RESERVOIR QUALITY OF THE FRISCO FORMATION, HUNTON GROUP, SEMINOLE COUNTY, OKLAHOMA

By

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CHAPTER I

INTRODUCTION

Preface

Recent drilling activity in the Seminole District, Central Oklahoma, has provided new data and information that were used to develop the ideas discussed in this thesis. Various data examined from the Seminole County study area indicate the presence of previously undescribed carbonate mounds. These mounds were compared and correlated with the carbonate mound outcrop along Bois d'Arc Creek in Pontotoc County. It is these mounds that are of specific interest to this study and seemingly linked to the renewed production of hydrocarbons from the Hunton Group in the Seminole District.

Location

The focus of this investigation is the Hunton Group in Lincoln, Pottawatomie, Seminole and Pontotoc counties, central Oklahoma (Figure 1). These counties are within the area of a larger-scale regional study relating the Hunton in Pontotoc County to the Hunton in the subsurface of Seminole County approximately 40 miles to the north (Figure 2). In Pontotoc County, an outcrop of the Frisco Formation was studied approximately 4 miles south of Ada, Oklahoma along Bois d'Arc Creek. In Seminole County, the specific area of interest is in Townships, 10 & 11 North, Range 6 East. The

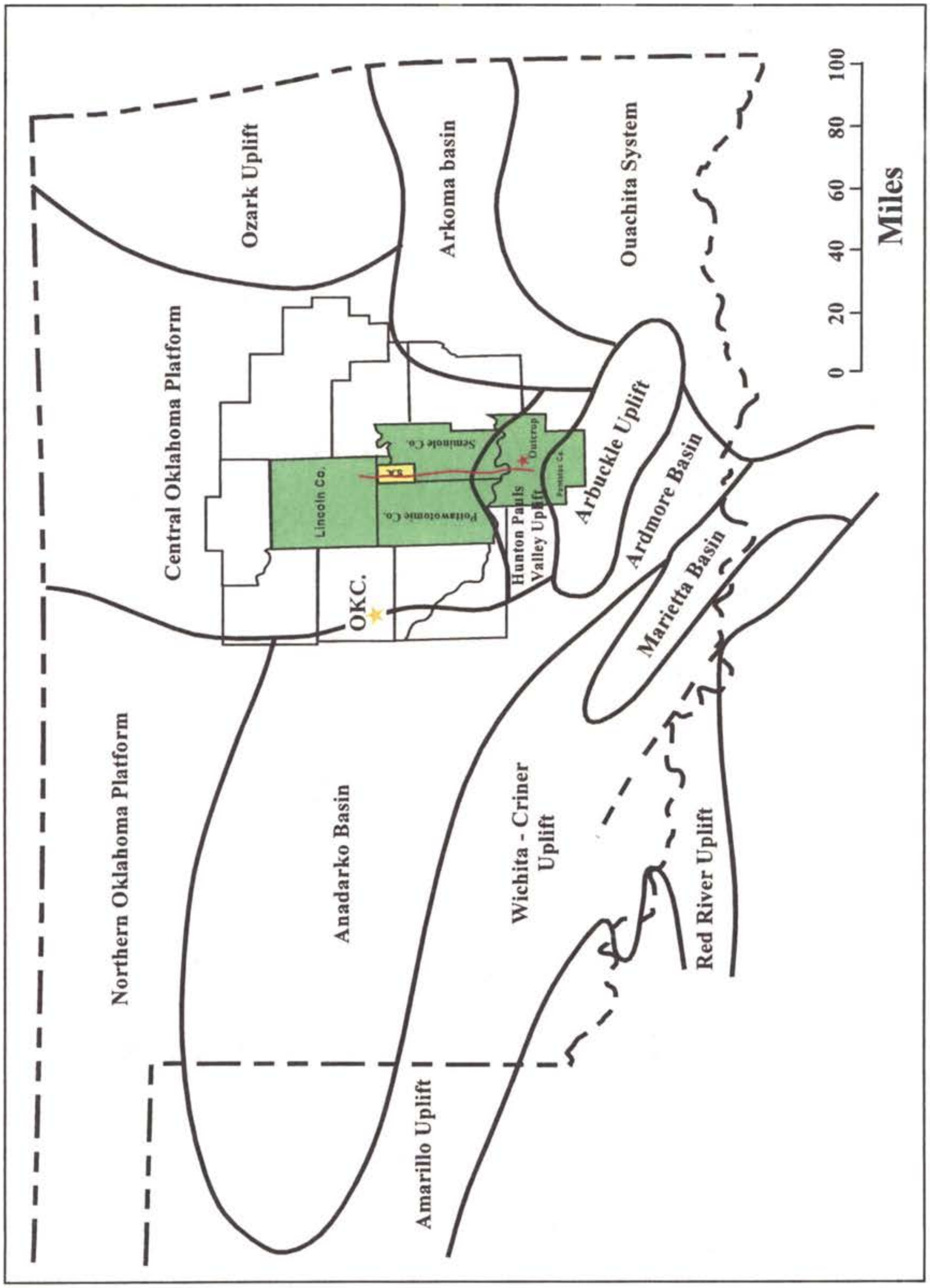


Figure 1. A geologic province map of Oklahoma, showing regional study area and regional cross section: Lincoln, Pottawatomie, Seminole and Pontotoc Counties, east central Oklahoma.

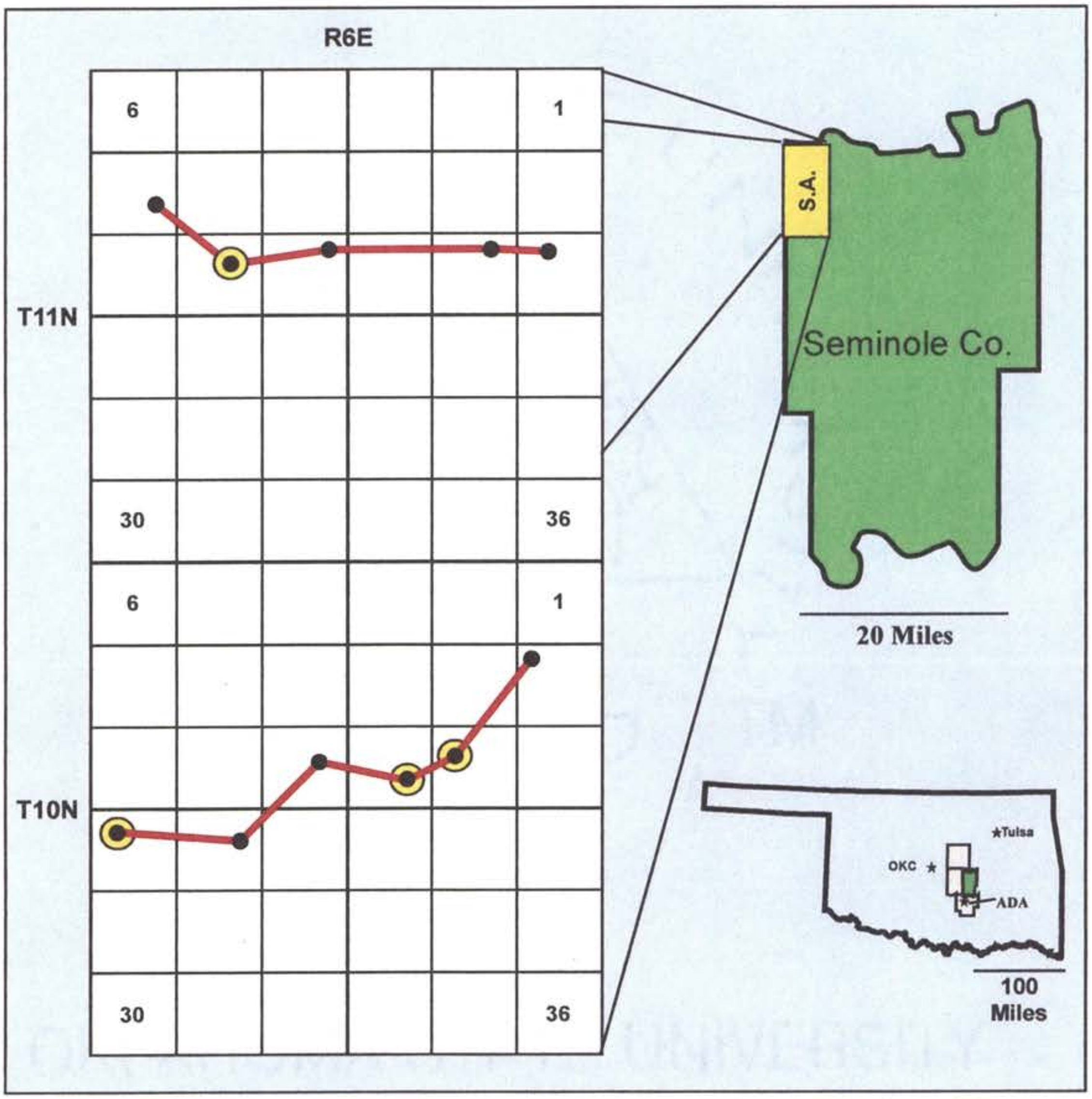


Figure 2. Location of the Seminole County, Oklahoma study area location with E-W cross sections.

Hunton Group here contains carbonate mound lithofacies. The conodont data explained later indicate these mounds are part of the Frisco Formation.

Statement of Purpose

The intent of this thesis is to describe and discuss evidence of carbonate mounds in Central Oklahoma and to compare it with the Frisco Formation in Pontotoc County, Oklahoma. It is important to note that the Frisco Formation is a producing unit within the Hunton Group and that much of the Hunton production in Seminole and Pontotoc counties, not previously assigned to specific formations may have produced from Frisco reservoirs. A variety of subsurface data were integrated to determine stratigraphy, depositional facies and estimate reservoir type, size and quality.

Stratigraphy

The Frisco Formation is part of the Ordovician-Devonian Hunton Group. Stratigraphically, the Frisco is lower Devonian in age, (Emsian, Pragian) (Barrick et al. 1990) the youngest and uppermost formation in the Hunton Group (Figure 3). The Frisco is separated from the underlying Hunton carbonate by an unconformity and represents a distinctly different style of deposition.

Methods of Investigation

A methodology was developed to investigate the intricacies of mound buildups in the Hunton Group of Seminole County, Oklahoma and compare them with the features in the Frisco Formation outcrop. Specifically, the following were considered: sedimentological, petrological, petrographical analysis as well as rock property data to evaluate reservoir

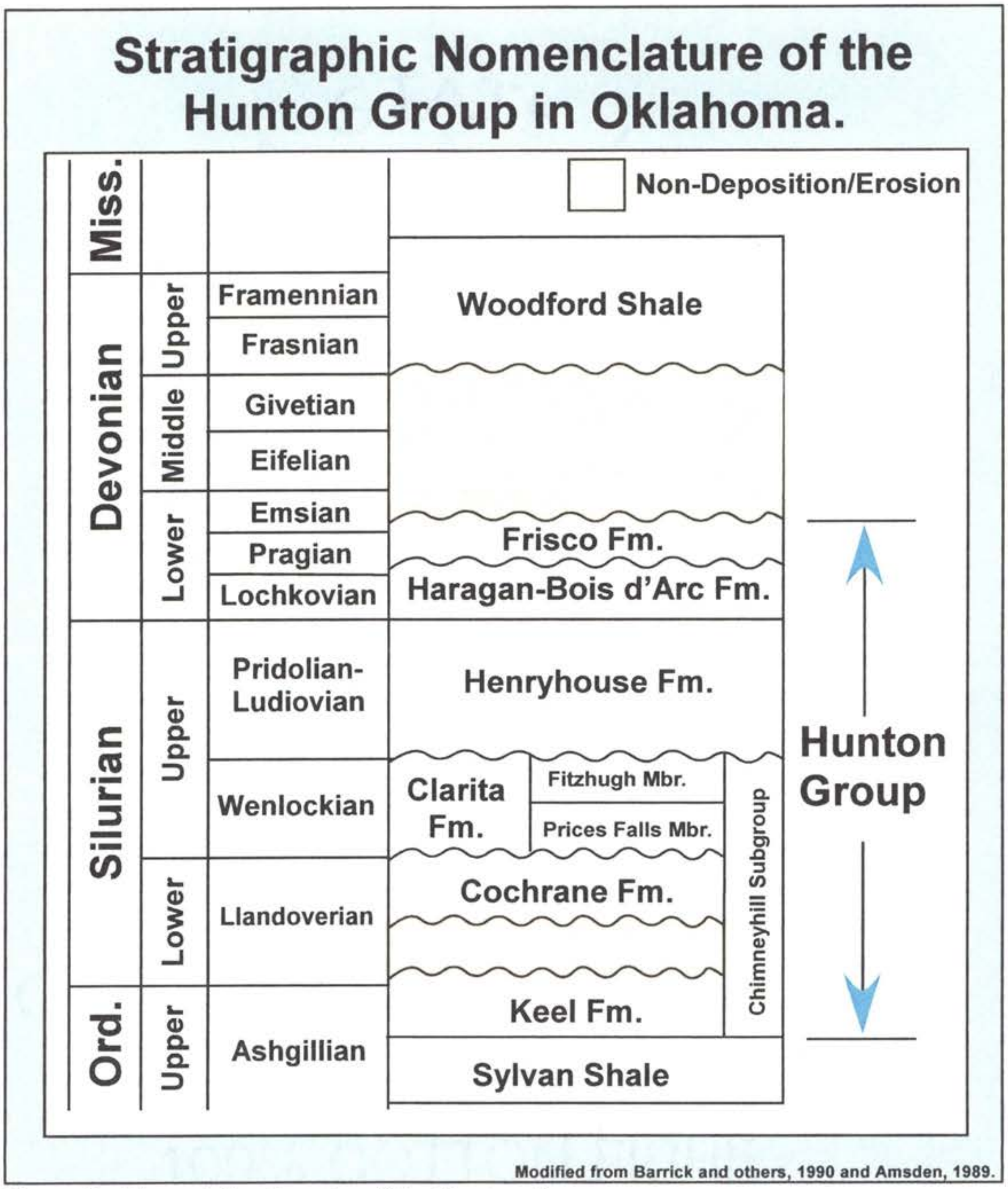


Figure 3. General Stratigraphy of the Hunton Group.

quality. Table I lists the study cores used, the number of thin-sections examined, and other available data. During the course of this study the following methods were used:

1. Analysis of cored intervals to identify sedimentological features.
2. Thin section petrography to determine constituents and porosity.
3. Wire-line log electrofacies analysis. Logs were divided into different divisions based on log signature (electrofacies) I-IV. These divisions were then later correlated to the core and local stratigraphy; correlations were confirmed with conodont biostratigraphy. (Al-Shaieb, personal communication)
4. Quantification of core plug data, including: porosity, permeability, grain density, S_w, So. Measurements were made at the Integrated Core Characterization Center, School of Petroleum and Geological Engineering, The University of Oklahoma, Tulsa.
5. Ultraviolet light analysis for petroleum shows.
6. Conodont biostratigraphy to determine relative age of specific Hunton intervals. Dr. Jim Barrick at Texas Tech University provided the conodont identifications.

Core Name	Location	Recovered (Ft.)	Thin-sections	UV Analysis	Core analysis	Biostratigraphy
Lola #1	SEC 17 T11N R6E	74	19	YES*	YES	3
Baxter #2	SEC 14 T10N R6E	122	20	YES	YES	4
Hitt #1	SEC 19 T10N R6E	119	25	YES	YES	-
Ponkilla #1	SEC 15 T10N R6E	147	44	YES	YES	4
Rentie No. 10-A	SEC 14 T9N R6E	78	19	YES	YES	1
E.F.U. No. 9-41	SEC 27 T2N R6E	102	-	YES	YES	1

*Indicated detailed UV analysis.
Wire-line logs were available for each of the cores studied.

Table I. Methods of investigation, data examined.

CHAPTER II

PREVIOUS INVESTIGATIONS

The Hunton strata which, were originally named by J. A. Taft in 1902, were later differentiated by Reeds (1911) and Maxwell (1931). Fifteen years later, Reeds (1926) described the uppermost section of the Hunton as a "coquina-like limestone" and named it the Frisco Formation. T. A. Amsden (1958, 1959, 1961, 1962, and 1988) conducted some of the most extensive work done on the Hunton paleontology and stratigraphy. The concentration of Amsden's work was on the paleontology and description of the different formations within the Hunton Group. According to the current definition from Amsden, (1975), the Hunton is comprised of strata ranging from late Ordovician to early Devonian. Others, including Al-Shaieb and Puckette (2000, 2001), Manni (1985), Mathews (1992), and Beardall (1983), have described depositional environments and diagenesis of the Hunton Group, with particular attention to the productive horizons in the Anadarko basin region of Oklahoma. Medlock (1984) focused on the Frisco Formation outcrops as well as the Henryhouse Formation in the Pontotoc County area. Hollrah, (1977) described the lithostratigraphy of the Hunton in Payne, Lincoln, and Logan counties of Oklahoma. Considering the amount of oil and gas production from the Hunton Group in the Seminole county area, surprisingly little detailed work has been done there. For this reason, Seminole County was chosen as the general study area for this thesis. After determining the availability of core and wire-line logs, an area for detailed study was selected in T.10N & T.11N., R.6E.

CHAPTER III

STRATIGRAPHY AND WIRELINE CHARACTERISTICS OF THE HUNTON GROUP GEOLOGIC HISTORY

The geologic history of the Hunton is very complex and begins with the history of the Southern Oklahoma Aulacogen. The Southern Oklahoma Aulacogen, began its rifting stage (Figure 4a), in the Cambrian, which is dominated by igneous activities (Hoffman, 1974). The subsidence stage (late Cambrian to Mississippian time) of the aulacogen is marked by accumulation of thick sections of rock, dominated by carbonates with lesser pulses of silicaclastics (Figure 4b). This is represented in the rock record of Oklahoma as the Cambro-Ordovician Arbuckle Group, the Ordovician Simpson Group and Viola Group, and the Ordovician-Silurian-Devonian Hunton Group. This accumulation of carbonate was the result of the relatively shallow water depths and continued subsidence in the basin. Carbonate sediments were continually deposited, keeping pace with the slow subsidence.

The Hunton Group was deposited in a ramp type environment (Figure 5). The shallow ramp setting was responsible for Hunton deposition on the shelf of the present day Anadarko basin and was the depositional setting in the study area. A ramp has a very gentle slope of generally less than one degree, which allows for the wave energy to be released directly on shore, thus the intertidal zone is the highest energy facies.

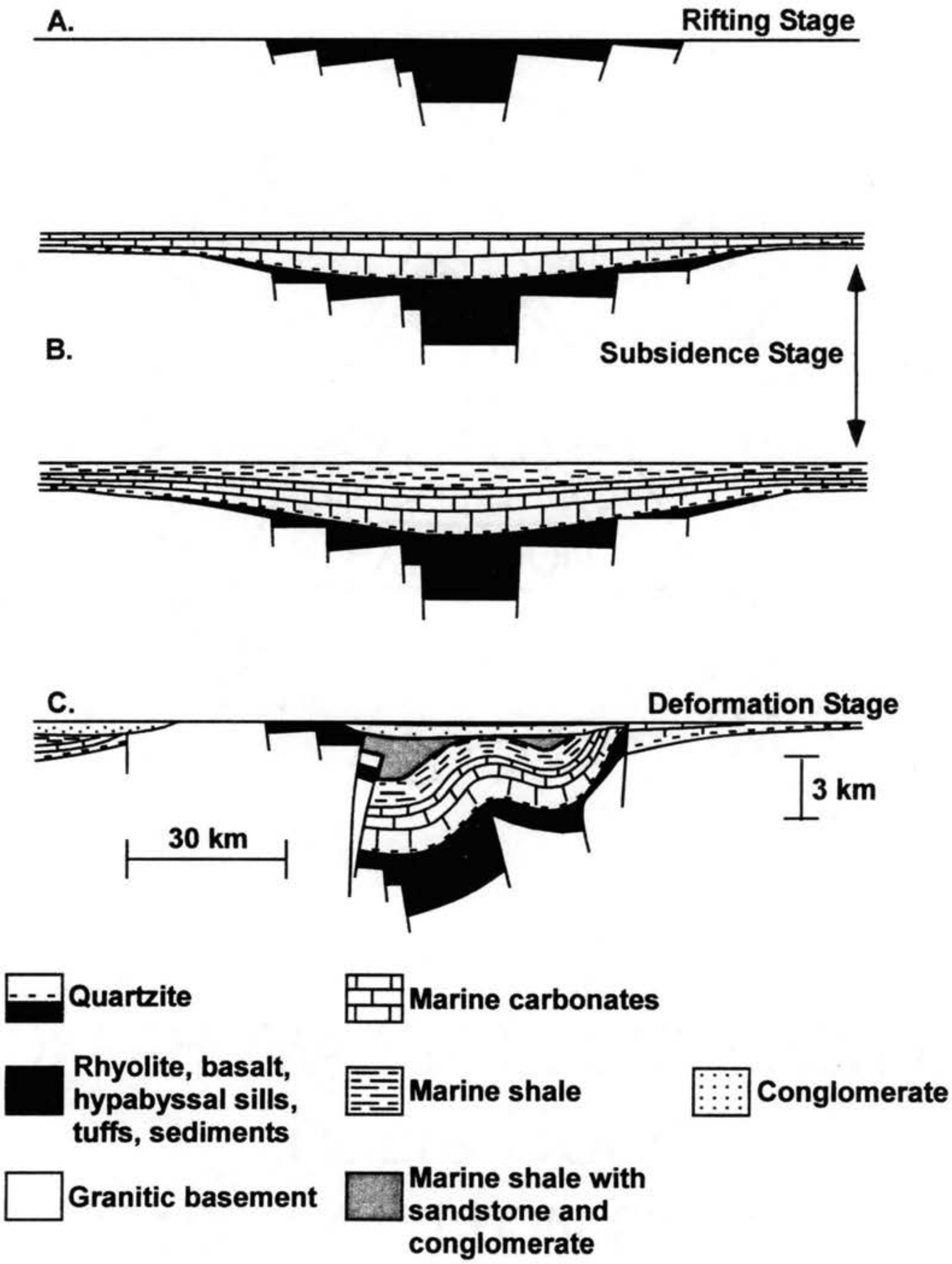


Figure 4 Schematic illustration of the evolution of the Southern Oklahoma Aulacogen (after Hoffman et al., 1974).

