



A Preliminary Report to the U.S. Coast Guard, Part 2

Petroleum Hydrocarbons in Sediment from the Northern Gulf of Mexico Shoreline, Texas to Florida

By Robert J. Rosenbauer, Pamela L. Campbell, Angela Lam, Thomas D. Lorenson, Frances D. Hostettler, Burt Thomas, and Florence L. Wong



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Cover: A beach just south of Tampa, Fla. before a coming storm, photograph by Tom
Lorenson

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Abstract

Petroleum hydrocarbons were extracted and analyzed from shoreline sediment collected from the northern Gulf of Mexico (nGOM) coastline that could potentially be impacted by Macondo-1 (M-1) well oil. Sediment was collected before M-1 well oil made significant local landfall and analyzed for baseline conditions by a suite of diagnostic petroleum biomarkers. Oil residue in trace quantities was detected in 45 of 69 samples. With the aid of multivariate statistical analysis, three different oil groups, based on biomarker similarity, were identified that were distributed geographically along the nGOM from Texas to Florida. None of the sediment hydrocarbon extracts correlated with the M-1 well oil extract, however, the similarity of tarballs collected at one site (FL-18) with the M-1 well oil suggests that some oil from the Deepwater Horizon spill may have been transported to this site in the Florida Keys, perhaps by a loop current, before that site was sampled.

Introduction

From April 20 through July 15, 2010, an estimated 4.93 million barrels (1 barrel = 42 gallons) of crude oil spilled into the northern Gulf of Mexico (nGOM) from the ruptured British Petroleum (BP) Macondo-1 (M-1) well located in the Mississippi Canyon lease block 252 (Operational Science Advisory Team, 2010). This event, resulting from the explosion of the Deepwater Horizon drilling rig, exceeds the previous largest spill in U.S. waters of as much as 750,000 barrels of crude oil from the Exxon Valdez in Prince William Sound in 1989 (Bence and others, 1996; Wolfe and others, 1994). In addition, 1.84 million gallons of Corexit™ dispersants were applied to the oil both on and below the sea surface (British Petroleum, 2010). By April 30, estimates placed the total spread of the oil at 3,850 square miles (10,000 km²) (National Oceanic and Atmospheric Administration, 2010; fig. 1), and it reportedly first made landfall at Santa Rosa Island in the Gulf Islands National Seashore on June 1, 2010 (National Park Service, 2010). Spilled oil from this event poses a potential threat to sensitive habitat along the shores of the nGOM. In response, the U.S. Geological Survey (USGS) collected near-surface beach and coastal sediment from 70 sites along the shores of the nGOM from Texas to Florida before estimated local landfall of oil. These sites included priority areas of the nGOM, such as coastal wetlands and Department of Interior (DOI) wetlands, shorelines, and barrier islands at highest risk for oil contamination that could suffer severe environmental damage if a significant amount of oil came ashore. The purpose of this effort was to document conditions before oil made landfall at a given site and to characterize petroleum hydrocarbons that reside in coastal sediment samples before the M-1 oil spill could have any potential impact.

This report complements activities of other USGS scientists and USGS production and research laboratories that are analyzing aliquots of the same samples for volatile organic compounds and other hydrocarbons, oil and grease, trace metals, Corexit™ surfactants, total and dissolved organic carbon characterization, bacterial populations capable of degrading oils, nutrients such as nitrogen and phosphorus compounds related to oil releases, toxicity of pore water, and benthic macroinvertebrate indicators of shoreline habitat condition. Results from this effort will be compared to similar analyses of the postimpact samples (Rosenbauer and others, 2010) collected from the same sites and reported in a companion report.

Methods

Sampling

Preimpact samples of coastal sediment were obtained from 70 sites distributed in Texas, Louisiana, Mississippi, Alabama, and Florida that could potentially be affected by the 2010 Deepwater Horizon oil spill in the Gulf of Mexico. A separate tarball sample was isolated from sediment at one site (FL-18). Samples were collected from May through early July 2010 from coastal sediments at depths of 4–5 inches. The sample designation “preimpact” is not intended to imply a conclusion about the samples based upon analyses. The sampling effort extended over a time period of several weeks, so samples designated preimpact in one location may have been collected after oil made landfall in other parts of the gulf. For comparison, an aliquot of the Macondo-1 well oil from a previous study (Rosenbauer and others, 2010) was provided by B & B Laboratory, College Station, Texas. The well oil was obtained by BP from the riser insertion tube aboard the drillship Discoverer Enterprise on May 21, 2010, and was absent of any defoamer or dispersant. All samples were collected, processed, and shipped under standard chain-of-custody protocols according to methods listed in the USGS National Field Manual for the Collection of Water-Quality Data (NFM) (<http://pubs.water.usgs.gov/twri9A/>) as well as other USGS standard operation procedures (Wilde and others, 2010). This standardized and documented set of protocols encompassing the entire data-collection process ensured the integrity, consistency, and comparability of the data from site to site and within sites.

Analytical

All samples were extracted and processed in the USGS Pacific Coastal Marine Science Center (PCMSC) organic geochemistry laboratory located in Menlo Park, California. Samples were kept frozen in their glass jars, then thawed in the same containers before extraction. Sediment from one site, LA-36, was not analyzed because of container breakage during transit (table 1). Following homogenization of the sediment sample, ~ 100 g of wet sediment was weighed directly into a 300-mL stoppered flask. Two hundred mL of dichloromethane (DCM) and 40 g of NaSO₄ were added to each flask, which was then placed in a sonicating water bath for 90 minutes at 30°C (after Bekins and others, 2005; Hostettler and others, 2007). The extract was then filtered through a champagne funnel lined with glass wool and containing 30 g NaSO₄ into turbo-vap vessels. An additional 100 mL of DCM was added to the previously extracted sediment, and the sample was again sonicated for 60 minutes at 30°C. The extracts were

combined in the turbo-vap vessels, evaporated with N₂ to near dryness, and transferred to 10-mL KD tubes and adjusted 5 mL with hexane. For the tarball sample, ~30 mg were dissolved in DCM, filtered through glass wool to remove particulates, air-dried to remove the DCM, then taken up in 5 mL of hexane. Both sediment and tarball extracts were then loaded onto liquid chromatography columns for compound class separation. Each column was layered with 2.5 g of 5-percent deactivated neutral alumina and 2.5 g and 5.0 g of 62 and 923 silica gels, respectively.

Two separate fractions were collected—saturate (hexane eluent) and aromatic (30-percent DCM eluent). The saturate and aromatic fractions, evaporated to 0.5 mL, were analyzed by gas chromatography/mass spectrometry (GC/MS). The gas chromatograph was first maintained at 90°C for 2.0 minutes and then programmed at a 5°C/min ramp to 310°C. The capillary column (DB-5MS: 30 m, 0.25 mm I.D. containing a 0.25- μ m bonded phase) was directly interfaced to the ion source of the mass spectrometer. A separate analysis was carried out with the GC/MS in the single-ion monitoring mode (SIM). Compound identifications were made either by comparison with known standards or with published reference spectra. Selected biomarker ratios (appendix 1) were calculated from GC/MS/SIM chromatograms of *m/z* 191 (terpanes/hopanes) and 217 (steranes) using peak heights. Other ratios are generally calculated from the chromatograms of the aromatic fraction using appropriate extracted ion (EI) values, but because of the low aromatic content in preimpact sediment, this fraction was archived. Either summed areas or peak heights of the compounds identified in the GC/MS/SIM chromatograms were used to determine parameter ratios. Biomarker values were used to correlate the samples and group them according to their probable sources (Peters and others, 2008; Lorenson and others, 2009). Laboratory ID numbers were cross-referenced to site locations (appendix 2).

Statistical Analysis

Statistical analysis (JMPTM software) of the data included hierarchical cluster analysis (HCA) and principal components analysis (PCA) to establish correlations among the oil residues. Oil-oil and oil-source rock correlations are based on the concept of similarity through heritage, where migrated oil collected from the environment has source-related compositional parameters (biomarkers) similar to the seeps or reservoirs and bitumen remaining in the effective source rock from which it was derived. Biomarkers are complex organic compounds that occur in petroleum, rocks, and sediments and show little change in structure from their parent organic molecules in living organisms; these have been used in oil and source rock correlations (Peters and others, 2005). The statistical chemometric analysis includes source-related biomarkers (appendix 1) that are not readily affected by migration, biodegradation, or thermal maturation and are key indicators of genetic relationships among oil and source rock bitumen samples (Peters and others, 2005).

Hierarchical clustering was carried out by both the Ward's minimum variance method and the K-means iterative alternating fitting process to group oil residues with similar characteristics. Principal components were calculated from the parameter list and displayed on a three-dimensional plot to discriminate between groups and detect outliers. The PCA also helps reduce the dimensionality of the dataset.

Results

Macondo-1 Well Oil

Although the focus of this study is on preimpact baseline conditions, knowledge of the biomarker composition of the M-1 well oil was important because (1) some M-1 oil had reportedly made landfall at Santa Rosa Island June 1, 2010 (National Park Service, 2010), within the timeframe of sample collection for this study and (2) although designated as preimpact samples, some may have been obtained after an unrecognized landfall of the M-1 well oil. We therefore compared the M-1 oil signature to hydrocarbons in potentially impacted shoreline sediments. A second determination of the biomarker composition of the M-1 well oil, made for this study, was consistent with previous results (Rosenbauer and others, 2010).

