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Lithology and X-ray mineralogy of the Conoco 145-1 well, U.S. North Atlantic Outer Continental Shelf

by

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ABSTRACT

The exploratory Conoco 145-1 well was drilled to a total depth of 4420 m relative to the Kelly bushing in the southeastern portion of the Georges Bank Basin. X-ray diffraction and petrographic analyses and the examination of well logs show that the well penetrated a section composed of semiconsolidated mudstones and unconsolidated, glauconitic quartz sands (206 to 710 m); unconsolidated quartz sands interbedded with light gray siltstone, gray to dark gray carbonaceous shales and thin stringers of lignite (710-1555 m); chalky limestones (1555-1981 m); dark gray calcareous shales and siltstones (1981-2774 m); light gray, indurated, micritic limestones interbedded with dark gray shales (2774-3917 m); hard, white dolostone and light gray limestones interbedded numerous thin dark gray shales, anhydrite, and reddish-brown siltstones (3917-4420 m). The dolostone is more common than limestone below 4055 m; the anhydrite is more common than the shales and siltstones below 4075 m.

Calcite is the predominant cement throughout much of the section. Dolomite, hematite, goethite, chert, and siderite occur in smaller amounts that can be locally important. Glauconite, occasionally associated with phosphorite, is common above 1247 m, but occurs only in scattered trace amounts below this depth. Pyrite, which is found throughout the section, is concentrated in two zones between 588-725 m and 1329-1823 m.

INTRODUCTION

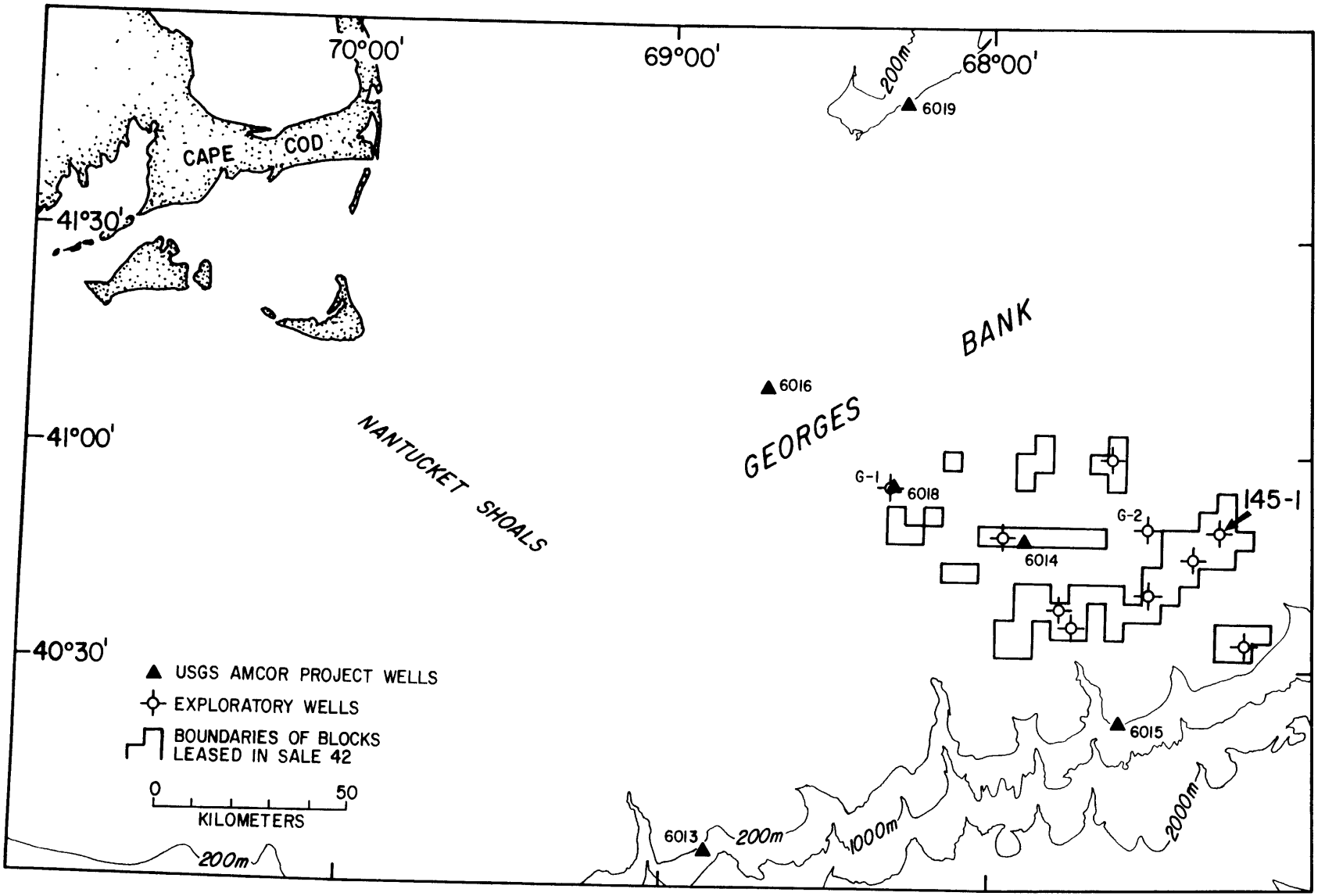
The Continental Oil Company (Conoco) Lydonia Canyon Block 145-1 well was drilled between May 17 and August 25, 1982 at latitude 40°49.977'N and longitude 67°17.117'W about 240 km southeast of Cape Cod, Massachusetts (Fig. 1). Drilling was conducted from the Keydril Company semisubmersible rig Aleutian Key in 91 m of water. Drilling operations continued to a total depth of 4420 m (14500') relative to the Kelly Bushing (RKB), a total penetration depth equivalent to 4304 m of section below the seafloor. The well was drilled to examine the petroleum potential in the northeastern portion of the Georges Bank Basin on the U.S. north Atlantic Continental Shelf; it was classified as a dry hole and plugged and abandoned after testing.

