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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 61-20

VAUDREUIL MAP-AREA, QUEBEC

Part I. Ground-water Resources of the East Half

J. J. L. Tremblay

Part II. The Seismic Method Applied to a Bedrock Channel Problem

George D. Hobson

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(Report, 5 figures, Map 30-1961)

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VAUDREUIL MAP-AREA, QUEBEC

Part I

GROUND-WATER RESOURCES OF THE EAST HALF

by J.J.L. Tremblay

Introduction

This report presents the results of a preliminary study started during the summer of 1960 to determine the occurrence, amount available, and quality of ground water.

The east half of Vaudreuil map-area is bounded by latitudes 45°15' and 45°30'N and longitudes 74°00' and 74°15'W; it comprises 330 square miles. It contains part of the counties of Vaudreuil, Soulanges, Two Mountains, and Beauharnois, and two cities—Valleyfield and Dorion-Vaudreuil. The centre of the map-area is 20 miles from Montreal Island.

The southern part of the map-area is a broad flat clay plain, which forms part of the St. Lawrence Lowlands; the northern part is a rugged terrain, typical of the Canadian Shield. Maximum relief is 530 feet.

An inventory of wells in the area was compiled, and from this, geologic and piezometric maps were made and analyzed. Elevations of wells north of the St. Lawrence River were determined by stadia, and those south of the river were determined from the topographic map. Four observation wells were located and water recorders were installed on them. All data on the pumping tests in this report were provided by International Water Supply Limited.

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Geology of Bedrock Formations

The bedrock geology shown on Figure 1 is based on Wilson's (1939)[1] geological map and on field observations by the author.

The undifferentiated Precambrian rocks consist of crystalline limestone, dolomite, gneisses, and quartzites, which are cut by bodies of granite, syenite, and other igneous rocks.

The Nepean formation consists of thick and thin beds of coarse-grained, reddish buff or white, grey-weathering sandstone. In some places, the lower part of the formation includes a conglomerate, which is underlain by a pink sandstone. As the formation was deposited on an irregular surface, its thickness varies considerably; its maximum known thickness in the map-area is more than 1,800 feet. There is no discernible break between it and the overlying Lower Ordovician March formation. The Nepean formation is thought to be of Ordovician age.

The March formation is transitional in composition from the underlying Nepean sandstone to the overlying Oxford limestone and dolomite. It consists of thin beds of grey dolomite with thick beds of sandstone having a calcareous cement. The base of the formation is placed arbitrarily at the lowermost layer of dolomite. The top of the formation is difficult to place for the dolomite layers grade into the overlying Oxford beds. The thickness of the March formation varies considerably, with a maximum of about 100 feet. The formation contains fossils of Early Ordovician age.

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[1] Dates in parentheses are those of publications listed in the Bibliography.

Table I

Geological Formations in the East Half of Vaudreuil Map-area and their Water-bearing Properties

Era	Period	Formation and Lithology	Aquifer (type)	Thickness (feet)
Cenozoic	Quaternary	Alluvial sands	Unconfined	0-10
		Fossiliferous sand and gravel (beach deposits)	Unconfined	Unknown
		Marine clay	Not confined an aquifer	0-90
		Sand	Confined	0-15
		Clay	Not considered an aquifer	0-30
		Till	Not considered an aquifer	0-20
		Till	Not considered an aquifer	0-25
		Sand and gravel	Confined	0-100
Unconformity				
Palaeozoic	Ordovician	Oxford formation: limestone and dolomite; March formation: dolomite and sandstone	Confined	0-400
		Nepean formation: sandstone	Confined	0-1,800
Unconformity				
Precambrian		Undifferentiated granitic complex	Confined	?