Rosenbauer and others (2010) identified a suite of 19 biomarker parameter ratios that defined a chemical signature (fingerprint) of the BP M-1 well oil. Such ratios are used to genetically relate oil and tar to their sources (Hostettler and others, 2004; Kvenvolden and others, 1995; Peters and others, 2008; Lorenson and others, 2009). Of these ratios, 12 were particularly diagnostic of the BP M-1 oil and could be determined in the preimpact sediment; these 12 ratios were used for statistical analyses in this study. Specifically excluded from this set of ratios were pristane and phytane, because there are confounding natural environmental inputs and losses in the oils caused by environmental degradation. Patterns from chromatograms of the tricyclic terpanes and hopanes in the 191 m/z traces and of the steranes in the 217 m/z traces obtained by the GC/MS in single-ion monitoring (SIM) mode showed several key visual relations for the M-1 well oil (fig. 2A, B). Particularly notable are the tricyclic terpanes that define the triplet, the C₂₄-tetracyclic terpane, and the C₂₆-tricyclic terpane (S and R epimers) that were uniformly equal (fig. 2A). Also of note is the prominence of the 18 α (H)-30-norneohopane (29D) relative to the 17 α ,21 β (H)-30-norhopane ($\alpha\beta$ 29) (fig. 2A). The prominence of the diasterane epimer pair ($\beta\alpha$ C27 diasterane, S & R) is also characteristic of this oil (fig. 2B).

Sediment

Total extractable organic matter was typically low in the preimpact sediment, ranging from less than 1 to 137 mg/kg and averaging 14.9 mg/kg, excluding one sample containing discrete tarballs that had an extractable weight of 1,830 mg/kg (table 1). The extractable organic content generally correlates with the presence of petroleum but often included some biogenic material and in some cases a water-soluble precipitate. Some samples with as little as 1 mg/kg extractable organic matter contained petroleum.

The identification of oil in the sediment samples was based on the presence of specific saturated hydrocarbons in the mass spectra of the sediment extracts. These are petroleum-related biomarkers, including the tricyclic terpanes, pentacyclic hopanes, and steranes (Peters and others, 2005; Wang and Fingas, 2003; Wang and others, 2006). In particular, we focused on the C₂₀ through C₂₉ tricyclics, C₃₀ hopane, C₂₉ nor-hopane, the homologous series of C₃₁ through C₃₅ homohopanes, and the C₂₇ through C₂₉ steranes. The polycyclic aromatic hydrocarbons (PAHs) were too low in abundance to be useful for any diagnostic purpose.

The extracted hydrocarbon composition of sediment ranged from below detection, containing only biogenic material, to oil or possibly a mixture of oils. There was no clear evidence of oil residue at 24 of the sites (35 percent). The remaining 45 sites contained at least some trace amount of oil residue, and many samples (16 of 26 in Florida, 5 of 10 in Alabama, 12 of 13 in Louisiana, 2 of 9 in Mississippi, and 10 of 11 in Texas) had distinct oil signatures. This oil likely represents inputs from either natural oil seepage, which can be prevalent in some areas of the nGOM (Sassen and others, 2001), or from other previous oil spills. One sample from Coco Plum Beach on the Florida Panhandle contained cubic-centimeter-size tarballs throughout. Coco Plum Beach is in the path of a loop current in the Straits of Florida where tarballs commonly occur (Van Vleet and others, 1984). Biodegradation ranking of the extracted oil ranged from 4 to 5, which is considered moderate (Peters and Moldowan, 1993) and allows for robust comparison with M-1 oil.

Except at the tarball site (FL-18), all the GC/MS spectra obtained from the solvent extracts of the preimpact shoreline sediment were distinct from the reference BP M-1 well oil (fig. 2). For example, the Ts/Tm ratio is lower, the $\alpha\beta\text{C}29/\alpha\beta\text{C}30$ ratio is higher (fig 2C), and the $\beta\alpha 27\text{D}/\alpha\alpha\text{C}29$ ratio is lower (fig. 2D) in sediment from site TX-48 than in the BP M-1 well oil. Terpanes and hopanes extracted from the tarball at site FL-18 were remarkably similar to the M-1 well oil (fig. 2A, E), but the sterane profiles were somewhat different (fig. 2B, F). Where the presence of oil residues was detected, a total of 17 individual biomarker parameters were calculated for each sediment sample using the saturate fraction (appendix 2). Biomarker parameters are listed in appendix 1, along with references to their use and other characteristics such as age, thermal maturity, depositional environment, degree of biodegradation, and general nature.

Statistical Results

Differences in the mass spectra of the sediment extracts suggest that some oils have different sources. Because of the variety of geological conditions and ages under which oil was formed, every crude oil exhibits a unique biomarker fingerprint. Often these differences are subtle and a statistical approach is required to separate oils into distinct groups with different sources (Lorenson and others, 2009). Hence we carried out a multivariate statistical analysis of the biomarker ratios obtained from the sediment extracts, using HCA and PCA.

Twelve biomarker parameters common to the preimpact sediment were used in the statistical analysis (appendix 3). Eight samples were excluded because of the absence of several of these 12 parameters. An additional four samples lacked a complete set of 12 parameters, but in these cases an average of the missing parameter was used, a technique used in other chemometric biomarker analyses (Peters and others, 2008). Data previously acquired for the M-1 well oil (Rosenbauer and others (2010) were also included in the statistical analysis.

Results of the HCA show three clusters of similar size (fig. 3) and three outliers. Each cluster defines a group of samples with a distinct combination of characteristic biomarkers (fig 4). Groups 1 (red) and 4 (orange) are distinguished by the lowest values for Ts/Tm and 29D/29H and the highest values for 35S/34S (table 2). Group 1 has the highest values for C29/C30 and C31S/C30 (table 2). Groups 1 and 4 were generally similar but differ by a factor of ~2 in average values of 26Tri/25Tri and C27DS/C29R

(table 2). Groups 1 and 2 (green) differ significantly in most parameters. Groups 2 and 4 differ especially in values for the triplet, C27DS/C29R, and C28R/C29R (table 2).

One outlier from these three groups, TX-50, plots close to group 2 but has a lower value for the triplet and an unusually high value for the C28R/C29R. The other outliers are the tarball from site FL-18 and the M-1 well oil. Statistically, with the limited parameter list, the tarball and the M-1 well oil are grouped together but differ somewhat in their sterane profiles (fig. 2F).

The results of the PCA depicted in a 3-D plot show the three clusters of genetically related oil residues in preimpact sediment (fig. 5). The first, second, and third principal components are the x, y, and z axes, respectively. Three and six principal components explain 60 and 82 percent of the total variance, respectively. Regions encircled and labeled G1, G2, and G4 correlate with groups 1, 2, and 4 determined by HCA. The two closely spaced blue crosses are analyses of the sediment and tarball from FL-18, and the isolated blue cross is the M-1 well oil.

The groups defined by the statistical analysis do not group geographically, but are found scattered along the entire nGOM coast from Texas to Florida (fig. 6). This widespread distribution of disparate oil types implies input from distant offshore seepage rather than from local seeps or spills as the probable petroleum sources. Geochemical analyses of surface seeps, produced oils, and gases suggest that the source rocks for GOM oils are Mesozoic and Tertiary (for example, Walters and Cassa, 1985). Walters and Cassa (1985) have shown that the ratio of tricyclic diterpanes to the sum of sesterterpane and triterpane tricyclics is a sensitive indicator of offshore Gulf Coast oils. Sofer (1988) used tricyclic terpanes, stable carbon isotopes of saturates, and aromatics to classify groups of Gulf Coast oils showing a wide range of thermal maturity. Genetically distinct oil groups correlate with differing source maturity and in many places overlap (Hood and others, 2002; Guzman-Vega and others, 2002).

None of the sediment extracts correlate with the M-1 well oil, but the similarity of the tarball collected at site FL-18 with the M-1 well oil brings up the possibility that some oil from the Deepwater Horizon spill entered a loop current and was transported to the Florida Keys before that tarball sample was collected. Sediment from site FL-18 was collected on May 24, 6 days after the National Oceanic and Atmospheric Administration (NOAA) reported that a small tendrill of M-1 well oil had entered the loop current on May 18 (Lubchenco, 2010). Additional analyses are underway to better compare tarballs intermixed with sediment collected at this site with the M-1 well oil and with other tarballs that are known to accumulate in this area (Van Vleet and others, 1984).

Conclusions

Sediment samples were collected at 69 sites along the northern Gulf of Mexico (nGOM) coastline that could potentially be impacted by Macondo-1 (M-1) well oil, and these samples were analyzed for petroleum hydrocarbons. Oil residue in trace quantities was detected in 45 of 69 samples. With the aid of multivariate statistical analysis, three different oil groups were identified that were dispersed geographically along the nGOM from Texas to Florida. None of the sediment extracts correlated with the M-1 well oil, but the similarity of tarballs collected at site FL-18 to the M-1 well oil is consistent with the possibility that some oil from the Deepwater Horizon spill entered a loop current and was transported to the Florida Keys before the sampling for this study. Further studies of

sediment both onshore and offshore are warranted to place these results into a larger context for the entire nGOM. Additional work is also required to determine the source of other oils found in this study, such as possible correlations with oils in the extensive database of petroleum biomarkers maintained by GeoMark Research LTD.

