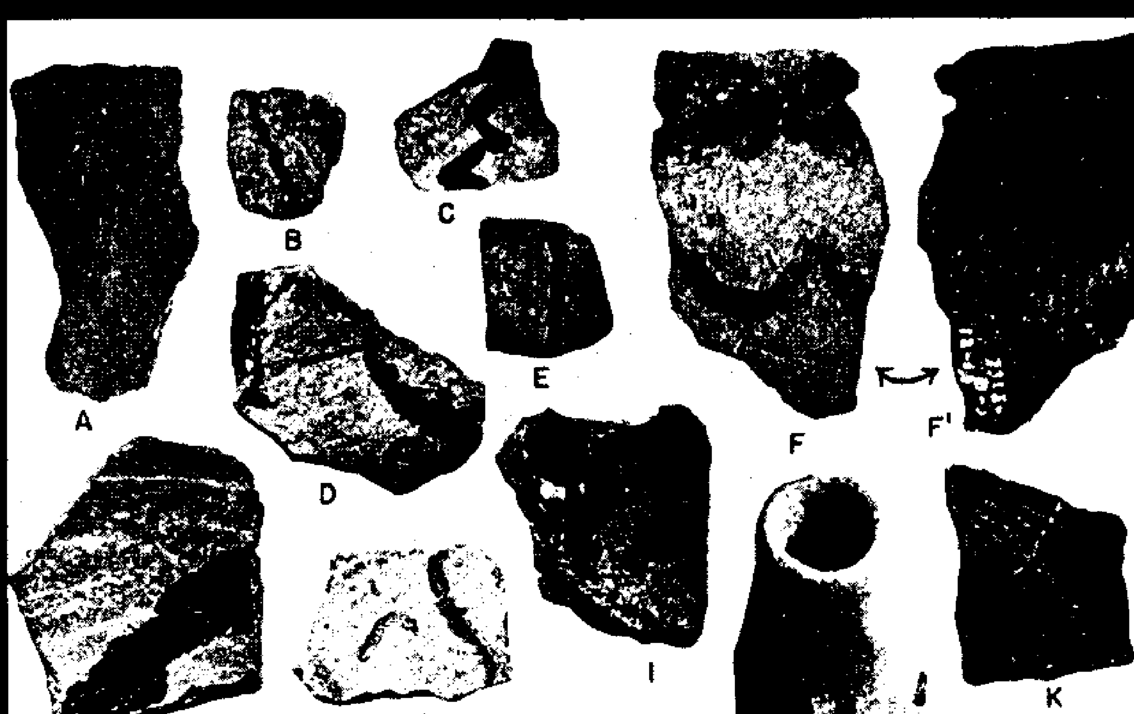
Naturally Occurring Hydrocarbon Seeps in the Gulf of Mexico and the Caribbean Sea

Karankawa Indians using tar from Texas beaches to decorate pottery and make it waterproof.



Karankawa Indian pottery from the Pre-Columbian Ken-Crane site on the Texas Coast. Darkened areas are tar decorations and markings.

FRONT COVER — *Gas bubbles seeping from coral reef formation at Flower Gardens Bank on the Texas Continental Shelf.*
BACK COVER — *Worldwide locations of some reported onshore and offshore hydrocarbon seeps.*

Introduction

The ocean environment is a dynamic and constantly changing system. In addition to supplying many of our basic needs including certain foods and oxygen, as well as a means of communication, it provides us with a source of recreation, and appeals to our aesthetic senses.

Countless substances enter the oceans as a result of material usage and energy production by society. Some are alien to the marine system, but others have already existed for millions of years. Petroleum hydrocarbons found today in the ocean are derived from serveral significant sources. These include hydrocarbons released into the marine environment resulting from, (1) mankind's need for energy and transportation, (2) from hydrocarbons produced by the marine organisms themselves, and (3) from hydrocarbons originating from natural geologic processes causing them to seep upward to the sea floor.

Recent scientific studies provide evidence for significant naturally occurring oil and gas seeps that have existed in the marine environment for thousands of years. Samples of the use of asphalt to decorate pottery and make it waterproof by Karankawa Indians living on Padre Island, Texas as far back as pre-Columbian times may be seen in the Sate Museum in Austin, Texas. There are also many references in the historical literature of the 16th and 17th centuries of Spanish explorers caulking their ships with tar found on the beaches off south Texas and Louisiana. In fact, this historical evidence was an important reason why the research program to study naturally occurring hydrocarbons in the Gulf of Mexico was started in 1971 by the Oceanography Department of Texas A&M University.

Recent investigations indicate that hydrocarbons in the marine environment are not necessarily detrimental to marine life. For example, ***off the coast of Trinidad oysters and clams grow prolifically in waters containing naturally occurring oil seeps.*** Large amounts of bacteria growing in the enriched hydrocarbon water may serve as food sources for these molluscs. Soviet scientists have demonstrated that a food chain of bacteria and certain small shellfish could be maintained by bubbling Carbon 14-labeled methane gas through a bacterial suspension in the water. ***Studies made from a submersible on the bottom of the Gulf of Mexico show fish swimming through streams of naturally occurring gas rising from beneath the sea floor into the water column.*** Unquestionably, the factors affecting the behavior of the organisms in the above samples is more complex than this, but it appears that all petroleum hydrocarbons in the marine environment resulting from natural or accidental causes are not necessarily harmful.

Oil and gas have been seeping into the marine environment for thousands of years.

Historical evidence of naturally occurring oil seeps

The appearance of petroleum hydrocarbons in various forms in the Gulf of Mexico dates back to the earliest history of this country. ***In pre-Columbian times, the Karankawa Indians used asphalt in their pottery making and in hafting their arrows.***

In 1977, permission was granted from the Texas State Museum to obtain samples of tar used in decorating and waterproofing the Karankawa pottery for chemical analyses. Samples of the pottery fragments are pictured on the inside front cover in this report. The pottery fragments have high sulfur values that are characteristic of many of the present day samples collected from beaches. Their origin is attributed to tar associated with Mexican and Venezuelan crude oils, that are found as natural seeps, as well as are being produced commercially. Details of the analysis are found in the following table.

Table I. Analysis of Indian Midden Tars

I. Organic elemental analyses of ancient tar samples

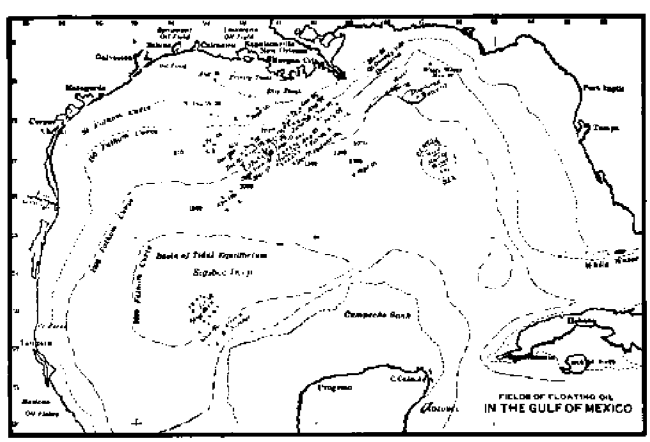
Sample Location	%Sulfur	%Nitrogen	%Carbon	%Hydrogen	Hydrogen/ Carbon
Neuces County Site Unknown	7.8	0.65	67.02	7.83	1.40
Live Oak Point Site Aransas County	6.6	0.53	71.23	8.68	1.46

According to DeGolyer, Oviedo y Valdes referred to asphalt in the New World in 1533, and Sebastian Ocampo in 1508 found liquid hydrocarbons in the Bay of Havanna, Cuba. Hydrocarbons have been reported by navigators at different times at different points, and in different forms. However, early fields of floating oil attracted little attention, although it is believed that they had always existed. In 1542, after the death of the great sixteenth century Spanish explorer, DeSoto, the remainder of his expedition sailed down the Mississippi and along the western Gulf of Mexico. Time and time again they found evidence of petroleum hydrocarbons, and after refuge from a storm in a creek, they found "a scum cast up by the sea like pitch". This was used to caulk the bottoms of their vessels.

"There is found in great quantities upon the coast, east and west of the Meschacebe (Mississippi), especially after high south winds, a sort of stone pitch the Spaniards called "copec"; they mixed it with grease to make it more liquid and used it as pitch for their vessels." ***Acosta, the famous author of history of the West Indies affirms it was generated from "an oil which empties itself into the ocean in great quantities." The English sent to discover the Meschacebe (Mississippi) found it in two places and noted that "the sea was covered with oil or slime which had a strong smell".*** Another writer says that ambergris, or gray amber, was found on the coast from Cape Florida to Mexico. It was said to be "a bitumen of naptha which comes from certain springs or fountains that empty themselves into the sea and is coagulated by the salt water as succinum, commonly called 'amber'".

A peculiar substance called "sea wax" was frequently found on the beaches between Sabine Pass and Matagorda in the late nineteenth and early twentieth centuries. It was found in large cakes as much as 6 to 8 feet long and 1 or 2 inches thick. It was undoubtedly a petroleum or asphalt type residue and its presence points to the existence of major seeps of liquid petroleum somewhere in the Gulf. ***Kennedy, in 1841, reported tar on the Galveston beaches.***

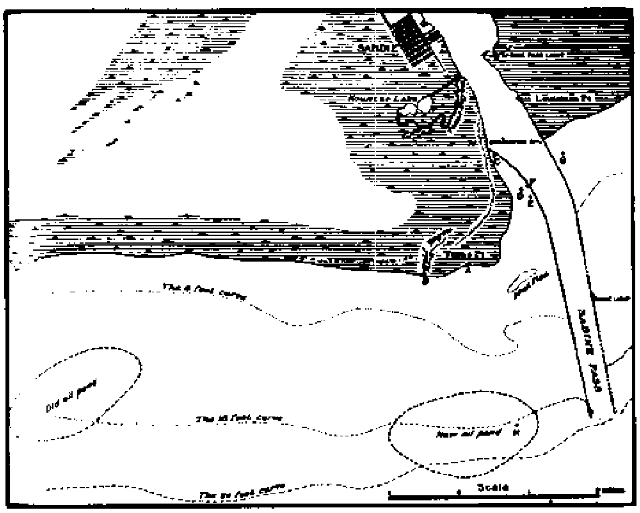
Before 1900, floating oil had been noticed from time to time and was occasionally reported in the newspapers, but in later years records were more carefully kept. It was, therefore, possible to locate the origin of the oil field and to determine its extent. In the early 1900's the Hydrographic Office in New Orleans supplied all ships crossing the Gulf of Mex-



1910 chart showing fields of floating oil in the Gulf of Mexico.