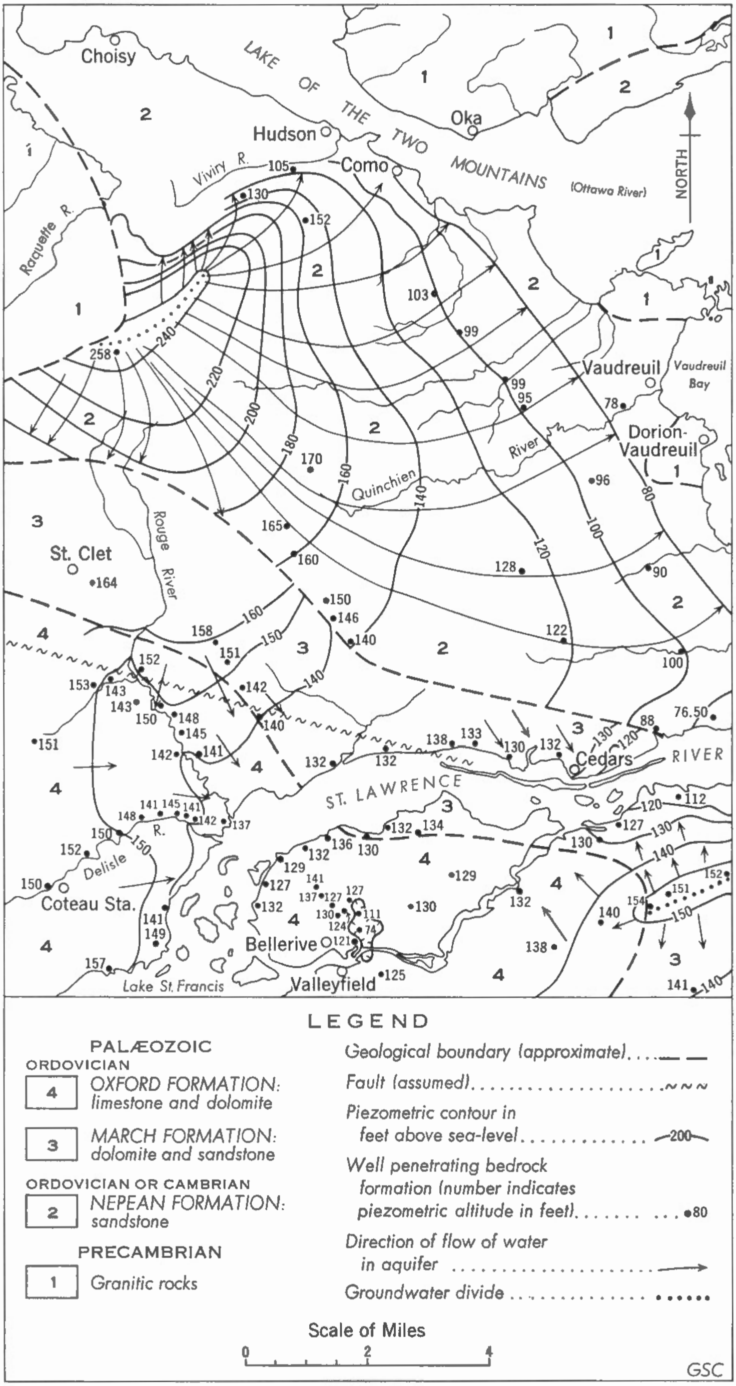

Figure 1. Bedrock geology and piezometric contours on the Nepean Sandstone and on March and Oxford Formations

The Oxford formation lies conformably on the March. It consists of grey limestone, magnesium limestone, and blue-grey dolomite. Locally in its upper part, is dark and somewhat argillaceous. The formation has a maximum thickness in the map-area of 300 feet, and contains fossils of early Ordovician age.

Occurrence of Ground Water

The ground water occurs partly in Pleistocene surficial deposits and partly in the underlying bedrock.

Bedrock Aquifers

The Palaeozoic rocks in Vaudreuil map-area consist of two aquifers: the Nepean formation, and the March and Oxford formations.

The Nepean sandstone in most of the map-area is a confined artesian aquifer. However, water in the sandstone in the southeastern part, along the north shore of the St. Lawrence, is not under artesian pressure. From the ground-water divide the water radiates east, north, and south. The slope of the water-table varies in different directions; the direction of flow is towards the surface streams.

The March and Oxford formations are considered as one aquifer because of their close lithological and hydrological characteristics. The piezometric surface of this aquifer indicates that the water in most places is flowing towards the major rivers of the region. Locally, however, this is not the case. At Valleyfield, for example, excessive pumping has induced recharge from the river at two different places: one is on the property of the Montreal Cottons Limited—outlined on Figure 1 by the depression of the piezometric surface to 110 feet above mean sea-level; the other is at the Schenley Company plant—directly south and across the river from the Montreal Cotton plant. A recharge from the river at the Schenley Company was detected in the temperature of the ground water by a sharp local rise of 10 degrees from the mean annual temperature. Recharge was further indicated by water analyses, which proved to be identical chemically to the analyses of the river water. Belief that the ground water at the Montreal Cotton plant was recharged by the river is based on information supplied by a pumping test.

These two aquifers are the major bedrock aquifers in the region. In some parts of the map-area water is taken from the Precambrian granitic rocks, but no hydrological studies and correlation have been done to delineate the aquifers they may contain.

Pleistocene Sand Aquifers

Overlying the bedrock are the Pleistocene sand and gravel aquifers, which can be divided into two groups: the confined sand aquifer, and the unconfined aquifer.

