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SUMMARY OF RESERVOIR CHARACTERISTICS OF SHORELINE BARRIER RESERVOIRS

Project BE1, milestone 4, FY92

by

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ABSTRACT

A summary of reservoir characteristics of shoreline barrier reservoirs identifies the degree of variability in reservoir characteristics in a specific class of reservoirs. This compilation will be immediately useful to companies operating in shoreline barrier reservoirs as well as address a longer term question of the degree to which reservoirs deposited in similar depositional environments have similar reservoir properties, characteristics and scale and type of heterogeneities.

Analysis of the characteristics of 319 shoreline barrier reservoirs listed in the TORIS data base was initiated to determine the range and average properties of shoreline barrier reservoirs. The majority of the shoreline barrier reservoirs listed in TORIS are in Texas (164), followed by Oklahoma (49), Wyoming (28), and California (26). The dominant age of the barriers is Tertiary and the dominant subenvironment represented is a strandplain/barrier core subenvironment. Histograms of permeability, porosity, oil gravity and formation water salinity indicated a high degree of variability in the reservoir parameters.

A compilation of the maximum facies dimensions reported in 15 references is presented in table and graphic form to illustrate the geometry and volume differences of the facies within the barrier island system. The shoreface and foreshore facies, predominant in Bell Creek field, have volumes over 10 times those of the tidal inlet, flood tidal delta, and tidal channel/creek facies that produce in the Patrick Draw field.

Future work will include the comparison of the reservoir characteristics identified from the detailed study of Patrick Draw and Bell Creek fields to those reservoirs reported in the literature to: (a) define the spectrum of reservoir characteristics found in shoreline barrier deposits, and (b) assess the degree to which the controls on production found in Patrick Draw and Bell Creek fields can be generalized to other reservoirs.

INTRODUCTION

A long standing question within the discipline of reservoir characterization has been: to what degree do reservoirs, deposited in similar depositional environments, have similar reservoir properties, characteristics, and scale and type of heterogeneities? The importance of the question is that if similarities can be identified, then the knowledge based on a few reservoirs in the group can be applied to the development of and production from other reservoirs in the same class. The difficulty of the question is underscored by the fact that few answers or even attempts to answer the question have be made. Many geoscientists, appreciating the high degree of variability in the natural world, believe that each reservoir is unique and only gross similarities exist. Certainly, some similarities exist, or the classifications based on depositional environments could not be made. The depositional interpretations made, however, are often of limited confidence level, due to the high variability of characteristics found in any one depositional system and the lack of unique diagnostic characteristics that unquestionably identify the deposystem. Even if reservoirs can be

broadly classified as to the depositional environment in which they were formed, the question that remains is: Are the similarities specific or detailed enough to make them useful in the characterization and development of those reservoirs deposited in the same depositional environment?

A discussion group at the Second International Reservoir Characterization Conference (Lake, et al. 1991) was charged with the task of identifying examples of how information about one reservoir can be applied to an unstudied but similar reservoir. The matrix of geological and reservoir properties presented in Fig. 1 resulted from the discussion. In Fig. 1, the rows are geological characteristics and the columns are reservoir parameters. An "O" was used at the intersection of rows and columns to indicate that an effect on the reservoir property could be exerted by the particular geological characteristic and that the effect could, under proper circumstances, be predicted by observing or sampling an analogous reservoir. To indicate characteristics not likely to carry from analogous reservoir, an "X" was used. Blank intersections indicate the geologic characteristic has no generally recognized effect on the reservoir property being addressed. The number of "O" marks indicate that a large amount of information at various scales can be obtained from analogous reservoirs and outcrops, given the correct set of circumstances.

The highest probability of finding transferable characteristics will be found in rocks that were deposited under analogous processes. In order to identify those deposits, depositional classes will have to be refined into subtypes of depositional environment classification beyond those typically used today, such as meso-tidal barrier island or fluvial-dominated deltaic deposit. The subclasses must also include depositional processes such as sedimentation rates, and the direction and rate of sea level changes. Regional scale structural and sequence stratigraphic framework have been shown to be important controls on reservoir heterogeneity (Jackson, et al., 1992) and must be considered when considering transfer of information from one deposit to another.

The degree of analogy depends on the features of interest. Purely depositional features such as geometries of facies require depositional process similarities, while petrophysical characteristics must include similarities in depositional and diagenetic processes. Since tectonic processes are important in controlling both diagenetic processes, illustrated by the relationship of clay content and distance from fractures found in the pilot area in Bell Creek field (Jackson, et al. 1991), and depositional processes such as the controls on the location of valley fill deposits in the Muddy formation (Weimer, et al., 1982), and the thickness of the Almond formation (Van Horn, 1979), the regional tectonic regime must also be considered.

The greatest probability for similar reservoir characteristics would be found in rocks that were deposited under similar depositional processes including sedimentation rate and direction and rate of sea level movement; within the same basins where the geochemical, diagenetic, and tectonic processes would be similar; and during similar geologic time period within a similar sequence stratigraphic framework.

TORIS DATABASE INFORMATION

Analysis of the data in the TORIS data base was initiated to determine the range and average properties of the barrier-island reservoirs listed in the data base. It is important to consider the source and accuracy of the data when analyzing the contents. For example, the interpretations of depositional environment are rarely clear cut, are usually contentious, and therefore may include deposystems other than shoreline barrier systems or mixtures of shoreline barrier systems with other systems. It is often difficult to distinguish between barrier islands, strandplains and delta front associated barriers because of their similarity in depositional processes and features, and their paleogeographic proximity. Further work should include verification, to the extent possible, of the

depositional interpretations listed in the data base and possibly more refined, depositional subclasses.

Three hundred and nineteen shoreline barrier reservoirs are listed in the TORIS data base. A list of the reservoirs, fields, formations, age and depositional environment is presented in appendix A along with the code definitions used. The distribution of reservoirs according to state, geologic age and subenvironment is shown in Fig. 2. The most of the shoreline barrier reservoirs listed in TORIS are from Texas (164), followed by Oklahoma (49), Wyoming (28), and California (26). One hundred sixty-seven of the reservoirs are Tertiary in age, 80 Cretaceous, 32 Pennsylvanian, and 19 Ordovician. The most common subenvironment represented in the reservoirs, in descending order, is as follows: strandplain/barrier core (113); strandplain/barrier shoreface (88); strandplain/undifferentiated (65); strandplain/back barrier (44); strandplain/tidal channels (6); strandplain/washover fan; and tidal delta (4). Clearly, the data set is dominated by Texas reservoirs. Whether or not this is truly representative of the geographic distribution of barrier island reservoirs in the United States is not known.

Selected reservoir properties of the 318 reservoirs are listed in Table 1. A highly variable nature of the reservoir properties suggests that the data set consists of more than one population (Figs. 3 and 4). Values for Bell Creek field and Patrick Draw field are indicated to illustrate where in the spectrum of values for barrier island reservoirs they lie. The majority (mode) of barrier island reservoirs fields are less than 2,000 acres (Fig. 3a), with well spacing of about 20 acres (Fig. 3d). Dominant gross and net pay thicknesses are around 20 feet (Fig. 3b-c). A broad distribution of reservoir depths, ranging from 530 to 11,260 feet (Fig 3e) and a correspondingly broad range of temperature, ranging from 60° to 260° F (Fig. 3f) are illustrated.

Histograms of permeability, porosity, oil gravity and formation water salinity are presented in Fig. 4. Multiple peaks in the histograms suggest polymodal distributions, and are most marked in the histogram of formation water salinity. The strong possibility of multiple populations indicates the need to determine the basis of grouping for the various populations.

