UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

PETROLEUM SOURCE POTENTIAL OF ROCKS DREDGED FROM THE CONTINENTAL SLOPE IN THE EASTERN GULF OF ALASKA

OPEN-FILE REPORT 79-295

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature

Menlo Park, California

January 1979

Petroleum source rock potential of rocks dredged from the continental slope in the eastern Gulf of Alaska

By George Plafker and George Claypool

Abstract

A bedrock dredging program by the R/V Sea Sounder in 1977 and 1978 along the continental slope in the eastern Gulf of Alaska revealed a previously unknown Eocene sedimentary sequence that includes argillaceous rocks with favorable petroleum source rock characteristics. Seven of 36 dredge hauls that sampled outcrop contain argillaceous rocks with more than 1 percent and as much as 1.64 percent organic carbon. Some of the rocks in samples of probable early Eocene age have undergone a thermal history that has resulted in generation of hydrocarbons. The organic matter appears to be hydrogen deficient, however, which could indicate that the rocks are more likely to be a source of gas rather than liquid hydrocarbon, unless the hydrogen loss is due to weathering.

The Eocene rocks are associated with sandstone and conglomerate on the continental slope. They dip northward beneath younger Tertiary strata in the outer continental shelf where they could be an important petroleum source and exploratory target.

INTRODUCTION

As part of the U.S. Geological Survey's program of evaluating the regional geologic framework and petroleum potential of the outer continental shelf (OCS) in the eastern Gulf of Alaska, outcrop samples were dredged from the continental slope between the eastern end of the Aleutian Trench and the area offshore from Chichagof Island (fig. 1). The dredge program, carried out by the R/V Sea Sounder from June 5 to 15, 1977 and June 29 to July 10, 1978, sampled outcrop or probable outcrop, at the localities shown on figure 1.

Because the availability of source rocks adequate for generation of oil or gas is a major factor in assessing the petroleum potential of the OCS, we have evaluated selected argillaceous rocks from the dredge hauls for hydrocarbon generation potential using standard analytical techniques. The purpose of this report is to summarize our data and interpretations on the source rock potential and stratigraphic occurrence of the analyzed samples. Because the samples are adjacent to the area of the proposed OCS Lease Sale 55 scheduled for June 1980 (fig. 1), these data should help in evaluating the prospects of the area and in planning pre-sale exploration.

Acknowledgments

Collection of the samples was made possible by the outstanding cooperation and seamanship of the officers and crew of the R/V Sea Sounder and the dedicated efforts of the scientific and technical staff that participated in both of the eastern Gulf of Alaska cruises. Plafker was

co-chief scientist with Gary Winkler in 1977 and with Paul Carlson in 1978. Age assignments for the dredged samples are based largely on studies of the contained nannoplankton by David Bukry, the Foraminifera by Weldon W. Rau, and the siliceous microorganisms by John Barron.

GEOLOGY

Methods

Of the dredge hauls that are believed to have sampled outcrop, seven contained argillaceous rocks with organic carbon contents in excess of 0.5 percent, or within the general range of shaly source rocks (Tissot and Welte, 1978, p. 430). These localities, which are between Alsek Canyon and Yakutat Sea valley, are indicated by sample numbers in figure 1. Their location, lithology, and age are summarized in table 1. The 1977 sample numbers are preceded by the cruise locator code S2-77-EG and those for 1978 are preceded by S5-78-EG.

The samples were collected in water depths between 3,180 m and 250 m using a standard chain dredge having a bag capacity of about 300 kg. Positioning was by satellite navigation. To facilitate correlation of the outcrop geology with seismic reflectors, dredge sites were located as close as navigation would permit to single-channel seismic reflection lines made with the R/V *Sea Sounder's* 160 KJ Sparker system or along CDP reflection lines by the R/V *Lee* or R/V *Cecil Greene*.

TABLE 1.--*Lithology, age, and location of rocks from the eastern Gulf of Alaska that were analyzed for hydrocarbon source potential.*

[*Locations shown on figure 1; analytical data in tables 2 and 3*].

Sample number	Lithology	Fossils	Age	Water depth [1] (m)	Latitude [1]	Longitude [1]
S2-77-EG-11B	Shale--Light-olive gray, moderately well indurated, with silt-size mica, organic material, rare glauconite, and pyrite.	Siliceous microfossils, nannoplankton, Foraminifera.	late Eocene	890 500	58°39.16' 58°39.69'	140°36.89' 140°36.03'
S2-77-EG-17B	Sandy shale--Black, moderately well indurated, and fissile with partings of fine-grained, highly micaceous grayish-orange sandstone. Abundant organic material.	Dinoflagellates.				
S2-77-EG-17C	Shale--Medium-gray, soft to moderately well indurated, minor silt-size organic material, slightly expansive in water.	Poorly preserved and pyritized Foraminifera. Dinoflagellates.	late Eocene(?)	1,025 925	58°32.62' 58°33.02'	140°06.66' 140°06.49'
S2-77-EG-17E	Shale--Yellowish-gray, soft, with silt-size material including green hornblende and brown to black organic material.	Abundant siliceous microfossils, rare pyritized Foraminifera.				
S2-77-EG-18A	Slightly silty shale--Yellowish-gray, soft, abundant green hornblende, and weathered pyrite(?) nodules, expansive in water.	Abundant siliceous microfossils. Pollen.	late Oligocene	510 250	58°34.72' 58°35.92'	140°05.46' 140°04.67'
S2-77-EG-20B	Shale--Dark-gray, hard, very slightly calcareous, with finely divided pyrite.	---	Eocene(?)	3,180 3,080	58°53.17' 58°54.28'	142°03.21' 142°02.90'
S2-77-EG-22B	Shale--Medium-light-gray, moderately soft, minor silt-size mica and organic material.	---	Eocene(?)	2,575 2,300	58°58.60' 58°59.77'	141°59.68' 141°58.46'
S5-78-EG-22D1	Shale--Medium-gray, moderately well indurated, waxy, minor organic material.	Rare arenaceous Foraminifera.				
S5-78-EG-22D2	Silty shale--Light-brownish-gray, moderately well indurated, moderately expansive in water.	Foraminifera, rare pelecypods 0.6 cm across.	Eocene	2,415 2,465	58°59.93' 58°56.82'	142°08.55' 142°09.56'
S5-78-EG-22D3	Silty shale--Medium-gray, moderately well indurated, micaceous.	Rare Foraminifera.				
S5-78-EG-44D	Shale--Dark-olive-gray, very soft, waxy, moderately abundant silt-size grains including green hornblende, slightly expansive in water.	Abundant nannoplankton and Foraminifera. Dinoglagellates.				
S5-78-EG-44E	Shale--Dark-olive-gray, soft, laminated, glauconitic.	Very abundant siliceous microfossils, nannoplankton, Foraminifera, and fish scales. Rare small pelecypods.	late Eocene	1,500 1,270	58°45.22' 58°47.53'	141°08.84' 141°03.14'
S5-78-EG-44F	Shale--Light-olive-gray, poorly indurated, laminated, glauconitic. Abundant fish scales, nannoplankton, siliceous microfossils, and Foraminifera.	Dinoflagellates.				

