28 JUN 1971

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INTER-OFFICE CORRESPONDENCE / SUBJECT: Eldfisk 2/7-1X, Norwegian Sector, North Sea
BARTLESVILLE, OKLAHOMA

Er-116-71

June 24, 1971

Copy sent to Oslo Office 19/1/72

Mr. R. E. Beck
Phillips Petroleum Company
London, England

Attention: C. L. Wyndham

In accord with Mr. C. L. Wyndham's request of May 6, 1971, we are immediately transmitting the preliminary conclusions that have been obtained from a geochemical study that is in progress on the 2/7-1X well so that you may have the benefit of these data to aid in evaluating open acreage in the northern portion of the United Kingdom sector of the North Sea. We understand there may be an opportunity to obtain exploration licenses in this area in the next month or so of this year. This particular study involves 40 sidewall cores that were characterized for source rock properties and geochemically correlated with other samples from the North Sea Tertiary Basin area.

The sidewall cores were taken from the 8902-9670 and the 12,510-13,925 foot intervals. The cores from the 8902-9670 foot interval were taken in the Danian-Eocene section with the top of the Danian reported to be at 9573 feet and the top of the Paleocene at 9258 feet. This suite of cores was transmitted under L. Dale's cover letter LD/DB-023/70 dated September 17 and received September 27, 1970. The cores from the 12,510-13,925 foot interval were taken in the Upper Jurassic section with the top of the Upper Oxfordian reported to be at 12,153 feet. This suite of sidewall cores was transmitted under J. Rugland's cover letter SB-029-70 dated October 12 and were received October 20, 1970.

The conclusions from this study are based on data generated to date and a final interpretation will be made after all samples have been analyzed. The basic geochemical concepts and principles on which the conclusions and interpretations are based were presented in letters Er-132-69 and Er-239-69 concerning the Cod and Ekofisk fields respectively. Geochemical comparisons are made with data obtained from the study of the 2/4-4AX, 30/13-1X, and 2/4-5X wells which were presented in letters Er-103-71, Er-107-71, and Er-112-71.

Our present conclusions, comments and recommendations, based on a study of these two groups of sidewall cores are:

1. Sidewall cores from the 8902-9670 foot interval.

   a. This interval is represented primarily by greenish gray to dark gray, micaceous, silty and arenaceous, slightly calcareous, fractured and slickensided, laminated shales that contain blebs and finely-divided organic and plant remains distributed throughout. The laminated character is the result of closely spaced light gray paper-thin siltstone laminae which are argillaceous, arenaceous, generally very micaceous and contain glauconite, chlorite, and some pyrite. Plant material commonly is oriented parallel to the bedding planes and produces a lineated appearance to some of the shales.

b. All except the 8902, 8950 through 9048, 9131, 9150, 9227, 9303, 9450, 9471, 9495, and 9540 foot samples contain sufficient organic matter to meet the basic requirement of a source rock, that is, a rock in which petroleum has been generated in significant quantities and which has migrated from the rock. Based on the very high ratios of oil to kerobitumen for the samples, it appears that not all the oil in these shales is indigenous, for apparently oil is migrating within these shales. Probably the porous siltstones and siltstone laminae and fractures and faults within these units are serving as permeability channels for the migration of oil in response to the hydrodynamic pressure gradients in the area. The fact that oil is migrating within these units and that some of the more permeable thin siltstone layers are serving as reservoirs suggests that interbedded sandstones or tongues of Paleocene age having good reservoir characteristics would be good exploration targets in this region.

c. The organic matter in all the samples except the 9347-9397 foot interval originated in a marine environment of deposition. The organic matter from which the oil in the 9347 foot sample was generated originated in a brackish environment bordering on the terrestrial realm; the 9378 foot sample, terrestrial; and the 9397 foot sample in a brackish environment. It is considered likely that the organic matter in these particular samples, and probably some of the other as well, is allochtonous to the locality sampled.

d. The oil in these Tertiary and Danian samples is of similar composition and is relatively high in saturate and low in asphaltic content. Geochemically, the oils also are similar as illustrated by the fact that the odd-even predominance (OEP) curves have similar peak positions. This suggests that at the time of formation of the organic matter present in these units ecological conditions were rather uniform even though the organic matter was not deposited under uniform environmental conditions. The OEP curves for the oils present in these shales are similar to the curves for samples from the 9450-9845 foot interval in the 2/4-2X, the 9385-10,093 foot interval in the 2/4-5X, as well as the Tertiary cores from the 30/13-1X and the 2/4-4AX wells. This finding suggests that ecological conditions prevailing during the time of formation of the organic matter now present in these shales were quite uniform.

2. Sidewall cores from the 12,510-13,925 foot interval.

a. These dark gray to black Jurassic carbonaceous and limy shales are all quite rich in organic content, and only the 13,707 foot sample is eliminated from consideration as a source rock because its organic content exceeds 7 per cent. The high ratio of oil to kerobitumen suggests that not all the oil in these shales is indigenous for apparently oil is migrating within these stratigraphic units. This finding suggests that, as was the case in the 30/13-1X well, Mesozoic sandstones with good reservoir characteristics would be good exploration targets in the area.

b. With the exception of the 12,510 foot sample, the organic matter from which the oil in these shales originated was deposited in a rather uniform marine environment. The oil in the 12,510 foot sample originated from organic matter deposited in a brackish environment.

