OCS Report
MMS 86-0117

Murphy Wilmington Canyon 106-1 Well

Geological & Operational Summary

Edited By
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ABSTRACT

In the first Atlantic Outer Continental Shelf (OCS) lease sale, Mid-Atlantic Lease Sale 40 (August 1976), Murphy Oil Corporation successfully bid $212,000 and was granted an oil-and-gas lease on Block 106 in the Baltimore Canyon Trough. The Murphy 106-1 well was located about 79 miles offshore from Atlantic City, New Jersey, in a water depth of 412 feet. The well tested Lower Cretaceous and Upper Jurassic sandstones on the western flank of a simple anticline. Spudded on December 29, 1979, and completed on May 29, 1980, the well was drilled from the Ocean Ranger, a semisubmersible owned and operated by Ocean Drilling and Exploration Company (Odeco). The lease expired in April 1982.

The rig was repositioned five times before Odeco was successful in setting surface casing. Four strings of casing plus a 7-inch liner were set. Mud weight ranged from 8.5 pounds per gallon (ppg) to 12.0 ppg. A number of gas shows were reported, and four drill stem tests were run on sandstone intervals below 15,000 feet. All data confirmed the absence of commercial hydrocarbons. Total depth of the well was 18,405 feet.

The well penetrated 10 lithologic intervals which describe a Mesozoic and Cenozoic marine transgression accompanied by an Early Cretaceous influx of terrigenous sediments in the form of a prograding delta. Thick intervals of sandstone and shale characterize the Upper Jurassic and Lower Cretaceous, while siltstone, shale, and chalk characterize the Upper Cretaceous and Tertiary.

The paleontological dated section begins in the Late Pliocene, or possibly Early Pleistocene, and ends in the Middle Jurassic (Bathonian ?). Six hiatuses were identified.

Analysis of the type and thermal maturity of organic material in the cuttings samples indicates that immature marine (oil-prone) kerogen is abundant within the Tertiary section of the well. The Cretaceous and Jurassic sections are dominated by terrestrial (gas-prone) kerogen types. Mature palynomorphs were first observed below the top of the Jurassic section at 13,470 feet.

ABBREVIATIONS

ABS	American Bureau of Shipping
API	American Petroleum Institute
BOP	Blowout preventor
COST	Continental offshore stratigraphic test
DST	Drill stem test
E	Early
FEL	From east line
FSL	From south line
IBI	International Biostratigraphers Inc.
I.D.	Inside diameter
KB	Kelly bushing
L	Late
M	Middle
M/V	Motor vessel
OCS	Outer Continental Shelf
O.D.	Outside diameter
P & A	Plugged and abandoned
PBTD	Plugged back total depth
ppg	Pounds per gallon
S.P.	Spontaneous potential
TAI	Thermal alteration index
TD	Total depth
UTM	Universal transverse mercator
% R_o	Vitrinite reflectance

OPERATIONAL SUMMARY

by

Ray Vincent

Statistical Summary

The Murphy 106-1 well, in the northeast Baltimore Canyon Trough, is located about 79 miles offshore from Atlantic City, New Jersey (figure 1). Block 106 in Mid-Atlantic protraction diagram NJ 18-6 (Wilmington Canyon), was leased to the Murphy Oil Corporation in OCS Lease Sale 40 held on August 17, 1976. Murphy submitted the sole bid of $212,000 for the block. The bid was accepted, the exploration plan and drilling permit approved, and the well was located in the southeast quadrant of the lease block (figure 2) in 412 feet of water. The lease expired on April 21, 1982. Pertinent well information for the Murphy 106-1 well is outlined in table 1.

Murphy selected Ocean Drilling and Exploration Company (Odeco) as the drilling contractor. For the job, Odeco used their Ocean Ranger a semisubmersible drilling vessel, which was built for them by Mitsubishi Heavy Industries, Ltd., Hiroshima Shipyard and Engine Works, Japan. The vessel is classed by American Bureau of Shipping (ABS) "Rules for Building and Classing Offshore Mobile Drilling Units 1968" for unrestricted service. The vessel/rig is capable of drilling at water depths up to 3,000 feet. Initially, the Ocean Ranger was registered under the Panamanian Flag but was re-registered under the U.S. Flag when Odeco moved the vessel to the Mid-Atlantic area.

The Ocean Ranger was designed to have stress levels below ABS allowables for a 110-foot high, 15-second period wave with a 3-knot current and 100-knot winds. The mooring system consists of twelve 45,000 lb and six 30,000 lb (piggy-back) Baldt Moorfast anchors.

Odeco used Davisville, Rhode Island (approximately 200 miles northeast of the well's location) as an operations and supply base. During the drilling operations, Odeco used one standby vessel, which was normally stationed within a one-half-mile radius of the well location.

Odeco repositioned the rig four times before they were successful, at the fifth location, in landing the 30-inch casing string. The initial attempt to set surface casing was made on December 19, 1979, with success occurring on December 29, 1979. The records reveal that Odeco's major problem in setting the surface casing was caused by boulders falling into the hole. Although the rig was on location a total of 166 days, drilling was completed in 113 days on April 19, 1980, at a total depth of 18,405 feet. A graph showing the daily drilling progress for the Murphy 106-1 well (figure 3) plots the drilling depth versus time over the approximately 5-month

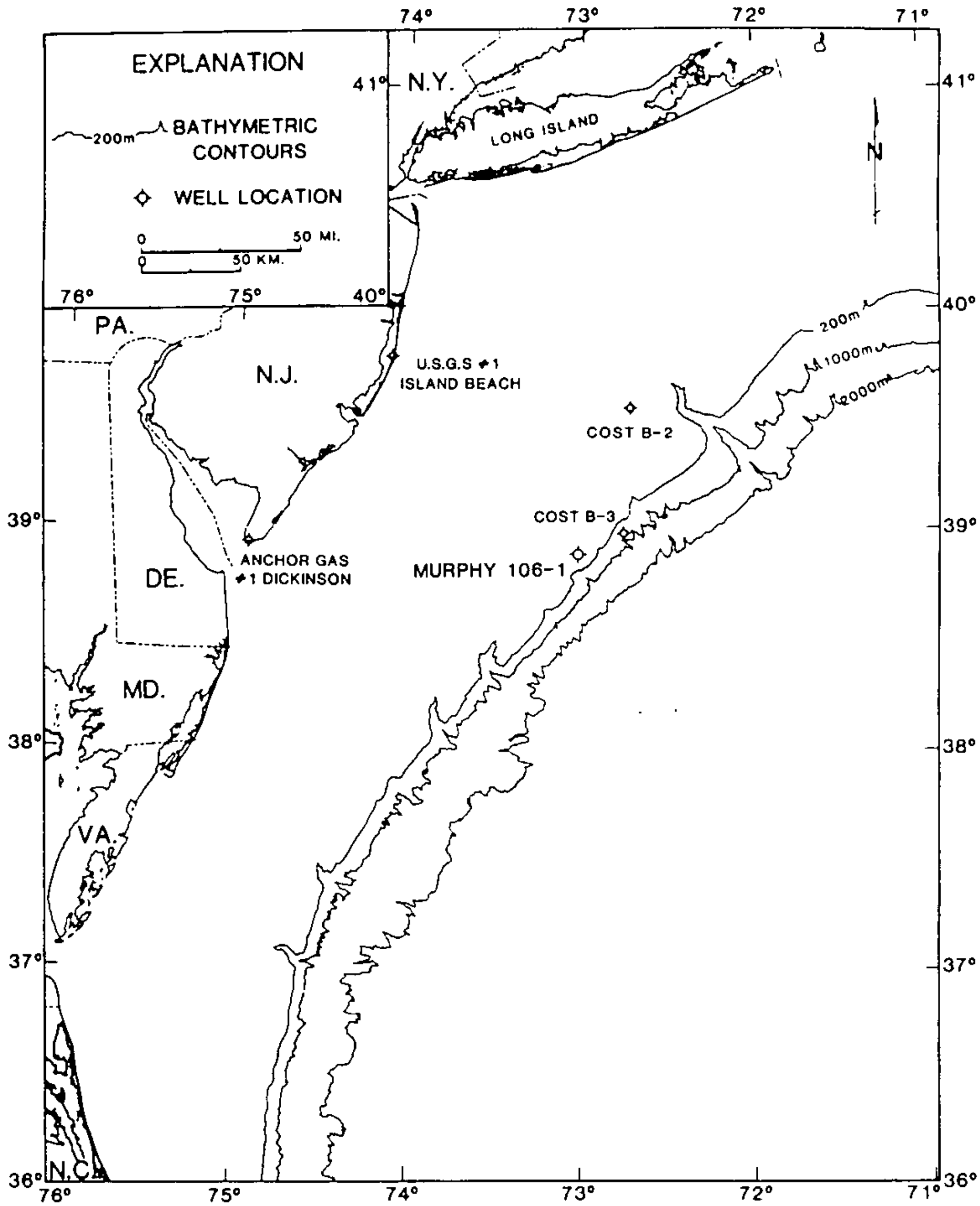

Figure 1.--Map of a portion of the Mid-Atlantic offshore area showing the location of the Murphy 106-1 well and other wells.

