

APPENDIX A SEDIMENT INVESTIGATION (GOLDER 2010)

(CONTINUED)

**APPENDIX C SUBTIDAL SURVEY OBSERVATIONS AND
VIDEO**

Transect: TR1

Location: IOCO Refinery, Pipeline, Port Moody BC

Date: May 28, 2009

North End of Transect (UTM): 10U 5460092 N, 508956.5 E

South End of Transect (UTM): 10U 5459946 N, 508954.4 E

Distance Along Transect (m)	Time of Data Collection	Gauge Depth (ft)	*Corrected Depth (m)	Substrate Type	Biological Observations	Other Observations
0**	15:33	4	-0.42	silt with shell debris	-	-
20	15:32	8	-1.64	silt with shell debris	-	-
20 to 60	-	-	-	silt with shell debris	dungeness crab (<i>Cancer magister</i>), ochre star (<i>Pisaster ochraceus</i>), sunflower star (<i>Pycnopodia helianthoides</i>)	-
60	15:31	17	-4.38	silt with shell debris		
60 to 80	-	-	-	silt	detrital macroalgae	
80	15:29	26	-7.13	silt	-	-
100	15:28	31	-8.65	silt	detrital macroalgae, holes in substrate (siphon holes or burrows)	-
100 to 120	-	-	-	silt	detrital macroalgae	-
120	15:27	32	-8.96	silt	holes in substrate (siphon holes or worm burrows)	-
120 to 140	-	-	-	silt	dungeness crab (<i>Cancer magister</i>), plumose anemones (<i>Metridium senile</i>), jellyfish (<i>Polyorchis penicillatus</i>)	abandoned crab trap (approx. 1m x 0.5m x 0.5m in size)
140	14:59	38	-10.79	silt		-
140 to 160	-	-	-	silt	dungeness crab (<i>Cancermagister</i>), plumose anemones (<i>Metridium senile</i> ,	-
160	14:51	40	-11.40	silt with shell debris	mottled star (<i>Evasterias troschelii</i>)	wood debris (sticks)

*Depths corrected to chart datum for Port Moody tidal predictions (Station #7755) (<http://www.tides.gc.ca/>)

**Southern extent of transect

Transect: TR2

Location: IOCO Refinery Pipeline, Port Moody BC

Date: May 29, 2009

North End of Transect (UTM): 10U 5460306 N, 508966 E

South End of Transect (UTM): 10U 5460155 N, 508960.8 E

Distance Along Transect (m)	Time of Data Collection	Gauge Depth (ft)	*Corrected Depth (m)	Substrate Type	Biological Observations	Other Observations
0**	11:27	44	-10.11	silt	-	-
20	11:32	42	-9.50	silt	holes in substrate (siphon holes or burrows)	-
40	11:36	42	-9.50	silt	holes in substrate (siphon holes or burrows)	-
60	11:40	40	-8.90	silt	holes in substrate (siphon holes or burrows)	-
80	11:42	40	-8.90	silt	holes in substrate (siphon holes or burrows)	-
100	11:45	40	-8.90	silt	holes in substrate (siphon holes or burrows)	-
100 to 120	-	-	-	silt	plumose anemones (<i>Metridium senile</i>)	-
120	11:49	38	-8.29	silt	holes in substrate (siphon holes or burrows)	-
120 to 140	-	-	-	silt	jellyfish (<i>Polyorchis penicillatus</i>)	-
140	11:51	39	-8.59	silt	-	-

*Depths corrected to chart datum for Port Moody tidal predictions (Station #7755) (<http://www.tides.gc.ca/>)

**Southern extent of transect

Transect: TR3
 Location: IOCO Refinery Pipeline, Port Moody BC
 Date: May 29, 2009

North End of Transect (UTM): 10U 5460094 N, 508907.9 E
 South End of Transect (UTM): 10U 5459948 N, 508901.9 E

Distance Along Transect (m)	Time of Data Collection	Gauge Depth (ft)	*Corrected Depth (m)	Substrate Type	Biological Observations	Other Observations
0**	15:02	9	-1.34	silt with shell fragments(90%), boulder (10%)	-	-
0 to 20	-	-	-	silt with shell fragments(90%), boulder (10%)	detrital macroalgae, dungeness crab (<i>Cancer magister</i>), plumose anemones (<i>Metridium senile</i>), giant pink star (<i>Pisaster brevispinus</i>), ochre star (<i>Pisaster ochraceus</i>)	-
20	14:59	23	-5.61	silt	-	-
20 to 40	-	-	-	silt	detrital macroalgae, plumose anemone (<i>Metridium senile</i>), holes in substrate (siphon holes or burrows)	-
40	14:56	30	-7.75	silt	-	-
40 to 60	-	-	-	silt	dungeness crab (<i>Cancer magister</i>)	-
60	14:55	36	-9.58	silt	-	-
80	14:50	37	-9.88	silt	-	-
80 to 100	-	-	-	silt	plumose anemones (<i>Metridium senile</i>)	-
100	14:47	38	-10.19	silt	-	-
100 to 120						
120	14:45	41	-11.10	silt	plumose anemones (<i>Metridium senile</i>)	-
120 to 140	-	-	-	silt	plumose anemones (<i>Metridium senile</i>)	-
140	14:43	43	-11.71	silt	-	-
160	14:41	44	-12.01	silt	-	-

*Depths corrected to chart datum for Port Moody tidal predictions (Station #7755) (<http://www.tides.gc.ca/>)

**Southern extent of transect

Transect: Intertidal Transect

Location: IOCO Refinery Pipeline, Port Mody BC

Date: May 28, 2009

Distance Along Transect (m)	Time of Data Collection	Substrate Type	Biological Observations	Other Observations
0* to 5.2	17:53	boulder sized rip rap	rockweed (<i>Fucus sp.</i>), limpets barnacles, mussels (<i>Mytilus sp.</i>)	-
5.2	-	boulder sized rip rap	sea lettuce (<i>Ulva sp.</i>)	-
5.2 to 8.9	-	shell fragments overlying silt	-	-

* High High Water Mark (HHWM)

APPENDIX D PAH FINGERPRINTING (ZYMAX RESULTS)



forensics

Chemical Fingerprinting of Sediment Samples at the IOCO Pipeline Right of Way (ROW)

Report Prepared for:

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A handwritten signature in black ink that reads "Alan Jeffrey".

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21 June 2010

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1.0 Introduction

1.1 Objectives

Sediment samples from locations along the IOCO pipeline ROW are to be analyzed by GC/MS techniques to identify and fingerprint the extractable organic compounds in the samples. These fingerprints are used to identify the origin of hydrocarbons and other organic compounds in the samples.

1.2 Chemical Fingerprinting

Chemical fingerprinting involves identification of chemical compounds or patterns of compounds in samples. By comparing fingerprints in different samples, similarities or differences in the source of chemicals in the samples can be determined. Certain fingerprints, particularly organic compounds, are characteristic of the method of formation of the compounds. Three major formation mechanisms of organic compounds in the environment are:

Biogenic – formed as part of recent plant or animal metabolism at ambient temperatures in soil and sediments. Many of these compounds are recognizable as the same as, or very similar to, organic compounds in plants and animals.

Pyrogenic – formed by high temperature destruction of organic material. The major product is a suite of polyaromatic hydrocarbons (PAHs). Examples of natural pyrogenic processes include forest fires and lightning. Examples of anthropogenic pyrogenic processes include creosote manufacture and Manufactured Gas Plant activities, and also factory and domestic burning and automobile exhaust, which are often combined in urban runoff.

Petrogenic – formed slowly by subsurface transformation of organic material at moderately high temperatures and high pressure. The major product is a suite of hydrocarbons, primarily alicyclic (straight chain) and cyclic hydrocarbons, with smaller amounts of aromatic hydrocarbons. Examples are crude oil, natural gas, and products refined from them. Examples of petrogenic sources include spilled crude oil and petroleum products, and asphalt residues. Urban and industrial runoff can contain hydrocarbons from a mixture of petrogenic sources including partially combusted petroleum fuels; discarded fuel oils, lubricating oils, and industrial oils; and particles of asphalt and hydrocarbons leached from asphalt.

Chemical fingerprinting has been developed over a considerable period of time in petroleum geochemistry to characterize oil and gas deposits and determine if they are from the same or different sources. The techniques have been applied in the last 20 years in environmental geochemistry to characterize petroleum products and other hydrocarbon products released into the surface environment, and to determine their source. It is relatively easy to compare chemical fingerprints of freshly released hydrocarbon products with potential source materials. However, weathering in the environment by evaporation, dissolution in water, and biodegradation, can alter the fingerprint of a hydrocarbon product, sometimes beyond obvious recognition. However, certain compounds are more resistant to weathering processes, and fingerprints of these resistant compounds can be used to compare weathered products with fresher versions of potential sources. In this way certain principles of chemical fingerprinting have been developed over the years to forensically examine hydrocarbons released into the environment. Although weathering

complicates source identification, the degree of weathering, combined with information on the sample environment, can provide an insight into the length of time a hydrocarbon product has been in the environment. Chemical fingerprinting techniques and interpretations based on the techniques have been widely used in environmental forensic studies overseen by regulatory agencies in North America, and in litigation cases.

One of the major techniques that have been used in both petroleum geochemistry and environmental geochemistry is Gas Chromatography/Mass Spectrometry (GC/MS). In this technique, organic compounds in a mixture, such as individual hydrocarbons in oil, are separated, often by slight differences in their boiling point, in a gas chromatograph. As each compound is separated, it is directed into an attached mass spectrometer, in which the compound is broken into fragments. The fragment pattern (mass spectrum) is characteristic for each compound, and the compound can be identified by comparing the mass spectrum with the mass spectra of standards in a computerized library.

2.0 Methods

2.1 Study Design

26 sediment samples, listed in Section 3.0, were received at ZymaX on December 15, 2009 for GC/MS Full Scan analysis. In the first stage of the study, no background information on the samples was provided. Determination of the origin of the hydrocarbons in the samples was based solely on the chemical fingerprinting. In the second stage, a site map with the locations of samples and potential hydrocarbon sources was provided. This helped to clarify hydrocarbon inputs, particularly where the sources were ambiguous. The locations of reference samples outside of the influence of the pipeline ROW were particularly useful in this regard.

2.2 Analytical Methods

The samples were sonicated with dichloromethane solvent, the solvent extracts concentrated, and GC/MS Full Scan analysis in the C₁₀-C₄₀ range performed on the extracts. Silica gel cleanup to remove polar compounds was not performed on the samples in order to enable characterization of all the organic compounds in the samples. The extracts were directly injected into a GC equipped with a 60 meter DB1 column to separate the hydrocarbons, which were detected with a mass spectrometer (MS) in full scan mode, interfaced to the GC. By scanning the ion fragments shown in the following table, chromatograms of a number of classes of hydrocarbons were generated.

ION (M/Z)	COMPOUND CLASS
TIC	All Compounds
85	n-Alkanes
113	Iso-Alkanes and Isoprenoids
83	Alkylcyclohexanes
134	C ₄ -benzenes
123	Bicyclanes
191	Terpanes
217	Steranes
253	Monoaromatic Steranes
231	Triaromatic Steranes
Bar Diagram	Aromatic Hydrocarbon Distribution

Aromatic hydrocarbons were identified by scanning over a large number of ion fragments, and the results were normalized in a bar diagram.

In this study, the interpretations relied primarily on the Total Ion Chromatograms (TIC) and aromatic hydrocarbon bar diagrams. The TIC shows peaks for all organic compounds extracted from a sediment sample, and the identity of individual peaks is obtained from comparison of peak mass spectra with the mass spectral library. The aromatic hydrocarbon bar diagram shows the distribution of PAHs and alkylated PAHs containing 1 to 4 carbon alkyl groups attached to the parent PAH.

2.3 Chemical Fingerprints that are Characteristic of Origin

2.3.1 *Biogenic*

Chromatograms of biogenic materials include:

- The presence of compounds the same as, or very similar to, organic compounds in plants and animals. This includes cholesterol, b-sitosterol, oleanene, vitamin E, triterpenes, and fatty acids. This category includes various compounds containing oxygen and nitrogen atoms, for which the identifications are tentative. Standards for these did not exist in the mass spectral library, so exact matches could not be made. However, the identifications were precise enough to identify the types of compounds within the samples that have a biogenic origin.
- A predominance of odd-numbered n-alkanes from C19 to C35. This is a characteristic of biogenic hydrocarbons from leaf waxes and from diagenesis of recent organic matter, and is illustrated by the n-alkane chromatogram of IA-SD09-REF3 in Fig 1.
- Presence of perylene, which is produced by degradation of plant pigments, and is one of the few PAHs that is believed to be biogenic in origin.

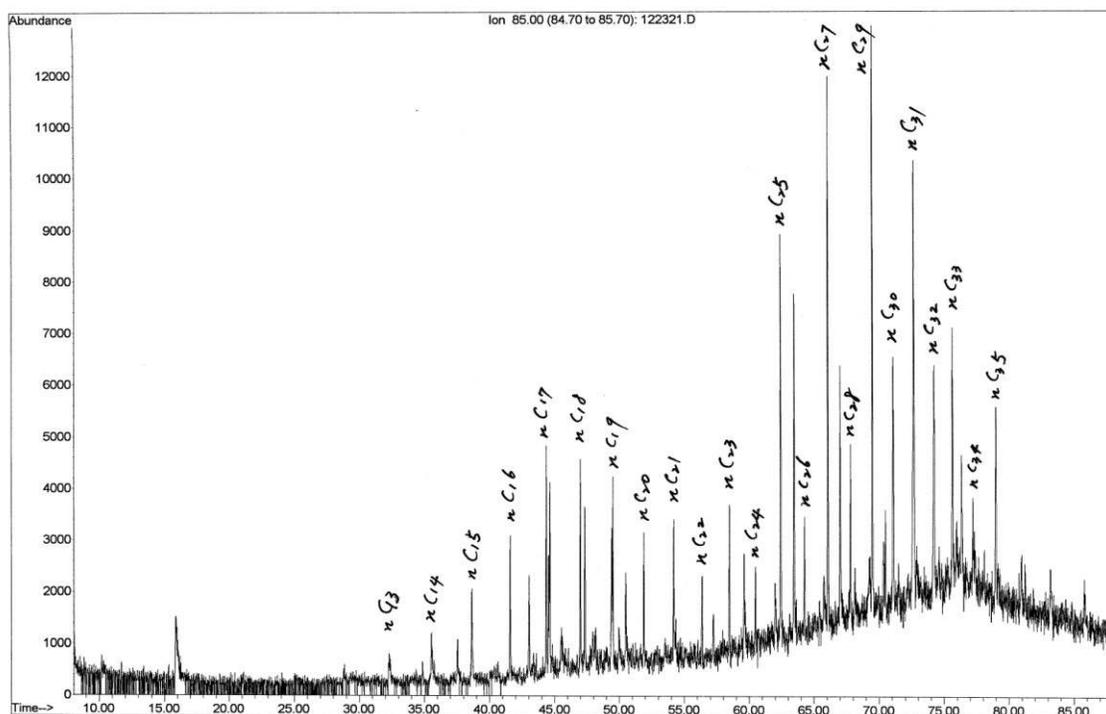


Figure 1. Chromatogram of n-alkanes in sample IA-SD09-REF3

2.3.2 Pyrogenic

Chromatograms of pyrogenic materials include:

- Identifiable peaks in the TIC corresponding to some or all of the PAHs: phenanthrene, fluoranthene, pyrene, benz(a)anthracene, chrysene, and benzo(b)fluoranthene, which are formed during high temperature pyrolysis processes
- A pattern in the aromatic hydrocarbon bar diagram where the abundances of C0-C4 phenanthrenes, fluoranthenes and pyrenes, and chrysenes, decrease from C0 to C4 (ski slope pattern). An example of this pattern in a Manufactured Gas Plant residue is shown in Fig 2, and is compared with the bell shaped pattern in a heavy petroleum fuel oil in Fig. 3.
- Characteristic ratios in the TIC of fluoranthene/pyrene (Fl/Py). This ratio has been reported to be influenced by a combination of the type of material from which the pyrogenic compounds were produced, and the pyrolysis temperature (EPRI, 2000; Costa, White, and Ruspantini, 2004). In the EPRI report, residues from Manufactured Gas Plants (MGP) using coal feedstocks had Fl/Py ratios >1, whereas residues from plants using petroleum product feedstocks had Fl/Py ratios <1. There has been some suggestion (Costa, White, and Ruspantini, 2004) that these differences in the ratio may relate more to the temperature of the pyrolysis process, as a common MGP process using petroleum products occurs at lower temperatures. However, it does appear that differences in the Fl/Py ratio at a site indicate differences in the source of the pyrogenic hydrocarbons.

2.3.3 Petrogenic

Chromatograms of petrogenic materials include:

- The presence of hydrocarbons, including n-alkanes, isoalkanes, alkylcyclohexanes, bicyclanes, and steranes that are characteristic of petroleum products, such as gasoline, diesel, fuel oils, and crude oil.
- The presence of terpane biological marker compounds. These are degradation products of terpenoid biological molecules. In biological organisms, terpenoid molecules that are assembled from isoprene units perform various cellular functions. Triterpenoids are constituents of bacterial cell walls, and after degradation to triterpanes, are inherited by petroleum from bacterial biomass in the petroleum source formation. Petroleum products heavier than diesel, such as heavy fuel oils and lubricating oils, in turn inherit these biological markers from the petroleum from which they are refined.
- The presence along with biological markers of an Unresolved Complex Mixture (UCM). The UCM contains a multitude of compounds that are poorly resolved by gas chromatography, and rather than appearing as distinct peaks, the peaks merge to form an elevated baseline resembling a broad peak, sometimes referred to as a hump. The UCM is regarded as being composed of hydrocarbons such as high molecular weight naphthenes (cyclic hydrocarbons) and other hydrocarbons that are resistant to environmental degradation. A UCM is present in many petroleum products – mainly middle distillate and heavier – and in crude oil, and is accentuated in degraded materials. UCMs have also been observed in the chromatograms of other organic materials, including resin acids, lignins, and manure. The key to the identification of a petrogenic origin is the presence of both a UCM and biological markers such as terpanes, which do not occur in recently formed organic matter. The location of the UCM in a TIC can give an indication of the hydrocarbon range of the petrogenic source. Multiple UCMs, such as a bimodal pattern in a chromatogram, may indicate multiple sources. In highly degraded petrogenic material, such as urban runoff, the UCM may be the most conspicuous evidence of petrogenic input. Examples of urban runoff chromatographic patterns are shown in Figure 4.
- A pattern in the aromatic hydrocarbon bar diagram where the abundances of C0-C4 phenanthrenes, fluoranthenes and pyrenes, chrysenes, and other PAHs increase from C0 to C1/C2, then decrease to C4 (bell-shaped pattern). An example of a heavy petroleum fuel oil is shown in Fig. 3.

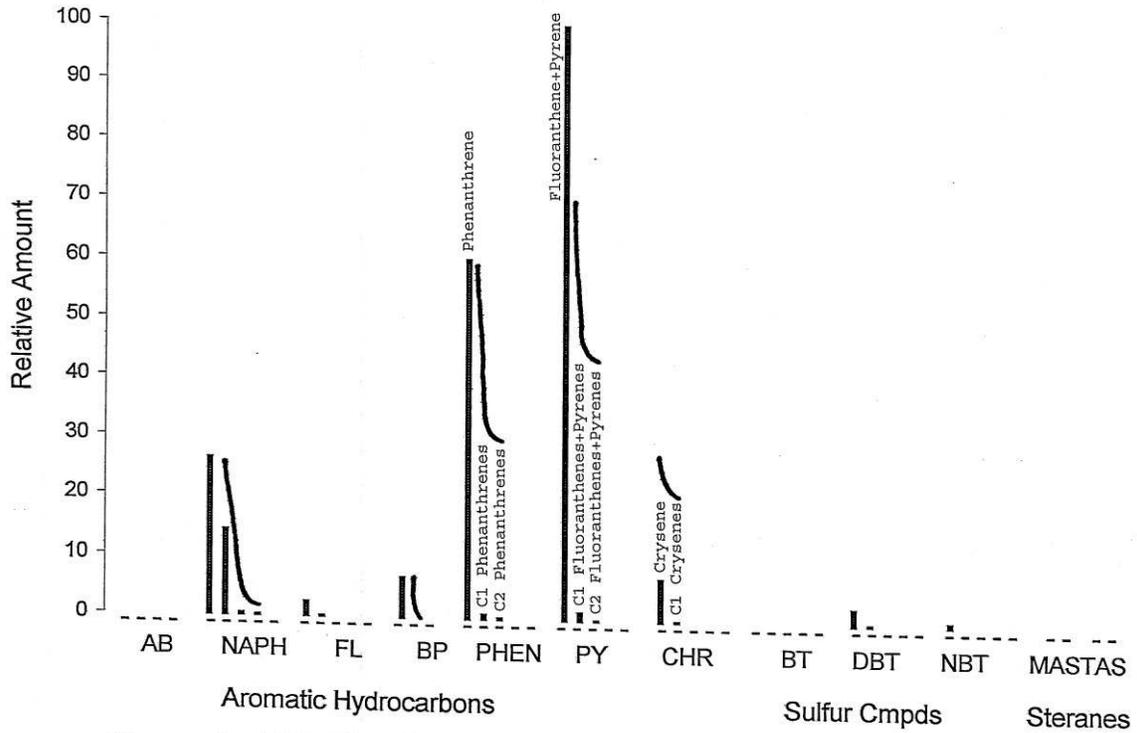


Figure 2. PAH distribution in a Manufactured Gas Plant residue

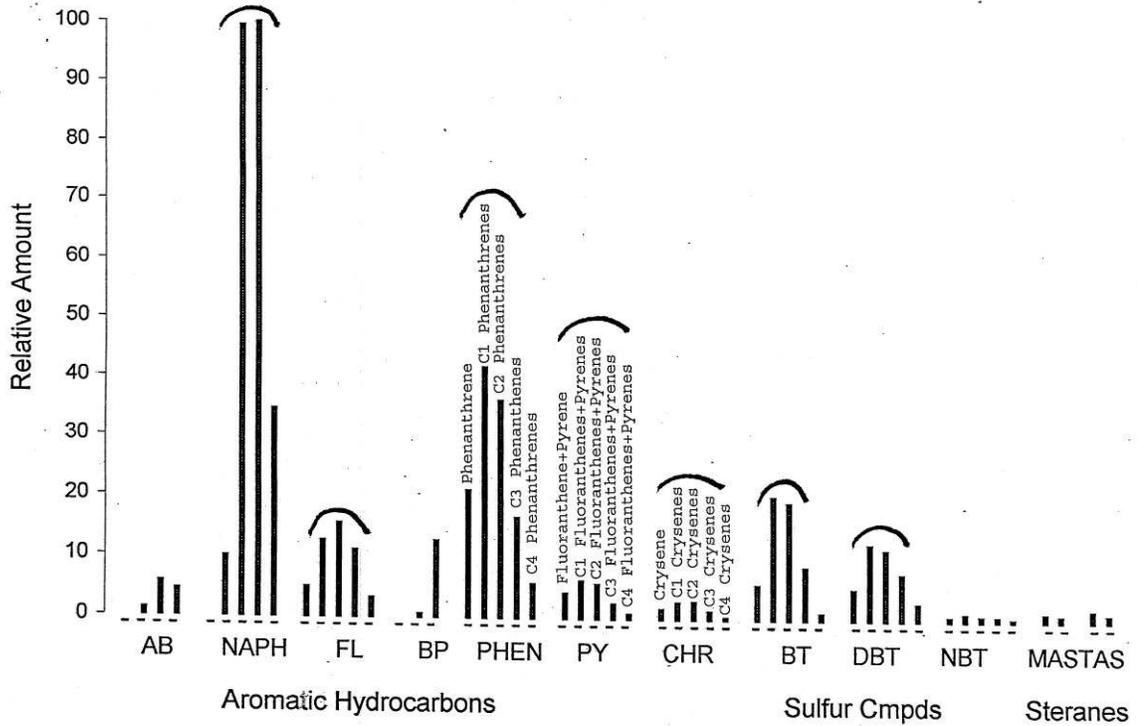


Figure 3. PAH distribution in a heavy petroleum fuel oil

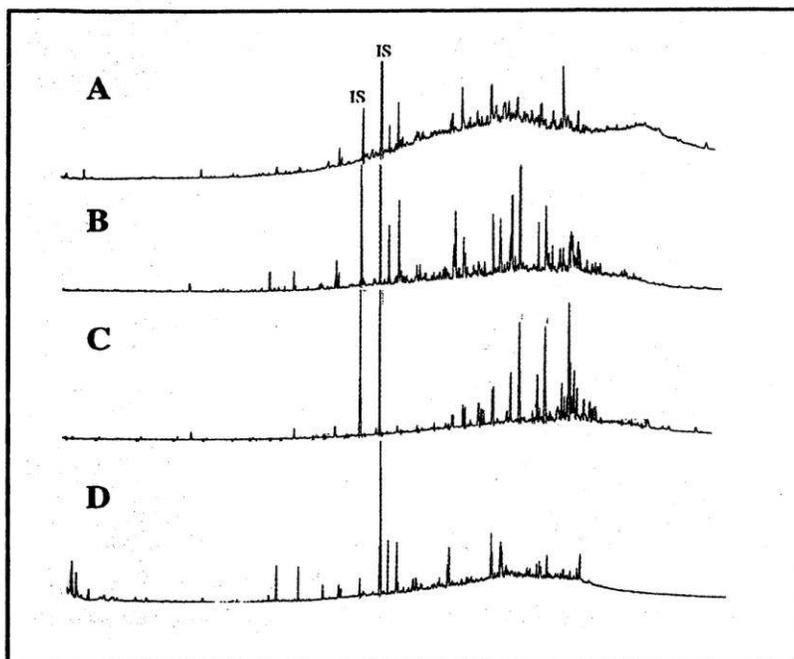


Figure 4. GC/FID chromatograms for extractable hydrocarbons for sediments impacted by urban background in (A) Thea Foss Waterway, (B) Eagle Harbor, (C) Portland Harbor and (D) Elizabeth River sites. Stout et al. (2003)

3.0 Chemical Fingerprints in the Samples

In this section, the organic compound constituents and patterns in each of the samples are compared with the criteria in Section 2.3 to identify the influence of biogenic, pyrogenic and petrogenic processes. The TICs and aromatic hydrocarbon bar diagrams that provide much of the evidence for the assessments are included in the Appendix.

