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GEOCHEMICAL EVALUATION OF THE JAMES P. DUNIGAN NO. 1 SANTA FE WELL, MCKINLEY COUNTY, NEW MEXICO

By Wallace G. Dow
Robertson Research, Inc.
Houston, Texas

March 8, 1982

ROBERTSON RESEARCH (U.S.) INC.

REPORT NO. 580

GEOCHEMICAL EVALUATION OF THE JAMES P. DUNIGAN NO. 1 SANTA FE, MCKINLEY COUNTY, NEW MEXICO

31-19N-5W

by

Wallace G. Dow

Project No. RRUS/812/II/T/127

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March 8, 1982

ROBERTSON
RESEARCH (U.S.) INC.

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I
SUMMARY

Geochemical data on samples from the James P. Dunigan, No. 1 Santa Fe well indicate good to very good source quality throughout the Cretaceous section and very low organic carbon contents in pre-Cretaceous rocks. The kerogen present in all of the samples analyzed is primarily dry gas-generating and terrestrial in origin, but a slightly higher convertability to liquid hydrocarbons occurs in the lowermost Cretaceous section. The organic-rich Cretaceous shales are not mature enough for gas generation at the location of the subject well, but oil could be generated below about 2,400 feet and preserved to about 7,200 feet. About 4,000 feet of erosion has occurred since maximum burial took place and hydrocarbon generation is, therefore, no longer active. Source bed distribution and the timing of hydrocarbon generation are important variables which must be considered in any economic evaluation of the area.

II
INTRODUCTION

Thirty-three very small bit cuttings samples from the subject well were analyzed according to a program outlined by the client. Because of very low organic carbon contents in most pre-Cretaceous samples, Rock-Eval pyrolysis could not be run and the number of samples analyzed with vitrinite reflectance was considerably reduced.

Analytical data are tabulated in Appendices I-III and selected parameters are plotted on Figures 1-4. Age and lithology designations shown on the figures were taken from a sample log supplied by the client. Lithology symbols used in generating the computer graphics are illustrated on Figure 6.

III
DISCUSSION

Organic Matter Concentration

The organic content of rocks is related to the weight percent organic carbon they contain. Total organic carbon is quite high in most of the Cretaceous samples analyzed, due primarily to the presence of coal. Most of the Cretaceous samples are rated as good to very good in source quality (Figure 1). Pre-Cretaceous samples are all very low in organic carbon and are rated as nonsources for producable amounts of oil or gas. If thin, source quality intervals exist in the pre-Cretaceous section, they have been masked by dilution with organic-lean material. Even if this is true, the volume of any possible source quality section which may be present and the amount of petroleum generated would be limited unless more favorable source facies are present in other portions of the basin.

Kerogen Type

The type of kerogen present, and hence its capability to generate oil or gas, was determined by Rock-Eval pyrolysis and by visual examination with reflected light microscopy. Both techniques indicate a predominance of gas-generating, terrestrial organic matter in all of the samples analyzed. Poor source potential (data from pyrolysis S_2 peak, Figure 2), low hydrogen index values (Figure 3), and low visual percentages of oil-generating amorphous and exinite organic matter (Figure 1), all are characteristic of low hydrogen, gas-generating kerogen. Somewhat more favorable convertability to oil defined by the pyrolysis S_2/S_3 ratios (Figure 2) is believed to be due to solid bitumen in the samples (Appendix III) and to unusually low oxygen index values (Figure 3). This ratio, therefore, is probably not a good kerogen type indicator for the subject samples. The best petroleum convertability appears to be in lowermost Cretaceous samples between 3,700 and 4,100 feet. Pennsylvanian samples were too low in organic carbon for pyrolysis but contain primarily terrestrial kerogen from visual analysis.

Kerogen Maturity

Kerogen maturity was determined with Rock-Eval pyrolysis (T-max) and vitrinite reflectance (R_o). Pyrolysis T-max values are nearly all the same throughout the Cretaceous section and are very close to the top of the oil-generation zone (Figure 2). The apparent lack of maturity increase with depth may be due to the presence of caving from the coal-rich interval near the top of the Cretaceous section. This is supported by the presence of low-rank vitrinite of uniform maturity in nearly all of the Cretaceous samples analyzed (Appendix III). Reflectance analysis, however, also revealed the presence of an indigenous vitrinite population in addition to the caving, and these data were used in constructing the maturation profile (Figure 4). In spite of contamination problems and poor quality data from most pre-Cretaceous samples, we believe the maturity profile to be reliable.

Figure 4 indicates that the oil-generation maturity zone (0.6-1.4 R_o) occurs between about 2,356 and 7,164 feet and that dry gas should be generated below about 5,256 feet (1.0 R_o). Crude oil could be preserved to about 7,164 feet and wet gas/condensate could survive to 8,188 feet (2.0 R_o). Projection of the maturity profile to 0.2 R_o demonstrates that about 3,877 feet of section has been lost to erosion since maximum burial took place. Cooling associated with this loss of overburden has caused hydrocarbon generation to become suspended and any source beds present would not be actively generating oil or gas at the present time. Expulsion, migration, and accumulation of hydrocarbons may have occurred during maximum burial but they would have had to survive the period of uplift and erosion. Recently formed structures, therefore, may not contain petroleum unless remigration has taken place. We recommend that a more detailed geological/geochemical study of the basin be undertaken to more accurately define source bed distribution, capacity, and the time of hydrocarbon generation, migration, and accumulation.

V
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JAMES P DUNIGAN #1, SANTA FE

