Geo-Note 2002-01

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Observations of Naturally Occurring Hydrocarbons (Bitumen) in Quaternary Sediments, Athabasca Oil Sands Area and Areas West, Alberta

Alberta Energy and Utilities Board

Alberta Geological Survey

AGS

Observations of Naturally Occurring Hydrocarbons (Bitumen) in Quaternary Sediments, Athabasca Oil Sands Area and Areas West, Alberta

L. D. Andriashek, P. Geol., and J. Pawlowicz

Alberta Geological Survey

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Telephone: (780) 422-3767 (Information Sales)
Fax: (780) 422-1918
E-Mail: EUB.AGS-Infosales@gov.ab.ca
Website: www.ags.gov.ab.ca

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Dr. Martin Fowler of the Geological Survey of Canada, Calgary, conducted the analysis on one of two hydrocarbon-rich till samples collected in this study, and prepared an interpretative report on the results.

Norwest Laboratories of Edmonton conducted the hydrocarbon analysis on the other till sample.

Abstract

Hydrocarbon odours were detected in samples of Quaternary sediment (till) collected from outcrops and drill core from locations in northern Alberta. Analyses of two hydrocarbon odour-rich till samples confirmed the petroliferous odours, and established that the source was most probably from bitumen derived from Cretaceous-aged oil sand deposits in northern Alberta. This report documents the locations where hydrocarbon odours were detected, it provides a brief description of the geological and stratigraphic setting of each site, and presents the analytical results of hydrocarbon analyses of two core samples of till. The relatively widespread distribution of observations indicates that naturally occurring hydrocarbons likely are regionally extensive within Quaternary sediments, particularly till. This becomes significant from an environmental site-characterization perspective if baseline values have not been established for the Quaternary drift prior to energy development in the region.

1. Introduction

During ongoing regional characterization of the bedrock topography and Quaternary stratigraphy in northern Alberta, the Alberta Geological Survey (AGS) encountered tills with anomalous occurrences of hydrocarbon, likely bitumen. This report presents observational information on the occurrence of hydrocarbons in surficial sediments and includes some of the analytical results obtained to date. Some brief comments are made regarding the possible origin and process of hydrocarbon enrichment within till.

2. Location and Sampling Methods

Figure 1 shows the locations of the core holes and surface outcrops where traces or odours of hydrocarbon were detected in tills. Core holes designated by the prefix 'WEPA' are located in the Stony Mountain and Mostoos uplands (Pettapiece, 1986) in the Athabasca Oil Sands (in situ) Area. Core hole PL01-1 and surface outcrop NAT98-244 are located north of the community of Red Earth in the Loon Lake Plain (Pettapiece, 1986), west of the Athabasca Oil Sands (in situ) Area. Additional observations of odours were made in cores and outcrops of till in the Wabasca region. Core samples were collected using a wet-rotary drill with 3-metre long, 7.5-cm diameter core barrels. Detailed field litholog descriptions record the natural occurrence of hydrocarbon odours in freshly-cut till samples as one of four subjective classes: faint, weak, moderate, and strong.

Cored samples of the till from two of the core holes, WEPA00-1 and PL01-1, were submitted for hydrocarbon analyses to confirm field observations and to determine possible hydrocarbon source. Hydrocarbon sample #1 was collected from core hole WEPA00-1. The sample consisted of approximately 15 cm of till core, or about 1 to 1.5 kg of sample collected from the most odour-rich part of the core at a 46 m depth. Sampling was carried out in the field during drilling. The 15 cm sample was stored in a glass vessel and later submitted to Norwest Labs in Calgary, within two weeks of drilling, for hydrocarbon determinations.

Hydrocarbon sample #2 was collected from core hole PL01-1. It consisted of 10 cm of core or approximately 1 kg of till with a pronounced bitumen odour. This core hole was logged in the field during drilling, stored in wooden core boxes for sampling at AGS' Mineral Core Research Facility, Edmonton. During follow up inspection of the core, approximately two weeks after drilling, a noticeable bitumen odour was still present. The sample was collected at this time, from a depth of 10 m, wrapped in a 5 mm plastic bag, and submitted to the Geological Survey of Canada Calgary for analysis under the direction of Dr. Martin Fowler.

3. Core Hole Log Descriptions

This section briefly discusses the occurrences of hydrocarbon with depth in glacial sediments within each of the core holes. A legend of the core hole lithologies is shown in Figure 2.

3.1 Core Hole WEPA99-1

Core hole WEPA99-1 is located on an upper terrace on the north side of the House River in LSD 3, sec 8, twp. 77, rge. 14 W4M (Figure 1). The hole was drilled, cored, and logged to a depth of 166 m, and was terminated after sampling a few metres into the top of the shale of the Colorado Group. The contact between Quaternary sediments and the bedrock was intersected at a depth of about 154 m (Figure 3).

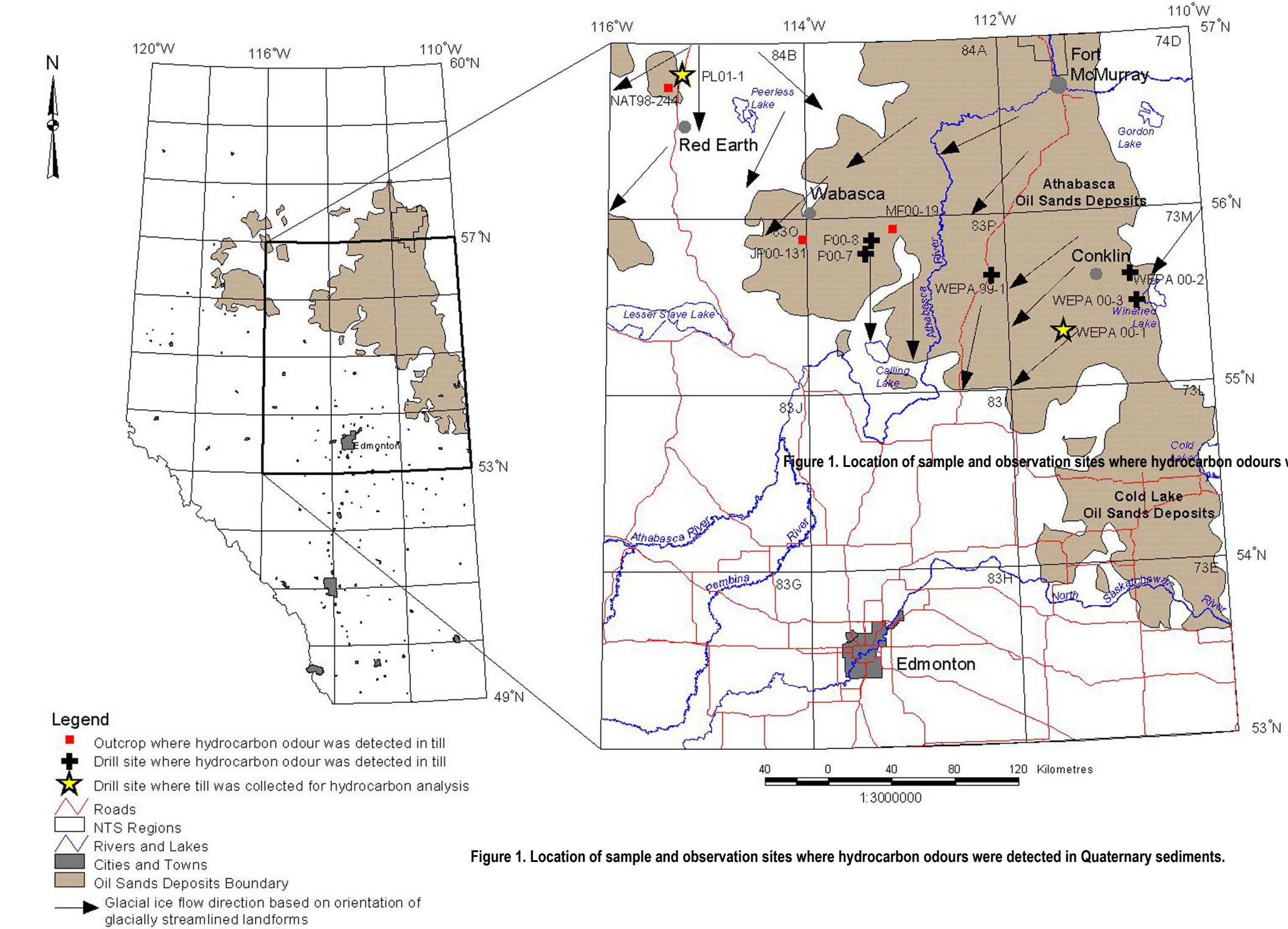


Figure 1. Location of sample and observation sites where hydrocarbon odours w

Figure 1. Location of sample and observation sites where hydrocarbon odours were detected in Quaternary sediments.

