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HYDROTHERMAL PETROLEUM GENESIS

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EXECUTIVE SUMMARY

Petroleum-like products are being generated at active ocean spreading centers as a result of naturally occurring thermal processes. The predominant control in hydrothermal petroleum genesis is temperature (150°C-350°C^{+}), where as time is a major control in geothermal petroleum genesis.

Hydrothermal petroleum production can in essence be called an "instantaneous" process. This is because generation times are tied closely to the magmatic processes (magma bodies, sill intrusions, and thermal water convection) operating at spreading centers. The temperatures generated have the effect of thermally cracking sedimentary organic matter into petroliferous products. Although the physical setting (spreading center with sediments) is fairly unique, it demonstrates that the thermogenic characteristics of active spreading centers provides a mechanism for the conversion of immature organic matter to petroleum-like products. Once generated, the petroleum is then removed by hydrothermal convection and diffusion through permeable sediments and along fault zones, followed by condensation at the seabed.

The type of organic matter incorporated into sediments is an important consideration in petroleum formation. The quality (hydrogen and lipid content) and quantity, as well as the diagenetic history of the organic matter, all play a role in the chemical composition of the final product. Marine source material is more desirable than terrestrial (higher plant) sources. Marine organic matter has a higher hydrogen content (desirable) and is more easily converted to petroleum than terrestrial organic matter. Recently deposited sedimentary organic matter undergoes diagenesis (microbial transformation, chemical rearrangements etc.). The end result is that the organic matter is in a chemical state that can then be converted to petroleum with increasing temperature.

The Guaymas Basin, Gulf of California is an excellent example of an ocean hydrothermal system that is generating petroleum-like products. Organic geochemical analysis of samples from the Guaymas Basin yields

information concerning the composition, the thermal origin, as well as the similarities and differences of hydrothermal petroleum to geothermal petroleum.

The products in the Guaymas Basin are generated from the thermal alteration of immature organic matter. The evidence of a thermogenic origin includes: (1) composition and stable carbon isotope data of interstitial gas; (2) the presence of gasoline-range hydrocarbons (and odorous compounds); (3) the relative amounts of aromatic (unsaturated hydrocarbons with at least one benzene ring)/naphthenic (saturated hydrocarbon rings) and asphaltic material versus straight chain hydrocarbons: and (4) the broad distribution of complex hydrocarbons.

The hydrothermal petroleum in the Guaymas Basin is derived from a high temperature pyrolysis process (150-350°C). The evidence for this process and not one of normal petroleum genesis (150° max) includes: (1) the presence of olefins (unsaturated hydrocarbons with double bonds), (2) large amounts of asphaltic material, and (3) the presence of polynuclear aromatic hydrocarbons.

Hydrothermal petroleum has both similarities and differences with reservoir petroleum. The similarities include: (1) gasoline-range hydrocarbons, (2) a full range of N-alkanes (saturated, straight chain hydrocarbons), (3) naphtheric hump (complex, unresolvable hydrocarbons) (4) pristane and phytane significant (biological fingerprints), and (5) stabelized molecular markers (chemically mature molecular fingerprints). The differences with reservoir petroleum include: (1) alkene content (olefins--double bond, unsaturated) (2) polynuclear aromatic hydrocarbons, and (3) immature molecular markers present.

The hydrothermal systems of ocean spreading centers are areas where significant energy resources are being discovered. Polymetallic sulfide ores, thermal waters with temperatures up to 350°C, diverse and abundant biota, and hydrothermal petroleum generation have all been documented. Serious consideration should be given to any or all aspects of ocean hydrothermal energy technology.

I. INTRODUCTION

This report presents a general overview into the genesis of petroleum-like products resulting from naturally occurring thermal processes at active oceanic spreading centers. The predominant control in hydrothermal petroleum genesis is temperature (e.g., 150°C- 350°C+). This is in contrast to geothermal petroleum processes where formation temperatures are 50-150°C (peak generation) and where "time" is an all-important parameter.

Hydrothermal petroleum can in essence be called an "instantaneous" process, with generation times tied closely to the magmatic processes occurring at the oceanic spreading centers. The temperatures generated in these areas have the effect of pyrolyzing (thermally cracking) sedimentary organic matter into smaller molecular weight compounds, which are then transported to the seabed by hydrothermal fluids and advection/diffusion. It should be noted that the formation of commercial amounts of petroleum at active oceanic spreading centers requires the deposition of sediments which contain organic matter of sufficient quantity and quality. Although this physical setting is fairly unique (e.g., Guaymas Basin, Gulf of California), it demonstrates that the thermogenic characteristics of active spreading centers provides a mechanism for the conversion of immature organic matter to petroleum-like products.

II. PHYSICAL ENVIRONMENT AND THERMAL PROCESSES

Hydrothermal petroleum genesis from an active oceanic spreading center can be illustrated by using the extensively studied Guaymas Basin, Gulf of California as an example. Guaymas Basin is a ridge-crest hydrothermal system with a sediment cover and a maximum water temperature measured at 315°C at 200 atmospheres (Simoneit, 1983). The process of ocean plate accretion results in high conductive heat flow (average 1.2 Wm^2) and dike and sill intrusions into unconsolidated sediments. Sediment accumulation is approximately 1-4 m/1000 years and sediment thickness is ≤500 m. (Curray et al., 1979, 1982). The most recent tectonic activity, inferred from seismic evidence and heat flow data, ranges in age from approximately

10 years to 18,000 years. (Williams et al., 1979). Leg 64 of the Deep Sea Drilling Project provided conclusive evidence of active hydrothermal vents, polymetallic sulfide ores, diverse and abundant biota and petroleum-like products in the Guaymas Basin.

Petroleum genesis occurs as a result of the thermal alteration of sedimentary organic matter. The temperatures of the intruding dikes and sills, the thermal waters, and also the deeper regional heat sources (magma bodies)--all result in the pyrolyzation of the sedimentary organic matter into smaller molecular weight compounds. Figure 1 shows that with increasing proximity to the sills and with increasing depth (e.g., toward

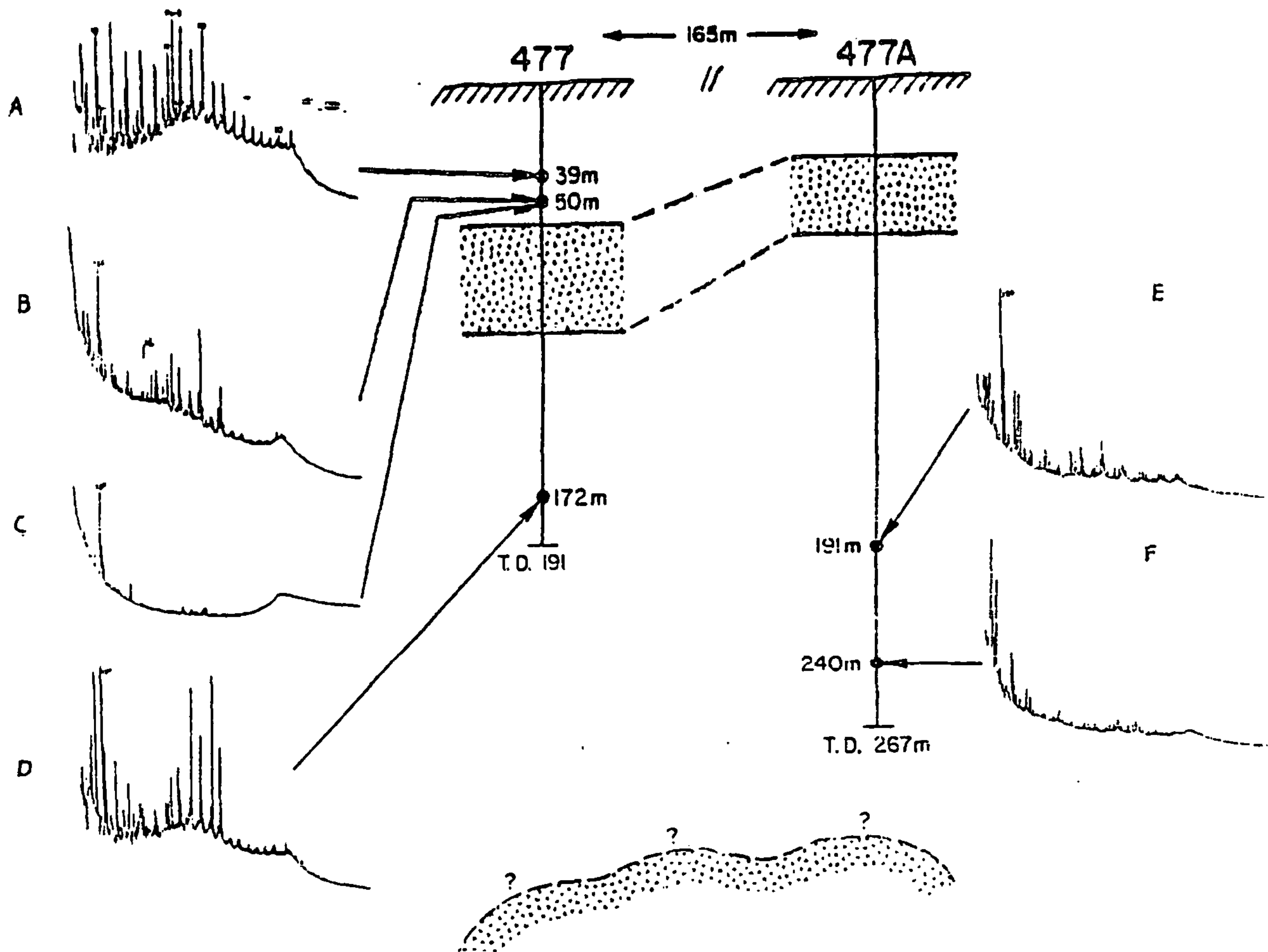

Figure 1. Effects of sill intrusion and deeper heat source on sedimentary organic matter. A, D--Immature, unaltered B, E--Moderate alteration C, F--Severely altered (Simoneit, 1984).

regional heat source), the resulting products give pyrogram traces that appear thermally altered, even though the sedimentary organic matter in the region as a whole is immature.

It appears that the sill intrusions have only a local and lateral thermogenic effect on the organic matter. They probably play a greater role in pore water expulsion and as a source of heat for thermal water generation and convection. The thermal alteration of the organic matter is primarily attributed to the convecting hydrothermal system and deep regional heat sources (oral communication, B. Simoneit, 1984). Thermal vent water has been measured as high as 315°C and there is evidence to suggest that temperatures at the sill-sediment contact may rise as high as 400°C.

1. Hydrothermal minerals present--epidote, chlorite, albite, etc. In ridge-crest geothermal systems, estimated temperatures at which seawater-rock interactions occur are at least 300°C (Einsele et al., 1980).

2. Increase in dissolved chloride, lithium and manganese.

3. C/N ratios approach infinity below 150 m and increase at sill contacts. The removal of organic N is an indicator of thermal stress (see Figure 2).

It has been suggested that the emplacement of sills in the Guaymas Basin leads to the heating and expulsion of pore waters. The heated pore water then reacts with the basalts and surrounding sediments, becoming laden with dissolved minerals and hydrocarbons. Migration occurs vertically and laterally through permeable sediments, eventually traveling along fault and fracture zones to the surface where the dissolved substances are precipitated. This mechanism does not require the recharge by seawater that has been suggested for sediment deficient spreading

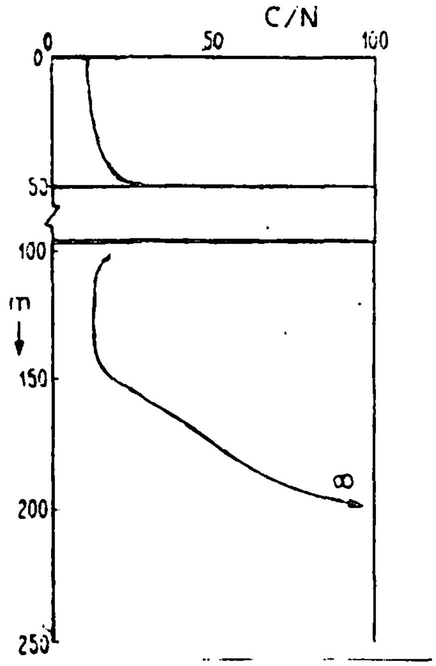

Figure 2. Atomic ratios of organic carbon to nitrogen versus depth.

centers. (Einsele et al., 1980.) Figure 3 gives a general overview of a hydrothermal system operating in the Guaymas Basin that incorporates a seawater recharge system. This model (less sediments and hydrocarbon products) is thought to operate at most spreading centers with hydrothermal systems. Note: It includes both a seawater recharge and a stockwork zone (e.g., mechanism of pore water expulsion). The figure also shows the process involved in polymetallic sulfide ore enrichment and the characteristics of the physical environment.

Summary

A mechanism for the generation of petroleum does exist at active ocean spreading centers. Deep-seated regional magma chambers, sill intrusions, and convecting thermal water all play a role in the conversion of sedimentary organic matter to petroleum. The temperatures generated at these spreading centers (350°C max.) are high enough to thermally crack the indigenous organic matter into smaller molecular weight hydrocarbon compounds. The petroleum is then removed by hydrothermal convection and diffusion, followed by condensation at the seabed.

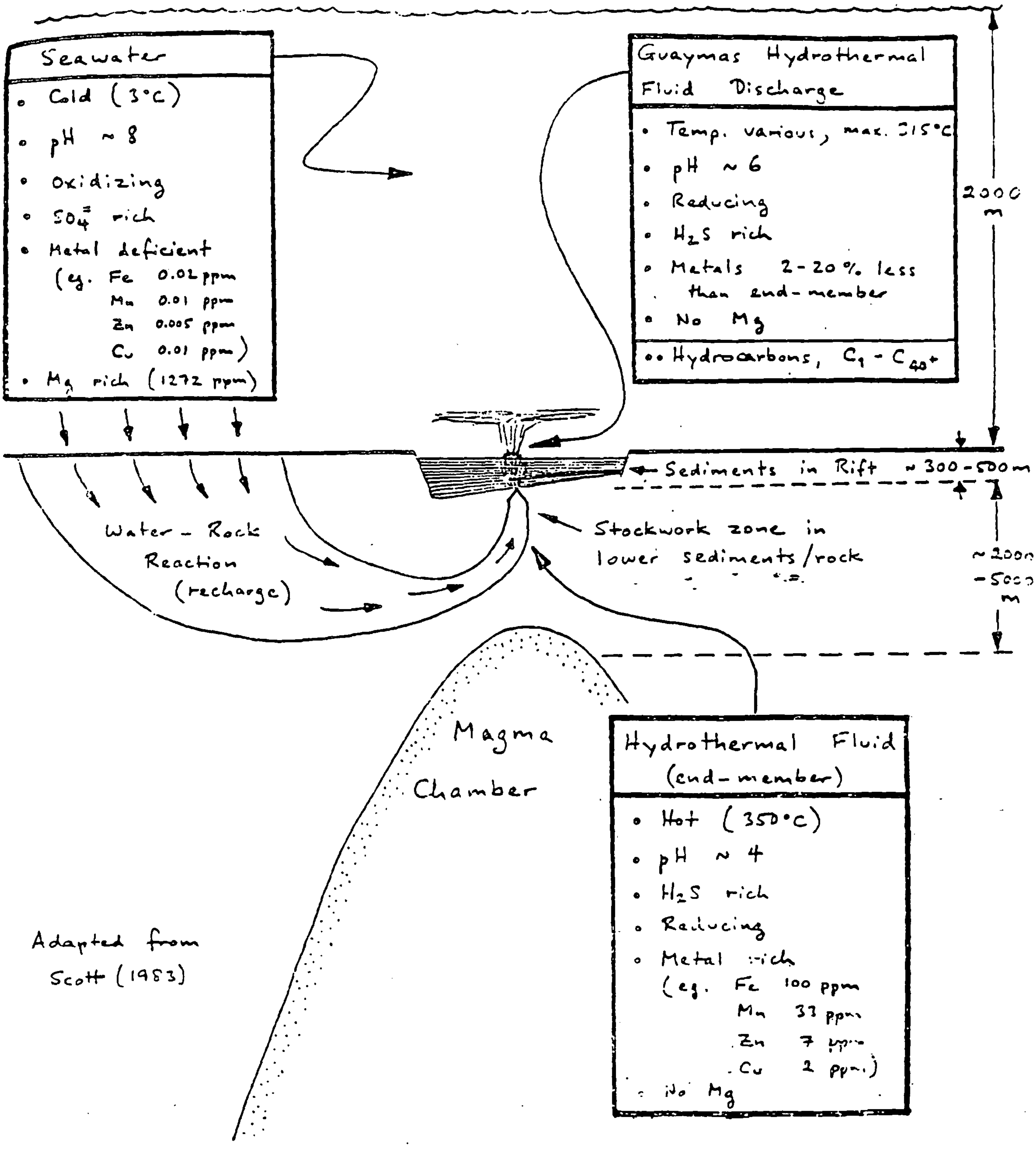

Figure 3. Overview of a hydrothermal system.

III. ORGANIC SOURCE MATERIAL CONSIDERATIONS

The quality of the source material used in the formation of petroleum has an important impact on the chemical composition of the final product. Although all organisms are basically composed of the same chemical constituents (lipids, proteins, carbohydrates and lignin in higher plants), there are characteristic differences with respect to relative abundances and detailed chemical structures. For example, terrestrial higher plants are mainly composed of cellulose and lignin which have supportive functions not needed in aquatic planktonic organisms. Higher plants have H/C values around 1.0 and are more aromatic in nature (due to lignin). On the other hand, marine plankton is mainly composed of proteins, carbohydrates and lipids, which have H/C values around 1.5 to 1.9 (desirable) and are more aliphatic or alicyclic in nature. Although aromatic compounds yield the highest octane ratings in petroleum, they also tend to be concentrated in the heavier fractions. Aliphatic compounds dominate in the gasoline range. Figure 4 presents examples of source material chemical constituents and their relative abundances.

The most desirable starting material is one that is both hydrogen and lipid rich (Demaison and Moore, 1979). Lipid concentrations and chemical structures are variable, being primarily dependent on the type of organic matter incorporated into the sediments. Lipids encompass fat substances, waxes and lipid-like components, such as oil-soluble pigments, terpenoids, steroids and many complex fats. Hydrogen concentrations are controlled to a large extent by the oxicity/anoxicity of the depositional environment and the diagenetic history of the organic detritus.

COMPOSITION OF BIOMASS AND PRODUCTIVITY OF VARIOUS TYPES OF ORGANISMS IN THE BLACK SEA

Organisms	Biomass, 10^6 t	Production per year 10^6 t	%
Plankton	15.0	2,745	13.22
Phytoplankton (without bacteria)	13.5	2,700	13.0
Zooplankton	1.5	45	0.22
Benthos	40.0	80	0.38
Makrophytae	20.0	40	0.19
Zoobenthos	20.0	40	0.19
Bacteria in water	30.0	12,000 - 18,000	57.60
Bacteria in sediment	10.0	6,000 - 8,000	28.80
Fish	1.0	0.17	—
Total	96.0	> 23,000	100

THE MAIN CHEMICAL CONSTITUENTS OF MARINE PLANKTON

	Protein	Lipids	Carbo-hydrates	Ash
Diatoms	24–48%	2–10%	0–31%	30–59%
Dinoflagellates	41–48%	2–6%	6–36%	12–77%
Copepods	71–77%	5–19%	0–4%	4–6%

(% dry weight)

MEMBRANE CONSTITUENTS OF BACTERIA

Type of organic compound	Percent of membranes of *Micrococcus lysodeikticus*	Percent of membranes of purple bacteria
Lipid	28–37	40–50
(neutral)	(9)	(10–20)
(phospholipids)	(28)	(30)
Protein	50	50
Polysaccharide	15–20	5–30

(% dry weight)

COMPOSITION OF LIPID FRACTION (WT. %) OF CALANOID COPEPODS

Fraction	*Calanus helgolandicus* wild type	*Gaussia princeps* wild type
Hydrocarbons	3	Trace
Wax esters	30	73
Triglycerides	4	9
Polar lipids	17	
Phospholipids	45	17
Total lipid (percent dry wt.)	15	28.9

Figure 4. Examples of source material chemical constituents and relative abundances. (Simoneit, 1984.)

