Creek, Atimoswe Creek, Moosehills Creek, Primula Creek and Frog Creek.

Many of the drainage valleys between Lloydminster and the North Saskatchewan River south of Elk Point are practically continuous, suggesting an old southeast glacial drainage system through the present Greenlawn-Dewberry-Streamstown trough. Test drilling in that portion of the map area substantiates this idea.

CLIMATE

The climate of the Vermilion area is humid continental (Government of Canada, 1957). The mean temperature in January, the coldest month, is approximately 1°F (-17°C); the mean temperature in July is 62°F (17°C).

The average annual precipitation is 16 inches (41 cm) but varies slightly from station to station as shown on the meteorological side map. Monthly rates of potential evapotranspiration have been approximated from maps prepared by Bruce and Weisman (1967) and are shown for Lloydminster. Potential evapotranspiration exceeds precipitation from April to October.

GEOLOGY

Bedrock Geology

Geological studies of significance have been carried out by Hume and Hage (1941), Nauss (1945), Shaw and Harding (1948) and Nichols and Wyman (1969).

In the Vermilion area the bedrock interval which supplies groundwater is a complex interfingering sequence of Upper Cretaceous sandstones and shales.

Table 1. Table of formations, Vermilion area

Hume & Hage (1941)	Shaw & Harding (1949)		McLean (1971)			Terminology used in this report	
Pale & Variegated Beds	Belly River Formation	Oldman member	Judith River Formation	Lea Park Formation	Unnamed member	Belly River Formation (lower part)	Upper part
Birch Lake Formation		Upper Birch Lake member			Birch Lake member		Upper Birch Lake member
		Mulga member			Mulga tongue		
		Lower Birch Lake member			Unnamed tongue		Lower Birch Lake member
Grizzly Bear Formation		Grizzly Bear member			Grizzly Bear tongue		
Ribstone Creek Formation		Ribstone Creek member			Ribstone Creek tongue		Ribstone Creek tongue
		Vanesti member			Vanesti tongue		
		Victoria member			Unnamed tongue		Victoria tongue
		Shandro member			Unnamed tongue		
		Brosseau member			Unnamed tongue		Brosseau tongue
Lea Park Formation	Lea Park Formation		Lea Park Formation			Lea Park Formation	
Alberta Formation	Colorado Group		Upper Colorado Group			Upper Colorado Group	

The general area has been studied by many geologists and as a result the stratigraphic nomenclature is confused. One of the most recent works which succeeds in sorting out some of the confusion is that of McLean (1971). The stratigraphic sequence shown in table 1 is based on the units of McLean (1971); the units of Shaw and Harding (1949) and Hume and Hage (1941) are also shown. The major bedrock aquifers are indicated with an asterisk.

All the near-surface bedrock formations are clastic units deposited in Late Cretaceous time. The dark grey marine shales of the Lea Park Formation are the oldest beds to outcrop in the area. Beneath them lies the thick shale sequence of the upper Colorado Group which has for its lowest layer the Fish Scales marker horizon. The basal boundary of this horizon delineates the Upper-Lower Cretaceous boundary.

The Lea Park Formation is overlain by the Belly River Formation. In the Vermilion map area the lower part of this formation is essentially tongues of sandstone interfingering with tongues of Lea Park marine shale (Nauss, 1945; McLean, 1971). The numerous sandstone and shale interbeds have been variously named by different authors. Unfortunately, correlation of these units is uncertain over even small distances. Within the map area, except for places where drillholes are closely spaced, it is difficult to correlate individual layers of either sandstone or shale to a suitable degree of accuracy. An attempt to correlate surface geology as mapped by Hume and Hage (1941) with subsurface information indicates that some of the surface units have been improperly mapped. This was also indicated by Nauss (1945) and results from a scarcity of exposures and borehole control and the difficulty of differentiating any one sandstone or shale tongue from another of the same lithology. The sequence of intertonguing deltaic sandstones and marine shales is therefore shown on the geological side map as a single geological unit, the lower Belly River Formation. The upper Belly River Formation comprises the Pale and Variegated Beds of Hume and Hage (1941) and the Oldman Member of Shaw and Harding (1949). This consists of continental interbedded and lenticular shales, siltstones, sandstones and coal beds. Marine shale is lacking. The formation contacts as shown on the geological side map are modified from Hume and Hage (1941) to fit bedrock topography contours and structure contours on the top of the Lea Park shale.

In spite of the uncertainty of correlation between the various sandstone and shale tongues, it is still useful to refer to some of these by name within small areas. Thus, on the geological side map the approximate depositional edge of the Victoria and Brosseau sandstone tongues, in the sense of Shaw and Harding (1949), is indicated. Structure contours drawn on the base of these units and on the base of the Ribstone Creek sandstone member are also shown. The term "Brosseau" sandstone is extended over rather a large area even though it is doubtful that this is everywhere the same unit. It is the name used here for the lowermost Belly River sandstone layer in the map area west of the depositional edge of the Brosseau sandstone.

The various sandstone tongues represent delta-front sheet sand deposits built out into the Lea Park sea. Shifting of deltaic lobes and coalescing of deltas resulted in complex lithologic changes which are bound to cause difficulties in correlation if detailed stratigraphic control is lacking. The best known sandstone layer within the area, the Ribstone Creek tongue, is well developed in the southeast part of the area and extends well out into Saskatchewan. It appears to be thinner and less well developed west of about range 3. This is reflected in the groundwater yield characteristics of the tongue, and correlation becomes difficult.

The Lea Park-Belly River contact as mapped is uncertain over much of the area due partly to difficulty in distinguishing loose bedrock sands from buried surficial sands and partly to a scarcity of reliable drillhole information.

The contact between upper and lower Belly River strata is approximately 500 feet (150 m) above the top of the Lea Park Formation.

Structure contours drawn on the base of the Fish Scales marker horizon (ERCB, 1969) indicate an approximate regional dip of 8 to 10 feet per mile (1.5-1.9 m/km) in a southwest drection, steepening to 16 to 20 feet per mile (3.0-3.8 m/km) in the southwest corner of the map area. Structure contours drawn on the base of selected sandstone horizons within the lower Belly River Formation indicate that the regional dip in these stratigraphically higher units is approximately the same as that indicated by contours on the base of the Fish Scales horizon over most of the area but is at variance with it in the southeast corner of the area where a local dip to the east-southeast of 10 to 15 feet per mile (1.9-2.8 m/km) is indicated. This difference in dip direction is probably attributable to progressively greater downwarping of the depositional basin in Upper Colorado-Lea Park time west from the Saskatchewan border.