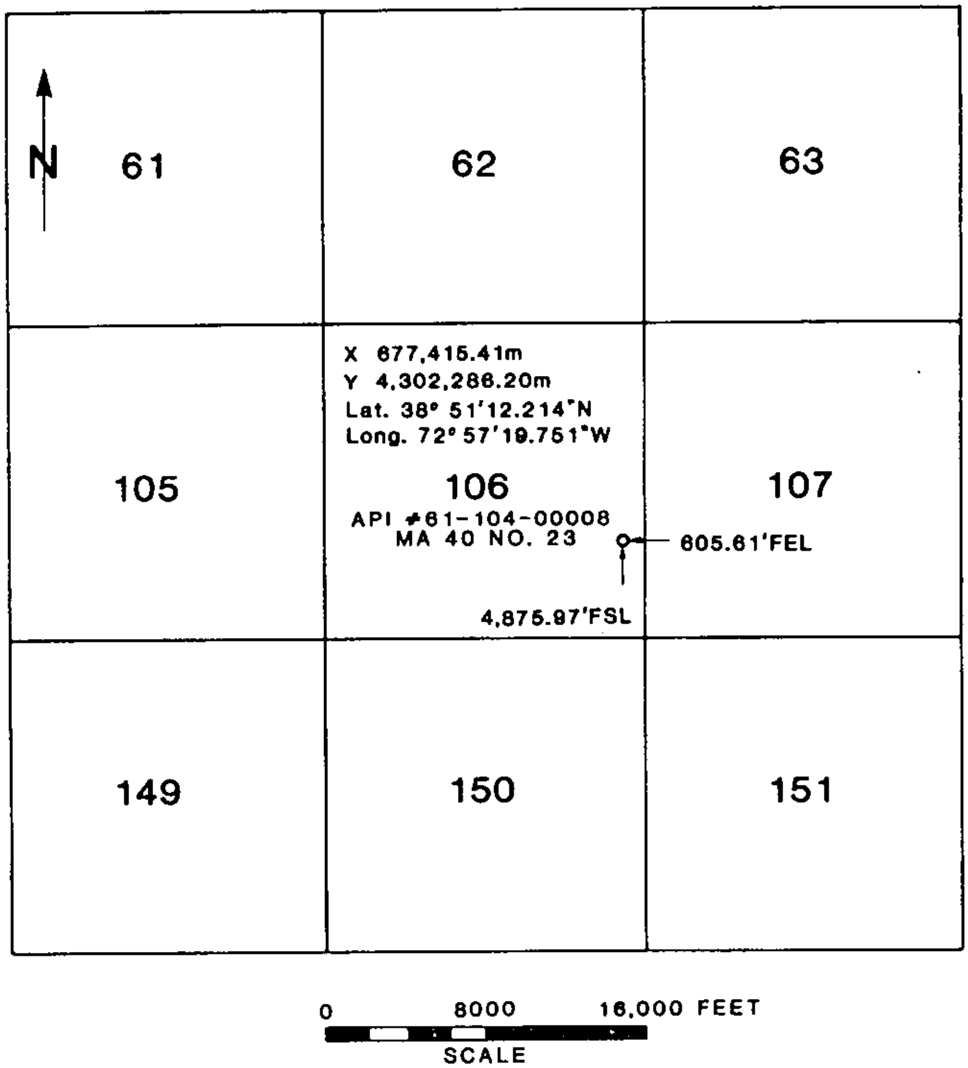

Figure 2.--Plat showing the final location of the Murphy 106-1 well in OCS Protraction Diagram NJ 18-6.

Table 1.-- Pertinent well information for the Murphy 106-1 well.

Well identification:	API # 61-104-00008 MA40 No. 23
Lease number:	OCS-A-0081
Protraction diagram:	NJ 18-6 (Wilmington Canyon)
Actual surface location:	UTM coordinates: x = 677,415 m y = 4,302,286 m Latitude: 38°51'12.214" N. Longitude: 72°57'19.751" W.
Distance from block lines:	4,875.97 feet FSL 605.61 feet FEL
Actual bottom hole location:	4,751.30 feet FSL 448.13 feet FEL
Initial proposed total depth:	17,500 feet
Final proposed total depth:	18,500 feet
Actual total vertical depth:	18,401.71 feet
Total measured depth:	18,405 feet
Spud date:	December 29, 1979
Completion date:	May 29, 1980
Kelly bushing elevation:	98 feet above mean sea level
Water depth:	412 feet (125.6 m) below mean sea level
Final well status:	Plugged and abandoned

Note: All depths in this report are measured from the kelly bushing unless otherwise indicated.

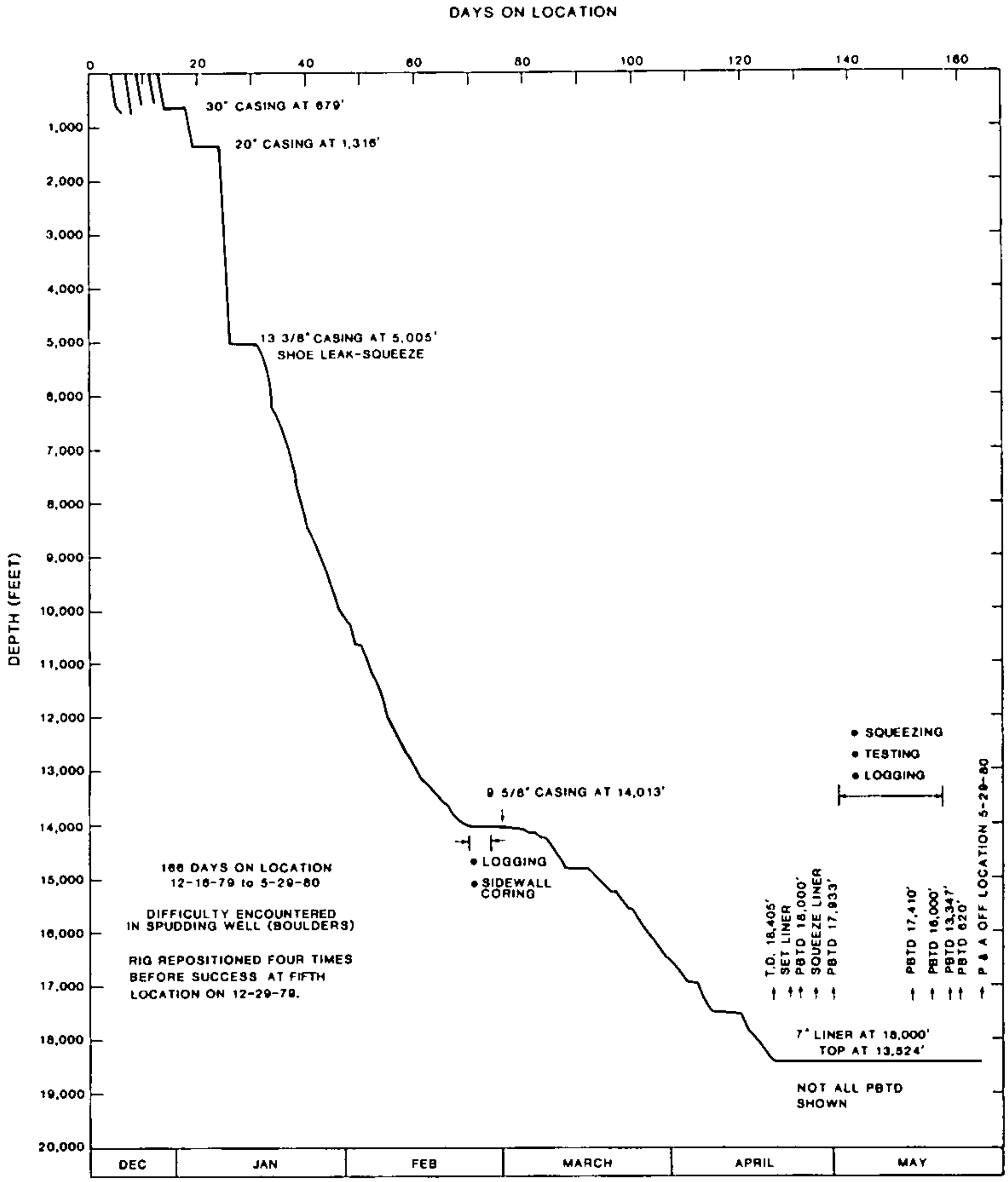

Figure 3.--Graph showing the daily drilling progress for the Murphy 106-1 well.

drilling period. Data from the well include electric logs, a mud log, cuttings samples, and sidewall cores. No conventional cores were cut. These data -- along with geologic information, operational reports, and results of drill stem tests -- were provided to the Minerals Management Service. From April 19, 1980, to May 29, 1980, (the day the well was plugged and abandoned), Murphy did extensive testing and logging of potential hydrocarbon zones between 15,724 to 15,751 feet and between 17,372 and 17,649 feet. No hydrocarbons were recovered in any of the four drill stem tests run. All of the well data obtained from the core, logs, and drill stem tests confirmed the absence of commercial hydocarbons in this well.

Drilling Program

Odeco used one 26-inch bit, two 17 1/2-inch bits, fifteen 12 1/2-inch bits and fifteen 8 1/2-inch bits. While reentering the hole at 14,803 feet, the drill pipe parted and dropped several stands plus a new 8 1/2-inch bit. Odeco successfully recovered the pipe and bit from the hole. Odeco had a maximum penetration rate of 1,916 feet per day, which occurred between the depths of 1,685 feet and 3,601 feet. From 5,000 to 14,000 feet, Odeco's average drilling rate was 234 feet per day, but this rate decreased to an average of 117 feet per day below 14,000 feet to total depth. Murphy ran and set four strings of casing plus a 7-inch liner as shown in figure 4. The 30-inch casing was set at 679 feet with 944 cubic feet of cement slurry; the 20-inch casing was set at 1,316 feet with 2,432 cubic feet of cement slurry; the 13 3/8-inch casing was set at 5,005 feet with 4,430 cubic feet of cement slurry; and the 9 5/8-inch casing was set at 14,013 feet with 1,484 cubic feet of cement slurry. The 7-inch liner was set at 18,000 feet (liner top at 13,524 feet) with 1,750 sacks (2,450 cubic feet) of Class H cement. Figure 4 also depicts the abandonment procedure. Murphy's numerous tests required the setting of a number of retainers and squeeze jobs to isolate the tested zones properly before plugging and abandoning the well.