Figure 5 represents various H/C[a] and O/C[b] ratios for source organic matter and their approximate maturation paths through oil and gas production. Type I Kerogen, which represents an algal or bacterial source material, has higher H/C and lower O/C values than Type III Kerogen (terrestrial source). Algae and bacteria also have lipid contents with dominate N-alkane[c] carbon chain lengths from C_{16} to C_{22}. Terrestrial higher plants, on the other hand, have lipids with dominate C-chain lengths around C_{29} to C_{31}. Therefore, algal and bacterial organic matter are more easily converted to petroleum than terrestrial plants with longer C-chain lengths.

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a. H/C = Hydrogen/Carbon.

b. O/C = Oxygen/Carbon.

c. N-alkane = normal (straight chain) alkanes.

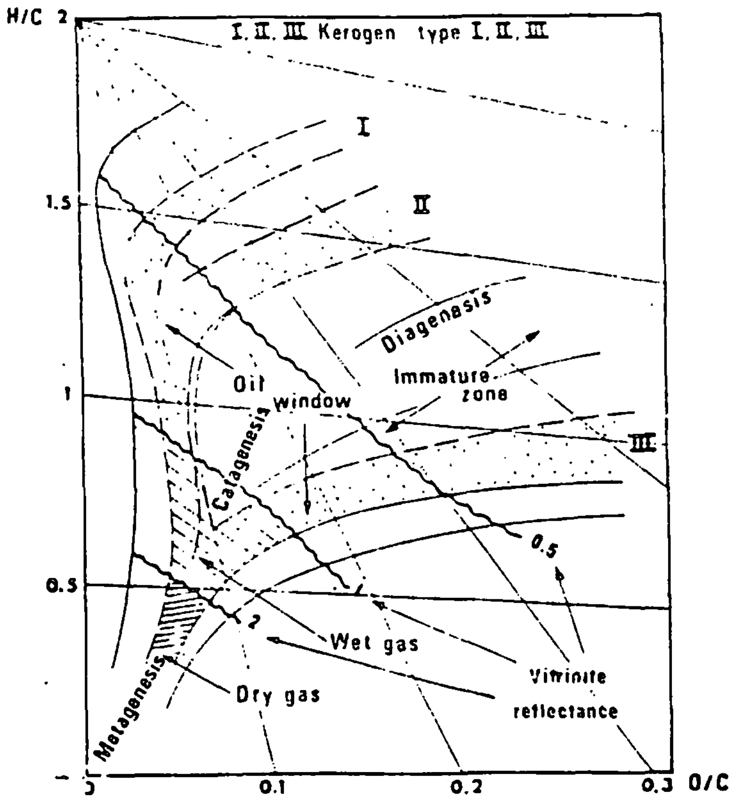

Figure 5. Van Krevelen maturation diagram for kerogen (Tissot et al., 1974).

I. High H/C, low O/C (possible algal origin)
II. Intermediate (possible mixed marine and terrestrial source).
III. Low H/C, high O/C (possible terrestrial source).

The organic matter of the Guaymas Basin is predominantly marine in origin with some terrestrial input and is composed of the various operational fractions as shown in Table 1. All these carbonaceous fractions are very sensitive to thermal stress and are thus easily pyrolyzed.

The interstitial gas in recent sedimentary environments consists primarily of methane, carbon dioxide, and sometimes hydrogen sulfide. Biogenic hydrocarbon gases usually have $C_1/C_2 + C_3$[a] ratios greater than 1000, while those of a thermogenic origin have ratios less than 50.

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a. $CH_4/CH_2H_6 + C_3H_8$

TABLE 1. ORGANIC MATTER OF SEDIMENTS: CONTEMPORARY AND RECENT (Generally Biogenic Components) Simoneit, 1983

Gas	Lipids	Humic and Fulvic Substances	Carbonaceous Detritus (humin, pseudokerogen)
(CH_4, CO_2, H_2S)	(C_8 - C_{40}+)	(macromolecular	(macromolecular,
minor amount of	minor amount	M.W. ~10^3 to >10^6)	>humates) major amount
total C_{org}	(max. ~10%)	variable amount	

The compound classes commonly found as lipid components in immature sediments are: hydrocarbons (normal, iso-, anteiso-, alkene, aromatic and isoprenoid), fatty acids (also normal, iso-, anteiso-, unsaturated and isoprenoid), fatty alcohols, ketones, wax esters, steroids, terpenoids (sesqui-, di-, sester-, tri- and tetra-) and tetrapyrole pigments (Simoneit, 1978a; 1982a; Cranwell, 1982; Mackenzie et al., 1982a). Other compound classes include: amino acids and peptides, pyrines and pyrimidines, and carbohydrates (Simoneit, 1978a; Simoneit, 1983).

Humic and fulvic substances (solubles in aqueous base) are mixtures of complex macromolecules, the latter are of lower molecular weights and thus soluble in dilute HCL. Little else is known about the detailed structures of the compounds. However, it has been shown that humic and fulvic substances decrease in concentration with depth of burial or geologic age (e.g., Nissenbaum and Kaplan, 1972; Huc and Durand, 1977; Stuermer and Simoneit, 1978).

Recent sediments yield a "pseudokerogen," which is a lipid macromolecular material, constitutionally less complex than ancient kerogen, but related to it. Figure 6 shows the fate of organic matter during sedimentation and diagenesis. Included is the approximate location of organic matter at the pseudokerogen state (represented by the horizontal dashed line).

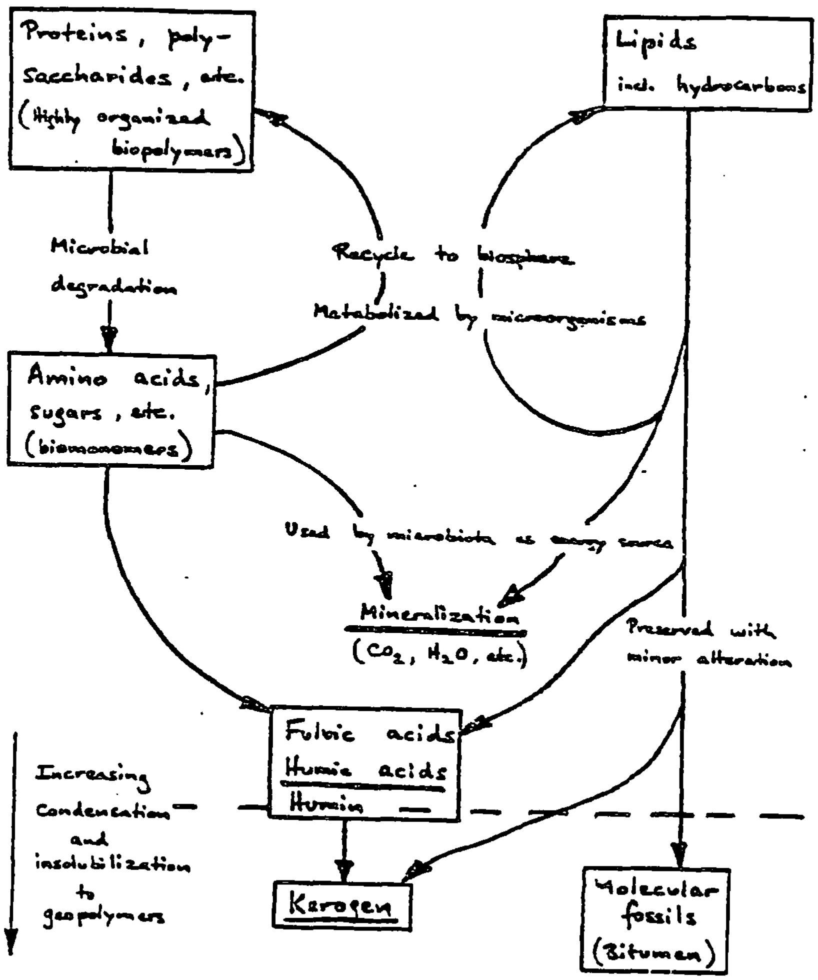

Figure 6. Fate of organic matter during sedimentation and diagenesis.

Summary

It is evident that the type of organic matter incorporated into sediments is an important consideration in petroleum formation. The quality (hydrogen and/or lipid content) and quantity, as well as the diagenetic history of the organic matter, all play a role in the chemical composition of the final product. Marine source material (e.g. algae and bacteria) is generally considered more desirable than terrestrial (higher plant) sources. Organic matter of marine origin has H/C values around 1.5^+ and dominant n-alkane carbon chain lengths around C_{16-22}, and is therefore more easily converted to petroleum than terrestrial organic matter (H/C ~ 1.0 to 1.2, C_{29-31} dominant).

IV. HYDROTHERMAL PETROLEUM PRODUCTS AND GEOCHEMISTRY

Organic geochemical analysis can yield extensive information concerning the formation, maturation and chemical make-up of petroleum (crude oil). Questions about such things as thermal history, source material, depositional environment and degradation can be answered, thus providing a better understanding of the mechanisms and processes involved in petroleum genesis. Analysis of the various hydrocarbon fractions (e.g. aliphatic, aromatic/naphthenic and asphaltic) and biological markers (geochemical and molecular finger prints) allows for the interpretation of the maturity, thermal history and source material of a given petroleum. The following discussion of the hydrothermal petroleum from Guaymas Basin will characterize its composition, give evidence of a thermogenic origin, as well as show some of the similarities and differences to geothermal petroleum.

Petroleum Products and Geochemistry (Guaymas Basin)

The collection and subsequent analysis of samples from the Guaymas Basin, Gulf of California has confirmed that petroleum is being generated at an active oceanic spreading center. The sediments recovered from coring and dredging operations were stained with a petroleum-like oil and also had a strong odor similar to diesel fuel (Simoneit and Lonsdale, 1982).

Thermogenic gas, as well as H_2S and CO_2 were identified from all sites based on composition and stable carbon isotope data. At shallow

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a. $$\delta^{13}C = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1000$$

where

R = $^{13}C/^{12}C$ ratio, expressed per million, 0/00.

depths (see Figure 7) the data shows a biogenic pattern. However, with increasing depth $\delta^{13}C^{a}$ valves become heavier, indicating the removal of the lighter $^{12}CH_4$ due to thermal stress (Simoneit, 1984).

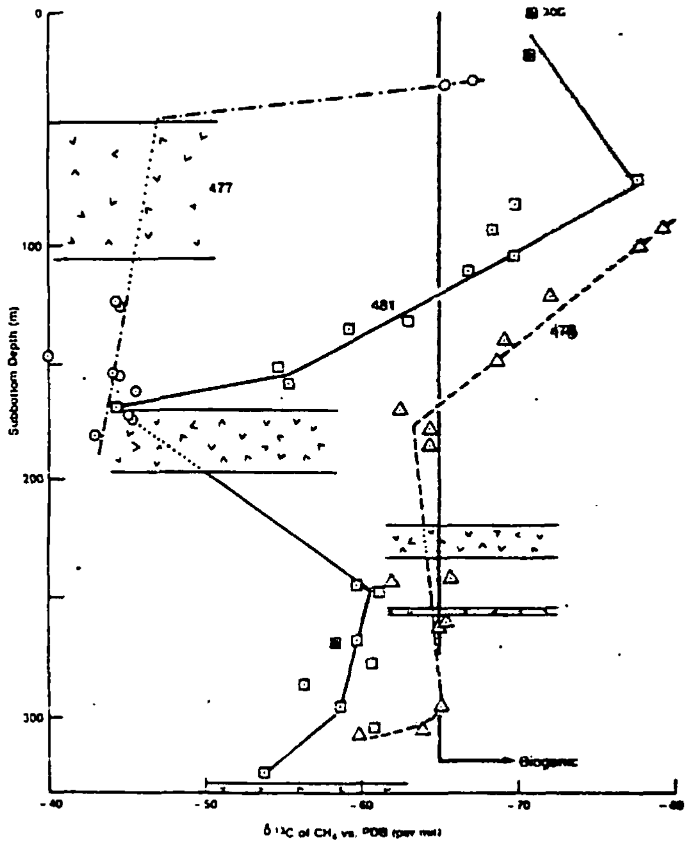

Figure 7. Trends of carbon-12 depletion versus depth in interstitial methane at DSDP sites 477 (--o--), 478 (--Δ--) and 481 (--□--), ■ = canned or frozen samples ($\delta^{13}C$ data reported versus PDB standard, the intrusions are indicated at the appropriate depth for each site). (Simoneit, 1984.)

Table 2 (A and B) gives concentrations and ratio values for the C_1-C_5 gaseous hydrocarbons as observed in the Guaymas Basin. It is evident from Figure 7 and Table 2 that the thermal alteration of organic matter has produced gaseous hydrocarbons (principally methane but also C_2-C_5 gases.

TABLE 2. CONCENTRATIONS AND VARIOUS RATIOS OF C_1-C_5 HYDROCARBONS OBSERVED ON LEG 64 OF THE DEEP SEA DRILLING PROJECT

A

Maximum Concentrations of C_1-C_5 Hydrocarbons Observed on Leg 64

Site	CH_4 (%)	C_2H_6 (%)[a]	C_3H_3 (%)[a]	C_4H_{10} (%)[a]	C_5H_{12} (%)[a]
474	98.8	0.08	0.017	0.007	--
475	No gas observed	--	--	--	--
476	No gas observed	--	--	--	--
s-rift 477	93.2	0.50	0.040	0.003	--
478	97.2	0.10	0.007	0.001	--
479	92.2	0.122	0.010	0.016	0.0015
480	91.8	0.035	0.003	0.0003	--
N-rift 481	98.7	0.634	0.024	0.015	0.022

a. Based on 100% methane, includes all isomers.

TABLE 2. (continued)

B

Various Ratios of C_1-C_5 Hydrocarbons Observed on Leg 64

Site/Core	$C_2/C_1 \times 10^{-4}$	$C_1/(C_2 + C_3)$	$C_1/(C_2$ to $C_5)$
474-8.3[a]	0.56	16050	16050
474A-11-3[b]	5.65	1470	1380
477-5-1[a]	0.30	22500	20810
Gasoline HC 17-3[b]	59.6	157	156
479-3-2[a]	0.50	17430	17430
44-2[b]	18.8	1020	878
Gasoline HC 481A-4-1[a]	7.0	15070	12330
12-5[b]	64.4	316	302

a. Biogenic gas.

b. Biogenic gas with admixed thermogenic gas.

Gasoline-range hydrocarbons were analyzed in two dredge samples and the results are listed in Table 3. In both cases the concentrations of branched and cyclic compounds (possibly also olefins) far exceed the abundance of normal hydrocarbons (Simoneit and Lonsdale, 1982). Although there are differences between the samples (e.g. total C_2-C_{10} concentrations are ~ 10 times greater in sample 7D-5A than in 7D-3B, etc.), the relative distributions of all hydrocarbons are very similar for both samples. It is the relatively large amounts of C_2-C_{10} hydrocarbons and their structural diversity that confirm an origin by thermal generation (Whelan and Hunt, 1982).

TABLE 3. VOLATILE HYDROCARBONS IN DREGDE SAMPLES FROM GUAYMAS BASIN (Simoneit and Lonsdale 1982)

Compound[a]	Retention time (min)	Approximate Concentration (ng cm^{-3} of headspace headspace--150 cm total) 7D-3B	7D-5A
2- Methylbuntane	5.1	2.6	14
n-pentane	5.4	1.4	39
Cyclohexane	7.3	0.5	6
4-Methyl-2-pentene	8.0	0.8	6.3
3-Methylpentane	8.3	1.4	11
2-Methylpentane + benzene	8.6	0.9	44
n-Hexane	9.7	9.2	260
C_2-Cyclopentane	10.3	3.3	46
Methylcyclohexane	10.7	14	1.050
3-Methylhexane	12.1	3.3	--
2-Methylhexane	12.4	5.8	210
n-Heptane + toluene	13.5	>130	950
n-Octane	16.4	24	29
n-Nonane	19.2	48	26
n-Decane	22.2	17	40
Total C_2-C_{10} hydrocarbons (mg)		80	875

a. Identifications based on GC retention time only.

To compare the effects of thermal stress, the total hydrocarbon fractions of the lipids were evaluated for two samples; one of unaltered biogenic lipids and one of thermogenic petroliferous bitumen. The examples are shown in Figure 8. The unaltered sample (8A) exhibits n-alkanes ranging from C_{14} to C_{35} with a strong odd carbon number predominance, especially $>C_{23}$ (terrestrial plant wax). There are also subordinate amounts of C_{20} and C_{25} natural cyclic olefins, triterpanes and S_8. The thermally altered sample (8B) is characterized by n-alkanes with a range from C_{15}-C_{31} and essentially no carbon number predominance. Primary olefins and elemental sulfur are also dominant components. The thermal alteration of lipids is indicated by the loss of the carbon number predominance of the n-alkanes, the appearance of a broad hump of unresolvable complex material, and the presence of large amounts of primary olefins and elemental sulfur, etc. (Simoneit, 1983).

Figure 9 represents gas chromatogram (G.C.) traces of the aliphatic hydrocarbon fraction for two samples dredged from a hydrothermal mound in Guaymas Basin. Trace 9a exhibits a pattern typical of petroleum, where the dominant n-alkanes range from C_{12}-C_{33} with no carbon number predominance (CPI_{12-33} = 1.03)[a] and a maximum at C_{21}. Also typical of petroleum is the complex, unresolved mixture of branched and cyclic hydrocarbons (hump) ranging from C_{11}-C_{31} (Simoneit and Lonsdale, 1982). Pristane and Phytane (Pr and Ph) are biological markers and their ratio is often used as an indicator of environmental conditions of sedimentation (oxidizing or reducing). The Pr/Ph value for 9a is 1.06. On the other hand, trace 9b exhibits a narrower G. C. profile skewed to lower carbon numbers. The major peaks represent mono- and di-olefins (alkenes) ranging from C_{12}-C_{19} and the unresolved hump ranges from C_9-C_{21}. This is very unlike typical petroleum as olefins are not found in mature crude oils. The n-alkanes are present only as minor components

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a. CPI - Carbon Preference Index: for hydrocarbons it is expressed as a summation of the odd carbon number homologs over a range divided by a summation of the even carbon number homologs over the same range; for fatty acids and alcohols it is the same ratio only inverted to have even-to-odd homologs (Simoneit, 1978a).