To distinguish the individual population of reservoirs, histograms of permeability of reservoirs within the same play were constructed (Fig. 5.). A play is a group of reservoirs with common geologic histories. The degree of variability in permeability is reduced when the various plays are distinguished. Similar permeability frequency distributions exist for three Texas plays (Fig. 5a-c), even though the plays are of different ages (Frio, Oligocene; Jackson, Eocene; and salt-related plays, Cretaceous). Fewer values exist for the other plays, however, modal permeabilities are generally lower than those found in the gulf coast reservoirs. The wide spread of values in the Muddy/Newcastle play are probably due in part to the fact that the fluvial and estuarine deposits of the Muddy Sandstone have erroneously been classified as strandplain/undifferentiated in the TORIS data base. In subsequent work, non-barrier reservoirs will be excluded from the data analyzed.

Future work will include the analysis of other parameters within the various plays and within the various facies (Fig. 2b) to determine the natural grouping of reservoir properties. Also, to determine whether the within-shoreline barrier variability is less than between deposystem variability, data from barrier island reservoirs will have to be compared with other depositional systems.

SAND BODY GEOMETRIES

After studying the Muddy Formation in Bell Creek field that produces primarily from shoreface and foreshore facies, the Almond Formation and Patrick Draw field was selected as a second reservoir to study because it represented a second type of shoreline barrier system—a

system dominated by tidal processes with production primarily from tidal delta, tidal channel and tidal inlet facies.

A study of facies volumetrics, dimensions and geometry was initiated because facies are an important control on compartmentalization and well drainage area. Prior knowledge of facies dimensions is important for determining the well spacing, patterns and locations. A compilation of the maximum facies dimensions reported in 15 references is presented in Fig. 6 and Table 2 and illustrates the geometry and volume differences of the facies within the barrier island system. The shoreface and foreshore facies predominant in Bell Creek field have volumes over 10 times those of the tidal inlet, flood tidal delta and tidal channel/creek facies that produce in Patrick Draw field. In addition to greater volumes, reservoirs composed of shoreface and foreshore facies have much better reservoir continuity and therefore can be developed with greater well spacing. Reservoirs composed of tidal inlet, flood tidal delta and tidal channel/creek facies have much less continuity, and suggests that closer well spacing (or infill drilling in mature reservoirs) or horizontal wells will be most effective production strategies. Differences in facies continuity between the Muddy formation and Almond formation are clearly illustrated in outcrop cross-sections. Foreshore and shoreface facies, along with corresponding permeability profiles can be traced over distances of over 1.3 miles in outcrop exposures of the Muddy formation (Jackson, et al., 1991), whereas in outcrop exposures of the Almond formation, correlations of tidal channel and tidal delta facies are difficult over 1,200 feet.

CONTINUED WORK IN FY93

To address the question of the transferability of characteristics from one deposit to another, the work planned for FY93 is to survey the literature and other information sources such as the TORIS data base for reservoir characteristics, heterogeneities, and controls on production common to shoreline barrier reservoirs. The reservoir characteristics identified from the detailed study of Patrick Draw and Bell Creek fields will be compared to those reservoirs reported in the literature to: (a) define the spectrum of reservoir characteristics found in shoreline barrier deposits, and (b) assess the degree to which the controls on production found in Patrick Draw and Bell Creek can be generalized to other reservoirs. The characteristics identified will be categorized into depospecific, play specific, or unique classes to assess the degree of similarity and therefore, the degree to which information from one reservoir can be used to maximize oil recovery from other reservoirs deposited in the same depositional environment

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Table 1 - Statistical Parameters Of Selected Reservoir And Production Characteristics Of Barrier Island Reservoirs Contained In The Toris Data Base.

Variable	Minimum	Maximum	Points	Mean	Median	Std Deviation
Field Acres (acres)	200.00	43,150.00	125.00	6,284.13	3,441.00	8,268.80
Well Spacing (acres)	1.70	160.00	310.00	38.00	20.00	40.95
Net Pay (ft)	2.00	600.00	318.00	36.18	20.00	51.09
Gross Pay (ft)	4.30	5,300.00	318.00	91.00	30.00	352.26
Porosity (%)	5.00	40.00	318.00	24.35	25.00	7.12
Initial Oil Saturation (%)	37.00	93.00	318.00	68.73	70.00	8.53
Current Oil Saturation (%)	9.50	72.40	318.00	39.42	39.40	12.25
Depth (ft)	530.00	11,260.00	318.00	4,820.67	4,830.00	2,294.85
Temperature (°F)	63.00	252.00	318.00	143.99	145.00	38.53
Permeability (mD)	0.50	8,200.00	318.00	739.14	350.00	1,064.67
Oil Gravity (°API)	10.00	60.70	318.00	33.44	36.00	8.76
Formation Salinity (PPM TDS)	42.00	300,000.00	191.00	64,790.17	49,999.00	60,412.74
Original Oil in Place (BBL)	519,075.00	1,071,520,000.00	318.00	96,069,923.00	40,320,644.00	160,410,720.00
Primary Recovery Factor (Fraction of OOIP)	0.00	0.86	318.00	0.30	0.27	0.19
Secondary Recovery Factor (Fraction of OOIP)	0.00	0.75	162.00	0.21	0.16	0.18
Cumulative Oil Production (BBL)	16,337.00	515,923,010.00	318.00	33,968,767.00	11,806,400.00	62,802,057.00
Primary Recovery (BBL/AC-FT	1.70	1,732.00	318.00	465.60	346.65	385.23
Primary Recovery (BBL)	40,870.00	600,052,030.00	318.00	27,426,443.00	8,531,765.00	61,527,900.00
Ultimate Recovery Factor (Fraction of OOP) (Primary Plus Secondary)	0.00	0.86	318.00	0.38	0.38	0.18

TABLE 2 - Common shapes and dimensions of major tide related facies in Recent and ancient mesotidal shoreline barrier systems [1]

Facies Name and shape	Thickness (ft)	Width (mi)	Length (mi)
Mesotidal Barrier (Shoreface & Foreshore Facies); elongated oval, drumstick	12.0 to 90.0	0.6 to 4.0	2.0 to 12.0
Washover Fan & Terrace; fan or terrace	0.5 to 6.0	0.4 to 1.6	0.8 to 1.8
Spit Platform; accreted cycles	3.0 to 15.0	0.5 to 3.0	0.3 to 1.0+
Tidal Inlet; strait or slightly curved	5.0 to 100.0+	0.1 to 1.0+	0.6 to 4.0+
Tidal Channel & Tidal Creek; convergent, sinuous	5.0 to 100.0+	0.02 to 0.8	1.0 to 3.0+
Flood Tidal Delta; lobate fan, tear-shaped	6.0 to 30.0	0.3 to 4.0	1.0 to 3.0
Ebb Tidal Delta & Shoal; lobate fan, oval	15.0 to 75.0	1.0 to10.0	1.5 to 6.0

[1]Data compiled from Bernard et al., 1959; Cuevas et al., 1985; Donselaar, 1984, 1990; Fitzgerald et al., 1984; Flores, 1978; Hayes and Sexton, 1989; Hoyt and Henry, 1965; Reinson, 1984; Roehler, 1979, 1988; Sha Li Ping, 1990; Sneider et al., 1984; Van Horn, 1979, and from NIPER's field observations (Szpakiewicz et al., 1986, 1990-91).

	Volumetrics	Continuity	Porosity	Absolute Perm.	Rel. Perm.	Saturations	Fluid Type	Pressure Temp.
DEPOSITIONAL CHARACTERISTICS								
External Geometry		0	0					
Internal Geometry			0	0	0	0	0	
Pattern of Variation (Quantitative Res. Properties)			0	0	0	0	0	
Absolute Values (Quantitative Res. Properties)	X	X	X	X	X	X	X	X
DIAGENETIC CHARACTERISTICS								
Compaction (including geopressure)				0	0			0
Cementation				0	0	0	0	0
Dissolution				0	0	0	0	0
Recrystallization				0	0	0	0	0
TECTONIC CHARACTERISTICS								
Folding		0	0	0				
Faulting		0	0					
Fracturing		0	0			0		
FLUID CHARACTERISTICS								
Hydrocarbons								0
Formation Water					0	0		
Injected Fluids					0	0		

0 = Property transferable
X = Property not transferable

Fig. 1. Degree if transferability of geological and reservoir properties between analogous deposits (from Lake, et al., 1991).

