Oklahoma Geological Survey

Open-File Report 9-97

Upper and Lower Morrow core Descriptions from Three Wells in Dewey and Texas Counties, Oklahoma

Prepared to supplement

Special Publication, SP 95-1

Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma: The Morrow Play

By
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October 1997

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INTRODUCTION

Three Morrow cores were slabbed and described to supplement the original FDD Morrow play publication, SP 95-1. Two of the cores represent the lower Morrow in the Canton area (eastern Dewey county) and the third is an upper morrow core from the Oklahoma panhandle in western Texas county. All three cores are typical of the Morrow in their respective producing areas and are fluvial or fluvial-influenced but not deltaic. The cores interpreted in this report include:

1. Cities Service Oil Co., Buzzard "D" #2
   C N/½SE/¼ sec. 23, T. 4 N., R. 12 ECM
   Core depth: 6,030 - 6,056 ft.

2. Texas Pacific Co., Tidball #4
   SW/¼NE/¼NW/¼ sec. 22, T. 18 N., R. 14 W.
   Core depth: 9,162 - 9,213 ft.

3. Ladd Petroleum, Wills "A" #5
   CNE/¼SW/¼ sec. 25, T. 18 N., R. 14 W.
   Core depth: 9,018 - 9,086 ft.

All of the cores have been slabbed, cleaned, and varnished on cut surfaces. The slabbed samples were described using a standard protocol consisting of rock type, color, grain size, sedimentary structures and bedding characteristics. Sequences within the cored interval that are characteristic of a specific depositional event or facies are identified and a generalized interpretation of depositional environment is included. All of the cored wells have a composite electric log profile showing the total cored interval, slabbed interval (depth corrected), perforated zones, and regional stratigraphic markers. Digital images were made of selected intervals in all cores. These images are equivalent to black and white photographs and their stratigraphic position is identified within the center track separating the two log suites. Each visual image shows one or more sedimentary features that characterize the particular core. A brief statement is also made regarding the relationship of the rock feature to certain depositional processes or environments.

DEPOSITIONAL ENVIRONMENT CONSIDERATIONS

Common sedimentary structures, textures, and mineralogy such as ripple and cross bedding, contorted or deformed bedding, bioturbation, rip-up clasts, graded bedding, and carbonaceous-micaceous interbeds are common to a variety of depositional environments. Many different sedimentary facies also contain these features thereby making the interpretation of environments difficult or impossible from a single or small assemblage of sedimentary structures and textures. However, certain textures, minerals, and sedimentary structures are more prevalent in specific zones within a sand body. As an example, large scale, high angle cross bedding is common both in marine and channel environments. However, if it occurs near the top of a fining upward sequence, it is more likely to indicate a marine facies equivalent to an upper shoreface or central bar rather than a channel. In a similar manner, glauconitic sands are common within shelf (detached) bars but not common in distributary mouth bars. Conversely, distributary mouth bars have considerably higher concentrations of mica and coarse organic debris as compared to self bars. Ripple bedding is one of the most common sedimentary structures yet it is abundant in only certain facies of marine and fluvial deposits. It is rare in marine upper shoreface or central bar facies but is common in the lower shore face and underlying transition facies. The opposite relationship holds for pointbars where rippling is common in the upper facies but rare in the lower channel facies. Grain size is also important to examine since upper and lower facies of a particular sandstone sequence are often very different. This is commonly noticed in marine bars were the coarsest and cleanest sand is generally near the top of the bar. The opposite is also generally true for point bars which has the characteristic fining upward textural profile. These are just a few examples of using common sedimentary characteristics to interpret depositional environments and sandstone facies. Although many exceptions can be demonstrated, a good interpretation can be made by understanding depositional processes and relating sedimentary structures, texture, and mineralogy to a vertical sandstone sequence.

The conception that the Morrow and other Cherokee plays are primarily FDD is largely a misnomer. This occurs because of an inadequate understanding of what really constitutes a delta. Certainly, not all channels are deltaic and not all marine bars are deltaic. The interpretation of depositional origin must incorporate additional facies in a vertical stratigraphic sequence in order to see if components of a delta really exist. The largest component of any delta is the delta front or distributary mouth bar. This is the subaqueous part of the delta. It may be modified by waves or tides but it is still the foundation from which the delta plain originates. The delta front is usually much thicker than any distributary channel or point bar that develops in the delta plain above the delta front. However, when progradation of a delta ceases, a delta plain cannot develop in places overlying the subaqueous delta front for obvious reasons. In many places then, the termination of a delta will appear as a series of fine grained lobate sand bars that may be interpreted as near shore, attached, or shallow marine shelf bars.

CORES

UPPER MORROW CORE

Cities Service Oil Co., Buzzard "D" #2
C N/½SE/¼ sec. 23, T. 4 N., R. 12 ECM
Core depth: 6,030 - 6,056 ft.

This core is a good example of an incised fluvial channel. The channel sandstone consists of medium to coarse grained quartz with a relatively high percentage of rock fragments. It lies directly on black marine? shale and there are no other facies that can be interpreted as delta components within the stratigraphic interval immediately above or below this sandstone. The incised channel probably extended landward to the northwest for hundreds of miles into what is now southeast Colorado and southwest Kansas. However, sandstone that ultimately became preserved in this core was probably deposited in a relatively narrow coastal flood plain. Small downward variations in sea level probably resulted in seaward fluvial extensions covering a large area.

The Cities Service core was analyzed by Core Laboratories for basic permeability, porosity, and fluid saturation data. This information was donated by OXY USA (they acquired the Cities properties). Figure 1 is a graphical illustration showing various relationships of porosity, permeability, and depth.

LOWER MORROW CORES

Texas Pacific Co., Tidball #4
SW/¼NE/¼NW/¼ sec. 22, T. 18 N., R. 14 W.
Core depth: 9,162 - 9,213 ft.

Ladd Petroleum, Wills "A" #5
CNE/¼SW/¼ sec. 25, T. 18 N., R. 14 W.
Core depth: 9,018 - 9,086 ft.

These two cores are typical of the lower Morrow in the Canton FDD area. They were both described by South, (1983) who interpreted the main sand zones as being deltaic or marginal marginal marine in origin. South recognized several facies in the cores including non-marine channel deposits (point bars), distributary channels, tidal channels and tidal flat deposits. Interpretations of this report are somewhat similar and include tidal channel and intertidal deposits within an estuarine environment.

The Canton area is unusual for the Morrow because of the highly variable nature of hydrocarbon production and also because the lower Morrow is oil prone. The sandstone is mostly fine to very fine grained, chiefly quartz, and extremely variable in regards to sedimentary structures and biogenic alterations. For most geologists, the Morrow in the Canton area is difficult to understand for a number of reasons. Interpretations of depositional environments based on log profiles are often confusing because of the highly variable nature of log patterns. Lateral correlations of individual sandstone zones are also difficult even within short distances of a quarter mile. Nevertheless, the general pattern of depositional environments can be reasonably interpreted based upon these cores and their corresponding well log signatures.