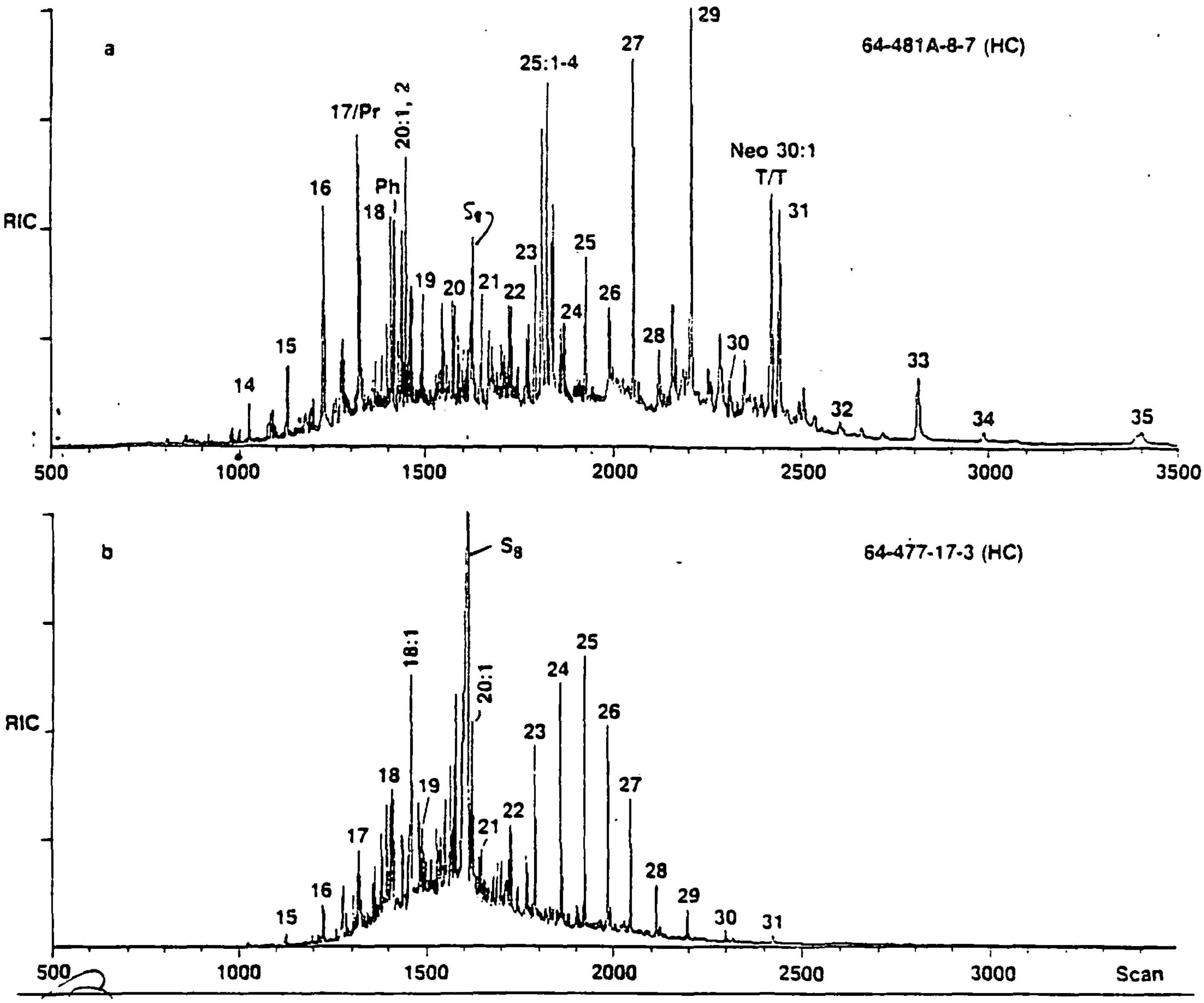

Figure 8. GC-MS total ion current traces for total hydrocarbon fractions from (a) an unaltered, immature sample and (b) a thermally altered sample (a: DSDP 64-481A-8-7; b: 64-477-17-3; numbers indicate n-alkanes) (Simoneit, 1983).

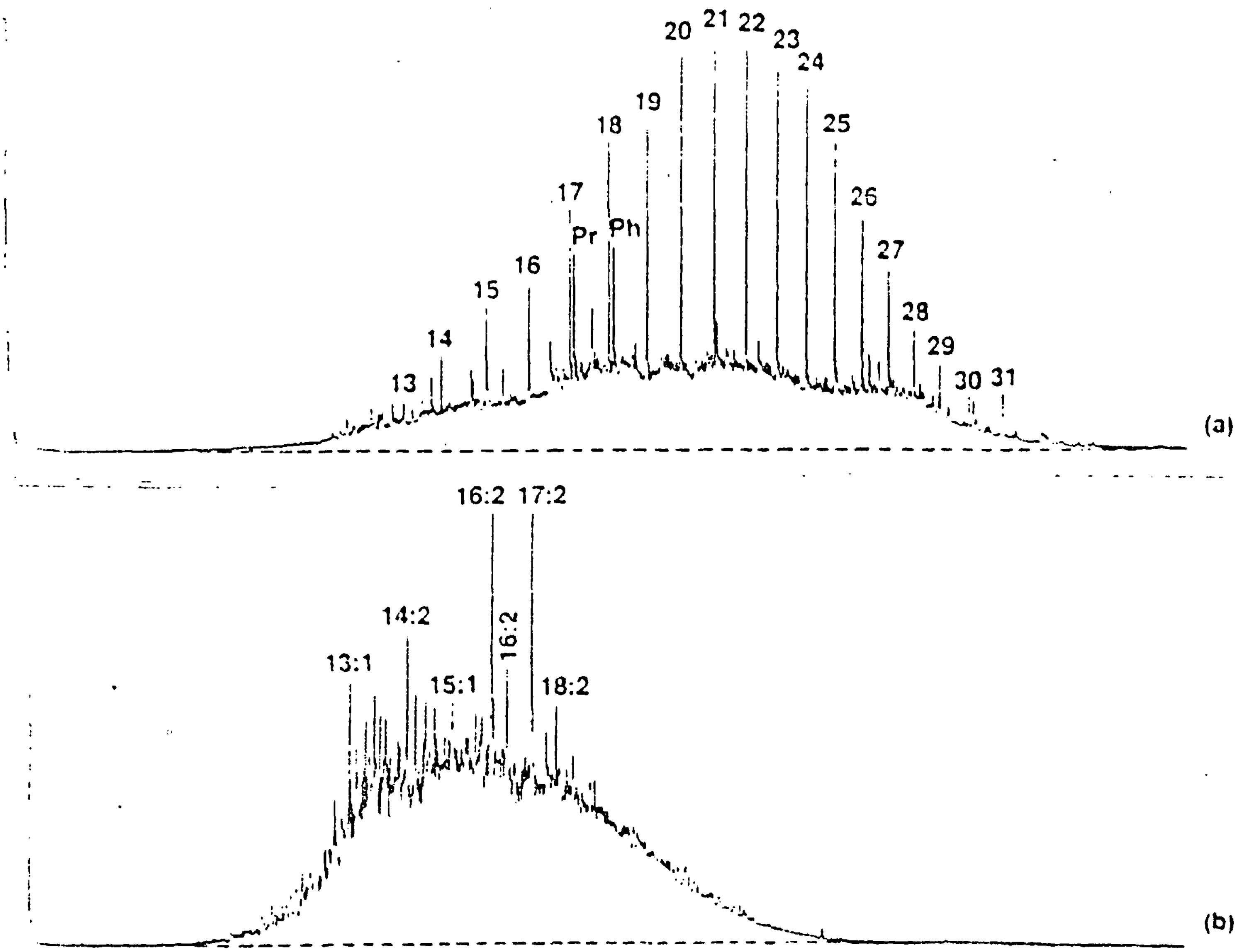

Figure 9. Gas chromatograms of the aliphatic hydrocarbon fractions for: (a) sample 7D-2B; and (b) sample 7D-4A,B. The carbon chain length of the n-alkanes is indicated by the arabic numerals, olefins are indicated by chain length: double bond equivalent, Pr = pristane, Ph = phytane (Simoneit, 1983).

(C_{10}-C_{23}), with a slight odd carbon number predominance (CPI_{10-23} = 1.2) and a maximum at C_{15}. Pristane is greater than Phytane (Pr/Ph = 1.6) (Simoneit and Lonsdale, 1982).

The G.C. trace of the aromatic/naphthenic fraction (Figure 10) indicates that the major resolved peaks are polynuclear aromatic hydrocarbons (PAH). This group of compounds, like olefins, are rare in petroleum but common in higher temperature pyrolysis residues. A further indication of a pyrolytic origin of the samples is the presence of five-membered alicyclic rings. A list of the compounds found in this fraction is given in Table 4. The fact that the dominant analogs for both samples (10a,b) are the pericondensed aromatic series (reactive form), indicates rapid quenching by hydrothermal removal and subsequent condensation at the seabed.

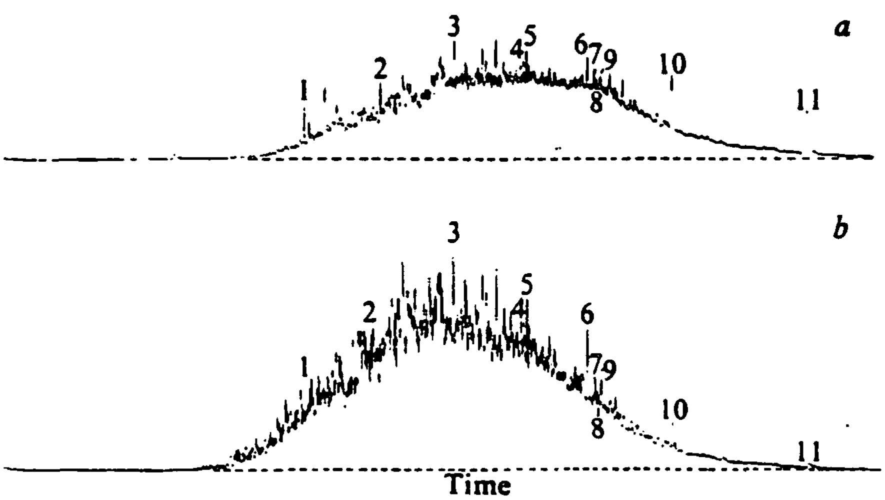

Figure 10. Gas chromatograms of the aromatic/naphthenic hydrocarbon fractions for: (a) sample 7D-2B; and (b) sample 7D-4A,B. Numbers and corresponding compounds are listed in Table 4 (Simoneit and Lonsdale, 1982).

Molecular markers are organic compounds whose carbon structure or skeleton is sufficiently stable to be recognized in crude oil. These markers are good indicators of thermal stress since they tend to go to their more stable (mature) form with increasing thermal stress. The major

TABLE 4. POLYNUCLEAR AROMATIC HYDROCARBONS IN DREDGE SAMPLES FROM GUAYMAS

Compound	No.[a]	Formula	MW	7D-2B (ng per g bitumen)	7D-4A.B (ng per g bitumen)
Indane		C_9H_{10}	118	0.5	0.4
Tetramethylbenzene	1	$C_{10}H_{14}$	134	0.6	4.5
Naphthalene		$C_{10}H_8$	128	4	12
2-Methylnaphthalene		$C_{11}H_{10}$	142	8	6
1-Methylnaphthalene		$C_{11}H_{10}$	142	6	4
Biphenyl		$C_{12}H_{10}$	154	3	1.2
Dimethylnaphthalene		$C_{12}H_{12}$	156	50	8
Acenaphthene		$C_{12}H_{10}$	154	0.8	2.8
Trimethylnaphthalene		$C_{13}H_{14}$	170	16	40
[a]Fluorene		$C_{13}H_{10}$	166	5	0.8
Dibenzothiophene		$C_{12}H_8S$	184	12	8
Phenanthrene	2	$C_{14}H_{10}$	178	27	8
Anthracene		$C_{14}H_{10}$	178	5	10
[a]Fluoranthene		$C_{16}H_{10}$	202	40	34
Pyrene	3	$C_{16}H_{10}$	202	200	178
2,3-Dibenzofluorene		$C_{17}H_{12}$	216	40	40
Benz(a)anthracene	4	$C_{18}H_{12}$	228	15	16
Chrysene (triphenylene)	5	$C_{18}H_{12}$	228	42	38
Benzo(b)fluoranthene		$C_{20}H_{12}$	252	40	28
Benzo(k)fluoranthene		$C_{20}H_{12}$	252	10	6
+Benzo(e)pyrene	7	$C_{20}H_{12}$	252	62	45
+Benzo(a)pyrene	8	$C_{20}H_{12}$	252	25	16
Perylene	9	$C_{20}H_{12}$	252	45	40
1,2,5,6-Dibeazanthracene		$C_{22}H_{14}$	278	3	2.4
Benzo(g,h,l)perylene	10	$C_{22}H_{12}$	276	100	24
Coronene	11	$C_{24}H_{12}$	300	64	5

a. See Fig. 10

diagnostic molecular markers consist of triterpenoids, extended diterpanes, and steranes with their rearranged analogs (diasteranes) (Simoneit and Lonsdale, 1982). Figure 11 gives the relative distributions of the major molecular markers for sample 7D-2B (thermally altered) and for sample 30G (unaltered). Sample 7D-2B (11a,c) shows the following marker distribution.

- Extended diterpanes: Distribution pattern similar to other mature petroleum samples, range C_{20} to C_{29}.

- Triterpenoids: In thermodynamically more stable form. Characterized by 17α, 21β(H)--hopane series from C_{27} to C_{35} (no C_{28}). Also present are the homologies from C_{31} to C_{35} as 22-S and R diastereomeric pairs in a ratio of about unity. This series constitutes the stable mature form of these compounds, and seems to have been generated by hydrothermal activity.

- Steranes: The large 5 α (H), 14 α (H), 17 α (H) sterane concentration is a result of elevated thermal stress, which probably converted other steroidal compounds to these hydrocarbons. The steranes range from C_{26} to C_{30} with cholestane the major homalogue.

In contrast to the thermally altered sample, 30 G (11b) shows a very different molecular marker distribution pattern.

- Extended diterpanes: There are no extended diterpanes found in sample 30G.

- Triterpenoids: Biogenic markers with the 17 β (H), 21 β (H) stereochemistry and other triterpanes predominate. This represents the immature form of the triterpenoids.

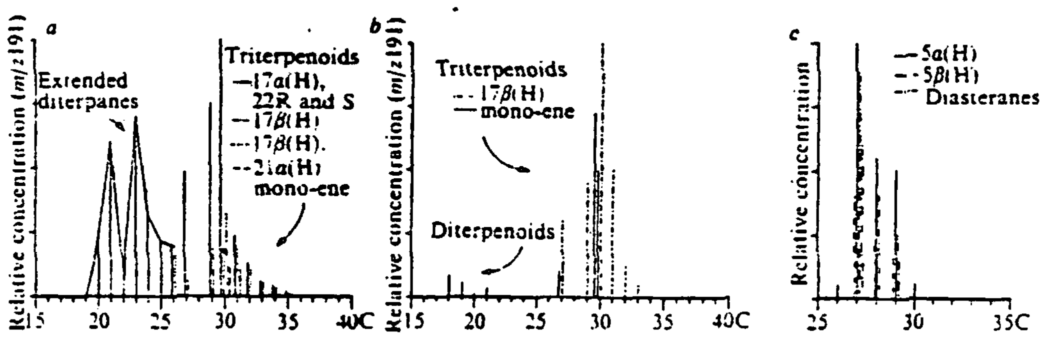

Figure 11. Relative distribution diagrams for triterpenoids in: (a) sample 7D-2B; and (b) an unaltered sample, station 30G, and steranes in C, sample 7D-2B (Simoneit and Lonsdale, 1982).

Table 5 shows the composition and yields of hydrothermal petroleum from the Guaymas Basin (does not include volatile compounds < C_{15}). The data for the various samples shows a wide variability. These differences can be attributed to varying degrees of thermal stress, the nature of the source material (marine or terrestrial predominance), the diagenetic history of the source material, etc. There are also differences between the compositions of average petroleum (geothermal) and hydrothermal petroleum. Guaymas Basin petroleum has large amounts of NSOs,[a] non-hydrocarbons and asphaltenes. These compounds are indicative of petroleum generated from immature organic matter by pyrolysis.

Summary

The petroleum products in the Guaymas Basin are generated from the thermal alteration of immature organic matter. The evidence for a thermogenic origin includes: (1) composition and stable carbon isotope data of interstitial gas; (2) the presence of gasoline range hydrocarbons (and odorous compounds); (3) the relative amounts of aromatic/naphthenic

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a. NSO compounds = Nitrogen, sulfur, oxygen compounds.

TABLE 5. COMPOSITION AND YIELDS OF HYDROTHERMAL PETROLEUM--GUAYMAS BASIN (Simoneit, 1984)

Sample	Total Extract Yield (mg/g sed)	C_{15} + Hexane Solubles Saturates (%)	Aromatics (%)F_2	NSOs (%)F_3	Non-Hydrocarbons (%)	Asphaltenes (%)
1168-1-2	81	7	16	25	78	52
-3B	19	2	7	21	91	70
1172-3	12	53	18	16	30	13
-4	350	72	12	11	16	5
1173-3	--	23	10	22	66	45
-8	97	45	23	23	32	9
1177-2E	63	41	25	18	35	16
-2D	71	48	25	15	27	12
-4B	10	51	15	20	34	14
Average		38	16.8	19	45.4	26.2
Average Petroleum	N/A	57.2	28.6	--	14.2	--
Average Source Rock Bitumen		29.2	19.7	--	51.1	--

and asphaltic material versus aliphatic hydrocarbons; and (4) the broad distribution of hydrocarbons (hump), C_{13}-C_{33}, and the presence of pristane and phytane.

These oils are derived from higher temperature pyrolysis processes (150-350°C). The evidence for this process and not one of normal petroleum genesis (150° max) includes: (1) the presence of branched and in-chain olefins, (2) large amounts of asphaltic material, and (3) the presence of peri-condensed PAH.

The presence of minor biogenic marker residues (17 β (H), 21 β (H)--hopanes and triterpanes) is another indication that these oils are derived from the thermal alteration of immature organic matter. These compounds are not found in mature petroleums (e.g. they have the more mature stable (17 α (H), 21 α (H) series, etc.).

It has been shown that the sediments at depth contain interstitial gas (admixed thermogenic and biogenic), as well as thermally derived bitumen. Also, there are petroleum-like products being precipitated at the seabed. These facts indicate that the vent water must be carrying the petroleum products to the surface where they condensate.

V. CONCLUSION

Hydrothermal petroleum genesis from an active oceanic spreading center has been illustrated by using the Guaymas Basin as an example. This ridge-crest hydrothermal system generates water temperatures up to 315°C at 200 atmospheres. It is different from most other active spreading centers in that there is a sediment cover ranging up to 500 m in thickness. The magmatic processes occurring at this spreading center generate temperatures which can thermally crack the sedimentary organic matter into smaller molecular weight compounds (e.g. petroleum-like products). Although most active spreading centers do not have a sediment cover, they do have the same thermal processes operating (e.g. deep regional magma bodies, hydrothermal systems, and dike and sill intrusions). Thus, if organic matter is present, there exists (at active spreading centers) a mechanism for its conversion to petroliferous products.

The type of organic matter present has an impact on the chemical composition of the final product. Terrestrial higher plants are predominantly composed of cellulose and lignin, whereas algae and bacteria (marine organisms) are mainly composed of proteins, lipids and carbohydrates. Marine organisms have higher H/C values, higher lipid contents, and smaller dominant C-chain length n-alkanes than terrestrial plants. Therefore, marine organisms are more easily converted to petroleum.

Closely associated with organic matter quality (e.g. hydrogen and lipid concentrations) is the diagenetic history of the organic matter. The conditions of the diagenetic environment (reducing or oxidizing) either promotes or inhibits the preservation of the organic matter in a form that is favorable to its subsequent conversion to petroleum.

There are both similarities and differences between hydrothermal petroleum and geothermal petroleum. Like geothermal petroleum, hydrothermal petroleum has a dominant n-alkane range from ~ C_{12} to C_{31}, no carbon number predominance (CPI ≈ 1.00), a pristane and phytane ratio of about unity and a complex, unresolved mixture of branched and cyclic hydrocarbons ranging from C_{11} to C_{31}. Hydrothermal petroleum differs from geothermal petroleum by the presence of branched and in-chain olefins, peri-condensed polynuclear aromatic compounds and minor biogenic marker residues.

