Natural vs Anthropogenic Hydrocarbon (BTEX, F1 to F4, and PAHs) Origins in the Alberta Foothills - Remedial Implications and Management

Ali H Chowdhury[1], Neil Barnsdall[2], and Dean M Quesnal[3]

[1]Shell Technology Centre, Houston, Texas
Shell Global Solutions, US
[2]Shell Global Solutions, Canada
[3]Stantec Environmental Services, Calgary, Canada

Copyright of Shell International B.V.

Acknowledgements

Stantec Environmental Services

Darren Heck | Mary Shaw | Wenhui Xiong

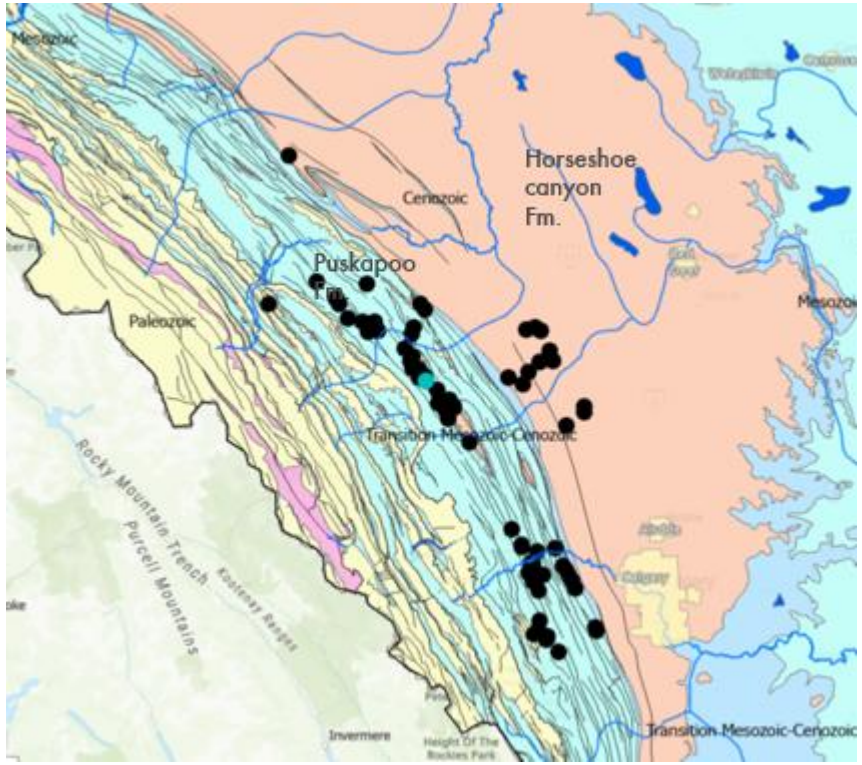
- Outcrop sampling and field support
- Field-data organization and review
- Laboratory and analytical-service coordination
- Discussions and data sharing

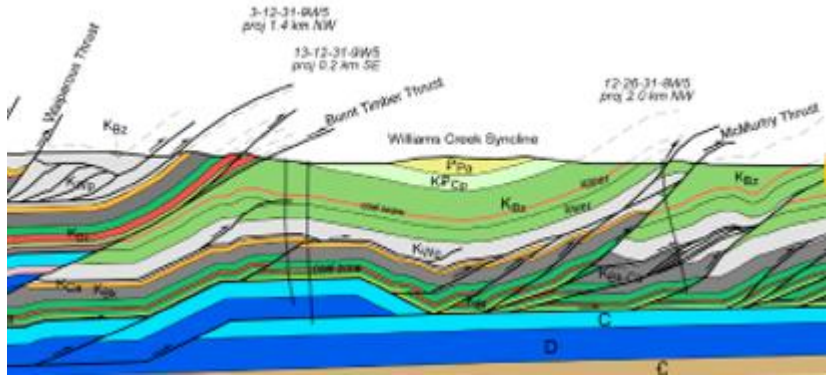
WSP

Stephanie Wegrzynowski

- Laboratory and analytical-service coordination
- Data sharing

Copyright of Shell International B.V.





Introduction

When an Exceedance is Not a Release

Naturally occurring BTEX, F1-F4, and PAH can complicate remediation decisions in the Alberta Foothills

The risk

Misattributing geological hydrocarbons to operations can drive unnecessary remediation, prolonged monitoring, and delayed closure

The response

Combine geological setting, spatial evidence, source-rock maturity and hydrocarbon fingerprinting to distinguish:

Natural background | Operational releases | Biogenic inputs

The outcome

Targeted remediation. Less soil disturbance. More defensible closure. Reduced liability.

Key message: The objective is targeted remediation based on source, not concentration alone.

Copyright of Shell International B.V.

Today's Story

The attribution challenge

- Why distinguishing natural background from operational impact matters

The Alberta Foothills setting

- How geology, stratigraphy, and petroleum systems create natural hydrocarbons

A multiple-lines-of-evidence workflow

- How spatial, chemical, and geochemical evidence differentiates sources

From evidence to action

- Implications of soil management, remediation, and defensible closure

Conclusions and Key Takeaways

- Sustainable implementation and reduction in liability

Copyright of Shell International B.V.

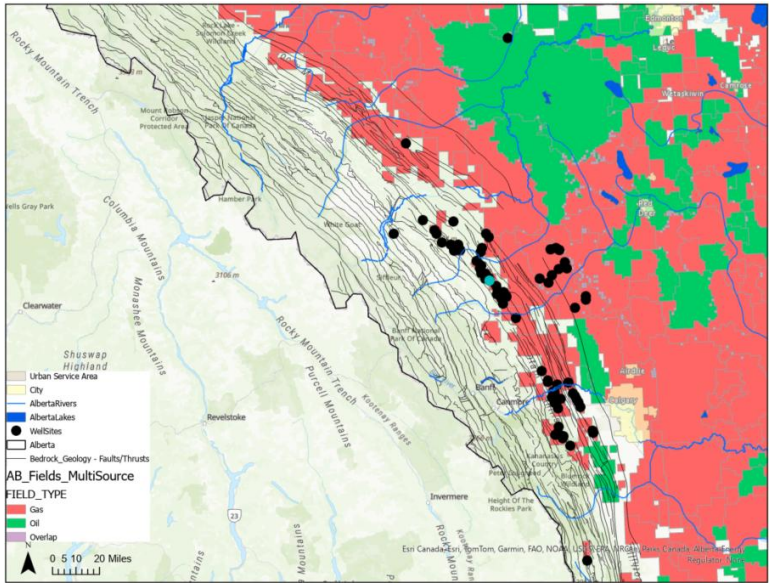
Background

Copyright of Shell International B.V.

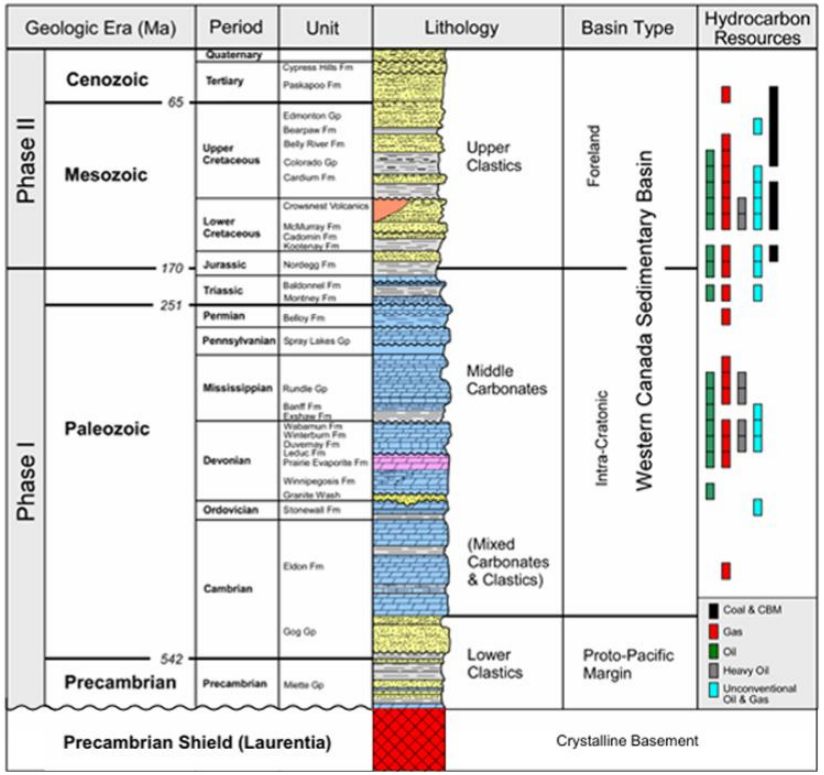
Geology and Environmental Setting

Key messages:

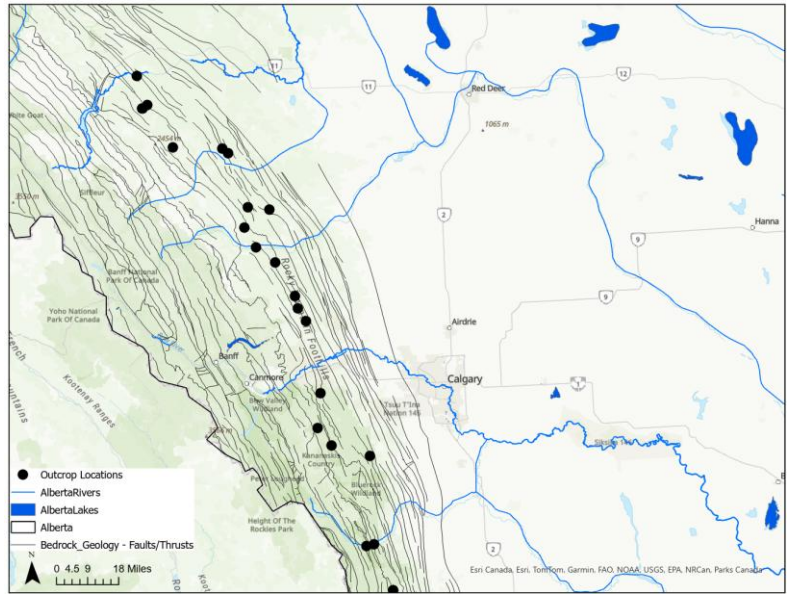
- Regional geology supplies the source, maturity history, and migration pathways
- Spatial overlap between hydrocarbon bearing geology and oil and gas activities
- The Foothills contain thermally mature organic matter that generated petroleum hydrocarbons and now at near surface
- Deep burial generated petroleum; later erosion made mature hydrocarbons appear at shallow surface and environmentally relevant
- Glacial and surficial processes can transfer bedrock-derived hydrocarbons/coals into soil



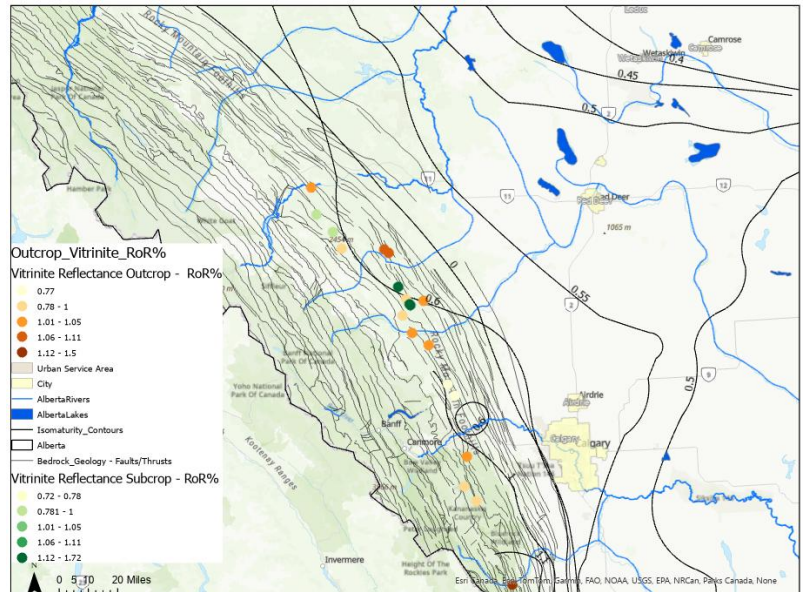
Well sites in the Alberta Foothills in a structurally complex petroleum province with extensive faulting and thrusting. Operational infrastructure and naturally hydrocarbon-bearing geology occur in the same landscape



Stratigraphic column showing oil and gas accumulations and coal throughout including shallower Cretaceous/Tertiary formations



Samples were analysed for thermal maturity and hydrocarbons at outcrop and well locations



Measured vitrinite reflectance values from outcrop and subcrop areas of the Alberta Foothills. Solid black lines are iso-maturity contours (Bustin, 1991)

Copyright of Shell International B.V.

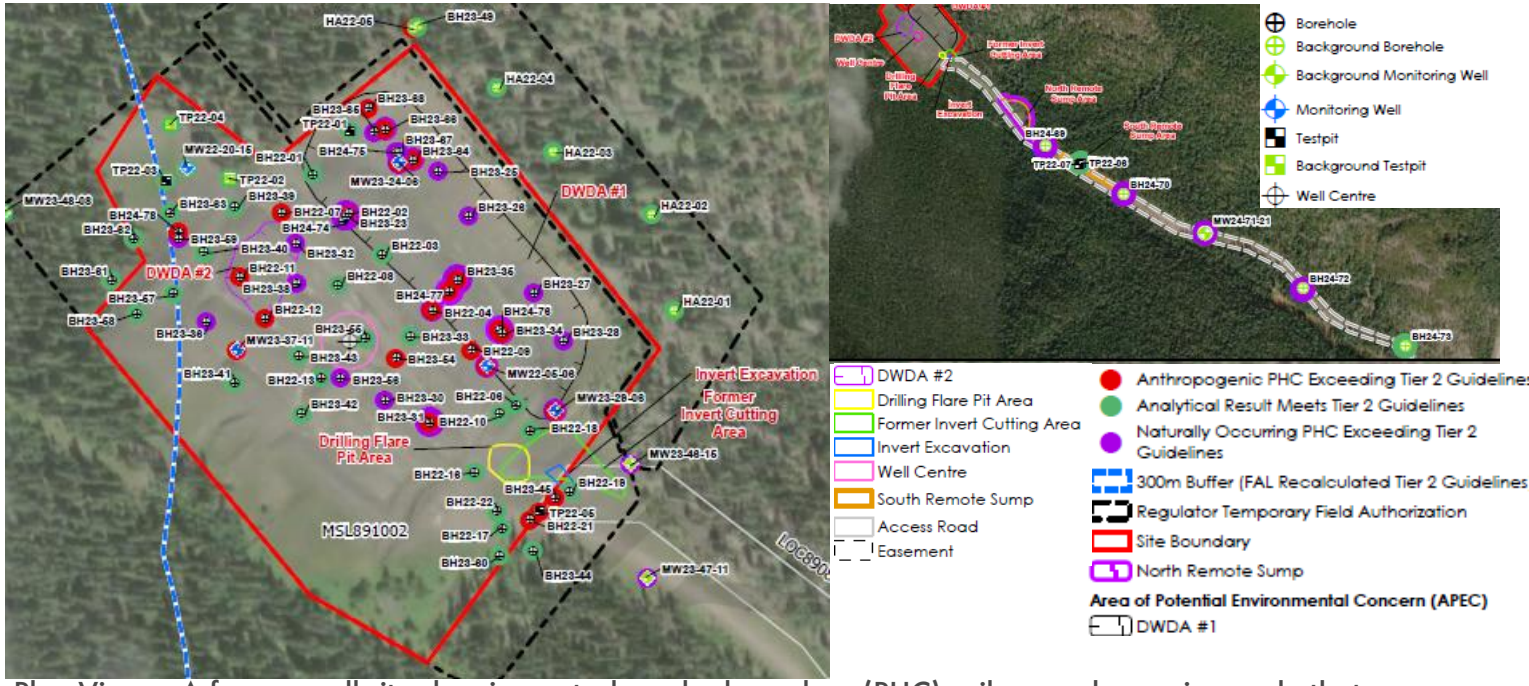
Background Definition and Evidence

- **Naturally occurring hydrocarbon (NOH) in soil, bedrock, groundwater, or seeps caused by natural geological processes including petroleum generation, migration, uplift, erosion, weathering and natural seepage, <u>independent of site operations.</u>**

