UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGICAL AND OPERATIONAL SUMMARY, SOUTHERN CALIFORNIA DEEP STRATIGRAPHIC TEST OCS-CAL 75-70 NO. 1, CORTES BANK AREA OFFSHORE SOUTHERN CALIFORNIA

By R. G. Paul, R. E. Arnal, J. P. Baysinger, G. E. Claypool, J. L. Holte, C. M. Lubeck, J. M. Patterson, R. Z. Poore, R. L. Slettene, W. V. Sliter, J. C. Taylor, R. B. Tudor, and F. L. Webster

Open-File Report 76-232

1976

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INTRODUCTION

by
R. G. Paul, U. S. Geological Survey
Los Angeles, California

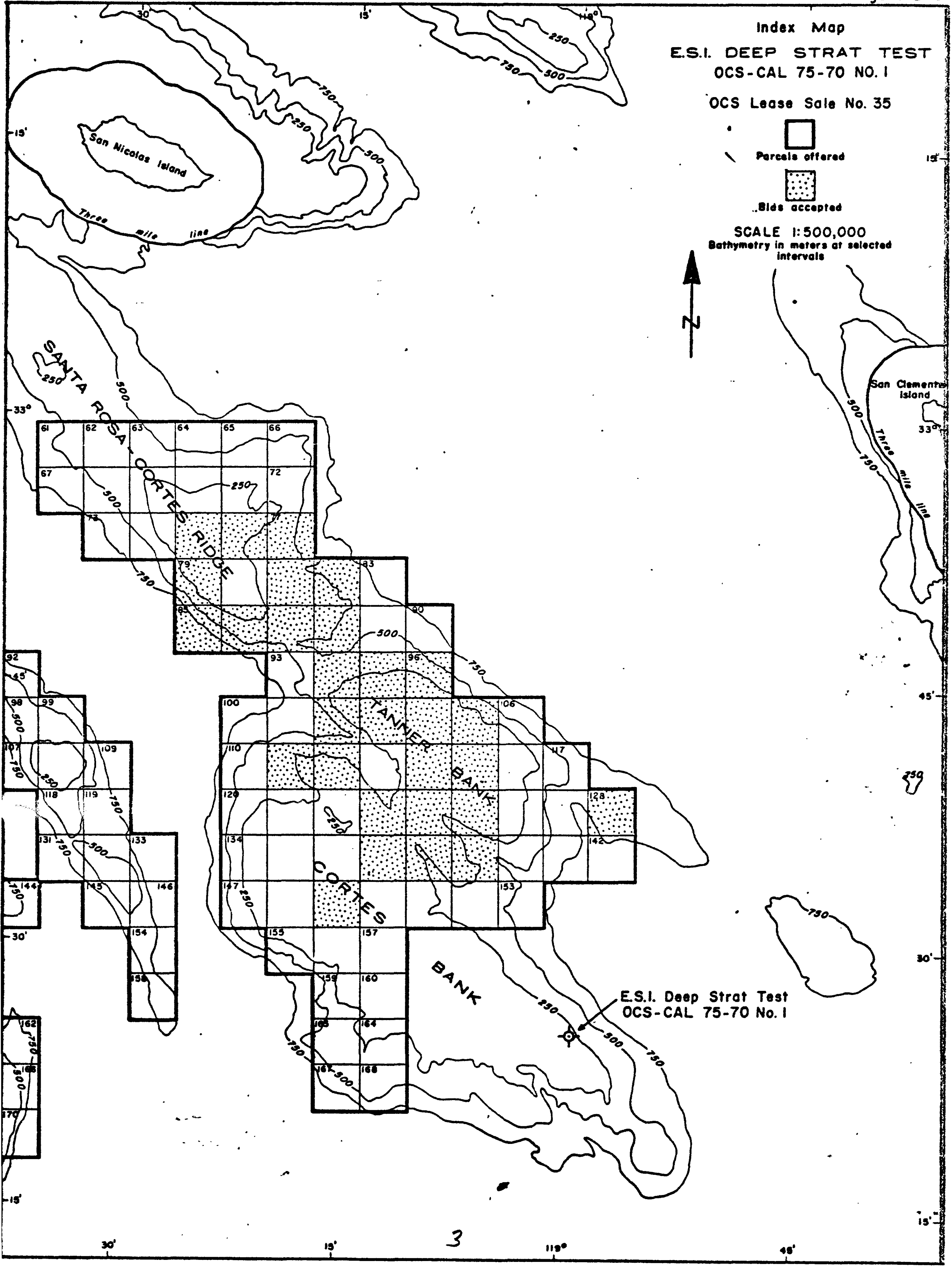
This open file report is presented in accordance with contingency No. 5 of the Director's letter of approval for the southern California deep stratigraphic test and stipulation A7b of the tentative stipulations for deep stratigraphic drilling, Outer Continental Shelf (OCS), Pacific Area, as revised June 26, 1975. Pursuant to these stipulations, resultant data and analytical results are to be disclosed to the public sixty (60) calendar days following the sale of the first Federal lease within 50 geographic miles (83 km) of the test site. Leases on tracts within 50 geographic miles of the test site were issued to the highest bidders in OCS Lease Sale No. 35 on January 13, 1976.

The southern California deep stratigraphic test OCS-CAL 75-70 No. 1 was drilled on the northeast flank of Cortes Bank in projected Block 7N-54W of the southern California Outer Continental Shelf. The well was located in 348 feet (106 m) of water approximately 50 miles (83 km) southwest of San Clemente Island and 85 miles (141 km) west of the southern California mainland coast (Figure I-1).

The well was drilled as a deep stratigraphic test to acquire further information on the stratigraphy, structure, and geochemistry of this unexplored area of the southern California Borderland. Eighteen companies participated in the drilling of the well on a cost-sharing basis, with Exploration Services Company, Inc. (E.S.I.), serving as operator for the group. The United States Geological Survey received geological information from this well as required in the drilling permit. The California State Lands Commission received the same data.

The southern California deep stratigraphic test was spudded in August 1975, drilled to a total depth of 10,920 feet RKB, and plugged and abandoned in early December prior to the southern California OCS Lease Sale No. 35. The well was located approximately eight miles southerly from the nearest parcel offered for leasing in the sale in a block which has not previously been considered for lease offer. The location of the well was purposely situated outside the lease sale area in a low geologic structural position based on geophysical data to ensure that the well would be drilled for geologic information only and minimize the possibility of penetrating zones containing commercial quantities of hydrocarbons.

The application to drill and abandon the deep stratigraphic test was reviewed and approved by the U. S. Geological Survey and a permit for such operations was issued in accordance with applicable Federal regulations.


Index Map
E.S.I. DEEP STRAT TEST
OCS-CAL 75-70 NO. 1
OCS Lease Sale No. 35
Parcels offered
Bids accepted
SCALE 1:500,000
Bathymetry in meters at selected intervals
N
San Nicolas Island
Three mile line
SANTA ROSA - CORTES RIDGE
TANNER BANK
CORTES BANK
San Clemente Island
E.S.I. Deep Strat Test
OCS-CAL 75-70 No. 1
33°
45'
30'
15'
119°

WELL DATA

by
J.L. Holte and R.B. Tudor
U.S. Geological Survey, Los Angeles, California

A. Summary of Well Data

1. Operator:

    a) Exploration Services Company, Inc.

2. Participants:

    a) American Petrofina Exploration Company

    b) Amoco Production Company

    c) Atlantic Richfield Company

    d) Burmah Oil and Gas Corp.

    e) Cities Service

    f) Exxon Company, U.S.A.

    g) Getty Oil Company

    h) Gulf Oil Company

    i) Marathon Oil Company

    j) Mobil Oil Corp.

    k) Phillips Petroleum Company

    l) Shell Oil Company

    m) Skelly Oil Company

    n) Standard Oil Company of California

    o) Sun Oil Company

    p) Superior Oil Company

q) Texaco, Inc.

r) Union Oil Company of California

3. Principal Contractor:

   a) Global Marine, Inc., CUSS I - Drilling Vessel

4. Support Contractors and Services:

a) C&C Fisheries, Inc.	M/V Calcasieu-Standby Boat
b) Global Marine, Inc.	CUSS I-Drilling Vessel
c) Halliburton Services	Cement, Chemicals
d) Leppaluoto Offshore Marine	M/V Francis-Crewboat
e) Magcobar	Drilling Fluids
f) Offshore Crane and Service Co., Inc.	Crane Service
g) Rotor-Aids, Inc.	Helicopter Services
h) Valenti Aviation	Aircraft Support
i) Western Boat Operators, Inc.	M/V Caldwell-Supply Boat

5. GeoScience Contractors and Services:

a) Anderson, Warren and Associates	Consulting Micropaleontology Sample Processing
b) BBN-Geomarine Services Company	Shallow Seismic Profiles
c) Core Laboratories, Inc.	Core Analysis
d) Dresser Olympic Operations	Deep Seismic Profiles
e) Exploration Logging	Mud Logging
f) GeoChem Laboratories	Geochemical Analysis
g) Intersea Research Corp.	Geophysical Biological Studies
h) Johnson Velocity Surveys	Velocity Surveying

i) Dr. Daniel Krummenacher — K/Ar Age Dating

j) Dr. Richard Merriam — Petrographic Sample Processing

k) Navigation Services, Inc. — Offshore Surveyors

l) Schlumberger Offshore — Well Logging, Formation Testing

6. Lease Designation: Unleased

7. Well No: OCS-CAL 75-70, No. 1

8. Location: California Coordinate System - Zone 6

   X = 1,152,428

   Y = 108,629

   Block 7N-54W (Projected)

   Longitude 118° 59' 49"

   Latitude 32° 26' 05"

9. Classification: Offshore Deep Stratigraphic Test

10. Elevation: RKB-28 feet

11. Water Depth: 348 feet MLLW

12. Spud Date: August 23, 1975

13. Date T.D. Reached: November 22, 1975

14. Completion Date: December 2, 1975

15. Status: Plugged and Abandoned

16. Total Depth: 10,920 feet RKB

17. Plug-Back Depth: 408 feet RKB

B. Operational Data

1. Mud Program:

The drilling fluid used in the mud program for the initial 100 feet of drilled hole below the ocean floor (476 feet RKB) was salt water. From this point to total depth at 10,920 feet RKB a CMC-Gel-Barite mud was used to maintain a low pH level so that geochemical tests could be made.

2. Hole Dimensions:

A 36-inch hole was drilled to a depth of 100 feet below the ocean floor (476 feet RKB), thence a 26-inch hole to 358 feet below the ocean floor (734 feet RKB), a 17½-inch hole from 358 feet to 1,203 feet (1,579 feet RKB), a 12¼-inch hole from 1,203 feet to 3,515 feet (3,891 feet RKB), and an 8 3/4-inch hole to total depth of 10,544 feet below the ocean floor (10,920 feet RKB).

3. Open Hole Tests:

No conventional drill stem tests were run in the well. Schlumberger Wireline Repeat Formation-Tests were taken at 4,710 feet, 4,998 feet to 5,008 feet, and 6,490 feet. Eleven pressure tests were taken at selected intervals from 4,998 feet to 7,138 feet.

4. Cores:

A total of sixteen conventional cores were taken from 2,899 feet to 10,920 feet. These data are further detailed in Table II-1.

Sidewall cores were taken from 770 feet to 10,875 feet as follows:

Table II-1
E.S.I. DEEP STRAT TEST
OCS-CAL 75-70 No. 1
Core Operational Summary

Core	Depth	Feet Attempted	Feet Recovered	Percent Recovered	Samples Analyzed
1	2899'- 2932'	33'	0	0	0
2	3307'- 3332'	25'	21' 9"	87	3
3	3732'- 3760'	28'	16' 6"	58	6
4	4260'- 4275'	15'	6'	40	0
5	4775'- 4784'	9'	5' 6"	61	0
6	5022'- 5047'	25'	24'	96	10
7	5377'- 5395'	18'	18'	100	1
8	6008'- 6022'	14'	6'	42	2
9	6553'- 6578'	25'	25'	100	8
10	7102'- 7127'	25'	21' 6"	86	8
11	8304'- 8313'	9'	8' 9"	97	0
12	8734'- 8741'	7'	7'	100	4
13	9222'- 9236'	14'	14'	100	11
14	9639'- 9645'	6'	6'	100	3
15	10,696'-10,709'	13'	6'	46	0
16	10,912'-10,920'	8'	8'	100	0
Totals		274'	194'	71%	56

Number Taken	386
Samples Analyzed	93
Empty Sample Bottles	53

5. Geochemical Analysis:

Analysis of Mud, Ditch, and Core Samples from 810 feet to 8,740 feet

Number of Samples: 409

Number Analyzed: 118 (Final Report Data)

6. Potassium - Argon Age Dating Results:

A whole rock radiometric age date was obtained on a basalt sample from 2,718 feet.

7. Surveys:

Wireline Services: Operator - Schlumberger

Electric Logs:

Run No. 1 (8-28-75) 740 feet - 1,587 feet

1) Dual Induction - Laterolog	2 inch and 5 inch
2) Borehole Compensated Sonic Log	2 inch and 5 inch
3) Compensated Neutron - Formation Density	5 inch only
4) Continuous Dipmeter, Monitor and Arrow - Plot	5 inch only
5) Formation Factor	5 inch only

Run No. 2 (9-8-75) 1,587 feet - 3,927 feet

1) Dual Induction - Laterolog	2 inch and 5 inch
2) Borehole Compensated Sonic Log	2 inch and 5 inch
3) Compensated Neutron - Formation Density	5 inch only

4) Density Derived Formation Factor — 5 inch only

5) Continuous Dipmeter, Monitor and Arrow-Plot — 5 inch only

Run No. 3 (10-2-75) 3,894 feet - 8,115 feet

1) Dual Induction - Laterolog — 2 inch and 5 inch

2) Borehole Compensated Sonic Log — 2 inch and 5 inch

3) Compensated Neutron - Formation Density — 5 inch only

4) Density Derived Formation Factor — 5 inch only

5) Continuous Dipmeter, Monitor and Arrow-Plot — 5 inch only

Run No. 4 (10-22 & 29-75) 7,000 feet - 8,832 feet (DIL)

7,700 feet - 9,821 feet (all others)

1) Dual Induction - Laterolog — 2 inch and 5 inch

2) Borehole Compensated Sonic Log — 2 inch and 5 inch

3) Density Derived Formation Factor — 5 inch only

4) Continuous Dipmeter, Monitor and Arrow-Plot — 5 inch only

5) Compensated Neutron-Formation Density — 5 inch only

Run No. 5 (11-9-75) 7,700 feet - 10,354 feet

1) Dual Induction - Laterolog — 2 inch and 5 inch

Run No. 6 (11-23 & 25-75) 9,700 feet - 10,920 feet

1) Dual Induction - Laterolog — 2 inch and 5 inch

2) Borehole Compensated Sonic Log — 2 inch and 5 inch

3) Compensated Neutron-Formation Density — 5 inch only

4) Density Derived Formation Factor — 5 inch only

5) Temperature Log (3,802 feet - 10,920 feet) — 5 inch only

6) Continuous Dipmeter, Monitor and Arrow-Plot — 5 inch only

Repeat Formation Tester (11-25-75) 4,578 feet - 7,138 feet

14 tests

Johnson Velocity Survey (11-25-75) 650 feet - 10,727 feet

Hole Deviation:

The well was drilled as a vertical hole, but geological structural influence caused some deviation in the lower portion of the hole. Surveyed deviations were consistently in a south-west direction. Hole angles from 10° to $12\frac{1}{4}^{\circ}$ were surveyed below 7,900 feet. The bottom survey at 10,371 feet shows that point 288 feet south and 577 feet west from the surface location.

