THE LITHOLOGY, ENVIRONMENT OF DEPOSITION, AND RESERVOIR PROPERTIES OF SANDSTONES IN THE UPPER QUEEN FORMATION (GUADALUPIAN, PERMIAN) AT CONCHO BLUFF QUEEN FIELD, CRANE COUNTY, TEXAS

A Thesis

by

DOUGLAS FLOYD NEWSOM

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 1989

Major Subject: Geology

THE LITHOLOGY, ENVIRONMENT OF DEPOSITION, AND RESERVOIR PROPERTIES OF SANDSTONES IN THE UPPER QUEEN FORMATION (GUADALUPIAN, PERMIAN) AT CONCHO BLUFF QUEEN FIELD, CRANE COUNTY, TEXAS

A Thesis

by

DOUGLAS FLOYD NEWSOM

Approved as to style and content by:

James M. Mazzullo
(Chair of Committee)

Robert R. Berg
(Member)

Wilfred D. Gardner
(Member)

John H. Spang
(Head of Department)

December 1989

ABSTRACT

The Lithology, Environment of Deposition, and
Reservoir Properties of Sandstones in the Upper Queen Formation
(Guadalupian, Permian) at Concho Bluff Queen Field, Crane County,
Texas. (December 1989)

Douglas Floyd Newsom, B.S., Baylor University
Chair of Advisory Committee: Dr. James M. Mazzullo

The Permian Basin is a manifestation of very complex lithofacies and depositional environments. Present in the subsurface on the Northwest Shelf, Central Basin Platform, and Midland Basin of the Permian Basin, the Queen Formation (Guadalupian, Permian) contains a diverse sequence of interbedded carbonates, evaporites, and clastics. Sandstones represent the producing lithology of the Upper Queen Formation in the Concho Bluff Queen Field, which is located in the western part of the Midland Basin of the Permian Basin. Four discrete sandstone packages occur in this field and have been designated in order of deposition as the Queen A, B, C, and D. The purpose of this study is to determine the environment of deposition for these sandstones and to understand their influence on the reservoir formation.

Four facies are distinguished on the basis of texture and sedimentary structures. The principal lithofacies included in a complete cycle in ascending order are: 1) playa, 2) mudflat, 3) sandflat, and 4) eolian sand sheet. The playa consists of massive

and laminated anhydrite with minor amounts of interlaminated dolomitic mudstone. The mudflat overlies the playa and is characterized by wavy and discontinuous laminated siliciclastics. The sandflat rests above the mudflat and contains horizontal to slightly wavy, continuous laminated sandstones. The sandflat is overlain by an eolian sand sheet which displays inclined, planar, and continuous laminated sandstones. Bounding the Upper Queen Formation is a playa facies. This facies pattern indicates the sandstones were transported as a fan delta by fluvial-dominated processes and deposited into a desiccating playa. The lithofacies within the Upper Queen Formation in the Concho Bluff Queen Field are present in four packages of cycles.

Each of the four sandstone horizons has been perforated and is productive. Generally, the fluvial sandflat and the eolian sand sheet are the reservoirs facies. They have similar grain sizes which are very-fine grained (mean of 109 microns), and average 25 ft. in total thickness. They have an average porosity of 16.5% and an average permeability of 40 millidarcys. On the other hand, the mudflat facies is the non-reservoir, consisting of coarse-grained silt (mean of 55 microns).

The Concho Bluff Queen Field has recovered 84% of its cumulative production (as of July 1988) through secondary recovery and serves as an excellent model for waterflooding. The low gravity of the oil (28 - 32 degrees API), the homogeneity of the laterally continuous sandstones, and the peripheral pattern of water injection wells have contributed to this successful waterflood.

TO MY LOVING PARENTS

ACKNOWLEDGEMENTS

This thesis was made possible through the help of several individuals. Dr. Mazzullo directed the entire study, in addition to financing the research. Dr. Berg and Dr. Gardner reviewed the manuscript and made necessary suggestions for improvement. Paul Newsom, an independent geologist from Houston, was especially helpful with the sections concerning the reservoir properties and the production history. I also wish to thank Texaco for supplying cores and data from the Concho Bluff Queen Field.

The completion of this thesis would not have been attainable without the assistance of the graduate students in my office who freely offered me their time. Andy Alexander aided in the grain size and shape analysis. Ariel Malisce gave much insight to the interpretation of the depositional environment. Laura Bagwell provided guidance on the preparation of grain samples.

I would like to thank my parents who gave their love and support throughout my graduate work. Finally, I wish the best to my friends who are currently working on studies of the Queen Sandstone: James Harper, Chuck McKone, and Ben Price.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

INTRODUCTION

The Permian Basin contains a series of complex lithofacies and depositional environments, representing one of the classical geological areas of the world. Since oil was first discovered in the Permian Basin in 1921, the basin has produced more than 24 billion barrels of oil (Bebout et al., 1987). The Artesia Group (Late Permian, Guadalupian), from which more than 1.3 billion barrels of oil has been recovered since 1980, has been recognized as a major contributor to this Permian Basin production (Ward et al., 1986).

The Artesia Group is present in the subsurface on the Northwest Shelf, Central Basin Platform, and Midland Basin of the Permian Basin (Fig. 1). The Artesia Group contains a diverse sequence of interbedded carbonates, evaporites, and sandstones. Prolific hydrocarbon production occurs in both sandstone and carbonate beds. The Queen Formation is part of the Artesia Group (Fig. 2), the back-reef facies to the Goat Seep and Capitan Reef complex (Tait et al., 1962). Sandstones represent the producing lithology of the Upper Queen Formation in the Concho Bluff Queen Field, which is located in the western part of the Midland Basin of the Permian Basin.

The citations on the following pages follow the style and format of the American Association of Petroleum Geologists Bulletin.

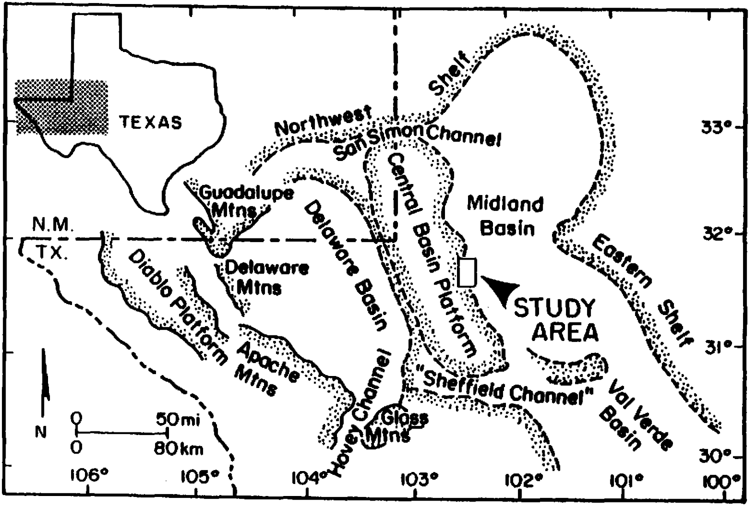


Figure 1: Physiographic features of Permian Basin and location of study area (After Ward et al., 1986).

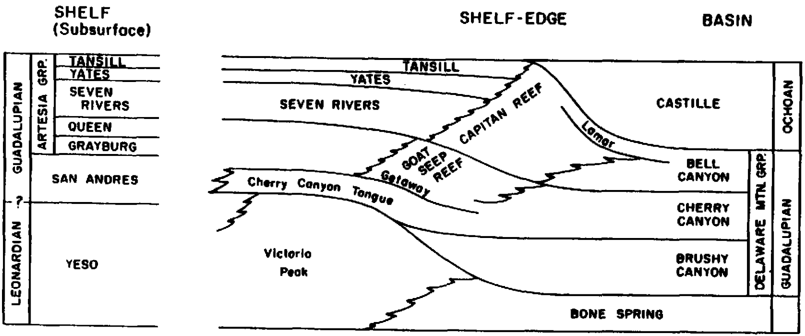


Figure 2: Diagrammatic cross section showing stratigraphic units in Permian Basin (After Ward et al., 1986).

Although the carbonates of the Artesia Group have been extensively studied and interpreted for many years, the siliciclastics in this group have had very few comprehensive investigations. The origins of these sandstones, including their environment of deposition, have received serious attention only recently. This study is part of a regional investigation of sandstones within the Queen Formation that was started in 1983 at Texas A&M University. The environments of deposition for the siliciclastics of the Concho Bluff Queen Field will be addressed in this thesis. Currently, three contrasting models have been proposed for their depositional environments.

These proposed models are: 1) the "wet" model, which suggests a shallow marine/lagoonal origin and deposition during a high stand of sea level (Bates, 1942; Mear, 1968; Pray and Estaban, 1977; Neese and Schwartz, 1977; Schmidt, 1977; Sarg, 1981; Candalaria, 1985). This model is based on a sea level that does not fluctuate and is supported by the massive appearance and sheet geometry of outcropping shelf sandstones in the Guadalupe Mountains. Furthermore, these sandstones are often closely associated with shelf dolomites. 2) the "dry" model, which suggests deposition in a non-marine environment during a low stand of sea level (Jacka and Franco, 1974; Kocerek, 1981; Williams, 1984; Porter, 1986; Glennie, 1987; Malisce, 1988; Siegel, 1989). This model is supported by the stratification of the subsurface sandstones of the Northwest Shelf and the Central Basin Platform. These sandstones display both eolian and fluvial environments of deposition. In addition, the "dry" model is based on sea-level fluctuations which most likely occurred throughout the Permian (Oriel et al., 1967; Hills, 1972; Crowell, 1982; Veevers and Powell, 1987). 3) the "hybrid" model, which suggests a non-marine (dry) sandstone origin deposited during a low stand of sea level and then reworked by marine (wet) processes during a high stand of sea level (Ball et al., 1971; Mazzullo 1985, 1986; Holley and Mazzullo, 1988). This model would explain the decrease in the amount of reworked shelf deposits found toward the landward direction. The "hybrid" model, therefore, accounts for not only the sheet geometry of the massive sandstones of the Guadalupe Mountains, but also the eolian/fluvial stratified sandstones of the Central Basin Platform and Northwest Shelf. Additionally, the glacio-eustatic sea level changes prevalent during the Late Paleozoic favor this model.

Although there is evidence supporting each of these models, controversy exists due to the weaknesses of each proposed model. For example, the "wet" model is not in agreement with most investigations of modern shelf sands, which strongly suggest that eolian/fluvial processes deposit shelf sands during low stands of sea level. Furthermore, present studies show that a littoral energy barrier prevents most sand from being carried past the coastal zone during high stands of sea level (Curray, 1960; Swift et al., 1982; Hobday and Morton, 1984; Brown et al., 1984; Mazzullo and Withers, 1984; Allen, 1985). The validity of the "wet" model is also weakened by its inconsistency with glacio-eustatic sea-level fluctuations which probably existed during the Permian. Since this hypothesis is based almost entirely on shelf marginal sandstones, which are exposed in outcrop at the Guadalupe Mountains, a regional understanding of the inner shelf sandstones is not even taken into account.

The "dry" model also has its limitations. Even though this model is in accordance with the study results of modern inner shelf sands, the outer shelf units, like the massive sandstones exposed in the Guadalupe Mountains, are not explained. These massive sandstones are thought to have formed from reworking by shelf processes and marine organisms during high stands of sea level (Swift et al., 1972). Therefore, the "dry" model also lacks a regional interpretation for the genesis of siliciclastics in the Permian Basin.

Although the "hybrid" model combines much of the supporting evidence of the two other models, it is not fully documented by regional studies of shelf sandstones throughout the Permian Basin. The lack of critical investigation is the primary weakness of this model. As a part of the regional study of sandstones in the Queen Formation, this thesis will help further the understanding of sandstone deposition in the Permian Basin.

Therefore, the primary purpose of this research is to test each of these models of deposition, and decide which one is representative of the Concho Bluff Queen Field. This will enhance the present body of knowledge concerning the nature and extent of Permian Basin sandstone facies. A secondary purpose of this thesis is to determine the relationship between the facies and the reservoir formation. Only through a comprehensive study of these facies, can one begin to understand their influence on hydrocarbon production. These results can be applied to improve reservoir development and exploitation, as well as to aid in the continued exploration of shelf sandstones throughout the entire Permian Basin.

REGIONAL STRATIGRAPHY

The Artesia Group of the Permian System consists of the back-reef facies of the Goat Seep and Capitan Reef complexes in the Permian Basin. Present in outcrop in the Guadalupe Mountains, the Artesia Group also extends in subsurface throughout the Northwest Shelf, Central Basin Platform, and Midland Basin. The Artesia Group conformably overlies the San Andres Formation and is unconformably overlain by the Ochoan Formation (Newell et al., 1953; Hayes, 1964). The shelf sediments of the Permian Basin region consist of interfingering carbonates, evaporites, and siliciclastics. Of these units, the carbonates are the thickest and have the greatest accumulation in a basinward direction. Toward the inner shelf, however, alternating thick beds of siliciclastics and evaporites are found with relatively thin sequences of carbonates (Hills, 1972).

In ascending order, the Artesia Group consists of five formations: The Grayburg, Queen, Seven Rivers, Yates, and Tansill (Tait et al., 1962; Fig. 2). A gross generalization can be drawn based on the formations contained within the Artesia Group. The Seven Rivers and Tansill Formations are considered the "carbonate" divisions, whereas the Yates and Queen/Grayburg Formations constitute the "clastic" divisions (Meissner, 1972). In many areas where the Queen and Grayburg Formations are similar in composition and stratigraphic position, they are undifferentiated and are considered as one unit (Newell et al., 1953). The Queen

Formation in the Concho Bluff Queen Field is separated into an upper and lower division. The sandstones of this study are contained in the Upper Queen Formation and are bound by conspicuous evaporite beds.

Based on fusilinid zones, bentonite markers, wire-line logs, and seismic lines, the Goat Seep Reef (shelf-edge) and Cherry Canyon Formation (basin) are considered coeval with the Queen Formation (shelf), and are correlative throughout the Permian Basin (King, 1942; Newell et al., 1953; Silver and Todd, 1969; Sarg and Lehman, 1986).

The type section for the Queen Formation, which is 421 ft. (128.4 m) thick, is located approximately two miles south of the old Queen Post Office in the Guadalupe Mountains (Moran, 1974). There, the Queen sandstone averages 30 ft. (9.2 m) in thickness and is located near the top of the Queen Formation. The sandstone in the type section consists of fine- to very fine-grained sandstone scattered with large, frosted, round quartz grains (Tait et al., 1962).

REGIONAL TECTONIC SETTING

The Tabosa Basin, the area which would eventually develop into the Permian Basin (Fig. 3), started forming at the southern margin of the North American plate during the Early Paleozoic due to subsidence (Galley, 1958). This basin continued to broaden and was inundated by marine waters throughout the Middle Paleozoic. Differential subsidence within the Tabosa Basin began in the Early Mississippian and produced a positive landform, the Central Basin Platform, which divided the area into two separate depocenters. These depressions became the Delaware Basin to the west and the Midland Basin to the east (Hills, 1972). However, the differential subsidence associated with the Delaware Basin was considerably more than that associated with the Midland Basin. Thus, the Midland Basin's shelf margins were not as well-defined as the shelf margins of the Delaware Basin (Bebout et al., 1987).

In the Early Pennsylvanian, the setting of the Permian Basin changed dramatically. Uplifting of the Central Basin Platform created highlands with steep erosional slopes which fed into both basins. In addition to these highlands, the Matador Uplift to the north and the Ouachita-Marathon Fold Belt to the south produced positive landforms which gave further definition to the Permian Basin region (McKee, 1967).

From the Late Pennsylvanian through the Permian, the region remained tectonically passive, allowing for extensive reef growth along the platform edges and the development of carbonate shelves

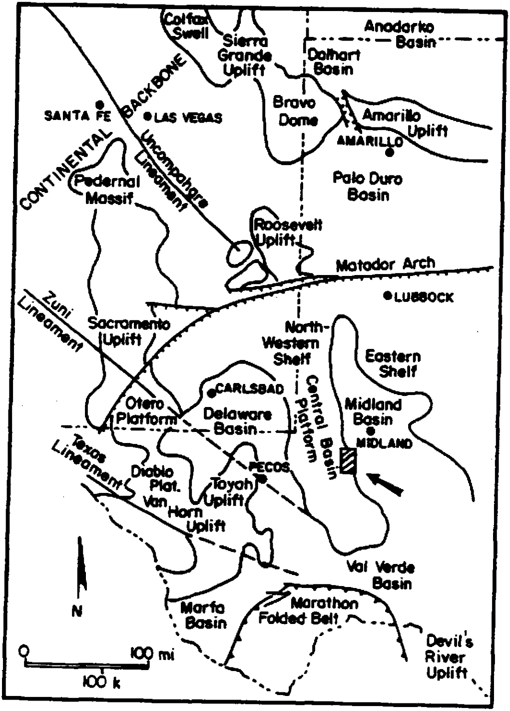


Figure 3: Permian tectonics of western Texas to southern Colorado (After Hills, 1963).

and banks. Vertical reef growth during this time suggests that an equal balance existed between reef development and subsidence for a major portion of the Permian (King, 1942). However, as circulation restrictions developed from continuous carbonate deposition and clastic influx outpaced subsidence, the Midland and Delaware Basins began to fill (Dean and Anderson, 1982). Prior to the deposition of Queen sandstones in the Middle Guadalupian, the Midland Basin was shallow, and characterized by extensive evaporite deposits which spread throughout the area (Ward et al., 1986).

By the end of the Permian, the area representing the Permian Basin had undergone extensive deposition. The Midland Basin had become completely filled with over 15,000 feet of sediment, and sediment accumulation in the Delaware Basin amounted to over 35,000 feet (Dolten et al., 1979; Ward et al., 1986).

The last major structural event that occurred in the Permian Basin was the Laramide Orogeny that uplifted the northern and western portions of the region (Hills, 1963; McKee, 1967). This caused the Permian rocks to be exposed and subjected to the processes of weathering and erosion, followed by another cycle of deposition during the Late Cenozoic.

METHODS

The primary methods of investigation used in the preparartion of this thesis involved the analysis and evaluation of subsurface cores and electric logs. Over 400 feet of slabbed cores from nine wellbores in the Concho Bluff Queen Field were reviewed (Fig. 4). The lithologies, sedimentary structures, vertical sequences, and color varieties (based on the Munsell Color Chart) were identified for each core. In addition, grains were sampled from over 70 locations in 9 cores (Fig. 4) and measured for their size and shape.

Core samples were gathered from selected intervals which would aid in the understanding of the cyclical nature and depositional environment of the sandstones in the Concho Bluff Queen Field. Due to the abundance and resistance of quartz, this mineral was isolated for size and shape analysis. Initial preparation of these core samples included disaggragation with a mortar and pestle. Each sample group was boiled in hydrochloric acid (50 percent solution) for 30 minutes to enhance the disaggregation of quartz grains, and then rinsed three times with distilled water. Stannous chloride was added to each of these solutions to help reduce the carbonate material. Next, the grains were bathed in hydrofluoric acid (52 percent solution) to dissolve grain etchings. This was followed by two rinsings of distilled water. Samples which still contained residual oil were given an additional flushing treatment with acetone. Lastly, each sample

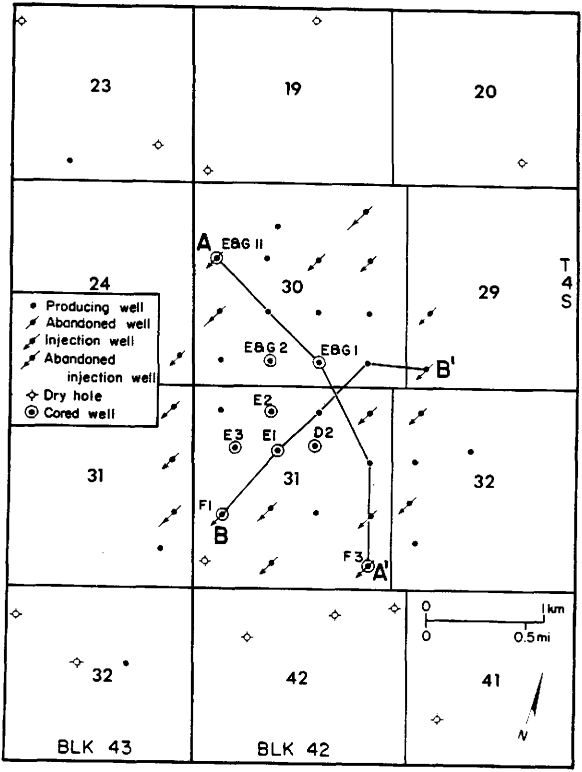


Figure 4: Reference map of Concho Bluff Queen Field showing cored wells and lines of cross sections.

was dried in an oven overnight in preparation for the digitization process.

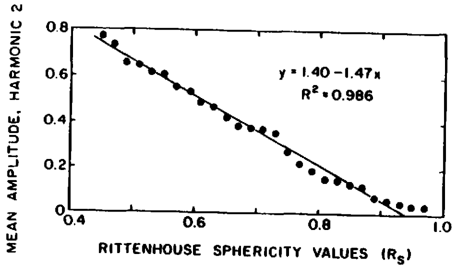
Modal grain size of these samples was determined, and grain shape measurements were then calculated from this size fraction. In the Concho Bluff Queen Field, the modal grain size was found to be the very fine-grained size fraction for the sandstone and coarse-grained silt for the siltstone. ARTHUR III, an automated image analysis system, was utilized to determine the modal grain size based on standard deviation (Fico, 1980; Mazzullo and Kennedy, 1985). By digitizing the edges of the greatest projected profile of the quartz grains, the nominal sectional diameters of each quartz grain were calculated. This diameter represents that of a circle which is the equivalent in area to the area of the maximum projection profile. For each sample location, 300 monocrystalline quartz grains were digitized.

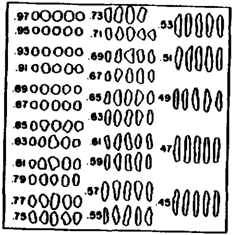
In determining the grain roundness, the modal grain fraction was first isolated through sieving. By concentrating on the modal grain size for the monocrystalline quartz, the grain shape was found independent from the influences of composition and grain size. ARTHUR III was also implemented to measure the grain roundness with the Fourier series in closed form (Ehrlich and Weinberg, 1970). For each sample, 200 monocrystalline quartz grains were measured for roundness by digitizing their greatest projected profile. Individual grain shapes were calculated by their amplitudes for the higher harmonies of the Fourier series.

Within the area of investigation, grain sphericity and roundness of Upper Queen sandstones are represented by their amplitude values of the 2nd harmonic and19th harmonic, respectively. The amplitude value of the 2nd harmonic can be converted to a Rittenhouse Sphericity Value through the following formula: $x = (1.40 - y)/1.47$; where x equals the Rittenhouse Sphericity Value, and y equals the amplitude value of the 2nd harmonic (Rittenhouse, 1943; Haines and Mazzullo, 1987)(Fig. 5). In a similar equation, the 19th harmonic amplitude value can be converted to a Krumbein Roundness Value through the following formula: $x = (0.0070 - y)/0.0076$; where x equals the Krumbein Roundness Value, and y equals the amplitude value of the 19th harmonic (Krumbein, 1942; Haines and Mazzullo, 1987).

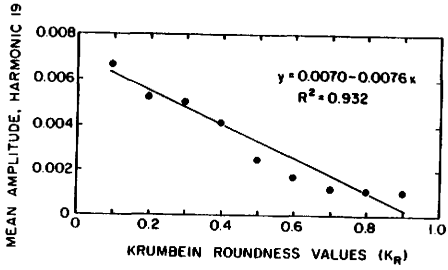
In addition to these data, which were derived from core samples, more than 50 wire-line logs, from within and surrounding the Concho Bluff Queen Field were studied. The thick evaporite layers which bound the Upper Queen Formation have a very low natural radioactive kick on the gamma ray and contrast sharply with the gamma ray signature of the siliciclastics. On a type log, the Upper Queen sandstones display a high natural radioactive kick on the gamma ray (Fig. 6) due to the abundance of potassium feldspar in their composition. Mudstones and siltstones divide the sandstones in the Upper Queen Formation into four separate genetic units. For the purpose of this thesis, these sandstones are designated the Queen A, B, C, and D Sandstone in order of deposition. Isopach maps were made for each sandstone unit. In addition, a structure map on the top of Upper Queen sandstones was constructed to understand the structural influences on trapping mechanisms within the field. In order to determine the continuity of the reservoir sandstones, both stratigraphic and structural cross sections were made.

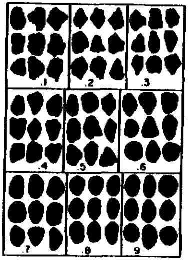
Figure 5: Mean amplitudes for the 2nd and 19th harmonics and corresponding representations of Rittenhouse (1943) sphericity values and Krumbein (1942) roundness values, respectively (After Haines and Mazzullo, 1987).





Rittenhouse (1943)





Krumbein (1942)

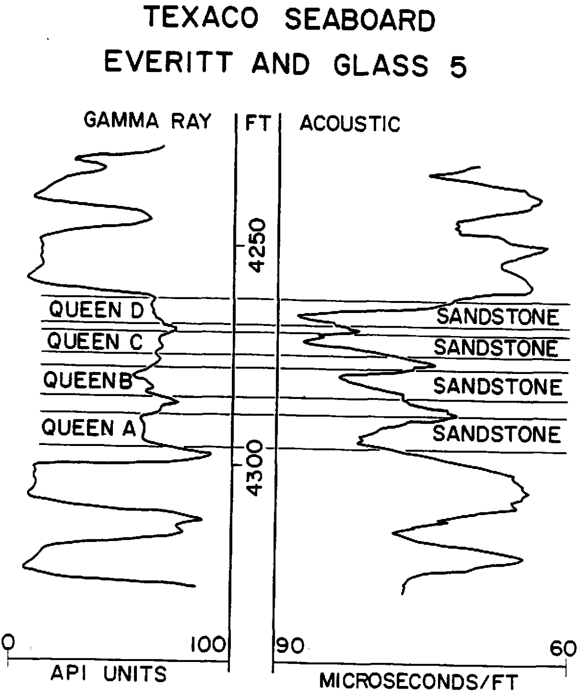


Figure 6: Typical electric log response (gamma ray and acoustic) of Upper Queen sandstones in study area.

CHARACTERISTICS OF UPPER QUEEN SANDSTONES

Introduction

The geometry and continuity of Upper Queen sandstones were determined through the analysis of nine cores, and the evaluation of more than 50 E-logs. Several cross sections, isopach maps, and a structure contour map were constructed from this data. The type E-log of the Upper Queen Formation in the Concho Bluff Queen Field displays a major division between the siliciclastic section and the bounding evaporite sections. Four discrete sandstone packages, separated by mudstones and siltstones, are contained in the clastic unit and have been designated the Queen A, B, C, and D Sandstone in ascending order. The relatively high gamma-ray log response in the sandstones is attributed to the large amount of potassium feldspar in their composition. The arkosic source of Upper Queen sandstones is difficult to determine, but the sandstones may have been derived from as far away as the ancestral Rocky Mountains to the north (Oriel et al., 1967).