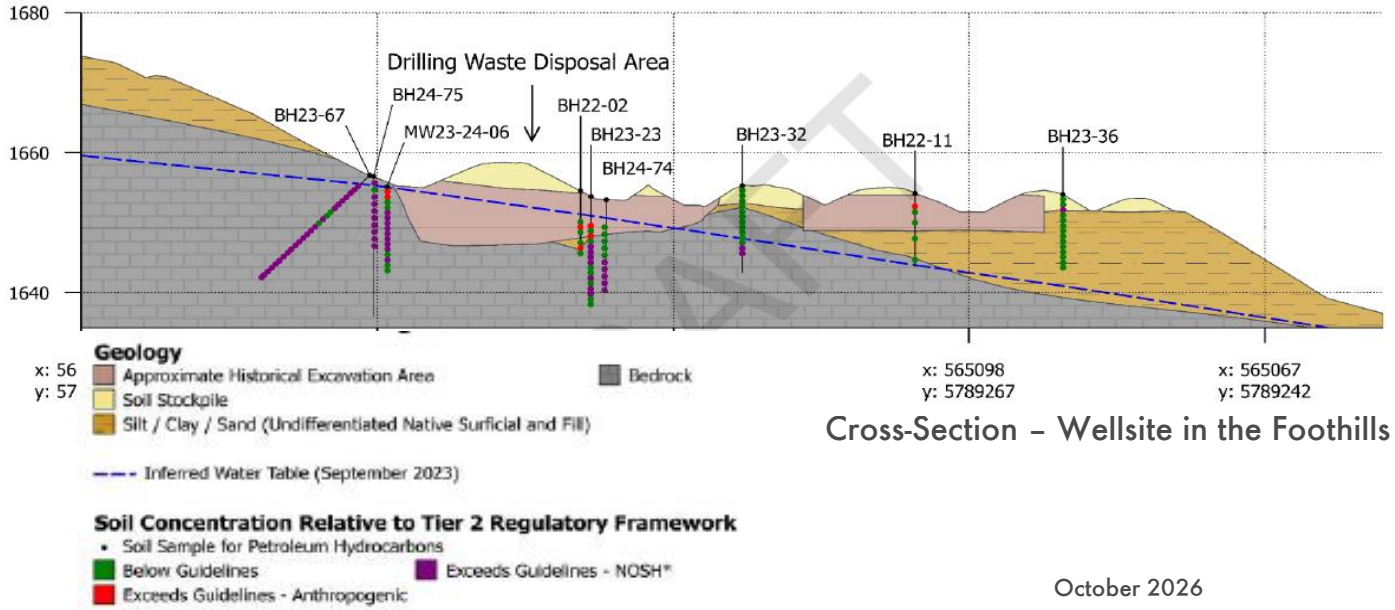
- **Spatial evidence**: exceedances extend beyond Areas of Potential Env Concern (APEC) boundaries.
- **Geological evidence**: detections occur within native soils and bedrock horizons.
- **Geochemical evidence**: background and operational areas may or may not share similar Benzene, Toluene, Ethylbenzene and Xylene (BTEX), Petroleum Hydrocarbon (PHC), and Polycyclic aromatic Hydrocarbon (PAH) fingerprints.

- ***A common misconception is that naturally occurring hydrocarbons should be uniformly distributed but in geological settings substantial variability is expected (e.g., depositional, lithology, porosity, permeability, fracture density, migration pathways, weathering, biodegradation)***

Key message: Background must be demonstrated spatially, geologically, and geochemically.



Plan View – A former well site showing petroleum hydrocarbon (PHC) soil exceedances in purple that are naturally occurring



Cross-Section – Wellsite in the Foothills

0.2

Hydrocarbon Differentiation Workflow

Copyright of Shell International B.V.

Multiple Lines of Evidence for Hydrocarbon Source Attribution

- Hydrocarbon Detection
- Geological and Spatial Context
- Hydrocarbon Fingerprinting
  - Gas Chromatograph - Flame Ionization Detection (GC-FID)
- Biomarker Characterization
  - Gas Chromatograph - Mass Spectrometer (GC-MS)
- Thermal Maturity Assessment
- Outcrop and Reference Comparison
- Operational Review
- Source Attribution

Key messages:

- No single test establishes source; confidence comes from convergence
- GC-FID shows the bulk hydrocarbon pattern; GC-MS identifies the molecular evidence needed to evaluate source and maturity.

GC-FID and GC-MS Provide Complementary Evidence

Analytical Capability	GC-FID	GC-MS
Primary measurement	Bulk hydrocarbon response	Individual compounds and molecular fingerprints
Best application	Rapid screening and hydrocarbon characterization	Detailed forensic characterization
Carbon-range distribution	Excellent for F1-F4 and F3a/F3b	Not typically used for regulatory PHC fractions
Fingerprint information	Overall pattern, n-alkanes, UCM, and product-range character	PAHs, alkylated PAHs, biomarkers, and diagnostic ratios
Weathering assessment	Indicates loss of light fractions and UCM development	Evaluates compound-specific alteration and biodegradation
Source correlation	Supports comparison between samples	Stronger oil-oil, oil-outcrop, and oil-source-rock correlation
Thermal maturity	Limited	Assessed using biomarker and aromatic maturity parameters
Role in NOH assessment	Characterizes hydrocarbon type and distribution	Evaluates source, maturity, and geological affinity

Criteria for Establishing Naturally Occurring Hydrocarbon (NOH)

Spatial/Geological
- NOH occur in both operational and non-operational footprints
- NOH are not centered on specific facilities
- NOH are stratigraphically controlled

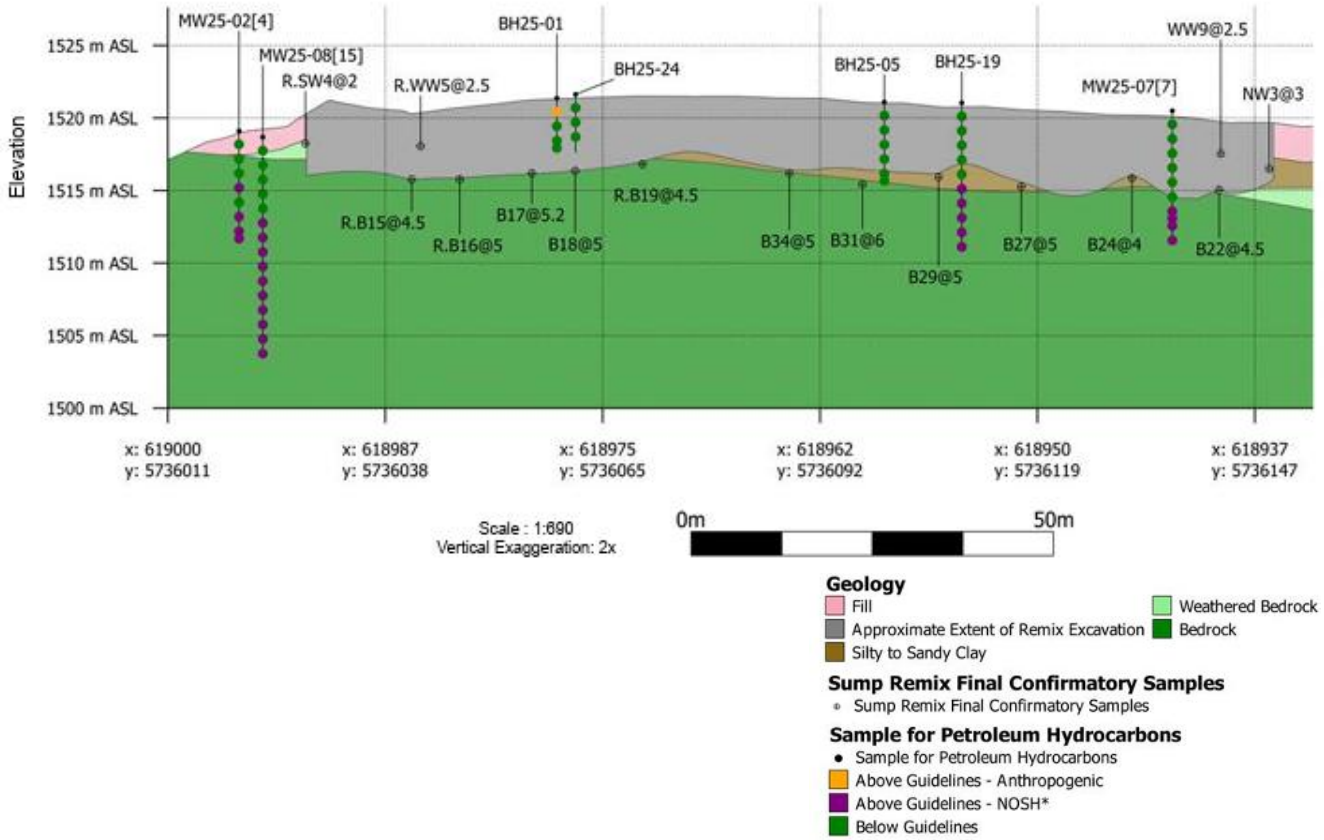
Geological
- Mature hydrocarbon-generating strata present (e.g., Cardium, Blackstone, Luscar Formations)
- Regional outcrop occurrences documented

Geochemical
- Characteristic GC-FID fingerprints across background and operational areas (e.g., natural vs refined products)
- Characteristic PAH distributions
- Alkylated PAHs of petrogenic origin
- Biomarkers present
- Biomarkers comparable to outcrop analogues

Thermal Maturity
- Ro values within oil/gas window
- Rock-Eval supports hydrocarbon generation potential

Operational Review
- No plausible facility-centered distribution
- No documented release mechanism explaining regional occurrence

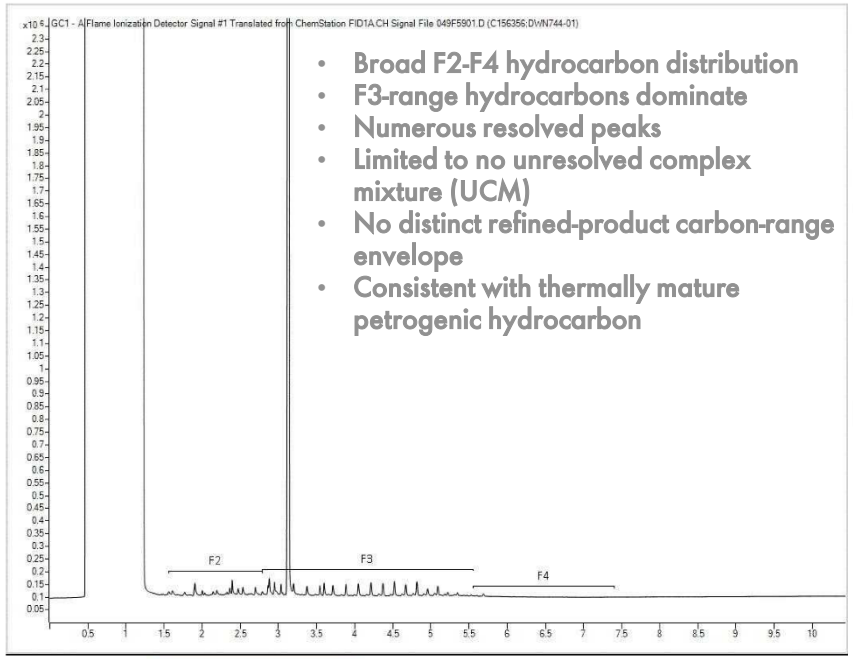
Key message: The spatial distribution of NOH hydrocarbons is controlled by geology, stratigraphy, and proximity to hydrocarbon-bearing bedrock



Hydrocarbon exceedances occur predominantly within weathered and competent bedrock, including beneath areas without an apparent surface source. The discontinuous, depth-related distribution supports stratigraphic control and localized migration from hydrocarbon-bearing bedrock

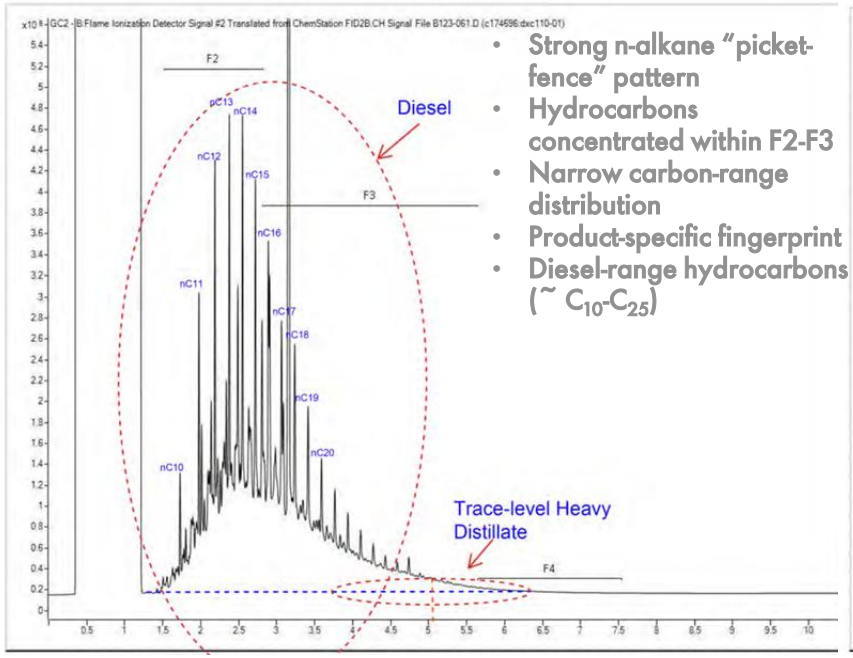
GC-FID Fingerprints of Naturally Occurring and Refined Hydrocarbons

Naturally Occurring Hydrocarbon (NOH)
Typical Features (GC-FID)



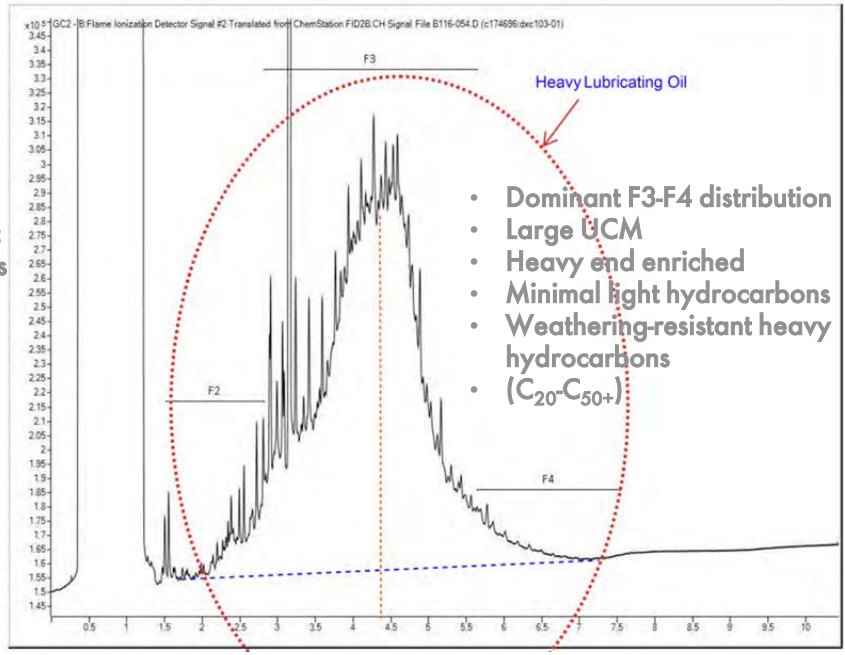
- Broad F2-F4 hydrocarbon distribution
- F3-range hydrocarbons dominate
- Numerous resolved peaks
- Limited to no unresolved complex mixture (UCM)
- No distinct refined-product carbon-range envelope
- Consistent with thermally mature petrogenic hydrocarbon