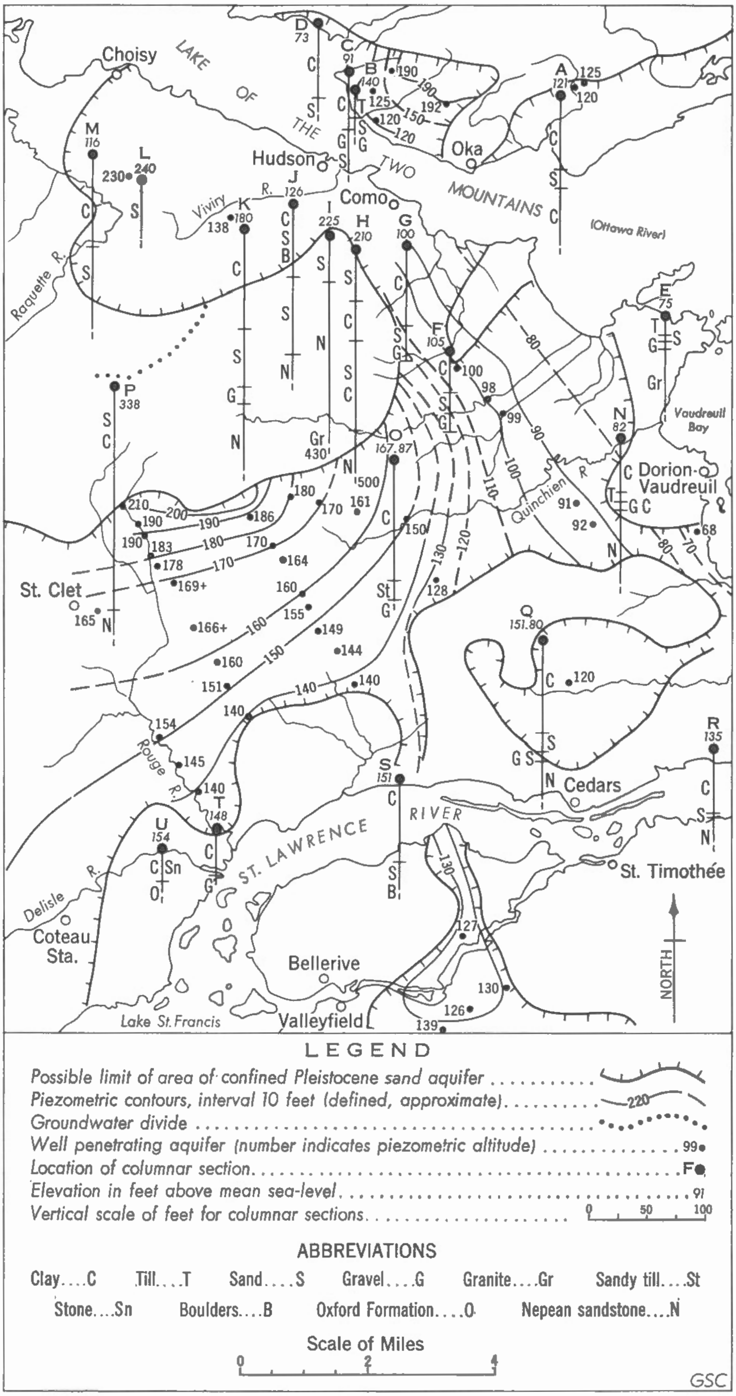

Figure 2. Piezometric contours and columnar sections in surficial deposits

Figure 2 shows the areas where borings have indicated the existence of a sand layer containing water under artesian pressure; maximum thicknesses of the sand layer are found in the more pronounced depressions of the bedrock (Figure 2). The ground-water divide corresponds with the height of land, which is in an area covered with sand and gravel (an excellent reservoir for water). From this region the water will flow in the direction of least resistance. North of the divide and extending in a northeasterly direction there is a bedrock high. To the south and west of the divide there are sand formations allowing the ground water to move with less impedence; this is especially true to the south where water flows at the surface under artesian head. It is here also that geophysical work has outlined an east-trending buried channel.

The areal extent of the confined sand aquifer has been outlined on Figure 2 on the basis of information gathered from logs of wells that tap this aquifer, and from seismic work done in the region (see Part II). From bore-hole and seismic data, it was established that the sand layers occur in depressions in the bedrock, which in turn are related to a major bedrock depression that extends from west to east and then northeasterly across the region (see Map 30-1961, in pocket).

The many unconfined sand aquifers are grouped together and shown on Figure 3 as perched aquifers. Most wells in them were dug into the sand until water was encountered. These wells are shallow, and thus are a poor and unreliable source of water during the summer when evapotranspiration is at its maximum. Many of the local domestic water problems could be solved by using well points instead of large-diameter wells, and the cost would be less than the cost of digging a large-diameter well.

Hydrology of the Aquifers

The known hydrology of the confined aquifers is shown on Figures 1 and 2, which illustrate the piezometric surfaces in each of the confined aquifers, and also the direction of flow of water in the aquifer for the summer of 1960. The water in the confined aquifers is flowing towards the major streams of the region. In and around Valleyfield, where the St. Lawrence River cuts across the bedrock structure, induced recharge from the river is possible when the head in the aquifer is sufficiently lowered to allow the water from the river to leak into the aquifer; this phenomenon will occur around an area of heavy pumping.

Figure 3 shows the areas where unconfined aquifers are found. The most southerly area is the most extensive. It contains a series of unconfined aquifers that are hydrologically connected with the confined sand aquifer which, in turn, is hydrologically connected with the bedrock aquifers of the region.

Thus the region of recharge for all the confined aquifers lying between the St. Lawrence and Ottawa Rivers is an extensive sand and gravel area from which the flow of ground water radiates south, east, and north. Flow on both banks is towards the river.

