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IMPROVED OIL RECOVERY FROM UPPER JURASSIC SMACKOVER CARBONATES THROUGH THE APPLICATION OF ADVANCED TECHNOLOGIES AT WOMACK HILL OIL FIELD, CHOCTAW AND CLARKE COUNTIES, EASTERN GULF COASTAL PLAN

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ABSTRACT

Pruet Production Co. and the Center for Sedimentary Basin Studies at the University of Alabama, in cooperation with Texas A&M University, Mississippi State University, University of Mississippi, and Wayne Stafford and Associates are undertaking a focused, comprehensive, integrated and multidisciplinary study of Upper Jurassic Smackover carbonates (Class II Reservoir), involving reservoir characterization and 3-D modeling and an integrated field demonstration project at Womack Hill Oil Field Unit, Choctaw and Clarke Counties, Alabama, Eastern Gulf Coastal Plain.

The principal objectives of the project are: increasing the productivity and profitability of the Womack Hill Field Unit, thereby extending the economic life of this Class II Reservoir and transferring effectively and in a timely manner the knowledge gained and technology developed from this project to producers who are operating other domestic fields with Class II Reservoirs.

The principal research effort for Year 1 of the project has been reservoir characterization, which has included three (3) primary tasks: geoscientific reservoir characterization, petrophysical and engineering property characterization, and microbial characterization. In the first year, the research focus has primarily been geoscientific reservoir characterization. This work was scheduled for completion in Year 1. Petrophysical and engineering property and microbial characterization were initiated in the last six months of Year 1.

Overall, the project work is on schedule. Geoscientific Reservoir Characterization is essentially on schedule with completion of subtasks 1 and 2, with significant progress with subtasks 3 and 4, and with initiation of subtasks 5 and 6. Petrophysical and Engineering Characterization is on schedule with progress in all of the four subtasks. Microbial Characterization is on schedule although no microbial growth has been observed to date from field core, oil or produced water samples.

INTRODUCTION

Pruet Production Co. and the Center for Sedimentary Basin Studies at the University of Alabama, in cooperation with Texas A&M University, Mississippi State University, University of Mississippi, and Wayne Stafford and Associates are undertaking a focused, comprehensive, integrated and multidisciplinary study of Upper Jurassic Smackover carbonates (Class II Reservoir), involving reservoir characterization and 3-D modeling and an integrated field demonstration project at Womack Hill Oil Field Unit, Choctaw and Clarke Counties, Alabama, Eastern Gulf Coastal Plain (Figure 1).

Estimated reserves for Womack Hill Field are 119 million barrels of oil. During the production history of the field, which began in 1970, 30 million barrels of oil have been produced. Conservatively (additional 10-20 percent), another 12 to 24 million barrels of oil remains to be recovered through the application of advanced technologies in optimizing field management and production. Womack Hill Field is one of 57 Smackover fields in the regional peripheral fault trend play of the eastern Gulf Coastal Plain. To date, 674 million barrels of oil have been produced from these fields. The fields in this play have a common petroleum trapping mechanism (faulted salt anticlines), petroleum reservoir (ooid grainstone and dolograinstone shoal deposits), petroleum seal (anhydrite), petroleum source (microbial carbonate mudstones), overburden section, and timing of trap formation and oil migration. Therefore, the proposed work at Womack Hill Field is directly applicable to these 57 fields and can be transferred to Smackover fields located along this fault trend from Florida to Texas.

Phase I (3.0 years) of the proposed research involves characterization of the ooid shoal reservoir at Womack Hill Field to determine reservoir architecture, heterogeneity and producibility in order to increase field productivity and profitability. This work includes core and well log analysis; sequence stratigraphic, depositional history and structure study; petrographic and diagenetic study; and pore system analysis. This information will be integrated with 2-D seismic data and probably 3-D seismic data to produce an integrated 3-D stratigraphic and structural model of the reservoir at Womack Hill Field. The results of the reservoir characterization and modeling