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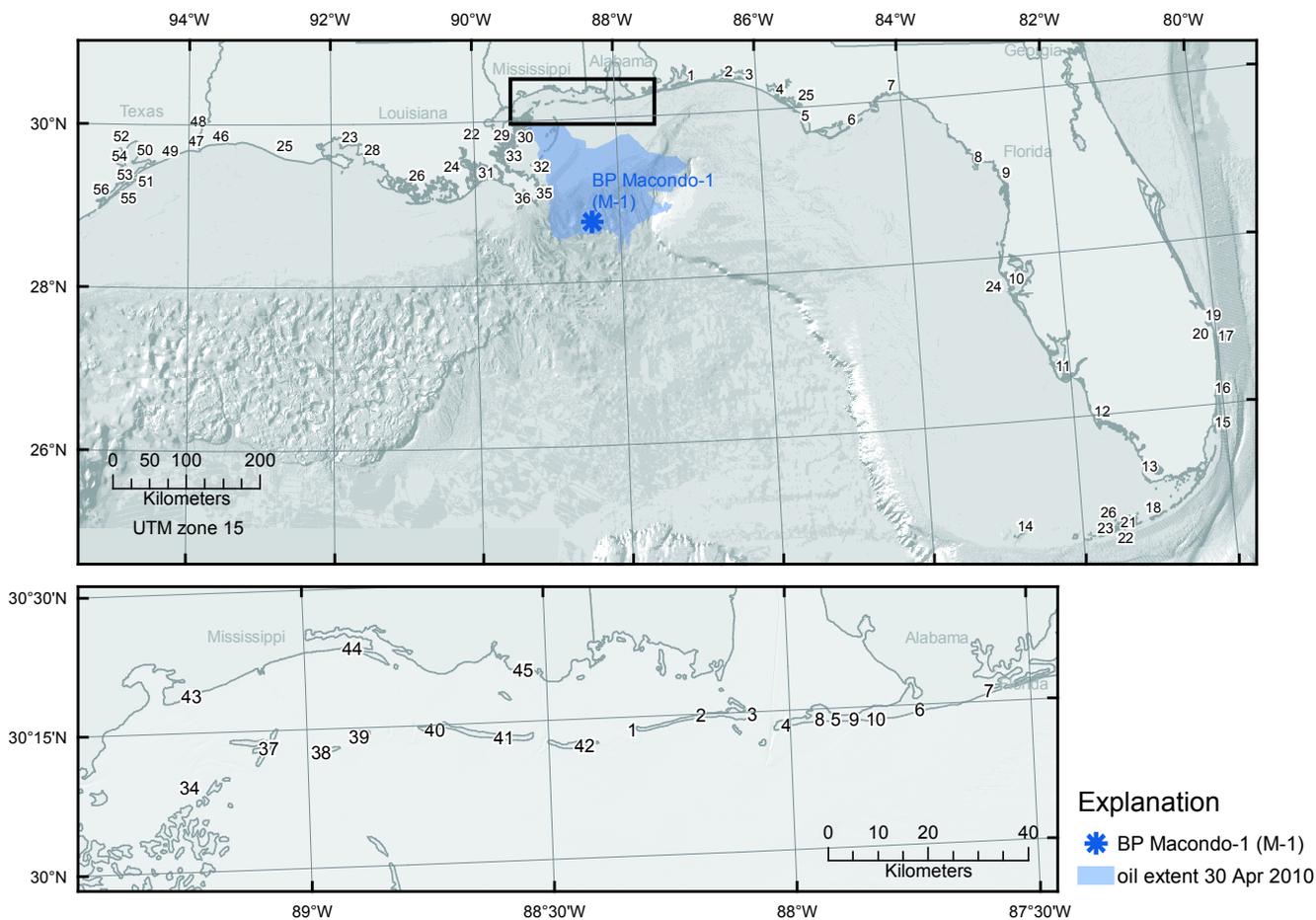


Figure 1. Location map of sediment samples collected for this study. The blue shading depicts the cumulative areal coverage of the BP M-1 well oil spill as of April 30, 2010, derived from wind, ocean currents, aerial photography, and satellite imagery (National Oceanic and Atmospheric Administration, 2010). Sample designations are abbreviated for clarity in location; complete sample numbers are listed in the tables and are prefaced by the two-letter state abbreviation. The location of the Macondo-1 well is also indicated.

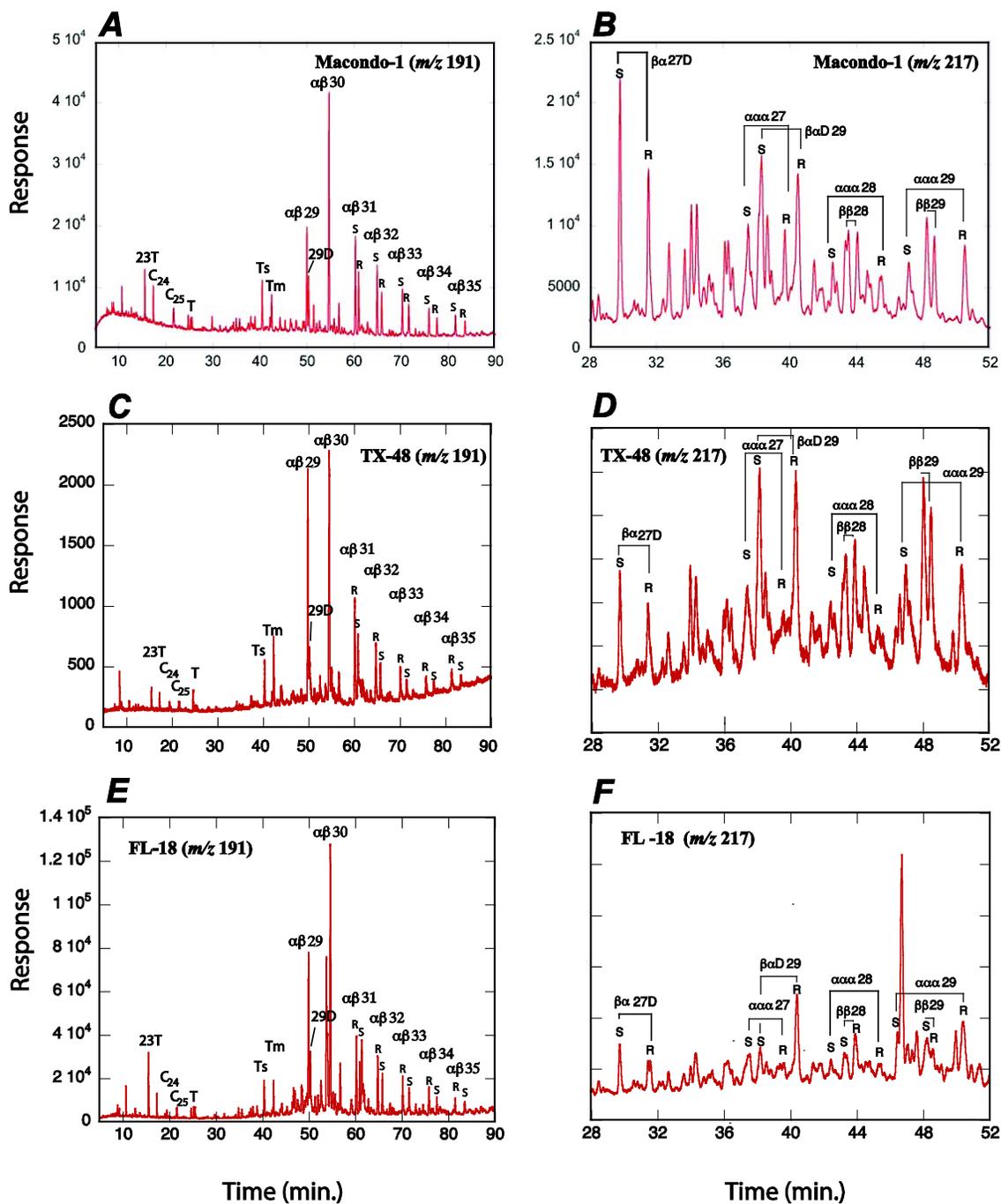


Figure 2. Chromatograms of M-1 well oil (reproduced from Rosenbauer and others, 2010) and sediment extracts (TX-48; FL-18). Selected ion monitoring (SIM) chromatograms of m/z 191, Hopanes (A, C, E), and m/z 217, Steranes (B, D, F).

Compounds identified in appendix 1. Legend : Steranes, C27 to C29 regular steranes; Hopanes, C29 to C35 regular hopanes; 23T, C20 through C26, tricyclic terpanes; T, triplet, Ts and Tm, defined in appendix 1; $\alpha\beta$ 29, $\alpha\beta$ 30, $\alpha\beta$ 31 through $\alpha\beta$ 35 (S & R epimers), $\alpha\beta$ -hopanes with carbon numbers.