c. The oil in these Jurassic shales is of similar chemical composition and also has a composition similar to the oil extracted from the Tertiary samples in this well. Geochemically, the oil in the Jurassic shales is quite similar as shown by the close similarity in peak positions of the OEP curves. This finding suggests that uniform ecological conditions prevailed during formation of the organic material present in the units sampled.

d. The OEP curves for the oils present in the Jurassic samples are generally similar to the OEP curves for the Tertiary cores in this, as well as the other wells that have been studied to date. However, the OEP curves for the Jurassic samples generally are nearer to unity than curves for the Tertiary samples. This finding suggests that the oil present in the Tertiary and Jurassic shales is geochemically similar but that the Jurassic is geochemically more mature and petroleum genesis is more advanced than in the Tertiary section.

e. The OEP curves for the oils extracted from the Jurassic shales is quite similar to the OEP curves obtained for crude oil samples from the carbonate reservoirs of Danian age in the 2/4-1AX, 2/4-2X, 2/4-4AX, and 2/4-5X wells and for the sandstone reservoirs of early Mesozoic age in the 30/13-1X well. On the basis of the data generated to date, it would appear that the crude oils obtained from these wells originated in source rock facies of Paleocene and Jurassic age but Jurassic source rock facies were the most important contributor of petroleum to the Danian and early Mesozoic reservoirs in the area. Geochemical evidence indicates that downward migration of oil into Mesozoic age reservoirs did not occur uniformly through the Paleocene section, but was concentrated along lateral and vertical permeability channels.

In order to assess more fully the source rock character of the section present beneath the Danian reservoir in the region, it is recommended that as opportunity permits additional samples be obtained of Triassic, Jurassic and Cretaceous stratigraphic units. Also, it is suggested that in sampling the Paleocene section in future wells, several sets of sidewall cores be obtained at the same depth. In this way, one sidewall core could be utilized for geochemical purposes and the other for paleontological examination. Such information would be helpful in determining whether the organic matter in some of the shales is allochtonous to the site of deposition as is suspected.

The data upon which these conclusions are based are presented in Attachment I, Table I, and Figures 1 through 5. Attachment I contains a lithological description of the sidewall cores, and in Table I are presented the source rock compositional data for the organic matter present in the shales. Odd-even predominance curves for the sidewall cores from the 2/7-1X as well as other wells from the North Sea Tertiary Basin for comparison are presented in the figures.

J. Gordon Erdman /DAM

J. Gordon Erdman

JGE/DAM:gml

Attachments: Attachment I
Table I
Figures 1-5

Attachment I

Lithological Descriptions[1] of Sidewall Cores From the 2/7-1X Well, Norwegian Sector North Sea

Geochem. Branch Code	
GXJ	Depth 8902 feet. Shale, dark greenish gray (5GY 4/1), silty, micaceous, irregular fracture, highly sheared and slickensided, some black rod-shaped plant debris common, faintly laminated, coherent.
GXK	Depth 8925 feet. Shale, medium dark gray (N 4), silty, micaceous, arenaceous, well laminated, well developed conjugate fracture system, brownish black organic coating along lamina locally, coherent.
GXL	Depth 8950 feet. Shale, greenish gray (5GY 6/1), silty, micaceous, abundant black specks and flakes of plant debris, irregular fractures, sheared and slickensided, some pyrite, brownish coatings and streaks locally on broken surfaces, coherent.
GXM	Depth 8975 feet. Shale, greenish gray (5GY 6/1), silty, micaceous, highly sheared and slickensided, portions of sample exhibit transformation to chlorite, suggesting diagenetic alterations.
GXN	Depth 9000 feet. Shale, light gray (N 7), silty, well developed conjugate fracture system, black specks and flakes of plant debris common along laminae, sub-conchoidal fracture, massive appearance, coherent.
GXO	Depth 9024 feet. Shale, greenish gray (5GY 6/1), silty, arenaceous, faintly laminated, mottled with streaks of darker gray shale, coloration suggestive of chlorite or chloritic mineral, some flakes of plant debris, fractured, minor mica, coherent.
GXP	Depth 9048 feet. Shale, dark greenish gray (5GY 4/1), silty, arenaceous, coloration suggests chlorite or chloritic mineral present, highly sheared and slickensided, brownish staining or coating locally prominent, minor mica, coherent.
GXQ	Depth 9075 feet. Shale, medium light gray (N 6), silty, arenaceous, well developed laminations, coherent, alternating light and dark laminae, abundant black plant debris concentrated along darker laminae, irregular fracture.
GXR	Depth 9110 feet. Shale, very light gray (N 8), silty, well developed laminations, alternating light and dark laminae, coherent, minor mica.

(1) Color designations according to Geological Society of America Color Chart.

GXS Depth 9131 feet. Shale, greenish gray (5GY 6/1), silty, coherent, sub-conchoidal fracture, coloration suggests presence of chlorite or chloritic mineral, dark gray mottling locally, minor mica, sheared and slickensided, some disseminated specks and flakes of plant fragments and debris; brownish black coating or staining common on broken surfaces.

GXT Depth 9150 feet. Shale, same as GXS but chlorite more conspicuous and prevalent especially in proximity to highly sheared and slickensided surfaces.

GXU Depth 9174 feet. Shale, consisting of two lithological types: (1) dark dray (N 3), silty, coherent, micaceous, well laminated, uniform character; and (2) dark greenish gray (5GY 4/1), silty, highly sheared and slickensided with original features obliterated, giving rise to cataclastic texture.

