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Surficial Materials and Ground Ice Information from Seismic Shotholes in the Mackenzie-Beaufort Region, Yukon and Northwest Territories: Digital Compilation

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1 INTRODUCTION

This Geological Survey of Canada (GSC) Open File contains a database of shothole records for the Mackenzie-Beaufort region of Yukon and Northwest Territories (Fig. 1).

The majority of the shotholes in the Mackenzie-Beaufort region are located within one of two terrestrial ecoregions within the Southern Arctic ecozone; the Yukon Coastal Plain west of the Mackenzie Delta, and the Tuktoyaktuk Coastal Plain to the east (Fig. 1) (Ecological Stratification Working Group 1996). A few shotholes fall within other ecoregions including the British-Richardson Mountains, the Peel River Plateau, and the Dease Arm Plain.

The two main ecoregions have a Low Arctic climate with a mean annual temperature of –10.6°C at Tuktoyaktuk, and –11.0°C at Komakuk Beach. The areas experience low annual precipitation of 168 mm at Tuktoyaktuk, and 161 mm at Komakuk Beach (Environment Canada 2003). Both regions are within the zone of continuous permafrost, with typical thickness ranging from 100 to 600 m (Judge 1973; Mackay 1974; Judge *et al*. 1987).

The major physiographic difference between the two ecoregions is the abundance of lakes in the Tuktoyaktuk Coastal Plain region, which cover 15 to 50% of the total surface area (Mackay 1963, 1988; Sellman *et al*. 1975). Taliks, unfrozen areas in an otherwise continuously frozen landscape, exist beneath lakes of sufficient size and depth. These taliks greatly influence the ground thermal regime in the land adjacent to lakes due to the ability of water to store and transfer heat. This can result in ground temperatures many degrees above those expected in absence of a lake (Williams and Smith 1989, 120).

The 13,574 shotholes in the database (Fig. 2) were originally collected by Gulf/Globe and Imperial Oil in the late 1960's and early 1970's during oil and gas exploration programmes and were acquired by the GSC for research purposes in the early 1970's. The database also includes information on type(s) and thickness(es) of surficial materials encountered at each shothole location.

The data are of primary interest for permafrost researchers concerned with the spatial distribution and characteristics of massive ice and icy sediments. Estimates of the volume and location of massive ice are important factors affecting rates of coastal retreat, and terrain subsidence associated with surface disturbance and/or climate change. The investigation of sediment associations above and below the ice layers can also contribute to the understanding of the origin of the massive ice layers.

A subset of approximately 5,000 of these shotholes was examined by Rampton and Mackay (1971) to summarize the extent of massive ice and icy sediments on Richards Island, Tuktoyaktuk Peninsula and nearby areas. Their analysis required the use of traditional map interpretation techniques involving manual manipulation of the data. Current advancements in computer-based technology, including Geographic Information Systems (GIS), allow large amounts of data to be more easily manipulated and effectively interpreted, facilitating the incorporation of all 13,574 shotholes in subsequent analyses.