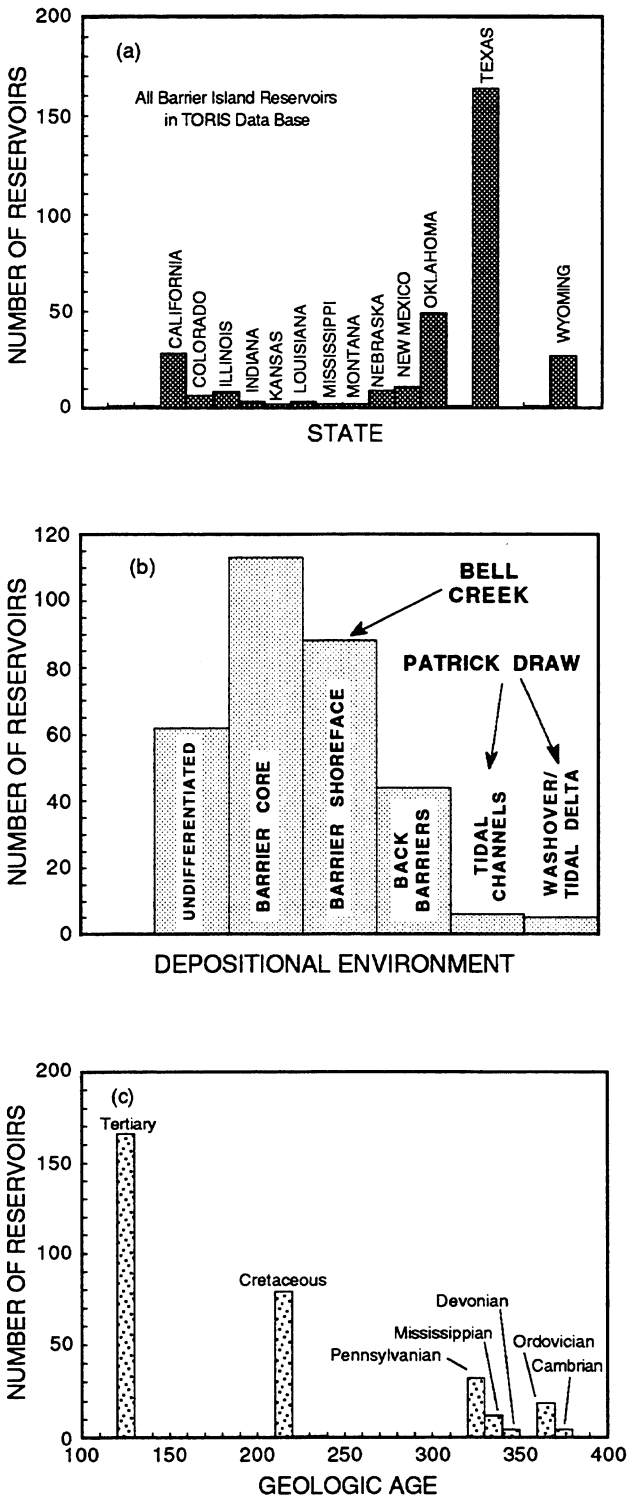

Fig. 2. Distribution of the barrier island reservoirs contained in the TORIS data base according to state (a), depositional environment (b), and geologic age (c).

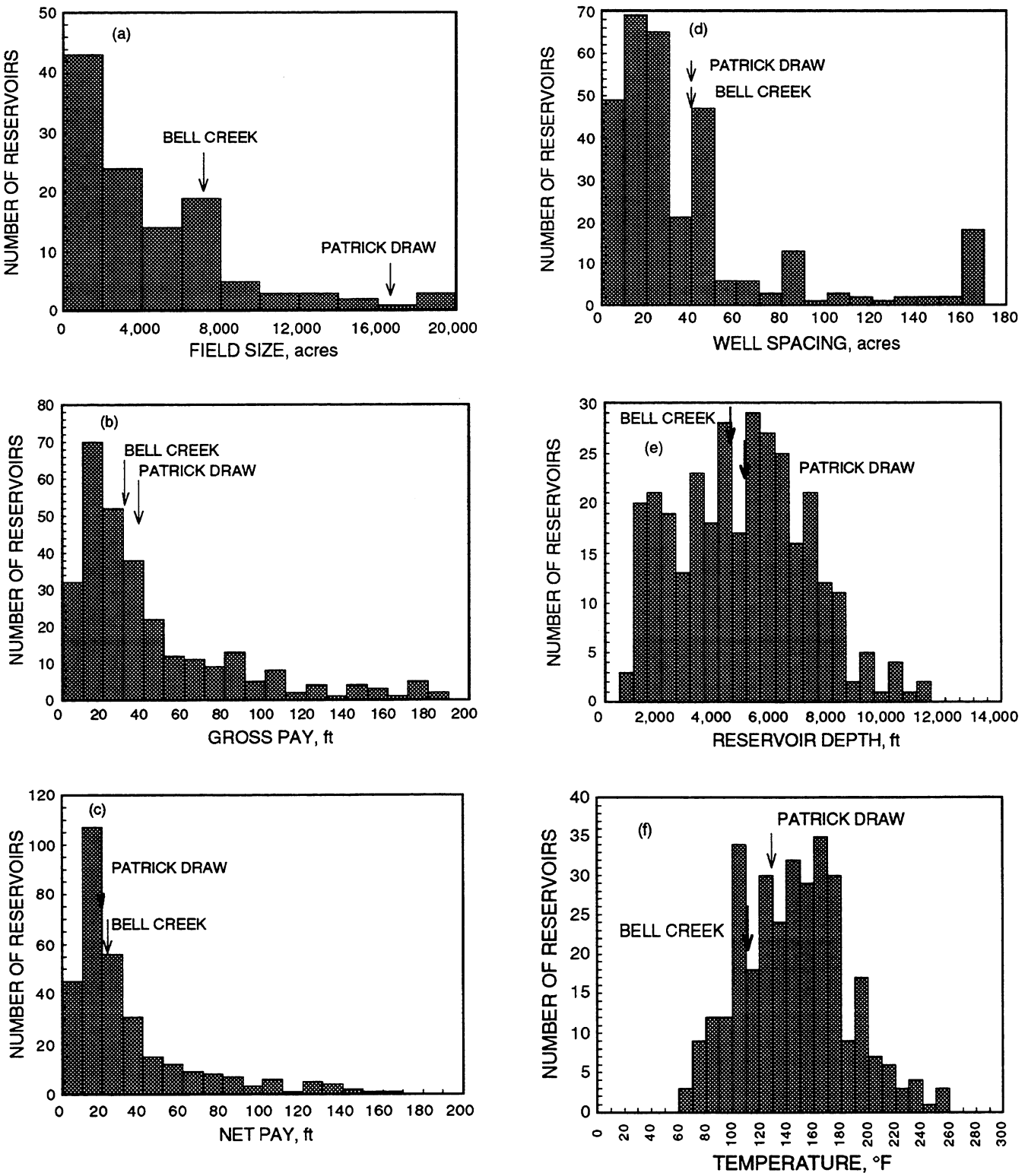

Fig. 3. Histograms of field size (a), gross pay (b), net pay (c), well spacing (d), reservoir depth (e), and temperature (f), from barrier island reservoirs contained in the TORIS data base.