All depth references in this report are based on depths RKB. The distance below the sediment/water interface for any given sample may be calculated by subtracting 117 m (the sum of the 91 m water depth and the 26 m distance between sea level and the Kelly Bushing) from the depth RKB.

SAMPLE INVESTIGATION METHODS

A total of 160 rotary drill cutting samples from 27.43 m intervals in the well were hand-picked to obtain sufficient amounts of representative lithologies for description and analysis. Subsamples were subsequently washed, sonified, and rewashed in the laboratory to exclude contamination by drilling fluids. Because of this washing procedure and because of the winnowing and abrasion associated with the circulation of drilling mud, some of the natural silts and clays have probably been removed from the less lithified sediments. Furthermore, because coarse sand and gravel tend to be easily disaggregated into their individual constituent grains during drilling, and because of other operational factors associated with drilling, such as caving, drill-cutting samples may sometimes misrepresent the actual material penetrated in a given interval and emphasize the more consolidated, fine-grained units. Therefore, the analysis and description of rotary drill cuttings are supplemented by electric and lithologic logs. These well logs, when used in conjunction with the cuttings,

Figure 1. Map showing the location of the Conoco 145-1 well drilled on Georges Bank, north Atlantic Outer Continental Shelf. The distribution of the other drilled wells and the boundaries of blocks leased during Sale 42 are also plotted on the map.


70°00'
69°00'
68°00'
CAPE COD
41°30'
41°00'
40°30'
NANTUCKET SHOALS
GEORGES BANK
200m
6019
6016
G-1
6018
G-2
145-1
6014
6015
6013
1000m
2000m
USGS AMCOR PROJECT WELLS
EXPLORATORY WELLS
BOUNDARIES OF BLOCKS LEASED IN SALE 42
0
50
KILOMETERS

helped delineate the lithologic variations within any given depth interval.

X-ray powder diffraction analyses were performed on 112 cutting samples from the 27.43 m intervals at 99 levels in the well. No samples were available for analysis above 206 m in the well. A split from each sample was mounted as a randomly oriented powder and X-rayed. Semiquantitative estimates of the mineral abundances determined from the randomly oriented aggregate mounts were made by comparing the sample diffraction peak areas and intensities with the areas and intensities recorded from a collection of external standards. The clay fraction (<2 μm) from each sample was separated by centrifuge and mounted as an oriented aggregate on a glass slide by a filter-membrane peel technique (Pollastro, 1980). Each oriented clay mineral sample was subjected to four treatments (air-drying, glycolation with ethylene glycol, heating to 400 °C, and heating to 550 °C) to determine which clay minerals were present.

Clay mineral abundances were estimated by a method described by Biscaye (1965). The data from the randomly oriented and oriented aggregate mounts were combined. The semiquantitative estimates are reported in relative weight percentages of crystalline material and are generally considered to be accurate to within 10 percent of their actual values; however, even if due only to rounding errors, the lower values (<10 percent) may vary considerably more than this.

A split was taken from each sample and mounted in Piccolite (N=1.52) as a smear slide. The slides were used to check the semiquantitative diffraction results, to generate textural descriptions, to identify layered silicates occurring in the silt fraction, to detect amorphous phases or those occurring in trace amounts, and to examine the biogenic debris.

The electric and lithologic logs and paleontologic data for the Conoco 145-1 well is on file at the USGS office in Woods Hole, MA. Copies are available from the National Geophysical Data Center, Boulder, CO.

LITHOLOGY

The stratigraphic column penetrated by the Conoco 145-1 well may be divided into six major lithologic units. Unit I, from 206 m down to 710 m, consists mostly of gray to bluish-gray, semiconsolidated, slightly calcareous and fossiliferous argillaceous claystones. However, pinkish-gray limestones are present between 423-533 m and glauconitic, occasionally phosphatic, unconsolidated sands are common between 369-561 m. Unit II, between 710-1555 m, consists predominantly of fine- to medium-grained, moderately sorted, subrounded, unconsolidated sands that contain abundant fossil fragments and thin stringers of lignite. These sands are interbedded with gray, calcite-cemented siltstones, light gray sandy limestones (1183-1283 m), and dark gray, carbonaceous shales. Unit III, between 1555-1981 m, consists mainly of white to light gray chalky limestones that are interbedded with and grade into light gray to dark gray calcareous shales and siltstones, and sparse sandstones. Granular dolostones having a limestone matrix occur between 1548-1591 m. Unit IV, between 1981-2774, consists mostly of gray to dark gray shales and gray to reddish-brown, slightly calcareous siltstones interbedded with light gray, micritic and oolitic limestones and hard, light gray, calcite-cemented sandstones. The heterogeneous lithology of this interval makes correlations and descriptions difficult. Unit V, between 2774-3917, consists mainly of dark gray to light gray, white, and brown, micritic and, locally, oolitic limestones that grade into and are interbedded with shaley limestones, calcareous dark gray to gray to reddish-brown fissile shales and siltstones, and pink to light gray sandstones. Unit VI, between 3917-4420 m, consists predominantly of hard, dense, gray to dark gray