Both Morrow cores show evidence of fluvial processes in a marginal marine environment. Channeling is everywhere apparent. The conspicuous presence of terrestrial material interbedded with marine constituents such as shell debris and bioturbation clearly show the episodic nature of deposition. Conglomeratic intervals in one interval may appear to be entirely terrestrial whereas bioclastic interlayering shows significant marine influence. Individual bed forms are generally thin (inches to a foot or two) and are laterally discontinuous. These sedimentary features are characteristic of tidal embayments and the principal reservoir appears to be tidal channels (or creeks) in an estuarine environment. In a landward direction (to the northeast), the depositional system is probably entirely terrestrial in a coastal plain environment. Basinward to the southwest, the lower Morrow is predominantly marine.

REFERENCES CITED

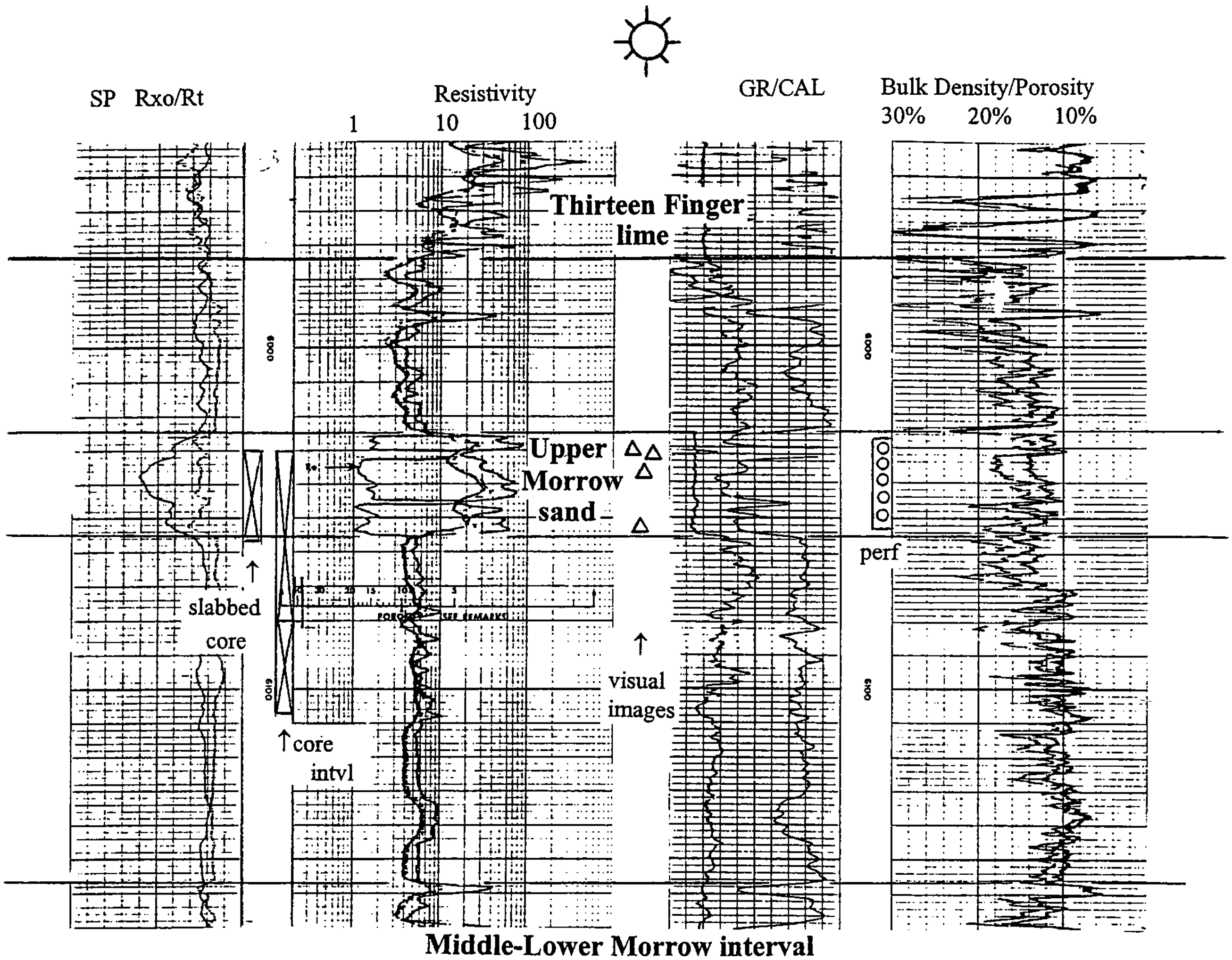
South, M. V., 1983, Stratigraphy, depositional environment, petrology and diagenetic character of the Morrow reservoir sands, southwest Canton field, Blaine and Dewey Counties, Oklahoma: Oklahoma State University unpublished M.S. thesis, 140 p.

Cities Service, Buzzard #2-D
N/½ SE/¼ sec. 23, T. 4 N., R. 12 ECM.
Upper Morrow sandstone
Incised Fluvial Channel

Log depth ≈ core depth ± a few ft — Described by: Richard D. Andrews

Core depth *(in feet)*	**Lithology and sedimentary structures**
6,030- 6,031.9	Sandstone, medium to coarse grained, massive to highly inclined cross bedding. Numerous carbonaceous shale or coaly laminations. Secondary quartz overgrowths (cement) is widespread. Porosity is mostly secondary and is generally good.
6,031.9- 6,033.4	Sandstone, fine grained, with numerous shale laminations. Highly inclined bedding with micro faults in slumped section at 6,032 ft.
6,033.4- 6,038.8	Sandstone, medium grained, relatively clean sand with few carbonaceous laminations . Bedding is mostly massive. Sandy rip-up mud clasts at 6,038.3- 6,038.7 ft. Good secondary porosity with quartz overgrowths between framework constituents of quartz and rock fragments.
6,038.8- 6,047	Sandstone, coarse grained, mostly massive bedding. Good secondary porosity with quartz overgrowths as above. Sandstone has numerous rock fragments, almost no partings, and appears very granular.
6,047- 6,048	Black shale with a few coarse grained sandstone interbeds. Shale is very fissile and carbonaceous. **Clay drape?**
6,048- 6,050	Sandstone, coarse to very coarse grained with numerous rock fragments. Bedding is massive with a few scattered mud clasts and carbonaceous fragments.
6,050- 6,054	Sandstone, as above, with numerous shale beds and laminations that are coalified. Sandstone has numerous rounded and elongated mud clasts. A very sharp basal contact with the underlying black shale defines the **channel base**.
6,054- 6,056	Shale, black, splintery, and coaly.