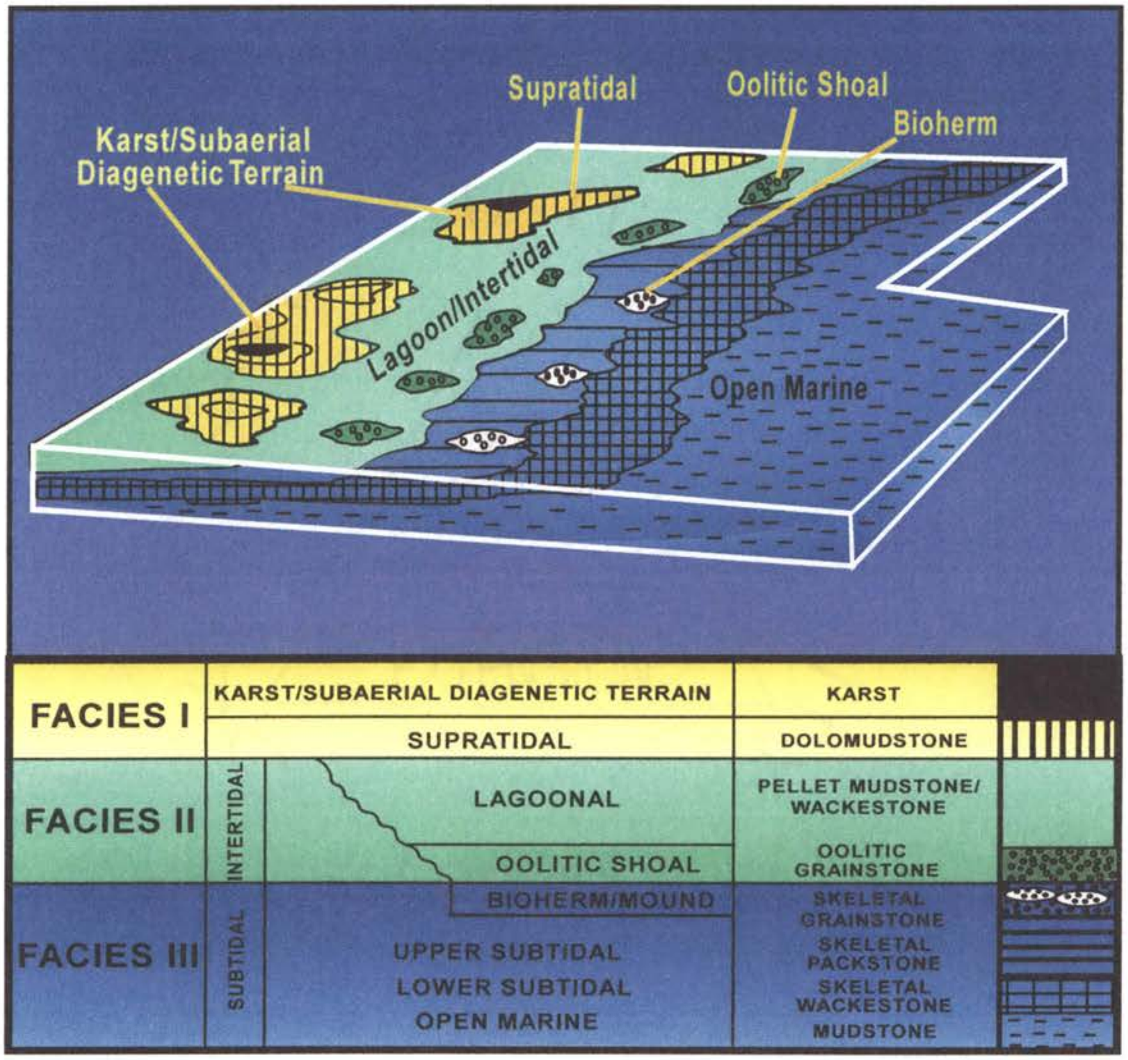


Figure 5. Diagram of typical ramp style environment, with generalized facies lithologic descriptions.

The Frisco was deposited in a relatively high-energy environment. Generally, this would be interpreted as an intertidal setting however, the Frisco Formation was deposited in a subtidal environment. The Ordovician-Devonian Hunton Group was deposited during the subsidence stage of the Southern Oklahoma aulacogen (Adler, 1971). Changes in sea level were occurring concurrently with subsidence. Evidence of this is found in the intra-Hunton unconformities (Amsden, 1960). The intra-Hunton unconformities were likely formed by drops in sea level that exposed vast areas of the carbonate to erosion/subaerial exposure. Another significant drop in sea level was responsible for the pre-Woodford unconformity above the Frisco. Evidence of subsequent widespread flooding was recorded in the rock record by deposition of the sediments that became the organic-rich, black Devonian-Mississippian Woodford Shale. The unconformity between the Frisco and the Woodford shale marks a period of erosion, which left the Hunton subaerially exposed and vulnerable to karstification. With deposition of the Woodford sediments directly on the Frisco in the study area and the Hunton Group in most areas of Oklahoma, the Woodford Shale the source of Hunton oil and gas (Johnson and Cardott, 1992). During the Mississippian, the deformation stage (Figure 4c) of the aulacogen began.

Significant deformation did not develop fully until Pennsylvanian time when the Pennsylvanian / Wichita Orogeny caused the present Anadarko basin floor to drop significantly (Figure 6). As the basin floor dropped, the carbonate factory could no longer produce carbonate quickly enough to remain in the photic zone and carbonate deposition all but ceased. Uplift provided a ready source of sediments and siliciclastics and became the dominant type of rock in the Pennsylvanian. Pennsylvanian time was marked by rapid basin deepening that accommodated the sediment deposits. The

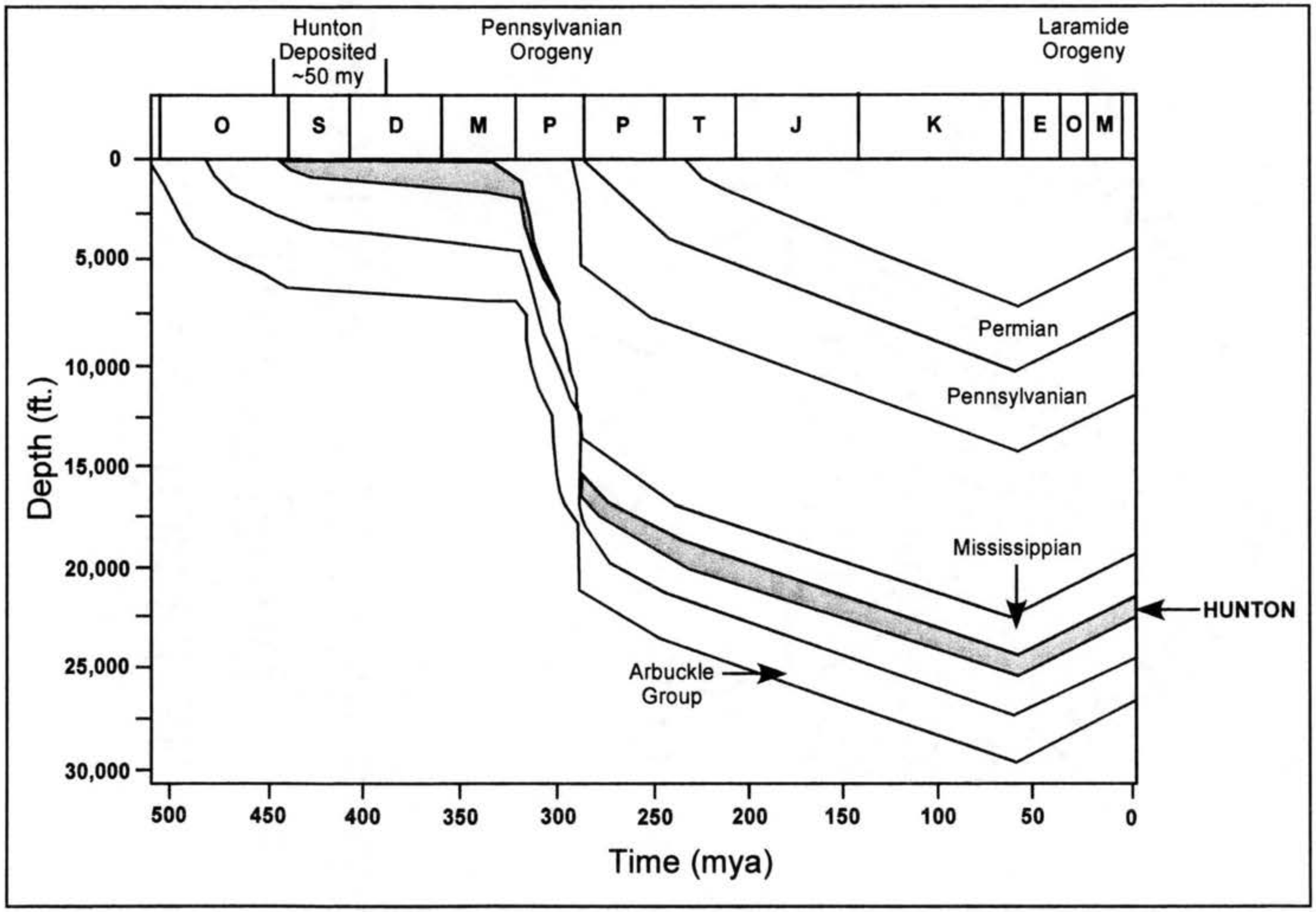


Figure 6. Burial history curve for the Anadarko Basin, showing slow subsidence, during Hunton time.

sediments include the Pennsylvanian sandstones that are prolific producers of oil and gas in much of Oklahoma. During the Pennsylvanian the Woodford Shale was buried deeply enough to become thermally mature in the Anadarko basin and much of present day Oklahoma. The Woodford generated oil and gas that began to migrate into the adjacent Hunton Group reservoirs. Structural flexures and faults also developed during Pennsylvanian time that also helped trap oil and gas in the Hunton. Post-Pennsylvanian burial, the Laramide orogeny and erosion changed much of the surface geology in the Mid-Continent, but did not structurally affect most Hunton rocks.

Wireline log characteristics

Identifying rock units and establishing the general stratigraphy of the Hunton Group, using SP and Gamma ray logs is effective with a reasonable margin of accuracy. However, the renewed drilling has provided higher resolution resistivity, PE curve, neutron and density porosity, and micro-resistivity logs that can greatly improve lithofacies identification and ultimately the success of establishing Hunton stratigraphy. With the knowledge of the local stratigraphy, logs can be used to create accurate maps and cross-sections for local or regional correlation (Plates 1-4).

Seminole County

Identification of the Hunton Group in Seminole County using wireline logs is completed without difficulty (Figure 7). The "hot" gamma-ray kick of the Woodford Shale, contrasts sharply with the underlying Hunton, which is indicated by a gamma-ray that indicates the rock "cleans" up significantly. Below the Hunton, the Sylvan Shale again shows a higher gamma-ray count signature. If no gamma is present, which is

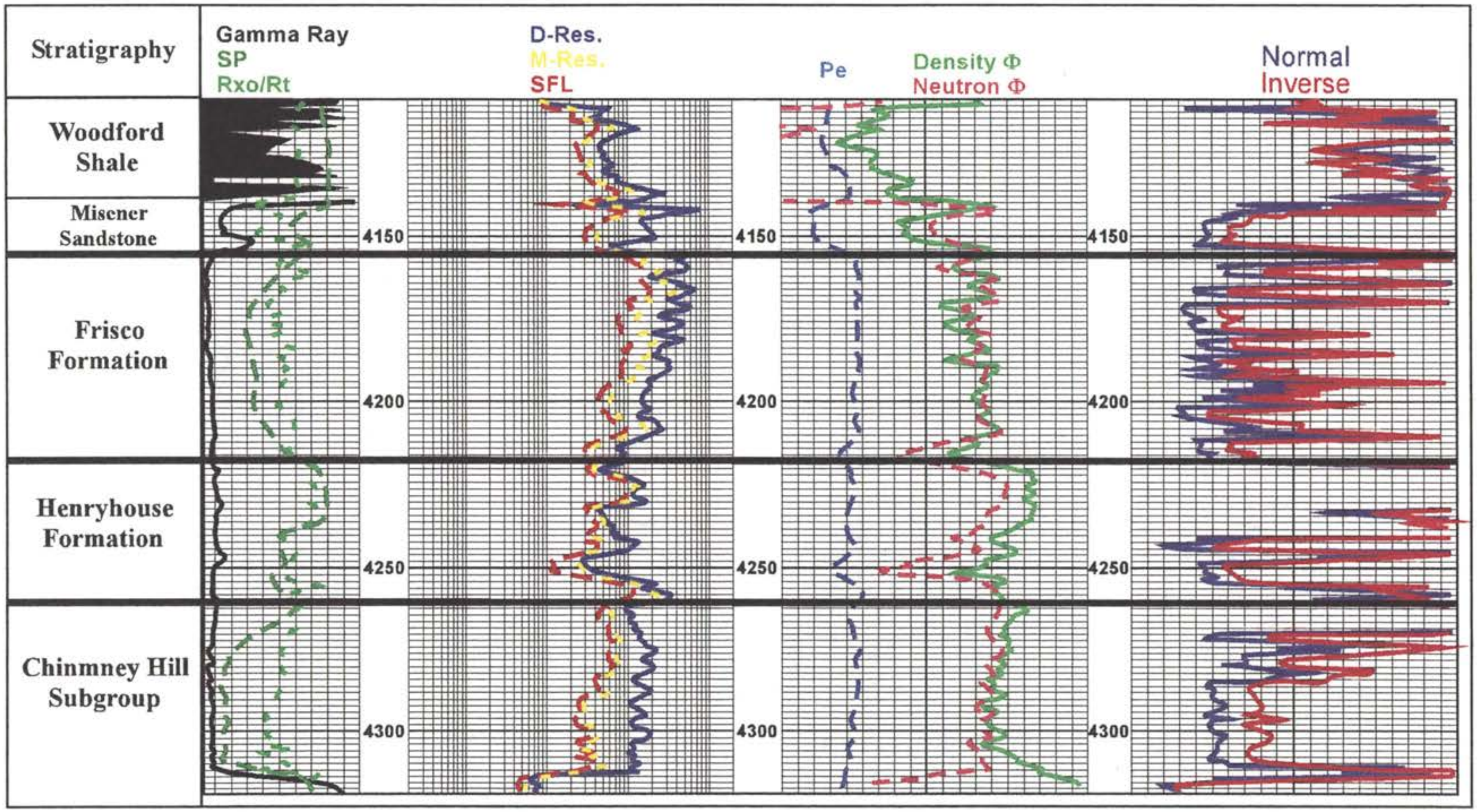


Figure 7. Typical log signature of a well in northern Seminole County. Electrofacies can be correlated throughout the regional study area.

sometimes the case on the vintage logs of the 1940's and 1950's, the Hunton can be identified using the deflection on the spontaneous potential (SP) log and corresponding higher resistivity.

In the Seminole area, the SP signature of the Woodford exhibits very little deflection due to the relatively low permeability of the Woodford Shale. In the Hunton Group, the SP signature can be broken into three distinct zones. The uppermost zone will appear to have a concave shape relative to the left side of the scale and displays a rounded gradational character. The uppermost zone with significant SP deflection is lithologically similar to the Frisco Formation. The middle zone, which has a gradational top and generally becomes a convex, curve that shifts to the right is petrologically similar to the Silurian Henryhouse Formation. The lowermost zone has a gradational concave zone. The lower zone, which is interpreted as Chimneyhill Subgroup exhibits a sharp change in signature where the Hunton is in contact with the Sylvan Shale. Note: Where present and in sufficient thickness, the Misener Sandstone will appear on the SP with a "clean" signature at the base of the Woodford Shale. Presence of the Misener Sandstone does not impact the validity of the above interpretation of the SP or Gamma signatures.

Pontotoc County

In Pontotoc County the wireline log signature of the Frisco Formation exhibits little difference from the signature depicted from Seminole County logs. However the remainder of the Hunton has a somewhat different log character (Figure 8). The gamma log can be used to identify the Hunton Group in the same manner as the Seminole area. The SP signature has a somewhat different character due to many variables that have changed the permeability of the rock; these permeability differences are likely a result of

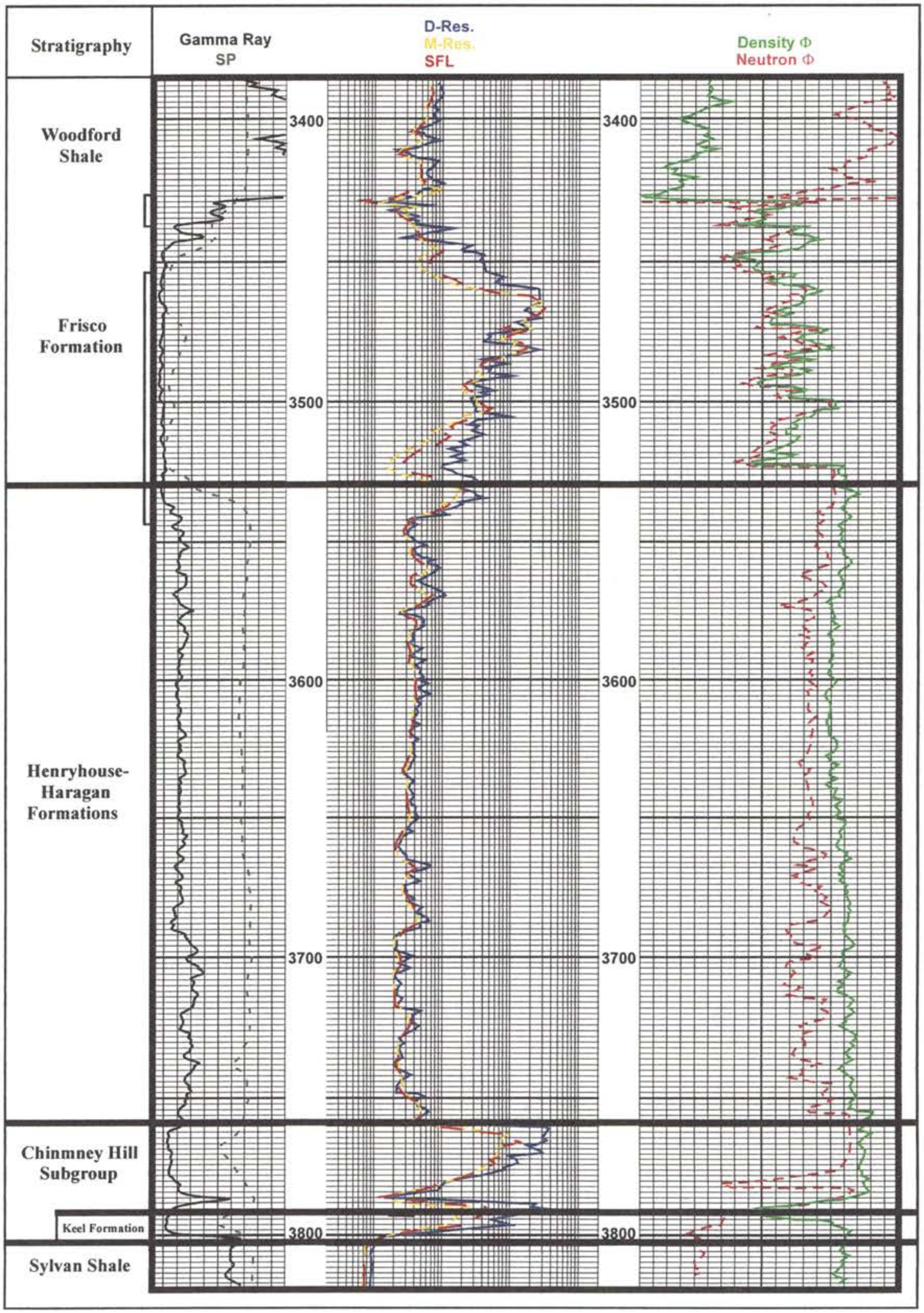


Figure 8. Typical log signature of a well in northern Pontotoc County. Electrofacies can be correlated throughout the regional study area.

differing depositional environments. The exact stratigraphy is different and is not the focus of the study. However, using conodont biostratigraphy, the Frisco Formation was verified as the uppermost section of the Hunton group in this area. The base of the Frisco was not determined using biostratigraphy. However examination of the core allowed for an accurate interpretation of lithofacies and stratigraphy.

Biostratigraphy

Conodont biostratigraphy was used to provide corroborating data to help correlate wire-line log signatures to stratigraphic boundaries. Direct correlation from the outcrop to the subsurface in the Seminole County area is difficult due to the Seminole Arch and Lawrence Uplift. The Hunton Group is exposed and totally removed for miles northward and does not redevelop until Township 9 North (Plate 1). Lithologically, the Hunton is difficult to delineate. However with the aid of wire-line logs, certain zones can be recognized by their wireline characteristics, or electrofacies. It is the electrofacies that allows for the correlation of the Hunton Group in this area. Dr. Jim Barrick from Tech University analyzed the conodont samples taken from the cores and outcrop (Table II). Table III groups the conodont names into the assemblages listed on Table II and allows for the correlation of fossil assemblages to specific stratigraphic units. The conodont data included in Table II provides the biostratigraphic link between wireline log electrofacies and Hunton stratigraphy in the Seminole County area. The conodont species *Icriodus claudiae* and *Dvorakia sp.*, which are indicative of the Frisco Formation, were identified at the Bois d'Arc Creek outcrop. This definitively identifies the mounds along Bois d'Arc Creek as Frisco Formation. *Dvorakia sp.* was recovered for Baxter, whereas *Icriodus sp.* was recovered from the Lola and Ponkilla. These data directly correlate the

Sample Name	Sample Location	Conodont Assemblage*	Related Stratigraphy/Relative age
Lola #1	4320 ft.	Lola 1	Frisco
	4396 ft.	Lola 2	Clarita ?
	4437 ft.	Lola 3	(lower) Clarita
Baxter #2	4155 ft	Baxter 1	Frisco
	4184 ft.	Baxter 2	Frisco
	4253 ft.	Baxter 3	(middle) Silurian
	4299 ft.	Baxter 4	(lower) Clarita
Ponkilla #1	4280 ft	Ponkilla 1	Frisco
	4330.9 ft.	Ponkilla 2	(upper) Clarita
	4361 ft.	Ponkilla 3	(lower) Clarita
	4380 ft.	Ponkilla 4	(lower) Clarita
Rentie No. 10-A	4035 ft.	Rentie 1	(upper) Clarita - early Devonian
E.F.U. No. 9-41	3455 ft.	E.F.U. 1	Frisco or younger
BDC #1	lower creek bed	BDC 1	Frisco or younger
BDC #2	~2 ft above creek	BDC 1	early to middle Devonian
BDC #3	roadside @ 3rd marker S of bridge	BDC 2	Frisco or younger

See Table III for conodont names.