microcrystalline dolostones interbedded with less abundant gray to white, micritic limestones having matrixes containing variable amounts of dolomite and anhydrite. Also present are numerous thin beds of dolomite-bearing anhydrites, fine-grained calcite-cemented quartz sandstones, and gray to reddish-brown siltstones. Some of gray siltstones are burrow-mottled. The amount of dolomite and anhydrite, both in and interbedded with the limestone, generally increases with depth. The dolostone is more common than the limestone below 4055 m; the anhydrite is more common than the shales and siltstones below 4075 m. Most lithologies in Unit VI are unfossiliferous.

These units can be correlated with the Scotian Shelf stratigraphic equivalents (Jansa and Wade, 1975; Poag, 1982; Libby-French, 1984) based on lithologic similarity (Table 1). The part of Unit I above 415 m is equivalent to the Banquereau Formation; the portion of Unit I below 424 m is the equivalent of the Dawson Canyon/Logan Canyon Formations. A thin pinkish-gray limestone penetrated between 615-627 m may represent the Petrel Limestone Member of the Dawson Canyon Formation. If this unit is the Petrel Limestone, then the shaley portion of Unit I between 424-627 m is the Dawson Canyon Formation and the sandy remainder of the section down to 1064 m, the top of the Missisauga Formation, may be the Logan Canyon Formation. In any case, Unit II is the equivalent of the sandy part of the Dawson Canyon/Logan Canyon Formations between 710-1064 m and the Missisauga Formation between 1064-1555 m. The limestone encountered in Unit II between 1183-1283 m probably represents the "O" marker found throughout the Georges Bank Basin (Poag, 1982). Unit IV is a Mohawk-Mic Mac equivalent. Units III and the part of V above 3158 m are the equivalents of the Baccaro Limestone Member of the Abenaki Formation. The Mohawk and Mic Mac Formations are shoreward (updip) siliciclastic units that intertongue with and grade into the overlying to time-equivalent, seaward (downdip) carbonate facies of the Baccaro Limestone Member (Given, 1977). The part of Unit V between 3271-3774 m is probably equivalent to the Scatarie Limestone Member of the Abenaki Formation. The gray to reddish-brown shales and siltstones in the middle of Unit V between 3158-3271 m and at the bottom of Unit V between 3774-3917 m are the Misiane Shale member of the Abenaki Formation and the Mohican Formation, respectively. Unit VI is an equivalent of the Iroquois Formation.

The descriptions of rotary drill cuttings (APPENDIX 1) and the analysis of lithologic and electric logs permits the determination of depth- and age-related variations in the abundances of the common rock types (Table 2). Carbonates make up a major portion of the section, especially between 1555-1981 m and below 2774 m. Sandstones, shales, and siltstones are the dominant lithologies above 1555 m and between 1981-2774 m. Coal/lignite, important both as an indicator of depositional environment and because of its sensitivity to diagenetic changes resulting from pressure and temperature, occurs in the intervals between 862-1073 m, 1091-1119 m, 1303-1310 m, 1384-1402 m, 2179-2286 m, 3222-3249 m, and 3464-3467.

X-RAY MINERALOGY

Layered silicates, which range in concentration from 1 to 83 weight percent of the samples are a major constituent of the siliciclastic well sediments (Table 3). Kaolinite, which usually forms by chemical weathering under nonalkaline conditions, is the dominant clay mineral in the section above 2070 m and in the calcareous shales, siltstones, and sandstones down to 3030 m. Below 3030 m, chlorite is usually more common than kaolinite. Illite/mica dominates the clay fraction in most of the less calcareous sediments below 2070 m and is always the most common layered silicate below 3825 m. Smectites are rare or absent below 3030 m, but are volumetrically important in the shales between 588-1686 m.

Table 1. Correlation of lithologic units penetrated by the Conoco 145-1 well with ages and Nova Scotian stratigraphic equivalents. Inferred ages are based on paleontologic analyses that were performed by International Biostratigraphers Inc. under contract to the Continental Oil Company and are available from the National Geophysical Data Center, in Boulder Colorado.

LITHOLOGIC UNIT	DEPTH (m)	AGE	NOVA SCOTIAN STRATIGRAPHIC EQUIVALENTS
I	206-415	Middle Miocene	Banquereau Formation
	424-710	Santonian to Cenomanian	Dawson Canyon/Logan Canyon Formations
II	710-1064	Albian to Aptian	Dawson Canyon/Logan Canyon Formations
	1064-1555	Aptian to Hauterivian-Berriasian	Missisauga Formation
III	1555-1981	Hauterivian-Berriasian to Lower Kimmeridgian	Baccaro Limestone Member of the Abenaki Formation
IV	1981-2774	Lower Kimmeridgian to Oxfordian	Mohawk-Mic Mac Formations
V	2774-3158	Oxfordian to Callovian-Bathonian	Baccaro Limestone Member of the Abenaki Formation
	3158-3271	Callovian-Bathonian	Misiane Shale Member of the Abenaki Formation
	3271-3774	Callovian-Bathonian	Scatarie Limestone Member of the Abenaki Formation
	3774-3917	Callovian-Bathonian	Mohican Formation
VI	3917-4420	Callovian-Bathonian	Iroquois Formation

Table 2. Groupings of rock types encountered in the Conoco 145-1 well. The values are presented in relative percent by volume. These data reveal the siliciclastic nature of the upper 1524 m of the section, an interval between 1524 and 3353 m composed mainly of shales and limestones, and a section below 3353 m dominated by carbonates.