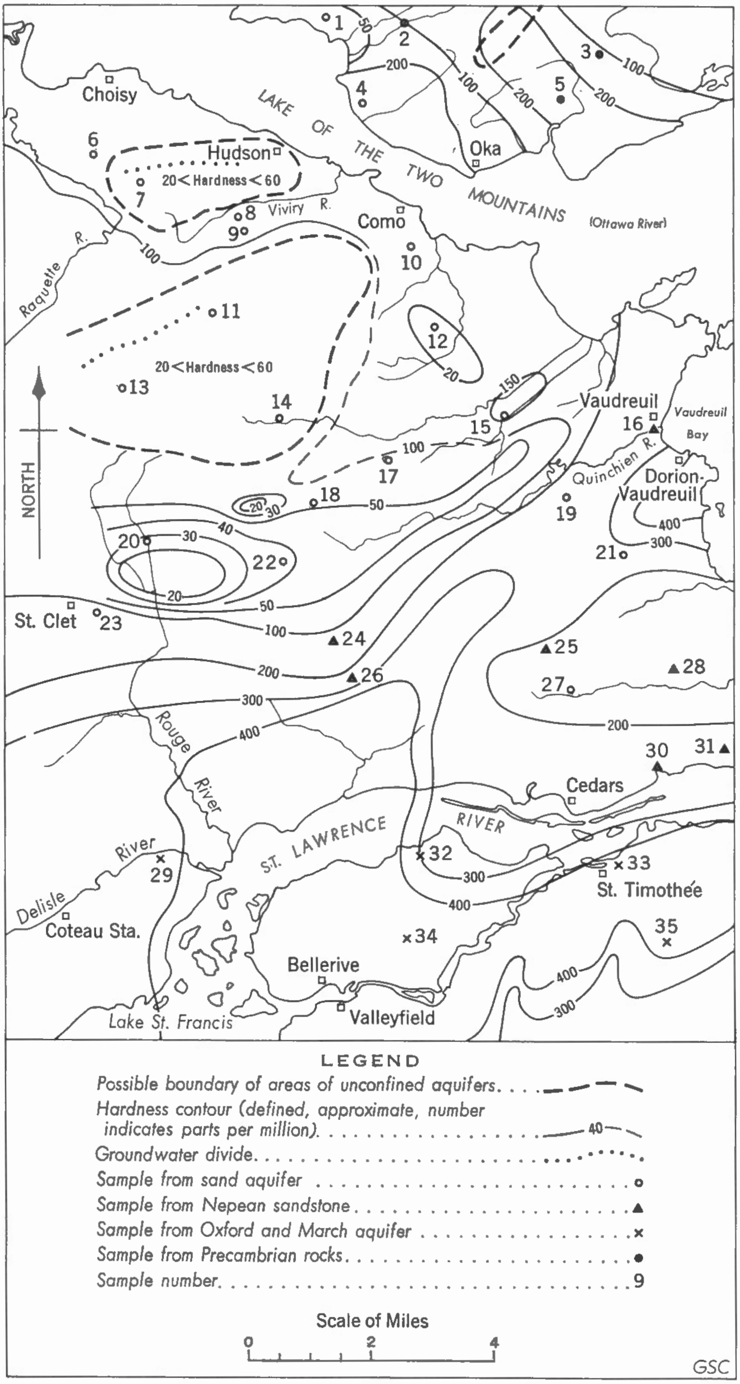

Figure 3. Total hardness contour map

Amount of Ground Water Available

One way to obtain quantitative information on water available in an aquifer is to conduct a pumping test on the aquifer and thus determine its hydrologic characteristics; these are usually expressed as the 'transmissibility' and 'storage'.

Theis (1935) defined the transmissibility as "the rate of flow of water, in gallons per day, at the prevailing temperature, through a vertical strip of the aquifer one foot wide, under a hydraulic gradient of 100 per cent". He defined the coefficient of storage as "the volume of water that is released from storage, from a vertical prism of the aquifer, one foot square and of the height of the saturated thickness of the aquifer, when the hydrostatic head of the column is reduced one foot".

Three confined aquifers were tested, and the drawdowns of the water levels and the rates of pumping were recorded. The Theis (1935) and Jacob (1946) equations were used for determining the aquifer characteristics. The Nepean sandstone aquifer was tested without an observation well, and therefore, yielded only a transmissibility value.

Test on Sandstone Aquifer (Nepean Formation)

This test was made April 30, 1959, on a well owned by the village of Vaudreuil and situated at lat. 45°23'20"N and long. 74°02'16"W. The well served the needs of the community and was pumped at the rate of 437 imperial gallons per minute. The slope of the recovery curve was 11 feet per logarithmic cycle, giving a transmissibility of 9.5×10^4 imperial gallons per day per foot. As there was no observation well in this test, the storage coefficient could not be determined, but the test did show the existence of a positive boundary condition in a radius of influence of the well after 30 minutes on the recovery curve. During the test period, which lasted for two days, the yield of the well was 11.3 gallons per minute per foot of drawdown.

Test on Carbonate Aquifer (March and Oxford Formations)

A test on this aquifer was done on the property of the Montreal Cottons Limited, situated at lat. 45°16'N and long. 74°08'W. It started May 23, 1960, and lasted five days, during which time four wells were pumped at once and one well was used as an observation well. The total rate of pumping from the aquifer was 3,085 imperial gallons per minute. Drawdown was measured in each pumped well and in the observation well. Using the drawdown data, the Theis non-equilibrium formula and the Jacob modified non-equilibrium formula, different values for the transmissibility and storage coefficient were obtained. These values which were not corrected for positive boundaries, are tabulated below (Table II).

Table II

Transmissibility of the March and Oxford Aquifer at Valleyfield

Transmis-sibility	Well No.	Type of Equation	Storage Coefficient	Thickness
1×10^4	1	Jacob's (drawdown)		220 - 280 ft.
5.9×10^3	2	" "		
1×10^4	3	" "		
5.1×10^4	4	" "		
6.90×10^4	4	Jacob's (recovery)		
1.25×10^4	5	Jacob's (drawdown)	10^{-4}	

An estimate made of the amount of water present in the formation showed that if there was no recharge, the pumping rate would have lowered the water-table 100 feet over an area of 1 square mile. Evidence from water recorders installed on wells in the March and Oxford formations away from the major pumping centres, however, indicate that the water-table has not been lowered to the calculated value of 100 feet.

A positive boundary that occurs close to the pumping centres is the St. Lawrence River, which cuts across the structure of the bedrock in the map-area. A calculated value of recharge to the aquifer by the river indicates a recharge exceeding by far the amount of water that is now being pumped out of the aquifer.

Because of the lithologic and hydrologic characteristics of the March and Oxford formations the values in Table II are not representative of the entire aquifer, but only of that part around the well field tested. Anomalies within this field, shown by wide variance in transmissibility, are the result of fracture and fissure flow in the bedrock.

Test on a Confined Sand Aquifer

A test was made on July 19, 1960, on a well owned by the town of Hudson at lat. 45° 26'55"N and long. 74° 08'55"W. Before that date the sole source of water for the town was derived from springs in unconfined aquifers south of the town.

The tested well, which tapped a confined sand aquifer, was pumped at the rate of 300 imperial gallons per minute for 24 hours. Drawdowns were measured in the pumped well and in an observation well 3 feet away from the pumped well. From the drawdown data, values of the transmissibility and the storage coefficient were found, and are tabulated below (Table III).

