Distribution of Miles Canyon basalt in the Whitehorse area and implications for groundwater resources

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ABSTRACT

Miocene Miles Canyon basalts play a critical role in the historical development and modern economics of the City of Whitehorse. Where cut by the Yukon River, the unnavigable waters at Miles Canyon and the Whitehorse Rapids formed a natural terminus that became a transportation hub that in turn encouraged settlement. Today, this basalt is responsible not only for efficient and economical hydroelectric power, but also for hosting the groundwater resources for many of Whitehorse's rural residents. Much of the city is underlain by Cretaceous granodiorite of the Whitehorse Batholith, which is a relatively poor aquifer due to its lack of porosity. Miles Canyon basalt however, has significantly higher innate hydraulic permeability and thus provides better opportunities for additional groundwater resources and aquifer development. Miles Canyon basalts have reported hydraulic conductivity values around 2×10^{-6} m/s, which are 20 to 50 times higher than reported hydraulic conductivity values for unfractured granodiorite aquifers. As such, the loci of basalt limits have important implications for the siting of productive private water wells.

This paper summarizes details of Miles Canyon basalt occurrences within the limits of the City of Whitehorse and provides updated mapping of the extent and distribution of the basalt within the City. The discussion includes a summary of six outcrop observations, twelve water-well record data, a shallow reflected seismic survey and interpretation of regional aeromagnetic data related to basalt distribution. Thickness of Miles Canyon basalt intersected in drill holes ranges from as little as 1.8 m up to 110 m, although most drill holes did not penetrate the total basalt thickness.

RÉSUMÉ

Le basalte de Miles Canyon, d'âge Pliocène-Pléistocène, joue un rôle stratégique dans l'évolution historique et l'économie moderne de la ville de Whitehorse. Ce basalte est non seulement à l'origine d'une source d'hydroélectricité efficace et bon marché, mais assure également des ressources en eau souterraine pour nombre de résidents ruraux de Whitehorse. La ville repose en grande partie sur le granodiorite du batholithe de Whitehorse, d'âge Crétacé, un aquifère relativement pauvre à cause de sa faible porosité. Le basalte de Miles Canyon a enregistré des valeurs de conductivité hydraulique d'environ 2×10^{-6} m/s, ce qui est de 20 à 50 fois plus élevé que les valeurs observées dans des aquifères de granodiorite non fissurés. Ainsi, la localisation exacte des limites de distribution du basalte est un facteur important pour le choix de l'emplacement des puits artésiens.

Dans cet article, nous présentons un compte rendu des observations de basalte de Miles Canyon à l'intérieur des limites de la ville de Whitehorse, et révisons l'étendue et la distribution du basalte sous la ville. Nous analysons un résumé des observations de six affleurements, les fiches de douze puits artésiens, un levé de sismique-réflexion à faible profondeur, et interprétons les données d'un levé aéromagnétique régional sur la distribution du basalte. Les trous de forage qui pénètrent le basalte de Miles Canyon ont recoupé une épaisseur de basalte allant d'à peine 1,8 m jusqu'à 110 m, bien que la plupart des forages n'ont pas traversé l'épaisseur totale du basalte.

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INTRODUCTION

Miles Canyon basalts were critical to the origin and historical development of the City of Whitehorse. Cataracts formed by these flows formed a transportation terminus that required travelers, the railhead, and head of shipping to pay homage to the treacherous rapids and canyon. This encouraged settlement, commerce and prospecting. In 1958 the Whitehorse Rapids were tamed by a hydroelectric dam and, with a current installed capacity of 40 MW, have since supplied southern Yukon with clean and reliable electricity. In recent years, widespread rural residential developments within the city limits have come to rely on groundwater for household domestic water supplies. In areas where unconsolidated aquifers are not available, aquifers formed in Miles Canyon basalt are increasingly recognized as yielding a sufficient groundwater supply. With consistent demands for rural residential development and increasing pressure on aquifers, information regarding host rocks is increasingly in demand.

