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Groundwater Resources Study 13

Early Silurian Sequence Stratigraphy and Geological Controls on Karstic Bedrock Groundwater-Flow Zones, Niagara Escarpment Region and the Subsurface of Southwestern Ontario

by F.R. Brunton[1] and C. Brintnell[2]

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Groundwater Resources Study 13 can be downloaded from
http://www.geologyontario.mndmf.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=GRS013

Introduction

This digital product comprises a regional outcrop and subsurface study of the early Silurian Lockport Group in southwestern Ontario, western New York State and Michigan, covering an area of 170 000 km^2. The study involved the development of protocols for investigating groundwater-flow zones in Silurian sedimentary dolostone caprocks that make up the Niagara Escarpment and cuesta. A key element of the borehole

investigations within the potable ground water region of the Niagara Escarpment and cuesta was the integration of optical and acoustic televiewer logs with gamma-ray logs to 1) improve regional stratigraphic pick criteria at formational rank; 2) improve subsurface karst identification; and 3) provide gamma-ray log profiles that highlight the stratigraphic complexity of the Lockport Group for comparison with deeper subsurface oil and gas well data. The study includes data compiled by Candace Brintnell for her Honours BSc and MSc theses at Western University, London, Ontario. The study addresses the historical challenges of the varied nomenclature applied to these early Silurian stack dolostones in Ontario and neighbouring USA States surrounding the Great Lakes region. Type sections are selected and described for the Eramosa and Guelph formations in the City of Guelph. The models for subsurface pinnacle structures are critically assessed relative to the updated stratigraphic nomenclature of the Lockport Group. The report summarizing the results of the study is provided as a portable document format (*.pdf*) file and is accompanied by 7 appendixes that include stratigraphic sections (*.tif*) for 346 boreholes and select carbon and oxygen isotopic geochemical profiles. Microsoft® Excel® for Office 365 (*.xlsx*) tables provide information on the locations of boreholes used in the study. A keyhole markup language zipped file (*.kmz*) is included that depicts the borehole and outcrop locations used for the creation of the conceptual block models as well as the relative stratigraphic positions of the key karstic bedrock flow zones. The file provides hyperlinks to all borehole logs provided in this study.

Report

The report and supplemental files of this digital data release contain information regarding the three-dimensional (3-D) character of early Silurian Lockport Group strata along the Niagara Escarpment cuesta and extending into the deeper subsurface of southwestern Ontario and the state of Michigan. The results of examining almost 80 new continuously cored boreholes, together with the reinterpretation of hundreds of municipal, industry and oil and gas wells across the study area, combined with the integration of borehole camera and select geophysical data (caliper, resistivity, gamma-ray, heat-pulse), and surface and subsurface sampling for isotope analyses (carbon, oxygen and strontium) and lithofacies descriptions, form the basis for the creation of subregional 3-D diagrams that show the predictive positions of the main karstic groundwater-flow zones across the Niagara cuesta.

The report contains 7 appendixes which comprise borehole logs and cross-sectional conceptual model diagrams for the Lockport Group strata. Appendix 1 has a master table with details of the 346 subsurface and outcrop stratigraphic logs found in Appendixes 2 to 6. Appendix 7 has 7 conceptual sequence stratigraphic cross-section diagrams for the Lockport Group and basal Salina A-units and includes a location map and table summarizing well and outcrop locations used to generate the cross-sectional model diagrams. Appendixes 1 to 7 are folders found at the root of GRS 13. Appendix 7 (figures and figure captions) has also been placed within the report of GRS 13.

Field and laboratory protocols were established to undertake the regional-scale, bedrock groundwater-flow system mapping within the early Silurian (Wenlockian) Lockport Group of the Niagara Escarpment. This mapping involved the development of a testable, early Silurian sequence stratigraphic framework for southwestern Ontario as well as an improved technique for sampling conodonts, and the application of chemostratigraphy.

The general approach to regional-scale bedrock mapping and groundwater-flow zone delineation involved 3 main components, or phases: 1) mapping and sampling of key outcrops, quarry sections and cores; 2) hydrogeological investigations of select deep bedrock wells; and 3) instrumentation of select deep bedrock wells.

Phase 1 involved the mapping of key outcrops within select quarry, roadside, railway and cliff sections. Stratigraphic sections were measured and used to establish and/or update reference and type sections for the various formations of the Lockport Group. The geologic data gathered from cores were combined with regional outcrop mapping to produce a 3-D geologic model for the City of Guelph, Hamilton and Region of Waterloo Source Water Protection Tier II and Tier III studies and groundwater exploration programs underway by the 3 jurisdictions. This information formed a testable 3-D geologic model for undertaking a regional, bedrock

groundwater exploration drilling program from 2009 to 2011, predominantly to the north of Guelph, to investigate the lithofacies character of the stacked dolostones of the early Silurian Lockport Group and the geologic controls on bedrock groundwater-flow zones. The HQ- and PQ-diameter deep-bedrock cores were logged, photographed and sampled for whole rock and select trace element geochemistry, and isotopes (carbon, oxygen and strontium). Select outcrops and cores were also sampled for conodont biostratigraphy purposes, and samples were processed using formic acid to improve conodont element yields in the dolostones.