IPS-SD09-REF1

This sample demonstrates a predominantly petrogenic influence, as indicated by the appreciable size of the UCM and the presence of terpanes. There is no evidence of refined petroleum products. Substantial amounts of biogenic compounds are present. Relatively small amounts of PAHs have a predominantly pyrogenic signature in the aromatic hydrocarbon bar diagram.

IPS-SD09-REF2

This sample demonstrates predominantly petrogenic and biogenic influences, as indicated by the somewhat lower UCM and more pronounced biogenic compound peaks. No evidence of refined petroleum products. Relatively small amounts of PAHs have a predominantly pyrogenic signature in the aromatic hydrocarbon bar diagram.

IA-SD09-REF3

This sample demonstrates a predominantly petrogenic influence, as indicated by the appreciable size of the UCM and the presence of terpanes. The terpane distribution is that in REF1, REF2, and the pipeline ROW samples. However, substantial amounts of biogenic compounds including odd-numbered n-alkanes are present. The biogenic alkane nC29 is one of the larger peaks in the TIC. There is also a small suite of alkanes from C13 to C20, in the carbon range of middle distillate products, which does not show a marked odd carbon preference. This suite of alkanes appears in many of the samples, located both near and far from the pipeline, and is always associated with the suite of odd-numbered biogenic alkanes. While it is likely that the C13 to C18 alkanes also have a biogenic origin, their presence in this reference sample indicates that they do not represent a petroleum input from the pipeline. Relatively small amounts of PAHs have a pyrogenic signature in the aromatic hydrocarbon bar diagram.

IA-SD09-REF4

This sample demonstrates a predominantly biogenic influence, as indicated by the pronounced biogenic compound peaks, small UCM, and the virtual absence of terpanes. No evidence of refined petroleum products. Relatively small amounts of PAHs have a predominantly pyrogenic signature in the aromatic hydrocarbon bar diagram.

IPS-SD09-REF5

This sample demonstrates a predominantly biogenic influence, as indicated by the pronounced biogenic compound peaks, and relatively small UCM. C13 to C20 alkanes are present in smaller amounts than in IA-SD09-REF3. Relatively small amounts of PAHs have a mixed pyrogenic and petrogenic signature in the aromatic hydrocarbon bar diagram.

IPS-SD09-19

This sample demonstrates a predominantly petrogenic influence, as indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. The substantial suite of PAHs evident in the TIC has a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is <1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs.

IPS-SD09-20

This sample demonstrates substantial petrogenic and pyrogenic influences. The petrogenic influence is indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. The suite of PAHs evident in the TIC is larger than in IPS-SD09-19 and has a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is >1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs.

IPS-SD09-21

This sample demonstrates substantial petrogenic, pyrogenic, and biogenic influences. The petrogenic influence is indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. The suite of PAHs evident in the TIC is slightly lower than in IPS-SD09-20 and has a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is >1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs. Biogenic compound peaks with a pattern similar to that in IPS-SD09-REF5 are pronounced.

IPS-SD09-22

This sample demonstrates substantial petrogenic, pyrogenic, and biogenic influence. The petrogenic influence is indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. The suite of PAHs evident in the TIC is similar to IPS-SD09-21 and has a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is ~ 1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs. Biogenic compound peaks are again pronounced.

IPS-SD09-23

This sample demonstrates substantial petrogenic and pyrogenic influence. The petrogenic influence is indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. The suite of PAHs evident in the TIC is larger than in IPS-SD09-22 and has a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is ~ 1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs. Biogenic compound peaks are also pronounced.

IPS-SD09-25

This sample demonstrates a predominantly petrogenic influence, as indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. Biogenic compound peaks are pronounced, particularly cholesterol. The suite of PAHs in the

TIC has a strongly pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is >1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs.

IPS-SD09-27

This sample demonstrates a strong pyrogenic influence, as indicated by the large PAH peaks in the TIC, which have a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is >1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs. A smaller petrogenic influence is indicated by the presence of a UCM and terpanes. No evidence of refined petroleum products.

IPS-SD09-28

This sample demonstrates a strong pyrogenic influence, as indicated by the large PAH peaks in the TIC, which have a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is >1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs. A minor petrogenic influence is indicated by a small UCM and small amounts of terpanes. No evidence of refined petroleum products.

IPS-SD09-29

This sample demonstrates a strong pyrogenic influence, as indicated by the large PAH peaks in the TIC, which have a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is lower than in most other samples. The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs. The fluoranthene/pyrene ratio is ~ 1 . A smaller petrogenic influence is indicated by the presence of a UCM and small amounts of terpanes. No evidence of refined petroleum products.

IPS-SD09-30

This sample demonstrates a strong pyrogenic influence, as indicated by the large PAH peaks in the TIC, which have a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is >1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs. A minor petrogenic influence is indicated by the presence of a small UCM and traces of terpanes. No evidence of refined petroleum products.

IPS-SD09-31

This sample demonstrates a predominantly petrogenic influence, as indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. Biogenic compound peaks are pronounced. PAHs are evident in the TIC, which have a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is ~ 1 .

IPS-SD09-32

This sample demonstrates a predominantly petrogenic influence, as indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. There appear to be a number of biogenic compound peaks. Small PAH peaks are evident in the TIC, which have a predominantly pyrogenic signature in the aromatic hydrocarbon bar diagram.

IPS-SD09-33

This sample demonstrates a predominantly petrogenic influence, as indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. There are some prominent biogenic compound peaks, and two phenolic compounds, which could have either a biogenic or anthropogenic origin. Small PAHs are evident in the TIC, which have a strongly pyrogenic signature in the aromatic hydrocarbon bar diagram.

IPS-SD09-34

This sample demonstrates a predominantly petrogenic influence, as indicated by the appreciable size of the UCM and the presence of terpanes. No evidence of refined petroleum products. There are no identifiable biogenic compound peaks. Relatively small amounts of PAHs have a predominantly pyrogenic signature in the aromatic hydrocarbon bar diagram.

IPS-SD09-38

This sample demonstrates substantial pyrogenic and petrogenic influences. The prominent suite of PAHs evident in the TIC has a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is <1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs. The petrogenic influence is indicated by the UCM and the presence of terpanes. No evidence of refined petroleum products.

IPS-SD09-39

This sample demonstrates a somewhat more pronounced petrogenic influence but a still substantial pyrogenic influence. The prominent suite of PAHs evident in the TIC has a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is <1 . The pronounced PAH peaks distinguish the TIC of this sample from the reference TICs. The petrogenic influence is indicated by the relatively large UCM and the presence of terpanes. No evidence of refined petroleum products. There appear to be larger biogenic compound peaks than in IPS-SD09-38.

IPN-SD09-16

This sample demonstrates predominantly petrogenic and biogenic influences. The petrogenic influence is indicated by the presence of the UCM and terpanes. No evidence of refined petroleum products. Aromatic hydrocarbons that do not appear to be PAHs, nitrogen containing compounds, and cholesterol are probably biogenic molecules. Small PAH peaks are evident in the TIC, which have a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is <1 .

IPN-SD09-17

This sample demonstrates a predominantly petrogenic influence indicated by the larger UCM and the presence of terpanes. No evidence of refined petroleum products. Relatively large biogenic compound peaks are present. PAH peaks are evident in the TIC, which have a pyrogenic signature in the aromatic hydrocarbon bar diagram. The fluoranthene/pyrene ratio is ~ 1 .

IPN-SD09-18

This sample demonstrates predominantly petrogenic and biogenic influences. The petrogenic influence is indicated by the presence of the UCM and terpanes. No evidence of refined petroleum products. Relatively large biogenic compound peaks are present. Small PAH peaks are evident in the TIC, which have a pyrogenic signature in the aromatic hydrocarbon bar diagram.

IPN-SD09-19

This sample is very similar to IPN-SD09-17, and demonstrates a predominantly petrogenic influence indicated by the large UCM and the presence of terpanes. No evidence of refined petroleum products. Relatively large biogenic compound peaks are present. PAH peaks are evident in the TIC, which have a pyrogenic signature in the aromatic hydrocarbon bar diagram.

IPN-SD09-20

This sample demonstrates a predominantly petrogenic influence indicated by the large UCM and the presence of terpanes. No evidence of refined petroleum products. Relatively large biogenic compound peaks are present. Small PAH peaks are evident in the TIC, which have a predominantly pyrogenic signature in the aromatic hydrocarbon bar diagram.

4.0 Conclusions

The 26 sediment samples contain compounds of biogenic, pyrogenic, and petrogenic origin. Almost all the samples contain compounds of all three origins.

Biogenic inputs include a number of sterols, alkenes, fatty acids, perylene, and other unidentified biological molecules. A large cholesterol component was present in IPS-SD09-25, which is one of the samples closest to a storm water outfall at the southern end of the pipeline ROW. This is the only obvious correlation of the sample chemistry with the outfall.

Pyrogenic inputs are a suite of PAHs that were detected in all the samples, including reference samples. Even samples that show no obvious indication of the PAH suite in the TIC show a pyrogenic PAH signature in the aromatic bar diagram. The IPS samples show the most pyrogenic influence. IPS samples in the southwestern transect are dominated to such an extent by pyrogenic PAHs that input from a pyrogenic product such as weathered creosote is likely. The samples closest to the railroad lines along the southern shore (IPS-SD09-25, IPS-SD09-23) have relatively small PAH components. The PAH components increase north of IPS-SD09-27. This suggests that the source of the large PAH impacts along the southwestern transect is not creosote leached from the ties along the railroad. Differences in the fluoranthene/pyrene ratio suggest more than one source for the pyrogenic product. The pyrogenic PAH component is lower in the IPN samples, but still higher in some (IPN-SD09-16, IPN-SD09-17) than in reference samples. This suggests that the IPN samples are influenced by a pyrogenic source other than background. The PAHs in samples with lower concentrations may be from urban runoff. In all the samples, the PAHs are almost exclusively of pyrogenic rather than petrogenic origin.

Petrogenic inputs include terpanes, and an Unresolved Complex Mixture (UCM) that is conventionally assigned to a petrogenic origin, but in some of these samples may contain biogenic material. These inputs are severely weathered. There is no evidence of refined petroleum products in the samples. The following lines of evidence point to a regional source such as urban runoff for the petrogenic hydrocarbons.

- a) The terpane distributions are very similar in all the samples. In particular, IA-SD09-REF3, located far from the other samples has a similar petrogenic terpane signature. Petrogenic inputs from, for example, localized crude oil releases would be unlikely to show this uniformity.
- b) The presence of a sizable UCM in three of the five reference samples, located away from the influence of the pipeline ROW.
- c) The similarity of the TIC patterns to those of documented urban runoff, particularly sites A and D shown in Figure 4.

There is no evidence of inputs from the pipeline ROW or pipeline operations to the sediment samples. Biogenic molecules likely result from biological activity in the water column and sediment with some input perhaps from storm water outfalls. Pyrogenic PAHs are likely from creosote and urban runoff. Petrogenic hydrocarbons show no input from refined petroleum products, and degraded petrogenic residues in the samples are more likely associated with urban runoff.

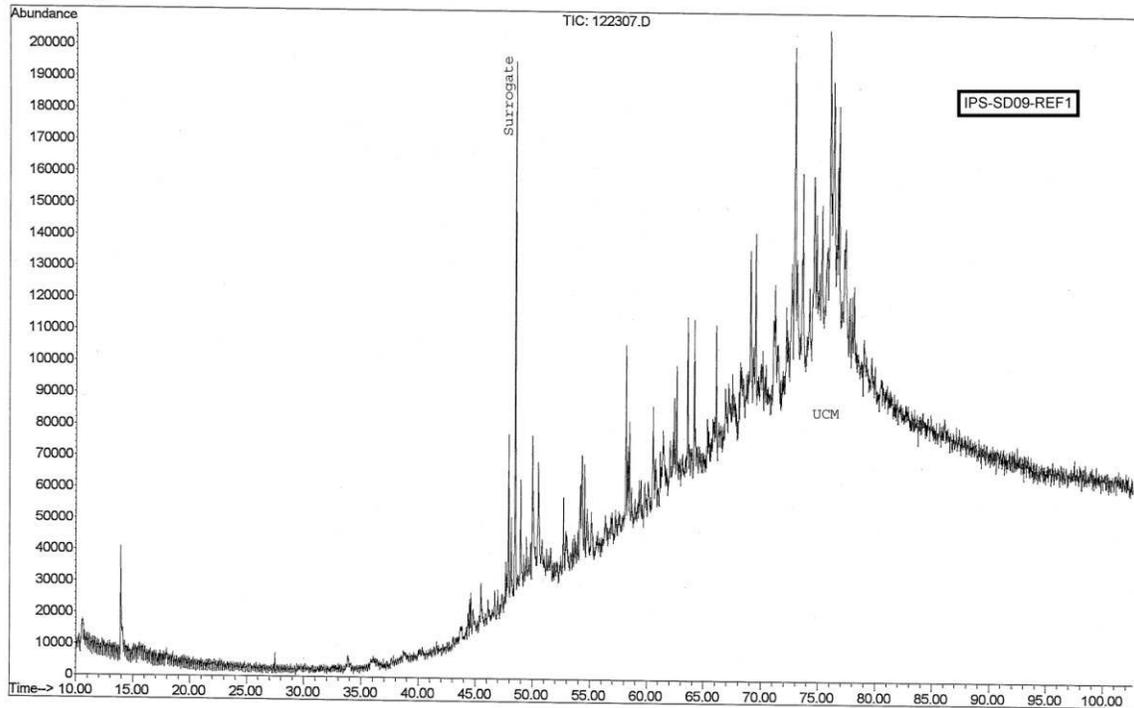
5.0 References

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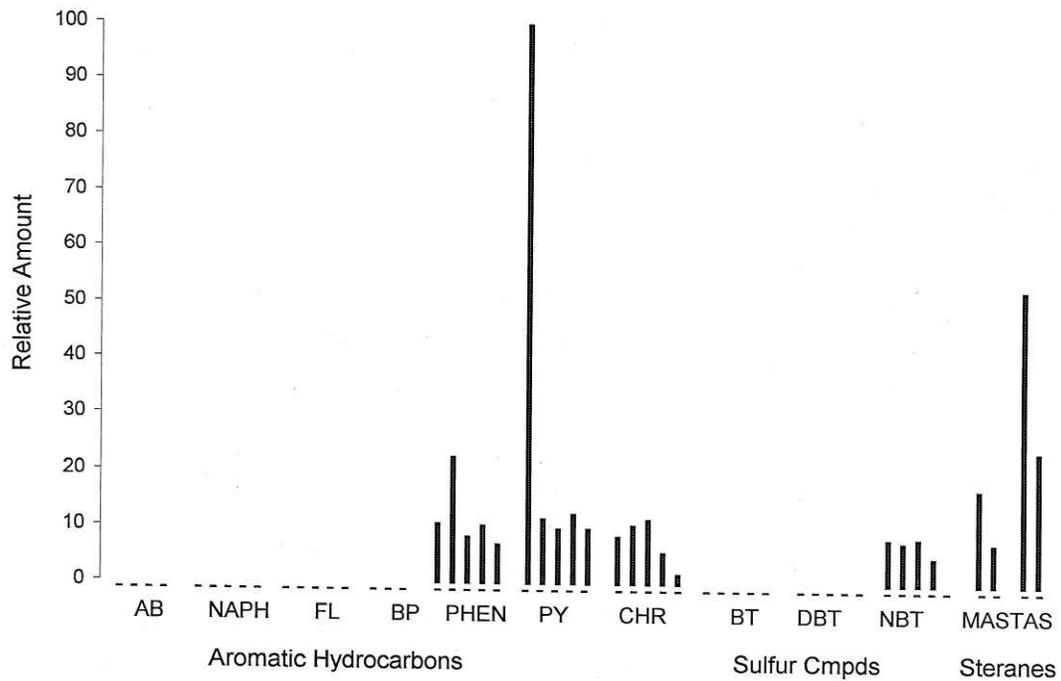
Electric Power Research Institute (EPRI) 2000. *Chemical source attribution at former MGP site, 1000728*, Palo Alto, CA: EPRI, Binghamton, NY.

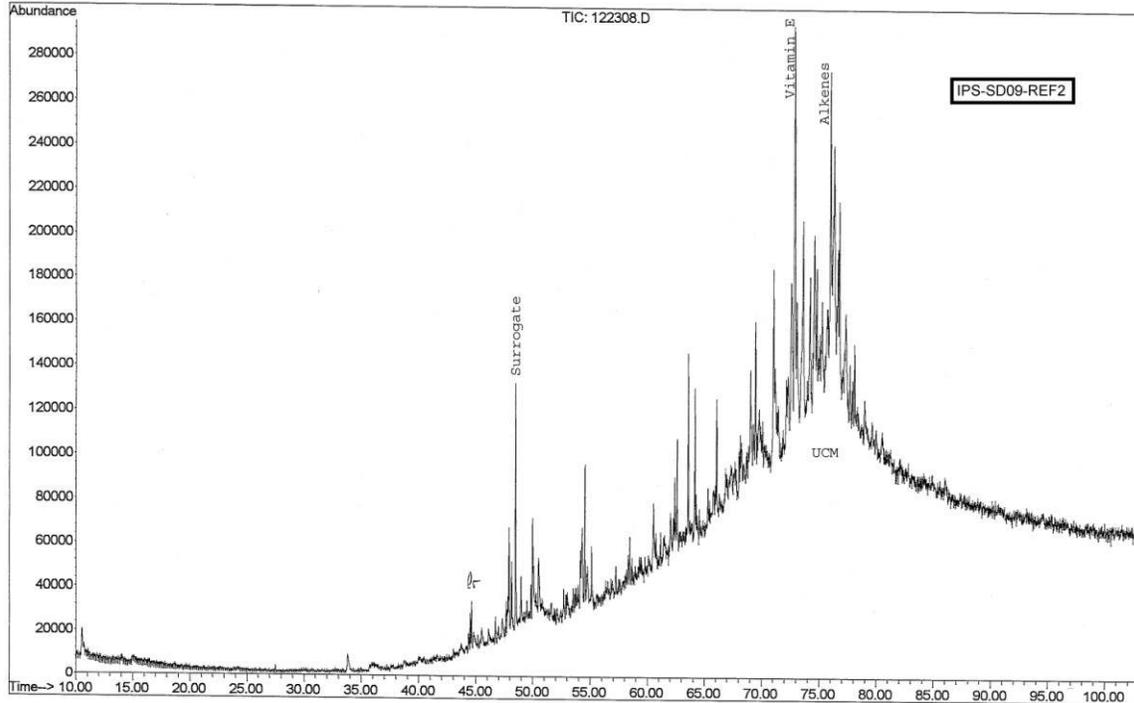
Stout, S.A., Uhler, A.D., and Emsbo-Mattingly, S.D. (2003) Characterization of “Urban Background” PAH in sediments. *Soil Sediment and Water*, September, 16-18.

6.0 Appendix: Chromatograms

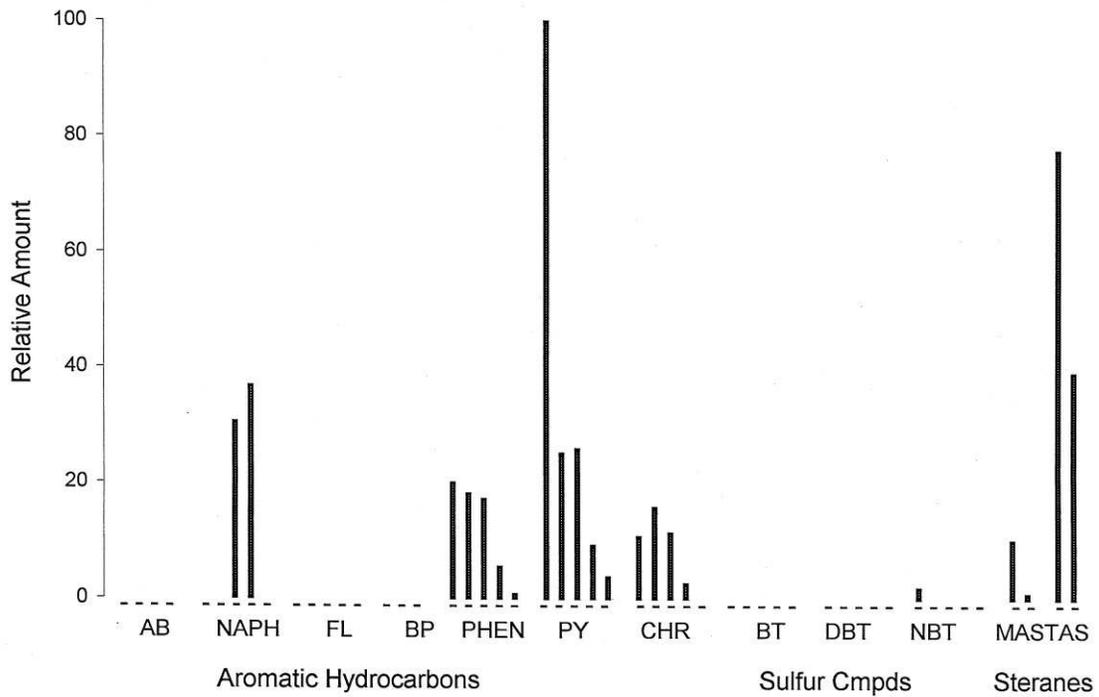


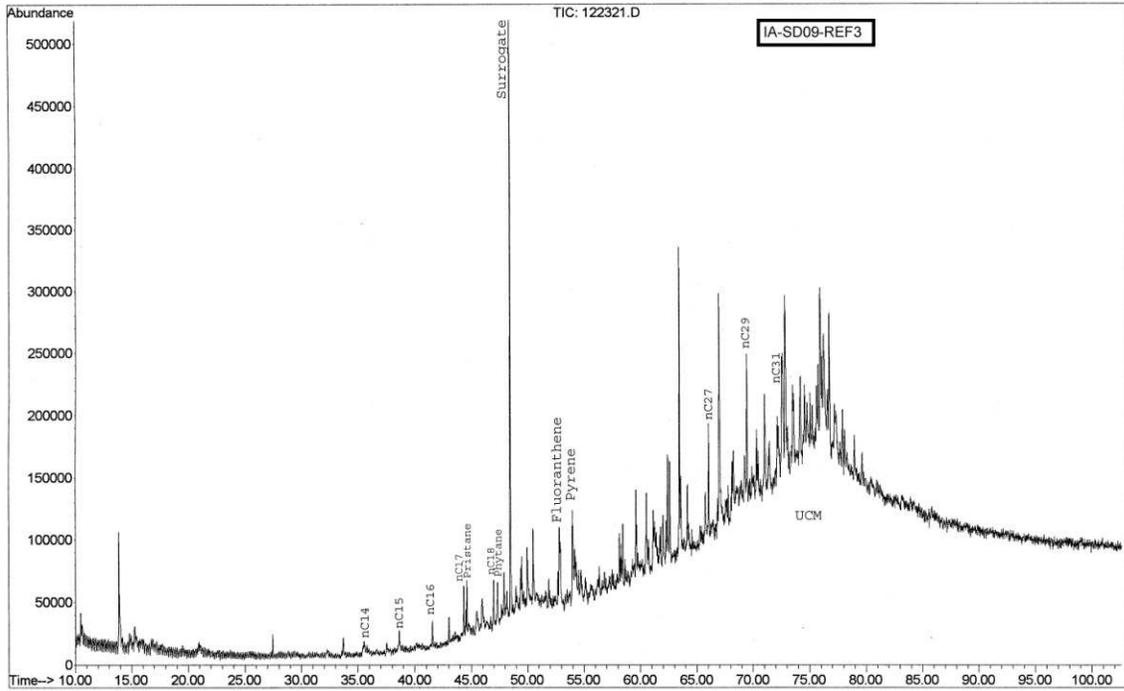
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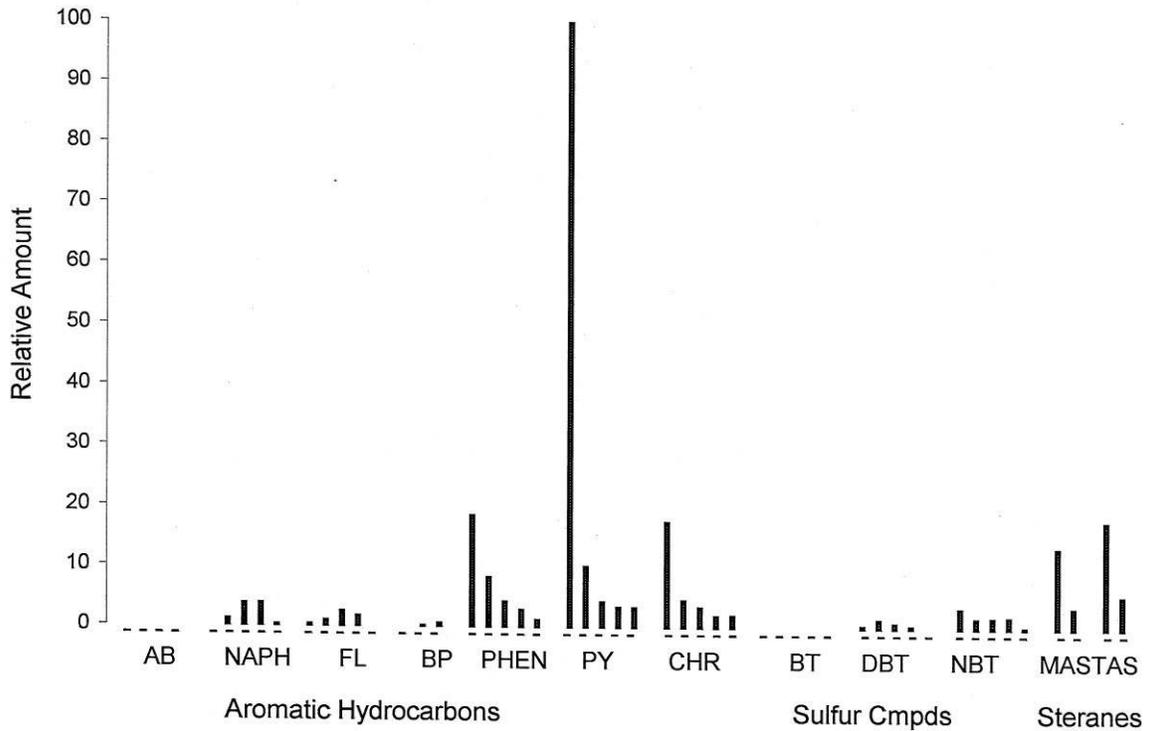