Hierarchical Clustering

Method = Ward

Dendrogram

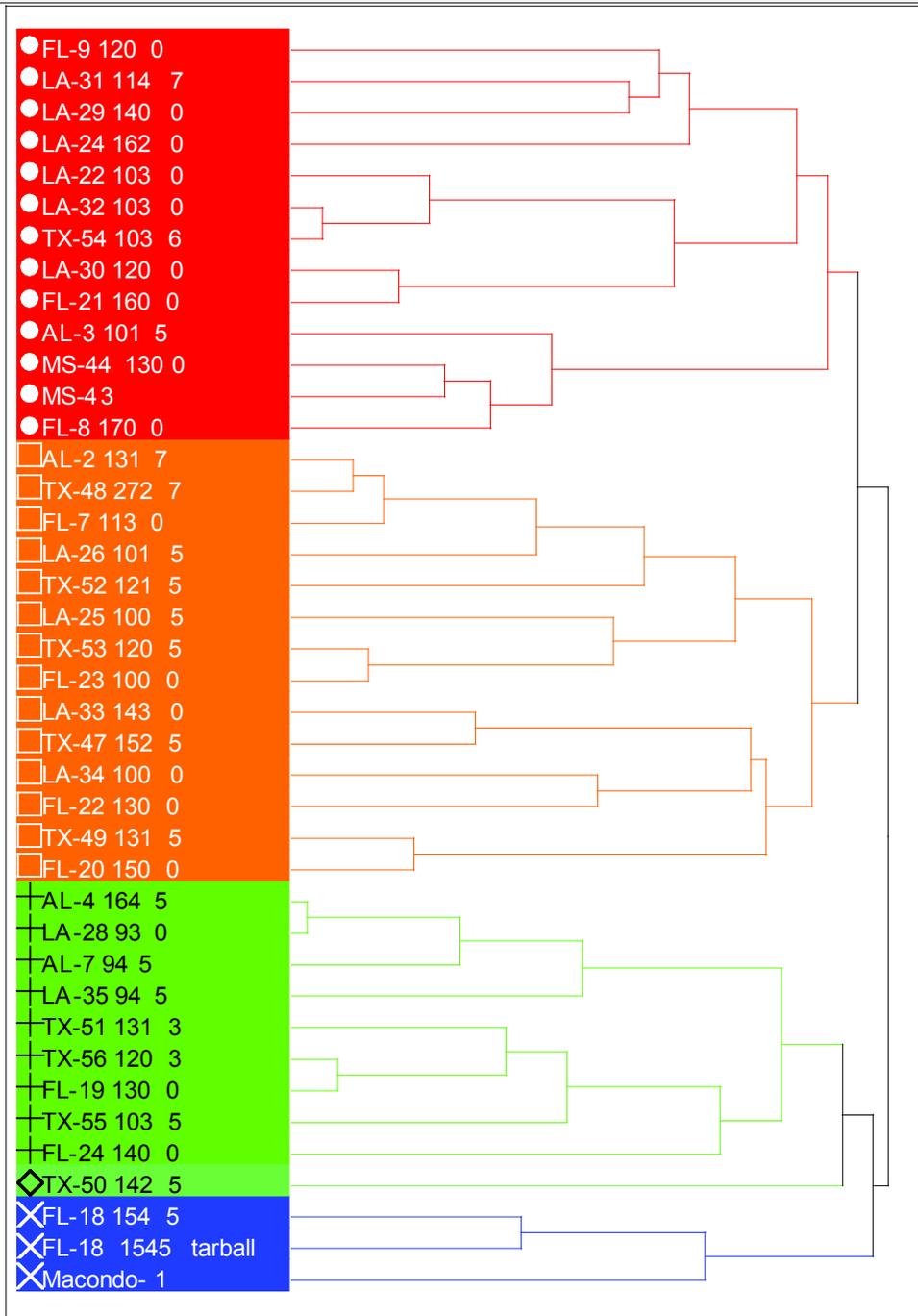


Figure 3. Hierarchical cluster diagram of 39 sediment samples, 1 tarball, and the M-1 well oil from the northern Gulf of Mexico coast. The clusters marked in red, orange, and green indicate sediments with similar distribution of petroleum biomarkers. The cluster of blue crosses contains the sediment and tarball from site FL-18 and the M-1 well oil.

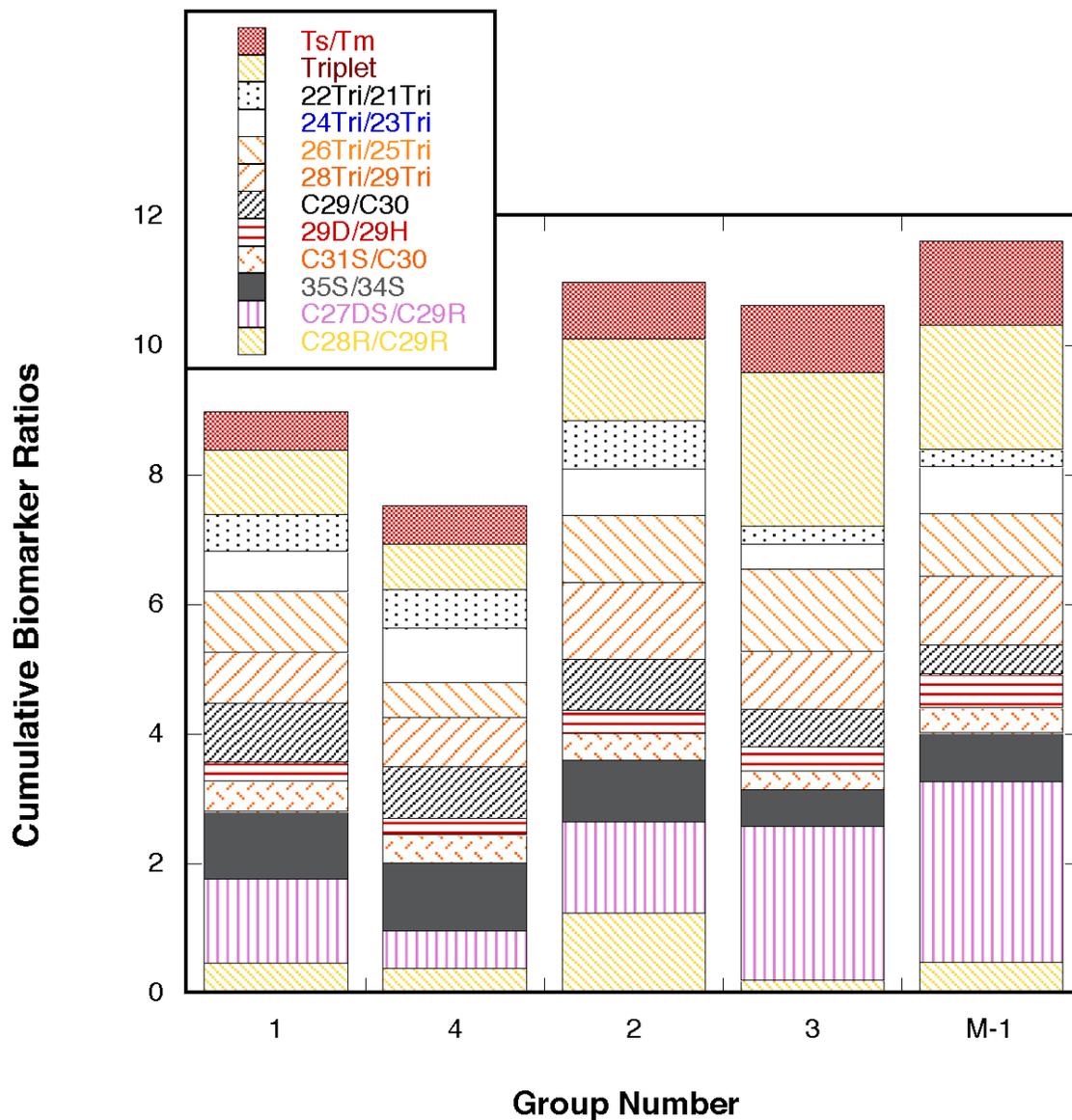


Figure 4. Graphical representation of the distribution of biomarkers within groups derived from the hierarchical cluster analysis (HCA). Biomarkers obtained from analyses of preimpact sediment. Group numbers are correlated oil residues (fig. 3).