INTERVAL FEET	INTERVAL METERS	PERCENT SANDSTONE	PERCENT SHALE	PERCENT LIMESTONE	PERCENT DOLOSTONE	PERCENT EVAPORITE	PERCENT COAL-LIGNITE
1350-2000	411-610	8.8	91.2	0.0	0.0	0.0	0.0
2000-3000	610-914	46.3	52.0	0.0	0.0	0.0	1.7
3000-4000	914-1219	67.5	23.2	2.1	0.0	0.0	7.2
4000-5000	1219-1524	67.4	23.0	8.8	0.0	0.0	0.8
5000-6000	1524-1829	5.4	21.6	71.5	1.5	0.0	0.0
6000-7000	1829-2134	3.2	47.1	49.7	0.0	0.0	0.0
7000-8000	2134-2438	26.6	51.9	21.4	0.0	0.0	0.1
8000-9000	2438-2743	16.8	76.2	7.0	0.0	0.0	0.0
9000-10000	2743-3048	6.0	44.4	49.8	0.0	0.0	0.0
10000-11000	3048-3353	2.3	32.2	65.4	0.0	0.0	0.1
11000-12000	3353-3658	0.3	5.4	93.0	0.0	0.8	0.5
12000-13000	3658-3963	26.8	19.2	51.3	2.2	0.5	0.0
13000-14000	3963-4267	0.0	11.9	22.0	51.7	14.4	0.0
14000-14500	4267-4420	0.0	1.2	33.2	55.4	10.2	0.0

Table 3. Estimated mineral modes, in relative weight percent, determined from X-ray powder diffraction and smear slides for drill cuttings from the Conoco 145-1 well. SMC: smectites; CHL: chlorite; I-S: mixed layer illite-smectite; I/M: illite and/or mica; KAO: kaolinite; GLA: glauconite; QTZ: quartz; AMO: amorphous silica and opal C-T; FLD: feldspar; CAL: calcite; D/A: dolomite/ankerite; SID: siderite; PYR: pyrite; HEM: hematite; GOE: goethite; GYP: gypsum; ANH: anhydrite; APA: apatite. G: gray; DG: dark gray; GG: greenish-gray; LG: light gray; RB: reddish-brown; DRB: dark reddish-brown. A blank indicates that the mineral was not detected; T = trace (<1 percent).

DEPTH (M)	SMC	CHL	I-S	I/M	KAO	GLA	QTZ	AMO	FLD	CAL	D/A	SID	PYR	HEM	GOE	GYP	ANH	APA	COMMENTS
206-232	2	7	6	10	15	1	46		6	T	T	T	6						G SANDY SILTSTONE
259-287	4	7	6	12	13		49		3	T	T	T	2						G SANDY SILTSTONE
314-341	4	7	5	10	16	2	43		8				5						OG SILTSTONE
369-396		2	4	8	7	T	14		1	58		T	4						LG LIMESTONE
396-424	T	T	T	T	T	32	30		6	17			1					12	GLAUCONITIC SANDSTONE
451-479		T	T	T	T			79							19				CHERT NODULE
479-506		T	T	T	T	10	21		2	64		T							LG SANDY LIMESTONE
533-561		T	T	T	T	23	T			8								66	PHOSPHATE NODULE
533-561		T	T	T	T	81	3			10			4					T	GLAUCONITIC SANDSTONE
588-616	7	T	1	7	15		5			18		2	20			24			CONCRETION
643-671	9	2	2	7	19	1	17			26			17						DG PYRITIC SHALE
698-725	10	2	2	9	19	T	23		2	21		1	10						DG SHALE
753-780	T	T	T	1	1	3	33		5	55			T						G SANDY LIMESTONE
808-835	8	1	4	9	30		27		3	11		1	6						G SHALE
863-890	T	T	T	T	1	11	29		3	50			3					1	G SANDY LIMESTONE
917-945	T	T	T	T	7	3	32		3	48			3					T	G SANDY LIMESTONE
945-972		T	T	1	2	7	30		1	57			T						LG SANDY LIMESTONE
1055-1082	T	T	T	3	2	4	34		1	49			6						G SANDY LIMESTONE
1110-1137	T	T	T	T	6	2	32		1	55			T						LG SANDY LIMESTONE
1073-1192	3	3	2	9	47		22		1					12	21				RB SHALE
1219-1247		T	T	T	2	5	18			72			2						G SANDY LIMESTONE
1274-1302	1	4	1	6	45		22		2	1		1		6	11				RB SHALE
1329-1356	4	2	4	10	33		23		1	T		T	22						DG PYRITIC SHALE
1384-1411	4	3	3	6	36	T	31		1	3		T	12						G SHALE
1439-1466	5	2	2	5	28		15		1	38			4						G CALCAREOUS SHALE
1494-1521	2	2	1	2	13	T	22		T	43	4	1	9						DG SHALEY LIMESTONE
1548-1576	14	T	T	2	3		1	65		13		1							CHERT
1658-1686	14	4	2	9	16		16		1	36		T	T						G CALCAREOUS SHALE
1686-1713		1	T	1	8	T	2			85	1	T	T						G LIMESTONE
1740-1768		T	T	T	1		1			96	T		T						LG LIMESTONE
1795-1823	T	6	3	7	32	T	6		T	31		1	12						G SHALE
1850-1878	3	4	1	5	23		15		1	42	T	1	4						G SHALEY LIMESTONE
1932-1960	1	5	4	7	29		23		4	19		3	5						DG SHALE
1987-2015	8	5	2	7	26		22		6	17	T	1	6						G SHALE
2042-2070	T	5	5	9	28		15		4	28		T	5						DG SHALE
2097-2125		T	T	T	T	T	2		T	95									G OOLITIC LIMESTONE