GXV Depth 9202 feet. Shale, consisting of two lithological types: (1) medium dark gray (N 4), silty, arenaceous, sheared and slickensided, faint irregular laminations, micaceous; and (2) same as GXU-2 above.

GXW Depth 9227 feet. Shale, gray red (5R 4/2), minor fine-grained mica, massive appearance, smooth surfaces, irregular fracture, coherent, sheared with minor slickensides.

GXX Depth 9257 feet. Shale, medium dark gray (N 4), silty, coherent, laminated, micaceous, flakey, pyrite common, conjugate fracture system, minor amounts of black organic detritus and plant remains.

GXY Depth 9280 feet. Shale, light gray (N 7), silty, well developed lamination, minor mica, coherent, hard, disseminated plant debris.

GXZ Depth 9285 feet. Shale, medium dark gray (N 4), silty, well laminated with light gray stringers serving to accentuate layering, some black flakes of plant debris, pyrite abundant, coherent, hard.

GYA Depth 9303 feet. Siltstone, light gray (N 7), coarse- to medium-grained, very calcareous, poorly sorted, clayey, calcareous foraminifera.

GYB Depth 9331 feet. Shale, medium dark gray (N 4), silty, well developed laminations, alternating light and dark laminae, pyrite common, micaceous, coherent, hard.

GYC Depth 9347 feet. Shale, medium gray (N 5), silty, well developed irregular laminations, coherent, hard, alternating light and dark laminae, black specks and flakes of plant debris, micaceous.

GYD Depth 9378 feet. Shale, medium lgith gray (N 6), silty, micaceous, coherent, hard, irregular fracture, disseminated plant debris gives rise to lineation on laminae surfaces, faint irregular lamination.

GYE Depth 9397 feet. Shale, light gray (N 7), silty, coherent, hard; similar to GYD.

GYF Depth 9425 feet. Shale, medium gray (N 5), very silty, very micaceous, laminated, coherent, flakey, sheared, traces of rounded sand-size glauconite grains, few large flakes of plant debris.

GYG Depth 9450 feet. Shale, light gray (N 7), silty, coherent, hard, highly sheared, minor slickensides, sub-conchoidal fracture, minor mica, brownish dendrites common.

GYH Depth 9471 feet. Shale, medium gray (N 5), same as GYE and GYD, except with minor reddish mottling locally.

GYI Depth 9495 feet. Shale, greenish gray (5GY 6/1), silty, arenaceous, same as GYD except very micaceous, sub-conchoidal fracture, smooth surfaces, faintly laminated, coherent, hard.

GYJ Depth 9515 feet. Shale, same as GXW except with faint lamination.

GYK Depth 9540 feet. Shale, gray red (10Y 4/2), same as GXW, with faint laminations.

GYL Depth 9565 feet. Shale, same as GYK.

GYM Depth 9590 feet. Shale, Same as GYK.

GYN Depth 9622 feet. Limestone, light gray (N 7), silty, argillaceous, micaceous, coherent, hard, minor plant debris, pyrite masses common, very fine-grained.

GYO Depth 9640 feet. Limestone, very light gray (N 8), same as GYN.

TABLE I

Source Rock Evaluation of Sidewall Cores from the 2/7-1X Well, Norwegian Sector, North Sea