Refined Hydrocarbon (Diesel)
Typical Features (GC-FID)



- Strong n-alkane "picket-fence" pattern
- Hydrocarbons concentrated within F2-F3
- Narrow carbon-range distribution
- Product-specific fingerprint
- Diesel-range hydrocarbons (~ C_{10}-C_{25})

Refined Hydrocarbon (Lube oil)
Typical Features (GC-FID)

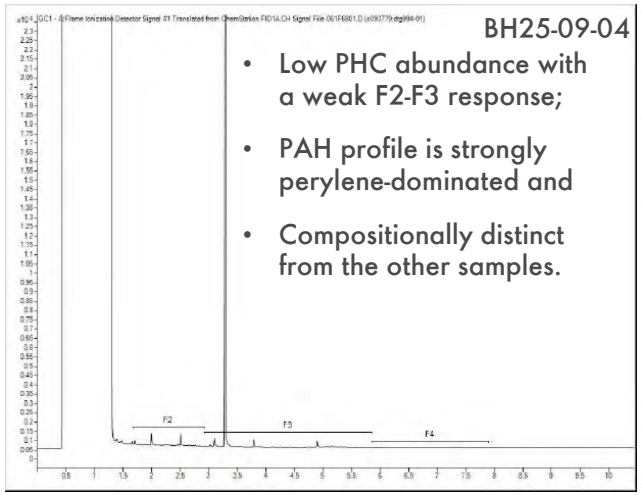


- Dominant F3-F4 distribution
- Large UCM
- Heavy end enriched
- Minimal light hydrocarbons
- Weathering-resistant heavy hydrocarbons
- (C_{20}-C_{50+})

Characteristic	Alberta Foothills NOH	Diesel	Lubricating Oil
Carbon Range	Broad F2-F4	Primarily F2-F3	Primarily F3-F4
n-Alkanes	Variable	Strong	Weak
UCM	Low	Low (fresh) to moderate (weathered)	High
Fingerprint Type	Geologically controlled	Product-specific	Product-specific
Source Attribution	Requires multiple lines of evidence	Characteristic refined product	Characteristic refined product

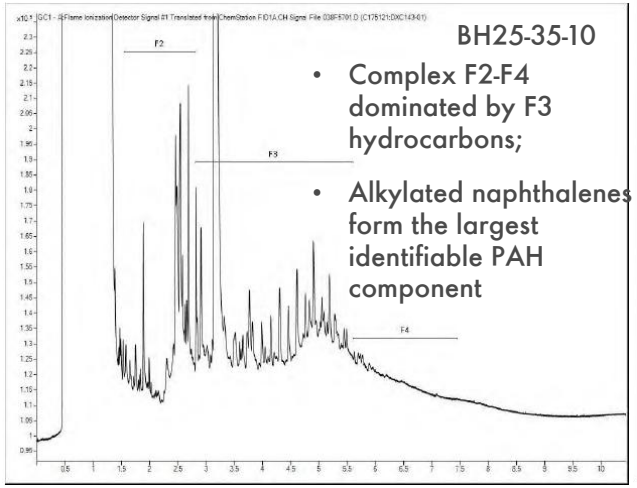
Key message: GC-FID characterizes hydrocarbon type, carbon-range distribution, and weathering; source attribution requires integration with PAHs, biomarkers, thermal maturity, and geological context.

GC-FID and PAH Characteristics of Hydrocarbons Associated with Coal-Bearing Strata



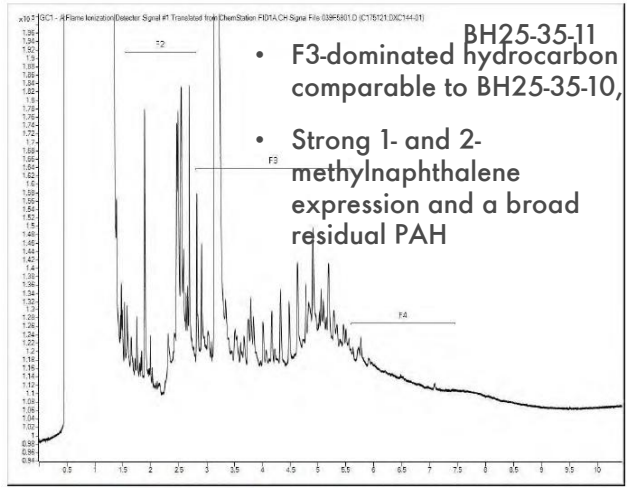
BH25-09-04

- Low PHC abundance with a weak F2-F3 response;
- PAH profile is strongly perylene-dominated and
- Compositionally distinct from the other samples.



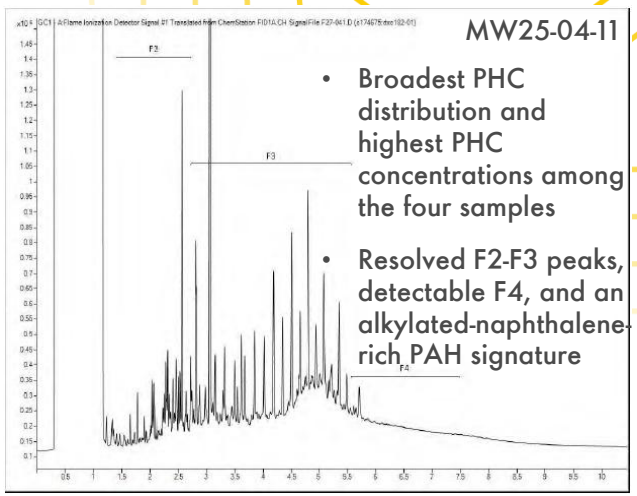
BH25-35-10

- Complex F2-F4 dominated by F3 hydrocarbons;
- Alkylated naphthalenes form the largest identifiable PAH component



BH25-35-11

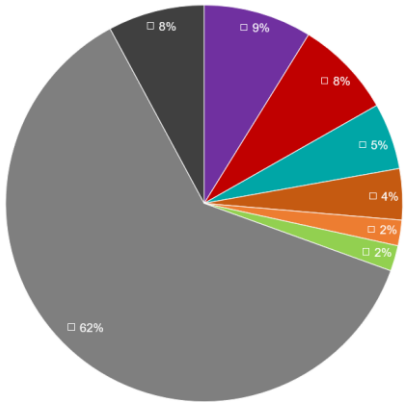
- F3-dominated hydrocarbon comparable to BH25-35-10,
- Strong 1- and 2-methylnaphthalene expression and a broad residual PAH

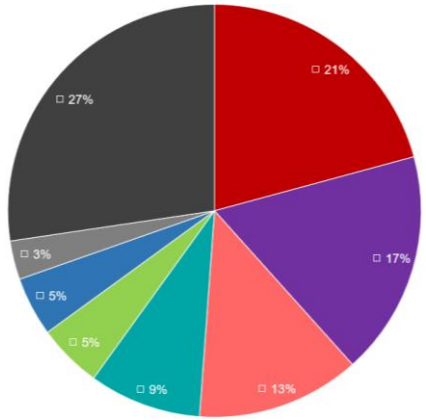


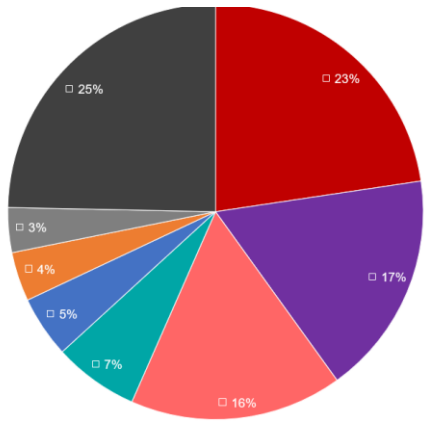
MW25-04-11

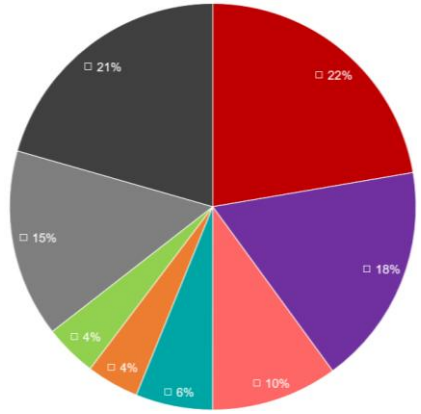
- Broadest PHC distribution and highest PHC concentrations among the four samples
- Resolved F2-F3 peaks, detectable F4, and an alkylated-naphthalene-rich PAH signature

PAH









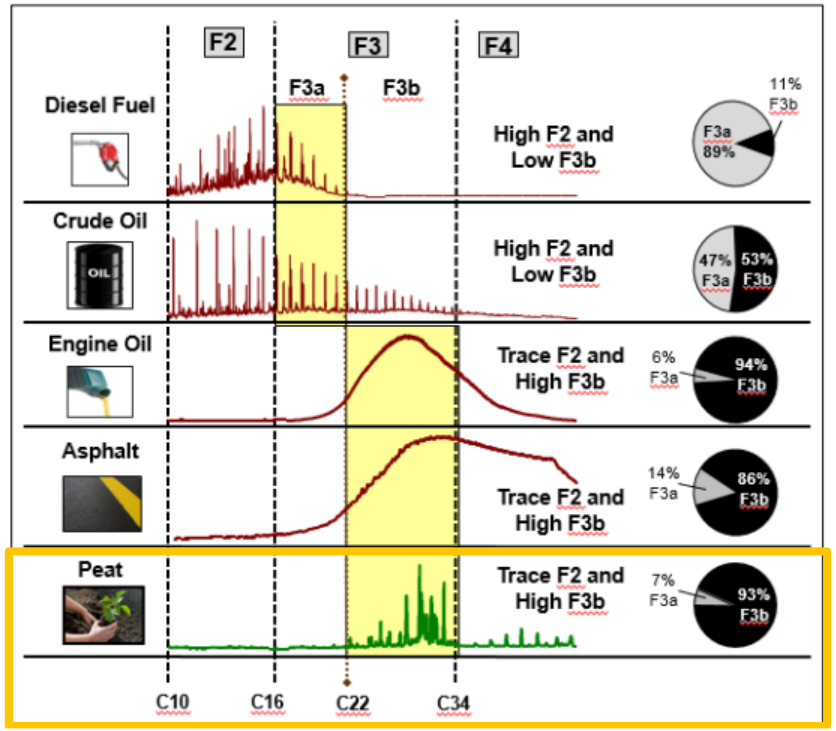


Key message:

Coal-bearing strata can contain variable F3-dominated petrogenic hydrocarbons, including alkylated-naphthalene-rich and perylene-rich profiles that may resemble environmental petroleum impacts. Source attribution requires geological context including borehole log observation.

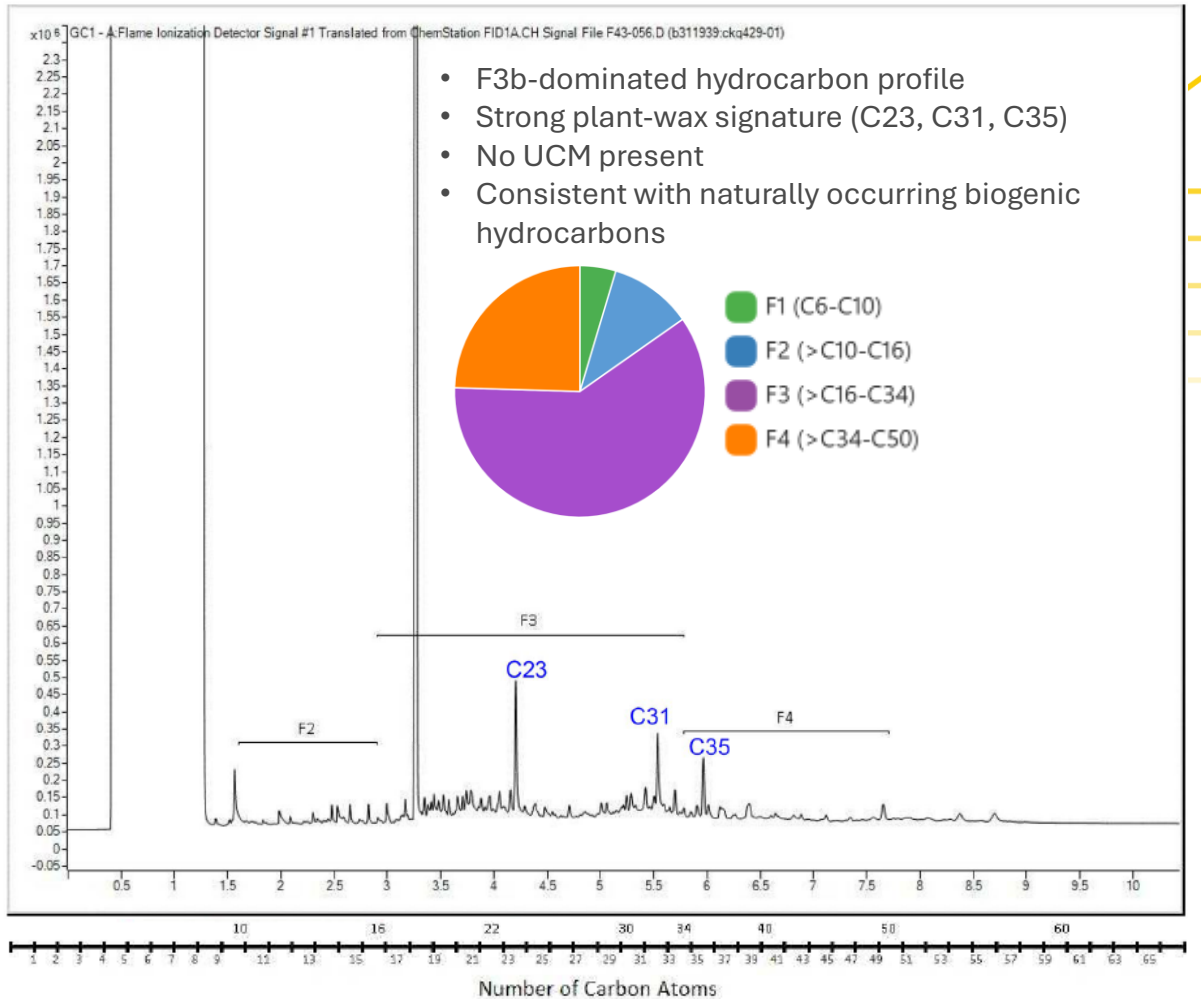
GC-FID - Biogenic Hydrocarbons

- **Key Characteristics**
- No unresolved complex mixture (UCM)
- F3b-dominated hydrocarbon distribution
- Strong odd-carbon n-alkane preference (C23, C31, C35)
- Consistent with predominantly biogenic organic matter input



BIC Value	Interpretation
< 10%	Likely a false biogenic exceedance
> 10%	Likely a true petrogenic (petroleum) exceedance