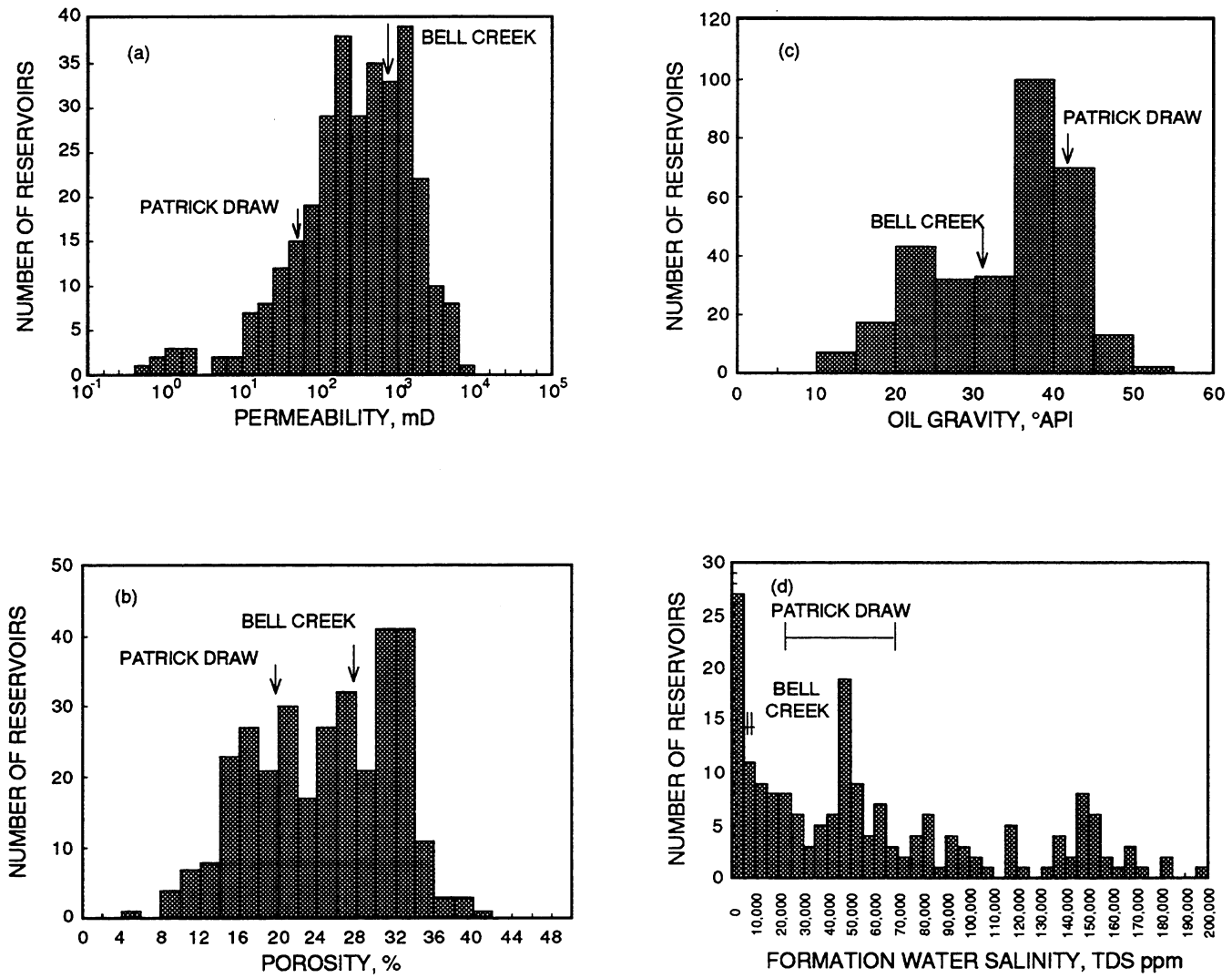

Fig. 4. Histograms of permeability (a), porosity (b), oil gravity (c), and formation water salinity (d), from barrier island reservoirs contained in the TORIS data base.

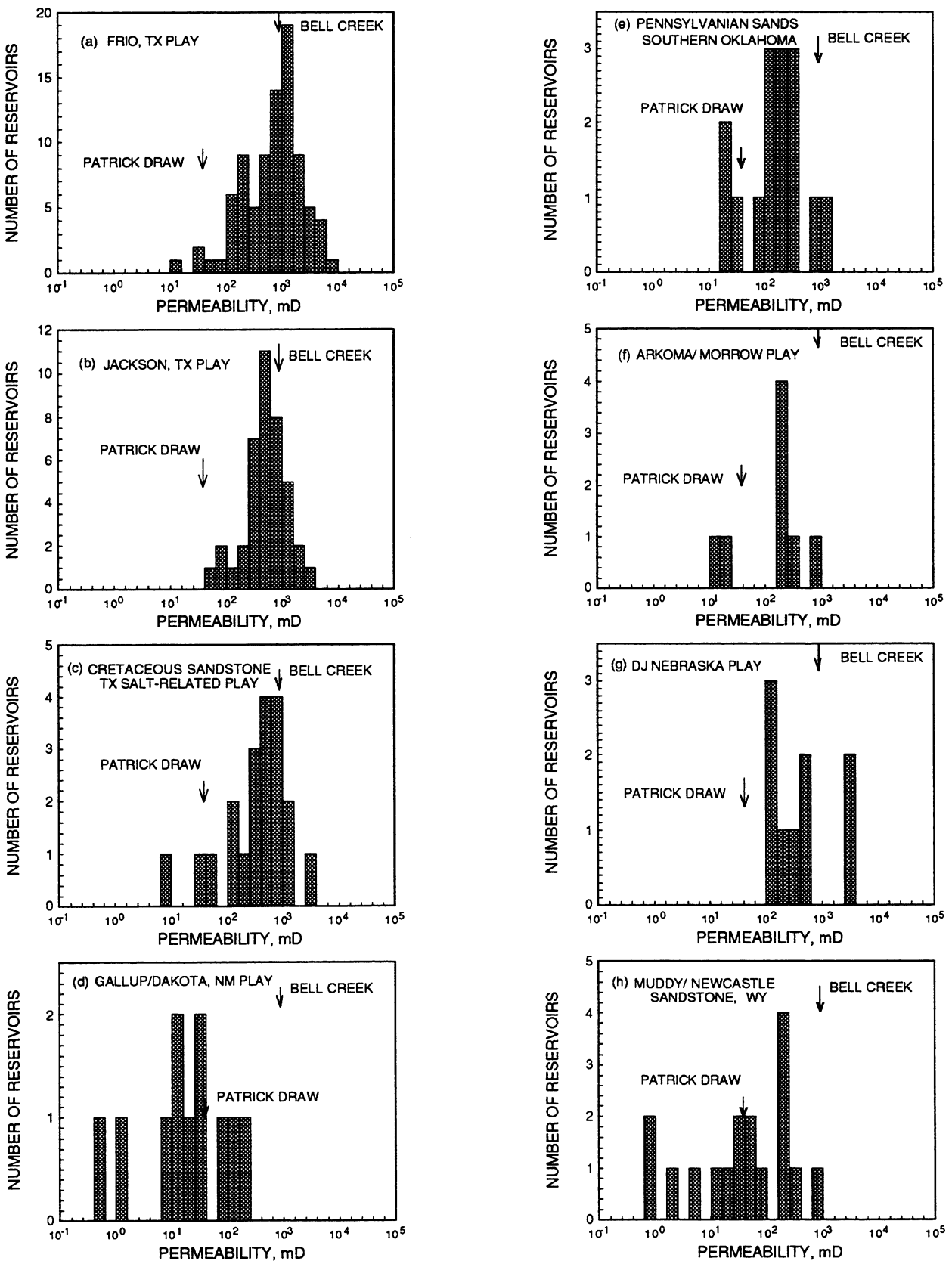

Fig. 5. Histograms of permeability from reservoirs in selected plays.