Cities Service, Buzzard 2-D (N/2 SE sec. 23, T. 4 N., R. 12 ECM.)			
Reservoir:	U. Morrow sandstone	Log depth:	~ 6,030-6,056 ft ± a few ft
Depositional environment:	Incised Fluvial channel	Core depth:	6,030-6,056 ft



T.D.: 6,515 ft
Completion date: 3-9-76
Core #1; 6,030- 80, rec 50' (slabbed 6,030-56')
Core #2; 6,080- 6,107, rec 27'
Perforated: 6,027- 6,053 ft
Frac 21,500# sand, 11,000 gal acid
IPF (Morrow) 2,300 MCFGPD + 1BWPH

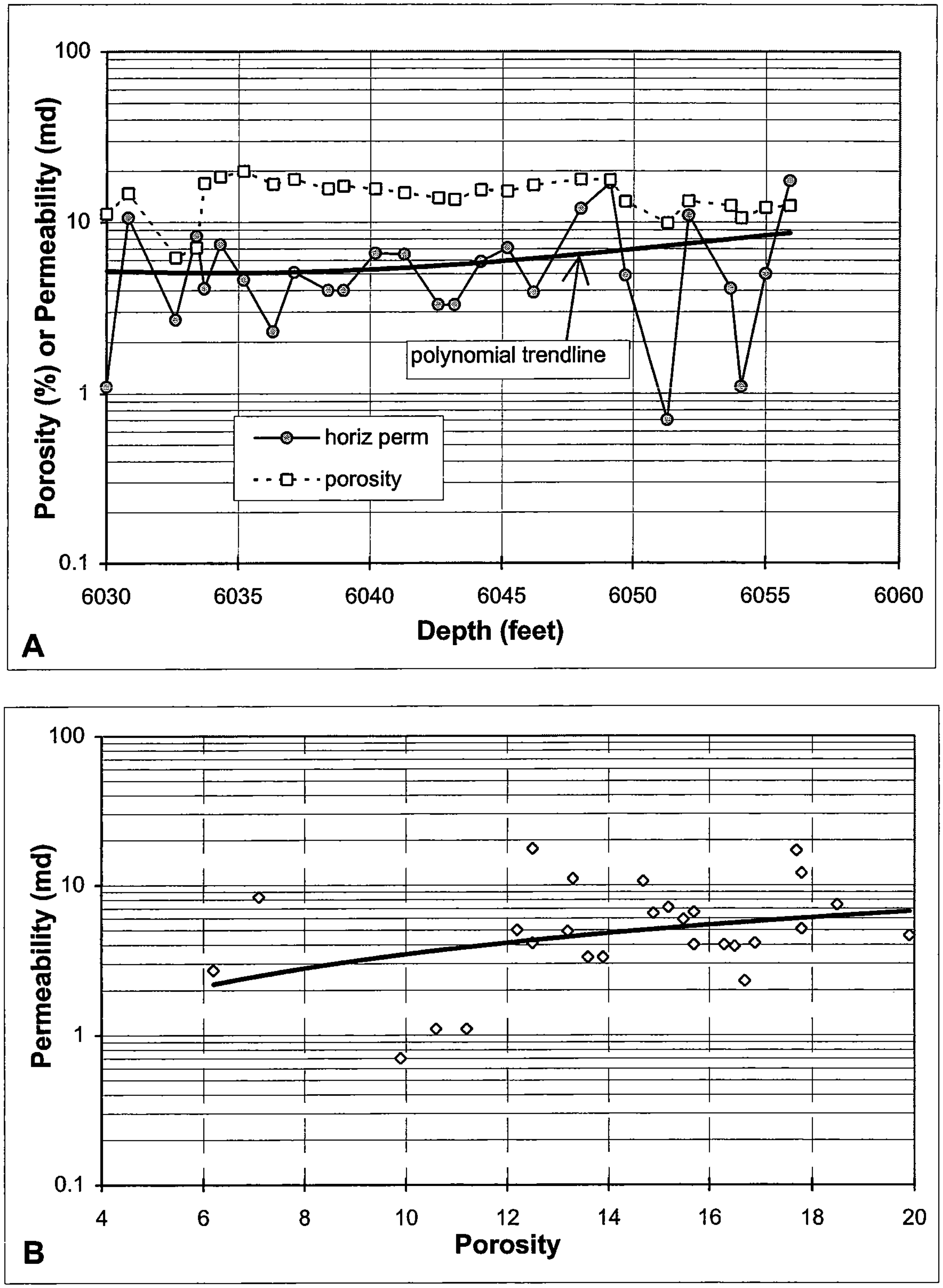
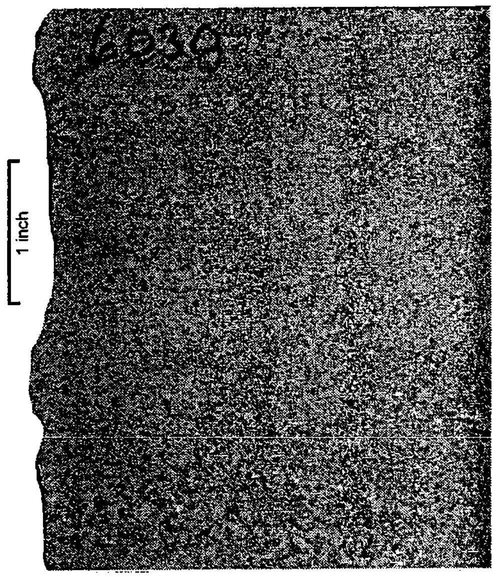


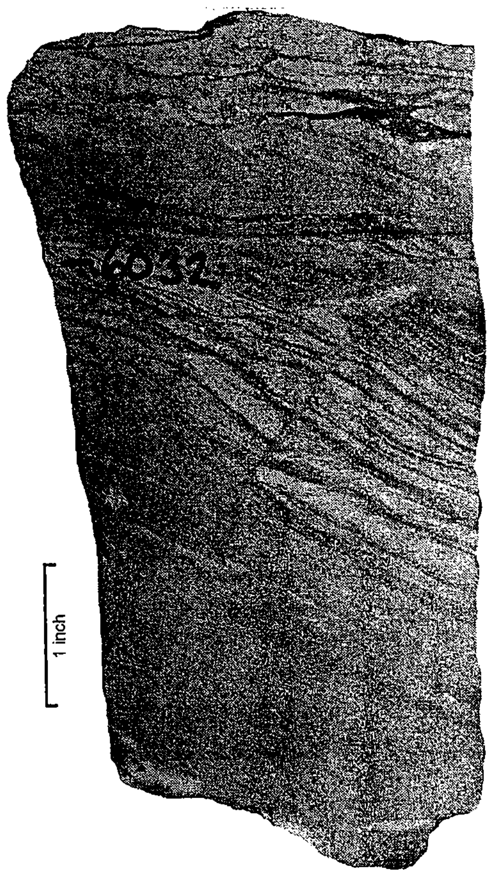
Figure 1. Core analysis data of the upper Morrow sandstone in the Cities Service #2 Buzzard well, CN/2 SE sec. 23, 4N-12ECM, Texas County, Oklahoma. The relationship of porosity or permeability to depth is shown in part A whereas the relationship of porosity to permeability is shown in part B.