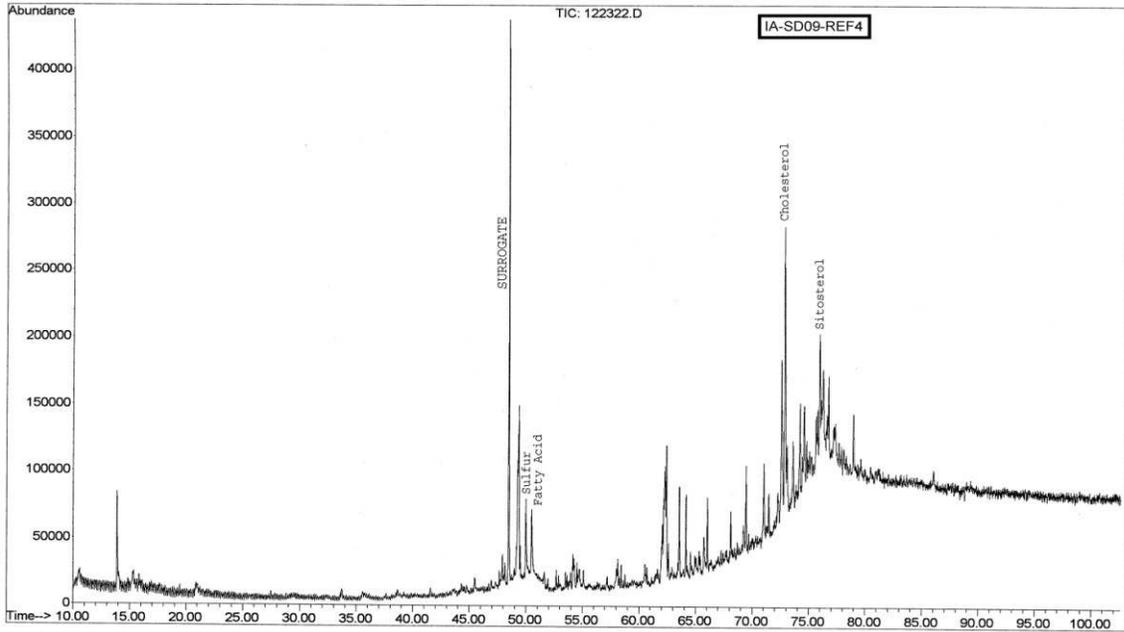
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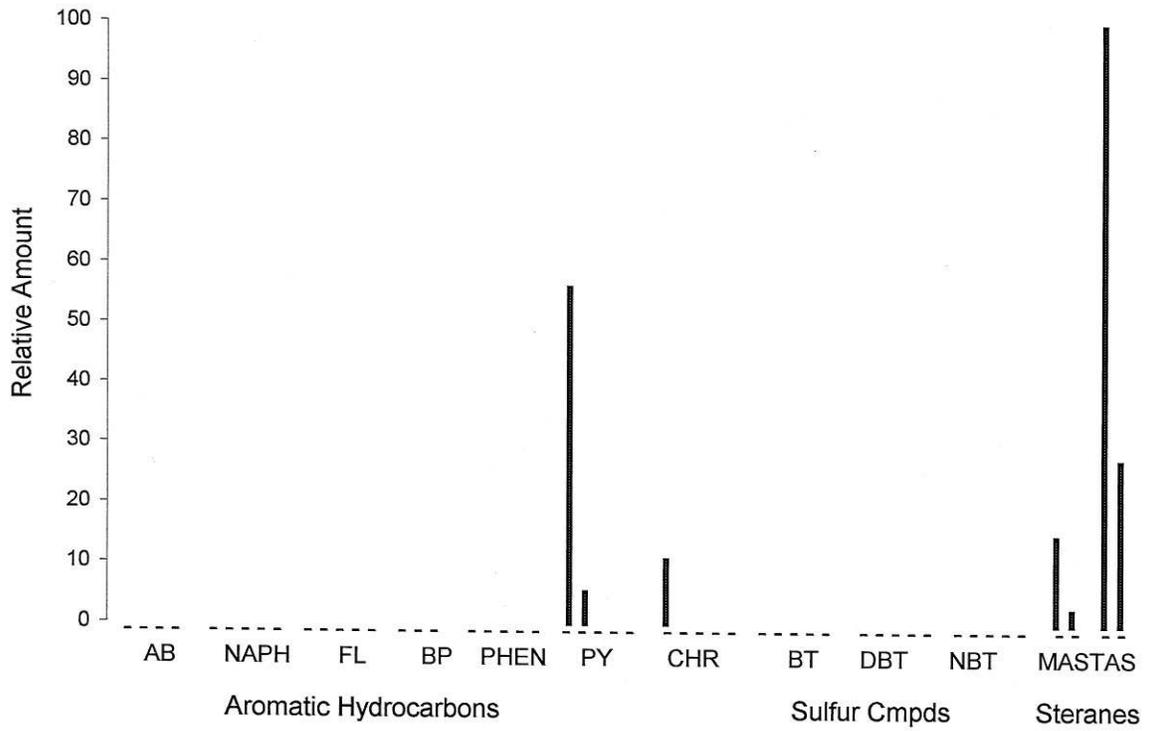


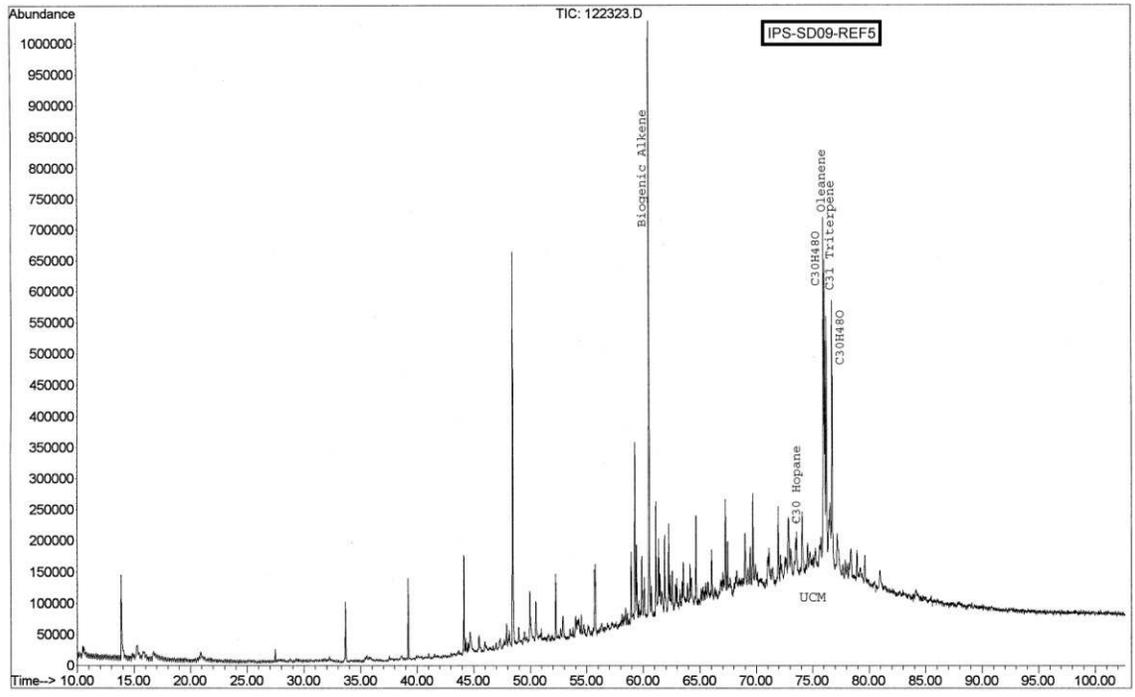
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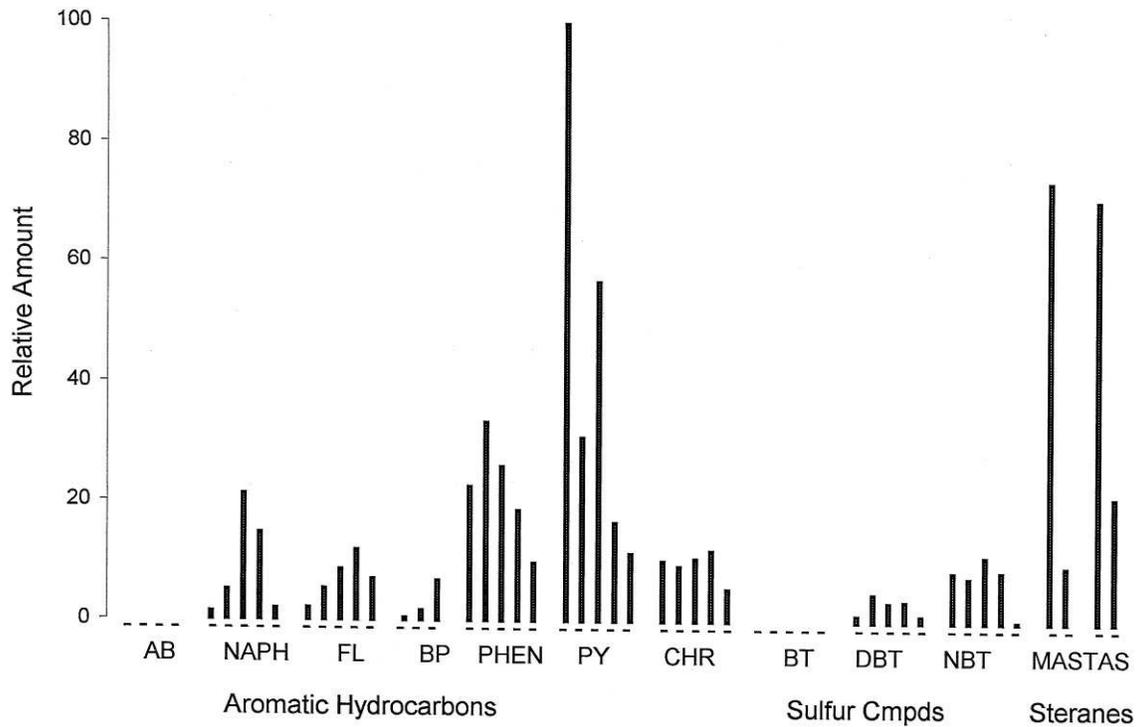


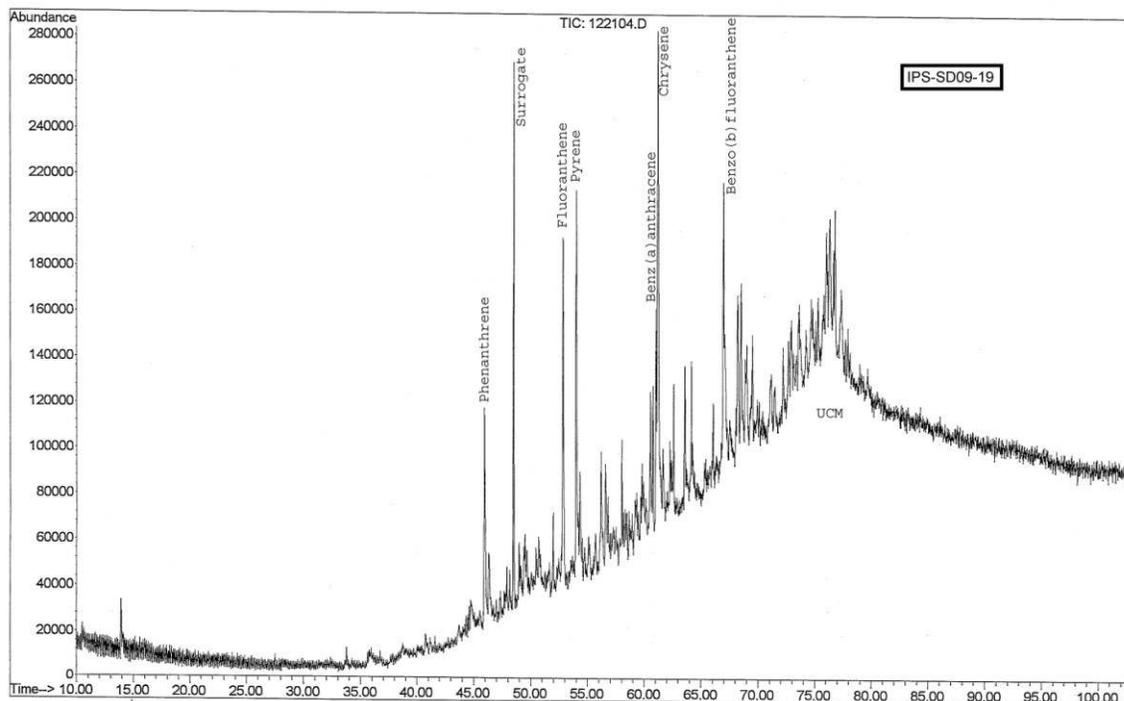
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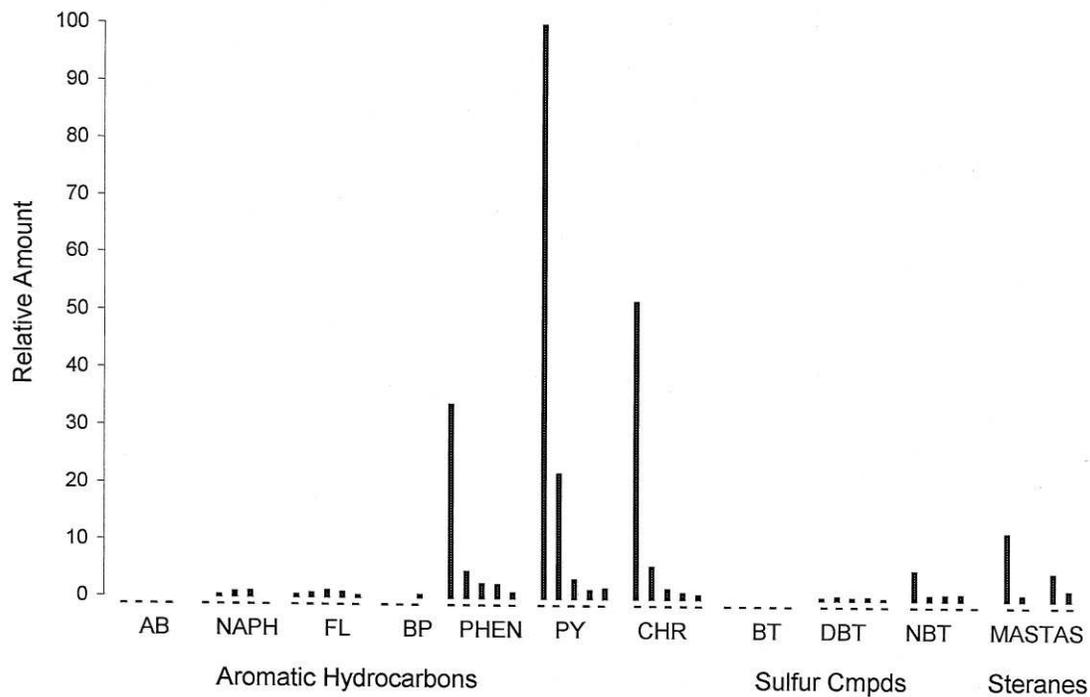


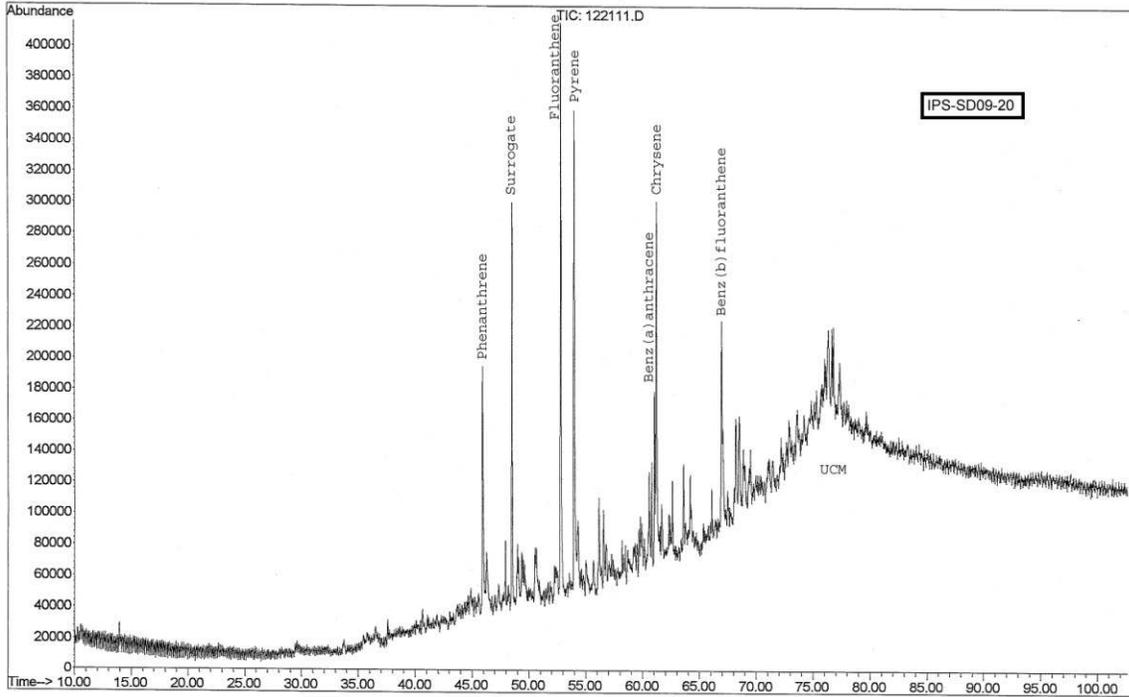
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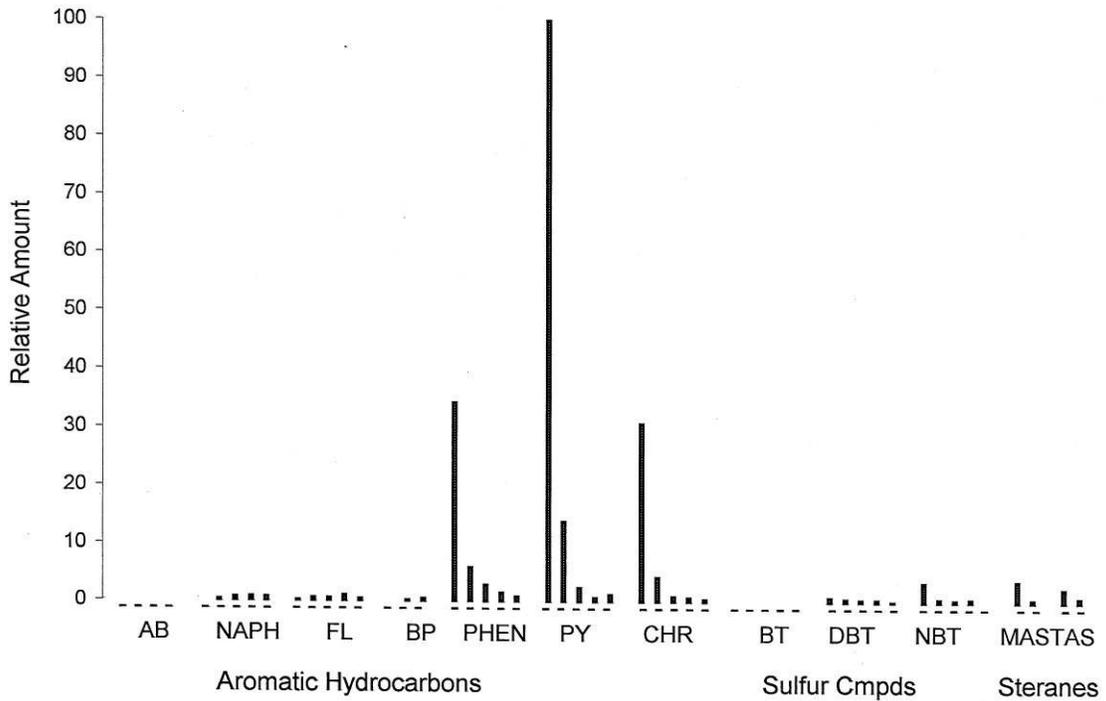


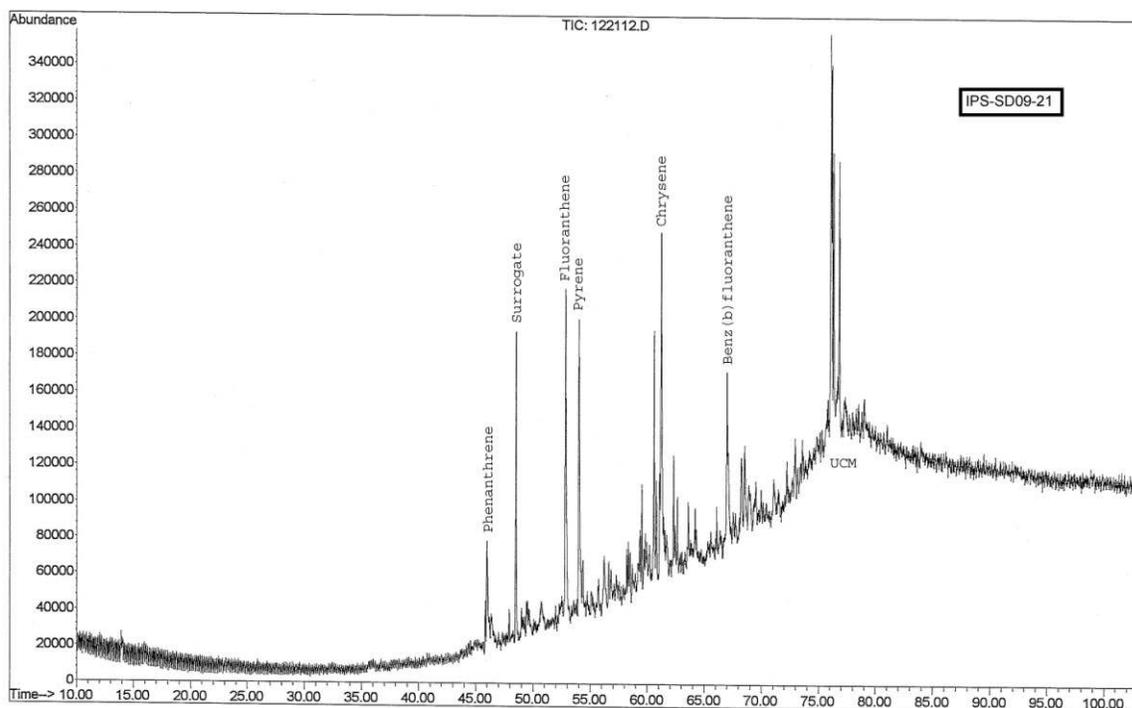
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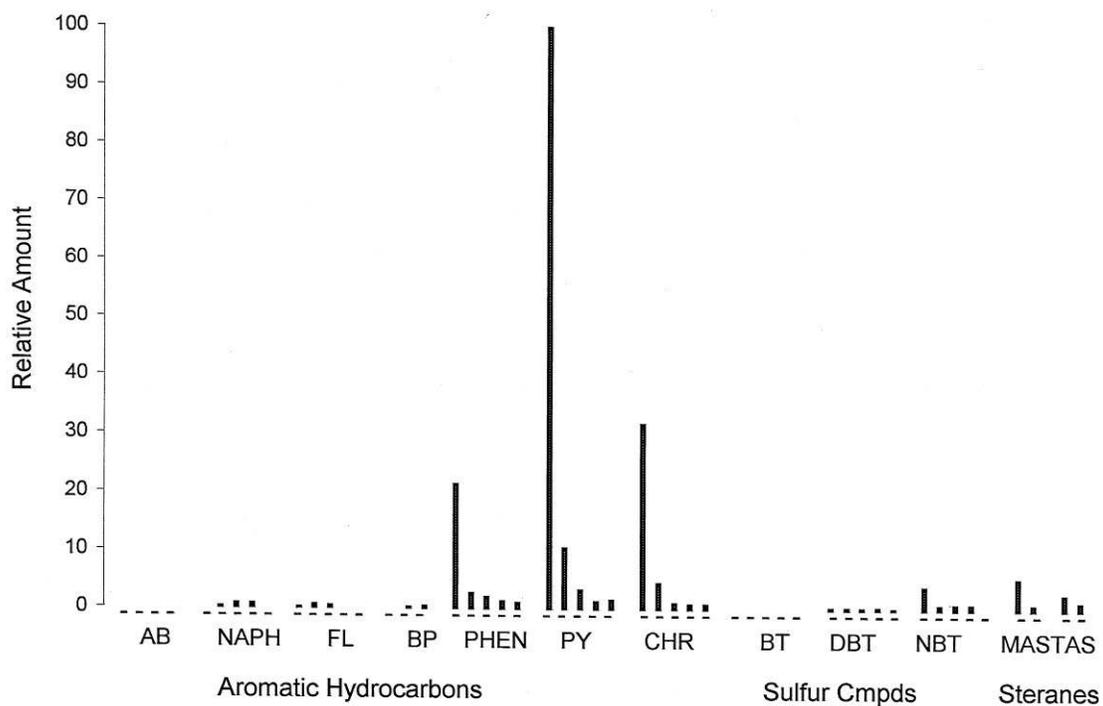