Table 2. Conodont sampling chart giving name, location and biostratigraphic ages of samples.

Lola assemblage 1:	**Elements recovered**	**Baxter assemblage 1:**	**Elements recovered**
Ozarkodina sp.	2	*Ozarkodina excavata*	11
Panderodus unicostatus	103	*Ozarkodina sp.*	1
Walliserodus sancticlairi	38	*Panderodus unicostatus*	30
Dapsilodus obliquicostatus	>500	*Walliserodus sancticlairi*	17
Decoriconus fragilis	20	*Dapsilodus obliquicostatus*	192
Pseudooneotodus bicornis	2		
Lola assemblage 2:	**Elements recovered**	**Baxter assemblage 2:**	**Elements recovered**
Panderodus unicostatus	30	*Panderodus unicostatus*	9
Walliserodus sancticlairi	7	*Walliserodus sancticlairi*	7
Decoriconus fragilis	2		
Pseudooneotodus bicornis	2		
Lola assemblage 3:	**Elements recovered**	**Baxter assemblage3:**	**Elements recovered**
Icriodus claudiae?	1?	*Dvorakia sp.*	1
		Baxter assemblage 4:	**Elements recovered**
		Icriodus claudiae?	1
Ponkilla assemblage 1:	**Elements recovered**	**Rentie assemblage**	**Elements recovered**
Panderodus unicostatus	18	*Ozarkodina excavata*	1
Walliserodus sancticlairi	6	*Panderodus unicostatus*	5
Dapsilodus obliquicostatus	73	*Belodella sp.*	1
Ponkilla assemblage 2:	**Elements recovered**	**E.F.U. assemblage**	**Elements recovered**
Ozarkodina excavata	3	*Icriodus sp.*	3
Panderodus unicostatus	108	*Dvorakia sp.*	3
Walliserodus sancticlairi	69		
Dapsilodus obliquicostatus	196	**BDC 1 assemblage**	**Elements recovered**
Decoriconus fragilis	17	*Icriodus sp.*	9
Pseudooneotodus bicornis	12	*Dvorakia? sp.*	1
Ponkilla assemblage 3:	**Elements recovered**	**BDC 2 assemblage**	**Elements recovered**
Ozarkodina excavata	1	*Dvorakia sp.*	2
Panderodus unicostatus	41		
Walliserodus sancticlairi	2	**BDC 3 assemblage**	**Elements recovered**
Belodella sp.	1	*Icriodus sp.*	1
		Dvorakia sp.	4
Ponkilla assemblage 4:	**Elements recovered**		
Icriodus claudiae?	4		

Table 3. Conodont assemblage chart, giving conodont name, and elements recovered for each sample set.

uppermost electro-facies division of the Hunton Group in Seminole County with Frisco Formation in outcrop and in Fitts Pool in Pontotoc County (Figure 9). One exception occurred, as samples analyzed from the Sunray DX Rentie 10-A well yielded no diagnostic conodont fauna. However, the sample yielded non-diagnostic conodonts: *Ozarkodina excavata*, *Panderodus unicostatus*, and *Belodella,* which give a wide age range from upper Clarita to Early Devonian in age.

For a complete listing of the fauna present in the Hunton including the Frisco Formation see the extensive works of Thomas W. Amsden, (1957), (1960), (1961), (1962), (1967), (1975), (1980), and (1988) that are published by Oklahoma Geological Survey.

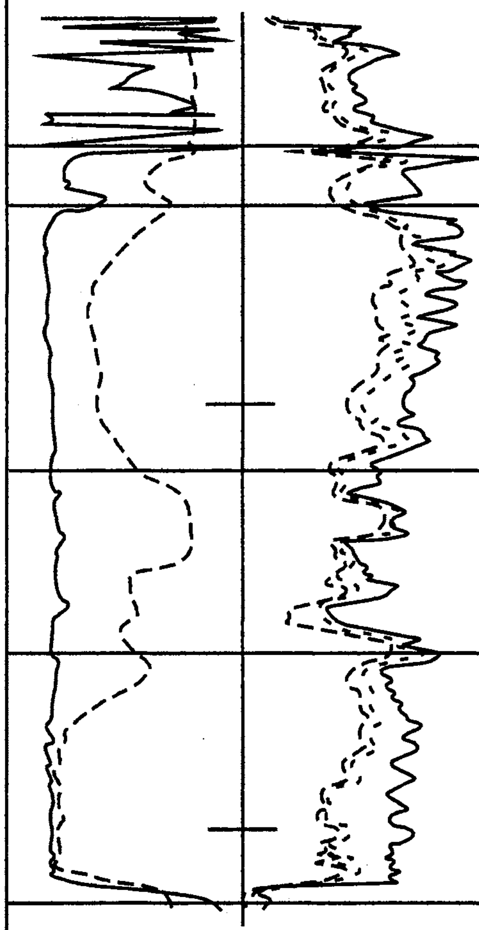
Typical Log Signature	Conodont Species Recovered	Stratigraphy
	not examined	Woodford Shale
	not examined	Misener Sandstone
	Icriodus claudiae *Dvorakia sp.*	Frisco Formation
	Panderodus unicostatus *Walliserodus sancticlairi*	Silurian (middle) possibly Henryhouse Formation
	Ozarkodina excavata *Ozarkodina sp.* *Panderodus unicostatus* *Walliserodus sancticlairi* *Dapsilodus obliquicostatus*	Clarita Formation
	not examined	Sylvan Shale

Figure 9. Biostratigraphic framework as applied to the Hunton Group and log electrofacies.

CHAPTER IV

The Frisco Formation

The type locality for the Devonian (Emsian, Pragian) Frisco Formation is along Bois d'Arc Creek in Pontotoc County, Oklahoma (Amsden, 1960). The type locality is approximately 4 miles south of Ada, Oklahoma (Figure 10). Here, the mound complex overlies the Bois d'Arc Formation.

The Bois d'Arc Creek outcrops contain three discrete lithofacies indicative of a mound complex: the core, flanking, and capping facies (Figure 11). The mound core, (Figure 12) which is generally described as a buildup of muddy/micritic sediments represents deposition in an area inhabited by baffling biota such as bryozoans and crinoids. The flanking facies, (Figure 13) which develops as a result of the shedding of bioclastic sediments off of the mound, are typically deposited as bioclastic rich sediment that become packstones and grainstones, depending on the amount of mud. The capping facies, (Figure 14) which were deposited and distributed by wave action, become grainstones that form a thin blanket-like deposit draped over the mound core and flanking facies. The capping facies can be distinguished by its relative stratigraphic position, and is better sorted than the flanking facies.

The mound facies in northern Seminole County rests upon Silurian rocks, possibly Henryhouse Formation paleotopographic highs. It was shown by Amsden

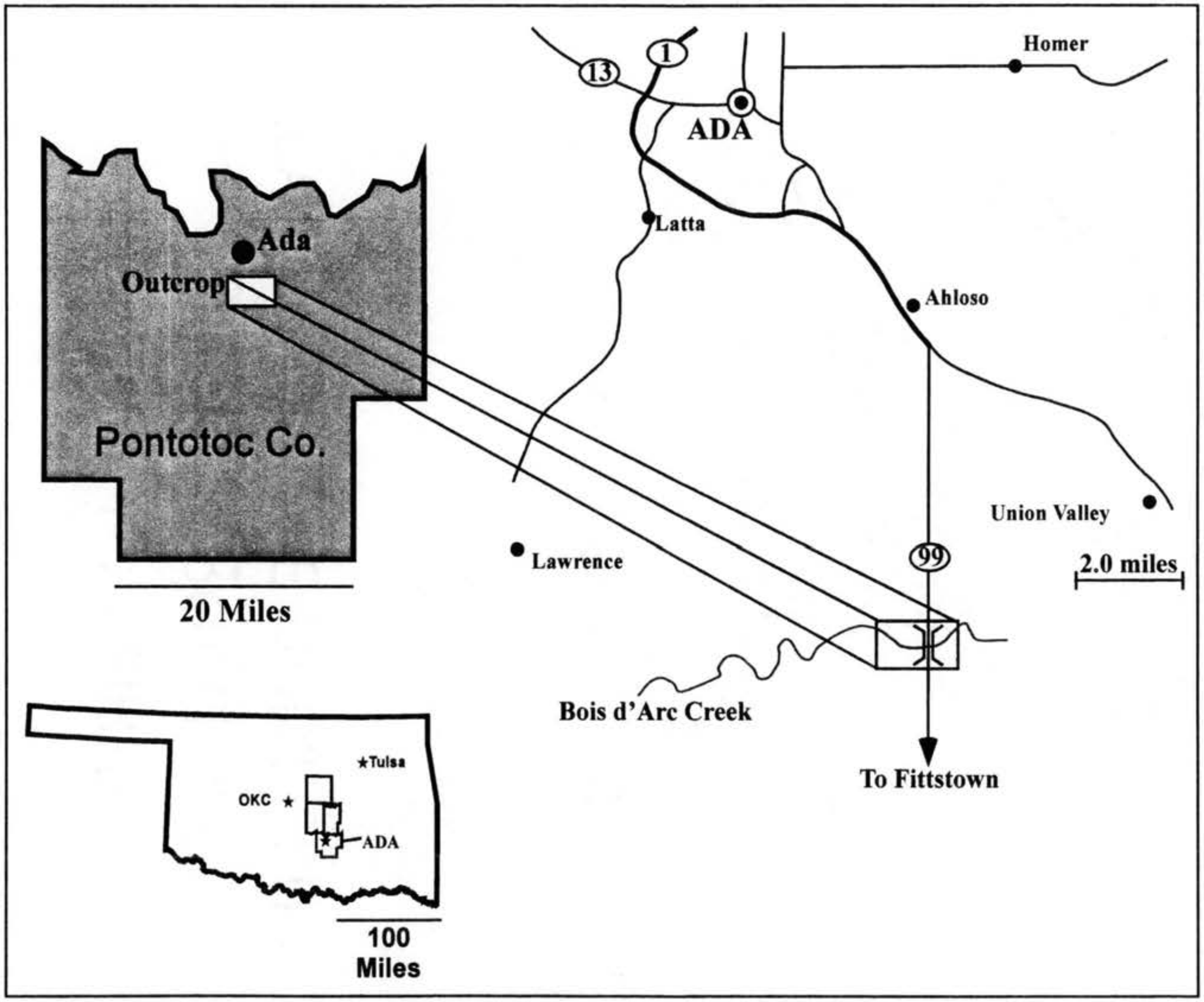


Figure 10. Frisco Formation type locality outcrop location, Pontotoc County, Oklahoma.

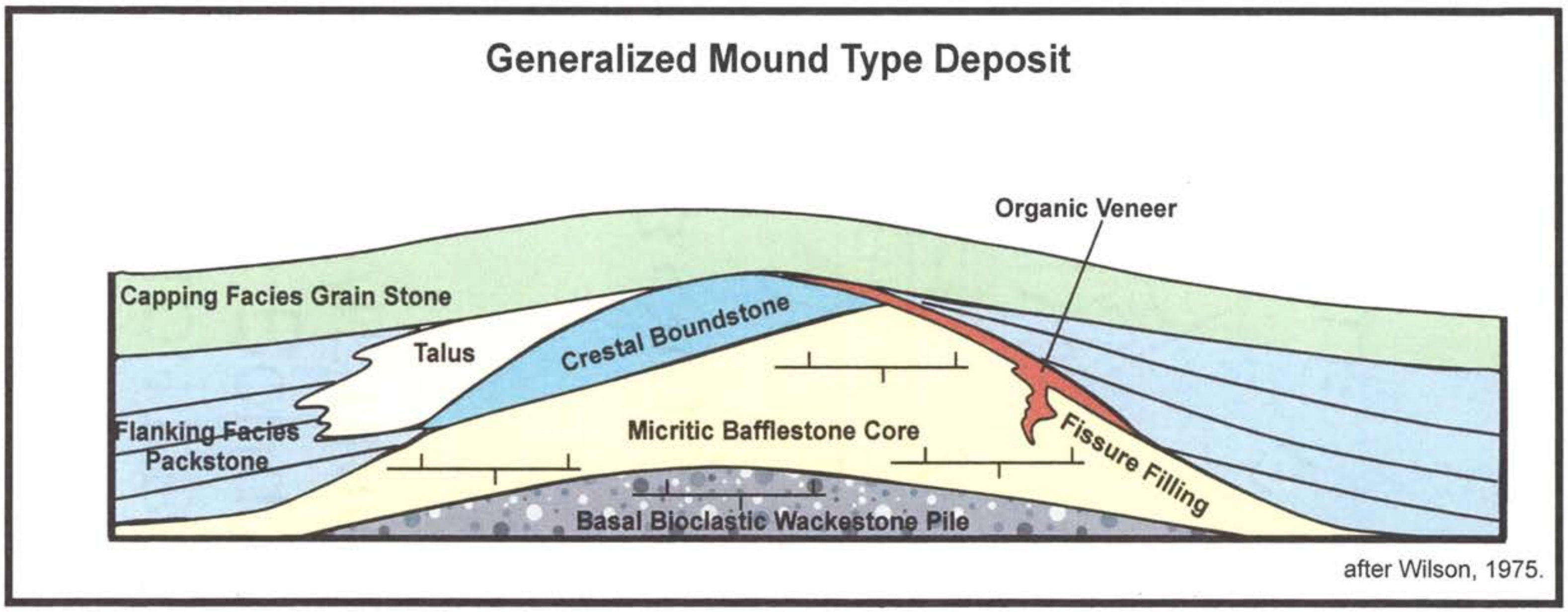
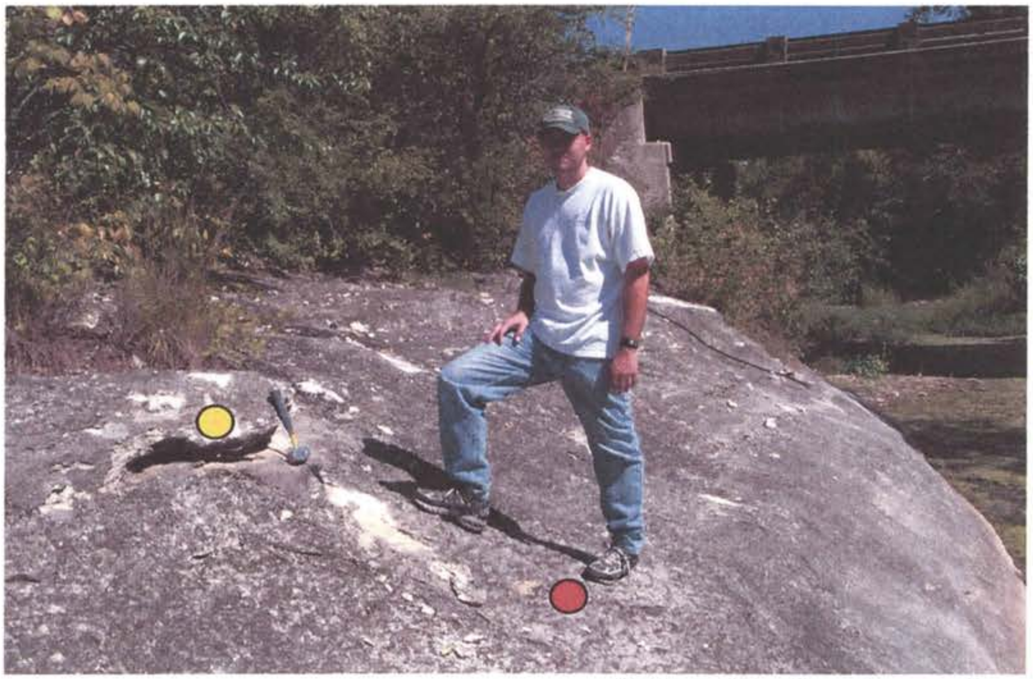


Figure 11. Generalized mud mound/bioherm diagram.



Author on Frisco Formation mound core.

Generalized Mound Type Deposit

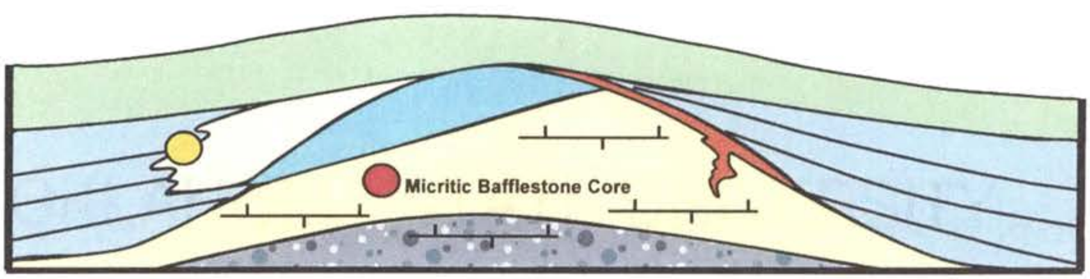


Figure 12. Outcrop photograph of the mound core along Bois d'Arc Creek near Ada Oklahoma. The diagram shows the relative position of facies within a generalized mud mound.

Author at Frisco Formation road outcrop.

Generalized Mound Type Deposit

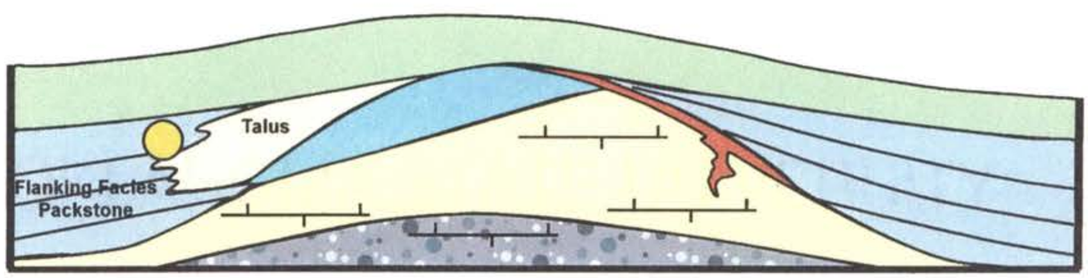


Figure 13. Outcrop photograph of the flanking facies along Bois d'Arc Creek near Ada Oklahoma. The diagram shows a relative position of facies within a mud mound complex. The flanking facies at the outcrop is on the HWY. 99 along the road, just south of the bridge crossing the creek.

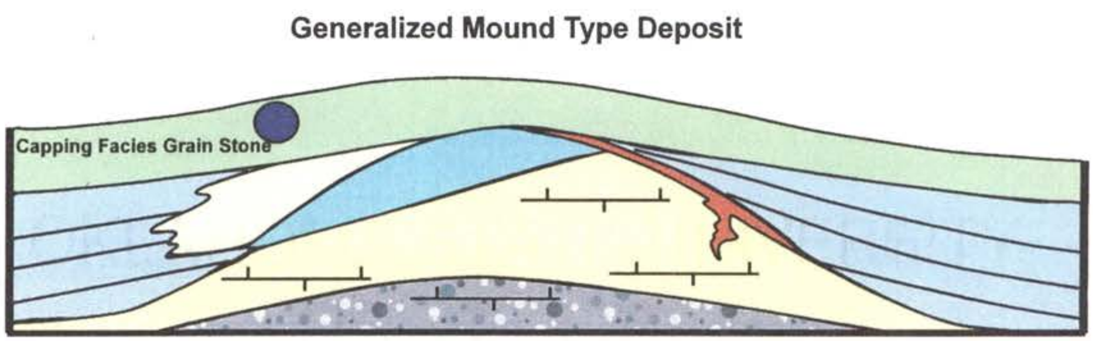


Figure 14. Outcrop photograph of the capping facies along Bois d'Arc Creek near Ada Oklahoma. The diagram shows the relative position of facies within a mud mound. The marked interval is the capping facies, at the creek level is the mud core.

(1961) that the Frisco Formation in the Pontotoc County type locality overlies the Bois d'Arc Formation. Here the Frisco mounds are likely influenced by the Bois d'Arc Formation paleotopography. The Frisco contact with Bois d'Arc does not occur north of the Seminole Arch due to the erosion/non-deposition of the Haragan/Bois d'Arc sections.

Many of the oil and gas producing Hunton reservoirs in the greater Seminole district may not have been correctly identified. Much of the production that was previously assigned to the Bois d'Arc/Haragan and/or Henryhouse Formations may be re-assigned to the Frisco. This is the result of conodont biostratigraphy reported in this thesis that identifies these productive zones as Frisco Formation. Additional producing zones are present in the lower Henryhouse and upper Chimneyhill sections of the Hunton Group. Recent renewed drilling activity in the greater Seminole district, which provided new core and wireline log information, has rekindled interest in oil and gas exploration and provided key cores necessary for this determination.

In the study area, the Frisco ranges from <10 to 70+ feet thick and has an average thickness of approximately 40 feet. Porosity values ranges from 1 to 18% and zones of permeability as high as 30 md (See Appendix II) are reported, making this reservoir an economically viable target if explored using current geological interpretation and produced using recently developed technology.