DEPTH (M)	SMC	CHL	I-S	I/M	KAO	GLA	QTZ	AMO	FLD	CAL	D/A	SID	PYR	HEM	GOE	GYP	ANH	APA	COMMENTS
2152-2179		2	T	5	4	T	40		14	34		T							LG SANDSTONE
2179-2207	T	14	3	23	14		16		6	T		6		16					DRB SHALE
2234-2262		14	6	16	16		25		10	5		2	6						DG SANDY SILTSTONE
2317-2344		T	T	1	1		3			93			1						LG LIMESTONE
2344-2399	T	9	4	10	12		22		10	26		3	3						G CALCAREOUS SHALE
2399-2426		5	T	4	12		49		15	9	T	3	1						LG SANDSTONE
2426-2454	T	16	7	24	18		23		7	2		1	T						DG SHALE
2481-2509	2	5	3	9	24	T	13		6	31		1	6						G CALCAREOUS SHALE
2509-2536		2	T	3	6		42		17	29									LG SANDSTONE
2563-2591		14	8	22	15		21		11	3		3	3						DG SHALE
2618-2646		4	4	19	11		28		15			2		11	6				RB SILTSTONE
2618-2646		7	5	25	8		35		15	T		2	2						GG SILTSTONE
2646-2673		4	T	4	9		44		20	17			T						LG SANDSTONE
2673-2701		6	33	11	18		37		11	10		2	2						G SANDY SILTSTONE
2728-2755		15	1	27	16		23		10	4		2	2						DG SHALE
2755-2783		4	6	24	8		31		13	1		2		11					RB SANDY SILTSTONE
2783-2810	1	10	11	27	10		23		10	5		1	2						DG SHALE
2810-2838		T	T	1	1		3		T	89	4	T	T						LG LIMESTONE
2865-2893	7	7	1	11	12		30		12	15		2	3						G SHALE
2892-2920		3	4	21	7		37		13			3		12					RB SANDY SILTSTONE
2920-2948	T	12	7	20	16		28		11			4	T						DG SHALE
2975-3002	4	6	1	8	17		23		5	31		T	4						G CALCAREOUS SHALE
3002-3030	2	9	2	13	17		23		10	17		1	6						GG CALCAREOUS SHALE
3030-3057		4	2	17	8		35		17	4		T		12					RB SILTY SANDSTONE
3057-3085		1	T	2	T		4		1	90			1						LG LIMESTONE
3085-3112		12	4	25	3		24		8	16		2	6						DG SHALE
3112-3140		13	3	29	4		19		8	16		2	6						DG SHALE
3167-3194		T	T	T	T		T			8						89			EVAPORITE
3194-3222		15	3	28	1		21		9	15		2	6						DG SHALE
3222-3249	T	5	2	10	19		29		12	18		2	2						G CALCAREOUS SILTSTONE
3249-3277		6	3	25	6		27		16	2		T		14					RB SANDY SILTSTONE
3304-3332		T	T	1			1		T	95	1		T						LG LIMESTONE
3359-3386		17	4	28	1		19		6	15	T	3	6						DG SHALE
3386-3414		T	T	3	T		3		T	90	1		1						DG LIMESTONE
3414-3441		1	T	3	T		3		T	90	1		T						LG LIMESTONE

