Poster presentations of Quaternary studies in northeastern British Columbia and northwestern Alberta; Mineral Exploration Roundup 2005

A.S. Hickin and R.C. Paulen (compilers)



BC Ministry of Energy & Mines
Resource Development & Geoscience Branch
Petroleum Geology Open File 2005-1

Alberta Energy & Utilities Board
Alberta Geological Survey
Information Series 131

Geological Survey of Canada,
Open File 4943

This publication contains the presentations by Northern Resource Development Project 4450 participants (Geological Survey of Canada, Alberta Geological Survey and British Columbia Resource Development and Geoscience Branch) on various Quaternary geology topics currently being undertaken in northeastern British Columbia and northwestern Alberta given at the Mineral Exploration Roundup 2005, “Discovering Our Future”, January 24-27, 2005.

Recommended Reference Format
When using information from this publication in other publications or presentations, the following reference format is recommended:

Plouffe, A., GSC, AGS, BCMEM, 2005: Shallow gas and diamond opportunities in northern Alberta and British Columbia: highlights and progress; *In* A.S. Hickin and R.C. Paulen, (compilers) 2005: Poster presentations of Quaternary studies in northeastern British Columbia and northwestern Alberta; Mineral Exploration Roundup 2005; British Columbia Ministry of Energy and Mines, Petroleum Geology Open-File 2005-1; Alberta Energy and Utilities Board, Alberta Geological Survey Information Series 131; Geological Survey of Canada, Open File 4943; CD-ROM.

ISBN # 0-7785-3832-X

Library and Archives Canada Cataloguing in Publication Data
Main entry under title:
Poster presentations of quaternary studies in northeastern British Columbia and northwestern Alberta : Cordilleran Roundup, 2005

(Petroleum geology open file ; 2005:1)
(Information series / Alberta Geological Survey ; 131)
(Open file / Geological Survey of Canada)

"Shallow gas & diamond opportunities in northern Alberta and British Columbia, 2003-2007."
"This publication contains the presentations by NRD Project 4450 participants ... given at the Cordilleran Mineral Exploration Roundup 2005, "Discovering our Future", January 24-27, 2005."--P.
Co-published by Alberta Energy & Utilities Board, Alberta Geological Survey and Geological Survey of Canada.
Includes bibliographical references: p.
ISBN 0-7785-3832-X

1. Geology, Economic - British Columbia, Northern - Congresses. 2. Geology, Economic - Alberta, Northern - Congresses. 3. Geology - British Columbia, Northern - Congresses. 4. Geology - Alberta, Northern - Congresses. 5. Geology, Stratigraphic - Quaternary - Congresses.
I. Hickin, A. S. II. Paulen, R. C. III. British Columbia. Resource Development and Geoscience Branch. IV. Alberta Energy and Utilities Board. V. Alberta Geological Survey. VI. Geological Survey of Canada. VII. Cordilleran Mineral Exploration Roundup (2005 : Vancouver, B.C.). VIII. Title. IX. Series. X. Series: Open file (Geological Survey of Canada). XI. Series: Information series (Alberta Geological Survey) ; 131.

TN799.7.C3P67 2005 553'.09711'87 C2005-960067-5

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INTRODUCTION

Starting in the spring of 2003, a four year collaborative project was undertaken by the Geological Survey of Canada (Natural Resources Canada), the Alberta Geological Survey (Alberta Energy and Utilities Board) and the British Columbia Resource Development and Geoscience Branch (British Columbia Ministry of Energy and Mines) in northwest Alberta and northeast British Columbia (Fig. 1).

The main objectives of this project are: 1) to find new sand and gravel (granular aggregate) deposits for road construction and energy infrastructure maintenance and development; 2) to evaluate the potential of the region to host kimberlite; 3) to better understand the shallow geological environment which can be used to identify areas of groundwater aquifers and shallow gas reserves; and 4) to assess the extent of permafrost and its potential impact on existing and future infrastructures. These objectives will be achieved by: 1) systematically conducting field studies of the unconsolidated sediments and natural landforms present at surface within this vast territory; 2) using this data to produce surficial geology maps which will be of considerable benefit to future land-use planning activities; 3) sampling and analyzing surface sediments; 4) conducting geophysical surveys to better define Quaternary-hosted shallow gas deposits; and 5) analyzing well data and constructing maps that show the topography of the buried bedrock surface and the thickness of unconsolidated sediments that overlie it. This four-year collaborative, multi-disciplinary project falls under the Geological Survey of Canada's Northern Resource Development Program (NRD Project 4450) and has additional support through the Federal-Provincial Targeted Geoscience Initiative (TGI-2).

This report contains the presentations by NRD Project 4450 participants on various Quaternary geology topics currently being undertaken in northeastern British Columbia and northwestern Alberta given at the Mineral Exploration Roundup 2005, "Discovering Our Future", January 24-27, 2005.

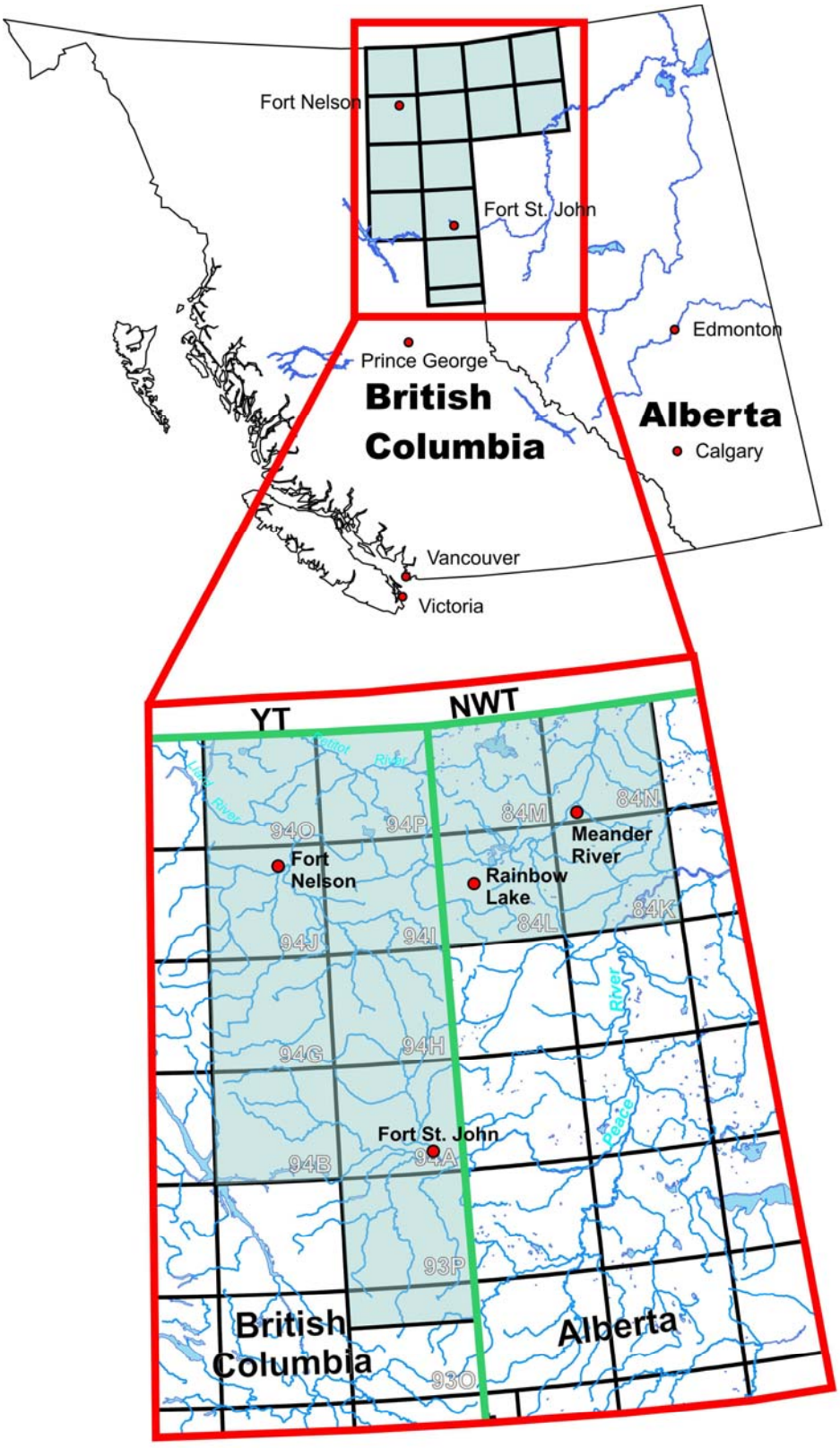

Figure 1: Project study area in northeastern British Columbia and northwestern Alberta.

Title:
Shallow gas and diamond opportunities in northern Alberta and British Columbia: highlights and progress

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Reference:
Plouffe, A., GSC, AGS, BCMEM, 2005: Shallow gas and diamond opportunities in northern Alberta and British Columbia: highlights and progress; *In* Hickin, A.S. and Paulen, R.C. (compilers) 2005: Poster presentations of Quaternary studies in northeastern British Columbia and northwestern Alberta; Mineral Exploration Roundup 2005; British Columbia Ministry of Energy and Mines, Petroleum Geology Open-File 2005-1; Alberta Energy and Utilities Board, Alberta Geological Survey Information Series 131; Geological Survey of Canada, Open File 4943; CD-ROM.

Abstract

Some of the progress and success of the second year of a four-year collaborative project between the Geological Survey of Canada, the Alberta Geological Survey and the British Columbia Ministry of Energy and Mines are highlighted on this poster. The project is partly financed by the Targeted Geoscience Initiative - 2 (TGI-2) and is producing geoscience information in support of exploration for aggregate resources, diamonds, and shallow gas reservoirs in Quaternary/Tertiary sediments in NW Alberta and NE British Columbia. Progress has been made on all components of the project including:

1. surficial geology mapping in NW Alberta and NE British Columbia including four recently published open file maps;
2. on-going progress in the production of bedrock topography and drift thickness maps in NW Alberta along with a seismic survey completed in collaboration with the University of Alberta;
3. discovery of granular resources in NE British Columbia;
4. stream sediment and water surveys in the Buffalo Head Hills region in support of diamond exploration;
5. bedrock stratigraphic drilling and geophysical logging of the boreholes in the Buffalo Head Hills region to better define the stratigraphic setting of known kimberlites;
6. preliminary glacial dispersal studies down-ice from known kimberlites of the Buffalo Head Hills region; and,
7. outreach activities with the Fort Vermillion School District and the local communities including the Dene Tha' First Nation.

Title:
Effective methods for mapping surficial geology and aggregate potential in areas of low relief, interior plains northeastern British Columbia

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Reference:
Ferbey, F., Church, A., Bednarski, J., Hickin, A.S., Demchuk, T.E., Kerr, B., Levson, V.M., Smith, I.R., Trommelen, M., and Peters, C., 2005: Effective methods for mapping surficial geology and aggregate potential in areas of low relief, interior plains northeastern British Columbia; *In* Hickin, A.S. and Paulen, R.C. (compilers) 2005: Poster presentations of Quaternary studies in northeastern British Columbia and northwestern Alberta; Mineral Exploration Roundup 2005; British Columbia Ministry of Energy and Mines, Petroleum Geology Open-File 2005-1; Alberta Energy and Utilities Board, Alberta Geological Survey Information Series 131; Geological Survey of Canada, Open File 4943; CD-ROM.

Abstract

This presentation summarizes methods that have been employed by the British Columbia Ministry of Energy and Mines (Aggregate Program) and the Geological Survey of Canada to map surficial geology in the Interior Plains of northeast British Columbia. As there is a chronic shortage of aggregate material in the region, discoveries of new deposits provide a much-needed local supply of sand and gravel, reducing construction and maintenance costs of petroleum development roads. Assessing aggregate potential in the region is challenging due to limited topographic relief, masking of landforms by vegetation, thick cover of silt and clay-rich morainal and glaciolacustrine deposits, and a general lack of glaciofluvial landforms outside of major river valleys and meltwater channel systems. As a result, new and innovative surficial mapping and aggregate exploration methods have been developed. This poster outlines the methods including use of seismic shot hole and other subsurface data sets, high resolution airborne electromagnetics (EM survey), LiDAR imagery (in partnership with EnCana Corporation), remote sensing, and more traditional methods such as aerial photograph interpretation, drilling and test pitting (excavations). The program has been very successful with several new aggregate prospects being discovered in the region since the inception of the program in 2003. At least three new producing aggregate pits have been developed from these discoveries.

Title:
Northeast British Columbia surficial geology and aggregate mapping program; implementing geomatics technology for aggregate exploration

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Reference:
Kerr, B., Ferbey, T., Levson, V.M., 2005: Northeast British Columbia surficial geology and aggregate mapping program; Implementing geomatics technology for aggregate exploration; *In* Hickin, A.S. and Paulen, R.C. (compilers) 2005: Poster presentations of Quaternary studies in northeastern British Columbia and northwestern Alberta; Mineral Exploration Roundup 2005; British Columbia Ministry of Energy and Mines, Petroleum Geology Open-File 2005-1; Alberta Energy and Utilities Board, Alberta Geological Survey Information Series 131; Geological Survey of Canada, Open File 4943; CD-ROM.

Abstract

The Aggregate Program at the Ministry of Energy and Mines was established in response to an increased demand for gravel in northeast British Columbia, an area with a chronic shortage of supply. From the outset this group has researched and implemented new technologies and used innovative datasets to assist in office and field based data collection, analysis, visualization and presentation to support aggregate exploration. Traditional methods (e.g. aerial photography interpretation and landform mapping) can be ineffective as large fluvial and glaciofluvial systems capable of transporting and depositing sand and gravel appropriate for construction aggregate are geographically limited. These challenges are compounded by subdued topography and the masking effect of vegetation. Field geologists have been equipped with GPS units, digital cameras and handheld computers which record locations, field data, geological interpretations and photographs in a relational database. Laptop computers connected to GPS units provide real-time tracking capabilities in a GIS environment while travelling in the field (e.g. truck, helicopter, ATV). Sites of interest can be navigated to quickly and easily through the incorporation of high resolution digital orthophotography and LiDAR data providing birds eye view of the immediate vicinity. The laptop based tracking system can be transferred to backpacks for traverses and used to confirm position while travelling by all-terrain vehicle or foot through complex networks of seismic lines. The use of high-resolution data and powerful, portable technology has realized several benefits, improving operational efficiencies and in discovering resources which may not have been found using traditional methods.

Title:
Quaternary geology and stratigraphy in the vicinity of Zama City, Bistcho Lake map sheets, northern Alberta (84M/2)

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Reference:
Kowalchuk, C., Ward, B.C., Plouffe, A., Paulen, R.C., and Smith, I.R., 2005: Quaternary geology and stratigraphy in the vicinity of Zama City, Bistcho Lake map sheets, northern Alberta (84M/2); *In* Hickin, A.S. and Paulen, R.C. (compilers) 2005: Poster presentations of Quaternary studies in northeastern British Columbia and northwestern Alberta; Mineral Exploration Roundup 2005; British Columbia Ministry of Energy and Mines, Petroleum Geology Open-File 2005-1; Alberta Energy and Utilities Board, Alberta Geological Survey Information Series 131; Geological Survey of Canada, Open File 4943; CD-ROM.

