GEOLOGICAL SURVEY OF CANADA

OPEN FILE 5893

Hydrogeological Regions of Canada: Data Release

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Abstract

The Hydrogeological Regions Map depicts first order regions of Canada that have distinct groundwater systems. The country is assigned to nine regions as determined by frozen ground, geology, and physiography. Frozen ground has a dominant affect in the continuous permafrost region and the southern limit of this region cuts across both physiographic and geological features. Geology controls surface expression of the landscape and subsurface water-bearing characteristics, and the bedrock contacts that delineate geological terrains and basins represent the major region boundaries. Physiographic features are influenced by geology and coincide closely with geological boundaries but also divide geological units where elevation dominates, primarily along the eastern limit of the Cordillera. Physiographic features provide hydraulic gradients for regional and local flow and combine with climatic and run-off characteristics to dictate the regional moisture surplus or deficit that affects recharge to and discharge from groundwater systems. Moisture index isolines based on the Thornthwaite classification overlay the regions to provide a sense of moisture deficiency or surplus.

Introduction

Groundwater is important to the economic development and welfare of Canadians and ecosystems of Canada. One third of all Canadians and up to 80% of the rural population rely on groundwater. It has been routinely surveyed since early in the 19th century, yet groundwater has only been mapped at regional scales in a limited fashion (Brown, 1967). To assist in understanding the range of factors and differences in hydrogeological systems nationally, the country can be assigned to 9 hydrogeological regions. Regions possess comparable characteristics related to geology, physiography, and climate (e.g. water balance) at ~1:5,000,000 scale.

This Open File documents the development process of the Hydrogeological Regions of Canada Map (Fig. 1) and the data sources used. It describes the general process used and documents the source files used to derive the shape files for the hydrogeological regions. It also provides a bibliography for the Hydrogeological Regions paper (Sharpe et al. in press).

Methodology

The delineation of hydrogeological regions identified in this document is guided by the methodology outlined by Heath (1982, 1984, 1988) for the classification of hydrogeological regions using five features of groundwater systems:

1) components of the system and their arrangement,

2) nature of the water-bearing openings,

3) composition of the rock matrix,

4) storage and transmission characteristics, and

5) recharge and discharge conditions.

Direct measurements or comprehensive national coverage of these five features is not available at a quantitative or even qualitative scale for Canada. Consequently, it is necessary to rely on geological and topographic data as surrogates to provide a national hydrogeological region classification. Heath (1982) similarly recognized the correlation between availability of groundwater and geology, stating that “groundwater regions are thus areas where the composition, arrangement, and structure of rock units are similar”. A not dissimilar approach using vegetation as a proxy indicator has been applied to climatic classification, Köppen classification (see Stern et al., 2000)

For the production of the Canadian Hydrogeological Regions map three national datasets have been employed:

i) *frozen ground or permafrost*- defines areas where temperatures in rock or soil remain at or below 0°C through the summer.