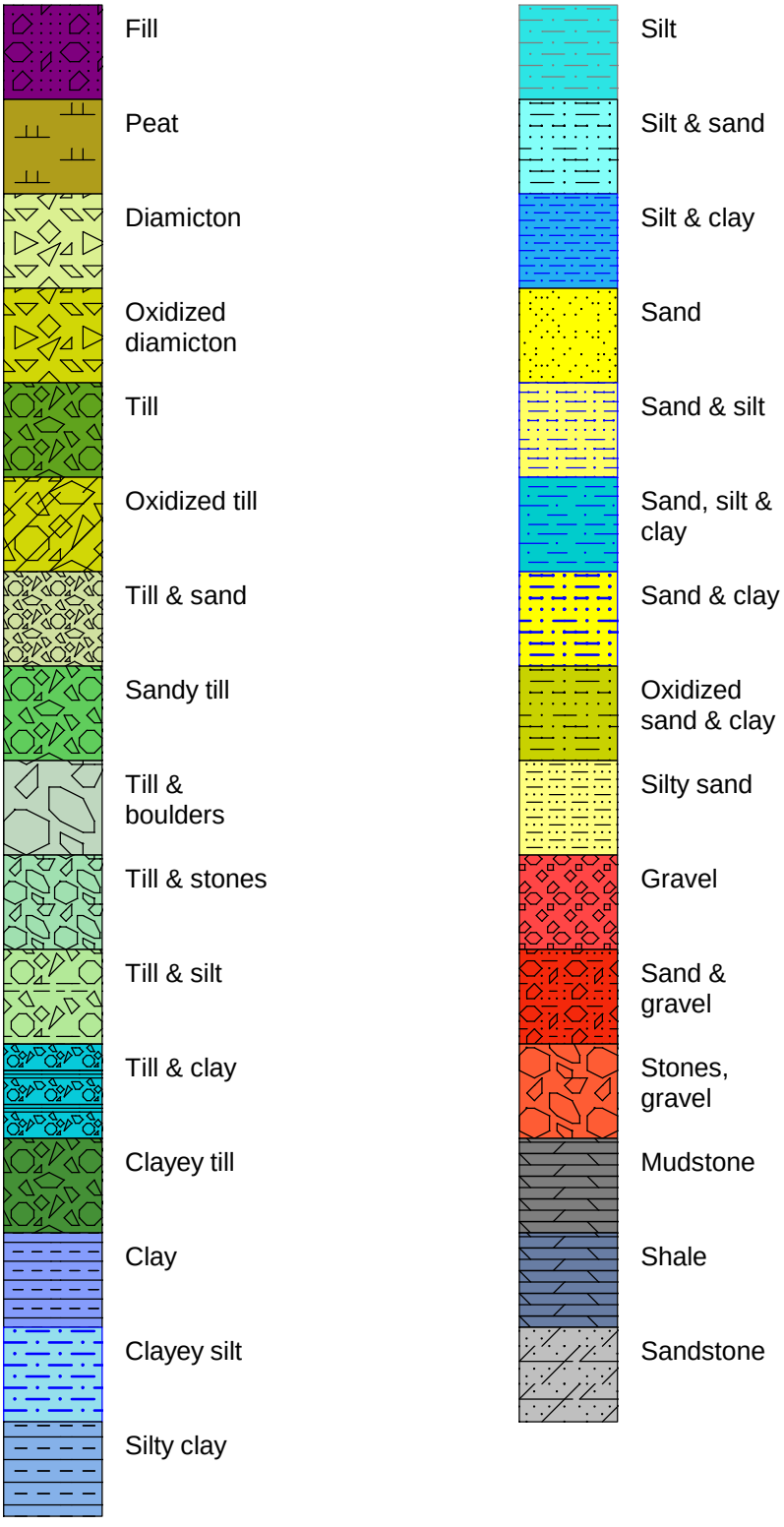
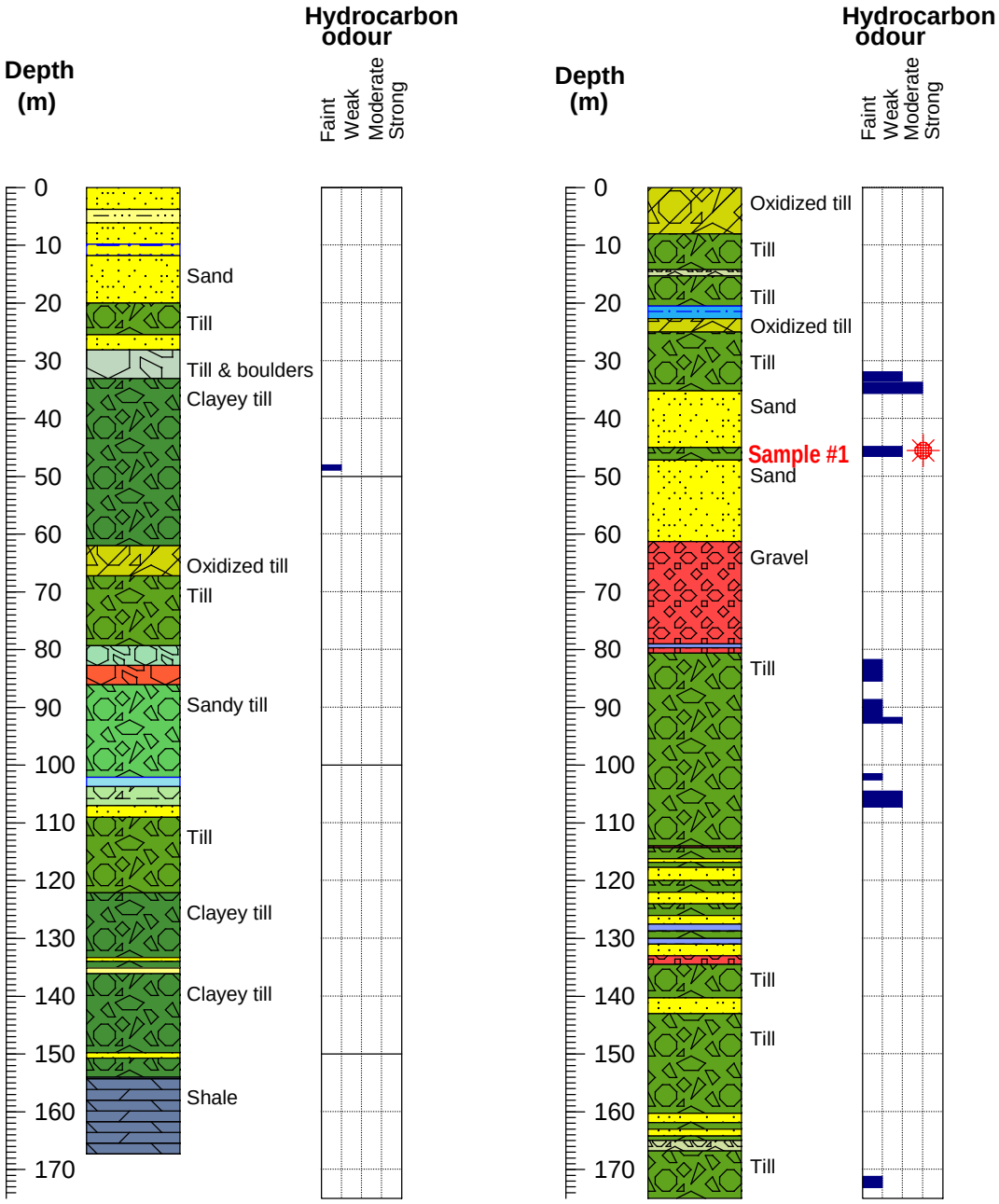


Figure 2. Core hole lithology legend.

Well Name:	WEPA99-1	WEPA00-1
Location (DLS):	03-08-077-14W4Mer	06-33-074-09W4Mer
Latitude:	55.6517371°	55.4513762°
Longitude:	112.1468557°	111.3298897°
Surveyed Ground Level:	660.92 masl	666.83 masl



Legend for lithological symbols in Figure 2.

Figure 3. Lithological properties and hydrocarbon-odour concentrations in Quaternary sediments, core holes WEPAA99-1 and WEPAA00-1.

From the surface down, the lithology of the core hole can be summarized as 20 m of terrace sand overlying 134 m of till, which contains a number of 2 to 3 m thick sand and gravel beds.

Some lithological aspects of note are:

- Enrichment of the till matrix with clay, and inclusions of clay clasts, at a depth interval of about 40 m to 50 m, interpreted to be the incorporation of shale by glacial erosion, and
- A 4-m-thick buried oxidized profile on the till at a depth of about 62 m, which is interpreted to be the unconformable, weathered surface of an older till.

Faint hydrocarbon odours were detected in only one core sample of till, at a depth of about 48 m, in the clay-enriched zone above the buried oxidized profile.

3.2 Core hole WEPA00-1: Site of Hydrocarbon Sample #1

WEPA00-1 is located in a low relief, hummocky moraine landscape adjacent to the abandoned Margie railway siding, directly north of Wiau Lake in LSD 6, sec. 33, twp. 74, rge. 9 W4M (Figure 1). The hole was drilled, cored, and logged to a depth of 174 m, and was terminated while still in Quaternary sediment (Figure 3).

Till is the dominant lithology in the core hole, with the exception of a thick succession of sand and gravel at a depth of 35 to 81 m. Numerous thin (1 to 2 m) interbeds of sand and till are in the lower part of the core hole. The tills encountered in this hole have grain-size properties typical for the area. That is, they generally have a pebbly clay loam to sandy clay loam composition with about 1 to 2% pebbles. Pebble concentrations increased abruptly at a depth of about 143 m, the composition of which was mainly siltstone and shale of the local Cretaceous bedrock. Of note is a 2.5 m thick buried, oxidized horizon at about 22.5 m, which is interpreted to represent an unconformable weathered surface of an older till.

Odours of hydrocarbon (similar to bitumen odour), and a faint ‘rotten egg’ smell, were first noted in core recovered from a depth of about 32 m, and hydrocarbon odour was evident in varying concentrations to a depth of about 108 m (Figure 3). None of the cores of till showed any evidence of free hydrocarbon, nor clasts or inclusions of hydrocarbon-bearing rocks such as bitumen saturated sandstone. In addition to hydrocarbon odour, a dark oily emulsion was evident on the surface of the drill mud in the circulation tank when the core bit reached a depth of about 32.5 m (Figure 4).

This emulsion persisted on the drill mud surface over a four-day period until the hole was abandoned. Also of note are observations of bubbles rising up the core hole when the drill operations ceased momentarily, at a depth of about 78 m in sand and gravel. The driller indicated the rig was not experiencing any problems with the seals on the mud pumps, which could be introducing air into the drill fluid.