The petroleum products of the Guaymas Basin have resulted from the high temperature pyrolysis (150°-350°C) of immature organic matter. This is different from geothermal petroleum genesis where formation temperatures are ≤ 150°C. This origin is indicated by the presence of the olefins, the peri-condensed PAH and the large amounts of asphaltic material.

One of the most important advantages of hydrothermally produced petroleum is time. This is an "instantaneous" process, where as geothermal petroleum genesis requires millions of years.

Whether or not areas like Guaymas Basin are commercially viable will be answered by further exploration. There is abundant energy available for use at active oceanic spreading centers and methods for its utilization should seriously be considered.

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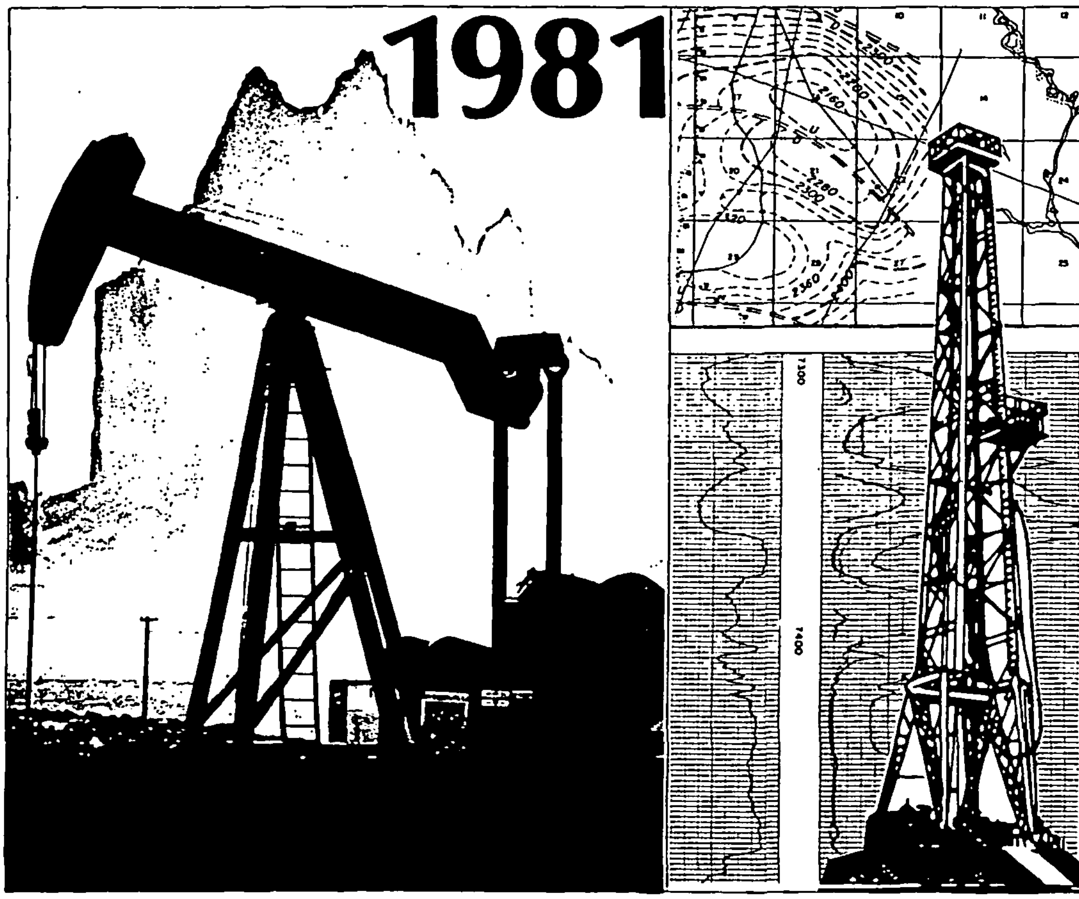

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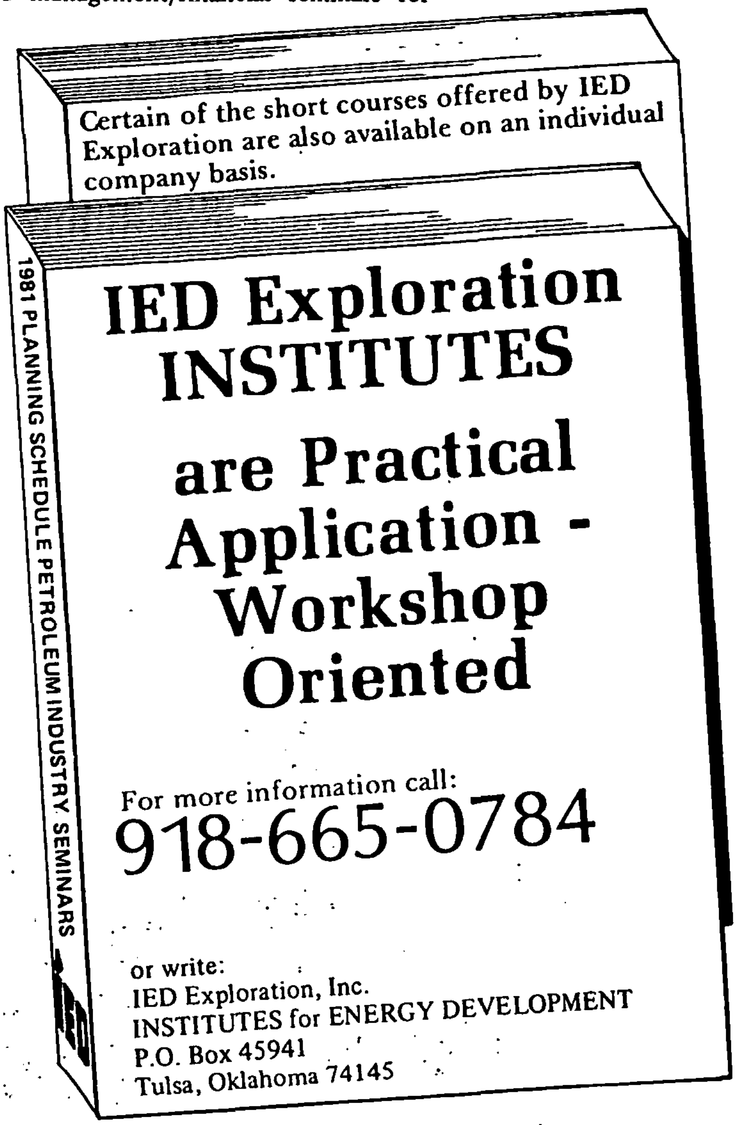

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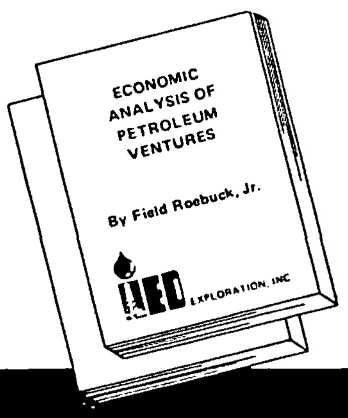

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Received B.S. degree in Geological Engineering from South Dakota School of Mines and Technology.

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Formerly: Director of Interpretive Techniques, Dresser Atlas . . . Assistant Professor of Petroleum Engineering, Montana School of Mines . . . Log Interpretation Research Engineer, Mobil Research and Development . . . Field Engineer, Schlumberger of Canada.
Received B.S. degree from University of Oklahoma and M.S. degree from University of Texas, both in Petroleum Engineering, and Ph.D. degree in Engineering Sciences from University of Oklahoma.

S. DUFF KERR, JR. . . . Independent Consulting Geologist, Denver, Colorado
25 years of experience with Shell Oil Company and Kirby Exploration Company includes research, exploration, and teaching activities throughout North America.
Received B.S. and M.S. degrees in Geology from University of Cincinnati.

R.W. KETTLE. . .Consulting Exploration Geophysicist, Professional Geophysics, Inc., Denver, Colorado
28 years of Geological and Geophysical experience in Europe, Gulf Coast, Rocky Mountains, and Alaska.
Received B.S. degree in Professional Engineering from Colorado School of Mines and MBA degree from Loyola University.

W.JERRY KOCH. . .Independent Consulting Geologist, Denver, Colorado
Prior industry experience includes positions with Shell Oil Company, Shell Development Company Research Laboratory, Filon Exploration, and MRO Associates conducting carbonate research and petroleum exploration in the U.S., Central America, Middle-East, and Southeast Asia.
Received B.S. degree in Geology from Washington State University and M.S. degree and Ph.D. in Geology from Harvard University.

R. MICHAEL LLOYD. . .Independent Consulting Geologist, Houston, Texas
20 years of Research, Exploration, and Teaching experience with Shell Oil Company includes most major carbonate plays in North America.
Received B.S. and M.S. degrees in Geology from University of Illinois and Ph.D. in Geology and Geochemistry from Caltech.

JOHN S. LOWE. . .Professor of Law and Associate Director, National Energy Law and Policy Institute, University of Tulsa
Broad legal and oil and gas law experience includes: practicing oil and gas law privately in Ohio, representing many independent oil and gas operators. . .teaching oil and gas law, University of Toledo. . .lecturing on oil and gas law problems at frequent seminars across the country.
Received B.A. degree in Economics from Denison University and LL.B. from Harvard University.

ALAN E. McGLAUCHLIN. . .Vice President, Director, and Geophysicist, Professional Geophysics, Inc., Dallas, Texas. . .Instructor of Seismic Techniques Seminars.
Formerly: 12 years with Mobil Oil Corporation as Seismic Party Chief, Special Problems Supervisor, and Superintendent of Processing Applications.
Received Geophysical Engineering degree from Colorado School of Mines.

LEWIS G. MOSBURG, JR.. . .Attorney-at-Law, Oklahoma City, Oklahoma.
Frequent Lecturer and Writer in the fields of Oil and Gas, Real Estate, and Tax Sheltered Investments. . .Special Lecturer in Law, University of Oklahoma Law School. Formerly: Staff Attorney, Standard Oil Company (Indiana).
Author: TAX SHELTER DESK BOOK. . .THE TAX SHELTER COLORING BOOK. . .REAL ESTATE SYNDICATE OFFERING HANDBOOK . . . HANDBOOK ON PETROLEUM LAND TITLES . . . plus numerous other publications.
Received B.A. and LL.B. degrees from University of Oklahoma.

FIELD ROEBUCK, JR. . . .Independent Petroleum Consultant, Dallas, Texas
25 years prior industry experience includes: Oil and Gas Reserve and Valuation Studies. . .Design and Evaluation of Fluid Injection and Gas Storage Projects. . .Reservoir Performance Projections. . .Industry Training Programs and Seminars. . .Property Operations. . .International Consulting and Project Work in Algeria, Argentina, Brazil, Canada, Egypt, Iran, Yugoslavia, Mexico, Saudi Arabia, Turkey, and the U.S.
Received B.S. and M.S. degrees in Petroleum Engineering from University of Texas.

E.W. "BILL" SENGEL . . . Consulting Well Log Analyst, Bella Vista, Arkansas
Frequent Well Logging Lecturer for University of Oklahoma . . . Oklahoma State University . . . University of Arkansas . . . University of Texas.
Formerly: Employed by Schlumberger Well Services in various capacities from 1941-1970.
Mr. Sengel is self-educated.

BURR A. SILVER . . . President, Olympic Exploration and Production Company. . . Associate Professor, School of Geology and Geophysics, University of Oklahoma . . . Industry Technical Training Consultant . . . Active Exploration Consultant
Formerly: Research Geologist, Cities Service Research and Jersey Production Research Corporation (Exxon) . . . Exploration Geologist and Senior Production Geologic Specialist, Humble Oil and Refining Company . . . Professor of Geology, Arizona State University.
Received B.S. and M.S. degrees in Geology from Baylor University and Ph.D. in Geology from University of Washington.

D.W. STEARNS . . . Holder of Monnett Chair, School of Geology and Geophysics, University of Oklahoma. Major oil companies for whom Dr. Stearns has led structural geology field seminars include Amoco Production Company . . . Atlantic Richfield Company . . . Cities Service Company . . . Phillips Petroleum Company
Formerly: Professor and Head of Geology Department, Texas A & M University.
Received B.S. degree in Geology from Notre Dame, M.S. degree in Geology from South Dakota School of Mines, and Ph.D. in Geology from Texas A & M.

LARRY D. VREDENBURGH . . . Independent Geologic Consultant. . . President, IED Exploration, Inc., INSTITUTES for ENERGY DEVELOPMENT, Tulsa, Oklahoma
Exploration and Management Experience includes: Projects Geologist, Operations Geologist, District Geologist, and Manager of Exploration Training, Amoco Production Company . . . Research Geologist, Mobil Field Research Lab . . . Geochemical Research, Iowa State Highway Commission.
Received B.S. and M.S. degrees in Geology from Iowa State University and Ph.D. in Geology from University of Washington.

SUBSURFACE EXPLORATION STRATIGRAPH

IED EXPLORATION, INC.

February 16-20, 1981. . .Calgary, Alberta
April 20-24, 1981. . .Houston, Texas
August 10-14, 1981. . .Denver, Colorado

This five-day SUBSURFACE EXPLORATION SEMINAR. . .provides an excellent update for experienced geologists, geophysicists, and managers . . .as well as a comprehensive exploration seminar for inexperienced geologists and geophysicists.

SUBSURFACE EXPLORATION STRATIGRAPHY is a comprehensive, three-part seminar that offers a practical application coverage of SUBSURFACE TECHNOLOGY. . .EXPLORATION FOR SANDSTONE RESERVOIRS. . .and EXPLORATION FOR CARBONATE RESERVOIRS, and demonstrates the interrelationship of geologic, geophysical, and engineering technology in affecting the exploration effort. . .whether it be trend evaluation or prospect generation.

Lectures, application workshops, and case history analysis are used to develop ability and confidence in reservoir prediction techniques. Emphasis is on how modern technology can be used to recognize and delineate oil and gas reservoirs.

Practical exploration workshops provide experience in using rock-fluid data with conceptual models to predict reservoir-seal situations.

Applicable conceptual models of sandstone and carbonate reservoirs are presented. . .with specific emphasis on HOW TO APPLY conceptual models in exploring for oil and gas reservoirs.

COURSE CONTENT

INTRODUCTION

A. Course Objectives
B. General Habitat of Petroleum
- Trap
- Reservoir
- Seal
- Source

C. Distribution of Petroleum

EXPLORATION TECHNOLOGY

A. Exploration Concepts
- Analogues
- Basin (Trend) Evaluation
- Prospect Generation
- Rock-Fluid-Log Calibration
- Organization of Data

B. Subsurface Data Sources
- Sample Cuttings
- Cores
- Rock Description
- Logs
- Drillstem Tests

C. Seismic Stratigraphy
D. Geochemistry
- Source Beds
- Petroleum Generation
- Expulsion
- Migration

E. Organization of Data

EXPLORATION FOR SANDSTONE RESERVOIRS

A. Introduction
- Reservoir Distribution
- Reservoir Quality
- Seal Facies
- Structure

B. Depositional Environments
- Alluvial
- Coastal
- Eolian
- Shallow Marine
- Deltaic
- Deep Marine

C. Mapping Techniques
D. Sandstone Rock Geometries (Size - Shape - Distribution)
- Fans
- Sheet Sands
- Channels
- Turbidites
- Bars

E. Field Case Histories

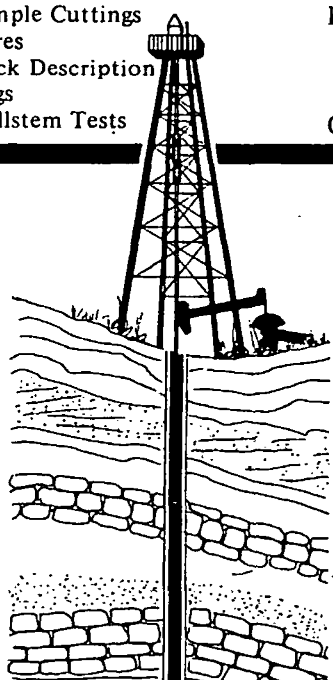
EXPLORATION FOR CARBONATE RESERVOIRS

A. Introduction
- Carbonate Rock Classification
- Pore Space Classification

B. Carbonate Depositional Environments
- Reefs
- Sands
- Mounds
- Tidal Flats
- Shelf Margins
- Chalks

C. Diagenesis
- Porosity Creation
- Porosity Destruction

D. Trap Types - Case Histories



Instructors
Burr A. Silver
Larry D. Vredenburgh

(See page 7 for instructors' vitas.)

TUITION: $645.00 U.S. Funds
Includes INSTITUTE manual, first-day social hour, daily coffee and cold drinks, workshops and workshop materials.

INSTITUTES FOR ENERGY DEVELOPMENT

STRUCTURAL GEOLOGY

Applied to Petroleum Exploration

EXPLORATION, INC.

Dates and Locations to be Announced.

PRESENTED BY...

Dr. D.W. Stearns

Dr. Stearns' STRUCTURAL GEOLOGY seminar for Explorationists and Technical Managers is designed to:

- Provide a practical working vocabulary of structural geology for application to petroleum exploration
- Demonstrate how analysis of structural attitudes, styles, and stress can be used to interpret local and regional deformation
- Update explorationists as to new concepts and applications of structural geology
- Present new and practical classification of faults and folds applicable to petroleum explorationists
- Demonstrate with on-site laboratory equipment critical structural principles applicable to understanding deformation of layered rocks

COURSE CONTENT

I. BASIC CONCEPTS OF STRUCTURAL GEOLOGY (Necessary for Effective Communication)
- Force
- Stress
- Strain
- Deformation
- Stress-Strain Laws
- Stress Trajectory Diagrams

II. EXPERIMENTALLY DETERMINED ROCK PROPERTIES OF COMMON SEDIMENTARY ROCKS
- A. Equipment
- B. Measurements (Stress-Strain Curves)
- C. Effects of Isolated Parameters
  - Confining Pressure (Lithostatic Gradient)
  - Pore Pressure (Hydrostatic Gradient)
  - Temperature (Geothermal Gradient)
  - Strain Rate (Geologic Time)

III. DEFORMATION MECHANISMS
- A. Cataclastic Flow
- B. Gliding Flow
- C. Solution

IV. EXTRAPOLATION OF LABORATORY DATA TO THE FIELD
- A. Materials
  - Petrologic Factors
  - Dimensional Consideration
- B. Pressure
- C. Temperature
- D. Time
- E. Mechanisms
  - Micromechanisms
  - Macromechanisms
- F. Physical Properties

V. PHENOMENA OF FRACTURE
- A. Regional
- B. Fractures Associated with Faults
- C. Fractures Associated with Folds
- D. Rock Model Studies that aid in Understanding Faulting
- E. New Fault Classification

VI. CONCEPTS OF FOLDING
- A. Important Mechanical Concepts
- B. Relationship Between A and Geology
- C. Practical Fold Classification

VII. STRUCTURAL STRATIGRAPHY

VIII. HORIZONTAL TECTONICS OF WESTERN U.S. CORDILLERIAN THRUST BELTS

IX. VERTICAL TECTONICS OF ROCKY MOUNTAINS FORELAND

X. EXERCISES AND DISCUSSION

Instructor
Dr. D.W. Stearns

(See page 7 for instructor's vita.)

TUITION: $645.00

Includes INSTITUTE manual, workshops and workshop materials, first-day social hour, and daily coffee and cold drinks.

INSTITUTES FOR ENERGY DEVELOPMENT

CARBONATE RESERVOIRS
(Exploration and Development)

IED EXPLORATION, INC.