The Ribstone Creek and Birch Lake members are the two major bedrock aquifers within the lower Belly River Formation. The Ribstone Creek member has wide areal distribution and underlies approximately two thirds of the 5600 square mile (14,660 km^2) map area. This member is predominantly unconsolidated sand and sandstone, and is grey to dark grey in the subsurface, olive yellow in outcrop, fine- to very fine-grained, salt and pepper in appearance, noncalcareous and subrounded; much carbonaceous material floats as a sheen on the mud tank when this unit is drilled with a rotary rig. The sand to shale ratio varies areally but generally the shaliness of the sand increases downdip towards the southwestern part of the map area.

The Birch Lake member is not as widely distributed as the Ribstone Creek member and therefore is not as widely used as a groundwater source. It is best developed in the western half of the area. The member is also predominantly unconsolidated sand and sandstone with varying sand to shale ratios within its area of distribution. The member can be described as an olive to yellow, fine- to medium-grained, subrounded and noncalcareous sandstone with rusty coloured, weathered, hard sandstone lenses and oyster beds.

The interfingers of shales and the "underlying" Lea Park Formation can be described as grey to olive grey, and soft with scattered hard, concretionary beds. The similarity between the interfingered shales and the "underlying" Lea Park Formation is a disturbing geological fact of life in east-central Alberta. Many wells have been terminated on the assumption that "the dark grey shale is Lea Park and there is no sense drilling deeper." Drillers in the area should be aware of the interfingering of sandstone and shale strata in this portion of Alberta. This interfingering phenomenon is further complicated in the Vermilion map area because the beds of the Belly River Formation have been sequentially eroded towards the northeast.

Glaciers during the Pleistocene epoch moved generally south across the soft Lea Park shales and laid down till deposits composed largely of local bedrock material. This fact makes the identification of the bedrock surface exceedingly difficult in most of the northeast half of the map area.

Bedrock Topography

Prior to the widespread Pleistocene glaciation a drainage system had been developed on the surface of Upper Cretaceous bedrock formations by rivers and streams flowing in a general east-northeast direction. The glaciations which covered the region buried some of the preglacial valleys under varying thicknesses of glacial deposits. These buried preglacial valleys sometimes contain thick deposits of gravel and sand which can be good aquifers where saturated. Delineation of the preglacial drainage network is difficult as it must be done from drillhole data. A bedrock topography map of the Vermilion (NTS 73E) area at 1:250,000 scale has been constructed (Carlson, 1974). It is published separately from the hydrogeological map and should be used to supplement any groundwater investigation in the area.

There are only two major buried preglacial valleys presently identified in the Vermilion map area: the Vermilion and Vegreville Valleys. The Vegreville Valley is restricted to the extreme northwest portion of the map area. The Vermilion Valley begins in the Birch Lake district, trends east, then turns to the northeast (Tp. 51, R. 5, W. 4th) and is thought to leave the map area in Tp. 58, R. 2, W. 4th. The predicted distribution of gravel and sand within this valley is shown on the main map. Tributary valleys to the main Vermilion Valley are most numerous in the portion of the area where the Lea Park Formation subcrops (NE 1/3 of map). A testhole program in this area helped to define more closely the drainage network. Accompanying this report are three detailed geological cross sections constructed using data obtained from the drilling program.

Several anomalously thick sections represented on the cross sections at 5-31-44-4W4 on section 2 and Lsd. 1-25-51-2W4 on section 1 can be explained by:

1) preglacial drainageways being poorly defined due to lack of sufficient testhole data;

2) the possibility of collapse structures caused by solution cavities in underlying salt beds of Devonian age (Christiansen, 1967).

Much more drillhole information is needed to delineate the bedrock erosional surface and determine the nature of the features on it.

Surficial Geology

Early workers in surficial geology include Warren (1944), Bretz (1943) and Bayrock (1955).

Ellwood (1961) mapped the surficial geology of the Vermilion area; his work is unpublished but has been used by the authors in the hydrogeological evaluation.

The major deposit of glacial origin is till — an unsorted mixture of earth materials deposited directly from a glacier. The geological cross sections mentioned previously exhibit variable thicknesses of till, often broken by lenses of sand and gravel. These sand and gravel lenses are the major source of groundwater where the Lea Park Formation subcrops, in the northeast portion of the map area.

HYDROGEOLOGY

The groundwater probability map shows the average expected well yields throughout the area. Average well yield is defined as the total quantity of water that can be obtained from a well drawing water from all the water-bearing intervals within the upper 800 to 1000 feet (240-300 m) of strata.

The value of the expected yields is based on calculations of 20-year safe rate using the formula (Farvolden, 1959):

$$Q_{s20} = \frac{TH}{2110} \quad (1)$$

where Q_{s20} = safe rate for 20 years in imperial gallons per minute (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 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 tests using the formula (Todd, 1959):

$$T = \frac{264Q}{\Delta s} \quad (2)$$

where Q = pumping rate in igpm; Δs = drawdown in feet per log cycle, the data plotted on semi-log paper.

Formula 2 was also used to calculate apparent transmissivity (Farvolden, 1959) from bail or pump tests in which only the static water level and the water level at the end of pumping (bailing) had been reported. The various yields assigned to areas on the map are based largely on "apparent transmissivity" values rather than on data from well-conducted pump tests.

The boundaries drawn between yield areas and the actual values assigned to these areas are generalizations, as rapid lateral and vertical changes in the geology are common. The map presents an estimate of probable well yields based on an evaluation of existing well data and geologic conditions. Yield values assigned to preglacial valley sediments are contingent on the presence of the valley sediments in the locations indicated. Drillhole control is too inadequate in many places to delineate the valley boundaries accurately. Carlson (1974) outlines the data control used in determining valley location.

The highest expected yield value in the map area is 100-500 igpm (450-2250 l/min). The area in the northeast part of the map area assigned this value is a region where one or more layers of coarse, well graded gravels can be expected in the well bore. A similar yield is assigned to the granular sediments in a melt-water channel north of the town of Kinsella in Tp. 48, R. 11.