Much of the southern City of Whitehorse is underlain by the Cretaceous granodiorite of the Whitehorse Batholith (Hart and Radloff, 1990; Hart, 1995; Morrison, 1979), which is typically a poor aquifer due to its low permeability. In order to develop water wells with sufficient water supply in this type of host-rock, drillers and homeowners must intersect a water-producing fracture zone, or risk having to drill to excessive depths in order to encounter one. In at least one known example in the Wolf Creek subdivision, a well that had been drilled 50 m into granodiorite bedrock yielded negligible water supplies. With the current cost of drilling (a cased hole approximating $130/m), it is in the homeowner's best interest to know that sufficient water supplies are likely available at a reasonable drilling depth and cost at a specific site. Miles Canyon basalt is a lithology that presents less risk in drilling water wells, as aquifers hosted in these rocks typically yield adequate volumes sufficient for domestic use, and may locally be developed for more demanding users. Understanding the extent of Miles Canyon basalt therefore offers developers, drillers and homeowners more information in order to decide whether developing an on-site water supply is cost effective with respect to trucked water delivery.

GEOLOGY OF THE WHITEHORSE AREA

WHITEHORSE BATHOLITH

The Whitehorse Batholith extends over 600 km^2 including much of the area in and around Whitehorse (Fig. 1). It consists of a variably zoned Cretaceous intrusive body ranging from diorite to granite, but dominated by granodiorite that intrudes folded sedimentary and volcanic rocks of the Triassic Whitehorse Trough (Hart and Radloff, 1990). Although variably jointed, the granodiorite lacks a continuous, systematic joint set in three planes. The rocks are brittle and variably fractured a most fractures are steeply inclined or nearly vertical. Although fracture analysis has not been undertaken, regional structures typically trend northwesterly, with a more closely spaced series of smaller east-northeasterly trending faults and fractures (Hart and Radloff, 1990).

MILES CANYON BASALT

Miles Canyon basalt is the youngest bedrock lithology in the Whitehorse area (Wheeler, 1961; Hart and Radloff, 1990). It forms numerous disparate occurrences, the largest being a continuous sequence of flows between the McRae, Miles Canyon and Whitehorse Rapids localities. Most other occurrences are erosional remnants of previously larger exposures, up to a few square kilometres in area. Isotopic dating indicates that the larger sequence of flows exposed below the dam and at McRae are ~8.5 ± 1 Ma (Hart and Villeneuve, 1999). Except for the Wolf Creek occurrence, dated at 7.4 ± 1 Ma, the other occurrences have not been dated, but are likely Late Miocene. Locally, the basalts contain peat or bedded silt between the flows. The basalts are dominated by columnar-jointed, variably vesicular and amygdaloidal flows and scoria. Individual flows are up to 20 m thick, but are thinner, down to 1 m, below the hydro dam. Most exposures unconformably overlie weathered and oxidized granodioritic bedrock of the Whitehorse Batholith. However, some basalts overlie variably consolidated gravel of probable Neogene age. These conglomerates have been intersected in drilling. The basalts include dominantly aphyric, but locally diabasic, plagioclase-, augite-, olivine- and magnetite-bearing, weakly alkalic basalts, basanite, hawaiite and pantellerite (Eiché, 1985).

Miles Canyon basalt deposition post-dates most structural features such as faults, but the basalts have extremely well developed columnar joints that give rise to good vertical secondary permeability, and the connectivity of these joints also provides considerable horizontal permeability.