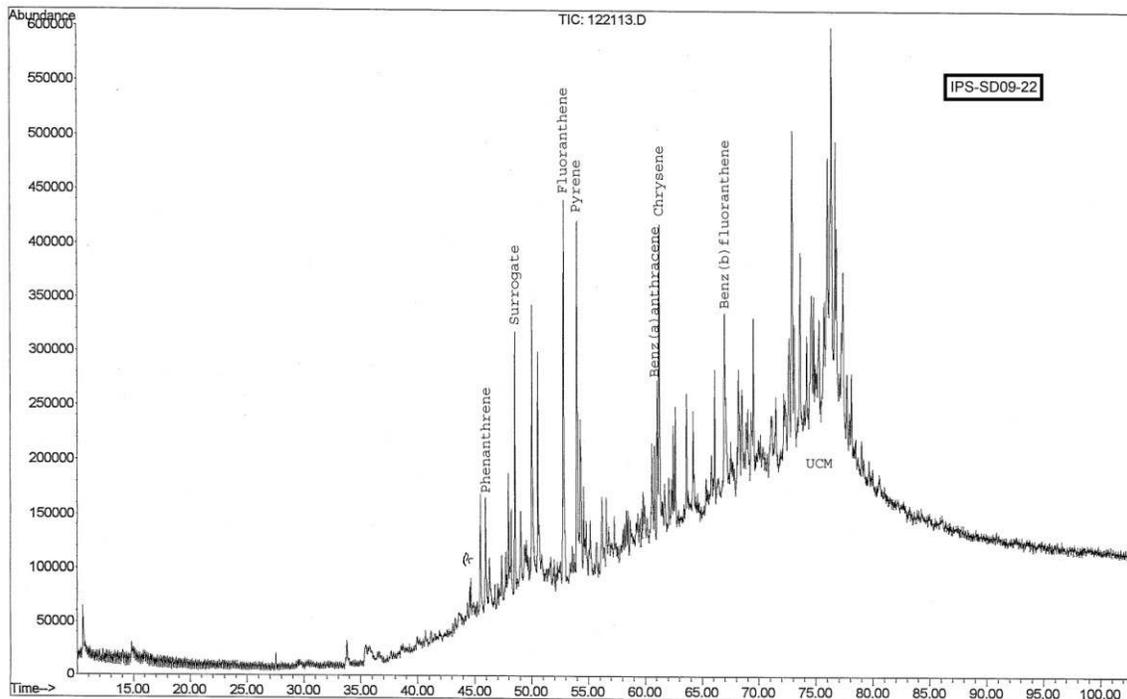
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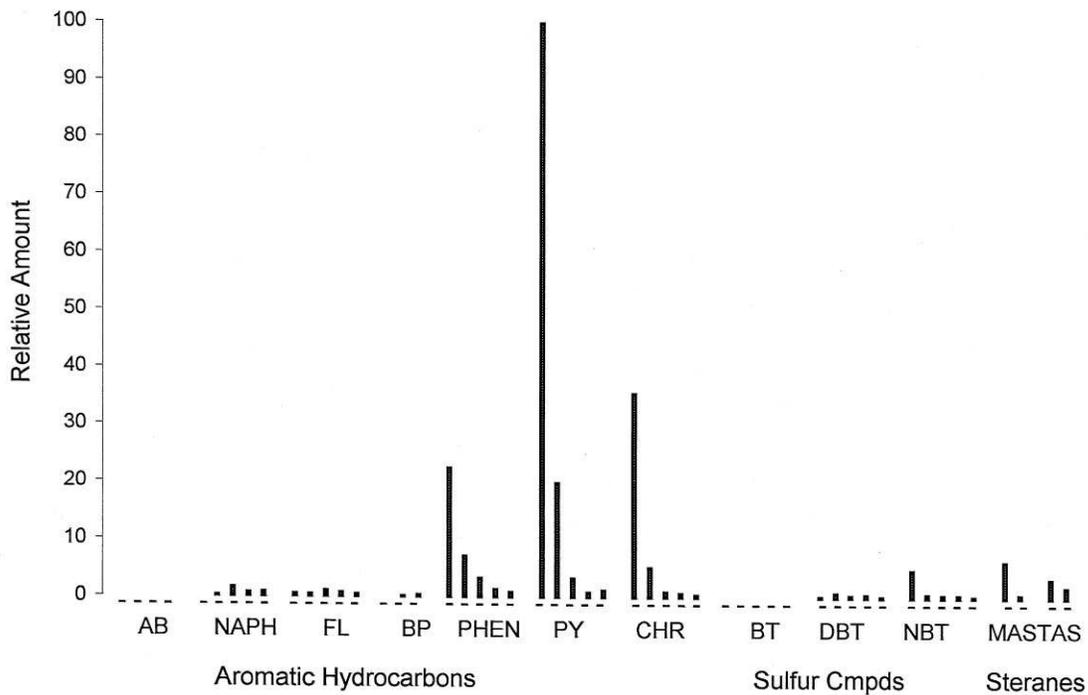


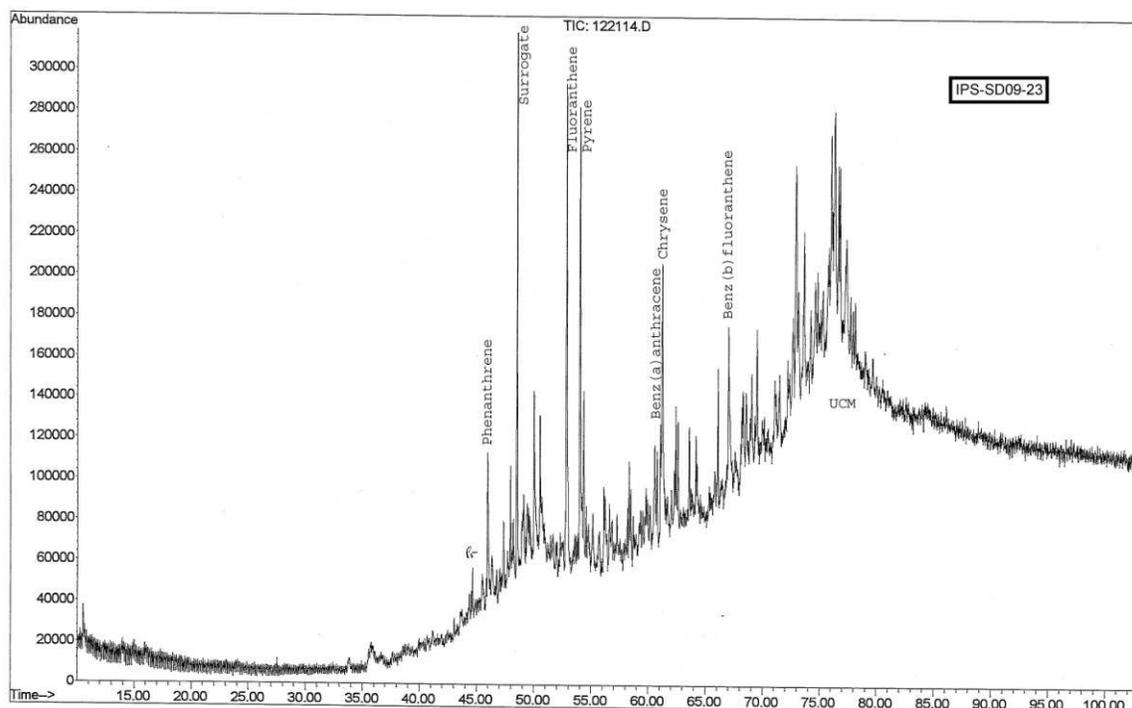
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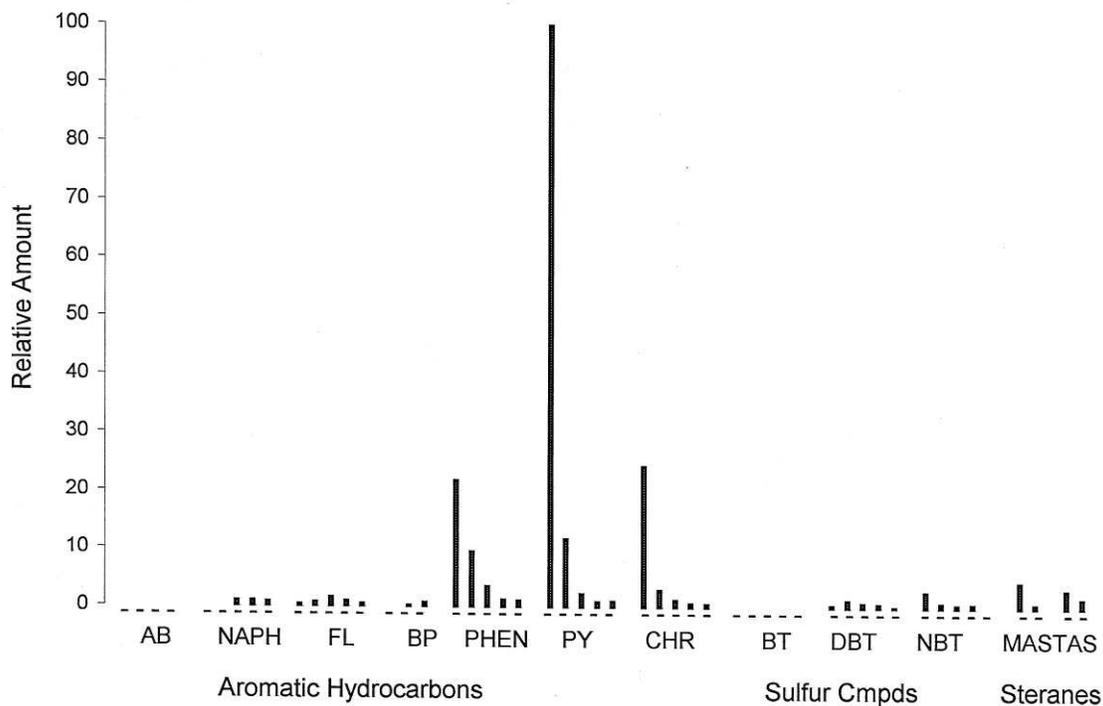


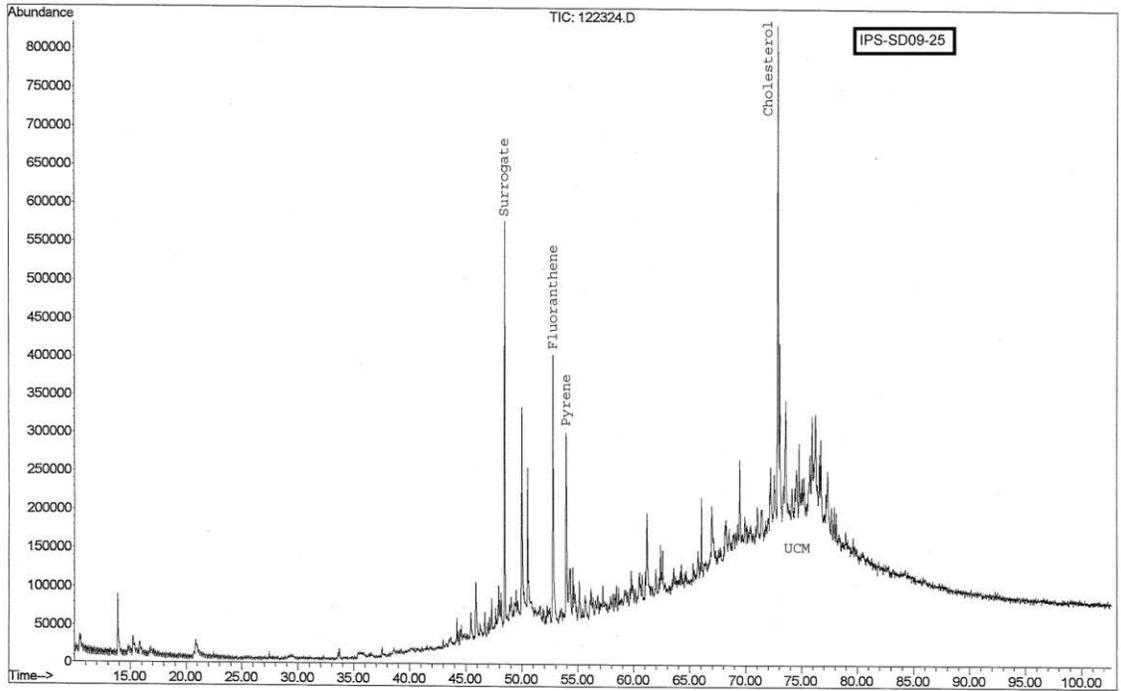
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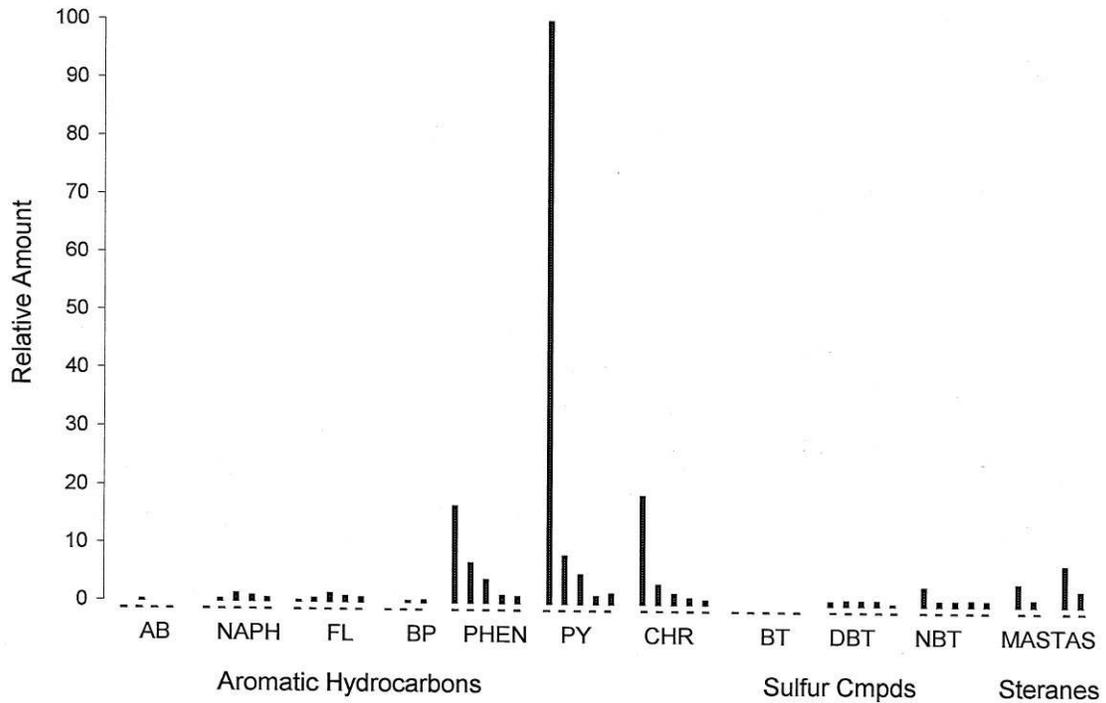


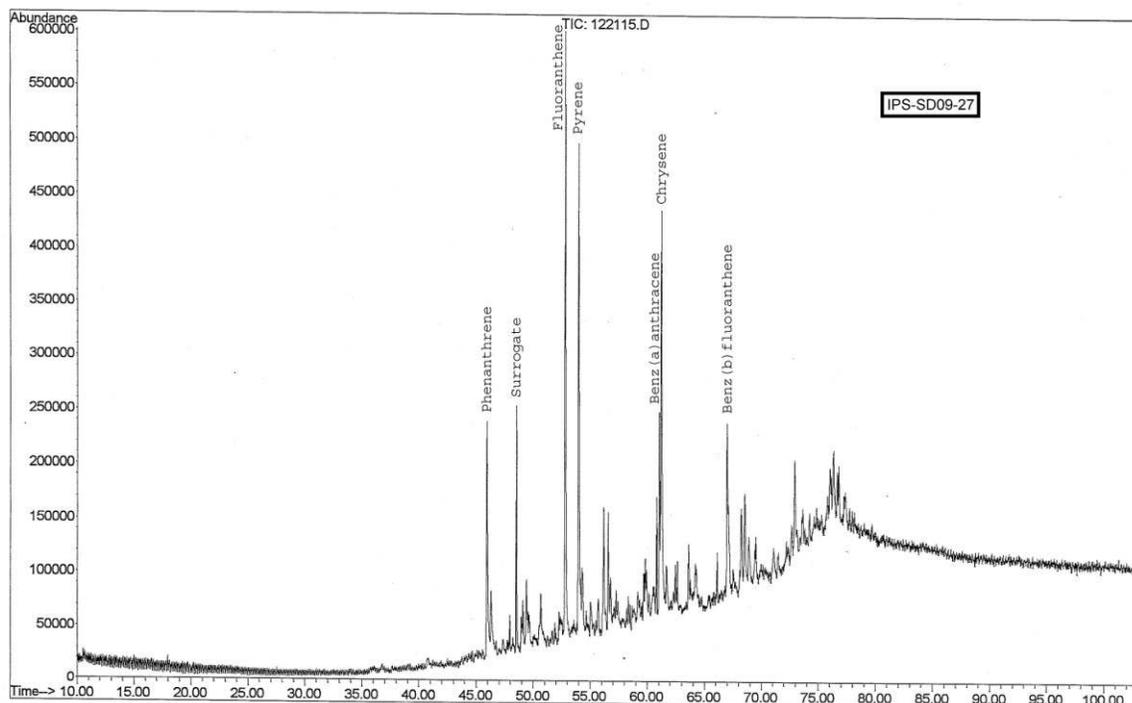
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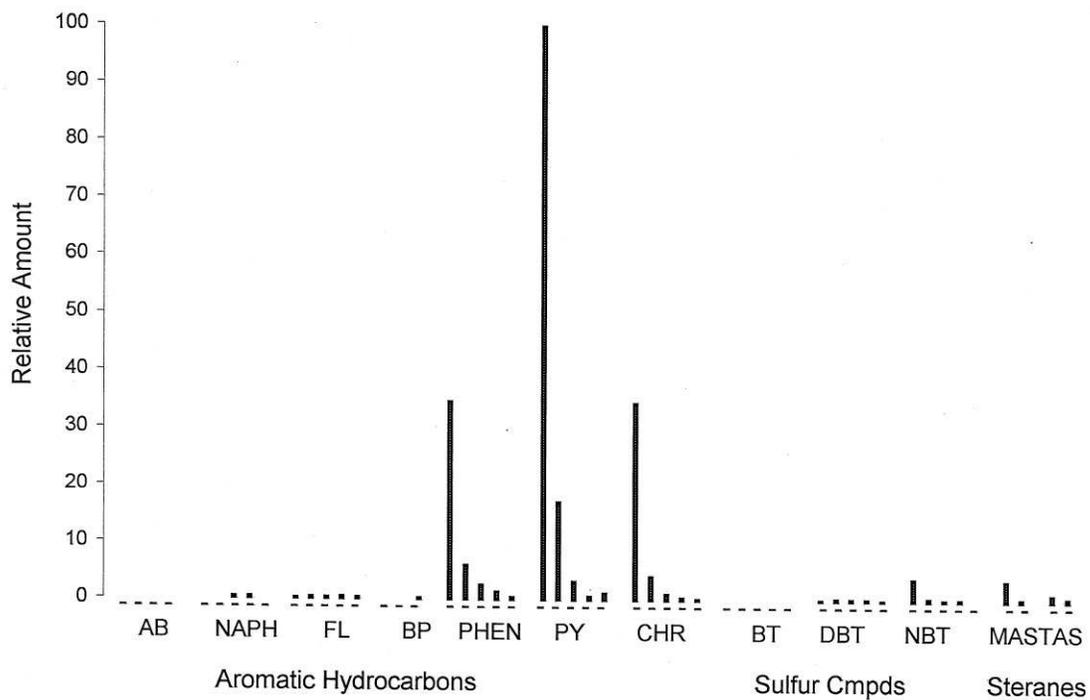


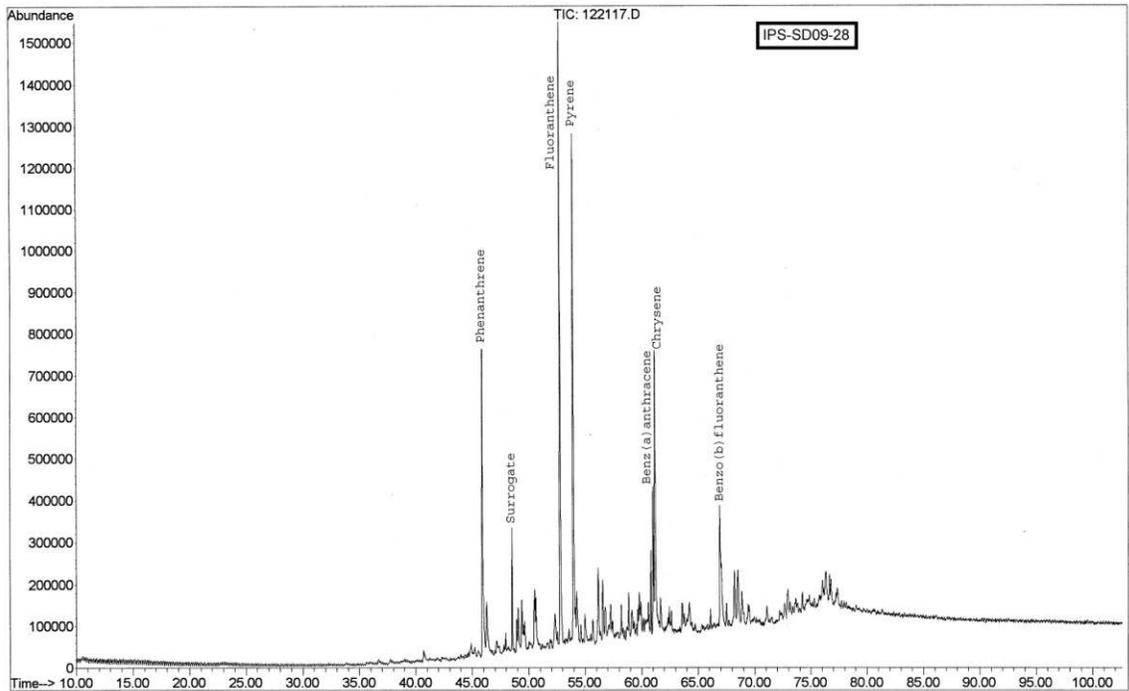
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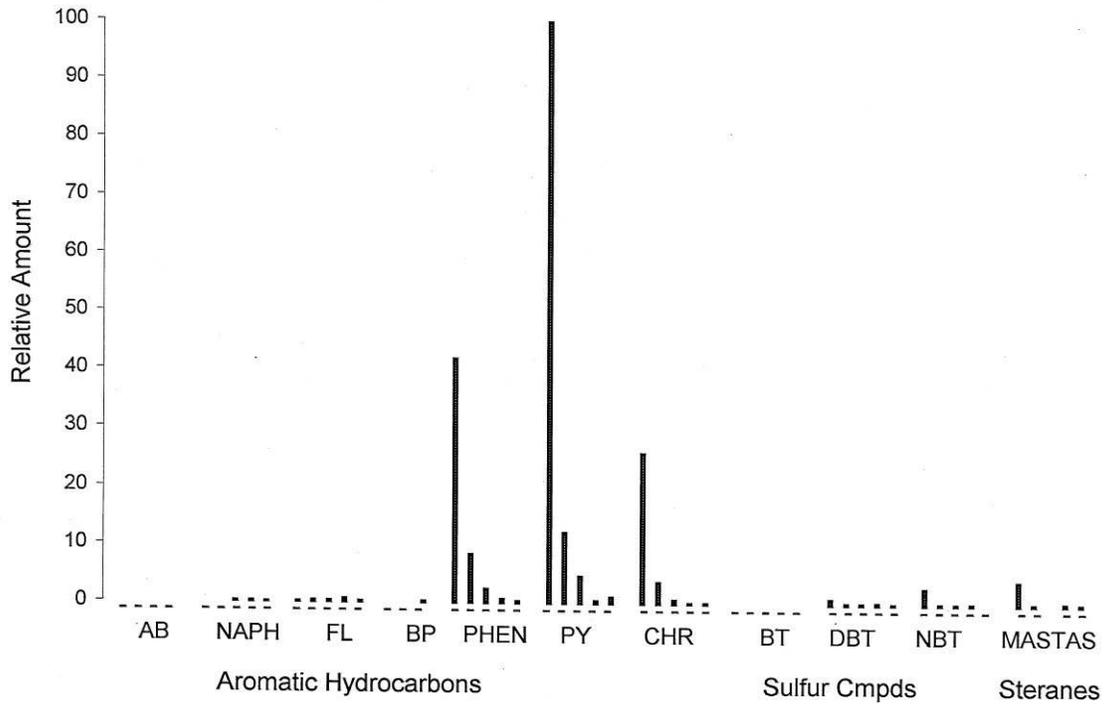


