UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PETROLEUM GEOLOGY OF COOK INLET BASIN, ALASKA--AN EXPLORATION MODEL

By

Leslie B. Magoon
U.S. Geological Survey
Menlo Park, California

and

George E. Claypool
U.S. Geological Survey
Denver, Colorado

OPEN-FILE REPORT
79-548

Menlo Park, California
January 1979

PETROLEUM GEOLOGY OF COOK INLET BASIN, ALASKA--AN EXPLORATION MODEL

By

Leslie B. Magoon
U.S. Geological Survey
Menlo Park, California

George E. Claypool
U.S. Geological Survey
Denver, Colorado

ABSTRACT

Oil exploration commenced onshore adjacent to lower Cook Inlet on the Iniskin Peninsula in 1900, shifted with considerable success to upper Cook Inlet from 1957 through 1965, then returned to lower Cook Inlet in 1977 with the COST well and Federal OCS sale. Lower Cook Inlet COST No. 1 well, drilled to a total depth of 3,776 m, penetrated the tops of Upper Cretaceous, Lower Cretaceous, and Upper Jurassic strata at 832 m, 1,541 m, and 2,112 m, respectively. Basinwide unconformities are present in this well at the tops of the Upper Cretaceous, Lower Cretaceous, and Upper Jurassic rocks. Sandstone of potential reservoir quality occurs in the Cretaceous and lower Tertiary rocks. All siltstones and shales analyzed are low (0-0.5 wt percent) in oil-prone organic matter, and only coals are high in humic organic matter. At total depth, vitrinite readings reached a maximum average reflectance of 0.65. Several indications of hydrocarbons were present.

U.S. Bureau of Mines and our oil analyses suggest that oils from the major fields of the Cook Inlet region, most of which produce from the Tertiary Hemlock Conglomerate, have a common source. More detailed work on stable carbon isotope ratios and the distribution of gasoline-range and heavy (C_{12+}) hydrocarbons confirms this genetic relation among the major fields. In addition, oils from Jurassic rocks under the Iniskin Peninsula and from the Hemlock Conglomerate at the southwestern tip of the Kenai lowland are members of the same or a very similar oil family. The Middle Jurassic strata of the Iniskin

Peninsula are moderately rich in organic carbon (0.5 to 1.5 wt percent) and yield shows of oil and of gas in wells and in surface seeps. Extractable hydrocarbons from this strata are similar in chemical and isotopic composition to the Cook Inlet oils. Organic matter in Cretaceous and Tertiary rocks is thermally immature in all wells analyzed.

Oil reservoirs in the major producing fields are of Tertiary age and unconformably overlie Jurassic rocks; the pre-Tertiary unconformity may be significant in exploration for new oil reserves. The unconformable relation between reservoir rocks and likely Middle Jurassic source rocks also implies a delay in the generation and expulsion of oil from Jurassic until late Tertiary time when localized basin subsidence and thick sedimentary fill brought older, deeper rocks to the temperature required for petroleum generation. Reservoir porosities, crude oil properties, the type of oil field traps and the tectonic framework of the oil fields on the west flank of the basin provide evidence used to reconstruct an oil migration route. The route is inferred to commence deep in the truncated Middle Jurassic rocks and pass through the porous West Foreland Formation in the McArthur River field area to a stratigraphic trap in the Oligocene Hemlock Conglomerate and the Oligocene part of the Tyonek Formation at the end of Miocene time. Pliocene deformation shut off this route and created localized structural traps, into which the oil moved by secondary migration to form the Middle Ground Shoal, McArthur River and Trading Bay oil fields. Oil generation continued into the Pliocene, but this higher API gravity oil migrated along a different route to the Granite Point field.

ACKNOWLEDGMENTS

Special thanks to Don Blasko, Bureau of Mines, for his help in collecting many oil and gas samples. Geologists from Marathon, Chevron, and Mobil Oil Companies generously supplied crude oil, core material, and cuttings from various wells. The State of Alaska provided drill cuttings from several wells critical to the study. Jeff Baysinger, Sister Carlos Lubeck, John Patterson, and Charles Threlkeld of the U.S. Geological Survey did the analytical work. Thane McCulloh, Chuck Kirschner, Irv Palmer, and John Bolm reviewed this paper and provided many helpful suggestions.

INTRODUCTION

Geological, geophysical, and more recently, geochemical information are collected, organized, and interpreted to provide a rationale for the oil explorationist to drill an exploratory well. The well will test the validity of the interpretation or exploration model which is interpreted from information that ranges from specific measurements to subjective descriptions. When the exploration well is successful by finding what is predicted in the model, then other wells will be drilled.

The Cook Inlet basin is used to demonstrate the exploration model based on the framework geology as interpreted from geological and geophysical information, and the petroleum geology as interpreted from geochemical information. When the explorationist, through the use of petroleum geochemistry, understands the oil forming processes--origin, migration, and accumulation of oil--, he will be able to create an exploration model on which to drill a well.

The Cook Inlet basin can be divided into upper and lower Cook Inlet at Kalgin Island. The commercial oil fields are located in upper Cook Inlet and are the source of some of the Tertiary oil samples. Other oil samples come from Tertiary rocks from wells on the Kenai lowland, and from Middle Jurassic rocks from wells on the Iniskin Peninsula; both areas are in lower Cook Inlet. An oil sample was collected from a seep near Becharof Lake on the Alaska Peninsula southwest of the Cook Inlet. Most rock samples came from wells in lower Cook Inlet, but a few rock samples came from wells in upper Cook Inlet.

An index map of the Cook Inlet area (fig. 1) shows geographic names, well locations, cross sections, and oil fields. Previous work on the origin of Cook Inlet oil is discussed by Kelly (1963), Osment, Morrow, and Craig (1967), Young, Monagham, and Schweisberger (1977), and Magoon and Claypool (in press). Publications that relate to the framework geology of this area are by Detterman and Hartsock (1966), Hartman, Pessel, and McGee (1972), Kirschner and Lyon (1973), Boss, Lennon, and Wilson (1976), Magoon, Adkison, and Egbert (1976b), and Fisher and Magoon (1978).

The lower Cook Inlet COST No. 1 well, the first well to be drilled in Federal waters, contains information on rock units that are not penetrated by adjacent onshore wells. The petroleum geochemistry and petroleum geology of oils and rocks provide information for the Cook Inlet oil exploration model.

COST NO. 1 WELL

Introduction.--Stratigraphic units penetrated in the Atlantic Richfield Company COST No. 1 well in lower Cook Inlet are Paleocene (West Foreland Formation), Upper and Lower Cretaceous, and Upper Jurassic (Naknek Formation) rocks. These units are shown in relation to Cook Inlet on figure 2. Sandstone of potential reservoir quality was found in the Tertiary and Upper Cretaceous rocks, and possibly in the Lower Cretaceous rocks. No rocks were found that contain sufficient organic material or thermal history to generate significant amounts of oil or gas.

The interpretation of this COST well is based on data submitted by industry as required by the U.S. Government (Wills and others, 1978). In our discussion we incorporate data from (1) paleontology reports by Boettcher (1977), Haga (1977), and Newell (1977a, b); (2) descriptions of sidewall and conventional cores by Ariey and McCoy (1977) and Ariey and Rathbun (1977); (3) porosity and permeability data by Core Laboratories, Inc. (1977a, b); (4) petrographic analysis of sandstones provided by Babcock (1977), Christensen (1977), Kuryvial (1977), Schluger (1977), and Swiderski (1977); and (5) organic geochemical data provided by Simpson (1977) and Van Delinder (1977). These reports can be consulted at the U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Upper Jurassic rocks.--The Upper Jurassic rocks (Naknek Formation) are penetrated from 2,112 m (6,930 ft) to total depth or 3,776 m (12,387 ft). All tops or thicknesses are log depths measured from the Kelly bushing. The top of the unit is placed just below the flood of *Inoceramus* fragments from the sidewall core at 2,109 m (6,920 ft) and just above the first indication of zeolites (laumontite) at 2,146 m (7,040 ft) on the indented resistivity, velocity and density curves. The big increase in interval velocity which occurs at 2,089 m (6,850 ft; Wills and others, 1978) is at the top of the lowermost sandstone of the Lower Cretaceous. The calcite rich sandstone contains no zeolite (laumontite), but is diagenetically altered (McCulloh, oral commun., 1978). The zeolite boundary in the well is 24 m deeper and is coincident with the top of the Naknek Formation. Paleontological data in this interval are sparse but a Late Jurassic age (Callovian to Tithonian) is suggested (fig. 3). Most of these rocks contain indications of a marginal to shallow marine environment possibly ranging as deep as middle neritic. Sidewall cores (fig. 4) indicate that siltstone, shale, and sandstone are the dominant rock types. Modal analyses of 28 thin sections indicate an average composition of $Q_{24}F_{55}L_{21}$ (quartz, feldspar, lithic) for the lithofeldspathic sandstone (Crook, 1960). Of 172 recorded sidewall cores, only 12 had favorable reservoir lithology. The average porosity and permeability of this sandstone is 17.9 percent and 39 millidarcies, respectively (table 1). Data from conventional cores indicate reservoir properties ranging from very poor to inadequate (table 1). The upper part (450-600 m) of the Naknek Formation in the well correlates with the rocks exposed along the southwest coast of the Kamishak Bay and the lower part (1,200-1,600 m) with the Naknek Formation exposed in the Iniskin-Tuxedni region (Detterman and Hartsock, 1966).

Lower Cretaceous rocks.--Lower Cretaceous rocks in the COST well are penetrated from 1,541 m (5,055 ft) to 2,112 m (6,930 ft) for a thickness of 571 m (1,875 ft). The top of these rocks is placed at the large abrupt excursion of the resistivity log and slight excursions of the velocity and density logs. A diverse population of marine microplankton and calcareous nannofossils indicates a Hauterivian to Barremian age, and the base may be as old as Valanginian. Foraminiferal data between 1,594 m (5,230 ft) and 2,109 m (6,920 ft) also indicate a similar age and middle bathyal to inner neritic marine environments. Sidewall cores of these rocks include sandstone, siltstone, shale, and *Inoceramus* fragments. Modal analyses of 37 thin sections indicate an average composition of $Q_{36}F_{44}L_{20}$ for the lithofeldspathic sandstone. The average porosity and permeability of the sidewall cores are 21.5 percent and 80 millidarcies, respectively (table 1). Conventional cores from depths of 1,642 m (5,390 ft) to 1,649.6 m (5,412 ft) average 13.9 percent porosity and 0.3 millidarcies permeability; these data are significantly lower than averages from sidewall cores, probably because sidewall cores are fractured by the core gun. These rocks are equivalent to the Lower Cretaceous rocks in the Kamishak Hills (Jones and Detterman, 1966) where they are 215 m (705 ft) thick (Magoon and others, 1978).

Upper Cretaceous rocks.--Upper Cretaceous rocks were penetrated in the COST well from 832 m (2,730 ft) to 1,541 m (5,055 ft) for a thickness of 709 m (2,325 ft). The top of this unit is placed on the abrupt excursion of the resistivity, velocity, and density curves at 832 m (2,730 ft). The age of this unit is Maestrichtian on the basis of palynomorphs, and Campanian and

Maestrichtian on the basis of foraminifers through intervals 832-1,036 m (2,730-3,400 ft) and 1,036-1,541 m (3,400-5,055 ft). Palynormorphs and foraminifers indicate that the water depth in which the rocks within these two intervals were deposited shallows upward from upper bathyal marine to nonmarine, or two prograding sedimentary sequences occur within Lower Cretaceous rocks (fig. 3). Sidewall cores indicate that this unit includes sandstone, siltstone, and some coal. Modal analyses of 21 thin sections indicate an average composition of $Q_{23}F_{61}L_{16}$ for the feldspathic sandstone. The average porosity and permeability of the sidewall cores is 22.8 percent and 43 millidarcies, respectively (table 1). The Upper Cretaceous rocks in this well correlate with the Maestrichtian parts of the Matanuska and Kaguyak Formations (Magoon and others, 1976a, b; Fisher and Magoon, 1978).

Lower Tertiary rocks.--The first indication (minimum depth) of lower Tertiary rocks (West Foreland Formation) is at 413 m (1,356 ft) and the deepest or bottom is at 832 m (2,730 ft) making this unit at least 419 m (1,374 ft) thick (fig. 3). On the basis of palynology, the age of this nonmarine unit is Eocene from 413 m (1,356 ft) to 552 m (1,810 ft) and Paleocene from 552 m (1,810 ft) to 832 m (2,730 ft). Mesozoic forms occur also in the Paleocene. Foraminifers, calcareous nannofossils and radiolarians are nondiagnostic. Rock types indicated by sidewall core samples are sandstone, siltstone, coal and some conglomerate (fig. 4). Modal analyses of eight thin sections indicate an average composition $Q_{23}F_{30}L_{47}$ for the feldspatholithic sandstone. The average porosity and permeability from sidewall cores is 22.7 percent and 108 millidarcies, respectively (table 1). This unit is presumed to be correlative with the West Foreland Formation which crops out on the west side of the Cook Inlet Basin (Magoon and others, 1976b; Fisher and Magoon, 1978).

Amount of thermal maturity of organic matter.--The kind and amount of organic matter and the degree of thermal maturity of the rocks penetrated in the lower Cook Inlet COST No. 1 well are unfavorable for generation of hydrocarbons (fig. 5). The organic carbon content from sidewall cores generally is less than 0.4 wt percent. The exceptions are four samples of nonmarine rocks of Late Cretaceous age that contain up to 1.44 wt percent organic carbon and one sample from Lower Cretaceous rocks with 0.68 wt percent organic carbon. The gas content (methane through butane, C_1-C_4) of drill cuttings is low and decreases in both total concentration (ppm C_1-C_4) and wetness content (C_2-C_4/ C_1-C_4 x 100 = %) with increasing depth of burial. Optical reflectance of vitrinite increases with depth and shows a significant and peculiar offset at the Lower and Upper Cretaceous unconformity. The average vitrinite reflectance reaches a maximum of 0.65 percent at the base of the section penetrated, where thermal alteration index (TAI) approaches a value of 3. These properties of the solid organic matter indicate that thermal alteration sufficient for hydrocarbon generation to have occurred. Extractable hydrocarbon-to-organic carbon ratios of greater than 1 percent support this indication (fig. 5).