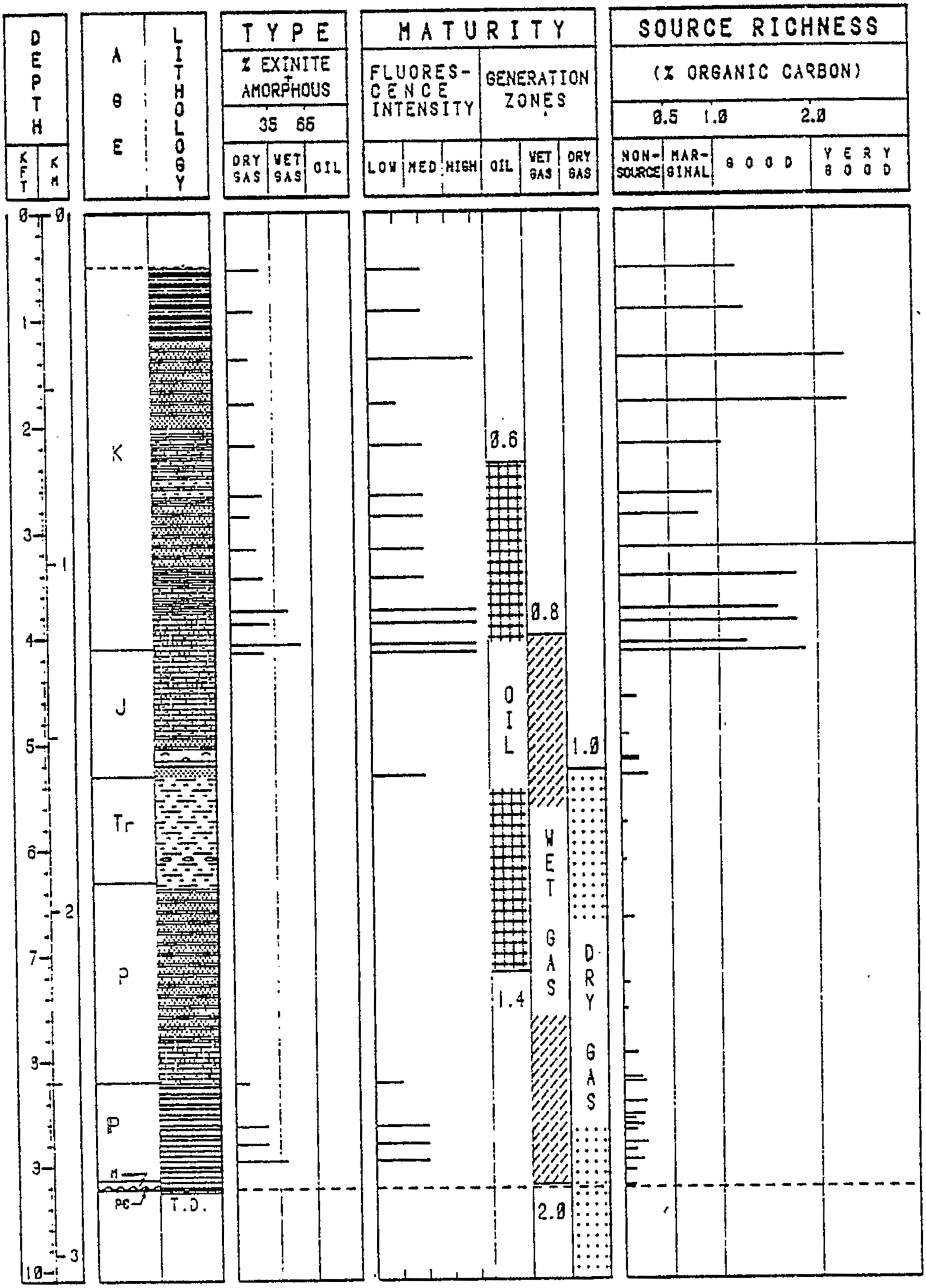

FIGURE 1: SUMMARY PLOTS SHOWING KEROGEN TYPES, MATURITY, AND SOURCE RICHNESS (SEE APPENDICES I AND III)

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JAMES P DUNIGAN #1, SANTA FE

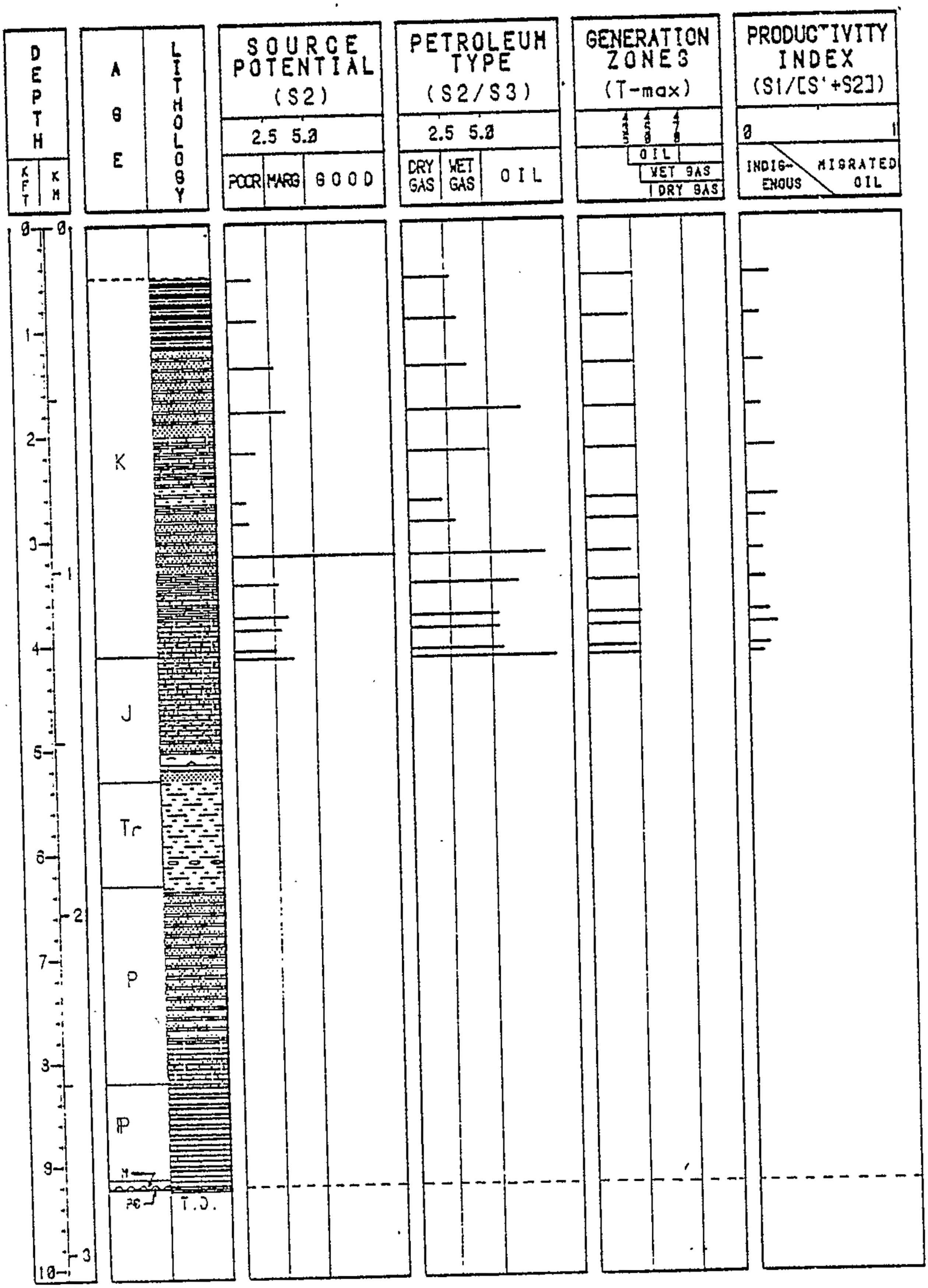

FIGURE 2: SUMMARY PLOTS OF ROCK-EVAL PYROLYSIS DATA (APPENDIX II)