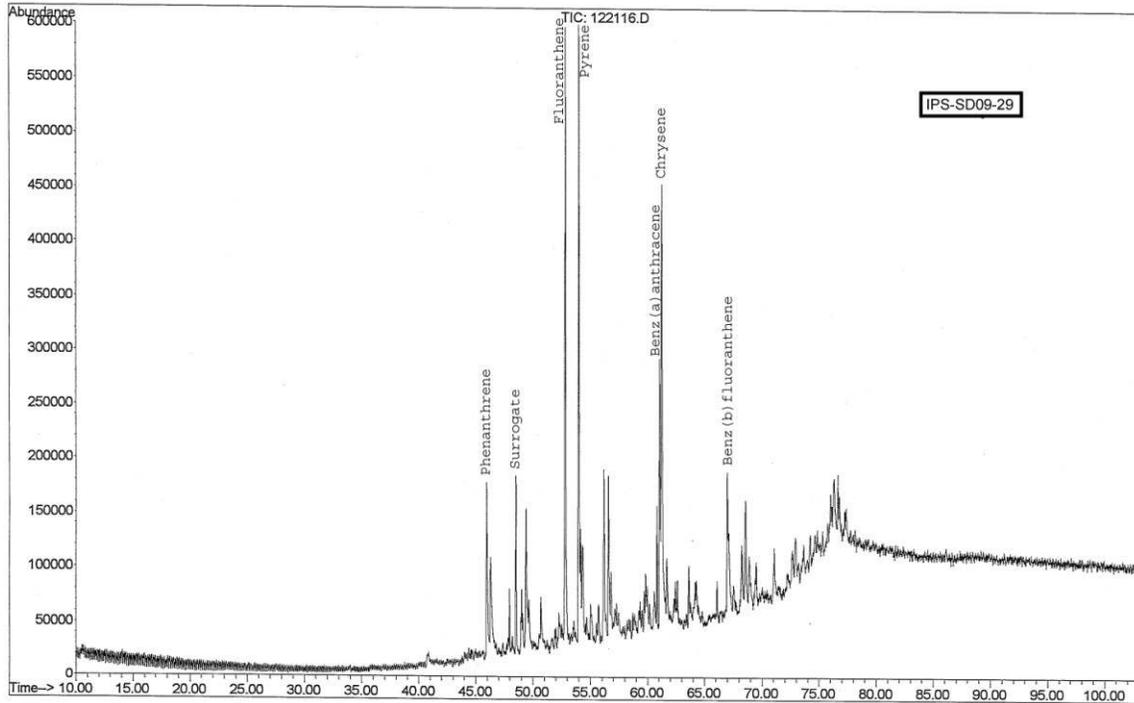
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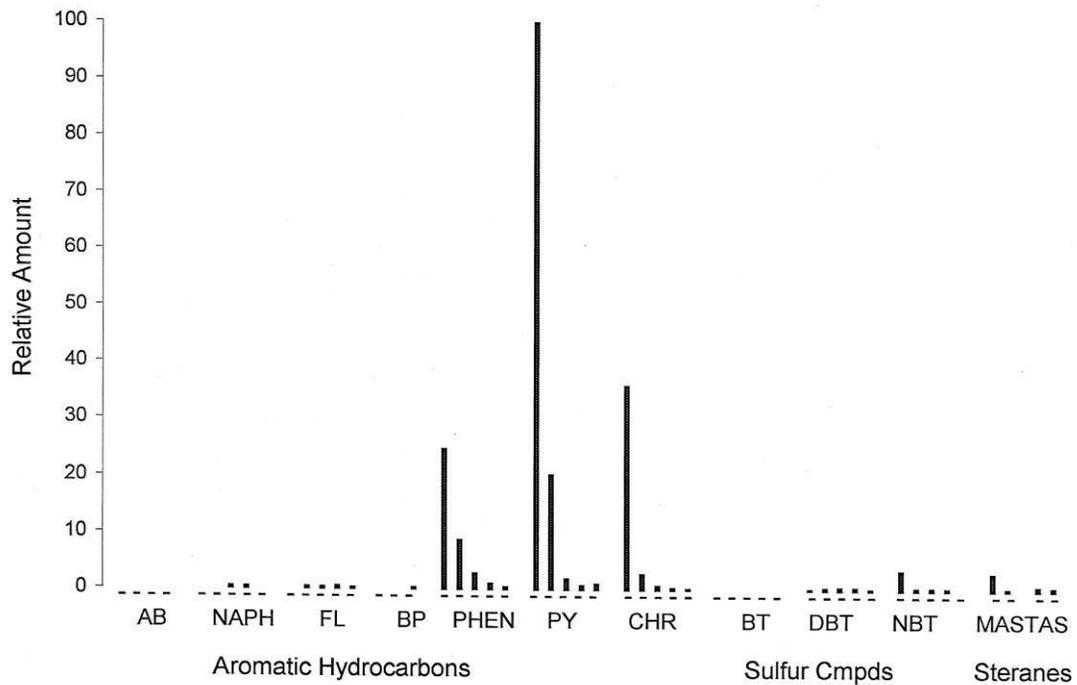


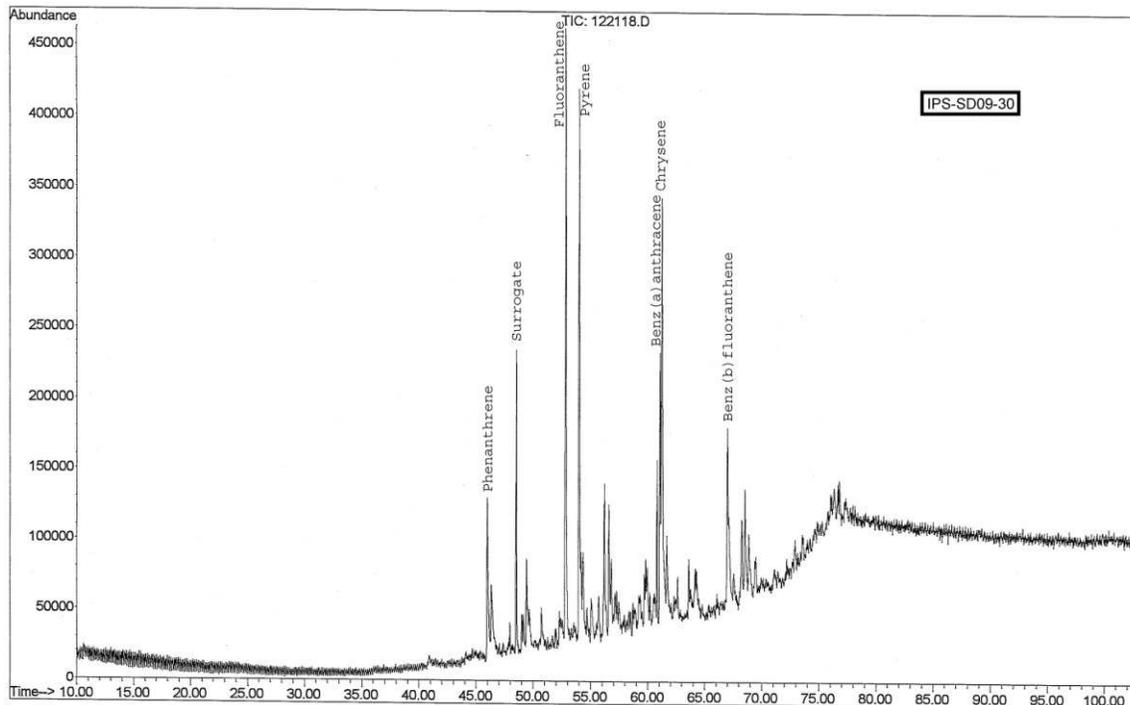
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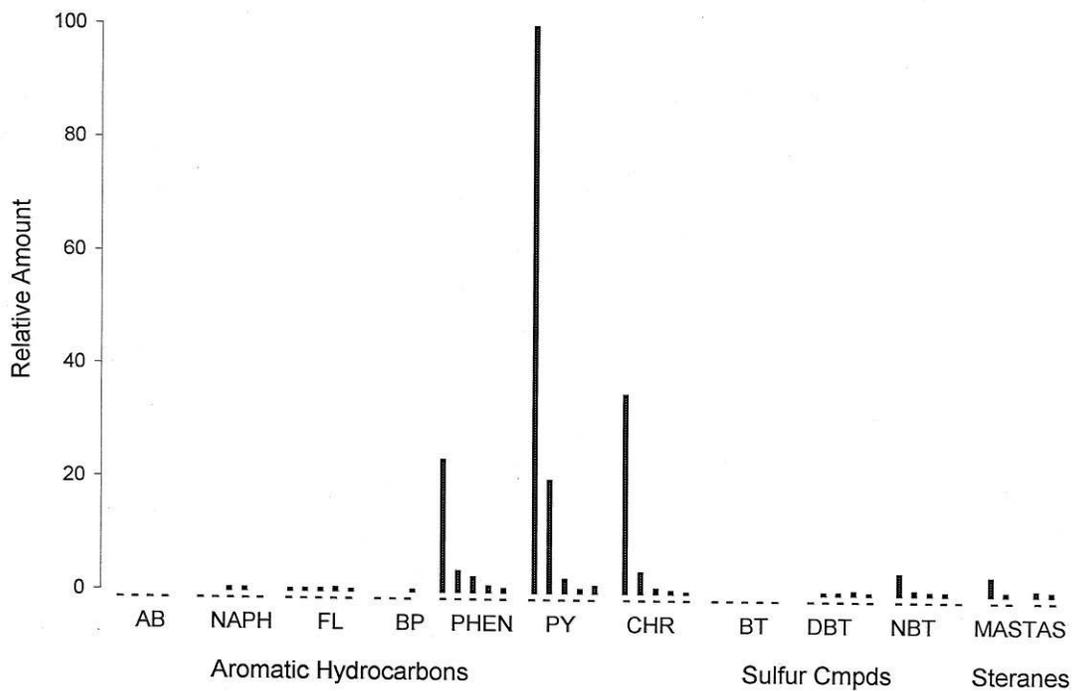


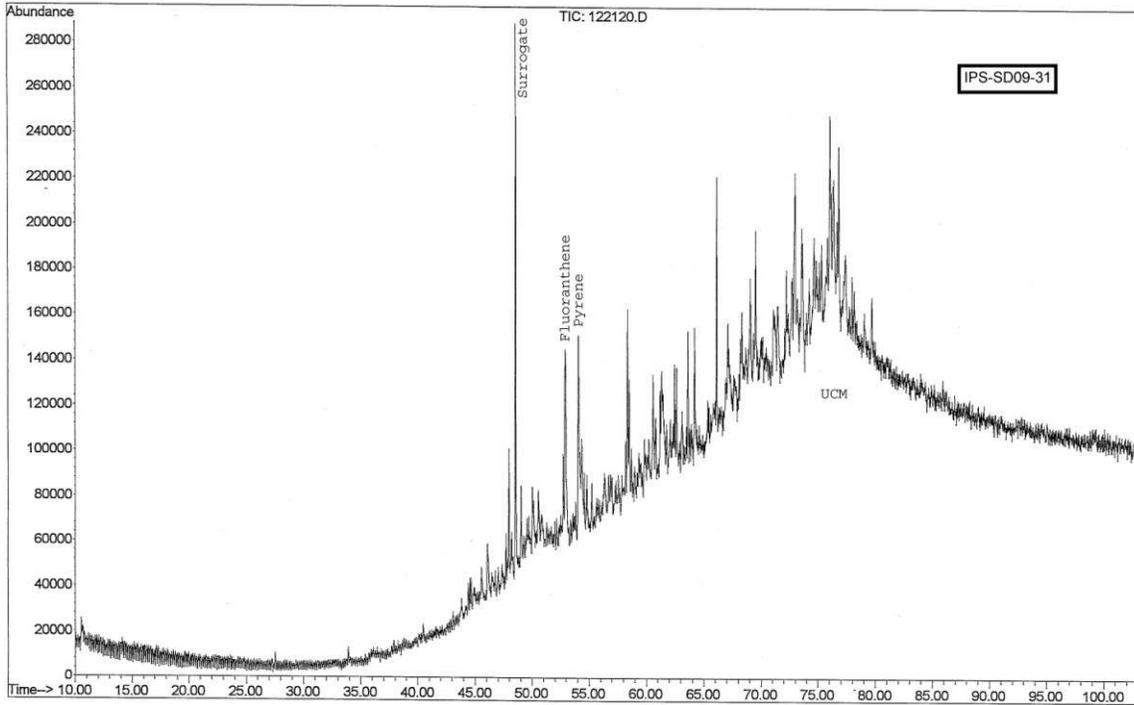
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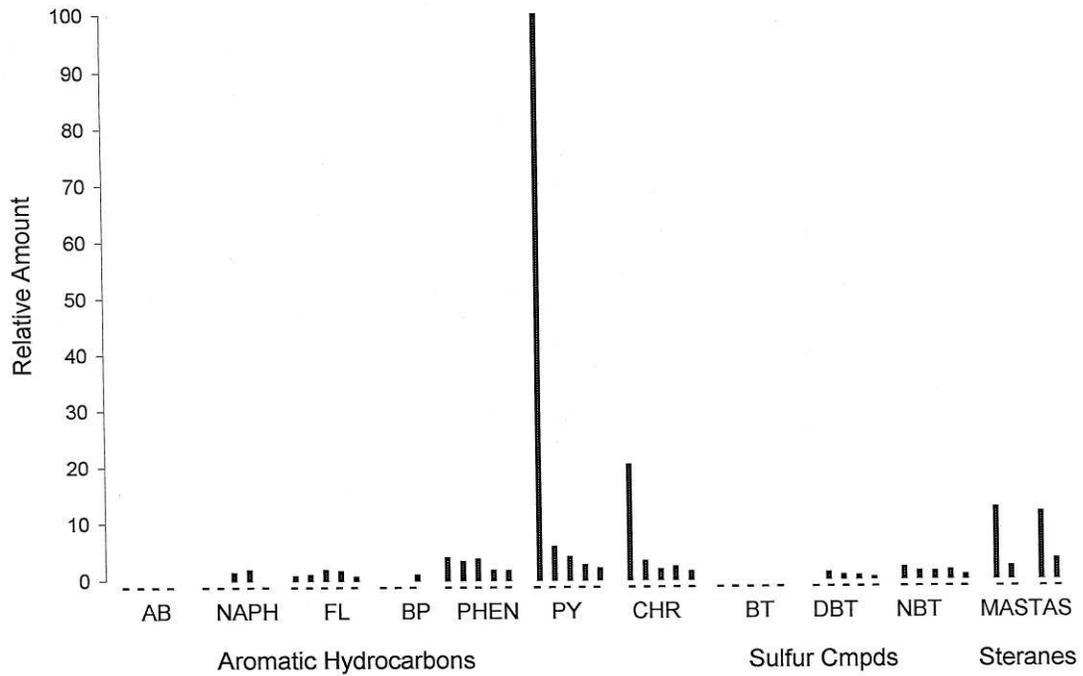


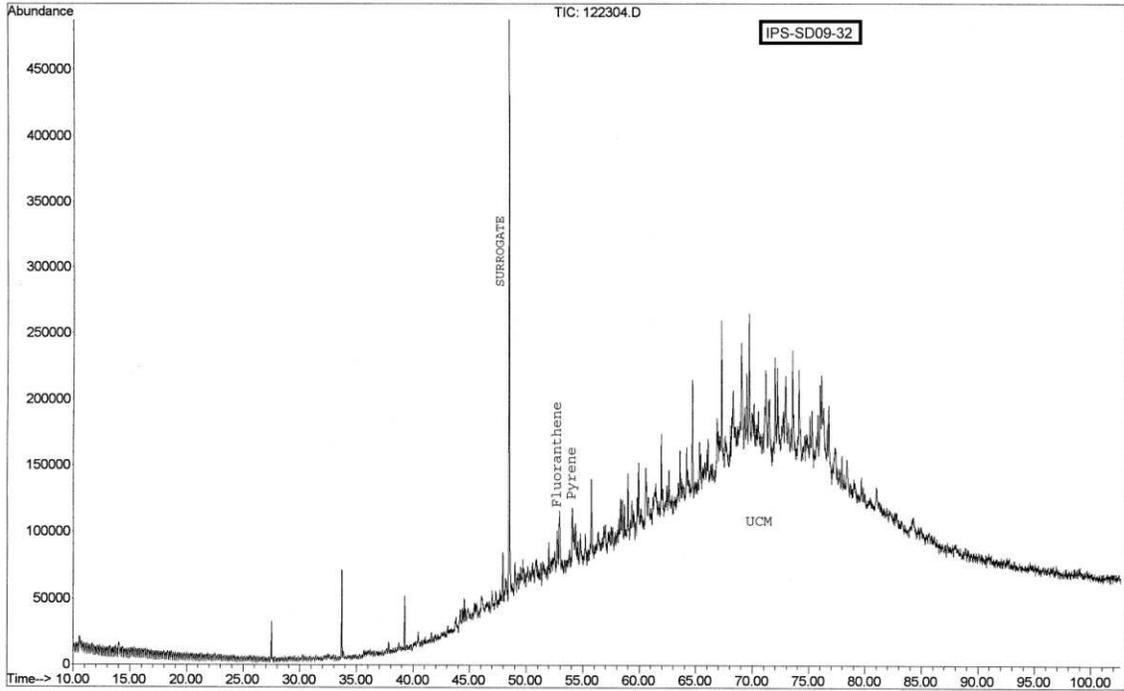
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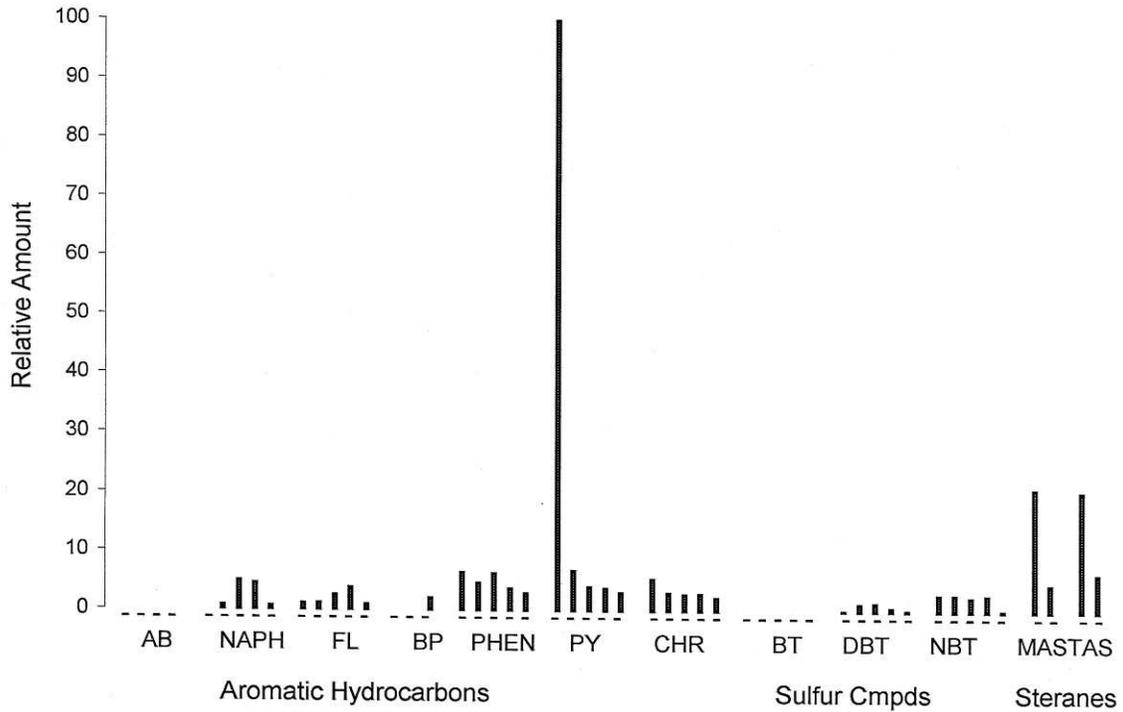


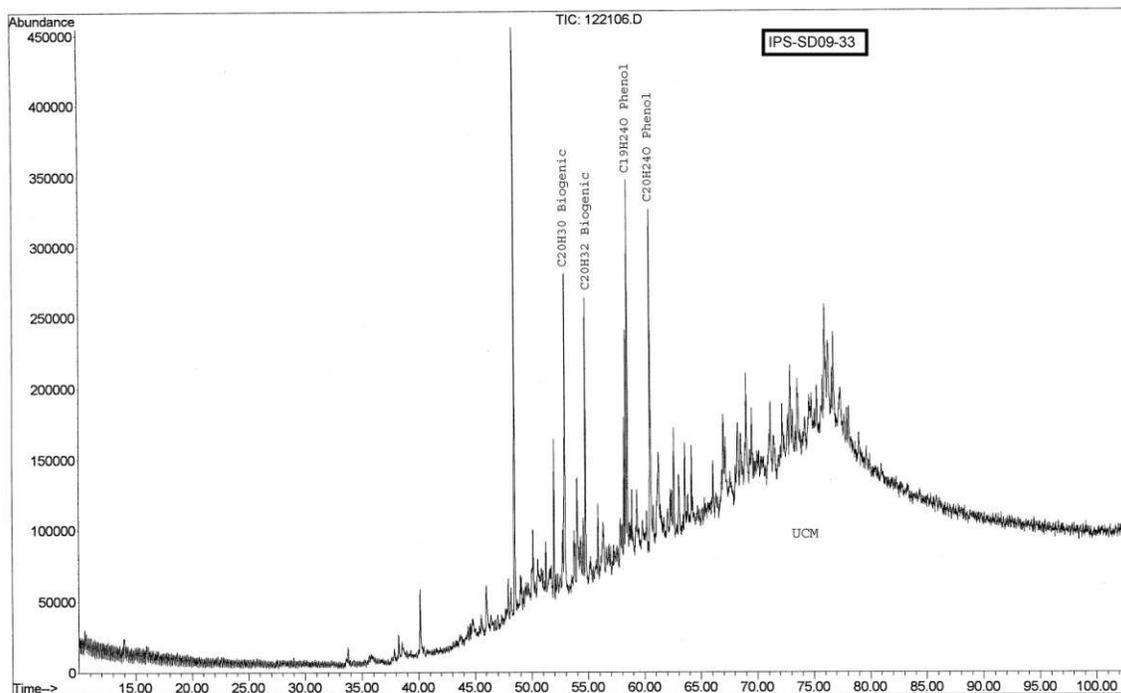
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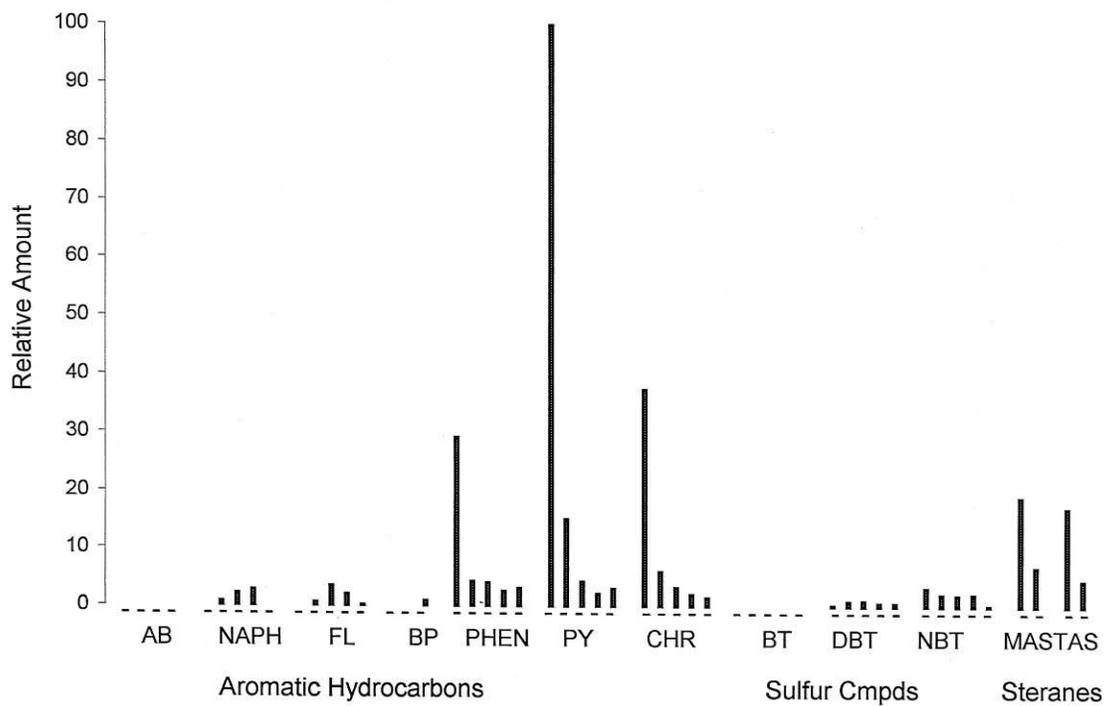


