Seismic Shothole Drillers' Litholog Database and GIS: Application and Benefits to Resource Development in the Mackenzie Corridor and Northern Yukon

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The Seismic Shothole Litholog Database and GIS (Smith et al., 2007) is a compilation of ~76,000 individual shothole drillers' logs recorded from geotechnical seismic operations conducted along the Mackenzie corridor, NWT, and northern Yukon Territory. The spatially heterogeneous shothole data provide baseline, shallow (<20 m) lithostratigraphic and geoscience information on surficial and bedrock geology, hydrogeology, geohazards, granular aggregate resources, massive ground ice, and permafrost distribution.

During 1974-1975, in response to the original Mackenzie Valley gas pipeline proposal, and as an aid to regional surficial geology mapping, seismic shothole drillers' log records from company archives were transcribed onto >80,000 individual 4"x6" file cards. Because of its unwieldy size and format, this archive has only been sporadically and selectively used since. As the relative sparseness of basic geoscience data represents a practical limitation to development and resource management in the Northwest Territories and northern Yukon Territory, and particularly in light of the renewed Mackenzie Valley gas pipeline proposal, a clear need was recognized to make the shothole data archive publicly available in an electronic format. The most effective means of doing this was to compile the card file shothole records into a Microsoft Access® database. The innate ability to query the database permits users to extract specific data, and through integration into a GIS, discern spatial relationships.

The benefits of assembling the seismic shothole database are considered many: 1) it converts an extensive card file archive of lithostratigraphic information into a digital format, preserving and enhancing the integrity of the data, thereby allowing their application to a broad range of purposes; 2) it creates a database structure, and base level of geoscience data, that will encourage the submission and integration of additional archival and future seismic shothole log data – data that are largely discarded by industry, and have a generally unrecognized usefulness; 3) it allows the creation of derivative GIS databases and shapefiles, thereby producing a synthesis and regional characterization of lithostratigraphy, which will highlight otherwise unknown economically and developmentally important data such as the presence of granular aggregate resources and massive ground ice; 4) it creates a database and GIS that could be used by industry to better constrain and plan future geotechnical seismic operations by allowing them to assess the nature of deposits and hazards that may be encountered, and then integrate this into logistical planning and cost estimates; 5) it provides a timely and important reference dataset of geoscience information for a wide variety of users in consideration of pipeline, road, and other

infrastructure development; 6) it provides baseline geoscience data in aid of the creation and review of land use classifications and environmental impact assessments by industry, government, communities and environmental consulting companies; 7) it provides predictive models and a dataset of unique site observations that can be used by geoscientists to constrain and guide field investigations into aspects of surficial and bedrock geology, hydrogeology, sedimentology, permafrost distribution, and landslides.

Shothole Records

Shothole log records are recorded by drill operators during geotechnical seismic operations when they auger drill holes to set explosive charges. The drillers are not, by nature, trained geologists and thus the material is logged at varying degrees of resolution and accuracy. The initial transcription of the card file archive produced over 10,000 unique permutations and combinations of lithostratigraphic unit descriptions. Standardization of terminology, spelling, punctuation, and the removal of extraneous or vague descriptors, reduced this to ~1750 unique lithological descriptions, most of which pertain to permutations and combinations of <20 key terms. Descriptors of unconsolidated drift include muskeg, clay, silt, sand, gravel, rocks, boulders, till; bedrock descriptors include shale, sandstone, limestone, coal, rock, and bedrock; sundry descriptors and adjectives include wet, water, flowing hole, frozen, permafrost, ice, sticky, and cemented.

In some cases, very detailed logs were made, recording the occurrence of even small lenses of material. Usually though, drillers simply noted major changes in lithology (e.g., 0-6 m, sand, clay, rocks; 6-10 m, shale). Elsewhere, they recorded the range of deposits encountered through the total depth of the hole, without actually identifying what individual unit thicknesses were (e.g., 0-10 m, clay, gravel, shale, sandstone). It is apparent, therefore, that differing quality of shothole records permits varying levels of insight into the regional lithostratigraphy. While the temptation to over-interpret the data exists, users are cautioned not to treat any single shothole record as “absolute,” but rather look to decipher regional and laterally continuous data trends, and clusters of similar materials, as being more reliable. It also helps, when assessing the accuracy and precision of the shothole data, to compare it with other geographically coincident lithostratigraphic records, such as that of Smith et al.’s (2005) Mackenzie borehole geotechnical database, Janicki’s (2005) formation top well database, and regional surficial geology maps (e.g., Duk-Rodkin, 2005).

GIS Databases and Shapefiles

The seismic shothole litholog database (Smith et al., 2007) presents an enormous amount of point lithostratigraphic data that has uncertain or at least unrecognizable value when viewed as individual records. The greatest potential for deciphering the range and scope of information from this database comes by placing it in spatial contexts such as are provided by a GIS. To this end, considerable effort has been applied to distilling various types of information and themes from the shothole litholog database. These are presented to the user in Smith et al. (2007) in a number of formats, including a GIS demo pmf file, which can viewed and analysed using a free downloadable version of ArcReader®, or with conventional GIS software. The included shapefiles, serve as models for how users may wish to construct their own queries. They also illustrate some of the inherent limitations of the data, and by example, show what kind of records were included in various analyses, and which were omitted. The following descriptions highlight the thematic shapefiles included in Smith et al. (2007), and briefly discuss their potential application.