[1] Depth and coordinates are given for start and finish of dredge casts.

Structural and stratigraphic setting

The general lithology and age of outcrop samples collected in 1977 from the continental slope in the eastern Gulf of Alaska has been outlined by Plafker and others (1978a) and the 1978 sampling cruise tends to confirm and add detail to the earlier work. Data on the structure and petroleum potential of the Outer Continental Shelf in this region were summarized by Bruns and Plafker (Plafker and others, 1978b). In general, the continental slope is underlain by a sequence of rocks that appears to be in normal stratigraphic superposition with the oldest rocks towards the base of the slope. Rocks from the outcrop are characteristically bored by marine organisms and weathered,with oxidized rinds in some samples extending as much as 10 cm in from the surface. Many of the older outcrops are mantled by latest Cenozoic marine glacial mud and erratics which are distributed across the slope and into the deep ocean basin as slope-rise prism and trench fill. Marked changes occur from east to west in the bedrock lithology and structure of the slope within the eastern Gulf of Alaska.

Between Cross Sound and Alsek Canyon much of the continental slope and the topographically high Fairweather Ground along the shelf edge consists of pre-Tertiary outcrops of hard volcanogenic graywacke sandstone, argillite, and greenstone that may be intruded by plutonic rocks of dioritic composition. This assemblage of rocks, which is lithologically similar to the Cretaceous Yakutat Group of the adjacent mainland, constitutes effective basement for petroleum. Sedimentary rocks of late Cenozoic age occur in isolated basins on the pre-Tertiary basement in the vicinity of Fairweather Ground. To the northeast, sedimentary rocks of probable middle to late Tertiary age lap onto the high from a broad basin with the axis near the coast and a thickness of at least 10,000 ft (3,000 m).

From Alsek Canyon to a zone which extends from Pamplona Ridge southwestward to the axis of the Aleutian Trench (Pamplona zone), the Tertiary section appears to thicken markedly, and includes rocks ranging in age from early Eocene and possibly older through late Oligocene. This sequence, roughly 10,000 ft (3,000 m) thick, is exposed along the lower part of the slope and locally overlies inferred pre-Tertiary basement which plunges northwestward from the vicinity of Alsek Canyon. The Eocene and probable Eocene sequence consists of well indurated cobble-boulder conglomerate, quartzofeldspathic sandstone, siltstone, shale, and palagonitized mafic tuff. The argillaceous rocks commonly contain abundant microfossils ranging in age from late early Eocene to late Eocene. The one Oligocene sample (S2-77-EG-18) is largely sheared gray glauconitic and pyritic siltstone containing an abundant late Oligocene siliceous microflora. The sequence includes strata that are coeval with the onshore Kulthieth Formation and an unnamed siltstone sequence of Eocene age and the Poul Creek Formation of Oligocene and earliest Miocene age. Seismic reflection data indicate that the early Tertiary strata comprise a wedge that dips and thins toward the coast. Overlying the older rocks is the Yakataga Formation of late Cenozoic age. The Yakataga is relatively undeformed, and fills a broad basin that is at least 20,000 ft (6,000 m) deep near the coast.

The shelf and slope west of the zone extending from the Pamplona Ridge to the Aleutian Trench (Pamplona zone) are characterized by numerous young anticlinal structures, some of which were unsuccessfully drilled for petroleum between 1976 and 1978. The easternmost folds of the Pamplona zone define the boundary between the relatively undeformed Yakutat block to the east and the Yakataga shelf to the west (Plafker and others, 1978). This segment of the continental slope is characterized by linear ridges with as much as 3,300 ft (1,000 m) topographic relief that probably reflect anticlinal structures. These ridges, in part at least, are underlain by rocks of early Tertiary age that constitute acoustic basement. They include siltstone, calcareous siltstone, concretionary siltstone, and quartzofeldspathic sandstone, some of which contains diagnostic late Eocene microfaunas. The older Tertiary strata in this part of the slope are generally mantled by Quaternary hemipelagic mud. Moderately folded to gently dipping strata of the Yakataga Formation overlap the older strata along the higher parts of the continental slope and fill basins that are ponded along the north flanks of some slope ridges.

HYDROCARBON SOURCE ROCK ANALYSES

Methods

Selected samples of argillaceous rocks from the dredge hauls were analyzed for organic carbon content by a wet oxidation-gravimetric method modified by Bush (1970). Two of the richest samples were analyzed by conventional extraction and chromatography techniques (Claypool and others, 1978). In addition, the hydrocarbon generating capacity of the organic matter for all these samples was evaluated by thermal analysis (Chromalytics MP-3 or Rock-Eval pyrolysis) using the general procedures described by Claypool and Reed (1976) and Espitalie and others (1977). Analytical results are summarized in tables 2 and 3.