Abstract

This study is part of an ongoing surficial mapping project in the Bistcho Lake map sheet (82/M) by the Federal and Alberta geological surveys, and involves a detailed investigation of the distribution and stratigraphy of glacial sediments in the vicinity of Zama City, northwestern Alberta. Sediments are generally clay-rich as a result of the weak Cretaceous shale bedrock that underlies the region. Till drapes the uplands and glaciolacustrine sediments fill the lowlands. Sub-till glaciolacustrine sediments provide evidence for proglacial lakes in front of the advancing Laurentide Ice Sheet. Glacial lakes were also present during deglaciation, denoted by glaciolacustrine sediments overlying the regional till sheet. Stratigraphic evidence for a possible readvance of Laurentide ice during deglaciation is observed in several pits where deformed, crudely stratified diamicton overlies proximal glaciolacustrine sediments.

Title:
Surficial mapping in northwest Alberta

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Reference:
Paulen, R.C., Plouffe, A., Smith, I.R., Kowalchuk, C., 2005: Surficial mapping in northwest Alberta; *In* Hickin, A.S. and Paulen, R.C. (compilers) 2005: Poster presentations of Quaternary studies in northeastern British Columbia and northwestern Alberta; Mineral Exploration Roundup 2005; British Columbia Ministry of Energy and Mines, Petroleum Geology Open-File 2005-1; Alberta Energy and Utilities Board, Alberta Geological Survey Information Series 131; Geological Survey of Canada, Open File 4943; CD-ROM.

Abstract

During the summers of 2003 and 2004, geologists from the Alberta Geological Survey (AGS) and the Geological Survey of Canada (GSC) completed the surficial mapping of the Zama Lake (NTS 84L) and Bistcho Lake (NTS 84M) regions as part of a four-year collaborative, multi-disciplinary project under the GSC's Northern Resource Development Program (NRD Project 4450). This research will provide crucial information on the Quaternary stratigraphy, sediment characteristics and glacial history that will have direct implications for infrastructure development and Quaternary-hosted shallow gas, aggregate and diamond exploration in northwestern Alberta. Our presentation will focus on the nature and distribution of surficial sediments and locations of previously undocumented bedrock exposures of the Zama Lake and Bistcho Lake regions. Complex ice flow reconstruction and deglacial history of the region will also be presented, which has implications for aggregate exploration and provides information for drift prospecting. Other environmental features, such as climatically sensitive fluctuating lake levels of Hay and Zama lakes and the distribution and sensitivity of permafrost will be presented.

Title:
Heavy mineral survey and its significance for diamond exploration, Fort Nelson area, British Columbia, Canada

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Reference:
Simandl, G.J., Ferbey, T., Levson, V.M., Demchuck, T.E., Hewett, T., Smith, I.R., and Kjarsgaard, I., 2005: Heavy mineral survey and its significance for diamond exploration, Fort Nelson area, British Columbia, Canada; *In* Hickin, A.S. and Paulen, R.C. (compilers) 2005: Poster presentations of Quaternary studies in northeastern British Columbia and northwestern Alberta; Mineral Exploration Roundup 2005; British Columbia Ministry of Energy and Mines, Petroleum Geology Open-File 2005-1; Alberta Energy and Utilities Board, Alberta Geological Survey Information Series 131; Geological Survey of Canada, Open File 4943; CD-ROM.

This poster presentation is also published as:

Simandl, G.J., Ferbey, T., Levson, V.M., Demchuck, T.E., Hewett, T., Smith, I.R., and Kjarsgaard, I., 2005: Heavy mineral survey and its significance for diamond exploration, Fort Nelson area, British Columbia, Canada. British Columbia Ministry of Energy and Mines, GeoFile 2005-13.

Abstract
Parts of northeast British Columbia are underlain by Precambrian basement that belongs to the North American craton. These areas have a moderate exploration potential for diamonds in terms of the traditional "diamondiferous mantle root model" (Simandl, 2004). The potential of any area to host kimberlite or lamproite-hosted diamond deposits may be assessed based on the thickness and age of basement rocks, geophysical anomalies, and other data sets including presence of kimberlite indicator minerals (KIMs) in Quaternary sediment. This study concentrates mainly on KIMs present in Late Pleistocence glaciofluvial sands and gravels. Of 22 samples collected and processed, 14 contain KIMs such as purple pyrope, yellowish eclogitic garnet, Cr-diopside, olivine, ilmenite, or spinel. It is possible that these minerals are derived from primary, secondary or tertiary sources within the Fort Nelson area. It is also possible, however, that they were brought into the region from the Northwest Territories and Alberta by Late Pleistocene glacial and glaciofluvial systems. Corundum and diaspore were also recovered from collected samples. At this stage, semiquantitative data does not allow for a definitive interpretation as to whether this corundum is kimberlite-related.

Title:
Quaternary geology studies in northeastern British Columbia

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Reference:
Smith, I.R., Trommelen, M., and Ferbey, T., 2005: Quaternary geology studies in northeastern British Columbia; *In* Hickin, A.S. and Paulen, R.C. (compilers) 2005: Poster presentations of Quaternary studies in northeastern British Columbia and northwestern Alberta; Mineral Exploration Roundup 2005; British Columbia Ministry of Energy and Mines, Petroleum Geology Open-File 2005-1; Alberta Energy and Utilities Board, Alberta Geological Survey Information Series 131; Geological Survey of Canada, Open File 4943; CD-ROM.

Abstract

This poster highlights activities undertaken in northeastern British Columbia as part of a multi-year, collaborative project between the British Columbia Ministry of Energy and Mines and the Geological Survey of Canada. Ongoing fieldwork, initiated in 2003, has focussed on producing 1:100 000 scale surficial geology maps and in the identification of potential granular aggregate deposits. Expanding the aggregate inventory is seen as key to supporting natural gas infrastructure development. This poster focuses on studies being conducted in NTS map sheets 94I (Fontas River) and 94J (Fort Nelson). The study area principally lies within the Fort Nelson Lowlands physiographic region, but also includes a section of the Alberta Plateau (in 94J). Overall the region is characterized by subdued topography and extensive bog and fen deposits. A thick blanket of clay-rich till, deposited by the Laurentide Ice Sheet, covers much of the region. Lowlying areas along Hay River and southeast of Fontas River are covered by glaciolacustrine sediment that was deposited in lakes impounded by retreating ice margins. Following drainage of these glacial lakes, deflation of sand-rich sediment led to the development of an extensive aeolian veneer and larger dune ridges in the southeast quadrant of 94I. Outside of bog and fen deposits, vegetation in the study area is characterized as Boreal Forest, comprised of Aspen, White and Black Spruce and minor Lodgepole Pine. Shale bedrock of the Upper to Lower Cretaceous Fort St. John Group is exposed in highlands in the north part of 94I, along stream cuts in the eastern part of 94I, and along reaches of the deeply incised Fontas, Fort Nelson, and Prophet rivers. Upper Cretaceous Dunvegan Formation channel deposits have also been observed on the uplands of 94J. Several new granular aggregate targets have been identified, including an intraglacial ice marginal (?subglacial) channel system, large kame deposits, eskers, and an extensive (>160 km2) glaciolacustrine delta (>35 m thick). The deeply-incised Fontas-Nelson river system, which extends across the two map areas, likely formed as both a subglacial tunnel valley and an outlet for glacial Lake Hay, and contains potential gravel resources in a large glaciofluvial terrace. Dunvegan Formation chert pebble conglomerates also represent a potential aggregate source.

FURTHER INFORMATION AND CONTACTS

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Northern Resources Development Program

La mise en valeur des ressources du Nord



Shallow gas and diamond opportunities in northern Alberta and British Columbia: highlights and progress

Geological Survey of Canada, Alberta Geological Survey, British Columbia Ministry of Energy and Mines

Shallow Gas & Diamond Opportunities in Northern Alberta and British Columbia 2003 - 2007

http://nrd.nrcan.gc.ca

http://nrd.nrcan.gc.ca

ABSTRACT

Some of the progress and success of the second year of a four-year collaborative project between the Geological Survey of Canada, the Alberta Geological Survey and the British Columbia Ministry of Energy and Mines are highlighted on this poster. The project is partly financed by the Targeted Geoscience Initiative - 2 (TGI-2) and is producing geoscience information in support of expoloration for aggregate ressources, diamonds, and shallow gas reservoirs in Quaternary/Tertiary sediments in NW Alberta and NE British Columbia. Progress have been made on all components of the project including:

1) surficial geology mapping in NW Alberta and NE British Columbia including four recently published open file maps;
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6) preliminary glacial dispersal studies down-ice from known kimberlites of the Buffalo Head Hills region; and,
7) outreach activities with the Fort Vermillion School District and the local communities including the Dene Tha' First Nation (R. Smith, R. Olson, G. Nowlan).

GSC Project Leader: A. Plouffe

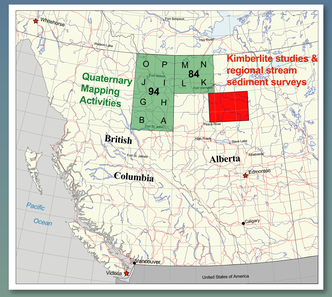
Quaternary geological mapping in northwest Alberta and northeast B.C. : A. Plouffe, R. Smith, J. Bednarski, R. Paulen, M. Fenton, J. Pawlowicz, V. Levson, A. Hickin, T. Ferbey, C. Kowalchuk, M. Tronnelen, B. Ward

Shallow gas: J. Pawlowicz, T. Nicoll, A. Plouffe, D. Schmitt, J. Ammad, D. Rokosh

Stream sediment surveys for kimberlite indicator minerals and stream water surveys in the Buffalo Head Hills: M. McCurdy, P. Friske, G. Prior, S. Day

Kimberlite volcanology-sedimentology-stratigraphy and host Cretaceous sediments in Buffalo Head Hills and Birch Mountains: R. Eccles, A. Sweet, J. Mwenifumbo

Community outreach: R. Smith, R. Olson



GEOSCIENCE OUTREACH

Outreach comprises an important component of this project, and includes activities that effectively communicate objectives and results to the public at large, that bolster and enhance geoscience-related school curriculum, and provide opportunities for establishing meaningful and cooperative interactions with local aboriginal communities. Examples of these activities, conducted as part of this project during the past year, are highlighted below.

The Spirit of the North Convention, held each September in High Level, Alberta is a trade fair and community celebration attended by companies and individuals throughout northwestern Alberta, northeastern British Columbia, and southern Northwest Territories. For the second year in a row, representatives of the Alberta Geological Survey staffed a booth at the Convention, and in addition to providing access to EUB geoscience reports and maps pertinent to the area, they created a composite satellite image of the High Level-Ft. Vermilion area. This kind of informal publication has great public appeal, as it provides a community perspective most would never have seen, and allows us to engage the public in discussions about the work we are conducting. Mark Fenton (AGS) has taken the lead to tailor this image to a format that will be incorporated into Communities-related curricula by the Ft. Vermilion School Division.

All schools in the Ft. Vermilion School Division, and another administered by the Dene Tha' band, were visited this past spring and were provided with a range of geoscience-related educational materials including: maps, posters (Geoscape and Climate Change series), pamphlets, rock, mineral and fossil kits. Each of these items is directed towards specific elements of the existing curricula (e.g., grade 3 - Rocks and Minerals, grade 5 - resources of Alberta, grade 7 - Planet Earth), and efforts have been made to follow up with subsequent visits to provide additional expertise and resources to local teachers. An example of this was the grade 7 Planet Earth teacher workshop that Godfrey Nowlan (GSC - Geoscience Education for Northern Communities Project) and Rod Smith (GSC) held in High Level this past September (see photo). This workshop was received with high praise by teachers that attended, and provided us with a number of additional geoscience education-related suggestions that we are currently following up on, including holding a grade 3 Rocks and Minerals workshop this coming September.

For the second year in a row, the GSC hired aboriginal field assistants. These individuals provide us with a tremendously positive and meaningful contact with the local Dene Tha' band. They also greatly facilitated the participation and interaction with these elders who accompanied us on a visit to the "Hot Pot," a continuously burning natural gas seep in the area. This was a unique experience for all of us, allowing us to develop an appreciation for cultural interpretations of what we otherwise see in a scientific viewpoint as a Quaternary-bounded shallow gas deposit. Continuing outreach efforts with the Dene Tha' band has included nominating the community of Chateh to be included in the Sustainable Communities Initiative (SCI; www.sci.gc.ca). This program seeks to build GIS capacity in remote communities that assists local decision making about economic, environmental and social development matters. We will work with the SCI group to develop the Dene Tha's capacity to integrate our surficial geology maps into their digital database, and demonstrate their usefulness in traditional landuse mapping, and assessment of future natural resource development (oil, gas, forestry and aggregate).











SURFICIAL GEOLOGY

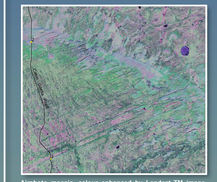
Introduction

During the 2004 field season, the Bistcho Lake (NTS 84M) sheet of Alberta and parts of the Fontas River (NTS 94 I) and Petitot River (NTS 94P) sheets were mapped in British Columbia. Aggregate potential mapping is also being conducted in British Columbia on NTS map sheets 94H and on the east half of 94G. The Zama Lake (NTS 84L) sheet was mapped in 2003 and the project objectives are to complete the surficial geology mapping of Steen River (NTS 84 N) in 2005 in Alberta. Petitot River (NTS 94 P) and parts of Fontas River sheets in British Columbia are to be completed by 2006.

Several theses related to this project are currently underway:

1) C. Kowalchuk, M.Sc. thesis, Simon Fraser University, Department of Earth Sciences, supervisor B.Ward, topic: surficial geology and glacial history of the Zama City map area (84M/02)
2) J. Ahmad, M.Sc. thesis, University of Alberta, Physics Department, supervison D. Schmitt, topic: seismic profile interpretation from the Rainbow Lake region
3) M. Trommelen, M.Sc. thesis, University of Victoria, School of Earth and Ocean Science, supervisor: Vic Levson, topic: Surficial geology mapping and Quaternary stratigraphy of the Fort Nelson Lowlands of northeast British Columbia

Activities in British Columbia: surficial geology mapping in 94P



Airphoto mosaic, colour enhanced by Landsat TM image, showing extensively fluted Etsho Plateau. Most of the flutings begin at the northeast edge of the plateau and extend along the ice flow direction; to the west-southwest for over 15 km.

For the 2004 field season, field work took place in September with members of the B.C. Ministry of Energy and Mines, and was concentrated primarily where the most recent road extensions are being built: the Cabin Geetla Road (94P/13), extension of the Kimea Road across the Petitot River (94P/12), and the Spruce - Walrus Roads (94P/1). Recent road construction provided numerous borrow pits to be examined. Of particular interest were pits through fluted terrain on the fluted Etsho Plateau, were sequences of tills, gravels and eroded rafts of local bedrock were evident.

The priority for the Geological Survey of Canada in this area of intense activity will be to produce large scale, 1:50 000, Open File surficial geology maps. Currently maps 94P/11, 94P/12, and 94P/13 are in production and will be released shortly.