The identification and delineation of potential granular aggregate deposits (e.g., sand, gravel, boulders), may be the most obviously useful application of the seismic shothole database. Granular aggregate is critical to all manner of infrastructure development. In the Territories, dense

forest cover and/or extensive bog and fen deposits can mask many granular aggregate-associated glacial/fluvial landforms and deposits. Studies in northeast British Columbia demonstrated the utility of using seismic shothole log records for identifying granular aggregate resources (Best et al., 2004; Levson et al., 2004). An initial report of gravel situated below 1-4 m of till in four consecutive shothole log records, led to a series of backhoe test pits, an auger survey, and eventually a regional airborne electromagnetic (EM) survey that identified two significant gravel deposits, one of which (Kotcho East, ~400 000 m^3) has since been mined out. The success of the investigation in B.C. was a major impetus to assembling the seismic shothole litholog database of Smith et al. (2007).

The methodology used to construct the granular aggregate subsets is described and illustrated in Smith et al. (2006a). As a rule, any layer description including clay and/or silt was deleted from the granular aggregate queries. Those records that were selected included individual citations or combinations of: gravel, rocks, boulders, and sand. Bedrock, and those records containing only sand were excluded from the query, but nonetheless can be selected from the database if a user wishes to include them. Granular aggregate deposits were further separated into those occurring at the surface from those in the subsurface. Thicknesses of deposits are illustrated by proportional symbols. The distribution of points in any area should be considered to represent “potential” granular aggregate deposits, or exploration targets, that still require ground truthing to confirm their existence, extent, and sedimentology.

Drift isopach shapefiles illustrate interpolated and minimum estimates of drift thickness (0 to >16 m) overlying bedrock. The methodology used to query and sort the shothole database and other data sources, and then construct the drift isopach surfaces, is described and illustrated in Smith et al. (2006b). Understanding of the regional drift cover is important to a wide variety of studies (e.g., landslides, hydrogeology), and users. The drift isopach shapefiles in combination with the shothole database should be of considerable benefit to industry as a means of more efficiently planning logistics of future geotechnical seismic operations by allowing them to predict the nature of ground materials and relative depths likely to be encountered.

The hazards shapefile, in a very general sense, seeks to highlight a number of litholog record entries that could be perceived as hazards to future development and/or geotechnical seismic operations. The following terms were queried from the databases, and included in the hazard shapefile: flowing hole, gas, ice, water (encountered below surface). In most cases, these are simply point data. There are areas though, where trends can be discerned in the presence of ground ice and aquifers that could be suitable for further investigation as part of more detailed permafrost and hydrogeological studies.

Permafrost and the presence of ice is one lithostratigraphic characteristic that many shothole drillers seemed to have noted with particular fervour. Permafrost is a significant concern for development (particularly ice-rich materials), owing to its sensitivity to disturbance and its link to ground subsidence and landsliding. Shapefiles highlighting records indicating the presence of permafrost and ice have thus been constructed. As with all other shapefiles, limitations in the extent of shothole records, and questions as to their accuracy and completeness, should be taken into account by anyone using these data. That said, it still serves a useful purpose in proposed development areas that geographically coincide with existing shothole records, and can also be used as a tool for identifying sites and ground conditions worthy of further geotechnical study.

Muskeg (bog or fen deposits, or peatlands) is another obstacle to development, as in its unfrozen condition, it renders vehicle traffic difficult, if not impossible. It is also recognized as a key insulator of underlying permafrost, which when disturbed and/or removed during development can lead to

extensive melting of permafrost, resulting in ground subsidence and/or thermokarst erosion. Awareness of the extent and thickness of muskeg is thus considered useful as it pertains to questions of regional development, and thus a muskeg shapefile has been created, providing point data records indicating both its simple presence, and where recorded, the thickness of the muskeg layer (represented by proportional symbols).

Database Evolution

The seismic shothole litholog database (Smith et al., 2007), constructed from the pre-1975 geotechnical seismic record card file archive, only represents a portion of the seismic shothole records potentially available from the Territories. To that end, considerable effort has been made towards retrieving additional shothole log records from company archives. Chevron Canada Inc. and Imperial Oil Ltd. have very generously provided the GSC access to extensive archival shothole records. Additional archival shothole records have also been provided by Apache Canada Ltd., Canada Southern Petroleum Ltd., Devon Canada Corp., Explor Data Ltd., Husky Energy, Purcell Energy Ltd., and Sigma Exploration Inc. (numerous other companies have assisted by providing authorization for release of joint-venture seismic operation data). All of these new data are presently being input into a database, and will be released in a subsequent GSC Open File report, likely incorporating well in excess of 150,000 individual shothole records.

It is hoped that with increased awareness of the usefulness of amassing regional shothole records into a single database, other companies will follow suit, providing both archival shothole records, and those from recent and future seismic programs. In this manner, the seismic shothole litholog database will become an ever-evolving data depository, keeping pace with ongoing geotechnical seismic exploration. Indeed, the National Energy Board has agreed to include a memorandum in future Territorial seismic exploration permitting applications informing the applicant of the existence of the GSC seismic shothole database, and requesting, on a strictly voluntary basis, that they submit their shothole log records for eventual inclusion. Any company wishing to provide recently acquired seismic shothole records, or access to archival records, is encouraged to contact the author. Comments and questions regarding the existing shothole database are welcomed.

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