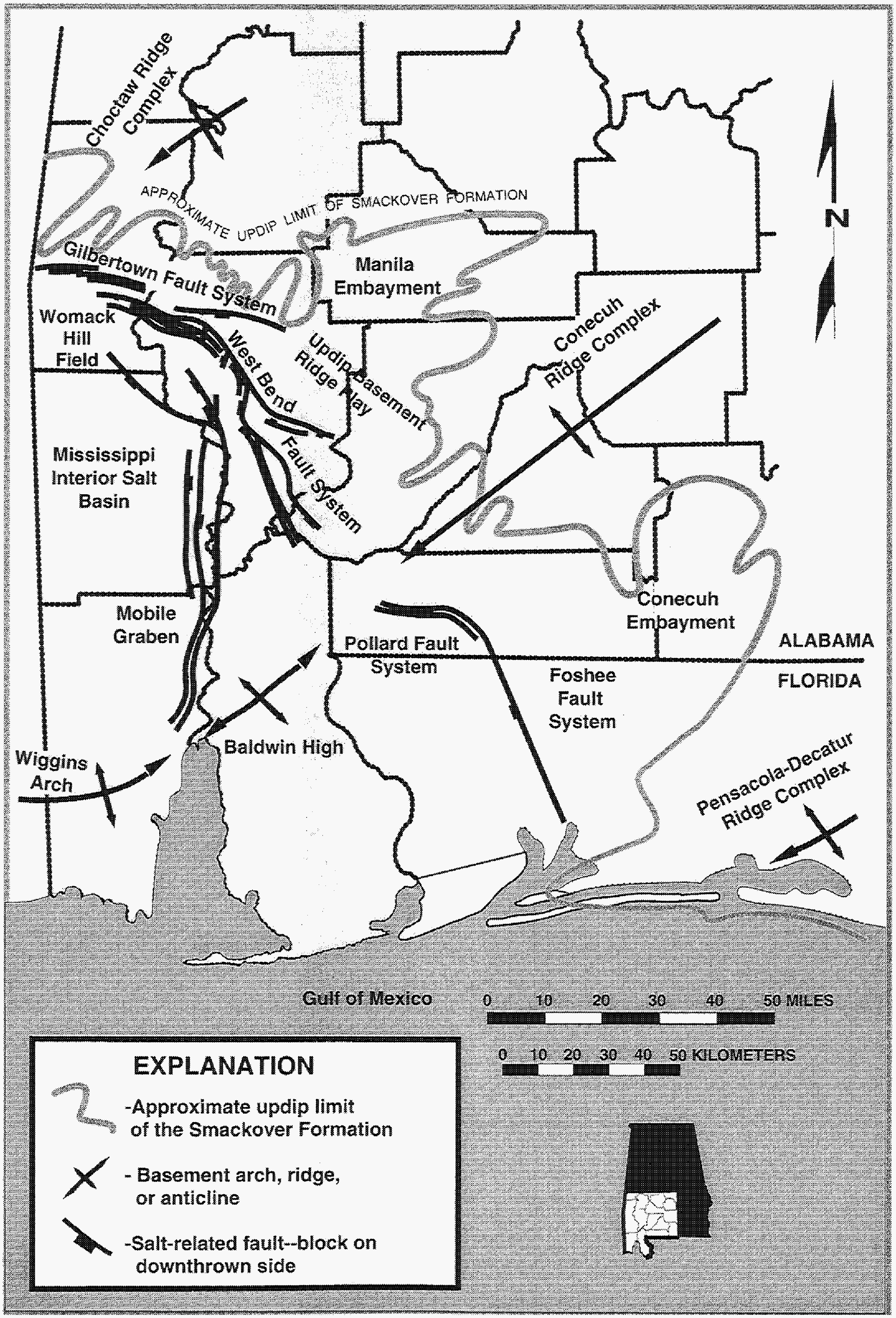

Figure 1. Womack Hill Field location map.

will be integrated with petrophysical and engineering data and pressure communication analysis to perform a 3-D reservoir simulation of the field reservoir. The results from the reservoir characterization and modeling will also be used in determining whether undrained oil remains at the crest of the Womack Hill structure (attic oil), in assessing whether it would be economical to conduct strategic infill drilling in the field, and in determining whether the acquisition of 3-D seismic data for the field area would improve recovery from the field and is justified by the financial investment. Parallel to this work, engineers will be characterizing the petrophysical and engineering properties of the reservoir, analyzing the drive mechanism and pressure communication (through well performance data), and developing a 3-D reservoir simulation model. Further, the engineering team members will determine what, if any, modifications should be made to the current pressure maintenance program, as well as assess what, if any, other potential advanced oil recovery technologies are applicable to this reservoir to extend the life of the field by increasing and maintaining productivity and profitability. Also, in this phase, researchers will be studying the ability of *in-situ* microorganisms to produce a single by-product (acid) in the laboratory to determine the feasibility of initiating an immobilized enzyme technology project at Womack Hill Field Unit.