There are indications of similar yields locally from sandstone layers within the lower part of the Belly River Formation. Bail tests or short pump tests have indicated such yields in a few areas.

By far the greatest part of the area is assigned an expected yield of 25-100 igpm (100-450 l/min). This yield is assigned to most of the portion of the area underlain by the Ribstone Creek tongue, the Birch Lake member and other interfingered sandstone layers within the lower part of the Belly River Formation. In areas where any one sandstone unit may not be capable of this production, a multi-aquifer completion in two or more such sandstones may be necessary to obtain the desired yield. Several pump tests conducted between Lloydminster (Tp. 50, R. 1, W. 4) and Two Hills (Tp. 54, R. 12, W. 4) indicate that the assigned yield range is valid for the area designated. Local increases in percentage of sand and hence increased permeability may provide yields in excess of 100 igpm (450 l/min).

Two areas located in preglacial valley sediments are assigned the 25-100 igpm (100-450 l/min) yield. These are the area of the Lloydminster town supply at Sandy Beach, 13 miles north of Lloydminster (Tp. 52, R. 1, W. 4), and an area northeast of Frog Lake. The first of these high yield areas occurs because of better well completion techniques applied to obtain the large supply of groundwater needed for the city. In fact, the authors noted a definite increase in well yields near centers of population.

The suspected courses of the Vermilion and Vegreville buried preglacial valleys and the tributaries to them have been variously assigned expected yields within the ranges of 5-25, 25-100 and 100-500 igpm (25-100, 100-450 and 450-2250 l/min) depending upon the nature of earth materials encountered in testholes drilled within these valleys. The sporadic distribution and rapid lateral gradation of the granular deposits flooring these valleys (as well as the perusal of several pump tests in these sediments) precludes a higher yield assignment. Once again improved well-completion techniques and well development time would improve the yield from the preglacial gravel and sands.

Meltwater channels cut by glacial meltwaters can be a source of groundwater if the channel contains granular materials. In the mapped area the best example of this type of groundwater occurrence is near the town of Kinsella in the center of Tp. 47, R. 11, W. 4th. Le Breton (1963) mapped the distribution of these channels and estimated their yield to be 25 to 100 igpm (100-450 l/min). Anyone seeking to exploit the groundwater resource, especially in the southwest part of the map area, should be cognizant of their distribution.

Three large areas underlain by sandstone lenses within the lower Belly River Formation have been assigned a 5-25 igpm yield. These are areas occurring along the subcrop edge of the formation but separated from the main body of sandstone by erosional processes. One such area is on the west borders of the map area near the town of Lavoy (Tp. 51, R. 13, W. 4); and another is in the south part of the map area.

Because of their isolated nature and lower calculated Q_{s20} values, these areas are expected to produce lower yields than the main body of sandstone. The stratigraphic section underlying the area near Lavoy indicates an increased percentage of bedrock sand and sandstone which results in higher calculated yield values than for the area immediately to the south. The large area in the southern part of the map area is assigned a lower yield than areas on either side of it because the sandstone lenses do not appear to be well developed here as elsewhere. The Ribstone Creek sandstone tongue is not as well developed as it is to the east and sandstones which were mapped as Birch Lake Formation by Hume and Hage (1941) are isolated and not as well developed as they are to the west and northwest.

The southwest part of the map area near Viking (Tp. 47, R. 12, W. 4) is assigned a 1-5 igpm (5-25 l/min) yield and has the poorest groundwater probability in the more populated part of the map area. The stratigraphic sequence in this area is more shaly and therefore low well yield can be expected.

The 1-5 igpm (5-25 l/min) yield value is also assigned to a broad area of glacial deposits northwest of the Vermilion River where the Lea Park Formation subcrops. Groundwater sources in this area are strictly sand and gravel lenses within till layers, outwash deposits, and materials in meltwater channels. The bedrock is almost 100 percent shale and provides no source of groundwater.

The northeast part of the map area is assigned a yield value of less than 1 igpm (>5 l/min) based on the knowledge that the area is underlain by thick sections of till and the Lea Park shales. Local lenses of sand and gravel may be encountered by the drill and suitable supplies provided. However, on the scale mapped the area has a low groundwater probability.

Water level elevations were determined for the southwest two thirds of the map area, from wells that were suspected or known to be completed in the Ribstone Creek tongue. This area has been contoured on a 100-foot interval and the resulting nonpumping water level map was *not* constructed for the area of the Lea Park Formation subcrop as the sources of groundwater are isolated lenses of sand and gravel within thick till sections and such a map would be meaningless.

The map area has not had the extensive seismic investigations that are common on the plains of Alberta; this fact makes for a lack of flowing shothole data — only one shothole is represented on the map (Tp. 57, R. 6, W. 4), and no flowing wells have been reported to the Groundwater Division.

Several springs occur in the map area and all are of the contact type, where a permeable water-bearing layer overlies a less permeable one and outcrops at the land surface. No springs of large magnitude were observed. Some of the springs can be easily observed on air photographs and this tool was used extensively in spring location. The airphoto interpretation was field checked and measurements of spring flow taken where possible.

Test Drilling

A fairly extensive test drilling program was conducted during the evaluation of the Vermilion area. The locations of the holes are shown on the map in red with the letters ARC over the symbol. All holes were sampled at five-foot intervals, the samples described at the drill site as drilling progressed, and the holes electrically logged. Some of the testholes were side-hole cored and logged using the gamma ray technique (Gearhard-Owen Industries, Inc., 1970). The purpose of the program, which was split into several projects (Streamstown, Primula and Frog Lake), was to determine the preglacial drainage patterns, and hence sources of groundwater, in the northeast part of the map area. Greater knowledge of the drainage pattern and discovery of significant gravel-sand aquifers was the result.

The information from the testholes is compiled in the form of three geological cross sections which appear in the pocket. The sections show the authors' interpretation of the correlation of the stratigraphic sequence. The sections should give a more detailed view than that possible by the cross sections on the main map.

HYDROCHEMISTRY

The chemistry of groundwaters is related to, among other things, the nature of earth material through which the water moves, the length of flow path and the duration of flow. Water quality is generally quite good in areas of groundwater intake (recharge areas), and becomes progressively more mineralized as it moves through the ground until, near the discharge portions of flow systems, it generally reaches its most mineralized state and is of poorest quality. There are, however, exceptions to this general relationship. Sulfate, for example, can build up to very high amounts very quickly in groundwater, which at the same time increases the total dissolved solids content. Reduction of the sulfate as the water passes through coal or carbonaceous beds and perhaps some other materials results in a lowering of the sulfate content and also in the amount of total dissolved solids.