Table III

Constants of a Confined Sand Aquifer

Transmis-sibility	Well No.	Type of Equation	Storage Coefficient	Thick-ness
1.15×10^4	Observ. well No. 1	Jacob's (drawdown)		10 ft.
1.88×10^4	Observ. well No. 1	Jacob's (recovery)		
5.36×10^3	Observ. well No. 1	Theis' (drawdown)	9.5×10^{-2}	
5.75×10^3	Pumped well	Jacob's (drawdown)		

While the test lasted, the yield of the well was 10 imperial gallons per minute per foot of drawdown.

Quality of the Ground Water

All water in Vaudreuil map-area is excellent drinking water. In the regions where a thick section of clay overlies the aquifer, the water has an odour of hydrogen sulphide. This is especially true where the aquifer is a sand formation.

During the summer of 1960, samples of water from all wells visited were analyzed (with the Hach chemical kit) for iron, hardness, chlorides, and pH. An additional 35 representative samples were collected throughout the region for complete chemical analyses by the Industrial Waters Section of the Mines Branch. The locations of these 35 samples are shown on Figure 3.

From the analyses made with the chemical kit, a hardness contour map of the region was made (Fig. 3), which shows an empirical relation between the hardness of the water and the flow of the water in the different aquifers. Indeed the hardness increases away from the region of recharge.

The other 35 complete analyses are given in Table IV and shown on a trilinear diagram (Fig. 4). On the diagram, the projection of the anion-cation plot of a water analysis in the diamond-shaped field gives the plotting point for that water sample. The radius of the larger circle is scaled to indicate the sum of the constituents of the analysis in parts per million.

The waters of the March and Oxford aquifer stand out in a group; they are high in bicarbonates and in calcium and magnesium. The ratio of calcium to magnesium is high in these waters and is indicative of the composition of the formation from which the water was obtained.

Table IV

Analyses of Ground Water in the Vaudreuil Area

(Analyzed by the Industrial Waters Section, Mines Branch, Department of Mines and Technical Surveys)