Regional relation.--The COST No. 1 well is shown on the cross section A-A' (Fisher and Magoon, 1978) that transects lower Cook Inlet between the Iniskin Peninsula and the Kenai Peninsula (fig. 6). The implications of this transect and the above interpretation of the COST well data for the exploration model for Cook Inlet basin can be evaluated further by considering the origin and possible migration routes for the commercial oil accumulations in upper Cook Inlet.

PETROLEUM GEOCHEMISTRY

Oil production is presently restricted to the Tertiary rocks in upper Cook Inlet. Eighty percent of the oil being produced is from the Hemlock Conglomerate, 18 percent from the Tyonek Formation, and the remaining 2 percent from the West Foreland Formation. Oil was recovered in tests of the Hemlock Conglomerate in the Standard Oil Company North Fork No. 41-35 and the Pennzoil Starichkof State No. 1 wells near Homer. Oil shows from the Middle Jurassic rocks were detected in wells drilled on the Iniskin Peninsula (Detterman and Hartsock, 1966; Blasko, 1976a), and a "dead" oil smell was reported and confirmed in Upper Jurassic rocks from the Douglas River area (Miller, 1959; Magoon and others, 1976a). Southwest of the Cook Inlet area on the Alaska Peninsula, a series of seeps around Becharof Lake was also reported from Jurassic rocks (Blasko, 1976b).

The data and interpretation presented in this section are preliminary; more detailed analytic data on oils and rocks are being collected. The general composition of Cook Inlet oils is discussed and compared with organic matter in sedimentary rocks to determine possible genetic relations. The type of organic matter and thermal maturity of possible source rocks are also summarized briefly.

Oils

General crude oil composition.--The API gravity of selected Cook Inlet crude oils is plotted against depth of producing interval in meters (fig. 7). These are Bureau of Mines data (Blasko and others, 1972, p. 21) except for the Iniskin Bay Association, IBA No. 1 well, for which API gravity and sulfur content was reported by Detterman and Hartsock (1966, p. 73). The API gravity and sulfur content of the Beal No. 1 oil is from our laboratory. There is no systematic trend of API gravity with depth. The IBA No. 1 and Beal No. 1 oils, both from the Red Glacier Formation of the Tuxedni Group of Middle Jurassic age, and the Granite Point and the North Cook Inlet oils, both from the lower Tyonek Formation of Oligocene age all have higher API gravity than other Cook Inlet oils. Sulfur content decreases with increasing API gravity (fig. 8). Sulfur compounds are predominant in the higher-boiling nonhydrocarbon fractions of crude oils. In a related family of crude oils, such as those produced from reservoirs of Tertiary age in the Cook Inlet, both API gravity and sulfur content reflect the proportion of these high-boiling compounds in the oil. If the sulfur contents for the oil samples from IBA No. 1 and Beal No. 1 wells are representative of all oils that originate in Jurassic rocks in the Cook Inlet region, they would argue against a common origin with other Cook Inlet oils. However, the sulfur contents of these Iniskin Peninsula oils also may reflect regional differences in organic matter in Jurassic source rocks or in oils which have undergone little or no migration.

In the results of U.S. Bureau of Mines Hempel distillation analyses (after Blasko and others, 1972, p. 23), plotted in figure 9, the correlation index is plotted against the number of distillation fraction. Correlation index, derived from the specific gravity of each distillation fraction, indicates relative but indeterminate proportions of paraffin-naphthene-aromatic hydrocarbon types in each distillation fraction. For example, a correlation index value of 100 indicates 100 percent aromatic ring structures, and a value of 0 indicates a hydrocarbon mixture composed only of paraffinic structures. Correlation index values are a useful tool for empirical correlation. As indicated, all of the Cook Inlet oils from Tertiary reservoir rocks have a similar shaped curve; only the average and the high and low extremes are shown in figure 9. The shallow Trading Bay oil is relatively depleted in paraffins (upper curve) and the North Cook Inlet high-gravity oil is relatively enriched in paraffins (lower curve). The oils from Middle Jurassic rocks under the Iniskin Peninsula were not analyzed by the Bureau of Mines.

Gasoline-range hydrocarbons.--The detailed gasoline-range hydrocarbon compositions of Cook Inlet oils (fig. 10) are similar, including the Jurassic oil from the Beal well, except for the shallow Trading Bay oil and the Kenai condensates. As was indicated by specific gravity or correlation index, the composition of shallow Trading Bay oil deviates from typical Cook Inlet oils because it has been depleted in normal paraffins, undoubtedly by the selective partial removal of *n*-paraffins by hydrocarbon-oxidizing bacteria. The activity of these bacteria in the deeper reservoirs is prevented by the higher subsurface temperatures. The other deviant hydrocarbon mixtures are condensate samples from the Kenai gas field. The high proportion of naphthenes in the C_7 saturates may be characteristic of hydrocarbons originating in the thermally immature Tertiary section.

Gas chromatography of C_{12+} *saturates*.--The heavy saturated hydrocarbon fractions of Cook Inlet oils were separated by elution chromatography and evaporation of the solvent leaving a residue of compounds with 12 or more carbon atoms. Analyses of these fractions are illustrated in figure 11. The response of the gas chromatographic detector is plotted against the temperature of the column, which is increased from 80° to 320° C at a rate of 10° C/min. All the oils produced from the Hemlock Conglomerate resemble the samples from North Fork and McArthur River (fig. 11), except for the shallow Trading Bay oil, which is depleted in normal paraffins. A dead oil stain from a sandstone outcrop of Jurassic age at the mouth of the Douglas River is even more extensively degraded. In comparison, the oil from the Beal No. 1 well on the Iniskin Peninsula is similar but not identical to the typical Cook Inlet oils. The distribution of saturated hydrocarbons in the oil from the Beal No. 1 well is shifted toward the lower boiling-point range relative to the typical Cook Inlet oils. This difference does not rule out a common source for these oils in Jurassic rocks. It is possible that the composition of the oil from the Beal No. 1 well reflects a history of higher temperatures, compared with oils to the northeast.

Stable carbon isotope ratios.--The C_{12+} saturated hydrocarbon fractions were analyzed for $^{13}C/^{12}C$ ratio (fig. 12). The samples shown are the typical Cook Inlet oils produced from the Hemlock Conglomerate and other Tertiary zones, plus the oils from the Beal No. 1 well and Becharof Lake seep, both from Jurassic rocks. All of the oils are within two parts per thousand, between -32 and -30 permil; an exception is the Kenai condensate at -26.7 permil. These results are consistent with the major hydrocarbon occurrences being generated from a common source in Middle Jurassic rocks.

Rocks

Possible source rocks.--Nonmarine Tertiary, marine Cretaceous, and marine Middle Jurassic sequences are the most likely sources of Cook Inlet oil. We have attempted to analyze representative samples of each of these sequences. In general, the nonmarine Tertiary sequence is rich in organic matter (mainly because of the presence of coal), but the samples analyzed to date are judged to be thermally immature. The Jurassic samples analyzed to date are only marginal in terms of organic richness but appear to have reached thermal maturity.

Gas chromatography of C_{12+} saturates.--Hydrocarbon mixtures of the C_{12+} saturated hydrocarbons extracted and analyzed by gas chromatography from Cretaceous and Tertiary rocks do not resemble Cook Inlet petroleum (fig. 13). However, extracts from Jurassic rocks on the Iniskin Peninsula are similar to Cook Inlet petroleum. The samples analyzed are the Tertiary (West Foreland Formation, Hemlock Conglomerate, and Tyonek Formation) and the Cretaceous (Matanuska Formation) rocks from the Deep Creek No. 1 well and the Middle Jurassic rocks from the Beal No. 1 well and the Mobil MUC I-1 wells. Samples from the Deep Creek No. 1 well all show odd-carbon predominance in the C_{23}-C_{32} *n*-paraffins. Even the Middle Jurassic sample from 4,556.8 m depth in the Granite Point field--Mobil MUC I-1 well--has a slight apparent odd-carbon predominance in the n-C_{29} region, although no more so than some of the Cook Inlet oils (see North Fork 41-35 oil in fig. 11). The sample of saturated hydrocarbons extracted from the Red Glacier Formation in the Beal No. 1 well closely resembles the oil produced from this well. This particular sample was a composite of washed drill cuttings collected over the interval 2,188 to 2,323 m. The organic carbon content is 1.1 wt percent and the extractable hydrocarbon (saturated plus aromatic) content is 715 ppm for the composite sample from the Beal No. 1 well (fig. 13). This sample and other samples of Middle Jurassic rocks in the same well are indications of the most likely source rocks for the Cook Inlet oils on the basis of organic richness, thermal maturity, and hydrocarbon composition.

Stable carbon isotope ratios.--Stable carbon isotope ratios for some of the rock extracts (table 2) are all heavier than comparable fractions from the crude oils (fig. 12); however, oils are often 1 to 1.5 permil lighter than extractable hydrocarbons in rocks from which the oils were derived (Baker and Ferguson, 1964). In summary, stable carbon isotope ratios do not exclude either the Jurassic or Tertiary rocks as a possible source for the Cook Inlet oil.

Type and thermal maturity of organic matter.--Thermal-evolution analysis employing a flame ionization detector (TEA-FID) was used to evaluate the richness, type, and thermal maturity of organic matter in sedimentary rocks of the Cook Inlet. In this analysis, a small sample of rock is heated under controlled conditions and hydrocarbons are measured as they are thermally evolved from the rock. Response of the detector is calibrated by analysis of known amounts of synthetic standard (4.24 percent n-$C_{20}H_{42}$ on Al_2O_3). Separately measured are (1) hydrocarbons present in the rock (peak I), (2) hydrocarbons produced by thermal decomposition of kerogen (peak II), and (3) the absolute temperature required to cause a maximum in pyrolysis products of the organic matter in the rock (peak II). General interpretation of the results of this type of analysis is summarized by Barker (1974a, b), Claypool and Reed (1976), and Espitalie and others (1977).

Type of organic matter and thermal maturity are considered for rocks from five wells, which are depicted on a stratigraphic section from the Iniskin Peninsula to the Kenai lowland (fig. 14). Only the Beal No. 1 well on the Iniskin Peninsula and North Fork Unit No. 41-35 on the Kenai lowland contain Middle Jurassic rocks. Four of the five wells were analyzed by TEA-FID (fig. 15). Total pyrolytic hydrocarbon yield (PHC)--peak I plus peak II--divided by organic carbon content (OC), expressed in percent, is plotted against sample depth. This parameter, PHC/OC, is sensitive to a type of organic matter and to the degree of thermal maturity of a type (hydrogen-deficient) which does not yield hydrocarbons upon pyrolysis, or (2) the organic matter is thermally postmature or "overcooked" and has previously yielded hydrocarbons. Since none of the rocks analyzed have other properties suggesting that they are postmature, the results can be interpreted in terms of type of organic matter, or the proportion of the total organic matter which is "live" and can be converted to hydrocarbons. In this sequence coals and organic matter believed to be more "gas-prone" have PHC/OC values of 0-30 percent. In terms of this measurement, Middle Jurassic rocks in the Beal No. 1 and North Fork Unit No. 41-35 are the only potential oil source rocks. It should be stressed that these results are preliminary, and interpretations may require modification on the basis of more detailed future work. Also, because much of this sample material is washed drill cuttings that may not have been air-dried, the sample quality is suspect. In the north, in the Granite Point field (Mobil MUC I-1), core material from the Middle Jurassic was recovered and analyzed (fig. 1). This gray siltstone from a drill depth of 4,463 to 4,789 m is submature to mature and organically lean; the sample however, is probably not representative of the complete Middle Jurassic sequences from upper Cook Inlet.

The thermal maturity of rocks from wells on the stratigraphic cross section and the Mobil MUC I-1 well can be estimated using the temperature of maximum pyrolysis yield from TEA-FID analysis (fig. 16) and vitrinite reflectance. The best or most probable fit lines drawn by eye are different for the Kenai lowland rocks and the Iniskin Peninsula rocks. Vitrinite reflectance measurements from the North Fork Unit No. 41-35 well were made by Shell Oil Company and made available through the State of Alaska. These measurements show reflectance values of 0.5 percent or less on coals from 3,655 to 3,883 m in this well. Such values are generally considered thermally immature.

OIL FIELDS

Producing oil fields in upper Cook are located on the east and west flanks of the basin (fig. 1). East-flank fields include Swanson River and Beaver Creek; west-flank fields include Middle Ground Shoal, McArthur River, Trading Bay (3 pools) and Granite Point. All these fields are structural traps: anticlines or faulted anticlines with separate oil pools or productive horizons having unique oil-water contracts (Alaska Geological Society, 1970; Blasko and others, 1972; Kirschner and Lyon, 1973; Boss and others, 1976; Petroleum Data System, 1977). The oil reservoirs are nonmarine sandstone and conglomerate. Initial gas-oil ratios (GOR) range from 65 to 1,110 (table 3). Also, none of the structures appear to be filled to capacity (Alaska Geological Society, 1970; Boss and others, 1970).

Reservoir porosity.--Reservoir porosity in the Hemlock Conglomerate from the producing oil fields, plotted against depth, is higher in the east flank than in the west flank (fig. 17). Porosities publicly available for rocks in the Beaver Creek field are extraordinarily high for burial depths of over 4.5 km. The average porosity of the Hemlock Conglomerate reservoirs on the west flank ranges from 8 to 13 percent, and individual values generally fall on a straight line "A" (fig. 17, table 3). The average porosities of the West Foreland and Tyonek Formations range from 14 to 21 percent and also fall on a straight line "B", parallel to "A" but separated from it by 6 porosity units. Projecting these straight lines "A" and "B" back to the surface indicate original porosities of 18 and 24 percent, respectively, which are much too low for unconsolidated sandstone and conglomerate (Maxwell, 1964; Zieglar and Spotts, 1978). Reservoir data on the east flank suggest that porosity was preserved during burial, which occurs when oil is emplaced at a shallow depth, in contrast to the porosity trends on the west flank, where reservoir bodies appear to have been tectonically relocated after maximum burial depth.

The porosity data available for these three stratigraphic units are restricted to commercially producing oil reservoirs; there are no data for water-saturated rocks in these units. The data presented here are from a small sample of a potentially large population, especially if the total lateral extent of these units is considered. Therefore, our conclusions about porosity trends are qualitative, not quantitative. Also, other factors not mentioned above should affect original porosities. For example, the original sediments of the Hemlock Conglomerate on the east flank should be better sorted and contain more quartz than those on the west flank because they are farther from the sediment source area.