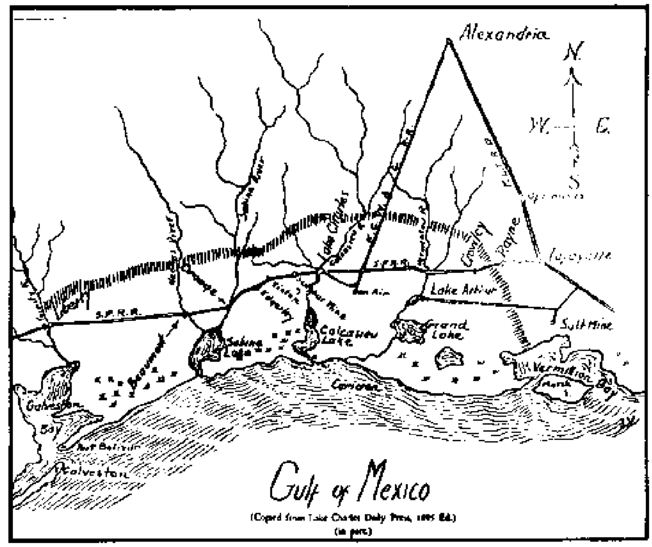
ico with oceanographic reporting forms. ***Many of the ships reported huge patches of oil, some more than 100 miles long and several miles wide, and others were oval-shaped and 30 or more miles wide.***

Although the locations vary, the general area of sightings were west of the Mississippi Delta and north of lattitude 26° N. ***A number of vessels reported that oil was seen bubbling on the surface, and a report on September 10, 1909 from the steamship COMEDIAN described it specifically "as coming up in three jets".*** It was generally described as dark or dark yellow, "sometimes so thick that vessels passing through will hardly make a ripple on the water. The oil floats away from the source in large fields, but it absorbs oxygen from the air and evaporates quickly. Upon evaporating, the oil residue of hydrocarbon disappears and the emulsion, mixing with the water, first has the appearance of slime. It is generally reported as discolored water, and later turns the water milky white. This appearance is often reported in the eastern part of the Gulf Current and as far south as the Florida Reefs."



Map from a 1902 publication showing oil pond locations along the Texas-Louisiana coast.

In 1954, Lynch prepared a chart showing 30 reported incidents of oil sightings in the Gulf believed to be oil seeps. Earlier, in 1933, Price reported a seep on the north end of St. Joseph's Island off the Texas coast.



Sketch from book by Vincent showing location of "tar gum" on Louisiana beach.

Hildebrand, in 1954 before any appreciable oil was produced commercially from the Gulf of Mexico, surveyed the beaches from northern Mexico to Bradenton, Florida to determine the amount of tar present. In summary, he noted, "Petroleum residues occur on all beaches in the north Gulf from Washington Beach, Tamaulipas, Mexico to Fort Walton Beach, Florida. In general it is most abundant around tidal inlets."

Naturally occurring hydrocarbons are not confined to the Gulf of Mexico and the Caribbean. In fact, they have been reported from all over the world — geographically and historically — as far back as biblical times. Noah used it for waterproofing the Ark, constructed of gopher wood, lined with pitch inside and out. The mother of Moses put her baby inside a bitumen-lined cradle for Pharaoh's daughter to find along the bank of the River Nile. Throughout the early ages in the countries that cradled civilization, peasant peoples living humbly and in fear of an unknown god, worshipped the mysterious fire that burned forever without cause. They also collected oil oozing from seepages for their lamps, for primitive domestic uses, and when set on fire, was a weapon against their enemies.

A world-wide summary of recent seep occurrences is shown on a chart on the back cover, compiled by Wilson and others, and published in **Science** in 1974.

Naturally occurring seeps in the Gulf of Mexico — contemporary times

Only a few marine petroleum hydrocarbon seeps are documented as compared with the number known on land. However, all evidence suggests that many more will be found. The limited record of marine seeps no doubt reflects the difficulty of observing them in this environment. It also results from the less extensive exploration of offshore as compared with onshore areas.

The residual evidence of seepage in the form of tar or asphaltic stains, so apparent on land, is hidden by water. In addition, the dispersing effect of ocean processes makes both observation and location of marine seeps especially difficult. Even in areas where marine seeps are known, it is expected that more detailed investigations will reveal additional seeps.

Many seeps occur in northern Mexican oil fields in the so-called Golden Lane trend south of Tampico. DeGolyer stated that over 6,000 seeps were found in Cerro Azul situated 300 miles south of Brownsville, Texas. For example, numerous seeps occur at the present time on and in Laguna de Tamiahua. Examples of related tar masses are illustrated on page 9.

The lagoon at Tamiahua is open to the Gulf on the south. Many of the other seeps are located inland near streams that eventually empty into the Gulf. Local residents estimated the Tamiahua seep to be about 50 years old. A biological sampling survey was made of this area by scientists from the Department of Oceanography, Texas A&M University. The first 500-600 feet of the survey consists of dry flatland and has the appearance of an asphalt parking lot badly in need of repair. This zone is followed by about 150 feet of sandy flat containing more tar. Within 300 feet of the edge of the lagoon, the flat exhibits characteristics more comparable to those of an ordinary mud flat. ***Vegetation is sparse, but enough examples of plant growth exist, such as marsh grass and mangroves, to dispell the idea that this tar seep was responsible for the absence of vegetation elsewhere in the area.*** Active oil seeps found on the bottom of the Gulf of Mexico are not as numerous as compared to active gas seeps located in the Gulf. This is discussed more fully in the Results Section.

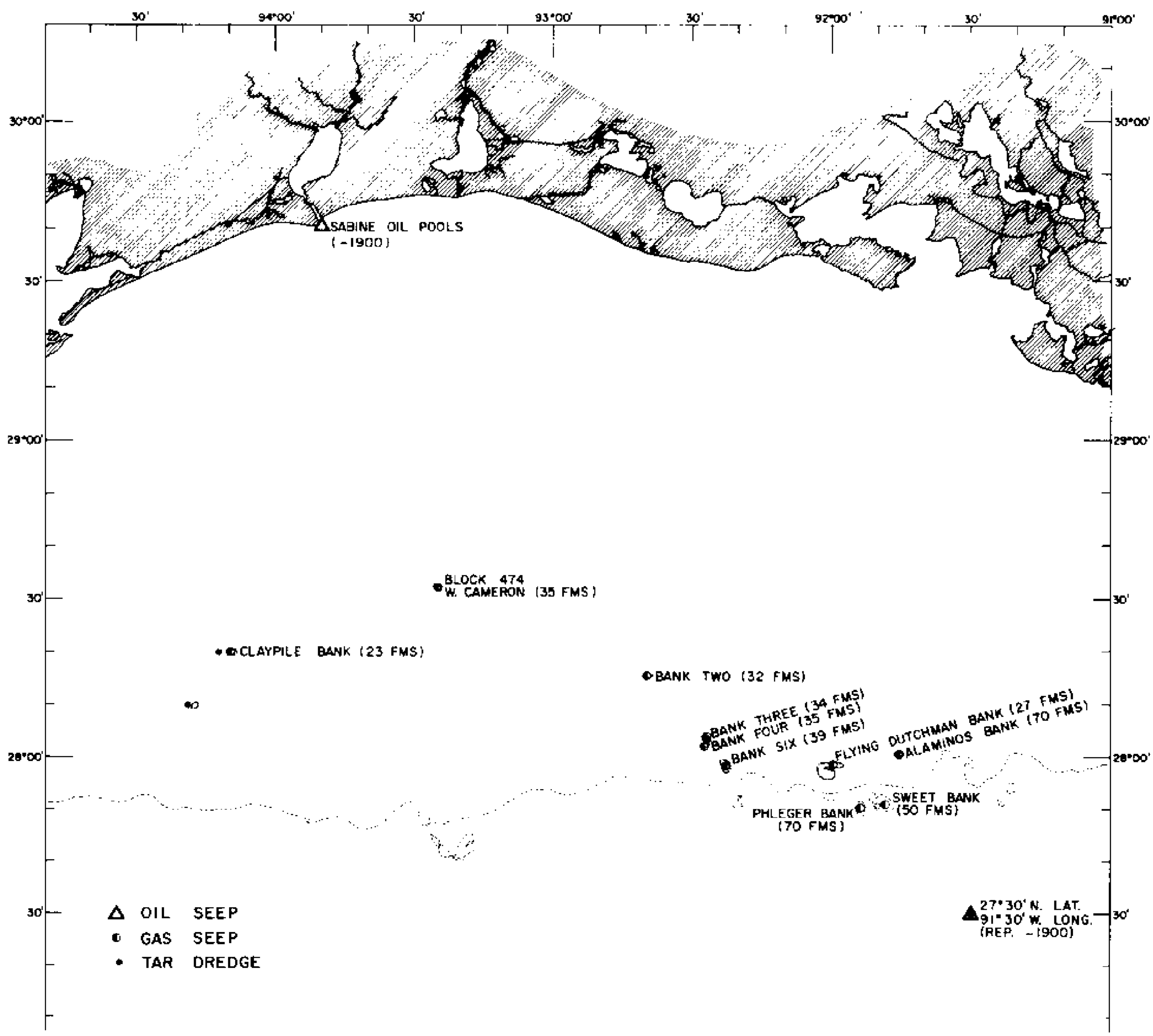
The Department of Oceanography at Texas A&M University has been engaged over the past eight years in a research program to study hydrocarbon seepage in the Gulf of Mexico and contiguous areas. This program has been funded at any one time during this period by as many as 14 major oil companies and the National Sea Grant program of the National Oceanic & Atmospheric Administration. ***Research in all major branches of oceanography was conducted with emphasis on the chemical, geological, and biological oceanographic aspects. The U.S. Coast Guard and U.S. Geological Survey have also cooperated in the study of currents in coastal waters.***

The methods used during this research program to search for and scientifically study naturally occurring hydrocarbons in the Gulf and its adjacent areas, fall into four major categories. Numerous oceanographic surveys were made to collect samples of oil and gas in the Gulf and Caribbean using ships, submersibles, and satellites, together with seasonal beach patrols along the Texas Coast. The chemical, physical, geological and geographical characteristics of the samples were then studied.