Structure

Within the area of investigation, the structure map on top of the Upper Queen sandstones (Fig. 7) shows a regional dip to the east at approximately 125 ft/m (23.5 m/km). The Concho Bluff Queen Field is characterized by an anticline with a domal fold that has an average gradient of 150 ft/m (28.2 m/km). These features

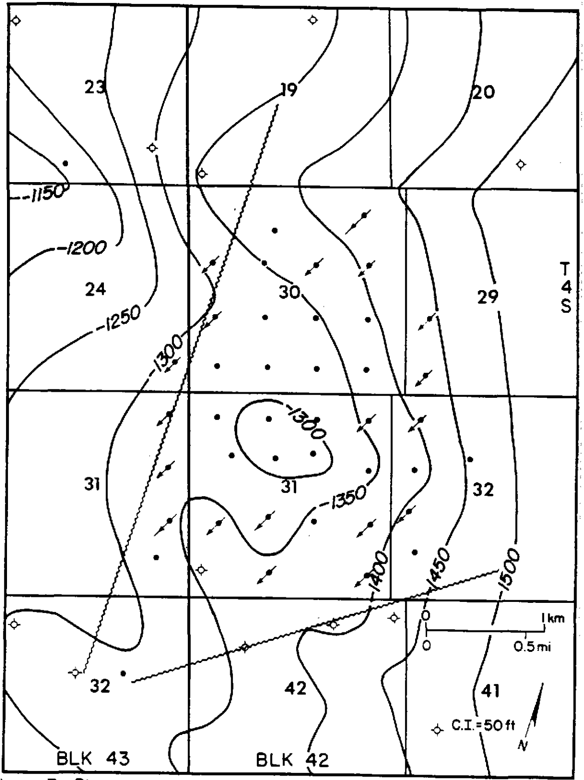


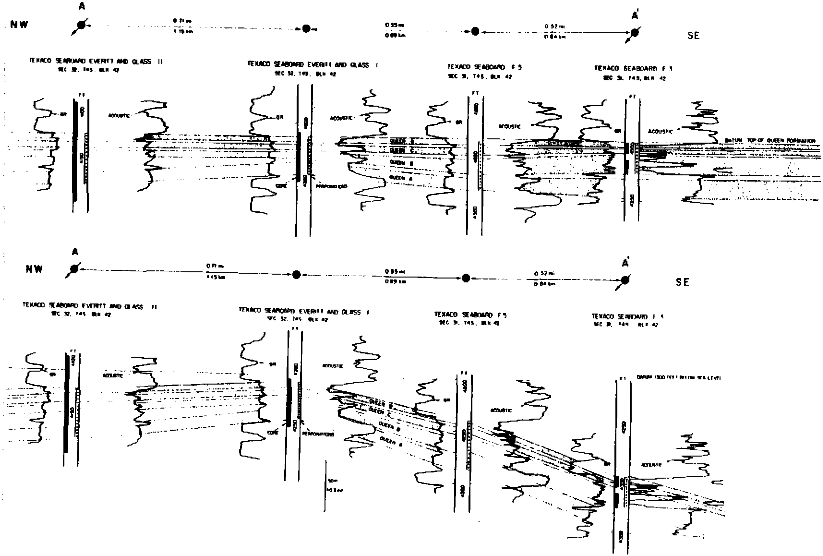
Figure 7: Structure map on the top of Upper Queen sandstones and stratigraphic traps at Concho Bluff Queen Field (Modified from Mear, 1964).

are flanked by plunging synclines which define the northern and southern boundaries of the field. Cross sections (Figs. 8 and 9) show that the nature of the hydrocarbon trap is partially attributed to structure.

Sand-body Geometry

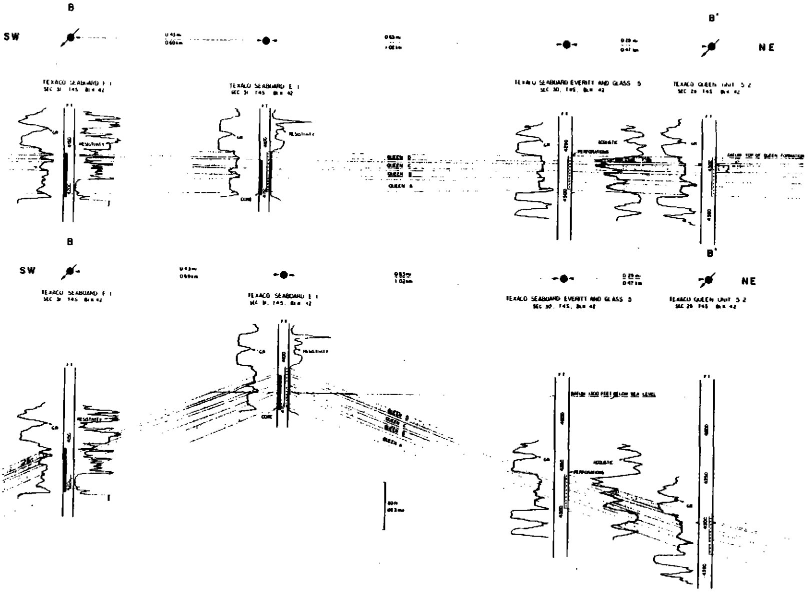
The sand-body geometry of Upper Queen sandstones within the Concho Bluff Queen Field represents a series of sheet sands with superimposed shoestring sands. The mean thickness of sandstones in the Upper Queen Formation averages 27 ft. (8.2 m), with a maximum thickness of 37 ft. (11.3 m) and a minimum thickness of 19 ft. (5.8 m). The Queen A Sandstone represents the thickest unit of Upper Queen sandstones, and it displays a general east to west trend (Fig. 10). In the field area, the Queen A Sandstone has an average thickness of 12 ft. (3.6 m), with a maximum thickness of 18 ft. (5.5 m) and a minimum thickness of 8 ft. (2.4 m). The Queen B Sandstone has its greatest accumulation in the central and eastern side of the field (Fig.11). The Queen B Sandstone has an average thickness of 7 ft. (2.1 m), with a maximum thickness of 11 ft. (3.3 m) and a minimum thickness of 3 ft. (0.9 m). The Queen C Sandstone is the least developed in the study area and has an east to west trend, similar to the Queen A Sandstone (Fig. 12). The Queen C Sandstone has an average thickness of 4 ft. (1.2 m), with a maximum thickness of 10 ft. (3.1 m) and minimum thickness of 2 ft. (0.6 m). The Queen D Sandstone

Figure 8: Stratigraphic and structural cross-section A-A' from northwest to southeast displaying the sand-sheet geometry of Upper Queen sandstones.



NW
A
SE
A'
0.71 mi
1.15 km
0.55 mi
0.89 km
0.52 mi
0.84 km
TEXACO SEABOARD EVERITT AND GLASS II
SEC 32, T4S, BLK 42
TEXACO SEABOARD EVERITT AND GLASS I
SEC 32, T4S, BLK 42
TEXACO SEABOARD F 5
SEC 31, T4S, BLK 42
TEXACO SEABOARD F 3
SEC 31, T4S, BLK 42
GR
ACOUSTIC
FT
CORE
PERFORATIONS
QUEEN D
QUEEN C
QUEEN B
QUEEN A
DATUM: TOP OF QUEEN FORMATION

Figure 9: Stratigraphic and structural cross-section B-B' from southwest to northeast displaying the sand-sheet geometry of Upper Queen sandstones.


B
SW
B'
NE
TEXACO SEABOARD F 1
TEXACO SEABOARD E 1
RESISTIVITY
CORE
QUEEN D
QUEEN C
QUEEN B
QUEEN A
TEXACO SEABOARD EVERITT AND GLASS 5
SEC 30, T4S, BLK 42
TEXACO QUEEN UNIT 5 2
PERFORATIONS
ACOUSTIC
GR
DATUM TOP OF QUEEN FORMATION
DATUM 1300 FEET BELOW SEA LEVEL

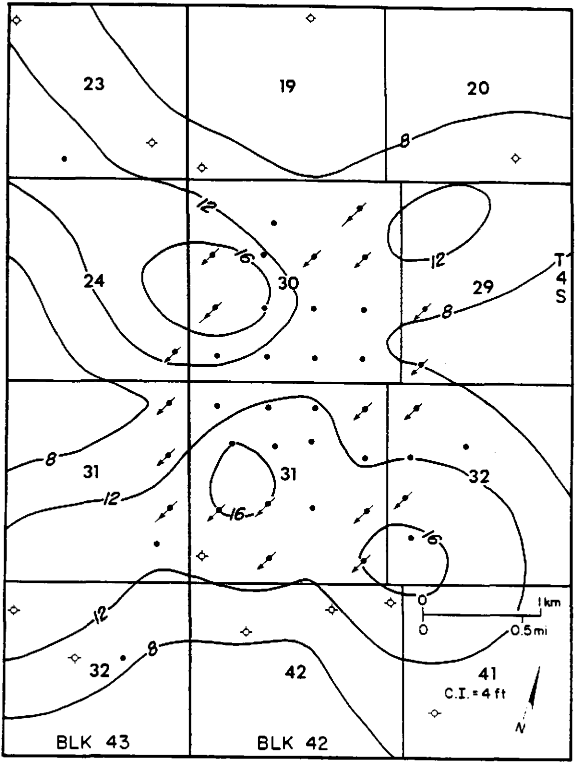


Figure 10: Net sand isopach map of Queen A Sandstone at Concho Bluff Queen Field.

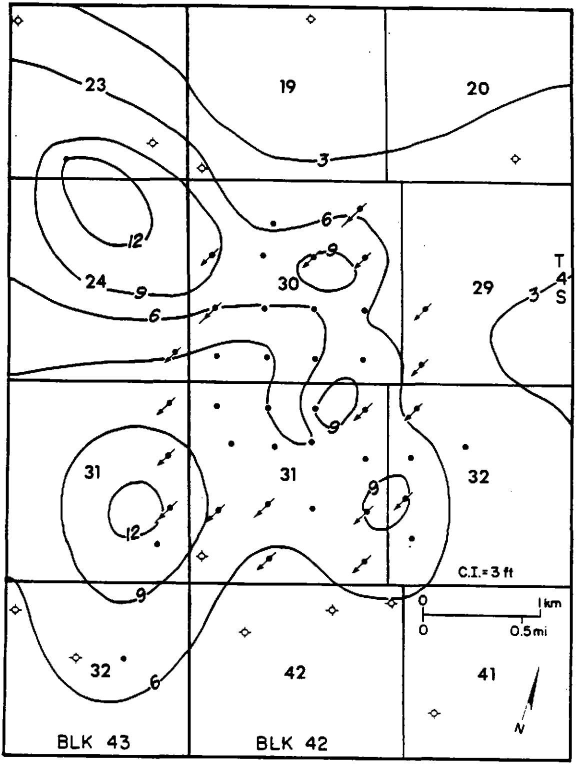


Figure 11: Net sand isopach map of Queen B Sandstone at Concho Bluff Queen Field.

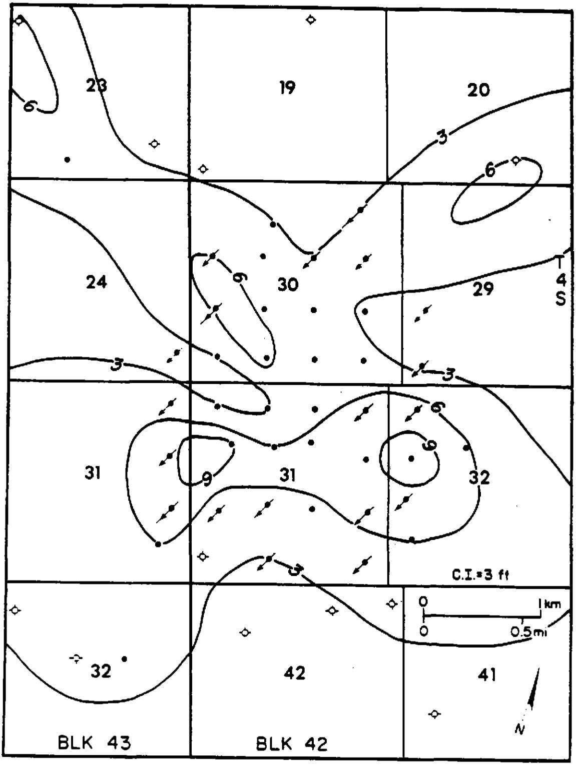


Figure 12: Net sand isopach map of Queen C Sandstone at Concho Bluff Queen Field.

has its greatest thickness near the central part of the study area, with a trend similar to that of the Queen B sandstone (Fig. 13). The Queen D Sandstone has an average thickness of 4 ft. (1.2 m), with a maximum thickness of 7 ft. (2.1 m) and a minimum thickness of 2 ft. (0.6 m).

Facies of Upper Queen Sandstones

Five major facies of a continental sabkha have been identified in the siliciclastics within the Upper Queen Formation at the Concho Bluff Queen Field based on lithologies and sedimentary structures. These facies are mudflat, saline mudflat, sandflat, saline sandflat, and eolian sand sheet. Both the mudflat facies and sandflat facies are respectively distinguished as a saline mudflat facies and saline sandflat facies in areas where the laminae have been disturbed by the continued precipitation and dissolution of salt. The saline mudflat has an associated brine pan facies which contains thin evaporite units. In addition, the Upper Queen Formation is bound by playa facies which are separate facies consisting of thick evaporite units.

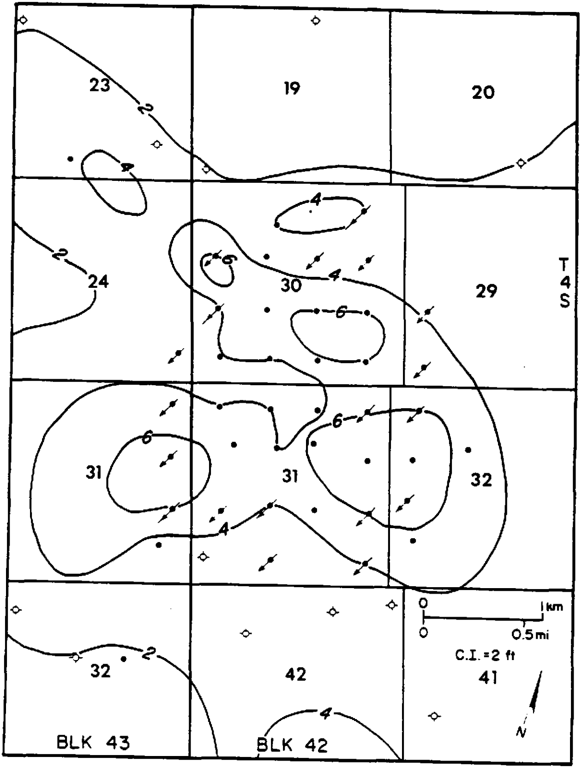


Figure 13: Net sand isopach map of Queen D Sandstone at Concho Bluff Queen Field.

LITHOLOGIES AND SEDIMENTARY STRUCTURES

Five distinct lithologies can be identified in the cores of the Concho Bluff Queen Field: sandstone, siltstone, mudstone, anhydrite, and halite.

Sandstone

The sandstones are very fine-grained, arkosic, moderately well to well sorted, and subrounded to subangular. Most sandstones are pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4), although some sandstones are moderate reddish brown (10R 4/6). The mean quartz-grain size is 108 microns, and ranges from 81 microns to 124 microns, with standard deviations (or sorting) which range from 15 microns to 22 microns. The mean 2nd harmonic amplitude is 0.145, the equivalent to a Rittenhouse Sphericity Value of 0.85, with a range from 0.129 to 0.164, the equivalent to Rittenhouse Sphericity Values of 0.87 to 0.84 respectively. The mean 19th harmonic amplitude is 0.0038, the equivalent to a Krumbein Roundness Value of 0.49, with a range from 0.0027 to 0.0042, the equivalent to Krumbein Roundness Values of 0.57 to 0.37 respectively.

The following sedimentary structures have been observed in the sandstones:

1) intermediate-angle, planar, and continuous laminated beds, which are 2.1 ft. to 4.8 ft. (0.64 - 1.46 m) thick. The sandstones are pale yellowish brown (10YR 6/2) to moderate yellowish brown

(10YR 5/4) with oil stains and contain irregular patterns of moderate reddish brown (10R 4/6). The relict laminae have an inclination which is recognized based on orientations from reduction lines and preferential core breaks (Fig 14a). These beds have foresets inclined up to 22 degrees and sometimes display slump structures with microfaults. The individual laminae, which probably developed from grainfall, range in thickness from 1 mm to 3 mm. They are associated with eolian sand sheets and have no discernable evidence of bioturbation. Examples of the dune cross beds were found in only two of the nine cores. Their lack of abundance may be due to the fact that in other cores they are concealed in massive sections, or that they are present in sections with poor recovery. However, evaporitic cementation and periodic flooding, in addition to the very fine-grained nature of the sediment, are thought to have produced conditions that inhibited extensive eolian development (Nance, 1988).

2) horizontal, planar, and continuous laminated beds, which are 0.1 ft. to 0.6 ft. (0.03 - 0.18 m) thick and usually bounded by massive beds. The laminae are thin (1-3 mm) and sometimes contain organic-rich layers. The faint laminae of these beds often occur with oil stains, and preferential oil stains are often the primary aid in discerning the laminae. Within the laminations, a normal textural grading is observed (Fig. 14b). These beds probably formed as sand sheets during shallow sheetfloods, perhaps only a few centimeters deep, and were transported primarily by traction in a plane bed flow regime (Hardie et al., 1978).

3) slightly wavy, continuous laminated beds, which are 0.1 ft. to 3.0 ft. (0.03-0.92 m) thick and usually dark yellowish brown (10YR 4/2) to moderate yellowish brown (10YR 4/6). Preferential oil stains are often used to distinguish the relict laminae (Fig. 14c). In most of these beds, the sandstone has poor recovery. Deposition of wavy-laminated beds occurs during flooding in upper flow regime currents (Parkash et al, 1983).

4) current-ripple bed, which is 0.6 ft (0.18 m) thick. The bed contains influxes of silty material, represented as mud rip-up clasts. The individual laminae are thin (1 - 4 mm) and inclined up to 7 degrees (Fig. 14d). Occasoinally, during periods of heavy flooding, small channels develop on the sandflat surface (Hardie et al., 1978). Although this bed occurs as an isolated section, it is the only indicator in the cores of a minor channelized flow. Ripple cross-laminae develop in sediments which are deposited in a low flow regime (McKee, 1965).

5) wavy, discontinuous laminated beds, which are 0.3 ft. to 12.3 ft. (0.09 - 3.75 m) thick. These beds are usually associated with anhydrite nodules which are less than 0.5 cm thick. The laminae are thin (1-3 mm), chaotic, and often argillaceous (Fig. 14e). Wavy, discontinuous laminated beds are usually adjacent to moderate reddish brown (10R 4/6) siltstones. These beds most likely developed during sheetfloods and were originally deposited as horizontal and continuous laminae, but the laminae were disturbed by salt precipitation and capillary flow of the saline ground water from a shallow source. The identification of anhydrite features suggests the presence of a shallow water table.

Evaporitic sandy plains, or sabkhas, have a topographic expression which is dependant upon such a shallow water table, usually 3 ft. to 6 ft. (0.91 - 1.83 m) below the surface (Fryburger et al., 1983).

6) salt-ridge structures, which are up to 0.5 in (1.2 cm) thick and occur as isolated deformational features (Fig. 14f). Salt-ridge structures occur in both the sandstone and siltstone beds, but the ones with the best preservation are generally found in the sandstone beds. As saline capillary water evaporates, salt-ridge structures develop from concentration of halite on the sabkha surface (Fryburger, 1983). When they form, the individual laminae are often truncated against the salt-ridge structure.

7) Massive beds, two types of massive beds occur:

a) massive pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4) beds, which are 0.2 ft. to 4.5 ft. (0.06 - 1.37 m) thick, often with oil stains, and have no identifiable sedimentary structures or features (Fig. 14g). Both solvent acids and the migration of hydrocarbons are thought to be responsible for this massive feature. In addition, these beds are usually void of any evaporitic structures.

b) massive moderate reddish brown (10R 3/4) beds, which are 0.3 ft. to 11.0 ft. (0.09 - 3.36 m) thick with isolated anhydrite nodules, usually less than 0.2 cm thick, and no discernable sedimentary structures (Fig. 14h). However, sometimes these beds contain extensive halite-filled fractures (Fig. 14i). The red color is in these beds is due to oxidized iron stains in clay and clay coats on sand grains.

Figure 14: Major sedimentary features found in eolian sand sheet facies (a), sandflat facies (b-d), saline sandflat facies (e,f), and massive beds (g,h,i) of Upper Queen sandstones at Concho Bluff Queen Field.

14A: Intermediate-angle (22 degrees), planar, and continuous laminae. This sandstone is moderate reddish brown (10R 4/6) and moderate yellowish brown (10R 5/4) and appears mottled due to reduction.

14B: Horizontal, planar, and continuous laminae. This sandstone is pale yellowish brown (10R 6/2) and contains organic-rich layers.

14C: Slightly wavy and continuous laminae. This sandstone is moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2) with preferential oil stains distinguishing the relict laminae.

14D: Current-ripple bed with rip-up clast. This sandstone is pale yellowish brown (10YR 6/2) and directly overlies the sandstones in figure 14B.

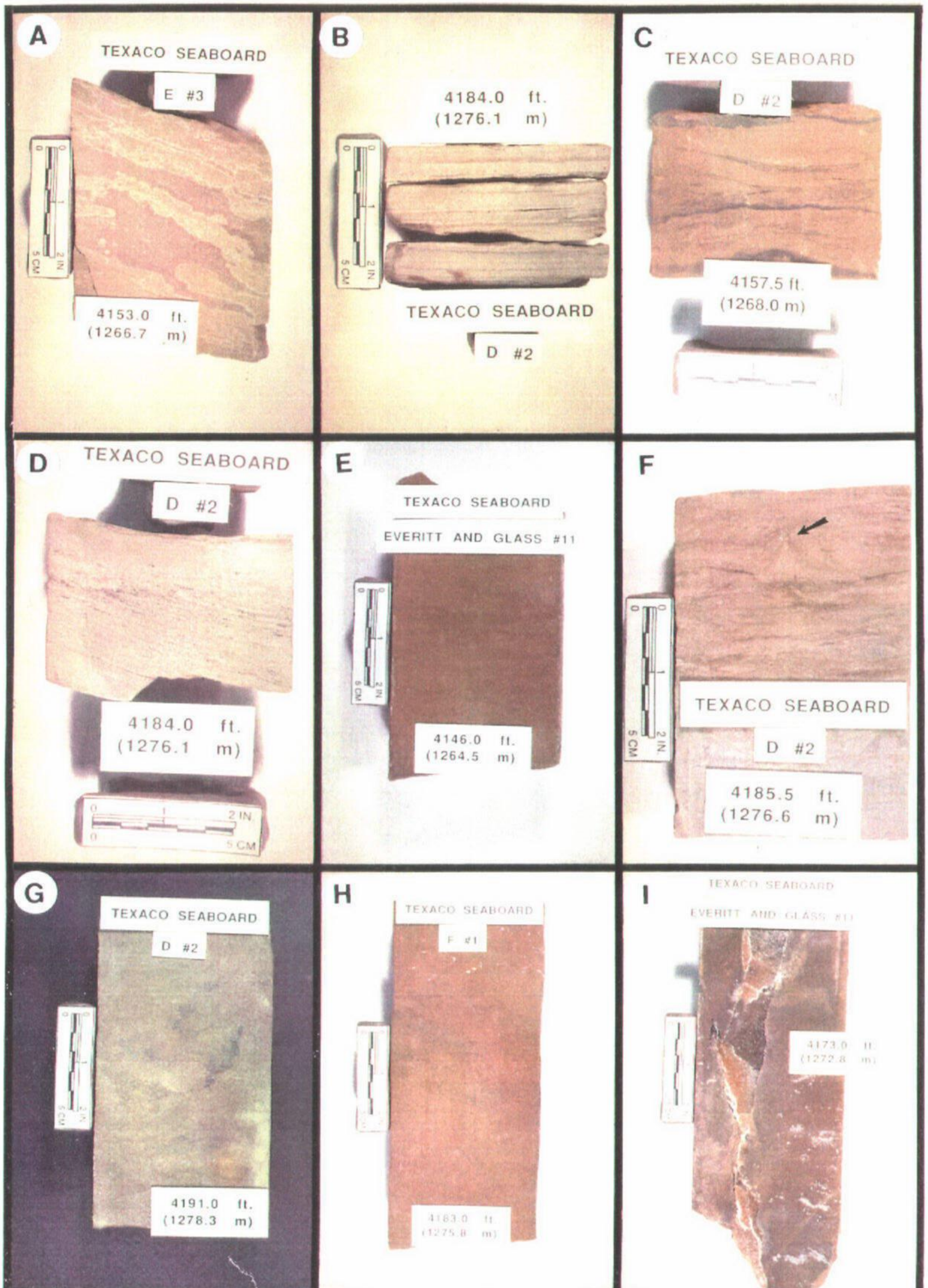
14E: Wavy and discontinuous laminae. This sandstone is dark reddish brown (10R 3/4) and contains small anhydrite nodules (up to 0.5 cm thick).

14F: Salt-ridge structure with upward truncating laminae. This sandstone is pale red (10R 6/2).

14G: Massive sandstone bed. This sandstone is moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2) with oil stains.

14H: Massive sandstone bed. This sandstone is moderate reddish brown (10R 4/6) with small anhydrite nodules (less than 0.2 cm thick).

14I: Massive sandstone bed. This sandstone is dark reddish brown (10R 3/4) with a large halite-filled fracture.


A
TEXACO SEABOARD
E #3
4153.0 ft.
(1266.7 m)
B
4184.0 ft.
(1276.1 m)
TEXACO SEABOARD
D #2
C
TEXACO SEABOARD
D #2
4157.5 ft.
(1268.0 m)
D
TEXACO SEABOARD
D #2
4184.0 ft.
(1276.1 m)
E
TEXACO SEABOARD
EVERITT AND GLASS #11
4146.0 ft.
(1264.5 m)
F
TEXACO SEABOARD
D #2
4185.5 ft.
(1276.6 m)
G
TEXACO SEABOARD
D #2
4191.0 ft.
(1278.3 m)
H
TEXACO SEABOARD
F #1
I
TEXACO SEABOARD
EVERITT AND GLASS #11

Siltstone

The siltstones consist of coarse-grained, moderately well to well sorted, subrounded to subangular silt. They primarily appear moderate reddish brown (10R 4/6) to dark reddish brown (10R 3/4) in color. The mean quartz-grain size is 55 microns, and ranges from 47 microns to 62 microns, with standard deviations (or sorting) which range from 10 microns to 19 microns. The mean 2nd harmonic amplitude is 0.145, the equivalent to a Rittenhouse Sphericity Value of 0.85, with a range from 0.137 to 0.172, the equivalent to Rittenhouse Sphericity Values of 0.86 to 0.84 respectively. The mean 19th harmonic amplitude is 0.0037, the equivalent to a Krumbein Roundness Value of 0.44, with a range from 0.0031 to 0.0046, the equivalent to Krumbein Roundness Values of 0.51 to 0.32 respectively.

The following sedimentary structures have been observed in the siltstones:

1) wavy, continuous laminated beds with interlaminated mudstones, which are dark reddish brown (10R 3/4) to very dusky brown (10R 2/2) and are 0.1 ft. to 0.2 ft. (0.03-0.06 m) thick. The individual laminations are up to 0.5 cm thick and have a normal textural grading. The thicker laminae are predominantly siltstone (Fig. 15a). After deposition, the laminae have a poor preservation rate, for the laminae are often disturbed by saline crystal growth (Hardie et al., 1978). Furthermore, desiccation cracks often form on the surface from exposure to the sun (Fig. 15b). These factors may account for the relative scarcity of these beds in the cores. In

some beds like these, vertically oriented mud cracks are sometimes filled with sand (Fig. 15c).

2) slightly wavy, continuous laminated beds, which are 0.1 ft. to 0.3 ft. (0.03 - 0.09 m) thick. The siltstones usually have been reduced from their original color and appear light bluish gray (5B 7/1). The laminae are 1 mm to 2 mm thick, and probably represent algal material (Fig. 15d). The presence of algal material may be responsible for the color reduction of these siltstones. Siltstones with possible crenulate algal material are found both above and below the brine pan facies (Fig. 15e). Algal material is often seen around modern bodies of hypersaline water, like the Ojo de Liebre on the west coast of Baja California (Phleger, 1969).

3) wavy, discontinuous laminated beds, which are 0.3 ft. to 5.8 ft. (0.09 - 1.77 m) thick. These siltstones are somestimes grayish red (10R 4/2) or very dusky red (10R 2/2). The argillaceous laminae are chaotic and have often been displaced by anhydrite nodules. The laminae are 1 mm to 4 mm thick, and have a highly disturbed appearance (Fig. 15f). The irregular laminae most likely formed by the repeated re-solution and re-precipitation of interstitial salts, a process known as "haloturbation" (Smith, 1972). Wavy and discontinuous laminated beds of siltstone comprise the greatest volume of beds found within all the cores, and are present between each of the four sandstone units.