Oil plumbing system.--A geologic reconstruction that shows the timing for the origin, migration routes and areas of entrapment for the oil on the west flank of the Cook Inlet depends on the interpretation of the data presented and also on certain assumptions: (1) Middle Jurassic source rocks are truncated by the West Foreland Formation somewhere between McArthur River and Middle Ground Shoal fields as depicted in the generalized cross section by Boss, Lennon, and Wilson (1976, fig. 18); (2) the deformation of the reservoir rocks occurred during the Pliocene and Pleistocene; and (3) faults are sealing and not avenues for oil migration.

For oil to migrate from the source rock into the lower Tertiary reservoir rocks requires that the west flank be reconstructed to its geologic configuration at the end of Miocene time (top of the Beluga Formation, fig. 19). The pre-Pliocene Tertiary rocks thin to the west and the reservoir rocks dip to the east. The high porosity and permeability in the West Foreland Formation in the McArthur River field area provides an avenue for oil migration into the Hemlock Conglomerate and Tyonek Formation. The narrow ranges of the API oil gravities (30-35, fig. 7) and porosity values (fig. 17, table 3) result because the oils were expelled at the same temperature, and the reservoir rocks experienced a similar burial history. A large stratigraphic oil field was on the west flank at the end of Miocene time.

Deformation during Pliocene and Pleistocene time caused the stratigraphically trapped oil to remigrate into the present fields and simultaneously shut off original oil migration routes from the source rock (fig. 18). The oil then may have been shunted to the Granite Point field (API 40°). By Pliocene and Pleistocene time, burial depth and deformation had greatly diminished the oil reservoir properties of the Hemlock Conglomerate, while the Tyonek Formation, which was shallower and inherently a better reservoir, was still capable of being charger (fig. 17). Gradually this oil system also was shut off. This migration pattern explains the lower gas-oil ratios (65-650) and API gravities (30-35) in the McArthur River field area compared to the higher gas-oil ratios (700-1,110) and API gravity (40) in the Granite Point field.

EXPLORATION MODEL

If upper Cook Inlet reservoirs were charged in the manner hypothesized, then this model can be applied to the Cook Inlet basin to explore for petroleum accumulations. This exploration model applied to upper Cook Inlet suggests three areas of exploration: (1) the updip pinch-out edge (fig. 19) of the Hemlock Conglomerate and Tyonek Formation west of the McArthur River field area; (2) the thrust-fault trap (fig. 19) on the east flank of the Middle Ground Shoal field; and (3) the fault blocks and structures (fig. 18) adjacent to the Swanson River field.

This exploration model can also be applied to lower Cook Inlet but there are several important differences between the areas. First, with the exception of the folded Jurassic rocks on the Iniskin Peninsula, structural deformation is mild in lower Cook Inlet compared to upper Cook Inlet. Second, in lower Cook Inlet the Tertiary strata thin toward the Augustine-Seldovia arch and then thicken gradually to the south (Fisher and Magoon, 1978) compared to the very thick (7,600 m; Hartman and others, 1972) Tertiary section in upper Cook Inlet. Last, in lower Cook Inlet the unconformity at the base of the Tertiary on the west flank truncated rocks only as old as Upper Jurassic in the Iniskin-Tuxedni area (Detterman and Hartsock, 1966) and, in the areas of the COST well and Cape Douglas, Upper Cretaceous (Magoon and others, 1976b). In upper Cook Inlet the unconformity at the base of the Tertiary truncates the complete Mesozoic section at one place or another (figs. 6 and 18). Only on the east flank in lower Cook Inlet does the Tertiary overlie all the Mesozoic rocks (fig. 6). The upper Cook Inlet model can be applied directly in this area.

SUMMARY AND CONCLUSIONS

The conclusions presented here must be considered tentative as they are drawn from a very limited data base. Generally, most of the geochemical data come from lower Cook Inlet whereas most of the oil data come from upper Cook Inlet. It is therefore difficult to make statements about possible oil sources for upper Cook Inlet oils from lower Cook Inlet rocks. Any stratigraphic interval could be an oil-prone source rock in an undrilled or deeper thermally mature part of the basin. Also, using different methods or approaches to the interpretation of geochemical data, other conclusions regarding the origin of Cook Inlet oil are possible (Young and others, 1977).

The potential of Cook Inlet for oil, evaluated with respect to the reservoir rocks encountered in the COST well and the relation of west flank fields to the oil system, can be stated more definitely. The potential is highest where Tertiary or Cretaceous reservoir rocks truncate Middle Jurassic source rocks.

Several lines of evidence suggest that Middle Jurassic rocks are a possible source of all the commercially important oil in the Cook Inlet basin. Nonmarine Tertiary rocks are tentatively eliminated as possible oil source rocks because they are thermally immature and because they contain a coaly type of organic matter that does not yield liquid hydrocarbons efficiently upon pyrolysis. Cretaceous rocks are also tentatively eliminated as possible source rocks because of their inadequate organic richness and thermal immaturity. Only Middle Jurassic rocks contain adequate amounts of thermally mature, oil-prone organic matter and extractable hydrocarbons that both chemically and isotopically resemble Cook Inlet oil.

The petroleum in west-flank oil fields first concentrated in a large stratigraphic trap in Tertiary rocks at the end of Miocene time. Plicoene and Pleistocene deformation caused secondary migration of this oil into present structural accumulations.

REFERENCES CITED

Alaska Geological Society, 1970, Oil and gas fields in the Cook Inlet basin, Alaska: Anchorage, Alaska Geological Society, 84 p.

Ariey, Cass, and McCoy, Scott, 1977, Sidewall sample description, Atlantic Richfield lower Cook Inlet COST No. 1: Atlantic Richfield Company, 45 p. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Ariey, Cass, and Rathbun, Fred, 1977, Core description report, cores 1-4, Atlantic Richfield lower Cook Inlet COST No. 1: Atlantic Richfield Company, 8 p. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Babcock, Laurel, 1977, Petrographic description of thin sections from lower Cook Inlet COST well: AMOCO Production Company, 3 p., 1 table, appendix (6 p.). Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Baker, D. R., and Ferguson, W. S., 1964, Stable carbon isotopes in petroleum and sediment hydrocarbons from the Cherokee petroleum province: Geological Society of America Special Paper 82, p. 71.

Barker, C., 1974a, Pyrolysis techniques for source-rock evaluation: American Association of Petroleum Geologists, v. 58, p. 2349-2361.

______ 1974b, Programmed-temperature pyrolysis of vitrinites of various coal rank: Fuel, v. 53, p. 176-177.

Blasko, D. P., 1976a, Oil and gas exploration of the Iniskin Peninsula, Alaska: Bureau of Mines, Open-file Report 69-76, 19 p.

______ 1976b, Oil and gas seeps in Alaska, Alaska Peninsula, western Gulf of Alaska: Bureau of Mines Report Investigations 8122, 78 p.

Blasko, D. P., Wenger, W. J., and Morris, J. C., 1972, Oil fields crude oil characteristics, Cook Inlet basin, Alaska: U.S. Geological Survey Report of Investigations 7688, 25 p.

Boettcher, R. R., 1977, Foraminifera Reports--Parts I, II, III: Atlantic Richfield Company, COST No. 1: Anderson, Warren and Associates, Inc., 38 p., 3 figs., 3 tables. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Boss, R. F., Lennon, R. B., and Wilson, B. W., 1976, Middle Ground Shoal oil field, Alaska, <u>in</u> Braunstein, Jules, ed., North American oil and gas fields: American Association of Petroleum Geologists Memoir 24, p. 1-22.

Christensen, E. W., 1977, Petrographic report, sidewall samples (23), 5,120-10,145 feet, Atlantic Richfield lower Cook Inlet COST No. 1: Chevron USA, 4 p., 1 table. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Claypool, G. E., and Reed, P. R., 1976, Thermal-analysis technique for source rock evaluation: Quantitative estimate of organic richness and effect of lithologic variation: American Association of Petroleum Geologists Bulletin, v. 60, p. 608-626.

Core Laboratories, Inc., 1977a, Core analysis results, cores 1-4, Atlantic Richfield lower Cook Inlet COST No. 1: Core Laboratories, Inc., 4 p. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

______ 1977b, Sidewall core analysis results, sidewall cores, Atlantic Richfield lower Cook Inlet COST No. 1: Core Laboratories, Inc., 4 p. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Crook, K. A. W., 1960, Classification of arenites: American Journal of Science, v. 258, p. 419-428.

Detterman, R. L., and Hartsock, J. K., 1966, Geology of the Iniskin-Tuxedni region, Alaska: U.S. Geological Survey Professional Paper 512, 78 p.

Espitalie, J., Macdec, M., Tissot, B., Menning, J. J., and Leplat, P., 1977, Source rock characterization method for petroleum exploration: Proceedings of the 9th Annual Offshore Technology Conference, Houston, Texas, p. 439-444.

Fisher, M. A., and Magoon, L. B., 1978, Geologic framework of lower Cook Inlet Alaska: American Association of Petroleum Geologists Bulletin, v. 62, no. 3, p. 373-402, 18 figs., 1 table.

Haga, Hideyo, 1977, Palynology report--Parts I, II, III--Atlantic Richfield Company COST well No. 1: Anderson, Warren and Associates, Inc., 14 p., 3 figs. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Hartman, D. C., Pessel, G. H., and McGee, D. L., 1972, Preliminary report of stratigraphy of Kenai Group, upper Cook Inlet, Alaska: Division of Geological Survey, Department of Natural Resource, State of Alaska, Special Report No. 5.

Jones, D. L., and Detterman, R. L., 1966, Cretaceous stratigraphy of the Kamishak Hills, Alaska Peninsula, in Geological Survey Research 1966: U.S. Geological Survey Professional Paper 550-D, p. D53-D58.

Kelly, T. E., 1963, Geology and hydrocarbons in Cook Inlet basin, Alaska, in Childs, O. E., and Beebe, B. W., eds., Backbone of the Americas: American Association of Petroleum Geologists Memoir 2, p. 278-296.

Kirschner, C. E., and Lyon, C. A., 1973, Stratigraphic and tectonic development of Cook Inlet petroleum province, in Pitcher, M. G., ed., Arctic geology: American Association of Petroleum Geologists Memoir 19, p. 396-407.

Kuryvial, R. J., 1977, Diagenetic alteration of sandstones from lower Cook Inlet COST No. 1: Cities Service Company. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Magoon, L. B., Adkison, W. L., Chmelik, F. B., Dolton, G. L., Fisher, M. A., Hampton, M. A., Sable, E. G., and Smith, R. A., 1976a, Hydrocarbon potential, geologic hazards, and infrastructure for exploration and development of the lower Cook Inlet, Alaska: U.S. Geological Survey Open-file Report 76-449, 124 p.

Magoon, L. B., Adkison, W. L., and Egbert, 1976b, Map showing geology, wildcat wells, Tertiary plant-fossil localities, K-Ar age dates and petroleum operations, Cook Inlet area, Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-1019, 3 sheets, color, scale 1:250,000.

Magoon, L. B., and Claypool, G. E., Origin of Cook Inlet oil: Proceedings of the Alaska Geological Society Symposium, April 4-6, 1977, Anchorage, Alaska, 16 p., in press.

Magoon, L. B., Egbert, R. M., and Petering, George, 1978, Upper Jurassic and Cretaceous rocks of the Kamishak Hills-Douglas River area, lower Cook Inlet, _in_ Blean, K. M., ed., The United States Geological Survey in Alaska: accomplishments during 1977: U.S. Geological Survey Circular 772-B, p. B57-B59, 1 fig., 2 plates.

Maxwell, J. C., 1964, Influence of depth, temperature, and geologic age on porosity of quartzose sandstone: American Association of Petroleum Geologists Bulletin, v. 48, p. 697-709.

Miller, D. J., 1959, Geology of possible petroleum provinces of Alaska, southern Alaska: U.S. Geological Survey Bulletin 1094, p. 8-52.

Newell, J. H., 1977a, Calcareous nannofossil reports--Parts I, II, III--Atlantic Richfield lower Cook Inlet COST No. 1: Anderson, Warren and Associates, Inc., 12 p., 2 tables. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

______ 1977b, Siliceous microfossil report--Part I--Atlantic Richfield lower Cook Inlet COST No. 1: Anderson, Warren and Associates, Inc., 1 p. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Osment, F. C., Morrow, R. M., and Craig, R. W., 1967, Petroleum geology and development of the Cook Inlet basin of Alaska (with French abs.), _in_ Origin of oil, geology, and geophysics: 7th World Petroleum Congress Proceedings, Mexico, 1967, London Elsevier Publishing Company, v. 2, p. 141-150.

Petroleum Data System, 1977, Oil and gas field data, Alaska to December 1977: Petroleum Data System (PDS), the University of Oklahoma, Oklahoma, 129 p.

Schluger, P. R., 1977, Petrographic summaries of sidewall cores from 1,810-4,560 feet, Core 1 and Core 2, Atlantic Richfield lower Cook Inlet COST No. 1: Mobil Oil Corporation, 10 p., 1 fig. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Simpson, H. M., 1977, Vitrinite reflectance, Atlantic Richfield lower Cook Inlet COST No. 1: Atlantic Richfield Company, 2 p., 5 figs., appendix, 43 p. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Swiderski, T. J., 1977, Petrographic analysis of Cretaceous and Jurassic samples from the lower Cook Inlet COST No. 1 well, Alaska: Phillips Petroleum Company, 10 p., 1 table. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Van Delinder, D. G., 1977, Hydrocarbon source facies analysis COST lower Cook Inlet No. 1 well, Cook Inlet, Alaska: Geochem Laboratories, Inc., 14 p., 6 figs., 8 tables. Basic data can be consulted at U.S. Geological Survey, Conservation Division, Office of the Oil and Gas Supervisor, Anchorage, Alaska.

Van Eysinga, F. W. B., 1975, Geologic time table: Elsevier, Amsterdam.

Wills, J. C., Bolm, J. G., Stewart, G. H., Turner, R. F., Lynch, M. B., Petering, G. W., Parker, John, and Schoof, Brian, 1978, Geological and operational summary, Atlantic Richfield lower Cook Inlet, Alaska, COST well No. 1: U.S. Geological Survey Open-file Report 78-145, 46 p.

Wolf, J. A., 1977, Paleogene floras from the Gulf of Alaska region: U.S. Geological Survey Professional Paper 977, 108 p., 30 plates.

Young, Allen, Monagham, P. H., and Schweisberger, R. T., 1977, Calculation of ages of hydrocarbons in oils--physical chemistry applied to petroleum geochemistry I: American Association of Petroleum Geologists Bulletin, v. 61, no. 4, p. 573-600.