Phase II (2.5 years) of the proposed research will proceed along three lines if the results from Phase I justify the continuance of this work. Line 1 involves the integration of the 3-D seismic imaging of the structure and reservoir into the 3-D geologic model to assess the merits of conducting a strategic infill drilling program in the field, including drilling in the interwell area and a crestal well, and if new well(s) are drilled assess by using fracture identification log technology whether a lateral-multilateral completion for these wells would be successful. Line 2 involves integrating the data obtained from the 3-D seismic imaging, petrophysical and engineering data acquired from drilling new wells using lateral-multilateral well completions, and the results of the analysis of the well performance data (field/well pressure and rate histories). These integrated data will be used to refine the 3-D reservoir simulation model, implement modifications to the pressure maintenance program, and initiate any additional activities, such as further infill drilling and/or advanced oil technology applications to improve recovery. Line 3 involves confirming the ability of *in-situ* microorganisms to produce a single by-product (acid) and injecting nutrients into the field reservoir to sustain the cells rather than to support cell proliferation for initiation of the immobilized enzyme technology project .

Phase III (0.5 year) of the proposed project involves monitoring the enhanced pressure maintenance program and advanced technology application project, and evaluating the viability of entering existing field wells for lateral-multilateral well completions to improve field productivity and profitability. Also, the immobilized enzyme technology project will be monitored to evaluate the impact of this technique on overall oil recovery from the field.

The objectives of this project are as follows:

1. Increase the productivity and profitability of the Womack Hill Field Unit, thereby extending the economic life of this Class II Reservoir and enhancing National economic and energy security.
2. Demonstrate the feasibility of transferring the knowledge gained and technology developed from previous studies of Class II Reservoirs to the analysis of the Womack Hill shallow shelf (ramp) carbonate reservoir.
3. Demonstrate to producers in the Eastern Gulf Region the significance and procedures for developing an integrated reservoir approach based on geological, geophysical, petrophysical, and well performance data, highlighting reservoir characterization activities and utilizing 3-D reservoir simulation as mechanisms for making decisions regarding field operations, such as selecting well locations for strategic infill drilling, identifying wells for recompletion (and/or simulation), as well as for constructing and implementing programs of reservoir surveillance.
4. Demonstrate to producers in the Eastern Gulf Region the value of 3-D reservoir simulation in the design, implementation, and maximizing of a pressure maintenance program, including optimization of injection wells, well locations, and injection-

production balancing, and the value of chemistry and chemical agents that can be used to improve injection conformance and increase oil recovery.

5. Demonstrate the usefulness of 3-D seismic imaging in defining the productive limits of the reservoir.
6. Demonstrate the value and utility of strategically targeted infill drilling to improve the productivity and profitability of heterogeneous carbonate reservoirs, including drilling wells that are optimal in the sense of location, well completion components, and well stimulation.
7. Demonstrate the usefulness of lateral-multilateral well completions in naturally fractured carbonate reservoirs to increase reservoir producibility.
8. Demonstrate the utility of an immobilized enzyme technology project to increase oil recovery effectiveness and efficiency.
9. Transfer the knowledge gained, technology developed and successes and failures of this project to producers who are operating other fields with Class II Reservoirs through technology workshops, presentations at professional meetings, and publications in scientific and trade journals.
10. Contribute to the knowledge base on carbonate sequence stratigraphy, depositional systems, lithofacies analysis, diagenesis, and pore systems and to the understanding of carbonate reservoir architecture, heterogeneity and producibility, carbonate petroleum systems, fluid-rock interactions, petrophysical properties of carbonates, reservoir drive mechanisms and pressure communication in carbonates, immobilized enzyme recovery process, 3-D seismic imaging in carbonates, lateral-multilateral well completions in fractured carbonate reservoirs, and the dynamics of effective and balanced pressure maintenance in heterogeneous grainstone and dolograinstone reservoirs.