8. Pipe Record

Size	Depth Set	Hole Size	Cementing Record
30 inch	476 feet	36 inch	450 SX Type G
20 inch	734 feet	26 inch	1027 SX Type G
13 3/8 inch	1,579 feet	17½ inch	690 SX Type G
9 5/8 inch	3,891 feet	12¼ inch	700 SX Type G

C. Sample and Circulation Data

1. Ditch Sample Program

From	To	Sample Interval	Total Samples
749 feet	10,912 feet	30 feet	339

2. Circulations

N. A.

3. Lost Circulation

N. A.

ELECTRIC LOG INTERPRETATION AND ROCK CHARACTERISTICS

by
R. G. Paul, U. S. Geological Survey
Los Angeles, California

A. Introduction

The electric log evaluation of well OCS-CAL 75-70 No. 1 includes derivation of formation porosities, fluid resistivities, fluid saturations, sand percentages, and where applicable, lithology cross plots using the Dual Induction-Laterolog (DIL), density derived formation factor, and three porosity logs (Tables III-1 and III-2, Figures III-1 and III-2). These data were complemented by core and sidewall sample porosities, permeabilities, and descriptions determined by Core Laboratories, Inc., (Table III-3, Figures III-3, III-4, and III-5). Core porosity measurements were also determined by U.S.G.S. (see Stratigraphy section, this report) and are shown on Figure III-3.

Additionally, the geothermal gradient in the well was calculated from wireline log data.

The upper portion of the logged hole from 740 feet to 7,965 feet RKB consists of an alternating sandstone-shale sequence with a steadily decreasing percentage and quality of sandstone beds with depth. This sequence is interrupted by a volcanic section from 2,283 feet to 2,850 feet. Below 7,965 feet to total depth at 10,920 feet the SP character is poor and induction resistivities high, and thus reservoir evaluation in this interval is not considered feasible.

B. Reservoir Characteristics

The logs from 740 feet to 2,283 feet show loosely compacted porous block sandstone beds as much as 120 feet thick with minor interbedded clay and shale above the volcanic sequence. The percentage of sandstone in this lower (?) to middle Miocene interval is 83.4 percent and a cursory check of density log measurements indicates porosities averaging 32 percent.

The interval sandstone percentage drops to 63.3 percent in the Oligocene section from 2,850 feet to 4,190 feet with density porosities averaging 30.1 percent. These appear to be clean reservoir quality sandstones with possible minor shale content. The shale content is questionable due to insufficient formation compaction, affecting the reliability of sonic and neutron log data. The log and sample data in the upper Eocene section from 4,190 feet to 4,570 feet indicates shale only. The Eocene sandstone section from 4,570 feet to 5,340 feet shows 37.5 percent sandstone in the interval with porosities averaging 17.3 percent. These sandstones are relatively thinner (3 feet to 25 feet) than the younger section with corresponding lower porosities and permeabilities (Table III-3, Figures III-3 and III-4). The formation water resistivities derived from DIL are consistent through the upper portion of the hole, ranging from .093 to .135Ω-M. A plot of density derived formation factor on the DIL deep induction curve indicates all sandstone beds are water saturated. In the Eocene shale, Paleocene, and Upper Cretaceous section from 5,340 feet to 7,965 feet the interval sandstone percentage further decreases to 21 percent with density porosities averaging 13 percent. Water resistivities are slightly higher than in the younger section, averaging .14Ω-M with all sandstones remaining water saturated.

The reservoir quality characteristics of the Upper Cretaceous interval from 7,965 feet to total depth at 10,920 feet are indeterminate as previously mentioned. However, based on the small amount of data available, the reservoirs are considered to be poor. Sidewall sample and core sample descriptions (Table III-3) indicate fine grained silty sandstone beds interbedded with hard calcareous siltstones and shales, which are locally fractured. Porosity and permeability values in this interval, derived from core sample analyses (Figures III-3, III-4, and III-5), seem to indicate poor reservoir quality sandstones.

C. Lithology Crossplots

Two lithology crossplots, the "M-N" plot, and the Matrix Identification (MID) plot were computed from the three porosity logs to determine matrix values in the lower portion of the hole. These points are listed in Table II and plotted in Figures I and II for that portion of the hole below 7,000 feet. The litho-porosity crossplot is used for interpretation of formations of complex lithology by presenting data simultaneously from all three standard porosity logs. This is accomplished by eliminating porosity from the sonic-density relationship and defining the parameter as "M". Similarly, porosity is also eliminated from the neutron-density relationship defining the resulting parameter as "N". These parameters are further defined for water saturated formations on Figure III-1. The "M-N" plot shows each rock mineral as a unique point regardless of porosity and the position of log data on the "M" vs. "N" grid relative to pure mineral points enhances identification of constituent minerals. The pure mineral matrix points for silica, calcite, dolomite, and anhydrite are identified on the crossplots for reference. The three plotted sandstone points (nos. 21, 22, and 26) show the effects of possible calcareous cementing material. The remaining shale points show the dominant locally fractured dense calcareous lithology, which is supported by sidewall and core descriptions. The sandstone beds above 3,000 feet were not plotted since neutron and sonic log data in that interval were considered unreliable.

D. Geothermal Gradient

The geothermal gradient calculated for the well averages 1.8^{o}F./100 feet in the upper intervals; however, it is slightly higher below 10,000 feet. The gradient was calculated from data taken from the several log runs utilizing a modified Horner pressure buildup plot (Dowdle and Cobb, 1975). Short circulation times prior to logging affects the reliability of extrapolated values used as input to determine the geothermal gradient. Circulation times of two hours or less are reported in this well prior to logging and did not allow completely reliable data plots.

Table III-1
E.S.I. DEEP STRAT TEST
OCS-CAL 75-70 No. 1
Log Interpretation Summary

Depth Interval	Age	Interval, Thickness, ft.	Interval Sand, ft.	Interval Sand, %	Avg ϕ_D,% 1)	Avg. Rw
740-2283	L. (?) To M. Miocene	1543'	1288'	83.4	32.0	.125
2283-2850	Volcanic Rocks	567'	----	----	----	----
2850-4190	Oligocene	1340'	849'	63.3	30.1	.120
4190-4570	Eocene (U. Eocene Sh.)	380'	0'	0	----	----
4570-5340	Eocene (Eocene SS.)	770'	289'	37.5	17.3	.112
5340-6140	Eocene (Eocene Sh.)	800'	156'	19.5	13.7	.143
6140-7965	Paleocene and U. Cretaceous	1825'	394'	21.6	12.8	.135
7965-10,920	U. Cretaceous	2955'	Indeterminate →			

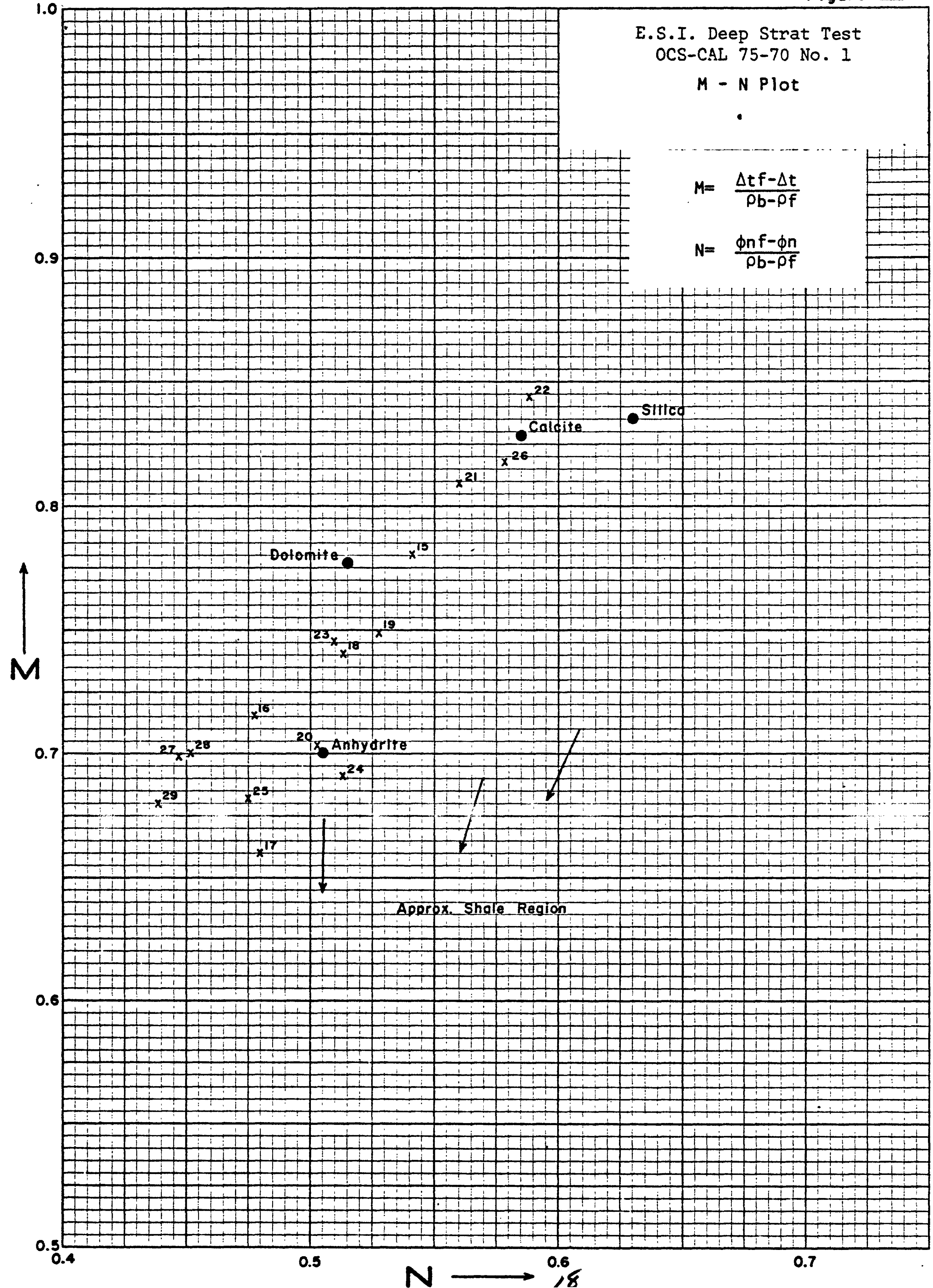
1) Inconclusive - random sampling to compare SWS analyses

Table III-2
E.S.I. DEEP STRAT TEST
OCS-CAL 75-70 No. 1
Lithology Crossplot
Data

Point	Depth	ϕ_{CNL}	ρ_B	ΔT	M	N	ΔT_{ma}	ρ_{ma}
1	1104-07	41	2.03	71	1.145	.573	V. Low	2.72
2	1147-50	48	1.92	58	1.425	.565	V. Low	2.76
3	1950-52	19	2.42	64	.88	.57	45	2.73
4	2119-21	22	2.34	86	.769	.582	53	2.71
5 (sh)	3076-79	39	2.27	118	.559	.48	64	2.90
6 (sh)	3162-67	38	2.24	122	.54	.50	70	2.87
7	3594-3603	29	2.24	112	.62	.572	73	2.73
8	3980-89	32	2.17	107	.70	.581	60	2.71
9 (sh)	4324-28	40	2.26	120	.547	.476	64	2.91
10	4996-5000	29	2.33	96	.699	.534	53	2.79
11(sh)	5410-14	25	2.57	90	.63	.478	52	2.88
12	5901-06	28	2.37	90	.723	.525	50	2.81
13(sh)	6241-49	26	2.48	86	.696	.50	49	2.85
14(sh)	6753-58	29	2.52	88	.665	.467	47	2.90
15	7100-10	22	2.44	78	.78	.541	47	2.78
16(sh)	7518-26	26	2.55	78	.716	.477	46	2.88
17(sh)	7836-50	25	2.56	86	.66	.48	50	2.88
18(sh)	8000-10	21	2.54	75	.74	.513	47	2.83
19(sh)	8194-8200	14	2.63	67	.749	.528	47	2.80
20(sh)	8342-49	19	2.61	76	.703	.503	48	2.85
21	8684-90	12	2.57	62	.809	.56	47	2.74
22	9235-40	10	2.53	60	.844	.588	47	2.70
23(sh)	9540-46	18	2.61	69	.745	.51	46	2.83
24(silt)	9774-77	22	2.52	84	.691	.513	51	2.82
25(sh)	9994-98	15	2.79	67	.682	.475	47	2.90
26	10,228-36	11	2.54	63	.818	.578	48	2.72
27(sh)	10,324-50	20	2.79	64	.699	.447	44	2.95
28(sh)	10,610-22	20	2.77	65	.70	.452	44	2.94
29(sh)	10,824-42	22	2.78	68	.68	.439	45	2.97

Note:
ϕ_{CNL} = Porosity from compensated neutron log (Adjusted to LS units)
ρ_B = Density log reading
ΔT = Sonic log reading
M, N = Calculated parameters
ΔT_{ma} = Calculated matrix travel time
ρ_{ma} = Calculated matrix density

Figure III-1


E.S.I. Deep Strat Test
OCS-CAL 75-70 No. 1
M - N Plot
M= $\frac{\Delta tf-\Delta t}{\rho b-\rho f}$
N= $\frac{\phi nf-\phi n}{\rho b-\rho f}$
Silica
Calcite
Dolomite
Anhydrite
Approx. Shale Region
M
N
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.5
0.6
0.7
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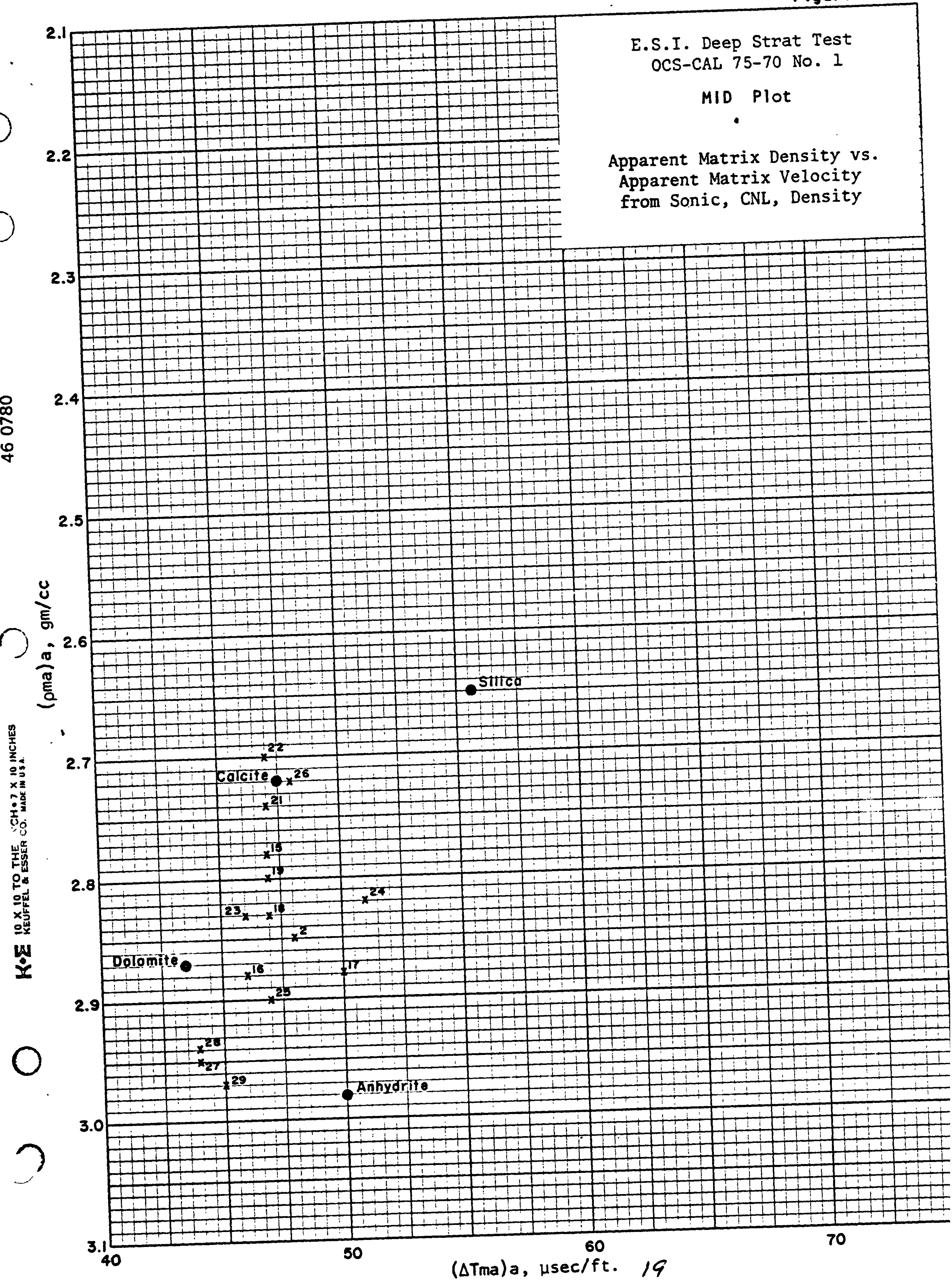