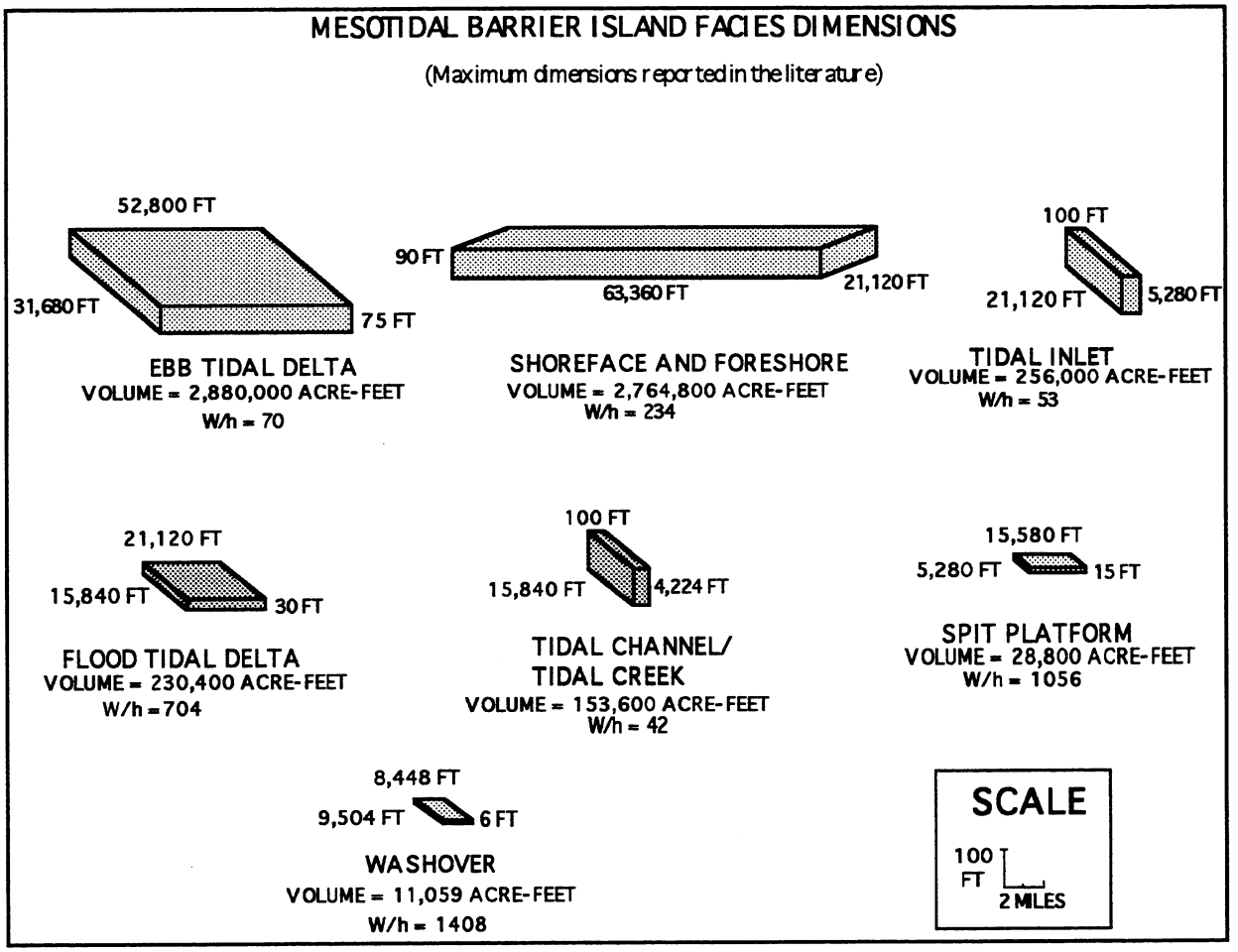

Fig. 6. Dimensions and geometries of barrier island facies. Data from references listed in Table 2.

APPENDIX A - Shoreline Barrier Reservoirs Listed in the TORIS Data Base.
Explanation of codes used is presented in Appendix B.

STATE	AGE	FIELD	RESERVOIR	FORMATION	DEP SYS	CONF
AL	210	POLLARD	UPPER TUSCALOOSA	LOWER TUSCALOOSA	162	1
AR	210	RITCHIE	BAKKER SAND	GRAVES	162	1
CA	121	PLACERITA	ALL AREAS	PICO	160	2
CA	121	ROSEDALE RANCH	LERDO	ETCHEGOIN	160	1
CA	121	WAYSIDE CANYON	PLIOCENE	PICO	160	2
CA	122	ANT HILL	OLCESE	OLCESE	160	1
CA	122	BLACKWELLS CORNER	TEMBLOR AND AGUA	TEMBLOR	160	1
CA	122	CAPITAN	VAQUEROS	VAQUEROS	160	1
CA	122	CAT CANYON WEST	ALEXANDER - MIOCENE	SISQUOC	160	1
CA	122	CUYAMA SOUTH	HOMAN	VAGUEROS	160	1
CA	122	EDISON	VEDDER FREEMAN	VEDDER & FREEMAN-JEWETT	160	1
CA	122	GREELEY	VEDDER	VEDDER	160	1
CA	122	KERN BLUFF	MIOCENE	SANTA MARGARITA	160	1
CA	122	MOUNT POSO	UPPER VEDDER	VEDDER	160	1
CA	122	OAKRIDGE	MIOCENE	TOPANGA/VAQUEROS	160	3
CA	122	PLEITO	CREEK AREA	SANTA MARGARITA	160	1
CA	122	ROUND MOUNTAIN	COFFEE CANYON-VEDDER & PYRAMID HILL	VEDDER & PYRAMID HILLS	160	1
CA	122	ROUND MOUNTAIN	ROUND MTN. - JEWETT & PYRAMID HILL	FREEMAN-JEWETT	160	1
CA	122	ROUND MOUNTAIN MAIN AREA	VEDDER	VEDDER	160	1
CA	122	RUSSELL RANCH	DIBBLEE SANDS	VAQUEROS	160	1
CA	122	SAN ARDO	AURIGNAC	MONTEREY	160	1
CA	122	SAN ARDO	LOMBARDI	MONTEREY	160	1
CA	122	SUMMERLAND OFFSHORE	VAQUEROS	VAQUEROS	160	1
CA	122	TEJON GR - TEJON GRAPEVINE	WESTERN AREA S	SANTA MARGARITA	160	1
CA	122	WHEELER RIDGE	CENTRAL AREA COAL OIL CANYON--MAIN	FRUITVALE	160	1
CA	122	WHITE WOLF	REEF RIDGE	REEF RIDGE	160	2
CA	123	ANTELOPE HILLS	WILLIAMS AREA EAST BLOCK AGUA	AGUA	160	1
CA	123	CAPITAN	COVARRUBIAS	SESPE EQUIVALENT	160	2
CA	123	JASMIN	CANTLEBERRY VEDDER (2 AREAS)	VEDDER	160	1
CA	124	SHIELLS CANYON	EOCENE	LLAJAS	160	1
CO	211	PRICE GRAMPS	MORRISON	DAKOTA-MORRISON	162	2
CO	218	BOXER	D SAND	DAKOTA	161	1
CO	218	MOFFAT	DAKOTA	DAKOTA	162	2
CO	218	SABER	D SAND	DAKOTA	161	1
CO	218	SABER	D SAND	DAKOTA	161	1
CO	221	WILSON CREEK	MORRISON SAND	MORRISON	161	2
IL	332	DALE CONSOLIDATED	AUX VASES	AUX VASES	164	2
IL	332	JOHNSONVILLE CONSOLIDATED	AUX VASES	AUX VASES	164	2