The principal problem at Womack Hill Field is productivity and profitability. With time, there has been a decrease in oil production from the field, while operating costs in the field continue to increase. In order to maintain pressure in the reservoir, increasing amounts of water must be injected annually. These problems are related to cost-effective, field-scale reservoir management, to reservoir connectivity due to carbonate rock architecture and heterogeneity, to pressure communication due to carbonate petrophysical and engineering properties, and to cost-effective operations associated with the oil recovery process.

Improved reservoir producibility will lead to an increase in productivity and profitability. To increase reservoir producibility, a field-scale reservoir management strategy based on a better understanding of reservoir architecture and heterogeneity, of reservoir drive and communication and of the geological, geophysical, petrophysical and engineering properties of the reservoir is required. Also, an increased understanding of these reservoir properties should provide insight into operational problems, such as why the reservoir is requiring increasing amounts of freshwater to maintain the desired reservoir pressure, why the reservoir drive and oil-water contact vary across the field, how the multiple pay zones in the field are vertically and laterally connected and the nature of the communication within a pay zone.

Several potential opportunities have been identified which could lead to increased reservoir productivity. First, the drilling of the Dungan Estate Unit 14-5 well in Sec. 14, T.10N., R.2W. suggests that undrained oil (attic) may be present on the crest of the Womack Hill Field structure (Figures 2 and 3). The 14-5 well encountered oil in the Norphlet and Smackover at a horizon that previously was not productive in the field. These productive zones were structurally higher in this well then encountered in any of the field wells prior to the drilling of the 14-5 well.

Second, field scale heterogeneity affects the producibility of the reservoir. A major barrier to flow separates the field reservoir into a western portion and an eastern portion and results in structural compartmentalization in Womack Hill Field. This flow barrier dramatically impacts production strategy in the field. Only the western portion of the field has been unitized and only this part of the reservoir is experiencing pressure maintenance. The reservoir drive mechanism in the eastern portion of the field is a strong bottom-up water drive, while the drive mechanism in the western portion of the field is primarily solution gas. This flow barrier has been interpreted to be a major fault (megascopic heterogeneity) or change in permeability. If the barrier to flow is a result