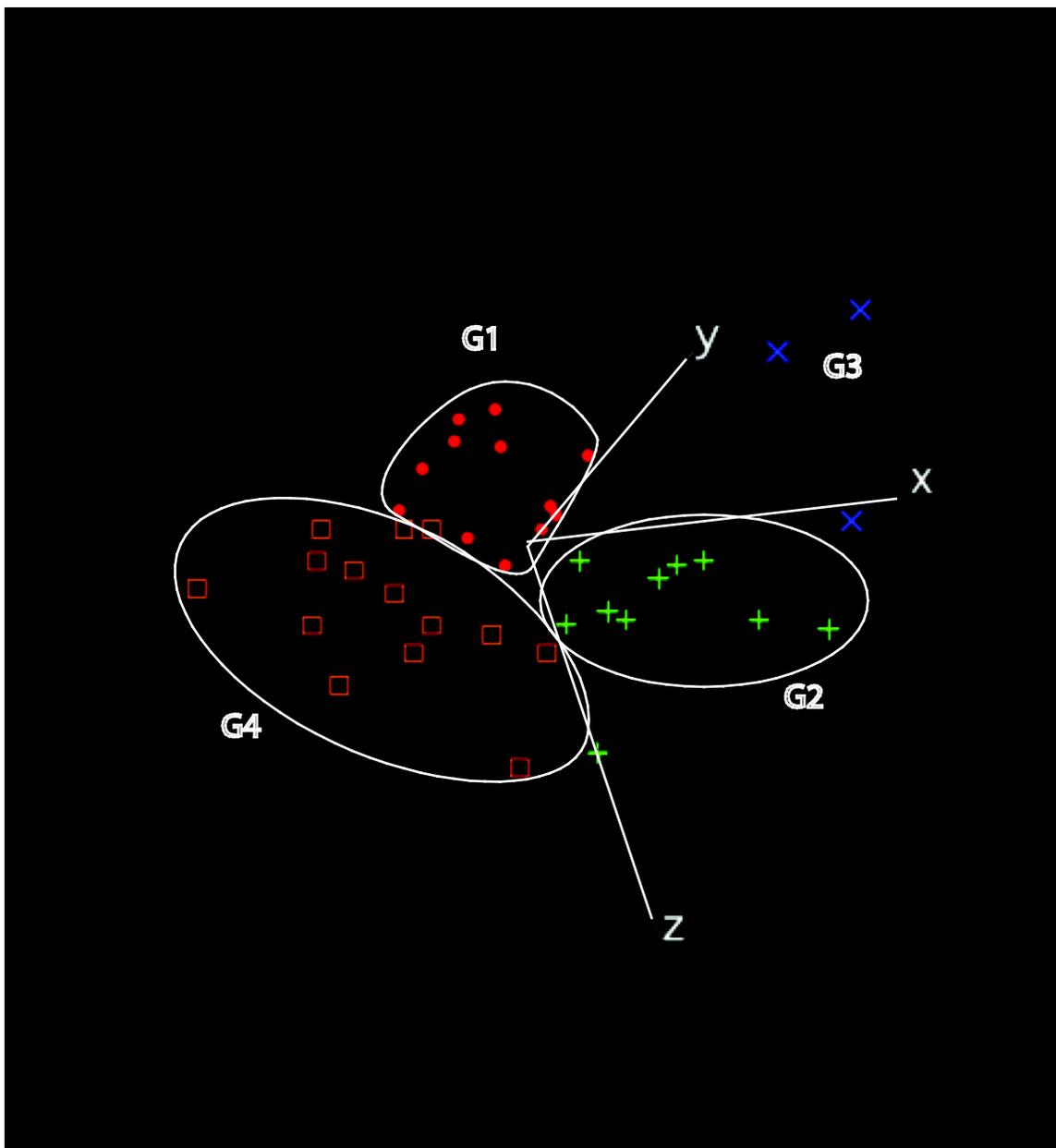


Figure 5. Three-dimensional depiction of principal components scores of the M-1 well oil, sediment, and tarball samples. The x, y, and z axes are the first three principal components PC1, PC2, and PC3, respectively. Regions encircled and labeled G1, G2, and G4 correlate with groups 1, 2, and 4 determined by hierarchal cluster analysis (HCA). The two closely spaced blue crosses are analyses of the sediment and tarball from FL-18 and the blue cross near the x-axis is the M-1 well oil.

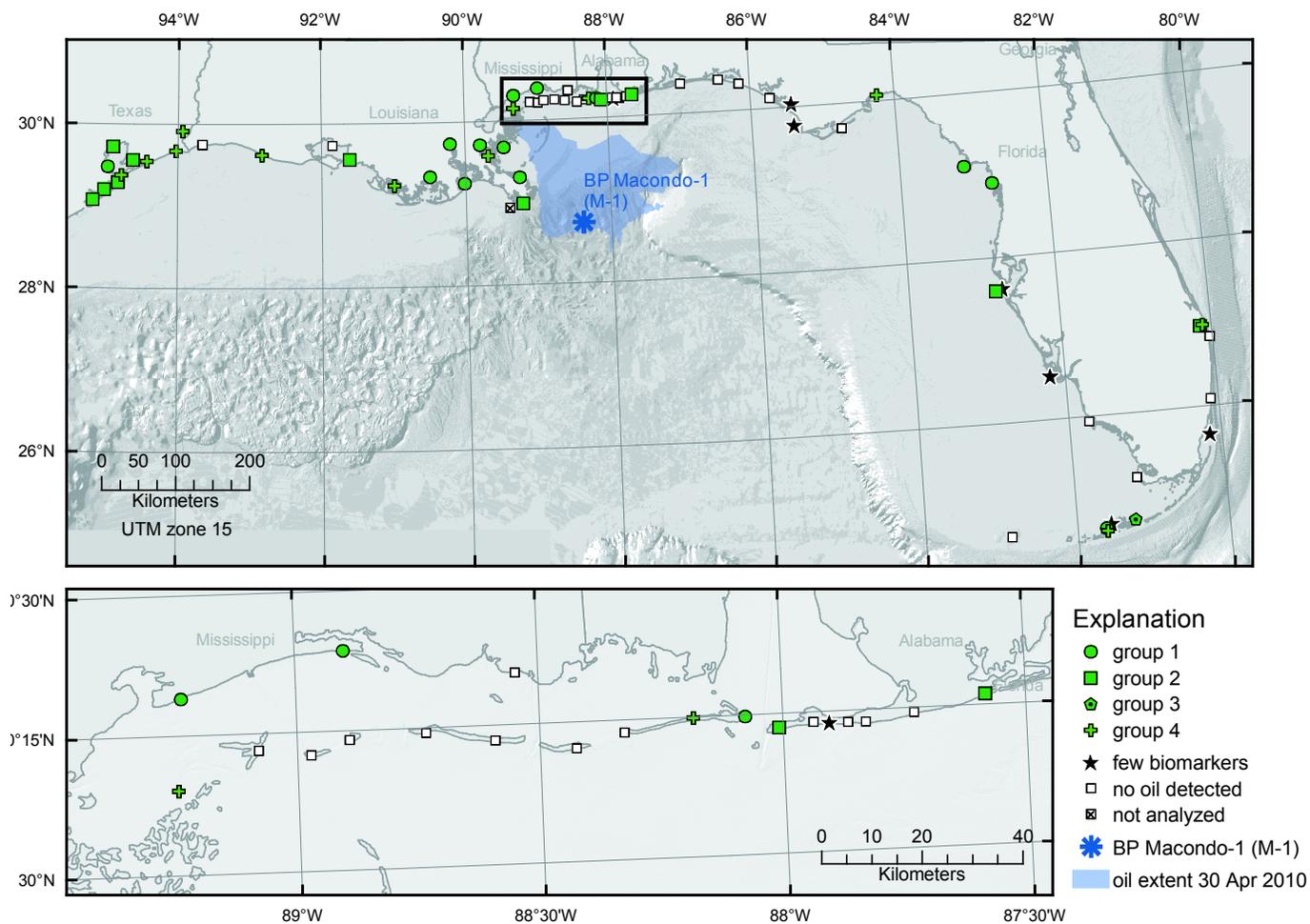


Figure 6. Location map of sediment samples containing oil. Oils groups are derived from the statistical analysis of the petroleum biomarkers. Group 1, circles; group 2, squares; group 3, pentagon; group 4, crosses. Oil not detected denoted by open white squares. The blue shading depicts the cumulative areal coverage of the BP M-1 well oil spill as of April 30, 2010 (National Oceanic and Atmospheric Administration, 2010).

Table 1. Gulf of Mexico preimpact Macondo-1 well oil spill sampling sites. [Site, USGS designated number for site locality; Lab ID, Internal PCMSC reference number; *, oil present but with limited biomarker dataset; ND, oil not detected; Group, statistically correlated oil residues]