Micromorphological analyses

Mark Tarplee (Ph.D. candidate at Queen Mary University of London under J.J.M. van der Meer) collected 31 samples for micromorphological analyses of the glacial sediments during the 2004 field season in northwest Alberta. The micromorphological analysis of the glacial sediments in this section will reveal their detailed sedimentological properties. Samples were collected in various sediment types including bedrock immediately below till, contacts between glacial lake sediments and till, and till near boulder pavements. In addition to provide information on sediment character, stereological analyses using mutually orthogonal thin sections and 3D X-ray microtomography should allow the microfabric(s) properties to be evaluated. The samples are currently being resin impregnated ready for thin sectioning.



Kubiena tin cut into a section to obtain an undisturbed sediment sample of the contact (sharp, subhorizontal) zone between two diamicts.

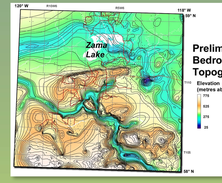
Shallow gas

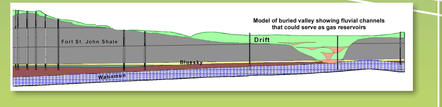
References:

Pawlowicz, J. G., Hickin, A. S., Nicol, T. J., Fenton, M. M., Paulen, R. C., Plouffe, A. and Smith, I. R. 2004: Shallow gas in drift: northwestern Alberta; Alberta Energy and Utilities Board, Edmonton, EUB/AGS Information Series 130, 1 sheet p.

Pawlowicz, J. G., Hickin, A. S., Nicol, T. J., Fenton, M. M., Paulen, R. C., Plouffe, A. and Smith, I. R. in press: Bedrock topography of Zama Lake area (NTS 84L), Alberta; Alberta Energy and Utilities Board, EUB/AGS Map 328, map scale 1:250 000.

Pawlowicz, J. G., Hickin, A. S., Nicol, T. J., Fenton, M. M., Paulen, R. C., Plouffe, A. and Smith, I. R. in press: Drift thickness of Zama Lake area (NTS 84L), Alberta; Alberta Energy and Utilities Board, EUB/AGS Map 329, map scale 1:250 000.





STREAM SEDIMENT AND WATER SURVEY IN THE BUFFALO HEAD HILLS, NORTHERN ALBERTA

McCurdy, M.W., Prior, G.J., Friske, P.W.B., Day, S.J.A., McNeil, R.J., Nicoll, T.J.,

Under a co-ordinated program by the Energy and Utility Board/Alberta Geological Survey (EUB/AGS) and the Geological Survey of Canada (GSC), a regional-scale geochemical survey of stream sediments and waters was carried out in the Buffalo Head Hills, northern Alberta, in September 2004. This survey, which completes coverage of the Buffalo Head Hills, was funded by the Alberta Government and, under the following programs, the Geological Survey of Canada:

· Targeted Geoscience Initiative 2 (2003-2005)

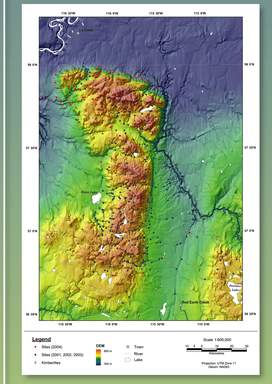
· Northern Resources Development Program, 'Shallow Gas and Diamond Opportunities in Northern Alberta and British Columbia (2003-2007).'

The sampling crew consisted of Glen Prior and Tami Nicoll (AGS) and Steve Day and Martin McCurdy (GSC). The crew was based in La Crete (14 days) and Red Earth Creek (3 days), northern Alberta between 15 September and 1 October. Bell 206B III helicopters were chartered from Highland Helicopters in High Level (Howard Vigneault) and Red Earth Creek (Steve Wotton).

Primary streams were the main targets for silts. Bulk sediment samples (10-15 kg) were collected from larger secondary streams, although silts and two water samples are collected at every site. One set of water samples was filtered and acidified to keep anions in solution for later analysis. Conductivity and pH of waters collected each day were measured each evening. Field observations recorded on site were entered into an MS Excel spreadsheet and sample locations from GPS units were downloaded and checked against locations recorded on maps. Approximately 120 sites were visited during 13 flying days, from which 65 bulk sediment samples were collected in addition to silts and waters.

From Red Earth Creek two helicopters were used to sample an area west of the Buffalo Head Hills, in an area generally considered too flat for stream surveys. Potential sites were pre-selected with the help of digital elevation maps (DEMs) generated at the Alberta Geological Survey. An additional 25 sites were identified and sampled in this manner.

Silt samples were forwarded to Acme Analytical Laboratories in Vancouver for preparation (drying and sieving) and are awaiting analysis by ICP-MS and INAA. Overburden Drilling Management in Ottawa are processing bulk sediment samples, separating the heavy mineral fraction and identifying heavy minerals, including kimberlite indicator minerals. Waters will be analysed by ICP-MS, ICP-ES and ion chromatography methods in Ottawa. Results will be released in 2005 in a combined Alberta Geological Survey/Geological Survey of Canada report.











KIMBERLITE

Northern Alberta Kimberlite - host rock studies

Art Sweet, Jonathan Mwenifumbo and Bill Hyatt (Geological Survey of Canada) ; Roy Eccles, Dong Chen and Glen Prior (Alberta Geological Survey)

Stefanie Schmidberger, Larry Heaman and Vadim Kravchinsky (University of Alberta) ; Tom McCandless and Jeff Ward (Ashton Mining of Canada Inc.)

GEOCHRONOLOGIC AND STRATIGRAPHIC STUDY OF EXISTING SAMPLES



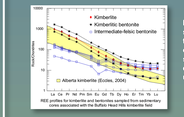
Core orientation for paleomagnetic study



During the 2004 summer, the project initiated logging and sampling of kimberlite and Late Cretaceous sedimentary host strata for geochronologic and stratigraphic relationships. A July field trip sampled open trenches at the Mountain Lake ultrabasic cluster, and the K5 and K6 kimberlite pipes in the Buffalo Head Hills kimberlite field for palynology, micropaleontology and paleomagnetics. The paleomagnetic study will be completed as a 4th year thesis to determine magnetic susceptibility, and the primary and different age components of the natural remnant magnetization.

Bedrock sampling continued during August at the Mineral Core Research Facility (MCRF) in Edmonton, where approximately 500 m of sedimentary rock core, made available by Ashton Mining of Canada Inc., were logged and sampled for geochemistry (major and trace elements, and possible extraction of zircon from bentonite for U-Pb isotope analysis), and palynology and micropaleontology. Physical examination of this core indicates that both fully marine and continental paleoenvironments were present close to the timing of kimberlite emplacement. Working out a more precise association between paleo-environmental conditions and kimberlite emplacement is one of the objectives of the biostratigraphic component of the study.





Initial interpretation of the whole rock geochemistry indicates interesting results. For example, one kimberlite and seven separate bentonite layers were sampled from the dominantly sedimentary core. The figure to the left shows that the rare earth patterns (REE) for two of the seven bentonites are similar to the kimberlite fragment and the field of REE for kimberlites from the northern Alberta kimberlite province. This suggests that sampling bedrock material, such as bentonite, in other parts of Alberta can be used as a tool to locate new discoveries of potentially diamondiferous kimberlite. Tests are currently being conducted to determine whether other types of bedrock yield unique geochemical fingerprints in settings proximal and distal to occurrences of kimberlite.

COLLECTION OF NEW MATERIAL FOR FUTURE STUDY

During December 2004, two stratigraphic study holes were drilled in the vicinity of the Buffalo Head Hills kimberlite field, north - central Alberta to obtain core from Upper Cretaceous sedimentary rocks. These rocks were previously inaccessible for study because they are covered by surficial deposits of variable thickness, and oil and gas wells typically case (core not recovered) through the Cretaceous stratigraphy.

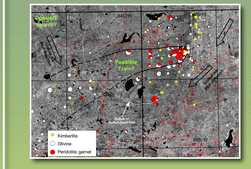
Drill hole BHH04-KHR -1 satisfied the sites objective to recover the uppermost Upper Cretaceous rocks in the area. Drill hole BHH04-KHR-2 intersected several zones of kimberlite and cored a major change in lithology from mudstone to organic-rich mudstone with intercalated bentonite to coarse-grained sandstone. Both drill holes intersected an inferred common marker horizon that will enable meaningful comparisons between sediments in proximal and distal kimberlite settings.

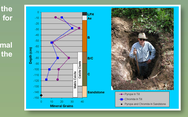


SURFICIAL KIMBERLITE - INDICATOR MINERAL (KIM) REGIONAL MAPPING STUDIES

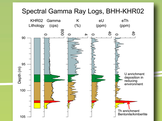
Glacial overburden is a recognized major impediment to exploration in northern Alberta. Knowledge of the regional distribution characteristics of kimberlite - indicator minerals (KIM) will provide important information for both continued kimberlite exploration and exploration for other mineral deposit types in northern Alberta.

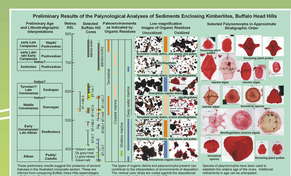
2004 fieldwork was limited to sequential till sampling to determine distribution of indicator-minerals and optimal depth for sampling in the Buffalo Head Hills area. While interpretations are still preliminary, the figure on the right shows that the B-horizon should not be ignored in reconnaissance KIM sampling.





In 2005, the project will focus on regional-scaled KIM distribution patterns in northern Alberta. In order to best plan a sample strategy, KIM 'picked-grain' and microprobe geochemical compilations from publicly available sources were compiled during June and added to the AGS KIM database. The figure on the left shows an olivine-rich cluster is present on the southwest flank of the Buffalo Head Hills. 2005 sampling may, for example, aid in the interpretation of whether the olivine cluster is related to previously discovered pipes (e.g., K4), or are related to areas with the potential for future discoveries (e.g., area west-northwest of the Buffalo Head Hills kimberlite field).





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http://www.nrd.nrcan.gc.ca

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Natural Resources Canada | Ressources naturelles Canada

Canada

Northern Resources Development Program
La mise en valeur des ressources du Nord
Northeast British Columbia Surficial Geology and Aggregate Mapping Program



Effective Methods for Mapping Surficial Geology and Aggregate Potential in Areas of Low Relief, Interior Plains, Northeast British Columbia

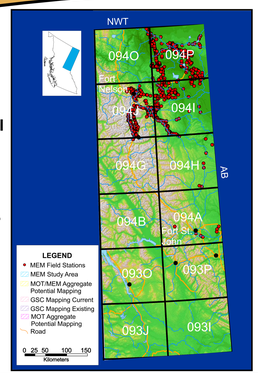
Shallow Gas & Diamond Opportunities in Northern Alberta and British Columbia 2003-2007

T. Ferbey[1], A. Church[1], J. Bednarski[2], A.S. Hickin[1], T.E. Demchuk[1], B. Kerr[1], V.M. Levson[1], I.R. Smith[3], M. Trommelen[1], C. Peters[1]

[1]British Columbia Ministry of Energy and Mines, Resource Development and Geoscience Branch, 6th floor - 1810 Blanshard Street, Victoria, BC, V8W 9N3
[2]Geological Survey of Canada, 9860 West Saanich Road, Sidney, BC, V8L 4B2
[3]Geological Survey of Canada, 3303-33rd Street NW, Calgary, AB, T2L 2A7

THE PROGRAM

- **Conduct regional and site specific geological inventories of aggregate resources in northeast British Columbia.**
- **Investigate the natural gas reservoir potential of Quaternary/Tertiary paleovalleys.**
- **Conduct reconnaissance-scale investigations of diamond potential in the region (see poster by Simandl *et al., Heavy Mineral Survey and its significance for Diamond Exploration, Fort Nelson Area, British Columbia, Canada).***



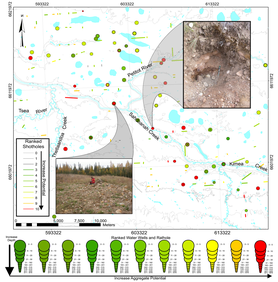
MAPPING CHALLENGES

- Assessing aggregate potential is challenging due to limited topographic relief, masking of landforms by vegetation, a thick cover of silt and clay-rich morainal and glaciolacustrine deposits, and a general lack of glaciofluvial landforms.
- Collaborative work between governments and industry allows for unique integration of datasets.

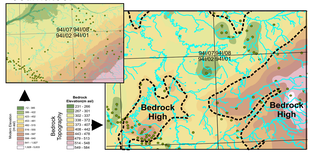


New and innovative surficial mapping and aggregate exploration methods have been developed.

SUBSURFACE



- Subsurface work has focused on identifying buried sand and gravel deposits through water wells, seismic shothole, and oil & gas rathole data.
- Bedrock topography and drift thickness maps provide a framework for shallow gas, assist seismic interpretation, and provides casing depth estimates.



DETAILED SITE INVESTIGATIONS



- Assess aggregate quality and estimate volumes of buried and surface sand and gravel showings.
- Hydraulic-powered, truck-mounted auger and tracked excavator are used to investigate to depths of >10 m.
- Cost effective and non-destructive ground-based EM and GPR surveys will be used to supplement sub-surface lithologic data.



HIGH RESOLUTION AIRBORNE ELECTROMAGNETICS (EM)

Fugro Airborne Surveys RESOLVE™

- Coplanar frequencies 400, 1500, 6400, 25 000 and 115 000 Hz, and total magnetic field are collected.
- Effective depth of exploration ~5 m (115 000 Hz) to ~100 m (400 Hz).
- Successfully confirmed known buried sand and gravel prospect (under ~2 m of till and glaciolacustrine sediments) and 2 other showings identified in shot hole data.
- ***Potentially expanded the known prospect by 100 000 m^3, or ~$2 000 000 of sand and gravel.***

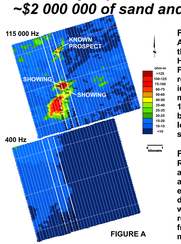


FIGURE A

FIGURE A
Apparent resistivity maps of the survey area for the 115 000 Hz and 400 Hz frequencies. Four areas with high resistivity zones were identified on the 115 000 Hz map. Flight lines 10110, 10130 and 10150 shown on both maps, correspond to the locations of resistivity cross-sections, shown in Figure B.

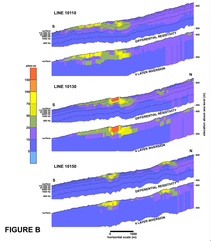
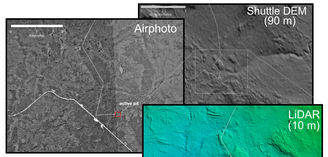


FIGURE B

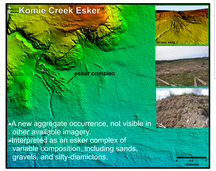
FIGURE B
Resistivity cross sections along flight lines 10110, 10130 and 10150. The upper plot for each flight line is of differential resistivity values while the lower plot is of resistivity values computed from the inversion of a 4 layer model.

LIDAR
(Light Detection and Ranging)

- An active airborne sensor that uses return times of a pulsed laser to determine surface elevation.
- High resolution models (up to 2 m) of earth's surface can be generated



- A comparison of three image types of different resolutions.
- Note location of active gravel pit in lobe of glaciofluvial delta.