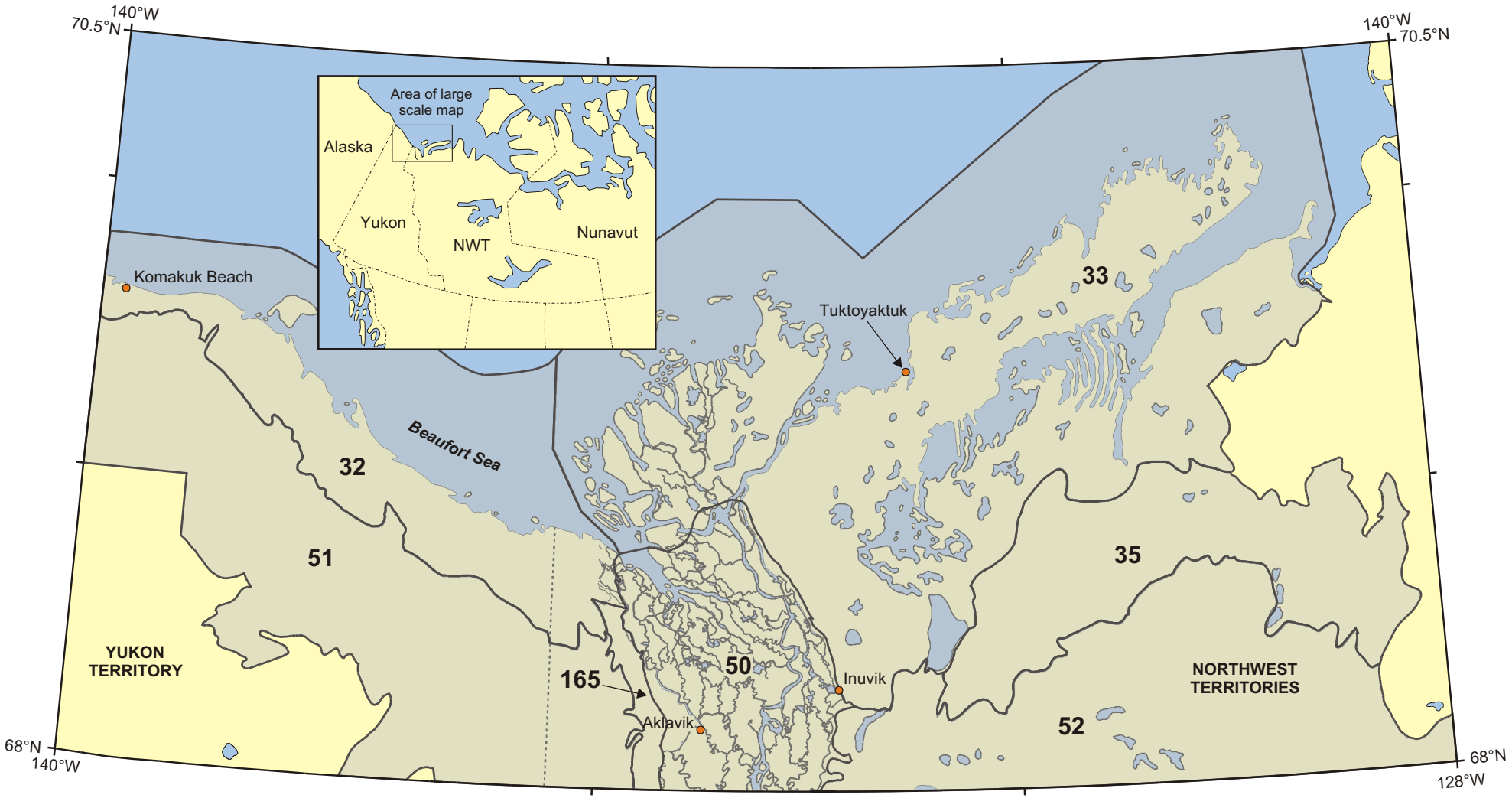

Figure 1 - Mackenzie-Beaufort region with outline of ecoregions overlapping with shothole data. Key to the ecoregions: 32 - Yukon Coastal Plain, 33 - Tuktoyaktuk Coastal Plain, 35 - Dease Arm Plain, 50 - Mackenzie Delta, 51 - Peel River Plateau, 52 - Great Bear Lake Plain, 165 - British-Richardson Mountains (Ecological Stratification Working Group 1996).