Site	Name	Lat-dd	Long-dd	Sample Date	Extracted Weight mg/kg	Oil present*	Group
FL-1	Gulf IS NS nr Navarre, FL	30.362389	-86.970167	5/11/10	7	ND	
FL-2	Henderson Bch SP nr Destin, FL	30.382944	-86.442778	5/11/10	4	ND	
FL-3	Grayton Bch SP nr Seaside, FL	30.324056	-86.155056	5/12/10	1	ND	
FL-4	St. Andrews SP nr Panama City, FL	30.124722	-85.736028	5/12/10	7	ND	
FL-5	St. Joe P SP nr Port St. Joe, FL	29.779167	-85.408528	5/13/10	8	*	
FL-6	St George IS SP nr E Point, FL	29.697861	-84.767750	5/13/10	0	ND	
FL-7	St. Marks NWR nr St. Marks, FL	30.074194	-84.180444	5/18/10	36	yes	4
FL-8	Piney Pt Bch at Cedar Key, FL	29.127750	-83.053361	5/18/10	1	yes	1
FL-9	Fort IS Gulf Bch nr Chassah., FL	28.907194	-82.690778	5/19/10	38	yes	1
FL-10	Fort DeSoto Pk nr St Pete, FL	27.624444	-82.738333	5/17/10	6	*	
FL-11	Captiva IS Bch nr Captiva, FL	26.525639	-82.194222	5/20/10	7	*	
FL-12	Tiger Tail Bch at Marco IS, FL	25.936139	-81.734583	5/21/10	17	ND	
FL-13	NW Cape Sable Bch nr Flamingo, FL	25.224806	-81.169972	5/22/10	3	ND	
FL-14	Dry Tortugas National Park, FL	24.627139	-82.873639	5/20/10	10	ND	
FL-15	B Baggs Cape nr Key Biscayne, FL	25.667417	-80.155528	6/1/10	1	*	
FL-16	Lloyd Bch at Ft Lauderdale, FL	26.081694	-80.109444	5/26/10	2	ND	
FL-17	MacArthur Bch at W Palm Bch, FL	26.822583	-80.038056	5/27/10	2	ND	
FL-18	Coco Plum Bch nr Marathon, FL	24.729250	-81.169972	5/24/10	1830	yes	3
FL-19	DBLM Tract1 nr Jupiter Inlet, FL	26.956111	-80.081667	6/16/10	6	yes	2
FL-20	BLM Tract2 nr Jupiter Inlet, FL	26.956111	-80.081944	6/16/10	58	yes	4
FL-21	BLM Tract1 nr Park Key, FL	24.650556	-81.557500	6/9/10	9	yes	1
FL-22	BLM Tract2 nr Sugarloaf Key, FL	24.617500	-81.543611	6/9/10	31	yes	4
FL-23	BLM Tract3 nr Sugarloaf Key, FL	24.616667	-81.539722	6/9/10	116	yes	4
FL-24	BLM Tract at Egmont Key, FL	27.601389	-82.763611	6/14/10	5	yes	2
FL-25	BLM Lathrop Bayou nr Panama City, I	30.040833	-85.432778	6/10/10	8	*	
FL-26	Great White Heron NWR, FL	24.700833	-81.548611	7/7/10	28	*	
AL-1	West Dauphin Island	30.227425	-88.326394	5/8/10	2	ND	
AL-2	Dauphin Is. AL-2	30.248815	-88.184168	5/9/10	9	yes	4
AL-3	Dauphin Is. AL-3	30.246870	-88.077777	5/9/10	11	yes	1
AL-4	Fort Morgan AL-4	30.224926	-88.008330	5/8/10	1	yes	2
AL-5	Fort Morgan AL-5	30.230481	-87.904438	5/8/10	1	*	
AL-6	Gulf Shores AL-6	30.241314	-87.730265	5/8/10	3	ND	
AL-7	Orange Beach AL-7	30.269091	-87.581649	5/8/10	6	yes	2
AL-8	BLM-1	30.231593	-87.937772	5/24/10	5	ND	
AL-9	BLM-2	30.228815	-87.867214	5/24/10	37	ND	
AL-10	Fort Morgan BLM-3	30.228259	-87.831102	5/24/10	0	ND	
LA-22	Jean Lafitte National Park, LA	29.742222	-90.141944	5/14/10	23	yes	1
LA-23	Cypremort Point, LA	29.735000	-91.853611	5/13/10	0	ND	
LA-24	Lake Felicity, LA	29.346111	-90.429167	5/18/10	10	yes	1
LA-25	Rockefeller Refuge Beach, LA	29.635556	-92.767222	5/13/10	23	yes	4
LA-26	Sister Lake, LA	29.251944	-90.921667	5/17/10	12	yes	4
LA-28	Point Chevreuil, LA	29.573333	-91.537778	5/13/10	23	yes	2
LA-29	Crooked Bayou, LA	29.723333	-89.723611	5/18/10	6	yes	1
LA-30	Mississippi R. Gulf Outlet, LA	29.685556	-89.395833	5/7/10	1	yes	1
LA-31	Grand Isle Bch at State Park, LA	29.260278	-89.950278	5/10/10	7	yes	1
LA-32	Mississippi R. at Main Pass, LA	29.320556	-89.181944	5/7/10	6	yes	1
LA-33	Breton Sound, LA	29.588333	-89.611944	5/7/10	7	yes	4
LA-34	Miss. Sound at Grand Pass, LA	30.151944	-89.245833	5/7/10	6	yes	4
LA-35	Mississippi R. at South Pass, LA	28.997500	-89.148889	5/7/10	1	yes	2
LA-36	Mississippi R. at SW Pass, LA	28.937500	-89.398889	5/7/10		NA	
MS-37	South Cat Island Beach, MS	30.219167	-89.079722	5/7/10	12	ND	
MS-38	West Ship Island Beach, MS	30.207500	-88.972222	5/7/10	10	ND	
MS-39	East Ship Island Beach, MS	30.232778	-88.892500	5/7/10	1	ND	
MS-40	West Horn Island Beach, MS	30.240278	-88.735000	5/8/10	5	ND	
MS-41	East Horn Island Beach, MS	30.222500	-88.592500	5/8/10	5	ND	
MS-42	Petit Bois Island Beach, MS	30.202222	-88.426667	5/8/10	1	ND	
MS-43	Pass Christian Beach, MS	30.316111	-89.236111	5/8/10	14	yes	1
MS-44	Biloxi Beach, MS	30.393333	-88.899444	5/8/10	1	yes	1
MS-45	Pascagoula Beach, MS	30.342778	-88.547778	5/8/10	3	ND	
TX-46	East Sabine, LA	29.748889	-93.663333	5/10/10	5	ND	
TX-47	Texas Point, TX	29.682500	-93.956389	5/10/10	14	yes	4
TX-48	Sabine Lake, TX	29.928333	-93.871389	5/10/10	16	yes	4
TX-49	High Island, TX	29.556667	-94.368333	5/10/10	137	yes	4
TX-50	East Bay nr Anahuac, TX	29.574722	-94.555833	5/10/10	5	yes	2
TX-51	Galveston Island, TX	29.304167	-94.769444	5/10/10	2	yes	2
TX-52	Trinity Bay nr Beach City, TX	29.735556	-94.836389	5/11/10	82	yes	2
TX-53	Bolivar Peninsula	29.388333	-94.719167	5/11/10	11	yes	4
TX-54	Galveston Bay nr Eagle Pt, TX	29.493611	-94.911111	5/11/10	50	yes	1
TX-55	West Bay, Galveston Is SPk	29.214167	-94.953889	5/11/10	24	yes	2
TX-56	San Luis Pass, TX	29.086667	-95.108611	5/11/10	4	yes	2

Table 2. Distribution of biomarkers within groups derived from the hierarchical cluster analysis.

[Group headings are color coded with cluster diagram (fig. 3); biomarker ratios are defined in appendix 1; values are group averaged]

Biomarker Ratio	Group 1	Group 4	Group 2	Group 3	Macondo-1
Ts/Tm	0.598	0.589	0.878	1.030	1.296
Triplet	0.988	0.704	1.259	2.380	1.922
22Tri/21Tri	0.574	0.601	0.741	0.270	0.268
24Tri/23Tri	0.625	0.835	0.728	0.385	0.720
26Tri/25Tri	0.936	0.540	1.028	1.280	0.968
28Tri/29Tri	0.778	0.756	1.193	0.890	1.065
C29/C30	0.925	0.794	0.786	0.585	0.448
29D/29H	0.274	0.263	0.362	0.365	0.523
C31S/C30	0.481	0.436	0.412	0.290	0.388
35S/34S	1.045	1.046	0.946	0.565	0.744
C27DS/C29R	1.292	0.584	1.412	2.385	2.789
C28R/C29R	0.467	0.379	1.236	0.195	0.483

Appendix 1. Biomarker parameter descriptions used in tarball, oil, and sediment statistical analyses

Parameters used for the chemometric analysis described in text are indicated in red.

Saturate fraction:

Triterpanes (hopanes), m/z 191 SIM chromatograms:

1. Ts/Tm, 18 α -22,29,30-trisnorhopane/17 α -22,29,30-trisnorhopane. This ratio is used as both a source and maturity parameter (Seifert and Moldowan, 1978).
2. Triplet, [C₂₆-tricyclic terpane (S?) + C₂₆-tricyclic terpane (R?)/C₂₄-tetracyclic terpane]. This source parameter was used to distinguish coastal tar residues in Prince William Sound (Kvenvolden and others, 1995). Abundant C₂₄ tetracyclic is cited (Peters and others, 2005) as indicating carbonate and evaporite source facies, therefore lower values of this ratio (since C₂₄ is the denominator) indicate this characteristic.
3. 20Tri/23Tri, C₂₀ tricyclic terpane/C₂₃ tricyclic terpane. Source parameter.
4. 22Tri/21Tri, C₂₂ tricyclic terpane/C₂₁ tricyclic terpane. Source parameter, used by Peters and others (2005) to help distinguish lithofacies.
5. 24Tri/23Tri, C₂₄ tricyclic terpane/C₂₃ tricyclic terpane. Source parameter, used by Peters and others (2005) to help distinguish lithofacies.
6. 26Tri/25Tri, C₂₆ tricyclic terpanes/C₂₅ tricyclic terpanes. peak areas. Source parameter; high values (>1) indicate a lacustrine depositional environment, whereas lower values indicate a marine source.
7. 28Tri/29Tri. C₂₈ tricyclic terpanes/C₂₉ tricyclic terpanes, peak areas. Source parameter.
8. C₂₉/C₃₀, 17 α ,21 β (H)-30-norhopane/17 α ,21 β (H)-hopane. This ratio is a source parameter adapted from Palacas and others (1984).
9. 29D/29H, 18 α (H)-30-norhopane/17 α ,21 β (H)-30-norhopane. Source parameter.
10. C₃₁S/C₃₀, 17 α ,21 β (H)-homohopane (22S)/ 17 α ,21 β (H)-hopane. Source parameter.
11. 35S/34S, 17 α ,21 β (H)-29-pentakishomohopane (22S)/17 α ,21 β (H)-29-tetrakishomohopane (22S). Higher C₃₅ than C₃₄ 22S homohopanes is an indication of carbonate/evaporite facies or anoxic depositional environment.
12. OI, Oleanane Index, 18 α + β (H)-oleanane/17 α ,21 β (H)-hopane. This commonly used source parameter indicates a contribution from Cretaceous and younger plant material (Peters and Moldowan, 1993). In the California coastal tars, oleanane is generally present, but in low amounts.
13. GI, Gammacerane Index, gammacerane/17 α ,21 β (H)-hopane. This ratio is used as a source parameter; abundant gammacerane is a carbonate/evaporite facies indicator and a marker for highly reducing, hypersaline depositional environments (Peters and Moldowan, 1993).