Sample No.	Location	Type of aquifer*	Colour (Hazen units)	pH	Conductance (micromhos at 25°C)	Hardness as $CaCO_3$		Chemical Constituents in Parts per Million																	
						Non-carbonate	Total	Total Alkalinity ($CaCO_3$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Total Iron (Fe)	Manganese (Mn)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Silica (SiO_2)	Sum of Constituents	% Sodium	Sodium Adsorption Ratio (SAR)
1	AS SHOWN ON FIGURE 4	S	15	8.3	315.8	0.0	54.8	170.0	10.7	6.8	52.5	1.7	0.23	0.0	207.0	0.0	1.0	0.7	0.4	0.6	9.6	186.0	67.0	3.09
2		Gr	7	8.6	568.9	0.0	95.3	264.0	13.9	14.8	88.0	3.8	0.36	0.0	302.0	9.6	19.0	3.6	0.6	0.6	13.0	316.0	66.0	3.92
3		Gr	5	8.5	567.9	0.0	181.0	280.0	38.3	20.8	55.7	1.5	0.03	0.0	323.0	0.0	26.0	2.8	2.0	1.8	14.0	331.0	40.0	1.80
4		S	5	8.3	444.2	0.0	174.0	216.0	40.4	17.9	26.2	1.6	0.03	0.0	263.0	0.0	22.1	1.9	0.0	0.4	11.0	251.0	24.0	.86
5		Gr	5	8.4	454.4	0.0	168.0	200.0	30.7	22.2	29.0	2.1	0.36	0.0	239.0	2.4	15.0	17.2	0.8	0.6	23.0	260.0	27.0	.97
6		S	15	7.8	278.8	0.0	116.0	138.0	23.9	13.6	13.5	3.6	1.4	0.0	168.0	0.0	7.9	2.9	0.0	0.0	16.0	164.0	20.0	.55
7		S	15	7.5	144.9	0.0	69.2	69.8	19.2	5.1	2.2	1.2	2.6	0.2	85.1	0.0	3.8	0.6	0.0	0.0	14.0	88.4	6.4	.11
8		S	7.0	8.0	264.6	5.7	121.0	115.0	31.8	10.0	5.3	0.7	0.24	0.0	140.0	0.0	16.4	3.3	0.0	1.0	9.4	147.0	8.7	.21
9		R	10	8.2	256.4	0.0	114.0	129.0	26.0	11.8	7.5	1.3	0.21	0.0	157.0	0.0	7.5	0.5	0.2	0.8	14.0	147.0	12.0	.31
10		S	15	7.7	330.6	0.0	105.0	123.0	28.3	8.4	28.5	1.8	2.2	0.0	150.0	0.0	12.3	23.9	0.2	0.0	14.0	191.0	37.0	1.21
11		S	15	7.2	200.6	0.0	77.9	104.0	15.2	9.7	11.0	3.3	0.05	0.0	126.0	0.0	1.7	0.9	0.4	0.0	61.0	165.0	23.0	.55
12		S	90	8.8	872.0	0.0	15.1	413.0	2.7	2.1	208.0	2.7	0.10	0.0	448.0	27.0	6.9	35.7	1.8	0.8	9.3	490.0	96.0	23.00
13		R	15	7.7	480.1	0.0	105.0	222.0	21.1	12.8	70.0	3.3	2.0	0.0	271.0	0.0	24.6	7.4	2.5	0.0	15.0	290.0	58.0	2.96
14		S	15	6.7	128.5	31.6	48.6	17.0	12.7	4.1	2.5	1.6	0.88	0.16	20.7	0.0	9.9	7.9	0.0	24.0	3.0	76.0	9.6	.16
15		S	50	8.2	2,947.0	0.0	126.0	521.0	8.2	25.7	610.0	12.5	0.31	0.0	635.0	0.0	18.5	642.0	0.8	2.0	8.4	1,641.0	90.0	23.50
16		R	45	7.8	2,701.0	0.0	123.0	504.0	11.2	23.0	575.0	12.0	2.3	0.0	614.0	0.0	48.0	565.0	0.8	1.2	8.7	1,545.0	90.0	22.60
17		S	20	7.8	470.5	0.0	85.8	149.0	16.2	11.1	67.0	4.3	1.4	0.0	182.0	0.0	1.2	60.3	0.0	0.0	11.0	260.0	61.0	3.14
18		S	15	7.7	185.2	0.0	73.3	97.4	19.0	6.3	11.0	1.8	1.1	0.0	119.0	0.0	1.9	1.2	0.0	0.0	13.0	112.0	24.0	.53
19		R	40	8.4	3,720.0	0.0	189.0	519.0	21.5	32.9	770.0	18.0	0.68	0.0	608.0	12.0	150.0	825.0	0.8	0.4	16.0	2,147.0	89.0	24.38
20		S	20	7.3	161.8	0.0	27.1	82.2	7.7	1.9	26.0	1.4	0.67	0.0	100.0	0.0	4.4	0.9	0.4	0.0	10.0	102.0	66.0	2.44
21		S	35	8.1	1,542.0	0.0	255.0	425.0	44.3	35.1	243.0	12.0	1.7	0.0	518.0	0.0	157.0	153.0	0.6	0.8	15.0	915.0	66.0	6.62
22		S	15	7.6	194.2	0.0	67.4	83.4	17.6	5.7	13.5	1.7	1.5	0.0	102.0	0.0	6.6	7.8	0.0	0.0	11.0	114.0	30.0	.72
23		S	20	7.7	1,607.0	0.0	109.0	170.0	11.2	19.8	288.0	6.5	1.4	0.0	208.0	0.0	8.5	396.0	0.4	0.8	9.9	843.0	84.0	12.00
24		R	30	8.1	3,216.0	0.0	128.0	471.0	3.3	29.0	670.0	9.6	1.1	0.0	574.0	0.0	51.9	738.0	0.8	0.0	9.2	1,795.0	91.0	25.80
25		R	15	8.3	867.8	90.2	411.0	321.0	106.0	35.0	24.5	10.1	1.5	0.0	391.0	0.0	76.6	47.2	0.0	0.8	10.0	503.0	11.0	8.25
26		R	45	8.1	1,802.0	0.0	152.0	602.0	17.4	26.3	375.0	10.5	3.0	0.0	733.0	0.0	74.5	204.0	0.8	1.0	12.0	1,082.0	83.0	13.25
27		S	40	8.0	2,244.0	0.0	97.6	721.0	7.6	19.1	500.0	10.0	1.2	0.0	878.0	0.0	28.0	300.0	0.8	0.0	5.2	1,303.0	91.0	22.60
28		R	70	8.5	2,137.0	0.0	188.0	697.0	7.2	13.9	490.0	10.5	1.1	0.0	788.0	30.0	69.5	259.0	0.8	1.0	8.9	1,279.0	92.0	24.21
29		R	15	8.0	584.8	61.8	284.0	223.0	71.0	26.0	17.0	2.3	2.7	0.0	271.0	0.0	69.7	15.7	0.2	0.0	12.0	348.0	11.0	.44
30		R	15	7.7	741.1	0.0	182.0	278.0	36.2	22.3	95.0	7.7	0.94	0.0	338.0	0.0	64.0	37.0	0.4	2.0	12.0	443.0	52.0	2.06
31		R	45	8.4	1,667.0	0.0	188.0	555.0	20.0	33.7	318.0	12.0	0.31	0.0	658.0	9.1	100.0	165.0	0.6	1.5	13.0	997.0	77.0	10.00
32		R	15	8.3	538.4	49.1	283.0	234.0	72.0	25.0	7.8	2.0	0.91	0.0	286.0	0.0	44.8	11.6	0.0	1.0	11.0	316.0	5.6	.21
33		R	15	8.3	867.8	90.2	411.0	321.0	106.0	35.0	24.5	10.1	1.5	0.0	391.0	0.0	76.6	47.2	0.0	0.8	10.0	503.0	11.0	.60
34		R	15	8.2	1,595.0	512.0	931.0	419.0	253.0	72.0	19.5	5.1	7.4	0.44	511.0	0.0	443.0	67.9	0.0	0.0	11.0	1,124.0	4.3	.28
35		R	15	8.0	825.5	112.0	429.0	317.0	105.0	40.7	13.5	5.5	1.3	0.0	387.0	0.0	86.1	24.3	0.2	12.0	13.0	490.0	6.3	.28

*Abbreviations: S = Pleistocene aquifer. Gr = Precambrian aquifer. R = Palaeozoic aquifer.

The waters in the Nepean sandstone do not have a similar grouping, but they are related to the composition of the water of the overlying sand aquifer or the sand aquifer near it. The waters from this aquifer contain a higher percentage of sodium chloride and lower percentages of bicarbonate, calcium, and magnesium than waters from the March and Oxford aquifer. However, the total dissolved solids is much higher.

Water in the confined sand aquifer varies considerably in total dissolved solids (see Table IV). The high concentration of both sodium chloride and sodium bicarbonate in some samples is due to two causes. The sodium chloride was probably trapped in the unconsolidated sediments through which the water now circulates. The high concentration of sodium bicarbonate is caused by the water circulating in a media derived from rich carbonate rocks with plenty of available sodium cations.