Geochem. Branch Code	Side-wall Core Depth, feet	Lithology	Carbonate Carbon, wt %	Organic Carbon, wt %	Ratio Soluble/ Total Carbon	Soluble Organic Matter: Total Wt %	Total δC^{13}_{PDB}	Saturates Wt %	Saturates δC^{13}_{PDB}	Aromatics Wt %	Aromatics δC^{13}_{PDB}	Asphaltics Wt %	Asphaltics C^{13}_{PDB}	Odd-Even Predominance, OEP	Inferred Depositional Environment of Soluble Organic Matter
GXJ	8902	Shale	0.17	0.47	0.089	0.052	-27.3	52.0	-	31.5	-27.1	16.5	-26.3	1.26	Marine
GXK	8925	"	0.45	0.88	0.833	0.916	-26.9	70.8	-27.2	26.3	-26.5	3.0	-25.7	-	"
GXL	8950	"	0.12	0.32	0.255	0.102	-27.4	69.6	-27.5	21.5	-27.3	8.8	-26.1	1.11(3)	"
GXM	8975	"	0.17	0.34	0.323	0.137	-27.1	66.8	-	22.2	-28.2	11.0	-	-	"
GXN	9000	"	0.10	0.17	0.448	0.95	-27.1	80.1	-27.1	14.5	-27.3	5.4	-26.0	1.14(3)	"
GXO	9024	"	0.20	0.23	0.143	0.041	-27.1	62.1	-	26.0	-26.7	11.9	-26.2	0.90(3)	"
GXP	9048	"	0.09	0.18	0.240	0.054	-26.4	68.7	-27.3	19.6	-27.2	11.7	-25.8	1.06(3)	"
GXQ	9075	"	0.46	0.58	1.215(2)	0.881	-26.9	62.7	-27.5	32.9	-26.4	4.4	-26.4	1.05	"
GXR	9110	"	0.09	0.66	0.225	0.186	-26.7	60.3	-27.3	29.5	-26.9	10.3	-26.4	1.13	"
GXS	9131	"	0.20	0.19	0.588	0.140	-26.5	78.1	-27.0	15.7	-28.1	6.2	-26.1	1.12	"
GXT	9150	"	0.09	0.25	0.321	0.100	-27.1	70.0	-	15.9	-	14.1	-	-	"
GXU	9174	"	0.67	0.61	0.235	0.179	-27.7	64.3	-26.8	28.4	-27.2	7.3	-26.1	1.24	"
GXV	9202	"	0.06	0.70	0.075	0.066	-27.0	51.6	-27.5	32.3	-26.7	16.1	-26.5	1.43	"
GXW	9227	"	0.12	0.34	0.338	0.144	-26.9	73.7	-	18.8	-26.4	7.5	-26.5	1.04	"
GXX	9257	"	0.01	3.26	0.062	0.252	-27.6	50.8	-28.5	37.9	-28.5	11.3	-28.2	1.50	"
GXY	9280	"	1.85	1.33	0.314	0.522	-27.5	68.8	-27.3	24.9	-27.3	6.2	-27.2	0.99	"
GXZ	9285	"	0.04	2.09	0.144	0.375	-28.5	49.0	-28.0	38.8	-28.1	12.1	-27.9	0.96	"
GYA	9303	Siltstone	3.48	0.16	1.461(2)	0.292	-27.7	59.6	-27.6	34.7	-26.8	5.7	-27.2	1.00	"
GYB	9331	Shale	0.06	1.88	0.100	0.235	-28.2	59.4	028.9	34.4	-28.3	6.3	-28.1	0.98	"
GYC	9347	"	0.04	1.62	0.160	0.324	-30.6	62.3	-28.8	27.7	-29.2	10.0	-33.3	0.89	Brackish to Terrestrial
GYD	9378	"	0.07	0.88	0.152	0.167	-31.3	59.6	-30.5	28.2	-30.2	12.1	-29.9	0.96	Terrestrial
GYE	9397	"	0.12	0.87	0.148	0.161	-30.6	40.2	-	37.0	-28.8	22.8	-28.3	0.99	Brackish
GYF	9425	"	0.06	1.05	0.258	0.339	-30.0	63.7	-27.9	27.3	-28.6	9.0	-28.4	1.06	Marine
GYG	9450	"	0.10	0.27	0.419	0.142	-27.9	73.6	-26.5	21.2	-27.0	5.2	-26.2	1.13	"
GYH	9471	"	0.34	0.24	0.732	0.220	-27.4	77.3	-27.1	17.2	-26.6	5.5	-	1.00	"
GYI	9495	"	0.28	0.49	1.093(2)	0.670	-26.7	78.3	-26.6	18.5	-26.3	3.3	-26.2	0.91	"
GYJ	9515	"	0.13	5.58	0.021	0.146	-27.4	77.1	-26.4	17.9	-26.8	5.0	-26.3	0.95	"
GYK	9540	"	0.09	0.16	0.484	0.097	-27.4	68.4	-28.9	14.6	-26.8	17.1	-26.5	1.09	"
GYL	9565	"	0.15	0.51	0.164	0.104	-27.0	69.6	-28.1	22.3	-26.9	8.1	-26.2	1.06	"
GYM	9590	"	0.81	0.89	0.386	0.429	-27.5	81.2	-25.4	15.0	-27.5	3.8	-	1.21	"
GYN	9622	Limestone	4.23	0.40	0.494	0.247	-26.9	80.2	-25.1	16.1	-26.7	3.6	-	1.19	"
GYO	9670	"	6.63	0.38	0.692	0.328	-27.2	77.7	-24.6	18.3	-26.7	4.0	-26.2	1.01	"

(Continued)

Er-116-71

TABLE I (Continued)

Geochem. Branch Code	Side-wall Core Depth, feet	Lithology	Carbonate Carbon, wt %	Organic Carbon, wt %	Ratio Soluble/Total Carbon	Soluble Organic Matter: Total Wt %	Total C^{13}_{PDB}	Saturates Wt %	Saturates C^{13}_{PDB}	Aromatics Wt %	Aromatics C^{13}_{PDB}	Asphaltics Wt %	Asphaltics C^{13}_{PDB}	Odd-Even Predominance, OEP	Inferred Depositional Environment of Soluble Organic Matter
HCG	12510	-(1)	5.61	1.39	0.654	1.137	-29.6	69.3	-29.0	27.8	-28.4	2.8	-28.9	1.01	Brackish
HCH	12605	-(1)	1.26	3.40	0.294	1.248	-29.2	50.6	-28.3	44.2	-28.9	5.2	-	0.99	Marine
HCI	13000	-(1)	0.88	2.52	0.129	0.405	-28.4	55.3	-29.6	42.1	-27.7	2.6	-27.5	1.01	Marine
HCJ	13090	-(1)	1.17	1.84	0.162	0.372	-28.7	61.3	-28.3	34.1	-28.0	4.6	-	0.95	"
HCK	13478	-(1)	2.80	4.30	0.215	1.157	-26.2	52.2	-28.5	43.0	-25.7	4.8	-26.1	1.04	"
HCL	13602	-(1)	3.88	2.39	0.115	0.343	-27.5	72.9	-30.9	22.8	-26.7	4.4	-	1.04	Marine
HCM	13707	-(1)	2.75	7.29	0.138	1.262	-24.8	47.2	-25.1	46.5	-23.8	6.3	-24.3	1.03	Marine
HCN	13925	-(1)	2.24	2.10	0.097	0.256	-26.4	69.0	-25.5	27.0	-25.8	4.0	-25.9	0.99	"

(1) Lithology of samples has not yet been described.