Mound Characteristics

The depositional environment of the Frisco Formation is representative of a Waulsortian type mound model. Waulsortian mound facies differ most notably from other mud mounds or bioherms because of the relative lack of frame building organisms (Wilson, 1975). These mounds are thought to accumulate at or below the normal wave base and near the boundaries of the photic zone (Wilson, 1975). The mound itself would likely have been current deposited (Figure 15). In addition, the absence of algae, suggests that the depositional environment was at or near the lower limits of the photic zone. Mound building bryozoans and crinoids (not as dependant on light but more so on current) acted as a baffle to the current allowing mud and other finer grained materials to accumulate below the wave base and thus provided a good substrate for further mound development. Other Waulsortian characteristics include formation below wave base (subtidal), multi-stacked reservoirs, 50-80% mudstone, and no domination of larger biota such as corals etc. composing the mound (Wilson, 1975). The geometry of the typical mound is generally thought to be roughly circular, although in the presence of higher velocity currents or long shore currents, mounds may be elongated to a roughly oval shape (Wilson, 1975). Mud mounds typically are not large features in the Devonian of Oklahoma and range in size from 500 sq. meters to a square kilometer. In other environments, they range from meter size to tens of square kilometers in size and can be up to hundreds of meters thick (Parkison, 1957).

The Wilson (1975) model of a typical mound (Figure 8) indicates that a mound-type deposit should have a mud core. Examination of the available core, indicates the flanking facies is generally present, usually as a grainstone to packstone as in the Baxter #2 and Lola #1. The Ponkilla #1 is an example of a core that may have penetrated closer to the center of the mound. It contains a large amount of micrite within the Frisco section. Another possible scenario for the Ponkilla well is that a facies change has occurred, where a Frisco age equivalent unit exists but, as a result of an increased water depth a mature mound facies did not develop in this location (Figure 16).

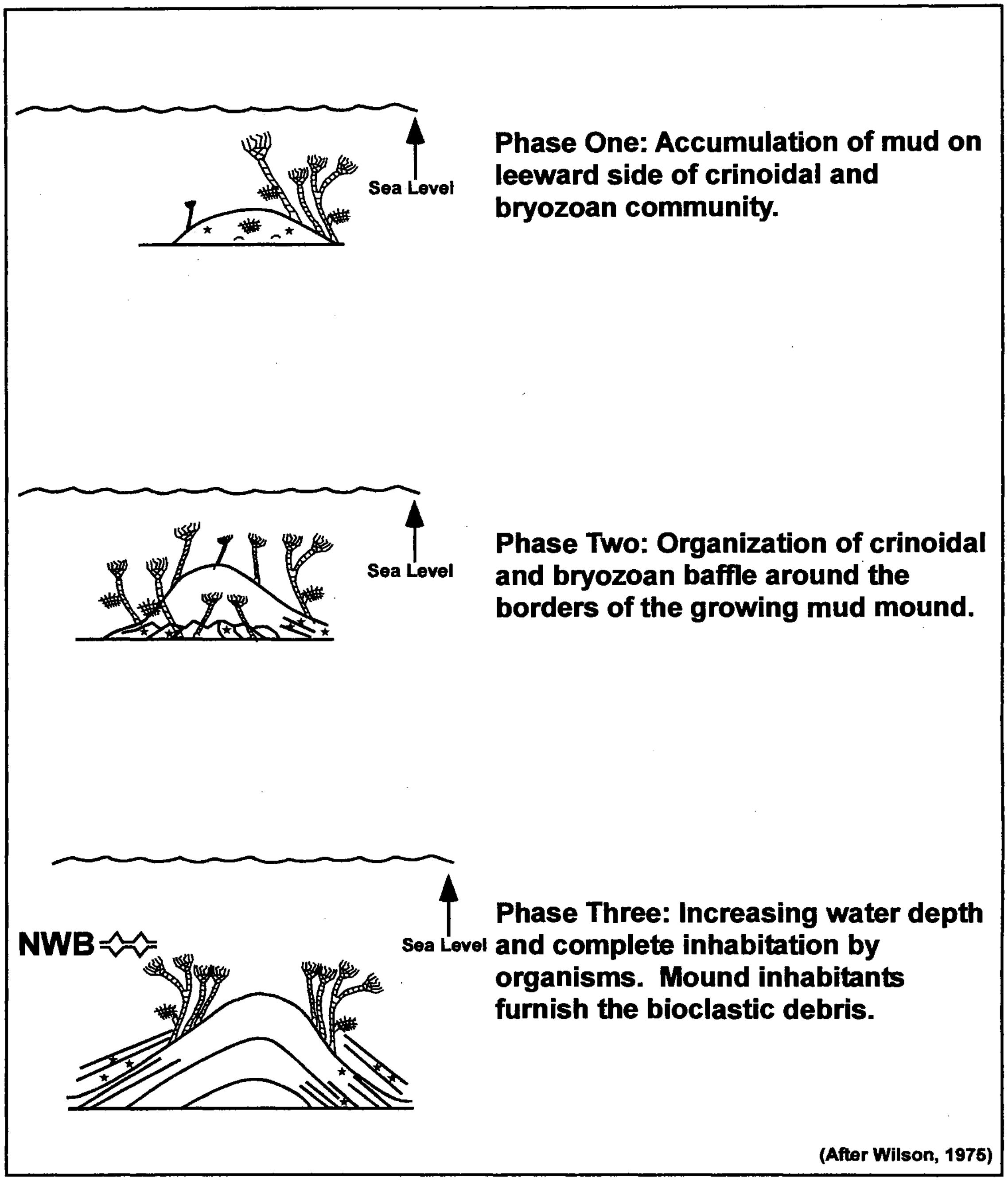


Figure 15. Phases of mud mound/bioherm development.

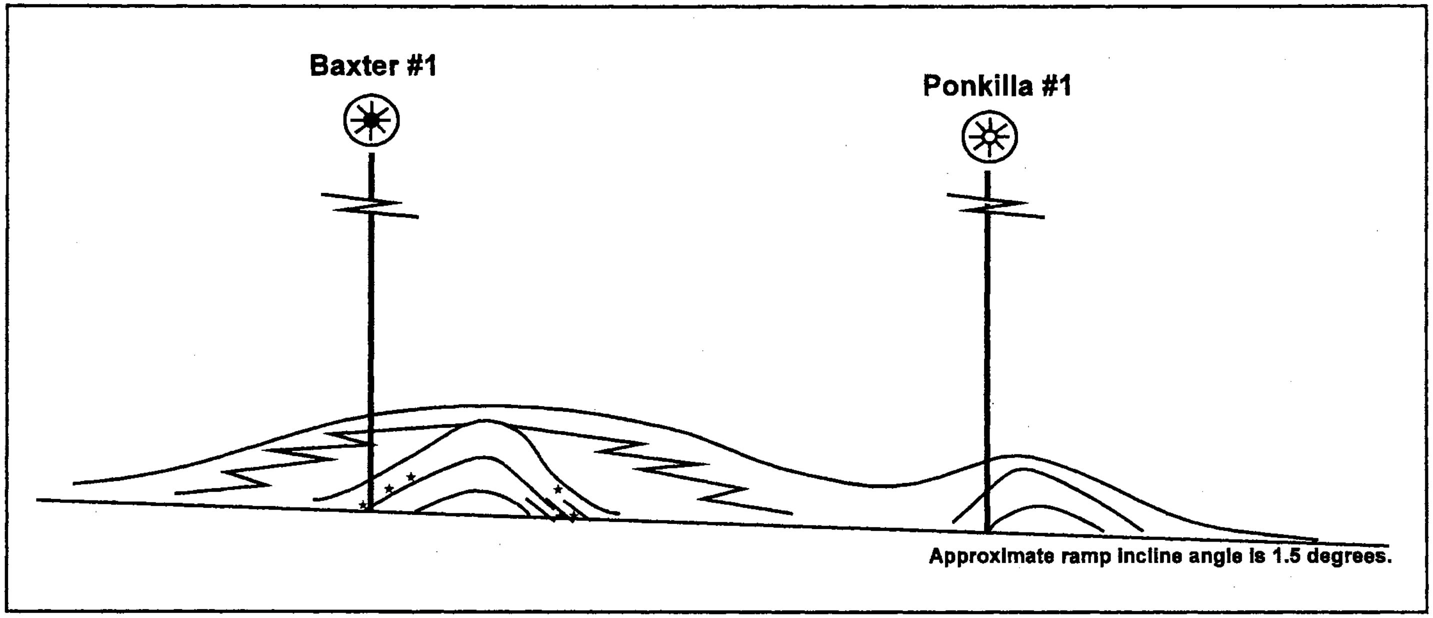


Figure 16. Diagram representing the time equivalent Frisco Formation depositional environment as related to the relative position of wells.

Surface Stratigraphy

The outcrop at Bois d'Arc Creek in Pontotoc County was first labeled the type section of the Frisco Formation by Amsden, (1957) and was subsequently described as a fossiliferous calcarenite and/or fossil rich coquina. Medlock, (1984) described the Frisco at this location as three distinct types of rock, and assigned them to specific facies: mound core, flanking and capping. The mound facies (mud core) is a wackestone-mudstone, Where as the intermound facies (flanking) and the capping facies are packstone-grainstone. The distinction between the flanking and capping facies is difficult to discern lithologically, however stratigraphic position and sorting allow for the two to be separated. The Medlock (1984) outcrop descriptions are similar to those of subsurface Frisco rocks in Seminole County to the north. Variations between the two are due primarily due to the physical and chemical diagenetic changes associated with weathering. These include, but are not limited to, porosity and permeability (enlarged fractures and vugs), and coloration. Harrison (1987) completed an outcrop study of relative percentages of mound forming constituents, specifically echinoderms and bryozoans (Figure 17). Figure 17 shows that echinoderms and bryozoans, likely baffling currents allowed for the settling of carbonate mud and increased topographic relief of the developing mound complexes. It is the topographic relief that makes these sites more conducive to the colonization by a more diverse biota. The outcrop is an excellent analog as to the size and geometry of known and potential Frisco reservoirs yet to be discovered.

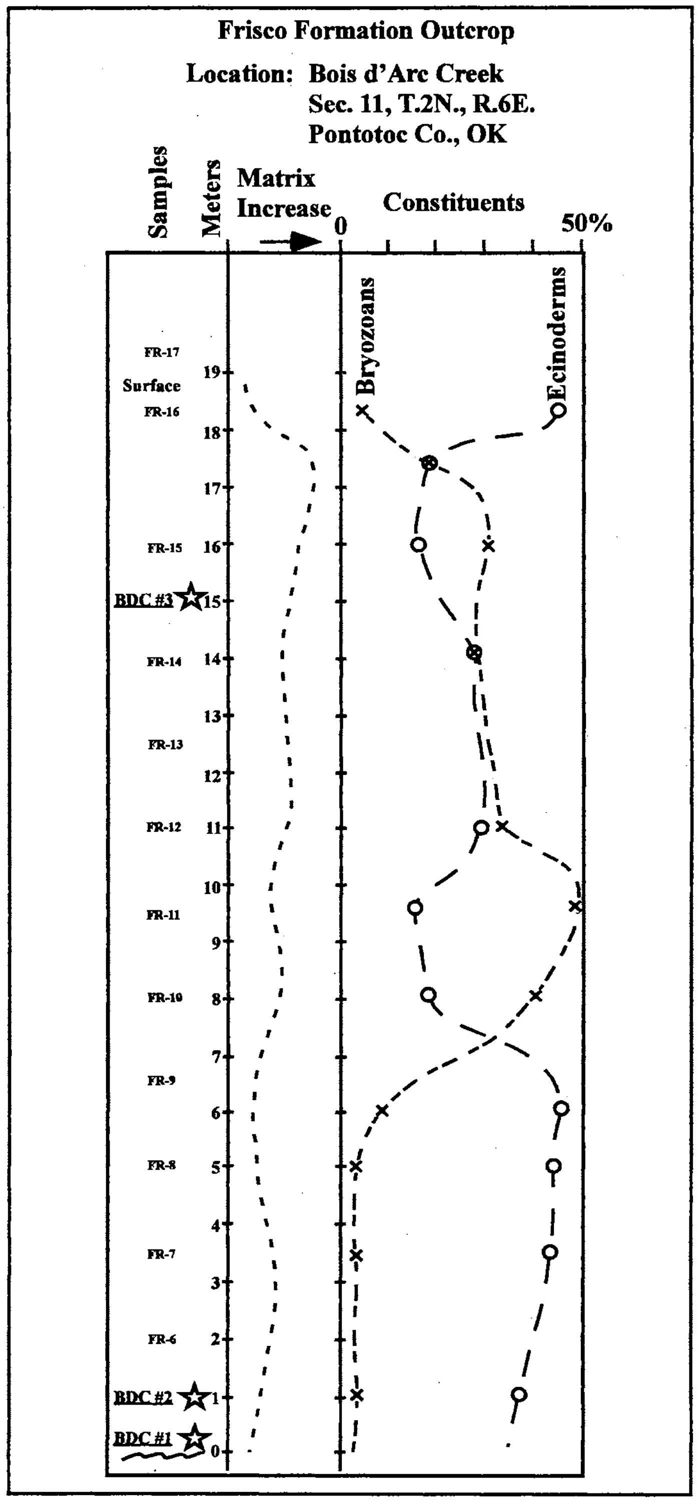


Figure 17. Measured section of outcrop showing composition and constituents in a Frisco Formation mud-mound sequence (after Harrison, 1987). Stars indicate samples taken in 2002, for conodont biostratigraphic analysis (See Table II).

Subsurface Stratigraphy

The Frisco Formation in the subsurface cannot be directly correlated to the Frisco outcrop located at Bois d'Arc Creek. However, it does provide an excellent opportunity to use the outcrop as an analog to the subsurface. A direct comparison is difficult for some rock properties such as permeability and porosity. Permeability and porosity can be affected by percolation of meteoric waters through the rock that results in dissolution or precipitation that either increases or decreases permeability and porosity. Direct comparison is also hindered by stratigraphic position at the outcrop. The Frisco mounds observed at the outcrop rest unconformably on the Bois d'Arc Formation, whereas the Frisco mounds in the subsurface in Seminole County overlie Silurian strata, likely the Henryhouse Formation. Using the outcrop as an analog, the subsurface geometry, compositional variations, and larger scale sedimentary features can be resolved and visualized, mapped and ultimately exploited.

In the subsurface the Frisco consists of a fossiliferrous packstone, which grades into wacke/mudstone containing fossils, usually bryozoans and crinoids. The role of crinoids and bryozoa in mound stabilization is covered in detail in Medlock (1984). Summarized, it states the baffling action of the crinods and bryozoa slows the current, resulting in deposition of sediments on the lee side of the baffle. Simultaneously, encrusting forms of the bryozoans helped to stabilize the mound.

Thin-section petrography as well as core examination allowed for the recognition of the lateral facies changes within the Frisco section. In the Baxter #1 (Figure 18) well in T.10N R.6E, the Frisco section is approximately 47 feet thick and composed primarily of wackestone which grades to packstone-grainstone in the uppermost 30 feet of the core.

Figure 18. Core photograph and photomicrograph of the Frisco Formation mud mound/bioherm facies. Baxter #1 well. Depth 4,156 feet.

The Baxter #1 core likely contains the flanking facies of the Frisco Formation and is not centered directly over the crest of the mound. In contrast, to the near-mound facies of the Baxter, the Ponkilla #1 well (Figure 19) which is located less than one mile distant and is structurally 48 feet lower and contains approximately 69 feet of Frisco. The Ponkilla is much different and contains only a thin grainstone (cap). The rest of the Frisco section is a mudstone to wackestone, believed to be a mud core.

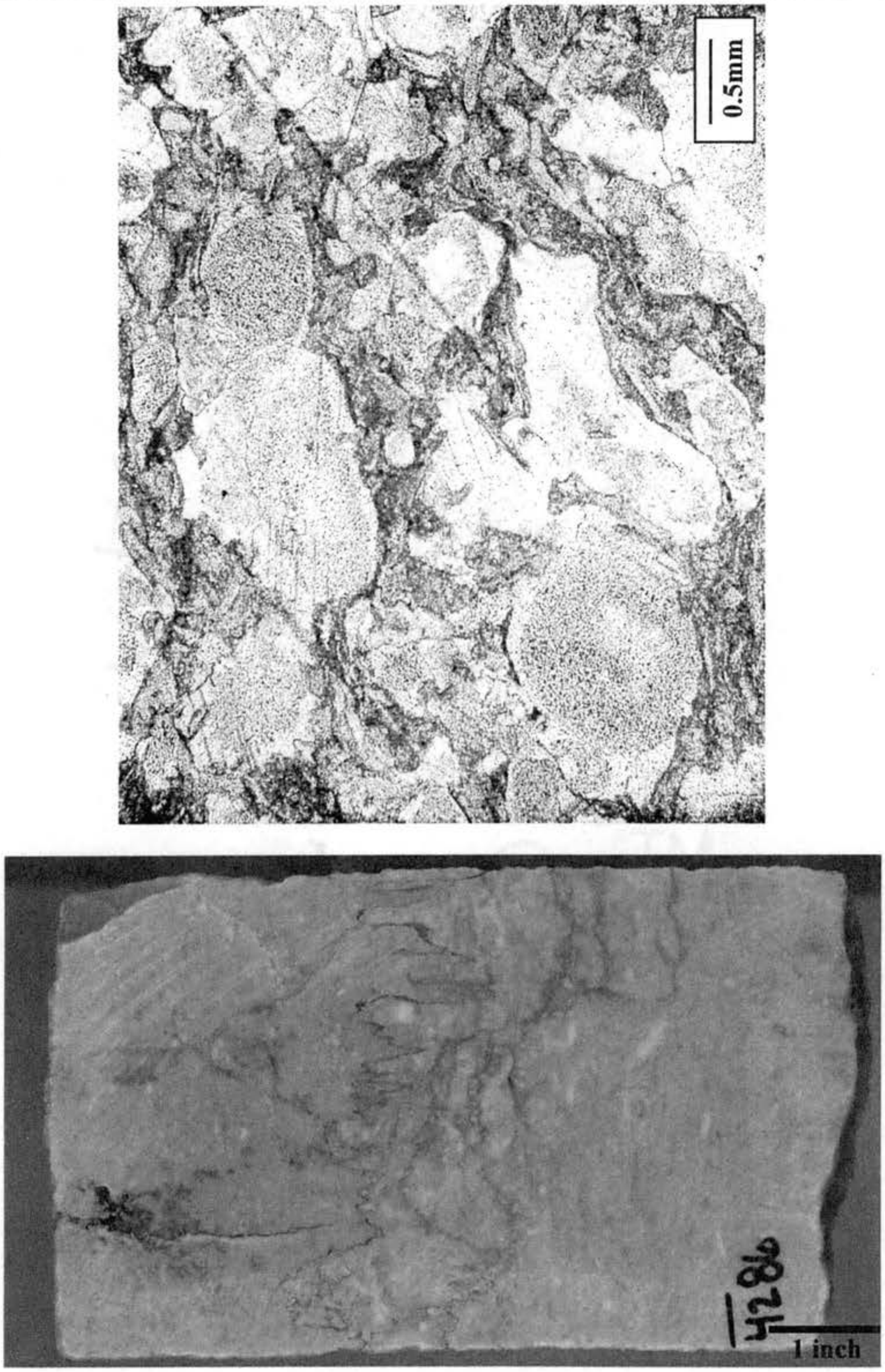


Figure 19. Core photograph and photomicrograph of the Frisco Formation non-bioherm facies. Ponkilla #1 well. Depth 4,286 feet.

CHAPTER V

CHARACTERIZATION OF RESERVOIR ROCKS

The Frisco Formation is a bryozoan and crinoid-rich limestone that generally contains less than 5% dolomite. Commonly, Hunton reservoirs improve with dolomitization, however, in this situation the relative lack of dolomite does not adversely affect reservoir quality. Generally, Frisco rocks range from grainstone to mudstone. The Frisco reservoirs are specifically classified as a Dunham (1961) biograin/packstone and/or a Folk (1959) biosparite. The quality of Frisco reservoirs varies with the degree of karstification and thickness. Thickness of the Frisco Formation affects reservoir quality by either increasing or decreasing the local volume of the reservoir, and in turn its potential oil reserves. On the other hand, karstification plays the major role in the quality of the reservoir by dramatically increasing porosity and permeability where dissolution removes rock material. In the study area, the Frisco is unconformably overlain by the Misener Sandstone, which in turn is succeeded by the Woodford Shale. The Woodford Shale is considered to be one of the major source rocks in much of Oklahoma, including Seminole County (Johnson and Cardott, 1992). The Woodford Shale likely sources the Frisco along with the rest of the Hunton section (Johnson and Cardott, 1992).

Diagenesis

Post-depositional mechanical/physical and chemical diagenesis includes compaction, dissolution, and precipitation of calcite in pore space. Stylolites can be used to determine the actual amount of compaction. Hunt (1979) suggests that 25-30 percent of rock material can be removed from the section through pressure solution of the rock grains. Evidence for pressure solution is seen microscopically in thin-section as sinuous grain contacts and macroscopically in the core as stylolites (Figure 20). Original Frisco thickness is unknown as the contact between the Frisco/Woodford is an unconformity with signature pre-Woodford erosion. Chemical diagenesis in the study area includes constructive and deconstructive diagenesis.

Karstification

Deconstructive diagenesis occurs throughout the Hunton Group as karstification. Vugs and small cavities in the rock are common in the Frisco and range in size from 1mm to 10mm. Solution enlarged fractures are also present and have been described within the Frisco. These are not only present within the Frisco, but occur throughout the Hunton group. These karstic zones are generally connected, thus greatly increasing the local permeability of the reservoir. Dissolution of fossil fragments or moldic porosity is also a typical feature in the Frisco Formation. Brachiopods, crinoids, and bryozoans are all present in the Frisco, but bryozoans were preferentially dissolved.