Cities Service, Buzzard #2-D
(N/½ SE sec. 23, T. 4 N., R.12 ECM)

Core depth: 6,030- 6,030.3 ft
Log depth: ~6,030- 6,030.3 ft

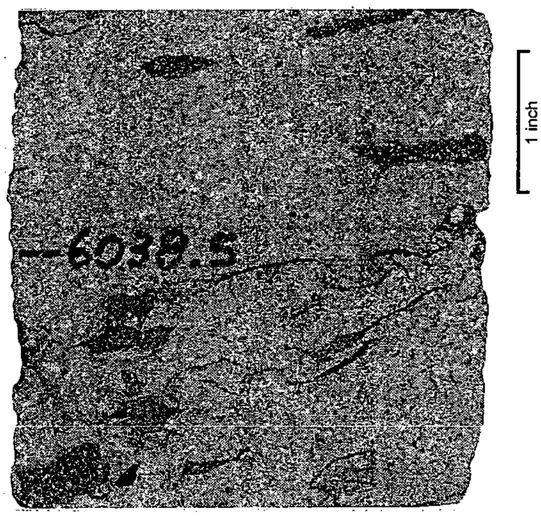
Massive to graded bedding in medium to coarse grained sandstone. With a hand lens, cementation can easily be determined as quartz overgrowths. The presence of dark fractions are rock fragments and the conspicuous appearance of porosity is entirely due to secondary destruction of unstable rock constituents. Although this rock has good porosity (~12%), the permeability is only a few millidarcies.



Cities Service, Buzzard #2-D
(N/½ SE sec. 23, T. 4 N., R.12 ECM)

Core depth: 6,031.9- 6,032.3 ft
Log depth: ~6,031.9- 6,032.3 ft

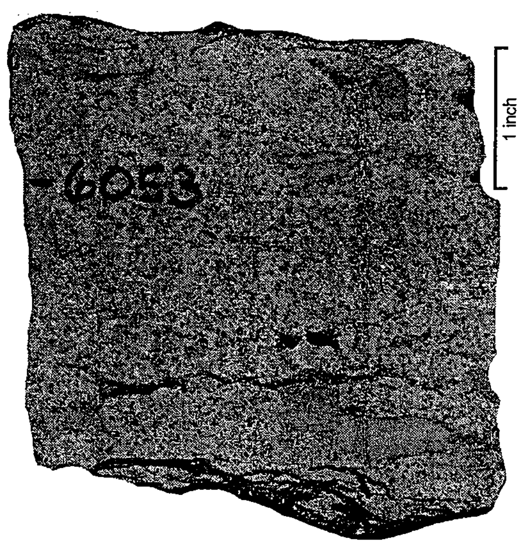
Slump structure or soft sediment deformation in fine grained sandstone occurs below 6,032 ft. High angle bedding with bed displacement is common in fluvial deposits such as this. Often, flowage (contorted bedding) accompanies such structures. The medium grained sandstone above the slump structure (above 6,032 ft) has interlaminations of highly carbonaceous shale. Many times, such deformation is more apparent in finer grained deposits because of the conspicuous orientation of dark shale layers.



Cities Service, Buzzard #2-D
(N/½ SE sec. 23, T. 4 N., R.12 ECM)

Core depth: 6,038.4- 6,038.6 ft
Log depth: ~6,038.4- 6,038.6 ft

Sandy mud clasts are floating within a medium grained sandstone. The dissolution of these rip-up clasts and other unstable rock constituents forms numerous voids that contribute greatly to the secondary porosity attributed to these rocks. Despite the presence of good secondary porosity, the permeability in this sample is only several millidarcies. The severe reduction in permeability is a big problem in the upper Morrow and is caused when aggregates of kaolinite plug up many of the pore throats. Kaolinite is a common alteration byproduct of rock fragments and feldspar, both of which are abundant in the Morrow.



Cities Service, Buzzard #2-D
(N/½ SE sec. 23, T. 4 N., R.12 ECM)

Core depth: 6,052.9- 6,053.2 ft
Log depth: ~6,052.9- 6,053.2 ft

Coarse to medium grained sandstone with mudstone rip-up clasts is typical of the lower channel facies. This sample is bounded on the top and bottom by a thin coaly layer having plant imprints. As in all other sandstone horizons within this channel sequence, secondary quartz overgrowths is the primary cementing agent. Less than a foot below this sample, the sandstone has a sharp basal contact with shale which is typical of channel deposits.

Texas Pacific Co., Tidball #4

SW/¼NE/¼NW/¼ sec. 22, T. 18 N., R. 14 W.