DEPTH (M)	SMC	CHL	I-S	I/M	KAO	GLA	QTZ	AMO	FLD	CAL	D/A	SID	PYR	HEM	GOE	GYP	ANH	APA	COMMENTS
3441-3469		7	2	26	T		12		7	27	8	3	7						DG CALCAREOUS SHALE
3469-3496		T	T	6	T		2		T	88	T	T	T						DG LIMESTONE
3524-3551		1	T	4	T		4		T	89	T		T						LG LIMESTONE
3578-3603		10	6	20	4		16		15	10	9	4	6						DG SHALE
3603-3633		T	T	2	T		5		2	87	1	T	T						DG LIMESTONE
3633-3661		1	T	3	T		5		2	86	1	T	T						LG LIMESTONE
3688-3716		1	T	3	T		2		T	92	T	T	T						DG LIMESTONE
3716-3743		T	T	1			3		1	93	T		T				T		LG LIMESTONE
3743-3770		10	4	32	2		14		7	16	8	3	4						G SHALE
3770-3798		T	1	2	1		3		1	89	T	1	T						LG LIMESTONE
3770-3798		T	T	1	T		3			92	2	T	1						G LIMESTONE
3798-3825	T	8	5	11	22		23		7	16			7						G CALCAREOUS SHALE
3825-3853		T	T	23			26		16	T	6			12			15		RB SILTY SANDSTONE
3853-3880		T	T	8			54		20	T	15			2					PINK SANDSTONE
3880-3908		T	T	25	T		27		17		4			15			11		RB SANDY SILTSTONE
3908-3935		T	T	1	T		2		T	90	1		T				4		LG LIMESTONE
3908-3935			T	11			46		17	T	19			4			1		PINK SANDSTONE
3935-3963	T	6	2	16	8		24		9	23	5	T	6						DG CALCAREOUS SILTSTONE
3963-3990		1	T	39	T		19		11	T	5			19			3		RB SANDY SILTSTONE
3990-4017		1	T	7	T		4		1	72	9	T	4				T		DG LIMESTONE
4017-4045		T	T	2	T		4		1	57						T	34		G LIMESTONE
4072-4100	T	11	5	17	9		27		18		T	T	4						DG SILTSTONE
4072-4100		3	1	11	1		4		1	73	1		4				T		DG LIMESTONE
4072-4100		5	5	25	10		20		9	T	T			24	T		T		RB SILTSTONE
4127-4155							T			3	5						91		EVAPORITE
4155-4182		8	3	17	4	T	24		11	23	5	T	3						G SANDY SILTSTONE
4155-4182		1	2	28	2		22		16	2	9			17			2		RB SANDY SILTSTONE
4182-4209		T	T	4	T		2		T	64	10						18		G LIMESTONE
4209-4237		1	T	5	1		4		T	2	62		2				22		DG DOLOSTONE
4237-4264		5	2	23	7		19		7	25	6		5				1		G CALCAREOUS SHALE
4237-4264		T		3	T		2			T	60		T				33		G DOLOSTONE
4237-4264		8	1	35	4		21		10		T			20			T		RB SANDY SILTSTONE
4264-4292				T			1		T	56	8						34		LG LIMESTONE
4292-4319		4	1	12	3		10		3	40	21		5				T		DG LIMESTONE
4319-4347		T		T	T		T		T	2	65		T				31		G DOLOSTONE

DEPTH (M)	SMC	CHL	I-S	I/M	KAO	GLA	QTZ	AMO	FLD	CAL	D/A	SID	PYR	HEM	GOE	GYP	ANH	APA	COMMENTS
4319-4347		3	T	11	2		8		2	53	17		3			T	T		DG LIMESTONE
4347-4374		2	T	7	2		7		2	24	54		T				T		DG DOLOSTONE
4374-4401		T		T	T		3		T	57	14		4				21		LG LIMESTONE
4374-4401		2	1	16	2		6		2	42	23		5				T		DG LIMESTONE
4401-4420		1	T	8	T		2		5	30	51		1				T		DG DOLOSTONE
4401-4420		T		1	T		2		3	90	2		T						LG LIMESTONE
4401-4420				27			28		21	T	3			13			7		RB SILTY SANDSTONE

Although minor amounts of mixed layer illite-smectite occur throughout the well, it is the most abundant clay mineral only in a gray sandy siltstone encountered between 2673-2701 m. No mixed layer chlorite-smectite or zeolites were detected in any of the X-ray diffraction patterns.

Quartz grains are present in every well sample; they range in size from gravel to fine silt. Although potassium feldspar is more common in the interval between 396-1576, plagioclase is generally the dominant feldspar in the remainder of the well.

Calcite is common throughout the section in both the carbonates and as a cement in the siliclastic sandstones, siltstones, and shales. Although calcite is clearly the primary cement in the section, dolomite (ankerite?) is important in a zone between 1548-1597 m and below 3853 m. Hematite and, above 2846 m, goethite cement the reddish-brown sediments. Chert is found in the intervals from 451-479 m and 1548-1576 m; small amounts of siderite are present above 4182 m.

Pyrite is common throughout much of the well, but the gray and dark gray shales in some intervals, notably 588-725 m and 1329-1823 m, are quite pyritic. Although the pyrite occurs chiefly as framboidal spheres, it also fills the tests of microfossils and is occasionally found as shiny octahedral euhedrons.

Glauconite occurs as well-rounded, black to dark green pellets and is concentrated above 1247 m in the well. This mineral, which is indicative of open marine depositional environments is noticeably depleted or absent below 2125 m.

Anhydrite is common in the dolostones, reddish-brown siltstones, and evaporites below 3825 m in the section. This mineral usually forms under evaporitic conditions and suggests the presence of restricted marine or supratidal depositional environments.

Phosphorite, probably calcium fluorapatite, is found in the glauconitic sandstones and limestones above 945 m in the well. The phosphorite, which typically occurs as course silt- and sand-sized pellets, was found in the interval between 533-561 as subrounded nodular clasts as much as 2 mm in diameter. Petrographic examination of the pellets reveals aggregates of cryptocrystalline texture usually observed in marine phosphorites.