IL	332	LAWRENCE	AUX VASES	AUX VASES	164	2
IL	332	LAWRENCE	JACKSON	FRAILEYS	164	1
IL	332	LOUDEN	CYPRESS	CYPRESS	161	1
IL	332	MAIN CONSOLIDATED	SAMPLE	RIDENHOWER	165	2
IL	332	PATOKA EAST	CYPRESS - BENOIST	CYPRESS	160	2
IL	332	ST. JAMES	CYPRESS	CYPRESS	161	2
IN	327	CABORN CONSOLIDATED	MANSFIELD	MANSFIELD	160	3
IN	327	HEUSLER CONSOLIDATED	MANSFIELD	MANSFIELD	162	3
IN	332	GRIFFIN CONSOLIDATED	TOTAL FIELD	CYPRESS	162	3
KS	371	OTIS	REAGAN	REAGAN	165	3
KS	371	RAY	REAGAN	REAGAN	165	3
LA	122	CHANDELEUR SOUND BLOCK 25	BB RA SAND	LA	162	2
LA	122	VINTON	UPPER MIOCENE	UPPER MIOCENE	161	2
LA	123	TEPETATE, WEST	MILLER	MILLER SAND	161	2
MS	210	CRANFIELD	LOWER TUSCALOOSA	LOWER TUSCALOOSA	162	2
MS	210	MC COMB	LOWER TUSCALOOSA 'B'	LOWER TUSCALOOSA	162	1
MT	217	BELL CREEK	MUDDY	MUDDY SANDSTONE	161	1
MT	326	ELK BASIN	EMBAR - TENSLEEP	TENSLEEP SANDSTONE	162	2
NE	210	ALLCHIN	DAKOTA J SAND	DAKOTA	161	1
NE	210	COOK	MUDDY D	DAKOTA	161	2
NE	210	DORMAN	DAKOTA D - G	DAKOTA	164	2
NE	210	HUNTSMAN	3RD DAKOTA J	DAKOTA	161	2
NE	210	JUELFS-GAYLORD	DAKOTA J	DAKOTA	161	2
NE	210	MALEY	DAKOTA J	DAKOTA	161	2
NE	210	SINGLETON	J SAND	DAKOTA	161	1
NE	325	SLEEPY HOLLOW	B PENNSYLVANIAN SAND	BASAL PENN. SAND	161	2
NE	377	SLEEPY HOLLOW	REAGAN	REAGAN SAND	165	2
NM	213	BISTI	LOWER GALLUP	LOWER GALLUP	162	1
NM	213	CHA-CHA	GALLUP	GALLUP	162	1
NM	213	DEVILS FORK	GALLUP	GALLUP	162	1
NM	213	ESCRITO	GALLUP	GALLUP	162	1
NM	213	HORSESHOE	GALLUP	GALLUP	162	1
NM	213	HOSPAH	UPPER SAND	UPPER SAND	161	1
NM	213	HOSPAH, SOUTH	LOWER SAND	LOWER SAND	161	1
NM	213	HOSPAH, SOUTH	UPPER SAND	UPPER SAND	161	1
NM	213	LINDRITH WEST	GALLUP-DAKOTA	GALLUP-DAKOTA	162	1
NM	213	MANY ROCKS	GALLUP	GALLUP	162	1
NM	213	OTERO	GALLUP	GALLUP	162	1
OK	322	SOLDIER CREEK	CISCO	CISCO	165	2

OK	323	HEALDTON	PENNSYLVANIAN	PENNSYLVANIAN	162	1
OK	323	HEWITT EAST	HOXBAR-DEESE	HOXBAR	162	2
OK	323	LOCO DISTRICT	LOCO DEEP - HOXBAR SAND	LOCO DEEP - HOXBAR SAND	162	1
OK	323	LONE ELM SOUTH	CLEVELAND SAND	CLEVELAND SAND	160	1
OK	323	SHO-VEL-TUM	HOXBAR	HOXBAR	163	2
OK	323	SOONER TREND	LAYTON AND OTHER SS	LAYTON AND OTHER SS	162	1
OK	325	BROCK	PENNSYLVANIAN (DEESE)	PENNSYLVANIAN (DEESE)	162	1
OK	325	CHEROKITA TREND	RED FORK	RED FORK	162	1
OK	325	CIVIT WEST	DYKEMAN	DYKEMAN	162	2
OK	325	GOLDEN TREND	DEESE AND OTHER PENN SS	DEESE	162	1
OK	325	GUTHRIE	BARTLESVILLE	BARTLESVILLE	162	1
OK	325	HEWITT	PENNSYLVANIAN	PENNSYLVANIAN	162	2
OK	325	KNOX	PONTOTOC,HOXBAR,& DEESE	DEESE	162	1
OK	325	LEON NORTH	DEESE	DEESE	162	1
OK	325	PAULS VALLEY	BASAL PENNSYLVANIAN	BASAL PENNSYLVANIAN	162	2
OK	325	SHO-VEL-TUM	DEESE	DEESE	162	2
OK	325	THACKERVILLE NORTH	DEESE	DEESE	162	1
OK	328	ALLEN DISTRICT	CROMWELL AND OTHERS	CROMWELL AND OTHERS	162	1
OK	328	CASTLE EAST	CROMWELL	CROMWELL	162	1
OK	328	CROMWELL	VARIOUS PENNSYLVANIAN	CROMWELL	162	1
OK	328	FITTS	CROMWELL	CROMWELL	162	1
OK	328	LITTLE RIVER	CROMWELL	CROMWELL	162	1
OK	328	LITTLE RIVER EAST	CROMWELL	CROMWELL	162	1
OK	328	MIDWELL	KEYES	KEYES	162	1
OK	328	PAPOOSE	CROMWELL	CROMWELL	162	1
OK	328	POSTLE	MORROW	MORROW	162	1
OK	328	WEWOKA DISTRICT	CROMWELL	CROMWELL	162	1
OK	331	KNOX	SPRINGER	SPRINGER	162	2
OK	342	KEOKUK	MISENER AND HUNTON	MISENER	160	1
OK	348	BOWLEGS	ALL	WILCOX	162	1
OK	365	APACHE	BROMIDE	BROMIDE	162	1
OK	365	AYLESWORTH	MISENER,WOODFORD,ETC. (ALL PROD)	BROMIDE	162	1
OK	365	CUMBERLAND	MCLISH, BROMIDE,& OTHERS	MCLISH, BROMIDE,& OTHERS	162	1
OK	365	DAVIS NE	OIL CREEK	OIL CREEK	163	1
OK	365	EDMOND WEST	SIMPSON AND 2ND WILCOX	SIMPSON AND 2ND WILCOX	162	1
OK	365	EOLA-ROBBERSON	SIMPSON	SIMPSON	162	1
OK	365	FITTS	VIOLA & SIMPSON	SIMPSON	162	1
OK	365	GOLDEN TREND	BROMIDE AND OTHER DEEP SS	BROMIDE AND OTHER DEEP SS	162	2
OK	365	LITTLE RIVER	WILCOX & OTHERS	WILCOX & OTHERS	162	1

OK	365	MADILL	BROMIDE	BROMIDE	162	1
OK	365	OCONEE EAST	OIL CREEK	OIL CREEK	163	1
OK	365	OKLAHOMA CITY	LOWER SIMPSON	LOWER SIMPSON	162	1
OK	365	OKLAHOMA CITY	WILCOX	WILCOX	162	1
OK	365	PAULS VALLEY SE	OIL CREEK (PROJECT)	OIL CREEK (PROJECT)	163	1
OK	365	SEMINOLE	WILCOX & OTHER SANDS	WILCOX & OTHER SANDS	162	1
OK	365	SEMINOLE WEST	WILCOX	WILCOX	162	1
OK	365	TONKAWA	WILCOX	WILCOX	162	1
OK	365	WATCHORN EAST	WILCOX	WILCOX	162	1
PA	341	FOSTER-RENO-OIL CITY	MERAMEC	VENANGO	160	1
TX	120	LOLITA	MARGINULINA ZONE	MARGINULINA ZONE	161	1
TX	122	BALDWIN		TX	161	1
TX	122	BENAVIDES		TX	163	1
TX	123	AMELIA	FRIO	FRIO	160	1
TX	123	ARMSTRONG	BRENNAN	BRENNAN	163	1
TX	123	ARNOLD DAVID	CHAPMAN SAND	CHAPMAN SAND	161	1
TX	123	BEAUMONT		TX	160	1
TX	123	BLESSING	F-14-B	F-14-B	161	1
TX	123	BLESSING	F-14-B	F-14-B	161	1
TX	123	BLESSING	F-3	F-3	161	1
TX	123	BLESSING	F-3	F-3	161	1
TX	123	BLOOMINGTON	4600	4600	161	1
TX	123	BONNIE VIEW	BONNIE VIEW	BONNIE VIEW	161	1
TX	123	CAMPANA, SOUTH		TX	160	1
TX	123	COLETTO CREEK	2800' POOL	2800 SAND	160	1
TX	123	CONOCO DRISCOLL	UPPER FIRST GOVERNMENT WELLS SAND	UPPER FIRST GOVERNMENT WE	163	1
TX	123	CORPUS CHRISTI		TX	161	1
TX	123	ELPAR	F-07, E	F-07, E	161	1
TX	123	ELPAR	F-07, EAST	TX	161	1
TX	123	ENCINO	6400 SAND	6400 SAND	161	1
TX	123	FLOUR BLUFF, EAST	MASSIVE, UP.	MASSIVE, UP.	161	1
TX	123	FRANCITAS, NORTH		TX	161	1
TX	123	GANADO		TX	161	1
TX	123	GANADO DEEP		TX	161	1
TX	123	GANADO DEEP	HULTQUIST	HULTQUIST	161	1
TX	123	GANADO, WEST	4700 ZONE	4700 ZONE	161	1
TX	123	GRETA	4400	4400	161	1
TX	123	HEYSER	5400 NO. 2	5400 NO. 2	161	1
TX	123	HEYSER	5400 NO. 3	5400 NO. 3	161	1