4) wavy, discontinuous laminated beds, which are 0.3 ft. to 2.4 ft. (0.09 - 0.73 m) thick. These siltstones are always greenish gray (5G 6/1), and when present are located directly below the anhydrite beds which mark the top of the Upper Queen Formation.

The laminae are 1 mm to 3 mm thick with occassional mud drapes (Fig. 15g). The color of this siltstone is thought to be primary in origin, possibly due to water seepage from the overlying playa facies, and is not associated with late event diagenesis.

Mudstone

Mudstones are usually dark reddish brown (10R 3/4) and are found in three types of bed:

1) chaotic and starved ripple-form laminated beds, which are 0.1 ft. to 1.1 ft. (0.03 - 0.33 m) thick. The mudstones contain lenticular patterns (up to 1 cm) of coarse-grained siltstone (Fig. 15h). The siltstone is lighter in color than the mudstone, usually appearing moderate reddish brown (10R 4/6). The starved ripple-form lenses of siltstone, surrounded by mud-rich laminae, may suggest traction deposition of migrating ripples (Presley and McGillis, 1982).

2) a chaotic halite-filled bed, which is 3.0 ft. (0.92 m) thick and dark reddish brown (10R 3/4). Most halite crystals in the bed are poorly developed, probably from dissolution by halite-undersaturated flood waters (Fig. 15i). However, a few crystals near the base of the bed have straight edges, suggesting they formed displacively within the host mudstone and were not subjected to dissolution by surface floodwaters. The halite crystals decrease in size and abundance toward the top of bed. This halite fabric has been termed "Haselgebirge" and is found

Figure 15: Major sedimentary features found in mudflat facies (a-c) and saline mudflat (d-i) facies of Upper Queen siliciclastics at Concho Bluff Queen Field.

15A: Wavy and continuous laminae. This siltstone is grayish red (10R 4/2) to dark reddish brown (10R 3/4) with interlaminated mudstone.

15B: Desiccation cracks associated with beds in figure 15A.

15C: Sand-filled mud crack associated with beds in figure 15A.

15D: Slightly wavy and continuous laminae. The laminae (cryptalgal?) are in a reduced area that is light bluish gray (5B 7/1).

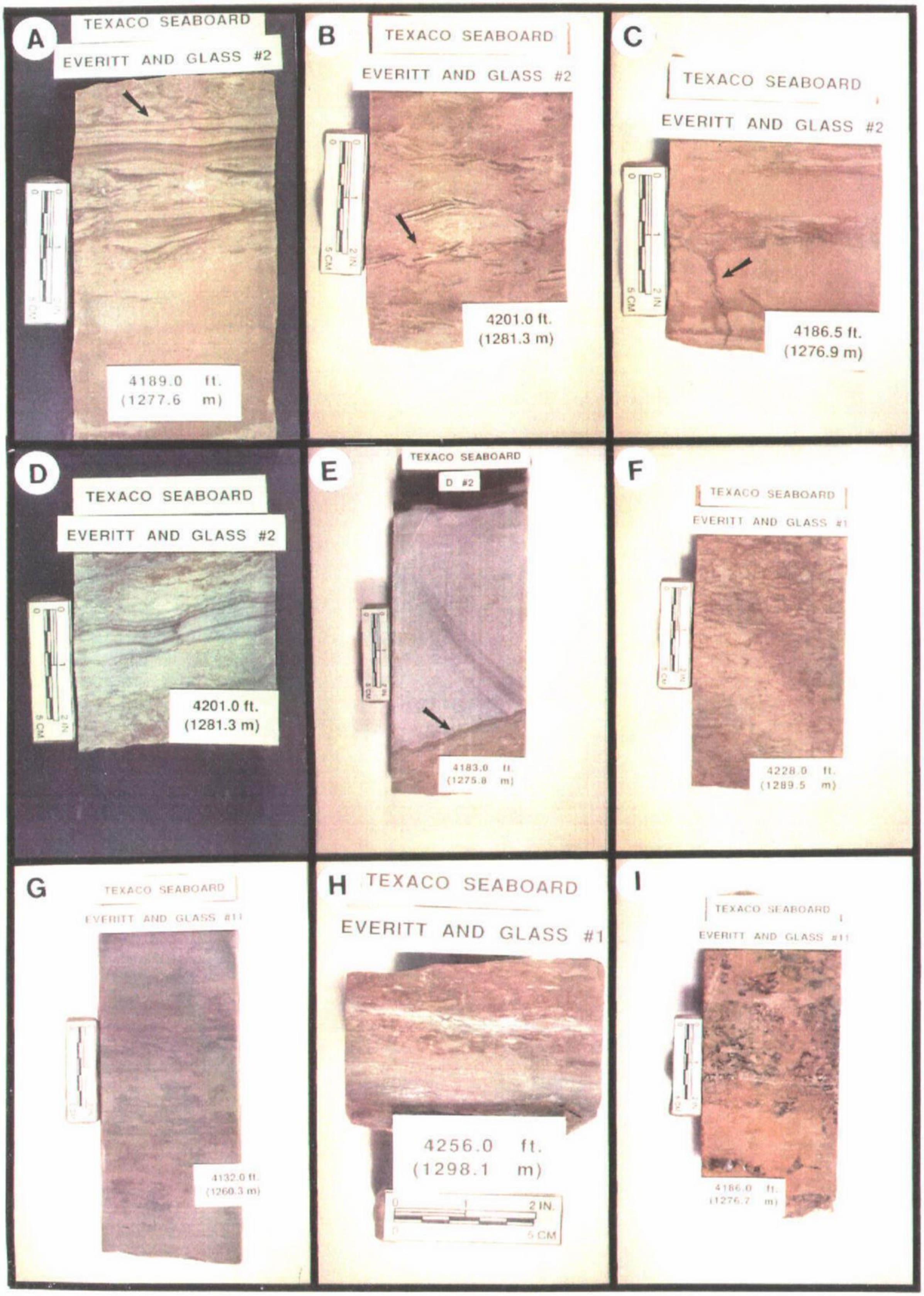
15E: Crenulate and continuous laminae. The laminae (cryptalgal?) separate a dark reddish brown (10R 3/4) saline mudflat facies from a pale blue (5PB 7/2) brine pan facies.

15F: Wavy and discontinuous laminae with argillaceous material. This siltstone is moderate reddish brown (10R 4/6) to dark reddish brown (10R 3/4).

15G: Wavy and discontinuous laminae with argillaceous material. This siltstone is greenish gray (5G 6/1) and is found directly beneath the upper playa facies.

15H: Chaotic and starved ripple-form laminae. The dark reddish brown (10R 3/4) mudstone contains lenticular units (up to 1.0 cm thick) of moderate reddish brown (10R 4/6) siltstone.

15I: Chaotic halite-filled mudstone. The mudstone is dark reddish brown (10R 3/4) and contains poorly developed halite crystals.


A
TEXACO SEABOARD
EVERITT AND GLASS #2
4189.0 ft.
(1277.6 m)
B
TEXACO SEABOARD
EVERITT AND GLASS #2
4201.0 ft.
(1281.3 m)
C
TEXACO SEABOARD
EVERITT AND GLASS #2
4186.5 ft.
(1276.9 m)
D
TEXACO SEABOARD
EVERITT AND GLASS #2
4201.0 ft.
(1281.3 m)
E
TEXACO SEABOARD
D #2
4183.0 ft.
(1275.8 m)
F
TEXACO SEABOARD
EVERITT AND GLASS #1
4228.0 ft.
(1289.5 m)
G
TEXACO SEABOARD
EVERITT AND GLASS #1
4132.0 ft.
(1260.3 m)
H
TEXACO SEABOARD
EVERITT AND GLASS #1
4256.0 ft.
(1298.1 m)
2 IN.
5 CM
I
TEXACO SEABOARD
EVERITT AND GLASS #1
4186.0 ft.
(1276.7 m)

bordering modern salt pan deposits (Arthurton, 1973). This bed directly overlies an interlocking-mosaic halite bed.

3) laminated dolomitic mudstone beds, which are interlaminated with anhydrite and are 0.2 ft. to 3.8 ft. (0.03 - 1.16 m) thick. The dolomitic mudstone is yellowish gray (5Y 8/1), and the anhydrite is usually dark gray (N 3). The laminae of the dolomitic mudstone are probably algal in origin. They are 1 mm to 8 mm thick, often crenulate and usually continuous. The anhydrite laminae are continuous, planar to slightly wavy, and 1 mm to 10 mm thick (Fig. 16a). Laminated dolomitic mudstones are found directly below the surface in modern hypersaline lakes on the coast of the Caribbean Island of Bonaire (Lucia, 1968).

Anhydrite

Anhydrite displays both bedded and non-bedded varieties in the core. The anhydrite is usually light bluish gray (5B 7/1) to medium bluish gray (5B 5/1). Five types of bedded anhydrite are present:

1) laminated anhydrite beds, which are 0.3 ft. to 3.8 ft. (0.09 - 1.16 m) thick. The anhydrite laminae are 1 mm to 10 mm thick, and divided by thin, dark, continuous laminae of probable algal origin. The laminae are slightly wavy, continuous, and often crenulate (Fig. 16b). Laminated anhydrite has been interpreted to form in a subaqueous environment, without disturbance by waves, currents, or burrowing organisms (Dean and Anderson, 1975).

2) chaotic-laminated massive beds, which are 0.4 ft. to 2.5 ft. (0.12 - 0.75 m) thick. The individual laminae are very irregular

(Fig. 16c). The highly disturbed nature of the laminae may be related to gypsum which grew within algal stromatolites. The conversion of gypsum to anhydrite during burial could have obscured the differences between these laminae (Kendall, 1985).

3) massive beds, which are 0.2 ft. to 3.4 ft. (0.6 -1.04 m) thick with individual laminae that cannot be distinguished (Fig. 16c). The massive anhydrite beds are often adjacent to laminated anhydrite beds, and the contact between these beds is gradational.

4) nodular-mosaic anhydrite beds, which are 0.2 ft. to 2.1 ft. (0.06 - 0.64 m) thick. The individual nodules appear to have merged together, creating a "chickenwire" fabric (Fig. 16d). These beds are similar to those found in the Jurassic Buckner Formation which have been interpreted as forming in the subsurface vadose and upper-phreatic zones of a sabkha (Lowenstein, 1987).

5) an enterolithic (ptygmatic) anhydrite bed, which is 0.2 ft. (0.06 m) thick. The bed contains deformational folds and displaces the surrounding beds (Fig. 16e). The growth of such layers, formed by nodules which have coalesced, occurs by host sediment displacement in the "middle supratidal" zone, as determined from the Abu Dhabi sabkhas of the Persian Gulf (Purser, 1985).

Anhydrite also occurs in three non-bedded forms:

1) anhydrite nodules, which are 0.1 cm to 3.8 cm thick. The individual nodules are usually found with a preferred orientation along bedding and are often ovate in form (Fig. 16f). Anhydrite nodules occur in both sandstones and siltstones, but the larger nodules are usually found in the siltstones. The nodules, which seem to have a displacive mode, are similar to those found in

modern sabkhas which have a subaerial origin (Kendall, 1969). Small nodules occur in the uppermost few inches of sabkha sediments along the Trucial Coast of the Persian Gulf, sometimes associated with a gypsum crystal mush (Kinsman, 1966). These features probably developed in the vadose zone during "evaporitic pumping" of hypersaline groundwater, attributed largely to the effects of capillary pressure. The hydraulic gradient under sabkhas is directed vertically toward the surface, creating an upward "Darcy-flow" (Hsu et al., 1969).

2) anhydrite-filled microfractures, which are 0.2 cm to 3.0 cm in length and from 0.1 cm to 1.2 cm in diameter. The anhydrite forms a white (N 8) surface crust where exposed on the cores. The microfractures are found in dark reddish brown (10R 3/4) to grayish red (10R 4/2) siltstones. Possible algal laminae often overlie these sections of anhydrite, and the anhydrite-filled microfractures are usually oriented in a vertical direction (Fig. 16g). These features may have developed as anhydrite pseudomorphs after rooting (rhizomes), or they may have formed from the filling of mud cracks (Crawford and Dunham, 1982)

3) poikilotopic anhydrite with halite crystals, that have individual crystals that are up to 2.0 cm high and 0.4 cm wide. They occur in laminated anhydrite beds 0.4 ft. to 0.6 ft. (0.12 - 0.18 m) thick (Fig. 16h). These beds have several layers of vertically oriented halite crystals which resemble stacked mats of grass turf, and thus have also been termed "grass mat" anhydrite (Kendall, 1978). Similar crystal features have been reproduced in laboratory experiments (Arthurton, 1973) and observed in modern

sediments (Lowenstein, 1985), and they are associated with bottom-nucleated growth within shallow brine pans. Since the halite crystals lack erosional surfaces in the core, the brine pan depth in which they formed appears to have been great enough to prevent surface exposure.

Halite

Halite represents the least abundant lithology and is found in one bedded form:

1) interlocking-mosaic halite beds, which are 2.1 ft. to 3.4 ft. (0.64 - 1.04 m) thick. These beds display an increasing amount of mudstone influx toward the top of the bed as the lower clear bands of halite become dark toward the top of the bed (Fig. 16i). The clear bands have a slight influx of mud between the individual crystals, whereas the dark bands contain abundant mud both between and within the individual crystals. Mudstone probably was introduced to the halite surface by eolian dust storms and sheetwash processes (Fracasso and Hovorka, 1986). The vertically increasing mudstone content in an evaporite cycle like this has been attributed to a progradation of terrestrial environments onto a desiccating playa (Nance, 1988). Modern near-surface analogues are known to exist in the hypersaline Bristol Dry Lake of California (Handford, 1981). Similar halite beds are also documented in Recent brine pans (Shearman, 1970). These findings imply that the halite bed in the core may have been a surface depositional feature which was preserved with depth.

Figure 16: Major sedimentary features found in playa facies (a-c,i), brine pan facies (a,b,h,i), and saline environments (d-g) of Upper Queen evaporites at Concho Bluff Queen Field.

16A: Interlaminated dolomitic mudstone and anhydrite. The mudstone is yellowish gray (5Y 7/2) and the anhydrite is light bluish gray (5B 7/1) to medium bluish gray (5B 5/1).

16B: Laminated anhydrite. The anhydrite is light bluish gray (5B 7/1) to medium bluish gray (5B 5/1).

16C: Massive anhydrite. The anhydrite is light bluish gray (5B 7/1) to medium bluish gray (5B 5/1) and has some chaotic laminae that are yellowish gray (5Y 8/1) in upper half of section.

16D: Nodular-mosaic anhydrite. The anhydrite is in a dark reddish brown (10R 3/4) mudstone bed.

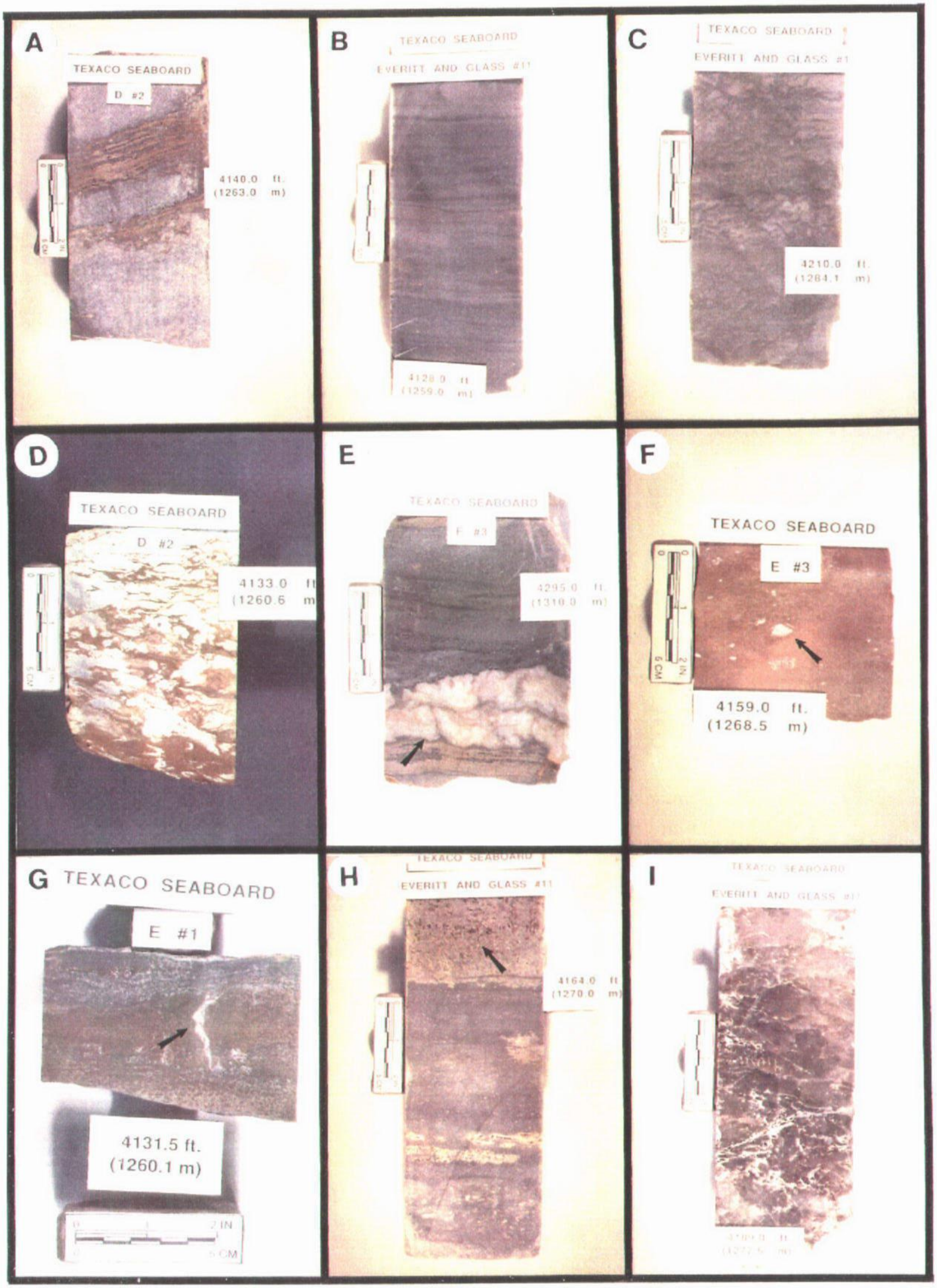
16E: Enterolithic anhydrite. The anhydrite is in a greenish gray (5G 6/1) siltstone bed.

16F: Nodular anhydrite. The anhydrite is in a dark reddish brown (10R 3/4) siltstone bed.

16G: Anhydrite-filled microfractures. The anhydrite is in a moderate reddish brown (10R 4/6) to grayish red (10R 4/2) siltstone bed. These anhydrite features are pseudomorphs after rooting (rhizomes).

16H: Poikilotopic anhydrite. The anhydrite is pale blue (5PB 7/2) and contains vertically oriented halite crystals.

16I: Interlocking-mosaic halite. The halite has brownish gray (5YR 4/1) bands and clear white (N 9) bands.


A
TEXACO SEABOARD
D #2
4140.0 ft.
(1263.0 m)
B
TEXACO SEABOARD
EVERITT AND GLASS #1
4128.0 ft.
(1259.0 m)
C
TEXACO SEABOARD
EVERITT AND GLASS #1
4210.0 ft.
(1284.1 m)
D
TEXACO SEABOARD
D #2
4133.0 ft
(1260.6 m
E
TEXACO SEABOARD
E #3
4295.0 ft.
(1310.0 m)
F
TEXACO SEABOARD
E #3
4159.0 ft.
(1268.5 m)
G TEXACO SEABOARD
E #1
4131.5 ft.
(1260.1 m)
2 IN
5 CM
H
TEXACO SEABOARD
EVERITT AND GLASS #1
4164.0 ft
(1270.0 m)
I
TEXACO SEABOARD
EVERITT AND GLASS #1

VERTICAL LITHOLOGY AND UNITS

The lithologies and sedimentary structures which were identified in the previous section are represented in the Texaco Seaboard, Everitt and Glass #1 core from the Concho Bluff Queen Field. This particular core, located near the center of the field, was selected for the type section because it contains the entire Upper Queen Formation, and also is representative of the cyclical nature of the stratigraphic sequences found in the field area. An interpretation of depositional environments (Figs. 17 and 18) is presented based on the observed lithologies and sedimentary structures from this core. The Texaco Seaboard, Everitt and Glass #1 core contains Upper Queen sandstones and their associated lithologies, and is located in Section 30, T4S, Block 42 of Crane County, Texas. The cored interval is from 1519.0 ft. to 1471.0 ft. (463.30 - 448.66 m) below sea level, which corresponds to an interval from 4257.0 ft. to 4209.0 ft. (1298.4 - 1283.8 m) below the surface.

The bottom of the core contains 0.9 ft. (0.27 m) of anhydrite that is light bluish gray (5B 7/1) to medium bluish gray (5B 5/1). The anhydrite is massive with chaotic laminae from the base of the cored section to 4256.6 ft. (1298.3 m) and becomes interlaminated with dolomitic mudstone from 4256.6 ft. (1298.3 m) to the top of the section. The anhydrite laminae are up to 0.9 cm thick, whereas the mudstone laminae are up to 0.3 cm thick. The upper contact is

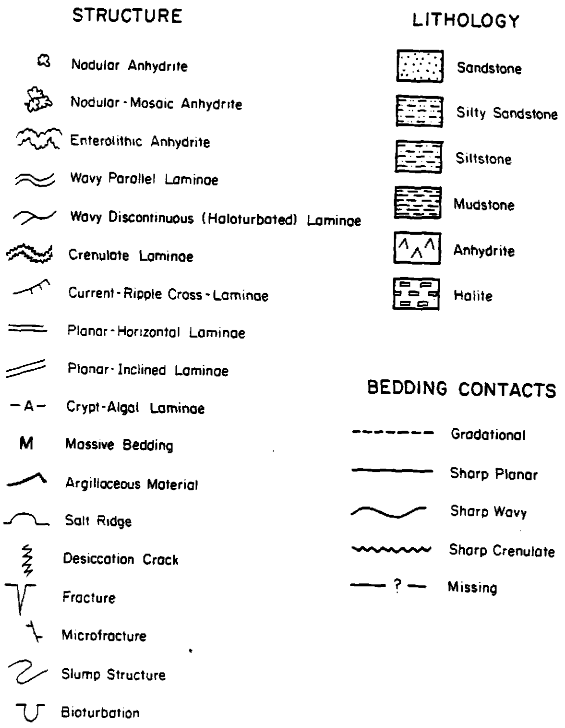


Figure 17: Legend for lithostratigraphic columns.

TEXACO SEABOARD
EVERITT & GLASS I

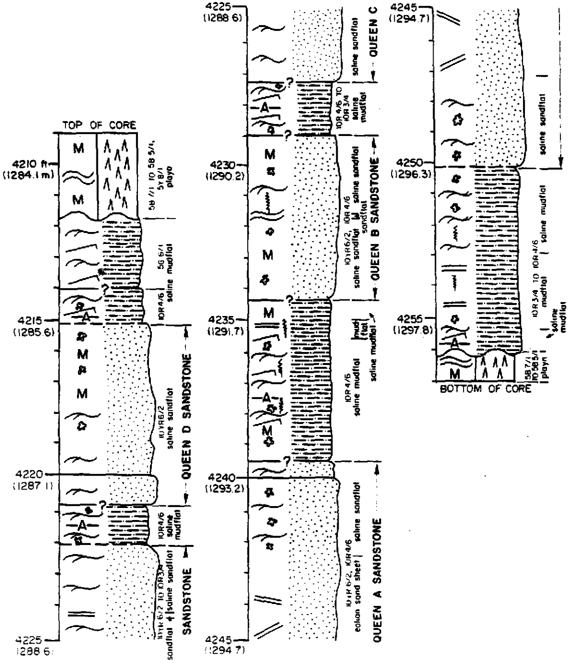


Figure 18: Detailed lithostratigraphic column and interpreted depositional environments of Upper Queen sandstones and associated lithologies from Texaco Seaboard, Everitt and Glass #1 well.

sharp and slightly wavy. This lithology represents the lower playa facies.

The siliciclastics of the Upper Queen Formation begin here and are divided into the following units:

UNIT 1: which consists of 5.9 ft. (1.80 m) of interlaminated mudstones and coarse-grained siltstone. The base of this unit contains 0.5 in. (1.3 cm) of dark, slightly wavy, and continuous laminae, probably of algal origin, in a light bluish gray (5B 7/1) area. Above is a dark reddish brown (10R 3/4) mudstone that is 0.5 ft. (0.15 m) thick and contains small (up to 1 cm) lenticular zones of siltstone. The laminae are irregular and characterized by a wavy, discontinuous pattern. The mudstone has a sharp contact with the moderate reddish brown (10R 4/6) and coarse-grained siltstone above it. The siltstone laminae are indistinct at the base, but towards the top of the unit they are wavy and discontinuous with drapes of argillaceous material. Both desiccation cracks and anhydrite nodules (up to 0.5 cm thick) are abundant in the siltstone. The contact between this and the overlying unit is gradational.

UNIT 2: which consists of 2.7 ft. (0.82 m) of a very fine-grained pale yellowish brown (10YR 6/2) sandstone with oil stains. The laminae are mostly indistinct with a only a few wavy, discontinuous ones present. Small, isolated anhydrite nodules (up to 0.5 cm thick) are found at the base of section. The contact between this and the overlying layer is gradational.

UNIT 3: which consists of 4.5 ft. (1.35 m) of very fine- to fine grained sandstone, pale yellowish brown (10YR 6/2), with oil stains.

Primary sedimentary structures are difficult to discern; however, oil stains along preferred migration routes suggest that relict laminae are planar and inclined (up to 13 degrees). The contact between this and the next unit is gradational.

UNIT 4: which consists of 2.7 ft. (0.82 m) of very fine-grained sandstone, pale yellowish brown (10YR 6/2), with oil stains. Isolated patterns of moderate reddish brown (10R 4/6) sand is present at the top of the section. Laminae are mostly indistinct with a few wavy, discontinuous ones present. Anhydrite nodules less than 0.2 cm. thick are found at the top of the section. The contact between this and the overlying layer is not present.

UNIT 5: which consists of 6.1 ft. (1.86 m) of interlaminated mudstone and coarse-grained siltstone that is moderate reddish brown (10R 4/6) to dark reddish brown (10R3/4). Most laminae are wavy and discontinuous with argillaceous material. Possible algal material is found in a light bluish gray (5B 7/1) section with dark, very thin, slightly wavy, and continuous laminae at 4237.4 ft. (1292.4 m). Laminae are planar, horizontal, and continuous from 4235.4 ft. to 4235.0 ft. (1291.8 - 1291.2 m) and become indistinct at the top of the section. Desiccation cracks are present in the middle of the section. Isolated anhydrite nodules less than 0.2 cm thick are present throughout the section. The contact between this and the next unit is not present.

UNIT 6: which consists of 4.4 ft. (1.34 m) of very fine-grained sandstone that is pale yellowish brown (10YR 6/2) sandstones with oil stains. Irregular patterns of moderate reddish brown (10R 4/6) are present from 4231.1 ft. to 4230.1 ft. (1290.5 - 1290.4 m).

Laminae are mostly indistinct with some wavy and discontinuous ones present. Isolated anhydrite nodules less than 0.2 cm thick occur in the moderate reddish brown (10R 4/6) section. The contact between this and the overlying unit is absent.

UNIT 7: which consists of 1.8 ft. (0.55 m) of interlaminated mudstone and coarse-grained siltstone that is moderate reddish brown (10R 4/6) to dark reddish brown (10R 3/4). Possible algal material is found in a light bluish gray (5B 7/1) section with dark, very thin, slightly wavy, and continuous laminae at 4228.2 ft. (1289.6 m) and at 4229.1 ft. (1289.9 m). The mudstone has small (up to 1.0 cm thick) lenticular zones of siltstone, whereas the siltstone contains thin mud drapes. The laminae in this unit are irregular and characterized by a wavy and discontinuous pattern. Anhydrite nodules are found throughout the lower part of section. The contact between this and the next overlying unit is not present.