February 23-27, 1981 . . . Houston, TX

September 21-25, 1981 . . . Denver, CO

INSTITUTES for ENERGY DEVELOPMENT is pleased to announce a "state-of-the-art" symposium on the EXPLORATION FOR AND DEVELOPMENT OF CARBONATE RESERVOIRS.

This five-day technical program is for explorationists, development engineers, and managers involved in carbonate reservoir exploration and development.

The Seminar Topics will include:

- A Review and Update of Carbonate Depositional Models Proven to be useful in Predicting Carbonate Trends.
- A Survey of Diagenetic "Overprints" on Depositional Facies that Determine Ultimate Reservoir-Seal Relationships:
  - Marine Cementation
  - Chemical Compaction
  - Fracturing
  - Subaerial Diagenesis
  - Dolomitization
- A Review of Rock-Fluid Properties Peculiar to Carbonates and Associated Rocks and How They Influence Exploration, Evaluation, and Development.
- A comprehensive Series of Case History Studies of Carbonate Plays Selected from Major Carbonate Basins of the World:
  - Williston Basin
  - Gulf of Mexico
  - Middle East
  - Permian Basin
  - Paradox Basin
- A Survey of the Use and Effectiveness of Various Exploration Techniques Applied to Carbonates.

PROGRAM

1. CARBONATE SEDIMENTS AND ROCKS
   - Terminology and Classification
   - Sources of Carbonate Sediments
2. CARBONATE DEPOSITIONAL PATTERNS
   - Ramps, Shelf Margins, Build-ups
   - Lateral Facies Variations
   - Vertical Sequences and Cycles
3. TYPES OF CARBONATE PLAYS
   - Shelf Margin Complex
   - Pinnacles and Platforms
   - Grainstone Shoals
   - Tidal Flats
   - Chalks
   - Fracture Trends
4. CARBONATE FACIES AND COMPLEX STRUCTURE— THE OVERTHRUST PROBLEM
5. DIAGENESIS
   - Early Marine and Fresh Water Diagenesis
   - Mineralogical Stabilization
   - Chemical Compaction
   - Dolomitization
   - Fracturing
6. TOOLS AND TECHNIQUES OF CARBONATE EXPLORATION
   - Seismic Geometry
   - Seismic Stratigraphy
   - Wireline Logs
   - Cores and Samples
7. CARBONATE ROCKS AS RESERVOIRS AND SEALS
   - Pore Properties
   - Fluid Distribution
   - Log Responses
   - Evaluation
8. CARBONATE EXPLORATION STRATEGY
   - Focus of Effort
   - Risk vs. Reward
9. SUMMARY

TUITION: $645.00
Includes INSTITUTE manual, first-day social hour, coffee and cold drinks, workshops and workshop materials.

Instructors
R. Michael Lloyd
S. Duff Kerr, Jr.
W. Jerry Koch

(See page 7 for instructors' vitas.)

INSTITUTES FOR ENERGY DEVELOPMENT

CARBONATE SEDIMENTATION FIELD TRIP

IED EXPLORATION, INC.

May 9-16, 1981 . . . . . . BELIZE, CENTRAL AMERICA . . . . . . May 16-23, 1981

PURPOSE:
To integrate study of depositional environments with petroleum exploration applications. The structural and topographic settings, carbonate sedimentation, influece of terrigenous clastics, and development of lagoonal-patch reef-barrier reef facies will be observed. Emphasis will be on exploration workshops, utilizing seismic data, well logs, maps, cores, and thin sections. Ancient analogies will include: Smackover, D2 reefs, Permian Basin facies, and Texas cretaceous facies.

STUDY AREA:
The Belize Shelf Complex is an ideal area for study of carbonate deposition because of the varied geologic processes found there:

- Extensive reef facies
- Influx of terrigenous clastics
- Abundance of reef building and sediment producing organisms
- Structural and topographic controls
- Reefs in all stages of development

ITINERARY

DAY 1
- Participants rendezvous in Houston
- Meeting at 8:00 p.m. for overview and orientation
- Overnight: Houston
- (Optional if participant has other arrival plans)

DAY 2
- Depart Houston for Belize City
- Snorkeling stops
- Reef building and sediment producing organisms
- Sediment sampling traverse
- Platform sedimentation
- Workshop: Develop Facies Model
- Overnight: Dangriga

DAY 3
- Influence of topography, structure, marine circulation, and nutrient supply on shelf reefs
- Frequent snorkeling stops
- Bottom sediment sampling
- Overnight: Dangriga

DAY 4
- Snorkeling stops across shelf margin sequence
- Overflight of Belize Complex
- Workshop: Texas Cretaceous Analogue
- Overnight: San Pedro, Ambergris Cay

DAY 5
- Mud mounds vs. reefs
- Shallow lagoonal deposits
- Workshop: Evaluate Source and Reservoir Rock Poten of Permian Basin Carbonates
- Overnight: San Pedro, Ambergris Cay

DAY 6
- Mixed clastic-carbonate coastal environments
- Tidal flats
- Workshop: Swan Hills Prospect Generation
- Overnight: San Pedro, Ambergris Cay

DAY 7
- Modern barrier and fringing reefs
- Pleistocene mapping workshop
- Exploration techniques for carbonate reservoirs
- Overnight: San Pedro, Ambergris Cay

DAY 8
- Return to Belize City
- Terminate field trip

NOTE:
A primary concern on this trip is the safety of all particip We will insist on a buddy system during all snorkeling s the use of life vests in the water, care about what is handl water, and above all, protection from the tropical sun.

FIELD TRIP LOGISTICS
Detailed information on field trip gear, itinerary, and logistics available from IED Exploration
Box 45941
Tulsa, OK 74145

Or Call:
918-655-0784.

Field Trip Coordinator
Burr A. Silver

(See page 7 for instructor's vita.)

FEE: $1,575.00 U.S. Funds
Fee includes travel and living expenses after arriving i Belize City. Participants are responsible for travel arra ments and costs to and from Belize City.

INSTITUTES FOR ENERGY DEVELOPMENT

EXPLORATION GEOLOGY

IED EXPLORATION, INC.

January 19-23, 1981 . . . . .Denver, CO
June 22-26, 1981 . . . . .New Orleans, LA
July 20-24, 1981 . . . . London, England
November 16-20, 1981 . . . . .Houston, TX

IED Exploration is proud to announce our new seminar. . .EXPLORATION GEOLOGY. . .which completes development of our three-seminar sequence of exploration short courses:

TECHNIQUES OF USING GEOLOGIC DATA & PREPARATION OF EXHIBITS. . .Basic
EXPLORATION GEOLOGY. . . . . .Intermediate
SUBSURFACE EXPLORATION STRATIGRAPHY. . . . . .Advanced

The EXPLORATION GEOLOGY seminar is designed to provide an introduction to the TECHNOLOGY and TECHNIQUES of oil and gas exploration. EXPLORATION GEOLOGY is for geophysicists, engineers, inexperienced geologists, senior technologists, and other technical persons with limited experience in prospect generation and evaluation.

Practical application workshops for the major structural and stratigraphic trap types emphasize:

- Art of Contouring
- Rock-Log Responses
- Cross-Section Usage (Correlation)
- Clastic and Carbonate Facies

COURSE CONTENT

I. PETROLEUM
   - A. Source Material
   - B. Source Rocks
   - C. Generation
   - D. Expulsion and Migration

II. POTENTIAL SANDSTONE RESERVOIRS
   - A. Fundamentals of Sandstone Geology
   - B. Depositional Environments
     - Continental
     - Deltaic
     - Interdeltaic
     - Marine
   - C. WORKSHOP: Use of Cores and Rock-Log Responses to Interpret Depositional Environments

III. POTENTIAL CARBONATE RESERVOIRS
   - A. Fundamentals of Carbonate Geology
   - B. Carbonate Models of Deposition
   - C. WORKSHOP: Reconstruction of Carbonate Depositional Environments

IV. RESERVOIRS IN TIME AND SPACE
   - A. Correlation Techniques
   - B. Time-Stratigraphic Framework
   - C. Mappable Horizons
   - D. Source Rock-Reservoir-Seal Relationships
   - E. WORKSHOP: Log Correlation Exercises

V. DIAGENESIS OF SANDSTONES AND CARBONATES
   - A. Pore Occlusion
   - B. Pore Enhancement
   - C. Dolomitization
   - D. WORKSHOP: Classification of Pore Types

VI. ART OF CONTOURING
   - A. WORKSHOP: Contouring Exercises

VII. STRUCTURAL TRAPS
   - A. Folds
   - B. Faults
   - C. Diapiric Structures
   - D. WORKSHOP: Contouring of Major Structural Styles

VIII. STRATIGRAPHIC AND COMBINATION TRAPS
   - A. Origin, Geometry, and Technique of Exploring for Stratigraphic Traps
   - B. WORKSHOP: Contouring of Major Types of Stratigraphic Traps

Instructor

Burr A. Silver

(See page 7 for instructor's vita.)

TUITION: $625.00 U.S. Funds ($750.00 U.S. Funds for London Session)

Includes INSTITUTE manual, workshops and workshop materials, first-day social hour, and daily coffee and cold drinks.

INSTITUTES FOR ENERGY DEVELOPMENT

APPLIED PETROLEUM RESERVOIR TECHNOLOGY

IED EXPLORATION, INC.

April 6-10, 1981 . . . Houston, TX

July 27-31, 1981 . . . London, England

September 14-18, 1981 . . . Denver, CO

. . . Designed to give geologists, geophysicists, managers, and other nonreservoir engineering personnel a new insight into physical properties, production characteristics, reserve determinations, and improved recovery methods for oil and gas reservoirs.

This five-day INSTITUTE provides a "nuts-and-bolts" blend of theory and practice . . . fundamental principles . . . case histories . . . application workshops . . . discussions . . . to assist the attendee in project work, decision making, and communication with reservoir engineers.

CONTENT includes: Reservoir rock properties (porosity, permeability, saturations, averaging) . . . Reservoir fluid properties (fluid types, physical properties, data reporting) . . . Fluid flow and production performance (reservoir drive mechanisms, volumetric balance, decline curves) . . . Well testing and sampling . . . Reservoir exploitation and improved recovery.

COURSE CONTENT

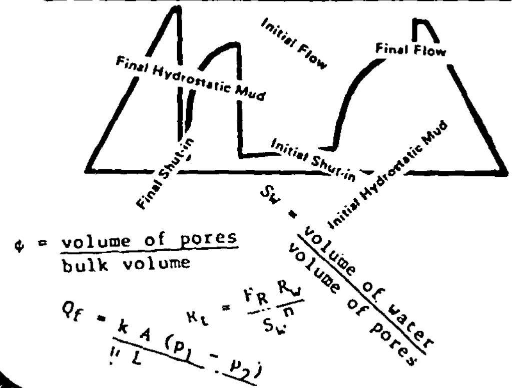
I. RESERVOIR ROCK PROPERTIES
- Porosity
- Fluid Saturations
  1. Wettability
  2. Capillary Pressure
- Permeability
  1. Absolute or Specific
  2. Effective
  3. Relative
- Statistical Manipulation of Rock Property Data
  1. Averaging
  2. Oil-in-place

II. RESERVOIR FLUID PROPERTIES
- Fluid Types
- Reservoir Oil
- Reservoir Gas
- Equilibrium Constants
- Reporting PVT Data

III. FLUID FLOW AND PRODUCTION PERFORMANCE
- Reservoir Fluid Flow
- Reservoir Drive Mechanisms
- Volumetric and Material Balance Calculations
- The Continuity Equation
- Fluid Displacement
  1. Frontal Displacement
  2. Layered-Flow Systems
- Decline Curves and Deliverability
  1. Oil Reservoirs
  2. Gas Deliverability
  3. Productivity Indices

IV. WELL TESTING AND SAMPLING
- Stabilization and Conditioning
- Pressure Measurements
- Well Completion Configurations

V. RESERVOIR EXPLOITATION AND RECOVERY ENHANCEMENT
- Secondary and Tertiary Recovery
  1. Gas and Water Injection
  2. Miscible Displacement
  3. Other Recovery Processes
- Reservoir Simulation
  1. Mathematics of Simulation
  2. Model Grid Systems
  3. Calculation Procedures
  4. Model Systems
  5. Reservoir Studies



Instructor Field Roebuck, Jr.

(See page 7 for instructor's vita.)

TUITION: $625.00 U.S. Funds ($750.00 U.S. Funds for London Session) Includes course manual, first-day social hour, daily coffee and cold drinks, all workshop materials.

Participants are requested to bring a pocket calculator with logrithmic functions for workshop calculations.

INSTITUTES FOR ENERGY DEVELOPMENT

FUNDAMENTALS OF WELL LOG INTERPRETATION

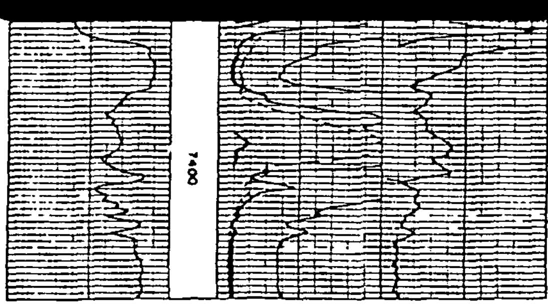
IED EXPLORATION, INC.

March 9-13, 1981 . . . . Houston, TX
July 20-24, 1981 . . . . Midland, TX
Oct. 12-16, 1981 . . . . New Orleans, LA
Nov. 30-Dec. 4, 1981 . . . . Tulsa, OK

Emphasis is on acquiring data from well logs, evaluating the quality of data, making quantitative analyses, interpreting results of calculations, and discussing applications and pitfalls of well log data. INSTITUTE is workshop and case history oriented with minimal effort given to logging-tool theory.

COURSE CONTENT

1. BASIC ROCK PROPERTIES
   - Porosity
   - Permeability
   - Saturation
   - Capillary Pressure
2. RESISTIVITY
   - Fluids
   - Reservoir Rocks
   - The Borehole Environment
   - Shale Resistivity
3. RESISTIVITY MEASURING DEVICES
   - Induction Concepts
   - Short Normal
   - Spherically Focused Log
   - Induction Borehole Corrections
4. SPONTANEOUS POTENTIAL (SP) LOG
   - Permeability
   - Factors Influencing the SP
   - Bed Thickness
   - Borehole and Invasion Influences
   - Shale Influences
5. THE INDUCTION ELECTRIC AND DUAL INDUCTION LOGS
   - Induction Electric Log
   - Dual Induction Log
   - Induction Spherically Focused Log
   - Invasion
6. ACOUSTIC AND GAMMA RAY LOGS
   - Porosity of Compacted and Consolidated Sandstones
   - Porosity of Carbonates
   - Gamma Ray (Natural) Logs
   - Gamma Ray Curve Characteristics
7. QUANTITATIVE ANALYSIS—WATER SATURATION CALCULATION AND Rwa
8. DENSITY LOGS
   - The Density Measuring Instrument
   - Porosity
9. NEUTRON LOGS
   - Sidewall (Pad) Neutron
   - Compensated Neutron Logs
10. COMBINED POROSITY LOGS
    - Complex Lithology
    - Compatible Porosity Scales
    - Density/Acoustic Crossplot
    - Tri-Lithology Solutions
    - Gas Detection with Porosity Logs
11. FOCUSED RESISTIVITY LOGS
    - Laterologs
    - Spherically Focused Log
    - The Dual Laterolog
    - Micro-Resistivity Logs
    - Focused and Guard Logs
    - Microlog
    - Laterolog 8
    - Microlaterolog
12. QUANTITATIVE ANALYSIS
13. SHALY SANDSTONE INTERPRETATION
    - Shale Influences on Logs
    - Density-Neutron Crossplot for Shale Determination
    - Porosity Log Correction for Shale Content
14. ABNORMAL PRESSURE DETECTION WITH WELL LOGS
15. FRACTURE DETECTION WITH WELL LOGS
16. DIPMETER PRINCIPLES



INSTITUTES FOR ENERGY DEVELOPMENT

Instructor
John S. Fischer

(See page 7 for instructor's vita.)

TUITION: $645.00
Includes course manual, first-day social hour, daily coffee and cold drinks, all workshop materials.
Participants are requested to bring a pocket calculator with logarithmic and exponential functions for workshop calculations.

SHALY SAND LOG INTERPRETATION

IED EXPLORATION, INC.

February 3-4, 1981 . . . Houston, TX

May 26-27, 1981 . . . New Orleans, LA

This new course is designed to give geologists and engineers already familiar with well logs some additional interpretive techniques which will help them identify and evaluate shaly productive formations.

The anomalous responses on well logs caused by the presence of shale and authigenic clays in reservoir rocks make quantitative well log analysis difficult and usually pessimistic. Several techniques using different combinations of well logs are described which can help locate hard-to-find productive shaly reservoirs.

Practical application workshop examples will be provided which illustrate various approaches to interpreting shaly sands.

COURSE CONTENT

- Effects of Shales and Clays on Various Logs
- Classical Approach to Shaly Sand Interpretation
- Determination of V_{sh} (Bulk Volume Shale) and q (Percent Shale in Pore Space)
- The Gamma Ray and SP Logs as Hydrocarbon Indicators
- Determining Total Porosity and Effective Porosity
- Gas Effects in Shaly Sands
- Water Saturation (S_w) Determination using:
  - Resistivity and Acoustic Logs
  - Resistivity and Neutron Logs
  - Resistivity and Density Logs
  - Resistivity, Acoustic, and Neutron Logs
  - Resistivity, Density, and Neutron Logs
- Effects of Various Clay Minerals
- "Dual Water" Interpretation
- Use of the Programmable Pocket Calculator for Interpreting Shaly Sands

Instructor
John S. Fischer

(See page 7 for instructor's vita.)

TUITION: $310.00
Includes INSTITUTE manual, workshops and workshop materials, first-day social hour, and daily coffee and cold drinks.

Participants are requested to bring a pocket calculator with logarithmic and exponential functions for workshop calculations.

INSTITUTES FOR ENERGY DEVELOPMENT

USE OF OLD ELECTRICAL LOGS

IED EXPLORATION, INC.

February 5-6, 1981 . . . Houston, TX

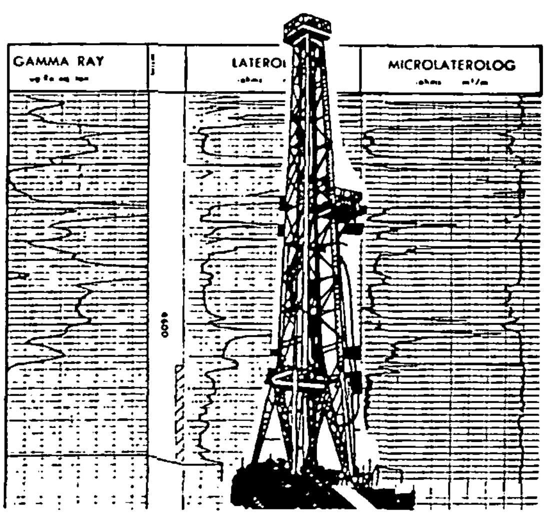
May 28-29, 1981 . . . New Orleans, LA

October 8-9, 1981 . . . Oklahoma City, OK

Because of the increasing importance of exploitation and enhanced recovery projects, this course is designed to help the geologist, geophysicist, and engineer maximize their use of electrical type logs run prior to the late 1950's.