Calcium-magnesium bicarbonate waters predominate in recharge areas while sodium-potassium waters of varying anion types occur in discharge areas — the bicarbonate and mixed bicarbonate-sulfate anions being most common in the map area. The amount of total dissolved solids in the most commonly used groundwaters in the area generally ranges between 500 and 1500 ppm of total dissolved solids, although much higher concentrations are also reached.

Hard, calcium-magnesium water is most common in drift aquifers, and soft sodium-potassium water predominates in bedrock aquifers. Chloride content is generally low within the most commonly used aquifers but can build up to quite high concentrations in shallow contaminated wells, and in deeper bedrock wells. Higher chloride content is found in wells of 100 to 300 feet (30 to 90 m) depth in the southwest corner of the map area within a general low permeability area.

The hydrochemical side map indicates the general chemical composition of groundwaters within the most commonly used aquifers of 100 to 300 feet (30 to 90 m) depth, except for the northeast part of the area where wells of this depth range are practically nonexistent. The chemistry of shallow groundwater is indicated in this northeastern area where calcium-magnesium bicarbonate water is predominant except locally within discharge areas of generally small flow systems where sodium-potassium bicarbonate water and sodium-potassium or calcium-magnesium sulfate or mixed bicarbonate-sulfate water may occur. The total dissolved solids content is quite high.

Hydrochemical changes with depth are indicated on the hydrogeological profiles. Due to small scale and to insufficient control, especially at depths below 300 feet (90 m), the hydrochemical picture presented on the profiles is idealized and interpretative. Local variations which are not shown are to be expected, especially within local, more poorly permeable aquifers where water will generally tend to be more mineralized than indicated.

CONCLUSIONS

The following conclusions can be drawn from this study:

1) The Ribstone Creek and other sandstone tongues are the major aquifers in the region and their yields average 25-100 igpm (100-450 l/min).

2) Preglacial and meltwater valleys are a good secondary source of groundwater, with average expected minimum yields of 5-25 igpm (25-100 l/min).

3) Groundwater quality is generally good with total dissolved solids within the limits of human consumption.

4) The presence of Lea Park Formation shales underlying the glacial and bedrock aquifers confines groundwater exploration in most areas to depths less than 500 feet (150 m).

5) Sand and gravel lenses within the till in the drift can be developed for domestic groundwater supplies, as for example at the Frog Lake Indian Reserve in Tp. 57, R. 2, W. 4th.

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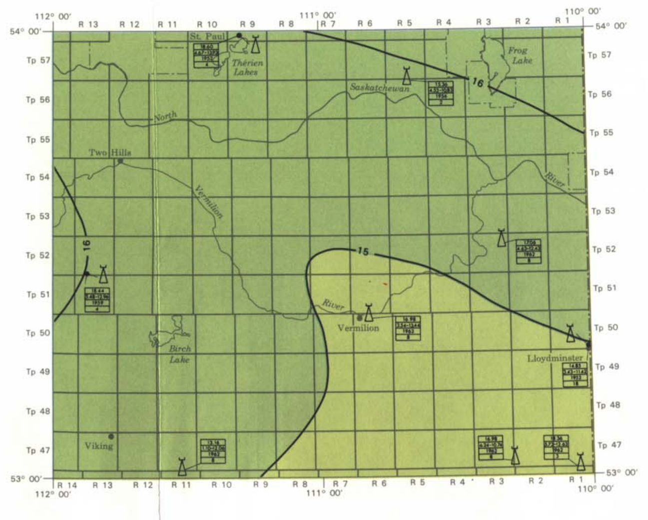
METEOROLOGY

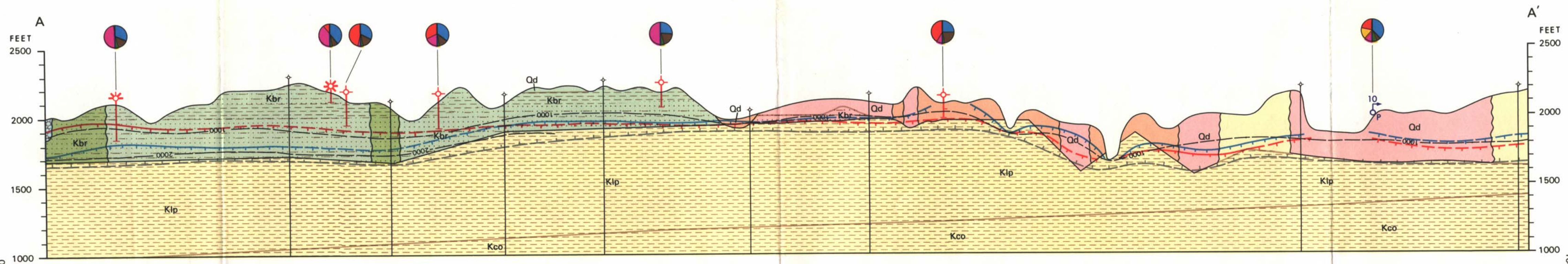


LEGEND

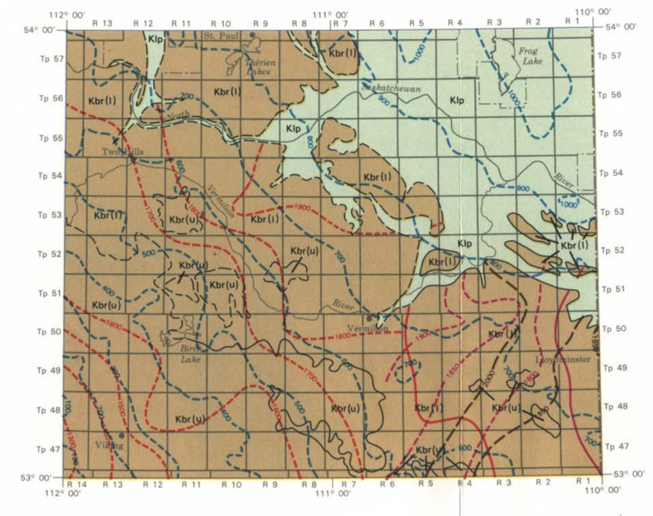
Isohyet, mean annual precipitation in inches 15
Mean annual precipitation in inches:
less than 15 ....
15-20 ....