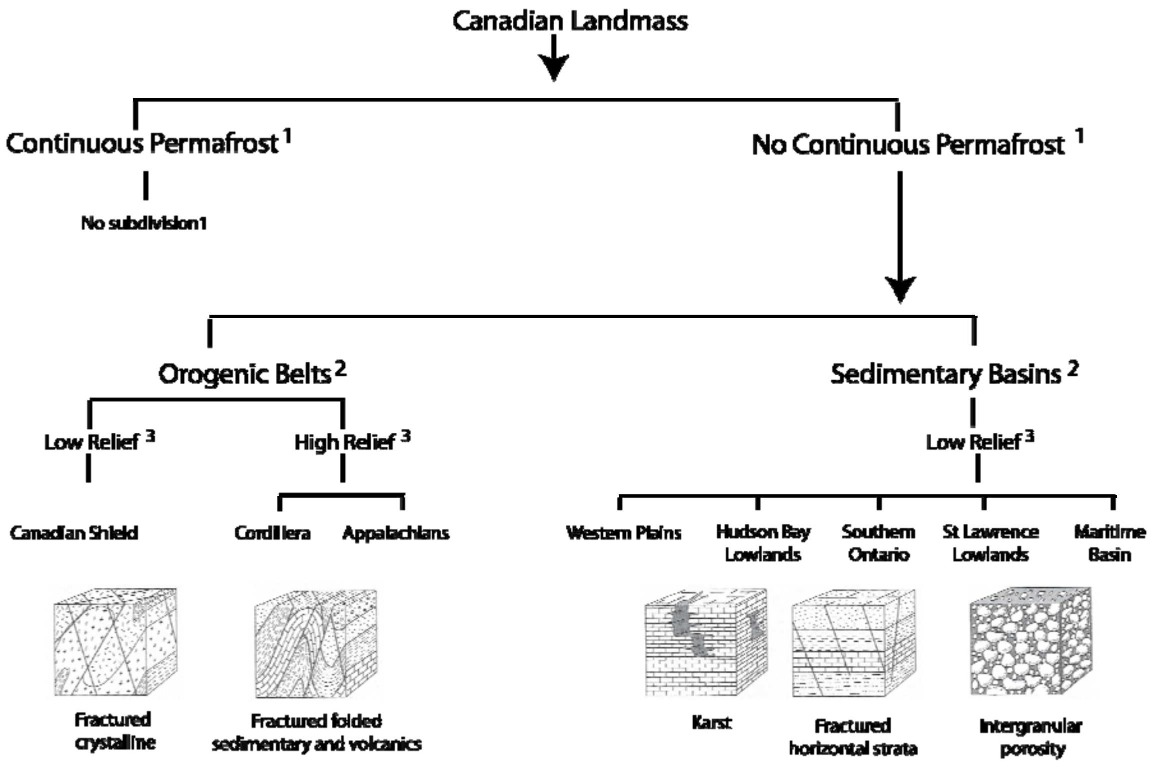
ii) *bedrock geology* - controls water-bearing characteristics of each region (e.g. porous, fractured media; water quality)

iii) *topography* - provides hydraulic gradients for regional and local flow systems

A fourth dataset that has not been integrated into the classification is a moisture index based on the Thornthwaite classification (NRCan, 1990). This attribute has been overlain on the Hydrogeological Regions as a further aid in understanding the influence of moisture deficit or surplus in dry or wet climate zones on hydrogeological characteristics of the regions.

The country is first classified into either a region of continuous permafrost or an area south of the continuous permafrost limit (Fig. 1). In the permafrost region no further subdivision is completed as the dominant control on groundwater distribution and flow is the presence of interstitial and massive ground ice. Nevertheless, the permafrost zone could, if necessary, be classified using the same criteria applied to the southern region of the country. As lithology, structure, and stratigraphy are the dominant controls on many of the five features identified by Heath (1982), the country is then assigned to either Orogenic belts or sedimentary basins. Orogenic belts include not only the relatively young and still strongly physiographically distinct regions of the Western Cordillera and the Appalachians, but all of the various tectonic provinces of the Canadian Shield. These regions are unified by their tectonic history as reflected in the deformation of the heterogeneous assemblage of lithological units that include sedimentary, extrusive and intrusive igneous and metamorphic rocks. Orogenic belts are dominated by fracture over porous media flow systems. Sedimentary basins are characterized by their relatively undeformed, subhorizontal to gently inclined strata of clastic and carbonate rocks. Depending upon the age, depth of burial, and lithology, flow is controlled by fracture or a combination of fracture and porous media. Where carbonates are extensive, karst may be a significant component of the system and form some of the most productive aquifers. The final element in the assignment is topography. For the most part the sedimentary basins all have relatively low relief, whereas the orogenic belts can be assigned to either low or high relief classes (Fig. 1). The classification does not currently identify various sedimentary basins within the Cordillera region that formed as either foreland or intramontane basins. Identification of these basins, the larger of which are the Nechako and Bowser basins, was considered unnecessary at a national scale due to the relative low groundwater use in these regions.