(2) Experimental error causes ratios to exceed one.

(3) Values are estimates.

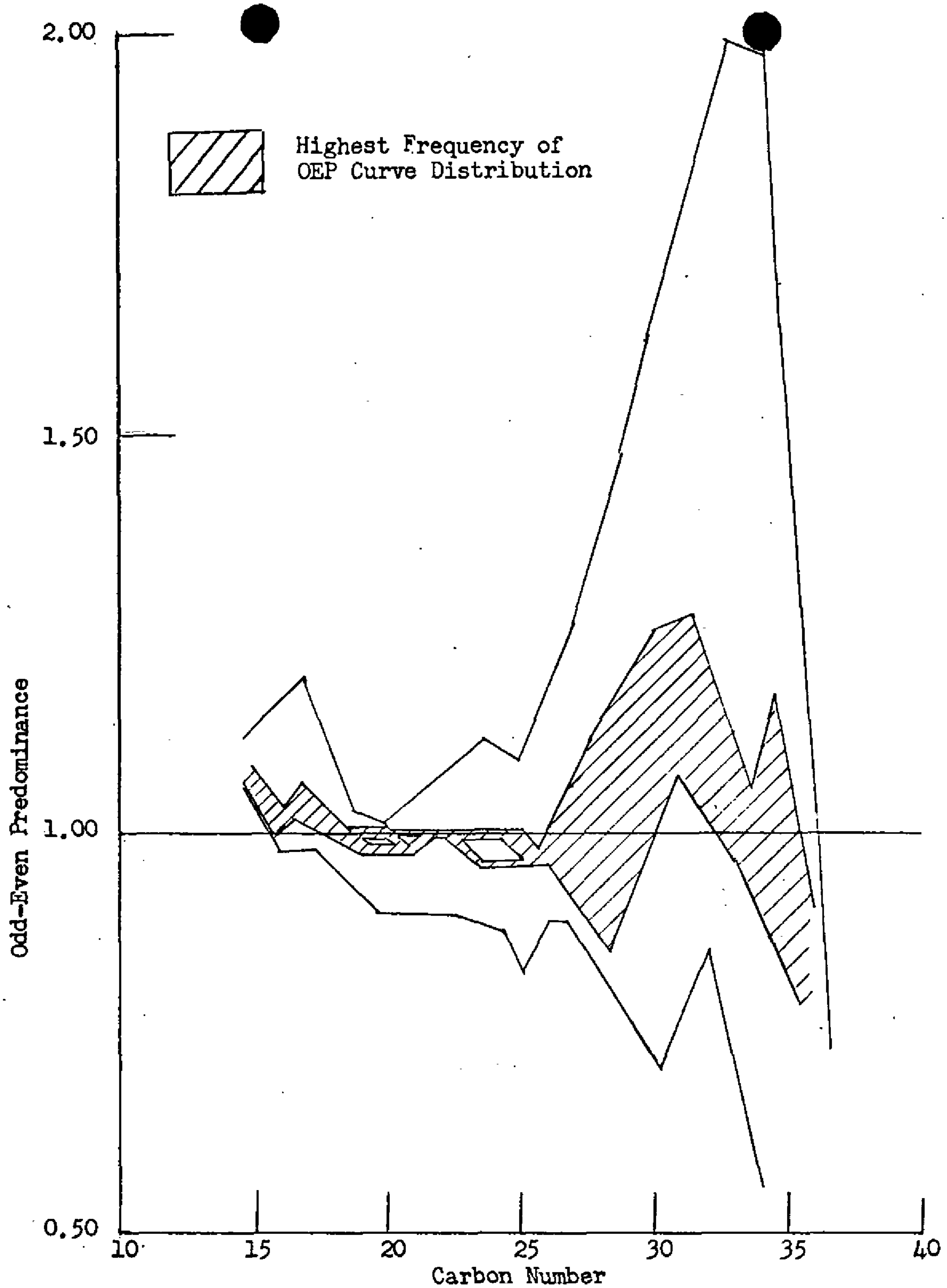

Figure 1. Representative Odd-Even Predominance (OEP) Curve Envelope for Oil in Tertiary Cores from the 8902-9670 Foot Interval in the 2/7-1X Well. Comparison of OEP Curves for Tertiary Cores From the 2/7-1X Well With Curves From the 2/4-2X Shown in Figure 2, and the 2/4-5X Well Shown in Figure 3, as well as the 30/13-1X and 2/4-4AX Wells shown in Figure 2 of Letter Er-112-71 indicate all are similar. This suggests that the organic matter in these Tertiary Shales Accumulated Under Rather Uniform Ecological Conditions.