TX	123	HOFFMAN		TX	163	1
TX	123	LA ROSA	5900 SAND	5900 SAND	161	1
TX	123	LAKE PASTURE	FT-569	FT-569	161	1
TX	123	LAKE PASTURE	H-440 SAND	H-440 SAND	161	1
TX	123	LOLITA	TONEY ZONE	TONEY ZONE	161	1
TX	123	LOLITA DEEP	4-WAY ZONE	4-WAY ZONE	161	1
TX	123	LONDON GIN	DOUGHTER SAND	DOUGHTER SAND	161	1
TX	123	LOUISE		TX	161	1
TX	123	LOVELLS LAKE	FRIO 2	FRIO 2	160	1
TX	123	MAGNET WITHERS	FRIO POOL	FRIO POOL	161	1
TX	123	MARKHAM N.-BAY CITY,N	CORNELIUS	CORNELIUS	161	1
TX	123	MARKHAM, NORTH	CORNELIUS	CORNELIUS	161	1
TX	123	MARKHAM, NORTH - BAY CITY N	EAST CAYCE	EAST CAYCE	161	1
TX	123	MARKHAM, NORTH - BAY CITY N	WEST CAYCE	WEST CAYCE	161	1
TX	123	MARKHAM, NORTH - BAY CITY, N	WEST CORNELIUS	WEST CORNELIUS	161	1
TX	123	MARKHAM, NORTH-BAY CITY, N	CARLSON	CARLSON	161	1
TX	123	MARKHAM, NORTH-BAY CITY, N	CAYCE	CAYCE	161	1
TX	123	MARY ELLEN OCONNOR	FQ-40 SAND	FQ-40 SAND	161	1
TX	123	MARY ELLEN OCONNOR	FQ-40 SAND	FQ-40 SAND	161	1
TX	123	MARY ELLEN OCONNOR	FS-96	FS-96	161	1
TX	123	MAURBRO	MARGINULINA	MARGINULINA	161	1
TX	123	MC FADDIN	4400'	4400'	161	1
TX	123	MIDFIELDS		TX	161	1
TX	123	MUSTANG ISLAND	6 SAND	6 SAND	161	1
TX	123	MUSTANG ISLAND	7-A	7-A	161	1
TX	123	MUSTANG ISLAND	8 SAND	8 SAND	161	1
TX	123	MUSTANG ISLAND	9 SAND	9 SAND	161	1
TX	123	NOME	ALL SANDS	ALL SANDS	160	1
TX	123	NOME	X - SAND	X - SAND	160	1
TX	123	ODEM	6700 B	6700 B	161	1
TX	123	ODEM	6700 B	6700 B	161	1
TX	123	ODEM	ODEM	ODEM	161	1
TX	123	OLD OCEAN		TX	161	1
TX	123	OLD OCEAN	ARMSTRONG	ARMSTRONG	161	1
TX	123	OLD OCEAN	CHENAULT	CHENAULT	161	1
TX	123	PHEASANT, SOUTHWEST	8150 B-1	8150 SAND	160	1
TX	123	PHOENIX LAKE		TX	160	1
TX	123	PICKETT RIDGE	FRIO	FRIO	161	1
TX	123	PLACEDO		4700 SAND	161	1

TX	123	PLACEDO, EAST		TX	161	1
TX	123	PLYMOUTH		HEEP	161	1
TX	123	PORTILLA	7300 SAND	7300 SAND	161	1
TX	123	PORTILLA	7400 SAND	7400 SAND	161	1
TX	123	PORTILLA	8100 SAND	8100 SAND	161	1
TX	123	REFUGIO HEARD	AREA	AREA	161	1
TX	123	REFUGIO NEW	6200 FB1	6200 FB1	161	1
TX	123	REFUGIO-FOX		TX	161	1
TX	123	ROCHE	C" SAND"	C" SAND"	161	1
TX	123	SAXET	DEEP	TX	161	1
TX	123	SAXET, DEEP		DEEP	161	1
TX	123	SUGAR VALLEY	LAURENCE A	LAURENCE A	161	1
TX	123	TAFT	4000' SAND	4000' SAND	161	1
TX	123	TOM O'CONNOR	CATAHOULA-FRIO-MIOCENE	CATAHOULA-FRIO-MIOCENE	161	1
TX	123	TOM OCONNOR	4500 GRETA MASS.	4500 GRETA MASS.	161	1
TX	123	TOM OCONNOR	5400 SAND	5400 SAND	161	1
TX	123	TOM OCONNOR	5500	5500	161	1
TX	123	WEST RANCH	41-A	41-A	161	1
TX	123	WEST RANCH	98-A	98-A	161	1
TX	123	WEST RANCH	GLASSCOCK	GLASSCOCK	161	1
TX	123	WEST RANCH	GRETA SAND	GRETA SAND	161	1
TX	123	WEST RANCH	OTHER ZONES	OTHER ZONES	161	1
TX	123	WEST RANCH	TONEY	TONEY	161	1
TX	123	WEST RANCH	VANDERBILT SAND	VANDERBILT SAND	161	1
TX	123	WEST RANCH	VENADO ZONE	VENADO ZONE	161	1
TX	123	WEST RANCH	WARD	WARD	161	1
TX	123	WHITE POINT EAST	FRIO	FRIO	161	1
TX	123	WHITE POINT, EAST	4600 HET	4600 HET	161	1
TX	123	WHITE POINT, EAST	5000 SAND	5000 SAND	161	1
TX	123	WITHERS, NORTH		TX	161	1
TX	124	ARMSTRONG	BRENNAN	BRENNAN	163	1
TX	124	AVIATORS	MIRANDO SAND	MIRANDO SAND	163	1
TX	124	BENAVIDES		TX	163	1
TX	124	CAMPANA, SOUTH		TX	163	1
TX	124	CEDRO HILL	COLE SAND	COLE SAND	163	1
TX	124	COLE, WEST	MIRANDO SAND	MIRANDO SAND	163	1
TX	124	EAGLE HILL		TX	163	1
TX	124	ESCOBAS	MIRANDO	MIRANDO	163	1
TX	124	EZZELL		TX	163	1