Lower Morrow sandstone

Tidal channel (point bar?), intertidal deposits

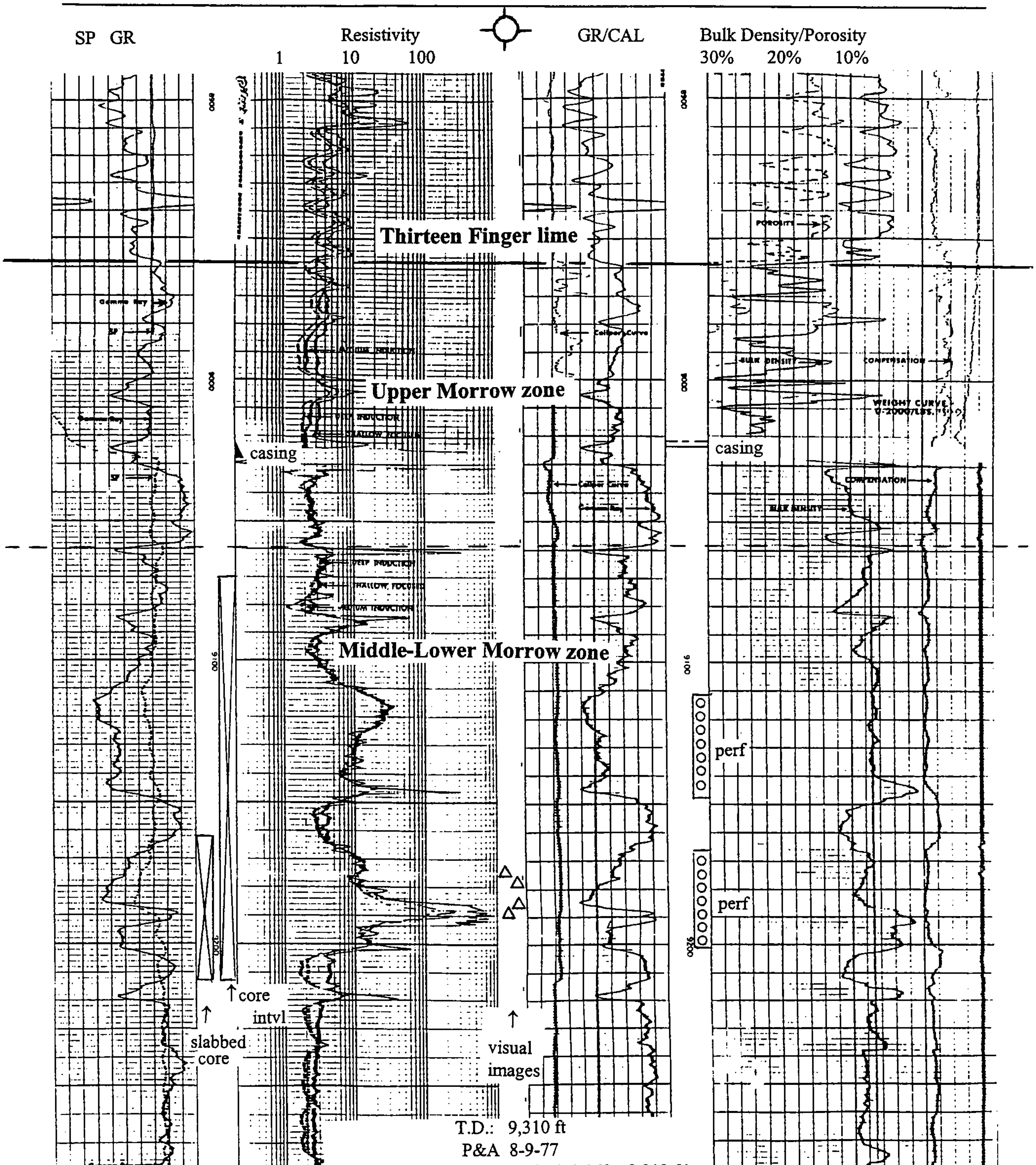
Log depth ≈ Core depth ± a few ft

Described by: Barbara Teichert and Richard D. Andrews

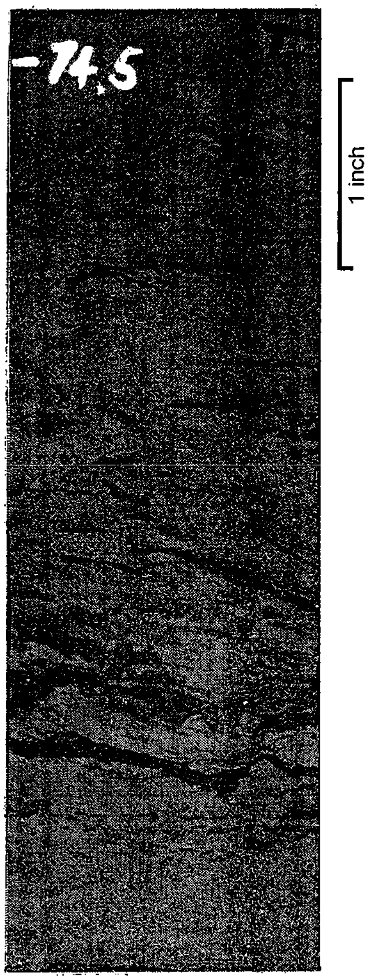
Core depth *(in feet)*	**Lithology and sedimentary structures**
9,162.0- 9,163.9	Shale, dark gray to black, organic rich with coaly layers.
9,163.9- 9,174.5	**Intertidal deposits** (tidal flat and/or upper tidal point bar facies). Sandstone, fine to very fine grained, dark gray to greenish, with thin shale beds and laminations. Abundant plant debris and coaly layers. Possible rooting at 9,165.2 ft. At 9,167.3 ft: ~3 cm of mud clasts and fossil fragments. Slumping structures at 9,169.2 to 9,169.5 ft. Bedding is often indistinct or irregular (bioturbation at 9,168-69 ft), sometimes planar (9,171.7 ft), and occasionally in the form of tidal? couplets (thin distinct alternating beds of sandstone and shale) at 9,174 to 9,174.4 ft.
9,174.5- 9,184.4	Sandstone, fine to very fine grained, medium gray with locally abundant shale fragments and intercalations. Bioturbation intense at 9,174.5 to 9,174.8 ft. Slump structures with steeply dipping beds at 9,175.3 to 9,179.5 ft. Lenticular and ripple/flaser? bedding dominates between 9,180-9,183 ft. Tidal couplets? at 9,182.2 ft. Large coalified plant fragment at 9,182.3 ft.
9,184.4- 9,187.4	Sandstone, fine grained, light gray to white, and tightly cemented with calcite. Rhythmic bedding consisting of alternating sandstone and highly carbonaceous shale is most common. Small scale, medium angle cross bedding occurs at 9,185.8 ft. Shale laminations contain abundant small pieces of plant debris.
9,187.4- 9,187.6	Sandstone, very fine grained with soft sediment deformation (i.e., slumping or flowage).
9,187.6- 9,192.4	**Lower tidal channel facies** (subtidal?). Conglomeratic layers with interbedded sandy layers. Conglomerate: mostly mud clasts (max. 3 cm) and some fossil fragments in calcareous matrix. Sandy layers: medium to fine grained, subrounded, light colored, calcareous, with abundant coalified organic material. Sharp basal contact with shale. **Channel base.**
9,192.4- 9,202.2	**Muddy tidal flat or lagoonal beds?** Shale and very fine grained sandstone and siltstone, calcareous, dark gray to black. Bedding is faint but is either laminated or indistinct (bioturbated?). At 9,193.4 ft: 1 inch layer of bivalve shells.
9,202.2- 9,213.0	Shale, dark gray to black. Top 3 ft are calcareous but diminishing with depth. Shale gets increasingly more fissile in the bottom of core. Several thin fossiliferous layers between 9,202.2 to 9,203 ft. Scattered bivalve? shells at 9,204.5 to 9,206 ft.

Texas Pacific Co., Tidball #4 SW¼NE¼NW¼ sec. 22, T. 18N., R. 14 W.

Reservoir:	L. Morrow sandstone	Log depth:	≈ 9,162 - 9,213 ft
Depositional environment:	Tidal point bar	Core depth:	9,162 - 9,213 ft



T.D.: 9,310 ft
P&A 8-9-77
Core: 9,070 - 9,213 ft, (slabbed 9,162 - 9,213 ft)
Perforated: 9,111-47, and 9,166-9,201 ft
Frac 84,000# sand, 89,500 gal oil
F 76 BLO + 31 MCFGPD



Texas Pacific, Tidball #4
(SW NE NW sec. 22, T. 18 N., R. 14 W.)

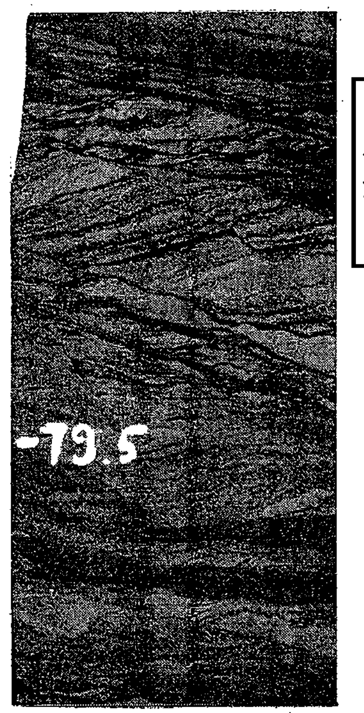
Core depth: 9,174.5- 9,174.9 ft
Log depth: ~9,174.5- 9,174.9 ft

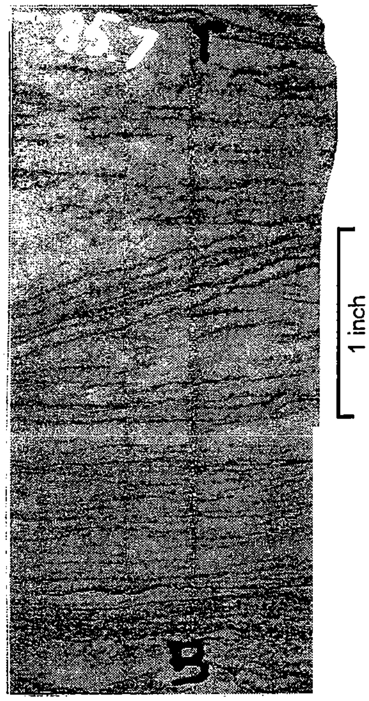
Bioturbated sandstone is very fine grained and contains numerous shale fragments. Bedding within the sandstone is amorphous but may have been ripple bedded prior to biogenic destruction of original bed forms. This type of post-depositional modification of sediments (diagenesis) is very common in tidal flat environments and distinguishes it from upper pointbar facies deposited within a flood plain which are not normally intensely bioturbated. In sandstone, bioturbation generally reduces porosity and permeability.