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APPENDIX I

Lithologic descriptions of the rotary drill cuttings and sidewall cores from the Conoco 145-1 well in the Georges Bank Basin. All sample depth intervals are in meters relative to the Kelly Bushing.

206-304 95% Clay-Shale-Siltstone: gray to olive gray, soft to hard, some calcite cement, mica, shell fragments, and quartz sand, trace glauconite and pyrite; 5% Sand: clear to translucent, very fine-grained, some mica and fossil fragments, trace glauconite.

304-457 55% Clay-Shale-Siltstone: gray to dark gray to black, sandy, sticky, slightly calcareous, abundant fossil fragments, trace glauconite, pyrite, and lignite; 45% Sand: clear to translucent, medium-grained, subrounded to subangular, poorly to moderately sorted, abundant glauconite, fossil fragments, occasional calcite cement and phosphate, trace mica; Trace Limestone, light gray, micritic, sandy, some glauconite and foraminifera and bryozoan debris, trace pyrite.

457-609 60% Clay-Shale-Siltstone: gray to dark gray, sticky, slightly calcareous, abundant fossil fragments, trace quartz sand, glauconite, and pyrite; 40% Sand: clear to green, median to coarse, abundant glauconite, some intervals phosphatic, some intervals cemented by calcite and others by chert.

609-762 65% Clay-Shale-Siltstone: gray to dark gray to black, hard to sticky, slightly calcareous, abundant fossil fragments, some intervals pyritic, some glauconite; 35% Sand: clear to translucent, fine- to medium-grained, subrounded, moderately to poorly sorted, abundant fossil fragments, trace glauconite.

762-914 50% Sand: clear to translucent to buff, fine- to medium-grained, subrounded but occasionally subangular, unconsolidated with a clay matrix, some glauconitic, fossil fragments, and lignite, trace pyrite and mica, some intervals partly cemented by calcite, sands grade into sandy limestones; 35% Siltstone: gray, soft but occasionally hard, some calcite cement, trace fossil fragments, glauconite, and pyrite; 5% Lignite: black, soft, rounded grains; 10% Limestone: light gray, abundant quartz sand, some glauconite and pyrite.

914-1069 65% Sand: clear to translucent, fine- to medium-grained, subrounded but occasionally subangular, unconsolidated with a clay matrix, some glauconite, fossil fragments, trace pyrite and mica, some zones cemented by calcite, sands grade into sandy limestone; 25% Siltstone: light to dark gray, calcite cemented, traces of mica, pyrite, fossil fragments and glauconite; 10% Lignite: black, moderately hard, rounded grains.

1069-1219 75% Sand: clear to translucent, medium-grained, rounded to subrounded, unconsolidated, trace lignite, mica, and pyrite, some intervals loosely cemented by calcite, good porosity; 20% Siltstone and Shale: light gray to dark gray to reddish brown, calcite cemented, some pyritic intervals, trace lignite and fossil fragments; 5% Limestone: light gray to white, soft, grainy texture, no visible porosity, occasional zones of quartz sand and other zones of clay matrix; Trace Lignite: black.

1219-1372 50% Sand: clear to translucent, unconsolidated, medium- to fine-grained, subrounded to rounded, moderately to poorly sorted, abundant mica, trace glauconite and lignite; 30% Shale: light gray to dark gray to reddish brown, slightly calcareous, trace lignite and pyrite; 20% Limestone: light gray, very soft, no visible porosity, some intervals with abundant quartz sand and other intervals with a clay matrix; Trace Lignite: black.

1372-1524 85% Sand: clear to translucent, unconsolidated, subangular to subrounded, poorly to moderately sorted, trace lignite and pyrite; 15% Shale: light gray to gray, calcareous, soft, trace pyrite and siderite; Trace Lignite: black, moderately hard.

1524-1676 70% Limestone: white to light gray, chalky texture, no visible porosity, trace fossil fragments; 20% Shale: gray, calcareous, grading into a gray siltstone; 5% Sand: light gray, unconsolidated, medium- to coarse-grained, angular to subangular but occasionally subrounded, moderately to poorly sorted, traces of glauconite and pyrite; 5% Dolostone: white to gray, some limestone in matrix; Trace Chert: gray, silty.

1676-1829 70% Limestone: white to light gray, chalky texture, no visible porosity, trace of fossil fragments; 25% Shale: gray and Siltstone: light gray to dark gray, calcareous, trace glauconite; 5% Sandstone: light gray, fine-grained, subrounded, well sorted, slightly calcareous.

1829-1981 55% Limestone: light gray to gray, micritic, fossil fragments locally common; 45% Shale: dark gray and Siltstone: gray to dark gray, slightly calcareous, trace glauconite, mica, siderite, and pyrite; Trace Sandstone: light brown to light gray, subangular to subrounded, medium to poorly sorted, poor visible porosity.

1981-2134 50% Shale: gray to dark gray, moderately calcareous, trace mica, siderite, and pyrite; 45% Limestone: light gray, micritic, oolitic; 5% Sandstone: white to light gray, hard, very fine-grained, moderately to poorly sorted, calcite cemented, trace glauconite, mica, pyrite, poor visible porosity.

2134-2286 50% Shale: gray to dark gray and Siltstone: gray, occasionally reddish brown, slightly calcareous, trace mica, siderite, and pyrite; 25% Sandstone: light gray, very fine-grained, moderately sorted, calcite cemented, trace glauconite and pyrite; 25% Limestone: light gray, micritic, dull, oolitic; Trace Lignite: black, angular fragments.