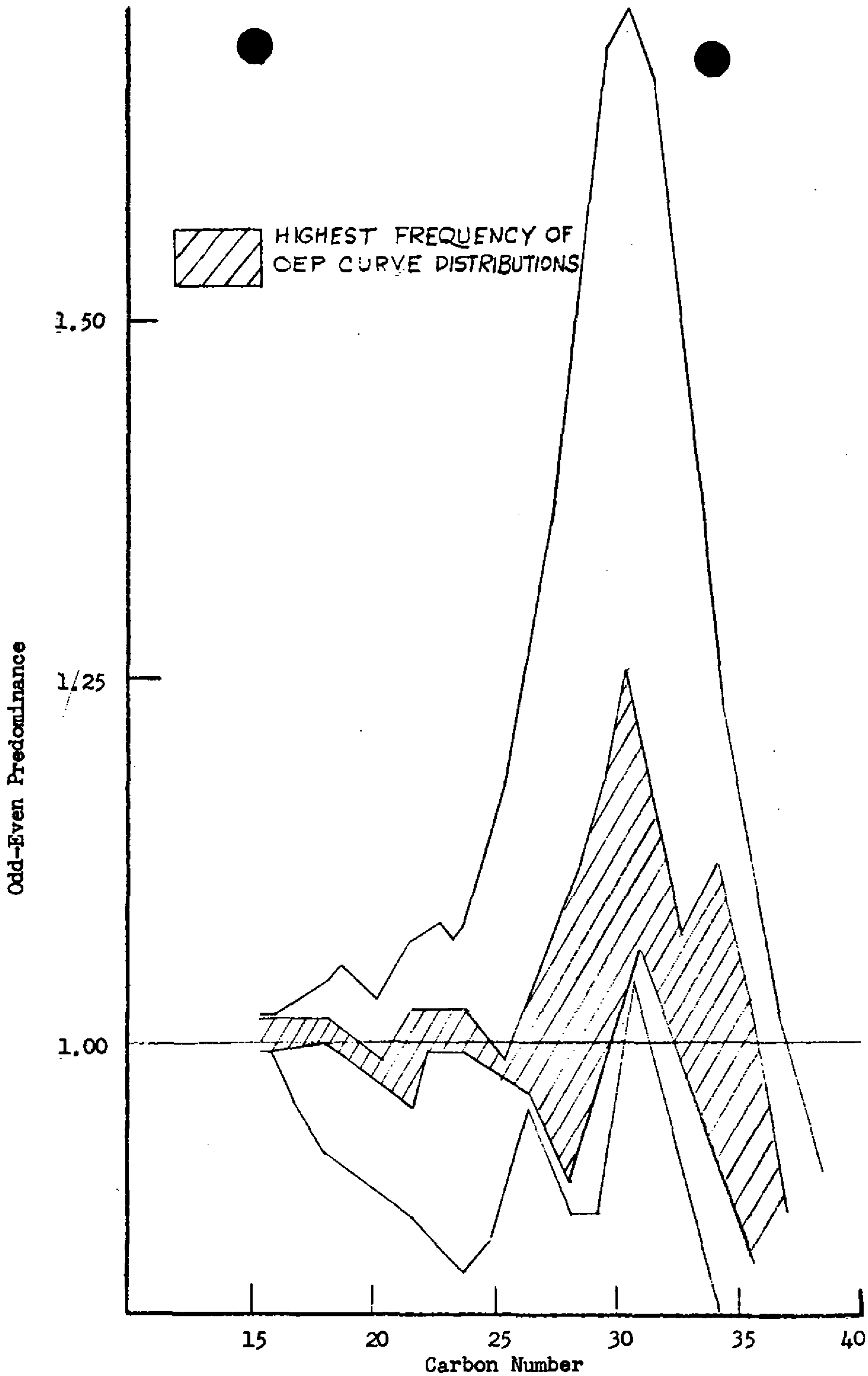

Figure 2 Representative OEP Curve Envelope for 38 Sidewall Cores From the 9450-9845 Foot Interval in the 2/4-2X Well.