Texas Pacific, Tidball #4
(SW NE NW sec. 22, T. 18 N., R. 14 W.)

Core depth: 9,179.3- 9,179.6 ft
Log depth: ~9,179.3- 9,179.6 ft

Slump structures or soft sediment deformation occurs in any sedimentary environment where deposition is rapid. It is most common in distributary mouth bars of the delta front but is also common in any type of channel bar. Therefore, this sedimentary structure is not diagnostic of a particularly environment but rather of a depositional process.





Texas Pacific, Tidball #4

(SW NE NW sec. 22, T. 18 N., R. 14 W.)

Core depth: 9,185.7- 9,186.0 ft
Log depth: ~9,185.7- 9,186.0 ft

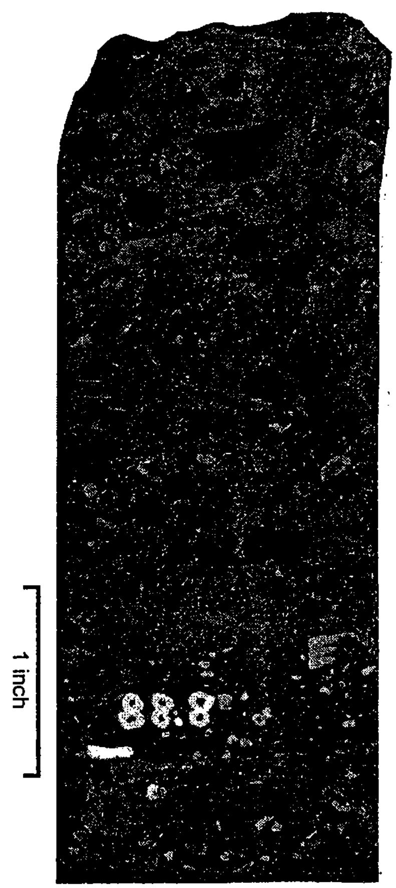
Cross bedding, small scale, medium angle is common in the upper part of fluvial/tidal channel facies whereas larger scale cross bedding is typically found in the lower channel facies. This sandstone is fine grained and tightly cemented with calcite - a characteristic of many sands deposited in a marine or marginal marine environment. However, the sandstone has numerous shale laminations containing abundant pieces of coalified plant material that are probably of terrestrial origin. These divergent rock characteristics are most commonly attributed to intertidal areas that are influenced both by the sea and by the land.

Texas Pacific, Tidball #4

(SW NE NW sec. 22, T. 18 N., R. 14 W.)

Core depth: 9,188.5- 9,188.9 ft
Log depth: ~9,188.5- 9,188.9 ft

Mud clast conglomerate with sandy matrix is moderately calcareous. Mud clasts are rounded or elongated and randomly oriented and supported by a matrix of fine to medium grained sand. At 9,188.8 ft, a distinct layer of fine grained, fossiliferous sandstone is interbedded within the mud clast conglomerate. Fossil debris in this ½ in thick zone consists mostly of crinoid fragments that may have been transported by flood tidal currents. Other distinct zones of interbedded sandstone similarly occur throughout the conglomeratic interval (9,187.6- 9,192.4 ft) and may represent oscillatory currents in a tidal channel. The log response through the conglomerate may be confusing since the gamma ray log indicates shale and the resistivity log is anonymously high. This can easily be explained by the abundance of mud clasts (clay) that have been tightly cemented by calcite in a sandy matrix.