The analyses of water samples 16 and 15 are similar in all respects. A pump test on the well from which sample 16 was taken revealed that there was a positive boundary to the aquifer. On the other hand, sample 15 was taken from a well in a confined sand aquifer that is situated in a major bedrock depression northwest of the tested well. From the analyses of these two samples it is concluded that this bedrock depression is the region of recharge for the sandstone aquifer nearby.

On the basis of the analyses in Table IV, the best waters in the map-area will be those bordering the region of recharge (samples 17, 18, 20, 22). Indeed these waters will have less dissolved solids, and will be soft to medium hard whether they are taken from the confined sand aquifer or the underlying sandstone aquifer.

The waters away from the recharge region are still very potable, but contain more dissolved solids, and are more apt to contain sodium chloride; and are therefore of more limited use. Heavy industry that needs ground water solely for cooling purposes should have no difficulty in locating a good supply of water anywhere in the map-area.

Certain parts of the map-area have a sufficient supply of water to support irrigation. In such areas, the quality of water for irrigation varies from excellent to fair.

Conclusions

The Pleistocene deposits are the principal aquifer in the region, but the underlying Ordovician rocks are also a good source of water. Recharge is locally by precipitation; where the St. Lawrence River cuts across the structure of the bedrock, induced recharge from the river is possible.

The ground water flows towards the major streams of the region. Quantitative information on the aquifers varies from good to excellent. The quality of the ground water between the St. Lawrence and Ottawa Rivers is related to its distance away from the recharge area.

The amount of ground water in most parts of the map-area greatly exceeds present consumption.

Part II

THE SEISMIC METHOD APPLIED TO A BEDROCK CHANNEL PROBLEM

by George D. Hobson

A seismic investigation to map the bedrock surface in Vaudreuil (31 G/8) map-area, Quebec, was carried out between September 19 and October 7, 1960, and between September 18 and October 16, 1961. The area is immediately west of the confluence of the Ottawa and St. Lawrence Rivers in the southwestern part of the province.

Some general statistics on the seismic program are tabulated below:

Total days worked	33
Total hours worked, including driving	321 1/2
Holes shot	343
Surface miles covered (not subsurface coverage)	110
Dynamite used (pounds)	172 3/16
Caps used	436
Prima cord used	110 ft.

The Seismic Refraction Method

To supplement the following general discussion on the seismic refraction theory the reader is referred to Nettleton (1940)[1] and Dobrin (1960)[2].

Elastic waves generated by explosions travel downward in all directions and, after being reflected and refracted at rock interfaces at depth, return to the surface of the earth. The interpretation of recorded seismic data consists of determining the velocity of propagation of these elastic waves and analyzing the refraction and reflection phenomena at the interfaces or boundaries between rock layers that are characterized by different acoustic properties. The refraction phenomena were of principal interest in this investigation.

In the refraction method of seismic prospecting the quantity observed is the time interval between the initiation of the elastic wave by an explosion and the first disturbance of the ground as detected by a seismometer at a known distance from the source of energy. The proportion of the energy refracted is dependent on the difference in propagation velocities on opposite sides of the acoustic boundary. At the critical angle of incidence of the incident ray upon an interface, most of the energy does not penetrate into the underlying layer but travels along the interface with the velocity of the underlying layer and follows the relations defined in optical theory by Snell's Law.

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[1]Nettleton, L.L.: Geophysical Prospecting for Oil; McGraw-Hill, 1940.

[2]Dobrin, M.B.: Introduction to Geophysical Prospecting; McGraw-Hill, 1960.

As the wave advances along the boundary, energy will be refracted back to the surface (after Huygen's Principle) at the same angle as the critical angle of incidence. This is the basis of the refraction method and its successful application is dependent on an increase in velocity with depth.

Field Procedure

Twelve channels of conventional seismic instruments (Texas Instruments model 7000B) were used to record the seismic events, using one geophone per trace or channel; the natural frequency of the geophone is 7 cycles per second. These geophones were placed at various stations equidistant from the shot point, depending on the depth to bedrock. The spread length (the distance between shot point and farthest detector) varied between 120 and 1,440 feet. Explosive charges varying from 2 feet of Prima Cord to 5 pounds of Geogel 60-per-cent were detonated in holes generally 4 feet deep. The average detonation of 1/2 pound was usually adequate to yield very good first arrivals of energy.

Personnel consisted of an observer, a shooter, and two helpers equipped with two vehicles for recording and shooting. Surveying was carried out by supervisory personnel during field visits in 1960, and a surveyor with a vehicle was added to this crew in 1961. Levels were carried from geodetic bench marks by plane table and alidade.

Velocities Observed

Consistently good time-distance plots were obtained for locations in Vaudreuil map-area; poor graphs were rare. A few weathering shots using very short detector-spreads indicated a weathered layer or low-velocity layer approximately 15 feet thick. At locations where this weathered layer was not observed an error of a foot or two may have been introduced to the resulting observed thickness of overburden.

A study of the primary wave velocities observed and the material taken from the shot holes shows that there is no extensive variation in velocity in this area for hard clay, sticky clay, clay, or sandy clay at near-surface conditions. Seventy per cent of all observed overburden velocities fall in the 4,400- to 5,000-foot-per-second range, with an average value of 4,800 feet per second. The V_1 velocities observed in the sandy soil of the higher-elevation locations in the north-central part of the map-area are of a higher average value than the velocities of the general clayey conditions of the flat-lying areas to the south. This sand velocity has an average value of 5,500 feet per second.

The observed bedrock velocities indicate that some relationship exists between seismic velocities and rock types in Vaudreuil map-area. (See Fig. 1). The inliers of limestone shown on Figure 1 are probably thin, but the present seismic data do not permit an estimate of the thicknesses of either the limestone or sandstone formations in these inliers.