At a depth of about 35 m a decision was made to sample a section of till from the next core run which, on the basis of the previous run, was expected to have the most concentrated hydrocarbon odour. However, the lithology changed from till to sand at about 35.5 m, and the next encounter of sediment with odour was the relatively thin till bed between 45 and 47 m, at which depth a 15 cm thick sample of core was extracted and sealed in a glass vessel. Results of the hydrocarbon analysis of this sample, sample #1, are shown in Table 1, and depicted graphically in Figures 5 to 7. A comparison of the shape of the hydrocarbon chromatogram curves from sample #1 with type curves of various hydrocarbon products (Figures 6 and 7) shows that the hydrocarbon in the till at WEPA00-1 most closely resembles heavily weathered crude oil, indicating that the source is probably bitumen.

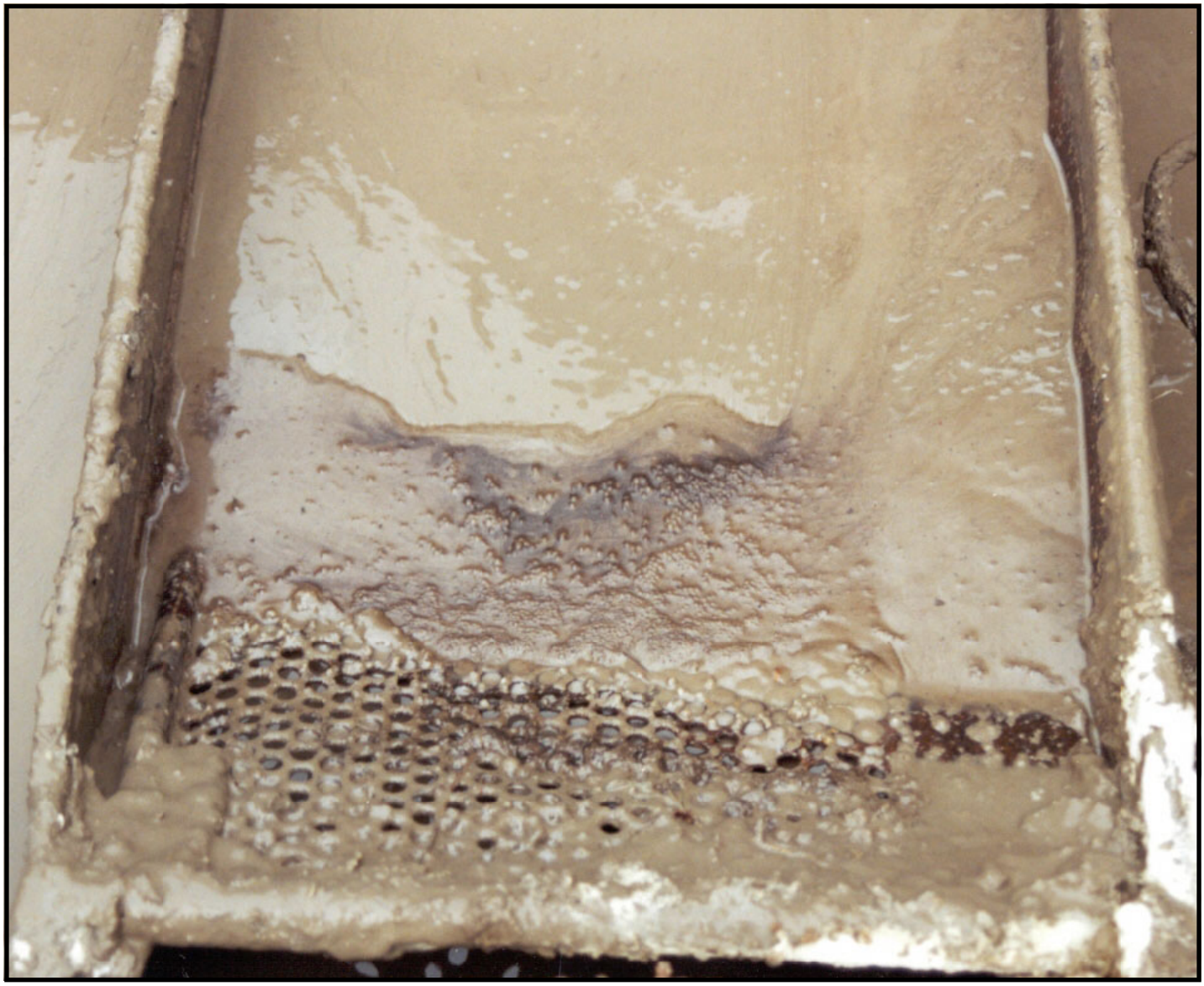


Figure 4. Oily emulsion in drill-mud tank, core hole WEPAA00-1. The emulsion was first observed when drilling in till at a depth of about 32.5 m, and was visible in the drill mud over the next four days, until the hole was abandoned at a depth of 173.5 m.

Table 1. Results from analysis of hydrocarbon sample #1 from core hole WEPA00-1.

Carbon Number	Total Sample dry wt. (mg/kg)	Saturates Fraction dry wt. (mg/kg)	Aromatics Fraction dry wt. (mg/kg)	Detection limit
C11	<1	1	<1	1
C12	<1	2	<1	1
C13	2	3	<1	1
C14	5	5	<1	1
C15	7	6	1	1
C16	13	12	2	1
C17	17	12	3	1
C18	24	18	3	1
C19	29	22	4	1
C20	29	21	6	1
C21	31	23	6	1
C22	33	20	6	1
C23	30	25	8	1
C24	31	22	8	1
C25	32	22	9	1
C26	33	21	10	1
C27	34	22	11	1
C28	28	18	9	1
C29	36	22	12	1
C30	37	26	15	1
C31	44	21	13	1
C32	35	19	13	1
C33	28	15	11	1
C34	34	17	16	1
C35	39	20	13	1

Carbon Number	Total Sample dry wt. (mg/kg)	Saturates Fraction dry wt. (mg/kg)	Aromatics Fraction dry wt. (mg/kg)	Detection limit
C36	32	15	13	1
C37	31	14	13	1
C38	25	14	11	1
C39	37	11	13	1
C40	25	13	13	1
C41	30	13	10	1
C42	17	10	13	1
C43	28	9	10	1
C44	28	11	12	1
C45	22	6	10	1
C46	22	8	10	1
C47	16	10	10	1
C48	27	8	10	1
C49	22	7	10	1
C50	22	7	7	1
C51	16	5	10	2
C52	21	7	10	2
C53	22	6	8	2
C54	16	5	8	2
C55	16	5	13	2
C56	16	4	8	2
C57	22	6	8	2
C58	17	6	8	2
C59	23	4	10	2
C60+	619	74	238	20
Total	1803	693	665	

C_{11} - C_{60}+ Hydrocarbon Characterization

Fraction	Concentration dry wt. (mg/kg)	% of Total
Total Saturates/Aliphatics (C11-C60+)	693	38.4
Total Aromatics (C11-C60+)	665	36.9
Polars and Asphaltenes (by difference)	445	24.7
Total Extractable hydrocarbons (C11-C60+)	1803	100.0

C_{60} Hydrocarbon Analysis Calibration Check

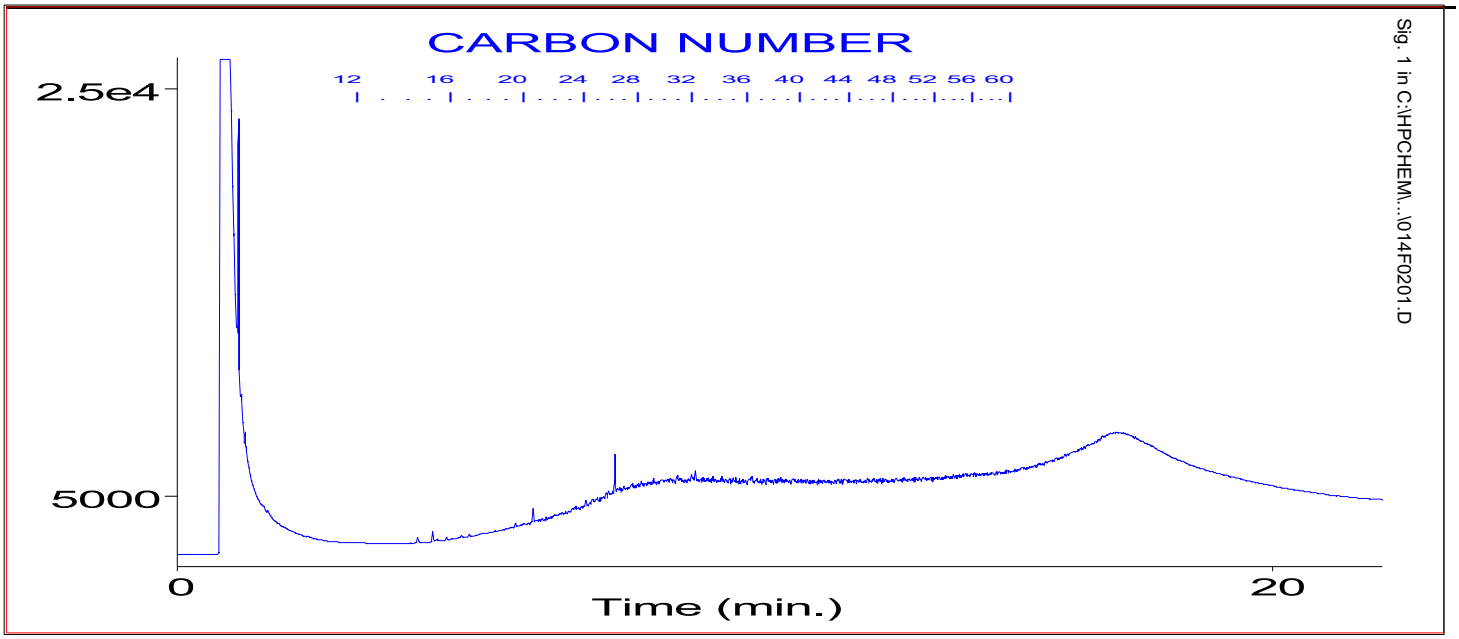
Carbon Number	Actual mg/L	Recovered mg/L	% Recovery
C12	20	21	105
C14	30	32	107
C16	40	42	105
C18	50	53	106
C20	60	64	107
C22	80	85	106
C24	100	105	105
C26	120	127	106
C28	120	126	105
C30	100	106	106
C32	80	84	105
C36	60	64	107
C40	50	52	104
C44	40	42	105
C50	30	32	107
C60	20	21	105