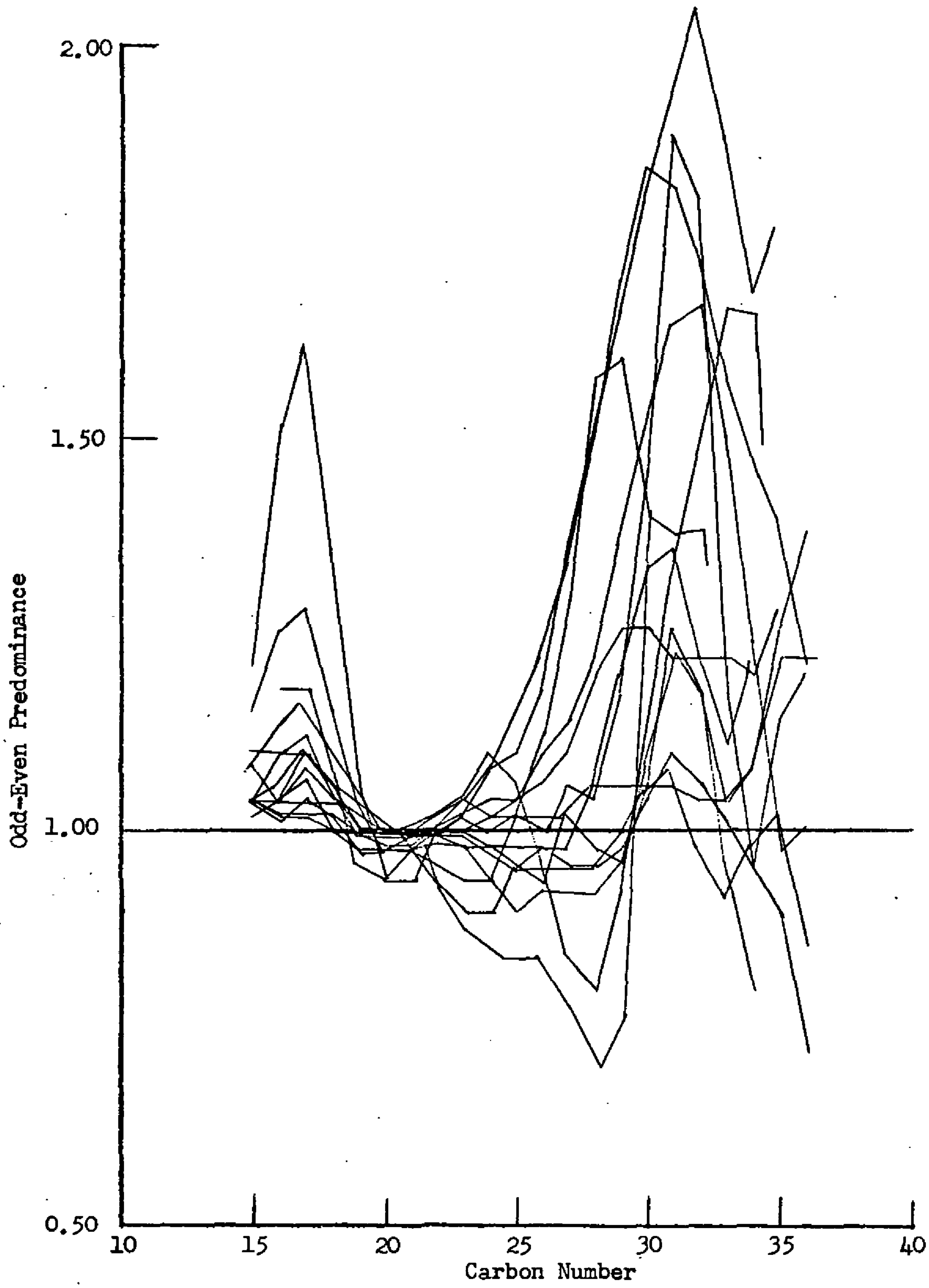

Figure 3. Odd-Even Predominance (OEP) As a Function of Carbon Number For Oil of Marine Origin in Sidewall Cores From the 9385-10093 foot Interval in the 2/4-5X Well. The Similarity in Peak Position of these OEP Curves Indicates That the Marine Organic Matter in these Shales Accumulated Under Rather Uniform Ecological Conditions.