Ladd Petroleum, Wills "A" #5

CNE/¼SW/¼ sec. 25, T. 18 N., R. 14 W

Lower Morrow sandstone

Intertidal deposits, possibly with thin tidal channels

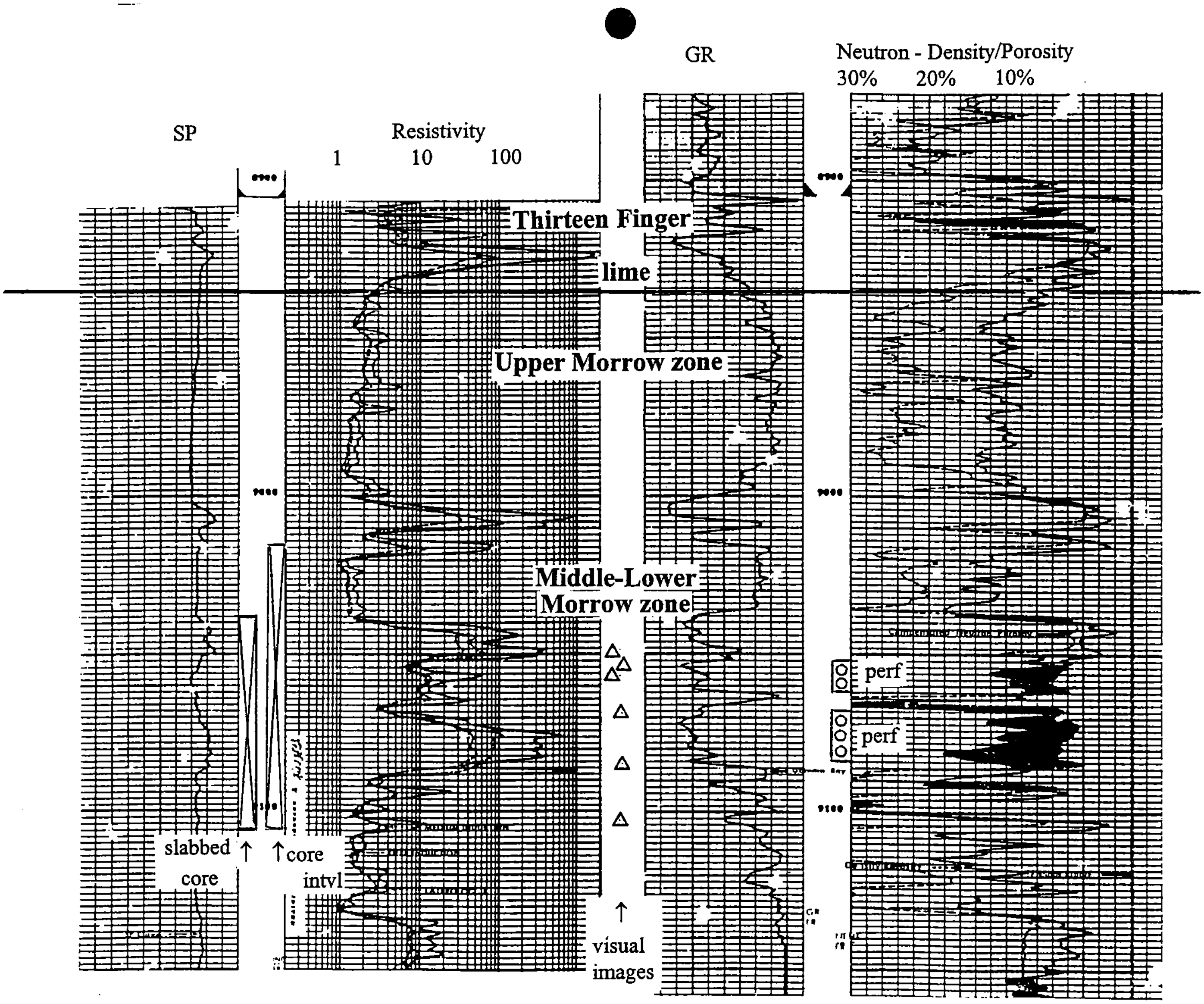
Log depth ≈ 20 ft lower than core depth

Described by: Barbara Teichert and Richard D. Andrews

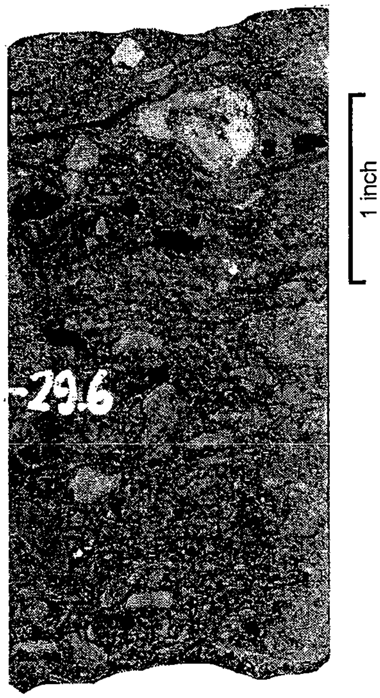
Core depth *(in feet)*	Lithology and sedimentary structures
9,018 - 9,019.9	Shale, dark gray to black, fissile, with small amount of very fine grained mica.
9,019.9- 9,027.0	**Top of tidal channel.** Bioclastic limestone (packstone) with fossil fragments consisting of bivalves, corals, crinoids, and ammonites mostly <2 mm (<.1") Numerous thin, black, shaly intercalations and flakes with very fine grained micas on bedding surfaces. Few mud clasts to max 1 cm (0.4").
9,027.0- 9,032.0	Limestone conglomerate (packstone), clast supported fossil fragments (as above) and mud clasts with minor amounts of fine grained matrix sand. Calcareous mud clasts to 3 cm (1.2") become larger and more abundant near base of this interval. Note the overall fining upward texture from 9,032 ft to 9,020 ft. Sharp basal contact between conglomerate and underlying shale at 9,032 ft. **(base of tidal channel).**
9,032.0- 9,035.2	Sandstone with interbedded black, carbonaceous shale lenses. Thin skeletal bed in shaly matrix at 9,032.7 - 9,033 ft.
9.035.2- 9,045.0	**Intertidal deposits?** Sandstone, medium gray, very fine grained with shale laminations. Some mica on bedding surfaces. The top 2 ft is mostly featureless having indistinct bedding due to bioturbation. The lower part may be relic ripple bedding in the aftermath of bioturbation as it consists of irregular lenses of sand and mud. Possible water escape structure at 9,039.15 ft.
9,045.0- 9,048.0	Shale, black, thinly bedded with some sandy intercalations.
9,048.0- 9,060.0	**Top of tidal channel.** Sandstone, mostly quartz (arenite). Intercalation of dark gray sandstone with greenish and brownish sandstone. All sandstone is very fine grained, contains carbonized plant debris, and has abundant (continued on next column) mica on bedding surfaces. Sandstone is tightly cemented but not calcareous (little or no fizz with acid). Contorted bedding (slumping structures) at 9,056.8 ft; 9,057.5 ft; and 9,058 ft. Bedding couplets (alternating sand and shale beds) or possibly flaser bedding (shaly material in ripple troughs) at 9,049.2- 9,049.6 ft; 9,050.1-9,053 ft; and 9,055.6- 9,056.2 ft.
9,060.0- 9,065.0	Missing.
9.065.0- 9,067.0	Sandstone, very fine grained, mostly quartz (arenite), tight, non-calcareous, flowage (contorted bedding) at 9,065.5 ft and 9,066.4 ft. Sharp basal contact with underlying shale at 9,067 ft. **Base of tidal Channel.**
9,067.0- 9,072.9	**Intertidal deposits?** Shale, dark gray, few micas, becoming increasingly interbedded with greenish sandy lenses with depth.
9,072.9- 9,073.9	Sandstone, very fine grained, light gray, quartz arenite, interbedded with thin shale lenses in the upper 3 inches. Some carbonaceous flakes, sharp basal contact with underlying shale.
9,073.9- 9,076.1	Shale, dark gray with thin, very fine grained sand lenses (tidal couplets?).
9,076.1- 9,080.4	Shale, medium gray, organic rich (carbonaceous plant debris).
9,080.4- 9,083.0	Sandstone with interbedded fossiliferous limestone. Sandstone is very fine grained to silty, calcareous, mostly greenish with a few brown zones, lenticular to horizontal bedded, and bioturbated. Fossiliferous layers consist of clay-rich skeletal limestone (packstone) containing bivalves.
9,083.0- 9,084.1	**Lagoonal or tidal flat deposit?** Crinoidal-bivalve packstone-wackestone consists of fossil debris in a black, highly carbonaceous, non-calcareous shale matrix.
9,084.1- 9,086.1	Shale, dark gray.

Ladd Petroleum, Wills "A" #5 CNE/¼SW/¼ sec. 25, T. 18 N., R. 14 W

Reservoir:	L. Morrow sandstone	Log depth:	≈ 9,038 - 9,106 ft
Depositional environment:	Intertidal deposits, possibly with thin tidal channel	Core depth:	9,018 - 9,086 ft



T.D.: 9,158 ft
Completion date: 10-15-78
Core: 8,995 - 9,086 ft, (slabbed 9,018 - 9,086 ft)
Perforated: 9,052 - 62, and 9,068 - 84 ft
Frac 165,000# sand + 115,000 gals gelled oil
IPF (Morrow) 10 BOPD + trace wtr, Gty 39.3



Ladd Petroleum, Wills "A" #5
C NE SW sec. 25, T. 18 N., R. 14 W.