Hydrocarbon Chromatogram

Project ID:	Wepa 00-1 46-46.5m	NWL Lot ID:	86819	Analysis conducted by Norwest Labs, Calgary
Name:	Wepa Hydrogeology Project	Control Number:	E 49396	
Location:		Date Received:	Oct 5, 2000	
LSD:	06-33-074-09W4M	Date Reported:	Apr 10, 2002	

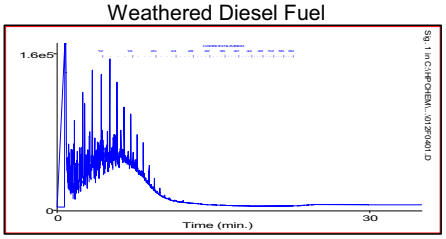
NWL Number:	86819-1	Sample Description:	Glacial Till Core
Sample Date:			46-46.5 m

Aromatics Fraction

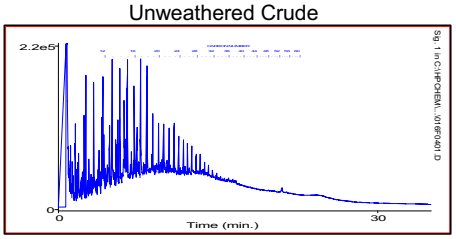


TYPICAL PRODUCT CHROMATOGRAMS

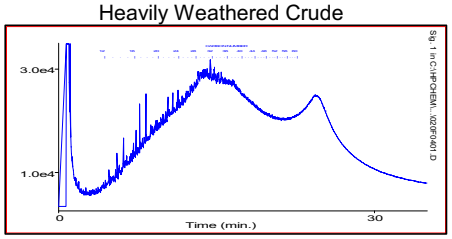
Weathered Diesel Fuel



Unweathered Crude



Heavily Weathered Crude



Product Carbon Number Ranges

Gasoline	C4-C12	Kerosene	C7-C16	Lubricating Oils	C20-C40
Varsol	C8-C12	Diesel	C8-C22	Crude Oils	C3-C60+

Accredited by the Standards Council of Canada (SCC) and by the Canadian Association for Environmental Analytical Laboratories (CAEAL) for specific tests registered with the Council and the Association

Figure 5. Hydrocarbon gas chromatogram (aromatics fraction) of sample #1, till core from WEPA00-1, 46m depth.

Hydrocarbon Chromatogram

Project ID: Wepa 00-1 46-46.5m
Name: Wepa Hydrogeology Project
Location:
LSD: 06-33-074-09W4M

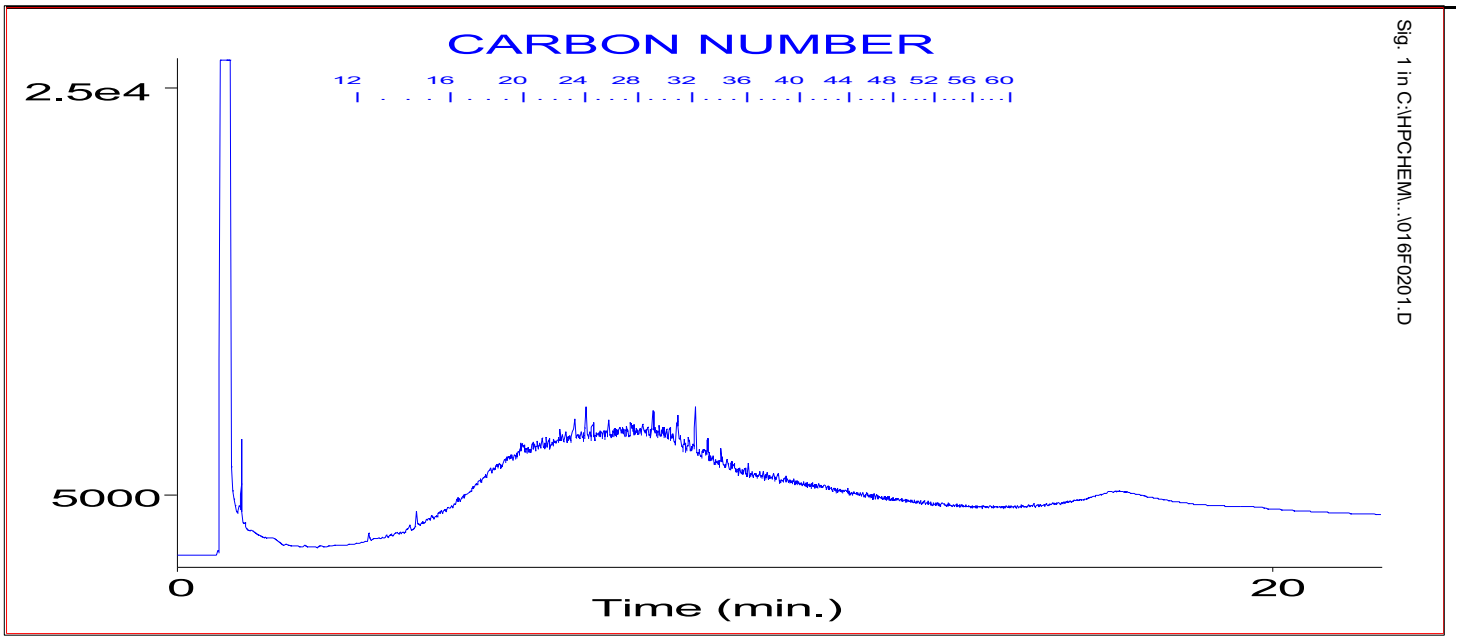
NWL Lot ID: 86819
Control Number: E 49396
Date Received: Oct 5, 2000
Date Reported: Apr 10, 2002

Analysis conducted by Norwest Labs, Calgary

NWL Number: 86819-1
Sample Date:

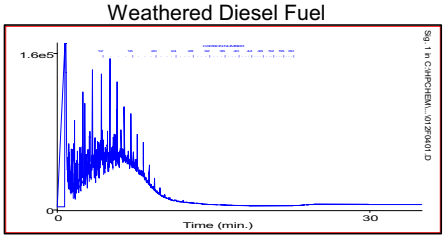
Sample Description: Glacial Till Core
46-46.5 m

Saturates Fraction

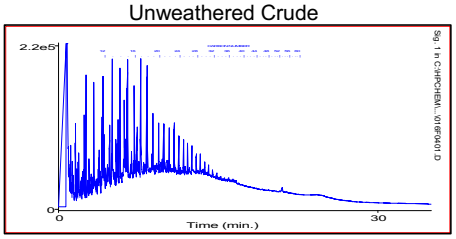


TYPICAL PRODUCT CHROMATOGRAMS

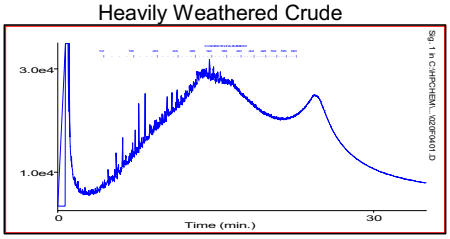
Weathered Diesel Fuel



Unweathered Crude



Heavily Weathered Crude



Product Carbon Number Ranges

Gasoline	C4-C12	Kerosene	C7-C16	Lubricating Oils	C20-C40
Varsol	C8-C12	Diesel	C8-C22	Crude Oils	C3-C60+

Accredited by the Standards Council of Canada (SCC) and by the Canadian Association for Environmental Analytical Laboratories (CAEAL) for specific tests registered with the Council and the Association