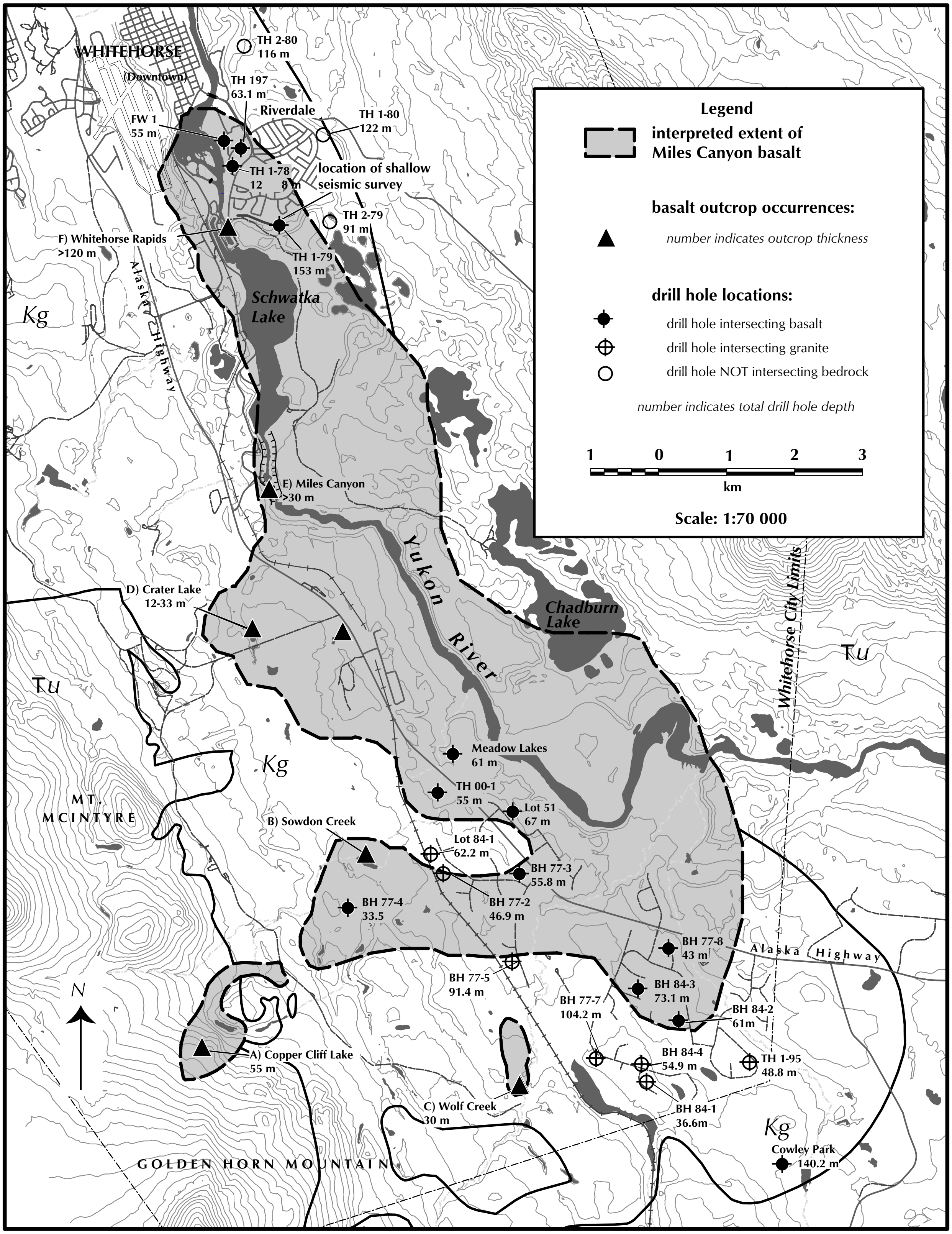

Figure 1. *Interpreted extent of Miles Canyon basalt in the Whitehorse area, with localities of drill holes and outcrops indicated in the Tables. Distribution of basalt was identified through compilation of outcrop localities, reported basalt intersections in drill hole data, interpretation of regional aeromagnetic data, and a reflected seismic survey.*
Kg = *Cretaceous granite;* **T**_u_ = *Triassic Whitehorse Trough sedimentary rocks.*

Additionally, many flow surfaces are marked by highly vesicular flow-tops and -bottoms, or scoria, and an unconsolidated break or porous materials. These provide thick regions of continuous horizontal primary permeability.

SURFICIAL GEOLOGY

Whitehorse is largely within the Yukon River Valley, which is a broad, terraced landscape composed of low-relief glaciolacustrine, fluvial and aeolian material dissected by the Yukon River. Elevations of the valley floor ranges between 660 m and 690 m above sea level (ASL). The landforms of the Whitehorse area are attributable to the last glacial retreat that likely occurred between 35,000 and 12,000 years ago. The area has a complex terrain of glacial, glaciofluvial and glaciolacustrine deposits that are typical of deglaciation in mountainous regions (Mougeot GeoAnalysis and Agriculture and Agri-Food Canada, 1997). These deglaciation features substantially affect and control the surface and groundwater resources in unconsolidated materials.

Thick sequences of glaciofluvial sand and gravel deposited in the centre of the Whitehorse valley form a dramatic knob and kettle topography seen in the Chadburn and Long lakes areas. This material hosts the very productive Selkirk aquifer that is the source of the City's municipal groundwater supplies (Gartner Lee Limited, 1998). At elevations above 730 m ASL, morainal material dominates the unconsolidated deposits. This material typically lacks sufficient permeability to be exploited for domestic water supplies. This necessitates that many developers of domestic water wells in rural residential areas (e.g., Wolf Creek, Cowley Creek) utilize bedrock aquifers.