Thermal analysis of samples collected on the 1977 Sea Sounder cruise was conducted only on the MP-3 instrument (which is why CO_2 yield is not reported); the 1978 samples were analyzed on both the MP-3 and the Rock-Eval. Hydrocarbon yields are comparable for the two techniques, but the furnace temperature at the time of maximum pyrolysis is significantly different for the two instruments. The temperature of maximum pyrolysis yield ($T(S_2)$, °C) reported in table 2 is that measured by thermocouple during Rock-Eval pyrolysis, except for the S2-77-series, in which case it is the MP-3 temperature minus 48 °C. The data in table 2 are reported in terms of the units, terminology and conventions of Rock-Eval source rock characterization, as discussed by Tissot and Welte (1978). S_1 is the integral of the first hydrocarbon peak produced by heating the rock sample in flowing helium at 250° C for 5 minutes (or from 50° to 325° C at 40° C/min in the case of the MP-3 analysis). S_1 is free or adsorbed hydrocarbons in the rock. S_2 is the integral of the second hydrocarbon peak produced mainly by pyrolysis of the solid organic matter when the rock is heated from 250° to 550° C at 25° C/min (or 325° to 720° C at 40° C/min in the case of the MP-3 analysis). S_3 is the integral of the carbon dioxide peak, determined by automated thermal conductivity gas chromatography on a split of the gas trapped during the heating interval 250° to 390° C. This CO_2 is mainly that produced by pyrolysis of organic matter. Detector response is calibrated by analysis of known weights

Table 2.--*Organic carbon content and Rock-Eval pyrolysis data for selected dredge samples from the eastern Gulf of Alaska*

[n.a. = no analysis; n.d. = no determination]

Sample number	C [1] (percent)	S_1 [2] (mg/g)	S_2 [2] (mg/g)	S_3 [2] (mg/g)	$T(S_2)$ [2] (°C)	Genetic Potential $S_1 + S_2$ (ppm)	Hydrogen Index S_2/C (mg HC/gC)	Oxygen Index S_3/C (mg CO_2/gC)	Transformation Ratio $S_1/S_1 + S_2$
S2-77-EG-11B	1.12	.035	1.405	n.a.	408	1,440	128	n.a.	0.02
S2-77-EG-17B	1.22	0	0.810	n.a.	420	810	66	n.a.	0
S2-77-EG-17C	0.71	.016	0.454	n.a.	420	470	66	n.a.	0.03
S2-77-EG-17E	0.63	.048	0.232	n.a.	n.d.	280	44	n.a.	0.17
S2-77-EG-18A	0.56	.036	0.314	n.a.	392	350	62	n.a.	0.10
S2-77-EG-20B	1.03	.030	0.100	n.a.	n.d.	130	13	n.a.	0.23
S2-77-EG-22B	1.45	.017	1.513	n.a.	426	1,530	105	n.a.	0.01
S5-78-EG-22D1	0.75	0.104	0.375	0.69	445	479	50	92	0.22
S5-78-EG-22D2	0.84	0.099	0.415	0.72	442	514	49	87	0.19
S5-78-EG-22D3	1.13	0.145	0.816	0.14	439	961	72	12	0.15
S5-78-EG-44D	1.64	0.034	1.42	2.03	421	1,452	86	123	0.02
S5-78-EG-44E	1.49	0.189	1.16	2.63	425	1,350	78	176	0.14
S5-78-EG-44F	1.41	0.140	0.943	3.11	421	1,080	67	221	0.13

[1] Total organic carbon analyses by Rinehart Laboratories, Arvada, Colorado.

[2] [illegible]

of eicosane (n-$C_{20}H_{42}$) and carbon dioxide. Yields are reported in milligrams of substance per gram of rock. Also reported is the genetic potential (S_1 plus S_2 in ppm or kilograms of hydrocarbon per metric ton), the hydrogen index (S_1 divided by organic carbon in milligrams of hydrocarbon per gram of organic carbon), the oxygen index (S_3 divided by organic carbon), and the transformation ratio (S_1 divided by the sum of S_1 and S_2).

Organic carbon content

Organic carbon contents of samples listed in table 2 range from 0.56 to 1.64 percent and average almost 1.1 percent carbon. These carbon contents are above the generally accepted minimum values of 0.5 percent organic carbon for argillaceous hydrocarbon source rocks (Tissot and Welte, 1978, p. 430-431). However, they are well below the concentrations of up to 7.6 percent organic carbon in the richest shales from the Oligocene sequence that crops out on Kayak Island in a zone up to 250 m thick (Plafker, 1974).

Extraction and chromatography

Results of the analyses of samples S5-78-EG-22D3 and 44D for extractable hydrocarbon content by solvent extraction, elution, chromatography, and gas chromatography are presented in table 3.

Sample 22D3 is exceptionally rich in extractable hydrocarbons (700 ppm). The saturated hydrocarbons have a mature, waxy petroleum-like distribution (fig. 2). The saturated hydrocarbon fraction predominates over aromatic hydrocarbons (S/A = 1.36), the extractable ditumen is

TABLE 3.--*Results of solvent extraction, elution, and gas chromatographic analyses of selected samples, eastern Gulf of Alaska*

Sample number	S5-78-EG-22D3	S5-78-EG-44D
Organic Carbon, wt. percent	1.13	1.64
Bitumen, extractable with chloroform, parts per million	980	224
Total hydrocarbons, ppm	700	101
Saturated-to-aromatic hydrocarbon ratio	1.36	0.55
Hydrocarbon proportion of bitumen	0.71	0.45
Hydrocarbon-to-organic carbon ratio, in percent	6.19	0.61
Carbon preference index (CPI)	1.25	not determined

71 percent hydrocarbons, and the hydrocarbon-to-organic carbon ratio is 6.2 percent. These characteristics of the extractable organic matter (assuming it is indigenous to the rock) in this sample indicate that petroleum hydrocarbons have been generated in sufficient quantities to consider the strata represented by sample 22D3 as possible source rocks. In addition, the relative amounts of hydrocarbons and total organic carbon indicates that the sampled rock has undergone close to the optimum thermal history for liquid hydrocarbon generation. However, the saturated hydrocarbon distribution still retains signs of slight immaturity, such as the large predominance of pristane over $\underline{n}$-C_{17}, and the carbon preference index (CPI) value of 1.25. Rocks with similar organic matter in a downdip position which had undergone an additional 500 m or so of burial should have even more favorable source rock properties.