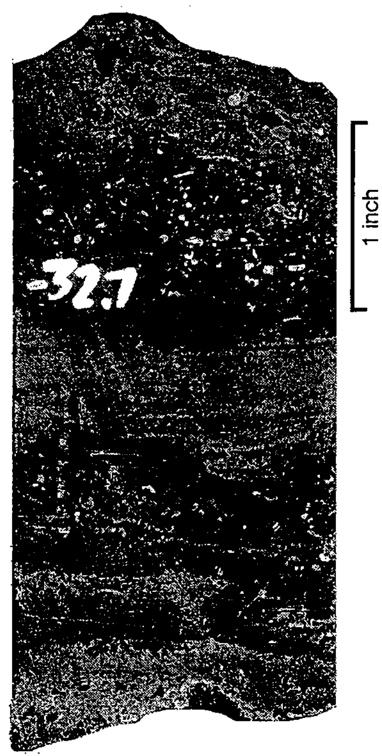
Core depth: 9,029.4- 9,029.7 ft
Log depth: ~9,049.4- 9,049.7 ft

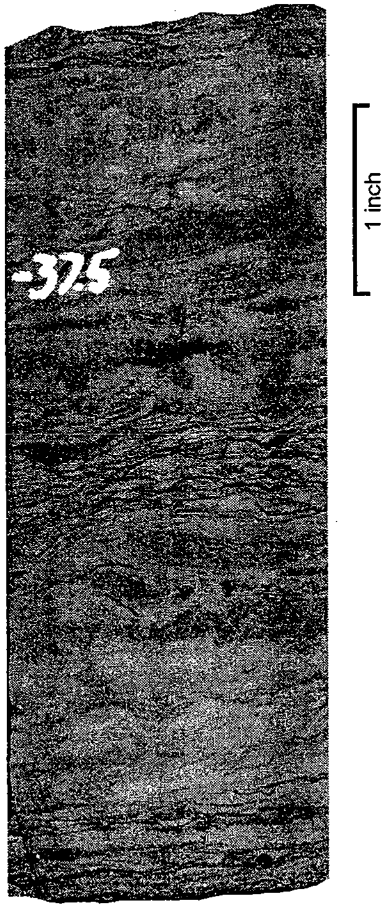
Limestone conglomerate (packstone) has numerous calcareous mud clasts with minor amounts of fine grained matrix sand. Fragments of crinoids, ammonites, and bivalves are present but more numerous immediately above and below this sample. Zones consisting of predominantly mud clasts alternating with zones containing mostly fossil fragments may reflect ebb tides (seaward flowing) versus flood tides (landward flowing) in a tidal channel (estuarine) environment.

Ladd Petroleum, Wills "A" #5
C NE SW sec. 25, T. 18 N., R. 14 W.

Core depth: 9,032.6- 9,032.9 ft
Log depth: ~9,052.6- 9,052.9 ft

Alternating layers of black shale lenses and skeletal packstone, and gray conglomeratic sandstone. The skeletal layers have abundant pieces of crinoids and small shell fragments whereas the sandy layers have small mud clasts. As in the above sample, this may reflect oscillating currents; ebb tides (seaward flowing) forming conglomeratic sandstone versus flood tides (landward flowing) forming skeletal layers.

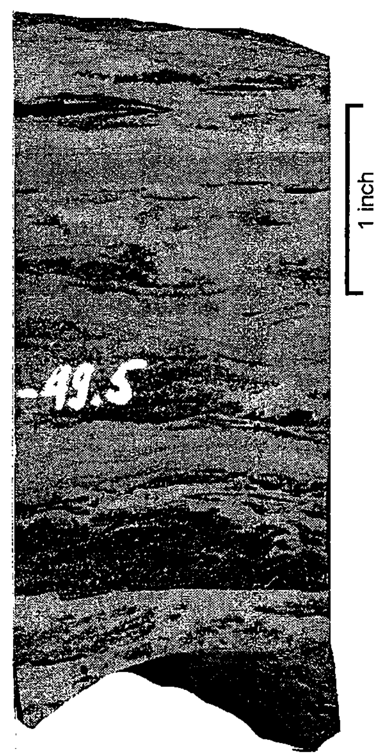




Ladd Petroleum, Wills "A" #5
C NE SW sec. 25, T. 18 N., R. 14 W.

Core depth: 9,037.4- 9,037.8 ft
Log depth: ~9,057.4- 9,057.8 ft

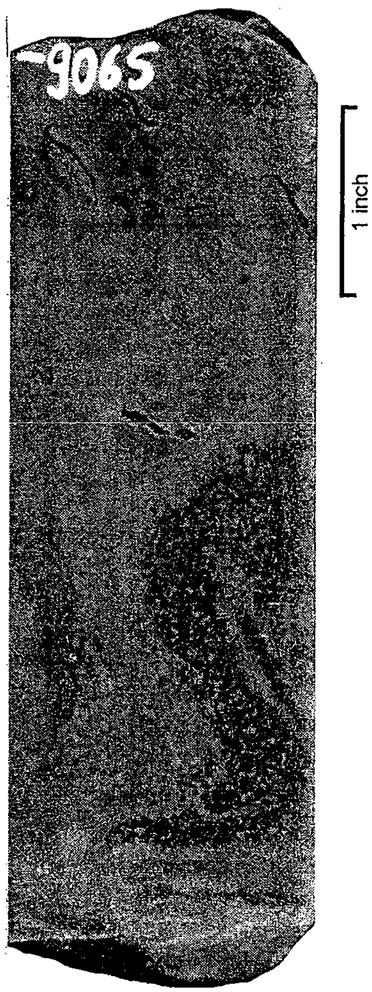
Intertidal?, bioturbated sandstone has amorphous distribution patterns of very fine grained sandstone and shale. The shale occurs as discontinuous lenses and laminations and is highly carbonaceous and slightly micaceous. Bioturbation in sandstones often reduces porosity and permeability. In this sample, bioturbation destroyed primary bedding features such as ripple marks. The importance of recognizing biogenic alterations in sandstone also serves in the interpretation of depositional environments. In this case, the effects of marine processes are evident and supports the interpretation of an intertidal environment rather than a terrestrial flood plain.



Ladd Petroleum, Wills "A" #5
C NE SW sec. 25, T. 18 N., R. 14 W.

Core depth: 9,049.3- 9,049.6 ft
Log depth: ~9,069.3- 9,069.6 ft

Bedding couplets consisting of alternating sandstone and shale beds is common to tidal flats. The distribution patterns of shale and sandstone in this sample also has similarities to flaser bedding whereby shaly material accumulates within ripple troughs. This is somewhat hard to see since the slab is not at the optimum orientation to see ripple bedding.



Ladd Petroleum, Wills "A" #5

C NE SW sec. 25, T. 18 N., R. 14 W.

Core depth: 9,065.0- 9,065.4 ft
Log depth: ~9,085.0- 9,085.4 ft

Flowage or contorted bedding is evident by the near vertical swirly pattern of darker colored material. This core sample is from the base of a 20 ft thick sand bed and consists of very fine grained quartz. The sandstone is tightly cemented (probably quartz overgrowths) and is mostly non-calcareous. Although flowage occurs in a variety of depositional settings, in this sample, it is more indicative of channel slumping rather than marine bar slumping because it occurs at the very base of the sand bed.

Ladd Petroleum, Wills "A" #5

C NE SW sec. 25, T. 18 N., R. 14 W.

Core depth: 9,083.0- 9,083.4 ft
Log depth: ~9,103.0- 9,103.4 ft

Lagoonal or muddy tidal flat deposit (crinoidal-bivalve packstone-wackestone) consists of fossil debris in a shale matrix. Small bivalve and crinoid fragments are abundant in a very carbonaceous, black, non-calcareous shale matrix. This type of deposit is very characteristic of marginal marine environments affected by tide water.