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JAMES P DUNIGAN #1, SANTA FE

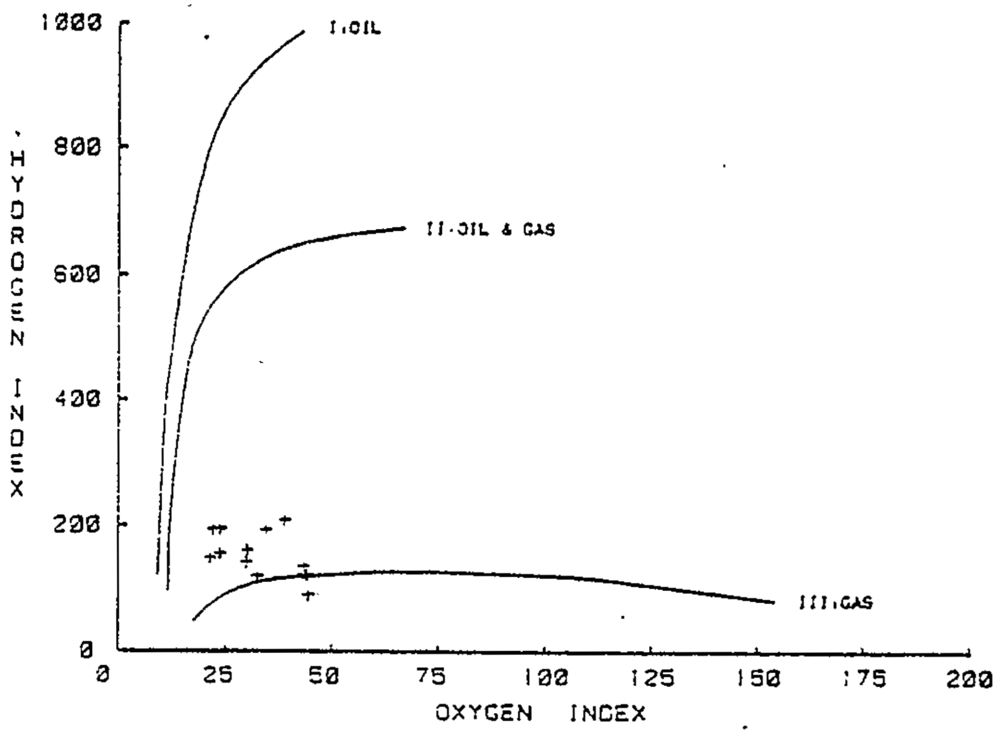

FIGURE 3: KEROGEN TYPE DETERMINATION FROM ROCK-EVAL PYROLYSIS DATA (APPENDIX II).

JAMES P DUNIGAN #1, SANTA FE

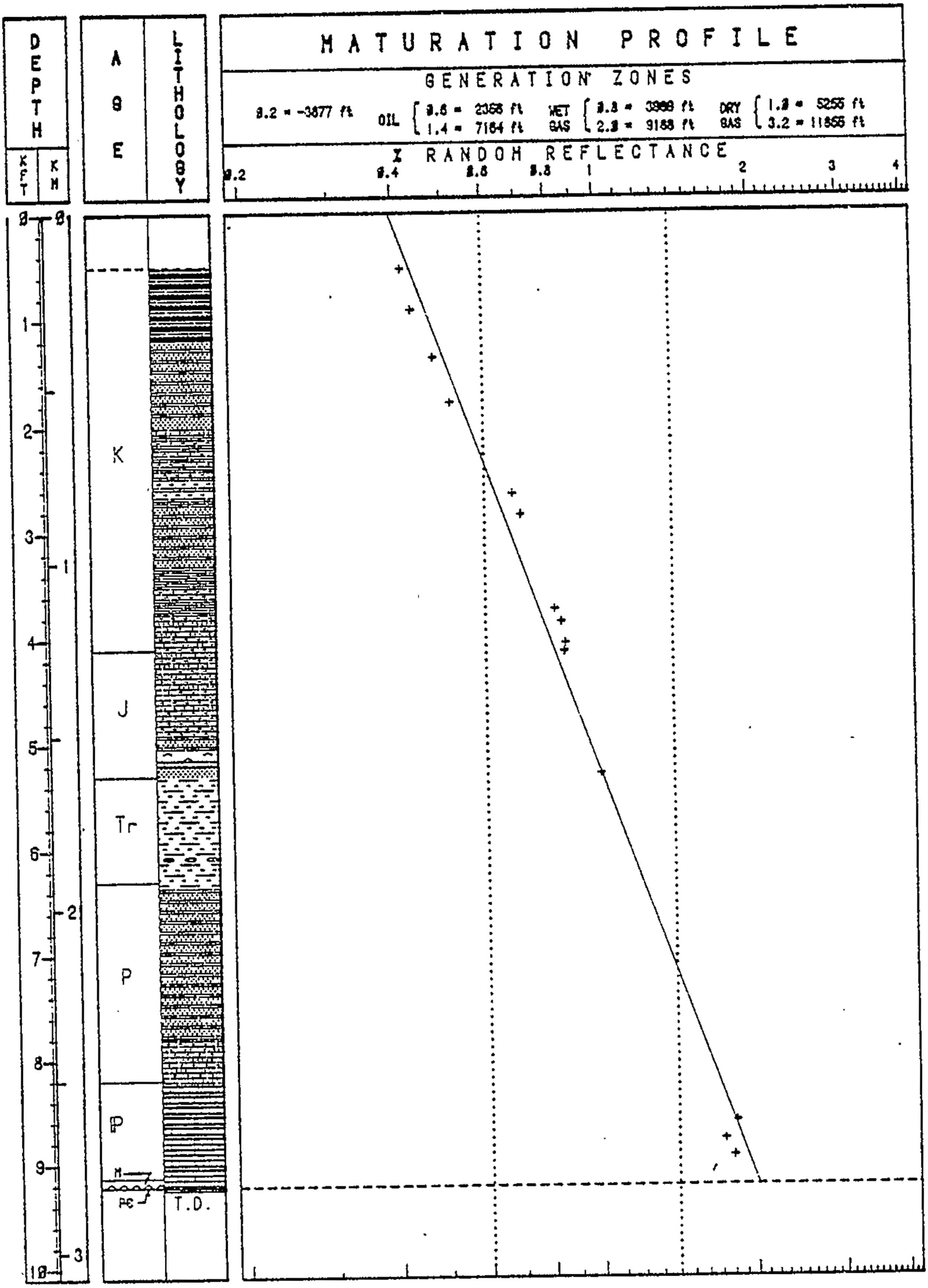

FIGURE 4: MATURATION PROFILE, BASED ON VITRINITE REFLECTANCE DATA (APPENDIX III)