Sample 44D is less rich in extractable organic matter, but it is still above average for immature shales. The content of extractable hydrocarbons is 101 ppm. The saturated hydrocarbons are subordinate to the aromatics (S/A = 0.55) and the gas chromatographic analysis (fig. 2) indicates a mixture of saturated hydrocarbons dominated by compounds which have undergone only slight, low-temperature modification of their biochemically-derived structures. These are the sterane, di- and triterpane compounds. The lower proportion of hydrocarbons in the bitumen (0.45) and the low hydrocarbon-to-organic carbon ratio (0.61 percent) are also indicative of the low degree of thermal maturity. The saturated hydrocarbons are the type usually associated with organic matter derived from aquatic plants under marine or lacustrine conditions, with exclusion of organic matter derived from vascular plants. Environments in which this type of organic matter is deposited and preserved usually result in rocks with capacity for liquid hydrocarbon generation. The indication of this type of organic matter, however, is in contrast to the pyrolysis results presented below.

Thermal analysis

The results of thermal analysis by Rock-Eval or MP-3 pyrolysis, summarized in table 2, suggest that the dredged samples have adequate organic matter content but not of the chemical type which generates liquid hydrocarbons. At the localities sampled, the rocks are immature to marginally mature with respect to the intensity and duration of geothermal exposure required for generation of significant amounts of petroleum.

The original hydrocarbon-generating capacity of the rocks is indicated in a semiquantitative fashion by the total hydrocarbon yield or genetic potential ($S_1 + S_2$, in ppm or kilogram of hydrocarbon per metric ton of rock). The values shown for the dredged samples on table 2 range from 130 to 1,530 ppm. This is less than the 2,000 ppm yield considered to be a minimum for oil source rocks but in the range of yield for rocks with some potential for gas generation (Tissot and Welte, p. 447).

The type of organic matter is indicated from Rock-Eval pyrolysis by the hydrogen index and the oxygen index, which are the pyrolytic hydrocarbon yield (S_2) and the pyrolytic organic CO_2 yield (S_3), respectively, each normalized by organic carbon content. Hydrogen indices for the analyzed 1977 samples, and both hydrogen and oxygen indices for the 1978 samples are calculated and shown in table 2. The 1978 data are plotted on the synthetic van Krevelen diagram (Espitalie and others, 1977; Tissot and Welte, 1978, p. 445 ff.), which shows the three main kerogen thermochemical evolution paths (fig. 3). The generally low hydrogen index suggests that the organic matter in the dredged samples is not the type that would generate mainly liquid hydrocarbons.

Taken at face-value, the results of thermal analysis indicate that the dredged samples from the Eastern Gulf of Alaska are not potential oil source rocks, but have limited potential for generating gas. However, the more detailed extraction analysis of the richest dredge samples from two localities revealed saturated hydrocarbon mixtures which are inconsistent with association with dominantly humic, gas-prone type of kerogen. This suggests that the hydrogen and oxygen indices may not reflect the original nature of the organic matter because of secondary alteration due to submarine weathering. Weathering can increase the oxygen content of organic matter, and this is reflected in lowered oil yields and increased water yields in Fischer assay of weathered shales (Brown and Breger, 1965). Rock-Eval pyrolysis of samples from weathering profiles obtained by shallow drilling into subaerial outcrops of uniform shale lithology shows occasional decrease of hydrogen index and increase of oxygen index in near-surface (<1 m) samples. The direction and magnitude of such possible effects are indicated by the arrows on figure 3.

Thermal maturity is interpreted from the temperature of maximum pyrolysis yield [$T(S_2)$] and the transformation ratio (S_1/S_1+S_2) given in table 2. In general, the transition from immature to mature with respect to oil generation is indicated by $T(S_2)$ values of about 440° C, and transformation ratios of about 0.1 (Tissot and Welte, 1978, p. 454). Based on these criteria, only the dredge samples near the western edge of the lease sale area give consistent indications of marginal thermal maturity. When the temperature of maximum pyrolysis yield is plotted as a function of latitude (fig. 4 , there is a suggestion of a gradient in thermal maturity increasing from east to west across the area of sample collection. However, because exceptionally rich rocks with the right type of kerogen can be effective source rocks at earlier stages of transformation, these criteria are best used as rough guides for interpretation and confirmation by use of other techniques is desirable.

The Rock-Eval pyrolysis data for the 1978 samples plotted on the kerogen classification diagram in figure 3 indicate that these rocks classify as Type III, or containing predominatly gas-prone organic matter. The extractable organic matter may be less representative of the bulk of the organic matter in the rock samples, because it constitutes such a small fraction of the total and because there is always the possibility that it is not indigenous. On the other hand, the pyrolysis results may reflect the deleterious effects of submarine weathering. Saturated hydrocarbons are known to be the most resistant fraction of the organic matter to the effects of nonbiological secondary alterations (Clayton and Swetland, 1978), and may be a better indicator of the original quality of the organic matter than the inference based on relative pyrolysis yields from weathered samples. In view of the pervasive oxidation of outcrop samples, with oxidized rinds to 10 cm thick, the latter alternative seems more likely. However, the contradiction cannot be resolved until fresh, preferably subsurface, samples of the same rock units are available.