Murphy's initial projected total depth for this well was 17,500 feet. After reaching this depth, Murphy requested and was granted permission to deepen the well, first to 18,000 feet and then to 18,500 feet. As a note of interest, four sections (60 feet in length) of an 8-inch outside diameter (O.D.) x 5 1/4-inch inside diameter (I.D.) core barrel were dropped onto the seabed during offloading from the M/V Dearborn 202 to the Ocean Ranger. After divers made two unsuccessful attempts to locate and recover the lost equipment, Murphy requested and was granted permission to abandon the core barrel without further search. On May 28, 1980, while anchors were being pulled on the Ocean Ranger in preparation for moving off location, a piggy-back anchor was lost from the No. 9 anchor. The M/V Dearborn 202 grappled for it but was unsuccessful in locating it.

From spud to 5,050 feet, Murphy used sea water for a drilling fluid, plus Drispac for a fluid loss control additive and viscosifier. From 5,050 to 18,405 feet, a fresh water lignosulfonate mud was used. From 5,000 to 12,000 feet, Murphy carried a mud weight ranging from 9.2 pounds per gallon (ppg) to 9.5 ppg with a viscosity between 40 and 57 seconds.

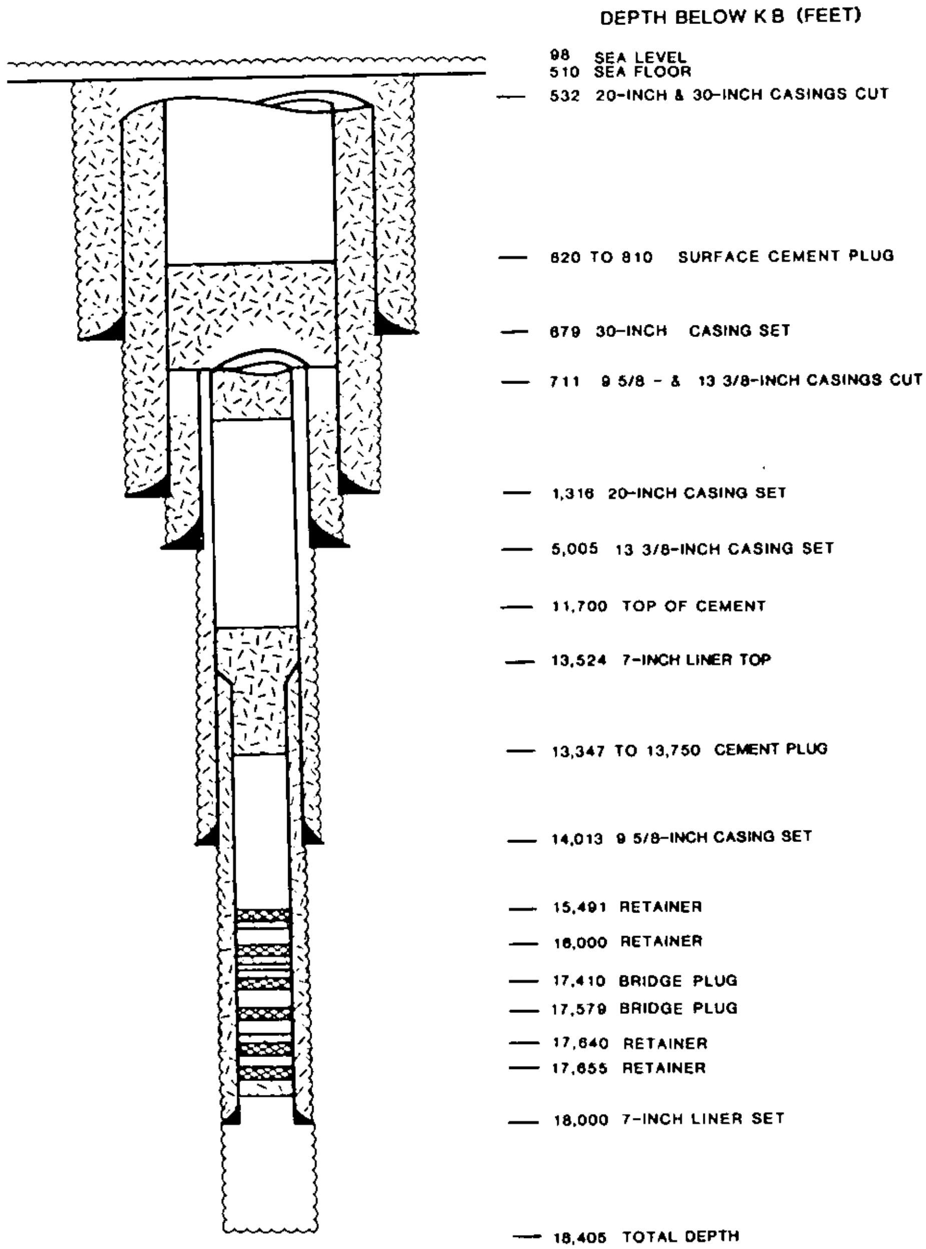

Figure 4.--Schematic diagram showing the casing and cement program for the Murphy 106-1 well.

Below 12,000 feet they increased the mud weight to about 9.7 ppg with viscosities between 40 and 47 seconds. At 15,700 feet Murphy increased the mud weight to 10.1 ppg and to 10.8 ppg at a depth of 15,800 feet. At 15,860 feet they increased the mud weight to 11.0 ppg with a viscosity of 47 seconds. From this depth (15,860 feet) down to total depth, Murphy gradually increased the mud weight to 12.0 ppg with a viscosity between 51 and 53 seconds. After setting the 7-inch liner and while testing at depths of 17,000 plus feet, Murphy maintained a mud weight of 12.0 ppg and viscosity of about 53 seconds. When testing above 16,000 feet and while preparing to plug and abandon the well, Murphy decreased the mud weight and viscosity to 10.5 ppg and 35 seconds, respectively.

Samples and Tests

Cuttings samples were collected from 1,370 to 18,405 feet in the well and aliquots were provided for analysis. Wet samples were collected as 30-foot composited samples from 1,370 to 5,540 feet and as 10-foot composited samples below 5,540 feet. Dry samples were provided from 1,370 to 5,540 feet as 30-foot composited samples and as 10-foot composited samples below 5,540 feet. Cuttings samples were used for lithologic studies, and fractions between 1,370 feet and the total well depth were processed and used for paleontologic examination and interpretations. Thin sections were also prepared from cuttings for selected intervals between 1,390 and 18,260 feet.

Between the depths of 1,665 and 18,397 feet, Murphy took 325 sidewall cores and recovered 306 samples. Core Laboratories, Inc. made a lithological description of the samples recovered and then analyzed 138 cores for porosity, permeability, and oil and water saturations. Core Labs did not analyze those samples that were all shale or those that contained a high proportion of shale, mica, or calcareous material. Sidewall core depths are recorded in figure 7, p. 21.

Schlumberger Ltd. ran electric log suites to provide information for stratigraphic correlation, lithologic analysis, and the evaluation of potential hydrocarbon bearing zones (table 2). Exploration Logging provided a physical formation log (mud log) from 1,369 to 18,405 feet.

A number of gas shows were reported below 15,000 feet with the majority of show ratings classified from trace to poor. Between 15,800 to 15,804 feet, drilling time did break from 7 to 80 feet per hour. However, the mud was not cut although there was a slight cut in the samples. Ninety units of gas were reported and the lithology of the interval was 85 percent sandstone.

Between May 7 and May 20, 1980, Halliburton Well Services ran four cased hole drill stem tests on sandstone intervals below 15,000 feet. The results of these tests are summarized in table 3.

Weather

Weather conditions delayed Odeco's spudding of Murphy 106-1 for about one day. Weather also affected running and testing the 18 3/4-inch BOP stack on January 8, 1980; running and setting the 9 5/8-inch casing on February 27, 1980; and drilling and directional survey operations on March 23, 1980. The operating time lost because of poor weather conditions is estimated to be less than 3 days.

Table 2.-- Wireline well logs run in the Murphy 106-1 well.

Log Type	Depth Interval (feet)
Dual Induction - Spherically Focused Log	1,316 - 18,396
Borehole Compensated Sonic Log	5,010 - 17,490
Compensated Neutron & Formation Density	5,010 - 18,398
Compensated Formation Density Log	5,010 - 18,398
Continuous Dipmeter	5,010 - 14,043 14,052 - 18,398
Dual Laterolog	14,022 - 17,481
Proximity Log & Microlog	14,022 - 17,492
Temperature Log	5,700 - 18,405

Table 3.-- Drill stem tests and results for the Murphy 106-1 well.

Test no.	Interval tested (feet)	Length of test (minutes)	Choke size (inches)	Results/recovery
1	17,633-17,649	60	3/8	No flow
2	17,425-17,434 17,440-17,460 17,478-17,500	120	3/4	No flow
3	17,372-17,405	33	3/4	No flow
4	15,724-17,751	135	3/4	No flow

LITHOLOGIC ANALYSIS

by

Frederick Adinolfi

Introduction

This report is based on data from electric logs, sidewall cores, the mud log, and drill cuttings collected from 1,400 feet to 18,405 feet (TD). Sample quality in this well was good. The well was drilled to test Lower Cretaceous and Upper Jurassic sandstones on the western flank of a simple anticline. A gas show was reported and tested from a Late Jurassic (Kimmeridgian) sandstone at a depth of 15,800 feet. A lithologic column and the depths of sidewall cores are included on the biostratigraphic chart (see figure 7, p. 21).

The stratigraphic sequence penetrated by the Murphy 106-1 well has been divided into 10 lithologic units. These lithostratigraphic units were delineated from well data. Spontaneous potential (S.P.), gamma ray, resistivity, and sonic log responses were used to determine lithologic breaks. The lithologic intervals correlate with the regional stratigraphic framework established from other Atlantic OCS and coastal plain wells. Figure 5 summarizes the 10 lithostratigraphic units which are described in detail below.