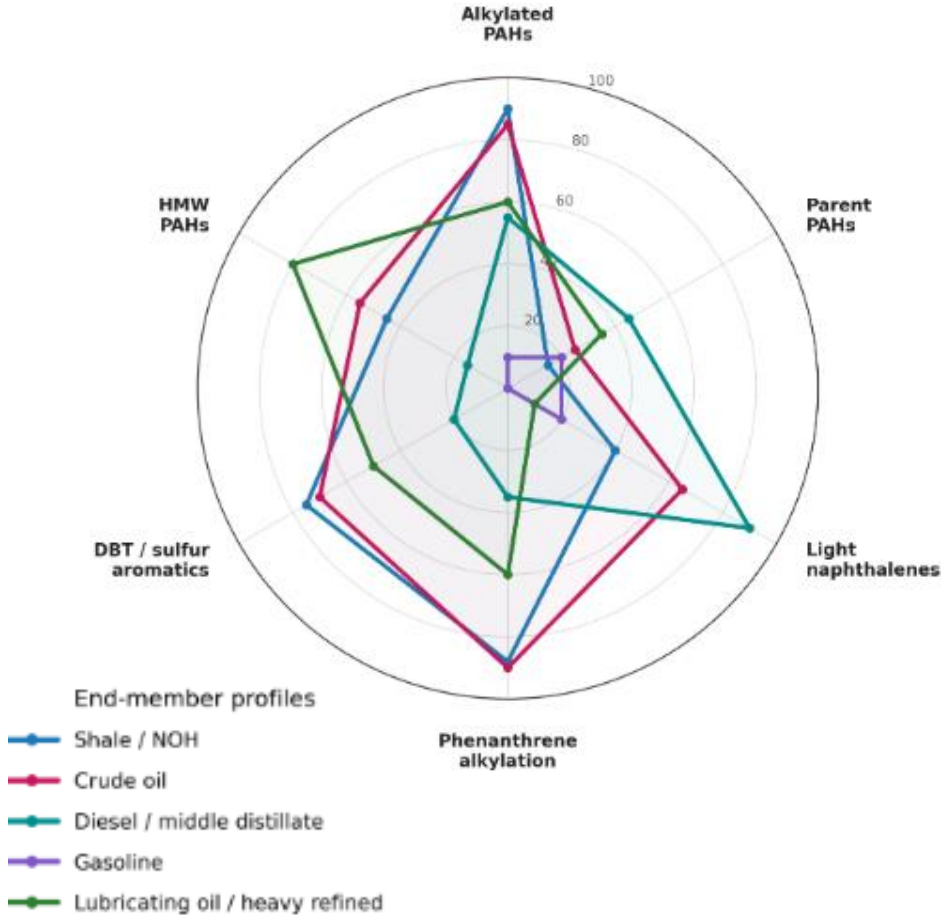
BIC Scale for Delineating Petroleum Hydrocarbons in Organic Soils and Compost Guide



Fingerprint indicates predominantly biogenic organic matter with no clear evidence of anthropogenic petroleum influence

Key Message:
Biogenic Interference Calculation (BIC) and odd-to-even carbon predominance can screen if hydrocarbon is biogenic or petrogenic

Conceptual PAH Signatures of Common Hydrocarbon Sources



Conceptual comparison of common PAH characteristics used in environmental forensics. Actual profiles vary with petroleum type, source rock, thermal maturity, biodegradation, weathering, and analytical method. (Ghetu et al., 2021; Stogiannidis & Laane, 2015; Tobiszewski & Namiesnik ,2012; Yunker et al. 2002).

NOH / Crude Oil

- Alkylated PAHs dominate over parent PAHs
- Bell-shaped alkyl homolog distributions
- Naphthalenes, phenanthrenes, and dibenzothiophenes are often abundant
- Low abundance of 5-6 ring PAHs

Diesel / Middle Distillate

- Enriched in alkylated naphthalene
- Lower abundance of heavier PAHs
- Moderate alkylation profile

Gasoline

- Low total PAH abundance
- Dominated by lighter aromatic
- Limited diagnostic PAH information

Lubricating Oil

- Enriched in higher molecular-weight aromatic compounds
- Depleted in lighter aromatic fractions
- Weathering-resistant signature

Petrogenic vs Pyrogenic

Petrogenic

- Alkylated PAHs > Parent PAHs
- Bell-shaped homolog distributions
- Common in crude oil, bitumen, petroleum products, and NOH

Pyrogenic

- Parent PAHs > Alkylated PAHs
- High molecular-weight compounds dominate
- Indicative of combustion and thermal alteration processes

Key Message:
Alkylated-PAH dominance and homolog distributions are key indicators of petrogenic hydrocarbons and provide supporting evidence for naturally occurring petroleum when integrated with biomarkers and geological context

Copyright of Shell International B.V.

Conceptual Comparison of Biomarker Among Hydrocarbon End Members

Petroleum biomarkers are molecular fossils that retain information on:

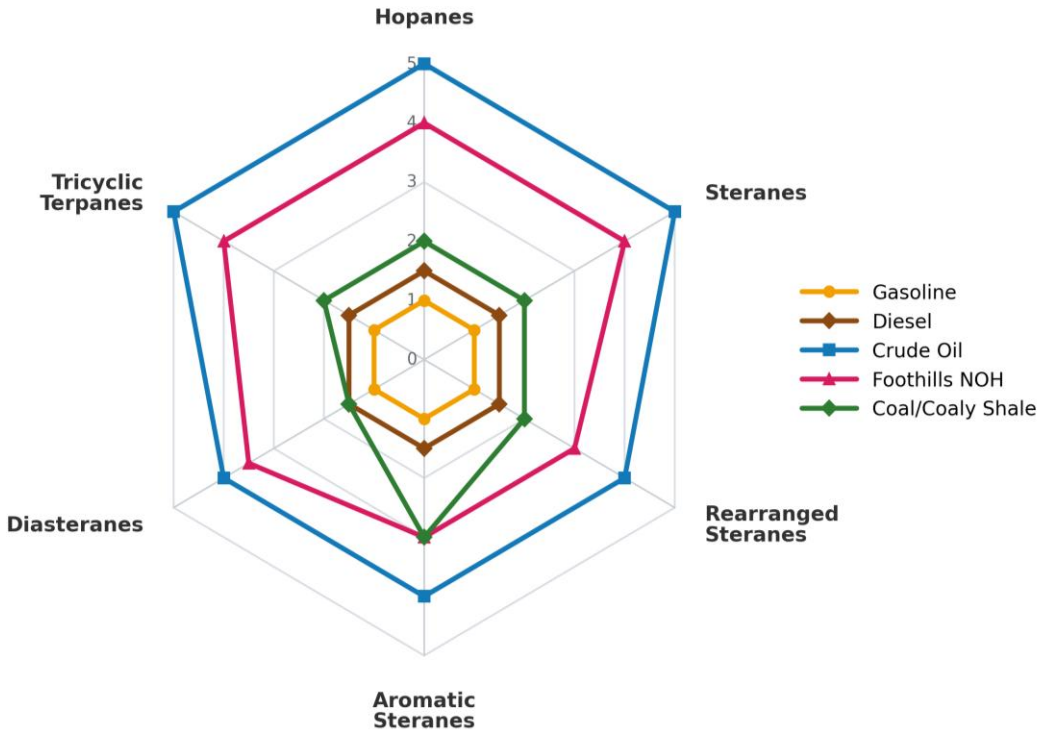
- Organic-matter source and depositional environment
- Thermal maturity and alteration
- Correlation between oils, source rocks, and impacted media

What GC-MS Biomarkers add

- Characterize source facies and thermal maturity
- Support oil-to-oil, oil-to-rock, and site-to-outcrop correlation
- Retain diagnostic information after weathering and degradation
- Differentiates geological petroleum from refined-product inputs

Biomarker Family	Geological Significance	Gasoline	Diesel	Crude Oil	Foothills NOH	Coal / Coaly Shale	Typical Carbon Number(s)
Hopanes	Oil correlation; biodegradation	Absent	Low	Very High	High	Very Low	C27-C35
Steranes	Organic-matter source	Absent	Low	Very High	High	Low	C27-C29
Tricyclic Terpanes	Source-facies characterization	Absent	Low	Very High	Moderate-High	Very Low	C19-C30
Diasteranes	Facies and maturity	Absent	Low	High	Moderate	Low	C27-C29
Aromatic Steranes	Thermal maturity	Absent	Trace-Low	Moderate-High	Moderate	Moderate	C26-C29*
Rearranged Steranes	Facies effects; clay catalysis; maturity	Absent	Low	Moderate-High	Moderate	Low	C27-C29

** Aromatic steranes commonly include triaromatic steranes (typically C26-C28) and monoaromatic steranes (commonly C27-C29).*



Conceptual comparison of biomarker family abundance across representative hydrocarbon end members. Scores reflect expected biomarker occurrence and preservation rather than measured concentrations

Key Message:

Biomarkers identify and correlate petroleum, while geological context distinguishes naturally occurring hydrocarbons from contamination

.

Copyright of Shell International B.V.

0.3

Hydrocarbon Differentiation Workflow Implementation

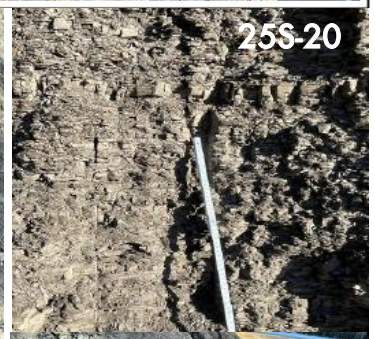
Copyright of Shell International B.V.

Outcrop Analogue Evidence











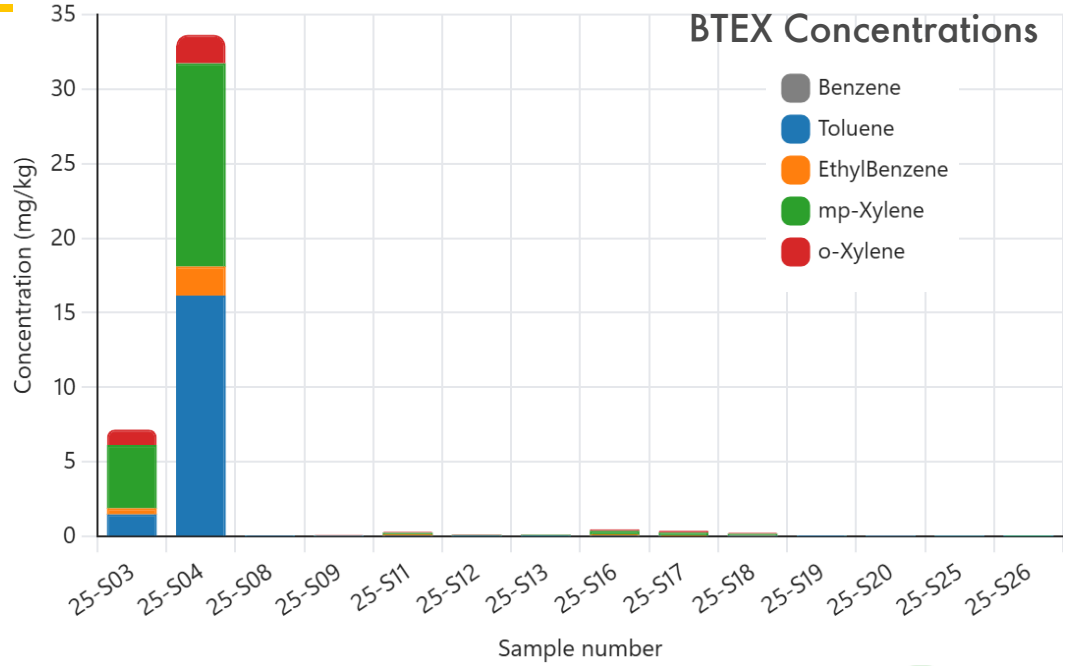


- Hydrocarbon-bearing bedrock exposed at surface
- Similar lithologies and structures extend beneath well site areas
- Located outside historical operational footprints
- Supports a naturally occurring hydrocarbon source model

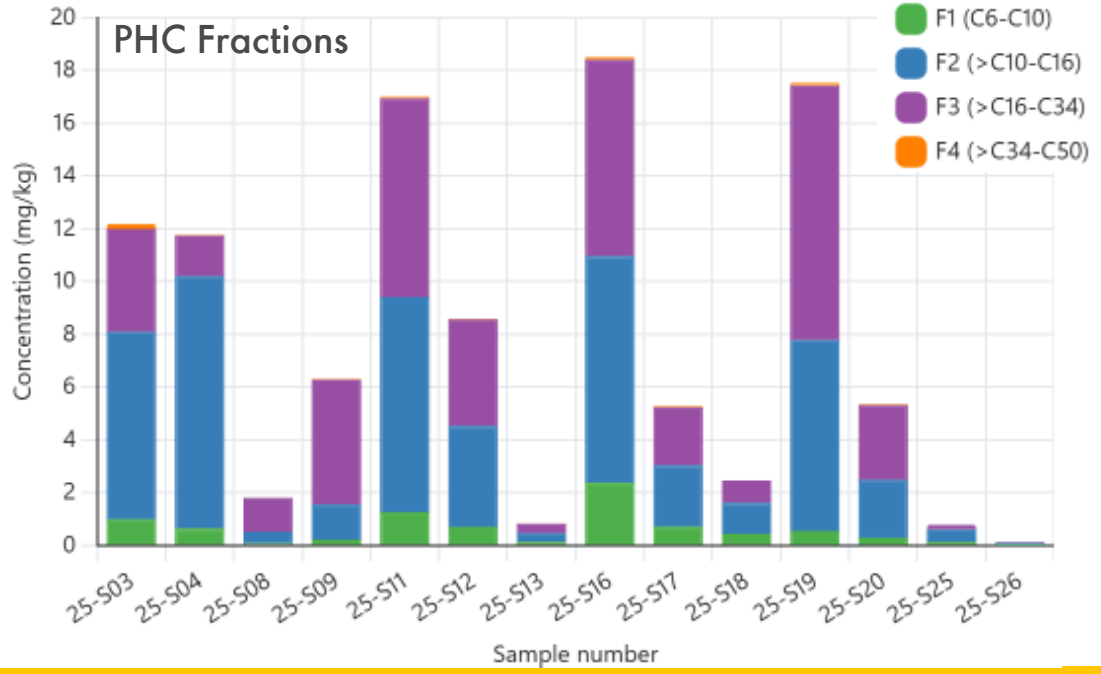
Key message: Off-site outcrops provide an independent natural-hydrocarbon source analogue.