Discussion

The results of analyses of argillaceous rocks of Eocene and Oligocene age dredged from the continental slope suggest that at least some of these rocks can be considered as possible source rocks on the basis of organic richness and thermal maturity. Considering that dredging is a random sampling technique, and that only a small number of dredge samples recovered pre-Yakataga argillaceous rocks, it is likely that rocks of comparable lithology are widely distributed on the continental slope and beneath the adjacent continental shelf.

The data indicate that at least one of the samples of probable early Eocene age from near the base of the slope (S5-78-EG-22D3) has generated petroleum hydrocarbons. A second sample of late Eocene age from about midway up the slope (S5-78-EG-44D) also contains extractable hydrocarbons, but of a type that indicates a somewhat lower thermal history. The Rock-Eval pyrolysis data, however, for all the samples are inconsistent with the extraction analysis in that the relatively low ratios of hydrogen index to oxygen index suggest that the organic matter present is predominantly of a chemical type which does not yield liquid hydrocarbons but could be a source of gas. Because of the high total organic carbon contents and abundance of marine organisms that should normally produce Type I kerogen in the samples (fig. 2) and the pervasive surface alteration of the rocks, we suggest that the discrepancy may be due to oxidation in the weathered zone.[1]

[1] Visual kerogen assessment (table 4) and vitrinite reflectance measurements (table 5), which became available after this paper was completed, tend to confirm our evaluation that the organic matter in the samples is of types that can generate both liquid hydrocarbons and gas but is more likely to be gas-prone, and that at least some of the organic matter is thermally mature.

Table 4. Visual Kerogen 1/

USGS Sample Identification	Visual Kerogen Percent Distribution of: Amorphous	Herbaceous	Humic	Inert	Thermal Alteration Index
S2-77-EG-11B	0	86	14	0	2.1
17B	0	83	17	0	2.2
17E	11	56	33	0	1.2
18A	0	56	44	0	1.2
20B	0	20	40	40	3.6
22B	0	83	17	0	2.3
S5-78-EG-22D2	0	71	29	0	2.4
22D3	22	44	33	0	2.6
44D	0	100	0	0	1.9
44E	0	83	17	0	1.9
44F	22	67	11	0	1.9

1/ Analyses by Geochem Research, Inc.)

MGG 0

Table 5. Vitrinite Reflectance [1/]

USGS Sample Identification	Number of Readings	Minimum Reflectance(%R_o)	Maximum Reflectance(%R_o)	Average Reflectance(%R_o)
S2-77-EG- 11B	50	.31	.48	.39
17B	50	.34	.50	.43
17E	20	.18	.29	.22
18A	46	.21	.36	.25
20B (Pop.1)	4	.49	.59	.54
(Pop.2)	50	2.90	3.64	3.32
22B	50	.37	.49	.43
S5-78-EG-22D2	50	.53	.67	.60
22D3(Pop.1)	9	.37	.59	.49
(Pop.2)	41	.79	1.03	.90
43F (Pop.1)	2	.27	.31	.29
(Pop.2)	50	.43	.63	.55
44D	46	.23	.40	.32
44E	50	.21	.42	.33
44F	25	.21	.38	.29

1/ Analyses by Geochem Research, Inc.)

On the basis of the stratigraphic units in which most of the oil seeps and other indications of petroleum were found onshore a probable source in the middle part of the Tertiary sequence (Poul Creek and Katalla Formation) was inferred (Plafker, 1971, 1974; Plafker and others, 1975, 1978 b). Overlying bedded rocks of Miocene and younger age (Yakataga Formation) characteristically have low organic carbon contents and poor source rock potential. Bedded rocks of Eocene age onshore (Kulthieth and Tokun Formations and unnamed siltstone unit) are hard, complexly deformed, coal-bearing continental and nearshore marine rocks believed to have little petroleum potential (Plafker and others, 1978b). However, the coeval rocks that have been dredged from the continental slope indicate that a marked improvement in the petroleum potential of the sequence occurs offshore.

The Eocene rocks sampled from the continental slope dip northward beneath thick sequences of younger strata that underlie much of the continental shelf. The association in the dredge hauls of potential source rocks with relatively clean sandstones and coarse conglomerates that could provide hydrocarbon reservoirs suggests that the Eocene sequence should be considered a possible petroleum source and exploratory target in the eastern Gulf of Alaska outer continental shelf.

References Cited

Brown, A., and Breger, I.A., 1965, Evaluation of weathering in the Chattanooga Shale by Fischer assay: U.S. Geol. Survey Prof. Paper 501-C, p. C92-C95.

Claypool, G.E., and Reed, P.R., 1976, Thermal-analysis technique for source-rock évaluation: quantitative estimate of organic richness and effects of lithologic variation: AAPG Bull. v. 60, No. 4, p. 608-612

Claypool, G.E., Love, A.H., and Maughan, E.D., 1978, Organic geochemistry, incipient metamorphism and oil generation in black shale members of the Permian Phosphoria Formation, Western Interior United States: AAPG Bull., v. 62, No. 1, p. 98-120.

Clayton, J.L., and Swetland, P.S., 1978, Subaerial weathering of sedimentary organic matter: Geochim. Cosmochim. Acta, 42, p. 305-312.

Espitalié, J., Laporte, J.L., Madec, M., Marquis, F., Leplat, P., Paulet, J., Boutefeu, A., 1977, Methode rapide de charactérisation des roches meres, de leur potential petrolier et de leur degre d'evolution: Rev. Inst. Fr. Pet., v. 32, p. 23-42.

Plafker, George, 1971, Pacific margin tertiary basin, in future petroleum provinces of North America: Am. Assoc. Petroleum Geologists Memoir 15, p. 120-135.

Plafker, George, 1974, Preliminary geologic map of Kayak and Wingham Islands, Alaska: U.S. Geological Survey Open File Map 74-82.