Lithologic Descriptions

° Unit 1: 1,400 to 3,840 feet

This unit of Pliocene to Middle Miocene aged sediments consists predominantly of unconsolidated clay and sand. The clay is light grey, soft, and sticky. It contains glauconite and abundant shell fragments. Thin, very fine-grained sandstone stringers are present in the shale. These sandstone stringers are laminated and cemented with calcite. The sandy intervals consist of medium- to coarse-grained, clear to milky white quartz.

° Unit 2: 3,840 to 5,400 feet

Middle Miocene to Oligocene aged siltstone, sandy siltstone, and shale comprise the second lithologic unit. These fine-grained sediments are fossiliferous, grey, platy, and blocky. Traces of glauconite, lignite, and pyrite are reported. The sediments become moderately calcareous with depth.

° Unit 3: 5,400 to 6,500 feet

This third unit of Eocene to uppermost Cretaceous (Maestrichtian) sediments consists of micritic limestone, chalk, and calcareous shale. The chalk is white and tan with abundant foraminifera. The limestone is light grey. The chalk and limestone grade to dark grey, calcareous, silty shale. The shale is moderately hard, blocky, and platy and contains traces of pyrite and glauconite.

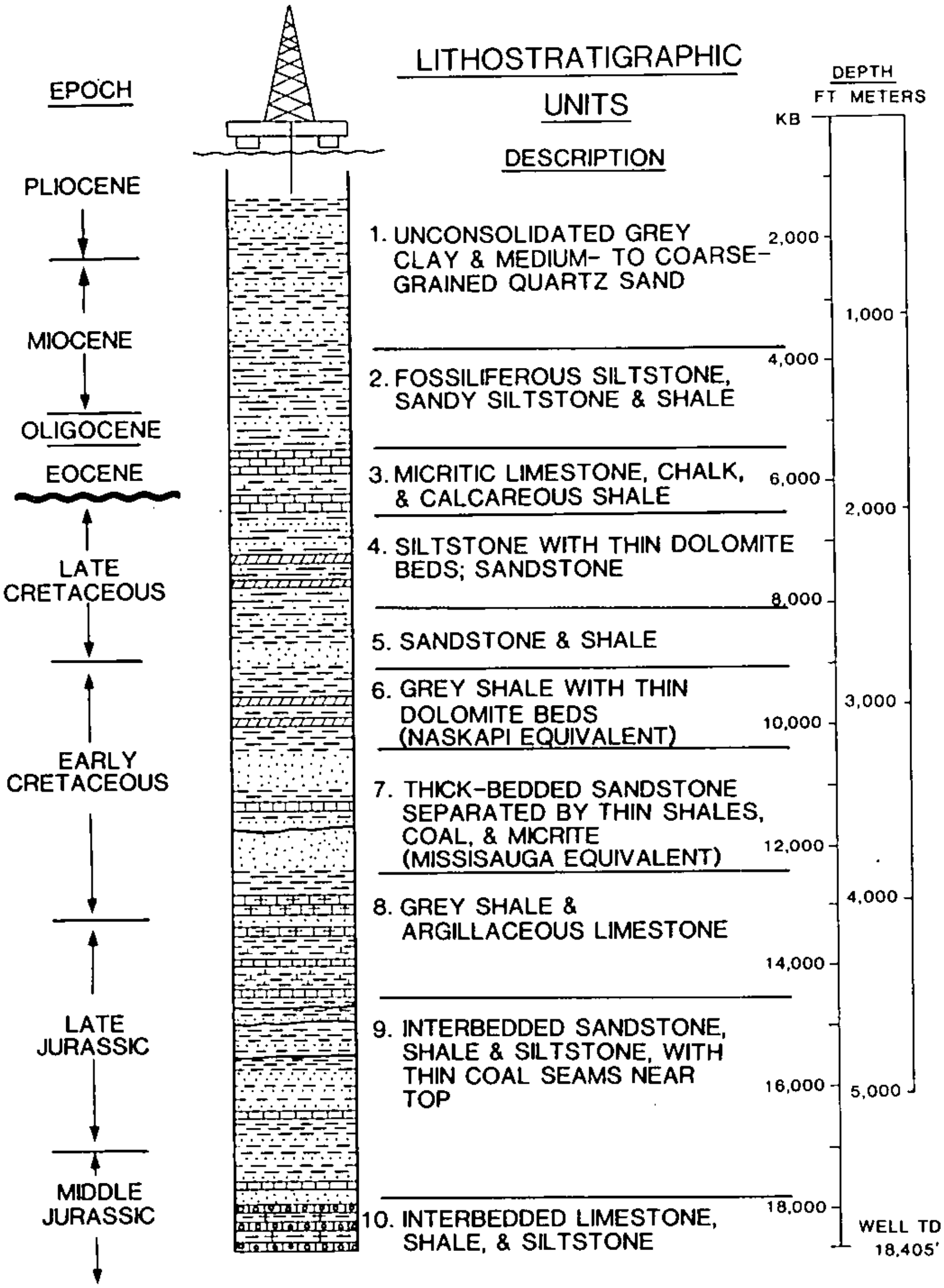

Figure 5.--Lithostratigraphic units penetrated by the Murphy 106-1 well.

° Unit 4: 6,500 to 8,220 feet

Siltstone dominates the fourth lithologic unit which includes Campanian to Turonian (Late Cretaceous) aged sediments. The siltstone is sandy, light grey to brown, soft, micaceous, and calcareous. Thin beds of brown, hard, dolomite are present in the siltstone. Thick sandstone beds are present from 6,680 to 7,080 feet. The sandstones are fine grained, poorly sorted, and immature.

° Unit 5: 8,220 to 9,130 feet

A single progradational sequence of interbedded sandstone and shale comprises the fifth lithologic unit. Sandstone dominates this Cenomanian to Albian (Late to Early Cretaceous) sequence which includes a 10-foot thick limestone bed at 8,880 feet. The sandstone contains white, frosted, and tan quartz grains which appear to be loosely cemented. These sandstones coarsen and thicken upwards. Electric log responses indicate that several of the sandstones contain calcite-cemented zones. The shales are light to dark grey, platy, and calcareous, with traces of mica and pyrite. Thin, light-colored limestone beds occur in the shales.

° Unit 6: 9,130 to 10,390 feet

The sixth lithologic unit consists of shale with thin dolomite beds. This Albian to Aptian (Early Cretaceous) uniform shale has been recorded in other wells in the Baltimore Canyon Trough and correlates with the Naskapi Formation on the Scotian Shelf (Libby-French, 1984). This shale unit provides a distinctive stratigraphic marker in the Baltimore Canyon Trough, where it varies in thickness from about 100 feet to over 1,500 feet. This shale has been identified in the Anchor Gas No.1 Dickinson well, near Cape May, New Jersey, where it provides a key onshore correlaton between the New Jersey coastal plain sediments and the sediments in the Baltimore Canyon Trough (Adinolfi and Jacobson, 1979). In the Murphy 106-1 well, the shale is grey and calcareous with abundant glauconite and traces of pyrite.

° Unit 7: 10,390 to 12,380 feet

Numerous thick sandstones separated by thin shales, coal, and limestone comprise the seventh lithologic unit, which is dated as Barremian to Hauterivian (Early Cretaceous). These deltaic deposits have been described in detail from many wells in the Baltimore Canyon Trough and correlate with the Missisauga Formation on the Scotian Shelf (Libby-French, 1984). In the Murphy 106-1 well, the sandstones vary from fine to coarse grained, being better cemented when fine grained. Toward the bottom of the unit, the sandstones are thicker and appear to coarsen upward indicating delta front deposition. Toward the top of the unit, the sandstones are thinner and appear to be fining upwards, indicating meander channels and point bars. The sandstones at the top and bottom of the unit are separated by 390 feet of shale and limestone. The shale is grey, firm, and fissile with abundant mica and pyrite. The shale grades to calcite-cemented siltstone and fine-grained sandstone. The limestone beds are thin, white to light brown, and blocky with laminae of pyritic shale.

° Unit 8: 12,380 to 14,600 feet

The eighth lithologic unit consists of Late Jurassic to Early Cretaceous (Kimmeridgian to Hauterivian) shale and limestone. Thin sandstone and siltstone beds are minor, but characterize the top of the Jurassic. The shale is medium to dark grey, firm, hard, and platy with numerous very fine-grained sandstone stringers. The shale grades both to micaceous siltstone with coal and pyrite and to argillaceous limestone which contains bryozoan fossils.

° Unit 9: 14,600 to 17,850 feet

Interbedded sandstone, shale, and siltstone characterize this Middle to Late Jurassic clastic unit. In this ninth unit, the sandstones are thinner bedded, lighter colored, and generally better sorted and rounded than sandstones in the seventh (Early Cretaceous) unit. The sandstones generally become finer grained upwards and often exhibit serrated S.P. log patterns toward the top of the individual sands, indicating channel and levee deposition. Pyrite, coal, and muscovite are often present in the sandstones, and asphalt was reported in the cuttings. The shales and siltstones are dark grey and very micaceous, resulting in a platy and fissile texture. The shales and siltstones have a high organic content as evidenced by an increased gas content in the drilling mud. The interval from 14,600 to 15,570 feet (Kimmeridgian) is characterized by the presence of numerous thin coal seams.

° Unit 10: 17,850 to 18,405 feet

Brown, grey, and white marbled limestone beds become abundant toward the bottom of the well. These limestones, interbedded with grey siltstone and shale, characterize the tenth and final lithologic unit. The limestone is oolitic, partly dolomitized, and contains sand grains as intraclasts. The shale and siltstone contain pyrite and lignite.

Conclusions

These 10 lithostratigraphic units generally describe a Mesozoic to Cenozoic marine transgression during which sea level rose to its maximum height during the Eocene. The marine transgression was accompanied by an Early Cretaceous influx of terrigenous sediments in the form of a prograding delta. Deposition of limestones, shale, and sandstones in fluvial and coastal environments during the Jurassic was followed by deposition of numerous thick delta front sandstones during the Early Cretaceous. Siltstone, shale, and limestone, deposited in deeper water, characterize the Late Cretaceous and Tertiary.