E.S.I. Deep Strat Test
OCS-CAL 75-70 No. 1
MID Plot
Apparent Matrix Density vs.
Apparent Matrix Velocity
from Sonic, CNL, Density
(ρma)a, gm/cc
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
40
50
60
70
(ΔTma)a, μsec/ft.
Silica
Calcite
Dolomite
Anhydrite
22
26
21
15
19
24
23
18
2
17
16
25
28
27
29
46 0780
K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

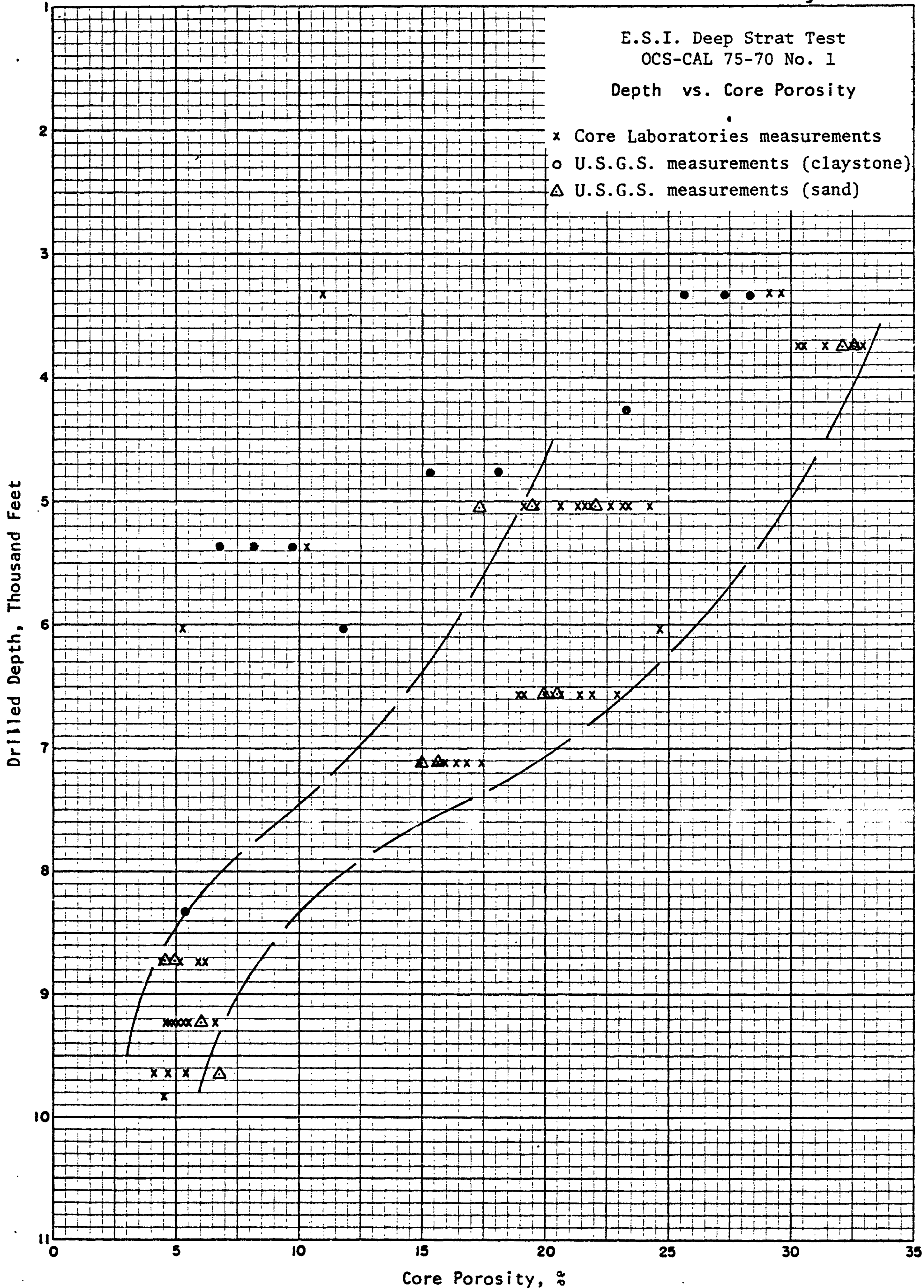
Table III-3
E.S.I. DEEP STRAT TEST
OCS-CAL 75-70 No. 1
Core and Sidewall Sample Measurements and Descriptions

DEPTH IN FEET	PERMEABILITY MILLIDARCYS	POROSITY PERCENT	SAMPLE DESCRIPTIONS
1348	53.0	33.1	Sd, gry, v/fn grn, v/slty
1392	821.0	30.2	Sd, brn, v/fn grn
1470	1275.0	26.1	Sd, gry, v/fn grn
1565	218.0	36.2	Sd, gry-tan, v/fn grn, slty
1580	114.0	31.7	Same as above
1929	116.0	28.3	Sd, gry, fn to med grn, slty
2000	618.0	19.1	Sd, gry, fn to med grn, slty, calc
2123	283.0	17.7	Sd, gry, fn to crs grn, slty, clayey
2855	732.0	18.1	Sd, gry, v/fn grn, v/slty
2870	396.0	26.7	Same as above
2890	153.0	15.6	Sd, gry-wht, fn grn, v/slty, calc
2920	1324.0	33.9	Sd, gry, fn grn, slty
2936	918.0	29.4	Sd, gry, med grn, slty
2945	735.0	26.9	Sd, gry to multi-colored, fn grn , slty
2955	329.0	21.9	Sd, gry, fn grn, slty
2960	646.0	29.6	Same as above
2970	586.0	27.6	Sd, lt gry, v/fn grn, slty
2972	88.0	16.4	Same as above
2983	936.0	25.8	Sd, gry to multi-colored, fn to med grn, slty
2990	819.0	25.6	Sd, gry, fn grn, slty
3000	539.0	27.5	Same as above
3010	103.0	17.8	Sd, gry, v/fn grn, slty
3023	18.3	26.8	Same as above
3030	403.0	21.1	Sd, gry, fn grn, v/slty
3040	170.0	18.9	Sd, gry, fn grn, slty
3050	738.0	25.5	Same as above
3060	552.0	21.0	Sd, gry, fn grn, v/slty, calc
3106	857.0	27.6	Sd, gry, fn to med grn, slty
3110	614.0	23.4	Sd, med gry, fn to med grn
3170	1142.0	29.2	Clayst, gry-brn, slty, mottled
3184	674.0	28.6	Same as above
(K2) 3317	777.0	29.2	Sd, lt gry, fn to med grn, calc
(K2) 3318.5	462.0	29.6	Same as above
3323	634.0	25.7	Sd, gry, fn to med grn, slty
(K2) 3327.5	50.0	11.0	Same as above
3365	528.0	22.6	Sd, gry, fn grn, v/slty
3393	843.0	26.9	Sd, gry, fn to med grn
3415	428.0	24.4	Same as above
3475	921.0	25.1	Same as above
3507	824.0	28.3	Same as above
3528	878.0	28.4	Same as above
3565	1163.0	32.8	Sd, lt gry, fn to med grn
3585	929.0	29.7	Sd, med gry, fn to med grn
3640	1022.0	33.7	Same as above
3690	773.0	30.3	Same as above
(K3) 3734.5	626.0	32.6	Sd, gry, fn to med grn, rx frags, calc
(K3) 3737	1631.0	30.3	Same as above
(K3) 3739	438.0	31.4	Same as above
3740	749.0	29.4	Sd, med gry, fn to med grn, v/slty
(K3) 3742.5	627.0	32.9	Sd, gry to lt gry, fn to med grn, rx frags
(K3) 3745.5	640.0	30.3	Same as above
(K3) 3747.5	923.0	32.5	Same as above
3795	504.0	26.6	Sd, gry, fn to med grn, slty

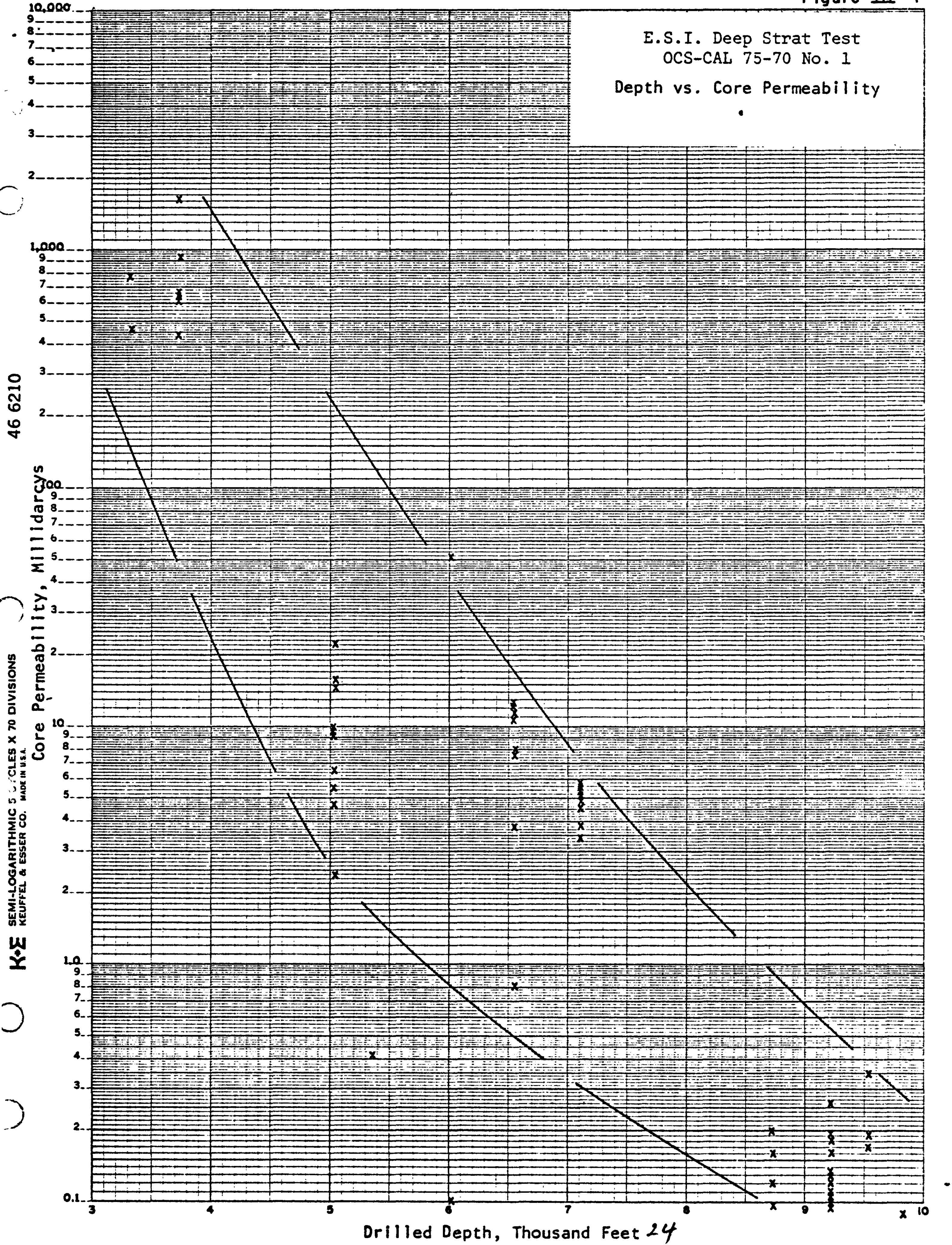
	DEPTH IN FEET	PERMEABILITY MILLIDARCYS	POROSITY PERCENT	SAMPLE DESCRIPTION
	3830	624.0	28.9	Same as above
	3875	792.0	29.4	Siltstn, med gry
	3900	744.0	31.1	Sd, gry, fn to med grn, slty
	3945	69.0	26.5	Same as above
	3975	114.0	29.3	Same as above
	4015	64.0	28.6	Same as above
	4050	38.0	29.4	Same as above
	4085	53.0	26.5	Sd, gry, fn to med grn, clayey
	4125	72.0	24.0	Sd, gry, fn tc med grn, w/mafics, clayey
	4155	87.0	30.3	Sd, gry, v/fn to fn grn, clayey
	4580	102.0	27.6	Sd, gry, fn grn, slty
	4605	0.3	9.7	Sd, gry, fn grn, v/slty
	4628	49.0	24.9	Sd, gry, fn grn, slty
	4713	14.2	30.2	Same as above
(K6)	5023.25	9.0	22.7	Sd, gry, fn to med grn, rx frags slty
(K6)	5024.5	2.37	21.3	Same as above
(K6)	5028	5.53	19.6	Same as above
(K6)	5031	9.28	21.6	Same as above
(K6)	5033.5	14.54	20.6	Same as above
(K6)	5036.25	4.76	19.1	Same as above
(K6)	5038.5	15.82	23.2	Same as above
(K6)	5040.25	9.94	23.2	Same as above
(K6)	5042.5	22.0	24.2	Same as above
(K6)	5045.25	6.47	21.8	Same as above
	5055	93.0	24.4	Sd, gry, fn to med grn
	5175	15.4	19.4	Sd, gry,fn to med grn, slty
	5232	31.0	25.0	Sd, gry, fn grn, slty
	5274	46.0	22.0	Sd, gry, fn to med grn, clayey, s/calc
	5324	76.0	27.2	Same as above
(K7)	5378	0.41	10.3	Sd, gry, v/fn to med grn, calc
	5436	23.0	20.9	Sd, med dk gry, fn grn, slty, calc
	6000	12.3	28.3	Sd, gry, v/fn grn, slty, calc
(K8)	6009	0.04	5.5	Siltst, gry,msv
(K8)	6012.5	51.0	24.6	Sd, gry, v/fn grn, slty,calc
	6029	24.0	29.8	Sd, gry, v/fn grn, clayey
	6062	43.0	30.7	Same as above
	6092	4.9	30.0	Clayst, dk gry, slty
	6185	1.7	24.7	Sd, gry, fn grn, v/slty
(K9)	6554.5	12.6	22.9	Sd, lt gry to gry, v/fn to fn grn, sl/calc
(K9)	6558.7	12.0	21.4	Same as above
(K9)	6559.6	11.2	21.9	Same as above
(K9)	6562.5	3.8	20.3	Same as above
(K9)	6564.3	7.5	20.0	Same as above
(K9)	6566.4	0.8	19.0	Same as above
(K9)	6568.6	10.6	19.0	Same as above
(K9)	6576.7	8.0	20.6	Sd, lt gry, v/fn to fn grn, rx frags
	6674	8.4	26.6	Sd, gry, fn to med grn, slty
	6730	1.9	22.8	Same as above
	7050	16.2	26.3	Sd, gry, fn grn, sl/clayey, sl/calc
(K10)	7106.5	3.4	15.6	Sd, lt/med gry, v/fn to fn grn, slty
(K10)	7107.5	5.7	15.8	Same as above
(K10)	7111	3.8	15.7	Same as above
(K10)	7114.4	5.4	14.9	Siltst, dk gry, v/sdy
(K10)	7116	5.6	15.5	Same as above