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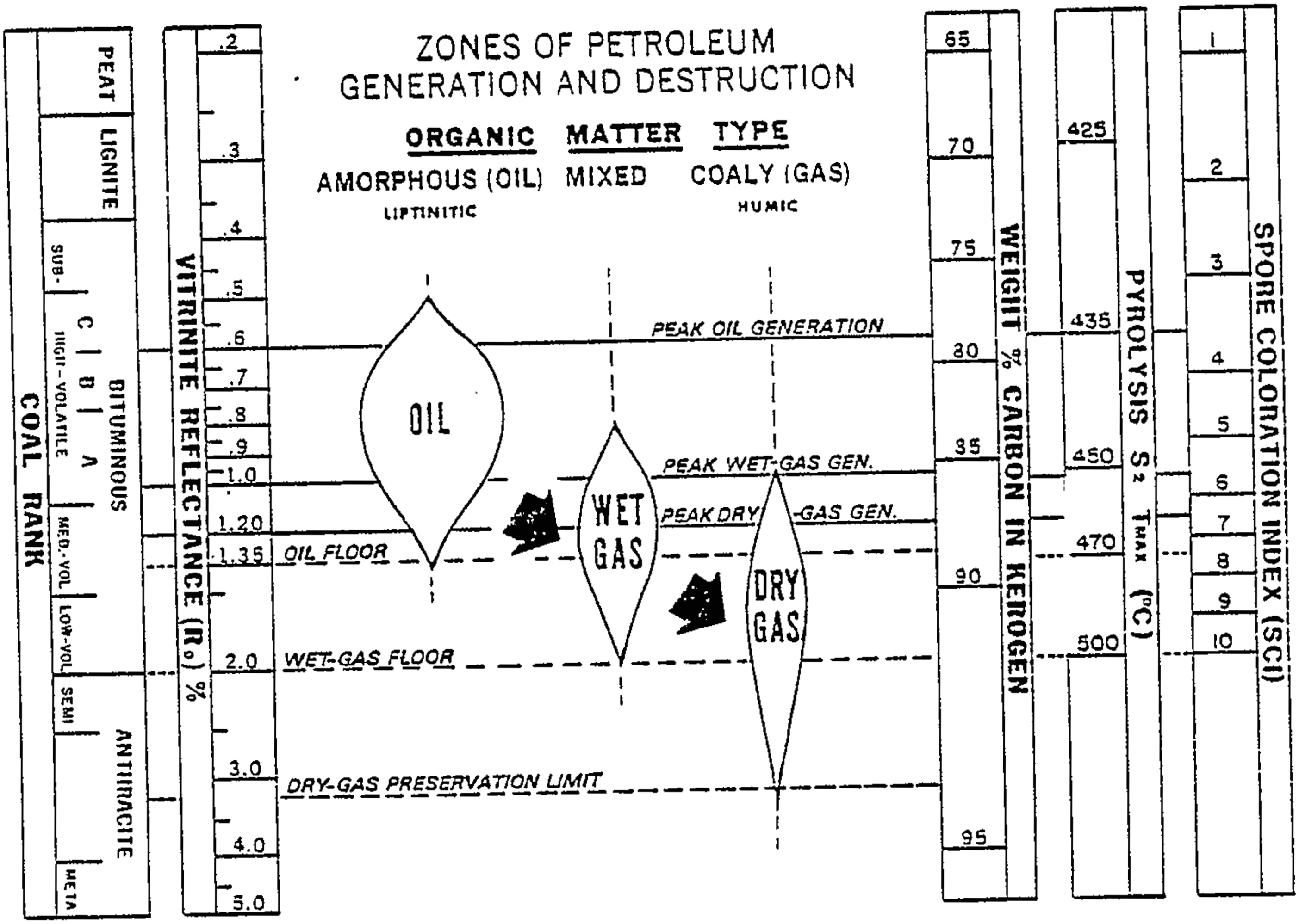

FIGURE 5: CORRELATION OF VARIOUS MATURATION INDICES AND ZONES OF PETROLEUM GENERATION AND DESTRUCTION.

LIST OF LITHOLOGY SYMBOL'S USED IN FIGURES

10 : GAP
20 : CLY/CLYST
31 : MDST
41 : SH
50 : SLTST
61 : SST,fn
62 : SST,med
63 : SST,crs
70 : CGL+
80 : CGL-
90 : MARL
100 : LST
110 : DOL
320 : CHK
820 : SHELL DEBRIS
120 : ANH
130 : SALT
140 : COAL
146 : COAL(I),Thin
150 : IGN/IGN BSMNT
151 : BSMNT(UD)
153 : BSMNT(MET)
154 : TUFF BANDS
160 : CHERT
161 : BRECCIA
170 : SLTY CLY(ST)
180 : SNDY CLY(ST)
171 : SLTY SH
181 : SNDY SH
191 : SLTY MDST
201 : SNDY MDST
210 : SLTY MARL
220 : SNDY MARL
230 : ARG LST
240 : ARG DOL
250 : SNDY LST
260 : SNDY DOL
270 : SLTY LST
280 : SLTY DOL
291 : DOL LST
292 : CALC DOL
300 : ANH LST
310 : ANH DOL
340 : I/B SST/SH
350 : I/B SST/MDST
360 : I/B SST/CLYST

FIGURE: 6

APPENDIX I

TOTAL ORGANIC CARBON DATA

Total organic carbon is determined by pulverizing the sample, treating a carefully weighed portion with warm hydrochloric acid to remove carbonate minerals, and analysing the residue for carbon content with a Leco carbon analyser. It is generally accepted that samples with less than about 0.5 percent TOC cannot yield sufficient petroleum to form commercial deposits and are therefore considered nonsources; samples with between 0.5 and 1.0 TOC are rated as marginal in source quality; and samples with more than 1.0 TOC are considered to be good in source quality.

TOTAL ORGANIC CARBON DATA

JAMES P DUNIGAN #1, SANTA FE

DEPTH (Feet)	TOC (%)
535	1.19
925	1.27
1375	2.29
1795	2.31
2185	1.03
2655	0.93
2855	0.79
3165	5.83
3435	1.78
3745	1.59
3865	1.78
4065	1.27
4145	1.87
4575	0.14
4925	0.06
5145	0.16
5165	0.16
5305	0.25
5755	0.04
6115	0.03
6655	0.10
7275	0.05
7525	0.03
7945	0.13
8175	0.17
8215	0.21
8405	0.21
8525	0.19
8565	0.10
8615	0.11
8625	0.18
8675	0.11
8795	0.22
8865	0.11
8955	0.18
9055	0.10
9195	0.10

APPENDIX II

ROCK-EVAL PYROLYSIS DATA

Rock-Eval data are expressed as mg/g of rock and include four basic parameters: 1) S_1 represents the quantity of free hydrocarbons present in the rock and is roughly analogous to the solvent extractable portion of the organic matter; 2) S_2 represents the quantity of hydrocarbons released by the kerogen in the sample during pyrolysis; 3) S_3 is related to the amount of oxygen present in the kerogen; and 4) T-max, in °C, is the temperature at which the maximum rate of generation (of the S_2 peak) occurs and can be used as an estimate of thermal maturity.