WELL VELOCITY PROFILE

by

S. A. Abernathy

Introduction

A checkshot velocity survey was run in the Murphy 106-1 well by Seismic Reference Service Inc. The checkshot provides a reference time between the beginning of the sonic log and the top of the well and supplies data used in the correlating of geophysical logs and seismic profiles. In addition, the checkshot is used to adjust the vertical travel times of the sonic log.

Figure 6 shows an interval velocity profile from 4,913 to 17,376 feet below sea level for the Murphy 106-1 well. The data were obtained from the adjusted sonic log and from the checkshot. With a few exceptions, velocities were calculated at 400-foot intervals. Velocity data were not available from the adjusted sonic log for the section from 413 feet (sea floor) to 4,913 feet. Consequently, the average/interval velocity for this section was calculated from the vertical travel time of the first return of the velocity survey.

Based on velocity breaks, the profile was divided into six velocity intervals. These intervals correlate well with major lithologic divisions based on geologic data. The interval velocities, ranging from 6,658 feet/second to 15,532 feet/second, indicate that clastic lithologies dominate in the well.

Major Velocity Intervals

° Interval I

This interval is identified on the basis of low velocities and poor data control. The anomalously high velocities from 4,913 to 5,303 feet may be related to the juxtaposition of younger and older rocks across the unconformity at 4,872 feet. An alternative explanation is that the preceding unknown interval velocity corresponds to a comparatively large interval in which similar fluctuations are not detectable. In this case, the high velocities may only be an apparent anomaly.

Depth range (feet)........................ 413 - 5,303
Interval velocity range (feet/second)..... 6,658 - 7,602
Average interval velocity (feet/second)... 6,724

These velocities are consistent with clastic lithologies.

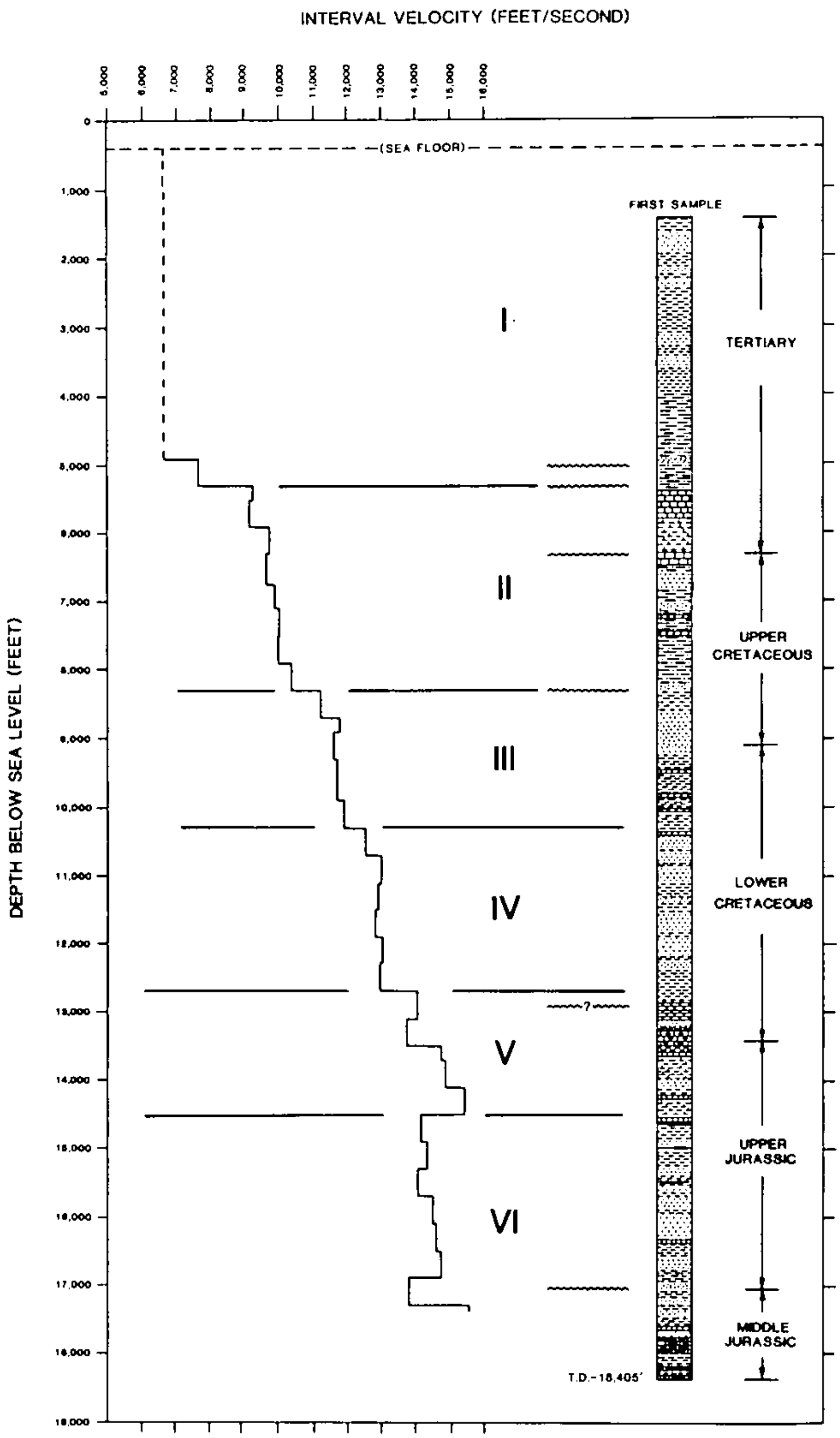

Figure 6.--Interval velocity profile for the Murphy 106-1 well.

° Interval II

This interval is defined by an abrupt velocity increase which correlates with an unconformity at 5,262 feet and with a change from clastic to carbonate lithologies at 5,300 feet.

Depth range (feet)........................ 5,303 - 8,303
Interval velocity range (feet/second)..... 9,112 - 10,336
Average interval velocity (feet/second)... 9,750

These velocities fall within the upper velocity range for siltstones and and sandstones. Because the velocities are relatively "fast" for clastics, carbonates interbedded with the clastics are thought to occur locally.

° Interval III

This interval is identified by higher velocities than those found in Interval II. Because the lithologies in Intervals II and III are similar, the higher velocities in Interval III are probably due to the unconformity near the top of the interval at 8,303 feet.

Depth range (feet)....................... 8,303 - 10,303
Interval velocity range (feet/second).... 11,204 - 11,905
Average interval velocity (feet/second).. 11,614

These velocities are close to the upper limit of clastic velocities, indicating an intercalated section consisting of carbonate and clastic rocks.

° Interval IV

This interval is delineated on the basis of an increase in the average velocity compared to Interval III and on fairly constant interval velocities.

Depth range (feet).......................... 10,303 - 12,703
Interval velocity range (feet/second)........ 12,539 - 13,014
Average interval velocity (feet/second)...... 12,869

These velocities are within the sandstone/siltstone range. However, the values are closer to the shale/clay range than the velocities in intervals II and III, suggesting that this interval has a greater clastic fraction. In addition, the relatively constant velocities suggest a homogenous lithologic section. This analysis is supported by the geologic data.

° Interval V

This interval is identified by a marked increase in velocities apparently caused by the change from clastic lithologies to interbedded carbonates and clastics. A possible unconformity at 12,800 feet may also be a factor.

Depth range (feet).......................... 12,703 - 14,503
Interval velocity range (feet/second)........ 13,740 - 15,385
Average interval velocity (feet/second)...... 14,481

These velocities are close to the maximum velocities of sandstone and siltstone. These velocities are consistent with interbedded carbonates and clastics.

° Interval VI

This interval is identified by a decrease in velocities.

Depth range (feet).......................... 14,503 - 17,376
Interval velocity range (feet/second)........ 13,746 - 15,532
Average interval velocity (feet/second)...... 14,286

The lower velocities indicate an increase in clastics.

BIOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

by

Harold L. Cousminer, William E. Steinkraus, and Frederick Adinolfi

Introduction

Initial biostratigraphic analysis of the Murphy 106-1 well samples was completed by International Biostratigraphers Inc. (IBI) in April 1980. Their report, based on both drill cuttings and sidewall cores, describes foraminifers and palynomorphs from the entire sedimentary section penetrated by the well. The report also examines calcareous nannofossils between 13,310 and 13,970 feet in an attempt to fix the position of the Jurassic-Cretaceous boundary.

Minerals Management Service biostratigraphic analysis of the Murphy 106-1 well included a study of calcareous nannofossils from the interval 6,290 to 14,520 feet, on the basis of 30-foot composite cuttings (274 slides), and a study of palynomorphs from the interval 1,370 to 18,320 feet, on the basis of 90-foot composite cuttings (188 slides). All depths are measured from the kelly bushing.

Three factors limit the reliability of these paleontologic data. They are: (1) Most analyses are made from drill cuttings which are often heavily contaminated by cavings from higher in the drill hole. For this reason, only "tops," or the uppermost appearances of species, are recorded. (2) Reworked, older fossil assemblages and individual specimens are commonly redeposited in younger detrital sedimentary rocks. These reworked fossils must be recognized so that misdating can be avoided. (3) Biostratigraphic control is poor in pre-Late Jurassic strata. Calcareous nannofossils and foraminifera are rare to nonexistent. Palynomorphs are more common, but their biostratigraphic distribution is not fully documented with reference to the European stage type localities.

The Minerals Management Service has relied on the Jurassic palynostratigraphy of offshore eastern Canada (Bujak and Williams, 1977) because many of their palynomorph marker species are also present in the United States offshore Atlantic. Although the European stage equivalence of many species is not fully resolved, several species have recently been documented in European type sections (Woollam and Riding, 1983; Riding, 1984; Davies, 1985).