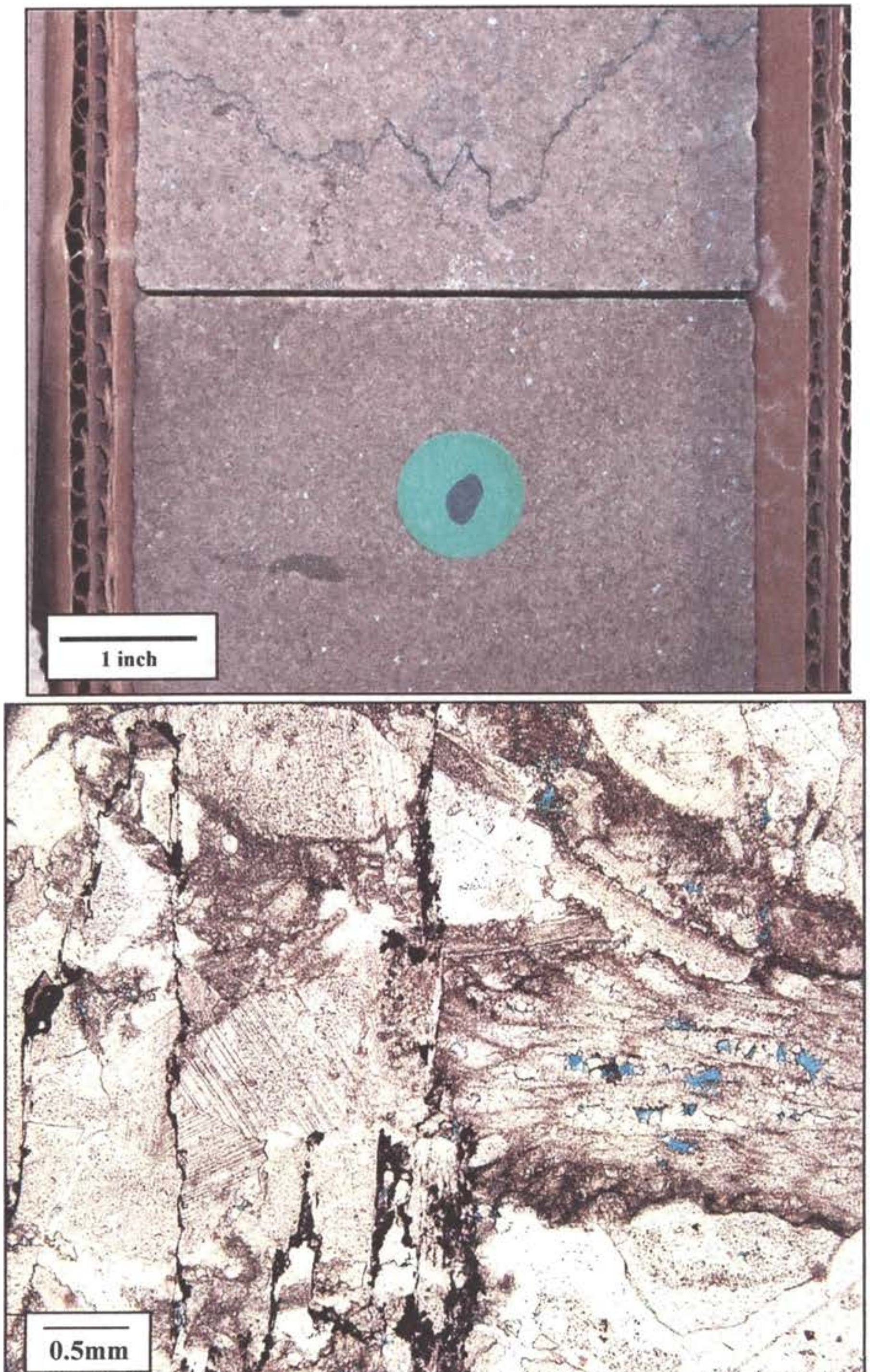


Figure 20. Pressure solution: Stylolite in core Baxter #2 well. Depth 4,155 feet. Stylolite/sineous grain contact photomicrograph bottom. Ponkilla #1 well. Depth 4,286 feet.

Constructive Diagenesis

While the vugs and enlarged fractures serve to increase the porosity and permeability of reservoirs, calcite precipitate occludes porosity. Calcite is precipitated within vugs, solution enlarged fractures, and intercrystalline pores diminishing the reservoirs' porosity and permeability. Generally, the calcite precipitation has not totally filled these pores. Syntaxial sparry calcite overgrowth on echinoderms fragments occludes primary intercrystalline porosity (Figure 21). Despite the occlusion of porosity as a result of diagenesis, Frisco reservoirs typically have 4-12% porosity.

Dolomite Formation

Dolomite mineralization, which is common in the Hunton is not siginificant in the Frisco Formation. There are several possible explanations for this, and the answer is likely a combination of them. The two most likely explanations are (1) depositional conditions (2) depth of burial was not adequate for dolomitization. (1) The Frisco flooded quickly and there apparently was insufficient time for "mixing" to occur. The mixed waters/Doorag model of dolomitization, states that fresh waters mixing with marine water can increase the Mg-Ca ratio to 3-1, thus precipitating dolomite. Secondly, the Frisco forms in a subtidal environment and the evaporitic dolomite model would not apply. In a core located outside the study area in Major County Oklahoma, gypsum is present and along with hypersaline dolomite, here the evaporitic model is likely the method dolomite precipitation. No hypersaline dolomite or evaporities have been noted in the Frisco. (2) The Frisco was buried to approximately 6,000-8,000ft (Schmoker, 1986) in the Seminole area, but not deep enough for the formation thermal dolomite. The

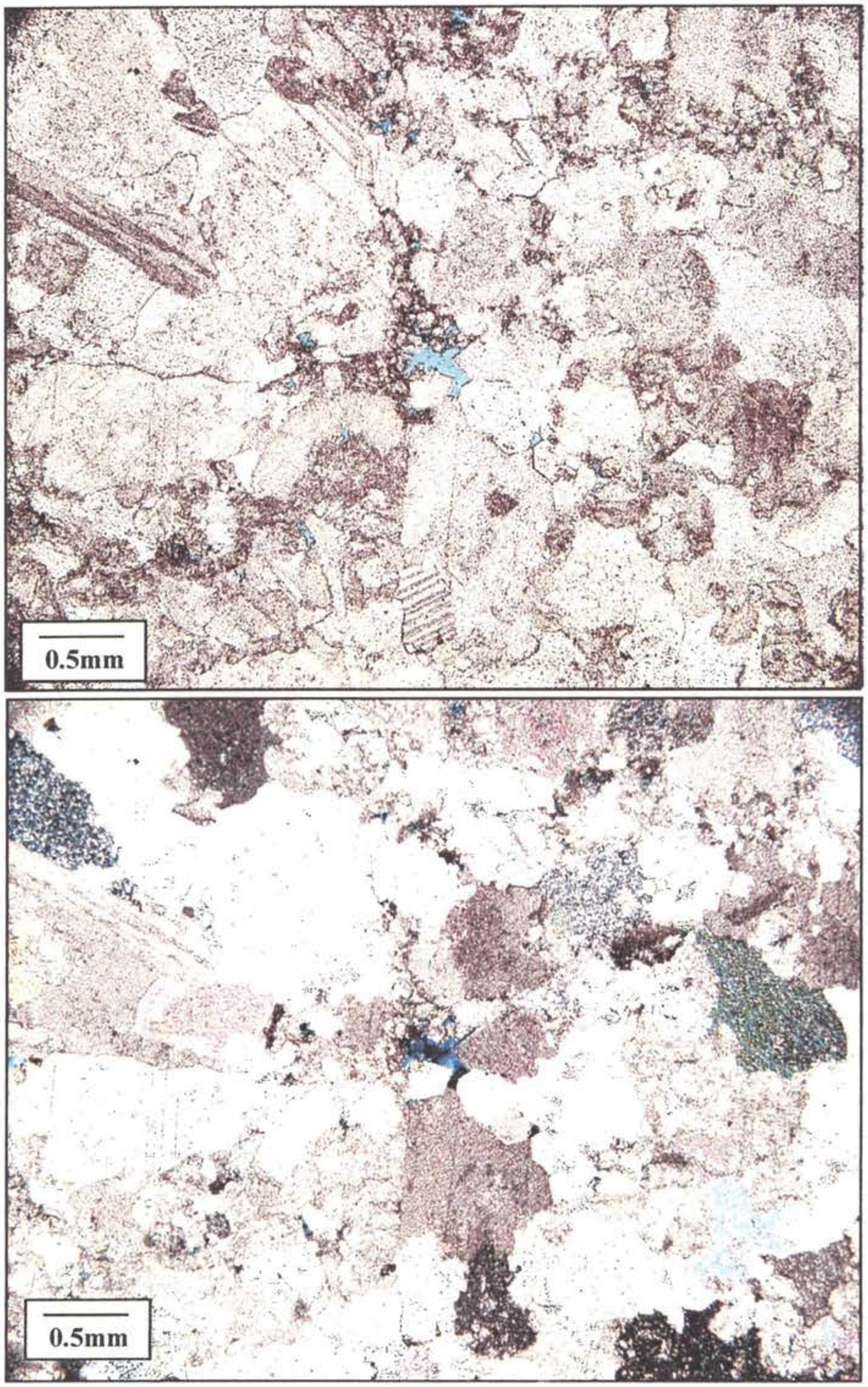


Figure 21 Remnant primary porosity, post mechano-chemical depositional diagenesis: Ponkilla #1 well. Depth 4,281 feet. Crossed nicols (XN) at bottom.

hydrothermal dolomite model requires that formation fluids reach temperatures in the range of 60-85^{0}C before baroque dolomite forms. In addition, there must be adequate porosity for fluid to move through the rocks and the fluid must contain both magnesium and iron. If there is space, saddle or Baroque type dolomite providing there is room for the dolomite crystals will grow. These crystals are identified in thin-section having an undulose (sweeping) extinction. No thermal or saddle type dolomite was detected in the Frisco.

Permeability

The Hunton Group reservoirs in Seminole County are laterally connected, due to interference between producing wells. Production data shows a correlation between pumping and production in adjacent wells (Kelkar, 2001). However, vertical permeability barriers do exist as seen on micro-permeability logs. The micro-log and inverse micro-log show distinct packages (which correlate to stratigraphic boundaries) of carbonate separated by relatively lower permeabilities (Figure 22). These boundaries are located at or near the unconformities that separate the different the different stratigraphic sections. This was confirmed with the conodont biostratigraphy.

Only core-analysis data were used in the analysis of permeability. These rock-based data are more accurate than the reading paper wire-line log data that was also available. The core permeability was measured using the Klinkenberg method. Air permeability measurements were performed, yielding very similar data, however the Klinkenberg method corrects for the gas slippage effect and is considered more accurate. Two separate wells were used to compare and contrast the permeability of bioherm facies to the non-bioherm facies (Figure 23). The Frisco Formation in the Baxter well, is used

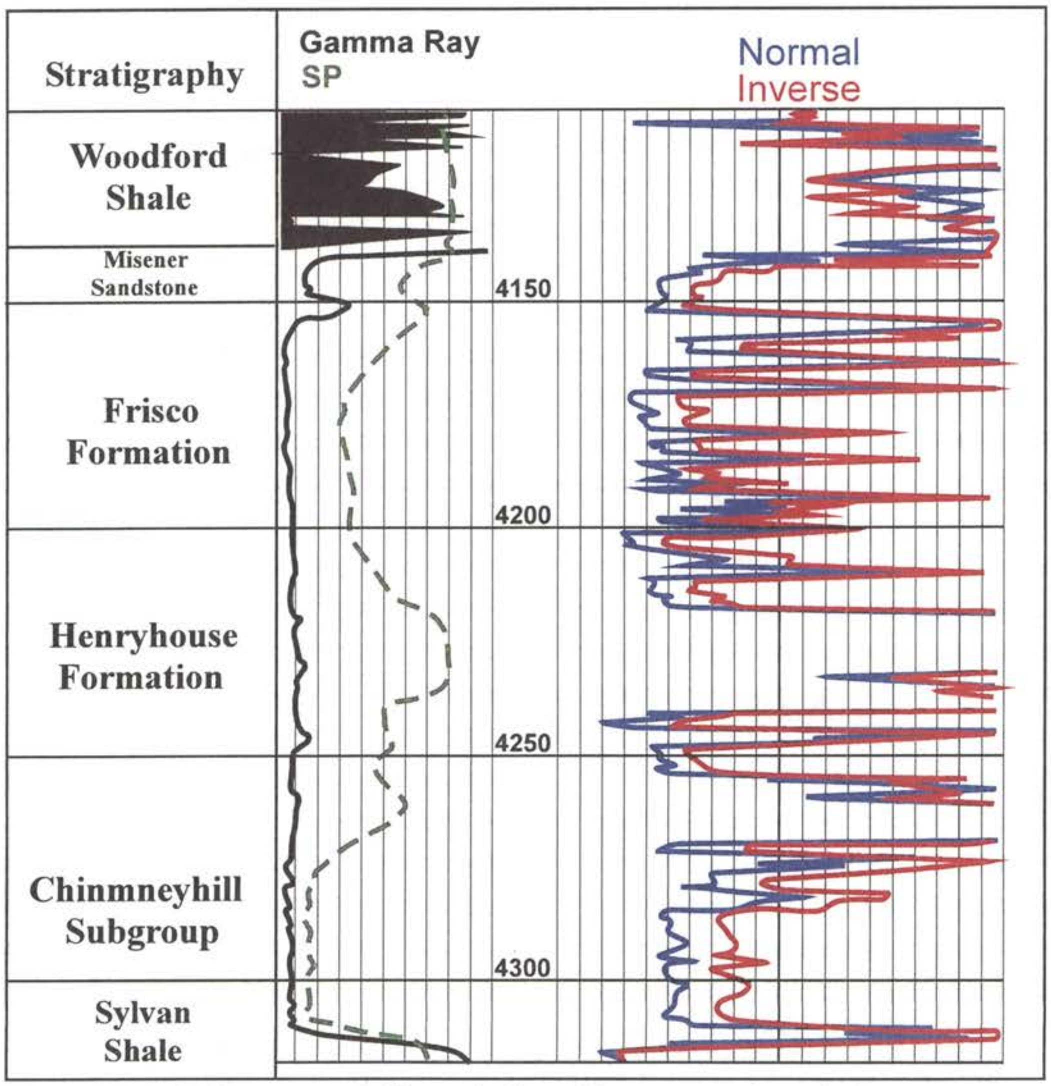


Figure 22. Wireline permeability as indicated by a separation of micro-resistivity curves, correlated to lithology.

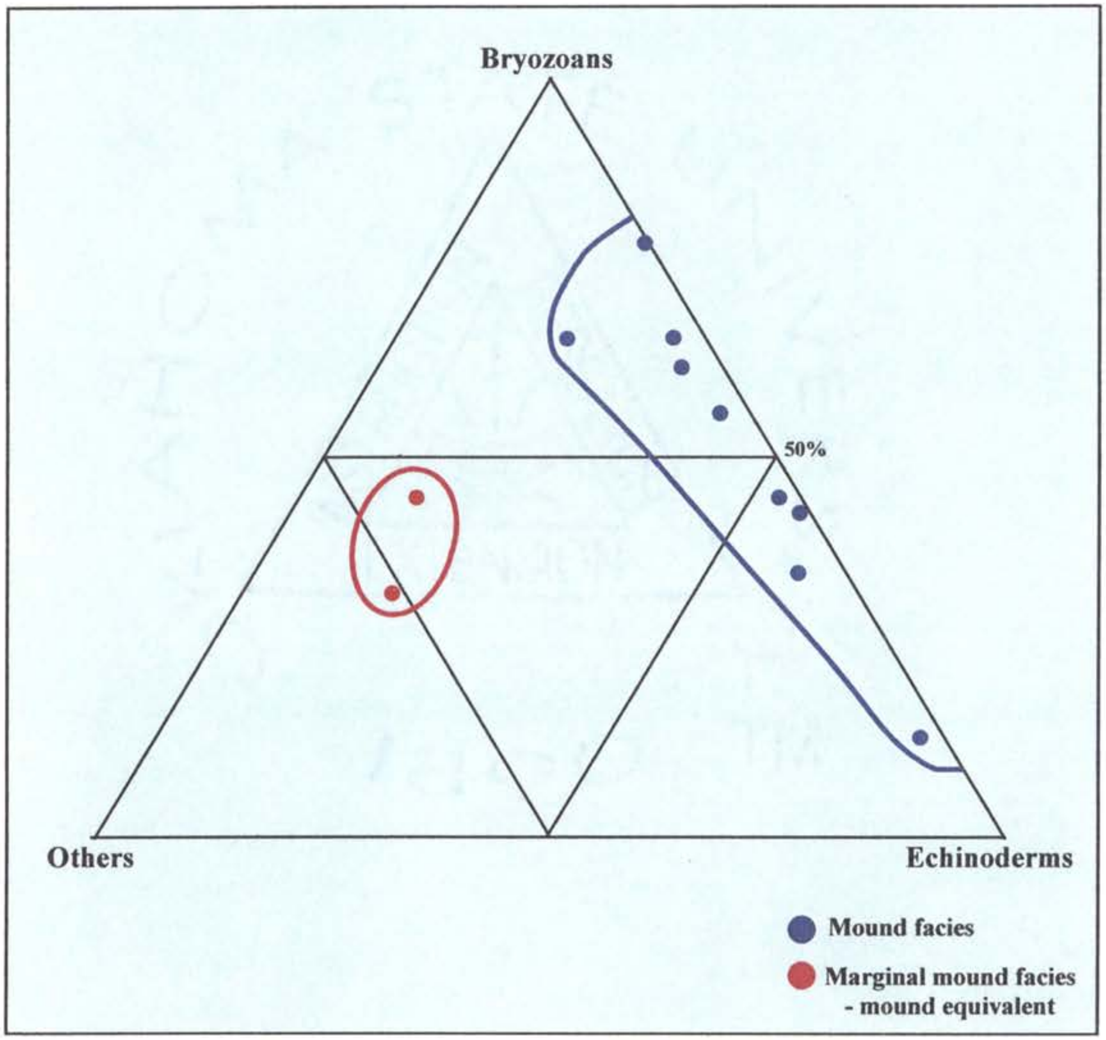


Figure 23. Triangle diagram of skeletal grain constituents in mound and non-mound facies. Data is from petrologic data, See Appendix III.

to demonstrate the bioherm facies. The Frisco Formation in the Ponkilla well, is used to Frisco that formed when the depositional condition as were not favorable to mound building. Permeability of the Frisco Formation varies widely from the bioherm/reservoir facies of the Baxter well to the non-reservoir/bioherm facies in the Ponkilla #1 well (Figure 24). In Figure 25, porosity values are similar, however the bioherm facies has a larger secondary population of porosity in the 6-9 percent range. It is porosity data coupled with the permeability data that allows for definite distinction between these facies. The overlaying of these two graphs shows that the secondary population of porosity in the bioherm facies coincides with the secondary peaks of the permeability. It is these two factors, which make the bioherm facies a possible reservoir.

Porosity

Within the study area, porosity ranges from <1 to 16% in the Frisco Formation. Core analysis data showed a distinct correlation between the measured core plug porosity and the porosity logs of the Hunton reservoirs (Figure 26). This correlation between core data and wire-line data is not 100 percent in all cases so only the core-analysis data will be utilized. A histogram of the porosity was completed using the Frisco section of both the Ponkilla well and the Baxter well. With these data alone it is difficult to distinguish between facies, however the non-bioherm facies does have a less porosity. Porosity within the Frisco Formation, as well as the entire Hunton section, is generally secondary in nature and developed within the Frisco as the result of two different mechanisms, fabric selective and fabric non-selective.

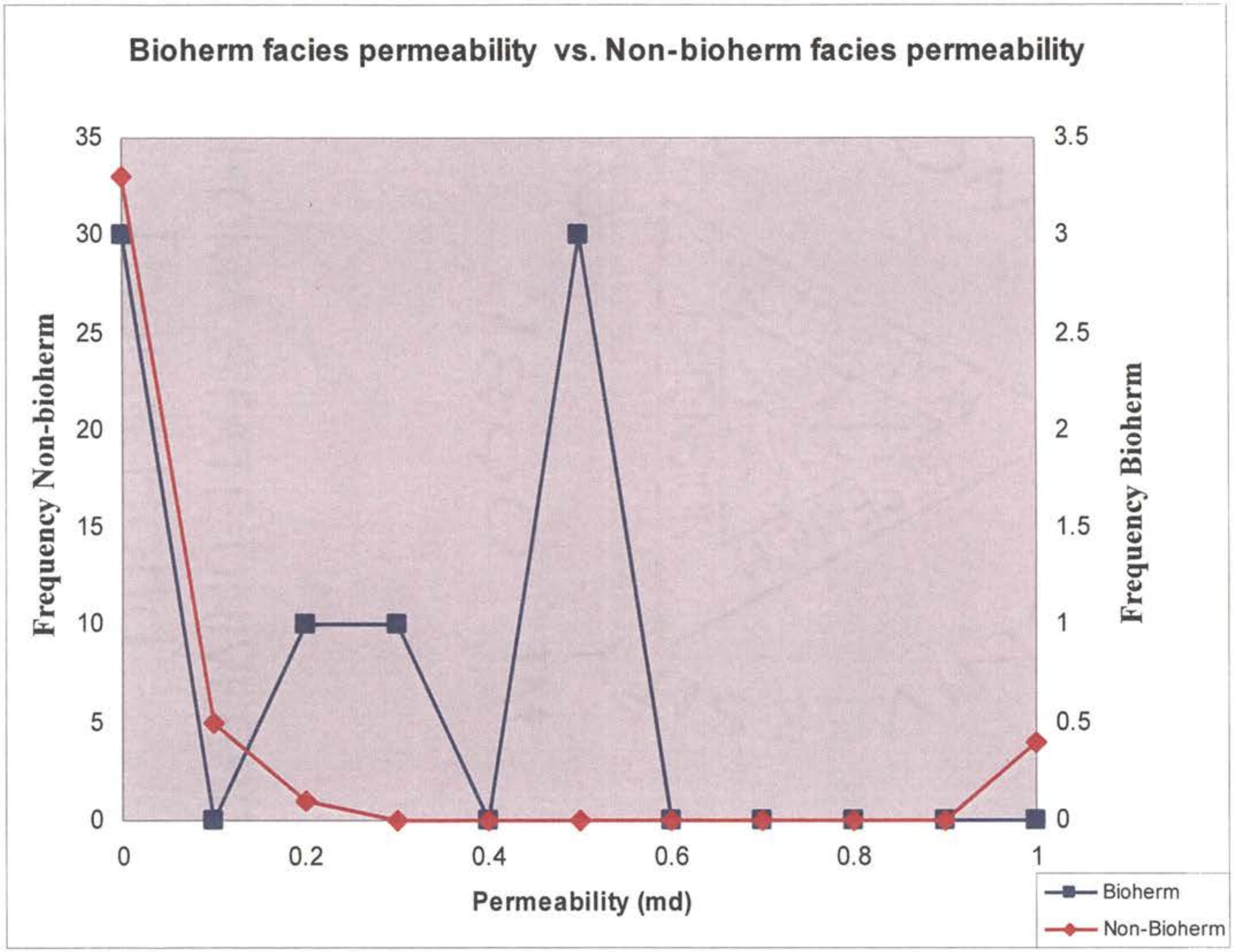


Figure 24. Histogram showing distribution of permeability in Frisco facies.