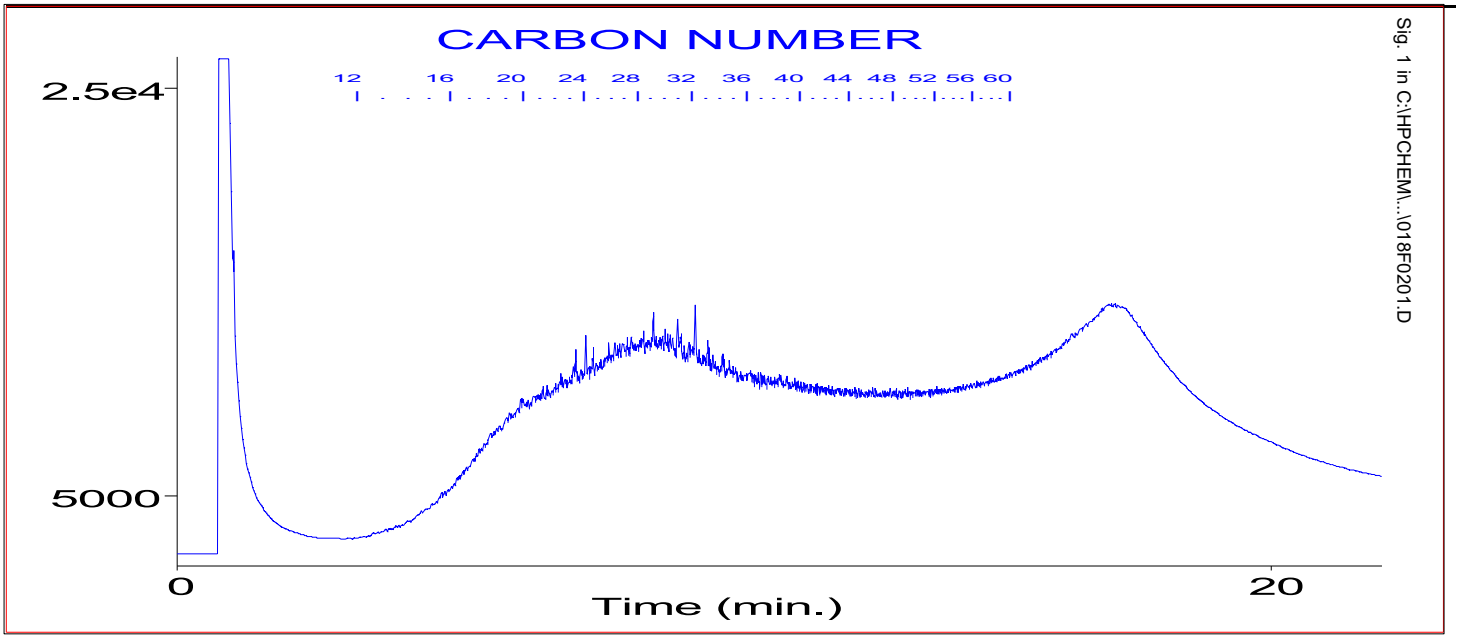
Figure 6. Hydrocarbon gas chromatogram (saturates fraction) of sample #1, till core from WEPAA00-1, 46 m depth.

Hydrocarbon Chromatogram

Project ID:	Wepa 00-1 46-46.5m	NWL Lot ID:	86819	Analysis conducted by Norwest Labs, Calgary
Name:	Wepa Hydrogeology Project	Control Number:	E 49396	
Location:		Date Received:	Oct 5, 2000	
LSD:	06-33-074-09W4M	Date Reported:	Apr 10, 2002	

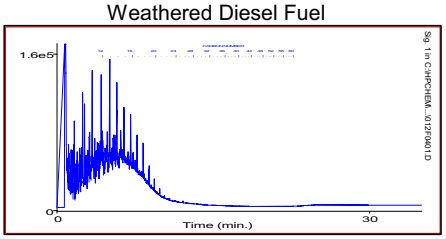
NWL Number:	86819-1	Sample Description:	Glacial Till Core
Sample Date:			46-46.5 m

Total Sample

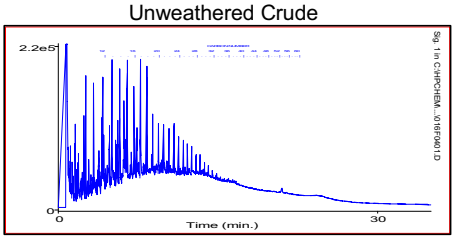


TYPICAL PRODUCT CHROMATOGRAMS

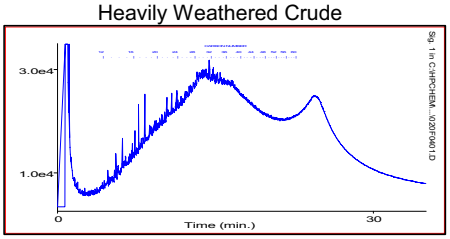
Weathered Diesel Fuel



Unweathered Crude



Heavily Weathered Crude



Product Carbon Number Ranges

Gasoline	C4-C12	Kerosene	C7-C16	Lubricating Oils	C20-C40
Varsol	C8-C12	Diesel	C8-C22	Crude Oils	C3-C60+

Accredited by the Standards Council of Canada (SCC) and by the Canadian Association for Environmental Analytical Laboratories (CAEAL) for specific tests registered with the Council and the Association

Figure 7. Hydrocarbon gas chromatogram (total) of sample #1, till core from WEPA00-1, 46 m depth.

It is worth noting that the till in the lower part of the core hole had no odour.

3.3 Core Hole WEPA00-2

Core hole WEPA00-2 is located on the edge of a gravel pit on the north flank of an ice-contact glacial meltwater channel complex directly east of Christina Lake in LSD 7, sec. 31, twp. 76, rge. 5 W4M (Figure 1). The hole was drilled, cored and logged to a depth of about 115 m, and was terminated while still in Quaternary sediment (Figure 8).

The generalized lithology, from the surface down, consists of about: 33 m of till, 55 m of lacustrine clay and silt, 23 m of till, and 4 m of clay and sand at the bottom of the hole. Two other aspects of the lithology of note are:

- The presence of roots in till at a depth of about 9 m from surface, which appeared similar to peat, or possibly lignite, and
- A buried oxidized profile on the till at a depth of about 108 m, which possibly represents an unconformable weathered surface of an older till.

Hydrocarbon odours were detected in only one core sample of till, at a depth of about 26 m from surface, directly below a 1 m thick bed of sand and gravel (Figure 8). There was no visible evidence of clasts or inclusions of hydrocarbon-bearing rock fragments in core samples of the till. As importantly, hydrocarbon odours were not detected in any of the samples from the thick silt and clay sequence below the upper till, nor in till at the bottom of the core hole.

3.4 Core Hole WEPA00-3

Core hole WEPA00-3 is located on undulating to hummocky, low to moderate relief topography directly west of Winefred Lake in LSD 16, sec. 4, twp. 76, rge. 5, W4M (Figure 1). The hole was drilled to a depth of 182 m and terminated after sampling a few metres into the top of the shale of the Colorado Group. The contact between Quaternary sediments and the bedrock surface was intersected at a depth of about 177.5 m (Figure 8).

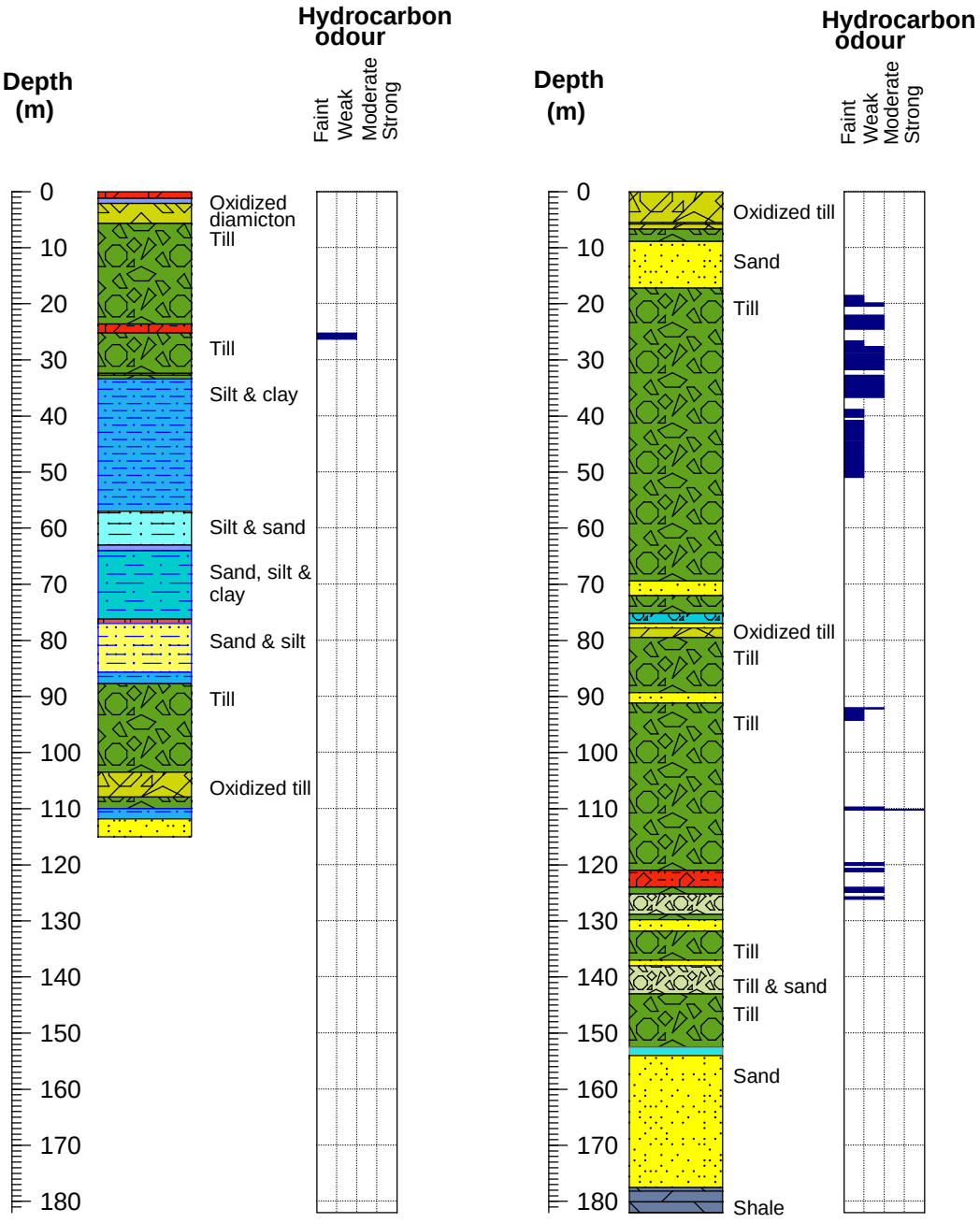
The generalized lithology, from top down, consists of about: 9 m of till, 8 m of sand, 136 m of till with minor sand beds, and about 25 m of sand, which overlies shale. Also of note is a 2 m thick buried oxidized profile on the till at a depth of about 77.5 m, which is interpreted to represent an unconformable weathered surface of an older till.