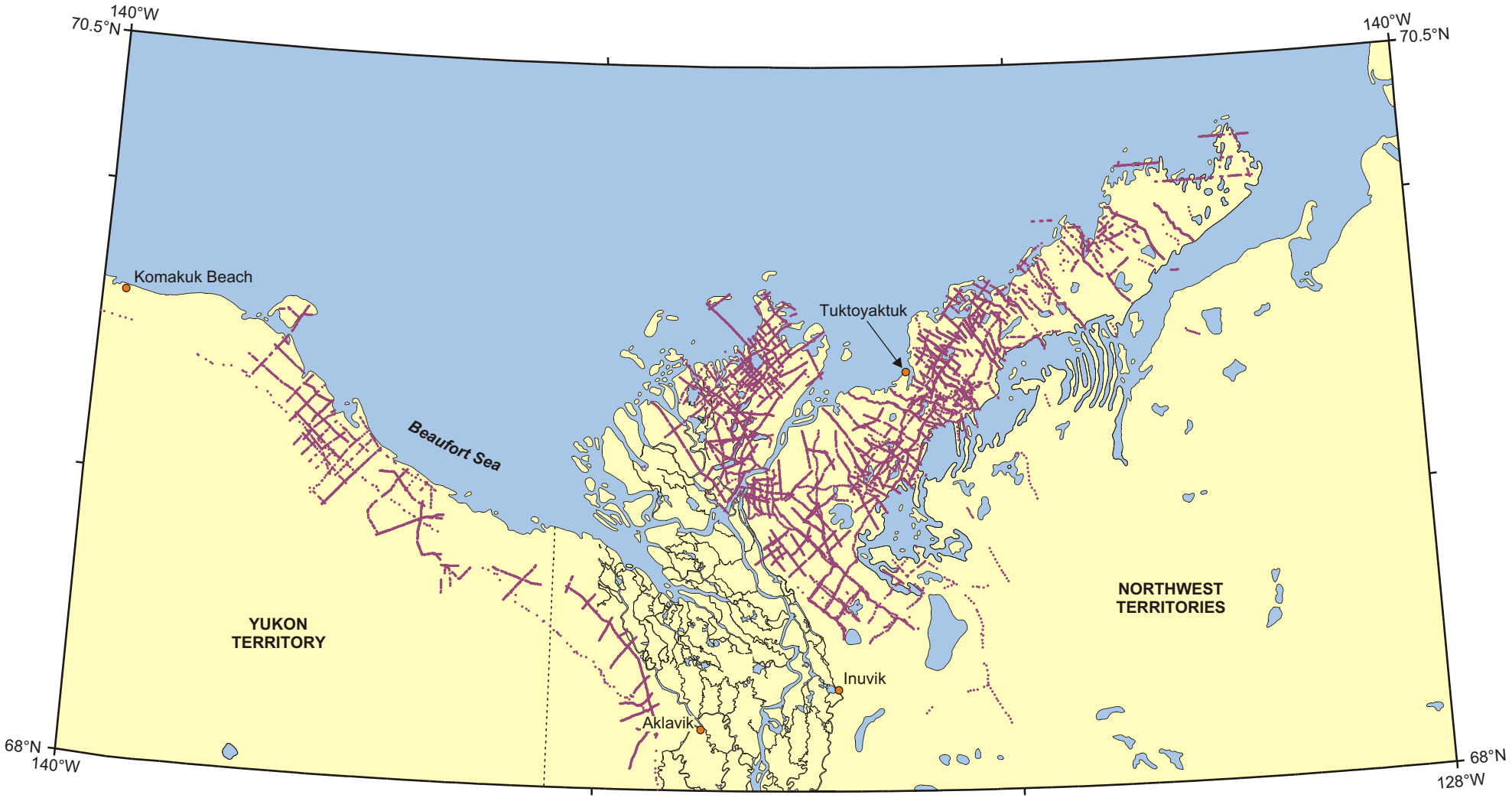

Figure 2 - Distribution of all shotholes in the Mackenzie-Beaufort region, YT and NWT.

The original paper maps were digitized and georeferenced as part of a joint project by the GSC and the Panel on Energy Review and Development (PERD), with the following objectives: 1) to preserve the data in digital format from these paper maps which are subject to degradation and, 2) to make the data readily available for GIS-based analysis.

This Open File presents the digital shothole database, and a cursory analysis of the distribution and characteristics of massive ice and icy sediments within the Mackenzie-Beaufort region.