Outcrop	Formation	Landmark
25S-01	Wapiabi Formation	McLean Creek Trail
25S-02	Wapiabi Formation	McLean Creek Trail
25S-03	Luscar Group	Highway 541
25S-04	Luscar Group	Highway 541
25S-05	Rundle Group	Highway 541
25S-06	Cadomin Formation	Highway 532
25S-07	Luscar Group	Highway 40S
25S-08	Brazeau Formation	Highway 40N
25S-09	Brazeau Formation	Highway 40N
25S-10	Luscar Group	Highway 40N at Highway 579
25S-11	Wapiabi Formation	Highway 40N (Burnt Timber area)
25S-12	Cardium Formation	Highway 40N (Pather River Bridge)
25S-13	Luscar Group	Highway 40N (Near Aylmer PP)
25S-14	Brazeau Formation	Highway 40N (Near RAM PRA)
25S-15	Cardium Formation	Highway 40 RAM area (cut slope)
25S-16	Cardium Formation	Highway 40 RAM Area (cut slope)
25S-17	Wapiabi Formation	Highway 40N (RAM Falls)
25S-18	Wapiabi Formation	Highway 40N(RAM Falls PP)
25S-19	Luscar Group	Highway 40N at 752 Junction
25S-20	Blackstone Formation	Highway 40N south 752 Junction
25S-21	Wapiabi Formation	Highway 40N (James River)
25S-22	Wapiabi Formation	Highway 40 Limestone area
25S-23	Wapiabi Formation	Highway 40N (Near James River Bridge)
25S-24	Luscar Group	Highway 68 (Powderface Trail)
25S-25	Wapiabi Formation	Highway 68 (Powerderface Trail)

BTEX/PHC Observations – Outcrop soil/bedrock (NOH)



- BTEX concentrations are generally low in outcrop samples.
- Detectable BTEX is primarily limited to samples **25-S03** and **25-S04**
- **Low BTEX abundance is consistent with weathering and volatilization of lighter hydrocarbons.**
- Sampling bias due to shallow surface collections

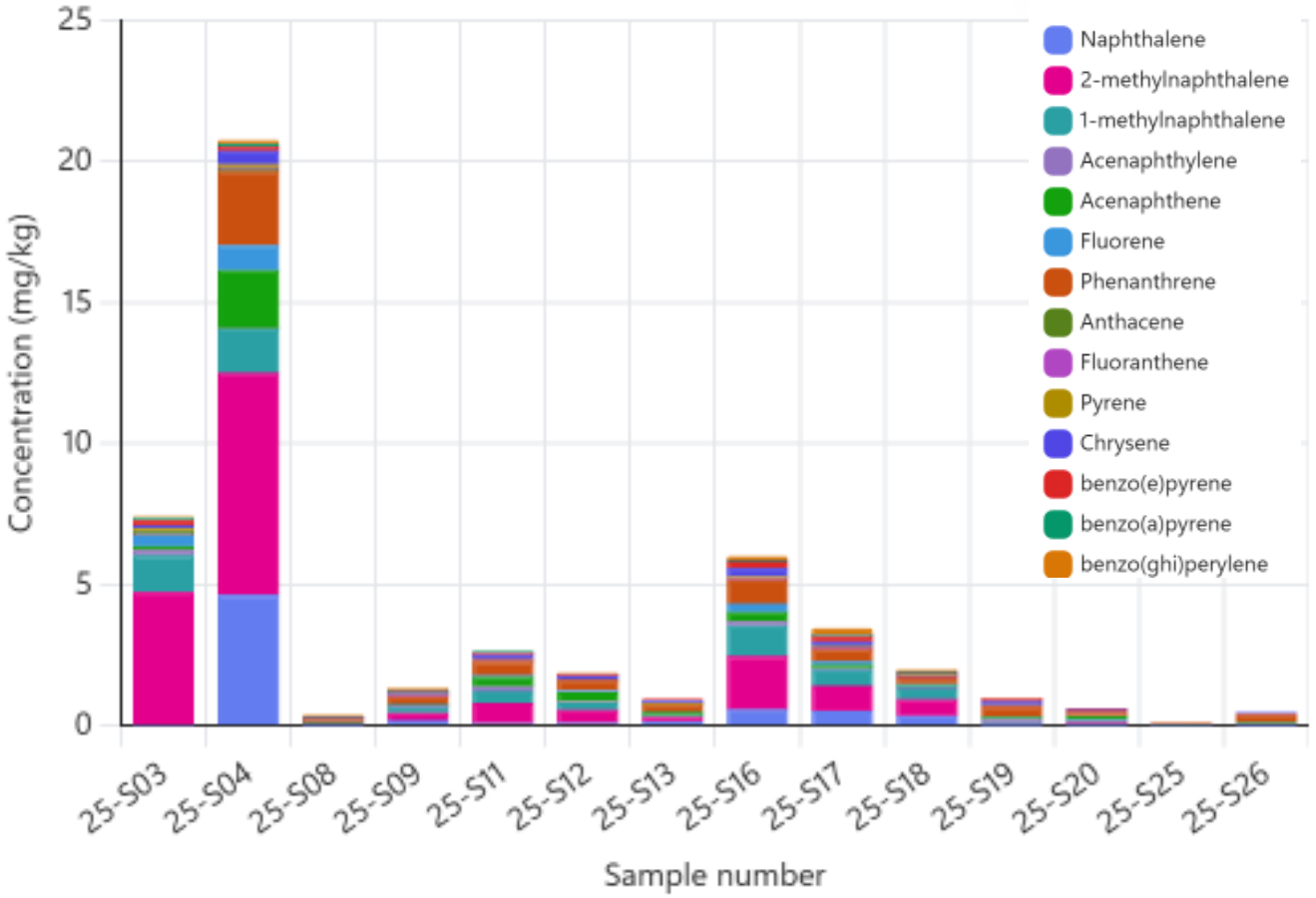


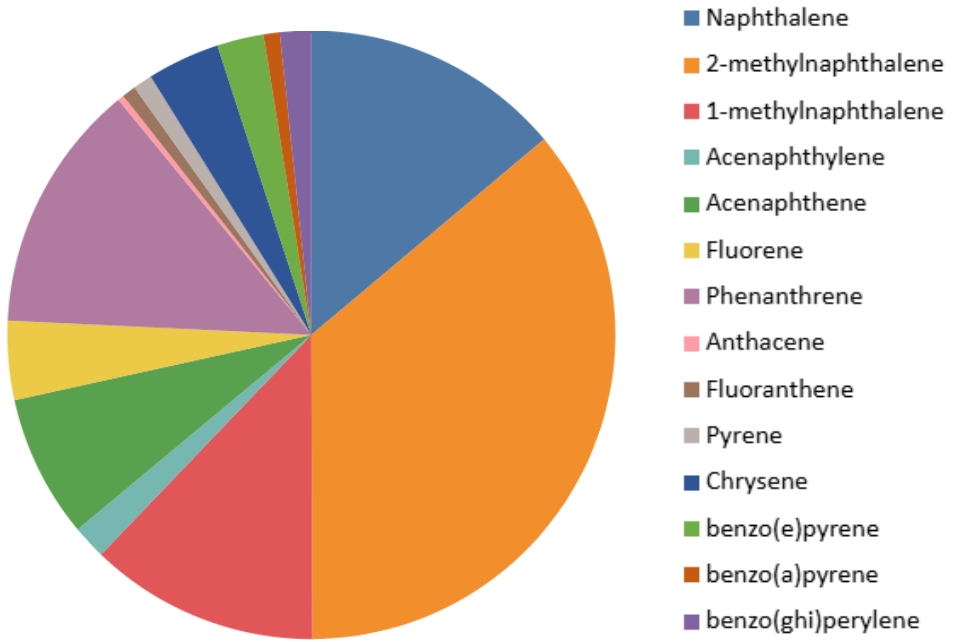
- Hydrocarbon occurrence is highly variable between adjacent outcrop locations
- Highest PHC concentrations occur in **25-S11, 25-S15, 25-S16, and 25-S19**.
- F2-F3 is the dominant fractions in most samples, minimal F1/F4.
- The distribution is consistent with weathered naturally occurring hydrocarbons, where lighter fractions have been preferentially depleted.
- Hydrocarbon occurrence appears controlled by localized stratigraphy and fracture pathways

Key message: Natural outcrop hydrocarbons are weathered, F3-dominant, and spatially heterogeneous.

PAH profiles – Outcrop soil/bedrock (NOH)

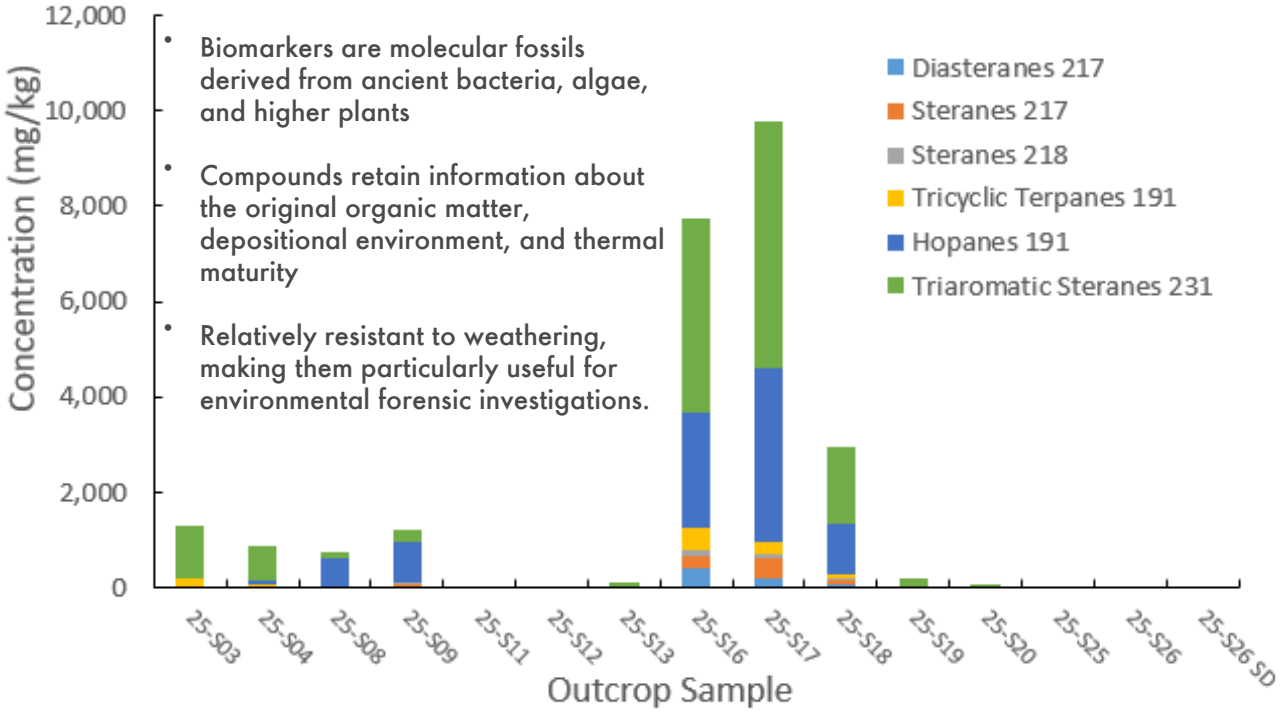
- PAH profile is dominated by low-molecular-weight (LMW) compounds.
- Alkylated naphthalenes and phenanthrenes are the predominant PAH species
- High-molecular-weight PAHs are minor or absent
- **Consistent alkylated, low-molecular-weight PAH provides a regional NOH reference signature for evaluating onsite hydrocarbons**





Key message: The outcrop provides a low-molecular-weight, alkylated petrogenic PAH reference signature

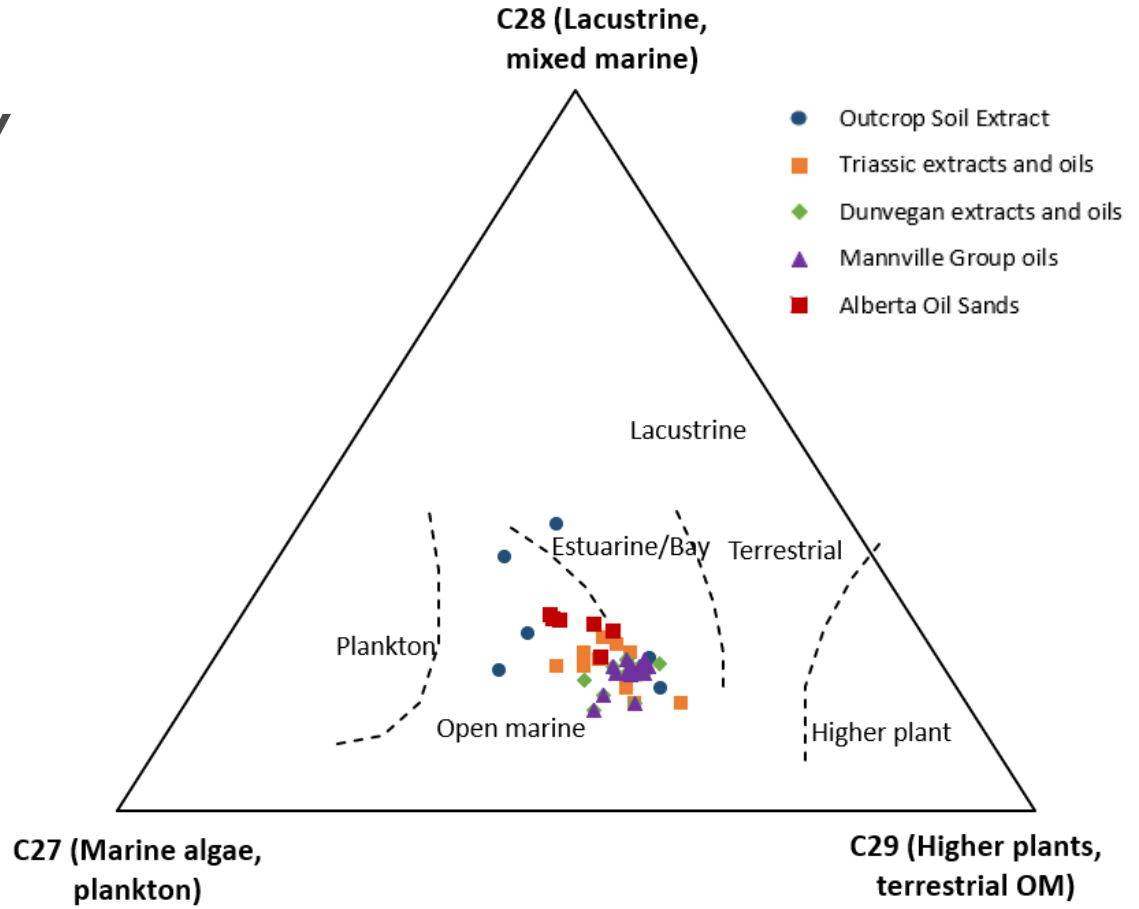
Outcrop Biomarker Signatures Confirm a Naturally Occurring Petroleum Origin



Outcrop samples contain abundant steranes, hopanes, tricyclic terpanes, diasteranes, and aromatic steranes. These molecular fossils originate from ancient biological organic matter and are characteristic components of thermally mature petroleum systems

- Broad sterane, hopane, terpane, and aromatic sterane suites are characteristic of thermally mature petroleum.
- Outcrop signatures provide a regional analogue for hydrocarbons observed at former well sites.
- Biomarker evidence supports a geologic petroleum source when integrated with geological and thermal-maturity data

Copyright of Shell International B.V.

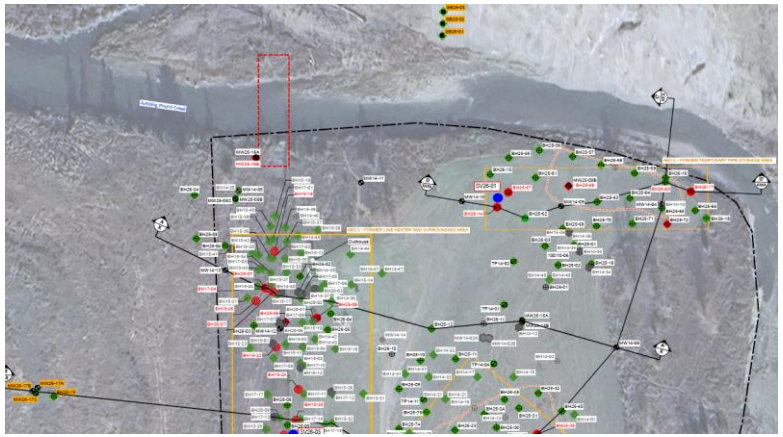


Relationship between the sterol compositions in biological sources and in open marine, estuarine or bay, lacustrine and terrigenous ecosystems.C27-C28-C29 regular sterane distributions from outcrop samples overlap the range reported for Alberta petroleum systems, including Western Canada source-rock extracts, crude oils, and oil-sands-derived hydrocarbons. The compositions indicate mixed marine-algal and terrestrial organic matter contributions that are typical of mature petroleum systems.