Texas A&M's research ship R/V GYRE, travelled many thousands of miles across the Gulf and Caribbean collecting hundreds of surface, near-surface and bottom water, as well as bottom sediment samples for chemical analysis. Bottom and sub-bottom geological characteristics were also recorded with acoustic devices. The 175 foot R/V GYRE provides accommodations for a 19 member scientific party and an 11 man crew. The Navy-designed ship cruises at 12 knots and is outfitted with the sophisticated oceanographic instrumentation and laboratories needed to work at sea. In addition to R/V GYRE, a variety of chartered vessels were used in this study, including one from which surface tars were sampled from Dakar, Africa to Trinidad in 1974. (See inside back cover.)

R/V GYRE was joined by the two-man research submersible DRV DIAPHUS on many occasions. The five ton DRV DIAPHUS is 21 feet long, cruises on battery power at 2 knots and can operate at maximum depth of 1200 feet. Geological features, biological communities and natural gas seeps on carbonate banks off the Texas and Louisiana coasts were investigated and documented using still and motion pictures.

"Oceanography from a satellite" — the words themselves sound incongruous. But because of the advancing spacecraft technology during the last 15 years, powerful remote sensors permit recognition of oil slicks on the ocean surface and the monitoring of these large-scale events. The satellite photograph shown is presumed to be an oil slick of undetermined origin in the Gulf of Mexico occurring about 150 miles SE of the Mississippi Delta. (Page 11.)



Location of eight naturally occurring hydrocarbon seeps choosen as representative of this type of hydrocarbon seepage phenomenon.

Tars on Texas beaches

Tar samples were collected several times a year during the last eight years from Texas beaches extending from the Rio Grande to the Sabine River. The tar masses collected occur in many shapes and sizes — from small fragments to large masses.

Both free floating and bottom dwelling marine organisms are occasionally found growing on tar masses collected from the beach. Tall beach grasses have also been recorded growing through the tar lumps. In 1975, much of the tar found on the beaches was associated with extensive deposits of sea weed, which several weeks earlier had been observed more than 100 miles offshore during an Oil Seep cruise. The head park ranger at the National Seashore Station on Padre Island also commented on this phenomenon These high concentrations of seaweed are comparable to a similar incident reported in 1954 by Hildebrand during his extensive beach survey, and again in 1978 by members of the Oil Seep research group. This does not necessarily mean that there was unusual growth of this algae in the Gulf at these times. However, it does indicate a marked change for these years in the major circulation pattern, both offshore and nearshore in the southwestern portion of the Gulf.

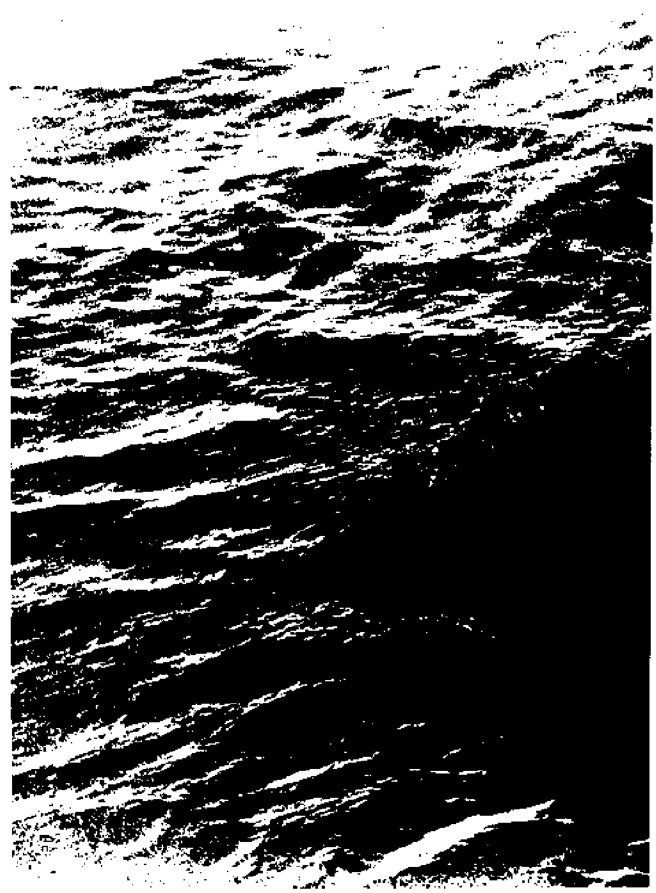
Drift bottles were released periodically from ships to determine the direction and rate of water movement in the western Gulf. Evidence for seasonal variations in general current directions were obtained in these studies. Data also indicate that very complex and variable currents exist in shallow coastal waters. ***These and other current studies show that tar originating in the Mexican seep zones off the Yucatan Peninsula and Laguna Tamiahua can drift northward to Texas and Louisiana beaches.***

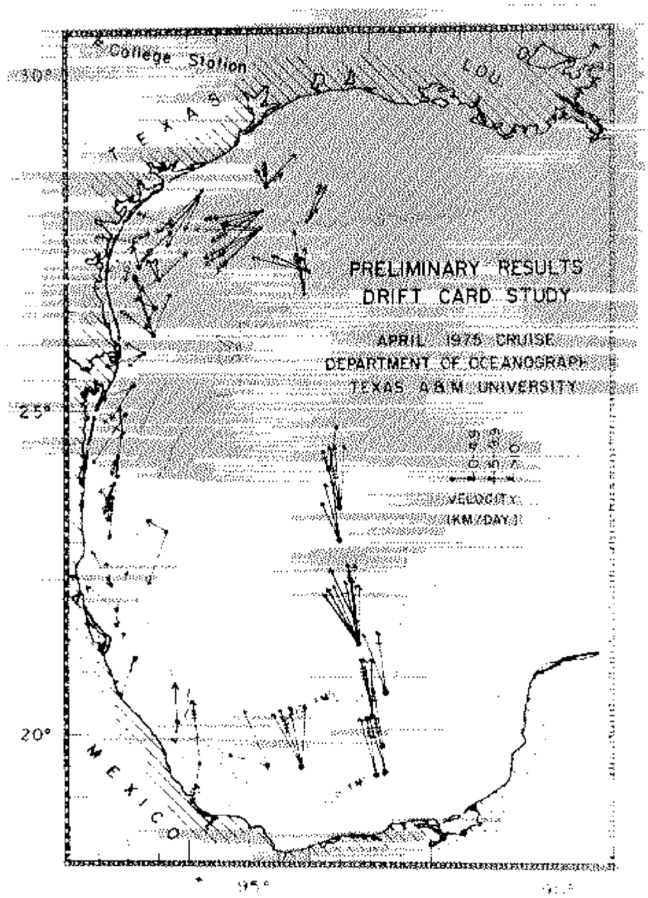
Different types of tar in various concentrations extending over 135 miles of the beach from Brownsville to Sabine suggest a constant and significant source. ***The concentration of shipping along the southern coast of Texas is not sufficient to supply the amount of tar observed. Therefore, it is suggested that the seepage of natural hydrocarbons is the primary source of this material.***

In April 1975, a major plankton bloom associated in a large wind row was observed from R/V GYRE south of Corpus Christi, Texas. Along with the seaweed, plankton, and tar, litter from man's activities was observed in the water. Flying fish, dolphin fish and Portuguese men-of-war were found in the same area.

From a distance, the wind row appeared to be a giant-oil slick. Five gallons of water was taken and net tows were made from the water surface. Microscopic examination of the net tows and extraction of the water sample with benzene showed that the "slick" was just a broth of living organisms and not an oil emulsion.

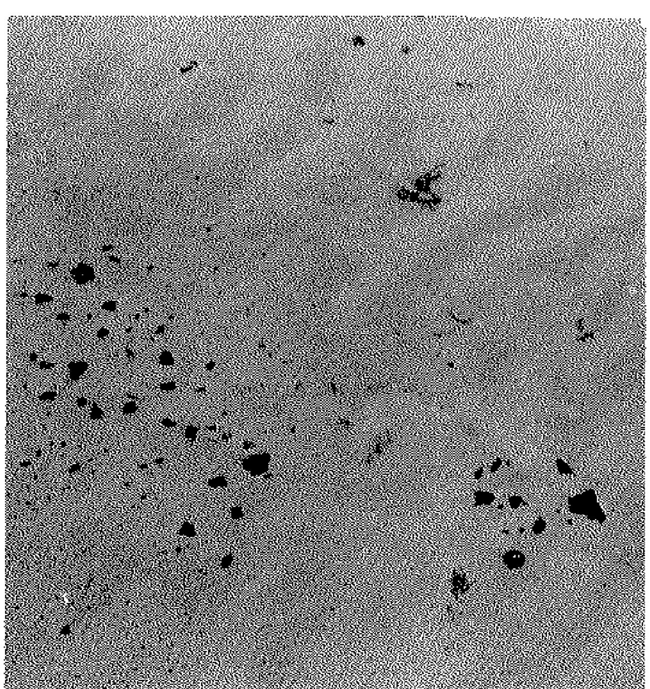
On the July 1975 beach patrol, more dark material was discovered washed on shore. A drift bottle thrown into the water in April as part of the current study was also found. ***Initially, field observers thought they may have found the remnants of an oil spill. Subsequent analysis of the material showed that the apparent "tar mass" was sewage sludge.*** Thus, some of the observations of "oil slicks" in the Gulf or tar masses on the beaches actually may be, for example, areas of thick plankton blooms or other organic debris.