Table 1. *Significant outcrop occurrences of Miles Canyon basalt in Whitehorse area,*

Site ID	Location	Description	Thickness	Reference	Underlying material
A	Copper Cliff Lake, Golden Horn Mountain	Massive flows and oxidized scoria. Topographically highest, and most southerly locality. Associated 1-3 m thick, east-northeast-trending dykes.	55 m	Hart and Villeneuve, 1999	
B	Sowdon Cr.—between Copper Haul Rd. and Wolf Creek Subdivision	A plateau of basalt with abundant outcrops and exposure along glacial meltwater channels.	Unknown		Probably granodiorite
C	Wolf Creek/ Keewenaw	Small exposure of columnar-jointed basalt flow on northwest side of Wolf Creek. Paleomagnetically reversed. 7.1 ± 0.4 Ma K-Ar date.	30 m	Hart and Villeneuve, 1999	Oxidized and altered Whitehorse Batholith granodiorite exposed in stream-cut under flows.
D	Mt. Sima Road/ Crater Lake/McRae	Large plateau of basalt exposed along Crater Lake and near McRae and in shallow boreholes in area. Paleomagnetically normal. 8.8 ± 0.6 Ma K-Ar date.	12 to 33 m	Piteau Engineering Ltd., 1991; Hart and Villeneuve, 1999	"Beneath the basalt layer, a 1.5-m-thick clay rich layer was encountered and below it a...zone of weathered feldspathic rock." Northerly exposures overlie strongly oxidized and deeply weathered Whitehorse Batholith granodiorite (gruss).
E	Miles Canyon	Type location – outcrop also found 1 km upstream near Canyon City and 1 km downstream near Schwatka Lake boat ramp. Paleomagnetically normal.	>30 m		Oxidized and altered Whitehorse Batholith granodiorite.
F	Whitehorse Rapids	Site of hydroelectric project, abundant outcrop along river. Paleomagnetically normal. Several Ar-Ar and K-Ar dates indicate age of 8.5 Ma.	>120 m	Hart and Villeneuve, 1999	Variably lithified gravel.

NATURE AND DISTRIBUTION OF MILES CANYON BASALT

Attributes of six significant Miles Canyon basalt outcrops are summarized in Table 1. This table presents the thickness of the basalt package at that site (if known) and the reported underlying material. Outcrop locations documented in the table are illustrated with triangular symbols on Figure 1. Subsurface exposures of Miles Canyon basalt are also known from water-well drilling of bore holes and mineral exploration diamond drilling.

Table 2. *Occurrence of Miles Canyon basalt in Whitehorse area.*

Site ID	Location	Description	Thickness	Reference	Underlying material
TH 1–97	near Selkirk Elementary School	Well drilled as part of 1997 warm water exploration program. Basalt intersected 52.1 m below surface (585.5 m ASL), total hole depth = 63.1 m	>11 m	Gartner Lee Limited, 1999	unknown
FW1	original fish hatchery well, Selkirk Well Field	Well abandoned. Basalt intersected 52 m below surface (585 m ASL), total hole depth = 55 m	>3 m	Drillhole log, Interior Water Wells Ltd., 1985	unknown
TH 1-78	near Nisutlin Dr. & Selkirk St.	1st deep test-well in Selkirk Well Field. Basalt intersected 67 m below surface (570.48 m ASL), total hole depth = 128.3 m	37.8 m	Stanley Associates, 1978	"- Sand & gravel, cemented (mainly granodiorite) - gravel, with greenish silt lenses - gravel, large number of rounded chert pebbles"
TH 1-79	near Chadburn Lake Rd., south of Firth Rd .	Deep test-well drilled in 1979. Basalt intersected 42.5 m below surface (609.5 m ASL), total hole depth = 153 m	110 m	Stanley Associates, 1980	"sand"
MLGC	Meadow Lakes Golf Course	Clubhouse well. Relatively productive (1 L/s). Basalt reported 50 m below surface (668 m ASL), total hole depth = 60.9 m	>11 m	Drillhole log, Lundgren Well Drilling Ltd., 1999	unknown
TH 00-1	test-well, Wolf Creek North	Thin layer of basalt intersected 37 m below surface (689 m ASL) overlying deeply weathered granite. Basalt sill or dyke encountered after 11 m of granite.	1.8 m	Gartner Lee Limited, 2001	11 m of weathered granodiorite (gruss), 4 m of basalt intersected below.
Lot 51	28 Harvey Rd., Pineridge subdivision	Residential well. Basalt reported 43 m below surface (684 m ASL), total hole depth = 66.7 m	>24 m	Drillhole log, Fredelena Enterprises Ltd., 1999	unknown
77-3	5 Harbottle Rd., Wolf Creek subdivision	Test-well drilled in 1977. Basalt reported 36 m below surface (700 m ASL), total hole depth = 55.8 m	>19	Golders Associate, 1977	unknown
77-4	west of Wolf Creek subdivision	Test-well drilled in 1977. Basalt reported 12 m below surface (775 m ASL), total hole depth = 33.5 m	>21	Golders Associate, 1977	unknown
84-3	Lot 78, Mary Lake subdivision	1984 test-well. Basalt reported 44.5 m below surface (694 m ASL), total hole depth = 73.1 m	> 29	Thompson Geotechnical, 1984	unknown
77-8	between Orchid Pl. & Alaska Hwy., Mary Lake subdivision	Test-well drilled in 1977. Basalt reported 40.2 m below surface (687 m ASL), total hole depth = 43.3 m	> 3	Golders Associates, 1977.	unknown
	Cowley Park	Mineral exploration diamond drilling intersected basalt at a depth of 49 m	22	Bidwell, 1987	gravel