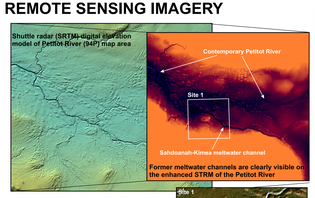
- Interpreted as an esker complex of variable composition, including sands, gravels, and silty-diamicton.



- Small features, <10 m across, <1 m high, are highly visible.
- The circled feature, interpreted as a kame ~4m high and 10m long, is a small sand and gravel occurrence.
- Features like this are common throughout the region, and may be prove to be potential sources for road maintenance aggregate.

- LiDAR is used to direct the aggregate program and resulted in the identification of new aggregate occurences.

REMOTE SENSING IMAGERY



Integration of shuttle RADAR (SRTM), LANDSAT 7TM and digital orthophotos to map surficial geology and aggregate potential at regional scales.



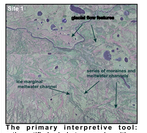
Enhanced STRM of the Pettitot River.



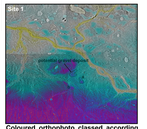
site a. Ice-contact glaciofluvial gravels forming a small hummocky upland (0.24 km²).



site b. A boulder-floored creek. The remnant of a former meltwater



The primary interpretive tool: orthorectified airphoto mosaic with a Landsat 7 TM overlay for colour.



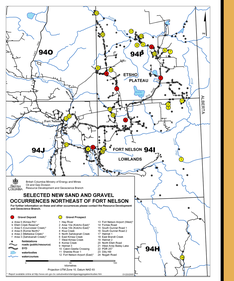
Coloured orthophoto classed according to elevation. Blue outliers of glaciofluvial gravels are evident within the green-coloured lowland.

EXPLORATION SUCCESSES

- **Regional-scale subsurface data sets have identified numerous buried sand and gravel showings.**
- **High resolution airborne EM surveys can be used to map sand and gravel prospects, particularly those buried.**
- **LiDAR is a useful tool for surficial mapping at various scales, particularly for detecting small, low relief glacial features.**

A number of new sand and gravel occurrences have been discovered from the use of there innovative methods.

- **Six new deposits identified proven resource of > 5 million m3.**
- **Aggregate costs for petroleum development roads reduced.**
  - ***e.g.* For SYD Road, $13 million direct savings to the Province**
- **24 new prospects identified that warrant follow-up investigations.**





Acknowledgements: LiDAR data are used here in partnership with EnCana Corporation. The cooperation and advice of Tyson Pylypiw and Doug Anderson (EnCana Corporation) are greatly appreciated.

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BRITISH COLUMBIA
MINISTRY OF ENERGY AND MINES
OIL AND GAS DIVISION

Northeast British Columbia Surficial Geology and Aggregate Mapping Program

Shallow Gas & Diamond Opportunities in Northern Alberta and British Columbia 2003-2007



Implementing Geomatics Technology for Aggregate Exploration

B. Kerr, T. Ferbey and V.M. Levson
Resource Development and Geoscience Branch
British Columbia Ministry of Energy and Mines
Victoria, BC

introduction

In response to an increase in demand for gravel and a chronic shortage of supply, a group was formed within the Ministry of Energy and Mines in June 2003 to explore for suitable construction aggregate deposits in northeast BC to support the upgrade and construction of oil and gas roads.

From the outset this group has researched and implemented new technologies and used innovative datasets to assist in office and field based data collection, analysis, visualization, and presentation. The implementation of geomatics technologies and high quality data has resulted in significant success both in improving operational efficiencies and in discovering resources which otherwise may not have been found.

Data Highlights

- Public and resource roads
- Digital orthophotography (Fig. 1)
- Landsat 7TM satellite imagery
- 1:20000 vegetation mapping

Data held by private companies was also compiled and included:

- 2m spacing, Light Detection and Ranging (LiDAR) elevation models (Fig 3, Fig 4)
- Petroleum industry seismic shothole drilling information



Fig.1 - 1m pixel digital orthophotography

data processing & analysis

Data are standardized and compiled into a comprehensive GIS database, used to identify potential aggregate targets prior to field investigations. This information is then transferred to the laptop computers to be taken to the field.

The same systems used in the office to generate potential aggregate targets are used in the field for ground-truthing. By far the two most beneficial data sets used thus far have been the digital orthophotography and LiDAR. The ability to have a birds eye view of a location while observing it from the ground has proven to be invaluable. The ability of the LiDAR to penetrate vegetative cover is also crucial in providing the ability to identify subtle features not always apparent using traditional photogrammetric methods. Using digital forest cover data, the relationship between forest stand attributes and surficial sediments continues to be investigated. Preliminary results suggest vegetation characteristics are influenced by localized differences in elevation and water table, and the colonizing ability of species after fire events.



Fig.2 - Real time navigation system. Current location shown by arrow.

Techniques used to identify potential aggregate deposits from the datasets compiled include:

- analysing the relationship between vegetation and ground conditions
- reprocessing elevation model data (LiDAR and traditional DEM) to automate delineation and classification of raised landforms
- classifying multiple, independent, subsurface data sets to identify areas where gravel was concurrently identified.



Fig.3 - 1m pixel full earth LiDAR

hardware & software

The backbone to the systems implemented is a Geographic Information System which allows for the combination and analysis of spatial data and geo-rectified imagery. Navigating in the plains region of northeast BC is challenging as the area is largely forested, has subdued topography and few natural landmarks suitable for establishing accurated locations. To overcome this difficulty, real-time tracking software on the laptop computers is used in combination with a GPS to provide consistent, accurate positional information (Fig 2). Real time tracking allows field crews to examine digital orthophotographs and other spatial data sets while making and recording observations from the ground. New roads can also be mapped and added to existing spatial datasets.

For field data collection, handheld personal digital assistant computers are used. A Palm OS based solution running Pendragon Forms data collection software was chosen. This allows for data to be downloaded into a MS Access database at field camps and distributed to all laptop computers frequently.

Hardware

- IBM ThinkPad laptops
- Palm V handhelds
- Nikon CoolPix 4500
- Garmin GPS 76

Software

- ESRI ArcGIS & ArcView
- DNR Garmin GPS
- Pendragon Forms 3
- Global Mapper

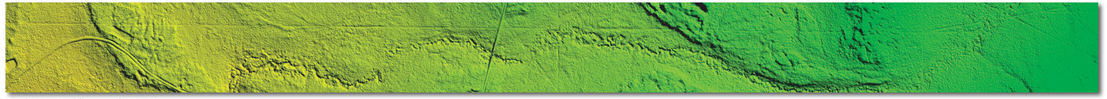

Fig.4 - 1m pixel bare earth LiDAR

summary

The technologies described have helped in the discovery of several proven sand and gravel deposits and many others with the potential to host significant amounts of sand and gravel, in a region where there was thought to be little or no remaining reserves. Real-time navigation has allowed for field geologists to gain a more thorough understanding of the characteristics of the region and the relationship between the appearance of features on aerial photographs and on the ground. We believe with the current trends in handheld computer and communications development geomatics technologies will continue to play an important role in fieldwork by improving operational efficiencies and contributing to project success.

acknowledgements

The authors would like to acknowledge the following organizations for their contributions: Alberta Geological Survey, for providing a template for the database developed for field data collection; Minnesota Department of Natural Resources, for the DNR Garmin ArcView GPS extension; Jan Bednarski, Rod Smith, Adrian Hickin, Tania Demchuk, Michelle Trommelen, Amber Church, Cheryl Peters, Tim Johnsen, Jacqueline Blackwell and Sheila Jonnes - geologists from the Geological Survey of Canada and the BC Ministry of Energy and Mines who accepted the intrusion of technology into their field seasons and provided valuable feedback. LiDAR data are used here in partnership with EnCana Corporation

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Quaternary geology and stratigraphy in the vicinity of Zama City, Bistcho Lake mapsheet, northern Alberta (84M/2)

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Northern Resources Development Program

La mise en valeur des ressources du Nord

Consolidating Canada's Geoscience Knowledge Program

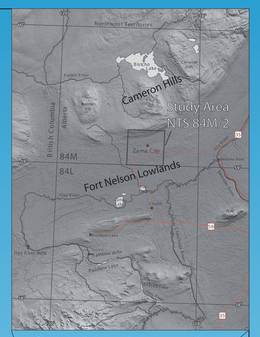
Consolidation du savoir géoscientifique du Canada

Abstract

This study is part of an ongoing surficial mapping project in the Bistcho Lake mapsheet (82/M) by the Federal and Alberta Geological Surveys, and involves a detailed investigation of the distribution and stratigraphy of glacial sediments in the vicinity of Zama City, northwestern Alberta. Sediments are generally clay-rich as a result of the weak Cretaceous shale bedrock that underlies the region. Till drapes the uplands, and glaciolacustrine sediments fill the lowlands. Sub-till glaciolacustrine sediments provide evidence for proglacial lakes in front of the advancing Laurentide Ice Sheet. Glacial lakes were also present during deglaciation, denoted by glaciolacustrine sediments overlying the regional till sheet. Stratigraphic evidence for a possible readvance of Laurentide ice during deglaciation is observed in several pits where deformed, crudely stratified diamicton overlies proximal glaciolacustrine sediments.

Introduction

- The study area lies in the northwest corner of Alberta, in the Moody Creek map area, NTS 84M/2
- The physiography comprises the Fort Nelson Lowlands, at the southern edge of the Cameron Hills
- The region lies near the western limit of Laurentide glaciation
- The area was glaciated during the Late Wisconsin by ice advancing from the east and northeast.



Shaded relief map of area surrounding study area in northwestern Alberta.

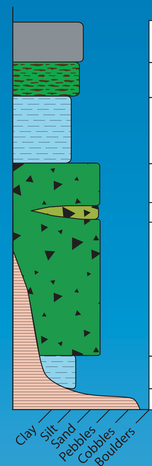


Map of Canada showing location of study area.

Objectives

- To determine the distribution and stratigraphy of Quaternary deposits
- To determine the geotechnical properties of Quaternary deposits
- To interpret the genesis of the various surficial materials
- To interpret the glacial history, including ice flow history of the area

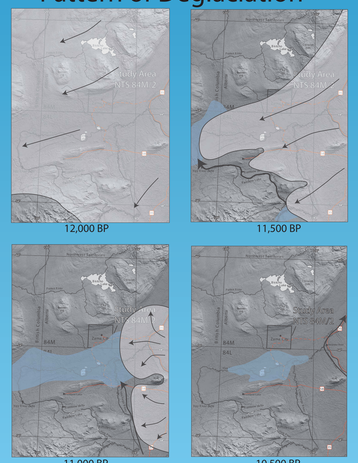
Generalized Stratigraphy



Holocene Bog and Fen Organics
Deformed Stratified Diamicton
Retreat Phase Glaciolacustrine
Lithologically Distinct Till Beds
Laurentide Till
Advance Phase Glaciolacustrine
Shale Bedrock

Clay Silt Sand Pebbles Cobbles Boulders

Pattern of Deglaciation



Generalized pattern of deglaciation. White shading indicates ice, blue shading indicates glacial lakes. Large arrows show meltwater channels, small arrows show ice flow direction (Mathews 1980, Lemmen et al. 1994).

1. Bedrock controlled slopes with a blanket to veneer of till

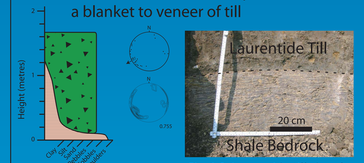


Fig. 1.1. Thin till over bedrock, and till fabric with eigenvalue

Fig. 1.2. Laurentide till sharply overlies microfaulted shale bedrock.

- Hillsides in the northern part of the map area have bedrock controlled topography.
- Fabric data show southwest dip of clasts within Laurentide till, perpendicular to slope, indicating topographically controlled ice flow to the southwest.

2. Thick till deposits

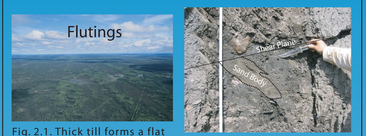


Fig. 2.1. Thick till forms a flat to undulating surface, and in some areas subtle flutings are exagerated by vegetation.

Fig. 2.2. Example of till showing a shear plane truncating a body of fine sand.

- Till forms the dominant surficial material in the map area
- Till is clay-rich, resulting from the poorly-lithified shale bedrock.
- Roads are typically built with till due to a shortage of aggregate, and are unsuitable for wet weather

3. Deformed diamicton: Evidence of a possible readvance ?

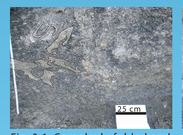


Fig. 3.1. Complexly folded and sheared silt, clay, and fine sand, overlain by massive, clast-poor diamicton.



Fig. 3.2. Deformed glaciolacustrine sediments overlain by massive diamicton with cobble sized clasts.

- Deformed glaciolacustrine sediments are overlain by thin, massive to crudely stratified diamicton.
- May be the result of a readvance, but further work is required.

4. Lithologically distinct till

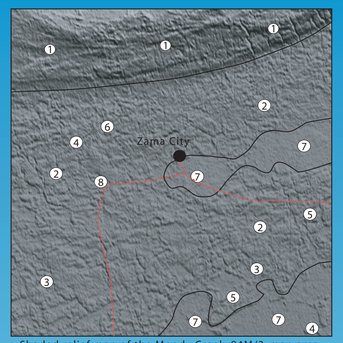


Fig. 4.1. Bed of pink till within Laurentide till.



Fig. 4.2. Deformed pink till within Laurentide till.

- Lithologically distinct till has a pronounced red to pink colour, and occurs as undeformed beds, and as highly deformed lenses and diapirs.
- This material was likely transported englacially from near Fort Vermillion to the east, and deposited subglacially through meltout or lodgement.
- An investigation into provenance and mode of deposition is ongoing



Shaded relief map of the Moody Creek, 84M/2, map area. Numbers refer to location of observations in text boxes.

5. Retreat phase glaciolacustrine sediments

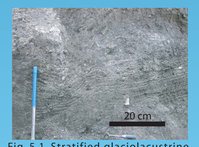


Fig. 5.1. Stratified glaciolacustrine sediments. Thin beds are fine sand and gypsum crystals. Thick beds are silt and clay.



Fig. 5.2. Convolutely laminated glacio-lacustrine sediments.

- Glaciolacustrine sediments were deposited in Glacial Lake Hay during the retreat of the Laurentide Ice Sheet.
- Sediments are typically clay-rich, and form a discontinuous veneer over much of the southern area of the mapsheet.

6. Advance phase glaciolacustrine sediments

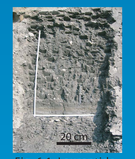


Fig. 6.1. Laurentide till overlying clast-free sheared clay.



Fig. 6.2. Undulating shear plane within the lower clast-free clay.

- Clast-free clay underlying Laurentide till is interpreted to represent deposition in a proglacial lake, impounded as Laurentide ice advanced up-slope.

7. Organic deposits: Bogs and fens



Fig. 7.1. Stunted black spruce growing in thick peat in a bog.



Fig. 7.2. Fen showing relict patterning from permafrost.



Fig. 7.3. Peat with dark charcoal layers

- Bogs are raised areas with thick peat, typically underlain by permafrost
- Fens are lowlying, with water tables at or near the surface, and commonly display patterning from relict permafrost.