2 DATA COLLECTION, COMPILATION AND ANALYSIS

Data were collected by seismic drilling crews during winter months and recorded in drill logs, which were subsequently manually transferred to 1:50,000 scale paper basemaps. Sediment characteristics were interpreted visually during the drilling process. Shotholes are believed to accurately represent the general spatial distribution of massive ice and icy sediments in the region (Rampton and Mackay 1971).

Data were digitized on-screen from scanned geo-referenced images of the original paper maps in ArcView® GIS. Attributes for each point were entered into a database file (.dbf) and subsequently verified for accuracy. Shotholes of interest were extracted from the complete database of 13,547 points based on specific criteria using the ArcView® query dialogue box and where then converted in shapefiles. Cursory analyses were performed using the database file in Microsoft® Excel®.

Geographic co-ordinates of each point were determined using the add x-y coordinate script in ArcView® GIS. The latitude and longitude values in decimal degrees were added to the database to allow users to access the spatial information associated with the dataset without a GIS by importing the database file into a standard spreadsheet.

3 LEGEND INFORMATION

Table 1 - Legend code with corresponding descriptive class found in the shothole database. Each legend item may be found individually or in conjunction with others.

Legend Code	Class
b	Boulder
c	Clay
coal	Coal
conglomerate	Conglomerate
g	Gravel
gas	Gas
h	Humus
i	Ice
limestone	Limestone
p	Peat
pebbles	Pebbles
s	Sand
shale	Shale
slate	Slate
sandstone	Sandstone
seasonal	Seasonal
$	Silt
till	Till
w	Water
wood	Wood

4 CAUTIONARY NOTES

a) Given that it can be difficult to discriminate between sediments dominated by silts and those dominated by clays on the basis of field observations, one should be cautious in drawing conclusions relying on a distinction between these two classes. A regrouping of these sediments as “fines” could circumvent this potential issue. In general, remaining sediment types, summarized in Table 1, are distinguishable in the field.

b) Positional accuracy of each shothole is low because the data were collected prior to the advent of Global Positioning Systems (GPS). Data were hand-recorded on 1:50,000 scale paper basemaps, which implies a level of human error as well as error associated with map distortion and degradation over time.

c) The digital basemap provided in this Open File is at a scale of 1:2,000,000, which is adequate for display purposes only. The user should obtain basemaps at a larger scale for spatial analysis.

5 DATABASE SUMMARY

5.1 Massive Ice

Massive ice can be defined as a body of ground ice having a gravimetric ice content exceeding 250%. Commonly, the definition of massive ice includes ice wedges, pingo ice, buried ice, and large ice lenses (Permafrost Subcommittee, Associate Committee on Geotechnical Research 1988). The occurrence of massive ice has been well documented in the Mackenzie-Beaufort region (e.g. Mackay 1971; Mackay and Dallimore 1996). Locations of other observations of massive ice in the Canadian Arctic and Subarctic include Banks Island (e.g. French and Harry 1988), Ellesmere Island (e.g. Pollard 1991; Pollard and Bell 1998), Slave geologic province (e.g. Wolfe 1998), Prince Patrick Island, Mackenzie King Island, and Victoria Island (Mackay 1973) (Fig. 3).

Within the shothole database, all layers specifically identified as “ice” were assumed to be some form of massive ice. Exceptions include ice in layer 1, the uppermost layer, when underlain by water. In this case, it was assumed to be seasonal sea or lake ice that is not frozen to the lakebed or seabed. As well, ice in layer 1 that is underlain by sediment when positioned near the centre of a lake or offshore was assumed to be sea or lake ice that is frozen to the lakebed or seabed. These data were reclassified from “ice” to “seasonal ice” in the database.

Shotholes with massive ice in layer 1 that overlap with waterbodies on the 1:250,000 scale basemaps are legitimate and are assumed to accurately represent the local surficial materials. Possible reasons for these overlaps include uncertainties in positional accuracy of the maps, changes in the shorelines and coasts over time, errors in positional accuracy with the shotholes, generalizations on the basemaps and the sudden catastrophic drainage of lakes (Mackay 1988).