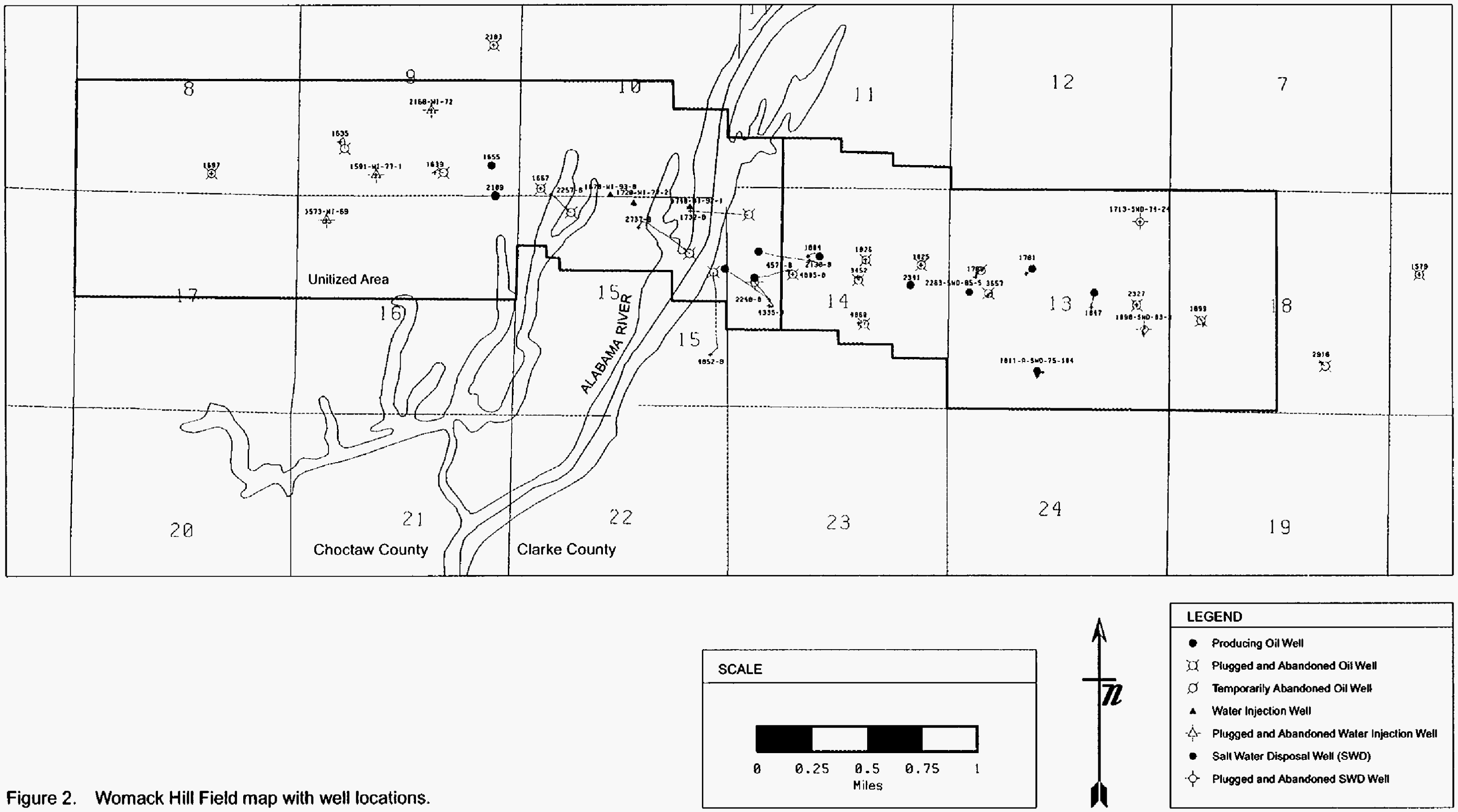

Figure 2. Womack Hill Field map with well locations.