UNIT 8: which consists of 5.1 ft. (1.56 m) of fine-grained sandstone that is pale yellowish brown (10YR 6/2) with oil stains. Irregular patterns of moderate reddish brown (10R 4/6) sandstones are found in the top half of the section. Most laminae are wavy, discontinuous with some continuous ones from 4227.1 ft. to 4226.8 ft. (1289.3 - 1289.2 m) and at 4224.3 ft. (1288.4 m). The contact between this unit and the overlying unit is sharp and wavy.

UNIT 9: which consists of 1.4 ft. (0.43 m) of coarse-grained siltstone that is moderate reddish brown (10R 4/6) with irregular lenses of pale yellowish brown (10YR 6/1) that have wavy, discontinuous laminae. Possible algal material is found in light bluish gray (5B 7/1) section with dark, very thin, slightly wavy, and continuous laminae from 4221.3 ft. to 4221.1 ft. (1287.5 - 1287.4 m). Isolated anhydrite nodules less than 0.2 cm thick are observed in the moderate reddish brown (10R 4/6) section. The contact with the next overlying unit is not present.

UNIT 10: which consists of 5.6 ft. (1.71 m) very fine-grained sandstone that is pale yellowish brown (10YR 6/1) with oil stains. Primary sedimentary structures are difficult to discern, but where visible the laminae are wavy and discontinuous. Isolated anhydrite nodules less than 0.2 cm thick are present at the very top of section. The overlying contact with the next unit is gradational.

UNIT 11: which consists of 2.4 ft. (0.74 m) of coarse-grained siltstone that is moderate reddish brown (10R 3/4) in the bottom half and grades into greenish gray (5G 6/1) in the top half of section. Laminae are irregular and appear wavy and discontinuous with some mud drapes. Possible algal material is at the very top of the section, represented by slightly wavy and continuous laminae. Isolated anhydrite nodules less than 0.2 cm thick are found at the base of the section. The contact between this and the overlying unit is sharp and slightly wavy.

Above this last unit is 3.7 ft. (1.12 m) of anhydrite which is mostly massive with chaotic laminae. The anhydrite is light bluish gray (5B 7/1) to medium bluish gray (5B 5/1) and contains yellowish gray (5Y 8/1) in the bottom half of the section. Some faint laminae are slightly wavy and continuous from 4211.3 ft. to 4210.1 ft. (1284.4 - 1284.1 m). The individual laminae are up to 0.9 cm thick where discernable. This unit represents the upper playa facies of the core and along with the lower playa facies bounds the siliciclastics of the Upper Queen Formation.

GRAIN SIZE AND SHAPE ANALYSIS

Introduction

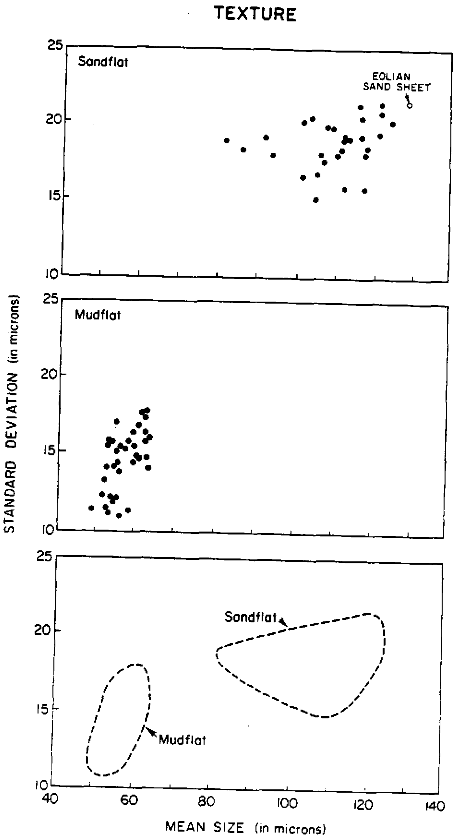
Samples were taken from 9 cores in over 70 strategic locations which best represented the depositional environment of the siliciclastics in the Concho Bluff Queen Field. The modal grain size was determined for each environment, and this size fraction was isolated before the grain shape analysis was performed. For the sandflat and eolian sand sheet, very fine-grained sand was the modal grain size, whereas coarse-grained silt was the modal grain size for the mudflat.

Size and Standard Deviation

The siliciclastics in the Upper Queen Formation at the Concho Bluff Queen Field are predominantly composed of very fine-grained sandstones and coarse-grained siltstones, both of which are well sorted. These siliciclastics have mean grain sizes that range from 47 microns to 129 microns and standard deviations that range from 10 microns to 22 microns.

The grain size characteristics of samples from the three major depositional environments are shown in figure 19. In evaluating grain size distributions, it is important to understand that these distributions reflect depositional processes in addition to depositional environments, and the two need not be the same (Solohub and Klovan, 1970). The eolian sand sheet sediments are

Figure 19: Plot of mean quartz grain size and standard deviation, illustrating textural trend of the sandflat and mudflat environments.



TEXTURE
Sandflat
EOLIAN SAND SHEET
Mudflat
Sandflat
Mudflat
STANDARD DEVIATION (in microns)
MEAN SIZE (in microns)
25
20
15
10
40
60
80
100
120
140

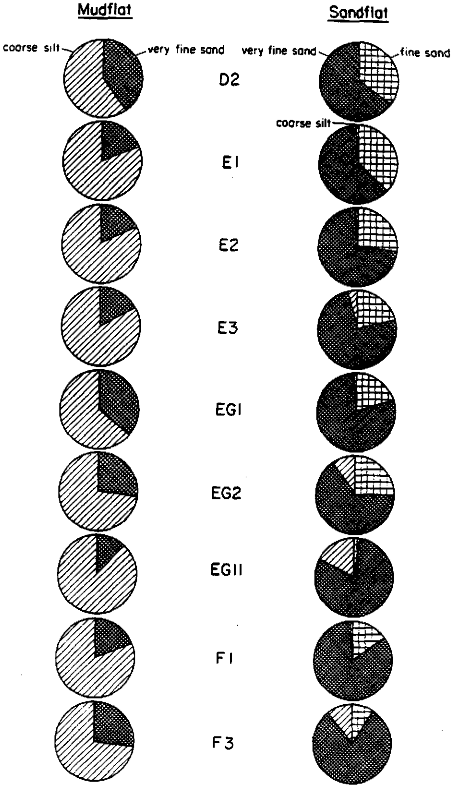
well sorted, fine-grained sand. The sample from the eolian sand sheet has a mean grain size of 129 microns, representing the largest mean size of sediments in the study area, and a standard deviation of 22 microns. No grains below the lower limit of the very fine-grained (63 microns) size fraction were found in these sediments. Samples such as these with good sorting reflect winnowing by the wind of silt-sized particles (Visher, 1969). Thus, the lack of silt serves as an important indicator for recognizing deposits from an eolian sand sheet.

The sandflat deposits are composed of moderately well- to well- sorted, very-fine grained sand that ranges in mean size from 81 microns to 124 microns with an average mean size of 108 microns. The standard deviation for sandflat deposits range from 15 microns to 22 microns, with an average standard deviation of 19 microns. The sandflat contains the greatest range of grain size because the sandflat is a transitional environment between the eolian sand sheet and the mudflat.

The mudflat sediments consist of well-sorted, coarse-grained silt, and range in size from 47 microns to 62 microns, with an average mean size of 55 microns. The deposits from the mudflat have standard deviations that range from 10 microns to 19 microns. Generally, these deposits do not contain grains larger than very fine-grained sand (125 microns), and they are usually argillaceous (Fig. 20). Silt and clay were transported into the mudflat environment during periods of flooding and were deposited from suspension. Shallow water table conditions in the mudflat

Figure 20: Pie diagrams comparing grain-size fraction distribution of the sandflat and mudflat environments.

TOTAL SIZE FRACTION



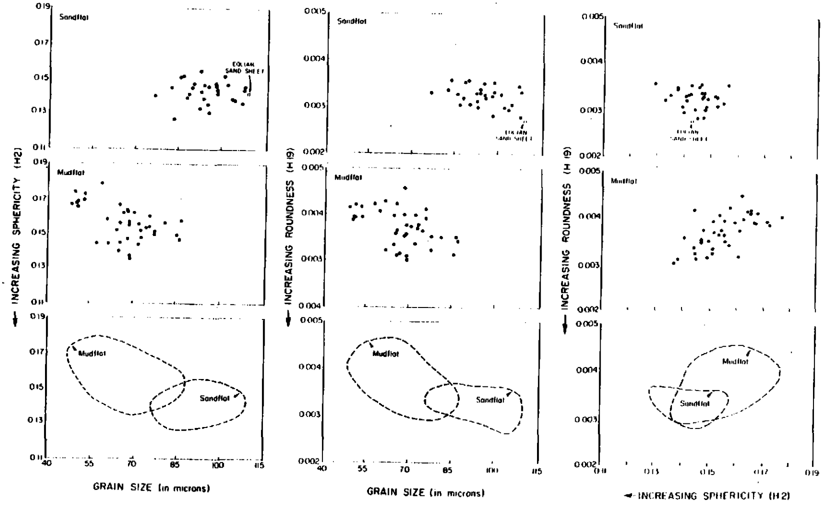
environment produced a damp depositional surface which promoted the adhesion and accumulation of silt (Glennie, 1972).

Sphericity

Quartz grains from all of the environments are spherical. All samples are characterized by 2nd mean harmonic amplitudes between 0.129 and 0.172 (R_S = 0.84 to 0.87)(Fig. 21). Quartz grains from the eolian sand sheet have a mean 2nd harmonic amplitude of 0.157 (R_S = 0.85). Sandflat deposits have a mean 2nd harmonic amplitude of 0.145 (R_S = 0.85), with a range from 0.129 to 0.164 (R_S = 0.84 to 0.87). The mudflat samples have a mean 2nd harmonic amplitude of 0.154 (R_S = 0.85), with a range from 0.137 to 0.172 (R_S = 0.84 to 0.86). A comparison of these sphericity values for the sandflat and the mudflat shows that the sediment from the sandflat appears to be slightly more spherical than that of the mudflat. Grain-shape variation is often a result of differences in subareal abrasion (Mazzullo and Ehrlich, 1983). Since the sandflat sediments were normally located above sediments afixed by surface moisture, they were sometimes subjected to abrasion by eolian processes. However, mudflat sediments were usually subjected to less abrasion since they often adhered to the damp surface very close to the water table.

Figure 21: Plot of quartz grain sphericity and roundness, illustrating textural trend of the sandflat and mudflat environments.

SPHERICITY AND ROUNDNESS



Roundness

Figure 21 also summarizes the roundness values for the environments of the Upper Queen siliciclastics. Generally, quartz sand grains from each of the environments are subangular to subrounded, for all samples are characterized by mean 19th harmonic amplitudes between 0.0027 and 0.0046 (K_r = 0.32 to 0.57).

The grains from the eolian sand sheet have a mean 19th harmonic amplitude of 0.0032 (K_r = 0.50). Similarly, quartz grains from the sandflat have a mean 19th harmonic amplitude of 0.0038 (K_r = 0.49), with a range from 0.0027 to 0.0042 (K_r = 0.37 to 0.57). Samples from the mudflat have a mean 19th harmonic amplitude of 0.0037 (K_r = 0.44), with a range from 0.0031 to 0.0046 (K_r = 0.32 to 0.51). These data show slightly higher roundness values for the sandflat and eolian sand sheet than the mudflat. In order to minimize the effects of analyzing roundness between samples of different size fractions, the mean 2nd harmonic amplitude and mean 19th harmonic amplitude were also compared (Fig. 21). In general, the quartz grains from the sandflat and eolian sand sheet are more rounded than the quartz grains from the mudflat. Although fluvial processes dominated the continental sabkha, minor differences in roundness suggest that sediments from all of the environments were also subjected to some degree of abrasion by eolian processes.

DEPOSITIONAL ENVIRONMENT

The cores of the Upper Queen Formation in the Concho Bluff Queen Field represent cyclical deposition of mudflats and saline mudflats with sandflats and saline sandflats. Units 1, 5, 7, 9, and 11 contain mudstones and siltstones which represent deposition in mudflat and saline mudflat environments of a continental sabkha. Sedimentary structures in the cores representative of these environments consist of wavy and discontinuous laminations, slightly wavy and continuous laminations (cryptalgal?), argillaceous (mud drape) laminations, starved ripple-form laminations, anhydrite nodules (up to 3.8 cm), nodular mosaic anhydrite, enterolithic anhydrite, anhydrite-filled microfractures, desiccation cracks, and salt ridge structures. However, units 2, 4, 6, 8, and 10 contain sandstones that were deposited in sandflat and saline sandflat environments of a continental sabkha. These units have sedimentary structures which consist of horizontal (planar) and continuous laminations with normal grading, slightly wavy and discontinuous laminations, massive structures, and anhydrite nodules (usually less than 0.5 cm). Unit 3 represents eolian deposition in a dry sand sheet environment. These sandstones have sedimentary structures characterized by intermediate-angle (inclined up to 22 degrees), planar, and continuous laminations. In addition, they often have associated slump structures with microfaults. Some anhydrite beds, with sharp upper and lower boundaries (cryptalgal?), occur within units 5, 7, and 9. These beds represent brine pan deposits in localized depressions on the saline mudflat surface. Toward the northwest portion of the field, one core has poikilotopic anhydrite with halite crystals in Unit 5, suggesting extremely hypersaline conditions existed in that area at the time of deposition.

In describing the depositional environments of the Concho Bluff Queen Field, a background knowledge of sabkhas is essential. Sabkhas have an equilibrium geomorphic surface, or sandflat, whose level is dictated by the local level of the groundwater table, and occasionally receives flood waters (Kinsman, 1969). Classification of sabkhas is based on their formational process and geographic location. In addition to evaporation, three general processes influence the development of sabkhas: marine, fluvial-lacustrine, and eolian (Handford, 1981). Sabkhas also occur in both coastal and continental settings. Coastal sabkhas are usually dominated by marine processes; playas are in the fluvial-lacustrine dominated category; and interdune sabkhas are eolian dominated (Handford, 1981). Coastal and continental sabkha deposits are commonly identical, and in some cases coastal sabkhas grade into continental sabkhas (Kendall, 1985). This makes determining the difference between coastal and continental settings in ancient sabkhas somewhat of a difficult exercise. However, the cores from the Concho Bluff Queen Field do favor a continental sabkha (Fig. 22), for extensive carbonate deposits associated with coastal sabkhas are not present. Furthermore, halite precipitation, as seen in the cores, requires extreme saline concentrations which probably would not be found in a coastal sabkha. The development of continental sabkhas depends on low hinterland relief, small eolian sediment supply, and arid climate (Kinsman, 1969).

Before the siliciclastics of Unit 1 were deposited, the area constituting the field consisted of an extensive playa. The cores reflect this environmental interpretation, as they consist of massive anhydrite, laminated anhydrite, interlocking-mosaic halite, and minor amounts of interlaminated dolomitic mudstone. A playa accumulates sediment through an internal drainage pattern and forms in the flat and generally barren lower portion of an arid basin (Neal, 1975). As the water table of the playa dropped, its areal extent began to diminish. Algal material which grew along the peripheral boundary of the lake, migrated with the retreating water line. Consisting of single- to multi-layered systems, microbial layers were confined within the upper "intertidal" and lower "supratidal" zones surrounding the playa (Kendall, 1985). Formation of these thin layers occurred both at the surface and within sediment near the surface (Krumbein, 1985).

Due to an increase in the sediment supply, coupled with a reduction in size of the playa, the mudflat siliciclastics of Unit 1 began to prograde into the field area. Muds were transported by sheet floods and then deposited on the saline mudflat, saturated with brine, which bordered the shrinking playa. Mud deposition was favorable because the sediments were kept moist by groundwater discharge (Eugster and Hardie, 1975). Surficial salt crust developed on the mudflats during periods of exposure, and interstitial precipitation of evaporites developed within the mud

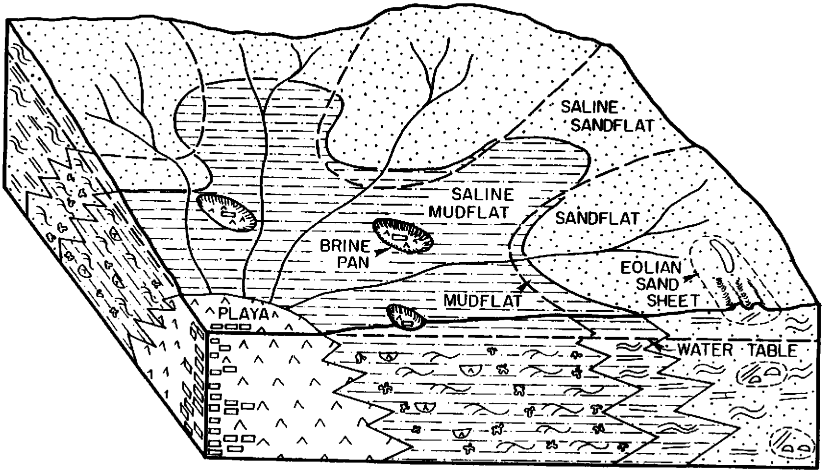


Figure 22: Depositional model for Upper Queen sandstones in the study area.

(Presley and McGillis, 1982). During later flood periods, freshwater dissolved the most soluble saline minerals, and as the salt-rich water percolated into the ground and evaporated, a new crust was formed at the surface (Glennie, 1970). In this manner, the sediments surrounding the playa were continuously deformed through haloturbation. The saline mudflat was subsequently covered by mudflat deposits, slightly above the brine saturation zone, consisting of mud and coarse-grained silt. Intense heat caused many of these deposits to become desiccated with cracks, and their original depositional forms were often poorly preserved.

The coarse-grained siltstones at the top of Unit 1 grade into very fine-grained sandstones of Unit 2. Continued siliciclastic progradation into the playa led to the development of sandflats in the field area. As the mudflats (Unit 1) migrated progressively toward the reducing playa, the sandflats (Unit 2) kept pace with the mudflats (Unit 1), and also migrated in the same direction. The sands were transported by unchannelled, unconfined sheet floods and were deposited on the mudflat surface (Hardie et al., 1978). The sandflat sometimes developed into a saline sandflat when the level of the water table rose, and the sediments were subjected to disturbances from the saturated brine water. Since wind-ripple lamination with inversely graded laminae are not observed in Unit 2, fluvial-lacustrine processes, as opposed to eolian processes, dominated at the time of deposition. Furthermore, lag deposits associated with deflation surfaces are absent, indicating that the sands most likely remained damp after deposition. Preservation of the sandflat after deposition was dependent upon a rising water table (Gunatilaka and Mwango, 1987).

Unit 3 represents dry eolian sand sheet encroachment onto the sandflat and the greatest extent of facies migration into the field area. The eolian sand sheet consists of well sorted, very fine-grained sandstone which was probably deposited by grainfall. Like the Queen eolian sand sheets of the Palo Duro Basin, the eolian sand sheets in the study area lack sharp lateral boundaries. This may be a result of the excellent sorting of these deposits (Nance, 1988). Recognition of eolian sand sheets within the field is quite limited, which may be due to their low preservation potential. Early cementation most likely occurred in the eolian sand sheets which were preserved, giving insight to possible conditions which existed shortly after their deposition. Factors that govern early cementation of eolian deposits like these are soil formation, deposition of evaporites from solution, and addition of windblown detrital cements from neighboring areas (Fryburger et al., 1983).

As the influx of siliciclastics began to diminish, the eolian sand sheets of Unit 3 retreated from the field area, followed by the sandflats of Unit 4. Then, the area returned to a mudflat environment again, as represented by Unit 5. Bioturbation is rare in each of these units which suggests that living conditions were much too harsh for organisms other than algae. Brine pan environments, parts of the evaporitic plain that contained standing water, occasionally developed in isolated depressions on the mudflat surface of Unit 5. After a rain, brine pans collected and temporarily retained terrestrial waters. The water of the brine pan is perched above the water table, held up by an impermeable floor of clay and silt (Flint and Bond, 1968). Peripheral halite is dissolved at each recharge of the pan and only accumulates in the center of the pan (Kinsman, 1969).

The depositional sequence from Unit 1 through Unit 5 represents the lowermost cycle (containing the Queen "A" sandstone) in the cores. This cycle displays a complete cycle of the Upper Queen sandstone and contains the greatest range of depositional environments. Unit 6 through Unit 11 display similar depositional cycles in the study area, except that they lack the progradation of the eolian sand sheet onto the sandflat. Thus, the fundamental mode of cyclicity appears to have been the same for each of the Upper Queen sandstones. The deposition of Upper Queen siliciclastics was truncated by a vast expansion of the playa which encompassed the field area. The dramatic rise in the water level of the playa resulted from a substantial increase in water supply, possibly due to a major rise in sea level. The contacts between the siliciclastics of Unit 11 and the overlying evaporites are sharp, implying that the growth of the playa was rapid. Shortly after the field area returned to a playa, evaporative precipitation began and deposition of siliciclastics was inhibited.

The history of the sediment which was deposited in the study area may have been quite complex, resulting from several cycles of erosion, transportation, and deposition. The following scenario addresses a possible low-relief source for sediment in the Concho Bluff Queen Field and also accounts for the availability of mud in the arid environment. During the high playa stand, the playa was fed by a series of fan deltas. However, as the playa level fell, playa-margin revines were eroded. Fluvial and deltaic facies that were deposited during the high playa stand were cut into by headward erosion in the arid climate (McGowen et al., 1979). In this manner, mud, silt, and very fine-grained sand were eroded from the remnant playa margins and transported into the study area. Such a low-relief clastic source for the very-fine grained sediment is consistent with an epeirogenic tectonic setting (Presley and McGillis, 1982). Furthermore, sediments in the study area may represent deposits from secondary fan lobes which formed downslope of primary fan deposits. Secondary fan lobes produce thin upward-coarsening sequences, consisting of finer grained and better sorted deposits than those of primary fan deposits (Heward, 1978).

Within the Concho Bluff Queen Field, the lithologies and sedimentary structures of the cores unequivocally support the "dry" model for the deposition of the Upper Queen sandstones. Sediment prograded as an arid fan delta and was deposited in a fluvial-dominated continental sabkha. The reduction-expansion of the playa was due to significant variations of the water table, probably as a result of major sea-level fluctuations. The "wet" model is refuted based on the depositional environments that are present in the cores. Furthermore, the "hybrid" model is not applicable since the sabkha formed in a continental setting and there is no evidence to support the reworking of sediment by marine processes.

CYCLICITY

Several orders of cyclicity can be observed in the cores from the Concho Bluff Queen Field. Before the deposition of the siliciclastics of the Upper Queen Formation, a vast playa encompassed the field area in a continental sabkha setting, to the west of the Midland Basin. Evaporite deposition was dominant in the study area, for clastic influx into the region was restricted by the extensive playa. The evaporites at the base of the cored interval represent the playa facies, void of any significant amount of siliciclastics. The top of the cored interval also shows similar lithologies and represents the upper playa facies. Since the entire Upper Queen Formation is bound by these playa facies, the first order of cyclicity is the change in primary sediment deposition from evaporites to siliciclastics, and then back to evaporites. Cyclical sedimentation is a prominent characteristic of Permian Basin stratigraphy (Jacka et al., 1969; Meissner, 1969; Silver and Todd, 1969; Smith, 1974; Presley and McGillis, 1982; Fracasso and Hovorka, 1986; Nance, 1988).

This first order of cyclicity, and alternating evaporite and siliciclastic deposits, is probably due to allocyclic controls associated with eustatic sea-level fluctuations. The sandstones of the Upper Queen Formation were deposited within the field when the water level of the playa dropped from continued evaporation and little surface recharge. Sandstone deposition continued in the field area as the water level of tha playa receded. However, siliciclastic progradation became restricted when the playa expanded, probably due to a major rise in sea level, and the site returned to evaporite deposition. As part of the regional investigation of sandstones in the Queen Formation, this analysis is consistent with the results of previous researchers (Williams, 1984; Mazzullo, 1985, 1986; Holley and Mazzullo, 1988; Malisce, 1988; Siegel, 1989). Glacial controls may have been responsible for eustatic sea-level changes throughout the Permian (Jacka et al., 1969; Silver and Todd, 1969; Crowell, 1982). Tectonic controls on eustatic sea-level fluctuations have also been suggested (Valentine and Moores, 1972). However, glacial controls appear to be primarily responsible for the magnitude and periodicity of these cycles, for the short-period cyclicity of the Queen Formation can not be explained by the long-period evolution of lithospheric plates (Guidish et al., 1984). The volumetric changes of mid-oceanic ridge systems related to tectonic events are also too long in duration and too high in amplitude to be responsible for such cyclicity (Pittman, 1978).

Alternating wet and dry environments within the Upper Queen Formation represent the second order of cyclicity. The lowermost cycle, containing the Queen "A" sandstone, is the only cycle with both wet and dry environments. Furthermore, the extent of the dry environment is quite limited, for its presence is found in only two of the nine cores. The autocyclic controls on these variations is attributed to a combination of 1) climatic changes, 2) minor eustatic sea-level fluctuations, and 3) land subsidence. The height of the water table is critical in each of these. Sabkhas display a deflation-sedimentation equilibrium phenomena which is closely associated with the surface depth to the water table (Gunatilaka and Mwago, 1987). A drop in the water table produces surface deflation, resulting in poor preservation of surface sediments (Hardie et al., 1978).

Regional climatic changes probably had the greatest influence on these wet and dry cycles. Although continental sabkha are characterized by a hot and arid climate, major storms sometimes develop which bring harsh rains. Flooding may occur as frequently as several times a year, but probably major flood events are years or even decades apart (Lowenstein and Hardie, 1985). Since the hostile environment of the sabkha inhibits the development of higher forms of plant life, roots which would normally stabilize the sediment during these floods are lacking. As a result, surface sediments are very unstable during flash floods. In a single flood event, sediment from sand sheets can be eroded and deposited as a package of laminated sand tens of centimeters thick (Hardie et al., 1978). After flooding, the water table becomes elevated and sedimentation is preserved by adhering to the damp surface. Eventually, evaporation lowers the water table back to its pre-flood level, and the environment returns to its normal dry condition.

Minor eustatic sea-level fluctuations may have also had an influence on the wet and dry environments of the Upper Queen Formation. During the deposition of the Artesia Group, of which the Queen Formation is a part, more than 250 minor oscillations of relative sea level are thought to have occurred (Smith, 1974).

Relatively small variances in sea level would directly influence the water table of the playa. Since the topography surrounding the playa is thought to have had subtle relief, extensive playa inundations on the land could result from a small increase, or vertical displacement, of the water table. A wet environment along the periphery of the playa could also shift to a dry environment by a sequential drop in the water table.

Dry and wet environment alterations can also be associated with localized ground subsidence. Assuming the height of the water table remained constant, subsidence could produce a low topographic area, possibly at or below the water table. In this manner, an area that had been characterized by a dry environment might drop below the water table. Ground subsidence produces active sites of sediment accumulation. Brine pan facies are often associated with centers of thickening, suggesting their formation is largely controlled by subsidence (Presley and McGillis, 1982). The wet environment may also change to dry as the depression becomes filled, and sediment is deposited above the water table.

The third order of cyclicity is the fluctuation between mudflat facies and sandflat facies within the wet environment. Four primary cycles of mudflat and sandflat alterations are present in the Upper Queen Formation. The autocyclic controls on these patterns are due to a combination of 1) siliciclastic sediment supply, 2) progradation/aggradation of facies, and 3) sediment compaction.

The amount of siliciclastics supplied to the study area would have an influence on facies cyclicity. A change from a sandflat to a mudflat may have been in response to a gradual abandonment of a proximal depositional lobe following an episode of sandflat deposition (Heward, 1978). Abandonment or lateral shifting of transport routes outside the field area would decrease the clastic supply into the field area (Galloway and Hobday, 1983). In a similar manner, lateral shifting could also increase the sediment supply into the field. Periods of reduced sediment supply would favor the formation of a mudflat. On the other hand, a sandflat would be more likely to develop from an increase in sediment supply.