Plafker, George, Bruns, T.R., and Page, R.A., 1975, Interim report on the petroleum resource potential and geologic hazards in the Outer Continental Shelf of the Gulf of Alaska Tertiary Province: U.S. Geol. Survey Open File 75-592, 74 p.

Plafker, George, Winkler, G.R., Hunt, S.J., Bartsch-Winkler, Susan, Coonrad, W.L., and Quinterno, Paula, 1978 a, Outcrop Samples from the continental slope in the eastern Gulf of Alaska: U.S. Geol. Survey Circular 772-B, p. 97-101.

Plafker, George, Bruns, T.R., Carlson, P.R., Molnia, B.F., Scott, E.W., Kahler, Rodger, and Wilson, Charles, 1978 b, Petroleum potential, geologic hazards, and technology for exploration in the Outer Continental Shelf of the Gulf of Alaska Tertiary Province: U.S. Geol. Survey Open File Report 78-490, 33 p.

Tissot, B.P. and Welte, D.H., 1978, Petroleum formation and occurrence: Springer-Verlag, 538 p.

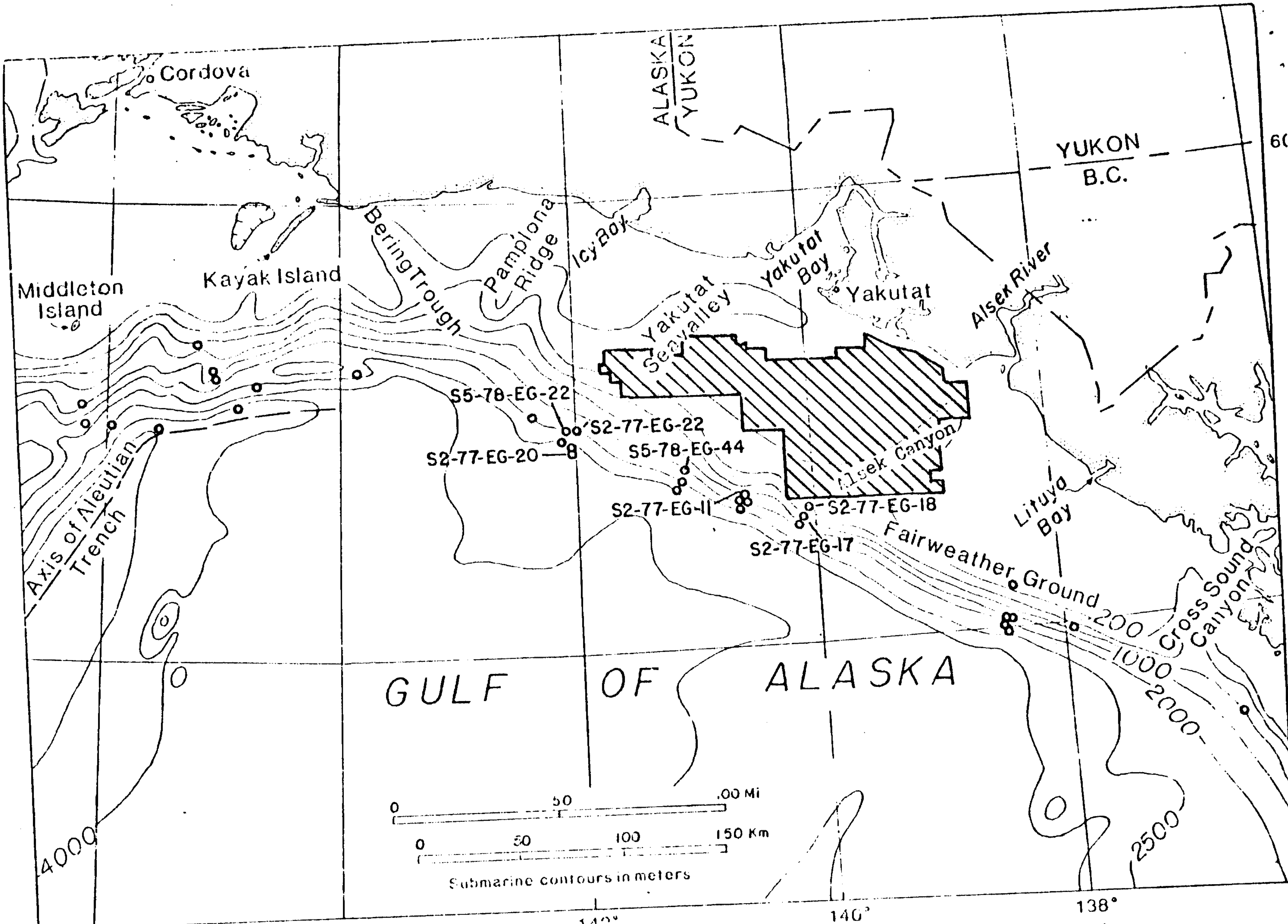

Figure 1.--Locations of dredged bedrock outcrop samples from the eastern Gulf of Alaska outer continental shelf. Numbered solid symbols indicate locations of samples analyzed for hydrocarbon source rock potential described in tables and text. Patterned area is the proposed OCS Lease Sale No. 55.