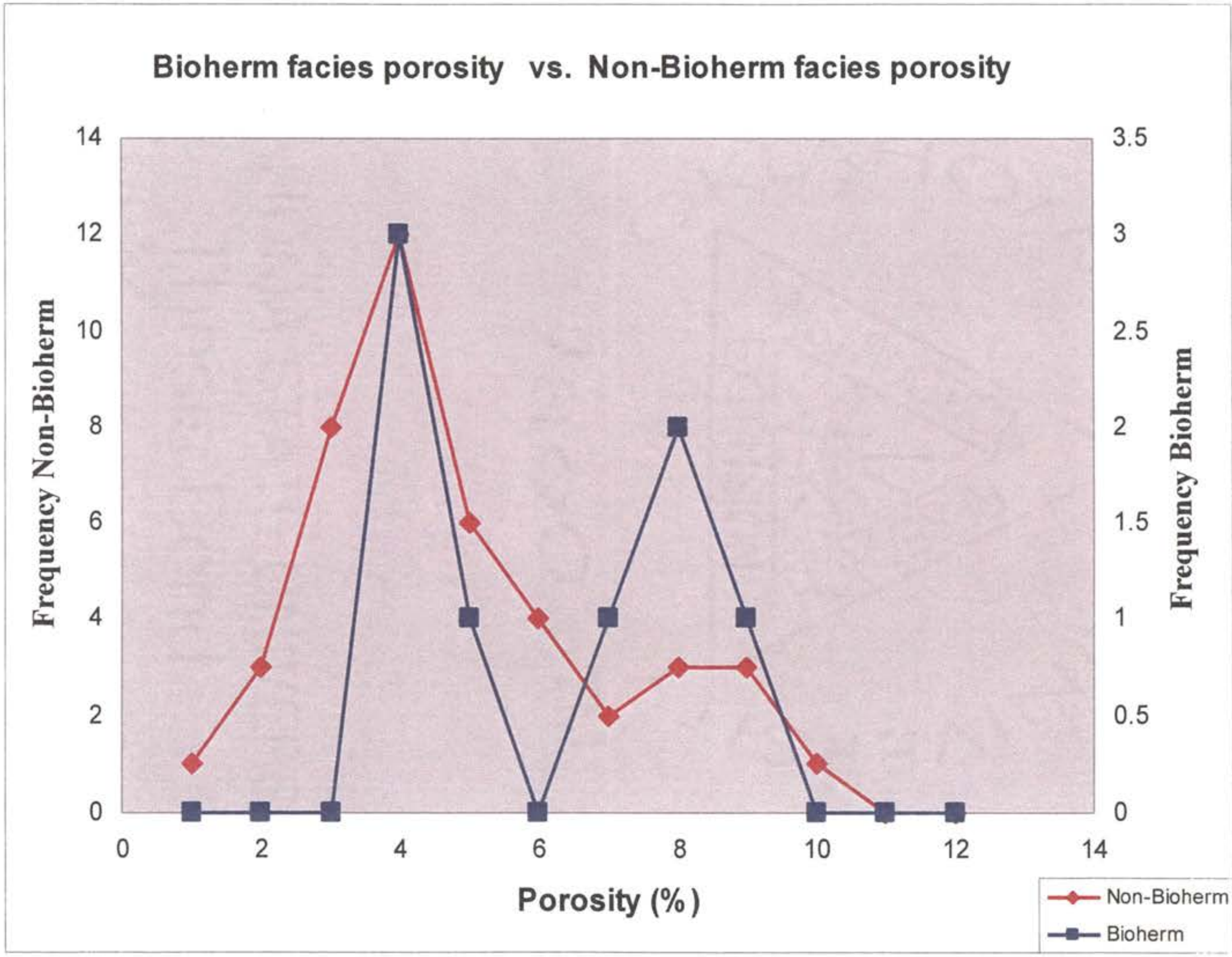


Figure 25. Histogram showing distribution of porosity in Frisco facies.

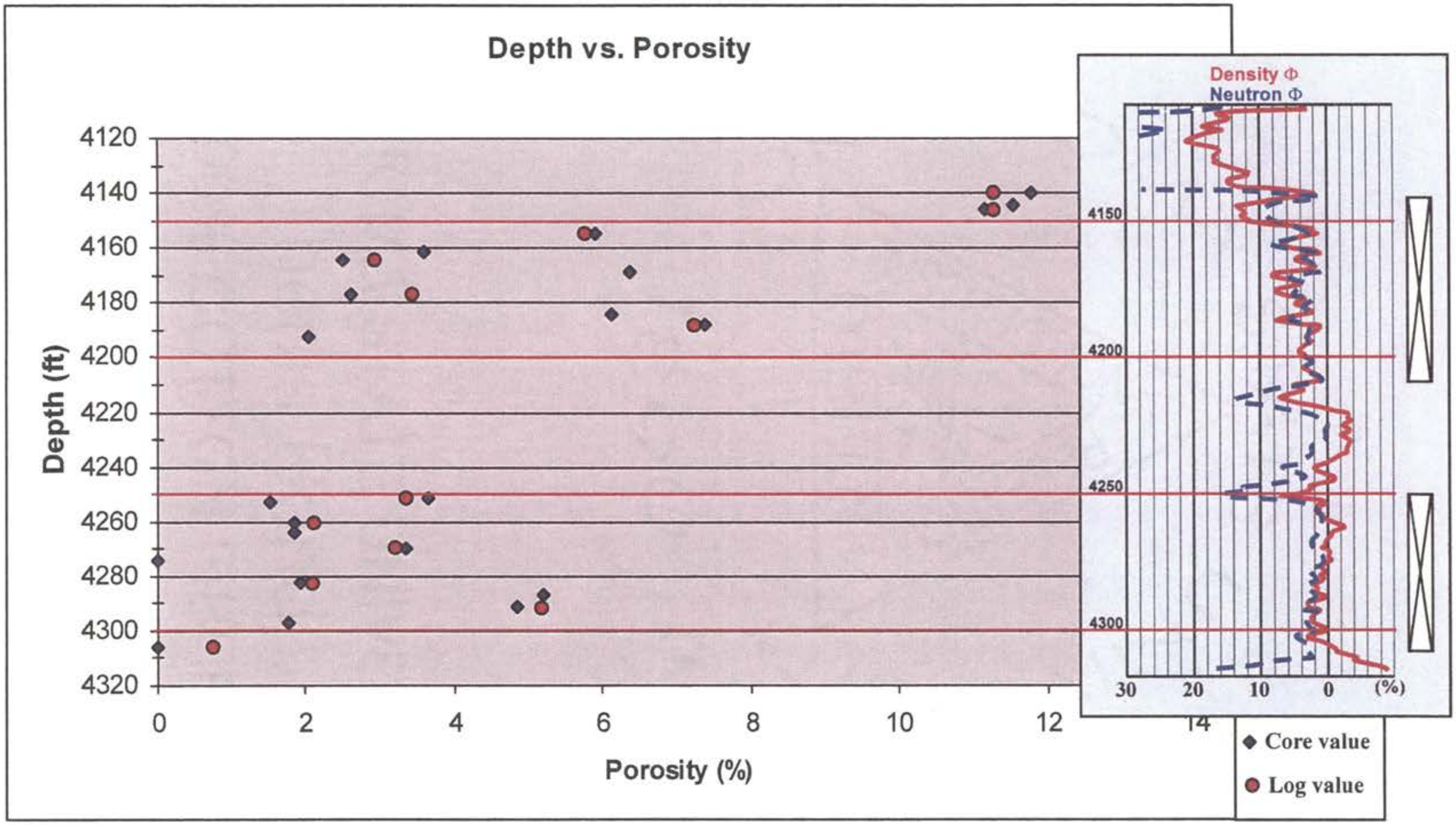


Figure 26. Graph comparing core porosity and porosity wireline logs. A positive correlation exists between core measurements and wireline log values.

Fabric Selective

Moldic porosity in the Frisco often begins as intraparticle dissolution that leaves casts of fossil grains. The zooecia within bryozoans seem to be preferentially dissolved. In some cases, sparry calcite has precipitated within the molds and occluded porosity. In other cases, the opposite has occurred and the intraparticle pore space has been enlarged (Figure 27). Some intrabryozoan porosity is a remnant of the primary porosity that was not destroyed by diagenesis and/or mechano-chemical compaction (Figure 28). Total elimination of porosity is not likely to have occurred through compaction alone, and preservation of primary porosity is critical to reservoir genesis. Some primary porosity and permeability remained that allowed fluids to migrate through the rock creating secondary porosity.

Fabric Non-selective

Karstification occurred as the Hunton was at or near the surface. It dissolved approximately 5-15% of the Frisco rock and occured as the water table within the Frisco dropped. This left the Frisco rocks exposed to surficial waters and allowed infiltration along fractures, beading planes, and other similar openings. The resultant dissolution is evident as enlarged fractures and vugs (Figure 29). The connective network of vugs and solution-enlarged fractures serve to dramatically increase the local permeability of the reservoir.

Oil Migration

Primary oil migration likely occurred when the overlying Woodford shale was buried sufficiently to attain thermal maturation and organic matter was transformed into

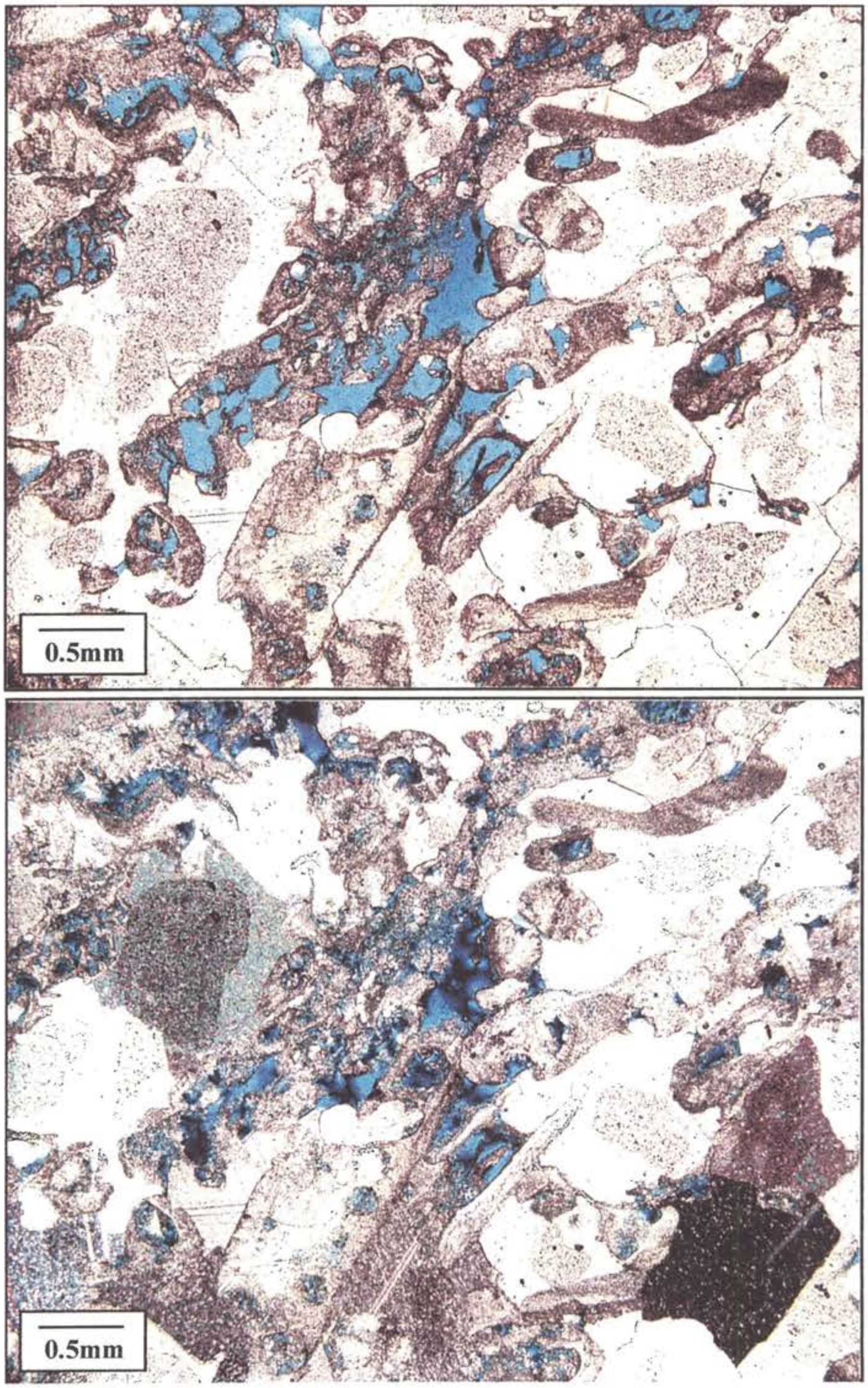


Figure 27. Enlarged intragranular porosity, porosity has developed within a bryozoan: Baxter #2 well. Depth 4,155 feet. Top: plane polorized light (PPL). Bottom: crossed nicols (XN).

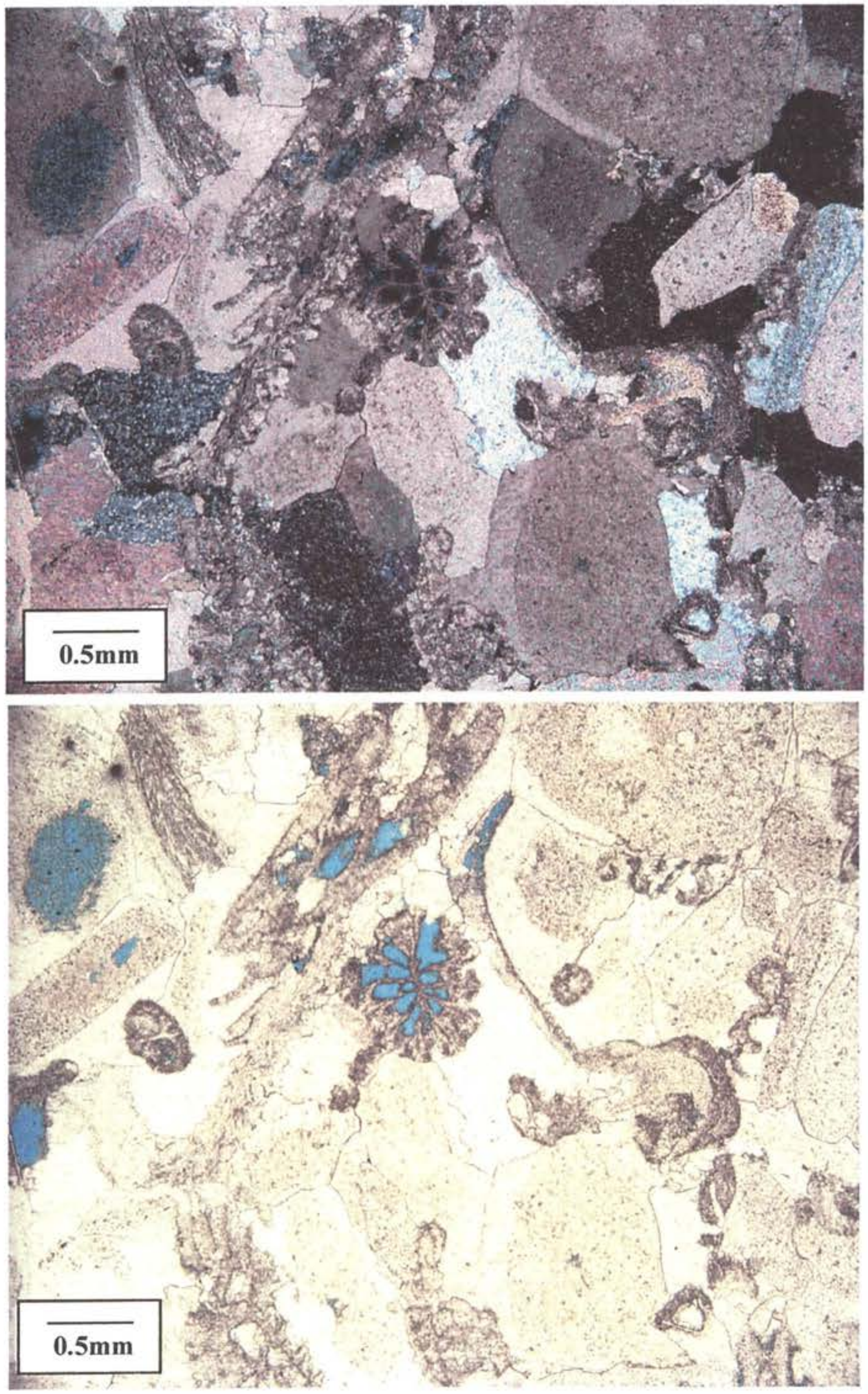


Figure 28. Photomicrograph showing intragranular porosity within a bryozoan fragment as well as syntaxial cemented grains. The syntaxial cement is surrounding echinoderm plates. Lola #1 well. Depth 4,314 feet. Top: (XN). Bottom: (PPL).

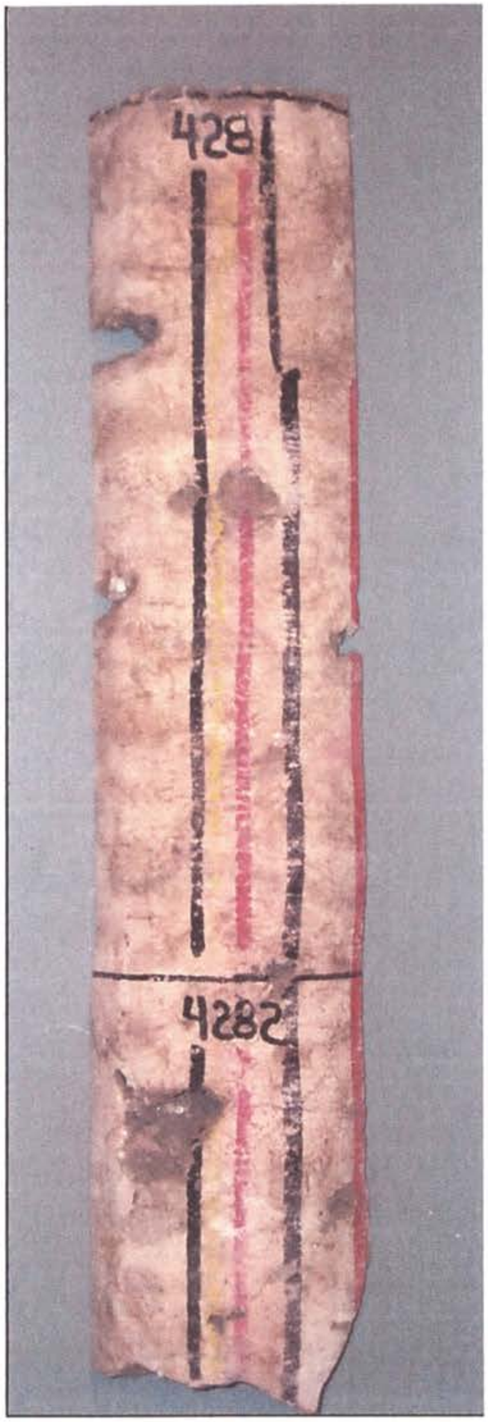


Figure 29. Photograph of core showing large vugs that reflect the extent of focused-flow karstification. Typical in Silurian section of the Hunton Group. The Frisco is generally karstified by more diffuse-flow type dissolution that results in moldic porosity. Ponkilla #1 well. Depth 4,282 feet.

hydrocarbons. These hydrocarbons were expelled from the Woodford and migrated into the underlying Hunton reservoirs or older Ordovician reservoirs where the Hunton was absent. The primary migration of hydrocarbons from the Woodford Shale into the Frisco reservoirs was likely driven by a lower potential (capillary pressure) created by larger intercrystalline pores and karstification features, including vugs and solution-enlarged fractures. Subsequent oil migration in the northern part of the study area is inferred by the relationship of water and oil production in the field. Oil is apparently migrating both laterally and vertically within the Misener Sandstone Hunton Group karstic reservoir system. The oil production to water production ratio is likely a result of a combination of permeability and reservoir pressure. The "dewatering" of this reservoir is thought to allow for the reduction of reservoir pressure near the well bore, thus allowing oil in the small pore spaces to move from an area with a high potential to an area with a relatively lower potential.

The Woodford Shale is arguably the most prolific source rock in Oklahoma, having a total organic content of <1% to 14% (Sullivan, 1985). The Woodford Shale has been shown to contain mainly type II kerogens, and to some extent type III kerogens (Buruss and Hatch, 1989). The Hunton Group also contains these kerogens, linking them to the Devonian-Mississippian hydrocarbon source (Figure 30).