Standard rain gauge ....
Precipitation data:
Mean annual total precipitation in inches ....
Mean annual rainfall and snowfall ....
Year of commencement of observations ....
Number of months of record per year ....

Sources of Data:
Climatic Maps of Alberta (Longley, 1968); Temperature and Precipitation Tables for the Prairie Provinces (Canada Department of Transport, 1967).



GEOLOGY



LEGEND

Kbr — Belly River Formation: *sandstone, siltstone, mudstone, ironstone beds.*
Klp — Lea Park Formation: *shale*
Rock unit, formation boundary:
defined ....
approximate ....

Structure contour on base of Ribstone Creek sandstone tongue 2000
Depositional edge of Victoria sandstone tongue ....
Structure contour on base of Victoria sandstone tongue 1800
Depositional edge of Brosseau sandstone tongue ....
Structure contour on base of Brosseau sandstone tongue 1600
Structure contour of Fish Scales marker horizon 1000

MAIN MAP LEGEND

Topography

Topographic contours in feet (interval 100 feet) 2000

Geology

Geological boundary ....
Buried valley boundary ....

QUATERNARY
Qd — Unconsolidated deposits

CRETACEOUS
Kbr — Belly River Formation
Klp — Lea Park Formation
Kco — Colorado Group

Lithology

Gravel ....
Sand and gravel ....
Sand ....
Sandstone ....
Shale ....

Hydrography

Lake or slough, perennial ....
Lake or slough, seasonal ....
Marsh or muskeg ....
Stream, perennial ....
Stream, intermittent ....
Surface water divide ....
Area of noticeable salt precipitate ....

Hydrometry

Stream gauging station ....
Average annual discharge in cubic feet per second 8240
Year of commencement of observations 1947
Number of years averaged for average annual discharge figure 18
Drainage area in square miles 21300

Hydrogeology

Spring, flow rate unknown ....
Spring, flow rate known 5
permanent or temporary .... P T
Nonpumping water level contour (Belly River Formation) 1900

Groundwater Probability†

Range of average expected yield of wells (in igpm)

Probable: estimated from quantitative information (pump or bail tests, etc.)
Possible: estimated from qualitative information (flow regime, lithology, etc.)

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

Yield 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 shortcoming 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, nonflowing ....
Water well, flowing ....
Water well, 20-year safe yield calculated from apparent transmissivity ....
Water well, 20-year safe yield calculated from 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 Alberta Research Council test well .... ARC
Seismic shothole reported to have flowed ....

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

Gas well ....
Abandoned well ....
Structure testhole ....
Storage reservoir ....
Dugout or borrow pit ....
Gravel pit ....
Lagoon for sewage disposal ....

Line of hydrogeological profile .... A A'

Hydrochemistry

Calcium
Magnesium
Sodium + potassium
Carbonate + bicarbonate
Sulfate
Chloride
0
50%
100%
Cations | Anions

Total dissolved solids, in ppm (approximate) 500

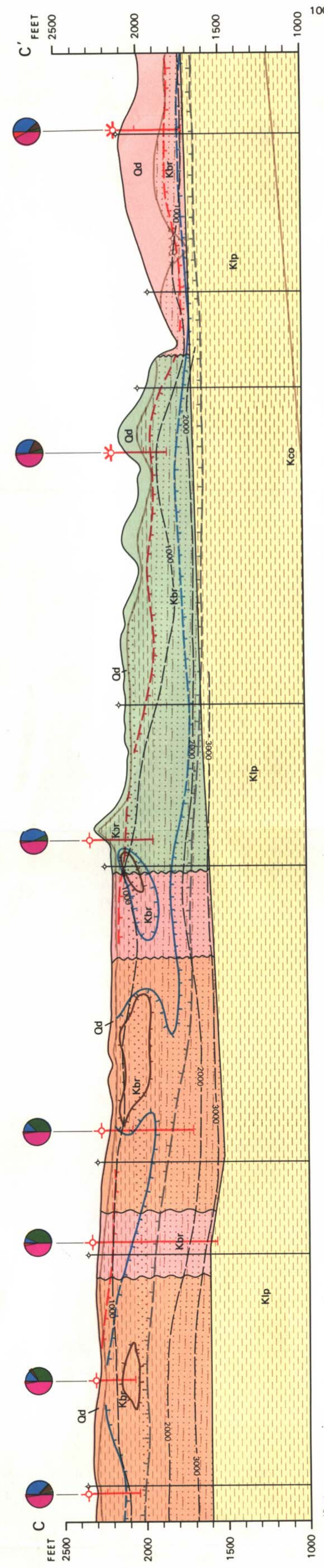
Isogram along which calcium + magnesium constitute 60 percent of total cations;* teeth indicate direction of lesser calcium + magnesium content
defined ....
approximate ....