In addition, the ratio S_2/S_3 provides a general indication of kerogen quality (type) and reveals whether oil or gas are likely to be generated. The ratio $S_1/(S_1+S_2)$, or the productivity index, is an indication of the relative amount of free hydrocarbons (in place or migrated) present in the sample. Hydrogen and oxygen index values are in mg of hydrocarbons (S_2 peak) or carbon dioxide (S_3 peak) per gram of organic carbon. When plotted against each other on a van Krevelen-type diagram, information on kerogen type and maturity can be obtained.

Data are interpreted in the following manner:

Source Potential - values of S2	<2.5	: poor
	2.5-5.0	: marginal
	>5.0	: good
Petroleum Type - value of S2/S3	<2.5	: dry gas
	2.5-5.0	: wet gas
	>5.0	: oil
Generation Zones - values of T-max	<435	: immature
	435-470	: oil
	450 +	: gas

Productivity Index - high values of S1/(S1+S2) indicate migrated hydrocarbons.

ROCK-EVAL PYROLYSIS RAW DATA

JAMES P DUNIGAN #1, SANTA FE

DEPTH (FEET)	S1	S2	S3	S2/S3	S1/(S1+S2)	T-MAX
535	0.273	1.425	0.521	2.734	0.161	435
925	0.179	1.698	0.546	3.109	0.095	431
1375	0.332	2.712	0.735	3.689	0.109	433
1795	0.328	3.394	0.484	7.017	0.088	435
2185	0.297	1.445	0.303	4.774	0.170	434
2655	0.180	0.820	0.409	2.005	0.180	435
2855	0.108	0.947	0.338	2.803	0.103	434
3165	1.010	11.283	1.362	8.287	0.082	429
3435	0.279	2.737	0.415	6.598	0.093	433
3745	0.436	3.285	0.612	5.371	0.117	436
3865	0.572	2.828	0.527	5.367	0.168	433
4065	0.325	2.427	0.432	5.614	0.118	432
4145	0.328	3.586	0.404	8.880	0.084	434

HYDROGEN AND OXYGEN INDICES FROM ROCK-EVAL PYROLYSIS DATA, WITH TOC DATA

JAMES P DUNIGAN #1, SANTA FE

DEPTH (FEET)	HYDROGEN INDEX (mg HC/g TOC)	OXYGEN INDEX (mg CO2/g TOC)	TOC (%)
535	120	44	1.19
925	134	43	1.27
1375	118	32	2.29
1795	147	21	2.31
2185	140	29	1.03
2655	88	44	0.93
2855	120	43	0.79
3165	194	23	5.83
3435	154	23	1.78
3745	207	38	1.59
3865	159	30	1.78
4065	191	34	1.27
4145	192	22	1.87

APPENDIX III

REFLECTED LIGHT MICROSCOPY DATA

A sample of ground rock is treated successively with hydrochloric and hydrofluoric acids to concentrate the kerogen, freeze-dried, mounted in an epoxy plug, and polished. Kerogen type is identified with the aid of blue light fluorescence.

The visual kerogen analysis data sheet contains visual percentage estimates of each principle kerogen type, notes on vitrinite description, and kerogen fluorescence data.

The histograms show measured reflectance values of all vitrinite present and on all material with the visual appearance of vitrinite. Shaded values are those used to calculate the interpreted vitrinite reflectance maturities. Unshaded values are interpreted to be oxidized vitrinite, recycled vitrinite, or possibly misidentified material such as solid bitumen, pseudo-vitrinite, or semifusinite. Sometimes the samples analysed contain no vitrinite or have an insufficient number of readings to allow a reliable maturity determination to be made. Alternate maturity calculations are possible on a few samples. The histograms are identified by a sequence number and depth or notation.

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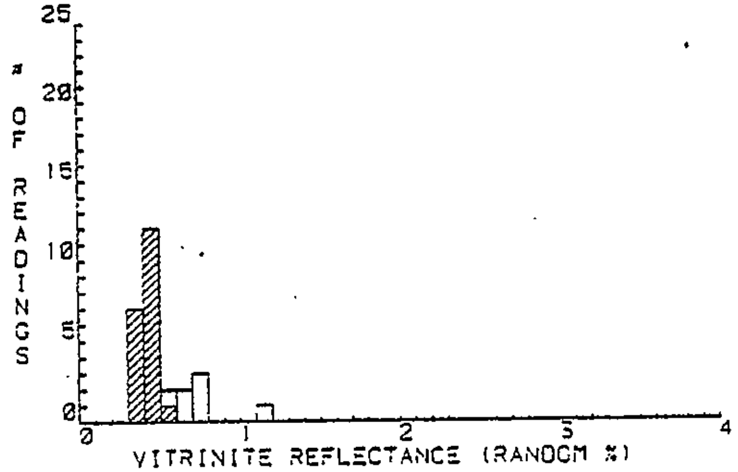
REFLECTED LIGHT
VISUAL KEROGEN ANALYSIS

PROJECT NO. RRUS/812/II/T/127
#1 Santa Fe

O = NONE
T = TRACE
— = SMALL AMT.
M = MODERATE AMT.
+ = LARGE AMT.

SAMPLE	DEPTH (FT.)	Ro MATURITY	AMORPHOUS	EXINITE	VITRINITE	INERTINITE	BITUMEN	AMT. ORGANIC MATTER	PYRITE	NORMAL	ROUGH, CORRODED, OILY	OXIDATION	COKE	Vitrinite low	Vitrinite med	Vitrinite high	Exinite low	Exinite med	Exinite high	BACKGROUND	REMARKS
1	535	0.41	10	15	?70	5	?	+	–	M	+	–		/	/		/	/			Vitrinite or bitumen?
2	925	0.43	10	10	75	5	?	+	M	M	+	–		/	/	/	/	/			Same.
3	1,375	0.48	10	5	65	20	–	+	M	M	M	–		/	/	/	/	/	/		Large coaly fragments.
4	1,795	0.52	15	5	60	20	M	+	–	–	–	–		/	/	/	/				
5	2,135	–	10	10	70	10	M	+	M	M	M	–		/	/	/	/	/			Bitumen Ro ~0.35.
6	2,655	0.63	20	5	55	20	?	+	–	M	M	–		/	/	/	/	/			Some higher Ro values may be semi-fusinite.
7	2,855	0.70	5	10	65	20	?	M	–	M	M	M		/	/	/	/	/			Some Ro values may be lowered by rough surfaces.
8	3,165	–	15	5	70	10	?	+	M	M	M			/	/	/	/	/			
9	3,435	–	15	10	60	15	?	+	M	M	M	–		/	/	/	/	/			
10	3,745	0.32	40	5	45	10	M	+	M	M	M			/	/	/	/	/	/		Bitumen Ro ~0.37 to 0.45.
11	3,865	0.34	25	5	60	10	M	–	M	M	+	–		/	/	/	/	/	/		
12	4,065	0.36	45	10	25	20	M	+	+	M	M	–		/	/	/	/	/	/		
13	4,145	0.35	15	10	60	15	?	+	M	M	M	M		/	/	/	/	/	/		
18	5,305	1.00	–	T	T	T	–	–	–	M	M	–					/	/			
26	3,215	–	10	0	80	10		–	–	M	M		–				/				
31	8,625	1.32	25	0	60	15	–	M	M	+	–	–	–				/	/			Some chitinous material? Good vitrinite Ro 1.30.
33	8,795	1.72	25	0	50?	25	–	M	M	–	–	–	?				/	/			
35	8,955	1.79	40	0	40?	20	?	M	M	+	–	–					/	/			Chitinous material ? Caving?