However, sandflat deposition may not have been a continuous process. Patterns of sediment supply may have changed due to faulting outside the field area. Tectonic activity during the Pennsylvanian created northwest trending en echelon faults which extended across the eastern edge of the Central Basin Platform (Galley, 1958; Ward et al., 1986). Reactivation of one of these faults during the Permian would have produced an upward-coarsening sequence, representing sandflat progradation, followed by an upward-fining pattern which represents mudflat progradation and a gradual return to equilibrium (Rust, 1978). Four cycles of sandflat deposition in the study area would suggest four separate periods of faulting, probably in small pulses.

During the time of Queen Formation deposition, mudflats and sandflats were often progradational, aggradational, or both. Facies shifted continuously in response to variances in the water level of the playa, and sedimentation trends adjusted accordingly with the different environments to maintain a "playa-marginal" surface

(Presley and McGillis, 1982). As mudflats migrated on the border of the playa, the sandflats kept pace with them and also migrated.

Still another factor which may have influenced the shifting of these facies is sediment compaction. Silt and mud of a mudflat have a greater ability to compress than sand of a sandflat. Thus, the altering of facies may have been due to a lesser degree of compaction in the previous sandflat as compared with its adjacent mudflat. When mudflat sediments became overburdened, they may have produced slight depressions on the surface that favored sandflat deposition. Thus, differential compaction may have influenced local topography, causing siliciclastic depositional systems to shift laterally through preferred sedimentation (Busch, 1974).

The fourth order of cyclicity is the fluctuation between the saline and non-saline environments of the sandflat and mudflat. The height of the brine-saturated water table distinguishes these environments. Salts form within sediments which are near the water table. Therefore, saline environments have sedimentary structures which have been completely destroyed by haloturbation, whereas the non-saline environments have sedimentary structures which are well preserved (Hardie et al., 1978). Groundwater discharge in continental sabkhas can be direct or indirect. Capillary rise and evaporative pumping indirectly supply water, while storms and springs directly supply water (Presley and McGillis, 1982). Continental sabkha are sites of extensive evaporation losses and concomitant of pore fluids (Kinsman, 1969). Thus, playas are areas of brine formation, regardless of the

FIELD SUMMARY

The Concho Bluff Queen Field was discovered in July of 1956 and has had a cumulative production of 7,229,623 bbls. of oil through July of 1988. The Atlantic Ref. Co's TXL #1-31, located in the NE SE of Section 31 of Block 43 and Township 4-S, was the discovery well with an initial pumping potential of 110 bbls. of oil and 14 bbls. of water. The hydrocarbon mixture recovered from the Upper Queen sandstones had a gravity of 28.2 degrees API. The well was perforated with 4 shots per foot in a 20 ft. (6.1 m) interval from -1341 ft. to -1361 ft. (-409.0 - -415.1 m). Stimulation of the discovery well included a sand fracture treatment with 500 gallons of mud acid along with 10,000 lbs. of sand in 50,000 gallons of propant. Each of the four Queen sandstones has been perforated and is productive. The average thickness of the pay zone is 25 ft. (7.6 m), and ranges in thickness from 19 ft. (5.8 m) to 37 ft. (11.3 m). Large fracture treatments, like the one used in the discovery well, were usually performed on the wells in the field during primary recovery. Well fractures increase oil recovery by reducing wellbore damage and increasing the effective permeability of the drainage area (Howard and Fast, 1970). Presently, 35 wells with 40 acre spacing operate in the field, of which 20 are producing wells and 15 are water injection wells.

The trapping mechanism in the Concho Bluff Queen Field appears to be a combination of stratigraphic and structural mechanisms (Fig. 7). The western extent of the field is delineated by an up-dip permeability barrier where the pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4) reservoir sandstone grades into a moderate reddish brown (10R 4/6) to dark reddish brown (10R 3/4) sandstone with evaporitic filled pores. The northern and southern limits of the field seem to be locally influenced by structural closure. The eastern side of the field is distinguished by an oil-water contact (Mear, 1964).

An analysis of wells which have displayed the greatest reservoir potential reveals an important relationship with the structural controls in the field. Although the structure map on top of the sandstones in the Upper Queen Formation displays significant closure, the trapping of the hydrocarbons also appears to be largely attributed to the complexity of the lithofacies. The wells with the greatest cumulative production are not located directly on the structural high, but rather slightly off of structure. When net isopachs of the Upper Queen sandstones are compared with production trends, there is no direct correlation between the thickness of the sandstone zones and the cumulative production. In fact, some wells with the thickest net sand along the edge of the field have very poor production due to the cementation of the pore spaces. Thus, secondary porosity from diagenesis within the individual facies seems to be the major controlling factor of the reservoir sandstones. These factors emphasize the importance of recognizing the types of lithofacies and understanding their influence on reservoir potential.

RESERVOIR PROPERTIES

A dramatic difference exists in the reservoir quality within the different facies of the Upper Queen Formation (Fig. 23). The Texaco Seaboard D #2 core, with measurements taken in 1 ft. (0.3 m) intervals, illustrates these reservoir characteristics (Fig. 24). The sandflat and saline sandflat facies have similar porosity that ranges from 8.5% to 26.1% with an average of 16.3%. The development of porosity is thought to be secondary in origin, developing from dissolution of cements and labile grains. The massive areas within these facies may also include the eolian sand sheet facies. Permeability throughout these facies varies from 0.1 md. to 220 md, but is usually 40 md. to 50 md. However, the siliciclastics in the mudflat and saline mudflat facies have permeability less than 0.3 md. Porosity in these facies range from 3.1% to 11.4%, with an average of 6.8%. Therefore, the mudflat and saline mudflat facies act as impermeable seals which bound each sandflat unit.

Of the 53 ft. of siliciclastics in this core, which is representative of the entire Upper Queen Formation, 36.5 ft. are from the sandflat and saline sandflat facies. These producing facies in this core have an average permeability of 22 md., resulting in a total observed natural capacity of 803 md-ft. The core report for this well also determined the original formation volume factor to be 1.28 barrels of saturated oil per barrel of stock tank oil. The sandflat and saline sandflat facies have an

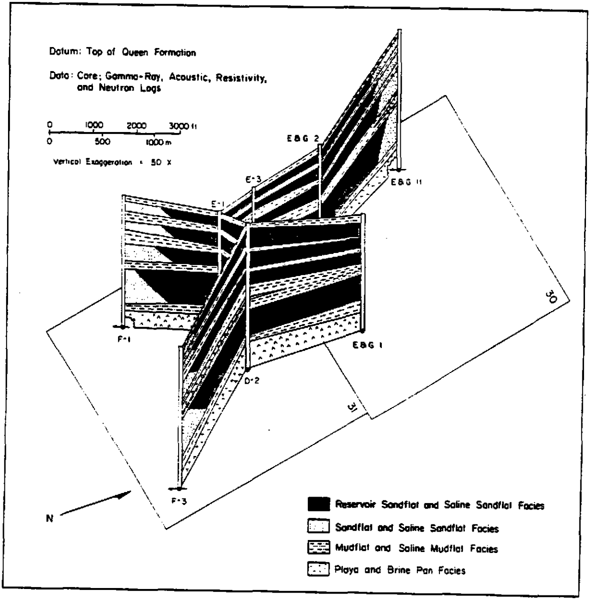


Figure 23: Fence diagram showing facies correlation and location of reservoir horizons within the Upper Queen sandstones.

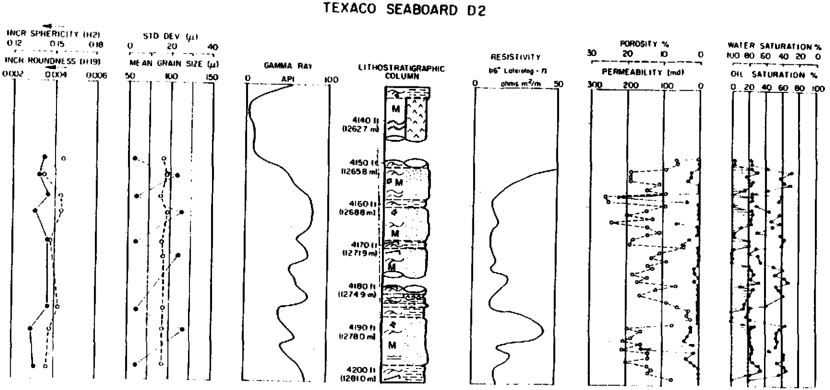


Figure 24: Lithostratigraphy, textural parameters, gamma-ray and resistivity log response, and reservoir properties of Texaco Seaboard D#2 well.

average water saturation of 42.3% of pore space, and an average residual oil saturation of 24.2% of pore space.

Estimates of the original volume of oil in place (N) for the Concho Bluff Queen Field can be calculated by the equation:

$$N = \frac{(7758)(P)(1-Sw)(A)(T)}{Bo}$$

where 7758 bbls. is the equivalent volume of 1 acre-ft., P is the porosity as a fraction of the bulk volume, Sw is the average water saturation as a fraction of the pore volume, A is the number of acres in the field, T is the average thickness in feet of the reservoir, and Bo is the initial formation volume factor of the reservoir (Craft and Hawkins, 1959). Thus, the original volume of oil in place (N) for the Concho Bluff Queen Field can be calculated using the reservoir properties of the Texaco Seaboard D #2 as follows:

$$N = \frac{(7758)(0.16)(0.58)(1600)(25)}{Bo}$$

$$N = 22.5 \times 10^6 \text{ bbls. of oil}$$

In the Concho Bluff Queen Field, the reservoir energy which enables the flow of hydrocarbons results from a combination of solution gas drive and artificial water drive. Solution gas drives are usually found in reservoirs which are sealed and completely filled with liquid (Pirson, 1958). As oil is produced and reservoir pressure is lowered, the light hydrocarbons separate from the liquid and form gas in pore spaces. A larger volume is occupied by these molecules when they are in the gas phase, and they partially offset the volume of oil produced as a result. The initial gas which develops from solution forms bubbles within the larger pore spaces and is usually immobile (Levorson, 1967).

In addition to solution gas drive, artificial water drive has played a major role in providing energy to move hydrocarbons through secondary recovery. As water is injected into the peripheral wells of the field, mobile oil which was not recovered from the solution gas drive is driven toward producing wells. The structural attitude of the field, a domal fold superimposed on an anticline, supplements this process by preferentially directing the hydrocarbons to the central wells of the field.

An interesting relationship can be drawn by visual inspection of the cores between those horizons which are productive and non-productive. The productive horizons, which often display oil stains, are usually pale yellowish brown (10YR 6/2) to moderate yellowish brown (10YR 5/4), whereas the non-productive facies are usually moderate reddish brown (10R 4/6) to dark reddish brown (10R 3/4). The red color of the non-reservoir rocks is thought to be associated with hematite and hematitic clay. Whether the hematite resulted from a desert origin (Walker, 1974) or was introduced into the desert (Van Houten, 1973), its presence is attributed to forming before deep burial. Thus, both hematite and hematitic clay originally existed in the reservoir rocks; however, they appear to have been removed by natural, solvent acids. During kerogen maturation, acids such as these are thought to be produced prior to hydrocarbon migration (Tissot et al., 1974).

PRODUCTION HISTORY

The reservoir sandstones of the Concho Bluff Queen Field have yielded 84 percent of their cumulative production since the implementation of secondary recovery methods. Several contributing factors are responsible for the success of the waterflood. Recognition of similar field characteristics in other Permian Basin fields may lead to substantial increases in their future production through secondary recovery.

The production history of the Concho Bluff Queen Field is divided into primary and secondary recovery (Fig. 25). Throughout the history of the field, the silt content of the sandflat facies greatly influenced the productivity of each well (Fig. 26). Wells drilled in sandflat facies which contained minor amounts of silt had the best production, for a low silt content permited the development of porosity and permeability needed for hydrocarbon migration.

The primary production stage covers from 1956 to 1965. During this time, annual production rates showed a steady increase through 1961, when a maximum of 186,197 bbls. of oil was recovered from 25 wells. However, annual production declined from these wells at a uniform rate until 1965 when 103,352 bbls. of oil were recovered. No gas recovery was reported in the primary production stage, and the cumulative production through 1965 was 1,144,264 bbls. of oil. The amount of original oil in place which can be produced from a reservoir during primary production is

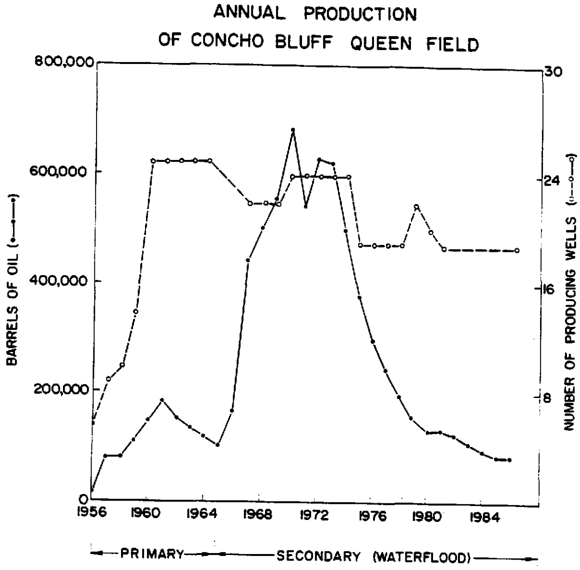


Figure 25: Historical production of Concho Bluff Queen Field, plotted annually, during primary and secondary recovery.

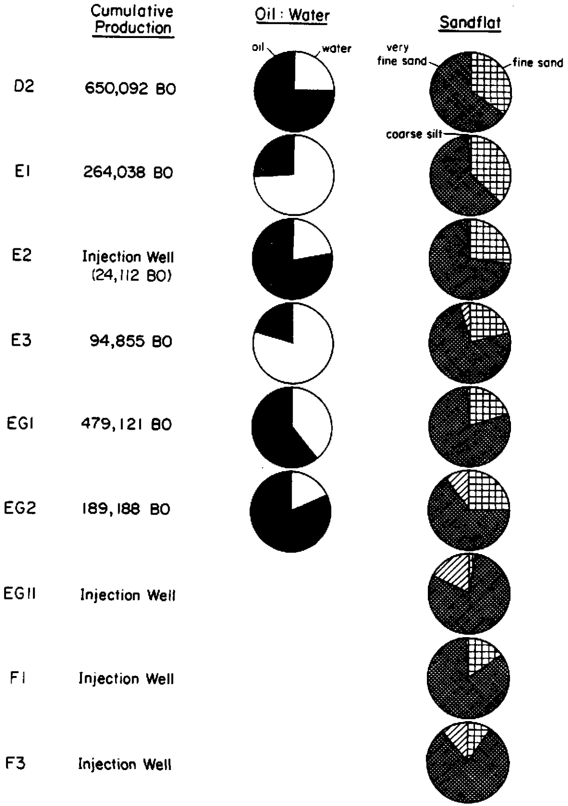


Figure 26: Pie diagrams comparing cumulative well production and corresponding sandflat grain-size fraction.

based on the natural reservoir drive mechanism. Recovery factors from solution gas drive, the drive mechanism for primary recovery of the field, are normally less than 30 percent (Bebout et al., 1987). Thus, the Concho Bluff Queen Field was an excellent candidate for waterflooding, since a vast amount of mobile oil remained in place after the primary recovery.

The second stage of production started in September of 1965 and is characterized by a successful waterflood, where annual production from 24 wells increased to a maximum of 685,488 bbls. of oil in 1970. Gas recovery during the waterflood was insignificant, consisting of annual production rates of 24 MCF of gas or less. The oil production decline curve associated with the secondary recovery appears hyperbolic in form. Cumulative oil production through July of 1988 was 7,229,623 bbls. (6,085,359 bbls. from secondary recovery). A peripheral waterflooding pattern was incorporated in the field due to its structural closure. In this arrangement, the injection wells are located at the outside boundary of the reservoir, and the oil is displaced toward the interior of the reservoir.

Several factors contributed to the impressive results from the waterflooding of the Concho Bluff Queen Field. The peripheral waterflood pattern, as mentioned above, is known to be the optimal pattern for maximum oil recovery with a minimum of produced water (Craig, 1974). The fact that Texaco was the sole operator of the field enabled such a pattern to be established. Since the waterflood was started when the field was relatively young, only 10 years old, the original reservoir pressures had been fairly well

In such a manner, the mobile oil continues to follow the path of least resistance, until it is recovered by a producing well (Slider, 1976).

Thus, the Concho Bluff Queen Field is an excellent model for secondary recovery. The reservoir contains homogeneous, very-fine grained sandstones with relatively uniform permeability. Low gravity hydrocarbons have been recovered in primary production through solution gas drive, leaving substantial quantities of mobile oil in place. The geometry of the producing facies is laterally continuous, and fluid migration is supplemented by the structural attitude of the field. These reservoir qualities are not unique to the field, and reservoirs with similar characteristics should be evaluated for waterflooding.

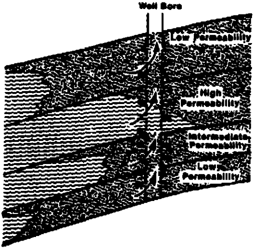


Figure 27: Diagrammatic illustration showing irregular water encroachment and early water breakthrough in a high permeability layer of reservoir rock (Clark, 1969).

CONCLUSION

The primary purpose of this thesis is to interpret the depositional environment of sandstones in the Upper Queen Formation in the Concho Bluff Queen Field and test the "wet", "dry", and "hybrid" models of deposition for Permian Basin shelf sandstones. A secondary purpose is to determine the influence of the different facies on hydrocarbon production, with a special emphasis on secondary recovery.

Four cycles of siliciclastic progradation/regression are contained in the Upper Queen Formation which represent deposition into a desiccating playa of a continental sabkha. The primary sequence of deposition was, from land to basin, eolian sand sheet, sandflat, mudflat, and playa. The level of the brine saturated water influenced the preservation of original sedimentary structures. In areas where the sandflat and mudflat have been haloturbated, they represent a saline sandflat and saline mudflat respectively. Included in the saline mudflat were brine pans which formed in localized depressions and collected terrestrial water.

This interpretation of environments is based on primary rock properties (grain size, sorting, lithology, and sedimentary structures) from nine cores. Sandstone deposition occurred during a low stand of the playa and was later truncated by an expansion of the playa. The changes in the water level of the playa are thought to be associated with a major sea-level fluctuation. Based on these premises, the sandstones in the Concho Bluff Queen Field unequivocally support the "dry" model for their deposition. However, due to the pervasiveness of sandstones in the Queen Formation, a complete understanding of their depositional history can only be attained through an extensive regional investigation.

The eolian sand sheet, sandflat, and saline sandflat are generally the reservoir facies, whereas the mudflat and saline mudflat are the non-reservoir facies. The Concho Bluff Queen Field has yielded 84% of its cumulative production (as of July 88) through waterflooding methods. The efficiency of its secondary recovery is largely attributed to the properties of the reservoir sandstone, which is homogeneous and laterally continuous. Furthermore, the sandstone has a relatively uniform permeability which enables the water drive to sweep the reservoir without preferential breaks. Additionally, maintained reservoir pressure and optimal injection pattern supplemented the water drive.

REFERENCES CITED

Allen, J.R.L., 1985, Principles of physical sedimentology: Boston, George Allen and Unwin, 272 p.

Arthurton, R.S., 1973, Experimentally produced halite compared with Triassic layered halite-rock from Cheshire, England: Sedimentology, v. 20, p. 145-160.

Ball, S., J.W. Roberts, J.A. Norton, and W.D. Pollard, 1971, Queen Formation (Guadalupian, Permian) outcrops of Eddy County, New Mexico, and their bearing on recently proposed depositional models: AAPG Bulletin, v. 55, p. 1348-1355.

Bates, R.L., 1942, Lateral gradation in the Seven Rivers Formation, Rocky Arroyo, Eddy County, New Mexico: AAPG Bulletin, v. 26, p. 80-99.

Bebout, D.G., F.J. Lucia, C.R. Hocott, G.E. Fogg, and G.V. Stoep, 1987, Characterization of the Grayburg reservoir, university lands Dune Field, Crane County, Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigation No. 168, 98 p.

Brown, P.J., R. Ehrlich, and D. Colquhoun, 1980, Origin of patterns of quartz sand types on the southeastern United States continental shelf and implications on contemporary shelf sedimentation: Jour. Sed. Petrology, v. 50, p. 1140-1154.

Busch, D.A., 1971, Prospecting for stratigraphic traps, in Sandstone exploration techniques: AAPG Memoir 21, p. 72-107.

Candalaria, M.P., 1985, Inferred tectonic control of Permian hemi-cyclic sandstone-carbonate sedimentation, Northwestern Shelf, Delaware Basin, New Mexico, in Pause, P. ed., Permian Carbonate/Clastic Sedimentology, Guadalupe Mountains: Analog for Shelf and Basin Reservoirs: Permian Basin Section of SEPM, p. 7-8.

Clark, N.J., 1969, Elements of petroleum reservoirs: Texas, The American Institute of Mining, Metallurgical, and Petroleum Engineers, 250 p.

Craft, B.C., and M.F. Hawkins, 1959, Applied petroleum reservoir engineering: Englewood Cliffs, New Jersey, Prentice-Hall, 437 p.

Craig, F.F., 1974, Waterflooding, in Dowd, W.T., ed., Secondary and tertiary oil recovery processes: Oklahoma, Interstate Oil Compact Commission, p. 1-30.

Crawford, B.A. and J.B. Dunham, 1982, Evaporite sedimentation in the Permian Yates Formation, Central Basin Platform, Andrews County, west Texas, in Handford, C.R., R.G. Loucks, and G.R. Davies, eds., Depositional and diagenetic spectra of evaporites - a core workshop: SEPM workshop no. 3, p. 238-275.

Crowell, J.C., 1982, Continental glaciation through geologic time, in Climate in earth history, Studies in geophysics: National Acadamy Press, p. 77-82.

Curray, J. 1960, Sediments and history of Holocene transgression, continental shelf, northwest Gulf of Mexico, in Shepard, F. P., F. B. Phleger, and T. J. Van Andel, eds., Recent Sediments, Northwest Gulf of Mexico: Tulsa, AAPG, p. 221-266.

Dean, W. and R. Anderson, 1982, Continuous subaqueous deposition of the Permian Castille evaporites, Delaware Basin, Texas and New Mexico, in Handford, C.R., R.G. Loucks, and G.R. Davies, eds., Depostional and diagentic spectra of evaporites - a core workshop: SEPM core workshop no. 3, p. 324-353.

Dolton, G. L., A.B. Coury, S.E. Frezon, K. Robinson, K.L. Varnes, J.M. Wunder, and R.W. Allen, 1979, Estimates of undiscovered oil and gas, Permian Basin, west Texas and southeast New Mexico: USGS Open-File Report 79-838, 118 p.

Ehrlich, R. and B. Weinberg, 1970, An exact method for characterization of grain shape: Jour. Sed. Petrology, v 40, p. 205-212.

Esteban M., and L. C. Pray, 1977, Origin of the pisolite facies of the shelf crest, in Upper Guadalupian facies, Permian reef complex, Guadalupe Mountains, New Mexico and west Texas: Permian Basin Section SEPM 1977, Pub. 77-16, v. 1, p. 479-484.

Eugster, H.P., and L.A. Hardie, 1975, Sedimentation in an ancient playa-lake complex: the Wilkins Peak Member of the Green River Formation of Wyoming: Geol. Soc. of Amer. Bulletin, v. 85, p. 319-334.

Fico, C., 1980, Automated particle shape analysis: development of a micro-processor-controlled image analysis system: Masters Thesis, University of South Carolina, Columbia, South Carolina, 60 p.

Flint, R.F., and G. Bond, 1968, Pleistocene sand ridges and pans in Western Rhodesia: Geol. Soc. of Amer. Bulletin, v. 79, p. 299-313.

Fracasso, M.A. and S.D. Hovorka, 1986, Cyclicity in the Middle Permian San Andres Formation, Palo Duro Basin, Texas Panhandle: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 156, 48 p.

Fryberger, S.G., A.M. Al-Sari, and T.J. Clisham, 1983, Eolian dune, interdune, sandsheet, and siliciclastic sabkha sediments of an offshore prograding sand sea, Dhahran area, Saudi Arabia: AAPG Bulletin, v. 67, p. 280-312.

Galley, J.E., 1958, Oil and geology in the Permian Basin of Texas and New Mexico, in L.G. Weeks, ed., Habitat of Oil: AAPG, p. 395-446.

Galloway, W.E., and D.K. Hobday, 1983, Terrigenous clastic depositional systems: applications to petroleum, coal, and uranium exploration: New York, Springer-Verlag, 423 p.

Glennie, K.W., 1970, Desert sedimentary environments, in Developments in sedimentology, v. 14: New York, Elsevier Scientific Publishing Co., 222 p.

Glennie, K.W., 1972, Permian Rotligendes of northwest Europe interpreted in light of modern desert sedimentation studies: AAPG Bull., v. 56, p. 1048-1071.

Glennie, K.W., 1987, Desert sedimentary environments, present and past - a summary: Sed. Geology, v. 50, p. 135-165.

Guidish, T.M., I. Lerche, C.G. Kendall, and J.J. O'Brien, 1984, Relationship between eustatic sea-level changes and basement subsidence: AAPG Bulletin, v. 68, p. 164-177.

Gunatilaka, A. and S. Mwango, 1987, Continental sabkha pans and associated nebkhas in southern Kuwait, Arabian Gulf, in Frostick, L. and I. Reid, eds., Desert sediments: ancient and modern: Geol. Soc. Spec. Pub. 35, p. 187-203.

Haines, J. and J. Mazzullo, 1987: The original shapes of quartz silt grains: a test of the validity of the use of quartz grain shape analysis to determine the sources of terrigenous silt in marine sedimentary deposits: Marine Geology, v. 78, p. 227-240.

Handford, C.R., 1981, Coastal sabkha and salt pan deposition of the Lower Clear Fork Formation (Permian), Texas: Jour. of Sed. Petrology, v. 51, p. 761-778.

Hardie, L.A., J.P. Smoot, and H.P. Eugster, 1978, Saline lakes and their deposits: a sedimentological approach: Int. Assoc. of Sed. Spec. Pub. 2, 48 p.

Hayes, P.T., 1964, Geology of the Guadalupe Mountains, New Mexico: U. S. Geol. Survey Prof. Paper 446, 69 p.

Heward, A.P., 1978, Alluvial fan sequence and mega-sequence models: with examples from Westphalian D-Stephanian B coalfields, northern Spain, in Miall, A.D., ed., Fluvial sedimentolgy: Can. Soc. Petrol. Geol. Mem. 5, p. 669-702.

Hills, J.M., 1972, Late Palezoic sedimentation in West Texas Permian Basin: AAPG Bulletin, v. 56, p. 2302-2322.

Hobday, D. and R. Morton, 1984, Lower Cretaceous Shelf storm deposits, northeast Texas, in Tillman R. and C. T. Siemers, eds., Siliciclastic Shelf Sediments: Tulsa, SEPM Spec. Pub. no. 34, p. 205-214.

Holley, C., and J. Mazzullo, 1988, The lithology, depositional environments, and reservoir properties of sandstones in the Queen Formation, Magutex, McFarland North, and McFarland Queen Fields, Andrews County, Texas, in Cunningham B., ed., Permian and Pennsylvanian stratigraphy, Midland Basin, West Texas: Studies to aid hydrocarbon exploration: Permian Basin Section SEPM Spec. Pub. 88-28, p. 55-63.

Howard, G.C. and C.R. Fast, 1970, Hydraulic fracturing: New York, Society of Petroleum Engineers of AIME, 203 p.

Hsu, K.J., and C. Siengenthaler, 1969, Preliminary experiments on hydrodynamic movement induced by evaporation and their bearing on the dolomite problem: Sedimentology, v. 12, p. 11-25.

Jacka, A.D., 1967, Guadalupian depositional cycles of the Delaware basin and the Northwest Shelf (abs), in Cyclic sedimentation in the Permian basin: West Texas Geol. Soc. Symposium, p. 49-50.