Field Data

Many oil and gas fields produce in the Seminole and Pontotoc county areas. One of the more notable is the Fitts Pool, discovered in 1933 (Hyatt, 1936). Initial production in the Fitts Pool, Pontotoc County, Oklahoma came from multiple formations including two productive zones in the Hunton Group. The lower and less significant was the oolitic

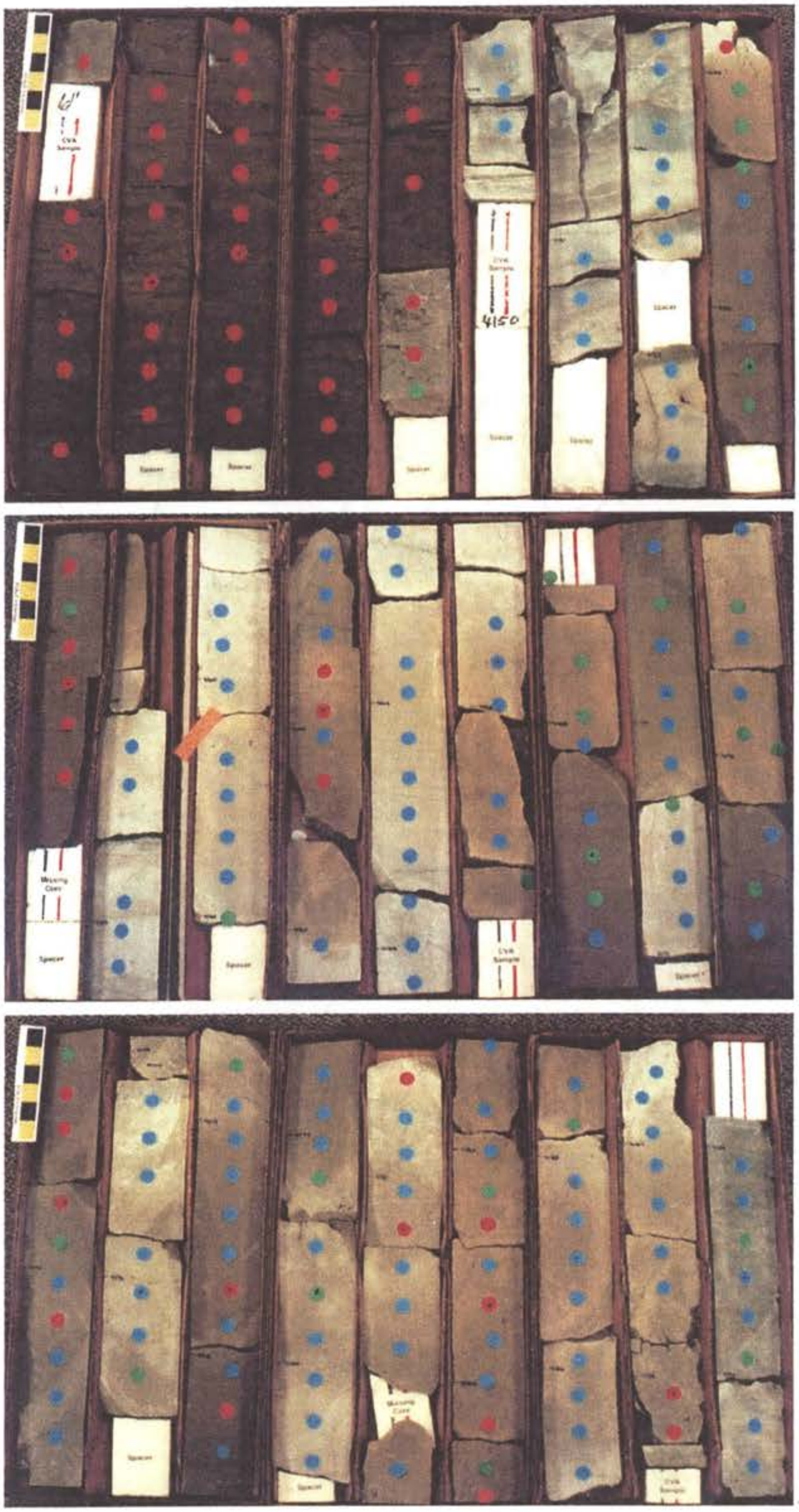
System	Producing Interval	Hydrocarbon Source Rock	Kerogen Type	TOC %
Mississippian	Pre-Chester Mississippian (undifferentiated)	Springer Formation	III	0.5 - 3.4
Devonian		Woodford Shale	II III	<1 - 14
Silurian	Hunton Group			
Ordovician	Simpson Group	Sylvan Simpson Group	II I III	<1 - 9
Upper Cambrian	Arbuckle Group			

Figure 30. Relationship of source rock kerogen to reservoir rocks. After Johnson and Cardott, 1992.

Keel Member of the Chimneyhill Subgroup, the more significant was the upper producing zone that was labeled the Bois d'Arc Formation. Conodont biostratigraphy confirmed that this formerly named Bois d'Arc zone is the Frisco Formation. The Frisco was a high volume producing zone and the initial production in the Hunton, discovery well (Wirick No. 1 SE., SE., SW., of T.2N.-R.7E.-SEC. 29) yielded approximately 20 Mmcf gas and 30 bopd (Hyatt, 1936).

North of the Fitts Pool and in the Greater Seminole District, where the Hunton is being revisited and re-drilled, similar high volume production is found in the Frisco Formation. Here the Frisco can produce in excess of 5000 bwpd. along with oil and gas. As a result of technology and new ideas on reservoir dewatering, oil is being produced from these Hunton rocks at a rate of 10-100 bopd along with several thousand barrels of water per day. One of the new wells producing from the Hunton is the Baxter #2, which produces from a thin 10 ft. thick Misener Sandstone, as well as the thicker, oil saturated Frisco section (Figure 31).

In the Fitts Pool and greater Seminole district areas, there are approximately 458 and 6500 wells respectivly (Dwights, 2001) penetrating the Hunton group. From the group of producing wells in Fitts Pool alone it is estimated that approximately 227,637,581 barrels of oil and 54,617,314 billion cubic feet of gas (Dwights, 2001) have been produced with an estimated 60% coming from the Hunton intervals (personal communication J. Puckette). Until recently the producing zones were thought to be Henryhouse (Greater Seminole District) or Bois d'Arc (Fitts Pool). It has now been verified through stratigraphic correlation and conodont biostratigraphy that the primary



4139 ft. - 4156 ft.

4156 ft. - 4173 ft.

4173 ft. - 4191 ft.

Figure 31. Misener Sandstone and Frisco Formation core photographs.

productive zones in the greater Seminole District and the Fitts Pool are the Lower Devonian Frisco Formation.

CHAPTER VI

CONCLUSIONS & IMPLICATIONS

1. Renewed drilling activity has provided new data and allowed for the detailed investigation of the Hunton Group, in Central Oklahoma.

2. Wire-line logs were used to correlate the Hunton section from Lincoln County to Pontotoc County. This regional North to South cross-section shows the general basin geometry and identifies areas of Hunton erosional truncation.

3. Hunton Group stratigraphy in Lincoln, Pottawatomie, Pontotoc, and Seminole Counties can be accurately differentiated and mapped using wire-line logs.

4. Cores were used to verify the presence of carbonate mound facies, which were identified as Frisco Formation, as well as establish the Hunton Group reservoir characteristics and quality in the Seminole County area.

5. Conodont biostratigraphy allowed the differentiation of Hunton strata on core calibrated wireline logs (electrofacies) and extension of the correlation to establish Hunton Group stratigraphic nomenclature.

6. Reservoir quality was found to be highest in the Frisco Formation. The Frisco is the focus of this study because of recent renewed drilling and production hydrocarbon production from the Hunton Group.

7. The Frisco Formation is a bryozoan and crinoid-rich limestone that generally contains less than 5% dolomite. It contains approximately 5-15% porosity in the Seminole County

study area. The Frisco Formation is overwhelmingly limestone throughout central Oklahoma.

8. Other Hunton units, including a zone at the base of the Henryhouse Formation and the Chimneyhill Subgroup are often dolomitized.

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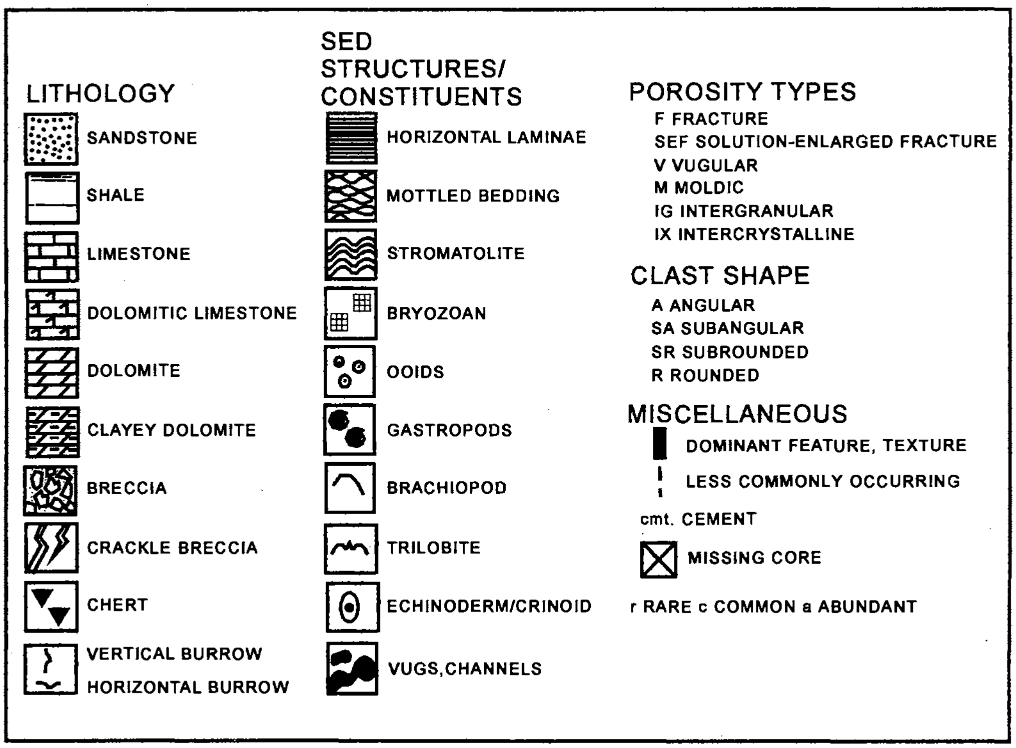
APPENDIX

Petrologs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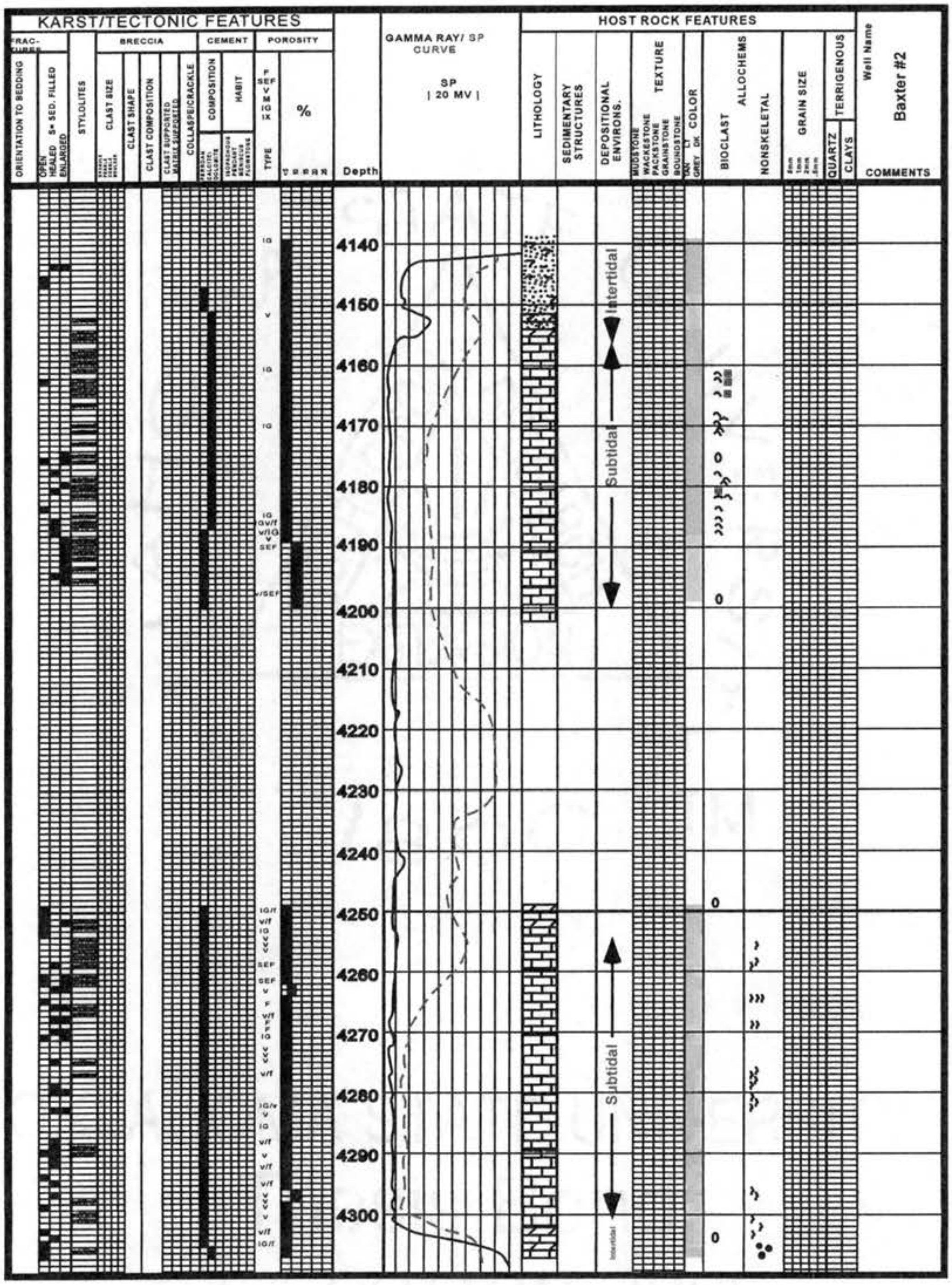
CRACKLE BRECCIA
CHERT
VERTICAL BURROW
HORIZONTAL BURROW
SED STRUCTURES/ CONSTITUENTS
HORIZONTAL LAMINAE
MOTTLED BEDDING
STROMATOLITE
BRYOZOAN
OOIDS
GASTROPODS
BRACHIOPOD
TRILOBITE
ECHINODERM/CRINOID
VUGS,CHANNELS
POROSITY TYPES
F FRACTURE
SEF SOLUTION-ENLARGED FRACTURE
V VUGULAR
M MOLDIC
IG INTERGRANULAR
IX INTERCRYSTALLINE
CLAST SHAPE
A ANGULAR
SA SUBANGULAR
SR SUBROUNDED
R ROUNDED
MISCELLANEOUS
DOMINANT FEATURE, TEXTURE
LESS COMMONLY OCCURRING
cmt. CEMENT
MISSING CORE
r RARE c COMMON a ABUNDANT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HOST ROCK FEATURES
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CEMENT
POROSITY
GAMMA RAY/ SP CURVE
SP
| 20 MV |
Depth
LITHOLOGY
SEDIMENTARY STRUCTURES
DEPOSITIONAL ENVIRONS.
TEXTURE
COLOR
ALLOCHEMS
BIOCLAST
NONSKELETAL
GRAIN SIZE
TERRIGENOUS
QUARTZ
CLAYS
Well Name
Baxter #2
COMMENTS
ORIENTATION TO BEDDING
STYLOLITES
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
COLLASPE/CRACKLE
COMPOSITION
HABIT
TYPE
%
4140
4150
4160
4170
4180
4190
4200
4210
4220
4230
4240
4250
4260
4270
4280
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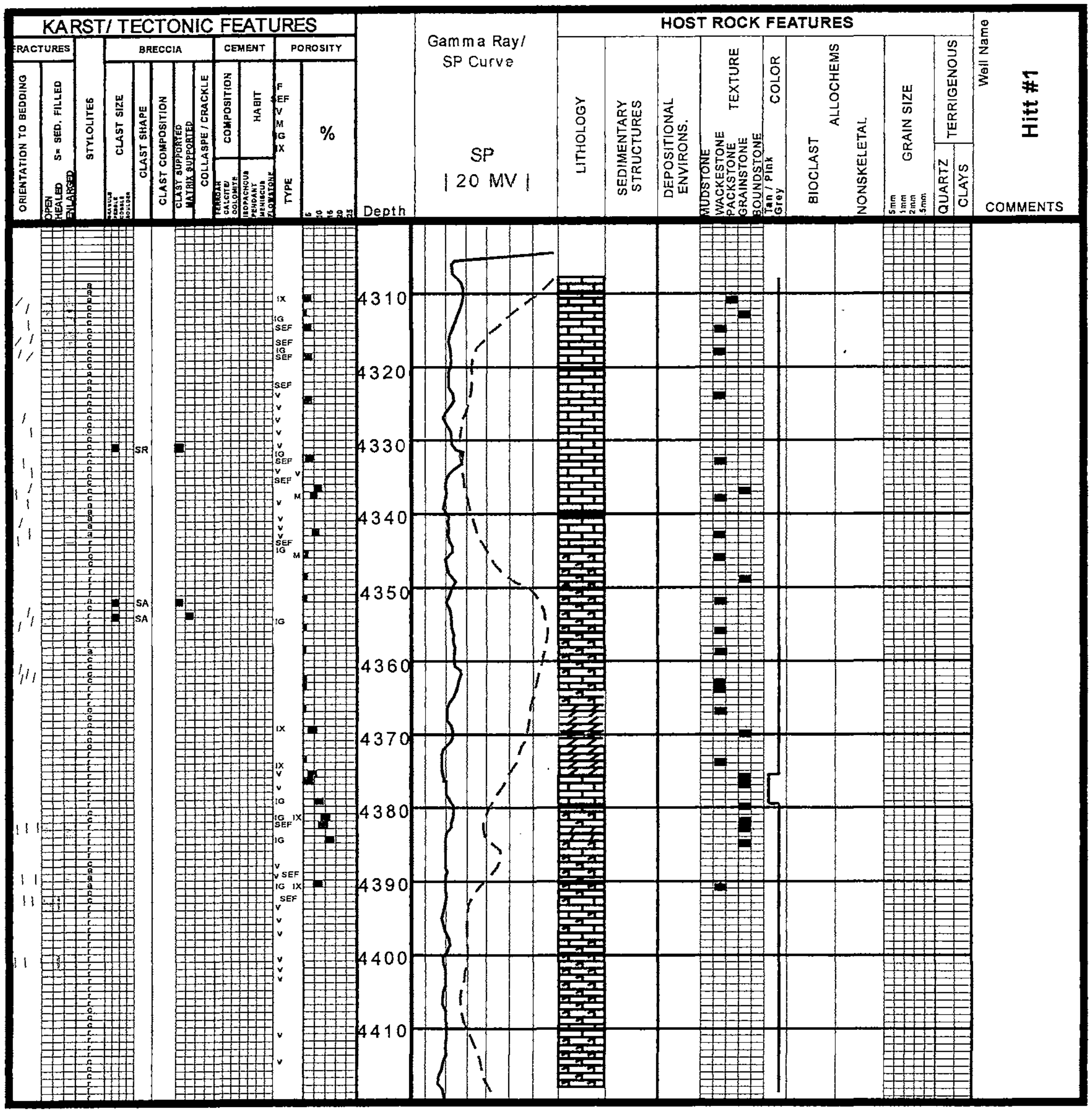
4300
Intertidal
Subtidal
Subtidal
Intertidal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HOST ROCK FEATURES
Gamma Ray/ SP Curve
SP
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Depth
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4320
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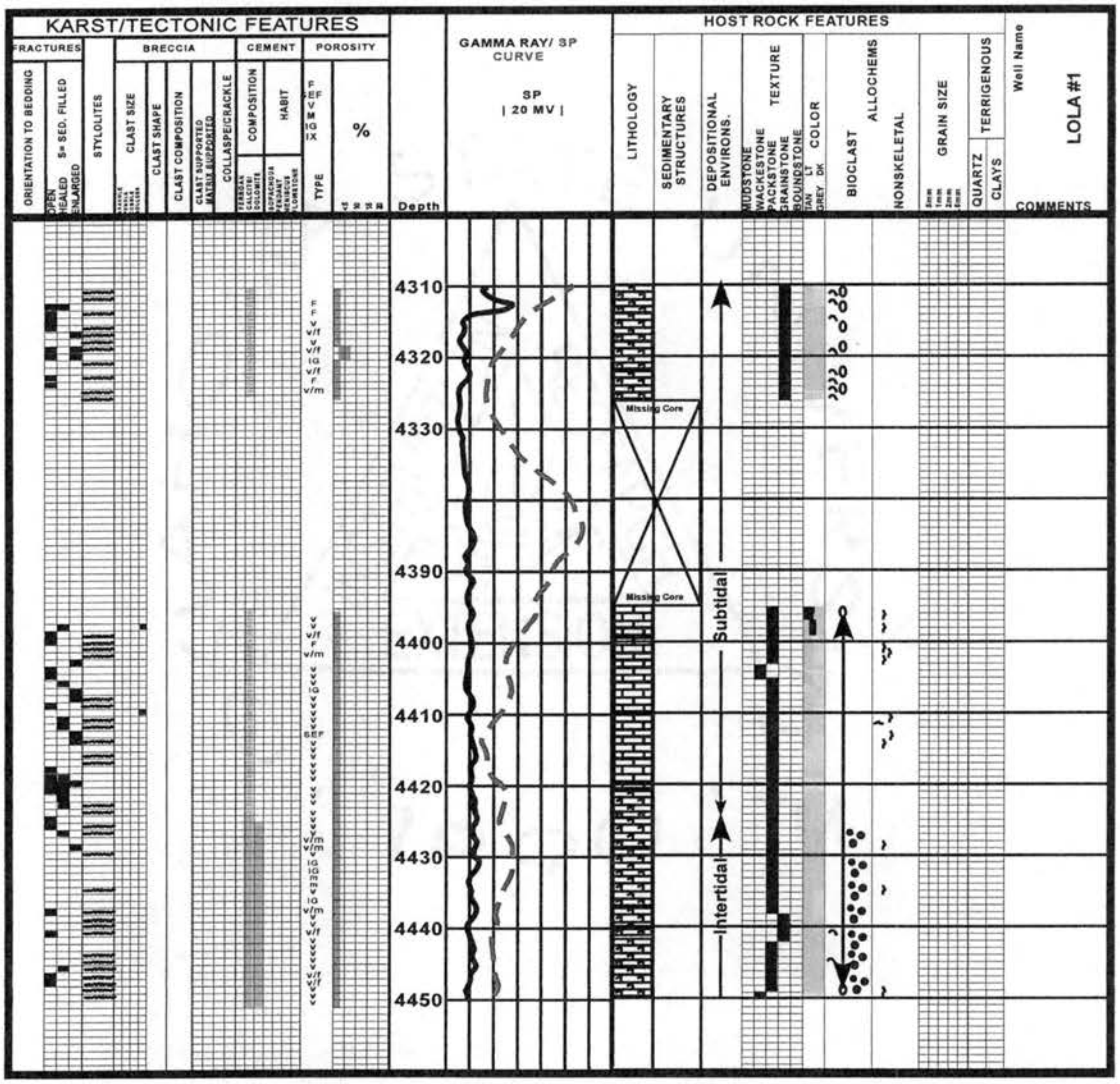
4350
4360
4370
4380
4390
4400
4410
LITHOLOGY
SEDIMENTARY STRUCTURES
DEPOSITIONAL ENVIRONS.
TEXTURE
COLOR
ALLOCHEMS
BIOCLAST
NONSKELETAL
GRAIN SIZE
TERRIGENOUS
QUARTZ
CLAYS
Well Name
Hitt #1
COMMENTS