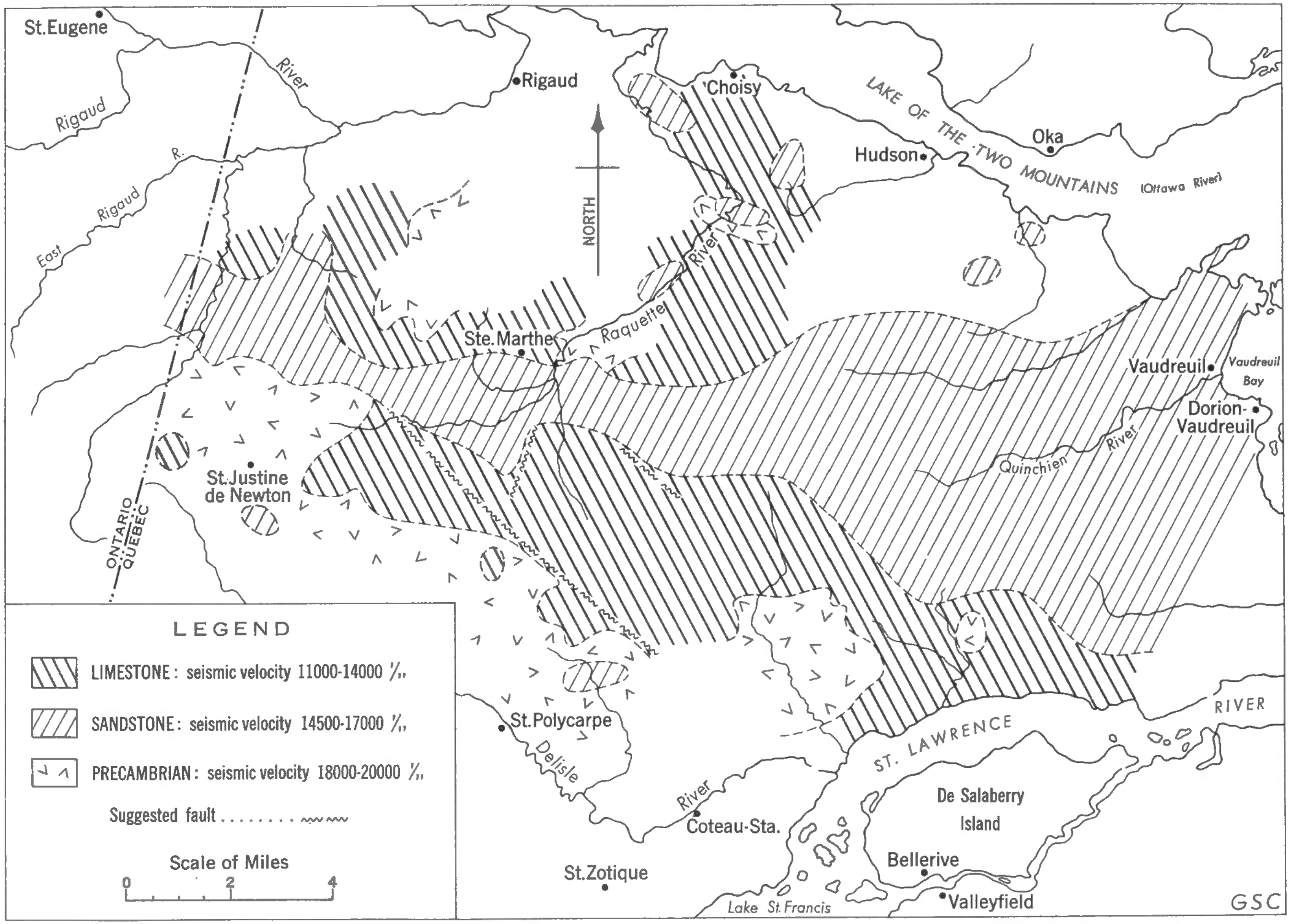

Figure 1. Bedrock lithology derived from apparent seismic velocities

Some Observed Reflections

Although the main purpose of the survey was to obtain refraction data for bedrock-depth determinations, some 20 locations, mostly in the south-central part of the map-area, yielded reflection events of considerable interest. Computations suggest that the depth to the Precambrian rocks is of the order of 1,500 feet in these particular places. Another reflector horizon is indicated about 1,000 feet below the surface, which may be the sandstone-conglomerate interface. A program employing the seismic reflection technique would be required before a more definite appraisal of these reflections could be undertaken.

Conclusions

1. Seismic investigations have outlined an elongated depression or channel in the bedrock; this channel is 1 mile to 2 miles wide and extends from Belle Plage west-southwesterly through St. Lazare Station and St. Clet, thence west-northwesterly through Ste. Marie de Ste. Marthe, and northeast to Choisy.

2. This buried channel has its lowest elevation below sea-level throughout its extent.

3. One definite side channel is interpreted south from St. Lazare Station to the St. Lawrence River. There are indications of other channels.

4. These side channels may provide access routes for recharge of the main channel, for their bedrock elevation is below that of either the Ottawa or St. Lawrence Rivers.

5. The contoured bedrock data on the accompanying depth-to-bedrock map indicate that seismic and boring data are compatible in Vaudreuil map-area.

6. A change in subsurface bedrock lithology in Vaudreuil map-area can be recognized by a change in average-bedrock seismic velocity.

7. The quality of the refraction arrivals on the records is very good and the time-distance graphs from these arrivals are exceptionally definitive.

8. The seismic velocities within both the overburden and the bedrock are unusually consistent.

9. Some buried valleys are good sources of ground water; therefore, information regarding their location, depth, and cross-sectional dimensions is important in water-supply investigations. The seismic method has successfully provided such information in Vaudreuil map-area.