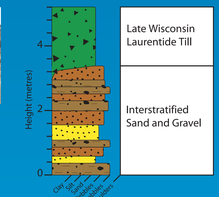
8. Aggregate souces:



Fig. 8.1. Folded contact between upper till and sub-till gravel.



Fig. 8.2 Interstratified sand and gravel.



- Both gravel pits servicing the Zama City area utilize gravel that lies stratigraphically below the regional till sheet.
- Sub-till sand and gravel are interpreted as subglacial conduit fills.
- Sub-till gravels have no surface expression, and their discovery through surficial mapping is difficult.
- Till is the primary road building material, as gravel deposits are not widespread and hauling costs are prohibitive.
- Aerial magnetic surveys may prove useful in locating new supplies of aggregate.

Future work

- Surficial mapping is nearly completed, and will result in the production of a 1:50,000 scale map-sheet for NTS map area 84M/2, Moody Creek, which includes Zama City
- Geotechnical samples and data were collected and will be analyzed to determine the geotechnical properties of the various material types in the area, including liquid and plastic limits, shear strength, grain size, and grading.
- The various material types will be analyzed sedimentologically and stratigraphically to characterize their mode of deposition and stratigraphic relationships, specifically to elucidate the glacial history of the area.
- The provinance and mode of transport of the lithologically distinct, pink-coloured till will be determined.

Conclusions:

- Surficial materials include:
  1. Bedrock controlled slopes covered in a veneer of till.
  2. Thick till with a flat to undulating topography.
  3. Retreat phase glaciolacustrine sediments in lowlying areas in the southern portion of the mapsheet.
  4. Bog peat and fen water-saturated organics.
- Till and glaciolacustrine sediments are very clay-rich, resulting from the pooly lithified shale bedrock.
- Aggregate is limited to two pits near Zama City, where gravel lies stratigraphically below till, and has little surface expression.
- Initial stratigraphic work reveals the presence of advance phase glaciolacustrine sediments, and a possible readvance during deglaciation.

Surficial Mapping in Northwestern Alberta

Alberta Geological Survey (AGS) & Geological Survey of Canada (GSC)

R.C. Paulen (AGS), A. Plouffe (GSC), I.R. Smith (GSC) & C. Kowalchuk (Simon Fraser University)



Shallow Gas & Diamond Opportunities in Northern Alberta and British Columbia 2003 - 2007



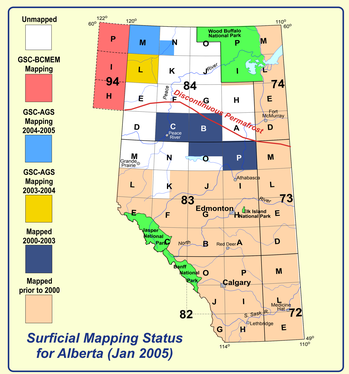
Abstract

During the summers of 2003 and 2004, geologists from the Alberta Geological Survey (AGS) and the Geological Survey of Canada (GSC) completed the surficial mapping of the Zama Lake (NTS 84L) and Bistcho Lake (NTS 84M) regions as part of a four-year collaborative, multi-disciplinary project under the GSC's Northern Resource Development Program (NRD Project 4450). This research will provide crucial information on the Quaternary stratigraphy, sediment characteristics, and glacial history that will have direct implications for infrastructure development and Quaternary-hosted shallow gas, aggregate and diamond exploration in northwestern Alberta.

Our presentation will focus on the nature and distribution of surficial sediments and locations of previously undocumented bedrock exposures of the Zama Lake and Bistcho Lake regions. Complex ice flow reconstruction and deglacial history of the region will also be presented, which has implications for aggregate exploration and provide information for drift prospecting. Other environmental features, such as climatically sensitive fluctuating lake levels for Hay and Zama lakes and the distribution and sensitivity of permafrost will be presented.

Introduction

Four 1:250 000 map sheets define the Alberta study area. The 2003 field season focussed on the Zama Lake map area (NTS 84L), while the 2004 field season focussed on the Bistcho Lake map area (NTS 84M). Subsequent fieldwork is planned for the Steen River (NTS 84N) and Mount Watt (NTS 84K) map sheets. The study area lies within the Fort Nelson Lowlands and Cameron Hills physiographic regions (Pettapiece 1986), and is blanketed by Boreal forest (white and black spruce, aspen, lodgepole pine) and extensive bogs and fens. Soils are generally poorly drained, commonly with shallow water tables, reflecting the high clay content of the tills (10–40 %) in which they have formed. In raised areas, where soil development is more advanced, gray luvisols predominate. Static and turbic cryosols are found in regions of sporadic discontinuous permafrost, and solonetzic soils are found in areas of thin drift overlying marine shale bedrock.



Surficial Mapping Status for Alberta (Jan 2005)











Fieldwork in northwest Alberta was conducted by four-wheel drive vehicle (dry weather), all-terrain vehicles, jet boat and helicopter.





Outcrops of Fort St. John Group shale (Shaftesbury Formation) exposed in the Chinchaga River (left) and the CDR Ridge (right) south of Hay and Zama lakes.

Outcrops of Dunvegan Formation sandstone are exposed in the southwestern part of the Zama Lake (NTS 84L) area. At the base of the Dunvegan Formation, beds of mudstone and shale occur.



Quaternary History of Northwest Alberta

Prior to this mapping, the Quaternary stratigraphy and glacial history in northwest Alberta have been poorly documented. Soil surveys were conducted in the region in the late 1950s (Lindsay *et al.* 1960) with only a brief report on the Pleistocene geology (Bayrock 1960). Hydrogeological studies were carried out in the late 1970s (Borneuf and Pretula 1980). Preliminary surficial geology and reconnaissance aggregate inventory studies were published in the mid 1980s (EBA Engineering Consultants Ltd. 1984a, 1984b, 1984c; Fox *et al.* 1987). Recent geotechnical research on the surface sediments and permafrost has been conducted along the Norman Wells to Zama oil pipeline route which terminates at Zama City (Pilon *et al.* 1989; Nixon and Burgess 1999).

The southwest-advancing Laurentide Ice Sheet inundated northwest Alberta during the Late Wisconsin glaciation. Ice-flow direction is recorded by large southwest trending flutings across upland regions, as well as by a subsequent set of smaller, superimposed and cross-cutting flutings that trend south-southwest (Plouffe *et al.* 2004; Paulen *et al.* 2005a, b; Smith *et al.* 2005). Chronological constraint on the advance of ice is provided by a radiocarbon date of 24 400 ± 150 yr BP (Beta 183598) on wood recovered from gravel underlying Late Wisconsin till in the adjacent region of northeastern British Columbia (Levson and Ferbey 2004; Levson *et al.* 2004). Retreat of ice from the area largely occurred between 11.5 and 11 ka BP (Lemmen *et al.* 1994; Dyke 2004).

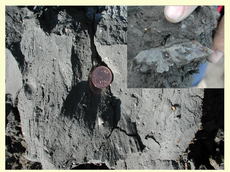
During the ice advance phase, the eastward drainage of regional rivers would have been impounded, leading to development of large proglacial lakes. Progressively, these were displaced by ice which then deposited a blanket of clay-rich till (10-40%) across much of the region. The high clay content of this till reflects glacial erosion and entrainment of regional shale-rich bedrock and reworking of advance-phase glaciolacustrine sediment. This till is interpreted to have been largely deposited through basal lodgement processes. Thicknesses in excess of 15 m have been observed in some areas. Clast content tends to be very low, generally between 1 and 10%, although in areas north of Bistcho Lake clast content tends to be higher (15-25%) reflecting the proximity of outcrops of Paleozoic carbonates and Canadian Shield igneous and metamorphic rocks. A second thinner and distinctly sandier till (30-45% sand in the <2 mm size fraction of the matrix) overlies this basal clay-rich till. Fabrics in the two tills tend to be very similar, and contacts between them are often diffuse suggesting that it is a second facies relating to deposition of a greater component of more far travelled (Canadian Shield-derived) coarser englacial sediment, rather than a different trajectory of ice.

During deglaciation, large proglacial lakes formed in lowland basins along the retreating margin (Mathews 1980; Lemmen *et al.* 1994; Dyke 2004). Extensive blankets of fine-grained glaciolacustrine sediment up to 3 m thick are found along the southern Hay River (Smith *et al.* 2005), while in the Hay-Zama lakes and Chinchaga River lowlands where glacial Lake Hay formed, glaciolacustrine blankets up to 10 m thick are found (Plouffe *et al.* 2004; Paulen *et al.* 2005a, b). Although glacial Lake Peace did not inundate the 84L and 84M map areas, several of its outlets are inscribed upon the landscape. The uppermost Haig and Hay river channels in southeast 84L (referred to as the Hay River spillway) served as a major outlet of glacial Lake Peace (late Indian Creek stage - Mathews 1980), draining westward into a nascent phase of glacial Lake Hay and the Fontas-Nelson river system. As ice continued to retreat, outlets of glacial Lake Peace drained northwards along the ice margin, incising three prominent meltwater channels, including the present channel of the Chinchaga River (Keg River stage - Mathews 1980; Paulen *et al.* 2004b; Plouffe *et al.* 2004).

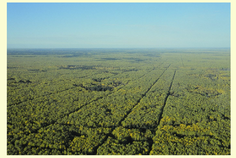
Holocene water levels in the Hay and Zama lakes basin have varied considerably. Strandlines formed during wet periods show maximum water levels of ~330 m and the lakes likely dried up completely during dry periods of the Holocene. Local aboriginal oral tradition also supports the geological evidence for climatically sensitive fluctuating lake levels.



Tilted ironstone bed in ice-thrusted bedrock



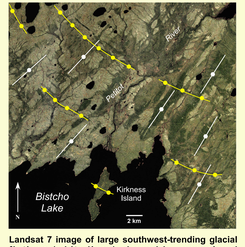
Large selenite (gypsum) crystals (inset) growing within the silty-clay lodgement till derived from Shaftesbury Formation shale.



Mature poplar (in fall colours) on a till plain northwest of the town of Rainbow Lake characterize the Fort Nelson Lowland. Seismic lines can be seen extending off into the horizon.

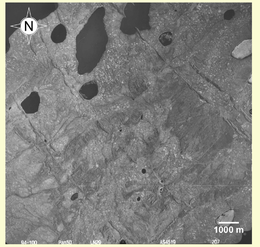


Contact between lodgement till and melt-out till. Note the iron oxidation in the joints of the lodgement till.



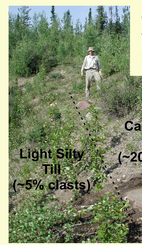
Landsat 7 image of large southwest-trending glacial flutings (white lines), draped by recessional moraines (yellow dotted lines), north of Bistcho Lake.

(Image courtesy of PhotoSat Information Ltd.)

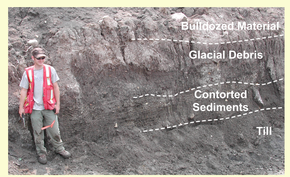


Prominent recessional moraines (aligned northwest-southeast) north of Bistcho Lake.

(Airphoto 94-100 Line 29 A54519-207, 1:60 000, ©Alberta Sustainable Resource Development)



A polished clast pavement separates the lower silty till derived from the local shale bedrock of the Fort St. John Group and the upper calcareous sandy till derived from the Paleozoic limestones that crop out to the northeast. The polished limestone boulder in the foreground indicates ice flowed southwesterly, parallel to the flutings seen in the figures above.





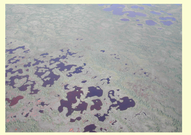
Hay River spillway, seen here west of Rainbow Lake, served as a major outlet of glacial Lake Peace. The horizon extends into the province of B.C.

The fall colours of poplar trees highlight a former shoreline of glacial Lake Hay that occupied the Hay-Zama lowland (at left).

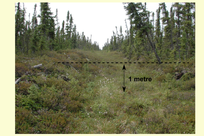
A thin veneer of glacial debris (diamicton) interpreted to be till overlies contorted rhythmically bedded silts and clays, which in turn, overlies a thick deposit of till. This documents a late glacial readvance into glacial Lake Hay.

Permafrost

Permafrost is extensive in the region. Polygonal patterns are common, and irregular ground surfaces and a characteristic patterning of ponds distinguishes active thermokarst. The permafrost terrain in this region appears to be extremely sensitive and susceptible to melting. Disturbance of surface peat with pipeline trenching and seismic line cutting can induce melting of ground ice. Lease sites with fill placed on them also induce melting. Pilings driven into the ground to support pumpjacks act as heat conductors into the permafrost and can cause wellpad subsidence, which can potentially make the producing pumps unstable.



Thermokarst ponds, forming from the melting of discontinuous permafrost lenses, occur in ribbed fens and peat land plateaus.



An older seismic line where the surface ground ice has melted down resulting in subsidence. Ice is melting laterally along the line boundaries, causing mature trees to bow and topple.

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Acknowledgements

Surficial mapping was completed in 2003 and 2004 as an Alberta Geological Survey (AGS) and Geological Survey of Canada (GSC) collaborative contribution to NRD Project 4450 and the Quaternary mapping initiative under the Alberta Mineral Strategy. The authors wish to acknowledge Laurence Andriashek, Mark Fenton, and John Pawlowicz (Alberta Geological Survey), Travis Ferbey, Adrian Hickin and Vic Levson (British Columbia Ministry of Energy and Mines), Brent Ward (Simon Fraser University), and Jan Bednarski (Geological Survey of Canada) with whom various discussions and collaborations have greatly benefited this work. Field assistance by Thomas Ahkimnachie, Rob Metchooyeah, Ryan Peterson, Mark Tarplee, Michelle Trommelen, Jill Weiss and Michelle White is also greatly appreciated.

Heavy Mineral Survey and its Significance for Diamond Exploration Fort Nelson Area, British Columbia, Canada.

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Geofile 2005-13

Suggested reference style:
Simandl, G.J.[1], Ferbey, T.[2], Levson, V.M.[2], Demchuk, T.E.[2], Hewett, T.[1], Smith, I.R.[3], and Kjarsgaard, I[4]. (2005): Heavy Mineral Survey and its Significance for Diamond Exploration Fort Nelson Area, British Columbia , Canada; British Columbia Ministry of Energy and Mines; Geofile 2005-13.

EXECUTIVE SUMMARY

Parts of northeast British Columbia are underlain by Precambrian basement that belongs to the North American craton. These areas have a moderate exploration potential for diamonds in terms of the traditional "diamondiferous mantle root model" (Simandl, 2004). The potential of any area to host kimberlite or lamproite-hosted diamond deposits may be assessed based on the thickness and age of basement rocks, geophysical anomalies, and other data sets including presence of kimberlite indicator minerals (KIMs) in Quaternary sediments (Simandl, 2004; Figure 1). This study concentrates mainly on KIMs present in Late Pleistocene glaciofluvial sands and gravels. Of 22 samples collected and processed, 14 contain KIMs such as purple pyrope, yellowish eclogitic garnet, Cr-diopside, olivine, ilmenite, or spinel. It is possible that these minerals are derived from primary, secondary or tertiary sources within the Fort Nelson area. It is also possible, however, that they were brought into the region from the Northwest Territories and Alberta by Late Pleistocene glacial and glaciofluvial systems. Corundum and diaspore were also recovered from collected samples. At this stage, semiquantitative data does not allow for a definitive interpretation as to whether this corundum is kimberlite-related. The location of samples indicating kimberlite indicator minerals shown on Figure 1.