2286-2438 60% Shale: dark gray and Siltstone: black to gray to reddish brown, shales and siltstones grade into each other, calcareous to slightly calcareous, trace mica, siderite, and pyrite; 25% Sandstone: light gray, calcite cement, subrounded to subangular, trace mica and pyrite; 15% Limestone: light gray, micritic, oolitic.

2438-2591 75% Shale: dark gray and Siltstone: gray to reddish brown, slightly calcareous, sand lenses common; 20% Sandstone: light gray, fine- to medium-grained, subangular to subrounded, calcite cement, trace pyrite and mica; 5% Limestone: light gray, micritic, oolitic.

2591-2743 75% Shale: dark gray to olive gray and Siltstone: gray to reddish brown, grades into shaley limestones, trace pyrite, lignite, and mica; 15% Sandstone: light gray, very fine- to fine-grained, poorly sorted, calcite cement, trace mica, pyrite, and glauconite; 10% Limestone: gray to white, micritic, occasionally oolitic, trace fossil fragments.

2743-2896 50% Shale: gray to dark gray, fissile and Siltstone: gray to reddish brown, slightly calcareous, trace pyrite and fossil fragments; 40% Limestone: white to light gray, micritic, oolitic intervals, grades to shaley limestone, trace fossil fragments and pyrite; 10% Sandstone: gray, fine- to very fine-grained, poorly sorted, calcite cemented, trace pyrite and lignite.

2896-3048 55% Limestone: light gray to gray with some white and brown intervals, micritic, occasionally oolitic, chalky, grades into calcareous shale; 40% Siltstone: gray to reddish brown and Shale: dark gray, calcareous, trace pyrite and mica; 5% Sandstone: gray, fine-grained, silty, calcite cemented.

3048-3200 55% Limestone: gray to white, micritic, occasionally oolitic, chalky texture, trace fossil fragments, sand-sized quartz grains, siderite, and pyrite; 40% Shale: dark gray and Siltstone: gray, slightly calcareous and micaceous, trace pyrite, 5% Sandstone: light gray to gray, fine-grained, angular to subangular, moderately to poorly sorted, calcite cemented, trace mica.

3200-3353 80% Limestone: light gray to white, micritic, chalky, occasionally oolitic, grades into shaley limestone, trace coarse calcite crystals, fossil fragments, pyrite, and mica; 20% Siltstone: gray to reddish brown, calcite cemented, trace pyrite and volcanic ash; Trace Sandstone: reddish brown, medium- to coarse-grained, poorly sorted, sand-sized calcite crystals in cement, feldspar overgrowths; Trace Coal/lignite: black, shiny, angular fragments.

3353-3505 90% Limestone: dark gray to light gray, micritic, occasionally oolitic, grades into shaley limestones, trace lignite and anhydrite; 5% Shale: dark gray, calcareous; 5% Siltstone: light gray, slightly calcareous; Trace: Sandstone; Trace Anhydrite; Trace Coal/lignite: black, shiny, angular fragments.

3505-3658 95% Limestone: dark gray to white, micritic, locally oolitic, occasionally chalky, grades into shaley limestone, traces of siderite and pyrite; 5% Siltstone and Shale: gray to dark gray, occasionally brown, calcareous, traces mica and pyrite.

3658-3810 75% Limestone: gray to white to brown, micritic, hard, occasionally chalky, grades into calcareous shales and siltstones; 15% Shale and siltstone: dark gray to gray to reddish brown, slightly calcareous and micaceous, traces anhydrite and pyrite; 10% Sandstone, light gray to pink, fine- to medium-grained, poorly sorted, calcite cemented.

3810-3963 40% Sandstone: light gray to pink, fine- to medium-grained, subangular to subrounded, poorly to moderately sorted, some dolomite cement, trace of mica and organic matter; 30% Limestone: gray to light

gray, hard, locally dolomitic with a trace of anhydrite; 25% Siltstone: gray to reddish brown, slightly calcareous and micaceous; 5% Dolostone: light gray to dark gray, occasionally light brown, micritic, abundant anhydrite.

3963-4115 35% Limestone: light gray to white, occasionally brown, micritic, very hard, locally chalky, some oolitic intervals, locally dolomitic, trace pyrite; 25% Dolostone: dark gray to white, occasionally light brown, micritic, commonly interbedded with limestone and anhydrite; 20% Anhydrite: white to gray, soft, occasionally interbedded with dolostone and limestone; 10% Siltstone: gray to reddish brown, slightly calcareous; 10% Shale: dark gray, soft, trace pyrite.

4115-4267 80% Dolostone: dark gray to light gray to brown, micritic, some anhydrite and calcite in matrix; 10% Anhydrite: white to gray to clear, occasionally interbedded with dolostone; 5% Limestone: gray to light gray, micritic, chalky texture; Trace Siltstone: reddish brown; Tracer Shale: dark gray, calcareous.

4267-4420 55% Dolostone: dark gray to light gray, micritic, occasionally interbedded with anhydrite, some hematite stained zones; 35% Limestone: white to light gray, micritic, hard to soft; 10% Anhydrite: white to gray to clear, occasionally interbedded with dolostone; Trace Siltstone: reddish brown.