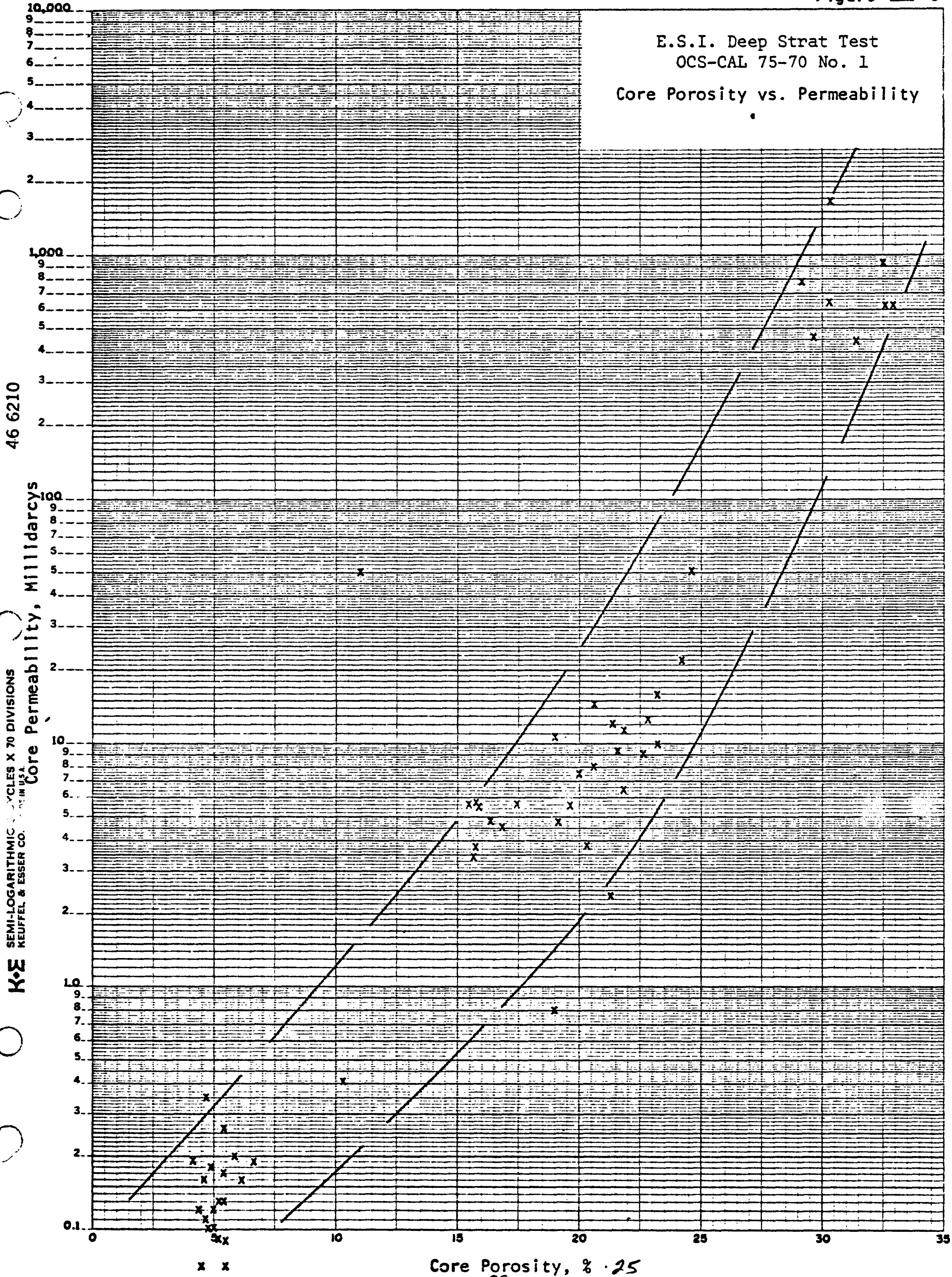
	DEPTH IN FEET	PERMEABILITY MILLIDARCYS	POROSITY PERCENT	SAMPLE DESCRIPTION
(K10)	7118.5	4.8	16.4	Same as above
(K10)	7121.5	5.6	17.4	Same as above
(K10)	7123.8	4.5	16.8	Sd, lt/med gry, v/fn to fn grn, slty
	7675	3.6	20.0	Sd, lt gry, fn grn, slty
	7710	4.3	22.0	Same as above
	8450	41.0	14.8	
	8554	80.0	19.2	
	8570	22.0	22.8	
	8615	18.2	21.2	
	8720	30.0	15.4	
(K12)	8735.7	0.2	5.9	Sd, med gry, med to crs grn
(K12)	8736.4	0.16	6.1	Same as above
(K12)	8737.7	0.12	4.4	Same as above
(K12)	8738.6	0.08	5.2	Same as above
	8778	12.2	15.2	
	8782	62.0	23.5	
	8793	3.9	27.6	
(K13)	9223	0.12	5.0	Sd, gry to grn gry, fn to med grn
(K13)	9224	0.13	5.2	Same as above
(K13)	9225.5	0.13	5.3	Same as above
(K13)	9226.5	0.19	6.6	Same as above
(K13)	9228.3	0.11	4.7	Same as above
(K13)	9229	0.26	5.4	½sd, as above, ½mudst, dk gry, slty
(K13)	9230.5	0.08	5.4	Same as above
(K13)	9231.4	0.10	5.0	Sd, gry to grn gry, fn to med grn
(K13)	9232.5	0.16	4.6	Same as above
(K13)	9234	0.10	4.8	Same as above
(K13)	9234.8	0.18	4.9	Same as above
	9280	3.01	18.2	Sd, lt gry, fn grn, slty
	9430	18.31	12.1	Sd, gry, fn to med grn, calc
	9530	165.0	23.5	½sd, gry, v/fn grn, slty, ½sh, gry
(K14)	9639.6	0.19	4.1	Sd, gry, fn to med grn, sl/calc
(K14)	9641.1	0.17	5.4	Same as above
(K14)	9644.5	0.35	4.7	Same as above
	9675	51.0	23.5	Sd, gry, fn to med grn, slty, sl/calc
	9765	110.0	19.6	Sd, lt gry, fn to med grn, slty, sl/calc
	9770	34.0	14.2	Sh, gry, slty, sl/calc
	9830	628.0	27.9	Sd, gry, fn to med grn, sl/slty, calc
(JBK)	9833	0.06	4.5	Sd, grn-gry, med to crs grn
	10,010	5.4	19.2	Sd, lt gry, fn grn, slty, v/calc
	10,085	0.46	17.2	Sd, lt gry, fn grn, slty, sl/calc

Figure III-3



E.S.I. Deep Strat Test
OCS-CAL 75-70 No. 1
Depth vs. Core Porosity
x Core Laboratories measurements
o U.S.G.S. measurements (claystone)
△ U.S.G.S. measurements (sand)
Drilled Depth, Thousand Feet
Core Porosity, %
1
2
3
4
5
6
7
8
9
10
11
0
5
10
15
20
25
30
35


E.S.I. Deep Strat Test
OCS-CAL 75-70 No. 1
Depth vs. Core Permeability
Core Permeability, Millidarcys
Drilled Depth, Thousand Feet
10,000
1,000
100
10
1.0
0.1
3
4
5
6
7
8
9
10
46 6210
K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.


E.S.I. Deep Strat Test
OCS-CAL 75-70 No. 1
Core Porosity vs. Permeability
Core Permeability, Millidarcys
Core Porosity, %
10,000
1,000
100
10
1.0
0.1
0
5
10
15
20
25
30
35
46 6210
K•E SEMI-LOGARITHMIC CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. IN U.S.A.

STRATIGRAPHY

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A. Introduction

Well OCS-CAL 75-70 No. 1 spudded in a middle Miocene sand/shale section and reached a total drill depth of 10,920 feet in the Upper Cretaceous after penetrating Miocene, Oligocene, Eocene, Paleocene and Upper Cretaceous sections. The well was on the northeast flank of an anticlinal structure. Dips from dipmeter and cores were consistently to the northeast at low angles (4 to 17°) with a change in dip direction at 8,500 feet from N75E to S65E. Except for a 567-foot interval of volcanic rock in the Oligocene(?) section and a 10-foot limestone in the lower Eocene, the entire Tertiary and Cretaceous interval consists of marine sand and shale units of which more than 40 percent is sandstone. With few exceptions the entire section is believed to have been deposited in a bathyal environment at depths greater than 660 feet (200 m).

Age determinations (see Paleontology section, this report) are based on examination of foraminiferal assemblages from cores, sidewall samples and ditch cuttings (Figure V-1). Nannofossils were not examined. Some stage boundaries are closely defined whereas others occur within zones several hundreds of feet thick. The Refugian Stage is considered late Eocene in age (see Paleontology section). No definitive Paleocene foraminifera were found, yet an 850-foot interval of probable Paleocene age was penetrated. Below 6,000 feet foraminiferal abundance is low and quality of preservation is only fair to poor. The penetrated stratigraphic section is divided into eight units (Figure IV-1) considered to be potentially mappable by using paleontologic control, lithologic character, seismic reflectivity, depositional environment, or major well log character change.

Organic geochemical studies on cored material for quality of source rock potential and maturity of organic matter were made by G. E. Claypool (see Organic Geochemical Analyses section). Porosity measurements on cored material were made by L. A. Beyer (Table IV-1) and agree with those measured by commercial laboratories and reported in the log interpretation section of this report (Figure III-3). Petrographic and X-ray diffraction identifications of cored material and selected ditch cuttings were made by J. C. Taylor.

B. Description of Stratigraphic Units

Unit 1: Upper Cretaceous (7,965 - 10,920 feet)

This unit includes the portion of the Upper Cretaceous that was penetrated below an unconformity at 7,965 feet. Faunal control suggests that portions of the Campanian, all of the Santonian and perhaps all or most of the Coniacian Stages are missing (Figure V-1). Evidence for an unconformity also includes changes in rock character based on higher log resistivity, higher sonic velocity up to 16,700 ft/sec (Figure VI-2), and lower density-derived porosities. Sandstone samples from cores below the unconformity have porosities of less than 6 percent, and are cemented with laumontite, whereas sandstones above the unconformity have porosities greater than 12 percent and no laumontite. The maturity of organic matter measured in core samples appears to change from immature to mature across this unconformity (refer to Organic Geochemistry Analyses section).

The age of this interval ranges from as old as Cenomanian in the bottom 500 feet of the well to possibly as young as Coniacian. The paleobathymetry of this section is believed to have been lower bathyal to abyssal. Basement of unknown composition is interpreted from magnetometer data to occur at a depth of 12,000 feet, or approximately 1,000 feet below the total depth penetrated by the well.

The argillaceous rocks are largely limy mudstones, dark gray to black, massive, very hard, brittle, fractured and slickensided. Part of the section consists of coarse grained turbidite sandstone containing laumontite cement. Sedimentary structures include normally graded bedding, flame structures or load deformation at basal contacts, and flattened rip-up clasts up to 1-inch long of dark gray shale. Thinly bedded to laminated siltstone containing carbonaceous material occurs between some sandstone beds, but is absent between others.

The sandstone beds are highly indurated, greenish-gray, and poorly sorted with angular to subangular clasts up to coarse grain size (0.5 mm). Lithic fragments account for 40 percent of the sandstone framework and include hornblende granite to granodiorite, quartzose metamorphic rock with accessory biotite, muscovite, epidote, and chlorite, and felty hypocrystalline andesite and basalt and minor porphyritic rhyolite. Quartz and feldspar grains are about equal in abundance and K-feldspar is equal to plagioclase. Heavy minerals include: biotite, common to abundant (C-A), hornblende, muscovite, epidote, chlorite, present (P), and rare (R) amounts of zircon, garnet, zoisite, and sphene.

Laumontite is a common cementing and pore filling mineral in three Cretaceous sandstone cores between 8,734 feet and 9,645 feet. It fills voids between sand grains; occurs as micro-veinlets crossing thin veins (1/8-inch wide) of solid bitumen at 8,734 feet; is present as a pore filling in the cells of woody carbonaceus material; and is common between the cleavage of biotite grains. The laumontite is believed derived in part from the albitization of plagioclase which has a mottled extinction and variable birefringence in many grains. The unstable glass in hypocrystalline andesitic and basaltic rock fragments is also a possible source for secondary zeolite. The burial metamorphism observed in these sandstones is similar to that described from the Great Valley Sequence by Dickinson, Ojakangas and Stewart (1969).

Sandstone cores have a maximum permeability of 0.35 millidarcies and a maximum porosity of 6.6 percent. Dips below 8,500 feet are approximately 10^{o} S65E, and asymmetric load casts in the direction of dip indicate possible transport of sediments toward the southeast.

Unit 2: Upper Cretaceous-Paleocene (6,140-7,965 feet)

The lower part of Unit 2, from 6,990 feet to 7,965 feet, is Upper Cretaceous (Maestrichtian (?)-Campanian) and the upper part, from 6,140 feet to 6,990 feet, is assumed Paleocene. The section exhibits a considerably lower induction log resistivity than Unit 1, and sonic velocity is approximately 12,000 ft/sec (Figure VI-2). Sandstone comprises approximately 14 percent of the Cretaceous section and 30 percent of the Paleocene section.

Cretaceous and Paleocene sandstones are similar with the exception that Cretaceous sandstone contains fragments and prisms from Inoceramus shells. Sandstone in Unit 2 is generally light to dark gray, silty to fine grained, hard, massive to microlaminated with small-scale cross beds, rip-ups, scour and fill structures, and locally abundant bioturbation. Dips are about 10^{o} N65E and crossbeds indicate sediment transport toward the southwest.

The Cretaceous sandstone core at 7,102 feet to 7,127 feet has permeabilities of less than 6.0 millidarcies and porosities less than 17.5 percent. In the Paleocene core samples, permeabilities range up to 12.6 millidarcies and porosities up to 22.9 percent. Log analysis indicates an average density-derived porosity of 12.8 percent for sandstone in the entire interval between 6,140 feet and 7,965 feet. The fine grained rocks consist of sandy, dark gray, hard siltstone and massive, dark gray, soft to firm claystone or mudstone.

A typical Paleocene sandstone sample at 6,563 feet, with a porosity of 20 percent, and a Cretaceous sample at 7,118 feet, with a porosity of 15.3 percent, were remarkably similar petrographically. Both were very fine grained but well sorted and micaceous. Compositionally, the sandstone in Unit 2 contains more metamorphic clasts than either the older

Cretaceous turbidites or the younger Eocene sandstone. Volcanic rock fragments are rare. Heavy minerals include epidote (C), glauconite (C), zircon (P), garnet (P), sphene (P), allanite (R), and chlorite (R). Hornblende, common in the underlying Cretaceous sandstone, was not observed. The texture, fabric and structures in these sandstones suggest they are winnowed sands deposited as turbidites. Paleobathymetry based on foraminifera suggests bathyal conditions of sedimentation.

Unit 3: Eocene Shale (5,340 - 6,140 feet)

The base of this dominantly mudstone and siltstone section begins with a 10-foot thick limestone bed at 6,130 feet to 6,140 feet, which marks an induction log break and an increase in sonic velocity. Abundant glauconite was noted in the ditch samples immediately below the limestone suggesting shoaling of the area. However, faunal assemblages in the section below and above suggest outer slope or bathyal environments, and both the limestone and glauconite may have been derived from upslope.

The 250-foot section above this limestone contains most of the thin beds of sandstone which comprise about 19.5 percent of the entire unit. Core permeabilities are as high as 51 millidarcies with up to 24.6 percent porosity values. Log analysis indicates an average density-derived porosity of 13.7 percent. Sandstone beds are thin-bedded, gray, firm to hard, laminated, and burrowed, with sharp basal contacts and some cut and fill features. Core samples are extremely well sorted, very fine grained with an average size of .07 mm, and contain about 30 percent lithic grains. Heavy minerals include opaque minerals, epidote, sphene, biotite and muscovite. The uppermost 600 feet consists of gray shale and greenish-gray to reddish-gray siltstone and claystone, which are similar in color and age to the "Poppin Shale" portion of the Anita Formation at Point Conception (Redwine, and others, 1952). Foraminifera indicate these rocks are Penutian and Ulatisian in age. Dips are 12^{o} N60E.

Unit 4: Eocene Sandstone (4,570 - 5,340 feet)

This Eocene unit consists primarily of sandstone of Narizian and Ulatizian age separated by a shale unit. These appear to be approximately equivalent in age and sequence to the Sacate sandstone, Cozy Dell shale, and Matilija sandstone units of the Point Conception area (Redwine, and others, 1952). The lower sandstone unit is fine-grained, light to dark gray, firm to hard, massive to laminated, and often micaceous. Sedimentary structures include clay-filled fractures, cut and fill structures, rip-up clasts, flute casts, small scale crossbeds and convolute bedding, indicating turbidite deposition, with sediment transport toward the southwest. The sandstones contain some thin dark laminae. Dips are approximately 4^{o} N65E.