A total of 1046 (7.7%) shotholes intersected at least one massive ice layer within the profile. In this summary analysis, the occurrence of pure ice in near-surface sediments was assumed to be the result of the intersection of the shothole with an ice wedge, which upon melting would not have the same terrain impacts as tabular massive ice. On this basis, a threshold depth of 5 m (~16 ft) (Rampton and Mackay 1971; Dallimore *et al*. 1996) was assumed such that 310 (30%) shothole observations of massive ground ice were reclassified as wedge ice, and were excluded from the subsequent analysis of massive ice distribution (Rampton and Mackay 1971). The remaining 752 massive ice layers were distributed in 736 shotholes, as 16 holes had multiple ice layers (Fig. 4). Finally, massive ice layers <1 m thick can be considered ice lenses and ice clasts (Dallimore *et al*. 1996), and were excluded from analysis of massive ice occurrence. However, in this dataset, only three observations of massive ice <1 m thick were made (all 0.9 m). These shotholes were retained in the database after taking measurement error into consideration. The mean thickness of the observed massive ice layers is 11.1±7.8 m with a skewness of 1.3 indicating a near-normal distribution. Additional descriptive statistics for the thickness of massive ice layers are presented in Table 2.

Figure 3 - Observations of massive ice, indicated in red, as documented in the literature.