Hydrocarbon odours were first detected in cores of till at a depth of about 18m (Figure 8). Odours persisted in core samples down to a depth of about 50 m and were not detected again until a depth of about 92 m, approximately 14 m below the top of the buried oxidized horizon. Odours were detected intermittently from 92 m to down to about 125 m, and none below that depth, specifically none in the samples of shale at the bottom of the core hole. As in all of the other core samples of till in which hydrocarbon odours were detected, there was no visible evidence of free hydrocarbon in the till, nor clasts or inclusions of hydrocarbon-bearing rock fragments.

3.5 Core Hole PL01-1: Site of Hydrocarbon Sample # 2

Core hole PL01-1 is located about 30 km north of Red Earth in a broad, north-south trending lowland occupied by the Loon River (Figure 1). Drilling was terminated at 141 m after intersecting the bedrock surface at 135.5 m (Figure 9). The cored bedrock consists of interbedded mudstone and sandstone that

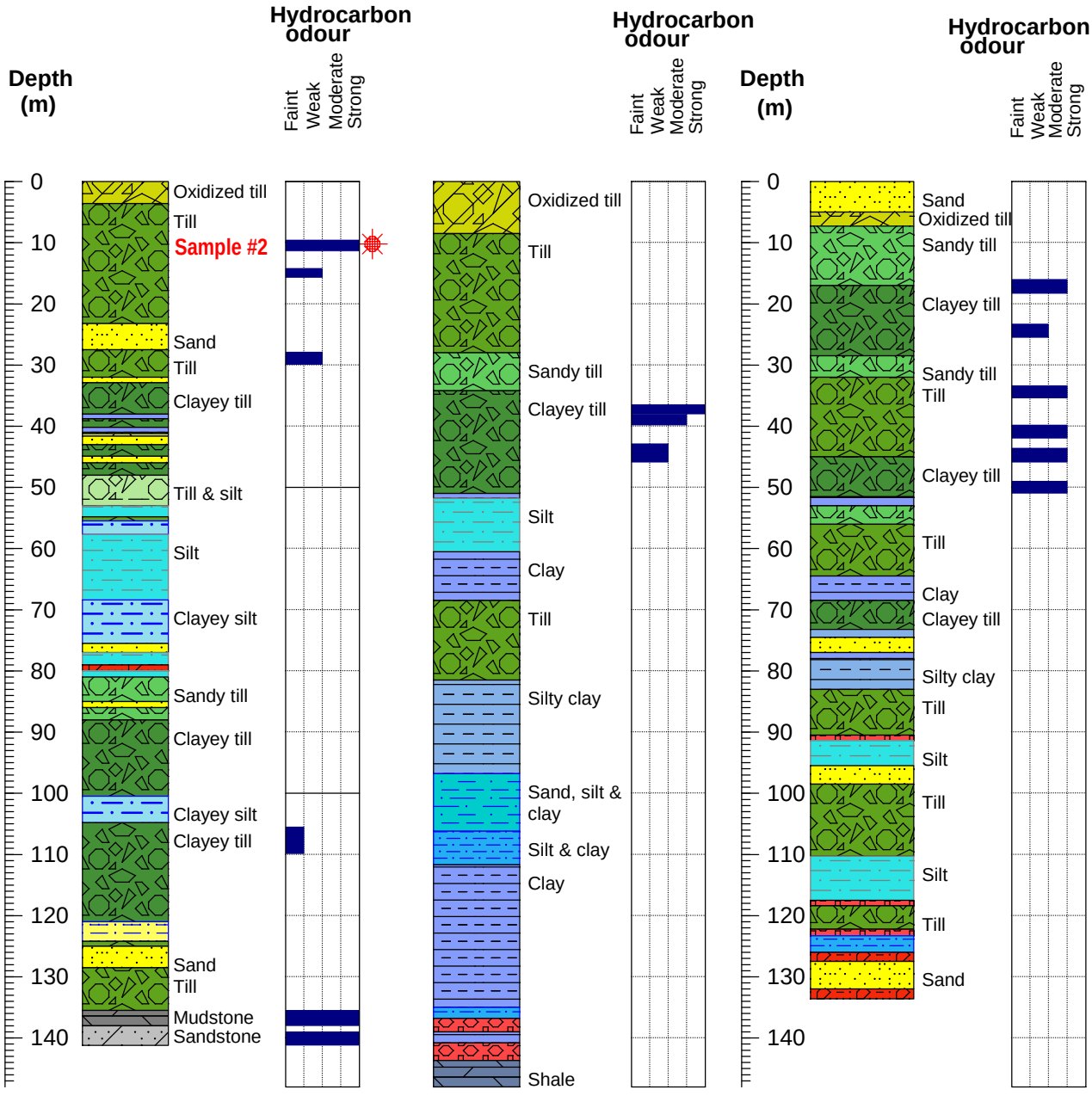
Well Name:	WEPA00-2	WEPA00-3
Location (DLS):	07-31-076-05W4Mer	16-04-75-05W4Mer
Latitude:	55.6275339°	55.4730401°
Longitude:	110.7614465°	110.7072983°
Surveyed Ground Level:	570.83 masl	648.17 masl



Legend for lithological symbols in Figure 2.

Figure 8. Lithological properties and hydrocarbon-odour concentrations in Quaternary sediments, core holes WEPA00-2 and WEPAA00-3.

Well Name:	PL01-1	P00-7	P00-8
Location (DLS):	04-27-090-22W5	15-30-78-22W4	4-26-79-22W4
Latitude:	56.82908°	55.79334°	55.86872°
Longitude:	115.24630°	113.4053°	113.34290°
Estimated Ground Level:	567 masl	571 masl	579 masl



Legend for lithological symbols in Figure 2.

Figure 9. Lithological properties and hydrocarbon-odour concentrations in Quaternary sediments, core holes PL01-1, P00-8.

was determined from pollen analysis to be of Albian age, and correlates to the contact of the Pelican and Joli Fou formations.

The drift sediments can be summarized in three main parts; 50 m of an upper silt and clay-rich till which overlies about 30 m of stratified glaciolacustrine silt and clay, which in turn overlies about 55 m of till with numerous sand and silt interbeds to a depth of 135 m from surface (Figure 9).

Indications of hydrocarbon within the drift were evident while drilling the upper till, and later while coring the lower till. At 10 m depth in the upper till, a black oil residue was first observed floating on fluid in the drilling mud tank. Core samples of till from this depth had a strong petroliferous odour when broken open along a fresh face. Hydrocarbon sample #2 was later collected from this depth at AGS' core storage facility. A weak odour was also detected in tills at 15 m and 28 m in depth. Below 30 m the oily residue in the drilling mud tank was no longer visible and no further evidence of hydrocarbons was detected until about 106 m, where a 4 m interval of cored till had a faint odour. The presence of hydrocarbons was also observed as an iridescent sheen emanating from bedding planes and fracture surfaces in wetted core of mudstone and sandstone between 135 and 141 m, as well as a strong odour.

Hydrocarbon analysis of a till sample from 10 m depth from core hole PL01-1 was carried out by Dr. Martin Fowler of the Geological Survey of Canada in Calgary. The results of the hydrocarbon extraction and fractionation of the extract are shown in Table 2. Figure 10 is the saturated fraction gas-chromatogram of the hydrocarbons in the till sample from core hole PL01-1. Figures 11, 12, and 13 show the relative abundances of terpanes and steranes in the hydrocarbon fraction, as included in the laboratory report.

Sample #2 had a strong petroliferous smell, but actually contained hydrocarbons at very low concentrations. The saturated fraction gas-chromatogram suggests that this sample contains a mixture of biodegraded and non-biodegraded hydrocarbons of both biogenic and petrogenic origin. The petrogenic hydrocarbons appear to be similar to biodegraded, bitumen-like hydrocarbons of the Athabasca Oil Sands deposit (M. Fowler, pers. comm., 2001).

3.6 Core Holes P00-7 and P00-8

Core holes P00-7 and P00-8 were drilled southeast of the community of Wabasca, within a broad plain extending from Wabasca to the Athabasca River (Figure 1). Hydrocarbon odours were detected in tills near the upper part of the stratigraphic sequence in both core holes. Both holes were strategically located above the western extension of the Amesbury Channel (Andriashek et al, 2001), a deeply buried bedrock channel. At core hole P00-7, about 50 m of till overlie 85 m of glaciolacustrine silt and clay, overlying about 10 m of glacial sand and gravel, which rests on shale of the Lower Colorado Group. A similarly thick sequence of till was encountered in the upper part of the stratigraphic sequence in core hole P00-8. Hydrocarbon odours were encountered in till between 15 and 50 m in both holes (Figure 9). No evidence of hydrocarbons was detected below 50 m.

4. Outcrop Descriptions

During surficial geological mapping in northern Alberta, AGS staff documented three separate occurrences of hydrocarbon odour in the surficial sediments (Figure 1). The collection of information on hydrocarbon odours has not hitherto been routinely done for mapping purposes; it should be noted that the locations presented in this report represent a minimum distribution of naturally occurring hydrocarbons. More shows may be present in the surficial sediments elsewhere in this region.

Table 2. Extraction and fractionation of extract results for sample #2 from core hole PL01-1.