A sandstone sample at 5,041 feet, with a measured porosity of 21.6 percent, was very fine to fine grained, moderately sorted, and very micaceous. Estimated grain composition was: quartz (25 percent), K-feldspar (10 percent), plagioclase (10 percent), and lithic rock fragments (55 percent) of intermediate to basaltic volcanic rock, and siliceous microcrystalline rock including muscovite schist. Heavy minerals include mostly biotite and muscovite, with minor amounts of garnet, chlorite and calcite grains. Permeability appears low.

The upper sands are very fine grained, silty and firm to loosely consolidated. Shaly layers interbedded with the sandstone are dark gray to black, and contain firm claystone with bands of light gray calcareous shale. Some are dark olive brown, sheared with slickensides, and contain abundant microfossils.

Sandstone comprises about 37.5 percent of the unit, with core permeabilities ranging up to 22 millidarcies and core porosities of 19.1 to 24.2 percent. Average density-derived porosity is 17.3 percent.

Unit 5: Upper Eocene shale (4,190 - 4,570 feet)

This unit consists of a shale section of Refugian age from 4,190 feet to 4,570 feet. It is equivalent in age to the Gaviota Formation of the Point Conception area (Redwine, and others, 1952). The section is primarily silty shale or mudstone, olive gray to brownish-black, hard, massive, with conchoidal parting, calcareous veinlets, very abundant microfossils, and rare fish remains. Dips are approximately 6° N45E.

The entire Eocene section containing Units 3, 4, and 5 is 1,950 feet thick. At San Nicolas Island 72 miles (120 km) to the north, a minimum thickness in outcrop of over 3,500 feet was measured by Vedder and Norris (1963). This northward thickening of the Eocene section suggests sediment supply from the north. This is consistent with the smaller percentage of sandstone in the well (23 percent), compared to the near 50 percent on San Nicolas Island; the finer grained texture of the sandstone compared to the often coarse and conglomeratic sandstone on San Nicolas Island; and with the south flowing direction of transport as seen on San Nicolas

Island by Cole (1975) and with the southwest direction observed in cores from this well.

Unit 6: Oligocene sandstone and shale (2,850 - 4,190 feet)

This unit contains a Zemorrian assemblage up to a well depth of 3,170 feet, but there is poor faunal control in the sandstone between 3,170 feet and the base of a volcanic sequence at 2,850 feet. The sequence is dominantly sandstone except for a shale interval between 3,070 feet and 3,360 feet. The unit is approximately equivalent in age to the Alegria Formation of the Point Conception area (Redwine, and others, 1952).

The sandstone is gray, weakly indurated and friable, well sorted, subrounded, fine to medium grained, with some faintly graded beds which become coarser downward. Sedimentary structures include rip-up clasts of calcareous tan to gray-green claystone up to 6 inches by 1/4 inch, some cut-and-fill structures, and thin undulating beds of argillaceous shale. Some hydrogen sulfide odor was detected in this interval. Petrographic estimates of sandstone grain composition from a sample at 3,742 feet are: quartz (35 percent), K-feldspar (25 percent), Na-Ca feldspar (10 percent), and lithic grains (30 percent) of chert, intermediate and mafic volcanic rock, and muscovite metamorphic rock. Heavy minerals include muscovite (C), mica (P), glauconite (P), zircon (R), and garnet (R). Faunal evidence suggests a bathyal environment of deposition.

The sandstone is well sorted with abundant pore space. Core permeabilities range from 438 to 1,631 millidarcies, and porosities are between 29.2 to 32.9 percent. Density-derived porosities from log analysis average 30.1 percent. Sandstone beds make up 63.3 percent of the entire unit. Dips are approximately 6° N45E.

Unit 7: Volcanic Rocks (2,283 - 2,850 feet)

This 567-foot interval consists primarily of dense to vesicular basalt in varying shades of dark gray, gray green, or red. Ditch cuttings were examined petrographically from an interval near the top (2,400 feet to 2,430 feet) and near the base (2,790 feet to 2,820 feet) of this sequence. Collectively, textures range from vesicular and amygdaloidal tachylytic basalt to holocrystalline subophitic diabasic basalt, with tachylytic varieties dominant near the base and diabasic types dominant near the top. A few basalts have radiating slender augite crystals interpreted as quickly quenched submarine basalts. Glass, if present, is black but more typically in the higher ditch sample is altered to clay minerals and/or celadonite.

Compositionally, these are olivine-bearing, alkaline basalts. The olivine has been altered to red-brown iddingsite. Fresh augite is titaniferous with crystals near the base of the sequence having a slightly deeper light violet hue than those near the top. Jagged-edged needles of ilmenite are common, and late-forming slender crystals of apatite are common inclusions in the plagioclase phenocrysts. These olivine diabasic basalts are petrographically similar to those described by Hawkins, Allison, and MacDougall (1971) from Northeast Bank, and by Taylor from Cortes and Tanner Banks (Vedder and others, 1974, 1976).

These basalts are interpreted as submarine flows. The upper surface of the sequence is an excellent seismic reflector which has been traced on seismic profiles taken in the vicinity of the well. The dip of this surface, supported by dipmeter control in the overlying and underlying sedimentary sequence, is approximately 10° to the northeast.

Interpretations on the age of this basalt are conflicting. A sample recovered from above the drill collar stabilizer blades at 2,718 feet yielded a whole-rock potassium-argon date of 35.0 $\pm$ 1 m. y., classified as a good run. This would place it in the Oligocene (early Zemorrian Stage). Cuttings from below the volcanics contain pyritized forams of questionable early Miocene (Saucesian) age. The beginning of post-Eocene volcanism in the southern California Borderland is in question, but most of the radiometrically dated samples center around the middle Miocene (Luisian) (15-16+ m.y.) with some as old as early Miocene (Saucesian) age (22-23 m.y.). This date suggests that volcanism in the Cortes Bank area is 12$\pm$ m.y. older than any other date known on the southern California Borderland region.

Unit 8: Lower (?) and middle Miocene (740 - 2,283 feet)

The lower portion of this unit, from 1,600 feet to 2,283 feet, is dominantly sandstone of indeterminate age, possibly Saucesian, with shark teeth and barnacle fragments common. The sandstone is light to medium gray, mostly fine to medium grained, partly calcareous, silty to clayey, fairly well sorted, subrounded and friable. Examination of ditch cuttings of the underlying volcanic rocks suggests that the basal sandstone in this unit may have been transgressive over a weathered and eroded surface of the volcanic rocks.

The upper portion is Relizian in age (middle Miocene), up to 950 feet, and Luisian above. From 740 feet to 845 feet the section is dominantly fine grained, gray, silty to clayey, well sorted, very friable sandstone, whereas the interval from 1,270 feet to 1,600 feet is interbedded fine grained, friable sandstone, claystone and siltstone.

Sandstone beds make up 83.4 percent of the unit, and they average 32 percent porosity from log analysis. Dips are about 10° N45E. The blocky and massive appearance of the sands on the log suggests shallower depths than the upper bathyal environment indicated by paleontology.

Table IV-1
E.S.I. DEEP STRAT TEST
OCS-CAL 75-70 No. 1
U.S.G.S. Porosity Measurements*

DEPTH	ASSUMED GRAIN DENSITY, (G/CC)	POROSITY, %	LITHOLOGY
3316	2.67	25.6	Clayst, dk gry, slty w/pos fish scales
3321	2.67	28.3	Clayst, gry, slty, sl/slty
3325	2.68	27.3	Clayst, gry, poss forams
3736	2.65	32.6	Sd, med gry, med grn, friable
3742	2.65	32.0	Sd, med gry, med grn, friable
4274	2.68	23.3	Clayst, dk gry, w/microfossils
4780	2.68	15.3	Clayst, lt gry, sl/fissile
4783	2.68	18.1	Clayst, dk gry, sl/slty, sl/fissile
5026	2.68	19.4	Sd, med gry, well cemented
5038	2.65	17.3	Sd, lt gry, med grn w/biotite
5041	2.65	22.0	Sd, lt gry, sl/slty, sl/friable
5384	2.68	9.7	Clayst, lt gry
5387	2.68	6.8	Clayst, med gry
5390	2.68	8.1	Clayst, lt gry, poss forams
6011	2.67	11.8	Clayst, med gry, sl/slty
6560	2.66	20.5	Sd, lt gry, fn grn, sl/friable
6563	2.66	20.0	Sd, lt gry, v/fn grn, sl/friable
7116	2.66	14.9	Sd, med gry, fn grn w/some silt
7119	2.66	15.7	Sd, lt gry, fn grn w/some silt interbe
8312	2.67	5.4	Clayst, dk gry, slty
8737	2.65	5.0	Sd, dk gry, med grn, well cemented
8739	2.66	4.6	Sd, med gry, med grn, well cemented
9232	2.65	6.0	Sd, med gry, med grn, well cemented
9643	2.66	6.8	Sd, med gry, med grn, sl/slty

* Measured by L.A. Beyer

PALEONTOLOGY

by
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A. Introduction

Age assignments were determined using foraminiferal assemblages obtained primarily from conventional cores and sidewall cores. In some cases ditch samples were used to supplement the core data. Tertiary benthonic foraminiferal assemblages are reported in terms of the provincial benthonic stages of Kleinpell (1938) and Mallory (1959). Tertiary planktonic assemblages are reported in terms of the zonations of Berggren (1972) and Blow (1969). Cretaceous foraminiferal species identifications and their stratigraphic ranges follow Marianos and Zingula (1966) and Douglass (1969). Paleobathymetric determinations were based mostly on benthonic foraminifers that are considered reliable depth indicators.

B. Tertiary

In general, Tertiary planktonic foraminifers are absent or too rare and poorly preserved to be of use in core samples from this well. A notable exception to this, however, occurs in the lower and middle Eocene section. Here several samples yielded moderately well preserved diagnostic planktonic assemblages. Calibration of zones with the Cenozoic time scale follows Berggren (1972).

The first occurrence of _Pseudohastigerina micra_ was observed at 5,250 feet. This suggests a level no lower than Zone P 10. Samples between 5,355 feet and 5,393 feet contain Morozovella aragonensis caucasica or Truncorotaloides bullbrooki or both and are assigned to Zone P 9. Thus the P9-P10 boundary and the lower Eocene-middle Eocene boundary as used by Berggren (1972) lies between 5,250 feet and 5,515 feet. Samples between 5,515 feet and 5,740 feet are referable to Zones P7-P8. Tertiary planktonic assemblages below 5,740 feet are very sparse and zonal assignments are tentative.

Benthonic foraminiferal stage determinations are shown on Figure IV-1. Downhole contamination in the ditch samples for benthonics was mostly from beds of Zemorrian to Refugian stages. Benthonic foraminifers were abundant in a few samples especially as follows: a Valvulineria californica and Siphogenerina reedi assemblage was observed in ditch samples approximately at 950 feet downhole depth. Fairly common planktonic specimens were also observed in the same assemblage. The next prolific group of benthonics was encountered in nearly 1,000 feet of section downhole from about 3,200 feet, where abundant specimens and several species of the genus Plectofrondicularia were found such as Plectofrondicularia cf P. packardi, Plectofrondicularia miocenica, Plectofrondicularia miocenica directa. Exceptionally well preserved Eocene Refugian foraminifers (Lipps, 1967; Brabb, Bukry, and Pierce, 1972) including Plectofrondicularia packardi, were found at depths from 4,200 feet to 4,300 feet in this stratigraphic test hole and are known also from ocean floor samples from Cortes and Tanner Banks. Middle and lower Eocene benthonics were not abundant.

C. Cretaceous

Cretaceous age determinations are based on planktonic foraminiferal assemblages. The foraminifers are generally poorly preserved and the species represented by few individuals. The first downhole occurrence of Cretaceous foraminifers occurs in an interval from 6,990 feet to 7,020 feet with the appearance of Planoglobulina ornatissima and Bolivina incrassata. These species plus planktonic species from 7,560 feet and 7,800 feet are late Cretaceous in age and range from the late Campanian to possibly the early Maestrichtian. The occurrence of Globotruncana pseudolinneiana, G. imbricata, G. cachensis and Heterohelix rumseyensis in samples at 8,155 feet and 8,250 feet suggest a possible Coniacian age. This is followed by an interval containing Turonian species such as Globotruncana marianosi, Praeglobotruncana helvetica, Hedbergella praehelvetica, Globotruncana sigali that extends from 8,247 feet to 10,310 feet. The appearance of rotaliporids at 10,468 feet together with Praeglobotruncana stephani and P. roddai indicates a Cenomanian age which extends to the lowest sampled interval at 10,699 feet to 10,702 feet.

D. Paleobathymetry

Cretaceous benthonic foraminifers are sparse but indicate lower bathyal water depths throughout most of the Cretaceous section. Shallow water depths of not less than upper bathyal are suggested for the Campanian -early Maestrichtian (?) interval. Occasional admixtures of sublittoral species within the bathyal assemblages are indicative of downslope transport within the Cretaceous interval.

Abundance of planktonic specimens throughout early and middle Eocene time suggest open ocean communication. The benthonic assemblages indicate water depth in the bathyal and especially lower bathyal zones. By late Eocene time the same depth range prevailed or was perhaps even greater but with very restricted basin conditions as suggested by large pyritized specimens often associated with radiolaria and diatoms. Lower bathyal or abyssal conditions probably persisted through Zemorrian time. Shallow conditions, possibly upper bathyal to outer sublittoral, are indicated for the interval of time between Zemorrian and Relizian as suggested by non age-diagnostic shallow water benthic foraminifers, some phosphatized fish teeth and possible barnacle fragments. Relizian-Luisian faunas indicate middle to lower bathyal conditions with proximity to more shallow regions as suggested by the mixture of depth indicators of sublittoral to mid-bathyal zones.

Paleontologic data are summarized on Figure V-1, (in pocket).

GEOPHYSICS

by
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The area surrounding the deep stratigraphic test location was mapped prior to OCS Lease Sale No. 35 by Petty-Ray Geophysical, Inc., under U.S.G.S. contract No. 14-08-0001-13508. The well is in projected block 7N-54W approximately eight miles southeast of the Tanner-Cortes Bank lease area. Structurally the well is low on the northeast flank of a southeasterly plunging anticline. This subsurface structure is interpreted from geophysical data to closely resemble the bathymetry of the Cortes Bank (see Figure I-1).

Figure VI-1 (in pocket) is a line drawing of the high resolution sparker data run in July 1975 by Intersea Research Corporation. The NE-SW line illustrates the location of the well in relation to the axis of the structure.

Figure VI-2 (in pocket) depicts the plots of the interval and average velocity derived from the sonic log run in the deep stratigraphic test. The outstanding feature on the interval velocity is the correlation with the volcanic section in the interval from 2,283 feet to 2,850 feet. The volcanics were also reflected in the large increase in average velocity as seen on the curve. Other distinct changes can be seen at the Refugian-Narizian contact at 4,570 feet, Eocene-Paleocene at 6,140 feet and the Upper Cretaceous unconformity at 7,965 feet. Close inspection reveals that many of the sandstones listed on the lithologic column in Figure VI-2 can be seen as high velocity stringers on the interval velocity curve.

ORGANIC GEOCHEMICAL ANALYSES OF CORES

by
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Ten samples of cored sediment from the deep stratigraphic test OCS-CAL 75-70 No. 1 have been analyzed to determine petroleum source rock potential. The samples ranged in depth from 3,307 feet to 10,920 feet, and in age from Oligocene through Cretaceous.

The results of these analyses are summarized in Table VII-1. The Oligocene and late Eocene samples from cores 2, 4 and 5 at depths ranging from 3,307 to 4,784 feet (see Core Operational Summary, Table II-1), are relatively rich in organic matter, but are thermally immature with respect to petroleum hydrocarbon generation. If elsewhere in the southern California Borderland these same stratigraphic units are as rich in organic matter and are buried to depths of about 10,000 feet under a similar thermal gradient, they should be considered very good to excellent potential source rocks of petroleum.