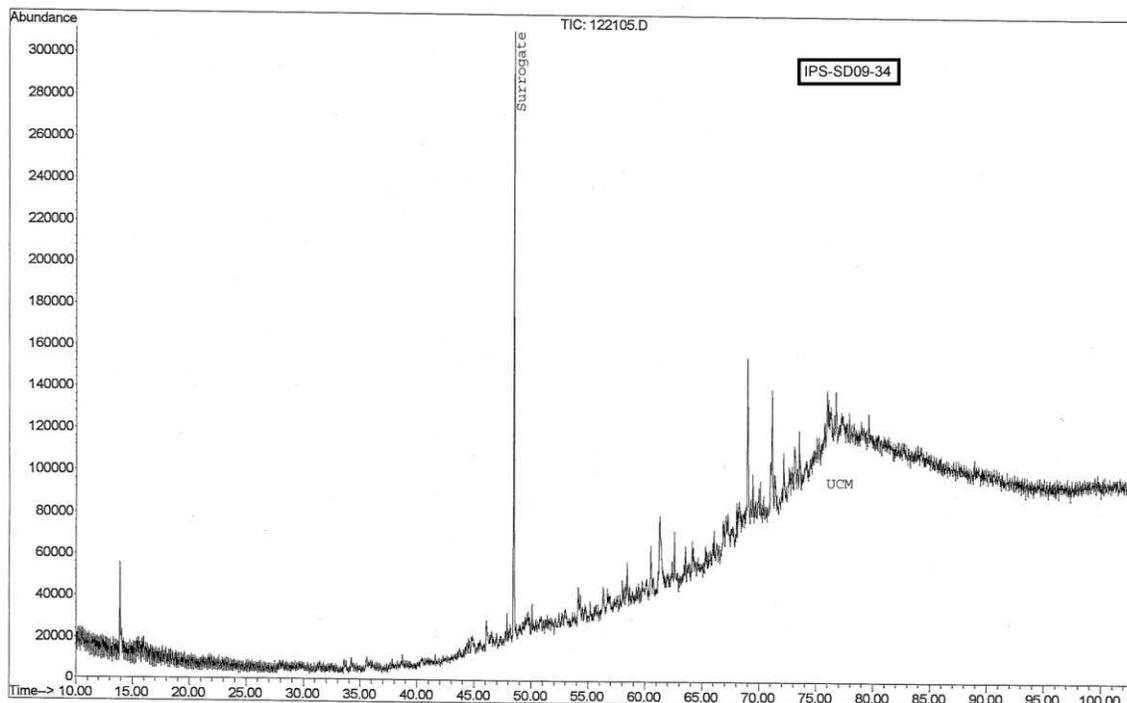
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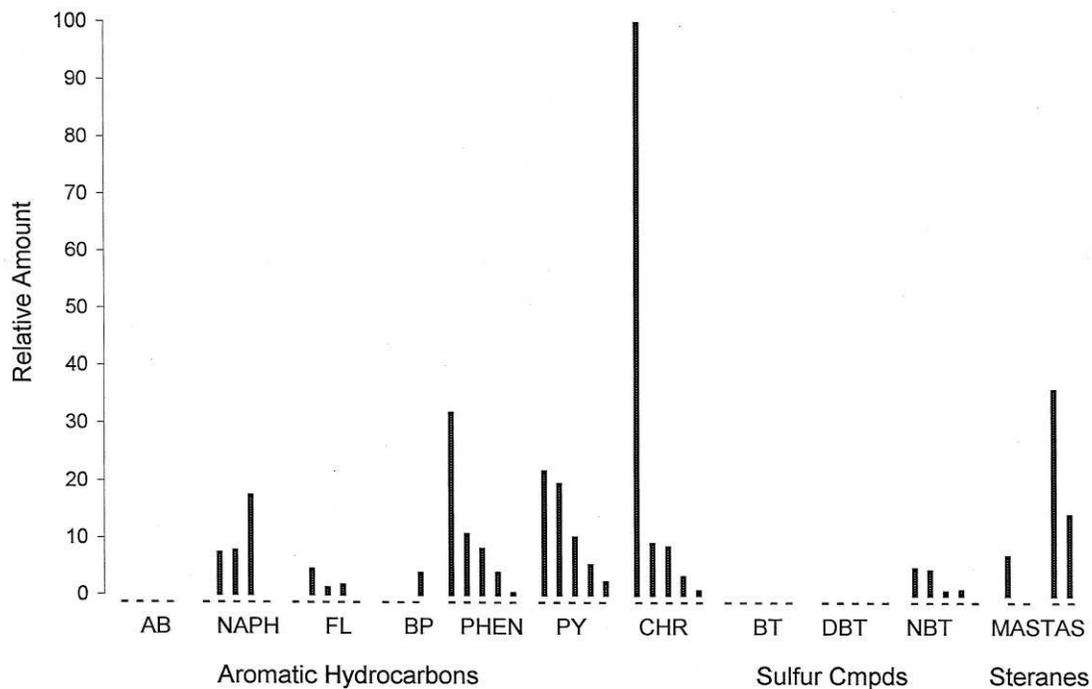


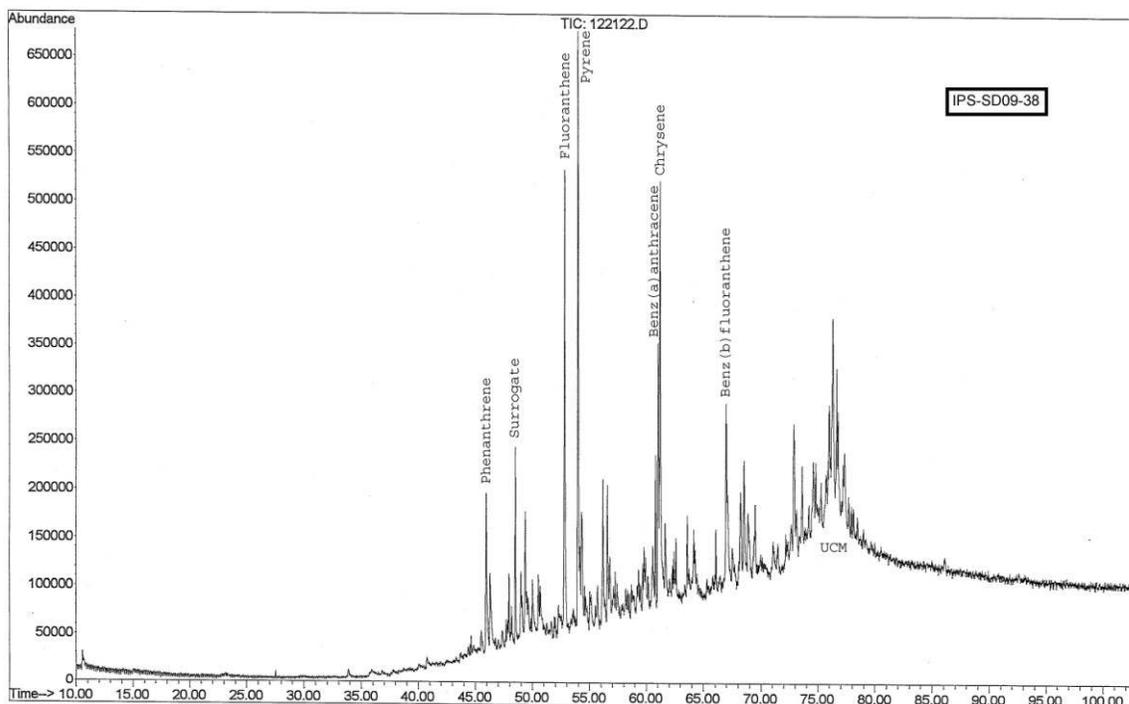
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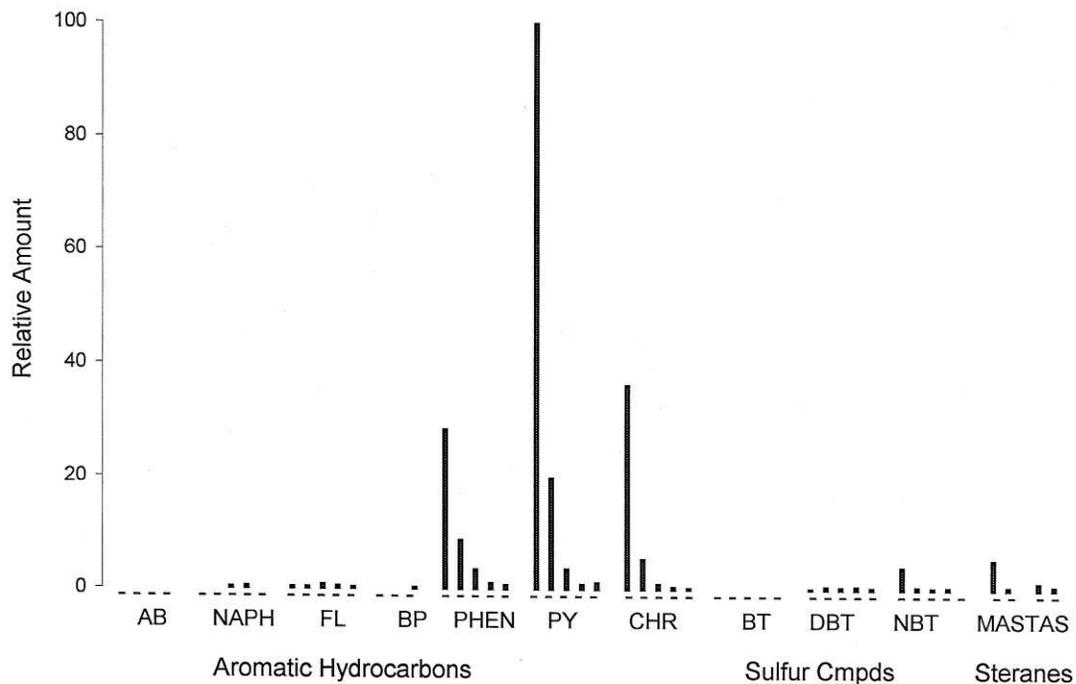


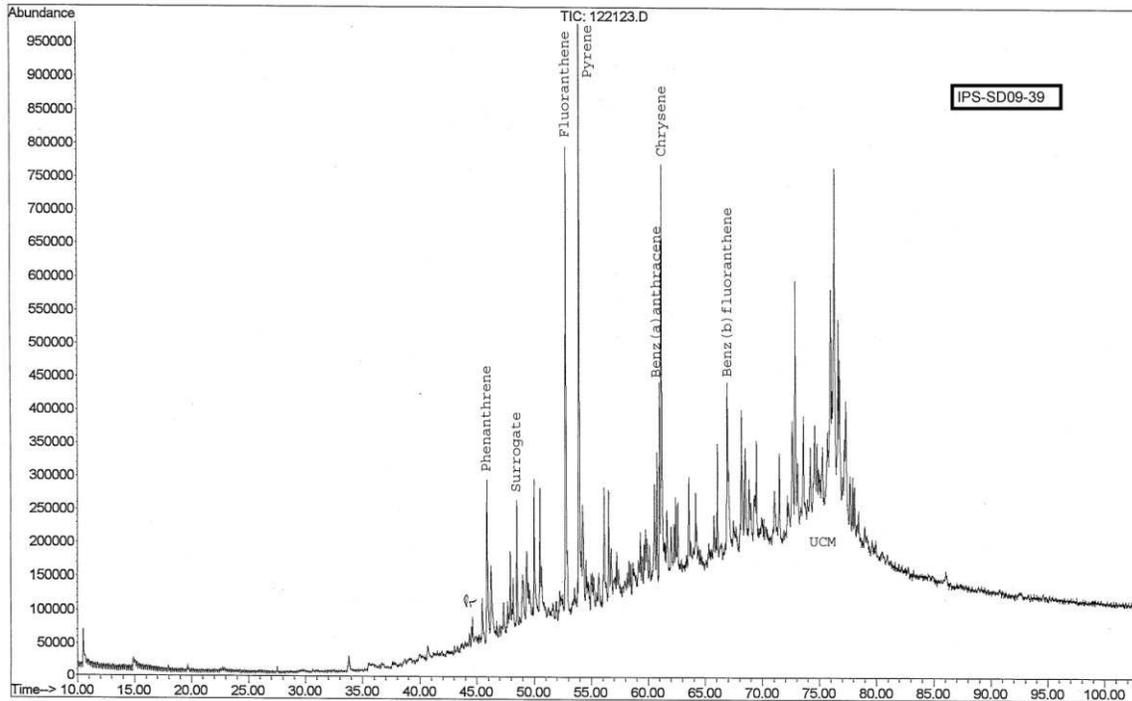
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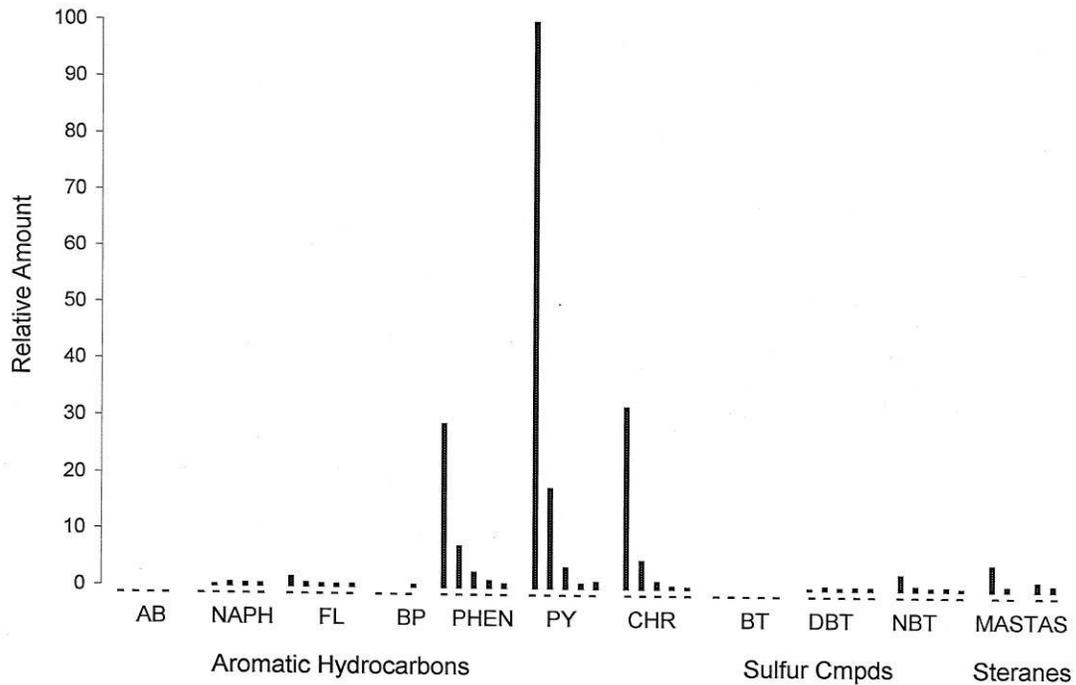


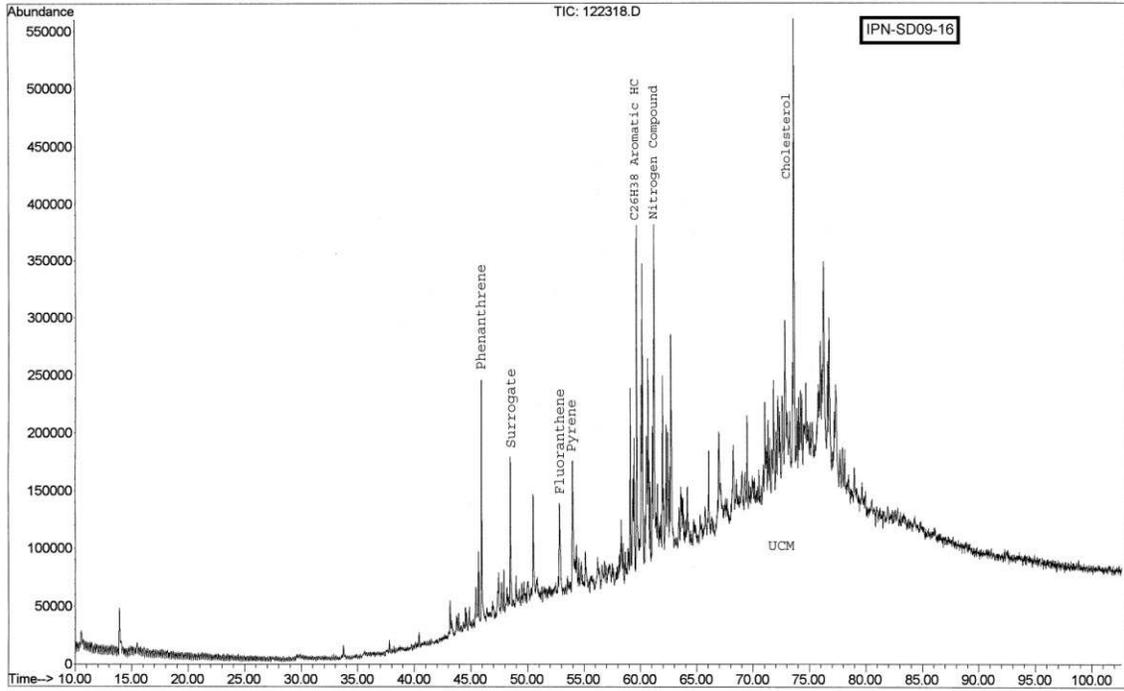
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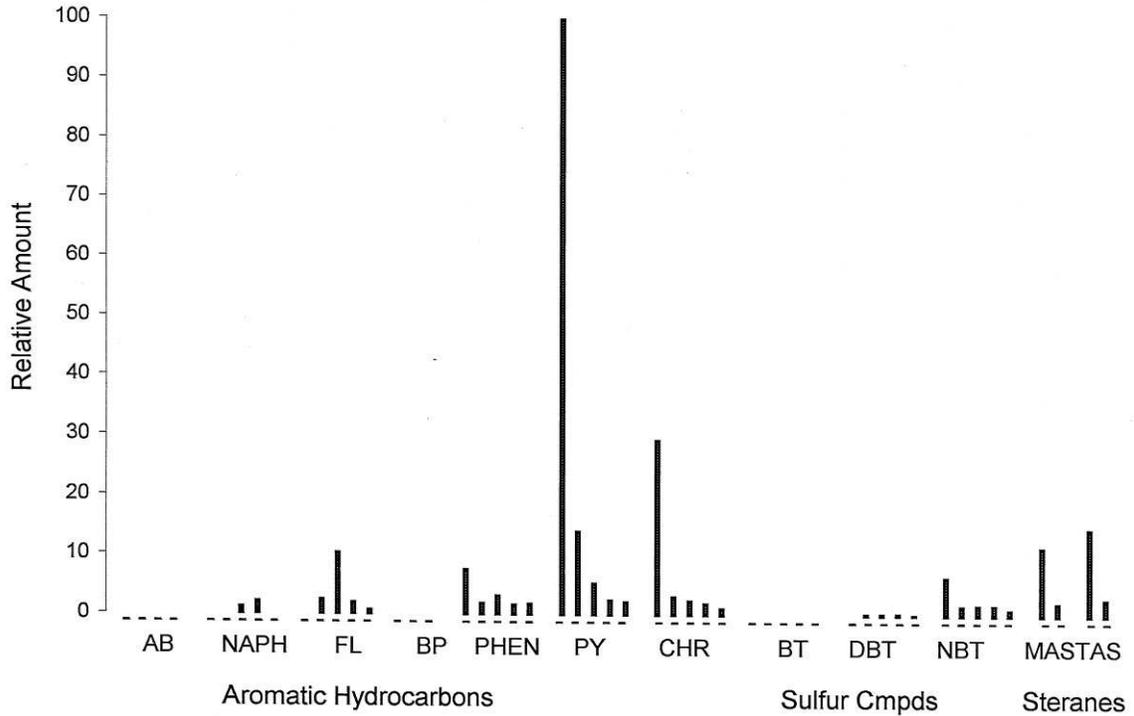


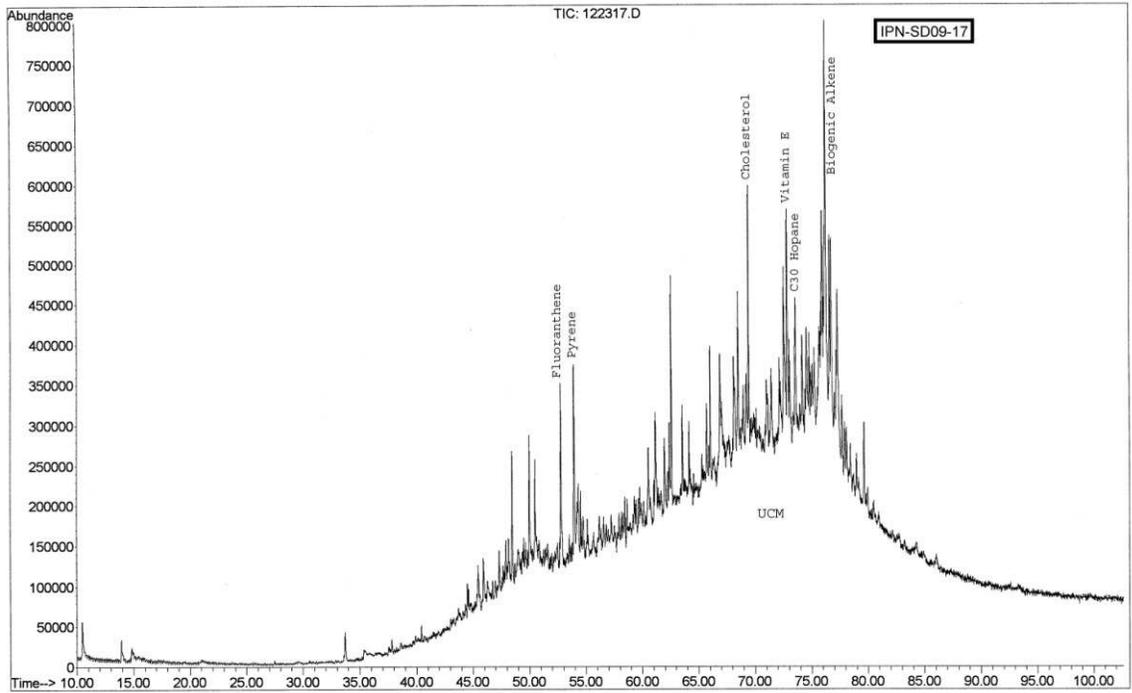
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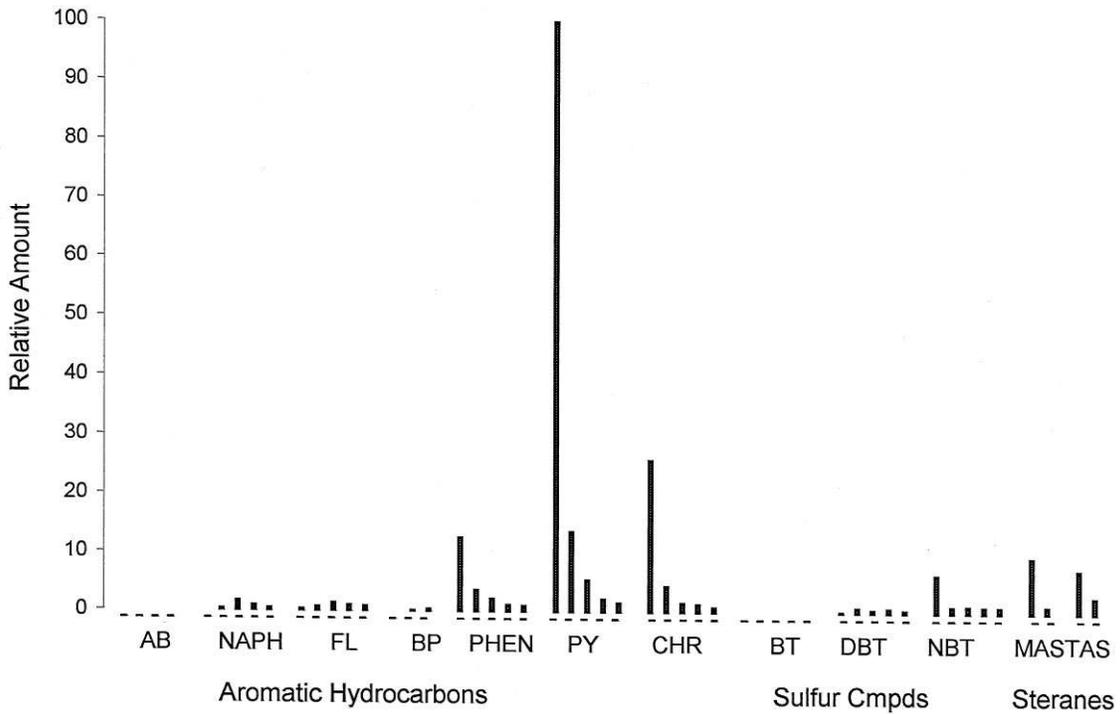