Jacka, A.D. and L.A. Franco, 1974, Deposition and diagenesis of Permian evaporites and associated carbonates and clastics on shelf areas of the Permian basin, in Fourth international symposium on salt: Cleveland, Ohio, Northern Ohio Geol. Soc., p. 67-89.

Kendall, C.G.St.C., 1969, An environmental re-interpretation of the Permian evaporite/carbonate shelf sediments of the Guadalupe Mountains: Geol. Soc. America Bulletin, v. 80, p. 2503-2526.

Kendall, A.C., 1985, Evaporites, in R.G. Walker, ed., Facies models: Ontario Geological Association of Canada p. 259-295.

King, P.B., 1942, Permian of west Texas and southeastern New Mexico: AAPG Bulletin, v. 26, p. 535-763.

Kinsman, D.J.J., 1966, Gypsum and anhydrite of Recent age, Trucial Coast, Persian Gulf, in Second symposium on salt: Northern Ohio Geol. Soc., v. 1, p. 302-326.

Kinsman, D.J.J., 1969, Modes of formation, sedimentary associations, and diagnostic features of shallow-water and supratidal evaporites: AAPG Bulletin, v. 53, p. 830-840.

Krumbein, W.C. 1942, The effect of abrasion on the size, shape, and roundness of sedimentary particles: Jour. Sed. Petrology, v. 11, p. 64-72.

Levorsen, I., 1967, Geology of petroleum, 2nd ed.: W. H. Freeman and Company, San Francisco, 724 p.

Lowenstein, T.K., and L.A. Hardie, 1985, Criteria for the recognition of salt-pan evaporites: Sedimentology, v. 32, p. 627-644.

Lowenstein, T.K., 1987, Evaporite depositional fabrics in the deeply buried Jurassic Buckner Formation, Alabama: Jour. Sed. Petrology, v. 57, p. 108-116.

Lucia, F.J., 1968, Recent sediments and diagenesis of South Bonaire, Neetherlands Antilles: Journal of Sedimentary Petrology, v. 38, p. 845-858.

Malisce, A., 1988, The environment of deposition and reservoir characteristics of the Shattuck Member of the Queen Formation (Guadalupian, Permian) at Caprock Field, Chavez County, New Mexico: Masters Thesis, Texas A&M University, College Station, Texas, 160 p.

Mazzullo, J., and R. Ehrlich, 1983, Grain-shape variation in the St. Peter Sandstone: A record of eolian and fluvial sedimentation of an early paleozoic cratonic sand sheet: Jour. Sed. Petrology, v. 53, p. 105-119.

Mazzullo, J., and K.D. Withers, 1984, Sources, distribution and mixing of Late Pleistocene and Holocene sands on the south Texas continental shelf: Jour. Sed. Petrology, v. 54, p. 1319-1334.

Mazzullo, J., 1985, Depositional history and stratigraphic significance of sheet sandstones of the Perman Basin: GSA annual meeting, abs. with program, p. 686.

Mazzullo, J., and S.K. Kennedy, 1985, Automated measurements of the nominal section diameters of individual sedimentary particles: Jour. Sed. Petrology, v. 55, p. 593-595.

Mazzullo, J., 1986, Sedimentology, stratigraphy, and reservoir characteristics of Guadalupian shelf sandstones on the Central Basin Platform and Northwestern Shelf of the Permian Basin: Gulf Coast Section of SEPM 7th annual meeting, abs. with program, p. 9.

McGowen, J.H., and C.G. Groat, 1971, Van Horn sandstone, west Texas: an alluvial fan model for mineral exploration: The Univ. of Texas at Austin, Bureau of Economic Geology, Reptort of Invest. No 72, p. 48

McKee, E.D., 1965, Experiments on ripple lamination, <u>in</u> Primary sedimentary structures and their hydrodynamic interpretation: SEPM Spec. Pub. 12, p. 66-83.

McKee, E.D., 1967, Paleotectonic investigations of the Permian System in the United States: USGS Prof. Paper No. 515, p. 237

Mear, C.E., 1964, Concho Bluff Queen Field, in Oil and gas fields in west Texas: West Texas Geol. Soc. Symposium, p. 92-144.

Meissner, F.F., 1967, Cyclical sedimentation in the Permian strata of the Permian Basin (abs.), in Cyclical sedimentation in the Permian Basin: West Texas Geol. Soc. Symposium, p. 37-38.

Meissner, F.F., 1972, Cyclic sedimentaion in Middle Permian strata of the Permian Basin, West Texas and New Mexico, in J. Elam and S. Chuber, eds., Cyclic sedimentation in the Permian Basin (second edition): West Texas Geol. Soc., p. 203-231.

Moran, Q.R., 1954, Proposed type sections for the Queen and Grayburg Formations of Guadalupian Age in the Guadalupe Mountains, Eddy County, New Mexico (abs.): New Mex. Geol. Soc. Guidebook 5th Field Conf., 1954, p. 147-150.

Nance, H.S., 1988, Interfingering of evaporites and red beds: an example from the Queen/Grayburg Formation, Texas: Sed. Geology, v. 56, p. 357-381.

Neal, J.T., 1975, Playas and dried lakes - occurrence and development: Benchmark papers in geology, v. 20, 411 p.

Neese, D.A., and A.H. Schwartz, 1977, Facies mosaic of the Upper Yates and Lower Tansill Formations, Walnut and Rattlesnake Canyons, Guadalupe Mountains, New Mexico, in Upper Guadalupian facies, Permian reef complex, Guadalupe Mountains, New Mexico and west Texas: Permian Basin Section SEPM, Special Pub. 77-16, p. 437-450.

Newell, N.D., J.K. Rigby, A.G. Fisher, A.J. Whiteman, J.E. Hickox, and J.S. Bradley, 1953, The Permian Reef complex of the Guadalupe mountains region, Texas and New Mexico: San Francisco, W.H. Freeman and Co., 236 p.

Oriel, S., D.A. Myer, and E.J. Crosby, 1967, Paleotectonic investigation of the Permian system in the United States - west Texas Perman Basin region: U.S. Geol Survey Prof. Paper 515, p. 21-60.

Parkash, B., A.K. Awasthi, and K. Gohain, 1983, Lithofacies of the Markanda terminal fan, Kurukshetra district, Haryana India: Inter. Assoc. of Sed. Spec. Pub. 6, p. 337-344.

Phleger, F.B., 1969, A modern evaporite deposit in Mexico: AAPG Bulletin, v. 53, p. 824-829.

Pirson, S.J., 1958, Oil reservoir engineering: New York, McGraw-Hill, 735 p.

Pittman, W.C., III, 1978, Relationship between eustacy and stratigraphic sequences on passive margins: Geol. Soc. of Amer. Bulletin, v. 89, p. 1389-1403.

Pray, L.C., 1977, The all wet constant sea level hypothesis of the Upper Guadalupian shelf strata, Guadalupe Mountains, New Mexico and Texas, in Upper Guadalupian facies Permian reef complex, Guadalupe Mountains, New Mexico and West Texas: Permian Basin Section SEPM Publication 77-16, v. 1, 433 p.

Presley, M.W. and K.A. McGillis, 1982, Coastal evaporite and tidal-flat sediments of the Upper Clear Fork and Glorieta Formations, Texas Panhandle: The Univ. of Texas at Austin, Bureau of Economic Geology Report of Invest. No. 115, 50 p.

Purser, B.H., 1985, Coastal evaporite systems, in Friedman, G.M., and W.E. Krumbein, eds., Hypersaline ecosystems: New York, Springer-Verlag, p.72-102.

Rittenhouse, G., 1943, A visual method of estimating two-dimensional sphericity: Jour. Sed. Petrology, v. 13, p. 79-81.

Rust, B.R., 1978, Depositional models for braided alluvium, in Miall, A.D., ed., Fluvial sedimentology: Can. Soc. Petrol. Geol. Mem. 5, p. 605-625.

Sarg, F.J., 1981, Petrology of the carbonate-evaporite facies transition of the Seven Rivers Formation (Guadalupian, Permian), southeast New Mexico: Jour. Sed. Petrology, v.51, p.73-96.

Sarg, J.F., and Lehman, P.J., 1986, Lower-middle Guadalupian facies and stratigraphy, San Andres/Guadalupian Formations, Permian Basin, Guadalupe Mountains, New Mexico, in Moore, G.E., and G.L.

Wilde, eds., Lower and middle Guadalupian facies, stratigraphy, and reservoir geometries, San Andres/Grayburg Formations - Guadalupe Mountains, New Mexico and Texas: Permian Basin Section , SEPM Pub. No. 86-26, p. 135-138.

Schmidt, V., 1977, Inorganic and organic reef growth and subsequent diagenesis in the Permian Capitan reef complex, Guadalupe Mountains, Texas, New Mexico and Texas: Permian Basin Section SEPM, Pub. 77-16, p. 93-132.

Schultz, D.J., 1980, The effect of hydroflouric acid on quartz shape - Fourier grain shape analysis: Jour. Sed. Petrology, v. 50, p. 644-645.

Shearman, D.J., 1966, Origin of marine evaporites by diagenesis: Trans. Inst. Min. Metall., v. 75, p. 208-215.

Shearman, D.J., 1978, Evaporites of coastal sabkhas, <u>in</u> Dean, W. E. and B. C. Schreiber, eds., Marine evaporites: SEPM Short Course no. 4, p. 6-42.

Siegel, J., 1989, The lithology, environment of deposition, and diagenesis of the Shattuck Member of the Queen Formation (Guadalupian, Permian) at Central Corbin Field, Lea County, New Mexico: Masters Thesis, Texas A&M University, College Station, Texas, 138 p.

Silver, B.A. and R.G. Todd, 1969, Permian cyclic strata of northern Midland and Delaware Basins, west Texas and southeastern New Mexico: AAPG Bulletin, v. 53, p. 2223-2251.

Slider, H.C., 1976, Practical petroleum reservoir engineering methods: Tulsa, Petroleum Publishing Company 559 p.

Smith, D.B., 1971, Possible displacive halite in the Permian Upper Evaporite Group of Northeast Yorkshire: Sedimentology, v. 17, p. 221-232.

Smith, D.B., 1974, Sedimentation of Upper Artesia (Guadalupian) cyclic shelf deposits of northern Guadalupe Mountains, New Mexico: AAPG Bulletin, v. 58, p. 1699-1730.

Solohub, J.T., and J.E. Klovan, 1970, Evaluation of grain-size parameters in lacustrine environments: Journ. Sed. Petrology, v. 40, p. 81-101.

Swift, D.J.P., J. Kofoed, F. Saulsbury, and P. Sears, 1972, Holocene evolution of the shelf surface, central and southern Atlantic shelf of North America, in Swift, D. J. P., D. B. Duane, and O. H. Pilkey, eds., Shelf sediment transport: processes and patterns: Stroudsburg, Dowden, Hutchinson, and Ross, p. 499-574.

Tait, D.B., J.L. Ahlen, A. Gordon, G.L. Scott, W.S. Motts, and M.E. Spitler, 1962, Artesia Group of New Mexico and west Texas: AAPG Bulletin, v. 46, p. 504-517.

Tissot, B., B. Durand, J. Espitalie and A. Combaz, 1974, Influence of nature and diagenesis of organic matter in formation of petroleum: AAPG Bulletin, v. 58, p. 499-506.

Valentine, J.W., and E. Moores, 1972, Global tectonics and the fossil record: Journal of Geology, v. 80, p. 167-184.

Van Houten, F.B., 1973, Origin of red beds a review: 1961-1972: Ann. Rev. Earth Planer Sci., p. 39-61.

Veevers, J.J. and C.M. Powell, 1987, Late Paleozoic glacial episodes in Gonwandaland reflected in transgressive-regressive depositional sequences in Euroamerica: Geol. Soc. Amer. Bulletin, v. 98, p. 475-487.

Visher, G.S., 1969, Grain-size distribution and depositional processes: Journ. Sed. Petrology, v. 39, p. 1074-1106.

Walker, T.R., 1974, Formation of red beds in moist tropical climates - a hypothesis: Geol. Soc. of Amer. Bulletin, v. 85, p. 633-638.

Wanless, H. R., and J. R. Cannon, 1966, Late Paleozoic glaciation: Earth-Sci. Rev., v. 1, p. 247-286.

Ward, R.F., C.S. Kendall, and P.M. Harris, 1986, Upper Permian (Guadalupian) facies and their association with hydrocarbons - Permian Basin, west Texas and New Mexico: AAPG Bulletin, v. 70, p. 239-262.

APPENDIX

Field Summary

CONCHO BLUFF QUEEN FIELD

INTRODUCTION

Location:	Crane Co., Tx., T4S, BLK 42 and 43, Western Midland Basin
Regional Tectonics:	Anticline with Dome
Regional Paleosetting:	Continental Sabkha with Playa

DISCOVERY WELL

Name:	Texaco #1-31
Location:	Sec. 31, T4S, BLK 42
Completion Date:	July, 1956

FIELD DATA

# of Producing Wells:	20 in 1988
# of Injection Wells:	15 in 1988
Cumulative Production	7,229,623 bbls. of oil 1,144,264 bbls. (primary) 6,085,359 bbls. (secondary)
Depth:	4100 ft. (to top of Upper Queen Sandstone)
Oil/Water Contact:	-1450 ft.
Initial Pressure:	1680 psi @ - 1350 ft.

PETROPHYSICS

Porosity:	9% - 26%, avg. 16.5%
Permeability:	1 md. - 1200 md., avg. 50 md.
Residual Saturation:	So = 24%, Sw = 43%
API Gravity	28 - 32 degrees, avg. 31 degrees

RESERVOIR ROCKS

Age:	Permian (Guadalupian)
Stratigraphic Units:	Upper Queen Sandstones (4 horizons)
Lithology:	Very Fine-grained Arkosic Sandstone
Thickness:	19 ft. - 37 ft., avg. 25 ft.
Nature of Trap:	Combination Anticlinal Fold and Facies Diagenesis
Drive Mechanism:	Combination Water and Dissolution Gas
Productive Facies:	Eolian Sand Sheet, Sandflat, and Saline Sandflat
Non-productive Facies:	Mudflat and Saline Mudflat

CORE DESCRIPTION
Texaco Seaboard "D" #2
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4133.0 - 4203.0 feet

Depth ft (m)	Thickness ft (m)	Description
4203.0 (1281.9)	0.3 (0.09)	ANHYDRITE: medium bluish gray (5B 5/1); mostly massive; some faint laminae are slightly wavy and continuous; upper contact is gradational.
4202.7 (1281.8)	2.7 (0.82)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to grayish red (10R 4/2); most laminae are wavy and discontinuous with argillaceous material; possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at 4202.0 ft. (1281.6 m); laminae are indistinct from 4200.9 ft. (1281.3 m) to top of section; isolated anhydrite nodules up to 1.2 cm thick oriented along bedding planes; anhydrite nodules decrease in abundance toward top of section; upper contact is gradational.

Texaco Seaboard "D" #2 continued

4200.0 (1281.0)	1.1 (0.34)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); irregular patterns of moderate yellowish brown (10YR 5/4) in upper half of section; laminae are wavy and discontinuous with argillaceous material; isolated anhydrite nodules up to 0.6 cm thick oriented along bedding planes; upper contact is gradational.
4198.9 (1280.7)	11.5 (0.60)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4); minor oil stains throughout section; section appears mostly massive; 3 bedsets present consisting of alternating massive beds and beds with faint planar, horizontal, and continuous laminae from base to 4197.0 ft. (1280.1 m); relict laminae are slightly wavy and discontinuous where visible from 4197.0 ft. (1280.1 m) to top of section based on preferential oil stains; anhydrite nodules less than 0.2 cm thick near top of section; upper contact is gradational.

Texaco Seaboard "D" #2 continued

4187.4 (1277.2)	2.4 (0.73)	SILTSTONE: coarse-grained silt; pale red (10R 6/2) with irregular patterns of moderate yellowish brown (10YR 5/4); light bluish gray (5B 7/1) area from 4186.4 ft. to 4186.2 ft. (1276.9 -1276.8 m); section appears mottled due to reduction lines; laminae are wavy and discontinuous from base to 4186.8 ft. (1277.0 m) and from 4185.9 ft. (1276.7 m) to top of section; laminae are indistinct from 4186.8 ft. to 4185.9 ft. (1277.0 - 1276.7 m); possible salt ridge structure at 4186.1 ft. (1276.8 m); upper contact is not present.
4185.0 (1276.4)	1.1 (0.34)	SANDSTONE: very fine grained; pale yellowish brown(10YR 6/2); laminae are organic rich with a normal textural grading and are planar, horizontal, and continuous from base to 4184.8 ft. (1276.4 m); laminae are slightly wavy and continuous at 4184.8 ft. (1276.4 m); cross-ripple bed inclined up to 7 degrees at 4184.7 ft. (1276.3 m); laminae are slightly wavy and discontinuous from 4184.6 ft. (1276.3 m) to top of section; mud rip-up clasts are present at 4184.7 ft. (1276.3 m); desiccation cracks at 4184.4 ft. (1276.2 m); several possible salt ridge structures are present in upper half of section; upper contact is gradational.

Texaco Seaboard "D" #2 continued

4183.9 (1276.1)	0.9 (0.27)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); most laminae are wavy and discontinuous with argillaceous material; laminae inclined at 15 degrees toward top of section due to slumping from overburden; possible algal material with crenulate and continuous laminae that are organic rich in light bluish gray (5B 7/1) area at top of section; anhydrite nodules up to 0.3 cm thick oriented along bedding planes; microfractures filled with anhydrite throughout section; upper contact is sharp and crenulate.
4183.0 (1275.8)	0.5 (0.15)	ANHYDRITE: pale blue (5PB 7/2); mostly massive with a few faint laminae that are slightly wavy and continuous; individual laminae are up to 0.9 cm thick where discernable; upper contact is sharp and slightly wavy.
4182.5 (1275.7)	0.5 (0.15)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); most laminae are wavy and discontinuous with argillaceous material; possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at base of section; microfractures filled with anhydrite present; abundant anhydrite nodules less than 0.2 cm thick throughout section; upper contact is not present.

Texaco Seaboard "D" #2 continued

4182.0 (1275.5)	6.0 (1.83)	CORE MISSING
4177.0 (1274.0)	4.2 (1.28)	SANDSTONE: very fine grained; pale yellowish brown (10YR 6/2) with minor oil stains; irregular patterns of moderate yellowish brown (10YR 5/4) from 4174.0 ft. (1273.1 m) to top of section; poor recovery from 4177.0 ft. to 4174.0 ft. (1274.0 - 1273.1 m); most laminae are indistinct; relict laminae are slightly wavy and discontinuous from 4174.0 ft. (1273.1 m) to top of section based on preferential oil stains; several microfractures with oil stains present throughout section; upper contact is not present.
4172.8 (1272.7)	1.4 (0.43)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); irregular patterns of moderate yellowish brown (10YR 5/4) oriented primarily along bedding planes; most laminae are wavy and discontinuous with a few slightly wavy and continuous ones present; argillaceous material increases toward top of section; several possible salt ridge structures in upper half of section; upper contact is gradational.

Texaco Seaboard "D" #2 continued

4171.4 (1272.3)	2.3 (0.70)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to blackish red (5R 2/2); most laminae are wavy and discontinuous with argillaceous material; possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at 4169.5 ft. (1271.2 m); microfractures filled with anhydrite at 4171.0 ft. (1272.2 m); upper contact is gradational.
4169.1 (1271.6)	3.1 (0.95)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4); base of section is heavily oil stained; laminae are mostly indistinct; some relict laminae are slightly wavy and discontinuous from 4168.0 ft. (1271.2 m) to top of section based on preferential oil stains; upper contact is gradational.
4166.0 (1270.6)	1.8 (0.55)	SANDSTONE: very fine grained; irregular patterns of dark reddish brown (10R 3/4) and moderate yellowish brown (10YR 5/4); laminae are wavy and discontinuous with argillaceous material; upper contact is gradational.

Texaco Seaboard "D" #2 continued

4164.2 (1270.1)	3.1 (0.95)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4); oil stains throughout section; laminae are wavy and discontinuous from base to 4162.0 ft. (1269.4 m) and from 4161.7 ft. (1271.0 m) to top of section; laminae are indistinct from 4162.0 ft. to 4161.7 ft. (1269.4 - 1271.0 m); possible salt ridge structure at base of section; anhydrite nodules up to 0.9 cm thick oriented along bedding planes at top of section; upper contact is gradational.
4161.1 (1269.1)	2.1 (0.64)	SILTY SANDSTONE: very fine grained; dark reddish brown (10R 3/4) with irregular patterns of moderate yellowish brown (10YR 5/4); most laminae are wavy and discontinuous with a few continuous ones present; possible algal material with wavy and continuous laminae in light bluish gray (5B 7/1) area at top of section; upper contact is not present.

Texaco Seaboard "D" #2 continued

4159.0 (1268.5)	8.3 (2.53)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) with oil stains; irregular patterns of dark reddish brown (10R 3/4) from 4155.8 ft. to 4155.3 ft. (1267.5 - 1267.4 m); poor recovery from 4159.0 ft. to 4156.0 ft. (1268.5 - 1267.6 m); relict laminae are slightly wavy and continuous from 4159.0 ft. to 4156.0 ft. (1268.5 - 1267.6 m) based on preferential oil stains; laminae are slightly wavy and discontinuous from 4155.8 ft. to 4154.2 ft. (1267.5 - 1267.0 m) and from 4151.5 ft. (1266.2 m) to top of section; laminae are indistinct from 4154.2 ft. to 4151.5 ft. (1267.0 - 1266.2 m); randomly dispersed and isolated medium-grained quartz grains from 4152.2 ft. (1266.4 m) to top of section; anhydrite nodules up to 0.5 cm thick oriented along bedding planes from 4152.2 ft. (1266.4 m); anhydrite nodules less than 0.2 cm thick in upper half of section; upper contact is gradational.

Texaco Seaboard "D" #2 continued

4150.7 (1266.0)	0.7 (0.21)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); lenticular patterns of moderate yellowish brown (10YR 5/4) oriented along bedding planes; most laminae are wavy and discontinuous with a few continuous ones present; laminae are accentuated by argillaceous material; upper contact is not present.
4150.0 (1265.8)	6.0 (1.83)	CORE MISSING
4144.0 (1263.9)	9.1 (2.78)	ANHYDRITE: light bluish gray (5B 7/1) to medium bluish gray (5B 5/1); dark gray (N 3) from 4142.8 ft. to 4141.0 ft. (1263.6 - 1263.0 m); faint laminae are slightly wavy and continuous from base to 4142.9 ft. (1263.6 m); some halite filled inclusions up to 0.7 cm thick from base to 4142.9 ft. (1263.6 m); anhydrite laminae are crenulate with interlaminations of dolomitic mudstone from 4142.9 ft. to 4140.1 ft. (1263.6 - 1262.7 m), mudstone laminae are wavy and discontinuous and often contain interstitial anhydrite nodules; anhydrite is nodular mosaic from 4140.1 ft. to 4136.2 ft. (1262.7 m - 1261.5 m); anhydrite is massive from 4136.2 ft. (1261.5 m) to top of section; upper contact is gradational.

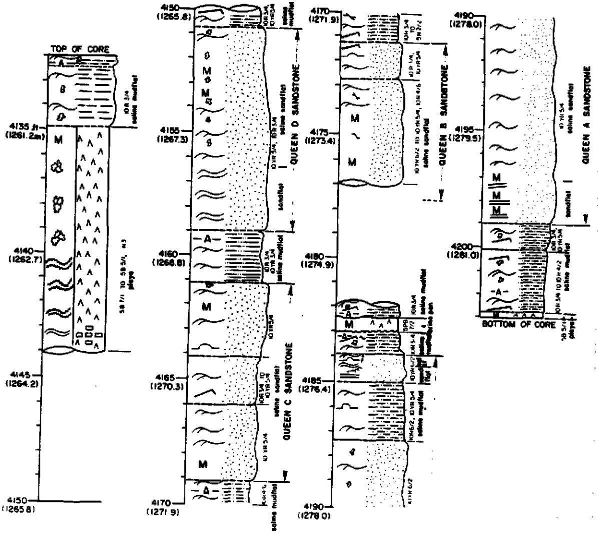
Texaco Seaboard "D" #2 continued

4134.9 (1261.1)	2.3 (0.70)	MUDSTONE: dark reddish brown (10R 3/4); laminae are wavy and discontinuous; abundant anhydrite nodules up to 3.8 cm thick oriented along bedding planes; upper contact is gradational.
4132.6 (1260.4)	0.6 (0.18)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); most laminae are wavy and discontinuous; possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at 4132.6 ft. (1260.4 m); isolated anhydrite nodules up to 1.2 cm thick oriented along bedding planes at top of section.

GRAIN SIZE AND SHAPE ANALYSIS
Texaco Seaboard "D" #2
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4133.0 - 4203.0 feet

Depth (ft./m)	Mean Size (microns)	Std. Dev. (microns)	Sphericity (H2)	Roundness (H19)
4150.0/1265.8	56.73	16.81	.15579	.00349
4153.5/1266.8	108.91	19.20	.14033	.00330
4159.5/1268.6	54.26	14.29	.15458	.00376
4163.0/1270.0	109.82	18.61	.15460	.00313
4170.0/1271.9	58.69	16.97	.14777	.00376
4173.5/1272.9	109.23	18.27	.14740	.00338
4186.5/1276.9	60.35	17.60	.15340	.00365
4191.0/1278.3	115.76	16.52	.14780	.00299
4199.5/1280.8	60.76	19.45	.14493	.00311

TEXACO SEABOARD D 2



CORE DESCRIPTION
Texaco Seaboard "E" #1
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4120.0 - 4156.0 feet

Depth ft (m)	Thickness ft (m)	Description
4156.0 (1267.6)	13.1 (4.00)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) with some irregular patterns of dark reddish brown (10R 3/4); minor oil stains throughout section; section is massive with a mottled appearance due to reduction; faint laminae are wavy and discontinuous where discernable; some relict laminae are planar and horizontal from 4149.6 ft. to 4147.9 ft. (1265.6 - 1265.1 m) based on reduction lines; anhydrite nodules less than 0.2 cm thick in upper half of section; upper contact is gradational.

Texaco Seaboard "E" #1 continued

4142.9 (1263.6)	2.9 (0.89)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to grayish red (10R 4/2); laminae are wavy and discontinuous; laminae are accentuated by argillaceous material at base and top of section; core broken along possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at 4141.6 ft. (1263.2 m); microfractures filled with anhydrite throughout section; anhydrite nodules less than 0.2 cm thick throughout section; desiccation cracks are abundant; upper contact is wavy and gradational.
4140.0 (1262.7)	7.2 (2.20)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 3/4) with irregular patterns of dark reddish brown (10R 3/4) at top and base of section; minor oil stains at top of section; section is mostly massive with a mottled appearance due to reduction; relict laminae are planar and horizontal based on reduction lines from base to 4138.4 ft. (1262.2 m); faint laminae at very top of section are wavy and discontinuous; upper contact is gradational.

Texaco Seaboard "E" #1 continued

4132.8 (1260.5)	1.0 (0.31)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to grayish red (10R 4/2) with irregular pattern of moderate yellowish brown (10YR 5/4); laminae are wavy and discontinuous with argillaceous material; microfractures filled with anhydrite at top of section; upper contact is gradational.
4131.8 (1260.2)	0.6 (0.18)	SILTSTONE: coarse-grained silt; grayish red (10R 4/2) to moderate reddish brown (10R 4/6); most laminae are wavy and continuous; possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) section at 4131.8 ft. (1260.2 m) and at 4131.3 ft. (1260.0 m); upper contact is gradational.
4131.2 (1260.0)	0.7 (0.21)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); most laminae are wavy and discontinuous with a few continuous ones at middle of section; upper contact is gradational.