Zieglar, D. L., and Spotts, J. H., 1978, Reservoir and source-bed history of Great Valley, California: American Association of Petroleum Geology, v. 62, p. 813-826.

Table 1.—*Petrophysical Properties of Sandstone, COST No. 1 Well*

Unit	Thick- ness (m)	Measure- ments	Porosity (%)			Permeability (md)		
			Low	High	Average	Low	High	Average
Sidewall Cores								
Tertiary rocks	419	17	13.2	28.1	22.7	2.2	565	108
Upper Cretaceous rocks	709	35	15.6	28.9	22.8	1.8	153	43
Lower Cretaceous rocks	571	28	17.7	25.2	21.5	1.7	265	80
Upper Jurassic rocks	1,664	12	12.6	25.5	17.9	.7	228	39
Conventional Cores								
Lower Cretaceous rocks	6.7	15	8.5	19.5	13.9	0	0.8	0.3
Upper Jurassic rocks	7.6	27	1.8	6.7	3.5	0	7.8	0.6
Upper Jurassic rocks	4.9	17	0.3	3.3	2.2	0	0	0
Upper Jurassic rocks	9.2	31	1.1	4.1	2.9	0	0	0

Table 2.--*Carbon isotope ($\delta^{13}C$) of C_{12+} saturated hydrocarbon rock extract*

Well	Rock unit	Depth (m)	$\delta^{13}C$, permil vs. PDB
Deep Creek No. 1	Tyonek Formation	2,823	-28.8
Deep Creek No. 1	Tyonek Formation	3,136	-28.8
Deep Creek No. 1	Hemlock Conglomerate	3,718	-29.9
Deep Creek No. 1	West Foreland Formation	4,175	-29.2
Beal No. 1	Red Glacier Formation	2,811-2,323	-29.5

Table 3.--*Oil Field Reservoir Properties, Cook Inlet, Alaska*

No.[1]	Field	Symbol[1]	Rock unit	Gas-oil ratio	Producing interval depth (m)	Porosity (%)			Permeability (md)		
						Low	High	Average	Low	High	Average
1	Trading Bay	□	Tyonek Formation	268	762-1,676	16	25	(21)[2]	100	300	—
2	Middle Ground Shoal	■	Tyonek Formation	650	1,615-2,103	—	—	16	—	—	60
3	Northeast Trading Bay	△	Tyonek Formation	—	2,484-2,713	10	23	(17)	1.4	200	—
4	Granite Point	●	Tyonek Formation	1,110	2,363-3,109	—	—	14	—	—	10
5	McArthur River	▲	Tyonek Formation	217	2,774-2,957	9.1	22.6	18.1	—	—	65.3
6	Trading Bay	□	Hemlock Conglomerate	318	762-1,829	9	16	(13)	30	150	—
7	Middle Ground Shoal	■	Hemlock Conglomerate	400	2,281-2,492	—	—	11	—	—	10
8	Northeast Trading Bay	△	Hemlock Conglomerate	—	2,713-2,819	7	16	(12)	0	70	—
9	McArthur River	▲	Hemlock Conglomerate	404	2,835-2,987	2.8	20.6	10.5	0.8	240	53
10	North Trading Bay	X	Hemlock Conglomerate	65	2,957-3,118	6	12	(9)	8	14	—
11	Granite Point	●	Hemlock Conglomerate	700	3,322-3,438	4.1	11	(8)	0.1	2	—
12	Swanson River	●	Hemlock Conglomerate	446	3,094-3,566	18	26	20	0	3,275	—
13	Beaver Creek	○	Hemlock Conglomerate	280	4,590-4,663	21.3	34.4	(28)	—	—	—
14	McArthur River	▲	West Foreland Formation	220	2,955-3,091	5.9	19.4	15.7	2.2	189	101.6
15	North Trading Bay	X	West Foreland Formation	65	3,176-3,203	—	—	15	—	—	47

[1] Use field no. and symbol in conjunction with figure 17.

[2] Average porosity values in parenthesis are the Authors.

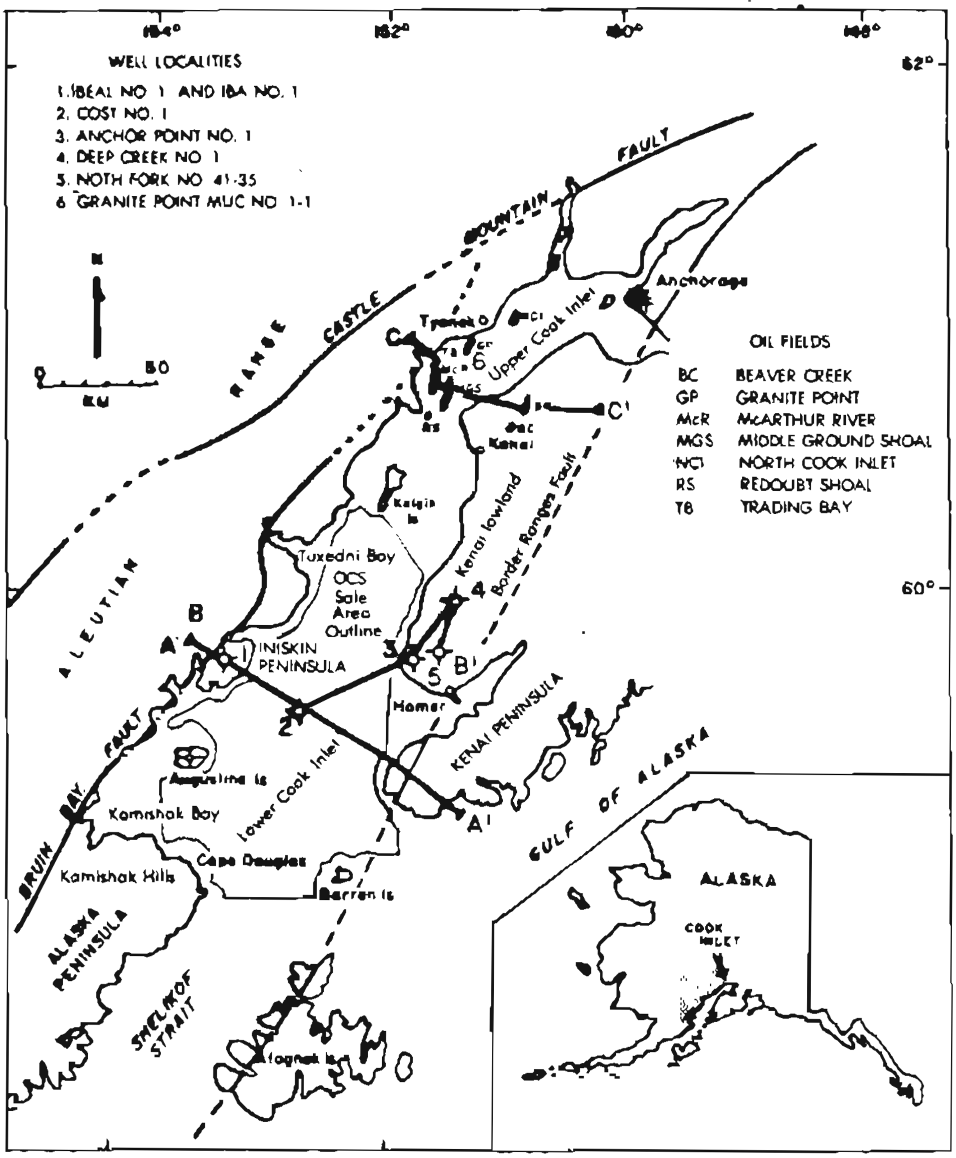

Figure 1. Cook Inlet area indicating geographic names, well locations, cross sections A-A', B-B', and C-C' and oil fields.

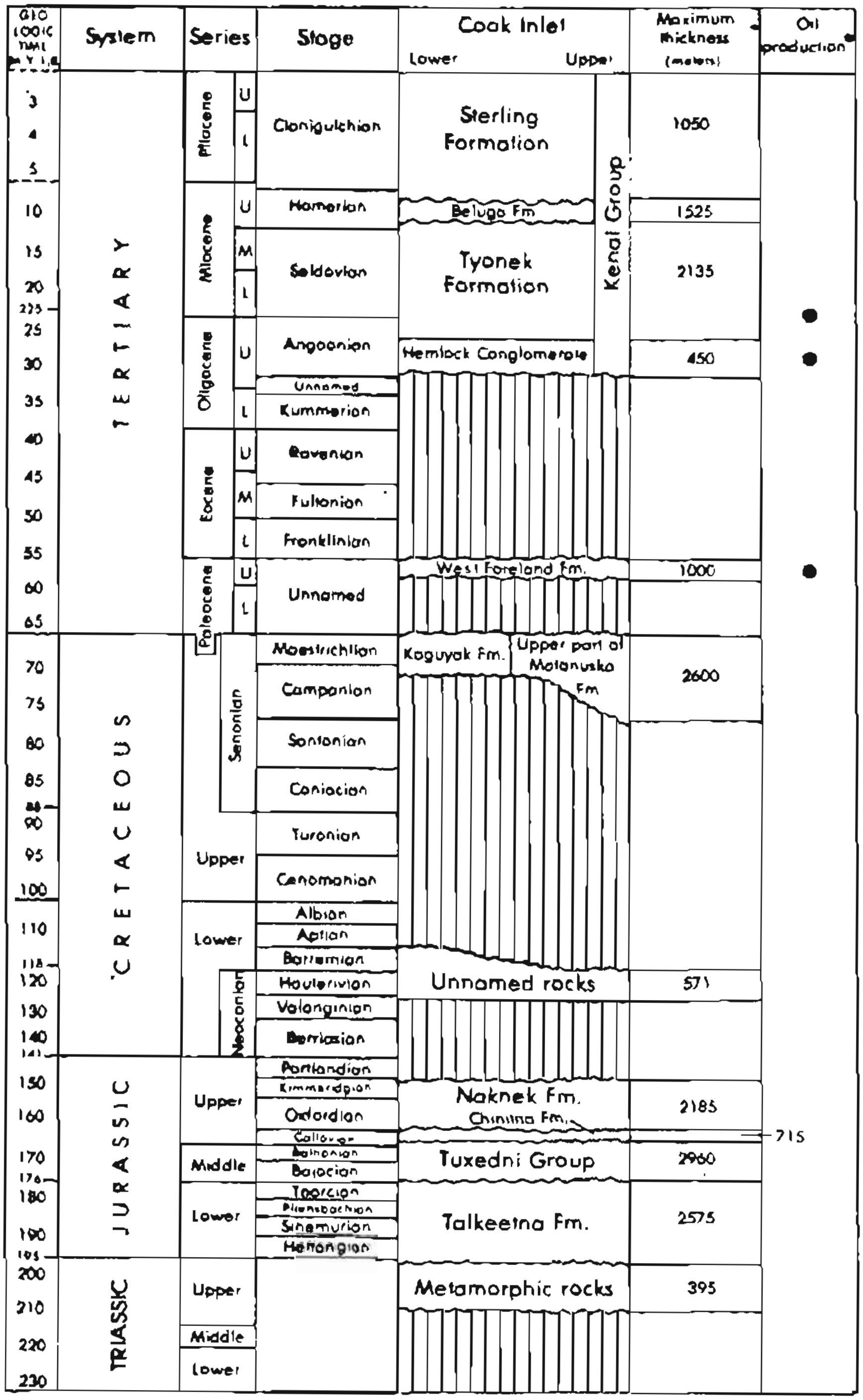

Figure 2. Stratigraphic column of Cook Inlet basin showing thicknesses and oil-producing horizons. Geologic time table modified after van Eysinger (1975); Tertiary stages from Wolfe (1977).

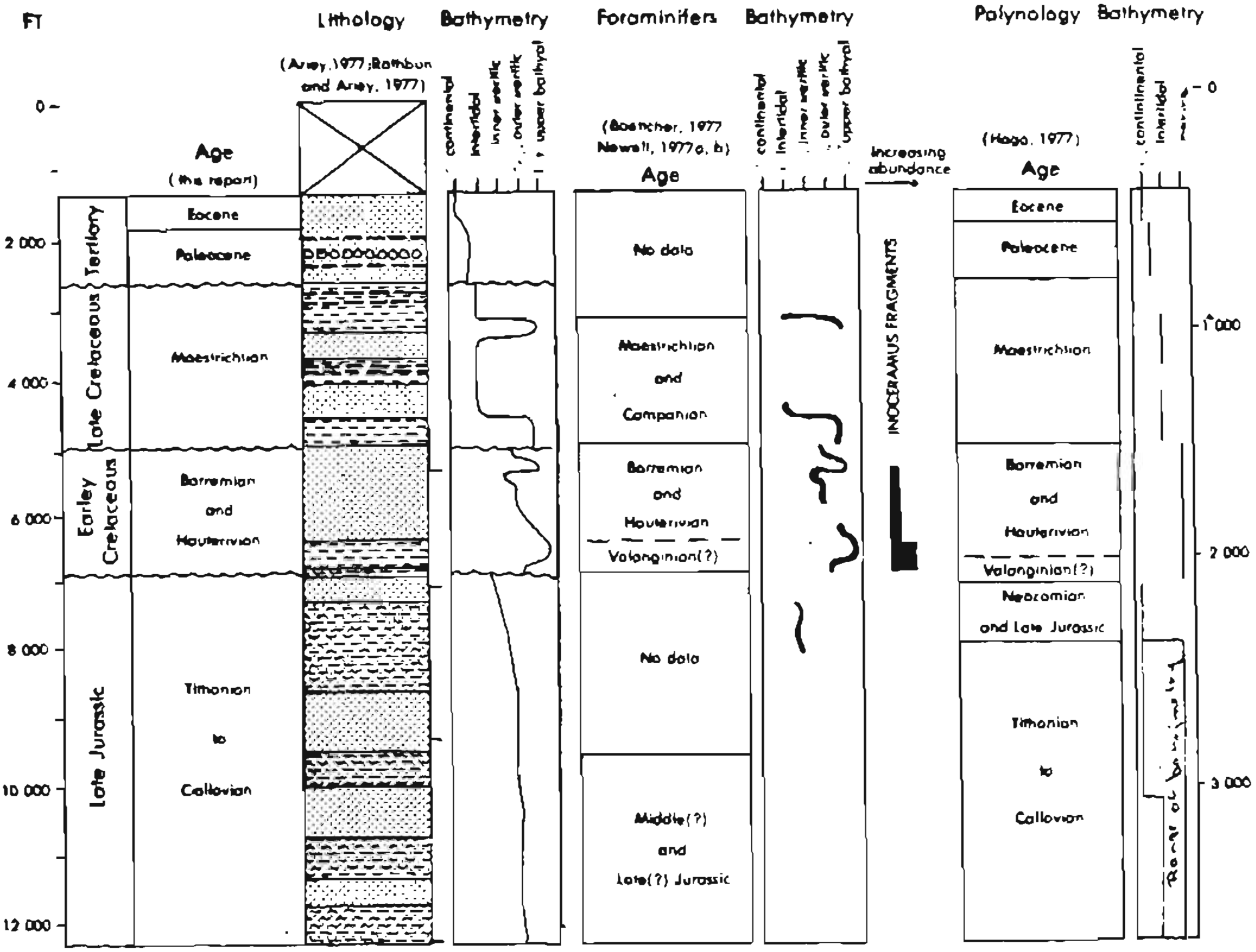

Figure 3. Rock units penetrated in lower Cook Inlet, COST No. 1 well from log response (not shown). The lithology symbols are (1) thick dashes are coal, (2) thin dashes are shale, (3) thin dashes and dots are siltstone, (4) dots are sandstone, and (5) circles are conglomerate.