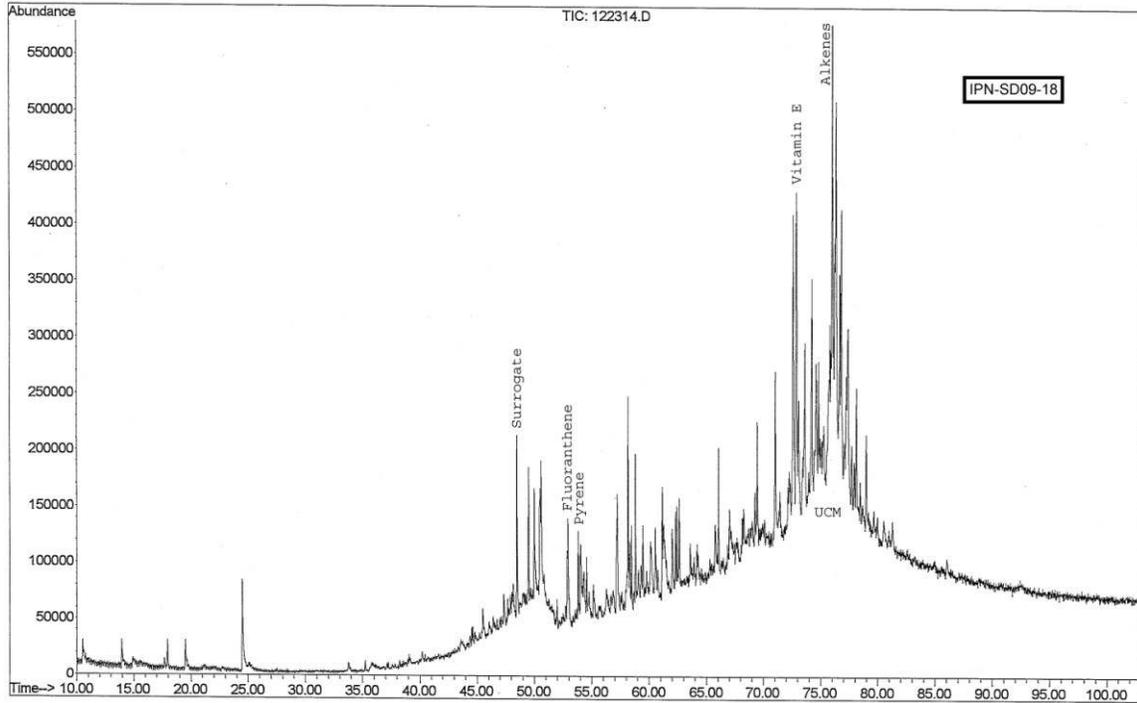
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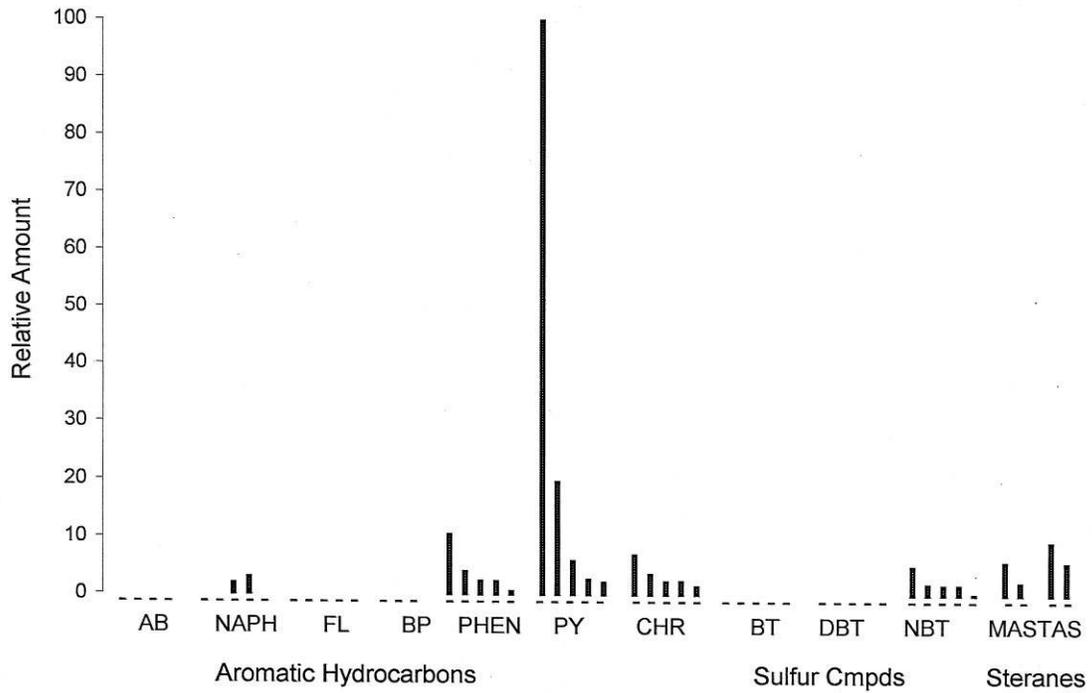


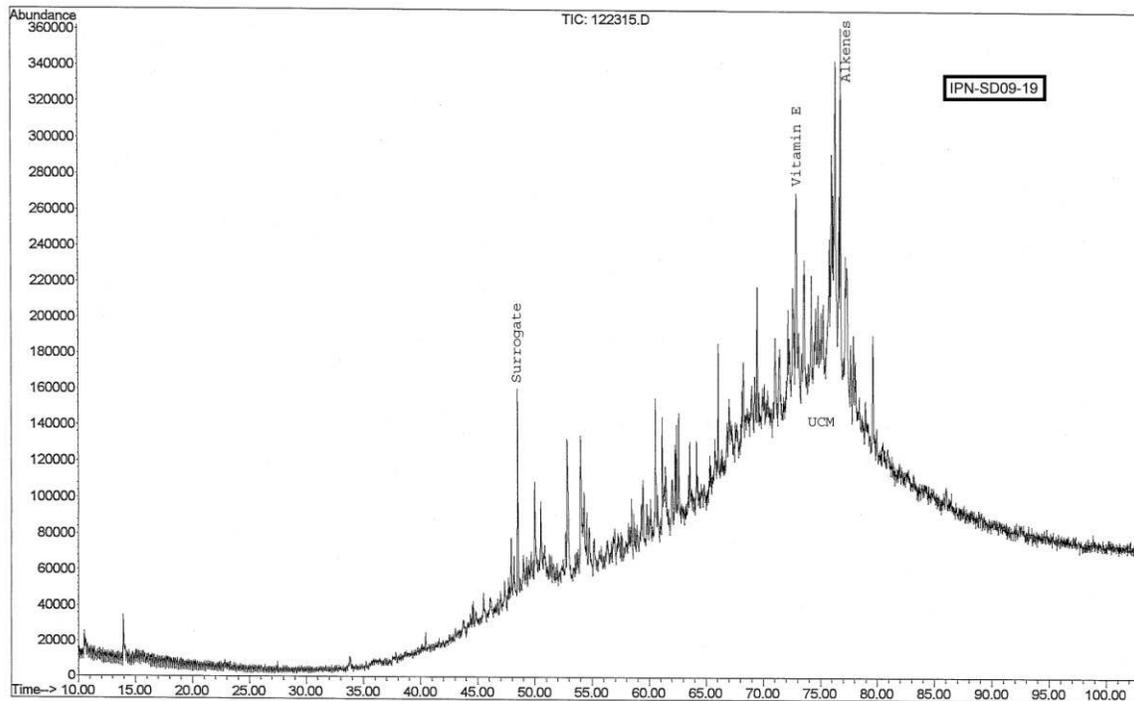
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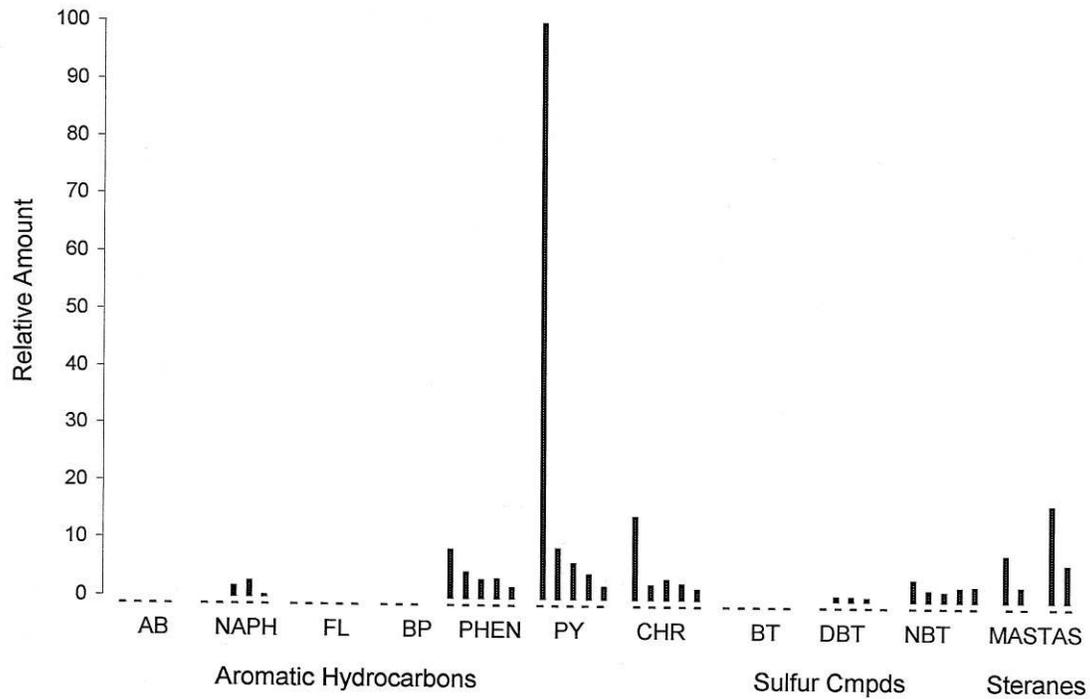


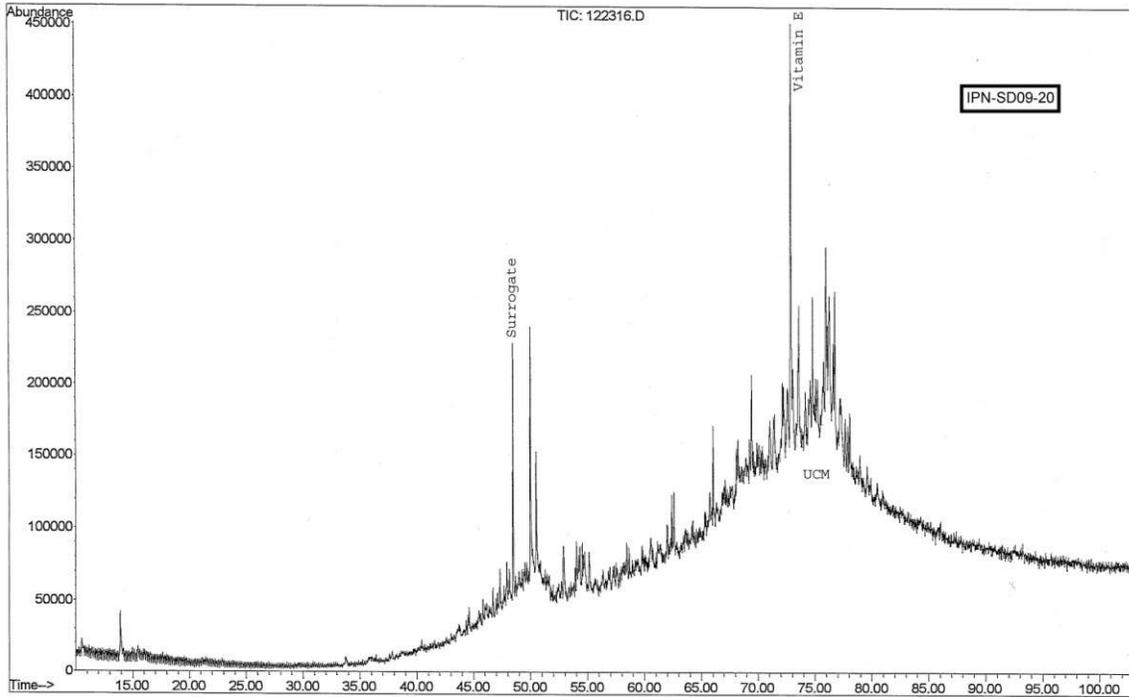
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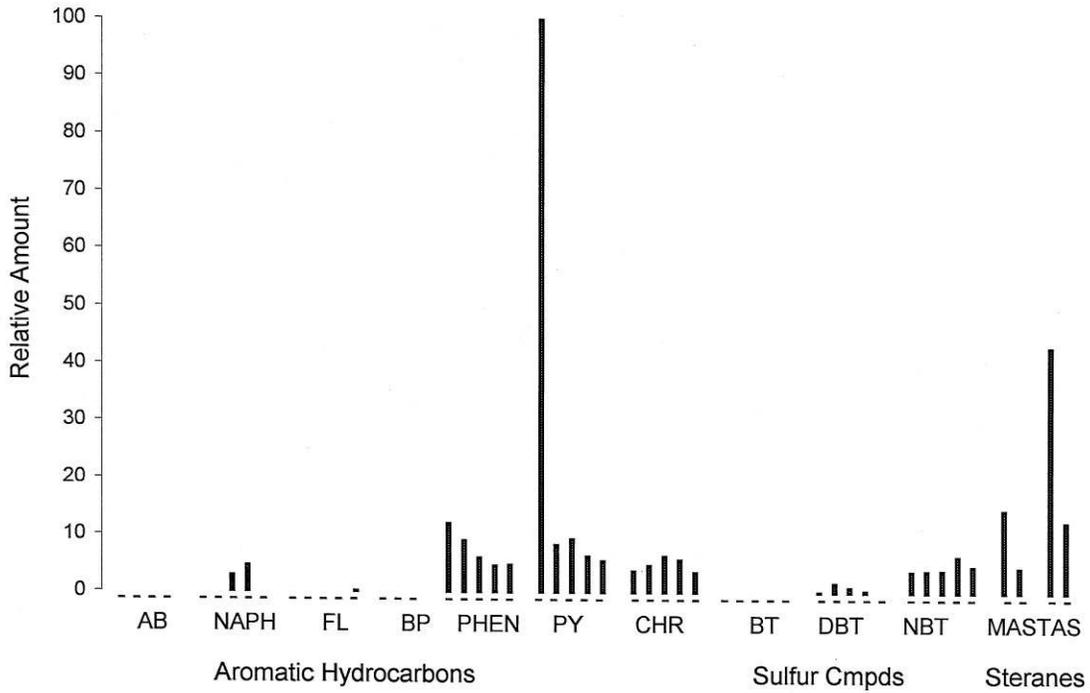


Aromatic Hydrocarbon Distribution
S07440-01R\IPN-SD09-19





Aromatic Hydrocarbon Distribution
S07441-01R/IPN-SD09-20



Dr. Alan W.A. Jeffrey

QUALIFICATIONS:

Over 20 years of US and international experience in environmental science, geochemistry, and oceanography. Expertise in management of research projects, including presentation and publishing of results for professional audiences; management of geochemical and environmental analytical laboratories; initiation and management of a countrywide water monitoring program; QA/QC management of analytical laboratories; and setting up and management of a small environmental consulting company.

EDUCATION:

B.Sc., Biochemistry, Queen's University, Canada, 1971.

M.Sc., Organic Chemistry, Queen's University, Canada, 1975.

Ph.D., Oceanography, Texas A&M University, USA, 1981

PROFESSIONAL EXPERIENCE :

Senior Geochemist, ZymaX Forensics, San Luis Obispo, USA 2000 - Present

- Responsible for client communications in environmental studies and forensic geochemistry, and providing quality assurance oversight of an expanding environmental geochemistry program.
- Management of environmental geochemistry projects including data interpretation and preparation of reports.
- Expert witness services in Environmental Forensics

Technical Director, JL Environmental Consultants, Singapore 1998-2000

- Initiated and directed environmental projects in water quality, air quality, soil surveys, environmental impact assessments, hydrocarbon contamination, and marine surveys.

Some major projects included:

- Prepared environmental legislative reports on Malaysia for General Electric Corp.
- Supervised HSE issues after a hazardous chemical fire at a Motorola facility in Singapore.
- Developed QA programs for analytical data for Montgomery Watson, Singapore.
- Directed environmental site assessments for Lifestyle Furniture International.
- Developed water monitoring programs for Cawalan Cecair, Malaysia.

Manager, Water Monitoring Division, Alam Sekitar Malaysia

1995-1997

Page 1

Dr Alan W.A. Jeffrey

- Implemented river water monitoring programs in Malaysia under a unique privatization program carried out by the Malaysian Government. These included:
 - Taking over a network of over 900 manual water monitoring stations throughout Malaysia, and collecting 400 samples per month for analysis of 30 water quality parameters.
 - Designing and setting up a network of continuous, on-line, river water monitoring stations.
- Hired and trained the local technical staff to carry out the monitoring.
- Set up regional offices for the monitoring teams.
- Negotiated contracts with local laboratories for analytical services.
- Instituted procedures for transfer of analytical and monitoring data and incorporation in monthly reports to the Malaysian Department of Environment.
- Regularly briefed Department of Environment senior technical staff on program status.
- Conducted technical workshops for Department of Environment staff on water monitoring and quality assurance.

Manager, Quality Assurance and Environmental Services
Alam Sekitar Malaysia

1995-1996

- Designed and implemented quality assurance programs for the water monitoring programs above and ambient air monitoring programs:
 - A network of 30 on-line stations continuously monitoring 14 air quality and meteorological parameters.
 - A network of high-volume ambient air samplers monitoring particulate matter concentration and composition.
- Compiled a Quality Manual for technical operations.
- Solicited contracts and prepared proposals for consulting projects in environmental impact assessments and industrial air and water monitoring.

Senior Chemist, Environmental and Chemistry Dept.
Core Laboratories Malaysia

1992-1994

- Managed an environmental and petroleum chemistry laboratory with 15 chemists and technicians.
- Co-ordinated, through a team of project managers, environmental and petroleum chemistry projects, including environmental impact assessments, baseline studies, soil, water, and air monitoring, oilfield gas, oil and water analysis.
- Advised clients on Malaysian and foreign environmental regulations, and set up sampling and analytical programs for regulatory compliance.
- Implemented a quality assurance program as QA/QC officer to enable the laboratory to achieve ISO 25 certification.
- Prominent projects included environmental impact assessments for the Lawit gas platform and pipeline to shore, and the PM5 and PM8 exploration blocks in offshore peninsular Malaysia, both for Esso Malaysia. In addition to EIA preparation, responsibilities included managing the baseline survey including planning and

supervising the month-long oceanographic program, co-ordinating the chemistry analytical program, and writing the baseline survey report.

- Other major projects included site surveys for Motorola, Esso, and Sarawak Shell, ambient air monitoring for Brunei Shell, and oilfield water and gas analysis for Esso, Shell and Total.

Laboratory Director and Senior Geochemist, Global Geochemistry Corp., 1990-1991
Los Angeles, U.S.A.

- Managed an integrated environmental/geochemical laboratory with 20 staff.
- Provided proposals and price quotations to clients.
- Scheduled analyses and monitored turnaround of data.
- Monitored data quality as QA/C Officer.
- Advised clients on California and U.S. EPA environmental regulations, and set up sampling and analytical programs for regulatory compliance.
- Solicited and managed projects utilizing geochemical techniques to solve environmental problems.

Major projects included:

- Monitoring progress in a large site remediation project for Roy F. Weston Co.
- Drinking water and effluent water analysis at the Naval Air Station, Port Huaineme, California for the Dept. of the Navy
- Long term analysis of lake water samples from throughout the U.S. for U.S. EPA.
- Characterizing Southern California beach tar samples and comparison with oil spilled from the American Trader tanker in Huntington Beach, for BP Petroleum.
- Detailed geochemical analysis and interpretation of several oil wells in Japan for Japex Oil Co.

Senior Geochemist, P.T. Robertson Utama, Indonesia 1989-1990

- Selected appropriate geochemical analytical schemes for oil, gas, and rock samples from oil company drilling operations in sedimentary basins in Indonesia, Malaysia Thailand, South China and Papua New Guinea.
- Prepared detailed interpretative reports on the oil and gas potential based on the geochemical results.
- Utilized computer-assisted basin modeling programs to assess exploration potential for oil companies.
- Major clients included Exxon, ARCO, Caltex, Mobil, Occidental Oil, Chevron, IPC (Japan), and Maxus Oil.

Research Geochemist Global Geochemistry Corp. 1984-1989

- Managed geochemical research projects funded by the Department of Energy and the Gas Research Institute to elucidate the origin of natural gas.
- Devised analytical schemes for natural gas and supervised analyses by a small team of technicians.

- Prerared detailed technical reports and publications based on the results.
- Presented results at scientific meetings.
- Prepared scientific proposals for research projects to funding agencies.

Research Associate, Texas A&M University

1981-1983

- Supervised the analysis of natural gas samples for both research and commercial projects.
- Prepared interpretative reports based on the results.
- Participated in oceanographic cruises to collect samples for both geochemical research and oil exploration.
- Prepared scientific proposals for research projects to funding agencies.

Welch Foundation Pre-Doctoral Fellow, Texas A&M University

1978-1980

- Conducted research on the origin of natural gas, leading to the Ph. D. Degree.

Professional Affiliations	:	American Chemical Society American Association for the Advancement of Science Groundwater Resources Association
Publications	:	14 research papers in scientific journals and books in the field of geochemistry, environmental chemistry and oceanography.
Presentations	:	23 presentations at American, Malaysian and international scientific meeting.
Oceanographic Cruises	:	Supervised and participated in over 10 cruises in the Gulf of Mexico, Caribbean Sea, Atlantic Ocean, Mediterranean Sea, and South China Sea, to perform oceanographic measurements and collect water and sediment samples for chemical analysis.

PUBLICATIONS

Sackett, W.M., Chung, H.M. and Jeffrey, A.W.A. (1979). Isotope effects during the pyrolytic formation of hydrocarbons from various carbonaceous materials, Proceedings of the Treibs Symposium, Wurzburg, Germany.

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Overview of Petroleum Fuel Identification and Dating Techniques. Presented at Environmental Litigation: Advanced Forensics and Legal Strategies. University of Wisconsin-Madison Professional Development Course, San Francisco, April, 2001

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Introduction to Environmental Forensics. Workshop presentation at the Annual West Coast Conference on Contaminated Soils, Sediments and Water, San Diego, March 2002.

Groundwater Geochemistry. Workshop presentation at the National Groundwater Association Conference on MTBE, Anaheim, CA, 4-6 July, 2002.

Application of Isotope Ratios in Forensic Geochemistry. Presented at Environmental Forensics: Advanced Techniques, an International Society of Environmental Forensics Workshop, Santa Fe, September, 1992.

Forensic Environmental Geochemistry: Petroleum Fuels. Workshop presentation at the 18th Annual International Conference on Contaminated Soils, Sediments and Water, Amherst, 20-23 October, 2002.

Fuel Fingerprinting. Presentation at the Workshop on Environmental Forensics, Groundwater Resource Association, Emeryville, CA, 14 November, 2002

Application of Isotopes and Specialized Ratios in Petroleum Hydrocarbon Forensics: Theory and Case Studies. Presented at Environmental Forensics: Theory, Application and Case Studies, International Society of Environmental Forensics Workshop, Honolulu, 14-15 April, 2003

Forensic Analysis of Fugitive Methane Gas Emissions. Platform presentation at the International Society of Environmental Forensics Workshop, San Diego, 4-5 November, 2003.

Classical Chemical Techniques in Environmental Forensics. Workshop presentation at the Annual West Coast Conference on Contaminated Soils, Sediments and Water, San Diego,

March 2005.

Petroleum Forensics. Workshop presentation at the California Environmental Law Conference, Yosemite, 22 October, 2005.

Use of Environmental Forensics in Environmental Investigations and Litigation. Workshop presentation to the Hawaii State Department of Health, Honolulu, 19 May, 2006.

Use of Carbon Isotope Ratios to Distinguish Perchloroethylene Plumes in Soil and Groundwater. Platform presentation at the Groundwater Resources Association symposium, Applications of Isotope Tools to Groundwater Studies, Concord, CA, 29 March, 2007

Environmental Forensics: Tools of the Trade. Workshop presentation at the Northwest Environmental Conference, Portland, 7 December, 2007

Forensic Techniques to Discriminate between Refined Product Releases. Workshop presentation at the Society of Environmental Toxicology and Chemistry 5th World Congress, Sydney, Australia, 3 August, 2008.

Refinery Leak Detection using Petroleum Forensics. Platform presentation at the Annual West Coast Conference on Contaminated Soils, Sediments and Water, San Diego, March 2009.