Additional localities, or the extent of known localities, are interpreted from aeromagnetic and seismic data.

DRILL HOLES

Attributes of 12 drill holes reporting intersecting Miles Canyon basalt are presented in Table 2. Similarly, this table summarizes the reported depth to basalt, basalt thickness and underlying material (if known). Drill holes are symbolized on Figure 1 with a solid, crossed circle and labeled with the total drill hole depth. Figure 1 also identifies drill holes intersecting granodiorite (shown as an open, crossed circle) and deep drill holes not intersecting bedrock (shown as a small open circle). Wells developed in granite are typically located at the southern end of the city. Deep overburden drill holes consist of a series of three deep holes drilled by Stanley Associates Engineering Ltd. (1979, 1980) in the Riverdale area.

Drill hole data has been compiled from hydrogeological studies conducted during subdivision developments, the city's hydrogeological exploration in the late seventies, and private water-well records (Gartner Lee Limited, 2000a). Regretfully, there is no archive of well-site information available to the public.

AEROMAGNETIC INTERPRETATION

The magnetic susceptibility of Miles Canyon basalt is several times greater than most of the Whitehorse Batholith. The only other rock-type with a high magnetic signature is the magnetite-rich skarn of the Whitehorse Copper Belt. As such, interpretation of regions of elevated magnetic response from existing aeromagnetic data can aid in locating sub-surface occurrences, or the limits of surface exposures. Unlike the skarn, Miles Canyon basalt likely yields relatively flat profiles contrary to the spiky profiles across skarn occurrences (Tenney, 1981). However, it should be noted that preliminary information indicates that at least some of the basalts are reversely magnetized, thus yielding negative anomalies.

Regional aeromagnetic data (Lowe et al., 1999) has been used to help identify the buried extent of Miles Canyon basalt; several local aeromagnetic highs in the southern Whitehorse area conform with drill hole intersections of the basalt. For example, there are two regions with anomalously high values in the Wolf Creek and Mary Lake subdivision areas. The Wolf Creek high coincides with basalt intersected in drill hole BH 77-3, while the Mary Lake high coincides with basalt intersected in drill holes BH 77-8, BH 84-2 and BH 84-3. A large aeromagnetic anomaly east of Schwatka Lake is interpreted to represent the buried extent of basalt between Miles Canyon and the Whitehorse Rapids. It should be noted that these data are coarse, and refinements could be made with better data.

SEISMIC SURVEY

A 575-m-long seismic survey was completed by the authors along the 138kV transmission line running east of the Whitehorse Rapids and the Riverdale subdivision (behind Boswell Crescent and sub-parallel to the Chadburn Lake road) in November 1998. The survey was undertaken as a test to find:

1) depth to bedrock,

2) attitude of contact, and

3) the eastern edge of the basalt flow.