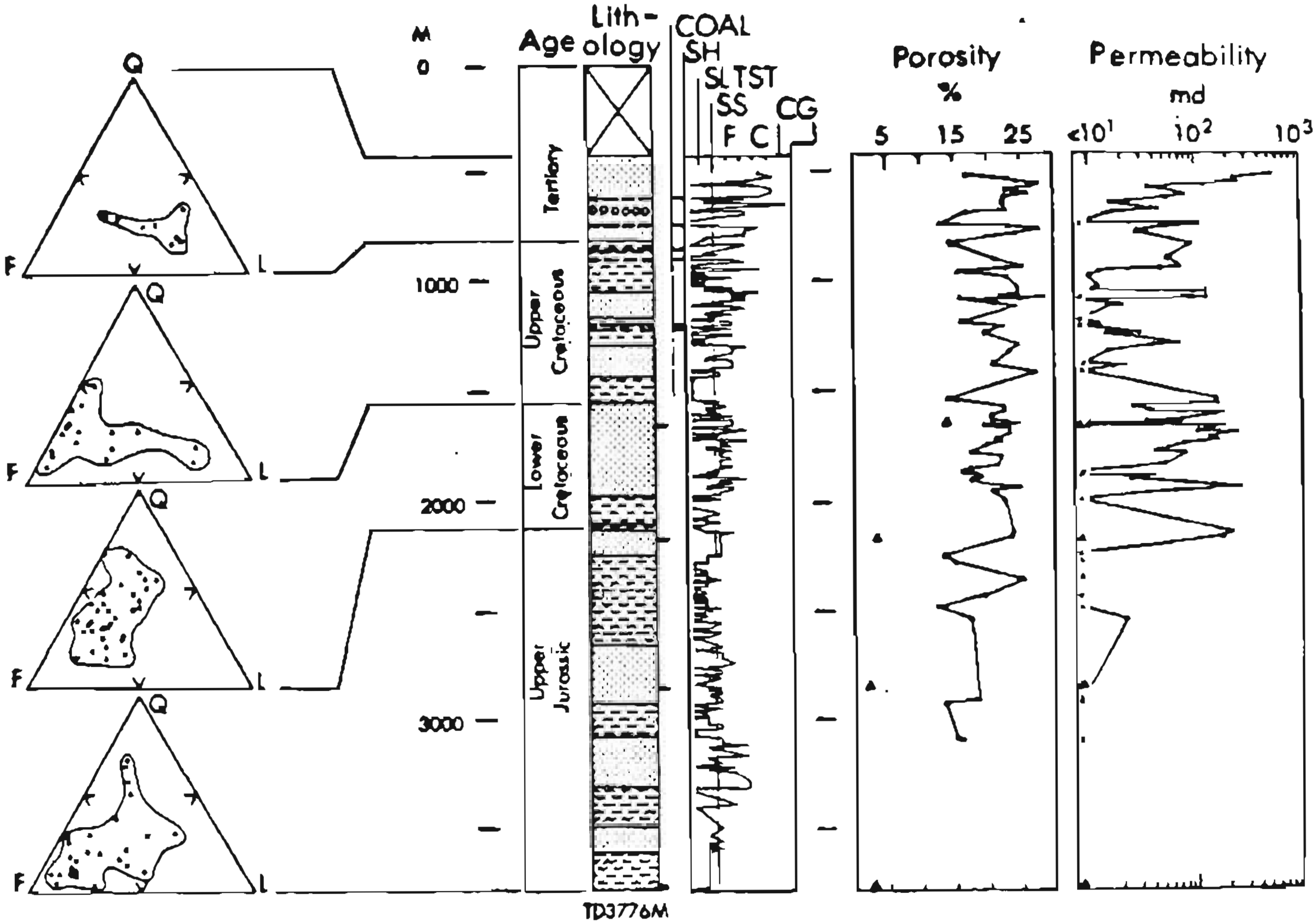

Figure 4. Sandstone composition, grain size, porosity, and permeability of stratigraphic units penetrated in lower Cook Inlet COST No. 1 well. Modal analyses done by oil company petrographers (Babcock, 1977; Christensen, 1977; Kuryvial, 1977; Schluger, 1977; Swiderski, 1977), grain sizes from sidewall sample descriptions (Ariey and McCoy, 1977), and petrophysical properties from Core Laboratories (1977 a, b). Abbreviations used are (1) SH is shale, (2) SLTST is siltstone, (3) SS is sandstone, (4) F is fine-grained sandstone, (5) C is coarse-grained sandstone, and (6) CG is conglomerate. The lithology symbols are (1) thick dahses are coal, (2) thin dashes are shale, (3) thin dashes and dots are siltstone, (4) dots are sandstone, and (5) circles are conglomerate.

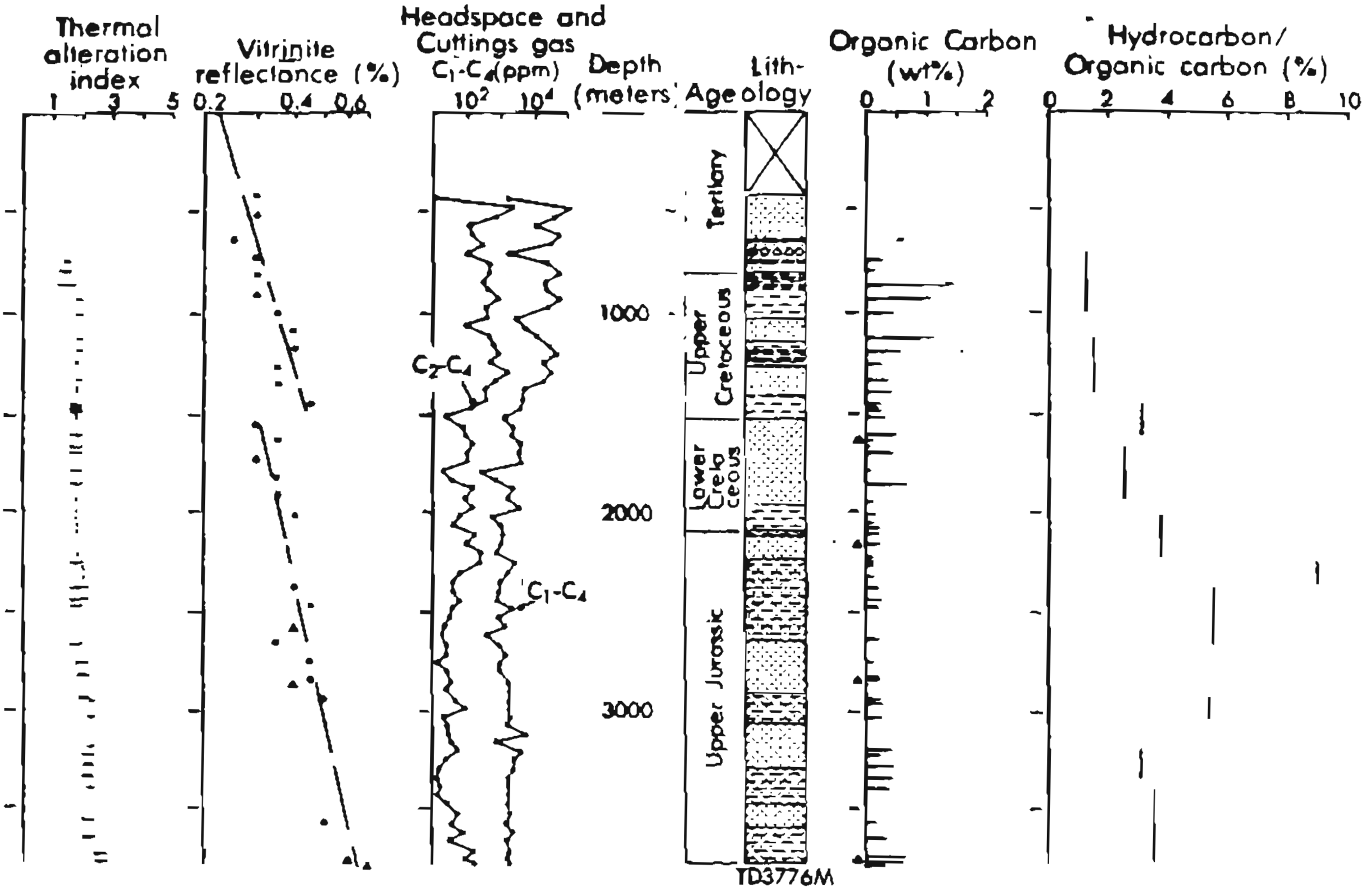

Figure 5. Organic geochemistry of stratigraphic units penetrated in lower Cook Inlet COST No. 1 well, from data provided by Geochem Laboratories (van Delinder, 1977) and ARCO (Simpson, 1977). The lithology symbols are (1) thick dashes are coal, (2) thin dashes are shale, (3) thin dashes and dots are siltstone, (4) dots are sandstone, and (5) circles are conglomerate.

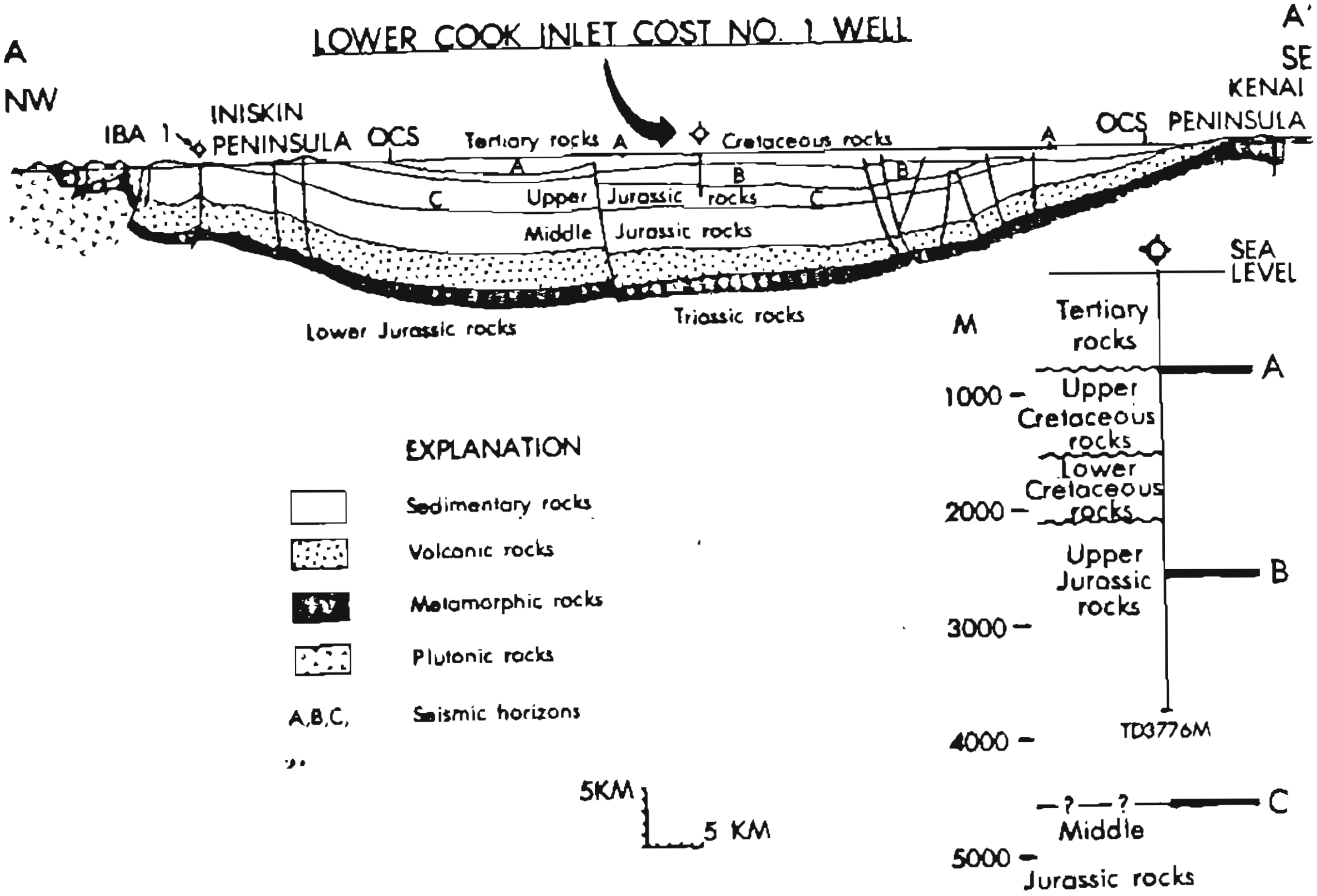

Figure 6. Lower Cook Inlet COST No. 1 well placed on cross section A-A' (fig. 1) from Fisher and Magoon (1978). Major reflectors are indicated on the cross section and in the enlarged inset at right.