COURSE CONTENT

1. RESISTIVITY AND SP INTERPRETATION FUNDAMENTALS REVIEW
   - Spontaneous (Self) Potential
   - Rw from the SP
   - Review of SP Curve Shapes
2. THE LATERAL CURVE
   - Lateral Curve Shapes
   - Lateral Corrections (General)
   - Borehole Correction
   - Bed Thickness and Adjacent Beds
   - More Complex Lateral Curve Shapes
3. THE NORMAL CURVE
   - The Point Electrode
   - Normal Curve Shapes
   - Borehole Correction
   - Bed Thickness and Adjacent Bed Corrections
   - More Complex Normal Curve Shapes
4. THE ELECTRICAL LOG (ES)
   - Using the Old ES
5. ELECTRICAL LOG DEPARTURE CURVES
   - Historical
   - Departure Curves
6. THE MICROLOG
   - The Measurement
   - Porosity
   - Porosity Calculation
   - Microlog Mud Log
7. POROSITY FROM THE SHORT NORMAL
   - Theory
   - Example Problems
8. THE LIMESTONE DEVICE
   - Porosity from the Limestone Device
9. SALT MUD SURVEYS (LATEROLOGS AND MICRO-LATEROLOGS)
10. THE OLD GAMMA RAY AND NEUTRON LOGS
11. THE ELECTRICAL LOG AND PULSED NEUTRON CAPTURE LOGS



Instructor
Douglas W. Hilchie

(See page 7 for instructor's vita.)

TUITION: $310.00
Includes course manual, first-day social hour, daily coffee and cold drinks.

INSTITUTES FOR ENERGY DEVELOPMENT

ECONOMIC ANALYSIS OF PETROLEUM VENTURES

EXPLORATION, INC.

July 14-17, 1981 . . . Vail, CO

October 27-30, 1981 . . . New Orleans, LA

THIS INSTITUTE WILL PROVIDE THE PARTICIPANT :

- Review of the role of economic analysis in exploration and development ventures.
- Working vocabulary of financial terms.
- "Hands-on" experience in preparing economic analyses.
- Workshop problems and case histories.

A typical comment received by a participant of this seminar: "I have attended several other courses which purported to cover the same material, invariably taught by economists from outside the industry. This course is in my opinion the best of the lot, owing largely—I suspect—to Mr. Roebuck's familiarity with economical evaluation as directly related to the exploration/production aspect of the oil industry."

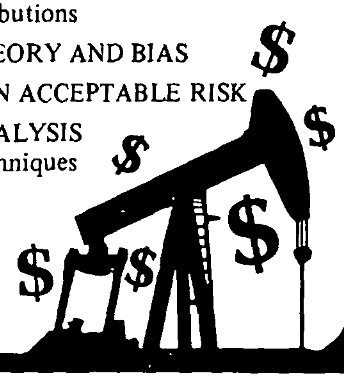
COURSE CONTENT

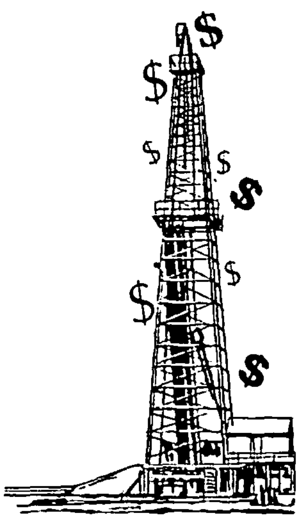
ANALYSIS OF INVESTMENTS

- CASH FLOW PROJECTIONS
  - Cash Items
  - Book Items
  - After-Tax Cash Flow
- PRESENT VALUE CONCEPTS
  - Discounting Methods
  - Selection of Discount Rates
- INVESTMENT CRITERIA
  - Payout
  - Profit to Investment Ratios
  - Rates of Return
  - Cost of Capital
- BUYING POWER AND INFLATION
- CONFIDENCE FACTORING

ANALYSIS OF RISK

- EXPECTED VALUE CONCEPTS
- DECISION TREES
- HANDLING PROBABILITIES
  - Joint and Conditional Probabilities
  - Single and Multi-Valued Estimates
  - Central Limit Theorem
  - Value of Additional Information
  - Frequency Distributions
- PREFERENCE THEORY AND BIAS
- ESTABLISHING AN ACCEPTABLE RISK
- MODELS AND ANALYSIS
  - Monte Carlo Techniques
  - Bidding Theory
- RISK PROFILES
- RISK REDUCTION





Instructor

Field Roebuck, Jr.

(See page 7 for instructor's vita.)

TUITION: $525.00

Includes course manual, first-day social hour, daily coffee and cold drinks, all workshop materials.

Participants are requested to bring a pocket calculator with logarithmic functions for workshop calculations.

INSTITUTES FOR ENERGY DEVELOPMENT

FUNDAMENTALS OF OIL & GAS LEASING

IED EXPLORATION, INC.

March 18-20, 1981 . . . Houston, TX May 13-15, 1981 . . . Dallas, TX
July 6-8, 1981 . . . Vail, CO

FUNDAMENTALS OF OIL AND GAS LEASING is a practical application oriented seminar outlining the practices of the petroleum industry in negotiating, taking, and administering oil and gas leases and focusing upon potential problems with a view to avoiding them. Its transactional analysis will be useful to explorationists, managers, and investors as well as landmen . . . to anyone who may have to make decisions or recommendations relating to land.

This three-day INSTITUTE mixes discussion of the principles of sound lease acquisition and administration with analysis of frequently occurring problems to inform the participant of current industry practices and current industry problems. Many actual current case studies will be used.

PROGRAM

I. Anatomy of the Oil and Gas Lease

II. Obtaining the Oil and Gas Lease
- Selection of form
- Negotiation of modifications
- Clearing title
- Execution of the lease

III. Problems During the Primary Term
- Failure of title
- Failure to comply with the drilling clause
- Failure to pay delay rentals
- Disputes over use of the land surface

IV. Problems in Extending the Lease to the Secondary Term
- Necessity of production
- Protective clauses and their requirements
  - Force Majeure
  - Dry hole
  - Drilling operations/continuous drilling/cessation of production clauses
  - Shut-in royalty clauses

V. Problems in the Secondary Term
- Pooling and unitization
- Allocation of expenses to royalty
- Calculation of royalties
- Payment of royalties

VI. Covenants Implied in Oil and Gas Leases
- The reasonable prudent operator standard
- The covenant to test
- The covenant to offset
- The covenent to reasonably develop
- The covenant to explore
- The covenant to market
- Other implied covenants

VII. Obligations and Problems Upon Termination of the Lease
- Duty to clean up and restore
- Duty to clear title
- Right to remove equipment

Instructor
John S. Lowe

TUITION: $455.00
Includes INSTITUTE manual, first-day social hour, and daily coffee and cold drinks.

INSTITUTES FOR ENERGY DEVELOPMENT

PETROLEUM LAND PRACTICE

(Acreage Acquisition)

IED EXPLORATION, INC.

April 6-9, 1981 . . . Houston, TX

August 10-13, 1981 . . . Vail, CO

November 16-19, 1981 . . . Denver, CO

A practical application land course for the explorationist-manager-investor. An in-depth coverage of the legal and technical aspects of petroleum land acquisition with particular emphasis on those practical problems encountered in day-to-day operations.

How to Acquire and Secure Leases
How to Avoid Legal Pitfalls
How to Satisfy your Company's Obligations
. . . are important to explorationists, land personnel, and managers when acquiring acreage and negotiating deals to process acreage.

This INSTITUTE has been approved by the Colorado Board of Continuing Legal and Judicial Education for 27 hours of credit and by the Minnesota Board of Continuing Legal Education for 23 hours of credit. Inquire about professional continuing education credit in your state.

COURSE CONTENT

1. PETROLEUM LAND TITLES
   - Evolution of Land Law
   - Private, State, Federal
   - Ownership
   - Transfer of Title
   - Ownership and Transfer of Title to Minerals
   - Curing Land Titles
   - Practical Exercises
2. THE OIL AND GAS LEASE
   - Basic Concepts
   - Granting, Habendum, and Pooling Clauses
   - The Royalty Clause; "Market Value" Royalty Problems
   - Drilling-Delay Rental and Shut-In Clauses
   - Practical Exercises
3. INTRODUCTION TO OIL AND GAS TAXATION
   - Basic Tax Concepts
   - Depreciation and Depletion
   - Intangible Drilling and Development Costs
   - Geologic, Geophysical, and Lease Acquisition Costs
4. OIL AND GAS CONTRACTS
   - What is a Contract?
   - Farmout Agreements
   - Revenue Ruling 77-176
   - Operating Agreements (AAPL Form 610)
   - Practical Exercises
5. UNITIZATION
   - Necessity for Unitized Operations
   - Drilling and Spacing Units
   - Pooling Clauses
   - Statutory Spacing Units
   - Federal Exploratory Units
   - Fieldwide Unitization

Instructor
Lewis G. Mosburg, Jr.

(See page 7 for instructor's vita.)

TUITION: $550.00
Includes INSTITUTE manual, first-day social hour, daily coffee and cold drinks.

INSTITUTES FOR ENERGY DEVELOPMENT

BASICS OF STRUCTURING EXPLORATION DEALS

(Acreage Processing)

IED EXPLORATION, INC.

March 4-6, 1981 . . . Houston, TX

June 10-12, 1981 . . . New Orleans, LA

September 16-18, 1981 . . . Denver, CO

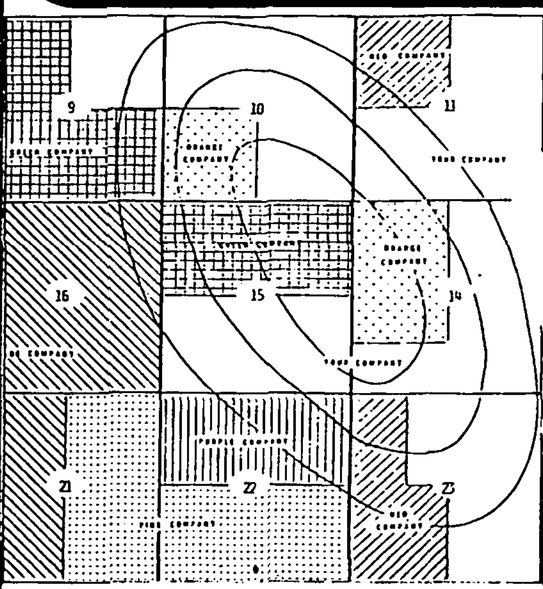
A basic course on the methods used to structure deals to evaluate oil and gas leases . . . Designed specifically for petroleum explorationists, managers, and investors.

The objective of this INSTITUTE is to provide a detailed coverage of the various contracts used in making exploration deals and the tax and financial advantages and pitfalls of alternative deals.

This INSTITUTE has been approved by the Minnesota Board of Continuing Legal Education for 17.5 hours of credit and by the Colorado Board of Continuing Legal and Judicial Education for 16 hours of credit. Inquire about professional continuing education credit in your state.

COURSE CONTENT

1. CONTRACTS USED IN STRUCTURING EXPLORATION DEALS
   - Acreage Contribution
   - Dry Hole/Bottomhole Contributions
   - Farmout/Farmin
   - Seismic Option
   - Drilling Option
   - Working Interest Units
2. BASIC CONCEPTS OF TAXATION
   - Basic Principles
   - Tax Treatment of Lease Acquisition Costs
   - Intangible Drilling Costs
   - Depreciation
   - Depletion
   - IRS Ruling 77-176
3. BASIC PRINCIPLES OF PETROLEUM ECONOMICS
   - Determining Company Goals
   - Determining Project Profitability
   - Evaluating Risk
4. KNOWING AND NEGOTIATING ALTERNATIVE DEALS
   - Problems and Pitfalls in Structuring Alternatives
   - Tax Consequences of Alternative Deals
   - Financial Aspects of Alternative Deals
   - Practical Application
5. PRACTICAL APPLICATION, CASE HISTORY WORKSHOPS
   - Practical application, case history workshops will give the participant experience in evaluating alternative types of exploration deals.



Instructor
Lewis G. Mosburg, Jr.

(See page 7 for instructor's vita.)

TUITION: $465.00
Includes INSTITUTE manual, first-day social hour, daily coffee and cold drinks.

Participants are requested to bring a pocket calculator for workshop calculations.

INSTITUTES FOR ENERGY DEVELOPMENT

(See page 7 for instructor's vita.)

PETROLEUM EXPLORATION TECHNOLOGY

IED EXPLORATION, IN^. (GEOLOGY and GEOPHYSICS)

May 26-29, 1981 . . . New Orleans, LA

July 28-31, 1981 . . . Vail, CO

October 6-9, 1981 . . . Houston, TX

FOR THE INDUSTRY BUSINESS PERSON WITHOUT A TECHNOLOGICAL BACKGROUND

This seminar is for land support personnel, non-technical managers, lawyers, and other professionals who have had minimal training in exploration *and engineering technology . . . YET routinely* associate and deal with geologists, geophysicists, and engineers in making financial decisions . . . negotiating deals . . . drawing up contracts . . . unitization hearings . . . reviewing recommendations . . . and routine business actions.

The objectives are to provide basic communication skills and practical application opportunities in using the technology of finding oil and gas fields.

COURSE CONTENT

1. SOURCES OF DATA USED IN EXPLORATION
   - Nature of Exploration Data
   - Wellbore Data
   - Outcrop-Ancient Rocks
   - Geophysics
   - Modern Environments
   - LOG CORRELATION WORKSHOP
2. DISPLAY OF EXPLORATION DATA
   - Block Diagrams
   - Contour Maps
   - Columnar Sections
   - Cross Sections
   - CONTOUR WORKSHOPS
3. BASIC GEOLOGIC PRINCIPLES
   - Uniformitarianism
   - Cross-Cutting Relationships
   - Superposition
   - Unconformities
   - GEOLOGIC EVENTS WORKSHOP
4. GEOLOGIC HISTORY OF PETROLEUM
   - Source Material
   - Expulsion
   - Source Rocks
   - Migration
   - Generation
5. PETROLEUM RESERVOIRS
   - Porosity
   - Permeability
   - Pore Size
   - Potential Clastic Reservoirs
     a. Clastic Geology
     b. Depositional Environments
   - Potential Carbonate Reservoirs
     a. Carbonate Geology
     b. Classification of Carbonate Rocks
     c. Classification of Carbonate Porosity
     d. Types of Depositional Environments
   - RESERVOIR PREDICTION WORKSHOP
6. PETROLEUM TRAPS
   - Definitions
   - Carbonate Porosity Pinchouts
   - Global Tectonics
   - Reefs
   - Folded Structural Traps
   - Stratigraphic Truncation Traps
   - Fault Traps
   - Salt Domes
   - Stratigraphic Clastic Traps
   - STRUCTURAL TRAP WORKSHOP
7. OVERVIEW OF GEOPHYSICAL METHODS
   - Reflection
   - Gravity
   - Refraction
   - Magnetics
8. BASIC PHYSICS OF SEISMIC REFLECTIONS
   - Ray Trace Concept
   - WORKSHOP
9. NATURAL ENHANCEMENT/INTERFERENCE OF REFLECTIONS
   - Weathering
   - Multiples
   - Moveout
   - "Noise"
10. DATA ACQUISITION (FIELD OPERATIONS)
    - Planning a Seismic Program
    - Types of Energy Source
    - Field Crews and Equipment
    - Recording Procedures
    - Permitting and Surveying
11. DATA PROCESSING
    - Data Corrections
    - Velocity Analysis
    - Stacking
    - Deconvolution
    - Filtering
    - Data Storage
12. INTERPRETATION AND APPLICATION
    - Identifying Geologic Features
    - Correlation
    - Mapping Techniques
    - Pitfalls
    - Case History
    - MAJOR WORKSHOP—MAPPING PROJECT

Instructors
Larry D. Vredenburgh
J.W. Garhart

(See page 7 for instructors' vitas.)

TUITION: $525.00
Includes INSTITUTE manual, workshops and workshop materials, first-day social hour, and daily coffee and cold drinks.

INSTITUTES FOR ENERGY DEVELOPMENT

PETROLEUM INDUSTRY OVERVIEW

IED EXPLORATION, INC.

March 12-13, 1981 .... Houston, TX
April 30-May 1, 1981 ..... New Orleans, LA
June 29-30, 1981 .... Denver, CO
September 24-25, 1981 .... Chicago, IL
October 1-2, 1981 .... Tulsa, OK
October 15-16, 1981 ..... San Francisco, CA
November 9-10, 1981 .... Dallas, TX

This seminar is designed to provide the participant a comprehensive OVERVIEW of the TECHNICAL and BUSINESS aspects of the petroleum industry.

Emphasis is placed upon. . .(1) familiarizing participants with terminology of the industry's technology and business practices and (2) providing an understanding of the functions and interrelations of the different departments and activities of Petroleum Companies.

A few of the many questions that will be answered include:

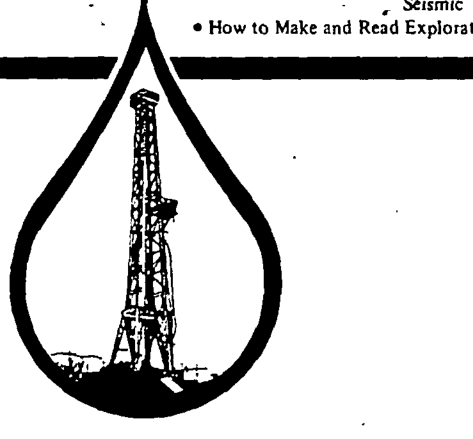
- How is an oil company organized?
- How are prospects generated?
- How is acreage acquired?
- How are wells drilled and completed?
- How are reservoirs evaluated?
- How are oil and gas produced?

Presentation Techniques include:

- Practical Application Workshops
- Two 35mm slide projectors in use simultaneously in order to provide one screen for definitions, outlines, or other reference material; while the other screen exhibits more detailed illustrations.

SEMINAR CONTENT

1. **PETROLEUM INDUSTRY HISTORY**
   - Early Beginning
   - Significant Highlights
   - Today's Industry
   - Typical Organization of Departments
   - Organization of Integrated Oil Companies
2. **WHAT IS PETROLEUM?**
   - Origin
   - Types
   - Composition
   - Uses
3. **EXPLORATION FOR PETROLEUM**
   - The Exploration Department
     Geologist, Land Personnel, Geophysicist
   - Exploration Methods & Data Sources
     Surface Mapping, Drillstem Tests, Wireline Logging, Cores, Sample Cuttings, Seismic
4. **PETROLEUM LAND PRACTICES**
   - Land Description
   - Ownership
   - Petroleum Land Titles
   - Leasing
   - Types of Drilling Deals
     Joint Ventures, Working Interest, Farmout, Royalties, Farmin, Bonuses & Rentals, Support
5. **EXHIBITING EXPLORATION IDEAS**
   - Maps
     Contour, Facies
   - Cross Sections
     Structural, Stratigraphic, Seismic
   - How to Make and Read Exploration Exhibits
6. **PETROLEUM RESERVOIR GEOLOGY**
   - Movement of Petroleum in Rocks
   - Reservoir Rock Properties
     Rock Types, Permeability, Porosity, Water Saturation
   - Petroleum Trapping Conditions
     Structural Folds and Faults, Stratigraphic Trap Types
7. **HOW ARE OIL & GAS WELLS DRILLED?**
   - Onshore and Offshore Rigs
   - Drill String and Bits
   - Mud System
   - Problem Drilling
     Stuck Pipe, Lost Circulation, Fishing, Abnormal Pressure
8. **HOW ARE OIL & GAS WELLS COMPLETED AND PRODUCED?**
   - Formation Evaluation
   - Types of Wells
   - Casing
   - Cementing
   - Perforation
   - Stimulation
   - Surface Equipment
   - Reservoir Drive Mechanisms
   - Enhanced (Secondary) Recovery
   - Units
   - Drilling/Completion Reports
9. **STORAGE AND TRANSPORTATION**
   - Field Equipment
   - Tankers
   - Pipelines
10. **U.S. PETROLEUM INDUSTRY OUTLOOK**
    - Oil and Gas Reserves
    - Alternative Energy Sources



Instructor
Larry D. Vredenburgh

(See page 7 for instructor's vita.)