JAMES P DUNIGAN #1, SANTA FE



ID 1

DEPTH	535.0 FT 163.1 M

* = Ro MATURITY

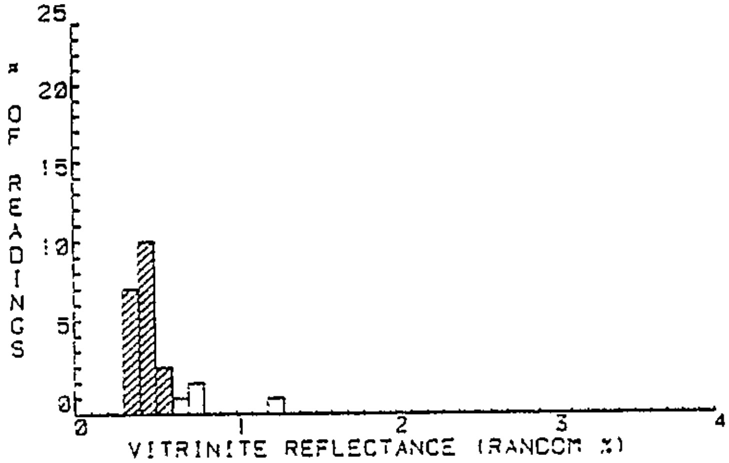
# VALUES	20.00
MEAN	0.41
STD DEV	0.05
MEDIAN	0.42
MODE	0.45

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

*0.30	*0.42	0.59
*0.34	*0.42	0.65
*0.38	*0.43	0.66
*0.38	*0.44	0.72
*0.39	*0.44	0.72
*0.39	*0.45	0.73
*0.39	*0.46	1.15
*0.40	*0.47	
*0.40	*0.49	
*0.40	*0.51	

JAMES P DUNIGAN #1, SANTA FE



ID 2

DEPTH	925.0 FT 282.0 M

* = Ro MATURITY

# VALUES	22.00
MEAN	0.43
STD DEV	0.06
MEDIAN	0.43
MODE	0.45

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

*0.33	*0.43	*0.53
*0.34	*0.43	*0.58
*0.35	*0.44	0.66
*0.39	*0.45	0.72
*0.39	*0.46	0.74
*0.39	*0.46	1.23
*0.39	*0.48	
*0.39	*0.49	
*0.40	*0.49	
*0.41	*0.53	

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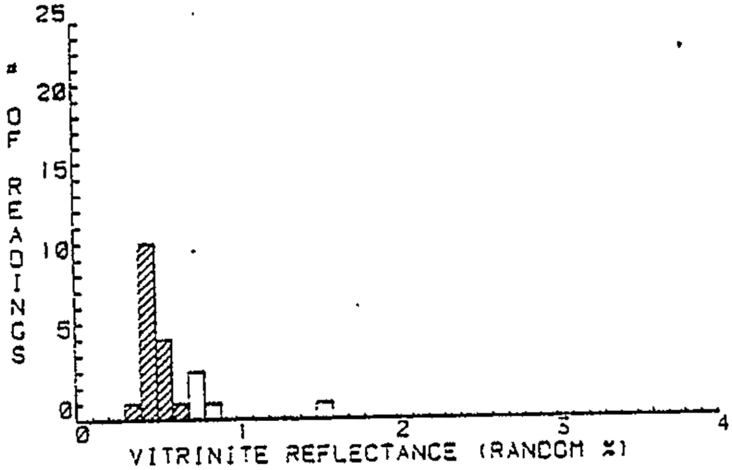

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DEPTH 1375.0 FT
419.2 M

* = Ro MATURITY

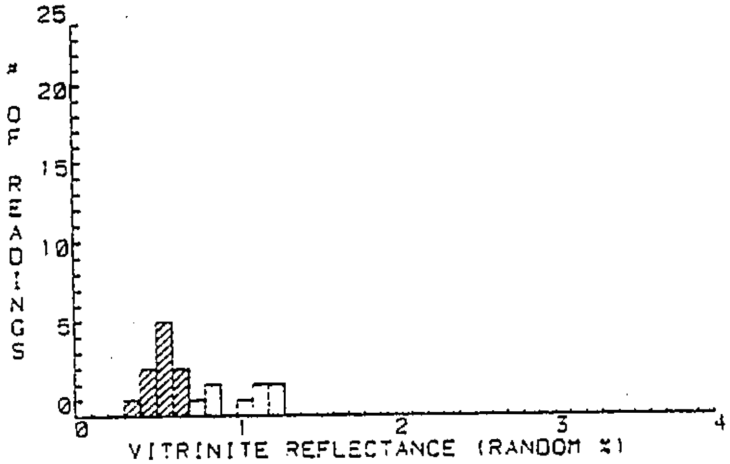
# VALUES	18.00
MEAN	0.48
STD DEV	0.26
MEDIAN	0.48
MODE	0.45

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

*0.34	*0.48	0.75
*0.42	*0.48	0.87
*0.43	*0.50	1.55
*0.44	*0.50	
*0.44	*0.51	
*0.45	*0.57	
*0.45	*0.59	
*0.46	*0.62	
*0.46	0.72	
*0.48	0.75	

JAMES P DUNIGAN #1, SANTA FE



ID 4

DEPTH 1795.0 FT
547.3 M

* = Ro MATURITY

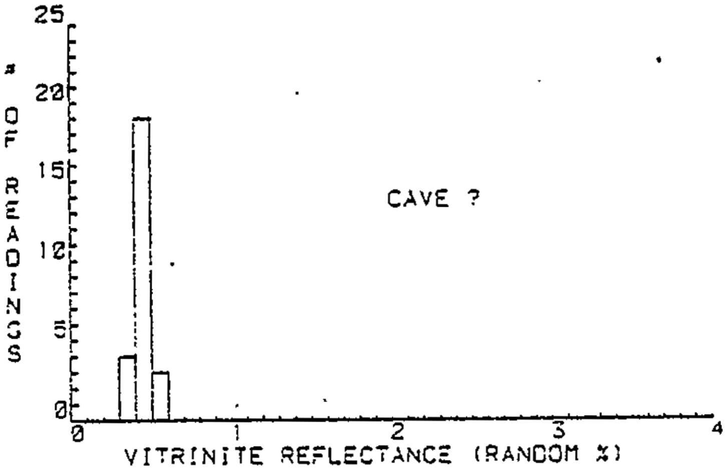
# VALUES	13.00
MEAN	0.52
STD DEV	0.07
MEDIAN	0.50
MODE	0.55