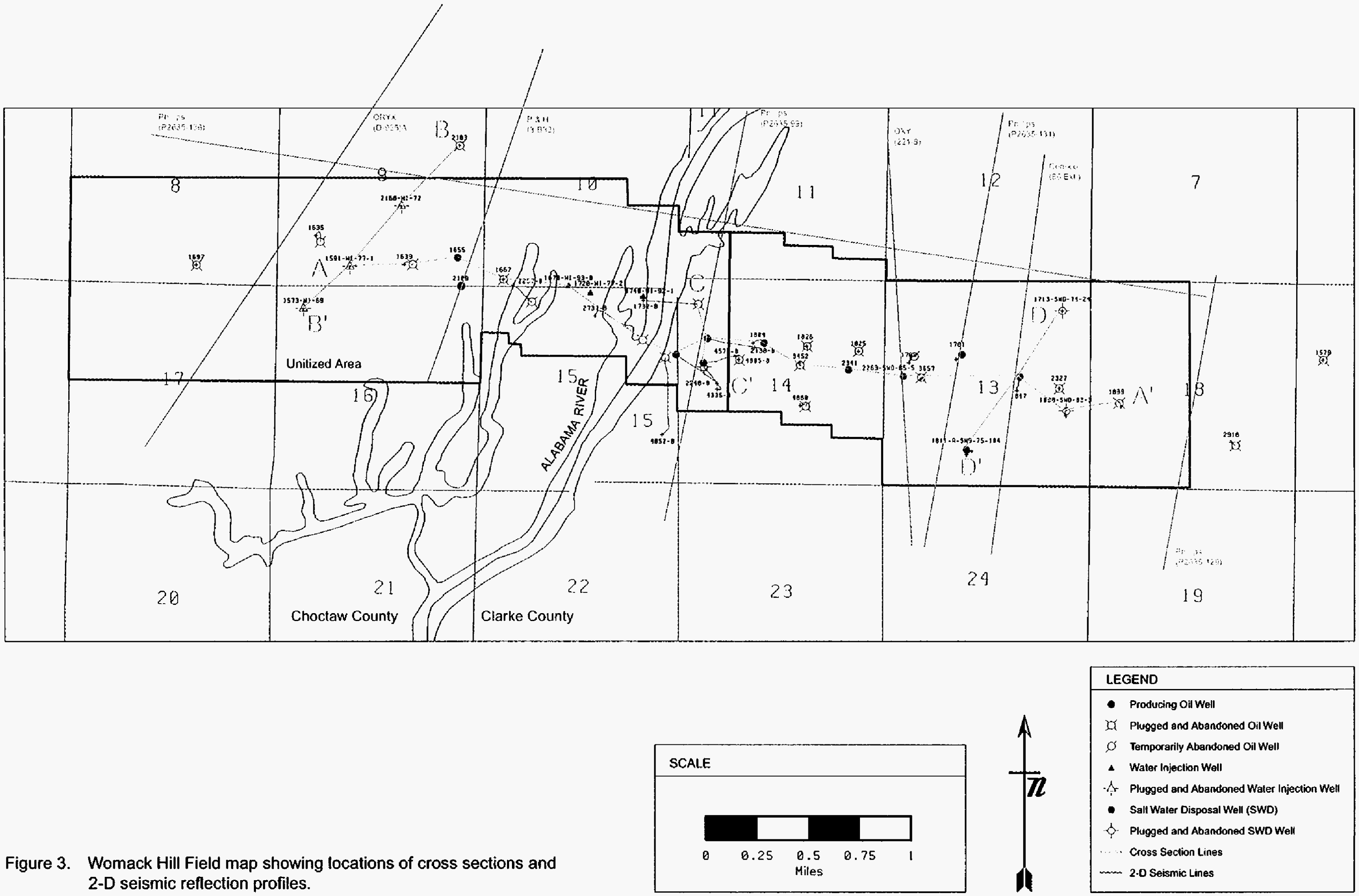

Figure 3. Womack Hill Field map showing locations of cross sections and 2-D seismic reflection profiles.

of lower permeability, the reduction in permeability could be due to a change in mesoscopic heterogeneity (depositional facies change), a change in microscopic heterogeneity (diagenetic change), or a combination of the two processes. Also, there are multiple shoal lithofacies in the field. The nature of the communication among and within these multiple pay zones is unclear at this time. Carbonate depositional systems involve the complex interaction of biological, chemical and physical processes. Further, the susceptibility of carbonates to alteration by early to late diagenetic processes dramatically impacts reservoir heterogeneity. Diagenesis is the fundamental influence in determining which carbonate deposits will become seals, which will become reservoirs, and what the nature of the reservoir quality and producibility will be. Reservoir characterization and the study of heterogeneity, therefore, becomes a major task because of the physiochemical and biological origins of carbonates and because of the masking of the depositional rock fabric and reservoir architecture principally due to dolomitization. Thus, greater lithofacies and/or diagenetic variability (greater reservoir heterogeneity) translates into more difficulty in predicting between wells (interwell areas) at any spacing but particularly at Womack Hill Field were the well spacing is as great as 120 acres.

Third, prior investigations have suggested that Smackover carbonate reservoirs should be naturally fractured at depths of 11,000 ft. Therefore, well completions, such as lateral-multilateral completions, that utilize the fractured nature of these carbonates should lead to increased producibility of the field.

Fourth, understanding and accurately predicting the flow units and barriers to flow in this heterogeneous reservoir is vital to improving producibility. An enhanced pressure maintenance program, advanced oil recovery application, and/or immobilized enzyme technology project that accounts for inherent properties of this heterogeneous reservoir, multiple pay zones, and the nature of the variable drive mechanisms and oil-water contacts in the field should result in increased producibility of Womack Hill Field. The improved connectivity in this compartmentalized reservoir should result in the production of more incremental oil.

The project will build on the experiences and lessons learned from the previous Class II Reservoir studies. First, techniques, methods and technologies utilized in previous studies will be applied and modified accordingly for application to the Womack Hill reservoir. These technologies and techniques include reservoir characterization and modeling, reservoir simulation, 3-D seismic imaging, infill drilling, horizontal/lateral drilling, and waterflood design for Class II reservoirs. The particular advanced technologies applied will include developing an integrated geoscientific and engineering digital database for Womack Hill Field, characterizing the Smackover reservoir and modeling (in 3-dimensions) these heterogeneous carbonates for cost-effective management of the reservoir on a fieldwide scale and for making decisions regarding field operations. These data and this modeling will be integrated with petrophysical properties of the reservoir, field pressure and production data, and other engineering information and used in 3-D reservoir simulation to evaluate the effectiveness of the existing pressure maintenance program and to assess the viability of initiating other advanced oil recovery applications in the field. These data and 3-D geologic modeling will also be utilized in developing an infill drilling strategy for this heterogeneous reservoir.