Phase 2 involved hydrogeological investigations of select OGS and municipal-partner bedrock boreholes. These select, deep bedrock holes extended to the regional Cabot Head Formation aquitard and were logged using a combination of well video cameras, spinner meter flow profiling, borehole geophysical (optical-acoustic televiewer, caliper, apparent conductivity, gamma, fluid temperature and conductivity) and heat pulse profiling, packer testing, aqueous geochemical sampling, and FLUTe™ blank liner installation and continuous hydraulic conductivity profiling. This latter profiling provided additional hydraulic data to complement existing data and further characterize the stratigraphic position of bedrock hydrogeologic units and karstic groundwater-flow zones. Bedrock wells that possessed karstic groundwater-flow zones had FLUTe™ multilevel systems installed.

Phase 3 involved the instrumentation of select, regional, deep bedrock groundwater exploration holes drilled by the Ontario Geological Survey and select holes with municipal partners.

Appendixes

Appendix 1 has 2 files. The first is a master Microsoft® Excel® for Office 365 (*.xlsx*) workbook containing information on all boreholes logged for the study and the second is a legend for some of the stratigraphic logs.

Appendix 2 provides a Microsoft® Excel® for Office 365 (*.xlsx*) table of borehole locations and portable document format (*.pdf*) and portable network graphic (*.png*) files of borehole logs for some of the OGS regional exploration wells. Data shown on these borehole logs include optical and acoustic televiewer logs of the bedrock wells, which are invaluable for describing stratigraphic cycles and textures and identifying the positions of horizontal and vertical karst. The logs also provide natural gamma-ray and caliper logs, information concerning flow profiling under pumping conditions and video logging, FLUTe™ hydraulic conductivity and transmissivity data and the positions of FLUTe™ multilevel ports.

Appendix 3 provides a Microsoft® Excel® for Office 365 (*.xlsx*) table of borehole locations as well as stratigraphic borehole logs (in tagged image file (*.tif*) format) with accompanying gamma-ray profiles in order to relate the lithofacies characteristics with geophysical character. This information is extremely helpful to establish geophysical profiles to correlate with those wells that do not have core or cuttings to correlate lithofacies alone.

Appendix 4 provides a Microsoft® Excel® for Office 365 (*.xlsx*) table of borehole locations as well as regional stratigraphic borehole logs (in tagged image file (*.tif*) format) with carbon and oxygen isotope profiles. This data is becoming increasingly useful for regional correlation purposes where biostratigraphic information is lacking or difficult to obtain due to the depositional regimes across the Laurentia craton.

Appendix 5 provides a Microsoft® Excel® for Office 365 (*.xlsx*) table of borehole locations as well as stratigraphic logs (*.tif*) of the remainder of the regional wells examined in the study. Some of the logs contain more detailed lithofacies descriptions and core photos and are *from* Brintnell (2012). A legend is provided for the more detailed logs.

Appendix 6 provides a Microsoft® Excel® for Office 365 (*.xlsx*) table of key outcrop locations as well as stratigraphic logs (*.tif*) of these outcrops located on the Niagara Peninsula between Hamilton and Thorold, Ontario.

Appendix 7 provides a Microsoft® Excel® for Office 365 (*.xlsx*) table of key boreholes used to create the conceptual cross-sections and depositional models for the Lockport Group formations through Salina Group A-1

unit. It also includes a location map of key boreholes used, a legend and a brief write-up (*.pdf*) of paleoenvironmental interpretations, which has also been placed within the main report. All images are provided as *.tif* files.

Google Earth

This folder contains a keyhole markup language zipped (*.kmz*) file (*GRS13.kmz*) that can be viewed using Google Earth™ mapping service or other applications compatible with *.kmz* files. The GRS13.kmz file depicts the borehole and outcrop locations used for the creation of the conceptual block models as well as the relative stratigraphic positions of the key karstic bedrock flow zones. The *.kmz* file has stratigraphic logs divided by each appendix. By clicking on a point representing a borehole location, a stratigraphic log will appear, which includes its identifier, source and type.

References

Brintnell, C. 2012. Architecture and stratigraphy of the Lower Silurian Guelph Formation, Lockport Group, southern Ontario and Michigan; unpublished MSc thesis, The University of Western Otnario, London, Ontario, 242p.