INTRODUCTION

The objective of this study is to collect and process glaciofluvial sands and gravels to analyze for the presence or absence of kimberlite indicator minerals (KIMs) in the Fort Nelson area (Figure 1). The majority of the study area occurs within the Fort Nelson Lowlands physiographic region, a subdivision of the Interior Plains. In general, this area can be characterized as having flat to subdued topography, which is an expression of the horizontally to subhorizontally bedded sedimentary rocks that underlie the region (Holland, 1976). The combination of low-relief topography and clay-rich soils results in poor drainage, and a shallow water table is present in most areas. Small shallow lakes and narrow, often meandering, low gradient streams are common. Larger river systems, such as the Fort Nelson, Prophet, and Petitot rivers, however do occur in the region. In contrast to the lowlands, the Etsho Plateau (~700 m above sea level; Figure 2) forms a topographic high, 140 by 80 km, that trends northwest-southeast.

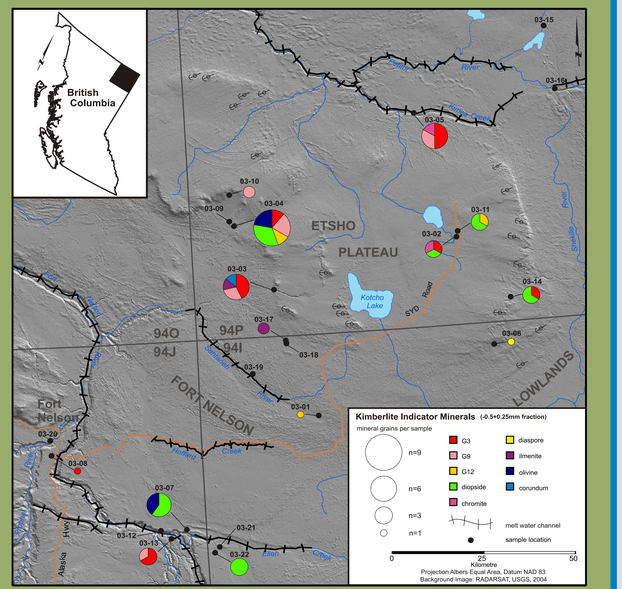


Figure 1. Distribution of kimberlite indicator minerals in glaciofluvial sands and gravels. The data is not corrected for sample weight.

BEDROCK GEOLOGY

The Fort Nelson area is underlain by a Precambrian basement that belongs to the North American craton (Hoffman, 1988, 1989, 1991; Villeneuve *et al.*, 1993; Ross *et al.*, 1991 and 1995) which is overlain by a thick Phanerozoic sequence consisting of the Lower Cretaceous Fort St. John Group. Overlying the Fort St. John Group, and forming the resistive cap of the Etsho Plateau, are sandstones of the Duvegan Formation, of the Upper Cretaceous Smoky Group (Stott, 1982; Thompson, 1977). The stratigraphy and sedimentology of the Dunvegan Formation recently have been discussed in detail by Plint *et al.* (2001), and Plint and Wadsworth (2003).

SURFICIAL GEOLOGY

Silt and clay-rich morainal deposits are the dominant surfical material. They typically occur at surface in better drained forested areas, and are invariably overlain by organic materials and (or) glaciolacustrine sediments in poorly drained areas. Morainal landforms include low relief plains, crevasse-squeeze ridges, flutes, and rolling, recessional, and interfluve moraines. Glaciofluvial landforms are uncommon, however, eskers, kames, fans, deltas and terraces can occasionally be observed. Most of the larger terraces occur within the Kimea Creek Petitot River meltwater channel system (Figure 1). Other large meltwater channel systems occur in the area (*e.g.* Fort Nelson River, Elleh Creek) and contain elevated glaciofluvial landforms that are thought to be ice-proximal and (or) subglacial in origin. Glaciofluvial sands and gravels were locally deposited in smaller meltwater channel systems (*e.g.* Hoffard Creek), however, many of these systems appear to be almost entirely erosional and may have formed subglacially (Levson *et al.*, 2004). Irrespective of type and size of glaciofluvial landform, the presence of clast lithologies from the Canadian Shield (*e.g.* red and pink granites and gneisses) indicate that these glaciofluvial sands and gravels have an eastern provenance, or are derived from tills with an eastern provenance.

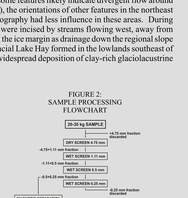
QUATERNARY HISTORY

The Late Pleistocene regional ice-flow record is preserved in flutes and crag-and-tail ridges that occur on, and along, the periphery of Etsho Plateau (Figure 1). The Laurentide ice sheet moved into the region from the east and northeast, however, there is variability in the details of this advance. Differing orientations of large-scale landforms suggest that multiple ice-flow events occurred in the region during the Late Wisconsinan and that ice lobes were active during the later stages of glaciation (Figure 1). While the orientations of some features likely indicate divergent flow around topographic barriers (*e.g.* southeast portions of Etsho Escarpment), the orientations of other features in the northeast and east-central portion of the Etsho Escarpment suggest that topography had less influence in these areas. During retreat of the Laurentide ice sheet, numerous meltwater channels were incised by streams flowing west, away from the retreating Laurentide ice sheet. Glacial lakes developed along the ice margin as drainage down the regional slope to the east was blocked by ice (Mathews, 1980). For example, Glacial Lake Hay formed in the lowlands southeast of Kotcho Lake, and extended east into Alberta. This resulted in the widespread deposition of clay-rich glaciolacustrine

SAMPLE COLLECTION

Twenty two samples of glaciofluvial sands and gravels were collected (Figure 1; Table 1). Average sample size ranged from 20 to 30 kg with some up to 40 kg. An effort was made to exclude clasts >4 mm in size and include as much sand-sized material as possible. Sample sites were vertical walls in gravel pits or road cuts and pits dug by an excavator. The sample distribution was limited due to the scarcity of glaciofluvial material. The sample depth was typically 1 to 4 m below surfaceand collected from undisturbed material. Heavy mineral concentrates were produced by Vancouver Indicator Processors Inc., as outlined in Figure 2. The -0.5+0.25 mm heavy mineral fractions were sent to I. & M. Morrison Geological Services Ltd. for KIM picking. Potential KIM's were sent to I. Kjarsgaard (Consulting Mineralogist) for microprobe analysis. From 197 mineral grains, 46 grains were confirmed as KIMs.

FIGURE 2:
SAMPLE PROCESSING FLOWCHART



GLACIOFLUVIAL ENVIRONMENTS

Table 1. Sampled glaciofluvial systems, features, and depositional environments.

Sample ID	Glaciofluvial System	Glaciofluvial Feature Sampled and Size	Depositional Environment	Clast Lithologies	Paleoflow Direction
03-01	Sahtaneah River	meltwater channel terrace - large1	subaerial	Canadian Shield	north
03-02	unnamed	esker - small2	subglacial		southwest
03-03	Courvoisier Creek	meltwater channel terrace - small3	subaerial		west
03-04	unnamed	delta - small3	subaerial		west
03-05	Kimea Creek - Petitot River	meltwater channel terrace - large1	subaerial	Canadian Shield	west
03-06	unnamed	buried sands and gravels4	?		unknown
03-07	Elleh Creek	kame? - large1	subglacial, ice-proximal	Canadian Shield	west
03-08	Fort Nelson River	meltwater channel - large1	subaerial	Canadian Shield	north
03-10	unnamed	outwash - small3	subaerial		west
03-11	unnamed	esker - small2	subglacial		southwest
03-13	Kloa Creek	fan-delta - small5	subaerial	Local shales	north
03-14	unnamed	buried sands and gravels4	?		uknown
03-17	unnamed	esker - small2	subglacial		southwest
03-22	Elleh Creek?	buried channel4	subglacial?		unknown

1. High energy meltwater systems, with channel widths from 1 to > 2.5 km, 10 to 30 m deep, and > 40m long, and transported distances (many 10's to 100's km).
2. Collected from small-scale esker systems (5 to 10 m wide, up to 5 m high, and >1 km long). Although Dominated by sand-sized material, transport distances could be long.
3. Smaller-scale melt water systems peripheral to the Etsho Plateau; channels typically 10 to 30 m wide, 5 to 10 m deep, and up to 10 km long, dominated by sand-sized material, and likely have shorter transport distances.
4. As they are now barried, it is difficult to assess the size of the transport and depositional systems.
5. Likely deposited in an aggragational and less mature system, suggesting shorter transport distances.

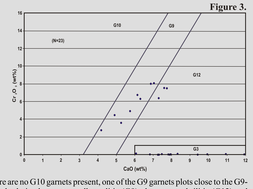
INTERPRETATION OF INDICATOR MINERALS

Of the 20 samples collected for this study, 14 contain KIMs. Of these, eight contain more than one indicator mineral. In total 46 KIM's were confirmed by microbe analyses. The following section presents microprobe data, and includes a discussion of KIMs identified in this study. The spatial distribution of KIM's is shown in Figure 1.

Garnet

Mantle-derived garnets are the most important KIM's. The scheme described by Grütter et al. (2004) is used to classify garnets. In this classification, garnets are divided into 12 categories (G1 to G12). Of these, harzburgitic (G10), pyroxenitic, websteritic and eclogitic garnets (G4, G5 and G3) are commonly associated with diamonds. Wehrlitic garnets are referred to as G12, low-Cr megacrysts as G1, and Ti-rich peridotitic varieties as G11. The garnets that do not fit any of the twelve categories, including crustal garnets, are referred to as G0. Microprobe analyses of hand-picked garnets, and results of classification are provided in Table 2. Of the 46 garnets that were visually picked and analysed, at least 23 can be considered as KIMs. Although there are no G10 garnets present, one of the G9 garnets plots close to the G9-G10 boundary (Figure 3). Eight of the mantle-derived garnets are lherzolitic (G9), three are wehrilitic (G12) and twelve can be considered as eclogitic (G3). The remaining garnets are classified as G0. The garnets with significant Cr content (>0.5 wt.%) define a trend from the G10-G9 to G9-G12 boundaries, forming an acute angle with the lherzolite field (Figure 3). No G3 grains recovered in this study have Na_2O content of more than 0.07 wt%. With one possible exception, kelyphitic rims were not observed, but some grains have orange-peel texture. This suggests that these garnets were subject to some degree of transport, or at least local reworking, after being liberated from their host rock.

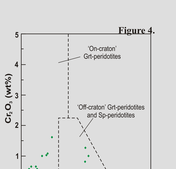
Figure 3.



Clinopyroxene (Cr-Diopside)

Cr-bearing clinopyroxenes (CPXs) are easy to identify in concentrates, and can be associated with diamonds. Unfortunately, CPXs with similar characteristics to those present in kimberlites are also found in other lithologies; Microprobe analyses are required to identify kimberlite-related CPXs. Twenty CPX grains were picked from concentrates. Their chemical composition is provided in Table 3. The Mg# (100Mg/(Mg+Fe) of these CPXs vary from 77.52 to 93.52. Cr-diopside grains with an Mg number >88 are likely to be from mantle peridotite, particularly if they have elevated Cr_2O_3 (> 0.5 wt.%). Based on Mg#, there is 10 CPXs classified as KIM's. The discrimination plot Cr_2O_3-Al_2O_3 of Ramsey and Tompkins (1994) is used to further refine this interpretation. Of the 10 CPXs identified as KIM's based on the Mg#, 4 plot within the 'on craton' field, and 3 plot within the 'off craton' field (Figure 4). Four additional CPXs plot within this field, however they have an Mg# <88. Of the 20 CPXs identified during this study, 14 could be considered as KIMs.

Figure 4.



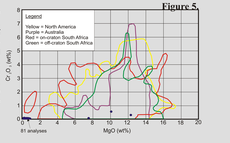
Spinel

Based on microprobe analyses, only one visually picked mineral grain is chromite (sample 03-05; Figure 1). This black chromite grain consists mainly of Al_2O_3 (30.56%), Cr_2O_3 (33.22%), FeO (21.01%), MgO (12.67%) and smaller components of TiO_2 (0.43%), ZnO (0.27%), MnO (0.21%), NiO (0.14%), SiO_2 (0.09 %); V,O, and CaO were not detected. The grain has MgO values comparable to chromites reported as inclusions or intergrowths in and (or) with diamonds. Its Cr_2O_3 content (33.22%), however, is too low relative to compositional fields of diamond-associated chromites which commonly contain >60% Cr_2O_3. Due to its association with other indicator minerals, however, this grain was identified as a potential KIM.

Ilmenite

The Cr_2O_3 and MgO plot suggests that the three ilemenite grains in Figure 5 are kimberlite-related. All of them have higher MgO values, and two of them have higher Cr_2O_3 content than their non-kimberlitic counterparts. The fields of typical North American, South African (on and off craton), and Australian kimberlitic ilmenites are provided in Figure 5, and are based on data from Wyatt *et al.* (2004). Most of the non-kimberlitic ilmenites have low MgO values and probably originated from the same, non-kimberlitic, crustal protolith (Figure 5).

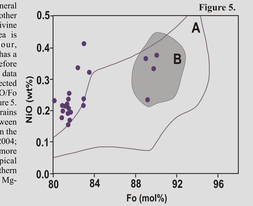
Figure 5.



Olivine

Although olivine is a common rock-forming mineral in kimberlites, it is also present in a variety of other ultramafic rocks. The Mg-rich variety of olivine identified in samples from Fort Nelson area is commonly pale yellow-green in colour, equidimensional, subrounded to rounded, and has a fresh appearance. Microprobe analyses are therefore required to establish provenance. Microprobe data on 28 olivine grains recovered from collected samples are presented in Table 5, while NiO/Fo diagram using the same data is presented in Figure 5. The MgO content of these kimberlite-related grains ranges from ~41 to 50 wt% and that of FeO between ~8 to 19 wt%. Kimberlite-related grains plot in the field delineated by curve A (Eccles *et al.*, 2004; Figure 5). Curve B (Figure 5) delineates a more restricted field, which represents the typical composition of olivine grains from the northern Alberta kimberlite province. Four of the most Mg-rich grains from this study fall within this field.

Figure 5.



Corundum

A single purple corundum grain was recovered during this study. Its colour and high Cr content indicate that it is similar to ruby. This grain is composed almost entirely of Al_2O_3 with minor concentrations of Cr_2O_3 (0.54%) and FeO (0.19%), and even less NiO (0.03%) and MnO (0.01%). Laser ICP-MS, or energy dispersive spectrometry, would be necessary if further interpretation of the data, based on chemical composition, is required. Similar Cr-corundum is reported in association with spinel in kimberlite pipes from Buffalo Head Terrane, Alberta (Hood and McCandless, 2004), in the Fort a la Corne area, Saskatchewan (Hutchison *et al.* 2004), and in Northwest Territories. Although corundum and spinel are commonly found in some rocks within the alkaline province, eastward transport of KIM's is unlikely. Sample 03-03 (Figure 1), which also contained several kimberlite indicators, including mantle-derived garnets and ilmenite, is worth follow-up both from diamond and gem corundum perspectives.