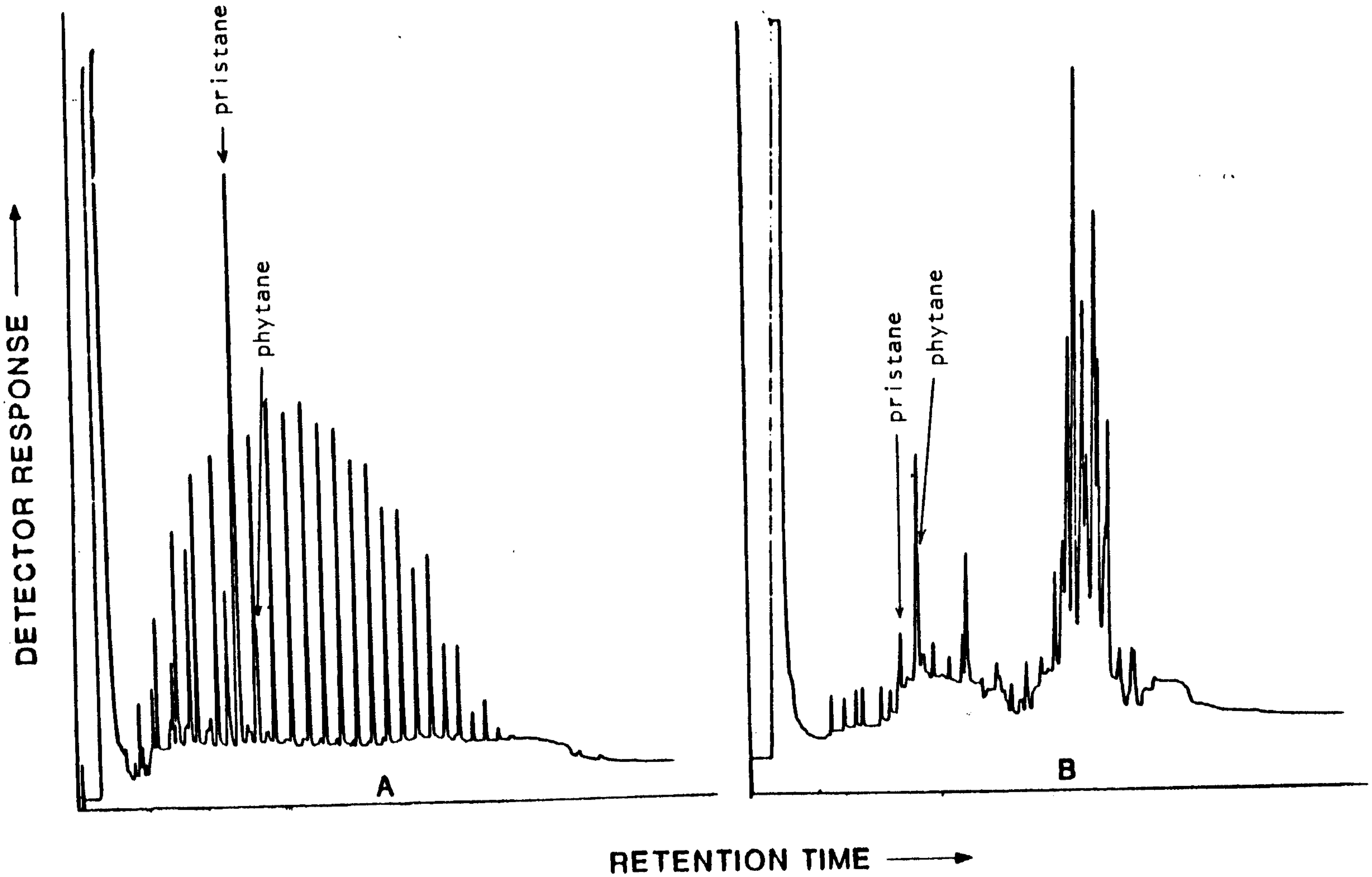

Figure 2.--Gas chromatographic analyses of saturated hydrocarbons in samples S5-78-EG-22D3 (A) and S5-78-EG-44D (B). Tentative compound identifications shown for index purposes.

