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Seismic shothole drillers' lithostratigraphic logs: Unearthing a wealth of regional geoscience information in northwestern Canada

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ABSTRACT

Seismic shothole drillers' logs, record the near-surface (avg. 18.6 m deep) lithostratigraphy encountered when drilling holes to place explosive charges. These records offer a largely unrecognized wealth of geoscience information in areas for which little may be otherwise known. Stored in the Basic Files archives of petroleum exploration and seismic acquisition companies, this study first convinced companies of the potential utility of this data, then recovered the hard copy and digitally scanned records (paper, fiche, microfilm) and rendered these into a digital database and GIS. The final database of 343,989 records provides the largest source of geoscience information of its kind in northwestern Canada, and in many cases contains unique and original records on a host of subjects including surficial-, bedrock-, and hydro-geology, permafrost, and geohazards. The drillers' log records have further been used to create geospatial models of drift, till, muskeg, massive ice and ground ice thicknesses, and continue to be applied to new avenues of research such as temporal variations of bottomfast ice extents in offshore shallow marine environments. Published in freely downloadable Geological Survey of Canada Open File reports and providing commonly used database and GIS file formats, this data rescue exercise preserves and greatly enhances what was becoming an increasingly discarded corporate data set of unrecognized potential.

1. Introduction

Petroleum exploration and development, particularly in frontier northern basins of Canada, United States of America (Alaska), and Russia, occurs in terrain for which there is often scant baseline regional geoscience information on near-surface (<20 m depth) earth materials and conditions. For this reason, any data that can significantly increase the state of geoscience knowledge is likely to be deemed highly beneficial to scientific inquiry, and issues of infrastructure design, development, risk assessment and mitigation, environmental assessment and regulatory review. With this in mind, it is perhaps serendipitous that the very activity of petroleum exploration seismic reflection surveys for which shotholes are drilled to place explosive charges, has yielded a formally unrecognized wealth of baseline geoscience data [25,27–29]. This study details how historical archives of seismic shothole drillers' lithostratigraphic logs from Canada's Northwest Territories (NWT) and Yukon have been digitally rendered into database and Geographic Information System (GIS) formats, such that they now provide an unparalleled level of local and regional insight into such diverse subjects as surficial and bedrock geology, permafrost, geohazards, granular aggregate resources and muskeg thickness [31,32,36,34,35].

The example of data rescue presented in this paper is not simply a case of identifying, preserving, and making a largely unrecognized geoscience information resource publically available. It equally draws attention to the notion that large archives of geoscience data can sometimes only, or best be made sense of when integrated into a digital database and spatial format, such as provided by a GIS.

2. Seismic shothole drillers' logs

Seismic reflection surveys that utilize explosive charges require the drilling of shotholes (generally 10–40 m deep), during which, as a course of practice in Canada, drill operators log the materials being drilled through. These lithostratigraphic (a.k.a. drillers') logs variously describe the thickness, sedimentology, composition, colour, and other distinguishing characteristics of unconsolidated and bedrock materials encountered. Shothole drillers are not trained to employ formal stratigraphic techniques and nomenclature, and thus material is logged at varying degrees of resolution and accuracy. Field-based transcription of logs vary in character widely,

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and range from individual hand-written cards, to more refined pick-list and annotated stratigraphic column figures (Fig. 1). Types of lithostratigraphic information reported include characterizations of unconsolidated sediments (e.g., muskeg, clay, sand, boulders), bedrock (e.g., shale, sandstone, coal), and sundry descriptors (e.g., wet, ice, cemented). In some ways the drillers' propensity for detailing conditions that were "difficult" (e.g., gravel and sand deposits which can collapse holes, or boulders below surface), "unusual" (e.g., flowing holes, fugitive gas seeps), or that slowed drilling progress (e.g., gravel, ice, hard bedrock), makes these records potentially more useful than might be originally conceived, as such characteristics may have important geological, developmental, and hazard considerations. This was found to be particularly the case with permafrost geology. Massive ice deposits were often reported as being difficult to drill through (reflecting an absence of grit to propagate the cutting), and thus drillers tended to acutely note the presence and thickness of these. Similarly, the practice in some areas of flooding holes to freeze in explosive charges (allowing for a better transmission of percussive energy downward, as opposed to upward out of the shothole (i.e., a blow-out)), led to widespread identification of frozen vs unfrozen subsurface conditions, and even the depths at which changes in thermal state occurred [36].

Prior to efforts undertaken by the author, only a few published studies, of generally limited scope, have attempted to use drillers' logs in near-surface geoscience studies [18–20,24,3,1,4,2]. There appears to have been a prevailing attitude, particularly within industry, that the drillers' logs were "junk" data, and this led to their discard from many corporate archives, and a progressive decrease in their reporting detail, if indeed they have been recorded at all during recent seismic exploration. While any individual drillers' log may be of uncertain value and reliability, when integrated with other records using GIS technologies, regional and laterally continuous data trends may be deciphered [25,29]. Further, by contrasting drillers' log data from intersecting or adjacent seismic lines, and correlating these with other geographically coincident lithostratigraphic records (e.g., Janicki's [13] formation top petroleum well database, and Smith et al.'s [37] Mackenzie borehole geotechnical database), and with regional surficial geology maps (e.g., [6,35]; see Section 3.1), it may be possible to increase interpretive confidence in the shothole data. Recent application of drillers' log data in the southern and central Mackenzie corridor, NWT, Canada, by Geological Survey of Canada (GSC) surficial geology mappers Duk-Rodkin and Huntley (pers. comm., 2010) has demonstrated their good agreement with field-based hand-dug and augered pits (1–3 m deep) and very rare, stratigraphic exposures. This has led to the extensive use of drillers' log data to help broadly define terrain units and focus field investigations on unusual deposits, and lateral changes in surficial materials.