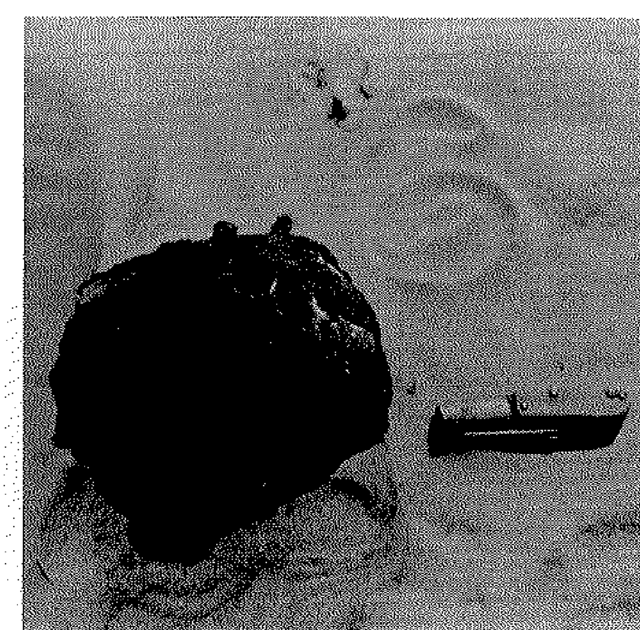




Results of one drift card study.

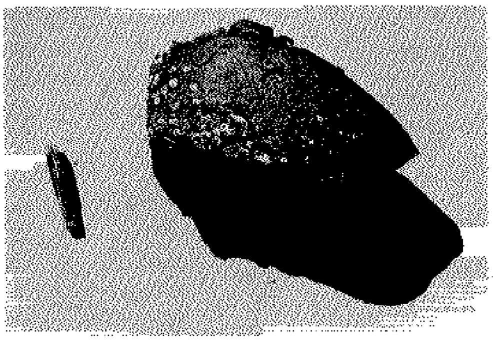
Tar floating in the open ocean.



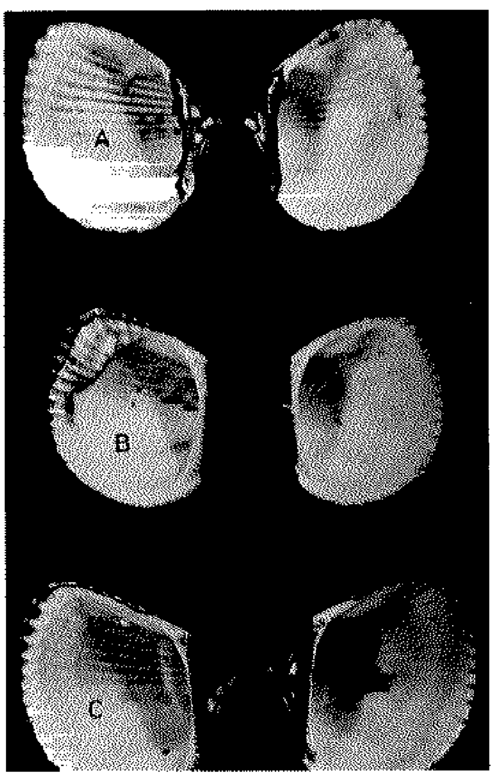


Tars found in all shapes and sizes along the beach.

Organisms associated with tar specimens . . .



. . . *on small tar specimens*



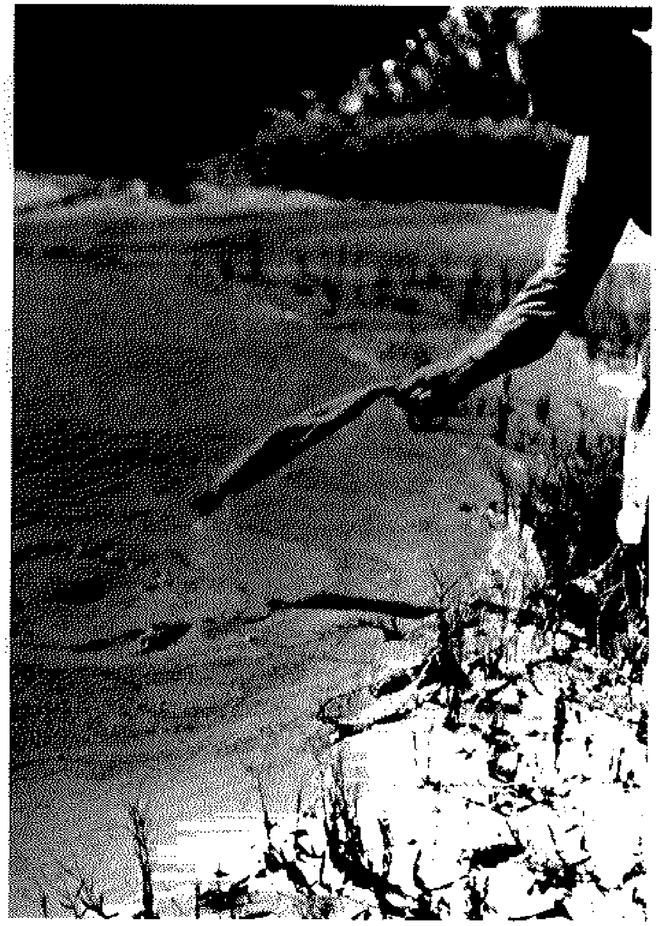
. . . *incorporated into clam shells*

. . . *growing on a tar lump*

. . . *or large tar mats*

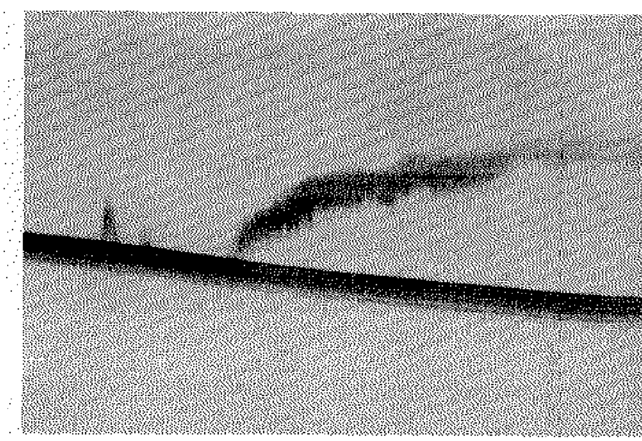
. . . *or growing through a tar lump.*

The Tamiahua oil and gas seep story

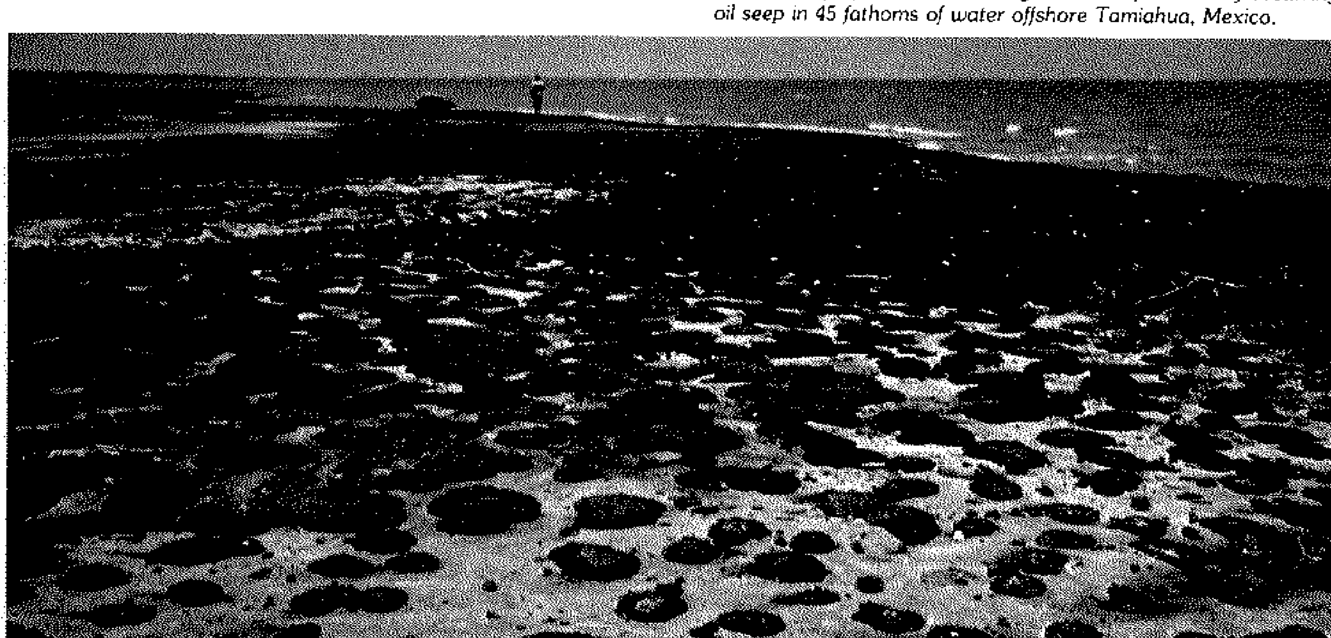


Hydrocarbon seep bubbling up near lagoon shore.

Hydrocarbon residue along shoreline of Laguna de Tamiahua. Also visible is a variety of marine vegetation both onshore and offshore.