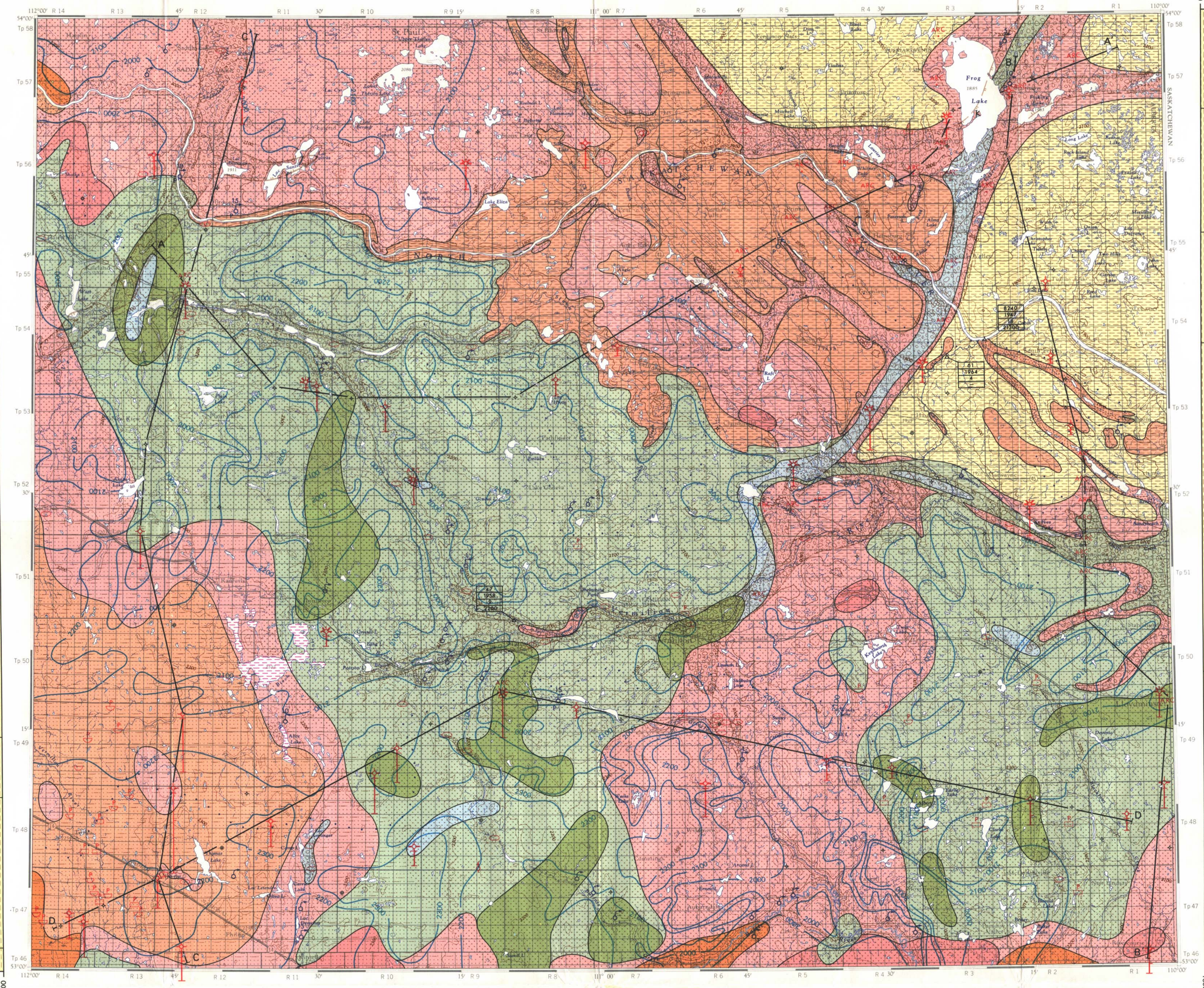
Isogram along which carbonate + bicarbonate constitute 60 percent of total anions;* teeth indicate direction of lesser carbonate + bicarbonate content
defined ....
approximate ....

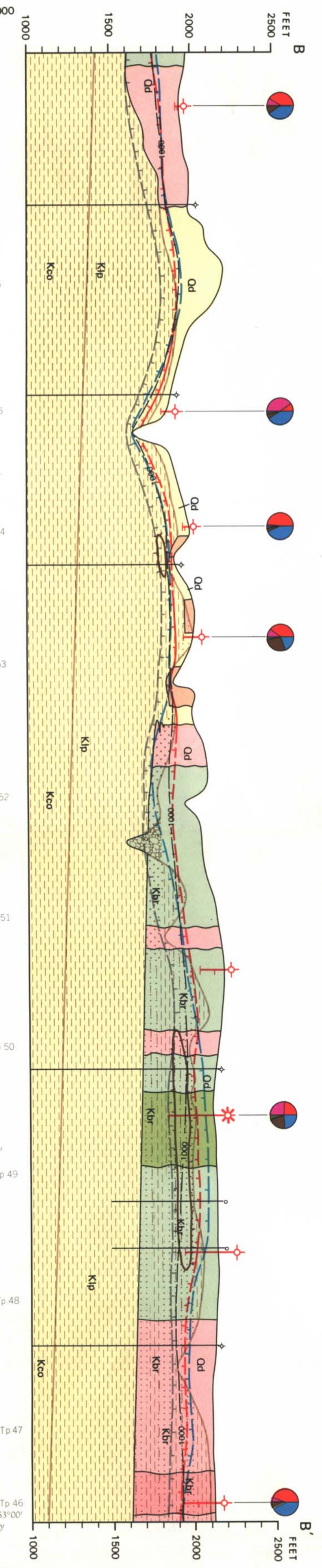
Isogram along which sulfate constitutes 60 percent of total anions;* teeth indicate direction of lesser sulfate content
defined ....
approximate ....

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

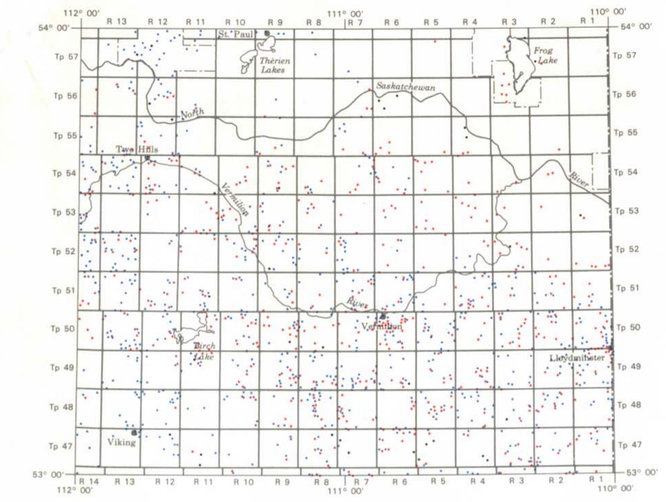
*Determined on equivalents per million basis.