TUITION: $285.00

Includes INSTITUTE manual, workshops and workshop supplies, first-day social hour, and daily coffee and cold drinks.

INSTITUTES FOR ENERGY DEVELOPMENT

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Or Call 918-665-0784

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PETROLEUM INDUSTRY SEMINARS

EXPLORATION INSTITUTES

- Subsurface Exploration Stratigraphy
- Structural Geology
- Carbonate Reservoirs
- Carbonate Sedimentation Field Trip
- Exploration Geology
- Seismic Interpretation Techniques

RESERVOIR EVALUATION INSTITUTES

- Applied Petroleum Reservoir Technology
- Fundamentals of Well Log Interpretation
- Shaly Sand Log Interpretation
- Use of Old Electrical Logs

MANAGEMENT/FINANCIAL INSTITUTES

- The Management Institute
- Financing Oil and Gas Deals
- Economic Analysis of Petroleum Ventures

PETROLEUM LAND INSTITUTES

- Fundamentals of Oil and Gas Leasing
- Petroleum Land Practices
- Basics of Structuring Exploration Deals

CROSS-DISCIPLINE INSTITUTES

- Techniques of Using Geologic Data
- Techniques of Using Geophysical Data
- Petroleum Exploration Technology
- Petroleum Production Technology
- Petroleum Industry Overview

PUBLICATIONS

Applied Openhole Log Interpretation
Economic Analysis of Petroleum Ventures
Old Electrical Log Interpretation
Applied Petroleum Reservoir Technology
Petroleum Production Technology
Techniques of Using Geologic Data
Petroleum Land Practices—Leases, Titles, Contracts, Taxation, Unitization
Basics of Structuring Exploration Deals
Financing Oil and Gas Deals
Basic Oil and Gas Accounting and Taxation
Contracts Used in Oil and Gas Law
Oil and Gas Taxation
Windfall Profits Excise Tax and Crude Petroleum Economics and Pricing
Pooling and Unitization

PETROLEUM INDUSTRY SEMINARS

EXPLORATION INSTITUTES

- Subsurface Exploration Stratigraphy
- Structural Geology
- Carbonate Reservoirs
- Carbonate Sedimentation Field Trip
- Exploration Geology
- Seismic Interpretation Techniques

RESERVOIR EVALUATION INSTITUTES

- Applied Petroleum Reservoir Technology
- Fundamentals of Well Log Interpretation
- Shaly Sand Log Interpretation
- Use of Old Electrical Logs

MANAGEMENT/FINANCIAL INSTITUTES

- The Management Institute
- Financing Oil and Gas Deals
- Economic Analysis of Petroleum Ventures

PETROLEUM LAND INSTITUTES

- Fundamentals of Oil and Gas Leasing
- Petroleum Land Practices
- Basics of Structuring Exploration Deals

CROSS-DISCIPLINE INSTITUTES

- Techniques of Using Geologic Data
- Techniques of Using Geophysical Data
- Petroleum Exploration Technology
- Petroleum Production Technology
- Petroleum Industry Overview

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Applied Openhole Log Interpretation
Economic Analysis of Petroleum Ventures
Old Electrical Log Interpretation
Applied Petroleum Reservoir Technology
Petroleum Production Technology
Techniques of Using Geologic Data
Petroleum Land Practices—Leases, Titles, Contracts, Taxation, Unitization
Basics of Structuring Exploration Deals
Financing Oil and Gas Deals
Basic Oil and Gas Accounting and Taxation
Contracts Used in Oil and Gas Law
Oil and Gas Taxation
Windfall Profits Excise Tax and Crude Petroleum Economics and Pricing
Pooling and Unitization

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INSTITUTE ENROLLMENT INFORMATION

ENROLLMENTS . . . can be made by returning an enrollment card (page 29) to:

IED Exploration, Inc.
INSTITUTES for ENERGY DEVELOPMENT
P.O. Box 45941
Tulsa, OK 74145

or by calling the registrar—918-665-0784.

TUITION FEES . . . may be enclosed with the enrollment card . . . or, if requested, IED Exploration will bill you or your company. Fees are payable in U.S. Funds.

SUBSTITUTIONS . . . of participants from the same company may be made at any time at no extra charge.

TRANSFERS . . . of a participant's tuition fee from one INSTITUTE to another may be made at any time.

CERTIFICATES . . . will be given to each participant upon completion of an INSTITUTE.

HOTEL ACCOMMODATIONS . . . IED Exploration has reserved a block of rooms at each INSTITUTE hotel. If you wish to stay there, please complete the appropriate space on the enrollment card and IED will make your reservation. INSTITUTE attendees are responsible for their own living costs.

CONFIRMATION LETTER . . will be mailed to each participant upon receipt of enrollment, wherein, INSTITUTE logistical information will be given.

TAX DEDUCTION OF EXPENSES . . . may be allowed for education expenses (including tuition fees, travel, meals, and lodging) incurred to maintain and improve professional skills. (Refer to Treas. Reg. 1-162-5, Coughlin vs. Commissioner, 203 F. 2d 307)

BOOK PURCHASE INFORMATION

THE FOLLOWING INSTITUTE MANUALS MAY BE PURCHASED

- Applied Openhole Log Interpretation
- Economic Analysis of Petroleum Ventures
- Old Electrical Log Interpretation
- Applied Petroleum Reservoir Technology
- Petroleum Production Technology
- Techniques of Using Geologic Data
- Petroleum Land Practices
- Basics of Structuring Exploration Deals
- Pooling and Unitization
- Financing Oil & Gas Deals (Obtaining Drilling Capital from Tax-Oriented Investors)
- Basic Oil and Gas Accounting & Taxation
- Contracts Used in Oil & Gas Law
- Oil and Gas Taxation
- Windfall Profits Excise Tax and Crude Petroleum Economics and Pricing

BOOK PRICES AND DESCRIPTIONS . . . . .Refer to Page 6
BOOK ORDER FORM . . . . .Refer to Page 29

FOR MORE INFORMATION CONTACT

IED Exploration, Inc.
INSTITUTES for ENERGY DEVELOPMENT
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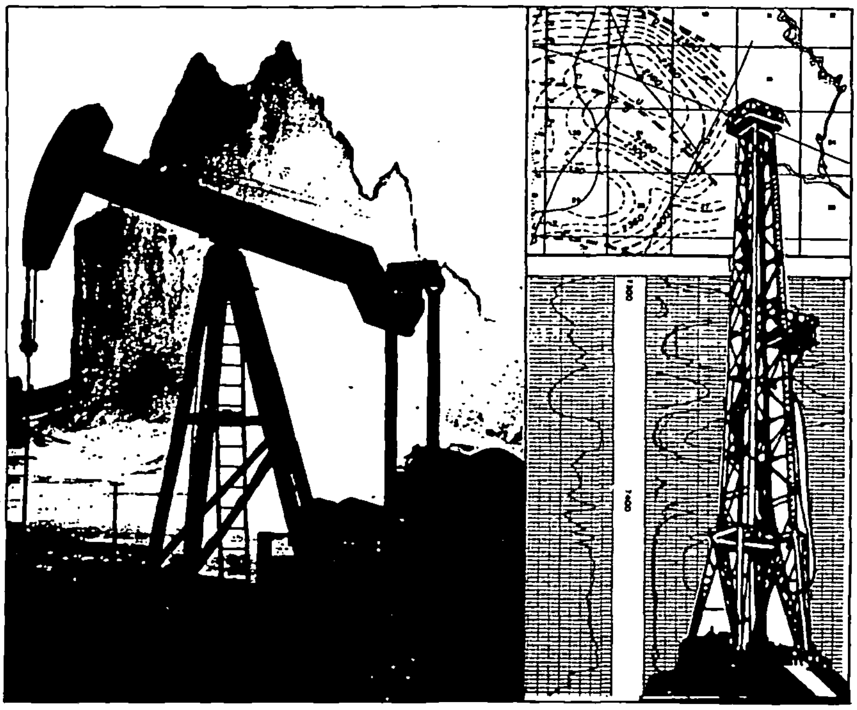

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NATIONAL GEOTHERMAL REPORT

Vol.1, No.1
February 23, 1979

TEXAS GEOTHERMAL/GEOPRESSURE DRILLING PROGRAM CONTINUING IN BRAZORIA COUNTY

General Crude, Houston, is drilling below 8500 ft at 2 Pleasant Bayou, located on a 320-acre lease in Perry & Austin Survey 2, Brazoria County, Texas. The scheduled 16,500 ft test is the company's second in a Department of Energy sponsored, Texas geothermal/geopressure program.

The 1 Pleasant Bayou, 45 miles south of Houston and about 500 ft northwest of the well being drilled was plugged in January because of mechanical problems encountered while drilling at 15,675 ft. If the 2 Pleasant Bayou is successful, it will be tested for two years and the 1 Pleasant Bayou will be used as an injection well. Total cost of the project was initially estimated at about $8.2 million, but, according to General Crude, may exceed $13 million.

This geothermal/geopressure program as well as similar DOE-sponsored studies in the Southeast are aimed at finding, evaluating and eventually developing geopressure areas as energy sources. In delineating geopressure resources from typical hydrothermal, pressure and temperature gradients must be analyzed. The average pressure gradient in hydrothermal exploration is about .4-.5 psi per ft, while pressure gradients encountered in geopressure drilling range from .7-.8 psi per ft, increasing. Temperature gradients encountered in geopressure drilling are higher than those in hydrothermal drilling...ranging upward from 300 degrees Fahrenheit. Studies indicate that geopressure wells will normally have total depths of 15,000 ft or below, and saline fluids found during drilling may contain natural gas in saturation.

The Texas project, according to DOE, will be ongoing with four to five wells drilled annually. The first wells in the program will be drilled in potential geopressure areas, while later wells will explore other thermal areas.

IN UPCOMING ISSUES. . .international news, special reports, ongoing coverage of national geothermal activity

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DOE DRILLING DEEP GEOTHERMAL WELL ON SNAKE RIVER PLAIN, IDAHO

Brinkerhoff Signal Drilling Co, Denver, under contract to the Department of Energy, is drilling below 380 ft at a proposed 7500 ft geothermal wildcat located on the Snake River Plain, southern Idaho. The well, 1 INEL in 1-3n-29e, Butte County, is to be drilled through volcanic rock into "much older basement rock underlying the plain." Drilling information will be used to assess geothermal potential in the area.

Temperatures of 250-300 degrees Fahrenheit are believed to exist at basement. DOE estimates about 21,500 square miles of potential geothermal reservoir in the area. Estimated cost of the project is $3 million.

EAST COAST'S FIRST DEEP GEOTHERMAL WELL SCHEDULED IN MARYLAND

The first deep geothermal well on the East Coast has been scheduled by the Department of Energy (DOE) on municipal airport lands in Crisfield, Maryland, in

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the central portion of the Delmarva Peninsula. Because permitting procedures for the deep well and an adjacent injection well are not complete, exact well locations have not been reported. Drilling of the proposed 5100 ft geothermal test is to begin in early April, with Gruy Federal Inc, Houston, acting as contractor. Estimated project cost is $750,000.

Selection of the Maryland site followed an eight-month temperature gradient study (part of a DOE program to determine economic feasibility of tapping East Coast geothermal heat sources) in which about 40, 1000 ft holes were drilled in New Jersey, Delaware, Maryland, Virginia and North Carolina between June, 1978 and mid-January. Results of tests, conducted with the aid of Virginia Polytechnic Institute and State University, revealed granite masses from New Jersey to North Carolina which are "acting as heat generators through slow decay of natural radioactive minerals."

Underground temperatures at the Maryland location were found to increase about 2.5 degrees Fahrenheit for every 100-ft interval. This increase, according to DOE, is more than twice the average. The anticipated temperature of underground water at the well's proposed total depth is 185 degrees Fahrenheit. Although too cool for electric generation, the temperature is suitable for "low to moderate temperature applications"...residential and industrial heating and agricultural use. The location is on a geophysical anomaly and, therefore, may result in a major geothermal find.

PROGRAM TO EVALUATE NEVADA GEOTHERMAL RESERVOIRS FUNDED IN PART BY DOE

Eight companies have been contracted by the Department of Energy to evaluate geothermal reservoir areas in seven counties in Nevada. In a $22 million cost-sharing project designed to "offset industry's high exploration costs and stimulate geothermal development by making technical data available," DOE will contribute $10 million of the total. Individual contract requirements vary by company and evaluation area; however, the entire program will involve geophysical surveys, drilling of 17 lithology and heat measurement holes to 1000-2000 ft, and the testing of about 14 exploratory wells ranging in depth from 4000-10,000 ft.

Information obtained during the two and a half year program will be turned over to the Earth Science Laboratory of the University of Utah Research Institute, Salt Lake City, and (in cooperation with DOE) evaluated and disseminated in the form of geothermal reservoir case history studies. According to the Research Institute, study areas range from "raw prospects" to those on which thermal gradient studies and drilling have been performed.

Companies receiving DOE funding are: Amax Exploration, $559,500 for contract area Tuscarora in Elko County and $594,500 for McCoy in Churchill and Lander counties; Chevron Resources, $263,000 for San Emidio in Washoe County, $273,000 for Soda Lake in Churchill County and $986,000 for Beowawe in Eureka County; and Earth Power, $573,255 for Baltazor in Humboldt County.

Others include Getty Oil, $986,895, Beowawe, Eureka and Lander counties and $859,330, Colado, Pershing County; Phillips Petroleum, $1.3 million, Rye Patch in Pershing County and Desert Peak in Churchill County; Southland Royalty, $1,428,523, Dixie Valley, Churchill County; and Union Oil of California, $801,000, Stillwater, Churchill County. Funding for Aminoil USA's operations in the Leach Hot Springs area of Pershing County is under negotiation.

LOUISIANA GEOTHERMAL/GEOPRESSURE PROJECT IN PRELIMINARY STAGE

For two and a half years members of the Petroleum Engineering Department at Louisiana State University (LSU), Baton Rouge, working with the Department of Energy, have been studying prospective geothermal/ geopressure areas in Louisiana. Within the past year university staff members, after studying geological and geophysical traits of some 63 prospects, have chosen five thermal areas along the

South Louisiana Gulf Coast for possible future exploration. The areas are South Johnson's Bayou, Rockfeller Refuge, Southeast Pecan Island, Atchafalaya Bay and LaFourche Crossing. A sixth prospect chosen by an independent consulting firm is Sweet Lake.

Preliminary environmental assessment of the six prospects concludes that all six areas would not be adversely affected by the drilling of one geothermal test well in each area. However, reassessment of each will be required if full scale drilling operations are planned. The assessment further suggests that Rockefeller Refuge be excluded from geothermal development, if possible, because of its classification as a national refuge and the existence within its boundaries of a "highly protected and unique eco-system."

Members of LSU's department of geology are awaiting DOE funding of another geothermal/geopressure project to assess more closely those prospects chosen, eventually leading to drilling site selection. Meanwhile, the petroleum engineering department hopes to select five additional prospects within a year.

Industry Briefs

Geothermal Resources Council members serving on that organization's 1979 Executive Committee include Bob Greider (Intercontinental Energy Corp, Denver), president; 1st vice president, C. W. Berge (Phillips Petroleum, Salt Lake City); and 2nd vice president, Ronald C. Barr (Earth Power Corp, Tulsa). Others are W. Leo Parchman, Jr. (Sunco Energy Development, Dallas), 3rd vice president; 4th vice president, John W. Lund (Geo-Heat Utilization Center, Oregon Institute of Technology, Klamath Falls); and secretary-treasurer, Phillip N. LaMori (Occidental Research Corp, Irvine, Ca.).

Members-at-large include Dr. Jay F. Kunze (Rexburg, Idaho), Dr. Jim Combs (San Diego), Thomas J. Neville (Bakersfield, Ca), Stanley H. Ward (Salt Lake City), and Reid T. Stone (Menlo Park, Ca.). The Executive Committee was elected at a January 30 meeting of the council's 1979 Board of Directors.

COMPLETIONS

FINAL CLASS: GTM - Producing-Potential Geothermal; GT - Unsuccessful Geothermal; GTD - Unsuccessful Geothermal Deepening; GTR - Unsuccessful Geothermal Redrill; IW - Injection Well; SUS - Suspended Geothermal; U - Stratigraphic, Temperature Gradient, Observation Geothermal.

CALIFORNIA

SONOMA COUNTY

16-11n-8w MD
UNION OIL OF CALIF — 1 Angeli — API 04-097-90379

GEYSERS: 12,000. (4-3-78 BK). El: 1880 KB. — GT
SW/c 961n 1820e.
Contr: Loffland. Spud 9-1-78, 20 @ 80, drld to 11,440, ran ES, TMPL, 9 5/8 @ 10,200, rr 1-11-79, TD 11,440 (Fractured Greywacke). Temperature observation well, comp 2-12-79.

IMPERIAL COUNTY

28-14s-14e SB
MCCULLOCH GEOTHERMAL — 2-28 Mercer — API 04-025-90171

BRAWLEY: (1-15-79 BK). El: -128 KB. — GT
NW/c 2700s 2041e.
Contr: Republic #4. Spud 1-27-79, 20 @ 422, drld to 4170, ran ES, TMPL, 13 3/8 @ 4145, TD 4170. ...Comp as temp observation well 2-12-79.

NEVADA

LYON COUNTY

34-10n-25e MD
CHEVRON RESOURCES — 76-1 U. S.

WILDCAT (WILSON HOT SPRINGS): (1-11-78 BK). El: 3750 (approx)KB. — GT
NW/c 400s 1300e.
Contr: Ecklund. Spud 1-11-78, 7 @ 200, drld to 2002, ran ES, TMPL, TD 2002. ...Comp 2-20-78.

UTAH

BEAVER COUNTY

29-30s-12w SL
REPUBLIC GEOTHERMAL — 57-29

WILDCAT (THERMAL HOT SPRINGS): (10-5-77 BK). — SUS
El: 4400 (approx) KB.
NW/c 4030s 3280e.
Spud 10-5-77, 20 @ 1200, 7 @ 4500, drld to 6980, ran ES, TMPL, TD 6980. ...Sus 6-25-78.

MILLARD COUNTY

21-17s-9w SL
GETTY OIL — 52-21 KGRA

ROOSEVELT HOT SPRINGS: (2-3-78 BK). — SUS
N/4 990s 330e.
Contr: Coastal #2. Spud 2-3-78, drld to 6200 (approx), ran logs, drld to 7500 (approx), ran ES, TMPL, TD 7500 (approx). ...Sus 5-10-78.

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FIRST REPORT SUMMARY

INITIAL CLASS: GT - Geothermal; GTD - Geothermal Deepening; GTR - Geothermal Redrill; GTX - Geothermal Recompletion; IW - Injection Well; U - Stratigraphic, temperature Gradient, Observation Geothermal.

CALIFORNIA

SONOMA COUNTY

34-11n-8w MD
AMINOIL USA — 3 Dillingham & Voight — API 04-097-90372

GEYSERS: (2-23-79 BK). — GT
Spud 2-16-79. ...@ 577, drlg ahead.

IDAHO

BUTTE COUNTY

1-3n-29e (BM)
DEPT OF ENERGY — 1 Inel — API 11-023-60001

WILDCAT: (2/21/79 BK). — GT
NE
Contr: Brinkerhoff-Signal. Spud 2/15/79. ...Drlg 382.

*** ** ***

DRILLING PROGRESS

INITIAL CLASS: GT - Geothermal; GTD - Geothermal Deepening; GTR - Geothermal Redrill; GTX - Geothermal Recompletion; IW - Injection Well; U - Stratigraphic, Temperature Gradient, Observation Geothermal.