Surficial geology is an important part of the hydrogeology of Canada as it hosts much of the groundwater used for potable water supply. Due to the diverse character of surficial geological units and relatively small areal extent of individual units, surficial geology was not explicitly integrated into the classification.



1. Permfrost - interstial and massive ground ice completely controls groundwater occurrence and flow. Porous and fracture flow is secondary to the interstial ice and consequently rock properties play a limited role in the hydrogeology.
2. In orogenic belts bedrock is heterolithic consisting of deformed sedimentary and igneous rocks, metamorphic rocks, and plutonic rocks. By contrast in sedimentary basins the succession is dominated by relatively undeformed subhorizontal to gently dipping clastic and carbonate rocks with very minor volcanic or intrusive rocks.
3. Relief controls hydraulic gradients and orographic effects can significantly effect climate.
4. Illustrative styles of porosity and permeability in various hydrogeological regions. Figures from Heath (1984)

Figure 1. Flow diagram illustrating the classification process for the Hydrogeological Regions Map of Canada.

The Regions

This document classifies Canada into nine hydrogeological regions (Cordillera, Western Plains, Canadian Shield, Hudson Bay Lowlands, Southern Ontario, St Lawrence Lowlands, Appalachians, Maritime Basin, Permafrost regions; Fig. 1; Table 1). Six of the nine regions are similar to the regions identified by Brown (1967) and Heath (1988). Significant differences are the recognition of the Maritime Basin as a separate element from the Appalachians, and Southern Ontario and Hudson Bay Lowlands as distinct elements from the St Lawrence Lowlands. The separation of these areas as individual regions illustrates the increased emphases on hydrogeological aspects of the areas rather than classification based on similarity of bedrock geology (age, lithology) or on tectonic classifications. For example the Maritime Basin is considered part of the Appalachian orogeny (Mossop et al., 2004) but based on information like geology, water bearing characteristics, and importance of groundwater, can be identified as a separate region, as it is by Mossop et al. (2004). Southern Ontario and the Hudson Bay Lowlands similarly deserve separate attention based on different geology climate, recharge – discharge patterns, and hydrostratigraphy. For example, Southern Ontario contains more shale and evaporite units than the St Lawrence Lowlands. The Hudson Bay Lowlands contains clay rich Mesozoic rocks, extensive karst, and widespread surface occurrence of peatlands.

Figure 2. Hydroregions of Canada drape on a DEM and overlain with Thornthwaite moisture regions