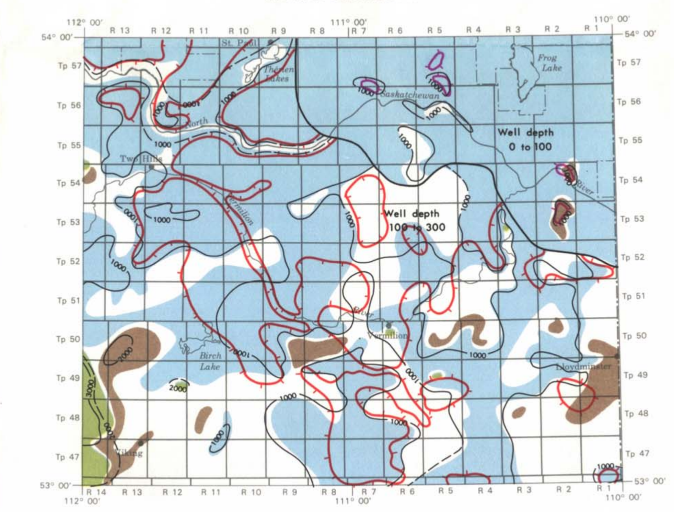
DATA DENSITY



LEGEND

Well with water level information only ....
Well with yield information (i.e. production tests) ....
Hydrogeological surface feature ....

HYDROCHEMISTRY



LEGEND

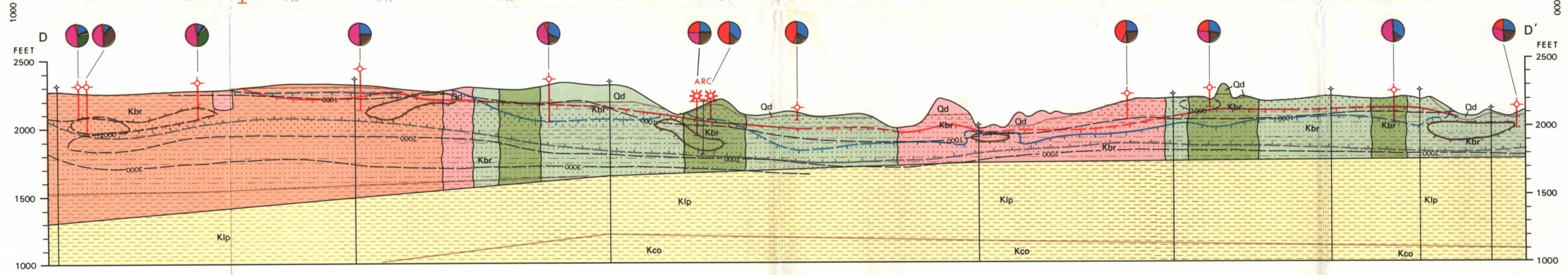
Total dissolved solids in parts per million:
defined 500
approximate 500

Isogram along which calcium plus magnesium constitutes more than 60 percent of total cations;* teeth indicate direction of lesser calcium plus magnesium content ....

Isogram along which sodium plus potassium constitutes more than 60 percent of total cations;* teeth indicate direction of lesser sodium plus potassium content ....

Bicarbonate plus carbonate constitutes more than 60 percent of total anions ....
Sulfate constitutes more than 60 percent of total anions ....
Chloride constitutes more than 60 percent of total anions ....

*Determined on equivalents per million basis.



SCALE 1:250,000
Miles 5 0 5 10 15 20 Miles
Kilometers 5 0 5 10 15 20 25 30 Kilometers

All elevations in feet above mean sea level.

Vertical exaggeration of the hydrogeological profiles is approximately 40X.

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

Map to accompany Report 75-5.

Hydrogeology by D. V. Currie 1971, based on data collected in 1971.

Drafted by R. W. Swenson.

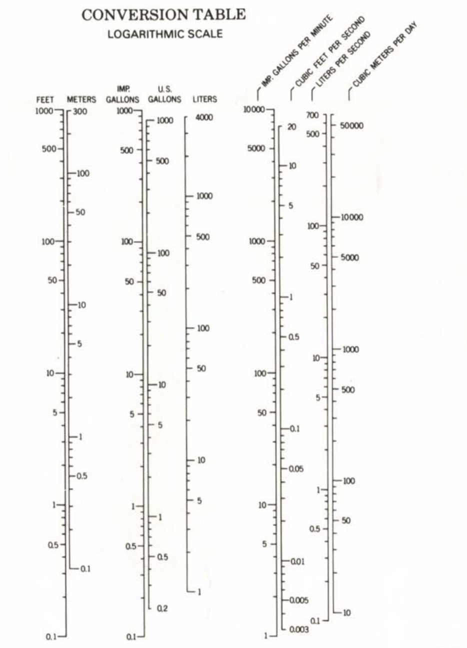
Cartographic editing by A. R. Campbell.