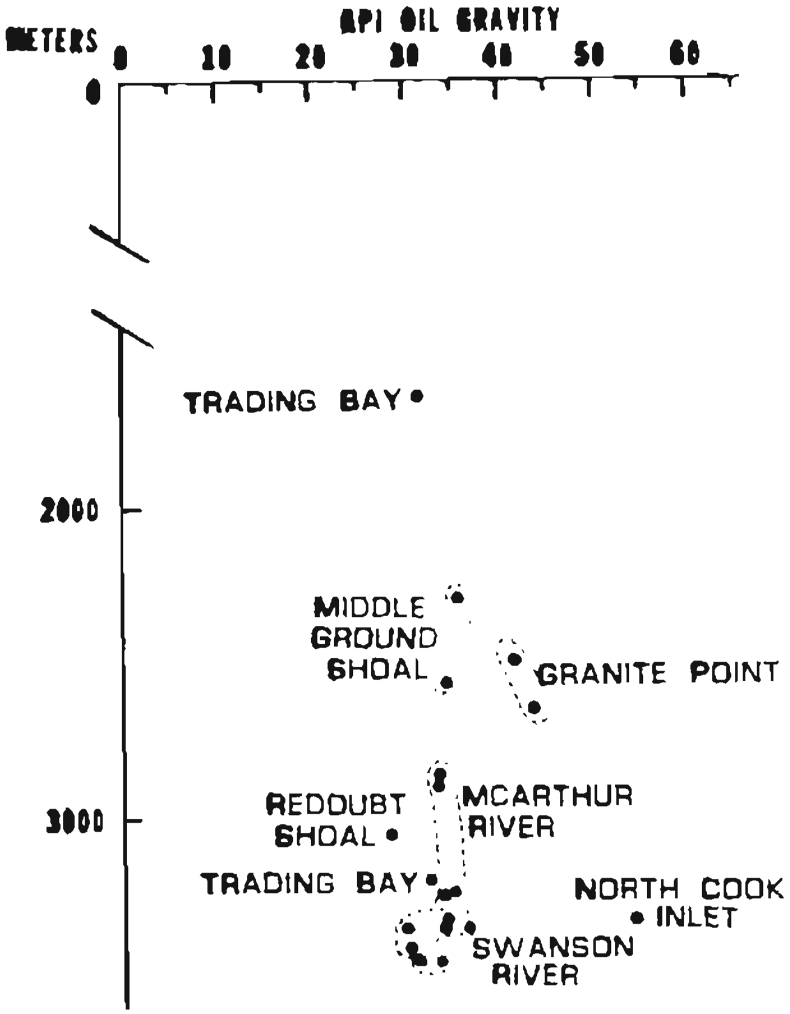

Figure 7. Plot of API gravity against depth of producing interval. Data from Blasko and others (1972).

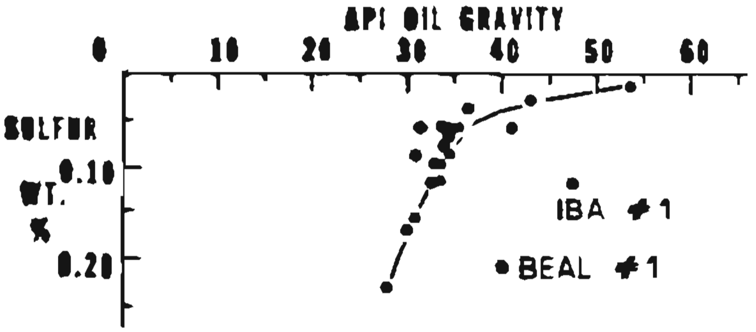

Figure 8. Plot of API gravity against sulfur content. Data plotted along curve were derived from oil from Tertiary reservoirs (Blasko and others, 1972). Data from IBA No. 1 oil (Detterman and Hartsock, 1966) and Beal No. 1 oil (our laboratory) are from Middle Jurassic rocks.

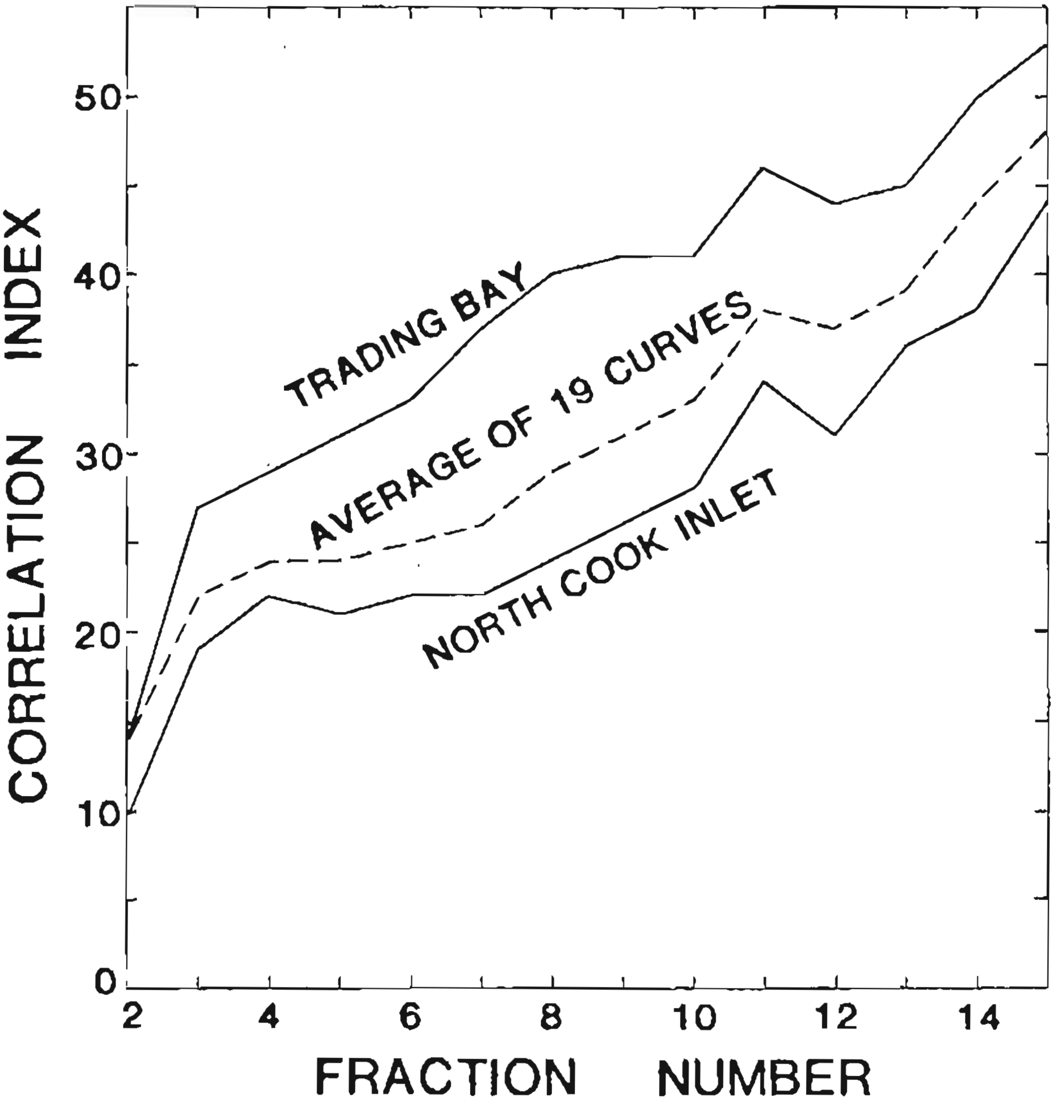

Figure 9. Correlation index curves of Cook Inlet oils (Blasko and others (1972).

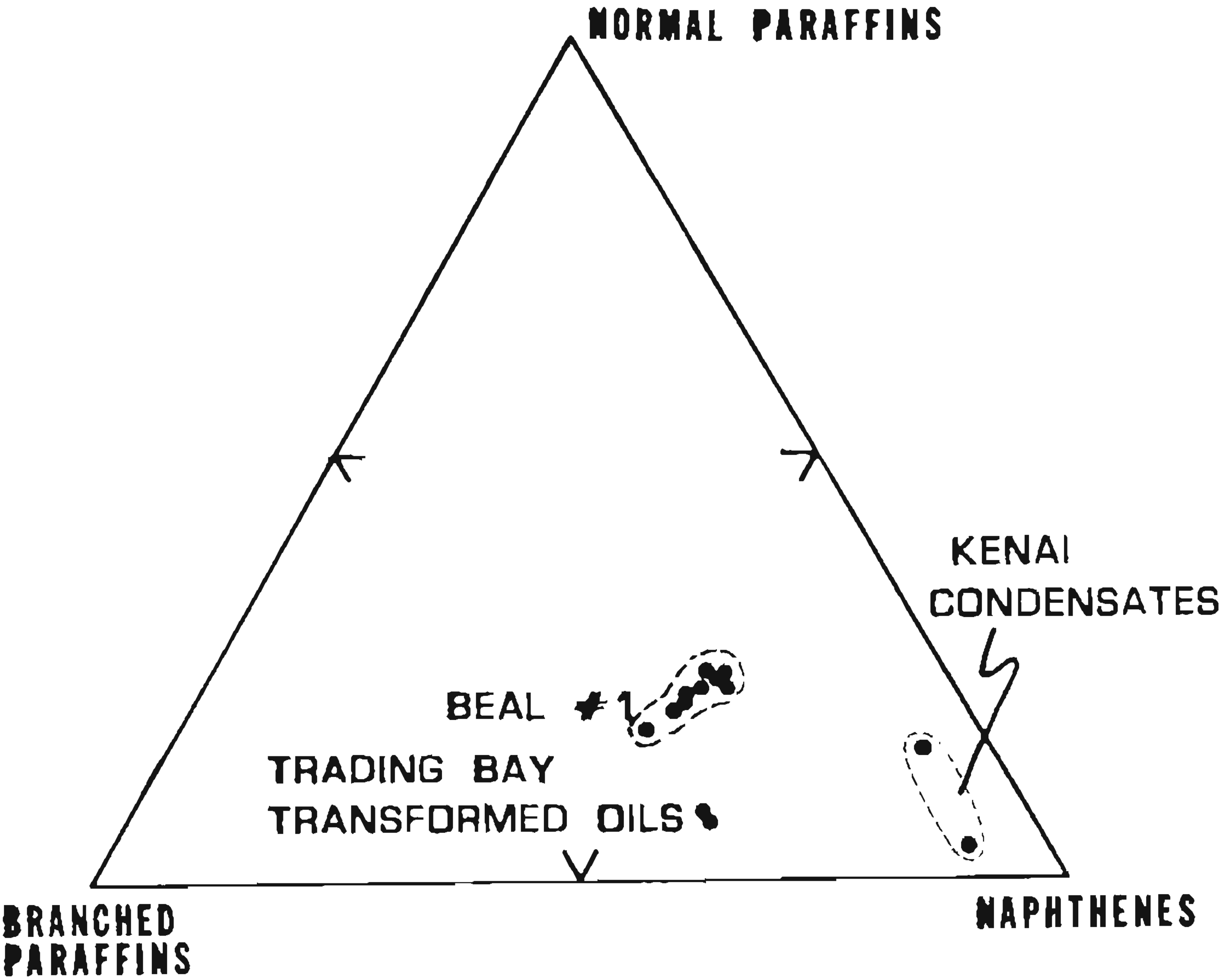

Figure 10. Total C_7 saturated hydrocarbons from Cook Inlet petroleum plotted on ternary diagram for comparison.

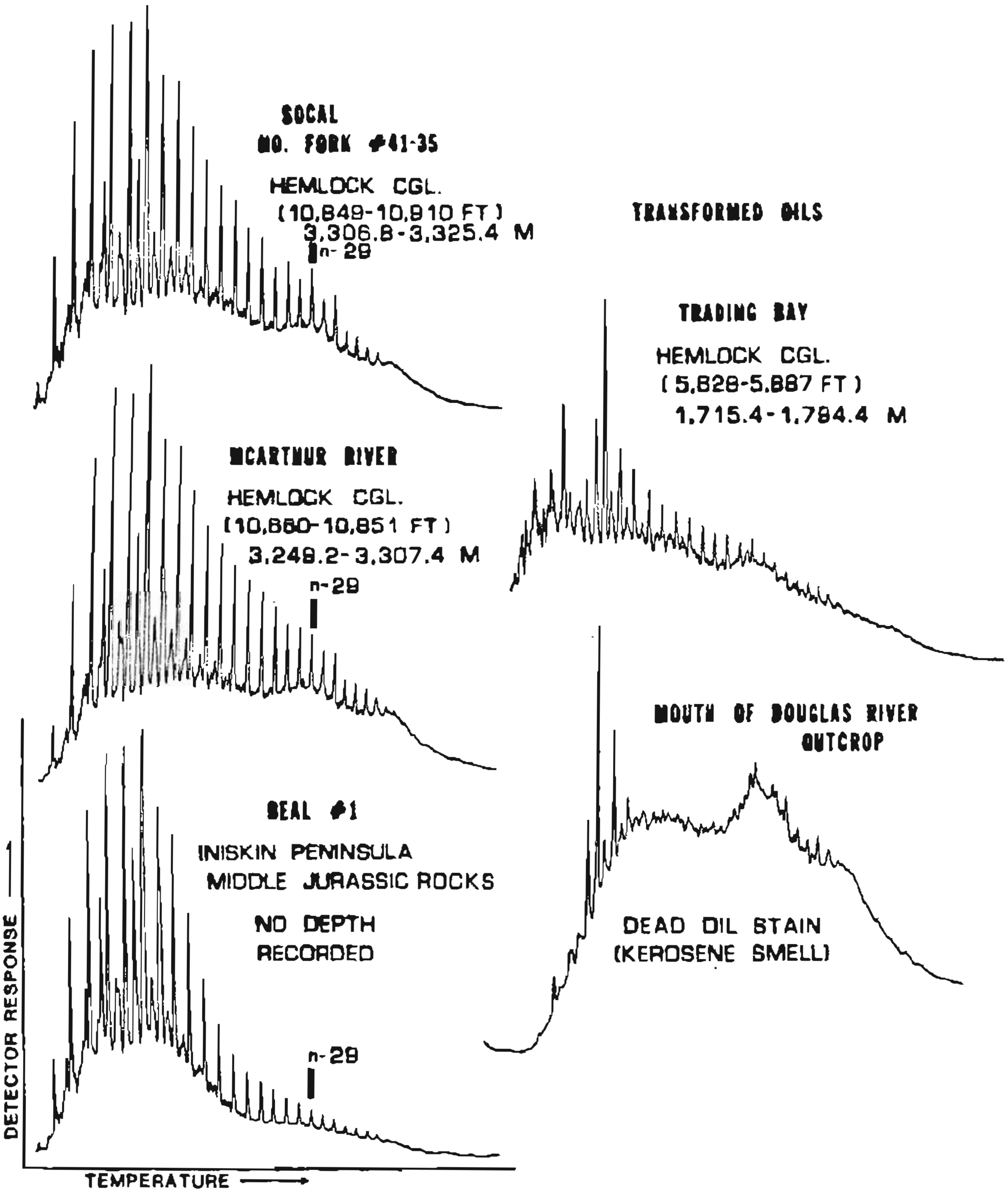

Figure 11. C_{12}-C_{32} saturated hydrocarbon analysis by gas chromatography depicts differences between biologically altered oils and normal oils.