Table 1. Summary of Hydrogeological Region characteristics

Region (area)	**Geological Character**
Cordillera (~1.4 million km^2)	High-relief mountains carry thin sediment over fractured sedimentary, igneous and metamorphic rocks. Intermontane valleys are underlain by glacial, alluvial fan and river deposits. Northwest-southeast trending mountains intercept west to east flowing weather systems and control moisture patterns. Ice-fields, glaciers and snow packs discharge water in the summer.
Plains- (~1.8 million km^2)	Region-wide basin of low-relief, sub-horizontal sedimentary rocks. Carbonate and fluvial rocks set in mudstone are key units. Overlying extensive glacial deposits are locally thick and contain buried valleys. Incised post-glacial valleys provide local relief. Shallow gas, coal, and brines may occur.
Canadian Shield (~2.9 million km^2)	Undulating region of complex deformed, fractured PreCambrian igneous, metamorphic and sedimentary rocks, with discontinuous cover of glacial sediment. Region contains several hydro-structural terrains: sedimentary basins, volcanic belts, and low-relief, glacial-lacustrine basins.
Hudson Bay (Moose River) basin (<1/4 million km^2)	Sedimentary basin of sub-horizontal carbonate and sandstone rocks; sediment cover consists of glacial and related glaciomarine mud deposits. Low relief and poor drainage results in large wetland terrains.
Southern Ontario (~72,000 km^2)	Low to moderate relief terrain underlain by gently-dipping, carbonate, clastic and gypsum-salt strata. Near-surface karst is locally important. Glacial sediment covers 90% of region, is up to 200 m thick in stratified moraines and buried valleys. Shallow gas and basin brines are also important.
St.Lawrence Lowlands (~44,000 km^2)	Low-relief, terrain underlain by shallow-dipping sedimentary rocks and thick glacial sediment in glaciomarine basins. Moderate relief Appalachian and Canadian Shield uplands discharge water to valleys. Shallow gas and saltwater intrusion are local issues.
Appalachian (~260,000 km^2)	High-relief upland to mountainous region of folded sedimentary and igneous rocks, with thin sediment cover. Range of rock types results in varying yields and water quality. Glacial sediment is thick in valleys; sand and gravel deposits may be protected by clay beds.
Maritimes Basin (~58,000 km^2)	Carboniferous lowlands with flat-lying, alternating sandstone–mudstone sequences. Coal, salt, gypsum and minor shallow gas can occur locally. Glacial sediment cover is thin and discontinuous. Salt water intrusion is generally balanced by high recharge fluxes.
Permafrost (~2.9 million km^2)	Arctic islands and most areas north of 60^o contain frozen ground that affects groundwater flow. Diverse topography, relief and geology define sub-regions of sedimentary basins and crystalline rocks. Glacial sediment is thin, discontinuous; local peat accumulations are significant.

Map Construction

GIS aggregation of frozen ground, geology, and topography, provides a framework to derive hydrogeological regions for the entire Canadian landscape. Five principal GIS layers were used to develop regional boundaries; three geology maps (Wheeler et al., 1997; Stockwell, 1970;

Mossop et al., 2004), a permafrost map (MCR 4177), and a digital elevation model for topography (NRcan, 2000).

Sources of Information

The primary dataset used for division of the country was the Geological Map of Canada (Wheeler et al. (1997). Geological terrains from this map that have greater similarity within than between terrains (sedimentary vs. igneous-metamorphic; horizontal vs. deformed; thick surficial sediment vs. thinner surficial sediment; elements of a geological province) are assigned to respective hydrogeological regions. The Canadian Shield hydrogeological region represents an aggregation of several geological provinces. By contrast, rocks of the St Lawrence Platform are assigned to two hydrogeological regions, Southern Ontario and the St. Lawrence Lowlands. Sedimentary basins from Mossop et al.,(2004), and from Wheeler et al. (1997) delineate the Maritime Basin as a hydrogeological region separate from the Appalachian hydrogeological region. The separate delineation of the Maritime Basin highlights the predominance of Carboniferous sandstone, relatively low degree of deformation (folding), common occurrence of small graben basins, relatively thin surficial sediment, and generally low relief.

The geologic divisions are refined according to physiographic and tectonic influences. In the Cordillera, where the Rocky Mountain Foothills meet the Western Canada Sedimentary Basin (WCSB), physiographic (Bostock, 1970) and tectonic (Stockwell, 1969) information is used to refine boundaries, dividing complex geological units that extend across the initially delineated hydrogeological regions based on Wheeler et al (1997). Interpretations from the Canada3D DEM (NRCan, 2000) complete boundaries where information from other sources does not provide a definitive regional limit.

The southern limit of Continuous (90% - 100%) Permafrost is defined by two sources (NRCan 1995; Brown, 1967). The continuous permafrost limit from MCR 4177 (NRCan, 1995) extends south into the Cordillera where the elevation and slope aspect are dominant controls on permafrost distribution. These factors potentially produce greater variation in continuity of permafrost and it was deemed appropriate to use the more northern limit from Brown (1967). This limit extends from the Alaska border to the western shore of Great Bear Lake. Permafrost and physiographic limits are influenced by geology and where limits from multiple sources are approximately coincident the geological contacts are used to ensure contiguous geology is captured within each region, where possible. This occurs primarily between sub-regions along the Cordillera, WCSB, and Hudson Bay Lowlands where limits from one of multiple sources must be selected. Offsets can be as much as 20 km where detailed geology diverges locally from the more generalized permafrost or physiographic limits. Along most limits the offsets are less than 5 km and deemed representative considering the criteria for selection and the scale of mapping.