Steranes, m/z 217 SIM chromatograms:

14. C₂₈/C₂₉, 24-methyl-5 α ,14 α ,17 α (H)-cholestane (20R)/ 24-ethyl-5 α ,14 α ,17 α (H)-cholestane (20R). This source parameter has been modified from discussions in Grantham and Wakefield (1988) and Waples and Machihara (1991).
15. C27d S/R, β α 27diasterane S/ β α 27diasterane R, source parameter
16. C27ds/C29s, β α 27diasterane S/24-ethyl-5 α ,14 α ,17 α (H)-cholestane (20S)

Aromatic fraction

- 17.** PAH-RI, Polycyclic Aromatic Hydrocarbon-Refractory Index. This index is a source parameter, the ratio of the second, usually major, peak containing the C₂₆R and C₂₇S members in the highly refractory C₂₆ to C₂₈ triaromatic sterane suite (TAS, m/z 231) to that of the first, usually dominant, peak in the monomethyl chrysenes (m/z 242) (Hostettler and others, 1999). In this very large data set it can be seen that this previously descriptive-only parameter does reflect a specific facies characteristic. PAH-RI goes from low values in shale, mid values in marl, and high values in carbonate (increasingly anoxic facies) environments. Since PAH-RI compares TAS to a typical petrogenic C₁PAH, high values indicate higher levels of TAS. TAS are known to be a stable product of diagenesis of steranes in a reducing or anoxic environment. Therefore, PAH-RI is another indicator of the anoxic nature of the source environment.
- 18.** Σ C2D/ Σ C2P, dimethyl dibenzothiophenes (m/z 212)/dimethyl phenanthrenes (m/z 206). Source parameter indicating relative levels of sulfur-containing PAH to regular PAH (Kaplan and others, 1997; Bence and others, 1996).
- 19.** Σ C3D/ Σ C3P, trimethyl dibenzothiophenes (m/z 226)/trimethyl phenanthrenes (m/z 220). Source parameter as #32.

Appendix 2. All biomarker parameters for oil, sediment and tarball samples
 [Parameter definitions are in appendix 1; ND, not detected]

Sample	Lab #	Ts/Tm	triplet	20Tri/23Tri	22Tri/21Tri	24Tri/23Tri	26Tri/25Tri	28Tri/29Tri	C29/C30	29D/29H	C31S/C30	35S/34S	BI	OI	GI	C27DS/C27DR	C27DS/C29S	C28R/C29R
FL-1 1330	10-224	0.50	1.70	ND	1.00	0.93	1.52	ND	0.92	0.36	0.49	ND	ND	ND	ND	ND	ND	ND
FL-2 1730	10-225	ND	ND	ND	ND	ND	ND	ND	0.69	ND	ND	ND	ND	ND	ND	ND	ND	ND
FL-3 1130	10-226	ND	ND	ND	ND	ND	ND	ND	0.69	ND	ND	ND	ND	ND	ND	ND	ND	ND
FL-4 1530	10-199	0.90	ND	ND	ND	0.82	ND	ND	0.94	0.59	0.78	ND	ND	ND	ND	ND	ND	ND
FL-5 900	10-227	1.67	1.37	ND	1.22	0.89	1.02	ND	1.00	ND	ND	ND	ND	ND	ND	1.57	ND	ND
FL-6 1200	10-174	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FL-7 1130	10-200	0.61	0.56	0.18	0.47	0.77	0.52	0.56	0.92	0.23	0.62	1.10	0.03	0.03	0.10	1.40	0.22	0.31
FL-8 1700	10-201	0.52	0.84	0.19	0.60	0.62	0.96	1.02	1.01	0.17	0.68	1.13	0.02	0.02	0.12	1.53	0.62	0.56
FL-9 1200	10-164	0.37	1.67	ND	0.30	0.78	1.00	1.05	0.69	0.35	0.40	1.01	0.05	0.07	0.04	1.44	2.30	0.54
FL-10 1600	10-202	0.86	ND	ND	1.00	1.11	ND	ND	0.72	0.57	0.47	ND	ND	ND	ND	ND	ND	ND
FL-11 1630	10-215	0.92	2.25	ND	ND	0.75	1.43	ND	1.00	ND	0.75	ND	ND	ND	ND	ND	ND	ND
FL-12 1500	10-209	ND	ND	ND	ND	0.78	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FL-13 1305	10-210	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FL-14 945	10-211	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FL-15 1300	10-212	1.17	2.25	ND	0.58	0.72	1.70	ND	0.85	0.59	0.47	ND	ND	ND	ND	ND	ND	ND
FL-16 1500	10-213	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FL-17 1530	10-216	ND	ND	ND	ND	ND	ND	ND	0.69	ND	ND	ND	ND	ND	ND	ND	ND	ND
FL-18 1545	10-217	1.07	2.44	0.16	0.27	0.39	1.23	0.91	0.59	0.38	0.29	0.57	0.11	0.67	0.12	1.50	3.36	0.18
FL-18 tarball	10-236	0.99	2.32	0.17	0.27	0.38	1.33	0.87	0.58	0.35	0.29	0.56	0.05	0.58	0.11	1.65	1.41	0.21
FL-19 1300	10-237	0.83	1.13	0.27	0.70	0.74	1.03	1.12	0.85	0.29	0.48	1.11	0.07	0.09	0.09	1.67	1.33	0.40
FL-20 1500	10-238	0.57	0.66	0.25	0.47	0.72	0.71	0.72	0.43	0.23	0.29	1.33	0.02	0.02	0.04	1.27	0.27	0.18
FL-21 1600	10-218	0.83	0.55	0.17	0.63	0.56	1.02	0.53	1.09	0.33	0.47	1.11	0.05	0.08	0.17	1.59	1.47	0.29
FL-22 1300	10-219	0.15	0.57	0.94	0.55	0.77	0.24	ND	0.69	0.19	0.25	0.82	0.13	0.18	0.06	1.67	0.65	ND
FL-23 1000	10-220	0.75	0.37	0.29	0.58	0.99	0.24	0.70	0.93	0.30	0.48	0.87	0.17	0.34	0.15	1.63	0.25	0.33
FL-24 1400	10-221	0.73	1.50	0.81	0.88	0.69	1.23	ND	0.81	0.55	0.57	1.00	ND	0.22	0.22	1.29	ND	0.63
FL-25 1100	10-222	0.76	1.85	ND	0.50	0.67	1.40	ND	0.80	0.35	0.56	1.05	ND	ND	ND	1.00	ND	ND
FL-26 1100	10-223	0.62	1.80	ND	0.56	0.65	1.72	ND	0.86	0.50	0.37	ND	ND	ND	ND	ND	ND	ND
AL-1 1115	10-175	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
AL-2 1317	10-165	0.63	1.16	ND	ND	0.75	0.85	0.78	0.87	0.23	0.59	1.17	0.04	0.02	0.06	1.40	0.38	0.36
AL-3 1015	10-166	0.56	1.36	ND	1.06	0.61	0.99	1.09	0.91	0.23	0.63	1.25	0.05	0.05	0.06	1.67	0.34	0.42
AL-4 1645	10-167	1.08	1.27	ND	0.59	0.67	1.03	1.31	0.80	0.34	0.47	0.96	0.06	0.15	0.08	1.42	1.27	0.58
AL-5 1500	10-168	1.27	1.75	ND	ND	0.77	1.24	ND	0.87	0.69	0.67	ND	ND	ND	ND	1.17	0.86	1.00
AL-6 1245	10-176	ND	ND	ND	ND	0.86	ND	ND	0.83	ND	ND	ND	ND	ND	ND	ND	ND	ND
AL-7 945	10-169	1.11	1.12	ND	0.56	0.73	1.44	1.76	0.72	0.36	0.38	1.00	0.05	0.16	0.05	1.38	0.93	0.53
AL-8 1300	10-184	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
AL-9 1500	10-185	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
AL-10 1630	10-186	ND	ND	ND	ND	ND	ND	ND	0.86	ND	ND	ND	ND	ND	ND	ND	ND	ND

Appendix 2. (continued)