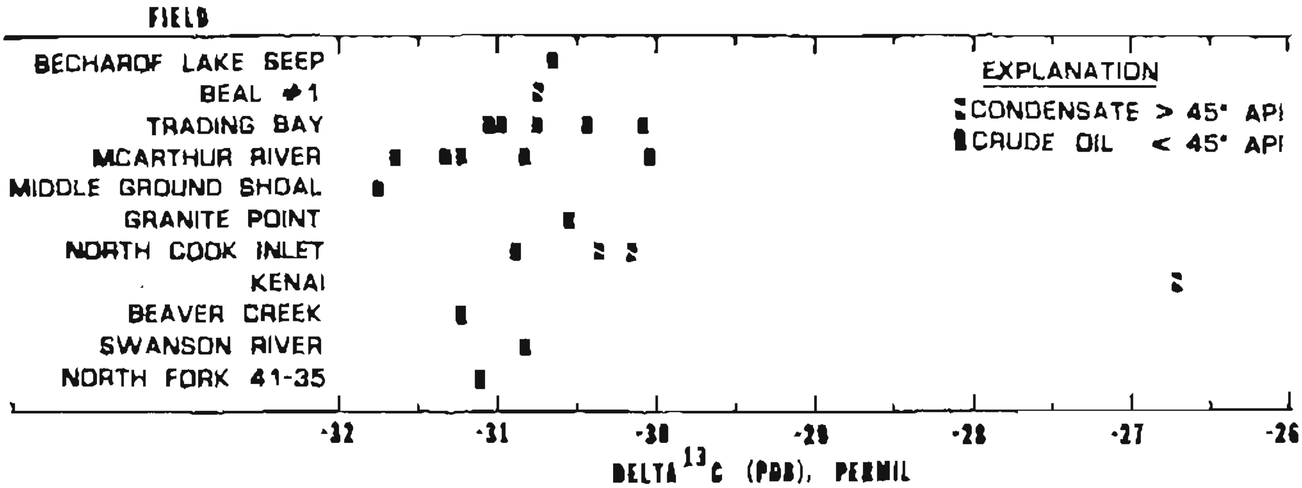

Figure 12. Carbon isotope ($\delta^{13}C$) data of saturated hydrocarbon fraction of oils from Cook Inlet and Alaska Peninsula. The Kenai condensate at -26.7 permil come from the gas separator.

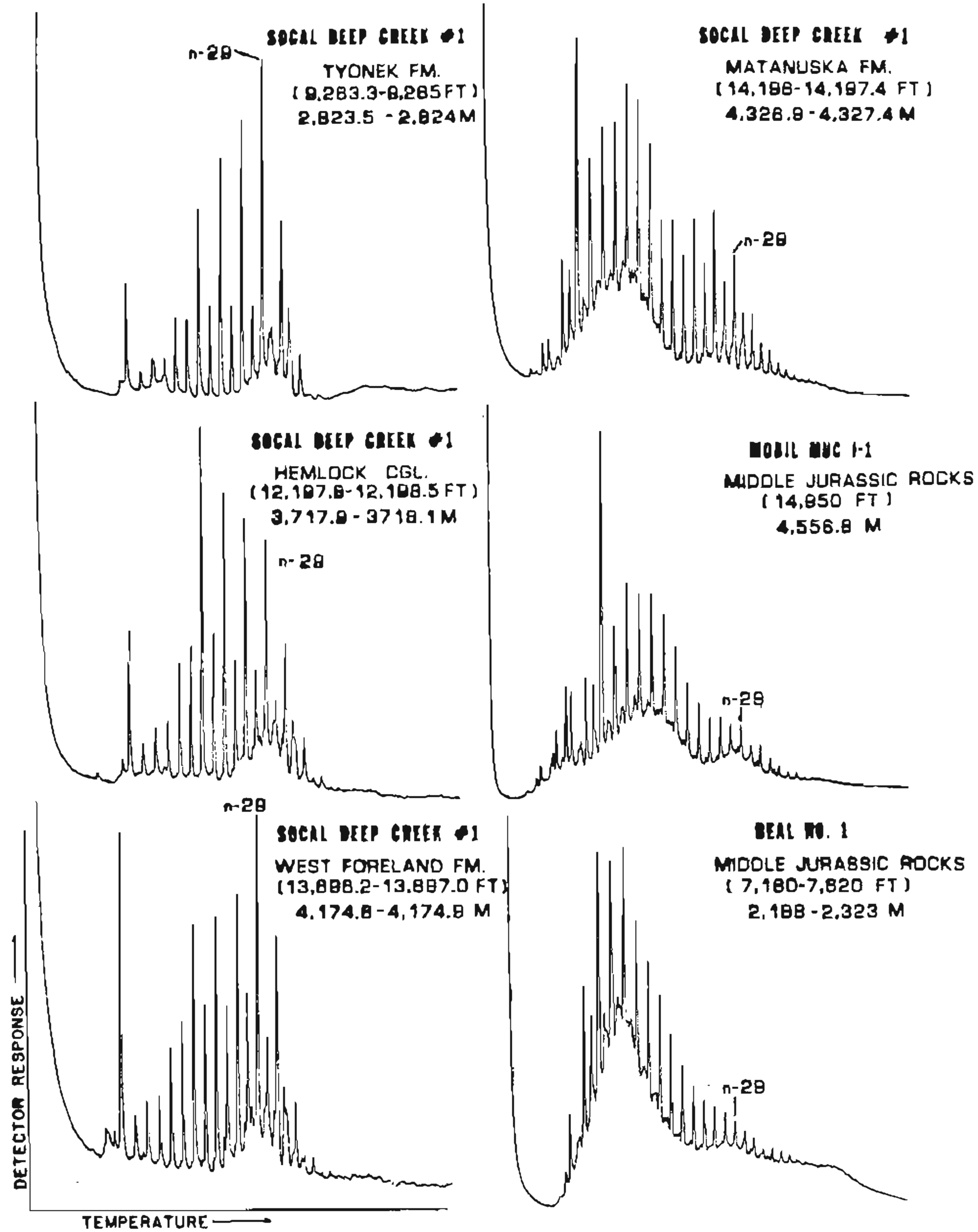

Figure 13. Gas chromatography analysis of saturated hydrocarbons extracted from sedimentary rocks.

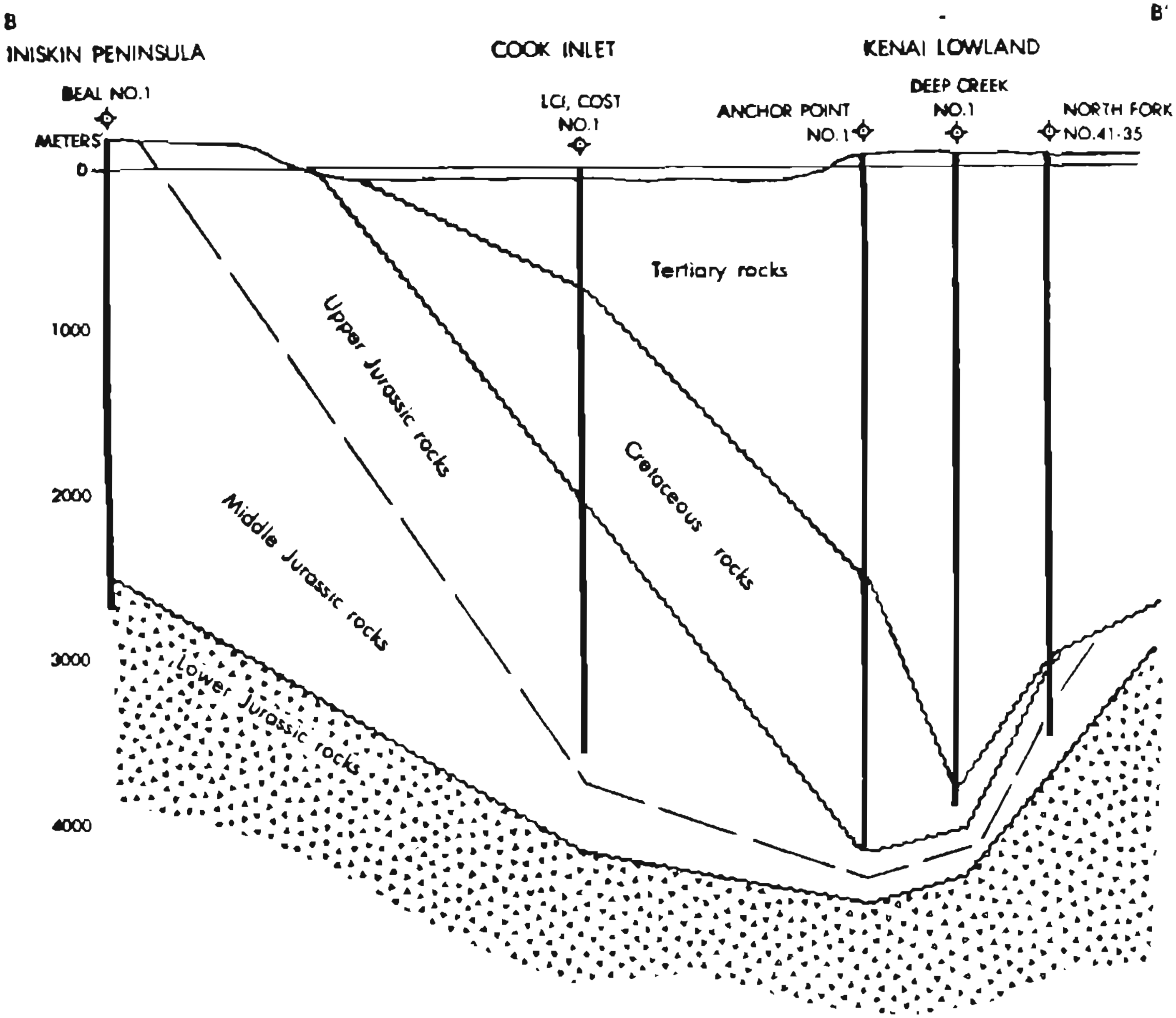

Figure 14. Stratigraphic cross section across lower Cook Inlet. Use with figure 15.

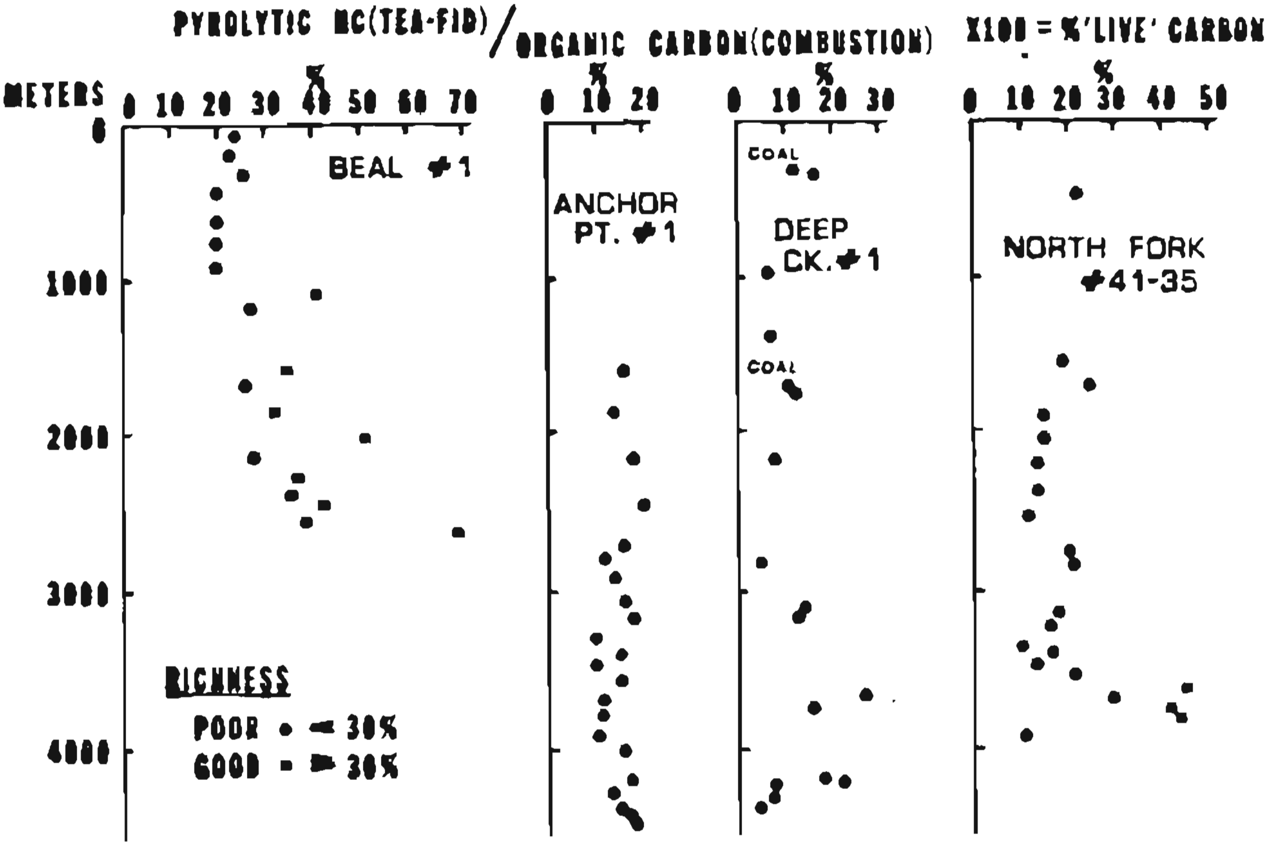

Figure 15. Type of organic matter from thermal-analysis FID and organic carbon by combustion plotted against depth for four wells across lower Cook Inlet. For stratigraphic intervals, see figure 14.