The earlier Eocene to Cretaceous samples (cores 7, 8, 11, 15, and 16 at depths ranging from 5,378 to 10,920 feet) are relatively lean in organic matter, as shown in Table VII-1. The transition from immaturity to maturity, with respect to the temperature history required for hydrocarbon generation, appears to occur in the 8,000 to 9,000-foot depth range, which is coincident with the unconformity within the Upper Cretaceous at 7,965 feet. These rocks do not contain sufficient amounts of the right kind of organic matter to be considered potential source rocks of significant quantities of petroleum.

*Sisters of Loretto

Results reported in Table VII-1 are: Weight percent organic carbon (determined by combustion of an acidified rock residue); parts per million by weight of chloroform extractable bitumen (by soxhlet extraction); parts per million by weight of total hydrocarbons (by summation of heptane and benzene eluates of the total extract chromatographed on silica-gel); the percentage of hydrocarbon in the chloroform extractable bitumen; the ratio of saturated hydrocarbons (heptane eluate) to aromatic hydrocarbons (benzene eluate); and the ratio of total hydrocarbons to organic carbon in percent.

Also shown in Table VII-1 are the results of Thermal Analysis/Pyrolysis, reported as pyrolytic oil yield in gallons per ton and weight percent (Fisher assay equivalent), and oil content in weight ppm. The temperature of maximum pyrolytic decomposition is also recorded.

Organic carbon content reflects the amount of organic matter deposited and preserved in the sediment, and generally indicates the petroleum hydrocarbon-generating potential of the rock. On this basis the samples are clearly divided into the organic-rich and organic-lean groups as indicated above, with the four shallowest samples having four or five times the organic carbon content of the six deepest samples.

A more direct indication of the oil-generating capacity of the rock is the Thermal Analysis/Pyrolysis oil yield shown in Table VII-1. In this analysis the rock is heated in a stream of helium at 40°C per minute from 30 to 800°C. The volatile organic compounds evolved from the rock as a function of temperature are monitored with a hydrogen flame ionization detector. The materials evolved during the 30 to 400°C heating period are mostly volatile organic compounds pre-existing as such in the rock, which are reported as ppm oil content and show a direct correlation with the amount of solvent extractable substance in the same sample. The materials evolved during the 400 to 800°C heating period are thermal decomposition products from the cracking of the solid organic matter (kerogen). In terms of the total pyrolytic oil yield the contrast between the two groups of samples is even more striking, with the four shallow samples having 20 to 100 times the oil yield of the six deeper samples.

The rate of thermal decomposition of the solid organic matter in sediments when heated at a 40°C/min rate of temperature increase is an indication of (1) the temperature history of the sediment, and (2) the molecular structure or type of kerogen. Rocks which contain the typical mixture of sedimentary organic matter, and have never been heated to temperatures in excess of about 50°C during their burial history, will begin to decompose thermally at about 350°C when heated at 40°C/min., and will give a maximum (peak) in the production of pyrolysis products in the temperature range of 450 to 490°C. Mature petroleum source rocks, when heated under the same conditions, will begin to decompose at about 400°C and give a peak in the temperature range of 510 to 530°C. Incipiently metamorphosed sediments (i.e., sediments heated above 175°C during normal burial history) give a greatly diminished pyrolysis response with a peak in the range of 600°C. In these samples, the temperature of maximum pyrolysis yield shows a general increase with depth from 475°C at 3,307 feet to 520°C at 10,920 feet. These samples thus span the transition from immature to mature organic metamorphic facies, with the transition apparently occurring in the 8,000 to 9,000 foot depth region.

The amount and quality of the extractable organic material in these samples is indicated in Table VII-1, and in Figure VII-1, which shows the results of the gas chromatographic analyses of the saturated hydrocarbons. The amounts of chloroform bitumen and total hydrocarbons in the sediment are primarily a function of organic richness, and generally parallel the organic carbon content. The percentage of hydrocarbons in the total extract is partially a function of the type of organic matter, but primarily reflects the thermal maturity. In this well the percent of hydrocarbons in the bitumen increases in a regular fashion from 21 percent at 3,307 feet to 71 percent at 10,920 feet. This confirms the interpretation of thermal maturity based on temperature of maximum pyrolysis yield.

Also shown in Table VII-1 are the ratios of saturated-to-aromatic hydrocarbons and of hydrocarbons-to-organic carbon. These ratios primarily reflect the type of organic matter and thermal maturity, respectively. However, immature, organic-rich sediments often have low saturated-to-aromatic hydrocarbon ratios by this analytical technique because of elution of nonhydrocarbon organic acids and esters with the so-called aromatic hydrocarbon fraction. Thermally mature sediments generally have hydrocarbon-to-organic carbon ratios greater than 1 percent. In this well the three samples below 8,000 feet have hydrocarbon-to-organic carbon ratios of 1.4 to 1.7, while six of the seven samples from above 8,000 foot depth have HC/C ratios of less than 1 percent. The sample at 5,388 to 5,395 feet has a hydrocarbon-to-organic- carbon ratio of 1.2, which probably reflects contamination rather than indigenous hydrocarbons. This possibility of contamination is supported by anomalously high ratios of saturated-to-aromatic hydrocarbons and of total hydrocarbons to bitumen for this sample compared with other samples above and below this depth. The contamination is probably present in the sample rather than being introduced during the extraction procedure, as indicated by the anomalously high oil content obtained in the (separate) Thermal Analysis.

The gas chromatograms in Figure VII-1 show saturated hydrocarbon assemblages which are generally unlike petroleum hydrocarbons. Three general features are noteworthy: First, the samples from cores 7 and 8 have very high odd-carbon predominance for normal paraffins in the carbon number range C_{28} to C_{31}, which is characteristic of thermally immature sediments. This further supports the interpretation that the sample from core 7, 5,388 to 5,395 feet, is contaminated. Second, the samples from cores 15 and 16 below 10,000 feet have assemblages of saturated hydrocarbons which are consistent with thermal maturity, in that there is a more random distribution of resolved compounds (on top of the hump) and the distribution is shifted toward the lower molecular weight range. Third, the samples from cores 2, 4 and 5 are much simpler mixtures, with a large proportion of the sample made up by a few characteristic compounds, namely the isoprenoids pristane and phytane and non-normal compounds with retention times in the region of n-C_{28} to n-C_{30} (steranes, triterpanes?). Saturated hydrocarbon assemblages with these characteristics are typical of an immature sediment deposited in a "Monterey shale-type" environment of deposition.

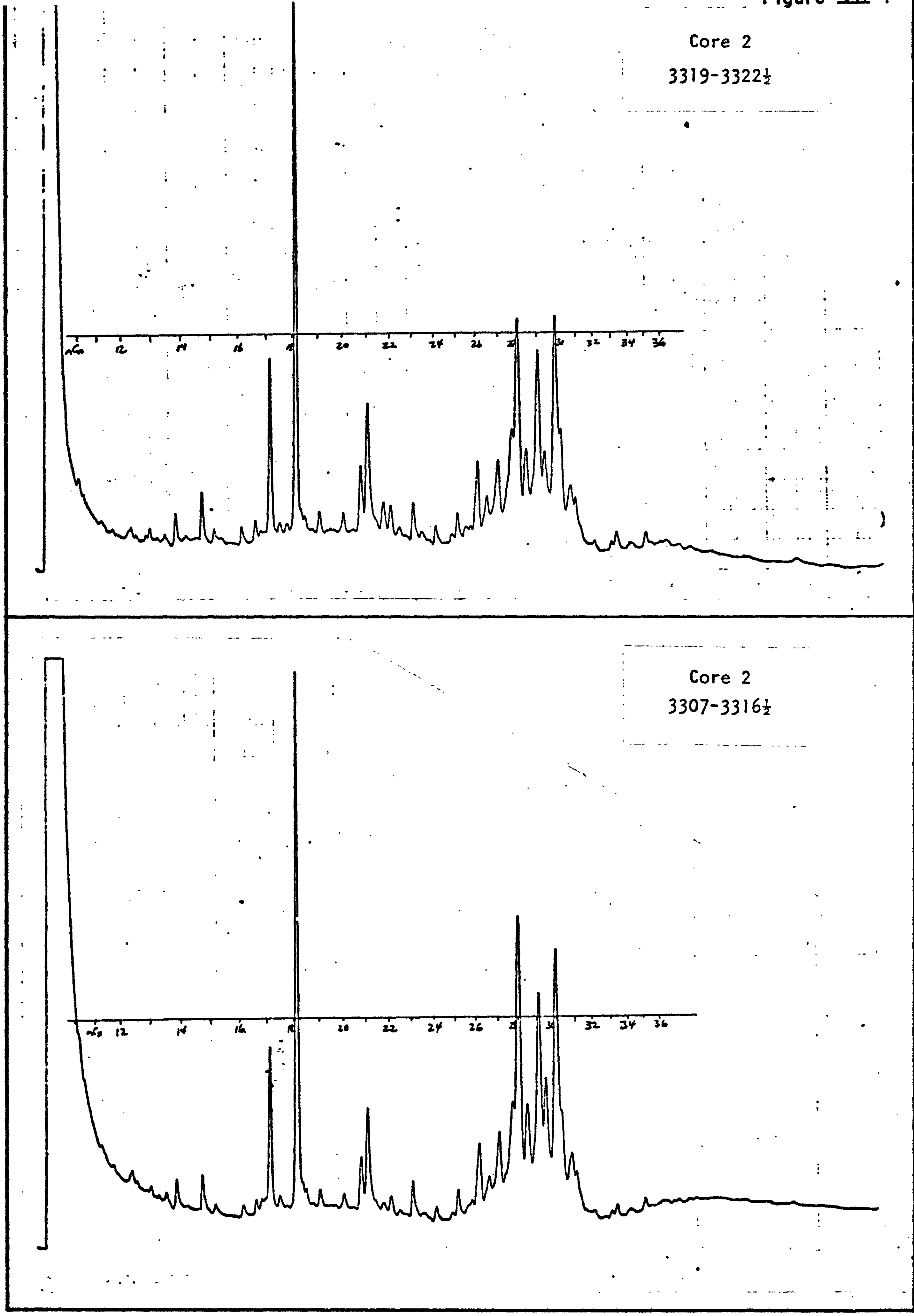
The last point may be especially significant. In a regional organic geochemical study of California Borderland submarine outcrop (dart core) samples, this characteristic organic facies was recognized in the Miocene, and especially in the upper Miocene (Taylor, 1976). It was not recognized in the Oligocene and Eocene, because of lack of samples in the Oligocene, and poor sample coverage in the Eocene, with no samples of the Eocene from as far south as this stratigraphic test. Since this rock type is known to be a prolific petroleum source rock in the onshore California basins, the deposition of similar sediments in the California Borderland during Late Eocene and Oligocene time has important implications for the possible occurrence of petroleum in this area. While it is unlikely that the Miocene is buried deeply enough in most areas of the Borderland to have generated petroleum, the same is not true for the Oligocene and Eocene.

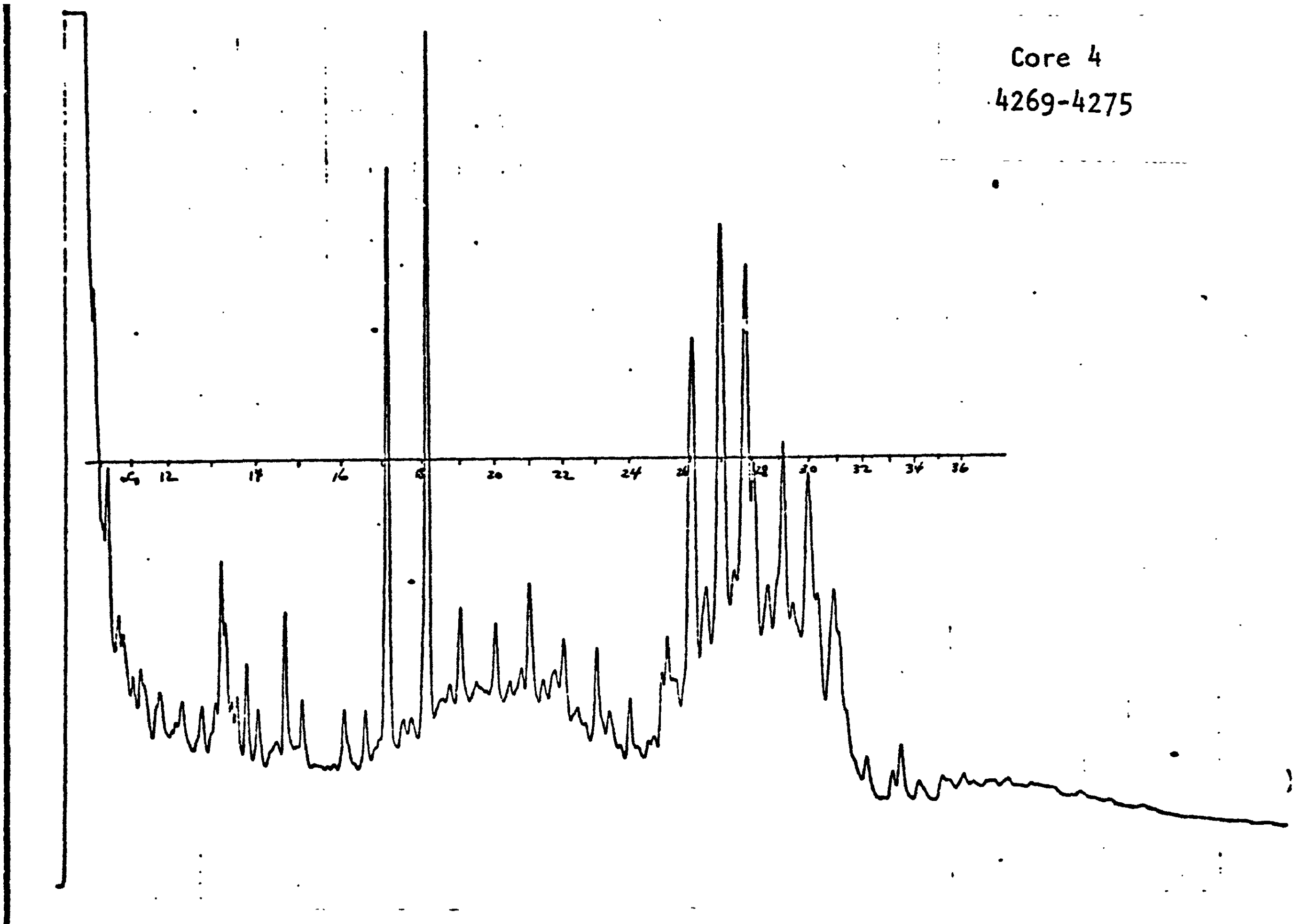
In addition to the cored sediments, two separate occurrences of solid carbonaceous substances were hand-picked from two depth intervals (4,020 to 4,050 feet and 8,734 to 8,735 feet.) The carbonaceous substance from 4,020 to 4,050 feet was recognized as gilsonite from the Uinta basin on the basis of geochemical analyses. It was later confirmed that this substance had been added to the drilling mud and/or cement.