Base data for the hydrogeological regions is from the 7.5 million scale version of the Atlas of Canada base map (NRCan, 2006). Integration of this base map coverage and the hydroregion polygons provides for a seamless national coverage.

Geological information from Wheeler et al., (1997) and Fulton (1995) describes the geology and identifies rock types and rock sub-types. GIS analysis of the geology data using the region polygons will facilitate further refinement of the classifications in the future. Additional data sets can be summarized and analyzed in a similar way to derive additional information about hydrogeologic and hydrologic processes that influence groundwater systems.

Sub-regions

Few sub-regions have been identified at this stage for much of the country. For the Cordillera region, however, sedimentary basins have been identified as sub-regions using the sedimentary basin map of Mossop et al., (2004).

Spatial Data Attributes

The GIS data was constructed for flexible editing as lines and points that create the polygons. Attributes for points (polygon labels) are the same as those for the polygons and one listing applies to both. Data types are included in the map metadata and only a summary of the descriptive information is provided.

Sources of the data used to compile the data are included for each feature in both the line and polygon/label data sets. Attributes are explicit rather than coded but F-CODE values from sources are included where possible. Files (*.csv and *.xls) of the attribute content is included for the lines (HGLines.csv/xls), polygons and labels (HGRegions.csv/xls), descriptions of the polygon/label attribute fields (HGAttributes.csv/xls), and descriptions of sources used for interpretation HGSources.csv/xls).

Hydrogeological Lines

F_CODE	CODE_DESC	F_TYPE
15	Shoreline	Canada Coastline
15	Shoreline	Inland Island
15	Shoreline	International Coastline
15	Shoreline	Lake
15	Shoreline	River
30	Political Boundary	International Boundary
101	Region Boundary	Continuous (90%-100%) permafrost
101	Region Boundary	Extensive Discontinuous (50%-90%) permafrost
101	Region Boundary	Fault Line
101	Region Boundary	Geologic Contact
101	Region Boundary	Physiographic Boundary
101	Region Boundary	Physiographic DEM
101	Region Boundary	Southern limit of continuous permafrost zone
102	Sub-Region Boundary	Continuous (90%-100%) permafrost
102	Sub-Region Boundary	Extensive Discontinuous (50%-90%) permafrost
102	Sub-Region Boundary	Fault Line
102	Sub-Region Boundary	Geologic Contact
102	Sub-Region Boundary	Physiographic DEM
102	Sub-Region Boundary	Sporatic Discontinuous (10%-50%) permafrost