GSC	AEUB	Rock	Extract	Extract	HC	Sats	Arom	Resins	Asph
#	#	wt	wt	ppm	%	wt	wt	wt	wt
9561	1852	2.9	3.1	1069	25.8	0.3	0.5	1.3	0.5

Notes: Except for the weight of the rock sample extracted (g), all other weights are in mg.
%HC is the percentage of hydrocarbons in the extract.
Sats, arom, resins and asp are the weight of the saturated hydrocarbons, aromatic hydrocarbons, resin and asphaltene fractions respectively.

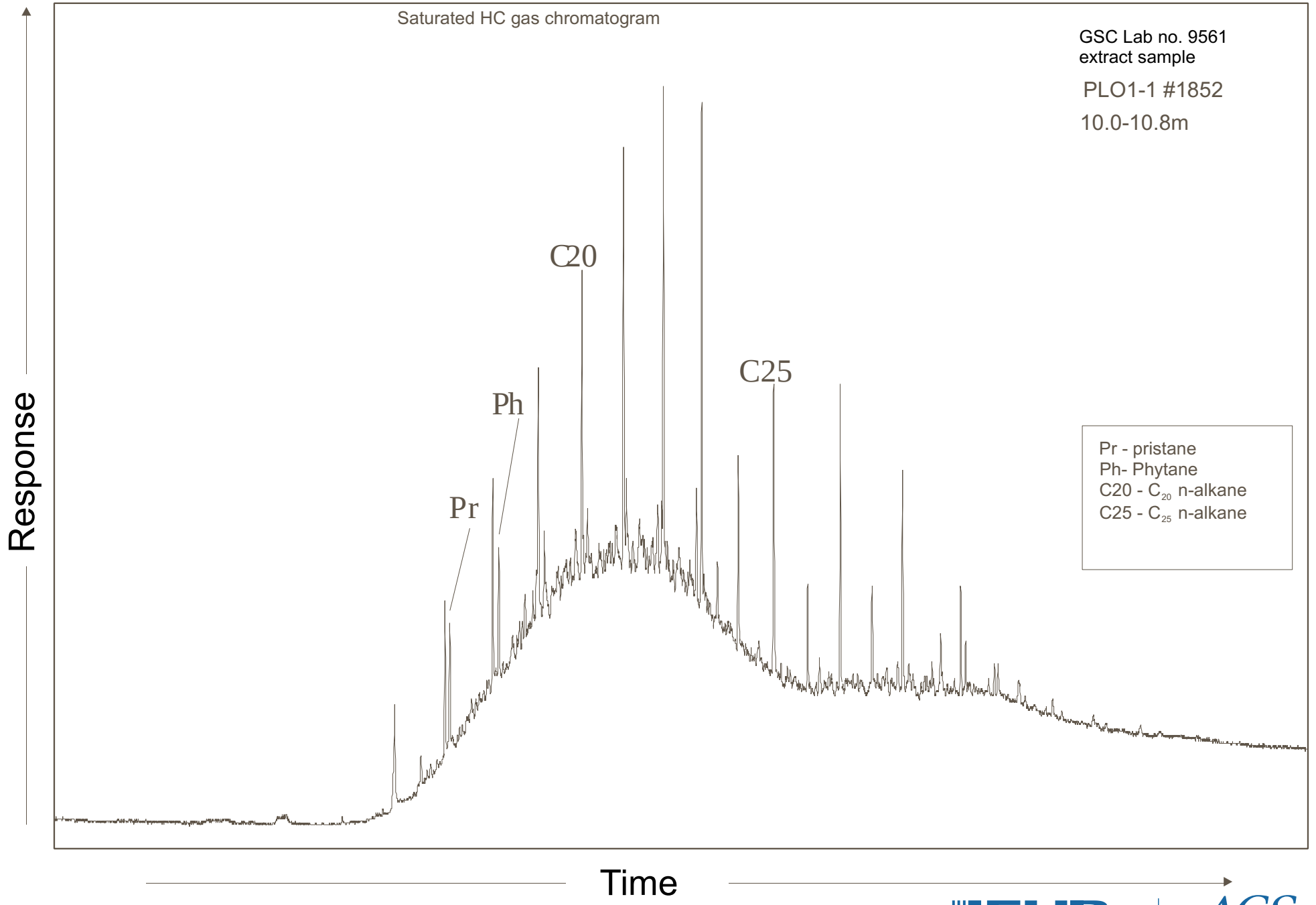


Figure 10. Hydrocarbon gas chromatogram (saturated) of sample #2, till core from PL01-1, 10 m depth.

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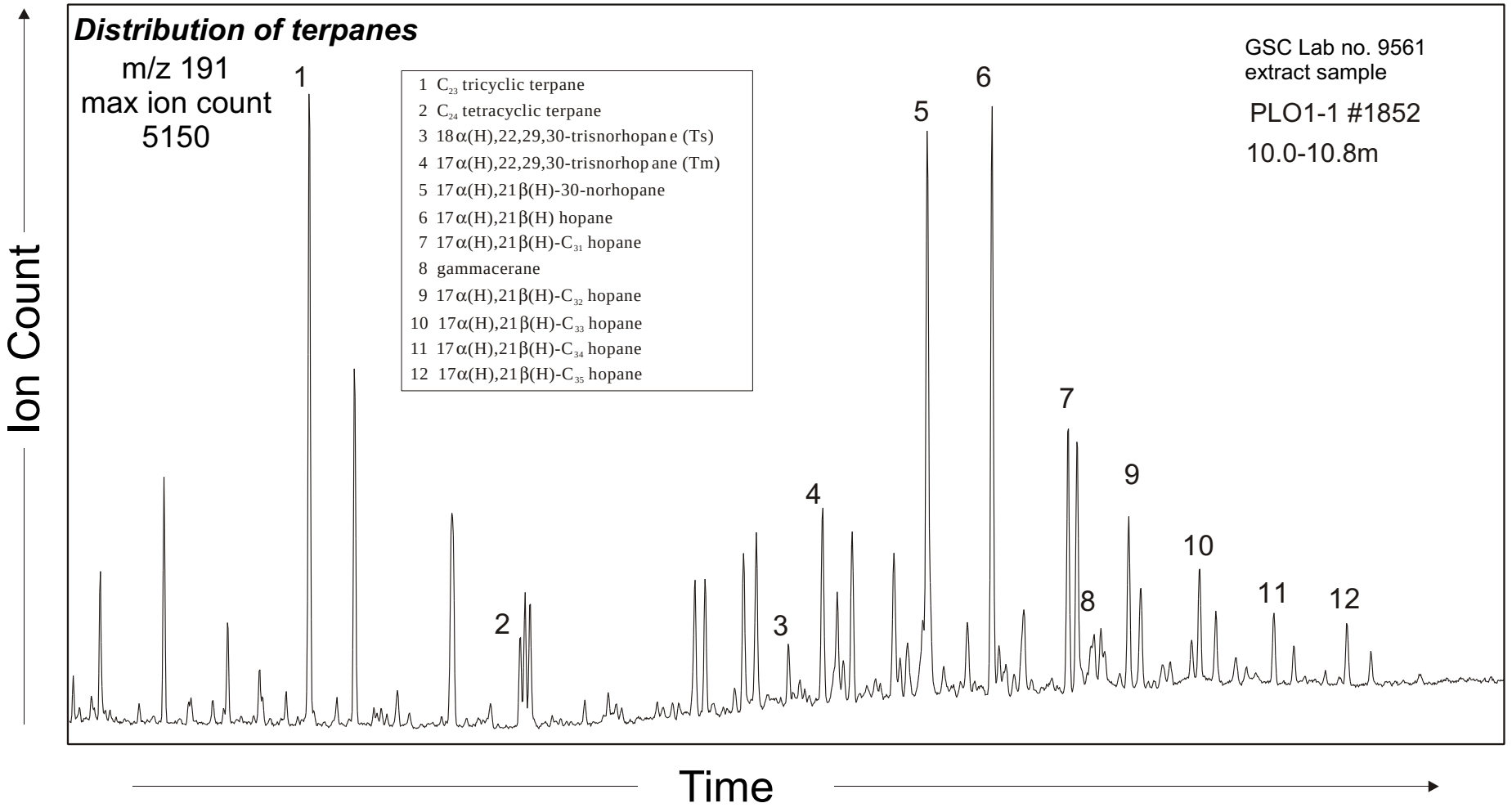

Figure 11. Distribution of terpanes in m/z 191 fragmentogram of sample #2, till core from PL01-1, 10 m depth.