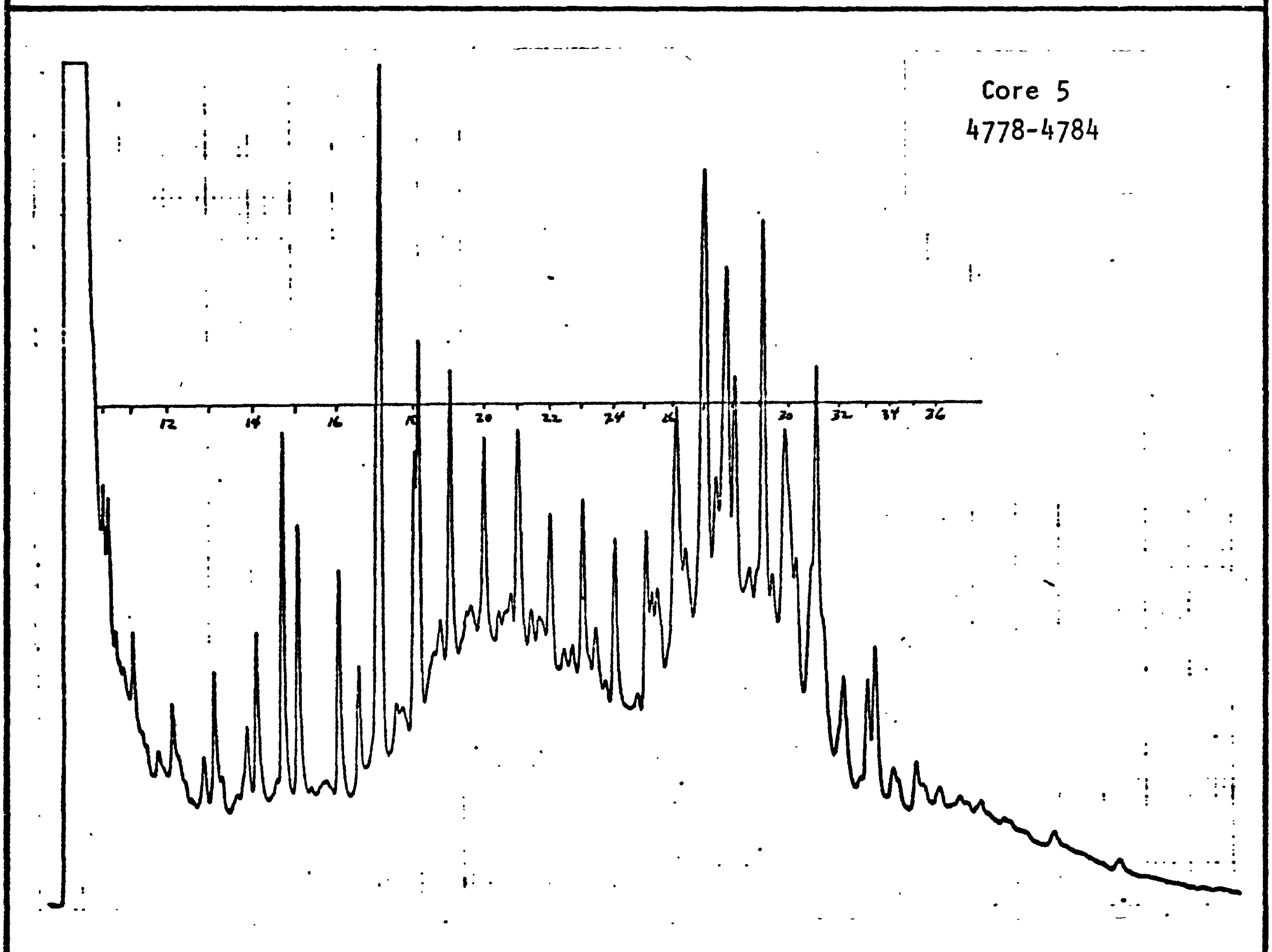
The other carbonaceous substance is apparently indigenous to the section, and occurs in veins in association with laumontite (J. C. Taylor, personal communication). The elemental composition is 77.7 percent carbon, 6.4 percent hydrogen, and 1.9 percent nitrogen. The atomic ratio of hydrogen to carbon is 1.0. This substance is apparently insoluble in chloroform and was analyzed by step-wise, pyrolysis-gas chromatography. The H/C ratio suggests a dominantly aromatic structure but the gas chromatographic analysis of the 750°C pyrolysis products indicated predominantly material with n-alkane and n-alkene retention times (J. Leventhal, personal communication), with material of n-C17 retention time being the most abundant.

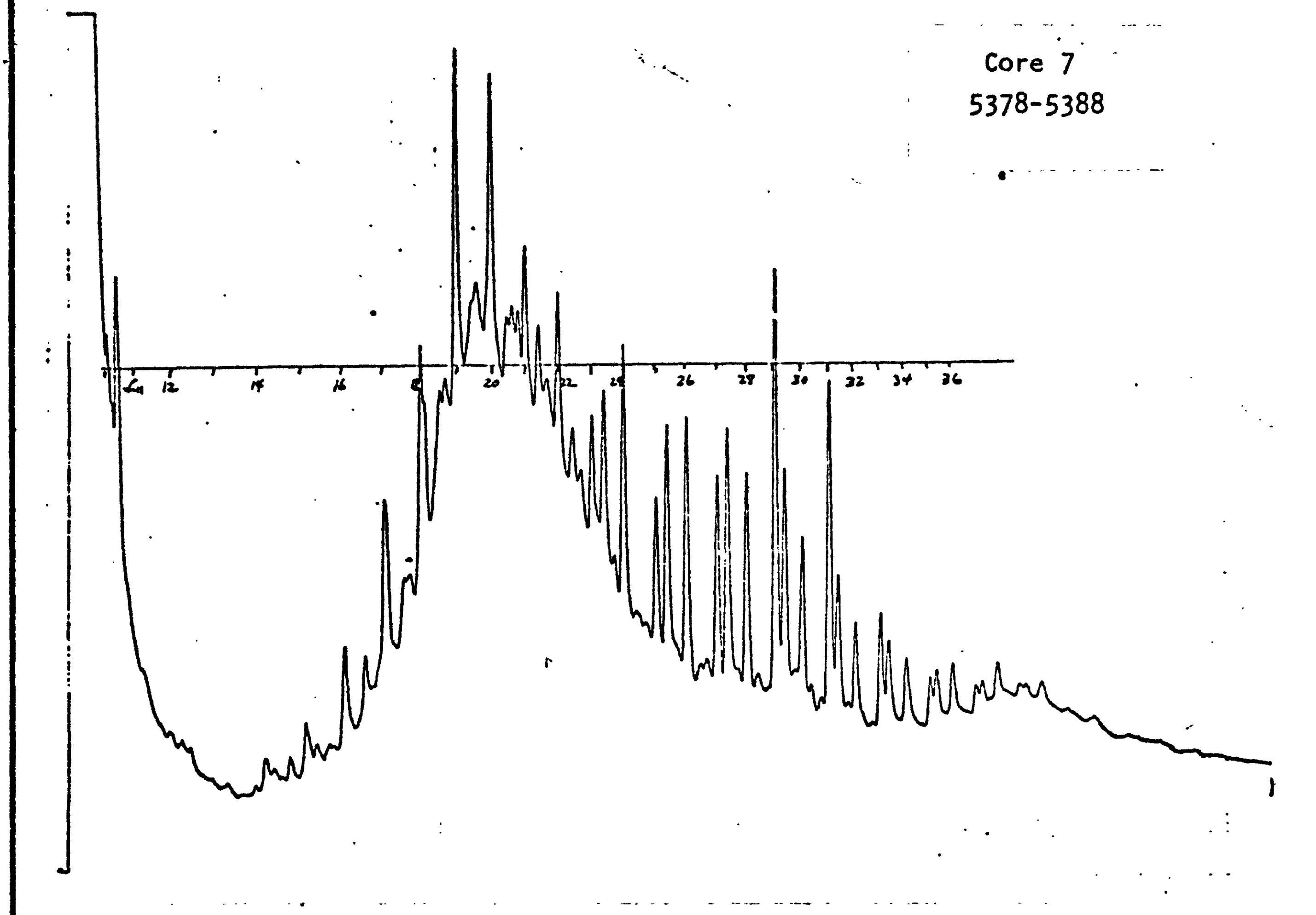
Table VII-1
E.S.I Deep Strat test
OCS-CAL 75-70 No. 1
Organic Geochemical Analysis of Cores

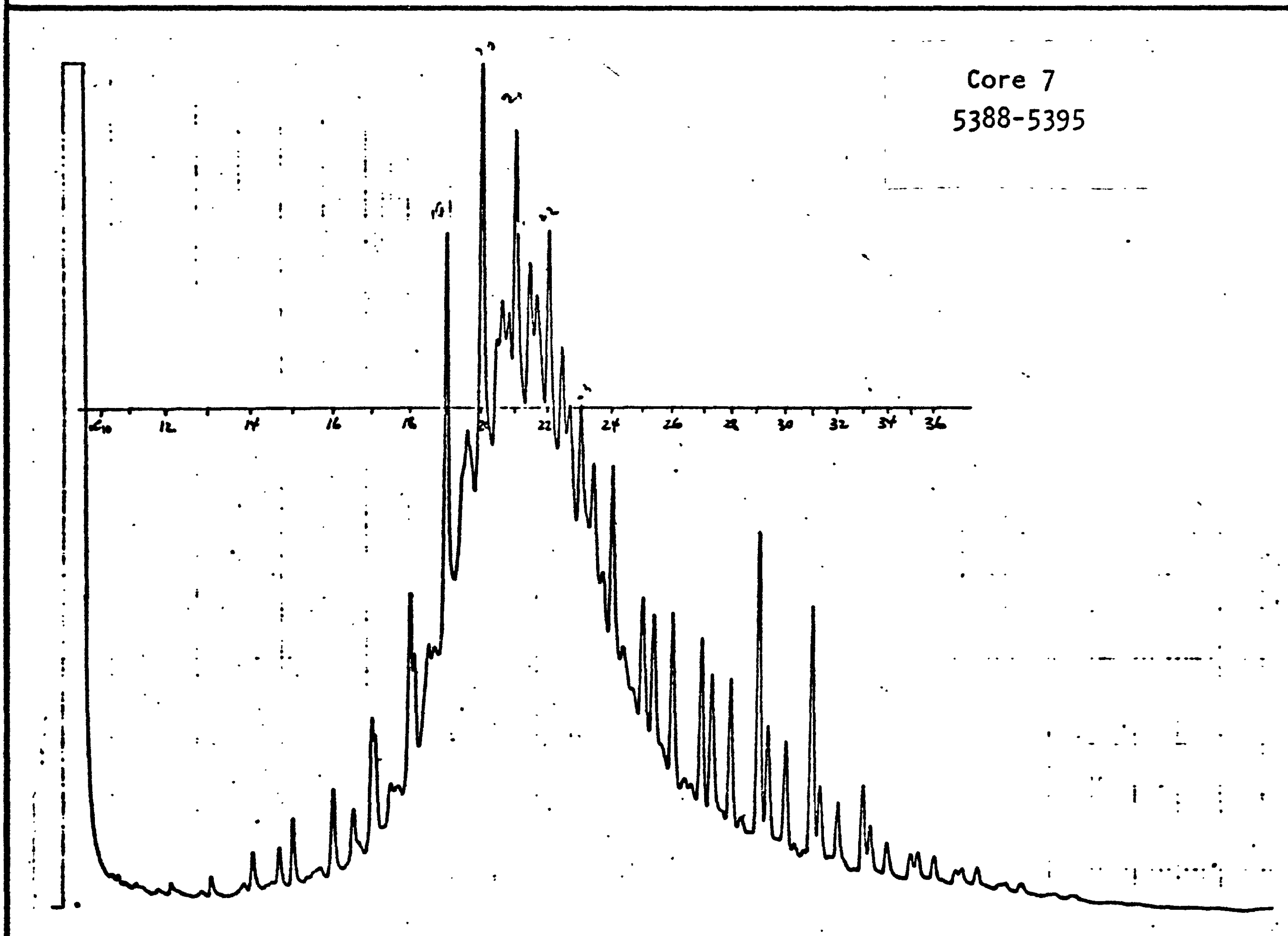
Core No.	Depth feet	Age, description	organic carbon wt. %	$CHCl_3$ bitumen ppm	total hydrocarbon ppm	hyd/bitumen %	Sat/ arom.	hyd./$C_{org.}$ %	Pyrolytic oil yield gal/ton	Pyrolytic oil yield wt.%	oil content wt. ppm	T_{max}, °C pyrolysis yield
2	3307-3316.5	Oligocene,shale	3.3	1392	289	21	0.28	0.88	1.71	0.64	732	475
2	3319-3322.5	Oligocene,Shale	4.3	1497	324	22	0.26	0.75	2.51	0.97	851	490
4	4269-4275	Eocene, shale	2.7	559	185	33	0.41	0.69	1.41	0.54	188	490
5	4778-4784	Eocene, shale	2.5	392	164	42	0.46	0.66	2.12	0.82	135	500
7	5378-5388	Eocene, shale	0.4	43	17	40	1.4	0.43	0.03	0.01	10	504
7	5388-5395	Eocene, shale	0.4	73	49	67	3.5	1.2	0.03	0.01	30	492
8	6008-6014	Eocene, shale	0.7	75	37	49	1.4	0.53	0.02	0.01	16	496
11	8304-8313	Cretaceous,shale	0.4	104	55	53	1.1	1.4	0.06	0.02	16	508
15	10,696-10,702	Cretaceous,shale	0.6	143	101	71	0.98	1.7	0.09	0.04	20	515
16	10,912-10,920	Cretaceous,shale	0.6	126	90	71	0.67	1.5	0.07	0.03	13	520

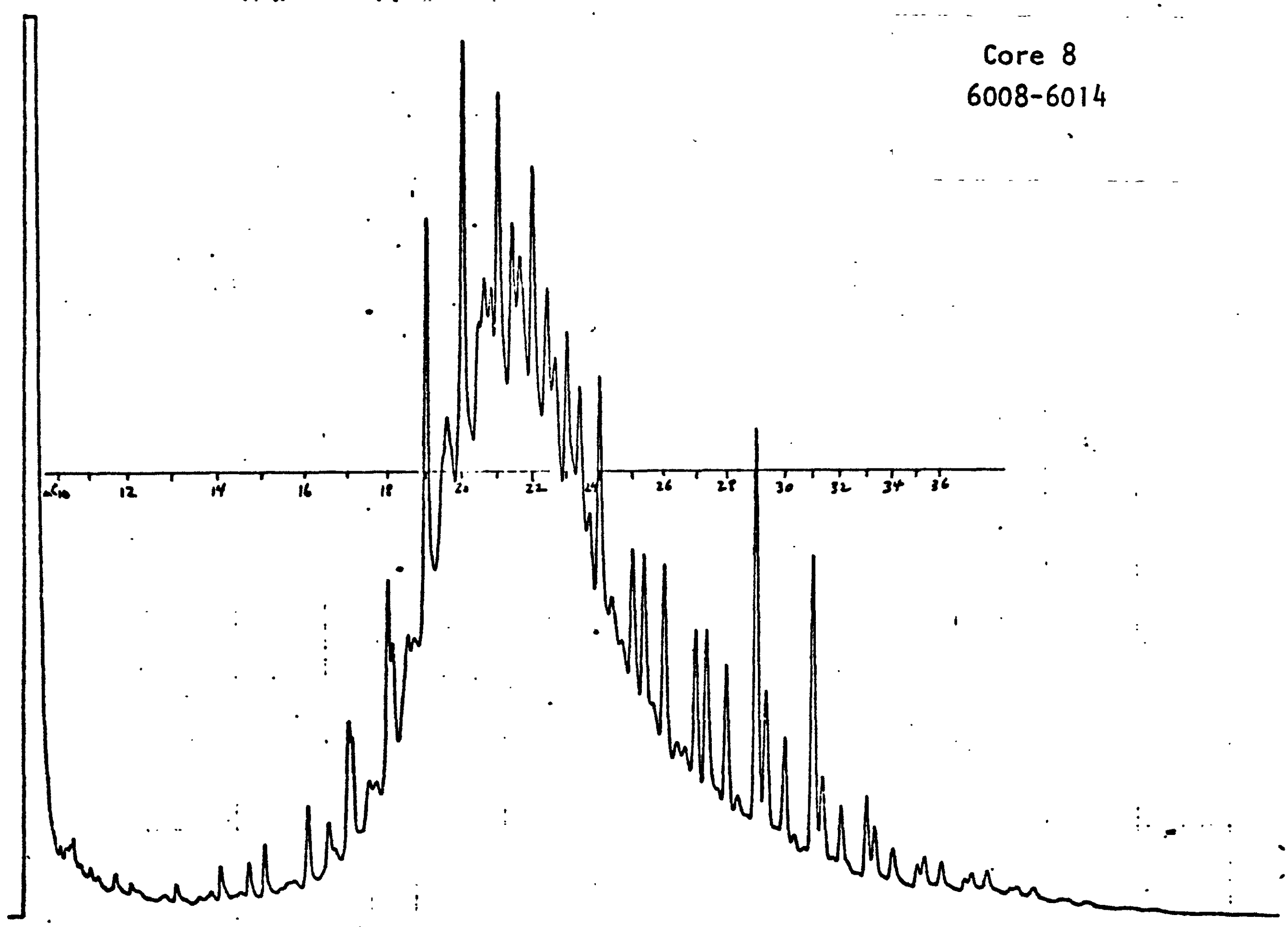

Core 2
3319-3322½
12
14
16
20
22
24
26
32
34
36
Core 2
3307-3316½
12
14
20
22
24
26
32
34
36