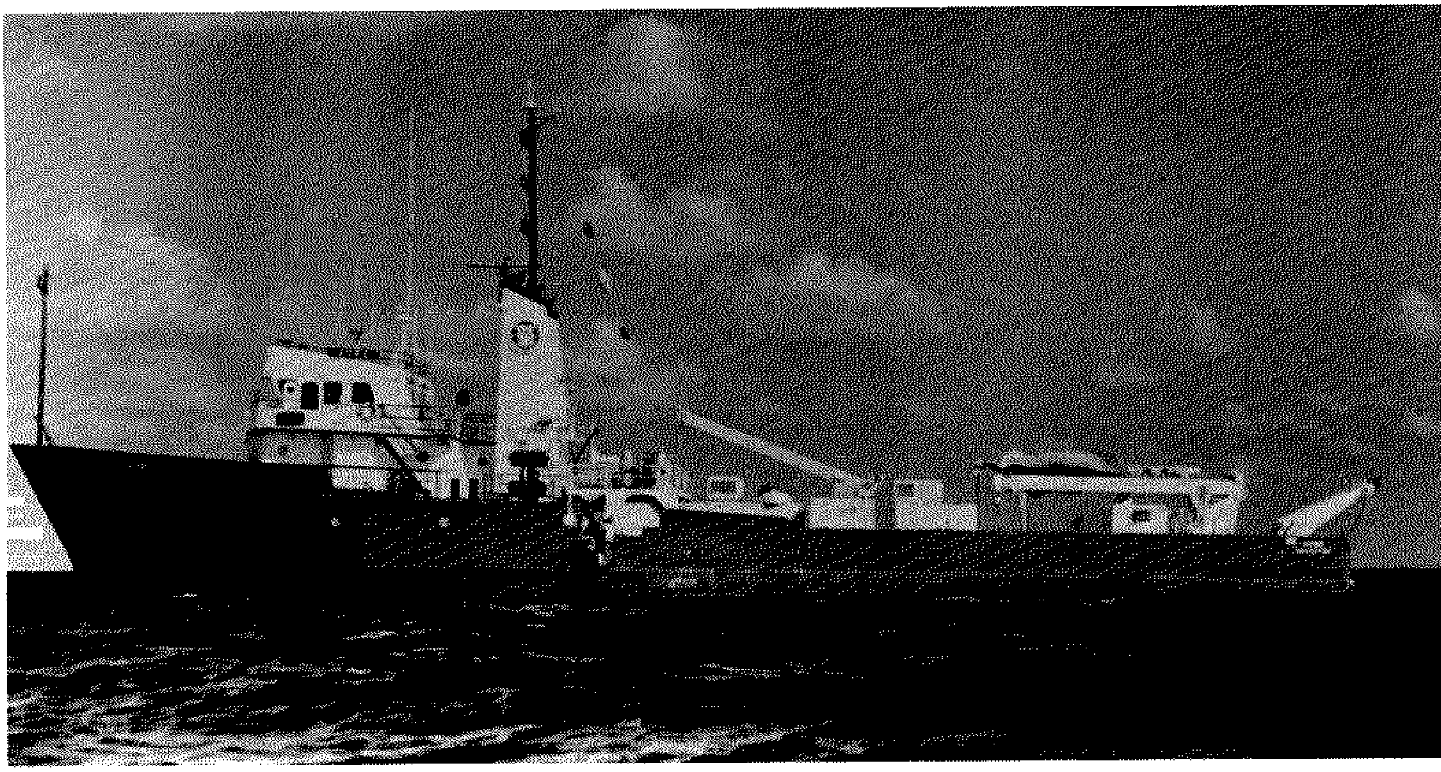


Subbottom profile record showing evidence of a naturally occurring oil seep in 45 fathoms of water offshore Tamiahua, Mexico.



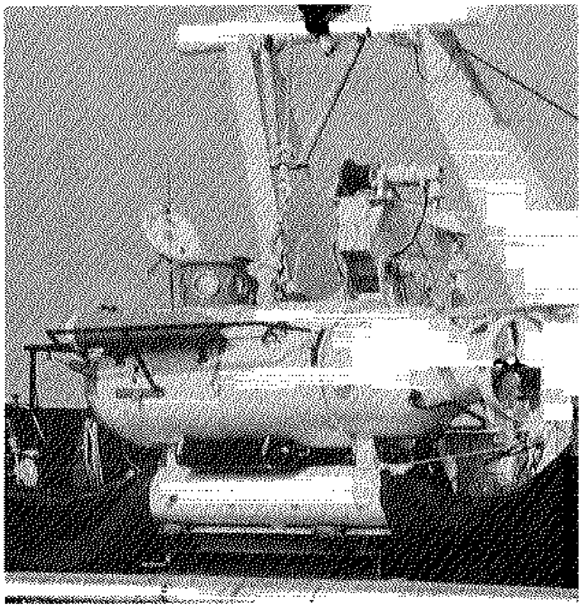
Sand flat area at Laguna de Tamiahua covered with tar from natural seeps.

Searching for hydrocarbons in the marine environment

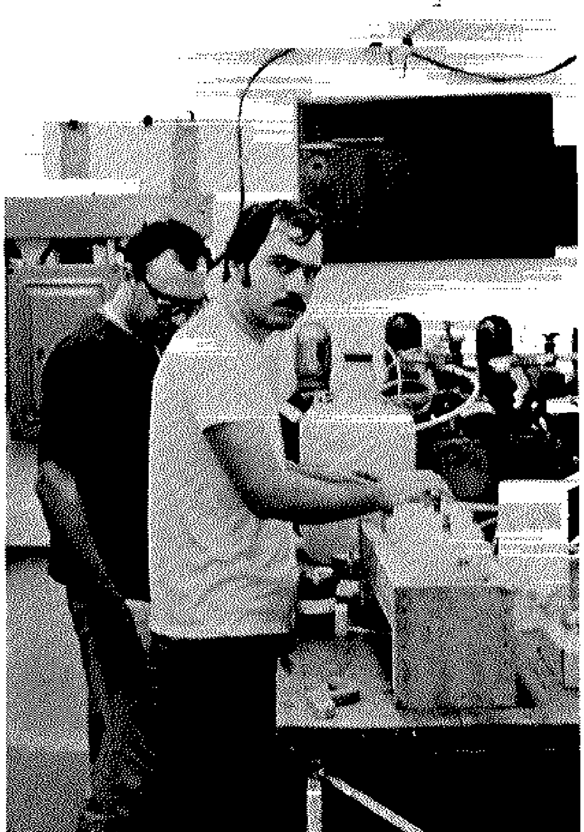


Research vessel R/V GYRE from Texas A&M University. One of several ships used on hydrocarbon collection cruises.

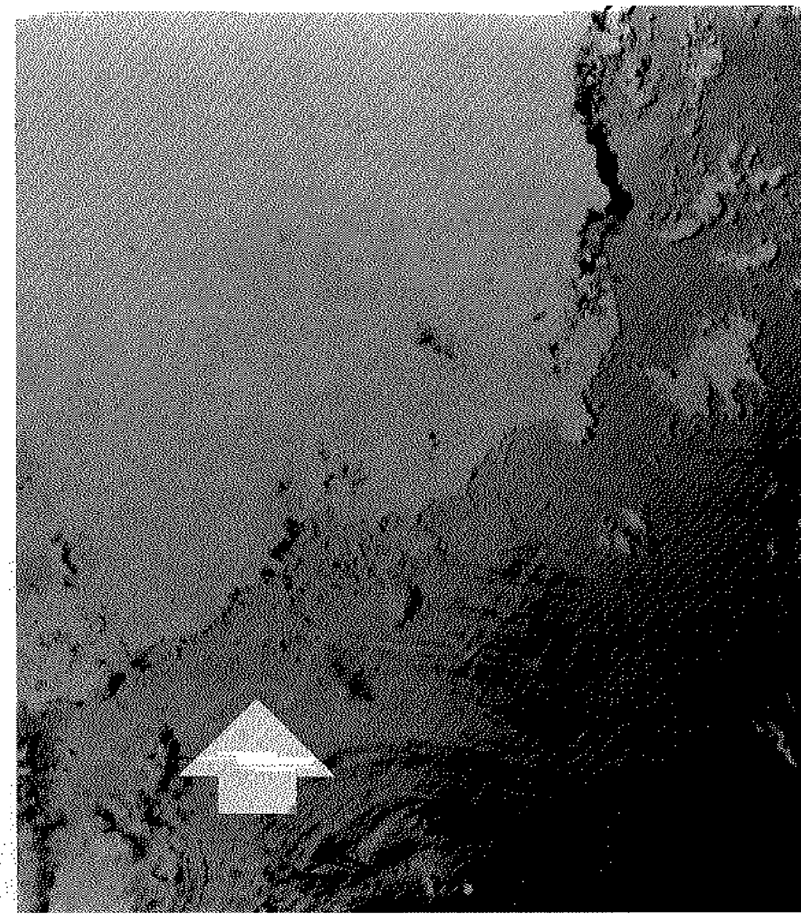
Tar samples were collected among debris and sea weed washed to shore during a seasonal beach patrol from Sabine Pass to Brownsville, Texas.



DRV DIAPHUS being launched off stern of R/V GYRE.



Texas A&M University scientists performing shipboard chemical analysis designed to detect hydrocarbons in the water.



Satellite photo of possible oil slick of undetermined origin in the Gulf of Mexico, 150 miles southeast of the Mississippi River.

DRV DIAPHUS exploring the ocean bottom.

Results of the research program "Naturally Occurring Hydrocarbons in the Gulf of Mexico"

CHEMICAL PROGRAM

Proper assessment of the components comprising the "hydrocarbon load" now carried by the oceans, defined as the proportions contributed by nature and by man, requires a reliable estimate of the rate of seepage from marine seeps. ***A major objective of this program was first to chemically analyze and categorize floating tars and tar-like substances obtained from the Gulf of Mexico, as well as from the beaches; and then to correlate them with their origin.*** The composition of petroleum is so complex that a single chemical diagnostic characteristic cannot be considered as definitively identifying it. The problem is further complicated by the severe physical, as well as chemical alteration to which tars are subjected after they enter the environment.

The method used in this research program was to employ diagnostic techniques standard to the petroleum industry, evaluate the results, and then either adopt the test on a routine basis or abandon it. If a petroleum residue is collected in a few days, or even up to 30 days for some materials, after it enters the marine environment, it can be relatively simple to identify its source. This assumes a library of information on properties of all possible sources is available. Matching the oil residue with the source is generally done by a chemical technique known as gas chromatography. A multiple-test can also be used requiring several chemical tests to study diagnostic properties of hydrocarbons. Identification of nitrogen, sulfur, oxygen or trace metals are a few typical tests that might be performed.

After a crude oil, fuel oil, or crude oil sludge has been in the marine environment for some months marked changes can occur in some of its initial properties. The extent of these long-term changes has not been studied adequately to the point where definite results can always be obtained. Scientists have identified some natural processes affecting the fate of oil on the sea, such as evaporation, mechanical transport by wind, tide and currents, true dissolution, and dispersion, bacterial action, formation of oil-in-water emulsions, and absorption by particles in the water. But there is still a special need for additional study of long-term weathering effects to determine which processes cause the greatest change in the chemical characteristics of oil, tar and gas in water.