Diaspore

Two yellow diaspore grains were visually picked from heavy mineral concentrates (samples 03-06 and 03-02; Figure 1). These grains have similar NiO values to those of the previously described corundum grain. The diaspore grains differ from the corundum grain by having no Cr_2O_3, higher FeO values, and detectable TiO_2 content (Table 6). The significance of these grains is not well understood. Diaspore is not typically considered a KIM. It commonly cocists with corundum in silica- undersaturated lithologies as a retrograde product in meta-morphosed corundum-bearing alumina-rich sedimentary rocks and bauxite deposits (Simandl and Paradis, 1999a; Hill, 1994) and with ultramafic-related corundum-bearing contact metamorphic rocks (Simandl and Paradis (1999b). However it may be present in corundum-bearing alkaline volcanics such as alkali basalts, kimberlites, and lamrophyres (Simandl and Paradis, 1999c). The chemical composition of these grains does not suggest a strong association with kimberlite indicators or the purple corundum grain.

SUMMARY AND CONCLUSION

Kimberlite indicator minerals including peridotitic and eclogitic garnets, ilmenite, Cr-diopside, olivine, and corundum were recovered from -0.5+0.25 mm heavy mineral concentrates of the Fort Nelson area. From glaciofluvial sands and gravels 14 of the 22 samples collected contained KIMs, some with more than one mineral type. Most of the indicator grains appear fresh and subrounded to subangular, but several have sharp edges. Garnets do not appear to have kelyphitic rims, but a few do have an orange peel texture, suggesting that they were subject to some degree of transportation or at least local reworking. Indicator minerals present in samples proximal to, or on, the Etsho Plateau, occur in small-scale, low energy glaciofluvial systems, and may have a local source possibly somewhere on the plateau itself. Others, particularly those occurring in large-scale, high energy glaciofluvial systems, were more likely transported into the area from Alberta and Northwest Territories. Possible sources include known diatremes located east of the study area in Buffalo Head Terrane and in the Slave Craton and undiscovered pipes cutting Mesozoic to Paleozoic-age sedimentary rocks in Fort Nelson area itself. The geology of the Precambrian basement in northeast British Columbia is poorly understood, and it should not be ignored in diamond exploration.

ACKNOWLEDGEMENTS

This study benefited from constructive comments of Dr. Suzanne Paradis of Geological Survey of Canada, at the Pacific Geoscience Center, Sidney, BC, and by Brian Grant of British Columbia Ministry of British Columbia Ministry of Energy and Mines, Victoria, BC. Enriching discussions with Dr. Herman Grütter, Mineral Services Canada, and Dr. Dan Schulze, University of Toronto, are gratefully acknowledged. Jan Bednarski (Geological Survey of Canada, Sidney, BC) is thanked for his insights into the Quaternary history of the region. Adrian Hickin (Resource Development and Geoscience Branch) is thanked for discussions on relevant topics.

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Table 2. Microprobe analysis of hand-picked garnet (values given in %).

Sample ID	UTM Easting	UTM Northing	grain	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
03-01	589380	6518892	6	40.65	0.06	19.33	8.45	8.39	0.54	0.04	17.19	0.00	0.00
03-01	589380	6518892	25	40.65	0.06	19.33	8.45	8.39	0.54	0.04	17.19	0.00	0.00
03-02	628743	6566536	25	39.20	0.10	22.04	0.04	22.38	0.41	0.00	14.74	0.03	0.00
03-02	628743	6566536	93	38.25	0.08	17.53	0.00	3.23	0.04	0.00	2.18	37.37	0.01	0.00
03-03	579851	6554264	4	41.86	0.03	22.26	0.01	5.26	0.03	0.00	0.00	0.00	0.00	0.00
03-03	579851	6554264	20	38.34	0.08	21.05	0.05	26.72	0.95	0.00	4.87	7.95	0.02	0.00
03-03	579851	6554264	21	38.83	0.05	21.68	0.00	33.59	3.76	0.00	3.82	1.00	0.01	0.03
03-03	579851	6554264	22	38.83	0.05	21.68	0.00	33.59	3.76	0.00	3.82	1.00	0.01	0.03
03-04	568767	6571934	1	40.67	0.02	18.43	7.56	8.32	0.52	0.00	17.29	7.59	0.00	0.00
03-04	568767	6571934	3	41.10	0.03	19.40	6.77	8.66	0.54	0.00	17.27	6.04	0.00	0.00
03-04	568767	6571934	5	41.10	0.03	19.40	6.77	8.66	0.54	0.00	17.27	6.04	0.00	0.00
03-04	568767	6571934	18	37.17	0.00	21.68	0.00	33.59	3.76	0.00	3.82	1.00	0.01	0.03
03-04	568767	6571934	19	38.66	0.04	21.68	0.00	33.59	3.76	0.00	3.82	1.00	0.01	0.03
03-05	619465	6601324	7	41.68	0.06	19.84	4.96	8.14	0.44	0.06	16.71	5.74	0.01	0.00
03-05	619465	6601324	8	41.68	0.06	19.84	4.96	8.14	0.44	0.06	16.71	5.74	0.01	0.00
03-05	619465	6601324	26	41.22	0.04	21.28	0.00	30.23	0.48	0.00	3.81	7.31	0.01	0.01
03-05	619465	6601324	27	37.75	0.04	21.28	0.00	30.23	0.48	0.00	3.81	7.31	0.01	0.01
03-06	637217	6536514	15	37.76	0.04	20.87	0.03	28.57	1.92	0.01	2.97	8.09	0.03	0.01
03-06	637217	6536514	16	37.62	0.15	20.87	0.03	28.57	1.92	0.01	2.97	8.09	0.03	0.01
03-07	552329	6489894	17	38.64	0.02	20.34	0.05	28.92	1.48	0.00	3.22	7.96	0.03	0.00
03-07	552329	6489894	23	38.68	0.02	20.34	0.05	28.92	1.48	0.00	3.22	7.96	0.03	0.00
03-10	567804	6580816	10	42.02	0.27	19.89	4.49	7.83	0.42	0.00	19.90	4.90	0.05	0.00
03-10	567804	6580816	11	41.52	0.14	17.24	8.11	7.04	0.52	0.00	17.29	7.74	0.02	0.00
03-10	567804	6580816	12	42.02	0.27	19.89	4.49	7.83	0.42	0.00	19.90	4.90	0.05	0.00
03-10	567804	6580816	13	39.43	0.01	21.04	0.00	30.58	1.01	0.00	3.03	7.84	0.01	0.02
03-10	567804	6580816	14	37.66	0.03	20.93	0.02	30.58	0.99	0.02	2.94	8.68	0.03	0.01
03-10	567804	6580816	24	37.66	0.03	20.93	0.02	30.58	0.99	0.02	2.94	8.68	0.03	0.01
03-11	584307	6584424	9	41.52	0.00	18.13	7.33	8.73	0.49	0.00	17.23	7.04	0.00	0.00
03-12	545705	6489131	36	37.87	0.03	21.17	0.05	31.97	2.91	0.04	4.17	2.29	0.01	0.03
03-13	548366	6484636	28	37.51	0.00	20.84	0.00	31.07	2.04	0.00	3.03	2.64	0.01	0.02
03-13	548366	6484636	29	37.51	0.00	20.84	0.00	31.07	2.04	0.00	3.03	2.64	0.01	0.02
03-13	548366	6484636	30	38.68	0.11	21.72	0.00	25.19	0.61	0.03	6.17	7.91	0.02	0.00
03-13	548366	6484636	31	38.68	0.11	21.72	0.00	25.19	0.61	0.03	6.17	7.91	0.02	0.00
03-14	642368	6545584	13	38.29	0.00	20.90	0.02	30.17	3.01	0.00	1.82	6.60	0.03	0.00
03-14	642368	6545584	14	38.29	0.00	20.90	0.02	30.17	3.01	0.00	1.82	6.60	0.03	0.00
03-14	642368	6545584	38	37.51	0.00	20.84	0.00	31.07	2.04	0.00	3.03	2.64	0.01	0.02
03-14	642368	6545584	39	39.14	0.11	21.78	0.00	21.97	0.44	0.01	8.56	9.42	0.03	0.00
03-14	642368	6545584	40	38.68	0.11	21.72	0.00	25.19	0.61	0.03	6.17	7.91	0.02	0.00
03-16	658803	6606763	42	38.49	0.03	21.01	0.04	26.38	1.15	0.00	2.89	10.83	0.02	0.00
03-16	658803	6606763	43	38.49	0.03	21.01	0.04	26.38	1.15	0.00	2.89	10.83	0.02	0.00
03-17	581298	6540066	44	38.68	0.05	21.51	0.07	29.63	0.51	0.06	5.42	4.90	0.01	0.01
03-17	581298	6540066	45	38.68	0.05	21.51	0.07	29.63	0.51	0.06	5.42	4.90	0.01	0.01
03-20	518511	6515041	46	37.59	0.12	21.12	0.02	23.48	0.18	0.00	8.74	9.11	0.01	0.03
03-20	518511	6515041	45	37.59	0.12	21.12	0.02	23.48	0.18	0.00	8.74	9.11	0.01	0.03

Table 3. Microprobe analysis of hand-picked diopside (values given in %).

Sample ID	UTM Easting	UTM Northing	grain	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
03-02	628743	6566536	53	52.34	0.38	6.77	1.29	2.25	0.04	0.10	14.40	21.24	1.55	0.03
03-02	628743	6566536	54	52.34	0.38	6.77	1.29	2.25	0.04	0.10	14.40	21.24	1.55	0.03
03-04	568767	6571934	47	54.49	0.19	3.77	1.04	3.71	0.04	0.07	17.42	20.89	0.14	0.04
03-04	568767	6571934	48	54.49	0.19	3.77	1.04	3.71	0.04	0.07	17.42	24.89	0.14	0.04
03-07	552329	6489894	50	55.18	0.12	2.00	1.02	3.16	0.11	0.12	13.97	23.70	2.50	0.01
03-07	552329	6489894	51	55.18	0.12	2.00	1.02	3.16	0.11	0.12	13.97	20.70	2.50	0.01
03-14	642368	6545

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Shallow Gas and Diamond Opportunities in Northern Alberta and British Columbia

Quaternary Geology Studies in Northeastern British Columbia

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ABSTRACT

This poster highlights activities undertaken in northeastern British Columbia as part of a multi-year, collaborative project between the British Columbia Ministry of Energy and Mines and the Geological Survey of Canada. Ongoing fieldwork, initiated in 2003, has focussed on producing 1:100 000 scale surficial geology maps and in the identification of potential granular aggregate deposits. Expanding the aggregate inventory is seen as key to supporting natural gas infrastructure development.

This poster focuses on studies being conducted in NTS map sheets 94I (Fontas River) and 94J (Fort Nelson). The study area principally lies within the Fort Nelson Lowlands physiographic region, but also includes a section of the Alberta Plateau (in 94J). Overall the region is characterized by subdued topography and extensive bog and fen deposits. A thick blanket of clay-rich till, deposited by the Laurentide Ice Sheet, covers much of the region. Low-lying areas along Hay River and southeast of Fontas River are covered by glaciolacustrine sediment that was deposited in lakes impounded by retreating ice margins. Following drainage of these glacial lakes, deflation of sand-rich sediment led to the development of an extensive aeolian veneer and larger dune ridges in the southeast quadrant of 94I. Outside of bog and fen deposits, vegetation in the study area is characterized as Boreal Forest, comprised of Aspen, White and Black Spruce and minor Lodgepole Pine. Shale bedrock of the Upper to Lower Cretaceous Fort St. John Group is exposed in highlights in the north part of 94I, along stream cuts in the eastern part of 94I, and along reaches of the deeply incised Fontas, Fort Nelson, and Prophet rivers. Upper Cretaceous Dunvegan Formation channel deposits have also been observed on the uplands of 94J.

Several new granular aggregate targets have been identified, including an intraglacial ice marginal (?subglacial) channel system, large kame deposits, eskers, and an extensive (>160 km²) glaciolacustrine delta (>35 m thick). The deeply-incised Fontas-Nelson river system, which extends across the two map areas, likely formed as both a subglacial tunnel valley and an outlet for glacial Lake Hay, and contains potential gravel resources in a large glaciofluvial terrace. Dunvegan Formation chert pebble conglomerates also represent a potential aggregate source.

ICE-FLOW HISTORY

The westward-advancing Laurentide Ice Sheet inundated the study area during the Late Wisconsinan glaciation, eventually coalescing with the Cordilleran Ice Sheet and Rocky Mountain montane ice in regions west of the study area. A generalized succession of ice-flow directions conformable to several ice sheet geometries are clearly indicated by a series of individual and cross-cutting large-scale flutings (Figure 2).

The first phase of ice flow is oriented west-southwest, largely independent of topography (Figure 2, red arrows). This is interpreted to reflect the advance of Laurentide ice across the region, prior to its abutting the mountain front and/or eastward flowing Cordilleran Ice Sheet and Rocky Mountain montane ice. Chronological constraint on this initial advance is provided by a radiocarbon date of 24 400 ± 150 yr BP on wood recovered from gravel underlying Late Wisconsinan till (hence, a maximum age; Figure 1, site 1; Levson and Ferbey 2004; Levson et al. 2004).

The second phase of ice flow illustrates a divergent north and southward flow (Figure 2, green arrows), and is interpreted to represent full glacial conditions, when the Laurentide and Cordilleran ice sheets were confluent. During this phase, the oblique patterns of ice flow suggest it occurred independent of topography. The central study area also appears to coincide with the southernmost location of an ice divide from which Laurentide ice flowed either northwards or southwards (it is likely that as the ice sheet geometry changed over time this divide would have shifted northwards, or similarly migrated south to here). Recognition of this divide is important in consideration of ice sheet modelling exercises, and for dispersal train studies of drift geochemistry and kimberlite indicator minerals. The divide would also represent the maximum elevational extent of ice along the entire Rocky Mountain front. At some point during full-glacial, or even deglacial time, a ~100 km wide spatulate belt of thrust moraine formed by southward flowing ice, south of the study area (Figure 2, black dashed line). Similar belts of thrust moraine in southern and central Alberta have been linked to surging glaciers. Surging may have been facilitated in the region by impoundment of eastward draining regional rivers, and the accumulation of saturated fine sediments which were subsequently overridden.

The third phase of ice flow corresponds to the deglacial period (Figure 2, blue arrows). Here, ice flow is seen to be increasingly topographically confined, as illustrated by radial flow paths around topographic highs. The formerly pervasive ice cover appears to have retreated as a series of lobes: an eastward retreating lobe south of the Etsho Plateau, that progressively converged with a northward retreating lobe perpendicular to the ice thrust moraine belt, a northeastward retreating lobe across Etsho Plateau and Bootis Hill, and two eastward retreating lobes along the Hay River channel on either side of Rainbow Ridge. Small-scale readvances (?surges) into glacial lake basins produced local fluting fields, oblique to regional ice flow trends. Drainage from the melting ice lobes and diversion of meltwater from glacial Lake Peace (to the east) led to the deposition of two large glaciolacustrine deltas (blue dashed lines). Retreat of ice from the region largely occurred between 12.5 and 11.5 C^{14} ka BP (Dyke 2004).