2.1. Archival records

Earlier attempts to use drillers' log data (cf., [18,4]) were unknown to the author when a collection of 76,000 hand-written and typed file cards was discovered in the GSC Calgary office archives in 2006. Based on prior experience using seismic shothole drillers' log data to identify a buried gravel deposit in northeastern British Columbia, Canada [16,2,26], the author envisaged a similar potential for this file card archive. The file card records had been collected in 1974–1975 by Owen Hughes (GSC) as a means of supporting stereo aerial photograph-based surficial geology mapping along the proposed Mackenzie Valley gas pipeline corridor. No publication of results or accompanying metadata was found to be

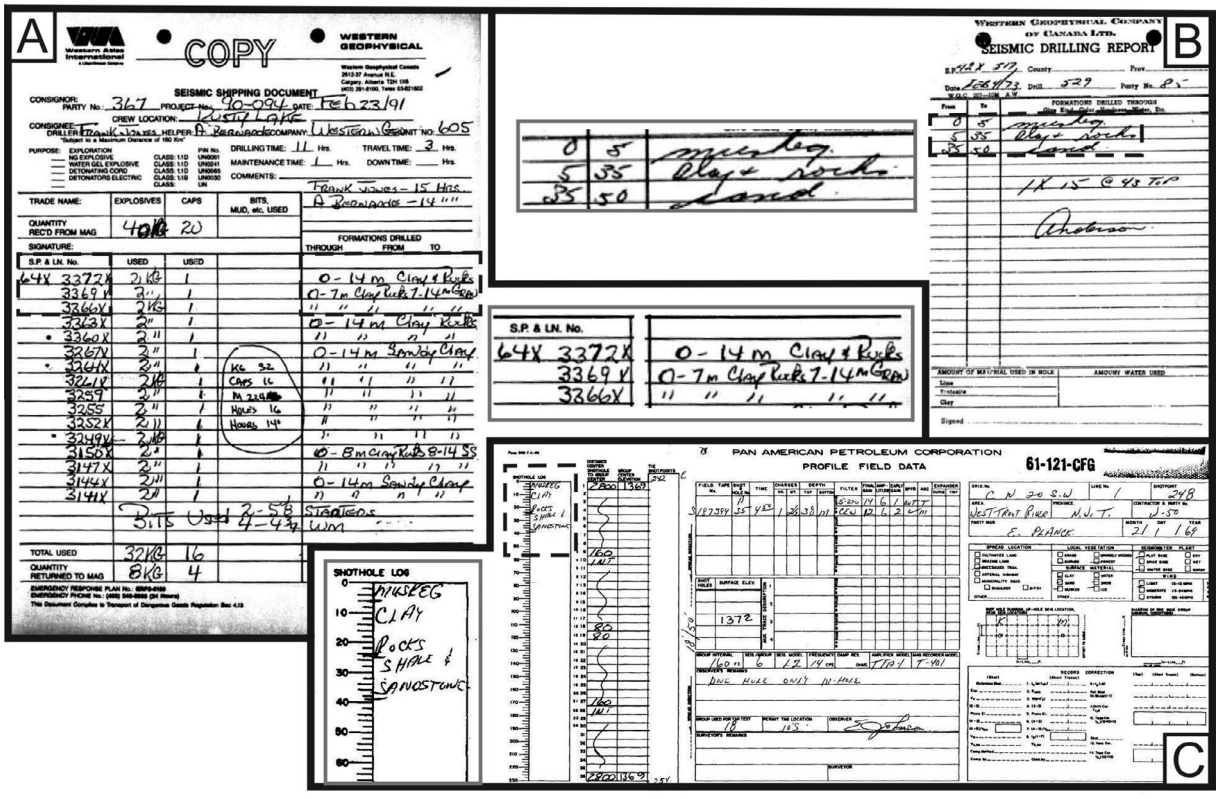

Fig. 1. Examples of 3 different Basic File records with drillers' log data; details of select lithologs have been enlarged for clarity. (A) Master Drill Sheet, seismic line 64X, shotpoints 3372X (0–14 m clay, rocks), 3369X and 3366X (0–7 m clay, rocks; 7–14 m gravel); (B) Field Drillers' Log Card, seismic line 42X, shotpoint 517 (0–5 ft muskeg; 5–35 ft clay, rocks; 35–50 sand); (C) Field Data Report, seismic line 1, shotpoint 248 (0–6 ft muskeg; 6–24 ft clay, rocks; 24–40 ft shale, sandstone; note, tick marks on scale bar indicate depths).