Table II. Examples of Evaporation Losses of Various Crude and Fuel Oils in Outdoor Sea Tanks at College Station, Texas After 6 Weeks

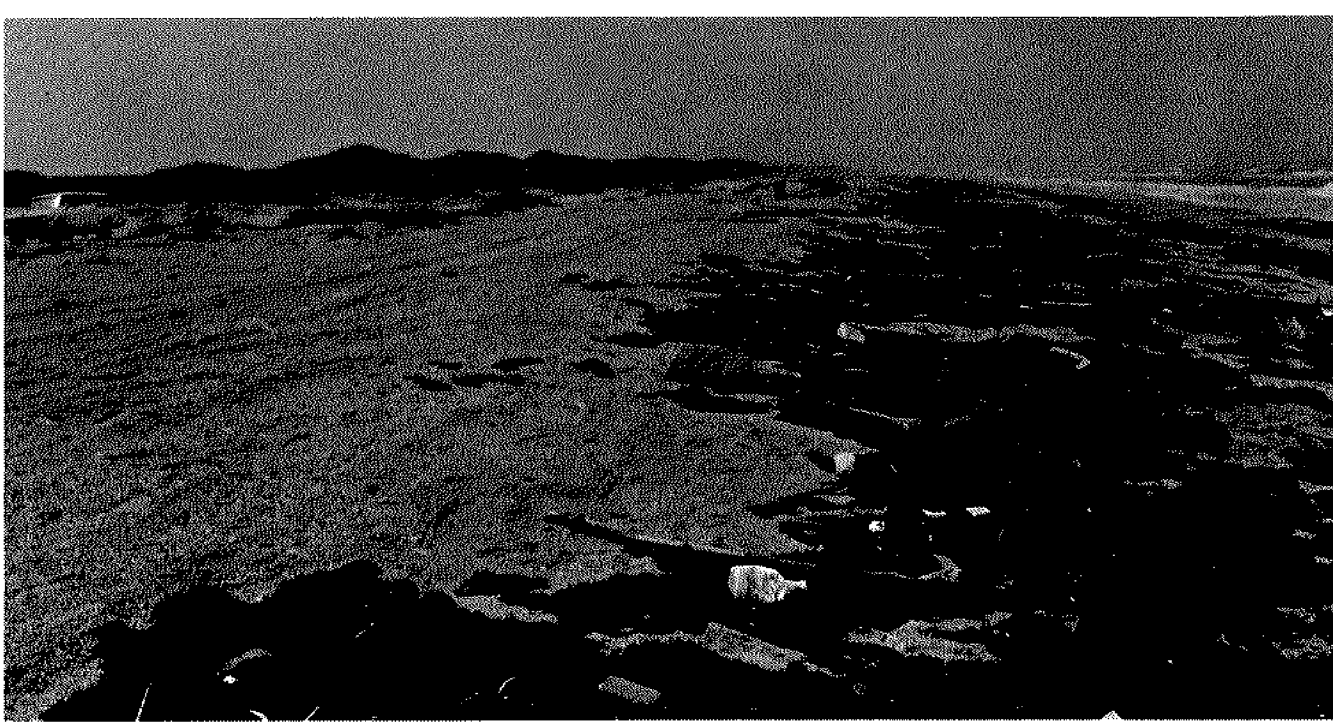
Oil	*% lost by evaporation in 6 weeks*
Gulf Coast Miocene Oil	77.9
Gulf Coast Pliocene Oil	61.7
Venez. Cretaceous Oil	38.1
Venez. Paleocene Oil	22.1
Kuwait Oil	39.0
Coal Oil Point Seep Oil	15.0
Venezuelan Crude	63.2
East Cameron Block Oil (Gulf Coast)	58.0
Gulf Coast Chevron	63.9
Bunker C Fuel	5.0
Exxon Fuel Oil	24.5
Diesel Fuel	65.0

One interesting result of this research program is that the soft beach tars collected from Sabine Pass to Brownsville, Texas have almost identical gas chromatograms. But these differed significantly from chromatograms obtained from hard asphaltic beach tars. An idea of the accuracy of this method is demonstrated by the fact that samples collected over this distance of about 150 miles could yield such identical gas chromatograms.

At first it was thought the soft tars might be the re-

This material, thought to be tar on the beach, was analyzed and found to be sewage sludge—not tar.

Plankton bloom and heavy seaweed concentration in Gulf of Mexico as observed from R/V GYRE, near Corpus Christi, Texas.



Seaweed and litter observed at sea was found washed up on a South Texas beach 3 months later.

sult of repeated Bunker C fuel oil spills. But when chromatograms of some Bunker C fuel oil and some weathered Bunker C oil were compared with those of the soft beach tars, the similarity was very poor between the Bunker C and soft tars. ***This indicates that the soft beach tars had some other heavy crude oil origin — possibly from an oil seep.*** Table III below shows a few of the properties of selected samples determined by chemical analysis.

Table III. Summary of Sulfur Content of Floating and Beach Tars in the Gulf of Mexico Area

General Location	No. of Samples	Average % Sulfur	% Sulfur > 3% Sulfur
S. Texas 10 Fathom Floating Tars, Aug. 1974	19	3.64	68.5%
Previous Gulf Floating Tars	69	1.36	6.0%
Trans-Atlantic; Floating Tars	20	1.49	5.0%
S. Texas Beach Tars, Aug. 1974	37	4.08	94.6%
Previous S. Texas Beach Tars	70	3.53	46.0%
Galveston Beach Tars	34	1.55	6.0%
West Florida Beach Tars	51	1.34	2.2%
Mexican Beach Tars	8	4.89	100.0%
Bottom Tars of S.W. Gulf of Mexico	12	6.10	100.0%

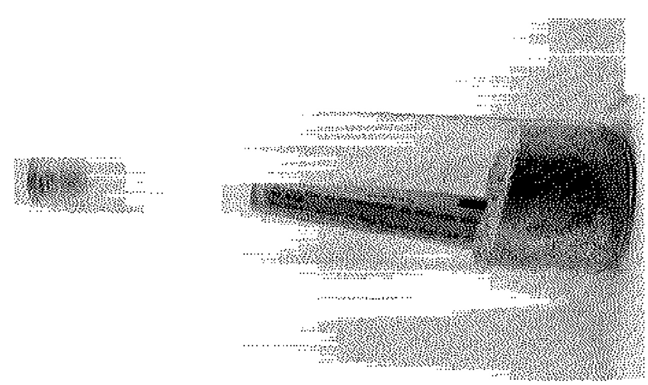
The hard, dense, asphaltic beach tars are also found all over the bottom of the Gulf of Mexico — even away from shipping lanes. Their wide distribution again suggests that they may originate from tar seeps within the Gulf.

In 1974, an Oil Seep Program study involved collection and analysis of floating tars from the equatorial Atlantic. Fifty stations were sampled, but only 20 had any measurable tar. The calculated average tar concentration was 1.20 mg/m^2 for this particular cruise. These Atlantic tars had a low average sulfur content of 1.49% comparable to the sulfur content of the floating tars of the Gulf of Mexico and Caribbean. Gas chromatography of the trans-Atlantic tars showed that about half the tars might be fuel oil residues.

As a result of these and previous studies of environmental tars, it may be concluded that a unique source or sources of high sulfur and high vanadium content oils exists within the Gulf of Mexico and Caribbean system. These could originate, for example, from seeps in the southwest part of the Gulf of Mexico. The residues from this source or sources are washed up on the south Texas beaches in late summer, when the current regime causes tars to be transported from these areas. (See drift card study, page 7.)

The average floating oil residue in the Gulf varies with weather conditions. For calm seas, floating tar in the Gulf averaged 1.46 mg/m^2; for rough seas the concentrations were lower due to turbulent mixing, 0.04 mg/m^2. Using 1.46 mg/m^2 as the maximum average concentration of floating tar yields approximately 2330 metric tons for the Gulf of Mexico (area of 1,602 x 10^{6}km^2). For the Caribbean (area of 2.64 x 10^{6}km^2) the amount floating at any one time is calculated to be 2640 metric tons assuming 0.98 mg/m^2 concentration. ***For comparison, the Mediterranean (area of 2.93 x 10^{6}km^2) has an estimated floating tar concentration of 50,000 metric tons. This is almost 20 times that in the Caribbean and/or Gulf of Mexico.***

The values for total tar in these areas are based on certain assumptions, and the floating concentrations change from time to time. However, the point to consider is that the oil residues in the Gulf of Mexico and Caribbean are substantially less compared with those found in the Sargasso Sea and especially the Mediterranean.



Drift card and container used in current survey.

No. 4495

R E W A R D

PLEASE FILL IN INFORMATION AS INDICATED, AND SEND BY MAIL

Sea Grant Natural Oil Seep Project Texas A&M University
Projecto sobre la filtracion del aceite de petroleo natural

Place card found
Lugar en que encontro la trajeta ....

Date card found
Fecha en que encontro la trajeta ....

Name & Address of finder (Nombre y direccion de quien encontro la trajeta)

NAME (Print) ....

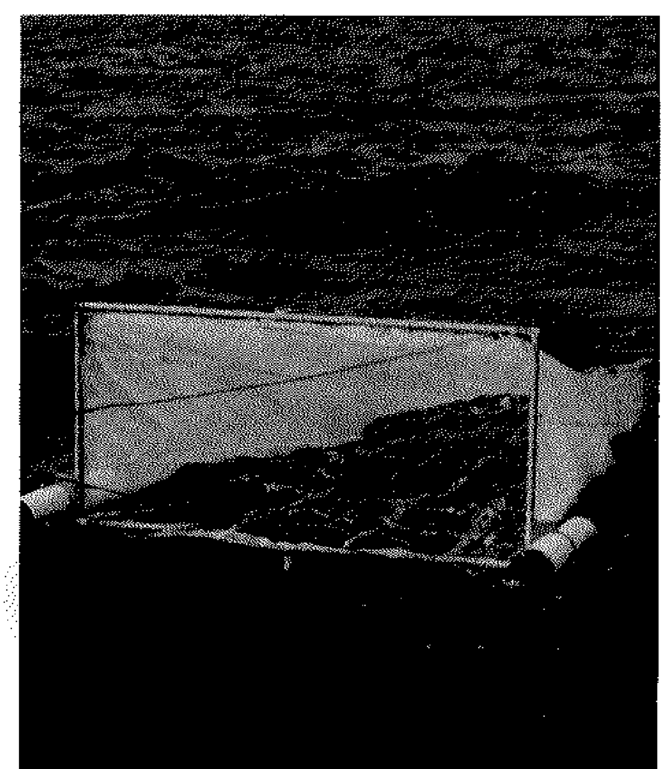
ADDRESS (Print) ....