FIGURE 1 Basemap showing study area and surrounding region. Letters refer to sites discussed in poster; black lines delineate all-weather roads. Green squares correspond to existing sand and gravel aggregate pits, red triangles indicate potential granular aggregate sites identified by this study. Red dashed line outlines a glacial Lake Hay delta. DEM prepared from Space Shuttle radar data set.

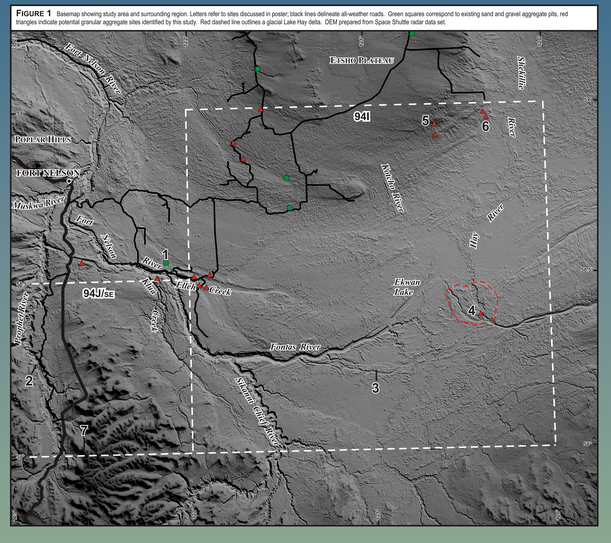
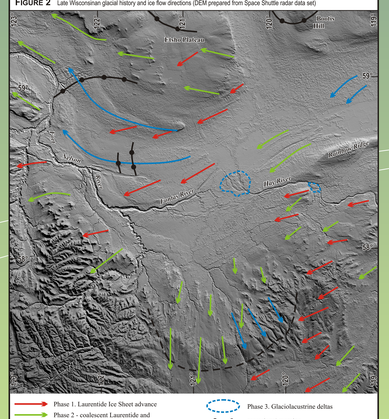


FIGURE 2 Late Wisconsinan glacial history and ice flow directions (DEM prepared from Space Shuttle radar data set)



REGIONAL STRATIGRAPHY

The following description and accompanying litholog (Figure 3) represent a composite section summarizing the glacial and preglacial stratigraphy of the Prophet and Fort Nelson River valleys.

Unit A. Massive and finely-laminated grey clay to fine sand; <1 – >7 m thick; drapes the landscape, at times obscuring underlying topography. Interpreted as glaciolacustrine sediment deposited during ice retreat when regional drainages were ice dammed. Topographic expression (polygonal patterning, mounds and hummocks) suggests melting of buried ice and/or periglacial alteration. Included within this unit is poor to well-sorted gravel occurring as crevasse-squeeze ridges, fans and channel fills, deposited during glacial retreat.

Unit B. Clast-poor (<10%), grey-black to brown clayey-silt diamict; 42 m maximum thickness observed. Clast lithologies are principally Canadian Shield material (granites and gneisses), but also include dolomite, limestone, volcanics, siltstone, chert, quartzites, and local shale, ironstone and sandstone. Interpreted to be a Late Wisconsinan Laurentide till.

Unit C. Fine, horizontally laminated and deformed silt and clay rhythmites. Interpreted as glaciolacustrine sedimentation in a lake created when the paleo-Prophet River was blocked by a tongue of ice from the north-northwest (?Montane). Deformation of beds reflects tectonism caused by overriding ice and overlies undeformed sediment.

Unit D. Boulder to pebble gravel variably cross-bedded. Interpreted as glaciofluvial outwash, deposited in advance of the glacier or possibly ice-marginally or subglacially. Wood in glaciofluvial sands, interpreted to have been deposited during glacial advance, and situated within or underlying the Elleh Creek gravel deposit (Figure 1, site 1) dated 24 400 ± 150 C^{14} yr BP (Levson et al. 2004).

Unit E. Organic-rich clay and silt with a 10 x 20 cm log and a 20 cm thick fibrous peat layer, dated at >44 730 and >45 100 C14 yr BP, respectively (Figure 1, site 2). Interpreted as lacustrine sediment deposited in an interglacial pond or in a pre-Late Wisconsinan ice-dammed lake that experienced considerable fluctuations in water level. The discontinuous diamict beds within this unit may represent debris flows, generated by oscillations in lake level (slumping), or from ice-contact sedimentation.

Unit F. Fluvially-bedded cobble to granule material in a coarse sand matrix; variably imbricated; open and closed-work deposits; >2 m thick. Clast lithologies are dominantly Dunvegan sandstone and chert pebbles, and also include quartz pebbles and minor siltstone, quartzite and ironstone. No Shield erratics observed. Interpreted to be fluvial deposits of a paleo-Prophet River, flowing northeast from the Rocky Mountains.

FIGURE 3 Composite stratigraphic section for the region, illustrating glacial and preglacial deposits, as seen in exposures along the Fort Nelson and Prophet rivers.

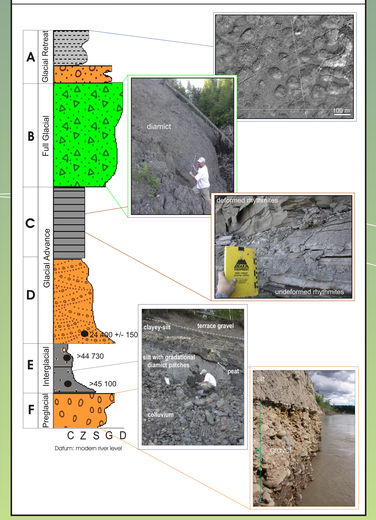




FIGURE 5 Ledcor CMI Ltd. sand and gravel extraction and processing operation, Elleh Creek deposit (Figure 4, site d)

ELLEH CREEK GRAVEL DEPOSIT

The Elleh Creek gravel deposit (Figure 1, site 1; Figure 4, sites a-d) represents the largest known single aggregate resource in proximity to the Sierra-Yoyo-Desan (SYD) road, east of Fort Nelson (the next known gravel source >20 000 m², east of Fort Nelson River, is >125 km away). Previously mined by BC Rail in a minor excavation along its southern margin, field studies and a core log from a single gas well drilled near its center (b-048-a/094-J-09) suggest that the entire 2.25 km x 1 km wide hill (25 – 50 m in height) is comprised of sorted sand and gravel. Estimates of total available granular resource at this site are >1 000 000 m³. In conjunction with construction of the Sierra bypass road and new bridge over the Fort Nelson River, Ledcor CMI Ltd. extracted and processed 165 000 m³ of sand and gravel (Figure 5) from the northeast corner of this deposit in winter 2003 (Figure 4, site d). Given the vastness of the potential granular resource of this site, and its proximity to both the SYD road and a rail line, it is likely that this deposit will continue to be exploited by the oil and gas industry for some time.

SEDIMENTOLOGY

The Elleh Creek gravel deposit is comprised of normally graded, open-work, planar and trough-cross bedded, well to moderately-sorted sand and granule-cobble beds (Figures 6 and 7). Well-rounded to subrounded boulders up to 1 m are found throughout the deposit (Figure 8) and clast lithologies in the deposit are dominantly Canadian Shield derived rocks (e.g., granite, gneiss), but also include sandstones, quartzites, dolomite, limestone, and minor shale.

The Elleh Creek gravel deposit is capped by 0.5–1 m of clayey-sand till, which in conjunction with observations of sheared and deformed (overturned) beds, indicates that this deposit formed preglacially and was then overridden, formed subglacially, or both. It is unknown what directly underlies the gravel deposits. East of here (Figure 1, red triangles), extensive sand and gravel deposits (0.5–4 m thick) were found underlying an upper clayey-sand till (1–3 m thick), and overlying a basal, dark grey clayey-silt till. Many factors suggest all of these gravel deposits may be related (but not necessarily contemporaneous), and therefore the Elleh Creek gravel deposit may similarly represent an intraglacial deposit. Regardless, interpretation of the date of 24 400 ± 150 C^{14} yr BP measured on wood found within sorted sands in an exposure near the base of the unit (Figure 4, site a; Figure 6; Levson and Ferbey 2004; Levson et al. 2004), is that it represents a maximum age, and that Laurentide ice advanced into this area some time after this.

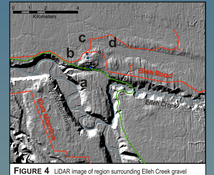


FIGURE 4 LiDAR image of region surrounding Elleh Creek gravel deposit (sites a-d)



FIGURE 6 Well-sorted sand and granule-cobble beds; wood in sands dated 24 400 ± 150 C^{14} yr BP (Figure 4, site a)



FIGURE 7 Poorly sorted planar gravel beds and trough scour (Figure 4, site b)

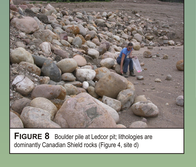


FIGURE 8 Boulder pile at Ledcor pit; lithologies are dominantly Canadian Shield rocks (Figure 4, site d)

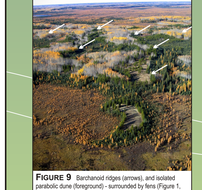


FIGURE 9 Barchanoid ridges (arrows), and isolated parabolic dune (foreground) - surrounded by fens (Figure 1, site 3). View looking north.



FIGURE 10 Small blowout in barchanoid ridge crest. View looking south.

AEOLIAN LANDFORMS

Dunes were discovered in the southeastern part of the 94I map area (Figure 1, site 3). They form a series of prominent 7 m high, >200 m long transverse barchanoid ridges and isolated parabolic dunes (Figures 9 and 10; paleo-wind flow of 98°). Preliminary observations suggests the dune field extends over 20 km. In addition to the dune ridges, there is an extensive veneer and blanket of aeolian sand that extends for >30 km east from the main dune field towards the Hay River. The source of sand is considered to be deflation of glacial lake sediments, derived from regional glacial erosion of poorly indurated Dunvegan Fm. sandstone. Attempts will be made in fall 2005 to sample dunes for OSL dating, which will provide a limiting age on deglaciation.

KOTCHO EAST GRAVEL DEPOSITS

Inspection of seismic shot-hole log data (supplied by EnCana Corporation) indicated the presence of subsurface sand and gravel in the Kotcho East area (Figure 1, site 5). This initial report was followed up by field investigations and test pitting that confirmed the presence of at least 5 m of sand gravel at a number of sites, situated below 1-2 m of glaciolacustrine silt and clay (Figure 11, upper right inset photo). Following this, an electromagnetic (EM) survey was flow over the area in an attempt to trace the extent of the gravel deposit beyond the field tested boundaries and to identify any new gravel targets in the region (Best et al. 2004; Levson et al. 2004). The results shown in Figure 11 clearly identify, not only the original northern gravel prospect site, but a much larger potential gravel occurrence to the south. Test pitting last year in this southern EM anomaly documented 1 to >4 m of gravelly sand underlying 1-5 m of overburden. Estimates of sand and gravel aggregate in the Kotcho East deposits are >450 000 m³.

It should be noted that there is no geomorphic or vegetative expression of these buried sand and gravel deposits. The success of finding such large aggregate deposits using high resolution EM surveys, indicates the importance and effectiveness such tools have in this kind of terrain.

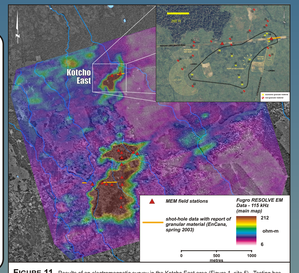


FIGURE 11 Results of an electromagnetic survey in the Kotcho East area (Figure 1, site 5). Testing has indicated that areas of high resistivity correspond to sand and gravel deposits. [Adapted from Levson et al. 2004, Figure 7]

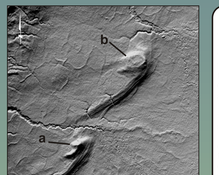


FIGURE 12 LiDAR image of two prominent topographic highs northwest of the Shekilie River (Figure 1, site 6), investigated as potential granular aggregate sites.

SHEKILIE GRAVEL DEPOSIT

Two prominent topographic highs were identified on LiDAR imagery, and chosen for further study this past fall (Figure 1, site 6). The southern feature (Figure 12, site a) is a 20-25 m high conical hill, tentatively interpreted to be a kame. Several pits dug across the feature reveal it to be composed of clean (<5% fines) sandy gravel. Gravel content was estimated as 30-70% by volume, and most clasts are well-rounded quartzites, but also includes Shield rocks (Figure 13). The quality of the gravel, and preliminary reserve estimates of >800 000 m³, would make this an excellent granular aggregate source.

The northern feature (Figure 12, site b) is a 15 m high conspicuously circular hill, with a 1-2 m raised rim along its eastern flank (up-ice flow direction). The upper surface is covered by a coarse stoney till that prevented excavation below 0.5 m. Around the lower eastern margin of the feature, the surface is covered by open-work, well-rounded fine cobbles and granules (abundant quartzites and Shield material) in a fine sandy-silt matrix. Interpretation of these deposits is uncertain, but they may similarly represent ice-contact features (?kames, kame terraces), and should be further investigated, particularly the circular hill, as it too may contain significant granular aggregate material.



FIGURE 13 Well-rounded quartzite and Shield cobbles dug from surface of kame (Figure 1, site 6; Figure 12, site a).

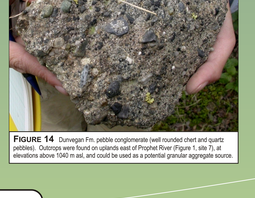


FIGURE 16 Open-work, well-rounded cobble bed (11 m thick) in middle of Hay River delta.

FIGURE 14 Dunvegan Fm. pebble conglomerate (well rounded chert and quartz pebbles). Outcrops were found on uplands east of Prophet River (Figure 1, site 7), at elevations above 1040 m asl, and could be used as a potential granular aggregate source.

HAY RIVER DELTA

The Hay River delta is likely the largest single source of sand (and lesser so, gravel) in the study area and surrounding region. Formed by meltwater draining from the eastward retreating Laurentide Ice Sheet, and decantation of glacial Lake Peace (to the east) into glacial Lake Hay, it exceeds an aerial extent of 160 km² (Figure 1, red dashed line). Maximum recorded thickness is 35 m (Figure 1, site 4; Figure 15), where 14 m of planar-laminate to massive, medium to coarse sand, overlies 11 m of well rounded open-work cobbles (Figure 16), all of which sits atop a further 10 m of medium to coarse sand. The source of the sand is considered to be glacial erosion of poorly indurated Dunvegan Formation sandstone. It is likely that upon drainage of glacial Lake Hay, sand from this delta and associated glaciolacustrine deposits became mobilized by aeolian activity, forming the dunes to the west (Figure 1, site 3). It is curious, however, that there is a near absence of fines (silt and clay) throughout the entire thickness of the Hay River delta. This may indicate that the lake was shallow and that currents moving through the lake were rapid, effectively decanting the fines out the Fontas River canyon outlet.



FIGURE 15 A 35 m section exposed along left cutbank in the Hay River delta. Delta is covered by aspen (in fall colours), and northern margin of delta is just seen at the top of the photo where the darker black spruce forest predominates.

ACKNOWLEDGEMENTS

LiDAR data is used here in partnership with EnCana Corporation.

The cooperation and advice of Tyson Pylypiw and Doug Anderson (EnCana Corporation) is greatly appreciated.

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