Paleontologic evidence indicates that the sampled section begins in the late Pliocene, or possibly early Pleistocene, at 1,370 feet and ends in the Middle Jurassic (Bathonian ?) at 18,320 feet. No nannofossils were found below 13,440 feet (Tithonian), and age diagnostic foraminifera were not found below 8,540 feet (Cenomanian). Many species of the planktonic foraminifer *Globorotalia* provided good Cenozoic age markers.

Cenozoic hiatuses are recognized at the top of the Oligocene at 4,970 feet, at the top of the late Eocene at 5,330 feet, and at the base of the Tertiary at 6,290 feet. Cretaceous unconformities have been interpreted in the Turonian at 8,300 feet and possibly at the top of the Berriasian at 12,900 feet. A hiatus is recognized at the top of the Middle Jurassic at 17,060 feet, between the Oxfordian and the Bathonian ?. Figure 7 shows the highest occurrences of the marker fossils and the locations of the unconformities.

Lithologic, paleontologic, and electric log analyses of the sediments have been applied to determine the environments of deposition represented in the well. Paleobathymetric interpretations are shown diagramatically in Figure 7. The paleobathymetry is based largely on the distribution of benthonic foraminifers in the continental shelf and slope deposits of the Tertiary and Early Cretaceous. These interpretations become progressively more tenuous with increasing geologic age because they are derived by comparing fossil benthonic assemblages with Holocene assemblages known to favor certain marine environments. Lithologic and electric log analyses were used to assign paleobathymetry to the fluvial, deltaic, and coastal deposits of the Early Cretaceous and Jurassic.

Cenozoic

Cenozoic sediments range from late Pliocene (or possibly early Pleistocene) to early Eocene in age and are interrupted by two recognizable hiatuses. Environments of deposition range from middle shelf to lower slope regimes.

° Late Pliocene - Pleistocene (1,370 to 2,360 feet)

No samples were collected above 1,370 feet. Foraminiferal species were observed throughout most of this section with the occurrence of Globorotalia crassaformis at 1,370 feet and below indicating a Pleistocene or older age. Abundant spruce pine pollen (Picea-Pinus) indicate the boreal cooling trend beginning in late Pliocene and extending into the Pleistocene. Environments of deposition reflect middle to outer shelf conditions.

° Late Miocene (2,360 to 2,540 feet)

This thin interval is dated Late Miocene on the basis of the planktonic foraminifer Sphaeroidinellopsis subdehiscens at 2,360 feet. Palynology also indicates a Miocene top in the interval 2,360 to 2,450 feet, with a well-developed, oak-hickory (Quercus-Carya) assemblage, lacking both grass (Gramineae) and herbaceous pollen common to post-Miocene sediments. These sediments reflect inner to middle shelf conditions during a major progradation of the continental shelf.

° Middle Miocene (2,540 to 4,970 feet)

The palynomorph Lejeunacysta tenella indicates a middle Miocene top at 2,540 feet. Phytoplankton occur frequently down to 3,081 feet. Deeper in the section at 4,160 feet, the foraminifer Globorotalia fohsi also establishes these sediments as middle Miocene.

Other foraminifera identified in the lower part of the section include Globorotalia siakensis, Uvigerina rustica, Schenkiella pallida, and Gyroidina venezuelana. Outer shelf conditions prevailed reflecting a relative rise in sea level.

° Oligocene (4,970 to 5,360 feet)

As in both the COST No. B-2 and B-3 wells, Eocene chalk is overlain by Oligocene shale. Specimens of several rare species of the foraminifer genus Globorotalia establish an Oligocene age for this interval. Foraminiferal assembleges are common and diverse. Common benthonic forms include Guttulina irregularis, Uvigerina mexicana, Bathysiphon eocenica, Cyclammina cancellata, and Karreriella mexicana. Abundant radiolarian and diatom fragments were found in this interval, probably representing the mid-Oligocene cooling event. The thick sandstone at the top of this interval may represent the late Oligocene regression recorded in other Mid-Atlantic wells and on the Scotian Shelf.

° Late Eocene (5,360 to 5,450 feet)

A conspicuous feature of the Mid- and South Atlantic wells is the occurrence of a lower Tertiary carbonate facies; these chalks were deposited at depths equivalent to those found on the continental slope. The occurrence of the planktonic foraminifer Globorotalia cerroazulensis marks the top of this brief late Eocene section. Several species of late Eocene, globigerinid foraminifera were also identified. The phytoplankton species Deflandrea phosphoritica, Cordosphaeridium inodes, and Thallasiphora pelagica support a late Eocene age for these sediments.

° Middle Eocene (5,450 to 6,200 feet)

The upper limit of the middle Eocene is determined by the highest occurrence of the planktonic foraminifer Truncorotaloides rohri. Other species of Truncorotaloides and species of Globorotalia also indicate a middle Eocene age for these sediments. Middle Eocene phytoplankton species identified include Rottnestia borussica and Adnatospheridium patulum in the sample interval 5,600 to 5,690 feet. Continental slope deposition continued throughout the middle Eocene.

° Early Eocene (6,200 to 6,290 feet)

This thin section of sediments is interpreted as early Eocene on the basis of the presence of the planktonic foraminifer Globorotalia pentacamerata at 6,200 feet. Several other species of Globorotalia, as well as the species Globigerina soldadoensis soldadoensis, also support the early Eocene date. This interval was found to be palynologically barren. Continental slope deposition began in the early Eocene. The regional unconformity at the base of the Tertiary has been identified in all exploration and COST wells on the U.S. continental shelf and on the Scotian Shelf. Paleocene sediments are generally very thin or absent in all these offshore wells.

Mesozoic

Late Cretaceous

Late Cretaceous sediments range from Late Maestrichtian to Cenomanian in age. A major unconformity occurs at the top of the Late Cretaceous at 6,290 feet, and another unconformity occurs in the Turonian at 8,300 feet. Outer shelf depositional environments prevailed throughout most of the Late Cretaceous period, resulting in mainly fine-grained sediments deposited as marine transgressive facies. The Late Cretaceous begins with a progradational (coarsening- and thickening-upward) sequence of sandstones and shales. A major marine transgression during the Late Cretaceous resulted in deposition of a deeper-water facies along the Atlantic continental margin. Owens and Sohl (1969) recognized two transgressive cycles of sedimentation during deposition of the Late Cretaceous Raritan and Magothy Formations of the New Jersey coastal plain. The Raritan Formation represents an earlier Cenomanian transgressive cycle, separated from the overlying Magothy Formation by a Turonian unconformity (Christopher, 1977). The Coniacian to Santonian aged Magothy Formation represents the second transgressive cycle. Coniacian regressive sandstone intervals have been identified in the United States Geological Survey No.1 Island Beach and the Anchor Gas No.1 Dickinson wells located along the New Jersey coast, as well as in the COST No. B-2 and B-3 wells (Adinolfi and Jacobson, 1979). In the Murphy 106-1 well, the two transgressive cycles have been identified. The two Late Cretaceous transgressive cycles are separated by a Turonian unconformity which is evident from the paleobathymetry (figure 7), and from the interval velocity profile (figure 6). The second transgressive cycle begins with a regressive sandstone dated as Turonian.

° Late Maestrichtian (6,290 to 6,470 feet)

Several species of the planktonic foraminiferal genus *Globotruncana* establish a Late Maestrichtian age for these uppermost Mesozoic sediments. The calcareous nannofossils *Arkhangelskiella cymbiformis* and *Tetralithus aculeus* also indicate a Maestrichtian age. This interval was palynologically barren; however, a large influx of inertinite from 6,230 to 6,410 feet suggests a biostratigraphic boundary within this interval. The chalks in this interval were deposited on the outer shelf.

° Campanian (6,470 to 6,630 feet)

The calcareous nannofossil *Eiffellithus eximus* occurs at 6,470 feet and establishes a Campanian age for this interval. This age is supported by several species of the planktonic foraminiferal genus *Globotruncana*. The dinoflagellate *Aereoligera senonensis*, whose lower range extends into the Campanian, is present in these sediments. Another large influx of blocky, coarsely fragmental, inertinite at 6,560 feet indicates that this may be within a biostratigraphic boundary interval. Oscillation of the shoreline during the Campanian resulted in deposition of silt and clay on the middle shelf.

° Santonian (6,630 to 7,550 feet)

Two Late Cretaceous regressive sandstones were penetrated at the top of the Santonian. These sandstones represent oscillation of the shoreline and a shift from outer shelf to possibly delta-front sedimentation. The siltstone separating the two sandstones represents the fine-grained muddy deposits of the prodelta.

The occurrence of the nannofossil Marthasterites furcatus at 6,630 feet indicates a Santonian age for these sediments. This age is supported by the occurrence of the foraminifer Globotruncana concavata in samples from 7,010 to 7,550 feet. The Santonian interval is palynologically barren.

° Coniacian (7,550 to 7,860 feet)

Although no restricted Coniacian age fossils were identified by the Minerals Management Service, the report of three species of the planktonic foraminiferal genus Globotruncana by IBI in the interval 7,550 to 8,300 feet indicates a Coniacian age for these sediments. The dinoflagellate species Chatangiella cooksoni, Deflandrea pirnaensis, and Xenascus ceratioides, recovered from 7,890 to 7,980 feet, all have partial Coniacian ranges. Outer shelf deposition continued through the Coniacian.

° Turonian (7,860 to 8,450 feet)

The occurrence of the nannofossils Corollithion achylosum and Radiolithus planus at 7,860 feet establishes this interval as Turonian in age, since neither of these species occurs above the Turonian. The interval is barren of plant fossils from 8,070 to 8,250 feet. Several palynomorphs identified at 8,340 and 8,430 feet do not range above the Turonian.

The regressive sandstone at 8,220 feet separates the two Late Cretaceous transgressive cycles. A large seismic velocity increase below this sandstone indicates the possibility of an unconformity. Environments of deposition range from delta front to prodelta and outer shelf.