Core 4
4269-4275

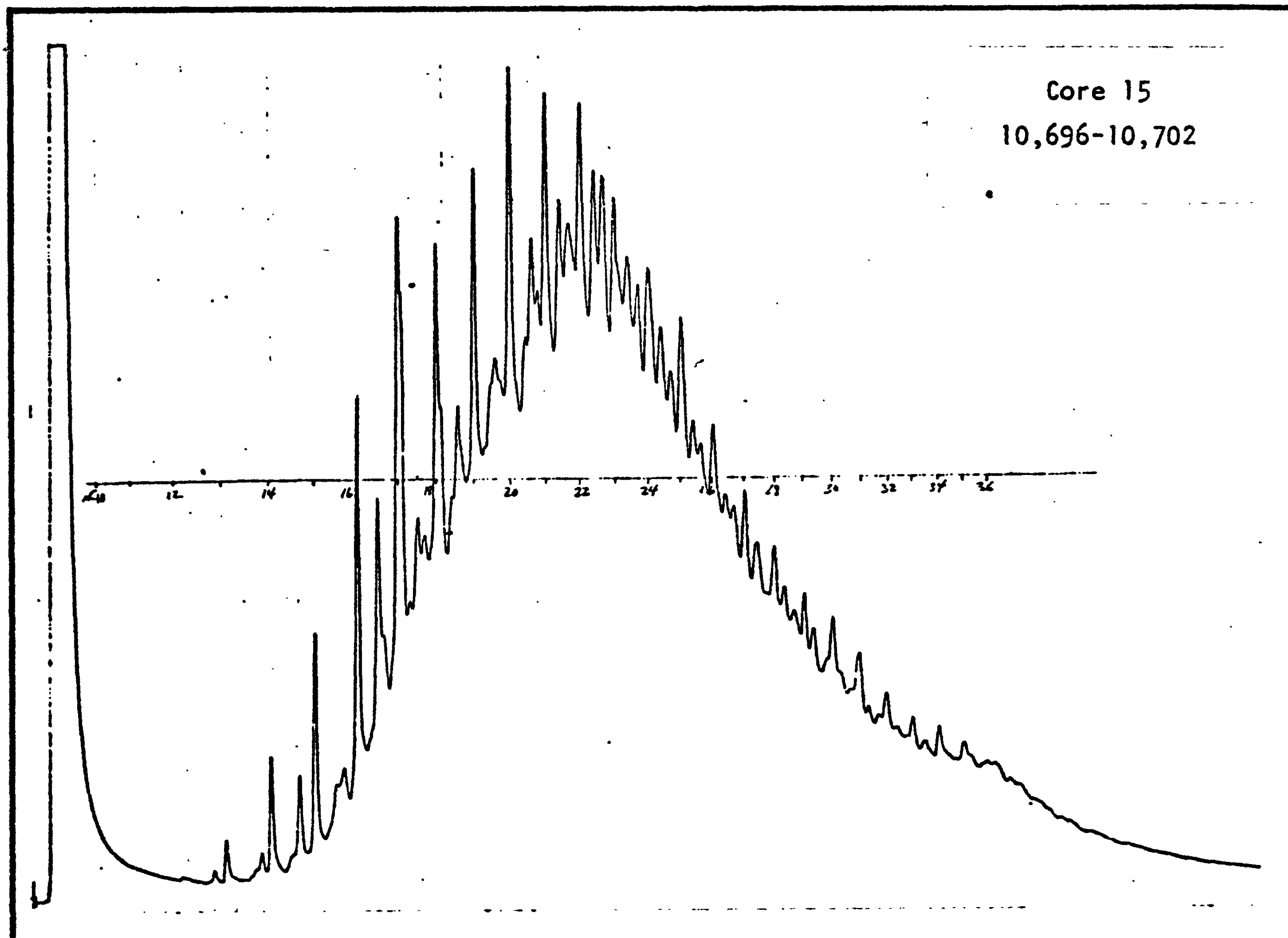

Core 5
4778-4784


Core 7
5378-5388

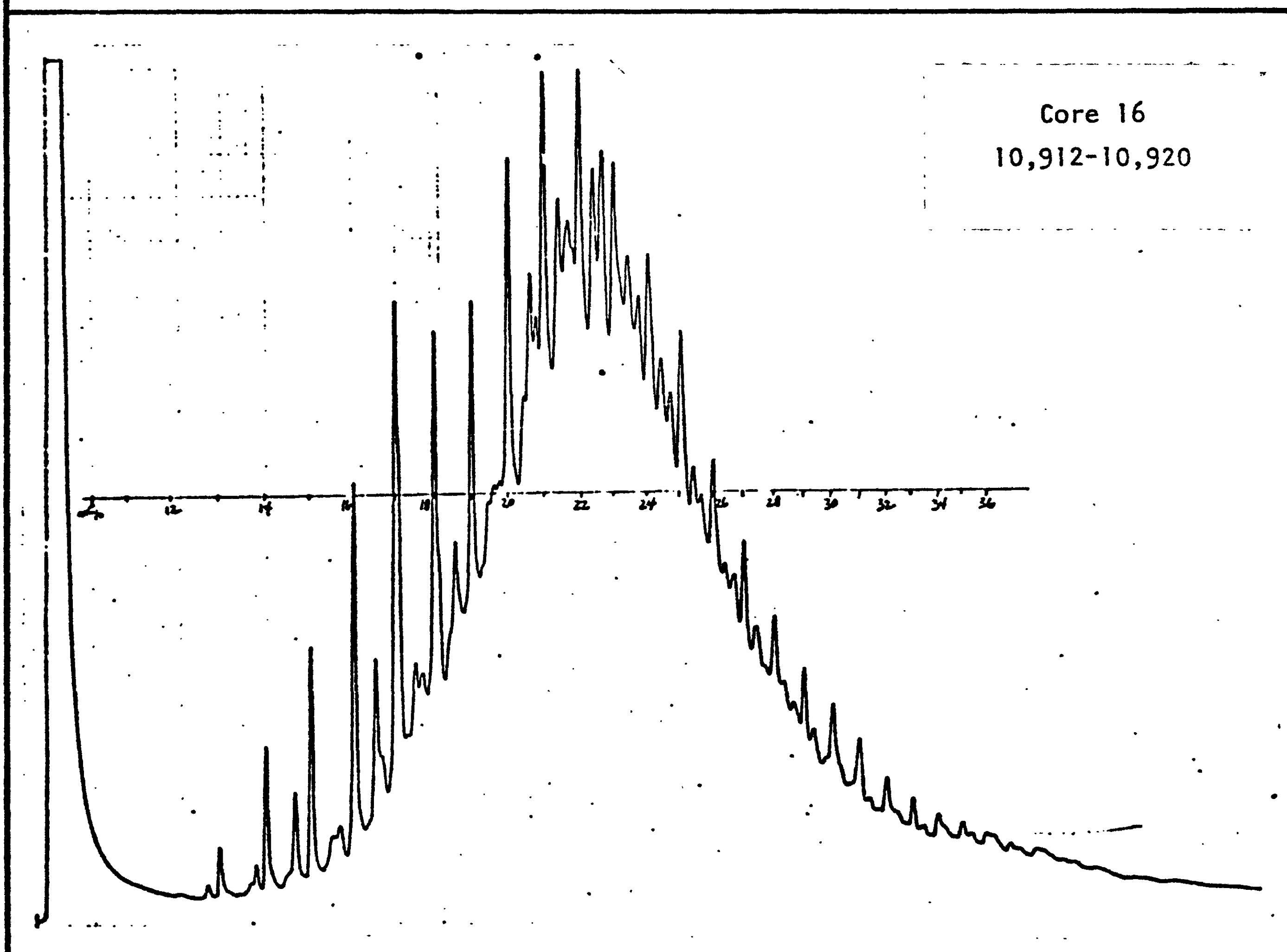

Core 7
5388-5395



Core 8
6008-6014



Core 15
10,696-10,702



Core 16
10,912-10,920

ENVIRONMENTAL CONSIDERATIONS

by
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A draft Environmental Analysis, Proposed Deep Stratigraphic Drilling Program, OCS Southern California, was prepared in late 1973. A detailed review by the U. S. Geological Survey, followed by extensive discussion with the operator, participants, and other involved governmental agencies relative to technological and environmental considerations, was conducted. On the basis of this review and subsequent discussion, a revised Environmental Analysis was submitted. The Director of the U. S. Geological Survey informed the Secretary of Interior on July 1, 1975, that the proposal to conduct a deep stratigraphic test did not constitute a major Federal action and therefore did not require an Environmental Impact Statement.

The project site was located on the northeast flank of Cortes Bank approximately 85 miles (141 km) west of the southern California mainland and 50 miles (83 km) southwest of San Clemente Island.

During the initial drilling phases, before the second string of casing was set and cemented and drilling fluid circulation established, the drill cuttings were directly deposited on the ocean floor. Subsequent cuttings were circulated to the drilling vessel, washed, and disposed of by dumping in the sea. The total amount of cuttings calculated did not exceed 300 cubic yards of material and a considerable portion of this amount was fine material spread thinly over a wide area by ocean currents.

Since the drilling mud used was non-toxic and the drill-cuttings were washed prior to dispersal, the effect of disposal on ocean floor biota was limited to the actual area of deposition. This effect is considered minimal and normal life pattern should have resumed shortly after completion of operations.

Well control was ensured by the installation and operational readiness of the 20 3/4-inch and 13 5/8-inch blowout prevention stacks and 24-inch and 20-inch riser systems prior to drilling out cement in the 20-inch and 13 5/8-inch casing strings. Blowout prevention equipment was periodically tested at pressures up to 2000 psi.

Upon completion of operations the hole was plugged and abandoned, and all subsurface casing was cut and recovered to a minimum depth of 11.5 feet below the ocean floor. A temporary guideplate covered with concrete remains on the ocean floor; however, divers inspecting the area have reported that all tubular goods and other possible obstructions have been removed and the bottom otherwise returned to original condition.

Any interruptions to commercial and sport fishing, military activities, or other activities in the area, were temporary and ceased to exist when the rig was removed from location upon completion of operations.

The drillsite was located outside of normal shipping routes and therefore did not interfere with commercial traffic. Short term effects on commercial fishing are considered nominal since the operational period during which the drilling vessel was on location did not include the normal cycle of active commercial fishing in the Cortes Bank area.

In summary, no long-term adverse environmental impacts are considered to have resulted from the drilling operation, and any possible short-term effects have now ceased to exist.

SUMMARY AND CONCLUSIONS

by
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The deep stratigraphic test OCS-CAL 75-70 No. 1 was located in the outer banks area of the southern California continental Borderland on the southeastern end of Cortes Bank in a structurally low position in order to minimize the possibility of penetrating zones bearing commercial quantities of hydrocarbon. The well was drilled to a total depth of 10,920 feet into the Upper Cretaceous section and abandoned.

The well furnished important data on the stratigraphy and petroleum potential of this part of the Borderland. The section represents an apparent continuous record of marine sedimentation from the Campanian Stage of the Upper Cretaceous into the middle Miocene (Luisian Stage) above an unconformity within the Upper Cretaceous at 7,965 feet. A marine regression and possible hiatus may be present near the base of the Eocene section with the deposition of limestone, and another may have occurred during or following the extrusion of volcanic rocks in or near the end of the Oligocene (?). Basement was not reached but is inferred from magnetometer studies to be at 12,000 ± feet.

The penetrated section includes 1,905 ± feet of middle and early Miocene age rocks, 567 feet of basalt flows of possible Oligocene age, 1,340 ± feet of Oligocene, 1,950 feet of Eocene, 850 feet of Paleocene, and 3,930 feet of Late Cretaceous age rocks. The age of the strata in the bottom 500 feet of the well is Cenomanian. The section missing within the Upper Cretaceous includes parts of the Campanian, all of the Santonian and most of the Coniacian Stages. Sandstone below the unconformity contains abundant secondary laumontite and may be in the zeolite facies of low-grade metamorphism. Late Cretaceous and younger age rocks above the unconformity appear to have had a burial history not greatly deeper than their present depths.

The sequence of Eocene and Oligocene sedimentary lithofacies in the well is similar to approximate age-equivalent rocks in the Point Conception area of the western Santa Ynez Mountains. A 1,465-foot sequence occurs above definitely dated Zemorrian (Oligocene) mudstone at 3,160 feet, and this dominantly sandstone sequence is interrupted by a 567-foot thick section of submarine basaltic flows, radiometrically dated at 35 ± 1 m.y. This date is not consistent with the paleontologic age determinations and is 12 m.y. older than the age of volcanic rocks found elsewhere on the Channel Islands and nearby mainland. The Sespe Formation, which ranges in age from late Eocene to early Miocene and is a widespread continental deposit occurring in the northern Channel Islands and onshore, is absent in the well. Likewise, the middle Miocene San Onofre Breccia, which is present in the northern Channel Islands, Santa Monica Bay area (Campbell, and others, 1970) and onshore north of Oceanside, is not present, and no detritus of Catalina Schist was found within the section penetrated by the well.

The direction of transport for the Eocene and Paleocene sandstone is from the northeast as inferred from sedimentary structures observed in cores. At San Nicolas Island, 72 miles (120 km) to the north, Cole (1975) measured Eocene paleocurrent flow from the north. This is consistent with the thinning of the Eocene section from north to south from a minimum measured thickness in outcrop on San Nicolas Island of over 3,500 + feet by Vedder and Norris (1963) to 1,950 feet in the well.

No liquid oil shows were reported in cores, sidewall samples, or ditch cuttings, and only methane gas of insignificant amount was noted on the mud log. Solid hydrocarbon chips (up to 1 mm) in the cuttings from 4,020 feet were identified as gilsonite, used in the casing cement at 1,549 feet and apparently knocked loose while setting a deeper casing string at 3,891 feet. Thin vein-like solid hydrocarbon material occurs in a 6-inch contorted sandy siltstone interval at the top of a graded turbidite sandstone bed at 8,734 feet. This insoluble material has been analyzed as solid bitumen (see Organic Geochemical Analyses section).

Petroleum source rock studies on samples from the well (see Organic Geochemical Analyses section) provide valuable supplemental data to analyses on Borderland samples reported by Taylor (1976) and extends the potentially good to excellent source rocks from the Miocene down into the middle to upper Eocene. Lower and lower middle Eocene, Paleocene and Cretaceous rocks have low organic carbon content and are considered poor potential source rock for the generation of petroleum. Organic matter is immature except for an apparent change in maturity within the Cretaceous that is coincident with the unconformity at 7,965 feet. The organically rich upper Eocene and younger rocks of similar high organic content should be potentially good to excellent source rocks for petroleum if buried to depths of 10,000 feet or more.

Porous sandstone of potential reservoir quality occurs in the well from the middle Miocene into the Upper Cretaceous section. There is approximately 1,280 feet of sandstone with an average porosity of 32 percent in the middle Miocene section, and approximately 850 feet of 30 percent porosity sandstone of Oligocene age. In the Eocene to Upper Cretaceous section there is a net sand thickness of around 839 feet above the unconformity at 7,965 feet. This sandstone occurs over several widely spaced intervals and the sandstone beds are thin. The grain size ranges from coarse silt to very fine sand. Although the sandstone is well to very well sorted, with moderate porosities, ranging from 13 to 17 percent, the mean permeability is less than 10 millidarcies. There are 289 feet of upper and middle Eocene sandstone, 156 feet of lower Eocene, 260 feet of Paleocene and 134 feet of Cretaceous sandstone above the unconformity. The Cretaceous sandstone below this unconformity is not considered prospective as an oil reservoir and is a poor prospect as a possible gas reservoir because of the very low porosities (6 percent or less).

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