CALIFORNIA

LAKE COUNTY

1-10n-8w MD THERMOGENICS, INC	K-1 Klau Mines API 04-033-90183	GEYSERS: 8503. (5-17-78 BK). El: 2546 KB. SE/c 1479n 1574w. Location.	GT
5-11n-8w MD MCCULLOCH GEO THERMAL	1-5 Coleman API 04-033-90201	GEYSERS: 8959 (1-31-79 BK). El: 2573 KB. NW/c 2505s 1020e. Contr: Republic. Spud 2-15-79, 13 3/8 @ 1813 w/1200 sx. ...Drlg 1817.	GT
5-11n-8w MD MCCULLOCH	2-5 Francisco	GEYSERS: Franciscan. (11-15-78 BK). El: 2569 KB. NE/c 1125s 3955w. Contr: H & C #4. Old Well Info: OTD 8910, 13 3/8 @ 1500, 9 5/8 @ 6200, redrld to TD 8730, no details. New Info: Resumed 11-15-78, PB & KO @ 5500, redrld to 8031, lost hole, PB & ST @ 6617, redrld to 6750, ran ES, TMPL, TD 6750 (RD #1). ..Susp oper 2-8-79.	SUS
9-11n-8w MD UNION OIL OF CALIF	3 Cobb Mountain Estate API 04-033-90186	GEYSERS: 12,000. (5-17-78 BK). El: 4686 KB. SE/c 300n 2274w. Location.	GT
15-11n-8w MD UNION OIL OF CALIF	4 Cobb Mountain Estate API 04-033-90187	GEYSERS: 12,000. (5-17-78 BK). El: 4686 KB. SE/c 3349n 635e. Location.	GT
16-11n-8w MD UNION OIL OF CALIF	1 Cobb Mountain Estate API 04-033-90184	GEYSERS: 12,000. (5-17-78 BK). El: 4125 KB. SW/c 4149n 300e. Location.	GT
16-11n-8w MD UNION OIL OF CALIF	2 Cobb Mountain Estate API 04-033-90185	GEYSERS: 12,000. (5-17-78 BK). El: 4323 KB. SE/c 3500n 2400w. Location.	GT
36-11n-8w MD NATOMAS	1 Davies-State 5206 API 04-033-90194	GEYSERS: 10,000 (approx). (9-27-78 BK). El: 1880 KB. SE/c 974n 2257w. Contr: Atlantic. Spud 1-5-79, 20 @ 100, 13 3/8 @ 830, drld to 3560, ran ES, 9 5/8 @ 3655, inst BOPE. ...Drlg 6206.	GT
36-12n-9w MD UNION OIL OF CALIF	1 Binkley Ranch API 04-033-90171	GEYSERS: 12,000. (3-29-78 BK). El: 2949 KB. NE/c 3998s 1200w. Location.	GT

MONO COUNTY

15-3s-28e MD UNION OIL OF CALIF	1 Clay Pit API 04-051-90021	WILDCAT-MAMMOTH LAKES AREA: 6499. (12-20-78 BK). El: 7316 KB. NE/c 1299s 499w (approx). Location.	GT
32-3s-28e MD UNION OIL OF CALIF	1 Mammoth API 04-051-90020	WILDCAT-MAMMOTH LAKES AREA: 6499. (12-20-78 BK). El: 7316 KB. NW/c 1601s 1749e. Location.	GT

SONOMA COUNTY

2-10n-8w MD SHELL OIL	69-2 U. S. Geothermal API 04-097-90392	GEYSERS: (1-24-79 BK). NE/c 3-10n-8w 5466s 2669e. Location.	GT
4-10n-8w MD SHELL OIL	33A-4 U. S. Geothermal API 04-097-90391	GEYSERS: 8000. (6-3-77 BK). El: 3178 KB. NE/c sec 3-10n-8w 1676s 8453w. Location.	GT
6-11n-8w MD UNION OIL OF CALIF	38 DX State 4596 API 04-097-90365	GEYSERS: 9778. (2-15-78 BK). El: 3064 KB. SW/c 2538n 1466e. Comp 8-5-78, potential geothermal well, no details.	GT
6-11n-8w MD UNION OIL OF CALIF	39 DX State 4596 API 04-097-90366	GEYSERS: 8500. (12-10-77 BK). El: 3136 KB. SW/c 2762n 1502e. Location.	GT

DRILLING PROGRESS

SONOMA COUNTY Contd

7-11n-8w MD UNION OIL OF CALIF	40 DX State 4596 API 04-097-90370	GEYSERS: 8000. (1-4-78 BK). El: 3302 KB. SW/c 36n 3250e. Location.	GT
7-11n-8w MD UNION OIL OF CALIF	41 DX State 4596 API 04-097-90373	GEYSERS: 9003. (1-25-78 BK). El: 3302 KB. SW/c 36n 3198e. Location.	GT
18-11n-8w MD UNION OIL OF CALIF	7 Cobb Mtn. Hunting Club API 04-097-90360	GEYSERS: 10,000. (1-4-78 BK). El: 2824 KB. SE/c 1601n 2178w. Contr: Loffland. Spud 1-27-79, ran surf csg, no details. ...Drlg 4308.	GT
18-11n-8w MD UNION OIL OF CALIF	33 DX State 4596 API 04-097-90258	GEYSERS: (6-22-77 BK). NW/c 481s 606e. Location.	GT
18-11n-8w MD UNION OIL OF CALIF	34 DX State 4596 API 04-097-90259	GEYSERS: (6-22-77 BK). NW/c 504s 558e. Location.	GT
18-11n-8w MD UNION OIL OF CALIF	35 DX State 4596 API 04-097-90260	GEYSERS: (6-22-77 BK). NE/c 497s 507w. Location.	GT
18-11n-8w MD UNION OIL OF CALIF	36 DX State 4596 API 04-097-90261	GEYSERS: (6-22-77 BK). NE/c 488s 459w. Location.	GT
18-11n-8w MD UNION OIL OF CALIF	42 DX State 4596 API 04-097-90382	GEYSERS: 10,000. (3-29-78 BK). El: 3290 KB. NW/c 26s 3188e. Location.	GT
18-11n-8w MD UNION OIL OF CALIF	43 DX State 4596 API 04-097-90381	GEYSERS: 10,000. (3-29-78 BK). El: 3378 KB. NW/c 830s 2470e. Contr: Loffland #27. Spud 1-1-79, 20 @ 600, 13 3/8 @ 1320. ...Drlg 8409.	GT
18-11n-8w MD UNION OIL OF CALIF	44 DX State 4596 API 04-097-90380	GEYSERS: 10,000. (3-29-78 BK). El: 3378 KB. NW/c 856s 2440e. Location.	GT
18-11n-8w MD UNION OIL OF CALIF	28 LF State 4597 API 04-097-90375	GEYSERS: 10,000. (1-25-78 BK). El: 3572 KB. NE/c 1781s 3549w. Location.	GT
18-11n-8w MD UNION OIL OF CALIF	29 LF State 4597 API 04-097-90374	GEYSERS: 10,000. (1-25-78 BK). El: 3572 KB. NE/c 1758s 1240w. Location.	GT
18-11n-8w MD UNION OIL OF CALIF	2 Occidental Federal API 04-097-90384	GEYSERS: 8500. (3-29-78 BK). El: 2818 KB. SE/c 1571n 2211w. Location.	GT
19-11n-8w MD UNION OIL OF CALIF	7 GDC API 04-097-90377	GEYSERS: 7000. (2-8-78 BK). El: 2014 KB. SE/c 1099n 869w. Location.	GT
29-11n-8w MD UNION OIL OF CALIF	9 GDC API 04-097-90362	GEYSERS: 8000. (2-8-78 BK). El: 2198 KB. NW/c 510s 1210e. Location.	GT
29-11n-8w MD UNION OIL OF CALIF	10 GDC API 04-097-90363	GEYSERS: 8000. (2-8-78 BK). El: 2198 KB. NW/c 590s 1161e. Location.	GT
29-11n-8w MD UNION OIL OF CALIF	11 GDC API 04-097-90364	GEYSERS: 8000. (2-8-78 BK). El: 2198 KB. NW/c 551s 1109e. Location.	GT
34-11n-8w MD AMINOIL USA	37A-34 CA-958 API 04-097-90395	GEYSERS: 6500 Franciscan. (1-5-79 BK). El: 2880 KB (approx). SW/c 660n 1800e. Contr: Montgomery. Spud 1-5-79, 20 @ 600, drld to 2425, ran ES, TMPL, 13 3/8 @ 2415, inst BOPE, drld w/air to unrptd TD below 4900, TD-NR. ...Potential geothermal well, comp 2-11-79, tight hole.	GT

DRILLING PROGRESS

SONOMA COUNTY Contd

12-11n-9w MD UNION OIL OF CALIF	2 Ottoboni Federal API 04-097-90269	GEYSERS: 6500. (11-2-77 BK). El: 2736 KB. NW/c 2788s 2040e. Location.	GT
12-11n-9w MD UNION OIL OF CALIF	25 Sulphur Bank API 04-097-90267	GEYSERS: (10-19-77 BK). SW/c 536n 2027e. Comp 1-6-79, potential geothermal well, no deatils.	GT
12-11n-9w MD UNION OIL OF CALIF	27 Sulphur Bank API 04-097-90371	GEYSERS: 8312. (1-4-78 BK). El: 2066 KB. SW/c 472n 1989e. Location.	GT
13-11n-9w MD GEOTHERMAL KINETICS INC	1 Rorabaugh API 04-097-90133	GEYSERS: (2-21-79 BK). El: 2035 KB. W/4 164s 237e. Location.	GT
13-11n-9w MD UNION OIL OF CALIF	1 Curry API 04-097-90386	GEYSERS: 8000. (5-17-78 BK). El: 1827 KB. NE/c 1299s 200w. Location.	GT
14-11n-9w MD THERMOGENICS	A-11 Rorabaugh API 04-097-90185	GEYSERS: 8315. (5-24-78 BK). EL: 1899. NW/c 2153s 2348e. Comp 1-6-79, potential geothermal well, no details.	GT

IMPERIAL COUNTY

15-9s-12e SB MCCULLOCH GEO- THERMAL	1-15 Hot Mineral API 04-025-90190	SALTON SEA: (7-15-78 BK). El: -141 KB. NE/c 369s 2650w. Contr: Republic. Spud 1-30-79, 13 3/8 @ 1076. ...Drlg 6981.	GT
15-9s-12e SB MCCULLOCH GEO- THERMAL	2-15 Hot Mineral API 04-025-90191	SALTON SEA: (7-15-78 BK). El: -156 KB. NE/c 660s 668w. Location.	GT
33-11s-13e SB IMPERIAL MAGMA	5 IW API 04-025-90203	SALTON SEA: 1500. (2-14-79 BK). El: -221 GR. S/4 450n 1650e. Spud 2-14-79, 13 3/8 @ 1100, drld to 1510, ran ES, TMPL, 10 3/4 slotted lnr 1080-1510, TD 1510. ...Temperature observation well, comp 2-20-79.	U
5-12s-13e SB UNION OIL OF CALIF	6 I. I. D. API 04-025-90194	SALTON SEA: 3500. (9-6-78 BK). El: -233 GR. NW/c 299s 2320e. Contr: Loffland. Spud 1-29-79, drld to unrptd TD below 2000. ...Well comp, no details.	GT
5-12s-13e SB UNION OIL OF CALIF	14 Sinclair API 04-025-90195	SALTON SEA: 6000. (9-6-78 BK). El: -230 GR. NW/c 2402s 699e. Contr: Petter Bawden. Location.	GT
16-13s-14e SB UNION OIL OF CALIF	9 Veysey API 04-025-90183	BRAWLEY: (3-1-78 BK). El: -141 KB. SE/c 499n 2644w. Location.	GT
16-13s-14e SB UNION OIL OF CALIF	10 Veysey API 04-025-90184	BRAWLEY: (3-1-78 BK). El: -141 KB. SE/c 499n 2778w. Location.	GT
23-13s-14e SB UNION OIL OF CALIF	1 Slater API 04-025-90189	BRAWLEY: 9500 Miocene. (6-30-78 BK). El: -55 KB. NW/c 2201s 800e. Contr: Peter Bawden. Spud 11-6-78, 20 @ 80, 13 3/8 @ 1200, drld to 8250, ran logs, TMPL, PB & KO @ 7080, redrld to 8520, ran ES, TMPL, PB & KO @ 6650 (approx). ...Redrlg 11,005.	GT
6-14s-16e SB PHILLIPS PET	1 East Brawley Strat Test API 04-025-90180	BRAWLEY AREA (Temp Observation): 2000 Pliocene. (5-17-78 BK). El: -15 KB. SE/c 1150n 1650w (approx). Location.	U
6-14s-16e SB PHILLIPS PET	1-A East Brawley Strat Test API 04-025-90185	BRAWLEY AREA (Temp Observation): 2000 Pliocene. (5-17-78 BK). El: -15 KB. SE/c 1150n 1620w (approx). Location.	U
9-14s-16e SB PHILLIPS PET	2 East Brawley Strat Test API 04-025-90197	BRAWLEY AREA (Temp Observation): 2000 Pliocene. (12-27-78 BK). El: -15 KB. NE/c 900s 2600w. Location.	U

DRILLING PROGRESS

IMPERIAL COUNTY Contd

18-14s-16e SB PHILLIPS PET	3 East Brawley Strat Test API 04-025-90198	BRAWLEY AREA (Temp Observation): 2000 Pliocene. (12-27-78 BK).U El: -48 KB. NE/c 2700s 2500w. Location.
5-17s-19e SB IMPERIAL OCCI- DENTAL	1 Imperial API 04-025-20002	WILDCAT-GRAYS WELLS AREA: 2000 Pliocene. (1-25-79 BK). GT El: -132 KB. SE/c 400n 200w. Contr: Co Tools. Spud 2-7-79, drld to 550. ...@ 550, SDR.

*** ** ***

DRILLING PROGRESS

NEW MEXICO

SANDOVAL COUNTY

11-19n-3e
UNION OIL OF CALIFORNIA 18-A Baca

REDONDO CREEK: 6000. (2-9-79 BK). El: 8735 GR. GT
sw se 252 fsl 1509 fel.
(Box 3100, Midland, TX).
Contr: Loffland. Drld to 4597. Stuck drill pipe, worked bit to 4339, top of fish @ 3181, TD 4597. ...Prep to PB to 2700 & set WS.

11-19n-3e
UNION OIL OF CALIFORNIA 19 Baca

REDONDO CREEK: 6000. (2-9-79 BK). El: 9340 GR. GT
se ne 1470 fnl 493 fel.
(Box 3100, Midland, TX).
Contr: Loffland. Location.

*** ** ***

DRILLING PROGRESS

NEVADA

CHURCHILL COUNTY

14-23n-35e MD
SOUTHLAND ROYALTY 45-14

DIXIE VALLEY: 8000. (1-15-79 BK). GT
C 660s 660w.
Location.

18-24n-37e MD
SUNOCO ENERGY DEV 1 S. W. Lamb

DIXIE VALLEY: (9-16-78 BK). GT
NW/c 330s 330e.
Spud 9-16-78, 20 @ 70, drld to 7250, ran ES, 9 5/8 @ 5620, TD 7250. ....Temp observation well.

PERSHING COUNTY

15-31n-33e MD
PHILLIPS PET E-2 Campbell

HUMBOLDT: (1-6-79 BK). GT
C 330s 330e.
Contr: Peter Bawden #11. Spud 1-6-79, 20 @ 80. ...Drlg 5700.

WASHOE COUNTY

15-32n-23e MD
SUNOCO ENERGY DEV 1-15-G Holland Livestock Ranch

GERLACH: 6000. (12-17-78 BK). U
SW/c 660n 200e.
Contr: Signal Drlg. Spud 12-17-78, 13 3/8 @ 2000 (approx), drld to 5871, ran ES, TMPL, TD 5871. ...Temperature observation well, comp 2-20-79.

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DRILLING PROGRESS

OREGON

CLACKAMUS COUNTY

7-3s-9e W WY'EAST EXPLORATION	1 Timberline Lodge	WILDCAT: 2000. (10-6-78 BK). Location.	GT

HARNEY COUNTY

14-33s-35e W ANADARKO OIL	A-8	WILDCAT: 2000. (10-6-78 BK). SE¼ Location.	U
6-33s-36e W ANADARKO OIL	A-5	WILDCAT: 2000. (10-6-78 BK). SE¼ Drld & comp 2-15-79 fr above 2000 as temperature observation well, no details being released.	U
7-33s-36e W ANADARKO OIL	A-6	WILDCAT: 2000. (10-6-78 BK). SW¼ Drld & comp 2-15-79 fr above 2000 as temperature observation well, no details being released.	U
18-33s-36e ANADARKO OIL	A-7	WILDCAT: 2000. (10-6-78 BK). SW¼ Location.	U
29-34s-34e W ANADARKO OIL	A-26	WILDCAT: 2000. (10-6-78 BK). NE¼ Drld & comp 2-15-79 fr above 2000 as temperature observation well, no details being released.	U
34-34s-34e W ANADARKO OIL	A-31	WILDCAT: 2000. (10-6-78 BK). SW¼ Location.	U
8-35s-34e W ANADARKO OIL	A-34	WILDCAT: 2000. (10-6-78 BK). NE¼ Location.	U
10-37s-33e W ANADARKO OIL	B-56	WILDCAT: 2000. (10-6-78 BK). SE¼ Location.	U
13-37s-33e W ANADARKO OIL	B-61	WILDCAT: 2000. (10-6-78 BK). SW¼ Location.	U
22-37s-33e W ANARARKO OIL	B-64	WILDCAT: 2000. (10-6-78 BK). NW¼ Location.	U

MALHEUR COUNTY

13-17s-42e W AMAX EXPLORATION	30 Geothermal Well Permit	TEMP GRADIENT: 2000. (4-4-78 BK). SE¼ Location.	U
24-17s-42e W AMAX EXPLORATION	29 Geothermal Well Permit	TEMP GRADIENT: 2000. (4-4-78 BK). SW¼ Location.	U
26-17s-42e W AMAX EXPLORATION	31 Geothermal Well Permit	TEMP GRADIENT: 2000. (4-4-78 BK). NE¼ Location.	U
5-18s-43e W CHEVRON RESOURCES	5-1-78	WILDCAT: 2000. (10-6-78 BK). SW¼ Location.	GT
9-18s-43e W CHEVRON RESOURCES	9-1-78	WILDCAT: 2000. (10-6-78 BK). NW¼ Location.	GT

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DRILLING PROGRESS

TEXAS

BRAZORIA COUNTY

GENERAL CRUDE 2 Pleasant Bayou API 42-039-31358

WILDCAT: (1/29/79), 16,500 test (se/6s-39e-3-31) 320 ac lse, Perry & Austin Sur 2, 107; 900 900 FNWL & 1600 FNEL lse; 11,404 fnel & 1499 fnwl sur; Elev: 12 GRD. C/Welsh. GT

Spud 12/26/78; Drld to 1350; set surf csg; drld to 8517. Ran logs 1395-8517. ...Drlg below 8517.

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DRILLING PROGRESS

UTAH

BEAVER COUNTY

7-26s-6w SL UNION OIL OF CALIF	42-7 Cove Fort Sulphurdale Unit	COVE FORT: (12-10-78 BK). Spud 12-10-78, drld to 3000 (approx), ran ES, TMPL, TD 3000 (approx). ...Comp, no details.	U

MILLARD COUNTY

30-24s-6w SL CAROLINE HUNT TRUST ESTATE	15-30 CHTE	WHITE SAGE FLATS: (3-23-78 BK). Contr: Loffland. Spud 3-23-78. ...Drlg, tight hole.	GT

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