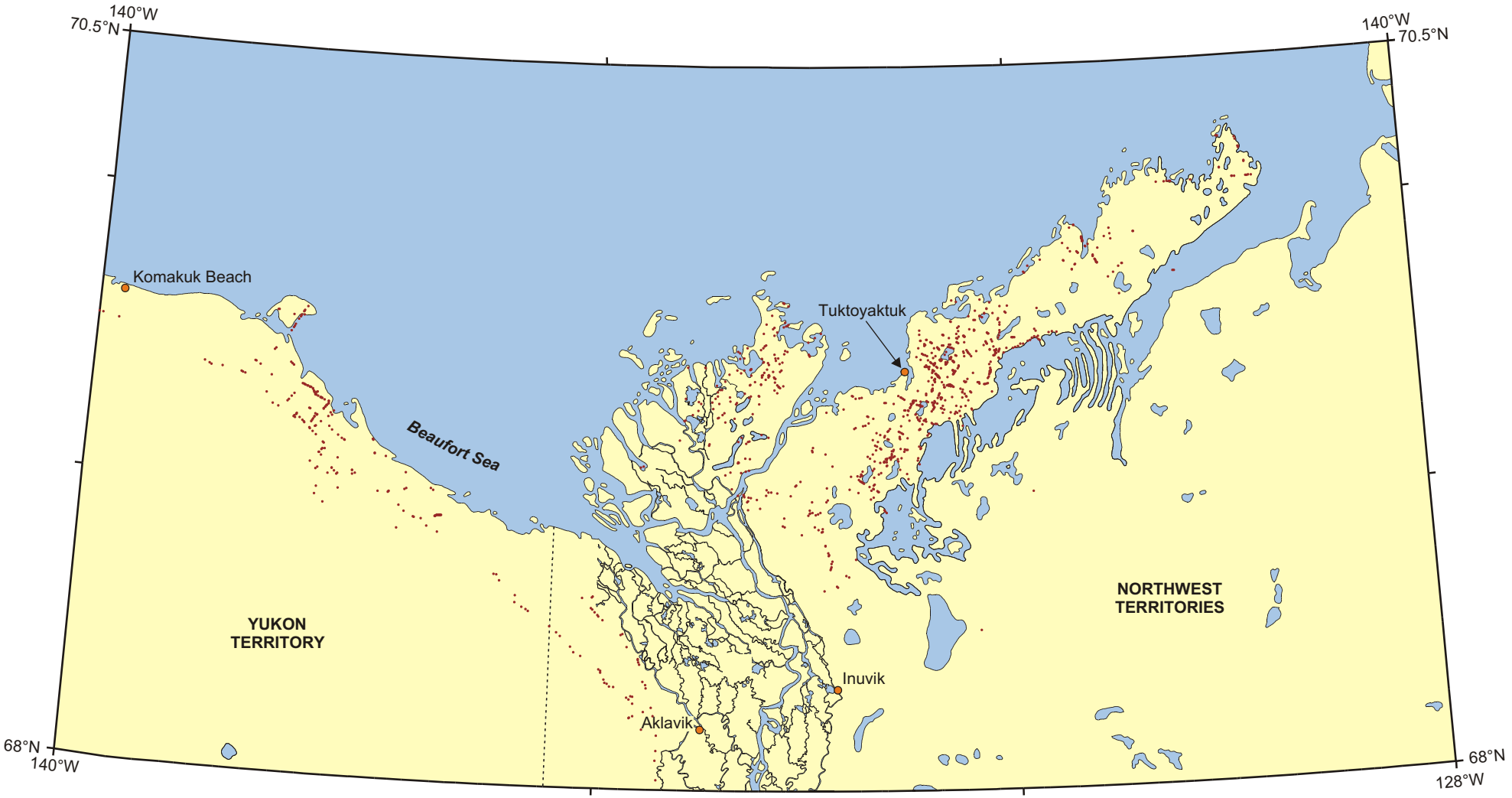

Figure 4 - Distribution of shotholes with non-wedge ice massive ice layers in the Mackenzie-Beaufort region.

Table 2 - Descriptive statistics* on thickness of massive ice layers.

Mean	11.1 m
Standard Error	0.3
Median	9.1 m
Mode	9.1 m
Standard Deviation	7.8 m
Kurtosis	2.7
Skewness	1.3
Range	60.1 m
Minimum	0.9 m
Maximum	61.0 m
Count	752

*159 shotholes did not penetrate through the massive ice layer, therefore the descriptive statistics under-represent the average thickness of the massive ice layers.

5.2 Icy Sediments

Icy sediments are sediments that contain volumes of ground ice that exceeds the total pore volume that the ground would have under natural unfrozen condition. Excess ice is often found in the form of ice lenses (Mackay 1966). No threshold thickness was defined for the classification of icy sediments; therefore all occurrences of icy sediments are included in this analysis (Fig. 5).

At least one layer of icy sediments is present in 2948 shotholes (21.8%). An additional 188 shotholes contained multiple layers of icy sediments, resulting in a total of 3151 icy sediment layers in the database. The mean thickness of icy sediment layers is 16.0±10.6 m, with a with a near-normal skewness value of 0.6 (Table 3).

Table 3 - Descriptive statistics* on thickness of icy sediment layers.

Mean	16.0 m
Standard Error	0.2
Median	15.2 m
Mode	18.3 m
Standard Deviation	10.6 m
Sample Variance	111.6
Kurtosis	-0.3
Skewness	0.6
Minimum	0.2 m
Maximum	54.9 m
Count	3151

*1588 shotholes did not penetrate through the icy sediment layer, therefore the descriptive statistics under-represent average thickness of the ice layers.