TX	124	FITZSIMMONS		TX	163	1
TX	124	GOVERNMENT WELLS NORTH	GOVERNMENT WELLS SAND	GOVERNMENT WELLS SAND	163	1
TX	124	GOVERNMENT WELLS, SOUTH	GOVERNMENT WELLS	GOVERNMENT WELLS SAND	163	1
TX	124	HOFFMAN	LOMA NOVIA 2730	LOMA NOVIA 2730	163	1
TX	124	JENNINGS	MIRANDO	MIRANDO	163	1
TX	124	JENNINGS, WEST	3000 SAND	3000 SAND	163	1
TX	124	LA WARD, NORTH	FRIO	FRIO	161	1
TX	124	LAS ANIMAS-LEFEVRE	COLE	COLE	163	1
TX	124	LOMA NOVIA	LOMA NOVIA SAND	LOMA NOVIA SAND	163	1
TX	124	LOPEZ	MIRANDO SAND	MIRANDO SAND	163	1
TX	124	LUCILLE	HOCKLEY, UPPER	HOCKLEY, UPPER	163	1
TX	124	LUNDELL	COLE SAND	COLE SAND	163	1
TX	124	LUNDELL	PETTUS	PETTUS	163	1
TX	124	LUNDELL	PETTUS	PETTUS	163	1
TX	124	MIRANDO CITY	MIRANDO SAND	MIRANDO SAND	163	1
TX	124	OHERN	PETTUS	PETTUS	163	1
TX	124	OILTON	BRUNI	BRUNI	163	1
TX	124	PETTUS		PETTUS	163	1
TX	124	PIEDRE LUMBRE	GOVERNMENT WELLS SAND	GOVERNMENT WELLS SAND	163	1
TX	124	PRADO	COMBINED ZONES	COMBINED ZONES	163	1
TX	124	PRADO	COMBINED ZONES	COMBINED ZONES	163	1
TX	124	PRADO	LOMA NOVIA MIDDLE II	LOMA NOVIA MIDDLE II	163	1
TX	124	RANDADO		TX	163	1
TX	124	SEJITA	HOCKLEY,JACKSON	HOCKLEY,JACKSON	163	1
TX	124	SEVEN SISTERS	GOVT. WELLS SAND	GOVT. WELLS SAND	163	1
TX	124	SEVENTY-SIX, SOUTH		TX	163	1
TX	124	SEVENTY-SIX, WEST	COLE	COLE	163	1
TX	124	VOLPE	LOPEZ	LOPEZ	163	1
TX	210	ALBA		TX	162	1
TX	210	MANZIEL	PALUXY	PALUXY	162	1
TX	210	MIDWAY LAKE		TX	162	1
TX	210	YANTIS		TX	162	1
TX	212	COKE	SUB-CLARKSVILLE	SUB-CLARKSVILLE	162	1
TX	212	CORSICANA	SHALLOW	SHALLOW	160	1
TX	212	FOREST HILL	HARRIS SAND (B-F SEGMENTS)	HARRIS SAND (B-F SEGMENTS)	162	1
TX	212	HAM GOSSETT, EAST		WOODBINE	162	1
TX	212	KERENS, SOUTH	WOODBINE	WOODBINE	162	1
TX	212	MEXIA	WOODBINE	WOODBINE	162	1
TX	212	POWELL		WOODBINE	162	1

TX	212	QUITMAN	SUB-CLARKSVILLE	SUB-CLARKSVILLE	162	1
TX	212	SLOCUM	CARRIZO SAND	CARRIZO SAND	162	1
TX	212	TRIX LIZ	WOODBINE B	WOODBINE B	162	1
TX	212	TRIX LIZ	WOODBINE D	WOODBINE D	162	1
TX	212	WORTHAM		WOODBINE	162	1
TX	217	CARTHAGE		TX	162	1
TX	217	CARTHAGE	BURNETT SAND	BURNETT SAND	162	1
TX	217	NEW HOPE	HILL SAND	HILL SAND	162	1
TX	217	NEW HOPE	PITTSBURG	PITTSBURG	162	1
TX	217	PITTSBURGH FIELD	PITTSBURGH SAND UNIT	PITTSBURGH SAND UNIT	162	1
TX	218	CHAPEL HILL	FREDRICKSBURG GROUP	FREDRICKSBURG GROUP	162	1
TX	218	COKE	PALUXY	PALUXY	162	1
TX	218	HITTS	PAULUXY	PALUXY	162	1
TX	218	QUITMAN		PALUXY	162	1
TX	218	QUITMAN, NORTHWEST	PALUXY	PALUXY	162	1
TX	218	SAND FLAT		PALUXY	162	1
TX	218	SHAMBURGER LAKE	PALUXY	PALUXY	162	1
TX	365	SANDUSKY	OIL CREEK SAND	OIL CREEK SAND	160	1
UT	341	LISBON	MCCRACKEN	MCCRACKEN	162	2
WY	211	DEAD HORSE CREEK	PARKMAN	MESAVERDE	161	1
WY	211	PATRICK DRAW (MONNEL UNIT)	ALMOND	ALMOND	161	1
WY	211	PATRICK DRAW (PECH UNIT)	ALMOND	ALMOND	161	1
WY	211	POISON SPIDER, WEST	MESAVERDE	MESAVERDE	160	2
WY	217	SPRINGEN RANCH	MUDDY	MUDDY SANDSTONE	160	2
WY	217	UTE	MUDDY	MUDDY SANDSTONE	160	2
WY	218	CHAN	MUDDY	MUDDY SANDSTONE	160	1
WY	218	COLLUMS	MUDDY	MUDDY SANDSTONE	160	1
WY	218	DONKEY CREEK	DAKOTA	DAKOTA (FALL RIVER)	161	1
WY	218	FIDDLER CREEK	NEWCASTLE	NEWCASTLE SANDSTONES	160	2
WY	218	GAS DRAW	MUDDY	MUDDY SANDSTONE	160	1
WY	218	GILLETTE	MUDDY	MUDDY SANDSTONE	160	1
WY	218	GRIEVE	MUDDY	MUDDY SANDSTONE	164	1
WY	218	HILIGHT	MUDDY, MINNELUSA	MUDDY SANDSTONE	161	1
WY	218	KITTY	MUDDY	MUDDY SANDSTONE	160	1
WY	218	MILL	MUDDY	MUDDY SANDSTONE	160	1
WY	218	MILLER CREEK	DAKOTA	DAKOTA (FALL RIVER)	161	2
WY	218	RECLUSE	MUDDY	MUDDY SANDSTONE	160	2
WY	218	ROCK RIVER	CRETACEOUS	MUDDY, DAKOTA, LAKOTA	160	3
WY	218	ROZET	MUDDY	MUDDY SANDSTONE	161	

WY	218	SANDBAR, EAST	MUDDY	MUDDY SANDSTONE	160	1
WY	218	SOUTH GLENROCK	UPPER MUDDY B CONOCO ONLY	MUDDY SANDSTONE	161	2
WY	218	WHITETAIL	MUDDY	MUDDY SANDSTONE	160	1
WY	230	GRASS CREEK	CURTIS	CHUGWATER (CROW MOUNTAI	160	1
WY	331	GRASS CREEK	DARWIN	AMSDEN (DARWIN SS)	160	2
WY	331	WERTZ	AMSDEN	AMSDEN (DARWIN SANDSTONE	160	2
WY	374	LOST SOLDIER	FLATHEAD	FLATHEAD SANDSTONE	160	

APPENDIX B. Codes Used in Appendix A.

GEOLOGIC AGE CODE

120	Tertiary
121	Pliocene
122	Miocene
123	Oligocene
124	Eocene
210	Cretaceous
211	Cretaceous/Upper
212	Cretacous/Gulf
213	Cretaceous/Coloradoan
217	Cretaceous/Lower
218	Cretaceous/Comanche
221	Jurassic/Upper
230	Triassic
322	Pennsylvanian/Virgil
323	Pennsylvanian/Missouri
325	Pennsylvanian/DesMoines
326	Pennsylvanian/Atoka
327	Pennsylvanian/Lower
328	Pennsylvanian/Morrow
331	Mississippian/Upper
332	Mississippian/Chester
341	Devonian/Upper
342	Devonian/Chautauquan
348	Devonian/Ulterian
365	Ordovician/Champlanian
371	Cambrian/Upper
374	Cambrian/Middle
377	Cambrian/Lower

DEPOSITIONAL SYSTEM CODE

160	Strandplain/Undifferentiated
161	Strandplain/Barrier Core
162	Strandplain/Barrier Shoreface
163	Strandplain/Back Barriers
164	Strandplain/Tidal Channels
165	Strandplain/Washover Fan/Tidal Delta

DEGREE OF CONFIDENCE

1	Highest
2	Moderate
3	Lowest