Second, we plan to acquire state-of-the-art 3-D seismic data for imaging the field structure and reservoir. The new seismic interpretation will be integrated with the 3-D geologic modeling of the field structure and reservoir to design an infill drilling strategy at Womack Hill Field. In selecting new drill sites, we will utilize data mining and associated neural networks to predict the expected lithofacies and to predict the expected quality of the reservoir at these drill sites. We also plan to evaluate the fracture systems present in the Smackover carbonates and determine whether lateral-multilateral well completions would increase producibility in this heterogeneous and fractured reservoir. We will evaluate the applicability of implementing an immobilized enzyme technology project at Womack Hill Field.

The project results will be vigorously transferred to producers through five technology workshops in project Years 4, 5 and 6. The first workshop (Year 4) will focus on the results of Phase I of the project and will include carbonate reservoir characterization, data integration, carbonate reservoir modeling, and 3-D reservoir simulation. The second workshop (Year 5) will focus on aspects of the integrated field demonstration project and will include the results of the 3-D seismic imaging and the new wells drilled in the field. Workshops 3, 4 and 5 (Year 6) will focus on the results of using lateral-multilateral well completions in the field, results of the enhanced pressure maintenance program and advanced oil recovery application project, and the results of the immobilized enzyme technology project. These workshops will be conducted in cooperation with the Eastern Gulf Region (EGR) of the Petroleum Technology Transfer Council (PTTC).

EXECUTIVE SUMMARY

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The principal research effort for Year 1 of the project has been reservoir characterization, which has included three (3) primary tasks: geoscientific reservoir characterization, petrophysical and engineering property characterization, and microbial characterization. In the first year, the research focus has primarily been geoscientific reservoir characterization. This work was scheduled for completion in Year 1. Petrophysical and engineering property and microbial characterization were initiated in the last six months of Year 1.

Geoscientific Reservoir Characterization is essentially on schedule. Subtask 1 has been completed. Graphic logs have been constructed for available whole cores from the field. Core samples (118) have been selected, and thin sections have been made from these samples. Study of the thin sections is in progress. The graphic logs have been compared to the respective core analysis for these wells, and the core analyses have been calibrated to the well log patterns. Electrofacies have been identified and are being used for correlation within the field. These data have been entered into the digital database for the field. Subtask 2 has been completed. Electrical and geophysical logs (42) and core analysis data (28) have been digitized and entered into the field database. Formation tops and key event horizons (3 high-frequency cycles, including porous and non-porous intervals) have been identified using the graphic core logs and electrofacies. The porous intervals in these cycles have the potential to serve as vertical and lateral flow units, while the non-porous intervals separating the porous intervals have the potential to act as vertical and lateral barriers to flow. Thus, potentially there are three reservoirs within the field. Cross sections have been drawn to illustrate these sequence stratigraphic relationships. Isopach maps of each of these cycles, and field structure maps have been prepared. Burial and thermal maturation history plots for wells in the field have been constructed and show that the oil at Womack Hill Field was sourced from outside the field area. Subtask 3 has commenced, and 2-D seismic reflection data are being acquired. Subtask 4 has been initiated through the study of existing thin sections (71) from Smackover cores in Womack Hill Field. Work will continue on petrographic analysis of the newly acquired thin sections (118).

Petrophysical and Engineering Characterization is on schedule. All four subtasks have been initiated and are progressing. Most of the critical data have been acquired and entered into the digital database for the field. Also, initial ultimate recovery and decline type curve analysis for certain field wells has been performed. Work on the reservoir simulation model has commenced. Because the modeling of reservoir performance requires reasonable estimates of flowing and shut-in reservoir pressures as a function of time, a concerted effort for the first six months of Year 2 will be to search files for additional pressure data for the Womack Hill Field reservoir. Preliminary analyses have shown that pressure data quality and quantity is an issue for the field. Also, acquisition of additional water production records for the field is important as shown from the preliminary well analyses. On the other hand, preliminary well analyses indicate that the injection data for the Unit are excellent. To resolve remaining questions regarding the flow barrier in the eastern part of the field, work in Year 2 will include a sequence of tracer and pressure transient tests within the Womack Hill Field. An apparent correlation of production and injection exists as observed from data from the 10-14 Well (P-1678), 15-2 (Well (P-1720), and 15-1 (P-1748) injectors, and 14-6 Well (P-1804) and 14-8A (Well P-2341) producers. The testing sequence is designed to confirm or dispute the flow barrier in the Womack Hill Field, to assess the permeability (flow thickness) in the drainage/injection area of the reservoir for a particular well, and to evaluate the near-well damage (or stimulation) for these wells.