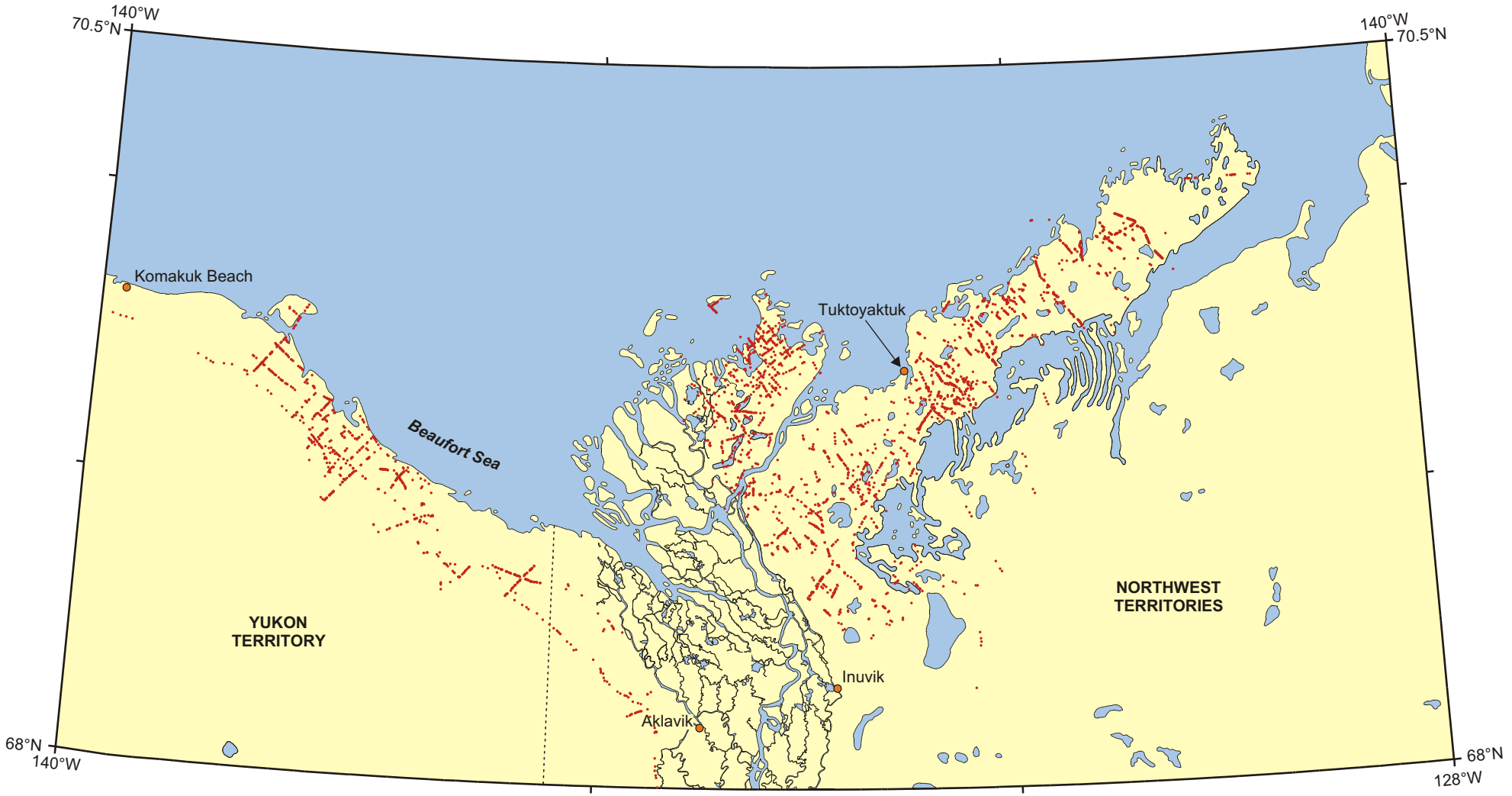

Figure 5 - Distribution of shotholes with icy sediment layers in the Mackenzie-Beaufort region.

6 DIGITAL DATABASE FORMAT

6.1 Shotholes

Map projection and attribute information apply to the Shotholes file, as well as the Non_wedge_ice, Icy_sediments, and Wedge_ice subset files.