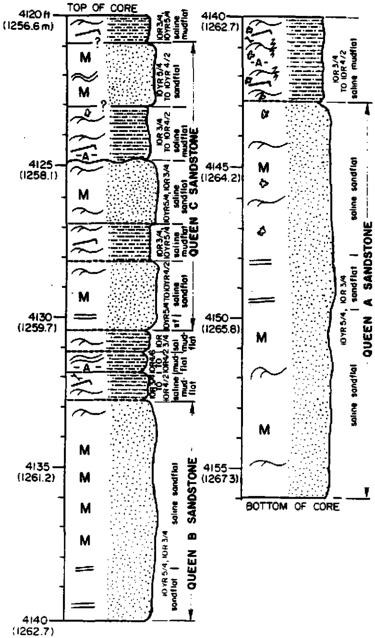
Texaco Seaboard "E" #1 continued

4124.7 (1258.0)	1.7 (0.52)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to grayish red (10R 4/2); laminae are wavy and discontinuous; laminae are accentuated by argillaceous material at base of section; possible algal material with slightly wavy and continuous laminae at 4124.7 ft. (1258.0 m) in light bluish gray (5B 7/1) section; sparse anhydrite nodules up to 0.2 cm thick at top of section; upper contact is not present.
4123.0 (1257.5)	2.1 (0.64)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) to dark yellowish brown (10R 4/2) with oil stains; laminae mostly indistinct; some relict laminae are wavy and continuous based on preferential oil stains; upper contact is not present.
4120.9 (1256.9)	0.9 (0.27)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) with patterns of moderate yellowish brown (10YR 5/4) along bedding planes; laminae are wavy and discontinuous with argillaceous material.

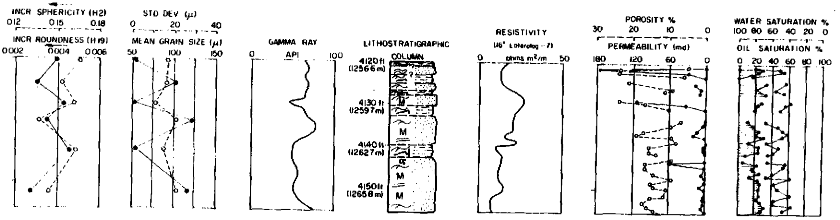
GRAIN SIZE AND SHAPE ANALYSIS
Texaco Seaboard "E" #1
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4120.0 - 4156.0 feet

Depth (ft./m)	Mean Size (microns)	Std. Dev. (microns)	Sphericity (H2)	Roundness (H19)
4120.5/1256.8	52.98	17.28	.16662	.00393
4126.0/1258.4	103.52	17.21	.15219	.00305
4131.0/1260.0	50.76	11.41	.15772	.00428
4135.0/1261.2	124.33	21.00	.13744	.00345
4142.0/1263.3	53.91	15.14	.16205	.00457
4152.0/1266.4	121.38	21.76	.14288	.00271

TEXACO SEABOARD E I



TEXACO SEABOARD E 1



CORE DESCRIPTION
Texaco Seaboard "E" #2
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4125.0 - 4150.0 feet

Depth ft (m)	Thickness ft (m)	Description
4150.0 (1265.8)	3.6 (1.10)	ANHYDRITE: pale blue (5PB 7/2); massive with chaotic laminae from base to 4147.2 ft. (1264.9 m); laminae are crenulate and up to 0.3 cm thick from 4247.2 ft. (1264.9 m) to top of section; upper contact not present.
4146.4 (1264.7)	2.2 (0.67)	SILTSTONE: coarse-grained silt; very dusky red (10R 2/2) to dark reddish brown (10R 3/4); most laminae are wavy and discontinuous with argillaceous material; possible algal material with slightly wavy and continuous laminae at base of section; desiccation cracks at top of section; abundant anhydrite nodules less than 0.2 cm thick; isolated anhydrite nodules up to 1.6 cm thick oriented along bedding planes; upper contact is gradational.

Texaco Seaboard "E" #2 continued

4144.2 (1264.0)	3.4 (1.04)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4) with minor spots of moderate yellowish brown (10YR 5/4); laminae are mostly indistinct with some wavy and discontinuous ones; isolated anhydrite nodules up to 1.0 cm thick; abundant anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.
4140.8 (1262.9)	11.4 (3.48)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4); irregular patterns of dark reddish brown (10R 3/4) along bedding planes, predominantly at base and top; section is mostly massive with a mottled appearance; some relict laminae are planar, horizontal, and continuous from the bottom of section to 4132.3 ft. (1260.4 m) based on preferential breaks and reduction lines; anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.

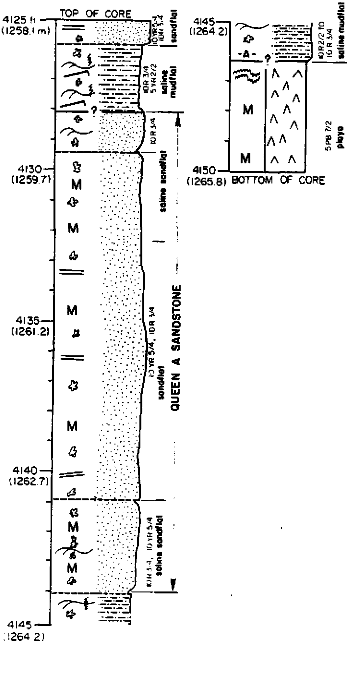
Texaco Seaboard "E" #2 continued

4129.4 (1259.5)	1.4 (0.43)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4) with minor spots of moderate yellowish brown (10YR 5/4); most laminae are indistinct with some wavy and discontinuous ones; abundant anhydrite nodules less than 0.2 cm thick; isolated anhydrite nodules up to 0.5 cm thick present throughout section; upper contact is not present.
4128.0 (1259.0)	2.2 (0.67)	SILTSTONE: coarse-grained silt; dark reddish brown(10R 3/4); dusky brown (5 YR 2/2) from 4127.8 ft. to 4127.5 ft. (1259.0 - 1258.9 m); laminae are wavy and discontinuous with argillaceous material; abundant anhydrite nodules less than 0.2 cm thick; desiccation cracks throughout section; upper contact is gradational.
4125.8 (1258.4)	0.8 (0.24)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) with irregular patterns of dark reddish brown (10R 3/4) oriented along bedding planes; some faint laminae are planar and horizontal; anhydrite nodules up to 0.5 cm thick present at top of section.

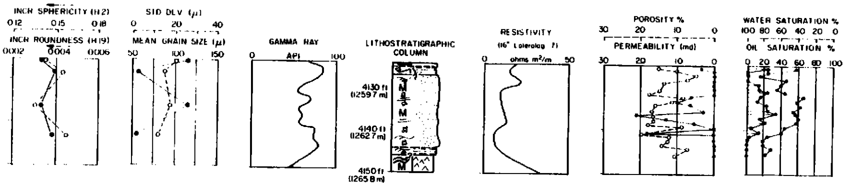
GRAIN SIZE AND SHAPE ANALYSIS
Texaco Seaboard "E" #2
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4125.0 - 4150.0 feet

Depth (ft./m)	Mean Size (microns)	Std. Dev. (microns)	Sphericity (H2)	Roundness (H19)
4125.0/1258.1	115.59	20.98	.14258	.00334
4128.0/1259.0	57.77	15.40	.15540	.00397
4136.0/1261.5	116.48	18.58	.13472	.00330
4143.0/1263.6	52.46	12.15	.15946	.00391

TEXACO SEABOARD E 2



TEXACO SEABOARD E2



CORE DESCRIPTION
Texaco Seaboard "E" #3
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4081.0 - 4161.0 feet

Depth ft (m)	Thickness ft (m)	Description
4161.0 (1269.1)	3.3 (1.01)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); laminae are wavy and discontinuous; anhydrite nodules up to 1.3 cm thick oriented along bedding planes; anhydrite nodules less than 0.2 cm thick present throughout section; upper contact is gradational.
4157.7 (2091.3)	12.3 (3.75)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) with irregular patterns of dark reddish brown (10R 3/4) oriented along bedding planes; section is mostly massive with a mottled appearance; relict laminae are planar and inclined (up to 22 degrees) from bottom to 4151.2 ft. (1266.1 m) based on reducing lines and preferential breaks; slump structures with microfaults present from 4156.4 ft. to 4155.7 ft. (1267.7 -1267.5 m); isolated anhydrite nodules up to 0.8 cm thick; abundant anhydrite nodules less than 0.2 cm thick present throughout section; upper contact is gradational.

Texaco Seaboard "E" #3 continued

4146.0 (2085.4)	1.2 (0.37)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4) with spots of moderate yellowish brown (10YR 5/4); laminae are indistinct; abundant anhydrite nodules up to 0.3 cm thick present throughout section; upper contact is gradational.
4144.8 (1264.2)	0.6 (0.18)	SILTSTONE: coarse-grain silt; very dusky red (10R 2/2); laminae are wavy and discontinuous with argillaceous material; core broken at top of section along laminae of possible algal origin that are slightly wavy and continuous; microfractures filled with anhydrite throughout section; upper contact is sharp and wavy.
4144.2 (2084.5)	0.2 (0.06)	ANHYDRITE: pale blue (5PB 7/2); interlaminated with mudstone; mudstone is yellowish gray (5Y 8/1); anhydrite laminae are slightly wavy and continuous and up to 0.6 cm thick; mudstone laminae are slightly wavy and discontinuous and up to 0.2 cm thick; upper contact is sharp and wavy.

Texaco Seaboard "E" #3 continued

4144.0 (1263.9)	1.4 (0.43)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to dusky red (5R 3/4); laminae are wavy and discontinuous with argillaceous material; desiccation cracks throughout section; microfractures filled with anhydrite in bottom half of section; anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.
4142.6 (1263.5)	2.4 (0.73)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4) with irregular patterns of moderate yellowish brown (10YR 5/4); most laminae are indistinct; laminae are planar, horizontal, and continuous with argillaceous material from 4141.1 ft. to 4140.7 ft. (1263.0 - 1262.9 m); upper contact is gradational.
4140.2 (1262.8)	3.5 (1.07)	SANDSTONE: very fine grained moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2); minor oil stains throughout section; some small spots of dark reddish brown (10R 3/4); section appears massive with no discernable laminae; sparse anhydrite nodules less than 0.2 cm thick; upper contact is gradational.

Texaco Seaboard "E" #3 continued

4136.7 (1261.7)	2.5 (0.76)	SILTSTONE: coarse-grained silt; dark reddish brown(10R 3/4) to very dusky red (10R 2/2); most laminae are wavy and discontinuous with some continuous ones; laminae are accentuated by argillaceous material; possible algal material with slightly wavy and continuous laminae in pale bluish gray (5B 7/1) areas from 4135.3 ft. to 4135.1 ft. (1261.3 - 1261.2 m) and at 4134.8 ft. (1261.1 m); microfractures filled with anhydrite at 4135.4 ft. (1261.3 m); anhydrite nodules less than 0.2 cm thick present throughout section; upper contact is sharp and sub-planar.
4134.2 (1260.9)	4.3 (1.31)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) with irregular patterns of dark reddish brown (10R 3/4); section is mostly massive; laminae are wavy and discontinuous from 4131.8 ft. to 4131.1 ft. (1260.2 - 1260.0 m); upper contact is gradational.

Texaco Seaboard "E" #3 continued

4129.9 (1259.6)	1.0 (0.31)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) and light bluish gray (5B 7/1); red color decreases toward top of section; laminae are wavy and discontinuous; possible algal material with slightly wavy and continuous laminae at very top of section; upper contact is sharp and slightly wavy.
4129.9 (1259.6)	6.8 (2.07)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) with oil stains and a few spots of dark reddish brown (10R 3/4); sandstone is friable and recovery is poor; section is mostly massive; some laminae are wavy and discontinuous from 4128.3 ft. to 4128.1 ft (1259.1 m) and from 4124.5 ft. (1258.0 m) to top of section; relict laminae are slightly wavy and continuous at 4127.5 (1258.9 m) based on preferential oil stains; possible algal material with slightly wavy and continuous laminae in pale bluish gray (5B 7/1) area from 4126.4 ft. to 4126.2 ft. (1258.4 - 1258.5 m); isolated anhydrite nodules up to 0.9 cm thick present toward top of section; upper contact is gradational.

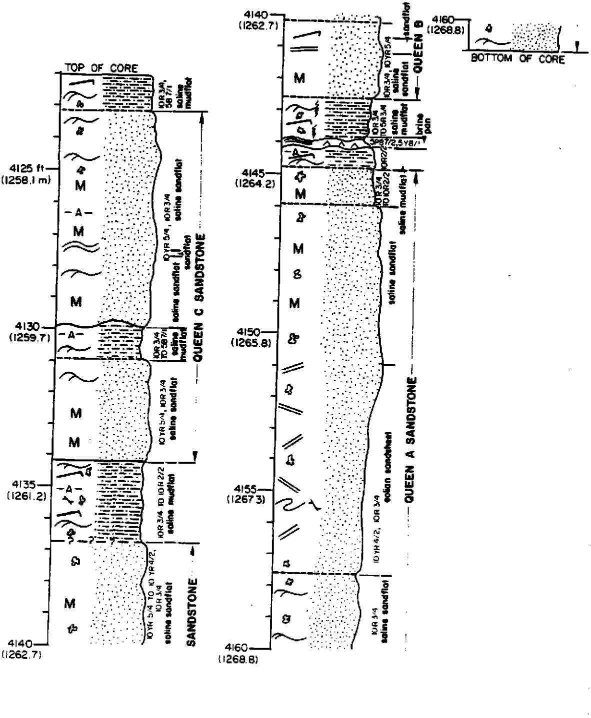
Texaco Seaboard "E" #3 continued

4123.1 (1257.5)	1.1 (0.34)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) and pale bluish gray (5B 7/1); most laminae are wavy and discontinuous with a few continuous ones; laminae are accentuated with argillaceous material; anhydrite nodules less than 0.2 cm thick present in red section.

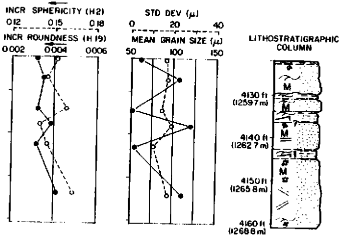
GRAIN SIZE AND SHAPE ANALYSIS
Texaco Seaboard "E" #3
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4081.0 - 4161.0 feet

Depth (ft./m)	Mean Size (microns)	Std. Dev. (microns)	Sphericity (H2)	Roundness (H19)
4122.5/1257.4	61.17	16.46	.15114	.00322
4127.0/1258.7	105.44	17.75	.14255	.00353
4134.5/1261.0	52.32	15.50	.16105	.00315
4138.0/1262.1	120.71	19.60	.13997	.00293
4143.0/1263.6	53.78	10.88	.14455	.00321
4154.0/1267.0	112.99	19.37	.16425	.00419

TEXACO SEABOARD E 3



TEXACO SEABOARD E3



CORE DESCRIPTION
Texaco Seaboard "F" #1
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4166.0 - 4211.0 feet

Depth ft (m)	Thickness ft (m)	Description
4211.0 (1284.4)	1.7 (0.52)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to grayish red (10R 4/2); most laminae are wavy and discontinuous; some laminae are slightly wavy and continuous from 4209.2 ft. (1283.8 m) to top of section; laminae are accentuated with argillaceous material; desiccation cracks are abundant; anhydrite nodules less than 0.2 cm thick present at top of section; upper contact is not present.
4209.3 (1283.8)	0.3 (0.09)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) with small spots of dark reddish brown (10R 3/4); laminae are indistinct; upper contact is not present.

Texaco Seaboard "F" #1 continued

4209.0 (1283.7)	1.0 (0.31)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); most laminae are wavy and discontinuous with argillaceous material; some laminae are slightly wavy and continuous from 4208.1 ft. (1283.5 m) to top of section; abundant anhydrite nodules less than 0.2 cm thick throughout section; upper contact is not present.
4208.0 (1283.4)	1.7 (0.52)	SANDSTONE: very fine grained; irregular patterns of dark yellowish brown (10R 4/2) and dark reddish brown (10R 3/4); sandstone is friable; laminae are planar, horizontal, and continuous; some laminae near top of section are organic rich; sparse anhydrite nodules up to 0.9 cm thick; upper contact is gradational.
4206.3 (1282.9)	1.3 (0.40)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); laminae are wavy and discontinuous; upper contact is not present.
4205.0 (1282.5)	3.0 (0.92)	GAP IN CORE

Texaco Seaboard "F" #1 continued

4202.0 (1281.6)	10.5 (3.11)	SANDSTONE: fine grained; moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2) with minor oil stains; irregular patterns of dark reddish brown (10R 3/4) from 4195.9 ft. (1279.7 m) to top of section; sandstone is friable and recovery is poor; section appears mostly massive; some relict laminae are wavy and discontinuous in upper half of section based on preferential oil stains; anhydrite nodules less than 0.2 cm thick at top of section; upper contact is gradational.
4191.5 (1308.9)	2.6 (0.80)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to grayish red (10R 4/2); most laminae are wavy and discontinuous with argillaceous material; laminae are slightly wavy and continuous from 4189.2 ft. to 4189.0 ft. (1277.7 -1277.6 m); microfractures filled with anhydrite from 4191.0 ft. to 4190.4 ft. (1278.3 - 1278.1 m); anhydrite nodules up to 1.1 cm thick oriented along bedding planes from 4189.4 ft. (1276.9 m) to top of section; abundant anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.

Texaco Seaboard "F" #1 continued

4188.9 (1277.6)	1.1 (0.34)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); most laminae are slightly wavy and continuous from bottom of section to 4188.3 ft. (1277.4 m); laminae are wavy and discontinuous from 4188.3 ft. (1277.4 m) to top of section; desiccation cracks from bottom of section to 4188.3 ft. (1277.4 m); isolated anhydrite nodules up to 1.8 cm thick oriented along bedding planes; abundant anhydrite nodules less than 0.2 cm thick present; upper contact is gradational.
4187.8 (1277.3)	7.6 (2.32)	SANDSTONE: very fine grained; moderate reddish brown(10R 4/6) to dark reddish brown (10R 3/4); randomly oriented reduction lines from 4184.9 ft. to 4184.7 ft. (1276.4 - 1276.3 m); faint laminae are planar, horizontal, and continuous from base of section to 4186.7 ft. (1276.9 m); section is massive from 4186.7 ft. (1276.9 m) to top of section; possible bioturbation trace at 4187.7 ft. (1277.2 m) that has been infilled with anhydrite; sparse anhydrite nodules up to 0.8 cm thick; upper contact is sharp and wavy.

Texaco Seaboard "F" #1 continued

4180.2 (1275.0)	4.1 (1.25)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); laminae are slightly wavy and discontinuous with argillaceous material; possible algal material with slightly wavy and continuous laminae in a light bluish gray (5B 7/1) area at 4179.4 ft. (1274.7 m) and at 4178.6 ft. (1274.5 m); upper contact is gradational.
4176.1 (1273.7)	0.9 (0.27)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4) to grayish red (10R 4/2); laminae are wavy and discontinuous with argillaceous material; anhydrite nodules less than than 0.2 cm thick throughout section; upper contact is gradational.
4175.2 (1273.4)	1.5 (0.46)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to grayish red (10R 4/2); laminae are wavy and discontinuous with argillaceous material; anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.
4173.7 (1273.0)	3.2 (0.98)	SILTY SANDSTONE: sandstone is very fine grained; dark reddish brown (10R 3/4); laminae are wavy and discontinuous with argillaceous material; anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.

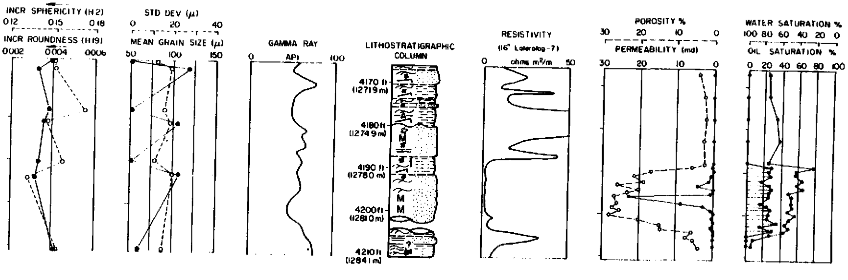
Texaco Seaboard "F" #1 continued

4170.5 (1272.0)	3.2 (0.98)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); most laminae are wavy and discontinuous; possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at 4169.7 ft. (1271.8 m); anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational
4167.3 (1271.0)	0.2 (0.06)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); laminae are wavy and discontinuous with argillaceous material; anhydrite nodules less than 0.2 cm thick throughout section; upper contact is sharp, horizontal, and planar.
4167.1 (1271.0)	0.2 (0.06)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); laminae are wavy and discontinuous; anhydrite nodules less than 0.2 cm thick throughout section; upper contact is sharp, horizontal, and planar.
4166.9 (1270.9)	0.9 (0.27)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); laminae are wavy and discontinuous with argillaceous material; anhydrite nodules less than 0.2 cm thick throughout section.

GRAIN SIZE AND SHAPE ANALYSIS
Texaco Seaboard "F" #1
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4166.0 - 4211.0 feet

Depth (ft./m)	Mean Size (microns)	Std. Dev. (microns)	Sphericity (H2)	Roundness (H19)
4166.0/1270.6	50.17	12.22	.15142	.00396
4168.0/1271.2	118.10	18.93	.15221	.00327
4178.0/1274.3	53.41	15.68	.17238	.00386
4181.0/1275.2	106.46	18.78	.14624	.00357
4190.0/1278.0	52.61	11.93	.15743	.00341
4194.0/1279.2	107.43	20.00	.13282	.00319
4211.0/1284.4	61.35	15.95	.15387	.00412

TEXACO SEABOARD F I



CORE DESCRIPTION
Texaco Seaboard "F" #3
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4295.0 - 4324.0 feet

Depth ft (m)	Thickness ft (m)	Description
4324.0 (1318.8)	1.1 (0.34)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); laminae are wavy and discontinuous with argillaceous material; desiccation cracks present at base; anhydrite nodules up to 3.4 cm thick oriented along bedding planes from base to 4323.6 ft. (1318.7 m); anhydrite nodules less than 0.2 cm thick throughout section; upper contact is not present.
4322.9 (1318.5)	4.9 (1.49)	SANDSTONE: very fine-grained; dark reddish brown (10R 3/4); sandstone is friable and recovery is poor; upper contact is not present.

Texaco Seaboard "F" #3 continued

4318.0 (1317.0)	2.6 (0.79)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to grayish brown (5YR 3/2); most laminae are wavy and discontinuous with argillaceous material; possible algal material with wavy and continuous laminae in pale bluish gray area at 4316.9 ft. (1316.7 m) and at 4316.6 ft. (1316.6 m); possible salt ridge structures near top of section; microfractures filled with anhydrite at 4316.6 ft. (1316.5 m); upper contact is not present.
4315.4 (1316.2)	0.4 (0.12)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4); section is massive; laminae are indistinct; upper contact is not present.
4315.0 (1316.1)	2.1 (0.64)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4), most laminae are wavy and discontinuous with argillaceous material; core broken along possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at 4314.6 ft. (1315.0 m); possible salt ridge structure at 4313.8 (1315.7 m); microfractures filled with anhydrite from base to 4314.7 (1316.0); anhydrite nodules up to 1.2 cm thick at 4314.4 (1315.9 m); anhydrite nodules less than 0.2 cm thick throughout section; upper contact is not present.

Texaco Seaboard "F" #3 continued

4312.9 (1315.4)	0.9 (0.27)	SANDSTONE: very fine grained; pale yellowish brown (10YR 6/2) with minor amounts of moderate yellowish brown (10YR 5/4) oriented along bedding planes; minor oil stains present; section is mostly massive; faint organic-rich laminae are planar, horizontal, and continuous from base to 4312.8 ft. (1325.4 m); relict laminae are slightly wavy and discontinuous from 4312.2 ft. (1315.2 m) to top of section based on reduction lines; upper contact not present.
4312.0 (1315.2)	8.0 (2.44)	GAP IN CORE
4304.0 (1312.7)	6.2 (1.89)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); most laminae are wavy and discontinuous with argillaceous material; some laminae are wavy and continuous from bottom of section to 4303.5 ft. (1312.7 - 1312.6 m); several possible salt ridge structures throughout section; anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.

Texaco Seaboard "F" #3 continued

4298.8 (1311.1)	0.5 (0.15)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4), laminae are wavy and discontinuous with argillaceous material; possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at 4298.5 ft. (1311.0 m); anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.
4298.3 (1311.0)	2.2 (0.67)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); laminae are wavy and discontinuous with argillaceous material; anhydrite nodules less than 0.2 cm thick throughout section; upper contact is not present.
4296.1 (1310.3)	0.4 (0.12)	SILTSTONE: coarse-grained silt; greenish gray (5G 6/1); laminae are wavy and discontinuous with argillaceous material; interlaminations of mudstone at very top of section; microfractures filled with anhydrite present throughout section; upper contact is sharp and wavy.
4296.5 (1310.4)	0.2 (0.06)	ANHYDRITE: very light gray (N 8); enterolithic layer with deformational folds; layer is displacive; individual nodules appear to have coalesced together; upper contact is sharp and wavy.

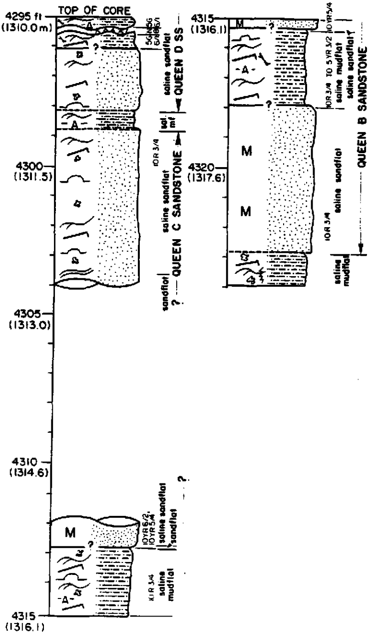
Texaco Seaboard "F" #3 continued

4296.3 (1310.4)	0.3 (0.09)	SILTSTONE; coarse-grained silt; greenish gray (5G 6/1); most laminae are slightly wavy and discontinuous; possible algal material with slightly wavy and continuous laminae throughout section; microfractures filled with anhydrite present.

GRAIN SIZE AND SHAPE ANALYSIS
Texaco Seaboard "F" #3
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 31
Core: 4295.0 - 4324.0 feet

Depth (ft./m)	Mean Size (microns)	Std. Dev. (microns)	Sphericity (H2)	Roundness (H19)
4295.0/1310.0	48.31	10.11	.14439	.00421
4297.0/1310.6	115.50	19.42	.14523	.00351
4298.5/1311.0	60.96	15.68	.14910	.00313
4303.0/1312.4	112.23	19.21	.14675	.00326
4312.5/1315.3	91.72	19.30	.14714	.00280
4323.5/1318.7	56.35	11.27	.16791	.00414

TEXACO SEABOARD F 3



CORE DESCRIPTION
Texaco Seaboard Everitt and Glass #1
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 30
Core: 4208.0 - 4257.0 feet

Depth ft (m)	Thickness ft (m)	Description
4257.0 (1298.4)	0.9 (0.27)	ANHYDRITE: light bluish gray (5B 7/1) to medium bluish gray (5B 5/1); massive with chaotic laminae from base to 4256.6 ft. (1298.3 m); interlaminated with mudstone from 4256.6 ft. (1298.3 m) to top of section; anhydrite laminae are up to 0.9 cm thick; mudstone laminae are up to 0.3 cm thick; upper contact is sharp and slightly wavy.

Texaco Seaboard Everitt and Glass #1 continued

4256.1 (1298.1)	5.8 (1.77)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to moderate reddish brown (10R 4/6); core broken along possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at base of section; laminae are wavy and discontinuous with argillaceous material from base to 4255.6 ft. (1298.0 m) and from 4252.9 ft. (1297.1 m) to top of section; laminae are mostly indistinct from 4255.6 ft. to 4252.9 ft. (1298.0 - 1297.1 m) with a few faint laminae that are planar, horizontal, and continuous; desiccation cracks present at 4252.8 ft. (1297.1 m); abundant anhydrite nodules less than 0.2 cm thick; upper contact is gradational.