Alberta petroleum system data from Riediger et al (1990) CSPG Bull v.38A; Snowdon et al, (1998) CSPG Bull v 46; Riediger et al (1999) CSPG Bull 47; Yang et al. (2011) Env Forensics v. 12. Chart is after Huang and Meinschein, 1979

Key message: Outcrop biomarker signatures demonstrate thermally mature petroleum and provide a regional analogue supporting a naturally occurring hydrocarbon interpretation

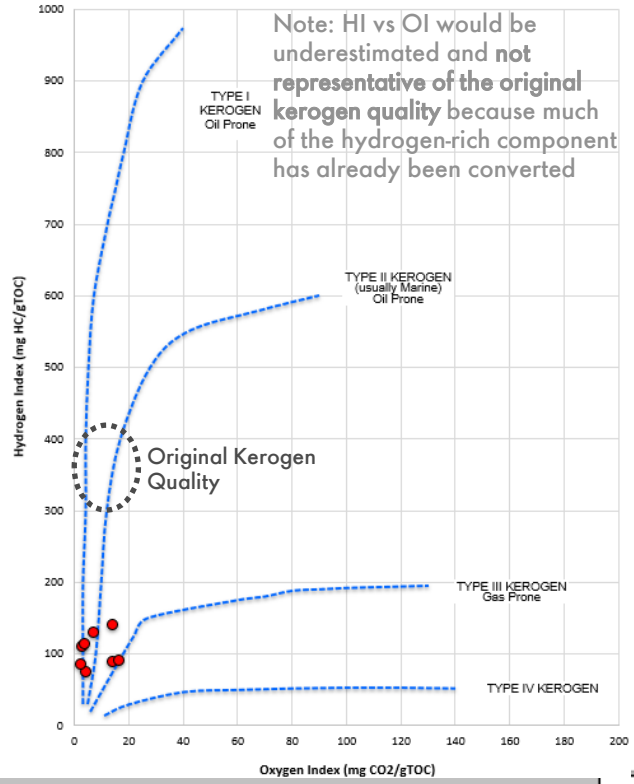
Case Study - Alberta Foothills Well site A

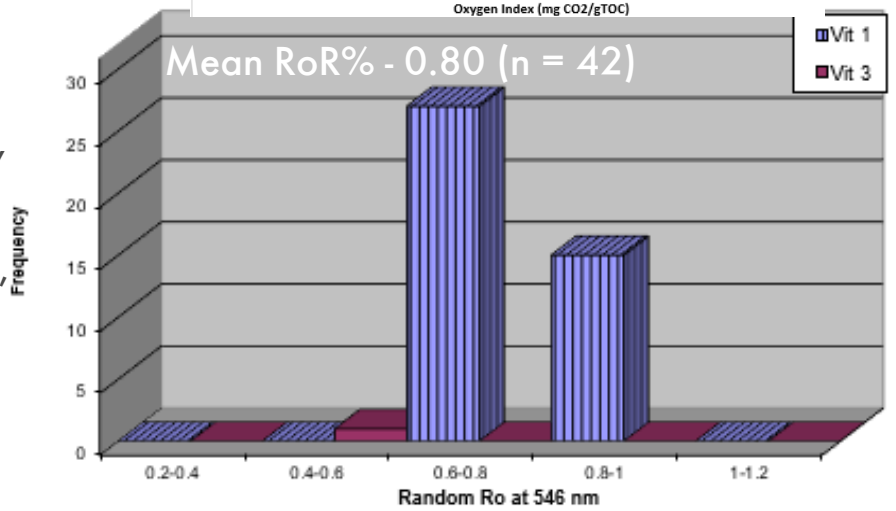


- Rock-Eval and vitrinite reflectance data indicate thermally mature residual organic matter dominated by Type III characteristics. Given the measured Ro values (~0.8%+), HI values likely underestimate the original hydrocarbon-generating potential because substantial petroleum generation has already occurred
- Petrography reveals Type I Kerogen (alginite, liptinite)

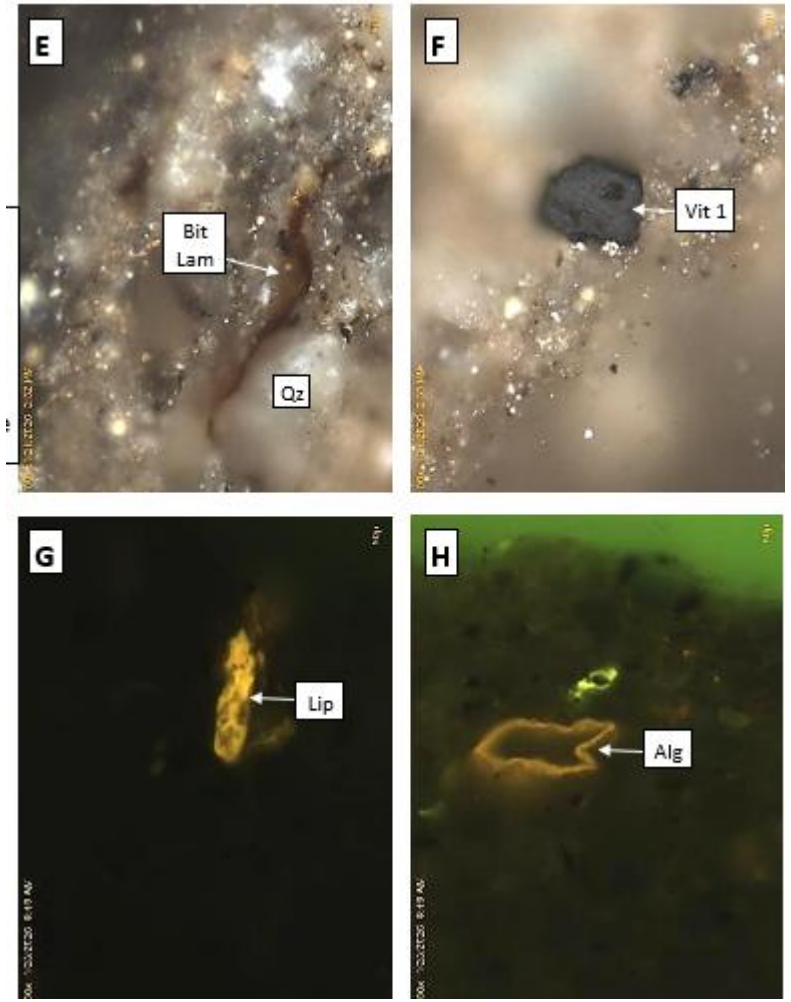
Key message: Site-specific maturity data support the regional NOH mechanism.

Rock-Eval Cross Plot of HI vs OI





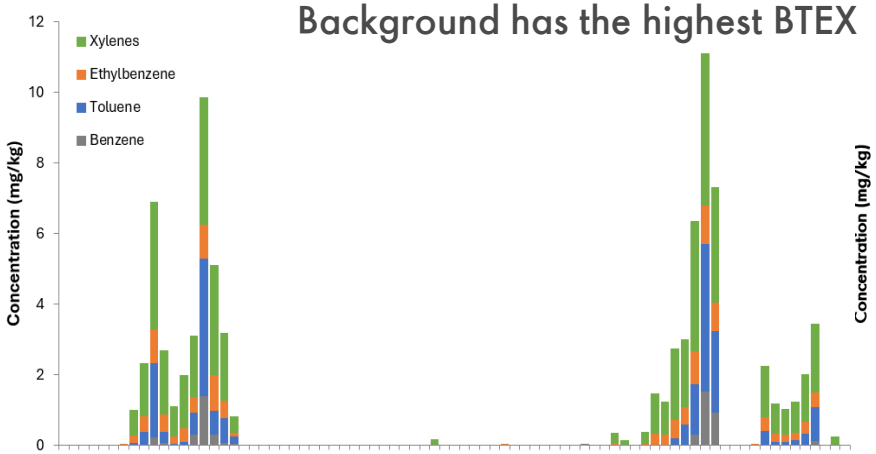
Rock-Eval and Thermal Maturity



Copyright of Shell International B.V.

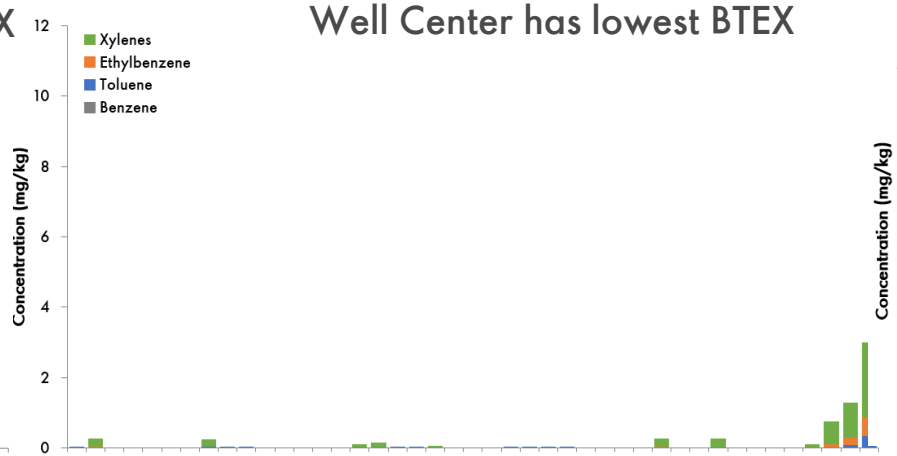
BTEX Distribution is Not Focused on Site Infrastructure – Well Site A

Background has the highest BTEX

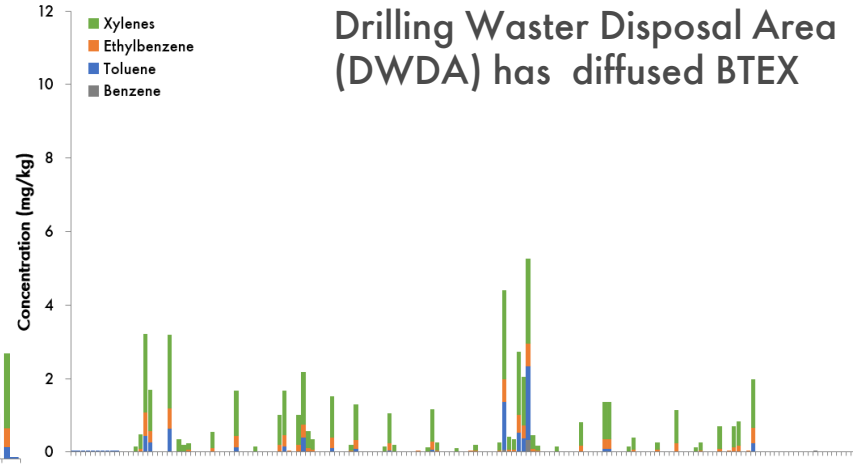


Each bar represents individual well bore concentration

Well Center has lowest BTEX

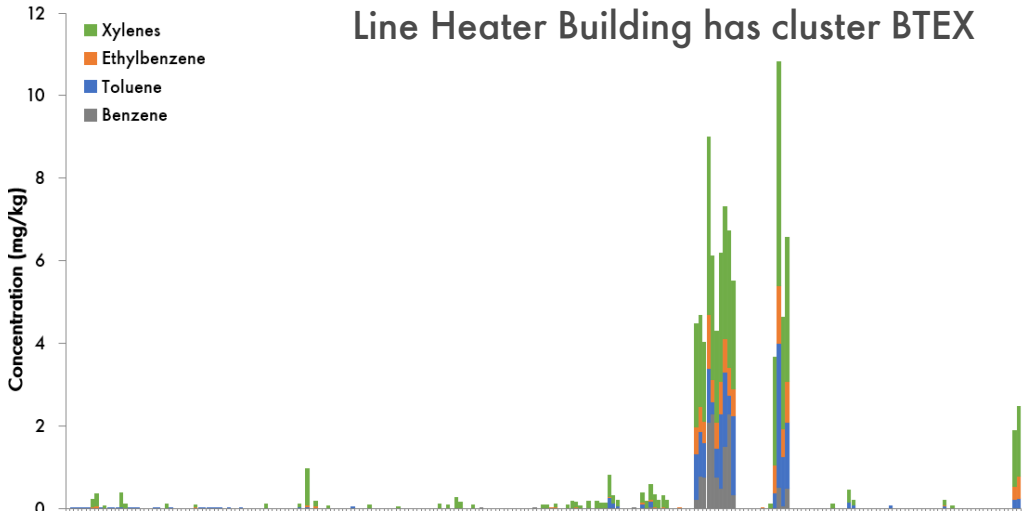


Drilling Waster Disposal Area (DWDA) has diffused BTEX

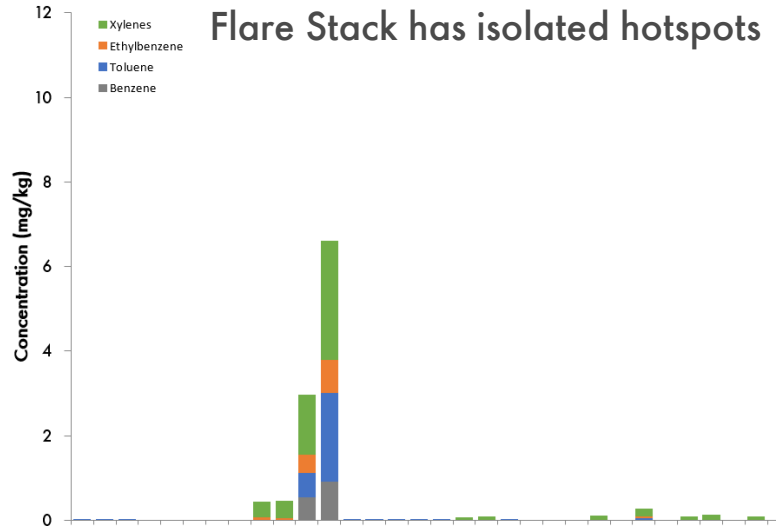


- Xylene dominates BTEX profiles across all site areas.
- Highest BTEX concentrations occur background locations rather than at operational infrastructure.
- No consistent source-centered BTEX gradient.
- Localized hotspots occur near some facilities, but regional distribution patterns indicate a substantial naturally occurring hydrocarbon contribution.
- **BTEX concentrations alone are insufficient for source attribution and must be evaluated alongside geology, PHC fractions, PAHs, and biomarkers.**

Line Heater Building has cluster BTEX



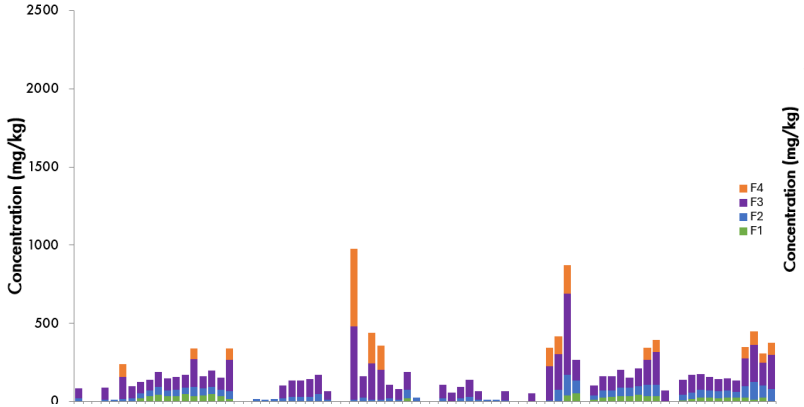
Flare Stack has isolated hotspots



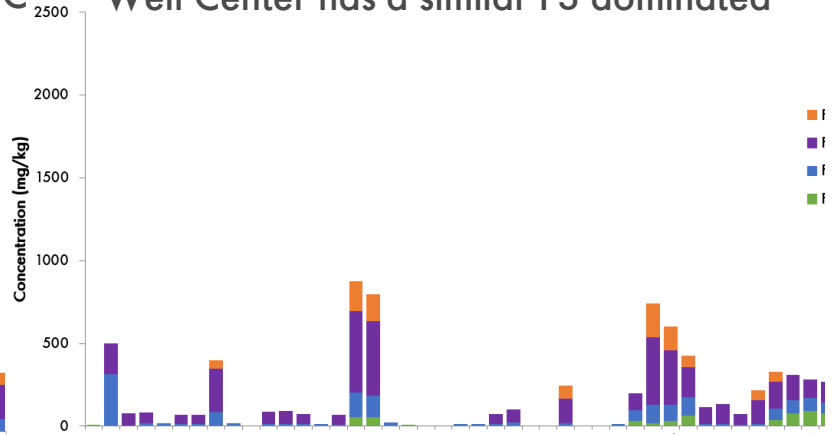
Key message: BTEX distribution indicates substantial regional contribution and does not define a single infrastructure-centered release