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

*0.39	*0.62	1.24
*0.41	*0.62	
*0.46	*0.63	
*0.47	0.71	
*0.50	0.82	
*0.50	0.87	
*0.50	1.05	
*0.52	1.15	
*0.54	1.16	
*0.54	1.20	

JAMES P DUNIGAN #1, SANTA FE



ID 5

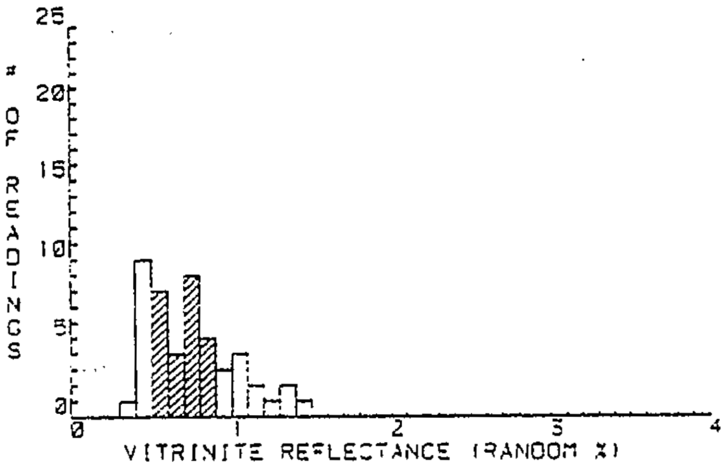
DEPTH	2185.0 FT
	666.2 M
# VALUES	26.00
MEAN	0.44
STD DEV	0.05
MEDIAN	0.44
MODE	0.45

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES

0.30	0.43	0.48
0.37	0.43	0.48
0.37	0.44	0.49
0.39	0.44	0.50
0.40	0.45	0.51
0.41	0.45	0.52
0.42	0.46	
0.43	0.46	
0.43	0.47	
0.43	0.47	

JAMES P DUNIGAN #1, SANTA FE



ID 6

DEPTH	2656.0 FT
	809.5 M

* = Ro MATURITY

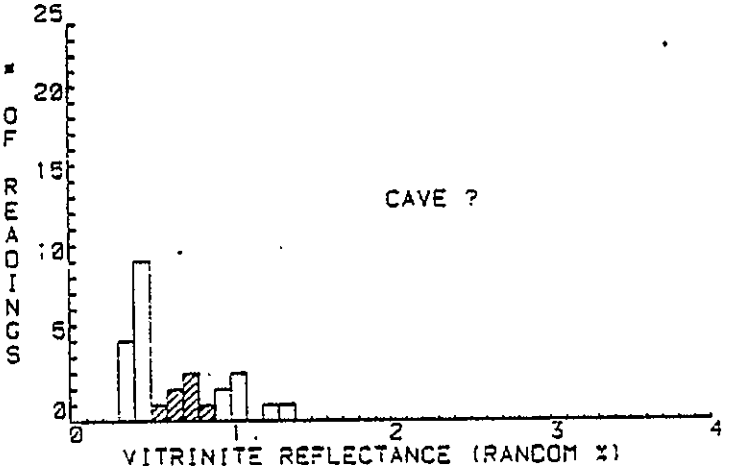
# VALUES	29.00
MEAN	0.68
STD DEV	0.12
MEDIAN	0.70
MODE	0.75

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES

0.38	0.46	*0.63	*0.78	1.01
0.41	*0.50	*0.65	*0.79	1.05
0.41	*0.50	*0.69	*0.82	1.05
0.42	*0.50	*0.70	*0.84	1.09
0.42	*0.51	*0.70	*0.86	1.13
0.43	*0.53	*0.71	*0.86	1.14
0.44	*0.54	*0.71	*0.88	1.28
0.45	*0.55	*0.71	0.96	1.30
0.46	*0.58	*0.74	0.99	1.38
0.46	*0.61	*0.78	0.99	1.41

JAMES P DUNIGAN #1, SANTA FE



ID 7

DEPTH 2855.0 FT
870.4 M

* = Ro MATURITY

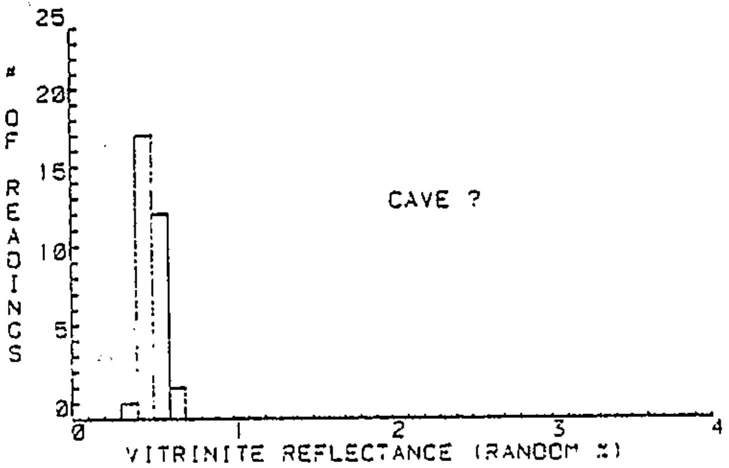
# VALUES	7.00
MEAN	0.70
STD DEV	0.10
MEDIAN	0.73
MODE	0.75

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

0.31	0.45	*0.78
0.36	0.46	*0.84
0.37	0.46	0.94
0.37	0.46	0.98
0.37	0.48	1.02
0.40	*0.53	1.02
0.41	*0.61	1.08
0.41	*0.68	1.26
0.42	*0.73	1.31
0.44	*0.76	