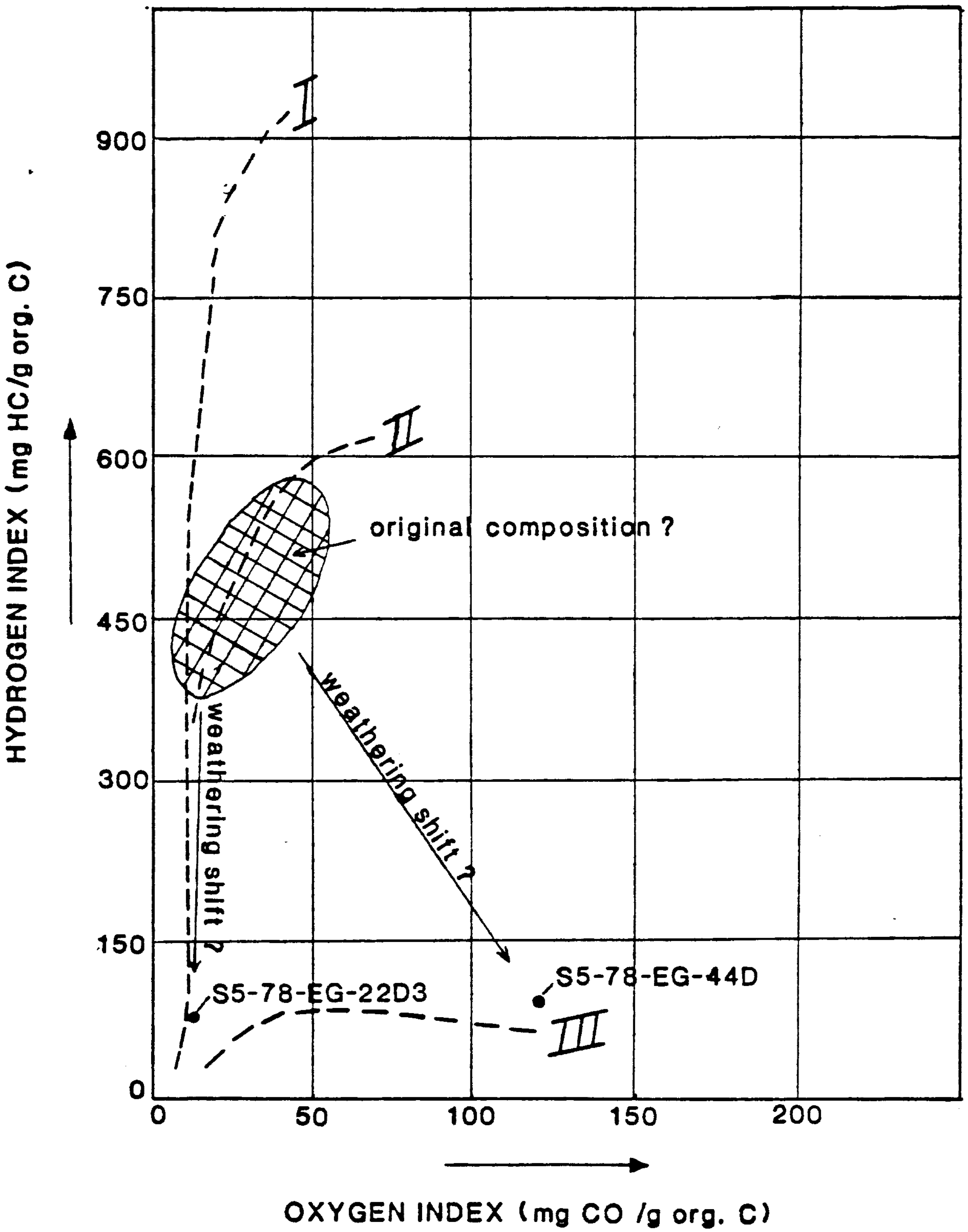

Figure 3.--Classification of source rock type for the 1978 samples using hydrogen and oxygen indices (Espitalié and others, 1977). The evolutionary trends of kerogen derived mainly from aquatic organisms (Type I), herbaceous plant material (Type II), and woody or coaly plant material (Type III) are shown by heavy dashed lines. Circled field indicates possible original composition, and arrows indicate possible shifts due to weathering of the pyrolysis response of the 1978 samples.

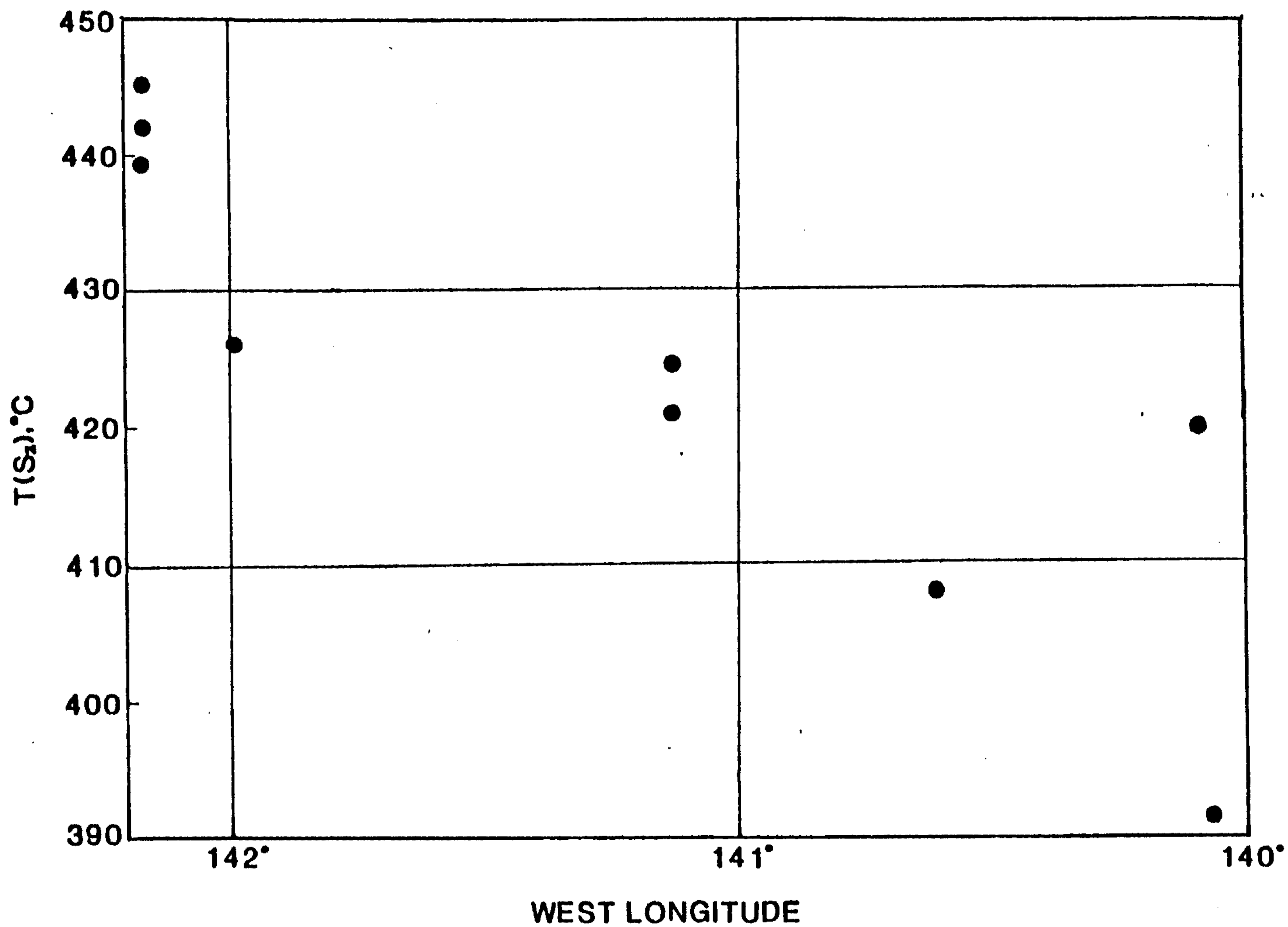

Figure 4.--Temperature of maximum pyrolysis yield [$T_{(S_2)}$, °C] versus approximate longitude of sample location for dredged samples.