Consistent F1-F4 Profiles Suggest a Common Mature Hydrocarbon Source – Well Site A

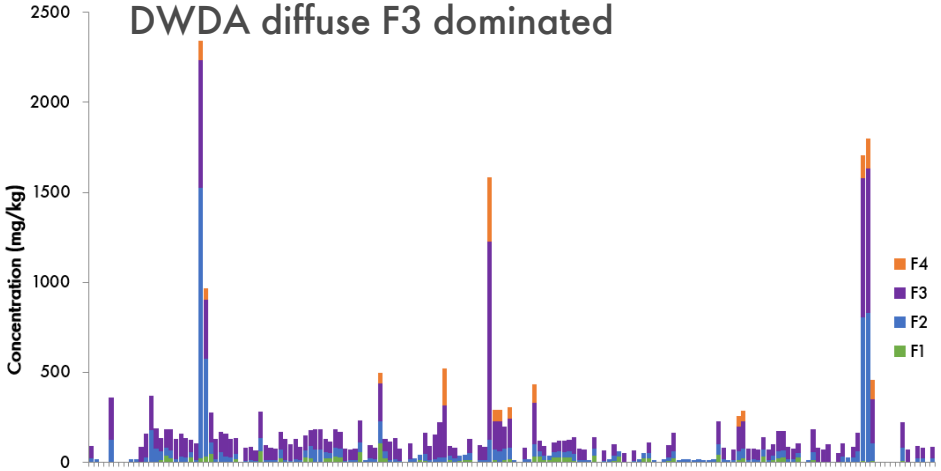
Site background broadly dominated F3 PHC



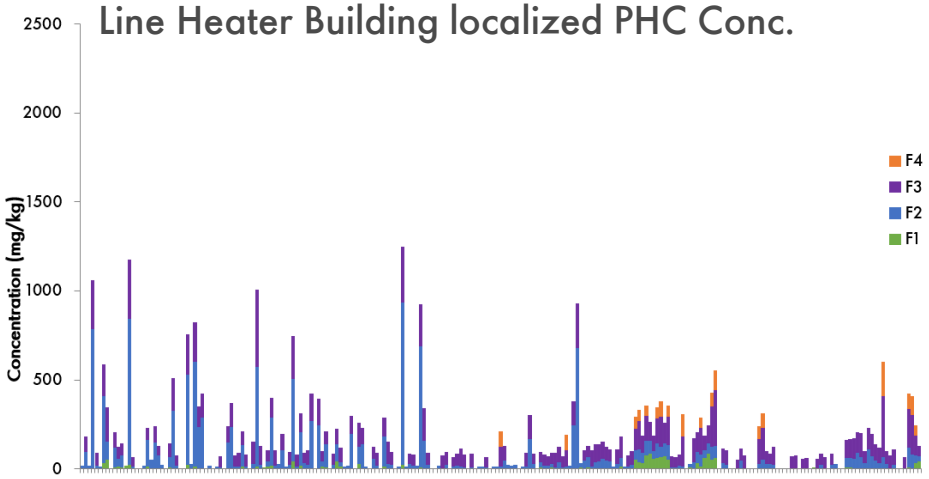
Well Center has a similar F3 dominated



DWDA diffuse F3 dominated



Line Heater Building localized PHC Conc.



Flare Stack localized hotspots

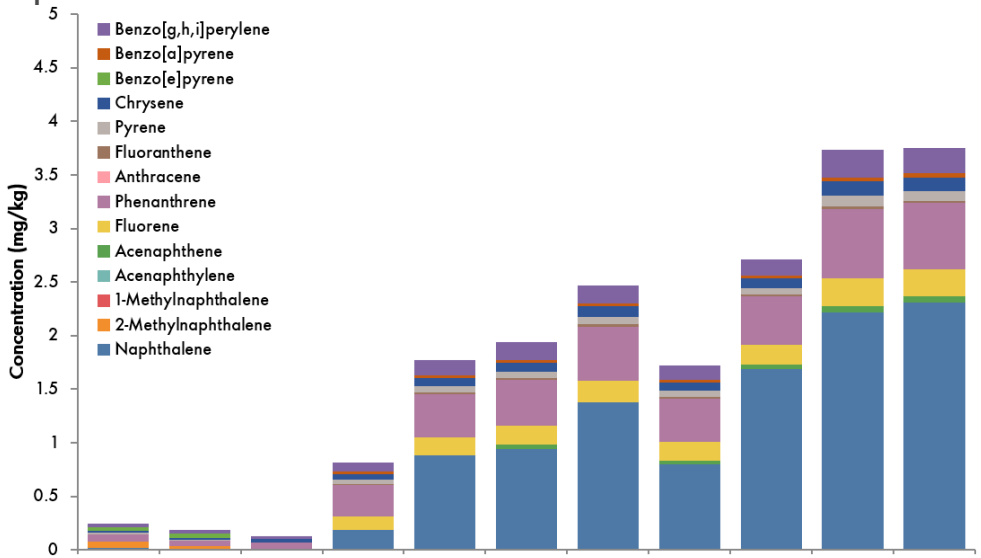


- PHC distributions are consistently F3-dominated across background and operational areas.
- Lighter hydrocarbon fractions (F1-F2) are minor and show no systematic enrichment at operational locations.
- **Concentration varies between locations, but hydrocarbon composition remains broadly similar.**

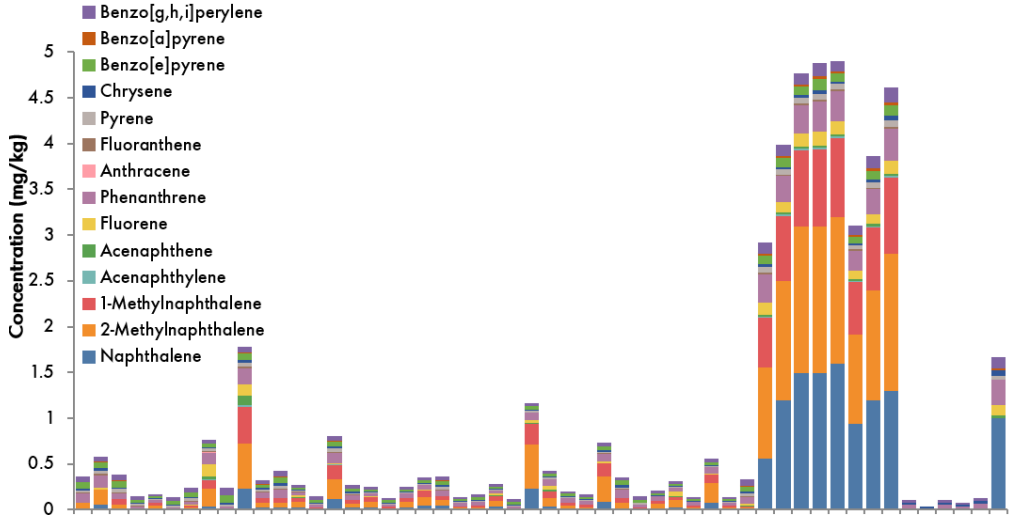
Key message: Hydrocarbon concentration varies, but the F3-dominated composition remains broadly consistent.

PAH Composition Suggests a Common Petrogenic Hydrocarbon Source – Wellsite A

Background PAHs are dominated by naphthalene and phenanthrene



Line Heater Building PAH has locally higher PAH, but compositional profile remains comparable



Dominant PAH Species

Naphthalene, 1-Methylnaphthalene, 2-Methylnaphthalene, and Phenanthrene

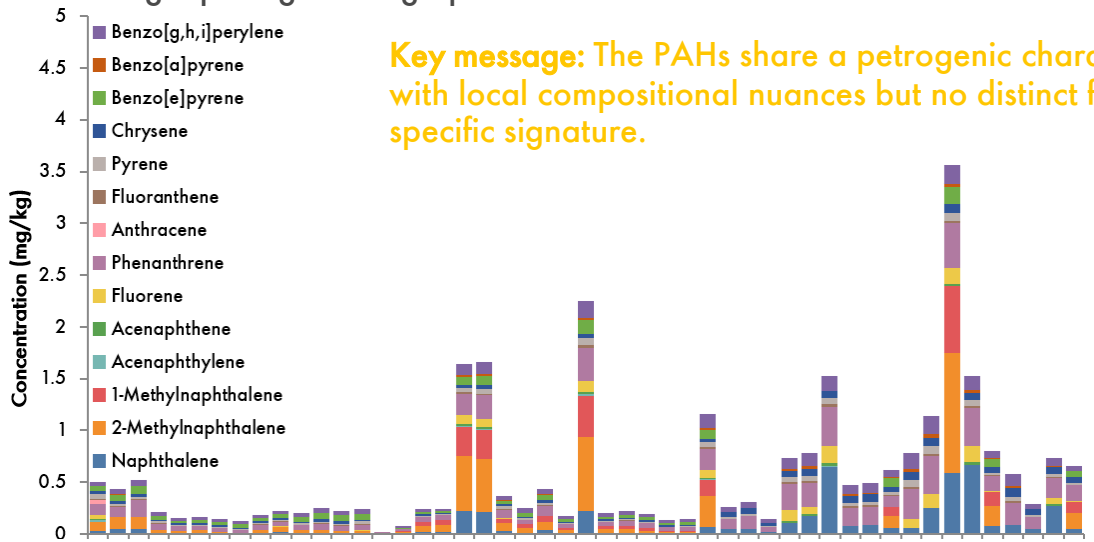
Hydrocarbon Character

- **Low-molecular-weight PAHs dominate, Alkylated PAHs exceed parent PAHs, and similar relative distributions occur across areas.**

Source Signature

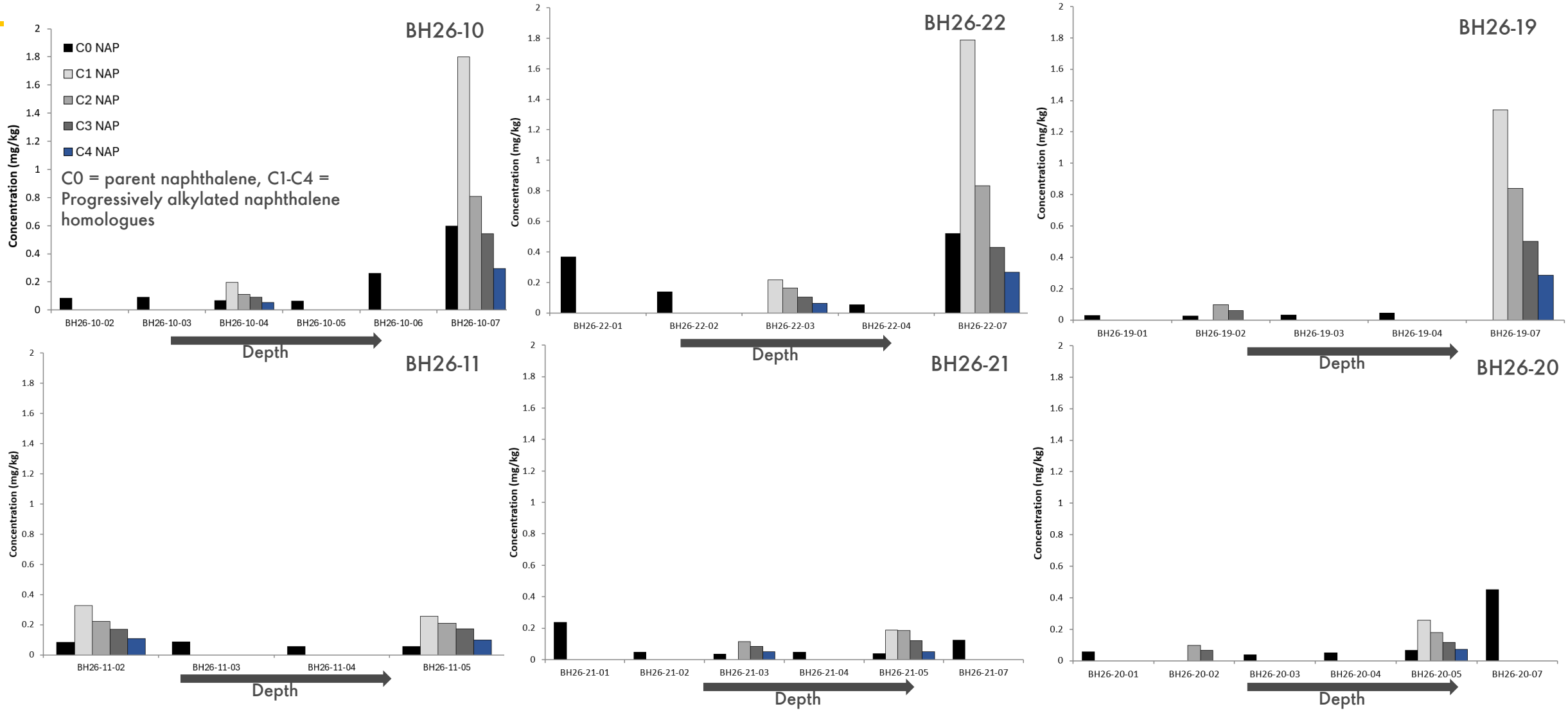
- **No enrichment of high-molecular-weight pyrogenic PAHs.**
- **No distinct flare-related or facility-specific PAH signature.**
- **Differences between areas are driven primarily by concentration rather than composition**
- Differences in alkylated naphthalene abundance due to varying degrees of hydrocarbon concentration, preservation, and weathering

Flare Stack Localized PAH enrichment exhibits the same low-molecular-weight petrogenic fingerprint



Key message: The PAHs share a petrogenic character, with local compositional nuances but no distinct facility-specific signature.