The data was acquired with a 48-channel Geometrics Strataview S-48, using 12-gauge shotgun slugs shot into frozen ground as the energy source. The survey was conducted using an inline array with a phone-spacing of 2 m and a shot-spacing of 4 m to yield 24-fold coverage. Shot records were 512 milliseconds long and recorded using a 500 Hz high-cut analog pre-acquisition filter. Post-acquisition processing consisted of bandpass filtering (30-150 Hz), surgical muting of the blast wave and ground roll, normal moveout analysis and application, CDP sort and stack, frequency filtering and trace balancing prior to final plotting.

The data are interpreted to show a weak but continuous reflector (A) that dips to the east on the section (Fig. 2). Above this reflection, there are a series of sub-parallel, west-dipping reflections (B) that appear to truncate against reflector (A). In the lower portions of the section, there are continuous flat reflections (C). A continuous reflection (A') is below and parallel to (A), and there are several poorly developed reflections (D) between (A) and (A'). Strongly curved arrivals have been ignored as they likely represent remnant reflections or multiples. The continuity of the reflection (A) across the section and its discordance with the reflections (B) and (C) suggest that this likely represents the upper surface of the basalt flow. Reflection (A') is likely a multiple reflector with no relevance. Depth to top of flow is highly dependent upon the velocity model chosen. A model assuming unsaturated, unconsolidated sediments yields a depth to surface (A) at approximately 30 m to 190 m across the section. This depth is generally supported by a drill hole

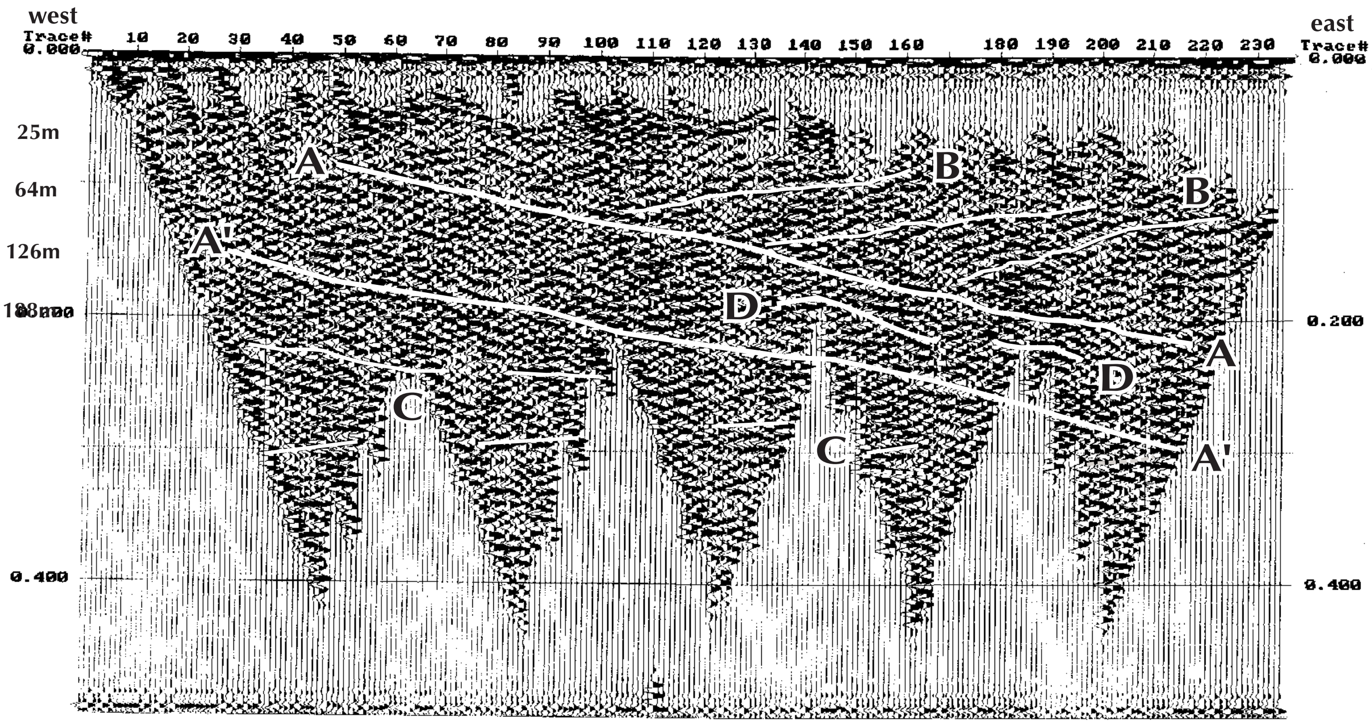

Figure 2. *Seismic profile generated from survey undertaken along the high-voltage transmission line south of Riverdale with highlighted reflectors. Vertical scale of two-way travel-time in milliseconds. Metre-scale approximate as it is model dependent. Numbers on horizontal scale are geophone sites. Total horizontal section is approximately 560 m. Interpretations of results are in the text.*