° Cenomanian (8,450 to 9,060 feet)

The highest occurrence of the foraminifer Rotalipora cushmani marks the top of the Cenomanian at 8,450 feet. The Cenomanian nannofossil marker Corollithion kennedyi was identified at 8,610 feet. The interval is barren of plant fossils.

The bottom of the Cenomanian interval consists of a 470-foot thick progradational sequence of sandstone and shale which coarsens and thickens upwards. This progradational sequence marks the beginning of the Late Cretaceous transgressive cycles during which delta front sands and open water, interdistributary bay sands and clay were deposited atop the shelf muds. This prominent shale/sandstone contact also occurs in the Cenomanian in the COST B-3 well.

However, closer to the present shoreline (in the COST B-2 well and wells drilled by Texaco and Tenneco in Hudson Canyon, blocks 598 and 642) this progradational sequence begins earlier in the Albian.

Early Cretaceous

An influx of clastics in the form of prograding delta wedges characterize the Early Cretaceous in the Baltimore Canyon Trough. In the Murphy 106-1 well, Early Cretaceous sediments range from Berriasian to Albian in age. These sediments were deposited in deltaic and coastal settings and consist of a complex stratigraphic section of interfingering marine and nonmarine strata. Lignite is present, and leaching fresh water partially dolomitized some thin limestones. Spontaneous potential responses exhibit cylindrical, funnel, bell, and serrated shapes depending on the delta or coastal facies position. Diagnostic electric log curves reflect changes in grain size. In sharp contrast to the marine transgressive facies seen in the Late Cretaceous, the resistivity curve is very active and clearly reflects coastal and delta system patterns.

Onshore, the Lower Cretaceous (and locally Cenomanian) Potomac group, exposed in the Salisbury Embayment and penetrated in the U.S. Geological Survey No.1 Island Beach and Anchor Gas No.1 Dickinson wells, consists of fluvial-deltaic gravels, sands, and varicolored silt and clays (Adinolfi and Jacobson, 1979). Generally, correlative onshore intervals are thinner and coarser grained than offshore intervals.

° Albian (9,060 to 9,800 feet)

The top of the Early Cretaceous section has been determined by the highest occurrence of the Albian nannofossil indicator Braarudosphaera africana at 9,060 feet. In addition, the dinoflagellate Spinidinium vestitum was identified in the composite sample 9,140 to 9,230 feet. Abundant inertinite and foraminiferal test linings at 9,060 feet correspond with the Albian top. These sedimentary rocks represent prodelta muds deposited in water depths of about 100 feet.

° Aptian ? (9,800 to 10,400 feet)

IBI reports the top of Aptian at 9,800 feet on the basis of the dinoflagellate Subtilisphaera pirnaensis which has a documented range of Cenomanian-Santonian. The Minerals Management Service found no evidence to paleontologically date this interval. The Aptian ? interval contains grey shale deposited in a distal delta front environment. These prodelta shales were deposited during the marine transgression that resumed during the Aptian and Albian. Limestone marks the base of the Aptian section and was deposited on the Barremian sandstones.

° Barremian (10,400 to 10,850 feet)

The top of the Barremian is reported at the highest occurrence of the dinoflagellate Aptea anaphrissa. This palynomorph was also identified below the Barremian, where it may represent caved material from above. Delta front, tidal channel, and barrier bar sandstones characterize this interval.

° Hauterivian (10,850 to 12,700 feet)

Thick sandstones, thin shales, and lignite characterize Hauterivian coastal and deltaic deposition. The occurrence of the dinoflagellate Batioladinium gochtii, which has a Hauterivian top, at 10,850 feet establishes this interval as Hauterivian in age. The dinoflagellate Muderongia simplex, which begins its range in the Valanginian-Hauterivian, was also identified. The plant spore Trilobosporites sp.1, with a Valanginian-Hauterivian range (Bebout, 1981), was reported in the shales. Although long ranging, the dinoflagellate Oligosphaeridium perforatum has a peak occurrence in the North and Mid-Atlantic OCS, in both the Valanginian and Hauterivian stages. Its occurrence in this interval supports the Hauterivian age for these sediments. Delta front, scour channel, and barrier bar sandstones characterize this interval.

In both the COST B-2 and B-3 wells, an unconformity separates Hauterivian from Barremian rocks. This unconformity formed as a result of subaerial erosion and, in the B-3 well, separates shaley limestone from overlying shaley sandstone (Poag, 1985).

° Valanginian ? (12,700 to 12,900 feet)

IBI dated this thin interval as Valanginian because of the presence of several dinoflagellate species with questionable age ranges. Minerals Management Service found no paleontological evidence to date this interval. However, the long-ranging Early Cretaceous dinoflagellate species Phoberocysta neocomica was identified from 12,840 to 12,930 feet.

According to global cycles of relative sea level change (Vail and others, 1977), a major marine regression occurred during the Valanginian. This thin, questionable section dated as Valanginian indicates that this location may have been intermittently exposed resulting in nondeposition and possibly erosion. A possible unconformity occurs at the top of the Berriasian.

° Berriasian (12,900 to 13,440 feet)

The occurrence of the nannofossil Polycostella senaria, a species which does not range above the Berriasian, establishes the Berriasian top at 12,900 feet. Shallow water carbonate deposition marks the beginning of the Early Cretaceous. These high-energy facies were deposited as reef talus or beach deposits composed of carbonate debris.

A possible unconformity occurs at the top of the Berriasian separating the nonmarine shales and sandstone from the underlying shaly limestone. In both the COST B-2 and B-3 wells, an unconformity at the upper surface of the Hauterivian section also separates overlying nonmarine sandstone and shale from shaly limestone (Poag, 1985). The age discrepancy between these two otherwise similar unconformities prevents their correlation.

Late Jurassic

Late Jurassic sediments range from Oxfordian to Tithonian in age. Carbonate deposition existed from Late Kimmeridgian time, through the Tithonian, and into the Early Cretaceous. Bryozoans, gastropods, occasional oolites, and abundant muscovite indicate that these uppermost Jurassic and basal lower Cretaceous calcareous shales and argillaceous limestones were deposited in subtidal backreef and lagoonal carbonate depositional environments. Carbonate deposition was preceded by deposition of clastics on a lower delta plain (delta front) during the Oxfordian and Early Kimmeridgian.

° Tithonian (13,440 to 14,100 feet)

Two dinoflagellate species reported from this interval, Ctenidodinium panneum and Muderongia sp. A, have well established Tithonian tops. In addition, the nannofossil species Hexalithus noelae, which also has a Tithonian top, was recorded at 13,440 feet and establishes this interval as Tithonian.

° Kimmeridgian (14,100 to 16,250 feet)

The topmost occurrence of the palynomorph Gonyaulacysta longicornis at 14,100 feet establishes this interval as Kimmeridgian. Below this, at 14,300 feet, several specimens of the dinoflagellate Senoniasphaera jurassica were identified. This form has a well established Kimmeridgian range and was also recorded from a sidewall core at 14,204 feet. Shale, numerous thin coal seams, thin meander channel sandstones, and natural levee sandstones indicate deposition in a delta front environment.

° Oxfordian (16,250 to 17,060 feet)

The dinoflagellate species Adnatosphaeridium aemulum, along with Hystrichogonyaulax nealei and Endoscrinium oxfordianum, establishes the Oxfordian top at 16,250 feet.

Adnatosphaeridium aemulum has an established Oxfordian top in both Western Europe and the offshore Canadian Scotian Shelf and Grand Banks. Very fine-grained sandstones, siltstones, and shale characterize this interval. The sandstones are mainly fining upwards, are poorly sorted, and exhibit log responses interpreted as meander channel, natural levee, and distributary mouth bar deposits. In the vicinity of the Murphy 106-1 well, lower delta plain sedimentation occurred during the Oxfordian.

Middle Jurassic

Slides made from the cuttings indicate that the interval from 16,520 to 17,060 feet is essentially barren. Since it is barren and IBI reports no sediments in this well to be older than Oxfordian in age, this interval was provisionally assigned to the Oxfordian. Possible Middle Jurassic sediments of Bathonian age were identified at 17,060 feet. However neither IBI nor the Minerals Management Service found any evidence for a Callovian section in the well. This suggests an unconformity at the top of the Middle Jurassic between the Oxfordian and the Bathonian. An unconformity at this stratigraphic position was also identified in the Shell 586-1 well (Steinkraus and others, 1986).

° Bathonian ? (17,060 to 18,320 feet)

This section consists of an upper clastic interval underlain by carbonates at the bottom of the well. The clastics represent the beginning of deltaic sedimentation which continued into Kimmeridgian time. The limestones at the bottom of the well contain detrital clasts and oolites. These carbonates were deposited as oolite banks within a lagoon with a terrigenous source of material.

Several specimens of the palynomorph species Gonyaulacysta filapicata were recorded within this interval beginning at 17,060 feet, indicating a possible Bathonian top.

KEROGEN ANALYSIS

by

Charles Fry

The kerogen and palynology slides were analyzed to determine the type and thermal rank of the kerogen contained in the cuttings samples of the Murphy 106-1 well. For this analysis, the insoluble organic material dispersed in sedimentary rock is classified as four major types: Algal, organic material mostly of marine origin, either recognizable algae or its unstructured remains; Herbaceous, leafy portion of terrestrial plants, including spores and pollen; Woody, plant detritus with a lignified fibrous texture; and Coaly, black opaque material considered to be chemically inert. This classification is adapted from Geochem Laboratories (1980) and Hunt (1979). Estimates are made for the percentages of each of these types that are contained on the kerogen and palynology slides. Algal and marine derived kerogen have proven to have the best potential for oil and gas generation depending on temperature and burial conditions. More structured terrestrial kerogen has less oil generation potential, but can generate gas hydrocarbons at higher temperatures (Tissot and Welte, 1978).