HYDROGEOLOGICAL MAP
VERMILION
ALBERTA

NTS 73-E

CONVERSION TABLE

LOGARITHMIC SCALE



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

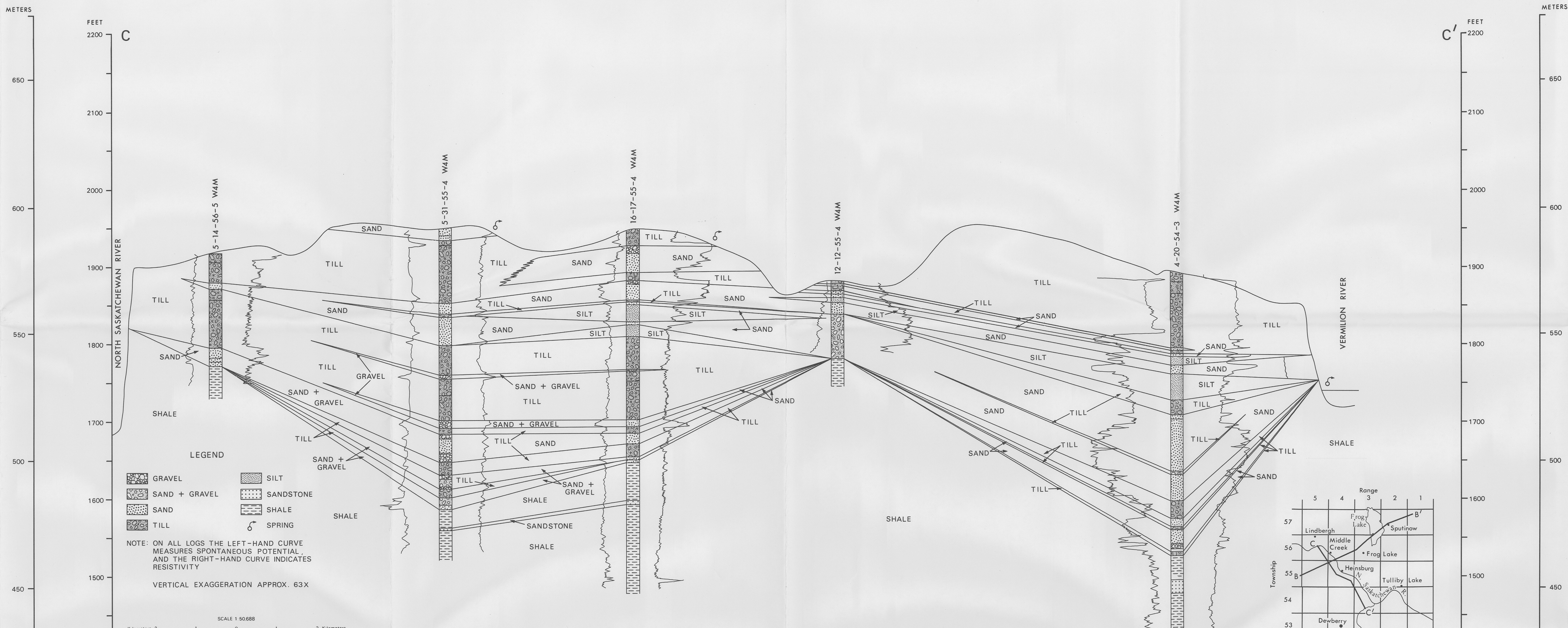


FIGURE 3. Geological cross-section: North Saskatchewan River to Vermilion River

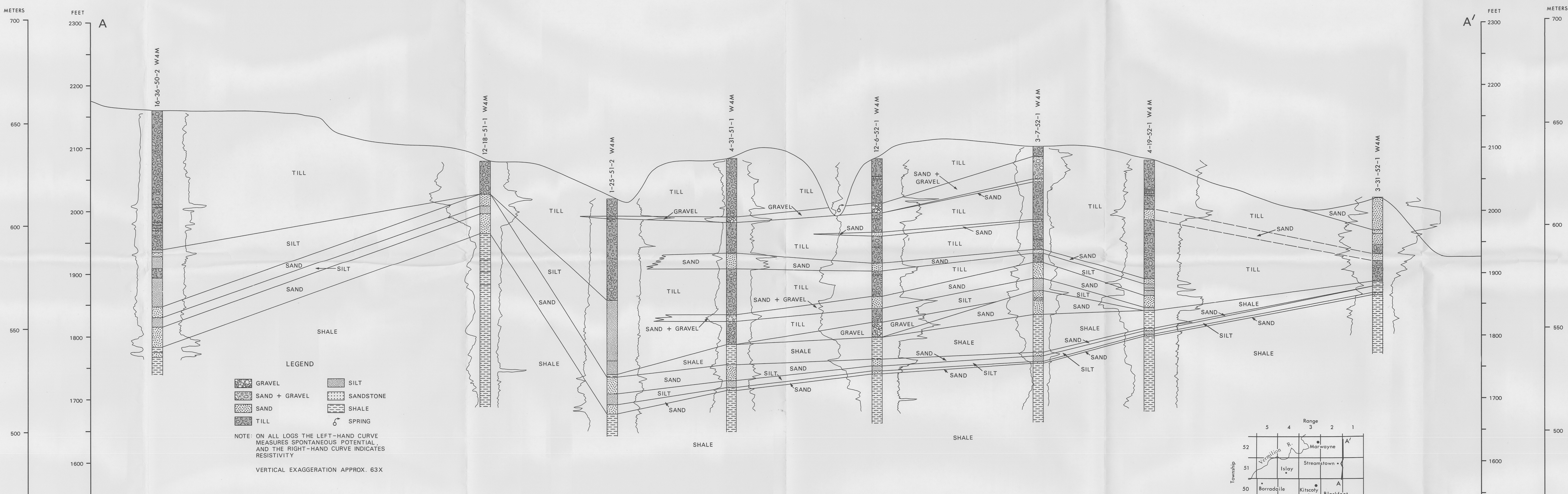


FIGURE 1. Geological cross-section: Streamstown Area

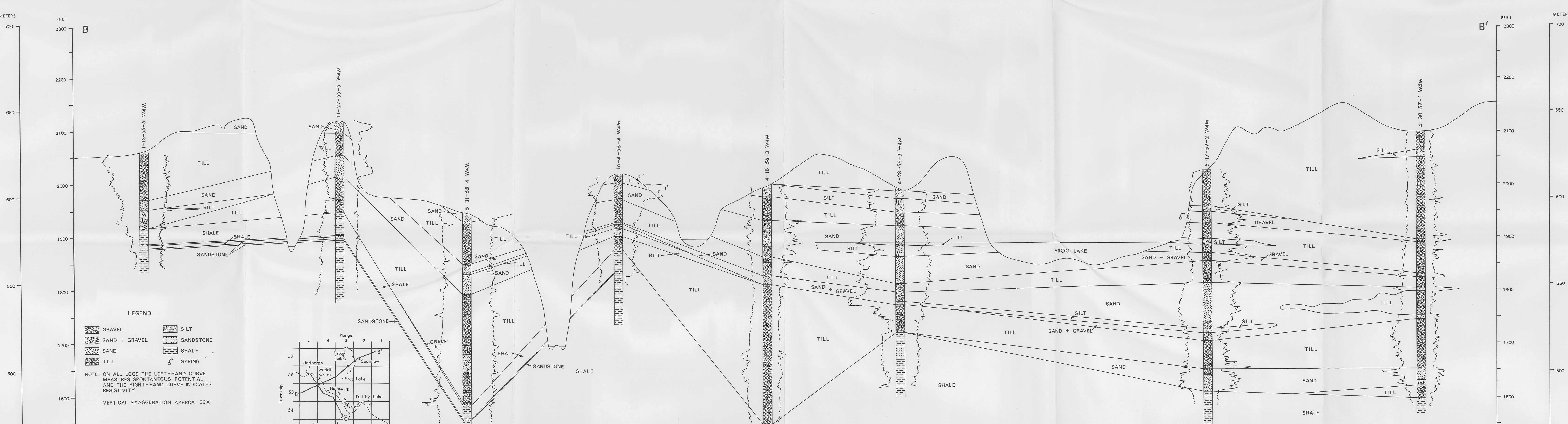


FIGURE 2. Geological cross-section: Primula to Frog Lake