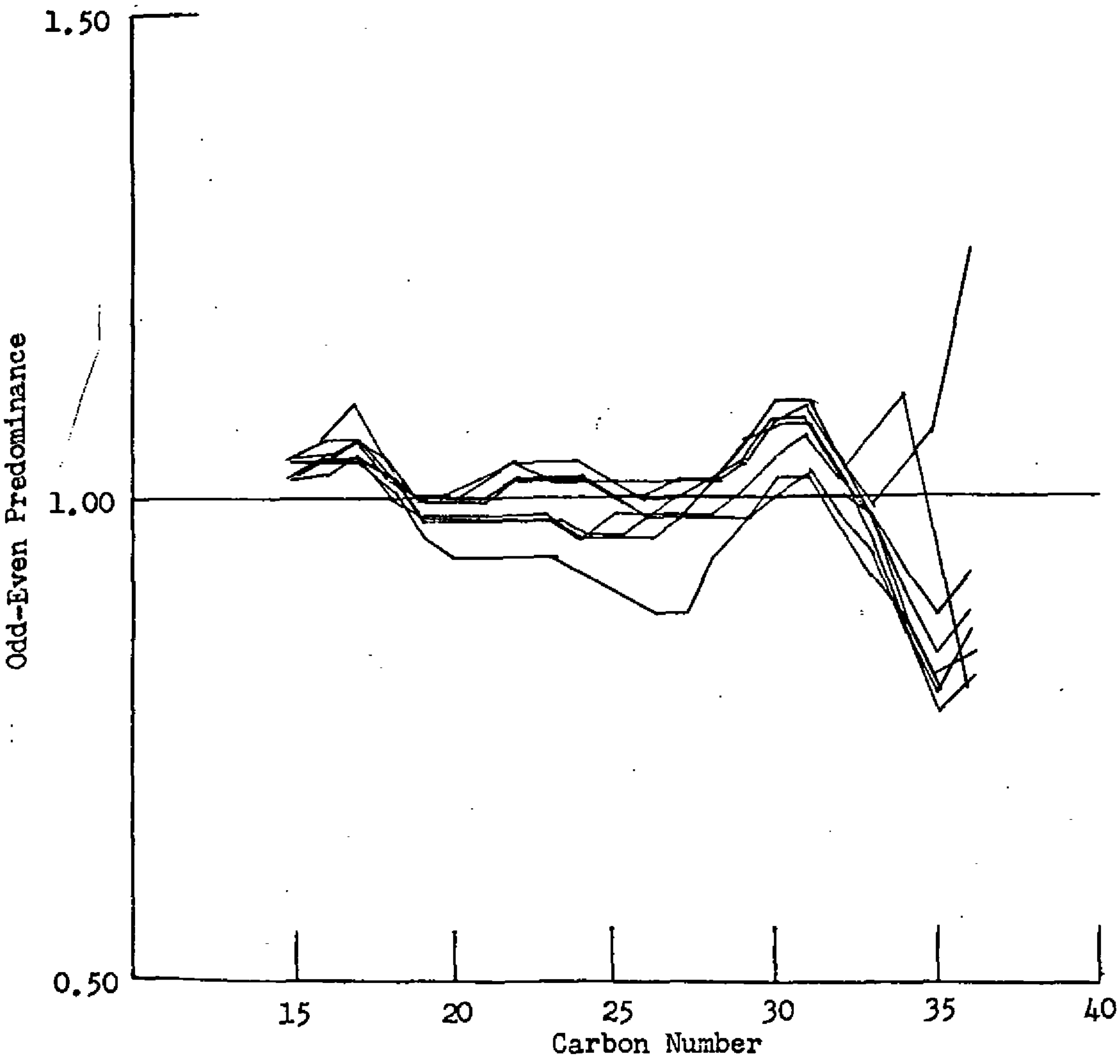

Figure 4. Odd-Even Predominance (OEP) as a Function of Carbon Number for Oils Extracted From Jurassic Sidewall Cores from the 12,510-13,925 Foot Interval in the 2/7-1X Well. The Similarity of Curves Indicates the Organic Matter Present in these Shales Accumulated Under Quite Uniform Ecological Conditions. The Close Similarity of these OEP Curves With the OEP Curves for Crude Oils from the Area Shown in Figure 5 Suggests That Source Rock Facies of Jurassic Age Were an Important Contributor of Petroleum in this Area of the North Sea Tertiary Basin.

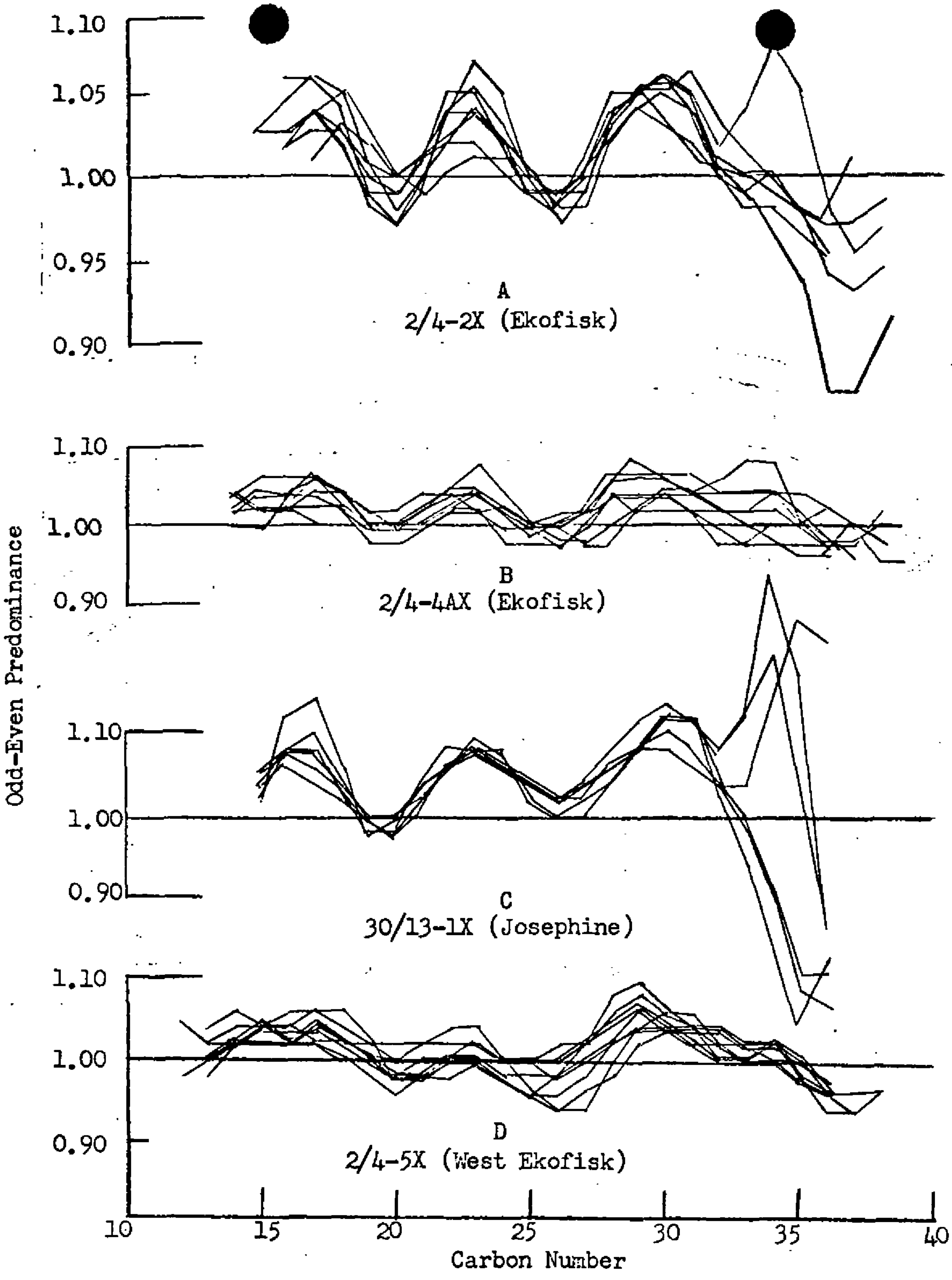

Figure 5. Odd-Even Predominance (OEP) As a Function of Carbon Number For Crude Oil Samples From the (A) 2/4-2X, (B) 2/4-4AX, (C) 30/13-1X and (D) 2/4-5X Wells. The Close Similarity in OEP Curves Indicates That These Crude Oils As Well As the Oil From the 2/4-1AX Well (Figure 5, Er-103-71) Are Similar and Apparently Originated From Source Rock Facies of Comparable Age and Deposited Under Similar Conditions.