Forensic Environmental Geochemistry: Petroleum Fuels and Chlorinated Solvents. Workshop presentation at the International Network of Environmental Forensics Conference, Calgary, Canada, 31 August – 2 September, 2009

EXPERT WITNESS AND LITIGATION SUPPORT

- Retained by Nossaman, Guthner, Knox & Elliott, LLP, Los Angeles, CA in July, 2001 to provide an expert witness declaration on the reliability of analytical data provided by the plaintiff on organic compounds in water samples.
- Retained by Cory J. Briggs Esq, Washington, DC in November, 2001 to provide an expert opinion on the methodology employed by the defendant to analyze organic compounds in water samples.
- Retained by Clements, O'Neill, Pierce, Wilson & Fulkerson, Houston, TX in April, 2002 to provide an expert opinion on crude oil contamination at a site in California
- Retained by Holmes Weddle & Barcott, Anchorage, AK in August 2002 to provide an expert witness declaration in Zurich American Insurance vs Whittier Properties
- Retained by Kelley, Hart & Hallman Austin, TX in April 2003 to provide an expert opinion in Elementis Chromium vs Coastal States et al.
- Retained by Demetriou, Del Guercio, Springer, & Francis, Los Angeles, CA in May 2003 to provide expert testimony in County of Los Angeles vs Kernview Oil Corp. et al. Deposed on May 22, 2003.
- Retained by Gallaher, Lewis, Downey & Kim, Houston, TX in May 2003 to provide an expert opinion in John H. Roam et al vs Texas-New Mexico Pipeline Co. et al.
- Retained by Winder & Haslam, Salt Lake City, UT in June 2003 to provide an expert opinion in Evans et al vs Maverik Country Stores Inc
- Retained by Butzel Long, Detroit, MI in August 2003 to provide litigation support in Sattorelli v. Wolverine Oil Co.
- Retained by Armstrong Teasdale, Kansas City, MO in December 2003 to provide litigation support in Cargill Inc v. ONEOK Inc
- Retained by Bernstein, Cushner & Kimmell, Boston MA in March 2004 to provide litigation support in Hudson Bus Lines v. Exxon Mobil
- Retained by Alexander, Holburn, Beaudin & Lang, Vancouver, BC, Canada in June 2004 to provide an expert opinion in a fuel spill case.
- Retained by Morgan Lewis, Los Angeles, CA in August 2004 to provide litigation support in City of Los Angeles v. Chevron U.S.A.
- Retained by Bandas and Laws, Corpus Christi, TX in September 2004 to provide an expert opinion in C.C. Sunrise v. Pittencrieff. Deposed on September 10, 2004

- Retained by Adamski, Moroski, Madden & Green, San Luis Obispo, CA in February 2005 to provide an expert opinion in Paso Robles Tank vs Thomas Saberi et al. Deposed on April 21, 2005. Testified at trial on May 19, 2005.
- Retained by the Law Offices of Patrick E. Catalano, San Diego, CA in August - October 2005 to provide expert opinions in underground water migration cases.
- Retained by Becnel Law Offices, New Orleans, LA in February 2006 to provide an expert opinion in Turner et al vs Murphy Oil USA Inc.
- Retained by Edgar Law Firm, Kansas City, MO to provide an expert opinion in City of Neodesha vs BP Corp. Deposed on February 28, 2007. Testified at trial on October 31, 2007
- Retained by Reed Smith LLP, San Francisco, CA in November, 2006 to provide an expert opinion on petroleum product contamination at a site in Northern California
- Retained by Osler, Hoskin & Harcourt, Toronto, Canada in December, 2006 to provide an expert opinion on petroleum product contamination at a site in Toronto.
- Retained by Trevett, Cristo, Salzer, & Andolina P.C. Rochester, NY in January, 2007 to provide and expert opinion in Cilibert vs Griffith Energy.
- Retained by Bracewell & Guiliani LLP, Washington, DC in February, 2007 to provide an expert opinion on petroleum product contamination at a site in West Virginia.
- Retained by Lambert & Nelson PLC, New Orleans, LA in July 2007 to provide an expert opinion on petroleum contamination at a site in Kansas
- Retained by Agajanian Law Group, LLP, Los Angeles, CA in July 2007 to provide an expert opinion in Doubletree vs Razi. Participated in mediation meeting on July 20, 2007.
- Retained by Bansbach Zoghlin, P.C., Rochester, NY in August, 2007 to provide an expert opinion on petroleum product contamination at a site in Rochester, NY
- Retained by Crandall, Wade & Lowe PC, Rancho Cucamonga, CA in August 2007 to provide litigation support in State Farm vs Union Oil of California. Presented opinion at mediation meeting on September 11, 2007
- Retained by Pillsbury Winthrop Shaw Pittman LLP in August 2007 to provided litigation support in Southern California Presbyterian Homes vs Chevron Products Co.
- Retained by Stanzler Funderburke & Castellon LLP, Los Angeles, CA in September 2007 to provided an expert opinion in City of Los Angeles vs Kinder Morgan Energy Partners. Deposed on October 15, 2007

- Retained by the Hudgins Law Firm PC, in November 2007 to provide an expert opinion in Tellus Operating Group vs Texas Petroleum Investment Co. Deposed on February 19, 2008.
- Retained by McInnes Cooper Law Firm, Nova Scotia, Canada in December 2007 to provide an expert opinion in Gunvaldsen-Klassen vs Bulpitt and Gray.
- Retained by the City Attorney of San Diego in January 2008 to provide litigation support in City of San Diego vs BNSF.
- Retained by Anastassiou & Associates, Salinas, CA in February 2008 to provide litigation support in Blech vs Oceano Packing Co. Deposed on February 23, 2009. Testified at mediation trial on March 17-18, 2009.
- Retained by Methfessel & Werbel, Edison, NJ in May 2008 to provided an expert opinion in Pillar of Fire vs Mercer Mutual.
- Retained by Lee.Smart Inc, Seattle, WA in June 2008 to provided an expert opinion in Grey vs Leach. Deposed on September 26, 2008
- Retained by Meyers Nave, Los Angeles, CA in April 2009 to provide litigation support in Bach vs Yoelin.
- Retained by Johannessen and Associates, Seattle, WA in December 2009 to provide an expert opinion in Louie et al vs Exxon Mobil Corp.

APPENDIX E QUALITY ASSURANCE/QUALITY CONTROL

QUALITY ASSURANCE/QUALITY CONTROL

In conjunction with the field investigations completed to date, a Quality Assurance/Quality Control (QA/QC) program was implemented to ensure the integrity of the sediment sampling and analytical testing results.

1.0 FIELD PROGRAM

All field activities tasks were completed in accordance with Golder Associates Ltd. (Golder) Technical Field Procedures by trained Golder personnel. All field activities were documented in field notes and results were recorded on standard field forms. All field equipment involved in the sediment sampling was decontaminated in accordance with Golder's Technical Procedures. Sediment samples were collected using appropriate handling protocols and were placed in sample containers provided by Maxxam. To help prevent cross-contamination, a new pair of clean nitrile gloves was used for collection of each sediment sample.

Samples were given unique identification numbers and the sampling containers were preserved in coolers with ice. Samples were logged onto formal Chain of Custody documents, and transported to Maxxam Analytics Inc. (Maxxam) in Burnaby, British Columbia for chemical analyses. Maxxam is a Canadian Association for Laboratory Accreditation Inc. accredited laboratory.

Blind duplicate sediment samples were submitted for analysis. Trip and field blanks were submitted for analysis, as necessary, to evaluate the potential for cross-contamination during the sampling and transportation of the samples. Submission of duplicate field QC samples was at a minimum rate of 10% of total samples.

2.0 LABORATORY PROGRAM

The laboratory QA/QC program included adherence to laboratory sampling and analysis protocols (e.g., hold times, sample containers, preservatives, detection limits and approved methodology) and the analysis of laboratory method blanks, laboratory sample duplicates, surrogate recovery and chemical spikes.

The laboratory method blank analysis results were used to detect interferences or impurities introduced by the laboratory equipment, reagents or solvents. Surrogate recovery is analyzed for organic analytes by spiking samples with known quantities of surrogate chemicals which have similar chemical properties to the parameters being analyzed. The reported recovery provides an indication of the analytical method accuracy for that sample. Matrix spikes were conducted by adding known concentrations of the analyte of interest to a sample to evaluate the effects of the sample matrix on the analytical method. The analysis of selected samples in duplicate is used to evaluate the reproducibility of the analytical method.

3.0 DATA RECEPTION

Once laboratory analytical results were received, Golder completed a review of field and laboratory quality. This included review of laboratory QC performance (e.g., standards, spike recoveries) to confirm results are within acceptable guidelines, as well as evaluation of field duplicate and various field blank results to confirm they were within alert limits. Upon receipt of the analytical results, Relative Percent Difference (RPD) values between the original samples and their blind duplicates were calculated as follows:

$$RPD\% = \frac{|S - D|}{\frac{1}{2}(S + D)} \times 100$$

Where: RPD = Relative Percent Difference

S = sample value

D = duplicate or replicate value

Because analytical error increases near the Reportable Detection Limit (RDL), an RPD was only calculated where the concentrations of both the original and duplicate samples were greater than five times the RDL. The calculated RPDs were then compared to parameter specific alert limits.

Exceedances of the QC acceptance or alert guidelines were investigated with the laboratory and, if warranted, a corrective action report was requested from the laboratory.

4.0 DATA QUALITY REVIEW RESULTS

Data quality review results for sediment analytical data including the laboratory analytical results are summarized in Appendix A.

The summary of data quality review of the quality control samples is presented in Table E1. RPD calculations for sediment samples and duplicates and are summarized in Tables E2 to E4.

A data quality waiver was issued by Maxxam on December 11, 2009 for sediment sample IA-SD09-REF3 due to matrix interference that would potentially represent low bias for the sulphide parameter in the sample. Golder accepted the waiver on December 16, 2009.

The concentrations of field samples and duplicates were within the acceptable alert limits.

5.0 SUMMARY OF RESULTS

Based on the review of the QA/QC results, there were no QA/QC issues identified. The data were considered reliable.

Table E1
Summary of Quality Control Sample Results
Former Refinery
2225 Ioco Road, Port Moody, British Columbia

Maxxam Job Number	Data Quality Waiver Issued (Yes/No)	Data Quality Waiver Number	Matrix	Maxxam Sample ID Affected	Test Affected	Data Quality Issue	Comments
A969147	No	not applicable	Sediment	not applicable	not applicable	There were no data quality issues identified.	The data were considered to be reliable.
A969396	Yes	3301	Sediment	S03718	Matrix spike recovery	Matrix spike recovery below control limit for sulphide.	The root cause is determined to be matrix interference. This may represent a low bias for Sulphide in this sample. The data were considered to be reliable.
A969851	No	not applicable	Sediment	not applicable	not applicable	There were no data quality issues identified.	The data were considered to be reliable.
A969867	No	not applicable	Sediment	not applicable	not applicable	There were no data quality issues identified.	The data were considered to be reliable.
A968904	No	not applicable	Sediment	not applicable	not applicable	There were no data quality issues identified.	The data were considered to be reliable.
A924638	No	not applicable	Sediment	not applicable	not applicable	There were no data quality issues identified.	The data were considered to be reliable.
A924651	No	not applicable	Sediment	not applicable	not applicable	There were no data quality issues identified.	The data were considered to be reliable.
A925081	No	not applicable	Sediment	not applicable	not applicable	There were no data quality issues identified.	The data were considered to be reliable.
A925416	No	not applicable	Sediment	not applicable	not applicable	There were no data quality issues identified.	The data were considered to be reliable.
A968598	No	not applicable	Sediment	not applicable	not applicable	There were no data quality issues identified.	The data were considered to be reliable.

Table E2
Summary of Quality Control Results - Total Metals
Former Refinery
2225 Ioco Road, Port Moody, British Columbia

Sample Location Sample Collection Date Maxxam Sample ID	Units	RDL	IPN-SD09-03	IPN-SD09-04	RPD (%)	IPN-SD09-09	IPN-SD09-10	RPD (%)	IPN-SD09-16	IPN-SD09-17	RPD (%)
			27-May-09	27-May-09		27-May-09	27-May-09		5-Dec-09	5-Dec-09	
			98901	98902		988907	988908		S07312	S07311	
Moisture	%	0.3	71	70	1%	72	72	0%	68	69	1%
Soluble (2:1) pH	-	0.3	7.13	7.21	1%	7.37	7.27	1%	8.14	8.18	0%
Total organic carbon	%	0.3	35	35	0%	40	40	0%	6	7	8%
Aluminum (Al)	mg/kg	100	22200	23000	4%	23200	22000	5%	16400	14100	15%
Antimony (Sb)	mg/kg	0.1	0.6	0.6	0%	0.6	0.6	0%	0.6	0.6	n/c
Arsenic (As)	mg/kg	0.2	15.0	15.4	3%	15.6	15.7	1%	14.1	12.6	11%
Barium (Ba)	mg/kg	0.1	59.0	119	67%	61.2	60.0	2%	46.4	39	17%
Beryllium (Be)	mg/kg	0.1	0.4	0.4	0%	0.4	0.4	0%	0.2	0.2	n/c
Bismuth (Bi)	mg/kg	0.1	0.5	0.5	0%	0.5	0.5	0%	0.3	0.3	n/c
Cadmium (Cd)	mg/kg	0.05	2.17	2.24	3%	2.68	2.76	3%	2.40	2.10	13%
Chromium (Cr)	mg/kg	1	55	57	4%	59	58	2%	48	43	11%
Cobalt (Co)	mg/kg	0.3	9.7	9.9	2%	9.6	9.4	2%	6.5	5.5	17%
Copper (Cu)	mg/kg	0.5	108	110	2%	114	113	1%	111	85.1	26%
Iron (Fe)	mg/kg	100	34600	35700	3%	35600	34600	3%	23700	20900	13%
Lead (Pb)	mg/kg	0.1	72.6	74.5	3%	87.1	84.0	4%	85.1	74.8	13%
Manganese (Mn)	mg/kg	0.2	339	353	4%	338	336	1%	213	187	13%
Mercury (Hg)	mg/kg	0.05	0.24	0.25	4%	0.28	0.28	0%	0.18	0.16	n/c
Molybdenum (Mo)	mg/kg	0.1	5.8	5.7	2%	4.4	4.4	0%	6.2	5.5	12%
Nickel (Ni)	mg/kg	0.8	31.5	33.3	6%	31.4	31.6	1%	22.4	19.5	14%
Selenium (Se)	mg/kg	0.5	1.3	1.9	38%	1.6	1.4	13%	1.3	1.1	17%
Silver (Ag)	mg/kg	0.05	0.67	0.69	3%	0.59	0.61	3%	0.35	0.31	12%
Strontium (Sr)	mg/kg	0.1	73.8	75.2	2%	75.5	79.8	6%	298	276	8%
Thallium (Tl)	mg/kg	0.05	0.34	0.34	0%	0.37	0.38	3%	0.32	0.27	17%
Tin (Sn)	mg/kg	0.1	3.0	3.0	0%	3.4	3.4	0%	3.5	3.2	9%
Titanium (Ti)	mg/kg	2	900	914	2%	919	894	3%	658	577	13%
Vanadium (V)	mg/kg	1	64	64	0%	65	63	3%	49	43	13%
Zinc (Zn)	mg/kg	1	186	192	3%	213	208	2%	241	205	16%
Zirconium (Zr)	mg/kg	0.5	3.9	4.0	3%	3.7	3.6	3%	2.8	2.4	15%

Notes:

RPD is not calculated if either the original or duplicate sample scores a result less than 5 times the RDL

mg/kg - milligrams per kilogram

RDL - reportable detection limit

RPD - relative percent difference

n/c - not calculable

< - less than

Table E2 (continued)
Summary of Quality Control Results - Total Metals
Former Refinery
2225 Ioco Road, Port Moody, British Columbia

Sample Location	Units	RDL	IPS-SD09-28	IPS-SD09-39	RPD (%)	IPS-SD09-29	IPS-SD09-38	RPD (%)
Sample Collection Date			2-Dec-09	2-Dec-09		2-Dec-09	2-Dec-09	
Maxxam Sample ID			S01929	S01924		S01925	S01926	
moisture	%	0.3	71	68	4%	72	74	3%
Soluble (2:1) pH	-	0.3	7.91	7.94	0%	7.92	7.83	1%
total organic carbon	%	0.3	37	37	0%	35	37	6%
Aluminum (Al)	mg/kg	100	14500	13900	4%	16100	16400	2%
Antimony (Sb)	mg/kg	0.1	0.5	0.5	n/c	0.4	0.5	n/c
Arsenic (As)	mg/kg	0.2	11.4	11.0	4%	10.5	10.6	1%
Barium (Ba)	mg/kg	0.1	42.4	38.4	10%	48.6	48.8	0%
Beryllium (Be)	mg/kg	0.1	0.3	0.2	n/c	0.3	0.3	n/c
Bismuth (Bi)	mg/kg	0.1	0.4	0.3	n/c	0.4	0.4	n/c
Cadmium (Cd)	mg/kg	0.05	2.12	1.65	25%	1.89	1.85	2%
Chromium (Cr)	mg/kg	1	32	30	6%	36	37	3%
Cobalt (Co)	mg/kg	0.3	7	6.5	7%	7.9	8.0	1%
Copper (Cu)	mg/kg	0.5	89	83.9	6%	96.3	97.4	1%
Iron (Fe)	mg/kg	100	24700	23000	7%	27800	28300	2%
Lead (Pb)	mg/kg	0.1	42.1	39.2	7%	42.3	42.3	0%
Manganese (Mn)	mg/kg	0.2	232	215	8%	266	271	2%
Mercury (Hg)	mg/kg	0.05	0.17	0.17	n/c	0.18	0.18	n/c
Molybdenum (Mo)	mg/kg	0.1	3.5	3.3	6%	4.1	4.1	0%
Nickel (Ni)	mg/kg	0.8	22.1	20.5	8%	25.9	27.3	5%
Selenium (Se)	mg/kg	0.5	0.9	0.8	n/c	0.9	0.9	n/c
Silver (Ag)	mg/kg	0.05	0.41	0.40	n/c	0.49	0.48	n/c
Strontium (Sr)	mg/kg	0.1	105	100.0	5%	110.0	126.0	14%
Thallium (Tl)	mg/kg	0.05	0.3	0.28	n/c	0.31	0.31	n/c
Tin (Sn)	mg/kg	0.1	1.9	1.8	n/c	2.0	2.0	n/c
Titanium (Ti)	mg/kg	2	556	507	9%	618	634	3%
Vanadium (V)	mg/kg	1	44	40	10%	47	48	2%
Zinc (Zn)	mg/kg	1	165	155	6%	162	163	1%
Zirconium (Zr)	mg/kg	0.5	2.2	2.0	n/c	2.6	2.7	n/c

Notes:

RPD is not calculated if either the original or duplicate sample scores a result less than 5 times the RDL

mg/kg - milligrams per kilogram

RDL - reportable detection limit

RPD - relative percent difference

n/c - not calculable

< - less than

Table E3
Summary of Quality Control Results - Polycyclic Aromatic Hydrocarbons
Former Refinery
2225 Ioco Road, Port Moody, British Columbia

Sample Location Sample Collection Date Maxxam Sample ID	Units	RDL	IPN-SD09-03	IPN-SD09-04	RPD (%)	IPN-SD09-09	IPN-SD09-10	RPD (%)	IPN-SD09-16	IPN-SD09-17	RPD (%)
			27-May-09	27-May-09		27-May-09	27-May-09		4-Dec-09	4-Dec-09	
			98901	98902		988907	988908		S07312	S07311	
2-Methylnaphthalene	mg/kg	0.02	0.13	0.10	26%	<3	<4	n/c	0.08	0.09	12%
Acenaphthene	mg/kg	0.01	<0.03	<0.03	n/c	<0.04	<0.04	n/c	0.03	0.03	0%
Acenaphthylene	mg/kg	0.01	0.05	0.05	0%	0.06	0.07	15%	0.08	0.14	55%
Anthracene	mg/kg	0.02	0.10	0.09	11%	0.12	0.16	29%	0.19	0.39	69%
Benzo(a)anthracene	mg/kg	0.02	0.13	0.12	8%	0.17	0.28	49%	0.27	0.68	86%
Benzo(a)pyrene	mg/kg	0.01	0.17	0.18	6%	0.25	0.36	36%	0.40	1.1	93%
Benzo(b&j)fluoranthene	mg/kg	0.01	0.34	0.34	0%	0.50	0.71	35%	0.80	1.8	77%
Benzo(g,h,i)perylene	mg/kg	0.02	0.15	0.14	7%	0.20	0.24	18%	0.26	0.46	56%
Benzo(k)fluoranthene	mg/kg	0.01	0.10	0.10	0%	0.15	0.22	38%	0.48	1.20	86%
Chrysene	mg/kg	0.01	0.18	0.16	12%	0.26	0.40	42%	0.60	1.40	80%
Dibenz(a,h)anthracene	mg/kg	0.02	<0.06	<0.06	n/c	<0.08	<0.08	n/c	0.08	0.19	81%
Fluoranthene	mg/kg	0.01	0.31	0.27	14%	0.34	0.53	44%	0.68	0.98	36%
Fluorene	mg/kg	0.01	0.04	0.04	0%	0.06	0.08	29%	0.06	0.09	40%
Indeno(1,2,3-cd)pyrene	mg/kg	0.02	0.12	0.12	0%	0.18	0.23	24%	0.21	0.42	67%
Naphthalene	mg/kg	0.01	0.11	0.13	17%	0.13	0.13	0%	0.12	0.12	0%
Phenanthrene	mg/kg	0.01	0.21	0.21	0%	0.22	0.29	27%	0.34	0.71	70%
Pyrene	mg/kg	0.01	0.55	0.51	8%	0.66	0.82	22%	1.8	1.9	5%

Notes:

RPD is not calculated if either the original or duplicate sample scores a result less than 5 times the RDL

mg/kg - milligrams per kilogram
RDL - reportable detection limit
RPD - relative percent difference
n/c - not calculable
< - less than

Table E3 (continued)
Summary of Quality Control Results - Polycyclic Aromatic Hydrocarbons
Former Refinery
2225 Ioco Road, Port Moody, British Columbia

Sample Location	Units	RDL	IPS-SD09-28	IPS-SD09-39	RPD (%)	IPS-SD09-29	IPS-SD09-38	RPD (%)
Sample Collection Date			2-Dec-09	2-Dec-09		2-Dec-09	2-Dec-09	
Maxxam Sample ID			S01925	S01924		S01925	S01926	
2-Methylnaphthalene	mg/kg	0.01	0.18	0.17	6%	0.19	0.18	5%
Acenaphthene	mg/kg	0.01	0.18	0.15	18%	0.22	0.24	9%
Acenaphthylene	mg/kg	0.01	0.18	0.21	15%	0.14	0.12	15%
Anthracene	mg/kg	0.01	0.59	0.78	28%	1.2	0.86	33%
Benzo(a)anthracene	mg/kg	0.01	1.3	2.0	42%	3.2	2.6	21%
Benzo(a)pyrene	mg/kg	0.01	1.3	1.6	21%	1.90	1.7	11%
Benzo(b&j)fluoranthene	mg/kg	0.01	2.4	2.9	19%	2.9	2.7	7%
Benzo(g,h,i)perylene	mg/kg	0.02	0.46	0.57	21%	0.56	0.52	7%
Benzo(k)fluoranthene	mg/kg	0.01	0.91	1.1	19%	1.1	1.0	10%
Chrysene	mg/kg	0.01	2.7	3.8	34%	4.3	3.0	36%
Dibenz(a,h)anthracene	mg/kg	0.02	0.13	0.17	27%	0.18	0.16	12%
Fluoranthene	mg/kg	0.01	4.5	5.6	22%	5.6	4.3	26%
Fluorene	mg/kg	0.01	0.28	0.28	0%	0.46	0.37	22%
Indeno(1,2,3-cd)pyrene	mg/kg	0.02	0.46	0.58	23%	0.57	0.52	9%
Naphthalene	mg/kg	0.01	0.18	0.17	6%	0.25	0.22	13%
Phenanthrene	mg/kg	0.01	3.0	1.60	61%	2.4	1.80	29%
Pyrene	mg/kg	0.01	6.8	8.0	16%	9.1	8	13%

Notes:

RPD is not calculated if either the original or duplicate sample scores a result less than 5 times the RDL

mg/kg - milligrams per kilogram

RDL - reportable detection limit

RPD - relative percent difference

n/c - not calculated

< - less than

Table E4
Summary of Quality Control Results - Extractable Petroleum Hydrocarbons
Former Refinery
2225 Ioco Road, Port Moody, British Columbia

Sample Location	Units	RDL	IPN-SD09-03	IPN-SD09-04	RPD (%)	IPN-SD09-09	IPN-SD09-10	RPD (%)	IPN-SD09-16	IPN-SD09-17	RPD (%)
Sample Collection Date			27-May-09	27-May-09		27-May-09	27-May-09		5-Dec-09	5-Dec-09	
Maxxam Sample ID			98901	98902		988907	988908		S07312	S07311	
EPH (C ₁₀ -C ₁₉)	mg/kg	100	163	116	34%	111	108	n/c	<100	<100	n/c
LEPH	mg/kg	100	162	115	34%	111	107	n/c	<100	<100	n/c
EPH (C ₁₉ -C ₃₂)	mg/kg	100	578	553	4%	708	696	2%	593	649	9%
HEPH	mg/kg	100	577	552	4%	706	693	2%	589	642	9%

Notes:

RPD is not calculated if either the original or duplicate sample scores a result less than 5 times the RDL

mg/kg - milligrams per kilogram

RDL - reportable detection limit

RPD - relative percent difference

n/c - not calculable

< - less than

Table E4 (continued)
Summary of Quality Control Results - Extractable Petroleum Hydrocarbons
Former Refinery
2225 Ioco Road, Port Moody, British Columbia

Sample Location	Units	RDL	IPS-SD09-28	IPS-SD09-39	RPD (%)	IPS-SD09-29	IPS-SD09-38	RPD (%)
Sample Collection Date			2-Dec-09	2-Dec-09		2-Dec-09	2-Dec-09	
Maxxam Sample ID			S01929	S01924		S01925	S01926	
EPH (C ₁₀ -C ₁₉)	mg/kg	100	<100	<100	n/c	<100	<100	n/c
LEPH	mg/kg	100	<100	<100	n/c	<100	<100	n/c
EPH (C ₁₉ -C ₃₂)	mg/kg	100	471	447	5%	460	498	8%
HEPH	mg/kg	100	457	430	6%	442	482	9%

Notes:

RPD is not calculated if either the original or duplicate sample scores a result less than 5 times the RDL

mg/kg - milligrams per kilogram

RDL - reportable detection limit

RPD - relative percent difference

n/c - not calculated

< - less than