Sample	Lab #	Ts/Tm	triplet	20Tri/23Tri	22Tri/21Tri	24Tri/23Tri	26Tri/25Tri	28Tri/29Tri	C29/C30	29D/29H	C31S/C30	35S/34S	BI	OI	GI	C27DS/C27DR	C27DS/C29S	C28R/C29R
LA-22 1030	10-187	0.74	0.63	0.26	0.48	0.55	0.37	0.44	0.76	0.26	0.40	0.88	0.01	0.02	0.01	1.75	0.73	0.30
LA-23 1230	10-188	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LA-24 1620	10-189	0.33	1.35	ND	0.15	0.69	1.36	0.44	1.12	0.29	0.50	1.29	0.07	ND	0.08	1.65	1.52	0.65
LA-25 1005	10-190	0.41	0.24	0.05	0.57	0.99	0.31	0.40	1.08	0.15	0.44	1.02	0.02	0.05	0.04	1.43	0.72	0.17
LA-26 1015	10-191	0.45	0.82	1.42	0.48	0.97	0.72	0.65	0.70	0.20	0.57	0.91	0.03	0.07	0.11	1.58	0.55	0.36
LA-28 930	10-192	0.97	1.39	0.10	0.53	0.78	0.99	1.23	0.73	0.34	0.36	0.87	0.05	0.17	0.03	1.57	1.37	0.30
LA-29 1400	10-194	0.29	2.07	ND	ND	0.70	1.19	0.54	0.99	0.23	0.46	0.89	ND	0.14	0.50	1.64	1.15	1.23
LA-30 1200	10-193	0.51	0.64	ND	0.64	0.58	0.87	0.42	0.92	0.28	0.45	1.07	0.08	0.04	0.13	1.55	2.40	0.36
LA-31 1147	10-170	0.35	0.83	0.40	0.44	0.74	1.03	0.41	0.88	0.34	0.37	0.71	ND	0.11	ND	1.62	1.40	0.32
LA-32 1030	10-195	0.81	0.95	0.14	0.55	0.64	0.74	0.96	0.82	0.28	0.40	0.92	0.02	0.07	0.06	1.65	1.94	0.32
LA-33 1430	10-196	0.73	1.16	0.20	0.62	0.87	0.44	0.86	0.63	0.39	0.33	0.82	0.03	0.04	0.05	1.70	1.57	0.59
LA-34 1000	10-197	0.34	1.47	0.53	0.57	0.76	0.36	1.38	0.79	0.31	0.38	1.00	ND	0.16	0.13	1.17	0.88	0.94
LA-35 945	10-198	1.03	1.68	0.26	0.69	0.80	1.12	1.55	0.70	0.47	0.39	0.71	0.09	0.16	0.14	1.37	2.17	0.75
MS-37 1530	10-177	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MS-38 1700	10-178	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MS-39 1845	10-171	ND	ND	ND	ND	0.80	ND	ND	0.93	ND	ND	ND	ND	ND	ND	ND	ND	ND
MS-40 1400	10-179	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MS-41 4641	10-172	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MS-42 1215	10-180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MS-43	10-181	0.87	0.54	0.10	0.91	0.52	1.07	1.09	1.05	0.24	0.58	1.03	0.04	0.03	0.09	1.47	0.92	0.37
MS-44 1300	10-173	0.79	0.93	ND	0.57	0.55	0.97	1.24	0.94	0.29	0.54	1.29	0.05	0.05	0.04	1.55	0.97	0.41
MS-45 1630	10-182	0.85	ND	ND	ND	0.70	ND	ND	1.05	0.67	ND	ND	ND	ND	ND	ND	ND	ND
TX-46 1317	10-183	ND	ND	ND	ND	ND	ND	ND	0.93	0.79	ND	ND	ND	ND	ND	ND	ND	ND
TX-47 1525	10-203	0.89	0.93	ND	0.77	1.09	0.61	1.05	0.74	0.37	0.33	1.03	0.05	0.19	0.08	1.63	0.81	0.36
TX-48 2727	10-214	0.65	0.59	0.33	0.49	0.77	0.77	0.83	0.88	0.21	0.47	1.15	0.05	0.07	0.06	1.44	1.02	0.26
TX-49 1315	10-228	0.68	0.47	0.04	0.77	0.70	0.74	0.60	0.64	0.30	0.32	1.13	0.13	0.10	0.06	1.38	0.33	0.29
TX-50 1425	10-229	0.85	0.70	0.31	0.64	0.74	0.71	0.92	0.72	0.35	0.31	0.89	0.03	0.11	0.06	1.69	1.32	5.57
TX-51 1313	10-204	0.67	0.98	ND	1.08	0.71	0.83	1.05	0.89	0.28	0.36	0.92	0.09	0.17	0.15	1.58	1.76	0.48
TX-52 1215	10-230	0.67	0.33	0.17	0.77	0.70	0.54	0.40	0.96	0.27	0.67	1.33	0.02	0.01	0.07	1.22	0.07	0.18
TX-53 1205	10-205	0.71	0.53	0.30	0.67	0.84	0.51	0.78	0.86	0.30	0.36	0.96	0.06	0.24	0.11	1.56	0.45	0.34
TX-54 1036	10-206	0.80	0.48	0.27	0.49	0.58	0.60	0.89	0.84	0.27	0.37	1.00	0.11	0.09	0.08	1.68	1.03	0.30
TX-55 1035	10-207	0.81	1.13	ND	0.86	0.65	0.99	0.85	0.80	0.30	0.39	0.90	0.09	0.08	0.07	1.47	1.47	2.47
TX-56 1203	10-208	0.70	1.69	ND	0.88	0.77	0.91	1.26	0.84	0.34	0.41	1.10	0.12	0.29	0.18	2.00	1.38	0.65

Appendix 3. Biomarker parameters for oil, sediment and tarball samples used in the statistical analysis.
 [Parameter definitions are in appendix 1; values in red are column averaged (see text); ND, not detected]

Sample	Lab #	Ts/Tm	triplet	22Tri/21Tri	24Tri/23Tri	26Tri/25Tri	28Tri/29Tri	C29/C30	29D/29H	C31S/C30	35S/34S	C27DS/C29S	C28R/C29R
FL-7 1130	10-200	0.61	0.56	0.47	0.77	0.52	0.56	0.92	0.23	0.62	1.10	0.22	0.31
FL-8 1700	10-201	0.52	0.84	0.60	0.62	0.96	1.02	1.01	0.17	0.68	1.13	0.62	0.56
FL-9 1200	10-164	0.37	1.67	0.30	0.78	1.00	1.05	0.69	0.35	0.40	1.01	2.30	0.54
FL-18 1545	10-217	1.07	2.44	0.27	0.39	1.23	0.91	0.59	0.38	0.29	0.57	3.36	0.18
FL-18 tarball	10-236	0.99	2.32	0.27	0.38	1.33	0.87	0.58	0.35	0.29	0.56	1.41	0.21
FL-19 1300	10-237	0.83	1.13	0.70	0.74	1.03	1.12	0.85	0.29	0.48	1.11	1.33	0.40
FL-20 1500	10-238	0.57	0.66	0.47	0.72	0.71	0.72	0.43	0.23	0.29	1.33	0.27	0.18
FL-21 1600	10-218	0.83	0.55	0.63	0.56	1.02	0.53	1.09	0.33	0.47	1.11	1.47	0.29
FL-22 1300	10-219	0.15	0.57	0.55	0.77	0.24	0.88	0.69	0.19	0.25	0.82	0.65	0.63
FL-23 1000	10-220	0.75	0.37	0.58	0.99	0.24	0.70	0.93	0.30	0.48	0.87	0.25	0.33
FL-24 1400	10-221	0.73	1.50	0.88	0.69	1.23	0.88	0.81	0.55	0.57	1.00	1.12	0.63
AL-2 1317	10-165	0.63	1.16	0.64	0.75	0.85	0.78	0.87	0.23	0.59	1.17	0.38	0.36
AL-3 1015	10-166	0.56	1.36	1.06	0.61	0.99	1.09	0.91	0.23	0.63	1.25	0.34	0.42
AL-4 1645	10-167	1.08	1.27	0.59	0.67	1.03	1.31	0.80	0.34	0.47	0.96	1.27	0.58
AL-7 945	10-169	1.11	1.12	0.56	0.73	1.44	1.76	0.72	0.36	0.38	1.00	0.93	0.53
LA-22 1030	10-187	0.74	0.63	0.48	0.55	0.37	0.44	0.76	0.26	0.40	0.88	0.73	0.30
LA-24 1620	10-189	0.33	1.35	0.15	0.69	1.36	0.44	1.12	0.29	0.50	1.29	1.52	0.65
LA-25 1005	10-190	0.41	0.24	0.57	0.99	0.31	0.40	1.08	0.15	0.44	1.02	0.72	0.17
LA-26 1015	10-191	0.45	0.82	0.48	0.97	0.72	0.65	0.70	0.20	0.57	0.91	0.55	0.36
LA-28 930	10-192	0.97	1.39	0.53	0.78	0.99	1.23	0.73	0.34	0.36	0.87	1.37	0.30
LA-29 1400	10-194	0.29	2.07	0.64	0.70	1.19	0.54	0.99	0.23	0.46	0.89	1.15	1.23
LA-30 1200	10-193	0.51	0.64	0.64	0.58	0.87	0.42	0.92	0.28	0.45	1.07	2.40	0.36
LA-31 1147	10-170	0.35	0.83	0.44	0.74	1.03	0.41	0.88	0.34	0.37	0.71	1.40	0.32
LA-32 1030	10-195	0.81	0.95	0.55	0.64	0.74	0.96	0.82	0.28	0.40	0.92	1.94	0.32
LA-33 1430	10-196	0.73	1.16	0.62	0.87	0.44	0.86	0.63	0.39	0.33	0.82	1.57	0.59
LA-34 1000	10-197	0.34	1.47	0.57	0.76	0.36	1.38	0.79	0.31	0.38	1.00	0.88	0.94
LA-35 945	10-198	1.03	1.68	0.69	0.80	1.12	1.55	0.70	0.47	0.39	0.71	2.17	0.75
MS-43	10-181	0.87	0.54	0.91	0.52	1.07	1.09	1.05	0.24	0.58	1.03	0.92	0.37
MS-44 1300	10-173	0.79	0.93	0.57	0.55	0.97	1.24	0.94	0.29	0.54	1.29	0.97	0.41
TX-47 1525	10-203	0.89	0.93	0.77	1.09	0.61	1.05	0.74	0.37	0.33	1.03	0.81	0.36
TX-48 2727	10-214	0.65	0.59	0.49	0.77	0.77	0.83	0.88	0.21	0.47	1.15	1.02	0.26
TX-49 1315	10-228	0.68	0.47	0.77	0.70	0.74	0.60	0.64	0.30	0.32	1.13	0.33	0.29
TX-50 1425	10-229	0.85	0.70	0.64	0.74	0.71	0.92	0.72	0.35	0.31	0.89	1.32	5.57
TX-51 1313	10-204	0.67	0.98	1.08	0.71	0.83	1.05	0.89	0.28	0.36	0.92	1.76	0.48
TX-52 1215	10-230	0.67	0.33	0.77	0.70	0.54	0.40	0.96	0.27	0.67	1.33	0.07	0.18
TX-53 1205	10-205	0.71	0.53	0.67	0.84	0.51	0.78	0.86	0.30	0.36	0.96	0.45	0.34
TX-54 1036	10-206	0.80	0.48	0.49	0.58	0.60	0.89	0.84	0.27	0.37	1.00	1.03	0.30
TX-55 1035	10-207	0.81	1.13	0.86	0.65	0.99	0.85	0.80	0.30	0.39	0.90	1.47	2.47
TX-56 1203	10-208	0.70	1.69	0.88	0.77	0.91	1.26	0.84	0.34	0.41	1.10	1.38	0.65