intersection (TH 1-79, 40 m off-section) with the upper basalt surface at a depth of 42 m (Fig. 1). If reflection (A′) is the base of the flow, the thickness of the unit is about 80-100 m, however if reflectors (D) are the bottom of the flow, the flows are considerably thinner.

DISCUSSION

From the information presented above, a few general observations should be made:

1. The extent and thickness of Miles Canyon basalt varies widely throughout the study area. The distribution shown on Figure 1 is likely much less extensive than when the basalt was originally deposited. Significant erosion by at least four glaciations and incision by the Yukon River substantially reduced the extent of the unit. Glacial erosion has also reduced thickness of the basalt substantially. For example, in well TH 00-1, drilled north of Wolf Creek, only 1.8 m of basalt flows were intersected, and erosional down-cutting is suspected. Local paleo-topographic highs of underlying granodiorite bedrock locally protrude through the basalt such as seen in Miles Canyon or in the Wolf Creek subdivision area.
2. The eastern extent of the Miles Canyon basalt in the Chadburn Lakes/Riverdale area is defined by the absence of lithified materials. Drill hole TH 2-79 south of Riverdale was drilled to a depth of 91 m without encountering any bedrock. Hole TH 1-79, less than 900 m further west, intersected Miles Canyon basalt 42 m below the surface. The seismic survey was conducted to follow up on this observation and investigate the eastern extent of the basalt. As stated earlier, an east-dipping reflector was observed and is interpreted to be the upper basalt surface. This surface shallowly dips eastward, which the authors currently interpret to represent an erosional surface.

3. In at least two water wells, basalt dykes or sills have been intersected within granodiorite host rocks (Gartner Lee Limited, 2001; R. Zuran, pers. comm., 2000). These basalt occurrences have been successfully developed for groundwater supplies, although it is not certain whether the permeability results from joints in the basalt, or fractures in the structure that host the basalt. Owing to the relative sparseness of bedrock information in water-well records, these two intersections of basalt dykes or sills suggest that these features may be more common in the Whitehorse Batholith than originally recognized.

IMPLICATIONS FOR GROUNDWATER RESOURCES

Bedrock lithology potentially has significant economic impact on domestic water-well development costs. In many rural areas of the City of Whitehorse, unconsolidated glacial deposits do not yield suitable aquifers for domestic water usage, and therefore bedrock aquifers are developed. These unconsolidated deposits may either be unsaturated or of insufficient permeability to yield adequate water supplies. In the Wolf Creek and Pineridge rural subdivision areas, 85% of homes use domestic wells for water supplies. Approximately half of those well records which reported stratigraphy, developed wells in bedrock aquifers (Gartner Lee Limited, 2000b).

A summary of documented bedrock aquifer performance characteristics is presented in Table 3. These data are compiled from a variety of hydrogeological studies conducted in the Whitehorse area over the last 30 years. These studies reported pumping test data of wells and calculated transmissivity (T) values for the wells. Transmissivity is a measure of the ability of the aquifer to transmit water and is defined as the hydraulic conductivity (K) times the thickness of the aquifer. Hydraulic conductivity generally is the ease at which water can flow through the soil or rock. It is measured as the volume of water (m^3) that flows through a unit area (m^2) in a given period of time (seconds) and a unit change in head of water. It is expressed as m/s (Freeze and Cherry, 1979). Well data presented in Table 3 has been grouped into three broad categories reflecting the reported bedrock type hosting the site's water well.