Alkylated Naphthalenes Support Petrogenic Hydrocarbon Signatures



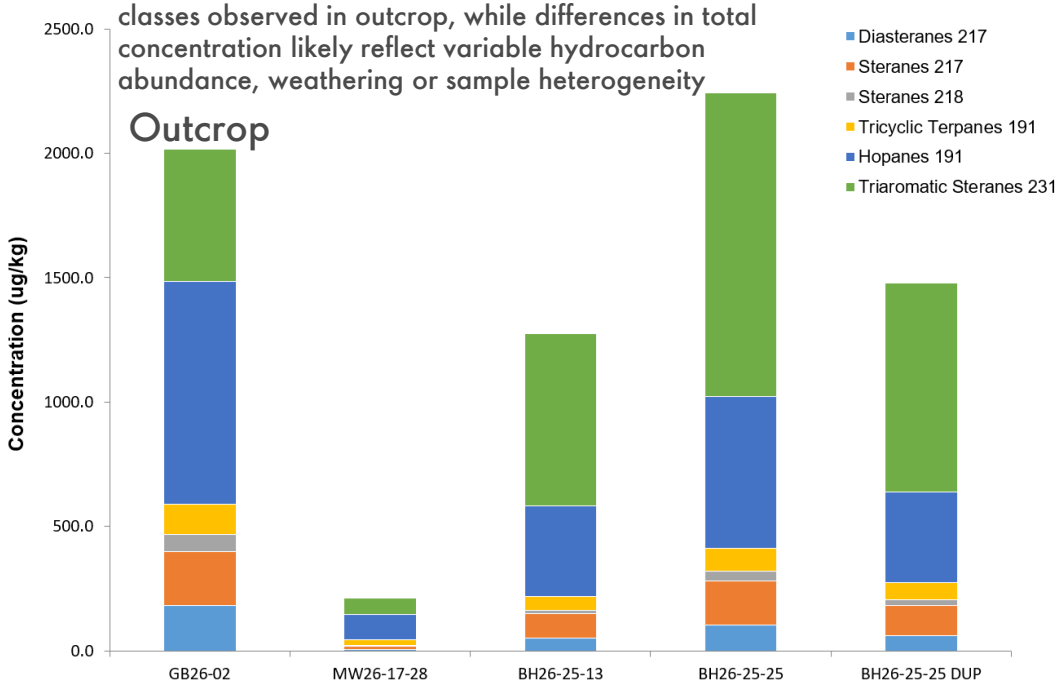
- C1-C4 alkylated naphthalene increase in selected deeper intervals, stronger petroleum influence with depth
- Repeated C1-C2 dominated alkylated naphthalene distributions across multiple boreholes provide independent geochemical evidence for thermally mature petrogenic hydrocarbon
- **Bell-shaped C0–C4 profiles are characteristic of petroleum-derived hydrocarbons and indicate increasing petroleum contribution in deeper intervals**

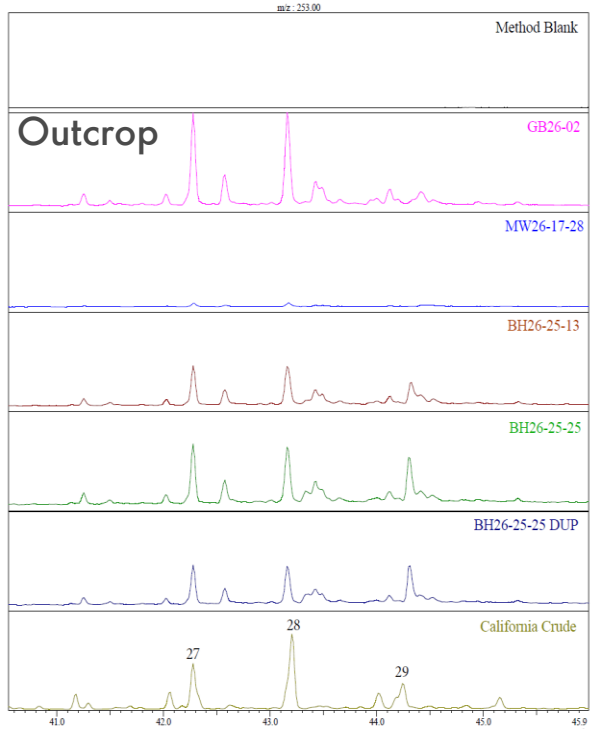
Key message: Increasing C1-C4 alkylated naphthalene abundance with depth is consistent with proximity to hydrocarbon-bearing bedrock, reduced weathering, and stronger expression of thermally mature petroleum hydrocarbons

Copyright of Shell International B.V.

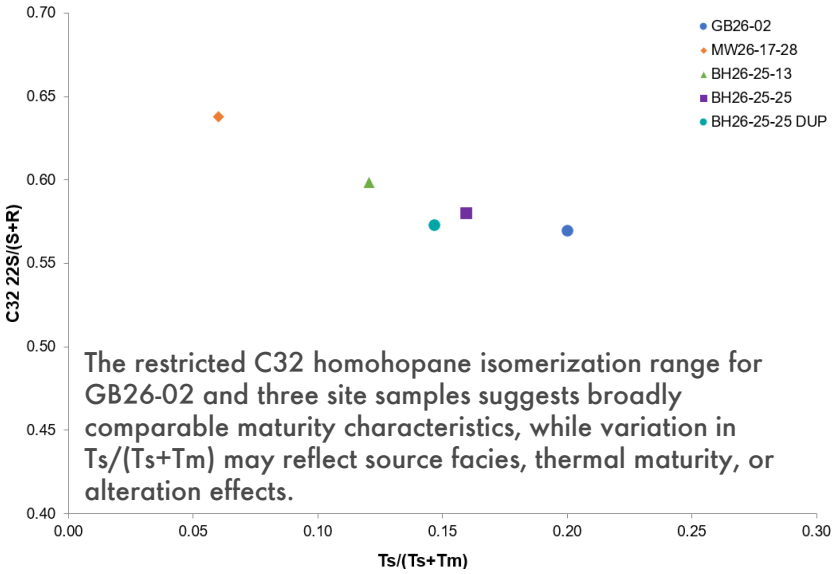
Site Samples Show Variable but Recurring Biomarker Similarity to the GB26-02 Outcrop

Site samples contain the same broad biomarker classes observed in outcrop, while differences in total concentration likely reflect variable hydrocarbon abundance, weathering or sample heterogeneity



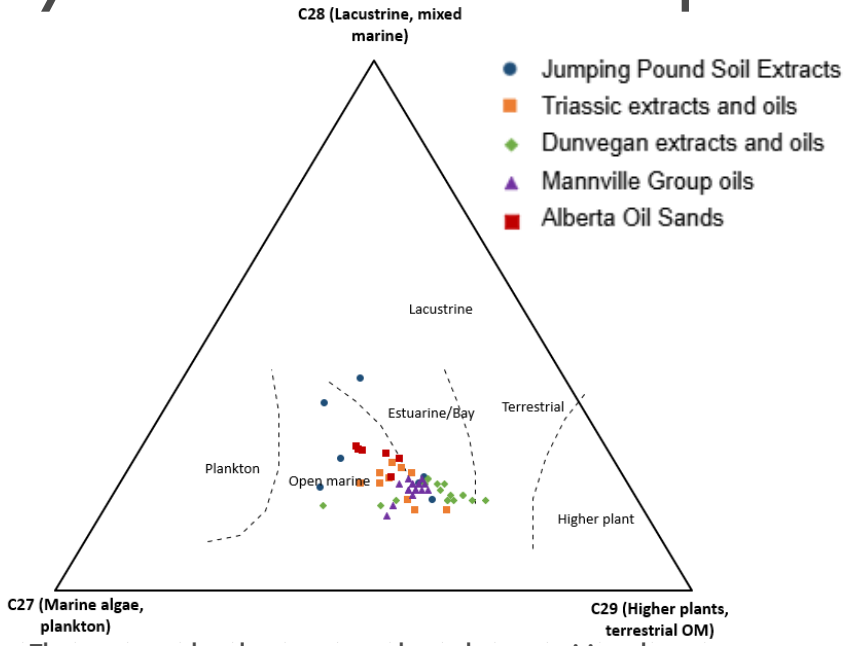


Extracted Ion Chromatogram (EIC) of m/z 253 for samples showing the major monoaromatic sterane compounds present in the soil extracts. **Recurring sterane peaks at comparable retention times support compositional similarity between outcrop and higher-signal site samples.**



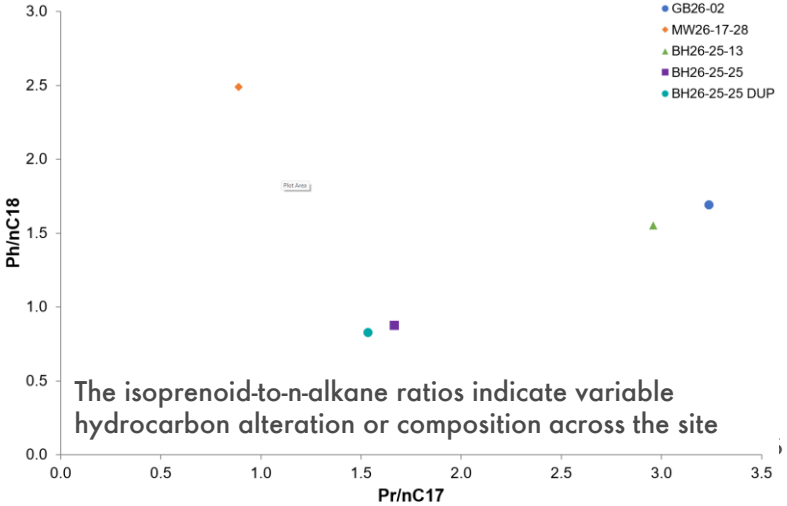
The restricted C32 homohopane isomerization range for GB26-02 and three site samples suggests broadly comparable maturity characteristics, while variation in Ts/(Ts+Tm) may reflect source facies, thermal maturity, or alteration effects.

Key message: Overlapping biomarker patterns support a geological connection between the site hydrocarbons and the GB26-02 outcrop



The ternary plot demonstrates broad compositional compatibility, rather than a unique source match, between the site samples, GB26-02, and several Alberta hydrocarbon dataset

Alberta petroleum system data from Riediger et al (1990) CSPG Bull v.38A; Snowdon et al, (1998) CSPG Bull v 46; Riediger et al (1999) CSPG Bull 47; Yang et al. (2011) Env Forensics v. 12



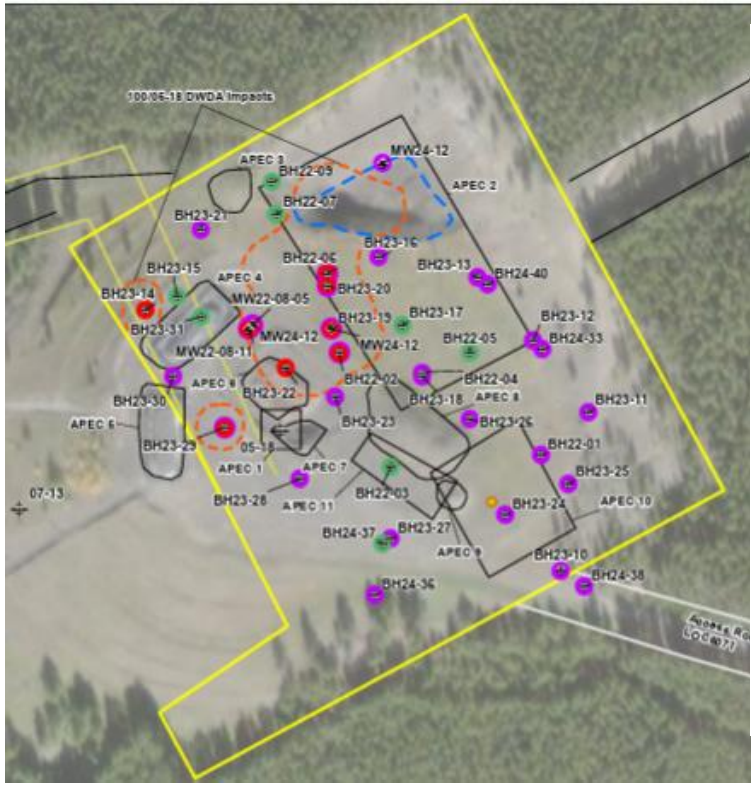
The isoprenoid-to-n-alkane ratios indicate variable hydrocarbon alteration or composition across the site

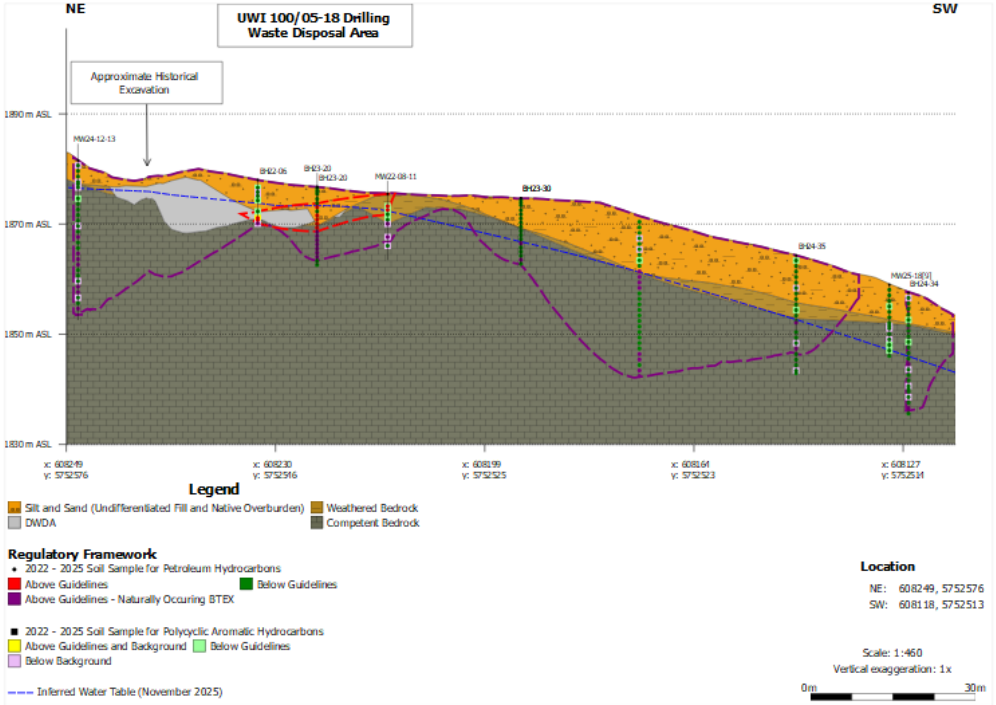
0.4

Conclusions

Copyright of Shell International B.V.

Example Site - Documenting NOH Avoid Unnecessary Remediation





Site-specific delineation separated naturally occurring hydrocarbon exceedances from impacts requiring corrective action

- Not every guideline exceedance represent a remediable site impact.
- NOH delineation potentially support leaving ~91,000 m³ of soil in place.

~91,000 m³ of NOH-affected soil excluded from remediation, equivalent to ~7,500 truckloads that would not require excavation, transport, treatment or disposal

Purple: NOH exceedances left in place
Orange outline: targeted remediation footprint
Outcome: reduced excavation, cost, and liability

Key message: Defensible attribution converted technical evidence into a smaller and more sustainable remediation footprint.

Conclusions

Naturally occurring hydrocarbons are present in Alberta Foothills surficial strata and bedrock

- Numerous undisturbed background locations, outcrops, surficial strata, and bedrock samples contain detectable BTEX, F1-F4 hydrocarbons, and PAHs independent of well-site operational impacts

Geological evidence supports a natural hydrocarbon source

- Regional and site-specific Vitrinite Reflectance, Rock-Eval data, and Foothills geological history indicate organic-rich strata achieved oil-window to gas-generation maturity prior to uplift and erosion

Hydrocarbon forensics can differentiate source origin

- Integration of spatial distribution, geological setting, GC-FID chromatographic patterns, PAH distributions, UCM characteristics, biomarker signatures provides a defensible framework for distinguishing naturally occurring hydrocarbons from gasoline, diesel, lubricants, and other anthropogenic releases

No single line of evidence is sufficient

- Defensible attribution requires a comprehensive conceptual site model (CSM) supported by multiple independent lines of geological, spatial, and analytical evidence.

Source attribution directly influences remediation outcomes

- Recognition of naturally occurring hydrocarbons can improve remedial targeting, reduce unnecessary excavation, optimize soil management, support risk-based decision making, facilitate regulatory closure discussions when accepted within the applicable regulatory framework

Key message: Multiple independent lines of evidence support targeted remediation and defensible closure.

Key Takeaways

- NOHs occur naturally across the Foothills geological setting.
- Regional geology provides a plausible hydrocarbon source and migration mechanism.
- Geochemical fingerprinting can differentiate natural and anthropogenic hydrocarbons.
- Sound source attribution requires multiple lines of evidence.
- Better attribution leads to better closure decisions.

Copyright of Shell International B.V.

Q&A

Copyright of Shell International B.V.