Nominal reward for return.
Nominal recompensa para quien la devuela.

BIOLOGICAL PROGRAM

The Texas A&M University submersible DRV DIAPHUS has been active for the past several years in an extensive interdisciplinary research program to study naturally occurring hydrocarbons in the Gulf. Earlier, surface vessels carrying bottom profiling equipment and gas "sniffers" were used for the reconnaissance portion of this program. An illustration of naturally occurring gases emanating from a seep on the ocean floor, obtained by a seismic sub-bottom profiler, is shown on page 16. However, the submersible was needed to investigate at first-hand, the geology and biology of the areas surrounding the hydrocarbon seeps.

It was determined from submersible observations, that streams of bubbles coming from the sea-floor, flow out sporadically rather than continuously. This is an important factor in determining the accuracy of estimates of the total amount of gas escaping from the bottom. ***Another important advantage of using a submersible in the study was to document with still and motion picture cameras the reaction of fish to these upward migrating gas bubbles. It became evident that they were not adversely affected by the gas; and appeared to be oblivious to the presence of the bubbles.***



Net for collecting floating surface tars.

Attempts were made in the earlier phases of this program to study the gas bubbles using a television camera trailing over the side of the ship. However, the results obtained in this manner did not yield the quantitative results achieved using DRV DIAPHUS. ***The results from submersible operations such as these can be used to reach meaningful decisions with regard to promulgating more realistic oil and gas production regulations, as they pertain to the effect of hydrocarbons on the environment.***

GEOLOGICAL ASPECTS OF HYDROCARBON SEEPAGE

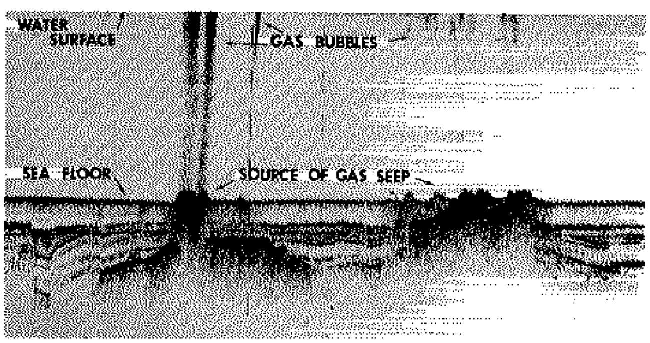
Marine hydrocarbon seeps are almost always found in sedimentary rocks, although seeps are found in different geologic formations all over the world. Comparison of the onshore and offshore seep frequency data with a worldwide seismic map shows a strong relationship between areas of high seepage and deformed areas of the earth's crust. A correlation does not exist between the size of commercial petroleum reserves and degree of seepage activity, but rather between the type of geologic structure and seepage activity. This means that all seepage areas are not necessarily commercial petroleum producing provinces. For example, despite extensive seepage in the northern half of Cuba, comparatively little commerical hydrocarbon reserves have been found.

Hydrocarbon seepage by its very nature implies that there is a physical conduit of some kind connecting the petroleum reservoir with the surface. A study of seismic records containing evidence of gas seeps shows a close association with a geologic phenomenon known as "faulting". It is a shifting of the near-surface rocks of the earth that can create a pathway or conduit through which hydrocarbons can readily migrate upward.

In the Gulf of Mexico, hydrocarbons can also seep up through older sediments as they are compressed by younger overlying ones. It was proposed by Sweet, formerly associated with this research program, that hydrocarbon migration toward the surface during the compaction of sediments may be the major source of material comprising tar balls found floating in the ocean. ***Many tar balls and tars have been dredged up from near-surface sediments in the Gulf of Mexico, or found in geologic core samples taken on the Sigsbee Knolls. Similar evidence is***

present in the southern Caribbean. Considering the volume and surface area of sediments in the Gulf of Mexico, ***one can conclude that seepage or oozing occurring in small amounts locally can spread over wide areas of the Gulf and Caribbean. These comprise the predominant source of tar, floating on the Gulf, on its beaches, and within and on the sediments of the bottom of the Gulf.*** There is no logical reason why this constant oozing should not be occurring worldwide under similar geological and oceanographic conditions.

Active gas seeps were located from evidence in the water column portion of the sub-bottom seismic profiles as seen below. In addition, bubbles were visually sighted from the surface and were recorded on video tapes. ***These video tapes also showed several different species of fish swimming through the gas bubbles.***



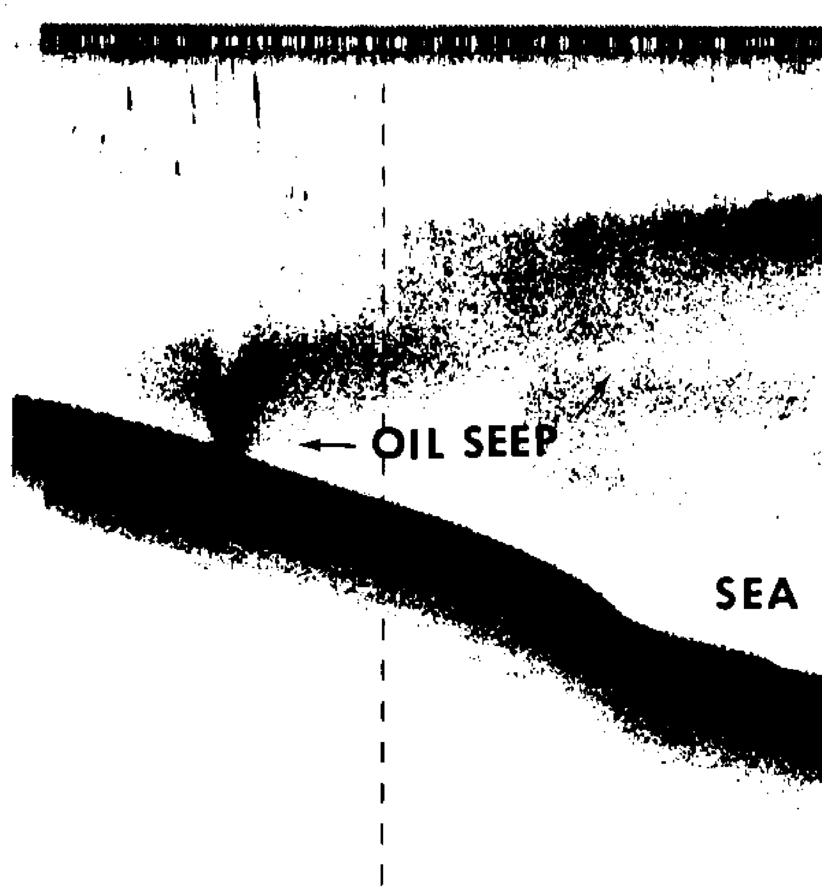
Gas seeps associated with salt domes in the northern Gulf of Mexico.

Gas coming from sea floor around a coral reef off the Texas coast.

CONCLUSIONS

Historical and contemporary data indicate that hydrocarbon seepage has been, and is, occurring in the Gulf of Mexico and elsewhere in the petroleum provinces of the world. It has proven difficult to pinpoint oil seeps in deep water areas of the Gulf, although many areas having anomalous concentrations of hydrocarbons in the water column are recorded on sub-bottom seismic profiler records. They have also been detected and analyzed with chemical "sniffers". These seeps occur at times even at considerable distances from commercial production. ***However, along the coast south of Tampico, Mexico, the oil seeps are conspicuous; and all available information also indicates active oil seepage has, and still exists in the northern Gulf.*** (See page 9.)

Emphasis in the Texas A&M Naturally Occurring Hydrocarbon Research Program was placed on studying the chemical composition, the quantity and distribution, as well as the biological effects of liquid, gaseous, and tarlike hydrocarbons found in the Gulf of Mexico. However, the basic issue with



Evidence of naturally occurring oil seep in Gulf of Mexico on a seismic subbottom this or any similar study is not only "how much" and "where", but "what is the total effect" on the environment.

Investigators have described in general terms the manner in which petroleum interacts with the rest of the marine environmental system. However, the ability to evaluate the specific effects of hydrocarbons, especially quantatively, is in its early stages. It is also difficult to predict accurately the complete chemical behavior of specific hydrocarbons. ***But, based on the results obtained from these studies of naturally occurring hydrocarbons, it is reasonable to state that a low intensity, persistent introduction of hydrocarbons over thousands of years into an ecosystem has not been deleterious to the marine environment.*** An ecosystem influenced in this manner can continue to be biologically active and should not be considered to have been irreparably harmed. Therefore, future marine pollution by petroleum hydrocarbons appears to be less of a problem than that caused by other materials of concern today.

profile record

Acknowledgements

This publication reflects the results of the substantial assistance and counsel provided throughout the past eight years by many Texas A&M University faculty, staff and graduate students. It is with sincere appreciation that their individual and collective contributions are acknowledged here; especially those of Drs. William Sweet, Lela Jeffrey, Thomas Bright, William Sackett, William Hottman*, Dan Taylor*, James Ray*, Richard Yuill*, Anton Bautz*, Anthony Tinkle*, Robert Abbott*, Lloyd May*, Donald Frank*, and Bernard Eadie*; as well as Anton Vos, Norma Powell, Dorothy Hogg*, and Hussein Abdul-Reheim.

In addition, the diversified activities of Dr. Charles P. Giammona in various phases of the preparation of this publication are gratefully acknowledged; and especially for the comprehensive review of the voluminous material in text and photographic form available from this program to aid in selecting possible items for use in this report.

Appreciation is also expressed to the private and government sources that contributed to the support of this program over the years, including Atlantic Richfield Company, Chevron Oil Company, Cities Service Oil Company, Columbia Gas Company, Continental Oil Company, EXXON Company, U.S.A., Gulf Oil Company—U.S., Marathon Oil Company, Mobil Oil Corporation, Pennzoil Company, Phillips Petroleum Company, Sun Oil Company, Superior Oil, Tenneco Oil Company, Texaco Inc., Shell Oil Company, Texas A&M University Sea Grant Program and the U.S. Coast Guard.

RICHARD A. GEYER

*Denotes those whose dissertations and/or theses were supported financially in whole, or in part, by this research program.