Hydrogeological Region Polygons and Hydrogeological Region Labels

HGR_NAME	ORDER_01	SOURCE_01	ORDER_02
Appalachians	Appalachian Orogen	GSC Map 1860a	
Appalachians	Appalachian Orogen	GSC Map 1860a	Grenville Province
Canadian Shield	Canadian Shield	GSC Map 1860a	
Canadian Shield	Canadian Shield	GSC Map 1860a	Extensive Discontinuous (50%-90%) permafrost
Canadian Shield	Canadian Shield	GSC Map 1860a	Sporatic Discontinuous (10%-50%) permafrost
Canadian Shield	Canadian Shield	GSC Map 1860a	Sporatic Discontinuous (10%-50%) permafrost
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Cordilleran Orogen
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Cordilleran Orogen
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Cordilleran Orogen
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Cordilleran Orogen
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Cordilleran Orogen
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Cordilleran Orogen
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Cordilleran Orogen
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Cordilleran Orogen
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Cordilleran Orogen
Cordillera	Cordilleran Region	Atlas of Canada Physiographic Regions	Interior Platform
Hudson Bay Lowlands	Hudson Bay Lowlands	GSC Map 1860a	
Hudson Bay Lowlands	Hudson Bay Lowlands	GSC Map 1860a	Extensive Discontinuous (50%-90%) permafrost
Hudson Bay Lowlands	Hudson Bay Lowlands	GSC Map 1860a	Sporatic Discontinuous (10%-50%) permafrost
Maritime Basin	Eastern Cratonic Basin	GSC Map 1860a	Appalachian Orogen
Maritime Basin	Eastern Cratonic Basin	GSC Open File 4673	Appalachian Orogen
Permafrost	Continuous (90%-100%) permafrost	Atlas of Canada Permafrost Map of Canada	
Permafrost	Continuous (90%-100%) permafrost	Atlas of Canada Permafrost Map of Canada	Arctic Continental Shelf
Permafrost	Continuous (90%-100%) permafrost	Atlas of Canada Permafrost Map of Canada	Cordilleran Region
Permafrost	Continuous (90%-100%) permafrost	Atlas of Canada Permafrost Map of Canada	Cordilleran Region
Permafrost	Continuous (90%-100%) permafrost	Atlas of Canada Permafrost Map of Canada	Hudson Bay Lowlands
Permafrost	Continuous (90%-100%) permafrost	Atlas of Canada Permafrost Map of Canada	Interior Platform
Permafrost	Continuous (90%-100%) permafrost	Atlas of Canada Permafrost Map of Canada	Interior Platform
Permafrost	Continuous (90%-100%) permafrost	Atlas of Canada Permafrost Map of Canada	Thelon Plain
Southern Ontario	St. Lawrence Platform	GSC Map 1860a	
St. Lawrence Lowlands	Appalachian Orogen	GSC Map 1860a	St. Lawrence Platform
St. Lawrence Lowlands	St. Lawrence Platform	GSC Map 1860a	
Western Plains	Interior Platform	GSC Map 1860a	Northern Interior Platform
Western Plains	Interior Platform	GSC Map 1860a	Northern Interior Platform
Western Plains	Interior Platform	GSC Map 1860a	Western Canada Sedimentary Basin
Western Plains	Interior Platform	GSC Map 1860a	Western Canada Sedimentary Basin

Hydrogeological Attributes

ATTRIBUTE	DESCRIPTION
HGR_NAME	Hydrogeological Region name, also used for display and colour attribution.
ORDER_01	Region designation that is equivalent to HGR_NAME. Based on name of predominant features in the source information used to delineate the region.
SOURCE_01	Source for ORDER_01 designation.
ORDER_02	Primary sub-region designation based on name of predominant features in the source information used to delineate the area.
SOURCE_02	Source for ORDER_02 designation.
ORDER_03	Subdivision of ORDER_02 sub-regions based on name of predominant features in the source information used to delineate the area.
SOURCE_03	Source for ORDER_03 designation.
ORDER_04	Subdivision of ORDER_03 sub-regions based on name of predominant features in the source information used to delineate the area.
SOURCE_04	Source for ORDER_04 designation.

Hydrogeological Sources

SOURCES	ALT_NAME
Atlas of Canada Permafrost Map of Canada	MCR_4177
Atlas of Canada Physiographic Regions	n/a
CTI Canada3D	Centre for Topographic Information - Canada3D
GSC Map 1246a	Permafrost in Canada
GSC Map 1254a	Physiographic Regions of Canada
GSC Map 1860a	Geological map of Canada
GSC Open File 4673	Sedimentary basins of Canada
Hydrogeology Regions	GSC Open File XXXX

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For descriptions of the 9 regions the reader is referred to the published sources of information (Sharpe et al., in prep). The following bibliography supports the published descriptions.

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