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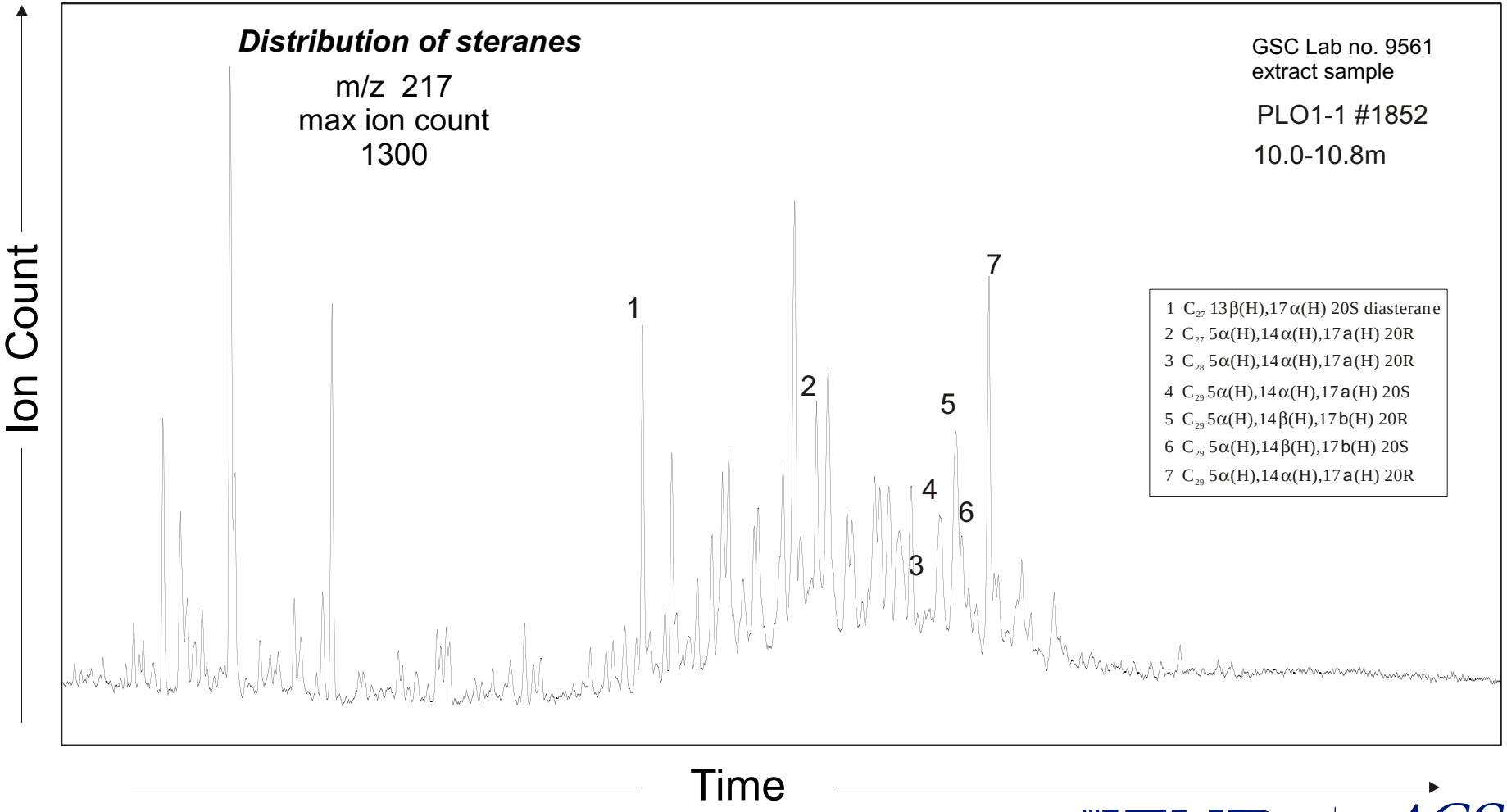

Figure 12. Distribution of steranes in m/z 217 fragmentogram of sample #2, till core from PL01-1, 10 m depth.

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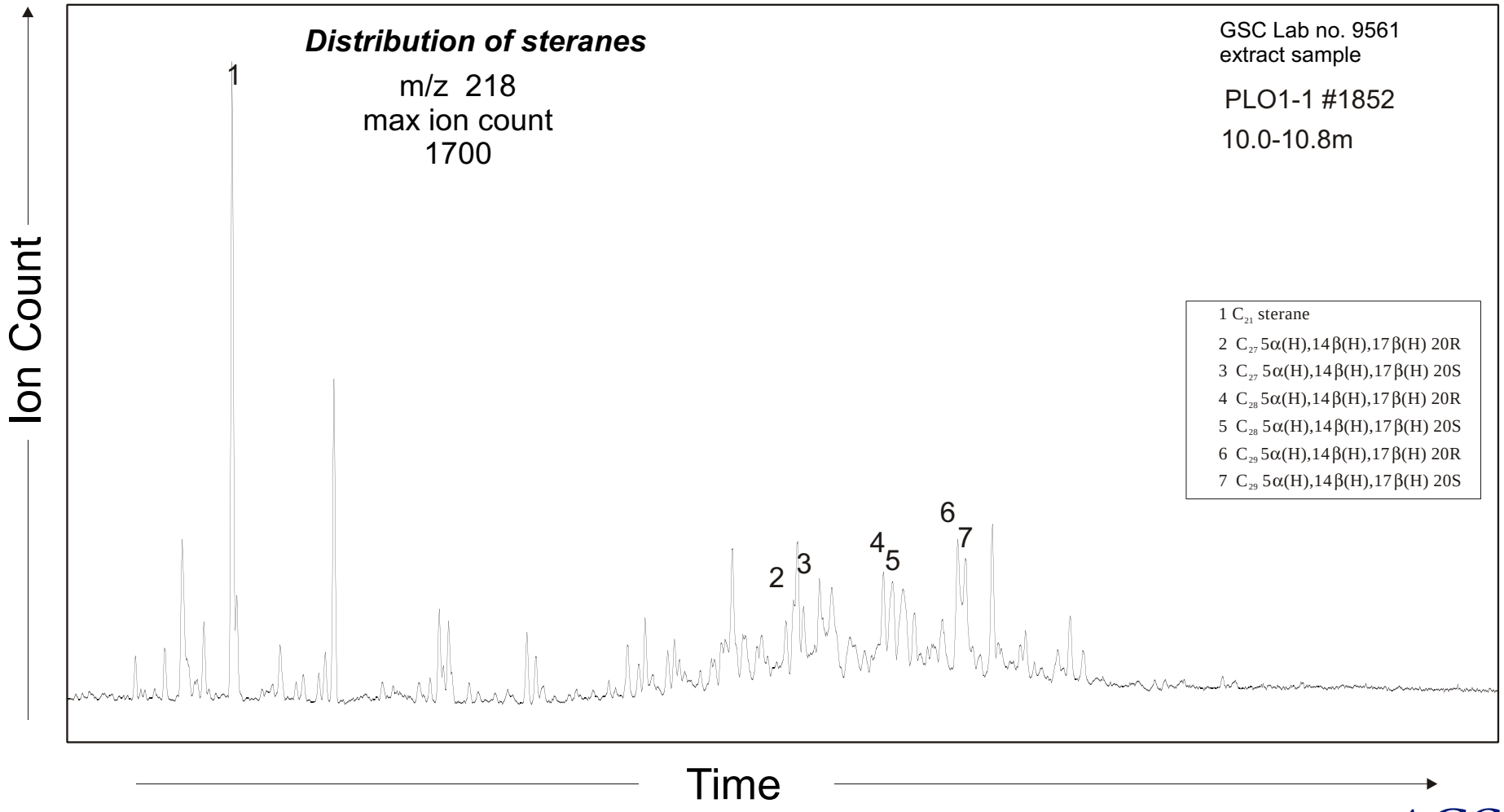

Figure 13. Distribution of steranes in m/z 218 fragmentogram of sample #2, till core from PL01-1, 10 m depth.

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4.1 Site NAT98-244

This site was a newly excavated borrow pit about 10 m deep in the Loon River Lowland north of Red Earth. The pit extended down through the surface weathered till to expose unoxidized dark grey sandy clay till. Hydrocarbon odours were detected when the till was freshly cut. Visible oil was also observed seeping from fractures in a 1.3 m diameter limestone boulder unearthed in the pit. Other glacial erratics observed at the site were granite, gneiss and Athabasca Sandstone, indicating sources from northeastern Alberta. Surficial mapping also confirmed ice flow directions from north to south in this area.

4.2 Sites JP00-131 and MF00-19

Hydrocarbon odour was noted in surface tills at two sites in the Wabasca area. At site JP00-131, dark grey unoxidized till was exposed in a newly excavated borrow pit about 8 m deep. Odour was evident in freshly cut till at the base of the pit. At Site MF00-19 bitumen odours were detected in surface-weathered till about 2 m deep in an old borrow pit. The odour was faint and could only be detected by excavating about 30 cm deep into the till face.

5. Discussion of Results

The laboratory results confirm the field observations of hydrocarbon odour, and that the compositions of both samples have characteristics similar to bitumen in the oil sands deposits in northeastern Alberta.

The hydrocarbons within the glacial drift sediments have not migrated freely from depth because:

1) Hydrocarbons do not appear in a visible free form in core of drift.

2) Hydrocarbon odours were not pervasive throughout the entire drift sequence in any of the core holes.

3) With the exception of core hole PL01-1, hydrocarbon odours were not detected in the Cretaceous bedrock beneath the glacial drift sequence.

Rather, the observations of odour appear to be restricted only to the till units within the glacial sequence. Almost all of the observations of hydrocarbon are at locations south and west of major oils sands deposits, and if glacially streamlined surface landforms can be considered to be an indicator of past glacier flow-directions, then all of the observations occur directly down-glacier of near-surface oil sands deposits (Figure 1). It seems likely, therefore, that glacial erosion and incorporation of bitumen from Athabasca oil sands is the most probable source for the anomalous hydrocarbon occurrences.

From the point of view of an environmental site characterization, documentation of the presence of any naturally occurring hydrocarbons in near-surface glacial sediments is important. If baseline values have not been established prior to energy development in an area, remediation strategies to mitigate the effects of an accidental release of hydrocarbon into the glacial drift may be poorly designed if the presence, or absence, of naturally occurring hydrocarbons was not established in advance. Given that northeastern Alberta has experienced multiple Laurentide glaciations, there is a high probability that glacially eroded and incorporated bitumen will be found within tills in many locations in this part of the province.

6 References

Pettapiece, W.W. (1986); Physiographic subdivisions of Alberta; 1:500,000-scale map; Agriculture Canada, Ottawa.

Andriashek, L.D., J. Pawlowicz, M. Fenton and I. Ranger (2001); Bedrock topography and drift thickness of the Athabasca Oil Sands (in situ) Area and Adjoining Regions; Alberta Geological Survey contributions to the Canadian Society of Petroleum Geologists annual convention June 18-22, 2001; AGS Information Series 124, CD-ROM.