Summary listing of theses and dissertations

I. Author	Thesis title, date
ABBOTT, Robert Edward	*The Faunal Composition of the Algal-Sponge Zone of the Flower Garden Banks, N.W. Gulf of Mexico.* May, 1975
HOGG, Dorothy Mae	*Formation, Growth, Structure and Distribution of Calcareous Algal Nodules on the Flower Garden Banks.* Aug., 1975
MAY, Lloyd Alexander	*Chemical Characteristics of Beach Asphalts.* Dec., 1973
TINKLE, Anthony Robert	*Natural Gas Seeps in the Northern Gulf of Mexico, A Geological Investigation.* Dec., 1973
YUILL, Richard Matthew	*The Distribution of Estuarine Benthic Invertebrates in the Vicinity of a Natural Asphalt Oil Seep in Laguna de Tamiahua, Mexico.* Dec., 1973

II. Author	Dissertation title, date
BAUTZ, Anton Frank	*Long Range Weathering Effects on the Chemical Properties of Two Venezuelan Crude Oils.* Aug., 1974

Bibliographical note

Available upon request is a bibliography dealing with naturally occurring hydrocarbons in the marine environment cited in this report.

To obtain a copy, please write to:

DR. RICHARD A. GEYER
Professor of Oceanography
Department of Oceanography
Ocean Hydrocarbon Research Study
Texas A&M University
College Station, Texas 77843

Photo credits

Outside Front Cover / Dr. T. J. Bright, Oceanography Department, Texas A&M University.

Inside Front Cover (top)/ *Cannibal Coast* by Ed Kilman, Naylor Company, San Antontio, Texas, 1959.

Inside Front Cover (bottom) / Pottery from Texas State Museum, Austin, Texas.

Page 1 / Dr. T. J. Bright, Oceanography Department, Texas A&M University.

Page 2, Table I / Dr. L. M. Jeffrey, Oceanography Department, Texas A&M University.

Page 2, Figure / J. C. Soley, "The Oil Fields of the Gulf of Mexico", *Scientific American Supplement*, number 1788, April 9, page 229, 1910.

Page 3, Figure (left) / "U. S. Geological Survey Bulletin", number 212, Series A, *Economic Geology*, 23, page 105, 1902.

Page 3, Figure (right) / *Streak O' Lean and Streak O' Fat* by Joe Vincent, Vantage Press, 1953.

Page 5 / File photo, Oil Seep Program.

Page 7 (upper and lower right, lower left) / File photos, Oil Seep Program.

Page 7 (upper left) / Drs. W. E. Hottman and R. A. Geyer, Oceanography Department Texas A&M University.

Page 7 (upper and lower right, upper left) / File photos, Oil Seep Program.

Page 8 (middle left) / Peter L. Perharde, Trinidad Ltd., Trinidad, W. I.

Page 8 (lower left) / Marine Pollution, edited by R. Johnston, page 360 Academic Press, 1976.

Page 9 / File photos, Oil Seep Program.

Page 10 (top) / File photo, Department of Oceanography, Texas A&M University.

Page 10 (bottom) / File photo, Oil Seep Program.

Page 11 (upper left) / *Submersibles and Their Use in Oceanography and Ocean Engineering*, Edited by R. A. Geyer, Elsevier Scientific Publishers, Amsterdam, 1977.

Page 11, (upper right) / NASA

Page 11 (lower left) / Dr. W. Sackett, Department of Oceanography, Texas A&M University.

Page 11 (lower right) / Dr. T. J. Bright, Department of Oceanography, Texas A&M University.

Page 12, Table II / Dr. L. M. Jeffrey, Oceanography Department, Texas A&M University.

Page 12 / File photo, Oil Seep Program

Page 13 (top) / File photo, Oil Seep Program, courtesy Dr. W. E. Hottman.

Page 13 (bottom) / File photo, Oil Seep Program.

Page 14, Table III / Dr. L. M. Jeffrey, Oceanography Department, Texas A&M University.

Page 14 / File photo, Oil Seep Program.

Page 15 / File photo, Oil Seep Program.

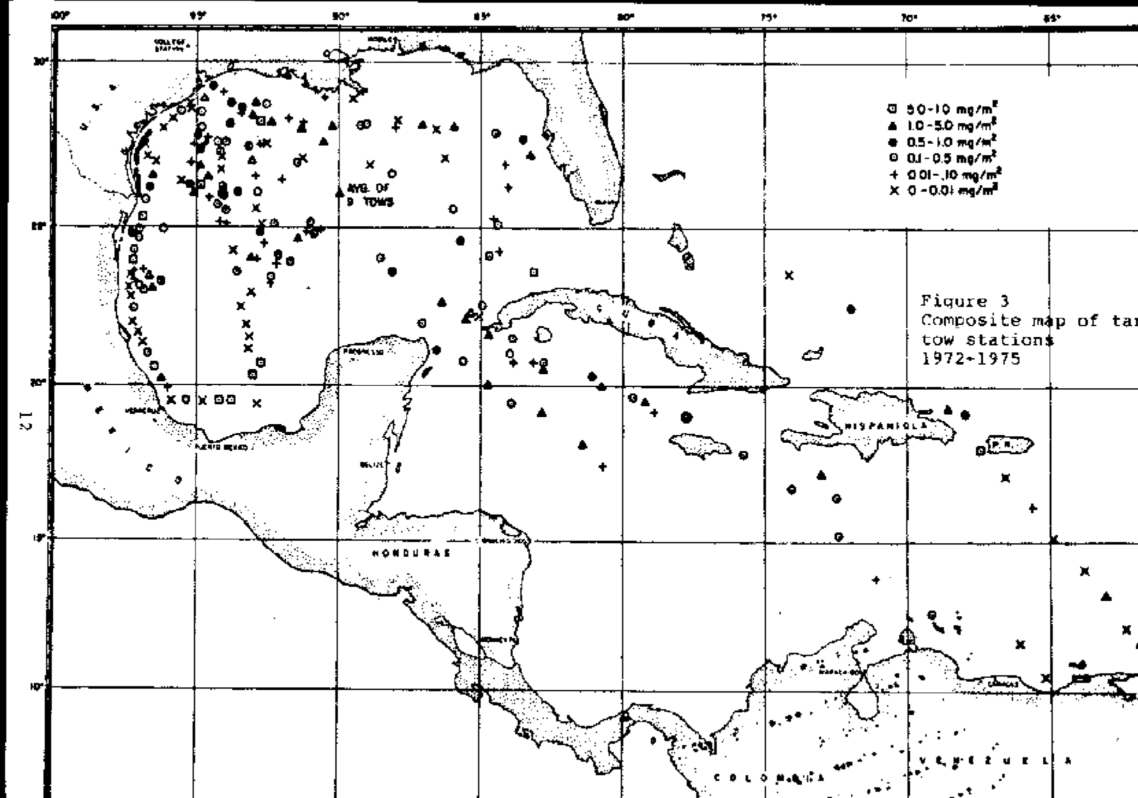
Page 16 (top) / File photo, Oil Seep Program.

Page 16 (bottom) / Dr. T. J. Bright, Department of Oceanography, Texas A&M University.

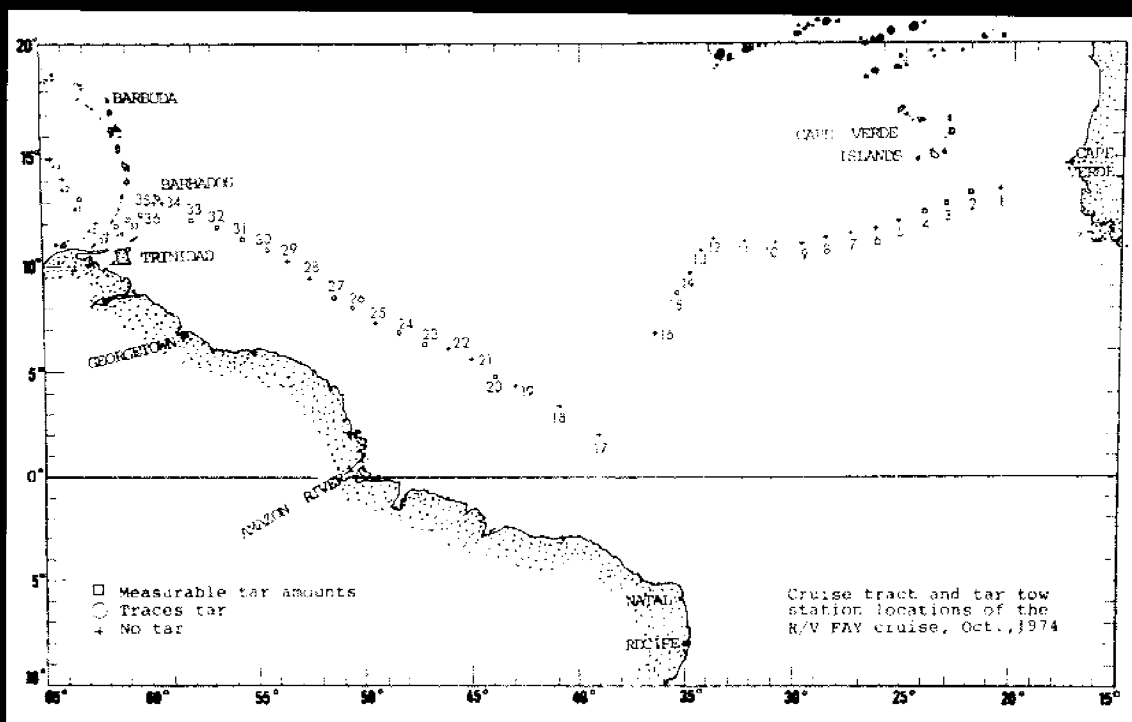
Page 16-17 / Oil seep profiler picture, Prof. T. K. Treadwell, Department of Oceanography, Texas A&M University.

Back Cover (outside) / Wilson, et. al. "Natural Marine Oil Seepage", *Science*, 184 (4139): 857-865, 1974.

Back Cover (inside) / Dr. L. M. Jeffrey, Oceanography Department, Texas A&M University.



Composite charts of tar tow stations from the Gulf, Caribbean, and tropical Atlantic.



Department of Oceanography