Wells developed in granodiorite generally fall into two broad groupings—those with very low hydraulic conductivity (K) values and a couple of wells with relatively high K values. It is interpreted that the two wells with high hydraulic conductivity (wells BH 84-1 and TH 1-95) intersected fracture zones within the granodiorite and therefore were able to produce higher

Table 3. *Summary of bedrock aquifer performance parameters.*

Well	Reported Transmissivity (m2/s)	Interpreted Aquifer Thickness (m)	Hydraulic Conductivity (m/s)	Reference
Miles Canyon Basalt				
BH 77-3	4.6×10^{-5}	12	3.9×10^{-6}	Golders Associates, 1977
BH 77-4	3.5×10^{-5}	21	1.7×10^{-6}	Golders Associates, 1977
BH 77-8	1.5×10^{-5}	3	5.1×10^{-6}	Golders Associates, 1977
BH 84-3	1.0×10^{-5}	11	9.3×10^{-7}	Thompson Geotechnical, 1984
TH 1-00	5.3×10^{-6}	5	1.1×10^{-6}	Gartner Lee Limited, 2001
Unfractured Granodiorite				
BH 77-1	4.6×10^{-6}	30	1.5×10^{-7}	Golders Associates, 1977
BH 77-6	-	53	2.3×10^{-8}	Golders Associates, 1977
BH 77-7	8.1×10^{-6}	47	1.7×10^{-7}	Golders Associates, 1977
BH 84-1	9.3×10^{-7}	25	3.7×10^{-8}	Thompson Geotechnical, 1984
Fractured Granodiorite				
BH 84-1	9.1×10^{-4}	4	2.3×10^{-4}	Thompson Geotechnical, 1984
TH 1-95	2.5×10^{-5}	2 (screened interval)	1.7×10^{-5}	Hydrogeological Consultants, 1995

yields. These two wells had K values of 2.3×10^{-4} and 1.7×10^{-5} m/s. The majority of wells developed in granodiorite, which had very low K values, are interpreted to be representative of unfractured granodiorite bedrock. Wells in unfractured granodiorite report K values ranging from 1.7×10^{-7} to 2.3×10^{-8} m/s. This range of K values is similar to that reported for silt or glacial till (Freeze and Cherry, 1979).

In addition to the wells reported in Table 3, the authors are aware of one water well drilled in granodiorite and located in the Wolf Creek subdivision that failed to produce any significant water after drilling through almost 50 m of bedrock. This well was abandoned, and the unfortunate homeowner advanced a second well elsewhere on the property. From the second hole, they were able to develop adequate water supplies at a total depth of 23 m.

The data in Table 3 demonstrate that the Miles Canyon basalt has relatively consistent hydraulic conductivity (K) values ranging from 5.1×10^{-6} to 9.3×10^{-7} m/s with a median K value of 1.7×10^{-6} m/s. These values generally are within the published range for hydraulic conductivity of permeable basalt, which range from 1×10^{-2} m/s to 1×10^{-7} m/s (Freeze and Cherry 1979) and equivalent to silty sand aquifer.

Based on the data, two broad conclusions can be drawn:

- Miles Canyon basalt has relatively consistent aquifer performance parameters. Aquifers in the basalt are not highly productive, but with sufficient thickness are commonly adequate for single residence usage.
- Wells developed in granodiorite have much more variable aquifer performance. If a fracture zone is intersected in the granitic rock, adequate water supplies can be developed. If a fracture zone is not intersected in the drill hole, the well may yield inadequate water supplies, or may require excessive drilling depths.

CONCLUSION AND RECOMMENDATIONS

In conclusion, the Miles Canyon basalt aquifers offer rural homeowners that are considering developing a water well greater certainty of success despite its typical lower yields. Areas underlain by granodiorite represent a greater financial risk due to the uncertainty associated with need to intersect a suitable water-bearing fracture within the crystalline bedrock. With drilling costs as much as $130/m, knowledge of bedrock type can help homeowners weigh the costs and associated risks associated with developing a private water well.

Based on the observations presented in this paper, we recommend that:

- Due to the significance of bedrock type and related hydraulic conductivity on domestic water well yields, all future wells drilled into bedrock report the rock type (lithology) intersected as part of the drilling log.
- A publically available water-well registry be established in the Yukon to record well locations, geologic materials intersected, and groundwater conditions. A well registry is needed to document groundwater conditions, protect groundwater resources, and provide a valuable information source for all water users, regulatory agencies and geoscientists. Well registries have been maintained in all provinces of Canada for many years and are often supported by regulatory requirements.
- Further work is required to more thoroughly understand the distribution of Miles Canyon basalt occurrences. Additional localities can be discovered by outcrop mapping, low-level airborne aeromagnetic survey, ground magnetic follow-up and seismic surveys.

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