Texaco Seaboard Everitt and Glass #1 continued

4250.3 (1296.3)	10.8 (3.29)	SANDSTONE: very fine to fine grained; pale yellowish brown (10YR 6/2) with oil stains; isolated lenses of moderate reddish brown (10R 4/6) oriented along bedding planes from 4241.4 ft. (1293.6 m) to top of section; section appears mostly massive; sandstone is friable; recovery is poor from 4246.0 ft. to 4244.0 ft. (1295.0 - 1294.4 m); some faint laminae are wavy and discontinuous from base to 4247.6 ft. (1295.5 m) and from 4242.4 ft. (1293.9 m) to top of section; some relict laminae are inclined (up to 13 degrees) from 4247.2 ft. to 4242.4 ft. (1295.4 - 1293.9 m) based on preferential oil stains and preferential breaks; isolated anhydrite nodules up to 0.9 cm thick at very base of section; sparse anhydrite nodules less than 0.2 cm thick throughout section; upper contact is not present.

Texaco Seaboard Everitt and Glass #1 continued

4239.5 (1293.0)	5.1 (1.56)	SILTSTONE: coarse grained silt; moderate reddish brown (10R 4/6); laminae are indistinct from base to 4238.4 ft. (1292.7 m) and from 4234.8 ft. to top of section; most laminae are wavy and discontinuous with argillaceous material; possible algal material with slightly wavy and continuous laminae at 4237.5 ft. (1292.4 m) in light bluish gray (5B 7/1) section; some planar and continuous laminae present from 4235.4 ft. to 4235.0 ft. (1291.8 - 1291.7 m); desiccation cracks present from 4238.4 ft to 4235.0 ft. (1292.7 - 1291.7 m); isolated anhydrite nodules up to 1.6 cm thick oriented along bedding planes; abundant anhydrite nodules less than 0.2 cm thick throughout section; upper contact is not present.
4234.4 (1291.5)	5.4 (1.64)	SANDSTONE: very fine grained; pale yellowish brown (10YR 6/2) with oil stains; irregular patterns of moderate reddish brown (10R 4/6) from 4231.1 ft. to 4230.7 ft. (1290.5 - 1290.4 m); section appears mostly massive; faint laminae are slightly wavy and continuous at 4231.7 ft. (1290.7 m); laminae are wavy and discontinuous from 4231.0 ft. to 4230.7 ft. (1290.5 - 1290.4 m); anhydrite nodules less than 0.2 cm thick throughout red section; upper contact not present.

Texaco Seaboard Everitt and Glass #1 continued

4229.0 (1289.8)	1.8 (0.55)	SILTSTONE: coarse-grained silt; moderate reddish brown (10R 4/6) to dark reddish brown (10R 3/4); most laminae are wavy and discontinuous with argillaceous material; possible algal material with wavy and continuous laminae at 4228.2 ft. (1289.6 m) and at 4229.1 ft. (1289.9 m) in light bluish gray (5B 7/1) section; microfractures filled with anhydrite from 4128.4 ft. to 4128.2 ft. (1259.2 - 1259.1 m); anhydrite nodules less than 0.2 cm thick from 4227.3 ft. (1289.3 m) to top of section; upper contact is not present.
4227.2 (1289.2)	5.1 (1.56)	SANDSTONE: very fine grained; pale yellowish brown (10YR 6/2) with oil stains; irregular patterns of moderate reddish brown (10R 4/6); faint laminae are wavy and discontinuous throughout most of section; laminae are planar, horizontal, and continuous at 4224.3 ft. (1288.4 m) based on preferential oil stains; upper contact is gradational.

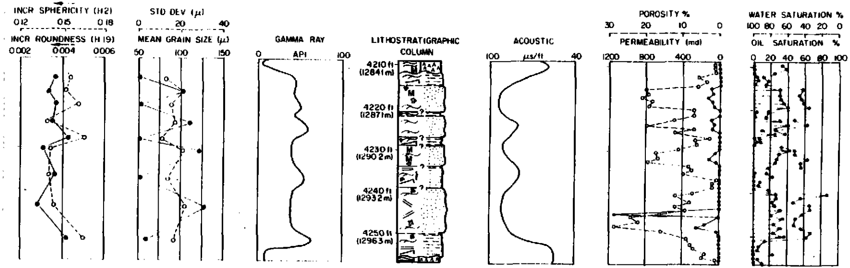
Texaco Seaboard Everitt and Glass #1 continued

4222.1 (1287.7)	1.4 (0.43)	SILTSTONE: coarse-grained silt; moderate reddish brown (10R 4/6); most laminae are wavy and discontinuous; possible algal material with wavy and continuous laminae at 4221.3 ft. (1287.5 m) in light bluish gray (5B 7/1) section; sparse anhydrite nodules less than 0.2 cm thick present in red section; upper contact is not present.
4220.7 (1287.3)	5.6 (1.71)	SANDSTONE: very fine grained; pale yellowish brown (10YR 6/2) with oil stains; section appears mostly massive; laminae are wavy and discontinuous from base to 4218.2 ft. (1286.6 m); laminae are indistinct from 4218.2 ft. (1286.6 m) to top of section; possible bioturbation trace at 4219.3 ft. (1286.9 m); isolated anhydrite nodules up to 0.7 cm thick in upper half of section; upper contact is gradational.
4215.1 (1285.6)	1.1 (0.34)	SILTSTONE: coarse-grained silt; moderate reddish brown (10R 4/6); most laminae are wavy and discontinuous with argillaceous material; possible algal material with wavy and continuous laminae at 4215.2 ft. (1285.6 m) in light bluish gray (5B 7/1) section; sparse anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.

GRAIN SIZE AND SHAPE ANALYSIS
Texaco Seaboard Everitt and Glass #1
Concho Bluff Queen Field
Crane County, Texas
T4S Block 42, Section 30
Core: 4208.0 - 4257.0 feet

Depth (ft./m)	Mean Size (microns)	Std. Dev. (microns)	Sphericity (H2)	Roundness (H19)
4214.5/1285.4	51.15	13.98	.15566	.00365
4217.0/1286.2	102.71	20.86	.15153	.00329
4220.0/1287.1	56.27	15.70	.16124	.00374
4224.0/1288.3	112.09	16.76	.13741	.00350
4228.0/1289.5	51.03	11.22	.16546	.00422
4230.5/1290.3	121.71	21.38	.13912	.00305
4236.5/1292.1	50.68	13.35	.14069	.00358
4244.0/1294.4	128.78	21.98	.15658	.00317
4252.0/1296.9	61.44	19.14	.14506	.00329

TEXACO SEABOARD EVERITT AND GLASS I



CORE DESCRIPTION
Texaco Seaboard Everitt and Glass #2
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 30
Core: 4174.0 - 4221.0 feet

Depth ft (m)	Thickness ft (m)	Description
4221.0 (1287.0)	1.2 (0.37)	ANHYDRITE: medium bluish gray (5B 5/1); massive with chaotic laminations from base to 4220.5 ft. (1287.3 m); laminae are crenulate and continuous from 4220.5 ft. (1287.3 m) to top of section; core broken at top of section along possible algal material with slightly wavy and continuous laminae; upper contact is not present.
4219.8 (1287.0)	2.2 (0.67)	SILTSTONE: coarse-grained silt; very dusky red (10R 2/2) to dark reddish brown (10R 3/4); laminae are wavy and discontinuous with argillaceous material from base to 4219.4 ft (1286.8 m) and from 4218.3 ft. (1286.6 m) to top of section; laminae are indistinct from 4219.4 ft. to 4218.3 ft. (1286.8 - 1286.6 m); anhydrite nodules less than 0.2 cm thick present in dark reddish brown (10R 3/4) area; upper contact is gradational.

Texaco Seaboard Everitt and Glass #2 continued

4217.6 (1286.4)	1.9 (0.58)	SANDSTONE: very fine grained; very dusky red (10R 2/2) with irregular patterns of moderate yellowish brown (10YR 5/4); section is mostly massive; some laminae are wavy and discontinuous with argillaceous material at 4217.4 ft. (1286.3 m); abundant anhydrite nodules less than 0.2 cm throughout section; upper contact is not present.
4215.7 (1285.8)	11.1 (3.39)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2) with oil stains; irregular patterns of dark reddish brown (10R 3/4) throughout section; section is mostly massive with a mottled appearance; relict laminae are wavy and discontinuous from base to 4213.1 ft. (1285.0 m); some relict laminae are horizontal and planar from 4213.1 ft. to 4212.1 ft. (1285.0 - 1284.7 m) based on reduction lines; laminae are indistinct from 4212.1 ft. (1285.0 m) to top of section; sparse anhydrite nodules up to 0.4 cm thick present toward top of section; upper contact is gradational.

Texaco Seaboard Everitt and Glass #2 continued

4204.6 (1282.4)	2.7 (0.82)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) to grayish red (10R 4/2) with small spots of moderate yellowish brown (10YR 5/4); laminae are wavy and discontinuous; anhydrite nodules up to 1.1 cm thick oriented along bedding planes; abundant anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.
4201.9 (1281.6)	1.0 (0.31)	SILTSTONE: coarse-grained silt; grayish red (10R 4/2); most laminae are wavy and discontinuous with a few continuous ones present; possible algal material with slightly wavy and continuous laminae at 4201.0 ft. (4331.3 m); upper contact is gradational.

Texaco Seaboard Everitt and Glass #2 continued

4200.9 (1281.3)	4.7 (1.43)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4) to grayish red (10R 4/2); most laminae are wavy and discontinuous with argillaceous material; laminae are slightly wavy and continuous from 4200.4 ft. to 4200.0 ft. (1281.1 - 1281.0 m); desiccation cracks present from base to 4200.4 ft. (1281.1 m); microfractures filled with anhydrite from 4200.2 ft. to 4199.1 ft. (1281.1 - 1280.7 m); sparse anhydrite nodules up to 0.4 cm thick in upper half of section; anhydrite nodules less than 0.2 cm thick at top of section; upper contact is gradational.
4196.2 (1279.8	1.7 (1.43)	SANDSTONE: very fine grained, moderate yellowish brown (10YR 5/4) with irregular patterns of dark reddish brown (10R 3/4); most laminae are indistinct with a few faint ones that are wavy and discontinuous; anhydrite nodules up to 0.4 cm thick at top of section; abundant anhydrite nodules less than 0.2 cm thick present throughout section; upper contact is gradational.

Texaco Seaboard Everitt and Glass #2 continued

4194.5 (1279.5)	2.3 (0.70)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); most laminae are slightly wavy and discontinuous with argillaceous material; possible algal material with slightly wavy and continuous laminae at 4192.8 ft. (1278.8 m); microfractures filled with anhydrite at 4193.1 ft. (1278.9 m); anhydrite nodules less than 0.2 cm thick present throughout section; upper contact is not present.
4192.2 (1278.6)	7.5 (2.29)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4) to grayish red (10R 4/2); some irregular patterns of moderate yellowish brown (10YR 5/4) oriented along bedding planes; most laminae are wavy and discontinuous with argillaceous material; three bedsets of planar and continuous laminae from 4187.6 ft. to 4186.5 ft. (1277.2 - 1276.9 m); possible bioturbation traces at 4186.3 ft. (1276.8 m) and 4185.5 ft. (1276.6 m); several desiccation cracks throughout section; sparse anhydrite nodules less than 0.2 cm thick; upper contact is gradational.

Texaco Seaboard Everitt and Glass #2 continued

4184.7 (1276.3)	1.1 (0.34)	SANDSTONE: very fine grained; moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2) with oil stains present; some irregular patterns of dark reddish brown (10R 3/4); relict laminae are slightly wavy and continuous based on preferential oil stains; upper contact is gradational.
4183.6 (1276.0)	0.4 (0.12)	SILTSTONE: coarse-grained silt; grayish red (10R 4/2) and light bluish gray (5B 7/1); most laminae are wavy and discontinuous with a few continuous ones present; gray color decrease toward top of section; upper contact is not present.
4183.2 (1275.9)	1.0 (0.31)	SANDSTONE: very fine grained; dark yellowish brown (10YR 3/4) with oil stains; laminae are indistinct; upper contact is gradational.
4182.2 (1275.6)	0.3 (0.09)	SILTSTONE: coarse-grained silt; dark reddish brown (10YR 3/4); laminae are wavy and discontinuous with argillaceous material; abundant anhydrite nodules less than 0.2 cm thick; upper contact is gradational.

Texaco Seaboard Everitt and Glass #2 continued

4181.9 (1275.5)	1.6 (0.49)	SANDSTONE: very fine grained; dark yellowish brown (10YR 4/2) with oil stains; some irregular patterns of dark reddish brown (10R 3/4); laminae are mostly indistinct; relict laminae are wavy and continuous from 4180.5 ft. (1275.1 m) to top of section based on preferential oil stains; upper contact is not present.
4180.3 (1275.9)	2.7 (0.82)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); patterns of moderate yellowish brown (10YR 5/2) near top of section; most laminae are wavy and discontinuous with argillaceous material; possible algal material with slightly wavy and continuous laminae in light bluish gray (5B 7/1) area at 4180.1 ft. (1274.9 m); anhydrite nodules up to 0.9 cm thick oriented along bedding planes; anhydrite nodules less than 0.2 cm thick present throughout section; upper contact is gradational.
4177.6 (1274.2)	0.6 (0.18)	SANDSTONE: very fine grained; dark yellowish brown (10R 4/2) with irregular patterns of dark reddish brown (10R 3/4); laminae are wavy and discontinuous; anhydrite nodules less than 0.2 cm thick in bottom half of section; upper contact is not present.

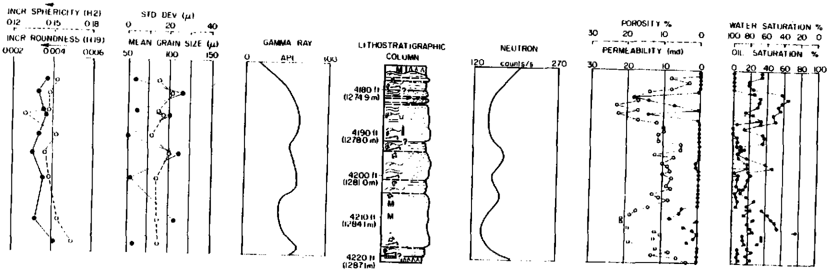
Texaco Seaboard Everitt and Glass #2 continued

4177.0 (1274.0)	0.8 (0.24)	SILTSTONE: coarse-grained silt; greenish gray (5G 6/1); laminae are wavy and discontinuous with argillaceous material; interlaminations of dolomitic mudstones at very top of section; anhydrite nodules up to 1.4 cm thick oriented along bedding planes at top of section; upper contact is sharp and wavy.
4176.2 (1273.7)	2.2 (0.67)	ANHYDRITE: pale blue (5PB 7/2) and medium bluish gray (5B 5/1); massive with chaotic laminae.

GRAIN SIZE AND SHAPE ANALYSIS
Texaco Seaboard Everitt and Glass #2
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 30
Core: 4174.0 - 4221.0 feet

Depth (ft./m)	Mean Size (microns)	Std. Dev. (microns)	Sphericity (H2)	Roundness (H19)
4179.0/1274.6	58.29	14.95	.15171	.00370
4182.0/1275.5	115.01	21.64	.14847	.00323
4186.0/1276.7	61.89	14.80	.14704	.00350
4187.0/1277.0	100.49	17.20	.12896	.00358
4192.0/1278.6	47.16	11.37	.15137	.00332
4196.0/1279.8	110.00	19.93	.14398	.00299
4202.0/1281.6	53.72	14.07	.14702	.00354
4212.0/1284.7	105.95	15.12	.15264	.00315
4217.5/1286.3	56.04	15.15	.16277	.00400

TEXACO SEABOARD EVERITT AND GLASS 2



CORE DESCRIPTION
Texaco Seaboard Everitt and Glass #11
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 30
Core: 4103.0 - 4189.0 feet

Depth ft (m)	Thickness ft (m)	Description
4189.0 (1277.6)	2.1 (0.64)	HALITE: white (N 9) and brownish gray (5YR 4/1); interlocking mosaic; clear bands at base become dark at middle of section; clear bands have slight influx of mud between halite crystals; dark bands have influx of mud within halite crystals; upper contact is gradational.
4186.9 (1276.7)	3.0 (0.92)	MUDSTONE WITH HALITE: dark reddish brown (10R 3/4); laminae are mostly chaotic and disturbed by halite; some laminae are wavy and discontinuous at top of section; most halite crystals are poorly developed; halite decreases toward top of section; upper contact is gradational.
4183.9 (1276.1)	0.9 (0.27)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); faint laminae are wavy and discontinuous; sparse anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.

Texaco Seaboard Everitt and Glass #11 continued

4183.0 (1275.8)	16.3 (4.97)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4) to very dusky red (10R 2/2); laminae are mostly indistinct; faint laminae are wavy and discontinuous from base to 4177.9 ft. (1274.3 m) and from 4169.7 ft. to 4168.1 ft. (1271.8 to 1271.3 m); fractures filled with halite from 4177.9 ft. to 4176.1 ft. (1274.2 to 1273.7 m), from 4173.7 ft. to 4171.4 ft. (1273.0 - 1272.3 m), and from 4167.5 ft. to 4167.1 ft. (1271.1 - 1271.0 m); isolated anhydrite nodules up to 1.4 cm thick throughout section; upper contact is gradational.
4166.7 (1270.8)	0.7 (0.21)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) with irregular patterns of light bluish gray (5B 7/1); laminae are wavy and discontinuous with argillaceous material; halite filled inclusions up to 0.3 cm; anhydrite nodules up to 1.5 cm present; abundant anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.

Texaco Seaboard Everitt and Glass #11 continued

4166.0 (1270.5)	1.0 (0.31)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); laminae are wavy and discontinuous; halite filled inclusions up to 0.2 cm; anhydrite nodules up to 1.4 cm thick which increase in abundance toward top of section; abundant anhydrite nodules less than 0.2 cm thick throughout section; upper contact is not present.
4165.0 (1270.3)	2.1 (0.64)	ANHYDRITE: pale blue (5PB 7/2); mostly massive; poikilotopic with halite crystals that are primarily vertical in orientation from 4164.0 ft. to 4163.6 ft. (1270.0 - 1269.9 m); faint laminae are slightly wavy from base to 4164.0 ft. (1270.0 m) and from 4163.6 ft. (1269.9 m) to top of section; beds are up to 1.1 cm thick where discernable; some individual laminae are poikilotopic with halite crystals; possible algal material with slightly wavy and continuous laminae at base and top of section; upper contact is sharp and wavy.

Texaco Seaboard Everitt and Glass #11 continued

4162.9 (1269.7)	2.6 (0.79)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); faint laminae are slightly wavy and continuous from base to 4162.5 ft. (1269.6 m); laminae are wavy and discontinuous from 4162.5 ft. (1269.6 m) to top of section; anhydrite nodules up to 2.4 cm thick oriented along bedding planes; abundant anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.
4160.3 (1268.9)	10.8 (3.29)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4) to grayish red (5R 4/2); laminae are slightly wavy and discontinuous from base to 4159.1 ft. (1268.5 m) and from 4151.6 ft. (1266.2 m) to top of section; inter-laminations of mudstone that are up to 0.3 cm thick from base to 4157.0 ft. (1267.9 m); most laminae are planar and continuous with some desiccation cracks from 4159.1 ft. to 4157.0 ft. (1268.5 - 1267.8 m); laminae are indistinct from 4157.0 ft. to 4151.6 ft. (1267.9 - 1266.2 m); halite filled inclusions up to 0.3 cm thick from 4150.5 ft. (1265.9 m) to top of section; halite filled fracture from 4154.7 ft. to 4154.2 ft. (1267.2 - 1267.0 m); isolated anhydrite nodules up to 1.1 cm thick from 4157.0 ft. (1267.9 m) to top of section; upper contact is sharp and wavy.

Texaco Seaboard Everitt and Glass #11 continued

4150.5 (1265.9)	3.1 (0.95)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4) and light bluish gray (5B 7/1); most laminae are wavy and discontinuous; possible algal material with slightly wavy and continuous laminae at 4149.9 ft. (1265.7 m); microfractures filled with halite from base to 4149.9 ft. (1265.7 m); 2.2 cm thick halite crystal at 4150.1 ft. (1265.8 m); anhydrite nodules up to 1.9 cm thick throughout section; upper contact is gradational.
4147.4 (1265.0)	1.1 (0.31)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); laminae are indistinct; sparse anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.
4146.3 (1264.6)	2.6 (0.79)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); laminae are wavy and discontinuous with argillaceous material; sparse anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.
4143.7 (1263.8)	0.7 (0.21)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); faint laminae are wavy and discontinuous; upper contact is gradational.

Texaco Seaboard Everitt and Glass #11 continued

4143.0 (1263.6)	4.5 (1.37)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); most laminae are wavy and discontinuous; possible algal material with slightly wavy and continuous laminae in a light bluish gray (5B 7/1) section at 4140.3 ft. (1262.8 m); isolated anhydrite nodules up to 2.2 cm thick oriented along bedding planes; sparse anhydrite nodules less than 0.2 cm thick throughout section; upper contact is gradational.
4139.5 (1262.5)	7.2 (2.20)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); laminae are wavy and discontinuous; halite filled fracture from 4137.9 ft. to 4137.0 ft. (1262.1 - 1261.8 m); isolated anhydrite nodules up to 1.3 cm thick oriented along bedding planes; upper contact is gradational.
4132.3 (1260.4)	1.3 (0.40)	SILTSTONE: coarse-grained silt; greenish gray (5G 6/1); laminae are wavy and discontinuous; upper contact is sharp and wavy.

Texaco Seaboard Everitt and Glass #11 continued

4131.0 (1260.0)	14.6 (4.53)	ANHYDRITE: light bluish gray (5B 7/1) to medium bluish gray (5B 5/1); dark gray (N 3) from 4125.8 ft. to 4122.0 ft. (1258.4 - 1257.2 m); massive with chaotic laminae from base to 4128.1 ft. (1259.1 m) and from 4119.0 ft. (1256.3 m) to top of section; faint anhydrite beds are up to 1.8 cm thick and are slightly wavy and continuous from 4128.1 ft. to 4126.1 ft. (1259.1 - 1258.5 m); interlaminated mudstone with crenulate laminae from 4126.1 ft. to 4119.0 ft. (1258.5 - 1256.3 m); most laminae are slightly wavy and continuous from 4118.3 ft to 4117.9 ft. (1256.1 - 1256.0 m); upper contact is sharp and wavy.
4116.4 (1255.5)	0.4 (0.12)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); laminae are wavy and discontinuous with argillaceous material; upper contact is gradational.
4116.0 (1255.4)	5.4 (1.65)	SANDSTONE: very fine grained; dark reddish brown (10R 3/4); laminae are wavy and discontinuous from base to 4112.9 ft. (1254.4 m); laminae are accentuated by argillaceous material at base of section; laminae are indistinct from 4112.9 ft. (1254.4 m) to top of section; upper contact is gradational.

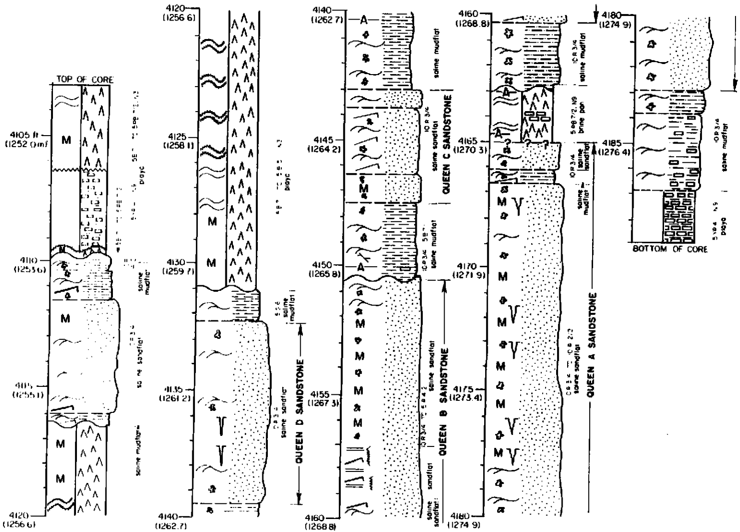
Texaco Seaboard Everitt and Glass #11 continued

4111.6 (1255.4)	1.2 (0.37)	SILTSTONE: coarse-grained silt; dark reddish brown (10R 3/4); laminae are wavy and discontinuous with argillaceous material; anhydrite nodules present up to 1.8 cm thick oriented along bedding planes; upper contact is gradational.
4110.4 (1253.7)	0.4 (0.12)	SILTSTONE: coarse-grained silt; grayish red (10R 4/2); laminae are wavy and discontinuous; anhydrite nodules up to 2.4 cm thick oriented along bedding planes; halite dissolution voids up to 0.2 cm thick present; upper contact is sharp and wavy.
4110.0 (1253.6)	0.2 (0.06)	ANHYDRITE: pale blue (5PB 7/2); mostly massive with a few faint laminae that are slightly wavy and continuous; halite filled inclusions up to 0.3 cm thick present; upper contact is sharp and crinkly.
4109.8 (1253.5)	3.4 (1.04)	HALITE: white (N 9) and brownish gray (5YR 4/1); interlocking mosaic; mostly clear bands; minor amounts of dark bands; clear bands have slight influx of mud between halite crystals; dark bands have influx of mud within the halite crystals; upper contact is sharp and crenulate.

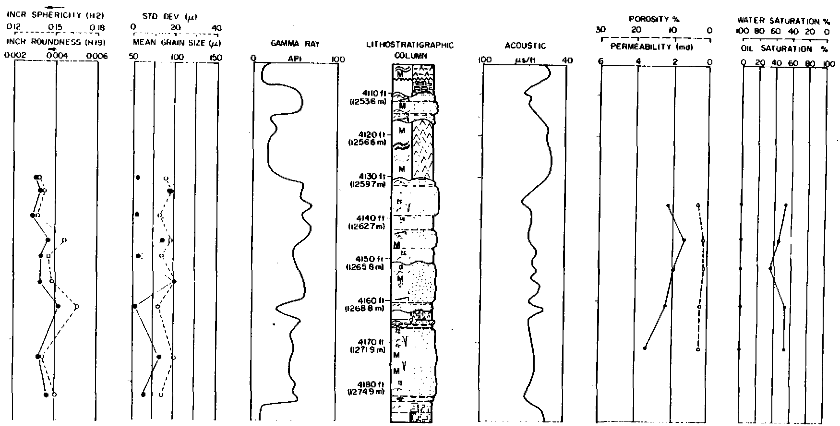
GRAIN SIZE AND SHAPE ANALYSIS
Texaco Seaboard Everitt and Glass #11
Concho Bluff Queen Field
Crane County, Texas
T4S, Block 42, Section 30
Core: 4103.0 - 4189.0 feet

Depth (ft./m)	Mean Size (microns)	Std. Dev. (microns)	Sphericity (H2)	Roundness (H19)
4131.0/1260.0	54.61	15.30	.13835	.00309
4134.0/1260.9	93.59	18.17	.14159	.00332
4140.0/1262.7	54.78	13.71	.13703	.00301
4146.0/1264.5	85.48	18.58	.15631	.00356
4149.5/1265.6	57.56	14.33	.14426	.00336
4156.0/1267.6	99.54	20.58	.14644	.00338
4162.0/1269.4	53.74	12.12	.16541	.00414
4174.0/1273.1	81.18	19.27	.14064	.00319
4183.0/1275.8	61.22	14.01	.14984	.00350

TEXACO SEABOARD
EVERITT AND GLASS II



TEXACO SEABOARD EVERITT AND GLASS II



VITA

NAME:	Douglas Floyd Newsom
BIRTHDATE:	June 9, 1964
BIRTHPLACE	Houston, Texas
PARENTS:	Floyd and Susan Newsom
EDUCATION:	Baylor University Waco, Texas B.S., Geology, 1987
B.S. THESIS:	The Depositional History and Petroleum Potential of the Tannehill Sandstone (Wolfcampian, Permian), Southeastern Knox County, Texas
PROFESSIONAL MEMBERSHIP:	American Association of Petroleum Geologists
PRESENT EMPLOYMENT:	Phillips Petroleum Company 366 West Sixth St. Borger, Tx. 79007
PERMANENT ADDRESS:	c/o Floyd Newsom 651 Ramblewood Houston, Tx. 77079