JAMES P DUNIGAN #1, SANTA FE



ID 8

DEPTH 3165.0 FT
964.9 M

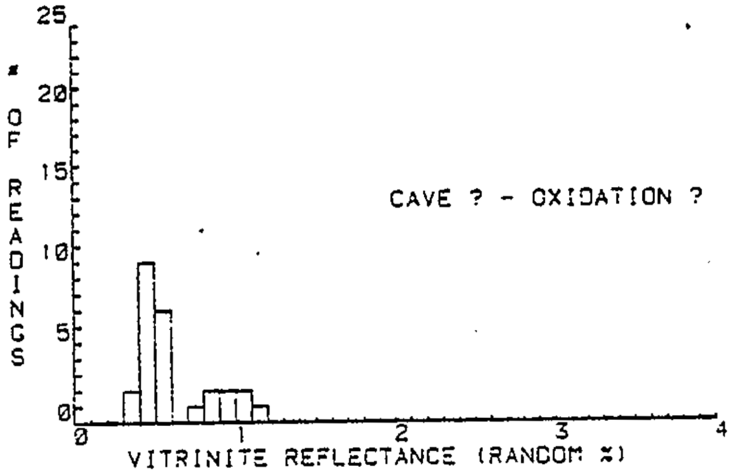
# VALUES	34.00
MEAN	0.50
STD DEV	0.06
MEDIAN	0.49
MODE	0.45

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

0.39	0.45	0.50	0.58
0.41	0.46	0.51	0.59
0.43	0.46	0.53	0.60
0.43	0.46	0.53	0.61
0.44	0.47	0.55	
0.44	0.48	0.55	
0.45	0.48	0.55	
0.45	0.49	0.56	
0.45	0.49	0.56	
0.45	0.50	0.58	

JAMES P DUNIGAN #1, SANTA FE



ID 9

DEPTH 3435.0 FT
1047.3 M

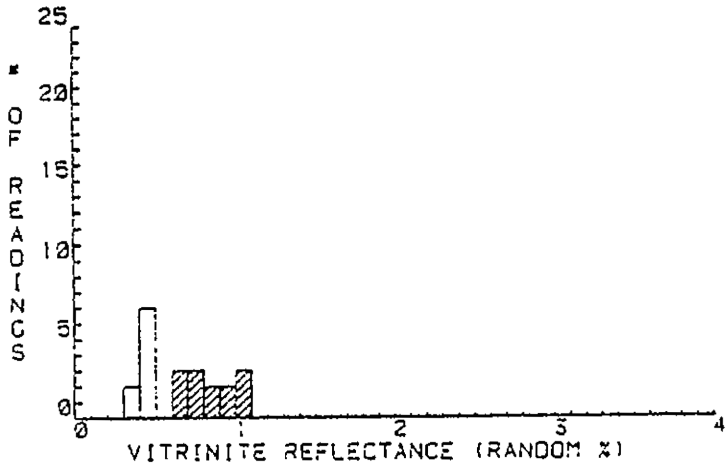
# VALUES	27.00
MEAN	0.61
STD DEV	0.23
MEDIAN	0.51
MODE	0.45

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

0.37	0.48	0.85
0.38	0.48	0.89
0.44	0.50	0.91
0.44	0.51	0.92
0.44	0.52	1.07
0.46	0.52	1.07
0.46	0.53	1.14
0.46	0.53	
0.46	0.57	
0.46	0.74	

JAMES P DUNIGAN #1, SANTA FE



ID 10

DEPTH 3745.0 FT
1141.8 M

* = Ro MATURITY

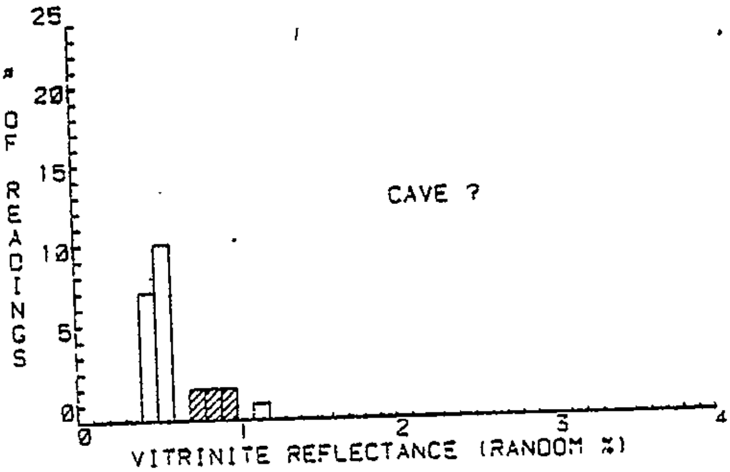
# VALUES	13.00
MEAN	0.82
STD DEV	0.14
MEDIAN	0.80
MODE	1.05

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

0.36	*0.64	*1.00
0 39	*0.65	*1.02
0.41	*0.72	
0.43	*0.78	
0.43	*0.78	
0 44	*0.80	
0.44	*0.82	
0.45	*0 90	
0.48	*0.92	
*0.61	*1.00	

JAMES P DUNIGAN #1, SANTA FE



ID 11

DEPTH	3865.0 FT	
	1178.4 M	

* = Ro MATURITY

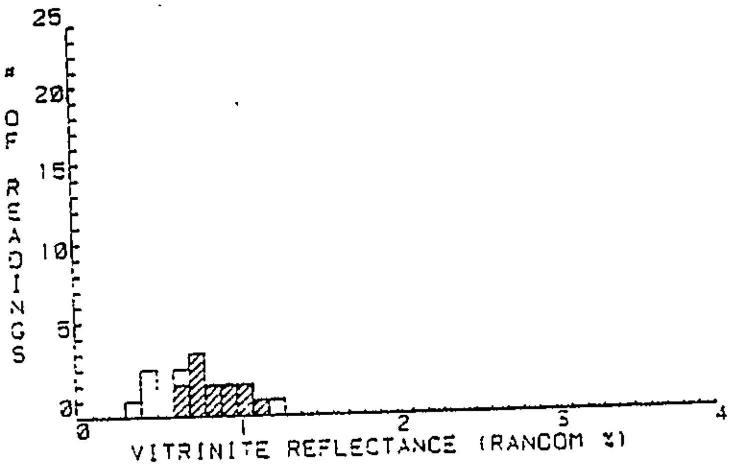
# VALUES	6.00
MEAN	0.84
STD DEV	0.08
MEDIAN	0.87
MODE	0.95

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

0.45	0.50	*0.77
0.46	0.51	*0.83
0.46	0.51	*0.87
0.47	0.51	*0.91
0.47	0.51	*0.96
0.47	0.52	1.19
0.48	0.56	
0.49	0.58	
0.50	0.58	
0.50	*0.72	

JAMES P DUNIGAN #1, SANTA FE



ID 12

DEPTH	4065.0 FT	
	1239.3 M	

* = Ro MATURITY

# VALUES	13.00
MEAN	0.86
STD DEV	0.14
MEDIAN	0.83
MODE	0.75

HISTOGRAM 0-4 (0.1)

ORDERED REFLECTANCE VALUES:

0.38	*0.77
0.41	*0.83
0.42	*0.87
0.42	*0.90
0.61	*0.90
*0.67	*1.04
*0.69	*1.09
*0.75	*1.11
*0.76	1.25
*0.77	