The thermal maturity of the organic material was estimated by comparing the color of various palynomorphs included on the kerogen and palynology slides against the Thermal Alteration Index (TAI) scale established by Jones and Edison (1978). The colors displayed by the organic matter indicate the degree to which the kerogen has been thermally altered (Staplin, 1969). Column (a) in figure 8 is a scale showing the relationships among TAI, spore color, and hydrocarbon thermal maturation.

The kerogen type and thermal alteration data are used to complement organic geochemical analyses in determining the depths of prospective petroleum source rocks in a well and whether the source rocks are expected to yield oil, gas, or condensate.

Kerogen Type and Distribution

The distribution of kerogen type with depth is shown, diagramatically, in figure 8. All depths are measured from the kelly bushing. Pliocene samples (1,370 to 2,360 feet) display a dominantly terrestrial kerogen distribution: 0 to 15 percent algal kerogen; 20 to 40 percent herbaceous; 30 to 65 percent woody; and 10 to 15 percent coaly. The percentage of algal kerogen increases up to 30 percent within the Miocene (2,360 to 4,970 feet) with herbaceous kerogen ranging from 30 to 35 percent; woody 40 to 50 percent; and coaly 5 to 15 percent. Marine kerogen dominates both the Oligocene and Eocene sections of this well (4,970 to 6,290 feet). Algal and herbaceous kerogen types range from 70 to 75 percent of the observed population.

Samples examined from the Late Cretaceous section of this well (6,290 to 9,060 feet) have a mainly terrestrial distribution: trace to 15 percent algal kerogen; 20 to 35 percent herbaceous; 30 to 40 percent woody; and 25 to 30 percent coaly.

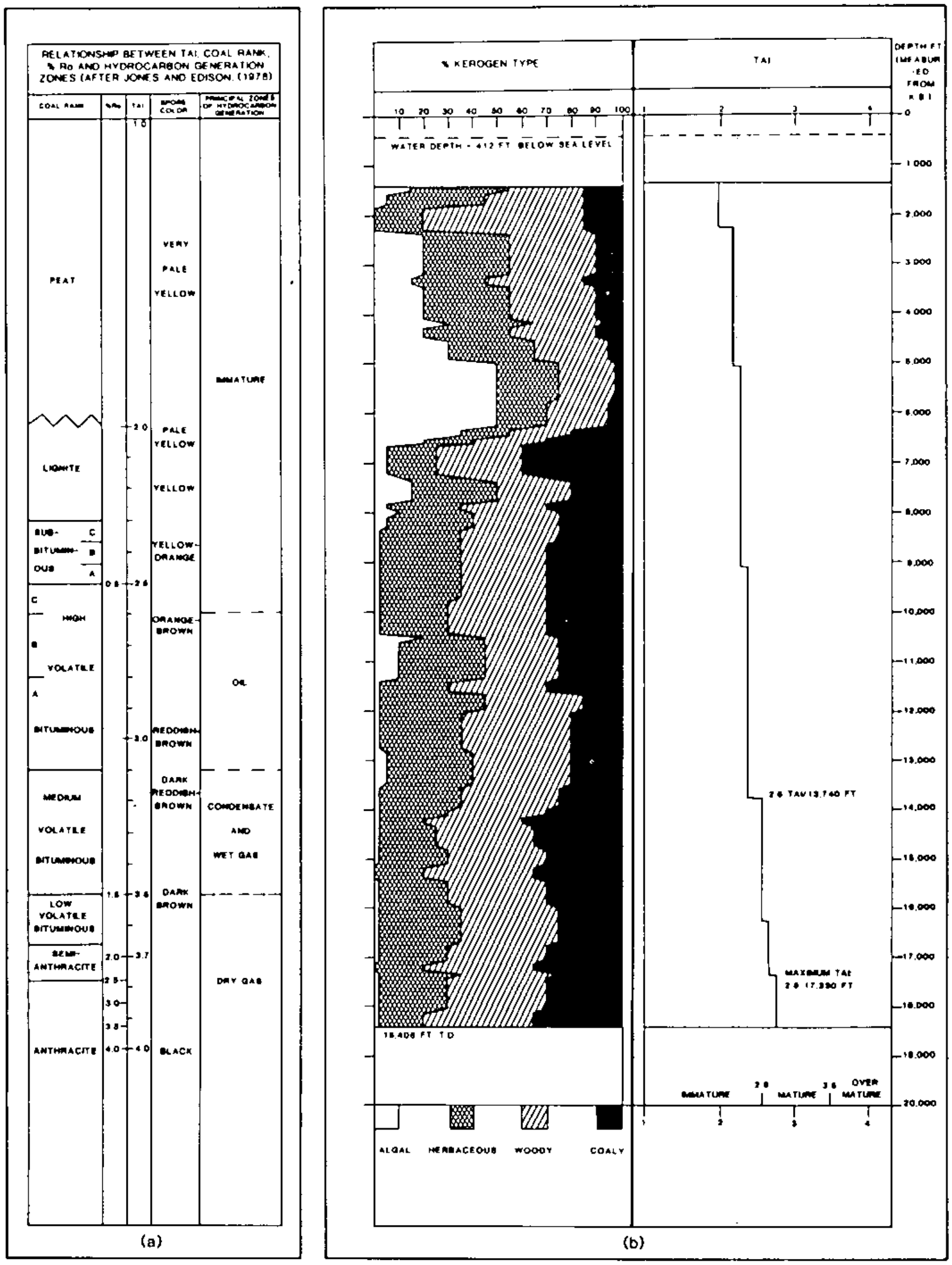

Figure 8.--Kerogen analysis for the Murphy 106-1 well.

The distribution of the herbaceous, woody, and coaly kerogen types observed in the Early Cretaceous is similar to that of the Late Cretaceous. Except for the interval 10,410 to 11,310 feet, where algal material ranges from 10 to 20 percent, all Early Cretaceous samples (9,060 to 13,440 feet) have 5 percent or less algal kerogen.

Jurassic samples (13,440 to 18,405 feet TD) are all dominated by terrestrial material. The woody and coaly kerogen types comprise 65 to 80 percent of the observed population with only trace amounts of algal kerogen visible.

In summary, the Tertiary section of the Murphy 106-1 well contains significant amounts of marine, oil-prone kerogen. Oligocene and Eocene sediments (4,970 to 6,290 feet) are especially rich in this material. The Cretaceous and Jurassic sections are dominated by the terrestrial gas-prone kerogen types.

Maturity

Judging thermal maturity from well cuttings must be done with great care to insure that the material being analyzed is indigenous to the level sampled. TAI values were recorded using palynomorphs considered to be in situ. Caved or reworked material give false indications of maturity. Oxidation caused by a high energy depositional environment can also alter the appearance of the kerogen.

The thermal maturity of the kerogen analyzed from the Murphy 106-1 well was estimated by the visual observation of palynomorph color which corresponds to it's TAI. Values of TAI are plotted versus depth in figure 8 and compared to the TAI maturity scale at the bottom of the graph. Orange-brown dinoflagellates were observed in the 13,740 foot sample. This color corresponds to a TAI value of 2.6 which represents borderline maturity. Dark, orange brown, dinoflagellates found in the 17,330 foot sample indicate an increase in thermal alteration (2.8 TAI) representing a level below peak maturity. Palynomorphs with this dark, orange-brown color were observed below this level to total depth (18,405 feet).

Conclusion

Marine oil-prone kerogen is abundant within the Tertiary section of the Murphy 106-1 well, especially in the Oligocene and Eocene interval between 4,970 to 6,290 feet. A maximum TAI value of 2.2 indicates the kerogen in these sediments is immature and significant hydrocarbon generation is unlikely.

Mature palynomorphs were first observed just below the top of the Jurassic section of this well at 13,470 feet. Palynomorphs with colors indicating increased alteration (2.8 TAI) were observed in Middle Jurassic samples at and below 17,330 feet. The color of the kerogen observed within the Jurassic samples suggests that hydrocarbon generation is possible within this section. The mainly terrestrial nature of the kerogen observed in all Jurassic samples is associated with the generation of gas hydrocarbons.

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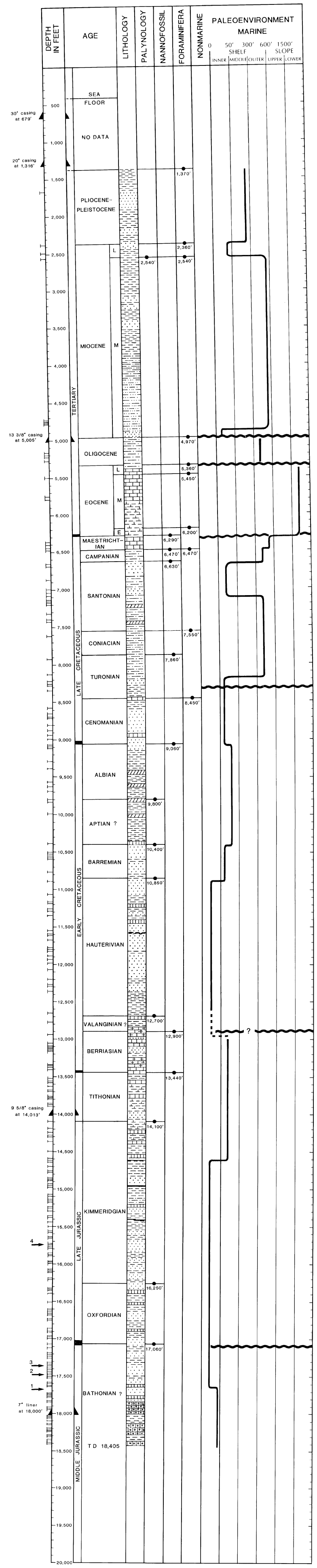

EXPLANATION

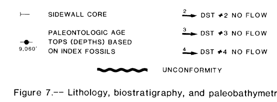

Figure 7.-- Lithology, biostratigraphy, and paleobathymetry of the Murphy 106-1 well, Mid-Atlantic OCS.