KARST/TECTONIC FEATURES
FRACTURES
BRECCIA
CEMENT
POROSITY
ORIENTATION TO BEDDING
S= SED. FILLED
OPEN
HEALED
ENLARGED
STYLOLITES
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLASPE/CRACKLE
COMPOSITION
HABIT
TYPE
%
Depth
GAMMA RAY/ SP
CURVE
SP
| 20 MV |
HOST ROCK FEATURES
LITHOLOGY
SEDIMENTARY STRUCTURES
DEPOSITIONAL ENVIRONS.
TEXTURE
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
COLOR
TAN
GREY
LT
DK
ALLOCHEMS
BIOCLAST
NONSKELETAL
GRAIN SIZE
TERRIGENOUS
QUARTZ
CLAYS
Well Name
LOLA #1
COMMENTS
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4320
4330
4390
4400
4410
4420
4430
4440
4450
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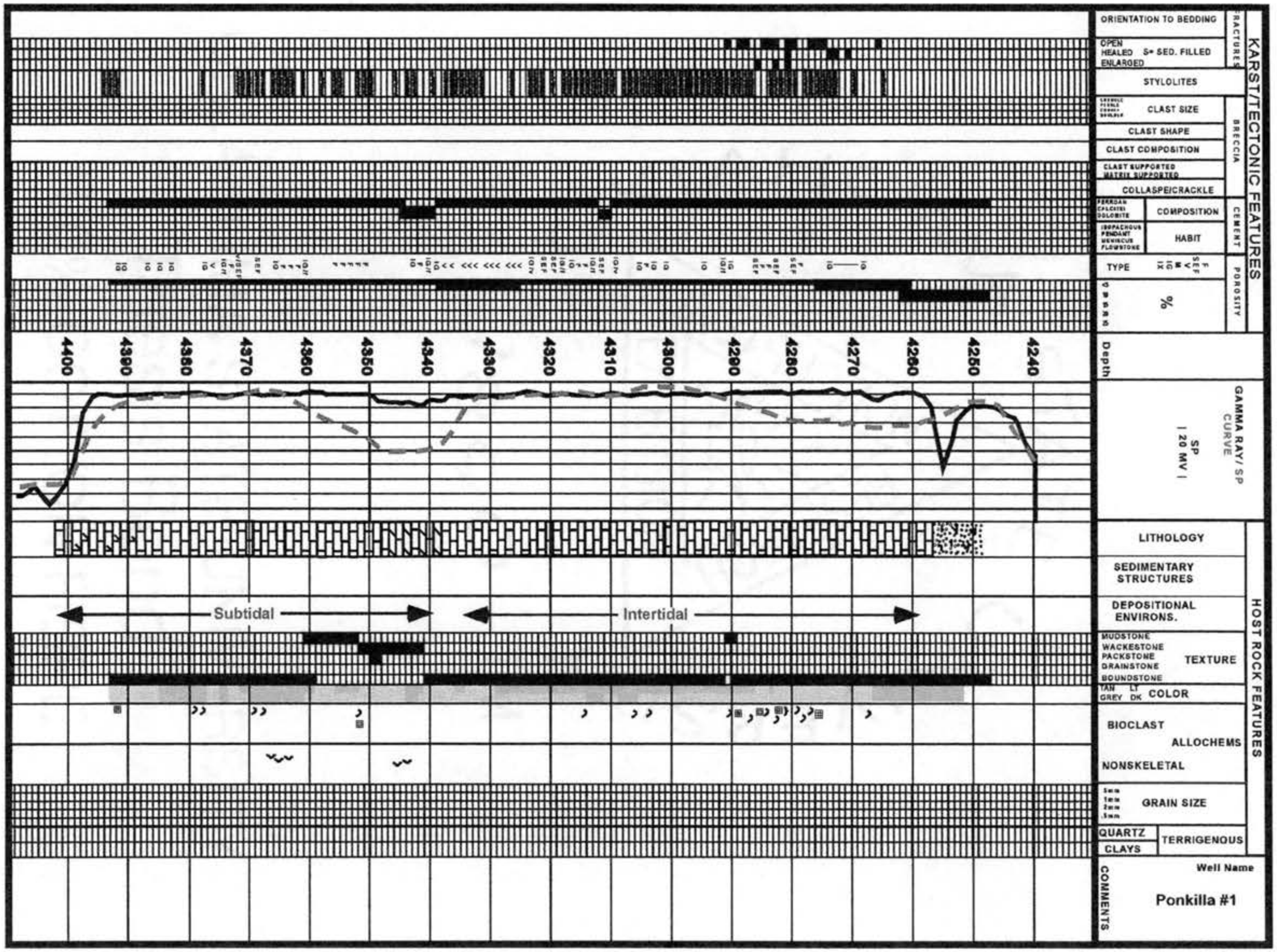
Missing Core
Subtidal
Intertidal



ORIENTATION TO BEDDING
OPEN
HEALED S= SED. FILLED
ENLARGED
FRACTURES
STYLOLITES
CLAST SIZE
CLAST SHAPE
CLAST COMPOSITION
CLAST SUPPORTED
MATRIX SUPPORTED
COLLASPE/CRACKLE
BRECCIA
COMPOSITION
HABIT
CEMENT
TYPE
%
POROSITY
KARST/TECTONIC FEATURES
Depth
4400
4390
4380
4370
4360
4350
4340
4330
4320
4310
4300
4290
4280
4270
4260
4250
4240
GAMMA RAY/ SP CURVE
SP
| 20 MV |
LITHOLOGY
SEDIMENTARY STRUCTURES
Subtidal
Intertidal
DEPOSITIONAL ENVIRONS.
MUDSTONE
WACKESTONE
PACKSTONE
GRAINSTONE
BOUNDSTONE
TEXTURE
TAN LT
GREY DK
COLOR
BIOCLAST
ALLOCHEMS
NONSKELETAL
GRAIN SIZE
QUARTZ
CLAYS
TERRIGENOUS
HOST ROCK FEATURES
COMMENTS
Well Name
Ponkilla #1

APPENDIX

Core-analysis data

Core Analysis Report
Well Name: Baxter

ID	Depth	Grain Density	Confining Stress	Porosity	Air Perm.	Klinkenberg Perm.	So	Sw
(#)	(ft)	(g/cc)	(psi)	(%)	(md)	(md)	(%)	(%)
1	4140.00	2.690	800	11.800	17.381	12.319	12.39	59.76
2	4142.00	2.708	800	12.940	123.743	120.445	19.66	54.95
3	4144.10	2.706	800	11.550	83.382	80.622	8.46	57.61
4	4146.00	2.701	800	11.170	84.556	81.650	8.53	54.62
5	4155.00	2.690	800	5.920	0.654	0.519	15.48	33.58
6	4161.00	2.701	800	3.590	0.116	0.078	18.81	16.67
7	4164.00	2.699	800	2.500	0.032	0.020	tr	24.49
8	4169.00	2.697	800	6.360	0.460	0.347	20.96	21.58
9	4177.00	2.688	800	2.610	0.311	0.250	18.20	31.25
10	4184.00	2.684	800	6.120	0.646	0.507	20.01	44.78
11	4188.00	2.685	800	7.380	0.797	0.589	21.68	39.22
12	4192.00	2.702	800	2.050	0.107	0.080	34.25	19.23
13	4251.00	2.720	800	3.640	0.037	0.024	23.91	31.25
14	4253.00	2.699	800	1.520	0.206	0.152	43.04	23.26
15	4260.00	2.766	800	1.840	0.007	0.003	tr	95.12
16	4264.00	2.705	800	1.860	0.016	0.007	3.49	71.43
17	4270.00	2.723	800	3.360	0.041	0.027	33.11	32.79
18	4274.00	2.727	800	0.010	0.010	0.004	46.53	17.86
19	4282.00	2.712	800	1.940	0.128	0.094	19.50	49.18
20	4287.00	2.735	800	5.210	0.401	0.306	48.03	15.75
21	4291.00	2.728	800	4.840	0.101	0.080	6.57	50.42
22	4297.00	2.711	800	1.780	0.033	0.021	tr	56.45
23	4306.00	2.807	800	0.010	0.003	0.001	10.27	49.02

Core Analysis Report

Well Name: **Hitt #1**

ID	Depth	Grain Density	Confining Stress	Porosity	Air Perm.	Klinkenberg Perm.
(#)	(ft)	(g/cc)	(psi)	(%)	(md)	(md)
1	4310.0	2.71	800	3.09	0.00431	0.00173
2	4312.7	2.71	800	2.08	0.00673	0.00284
3	4314.3	2.70	800	2.23	0.00516	0.00211
4	4318.0	2.71	800	6.96	1.83245	1.29723
5	4318.8	2.71	800	6.97	0.35860	0.27144
6	4324.2	2.70	800	1.07	0.00343	0.00134
7	4332.0	2.70	800	4.94	0.20167	0.16072
8	4336.0	2.70	800	4.65	0.20356	0.14178
9	4337.0	2.71	800	8.44	13.65364	8.28444
10	4338.7	2.70	800	3.73	0.04876	0.02862
11	4342.0	2.71	800	3.63	0.10253	0.00805
12	4345.0	2.73	800	4.82	0.03905	0.02439
13	4346.8	2.76	800	6.44	0.06869	0.04148
14	4348.0	2.69	800	3.52	0.02808	0.01708
15	4351.0	2.73	800	1.08	0.00191	0.00068
16	4355.0	2.75	800	1.05	0.00187	0.00066
17	4358.2	2.73	800	0.97	0.00189	0.00067
18	4362.0	2.73	800	1.19	0.00215	0.00077
19	4363.8	2.75	800	1.74	0.00413	0.00162
20	4366.0	2.79	800	6.28	0.02930	0.01960
21	4369.0	2.72	800	1.66	0.00666	0.00279
22	4373.0	2.77	800	4.06	0.00672	0.00283
23	4375.2	2.68	800	2.94	0.58730	0.04311
24	4376.0	2.69	800	3.72	0.02838	0.22722
25	4379.3	2.71	800	2.85	0.08138	0.05878
26	4381.2	2.79	800	5.43	0.02715	0.01737

Analysis Report
Well Name: **Lola**

ID	Depth	Grain Density	Confining Stress	Porosity	Air Perm.	Klinkenberg Perm.	So	Sw
(#)	(ft)	(g/cc)	(psi)	(%)	(md)	(md)	(%)	(%)
1	4314.00	2.70	800	3.87	0.0367	0.0234	12.27%	48.04%
2	4316.00	2.70	800	2.61	0.0219	0.0143	17.72%	20.64%
3	4318.00	2.67	800	3.62	0.0481	0.0305	5.88%	51.68%
4	4323.00	2.71	800	6.10	0.0633	0.0391	7.77%	34.53%
5	4326.00	2.70	800	3.18	0.0151	0.0069	9.09%	33.39%
6	4401.00	2.78	800	3.80	399.3466	331.0795	13.01%	54.60%
7	4405.00	2.82	800	14.53	9.1545	8.0783	4.74%	60.61%
8	4407.00	2.75	800	7.65	0.1614	0.1152	1.92%	48.33%
9	4412.00	2.71	800	3.23	0.0661	0.0540	0.17%	56.78%
10	4416.00	2.73	800	2.08	0.0120	0.0053	5.03%	75.79%
11	4422.00	2.72	800	2.64	0.0087	0.0037	11.01%	49.62%
12	4428.00	2.75	800	4.52	0.0476	0.0295	5.62%	46.65%
13	4431.00	2.77	800	6.88	0.2514	0.1826	0.48%	60.82%
14	4433.00	2.76	800	6.89	0.5664	0.4609	18.12%	19.31%
15	4437.00	2.79	800	7.66	0.5620	0.4618	2.30%	41.25%
16	4440.00	2.75	800	6.69	0.3645	0.2786	2.80%	53.50%
17	4445.00	2.82	800	9.12	0.7723	0.5863	2.72%	51.90%
18	4448.00	2.79	800	6.15	0.1122	0.0804	1.15%	50.81%
19	4450.00	2.78	800	5.13	0.0491	0.0326	6.27%	50.72%

Core Analysis Report

Well Name: **Ponkilla**

ID	Depth	Grain Density	Confining Stress	Porosity	Air Perm.	Klinkenberg Perm.	So	Sw
(#)	(ft)	(g/cc)	(psi)	(%)	(md)	(md)	(%)	(%)
1	4249	2.67	800	2.82	0.215	0.181	12%	51%
2	4250	2.65	800	9.99	111.858	109.550	2%	73%
4	4252	2.61	800	1.45	0.135	0.121	9%	75%
5	4253	2.66	800	8.18	8.999	8.188	55%	39%
6	4254	2.68	800	12.33	106.112	103.283	14%	48%
7	4255	2.70	800	11.57	60.415	58.185	10%	62%
8	4256	2.70	800	12.45	80.753	78.426	3%	75%
9	4257	2.70	800	11.07	49.776	47.749	3%	65%
10	4258	2.69	800	12.39	97.852	95.856	1%	71%
11	4259	2.71	800	12.46	69.955	67.347	9%	62%
12	4260	2.73	800	13.27	67.026	64.897	0%	70%
13	4261	2.69	800	10.41	46.275	43.988	8%	59%
14	4262	2.72	800	12.54	88.085	86.057	2%	72%
15	4263	2.66	800	6.32	0.368	0.299	44%	57%
16	4264	2.66	800	4.78	0.078	0.052	0%	66%
17	4265	2.69	800	5.04	0.160	0.115	21%	81%
18	4266	2.69	800	0.93	0.006	0.002	3%	74%
19	4267	2.68	800	2	0.011	0.005	36%	72%
20	4268	2.69	800	0.86	0.005	0.002	38%	60%
21	4269	2.69	800	2.82	0.019	0.013	1%	37%
22	4270	2.70	800	0.67	0.003	0.001	6%	69%
23	4271	2.70	800	0.78	0.007	0.003	6%	72%
24	4272	2.71	800	1	0.005	0.002	11%	77%
25	4273	2.70	800	0.83	0.009	0.004	26%	62%
26	4274	2.69	800	1.78	50.994	48.329	8%	87%

ID	Depth	Grain Density	Confining Stress	Porosity	Air Perm.	Klinkenberg Perm.	So	Sw
(#)	(ft)	(g/cc)	(psi)	(%)	(md)	(md)	(%)	(%)
27	4275	2.70	800	broken during measurement				
29	4277	2.74	800	0.76	0.002	0.001	1%	94%
30	4278	2.70	800	1.06	0.008	0.003	3%	82%
31	4279	2.70	800	broken during measurement				
32	4280	2.70	800	3.21	0.034	0.022	0%	96%
33	4281	2.70	800	4.31	0.043	0.027	1%	41%
34	4282	2.70	800	2.22	0.010	0.004	2%	69%
35	4282.5	2.70	800	2.7	0.013	0.006	14%	40%
36	4283	2.71	800	1.4	0.005	0.002	2%	73%
37	4284	2.70	800	2.17	0.014	0.006	27%	75%
38	4285	2.71	800	3	0.061	0.040	0%	51%
39	4286	2.70	800	1.43	0.008	0.003	9%	71%
40	4287	2.70	800	2.02	1.271	1.203	2%	96%
41	4288	2.70	800	0.91	0.012	0.006	4%	78%
42	4289	2.70	800	1.12	0.002	0.001		
43	4291	2.71	800	1.71	0.003	0.001		
44	4293	2.70	800	1.17	0.007	0.003	0%	99%
45	4295	2.71	800	3.51	3.302	2.730	0%	65%
46	4297	2.71	800	4.02	0.010	0.004		
47	4299	2.71	800	3.6	0.045	0.030	0%	55%
48	4301	2.70	800	1.96	0.013	0.010	16%	55%
49	4303	2.70	800	0.94	0.006	0.003	4%	80%
50	4305	2.71	800	2.47	0.009	0.004		
51	4307	2.71	800	3.5	0.024	0.016	2%	62%
52	4309	2.70	800	0	0.004	0.002		
53	4311	2.71	800	2.59	0.014	0.010	0%	70%
54	4313	2.71	800	2.76	0.219	0.182	0%	98%
55	4315	2.72	800	4.97	0.113	0.083		
56	4317	2.71	800	2.77	0.010	0.007	5%	78%
57	4319	2.75	800	7.03	0.357	0.259		
58	4321	2.71	800	6.49	66.779	41.373	21%	50%

ID (#)	Depth (ft)	Grain Density (g/cc)	Confining Stress (psi)	Porosity (%)	Air Perm. (md)	Klinkenberg Perm. (md)	So (%)	Sw (%)
59	4323	2.73	800	8.23	2.724	2.275		
60	4325	2.72	800	5.14	0.273	0.197		
61	4327	2.71	800	2.85	0.172	0.142	0%	95%
62	4329	2.72	800	5.58	0.143	0.108		
63	4331	2.72	800	4.02	0.060	0.040		
64	4333	2.71	800	3.89	0.018	0.012		
65	4335	2.71	800	2.85	0.119	0.095	5%	95%
66	4337	2.73	800	7.62	0.062	0.043	48%	35%
67	4339	2.73	800	6.29	0.068	0.042	22%	73%
68	4341	2.74	800	5.6	0.151	0.112	28%	77%
69	4343	2.76	800	3.22	0.009	0.004	5%	83%
70	4344	2.78	800	7.26	0.094	0.063	0%	67%
71	4345	2.79	800	6.31	0.036	0.022	5%	38%
72	4347	2.76	800	2.37	0.005	0.002		
73	4349	2.76	800	1.43	0.002	0.001	2%	75%
74	4351	2.83	800	2.87	0.003	0.001		
75	4353	2.77	800	2.19	0.003	0.001		
76	4355	2.79	800	3.83	0.050	0.028		
77	4357	2.79	800	3.31	0.004	0.001		
78	4359	2.79	800	3.42	0.003	0.001		
79	4361	2.73	800	2.37	0.004	0.001	0%	79%
80	4363	2.77	800	4.67	0.011	0.007	0%	57%
81	4365	2.76	800	5.9	0.066	0.046		
83	4369	2.71	800	1.06	0.019	0.009		
84	4371	2.74	800	5.56	0.129	0.095		
85	4373	2.72	800	4.68	0.248	0.181	0%	57%
86	4375	2.74	800	7.64	0.672	0.520		
87	4377	2.74	800	7.6	0.701	0.534	0%	48%
88	4379	2.73	800	8.73	0.832	0.610	0%	74%
89	4381	2.73	800	8	0.871	0.667		

APPENDIX

Petrographic data

Thin-Section Data Table for the Baxter #2

	Constituents (%)														
Depth (ft.)	Brachiopods	Bryozoans	Gastropods	Echinoderms	Trilobites	Calcite Spar	Micrite	Dolomite	Quartz	Hydrocarbon	Phosphate	Pyrite	Glauconite	Primary Φ	Secondary Φ
4140	-	-	-	-	-	-	-	13	68	4	2	tr	-	13	-
4142	-	-	-	-	-	-	-	25	58	3	2	-	-	12	-
4144.1	-	-	-	-	-	-	-	22	60	2	3	-	-	13	-
4146	-	-	-	-	-	-	-	10	68	6	3	-	1	12	-
4155	-	39	-	23	tr	31	-	-	-	tr	-	-	-	-	6.1
4161	-	47	-	13	-	31	-	-	-	3	-	-	-	-	7.6
4164	-	38	-	7	2	46	-	-	-	2	-	-	-	-	5
4169	2	43	-	16	2	21	6	tr	-	4	-	-	-	-	6
4177	-	33	-	18	1	43	-	1	-	2	-	-	-	-	2
4188	-	48	-	8	2	35	-		-	3	-	-	-	-	4
4264	-	8	-	18	3	39	11	14	-	5	-	-	-	-	2
4274	-	16	-	11	3	50	18	-	-	1	-	-	-	-	1

Thin-Section Data Table for the Lola #1

	Constituents (%)											
Depth (ft.)	Brachiopods	Bryozoans	Gastropods	Echinoderms	Trilobites	Calcite Spar	Micro Spar	Dolomite Spar	Pyrite	Hydrocarbon	Micrite	Secondary Φ
4314	18	13	-	7	3	58	-	-	-	-	-	1
4316	-	9	-	16	1	64	5	-	-	-	-	5
4318	1	8	-	48	-	39	-	-	-	-	-	4
4323	6	35	-	11	1	34	-	-	-	-	-	13
4326	26	30	-	9	2	30	-	-	-	-	-	3
4401	1	-	-	22	-	13	-	56	-	-	-	7
4405	-	-	-	-	-	20	-	61	-	-	-	19
4407	2	-	-	22	-	29	-	38	-	2	-	7
4412	4	1	-	28	1	29	30	5	-	-	-	2
4416	2	4	-	8	-	32	-	-	-	-	-	4
4422	2	-	-	18	-	31	40	6	-	-	-	3
4428	3	5	-	4	-	34	-	22	-	-	25	7
4431	2	-	-	5	-	26	7	45	-	tr	-	15
4433	-	7	-	18	-	28	3	32	-	-	-	12
4437	1	2	1	13	-	23	-	43	3	-	-	14
4440	-	-	-	7	-	38	2	41	-	-	-	12
4445	-	-	-	9	-	37	-	40	-	-	-	14
4448	3	-	-	9	-	30	-	47	-	-	-	11
4450	1	-	-	2	-	33	-	54	-	-	-	9

VITA

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