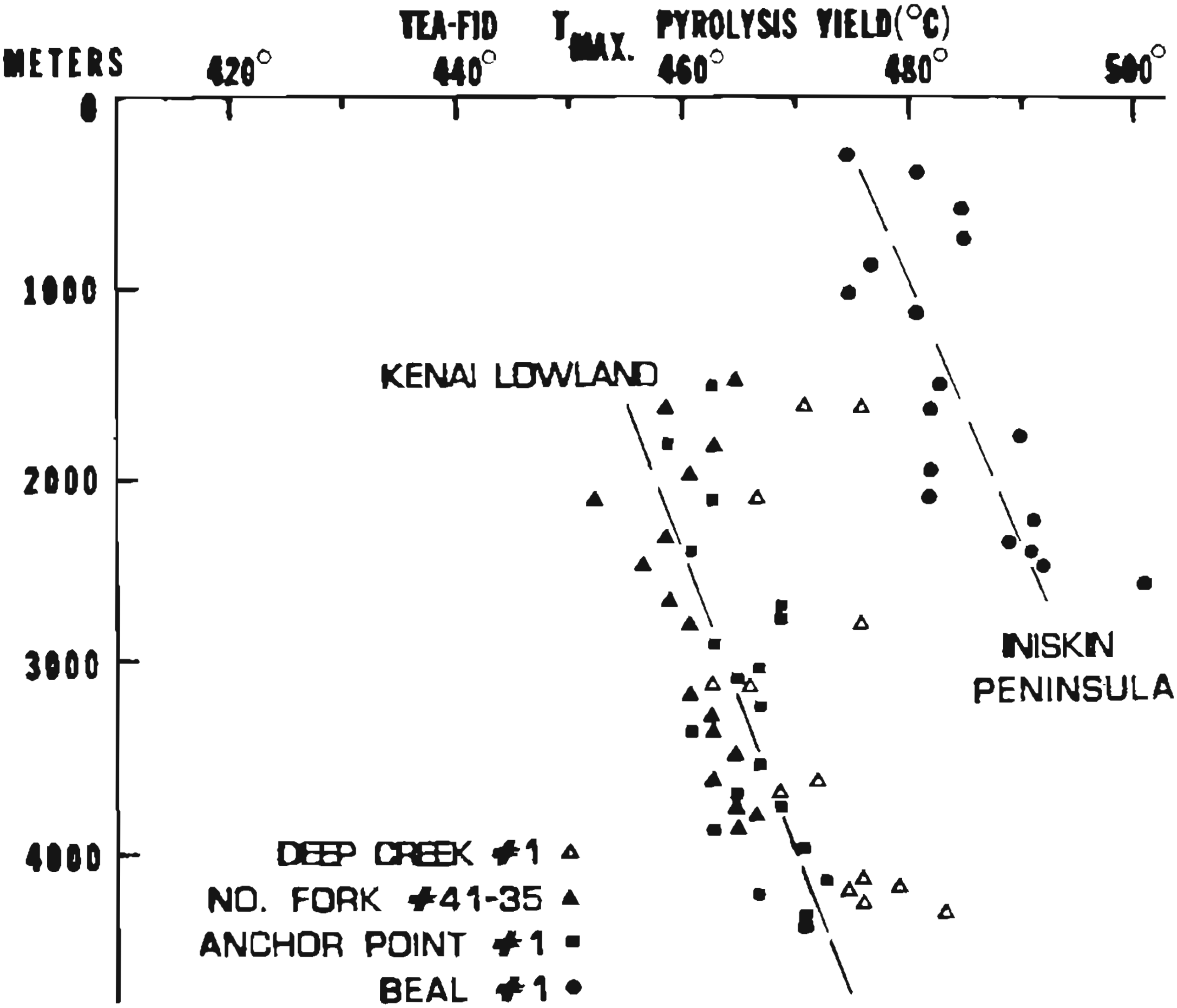

Figure 16. Maximum peak temperature (peak II) from thermal-analysis FID of rocks from five wells plotted against depth below ground surface.

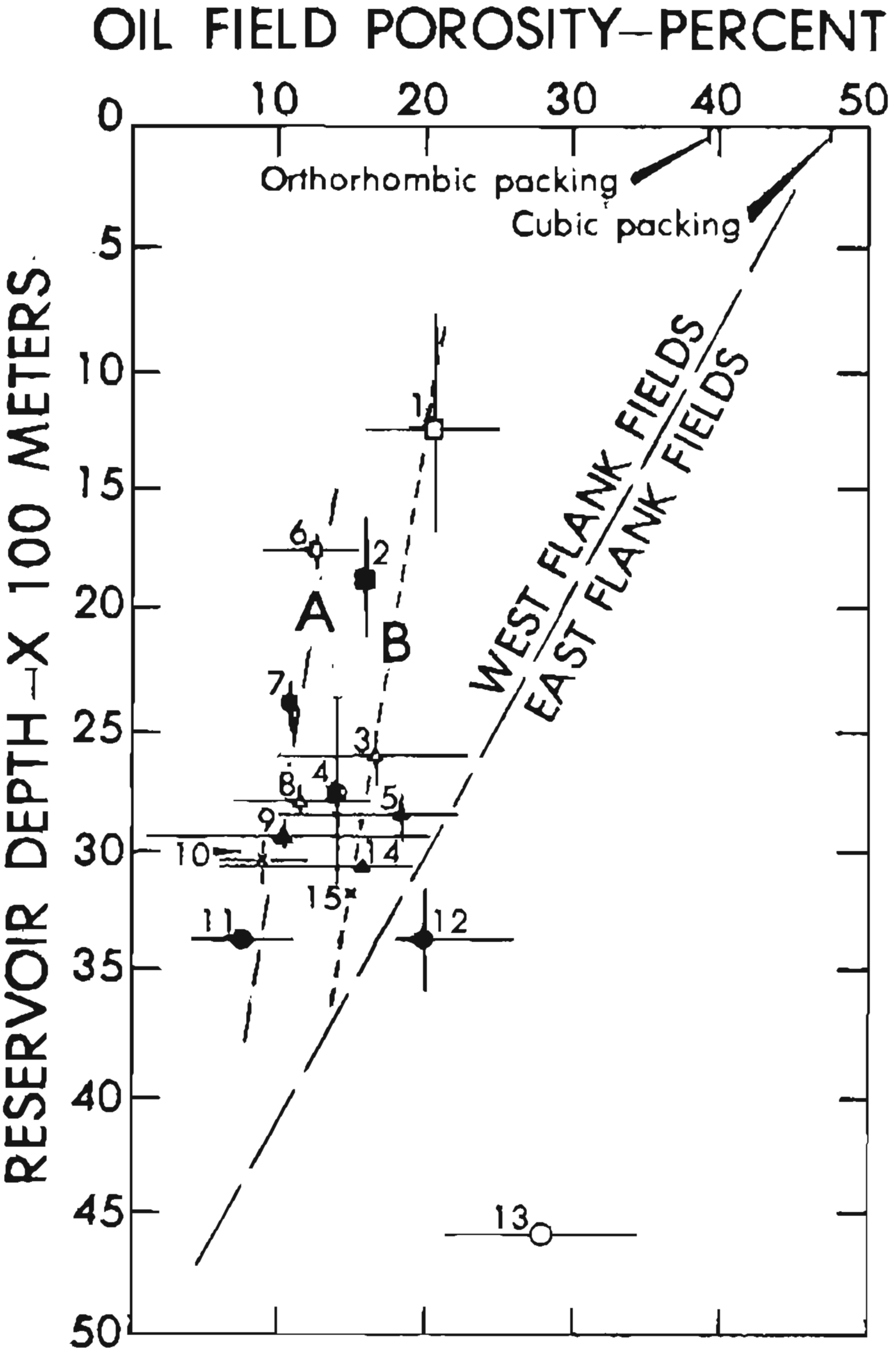

Figure 17. Decrease of oil field reservoir porosities for west and east flanks. Porosity values for each rock unit on west flank fall along parallel lines A (Hemlock Conglomerate) and B (West Foreland and Tyonek Formations) and are separated by 6 porosity units. Symbols and numbers refer to table 3.

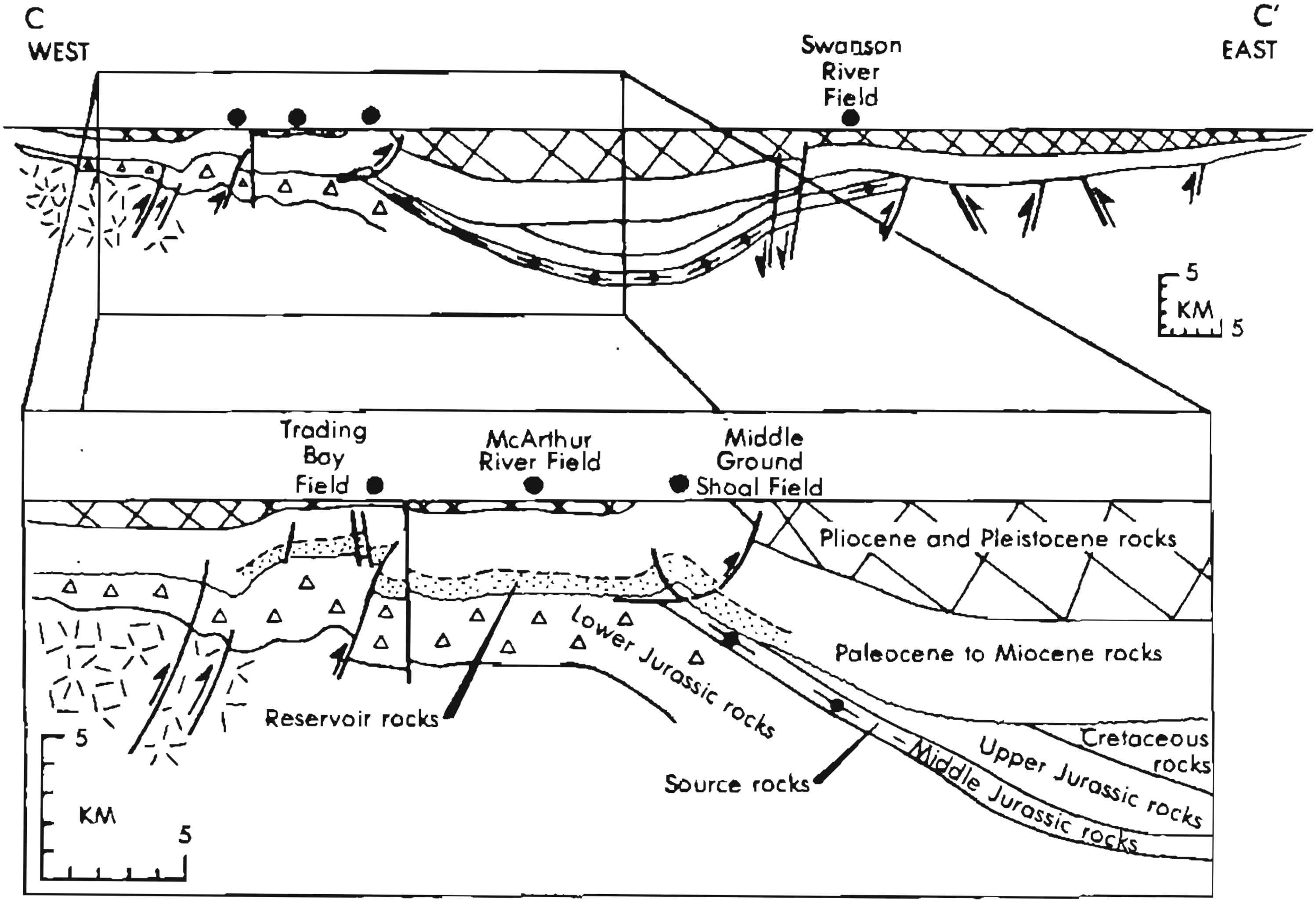

Figure 18. Cross section C-C' transects upper Cook Inlet (fig. 1). Detail of west flank depicts relation of Middle Jurassic oil source bed to Tertiary reservoir rocks. Cross section modified after Boss, Lennon, and Wilson (1976).

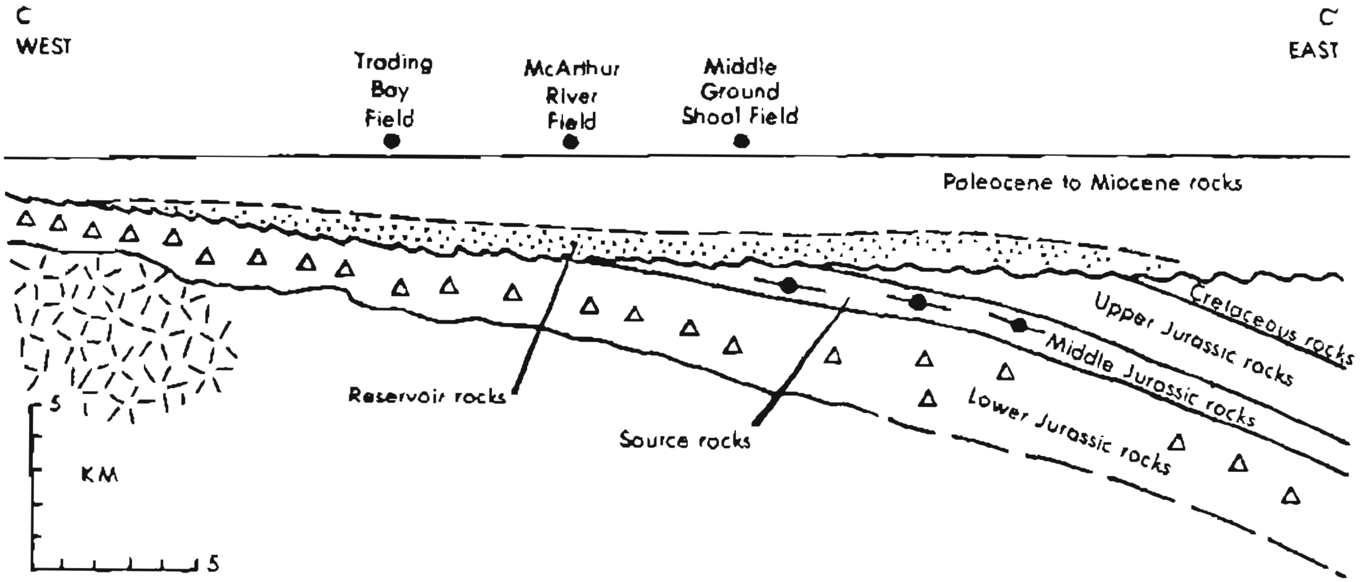

Figure 19. Geologic reconstruction of west flank of cross section C-C' (fig. 1) at end of Miocene time showing the location of the stratigraphic trap coincident with the oil fields.