6.1.1 File Description and Map Projection

File format (entity type):	Shapefile (point)
Filename:	Shothole (or Non_wedge_ice, Icy_sediments, Wedge_ice)
File title:	Seismic Shothole Database for the Mackenzie Delta-Beaufort Coastal Region, Yukon and Northwest Territories
File description:	Compilation of approximately 13,574 shotholes containing information about surficial materials and thickness of deposits.
File size:	~5.8 Mb

Projection:	Lambert Conformal Conic
Ellipsoid:	GRS 80
Central Meridian	95°W
Reference Latitude	49°N
1st Standard Parallel	49°N
2nd Standard Parallel	77°N
False Easting	0 m
False Northing	0 m

6.1.2 Attribute Field Names

Shape	Identifies shape type in ArcView®. Field is required by the software;
Recno	Record number for each hole in the dataset;
Layer_1	Thickness of first sediment layer in the shothole profile (ft);
Class_1	Sediment material of first layer in the shothole profile;
Layer_2	Bottom depth of second sediment layer in the shothole profile (ft);
Class_2	Sediment material of second layer in the shothole profile;
Layer_3	Bottom depth of third sediment layer in the shothole profile (ft);
Class_3	Sediment material of third layer in the shothole profile;
Layer_4	Bottom depth of fourth sediment layer in the shothole profile (ft);
Class_4	Sediment material of fourth layer in the shothole profile;
Layer_5	Bottom depth of fifth sediment layer in the shothole profile (ft);
Class_5	Sediment material of fifth layer in the shothole profile;
Layer_6	Bottom depth of sixth sediment layer in the shothole profile (ft);
Class_6	Sediment material of sixth layer in the shothole profile;
Layer_7	Bottom depth of seventh sediment layer in the shothole profile (ft);
Class_7	Sediment material of seventh layer in the shothole profile.

6.2 Basemap

6.2.1 File Description and Map Projection

File format (entity type):	Shapefile (polygon)
Filename:	Basemap
File title:	Basemap for the Mackenzie Delta-Beaufort Coastal Region, Yukon and Northwest Territories
File description:	Basemap data for the study area. Includes land and water at a scale of 1:2,000,000.
File size:	~1.2 Mb

Projection:	Lambert Conformal Conic
Ellipsoid:	GRS 80
Central Meridian	95°W
Reference Latitude	49°N
1st Standard Parallel	49°N
2nd Standard Parallel	77°N
False Easting	0 m
False Northing	0 m

6.2.2 Attribute Field Names

Shape	Identifies shape type in ArcView®. Field is required by the software;
Entity	Entity type.

6.3 Communities

6.3.1 File Description and Map Projection

File format (entity type):	Shapefile (point)
Filename:	Communities
File title:	Communities in the Mackenzie Delta-Beaufort Coastal Region, Yukon and Northwest Territories
File description:	Communities in the Mackenzie Delta-Beaufort coastal region, Yukon and Northwest Territories
File size:	<1 Mb

Projection:	Lambert Conformal Conic
Ellipsoid:	GRS 80

Central Meridian	95°W
Reference Latitude	49°N
1st Standard Parallel	49°N
2nd Standard Parallel	77°N
False Easting	0 m
False Northing	0 m

6.3.2 Attribute Field Names

Shape	Identifies shape type in ArcView®. Field is required by the software;
Community	Name of community.

6.4 National Topographic System (NTS) Limits

6.4.1 File Description and Map Projection

File format (entity type):	Shapefile (polygon)
Filename:	NTS
File title:	NTS limits for mapsheets in the Mackenzie Delta-Beaufort Coastal Region, Yukon and Northwest Territories.
File description:	NTS limits for mapsheets in the Mackenzie Delta-Beaufort coastal region, Yukon and Northwest Territories.
File size:	<1 Mb

Projection:	Lambert Conformal Conic
Ellipsoid:	GRS 80
Central Meridian	95°W
Reference Latitude	49°N
1st Standard Parallel	49°N
2nd Standard Parallel	77°N
False Easting	0 m
False Northing	0 m

6.4.2 Attribute Field Names

Shape	Identifies shape type in ArcView®. Field is required by the software;
NTS	National Topographic System identification for each map sheet;
Title	National Topographic System title for each map sheet.

7 ACKNOWLEDGEMENTS

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