Microbial Characterization is on schedule although no microbial growth has yet been observed in samples from old core samples, produced water, or oil from the Womack Hill Field reservoir. Microflora characterization will be enhanced as a result of the acquisition of a new Smackover core in the early part of Year 2. These new core materials will also be used in Subtask 2 which involves the validation of the program for chemical additions for the field demonstration using the sandpack methodology.

EXPERIMENTAL

Overview

The principal research effort for Year 1 of the project has been reservoir characterization, which has included three (3) primary tasks: geoscientific reservoir characterization, petrophysical and engineering property characterization, and microbial characterization. In the first year, the research focus has primarily been geoscientific reservoir characterization (Table 1). This work was scheduled for completion in Year 1. Petrophysical and engineering property and microbial characterization were initiated in the last six months of Year 1 (Table 2).

Work Accomplished in Year 1

Task RC-1. Geoscientific Reservoir Characterization

Description of Work.--This task is designed to characterize reservoir architecture, pore systems and heterogeneity based on geological and geophysical properties (Tables 1 and 2).

Rationale.--Reservoir characterization is fundamental to determining reservoir architecture, pore systems, and heterogeneity. It is critical in the design of a cost-effective fieldwide reservoir management strategy and for making sound operational decisions. Deformational (structural), depositional, and diagenetic processes exert the major influences on reservoir quality and evolution and produce heterogeneities at various scales. To predict accurately changes in reservoir quality, heterogeneity, and producibility in interwell areas, it is crucial to characterize and understand the processes that produce carbonate rock textures and the diagenetic fluid-rock interactions that have altered the primary rock fabric and pore system.

Subtask 1 includes detailed core descriptions, including lithologies, fossils, textures, mineralogy, sedimentary structures, pore types, marine flooding surfaces, unconformities, lithofacies, depositional environments, systems tracts, and depositional sequences. Graphic logs constructed from the core studies will depict the information described above. Core samples will be selected for petrographic, XRD, SEM, and microprobe analyses. The core descriptions and graphic logs will include qualitative and visual quantitative estimates for reservoir characterization. The graphic logs will be compared to available core analysis (porosity, permeability, grain density,

Table 1

Milestone Chart—Project

Year/Quarter

Task	2000			2001				2002				2003				2004				2005				
Phase I	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1
1. Reservoir Characterization																								
Task RC-1—Geoscientific	xxxxxxxxxxx																							
Task RC-2—Petrophysical and engineering			xxxxxxxxxxx																					
Task RC-3—Microbial			xxxxxxxxxxx																					
Task RC-4—Data integration					xxxxxxxx																			
2. Recovery Technology Analysis																								
Task RTA-1—3-D Geologic model							xxxxxxxx																	
Task RTA-2—3-D Simulation									xxxxxxxx															
Task RTA-3—Core experiments									xxxxxxxx															
3. Recovery Technology Evaluation																								
Task RTE-1—3-D Seismic										xxxxxxxx														
Task RTE-2—Pressure maintenance												xx												
Task RTE-3—IET concept												xx												
4. Decision to Implement Demonstration Projects												x												

Table 2
Milestone Chart—Year 1

Reservoir Characterization Tasks (Phase I)	M	J	J	A	S	O	N	D	J	F	M	A
Geoscientific Reservoir Characterization	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx
Petrophysical and Engineering Property Characterization							▨ xx	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx
Microbial Characterization							▨ xx	▨ xx	▨ xx	▨ xx	▨ xx	▨ xx

Work Planned ▨
Work Accomplished xx

water and oil saturation) and well log (SP, resistivity, gamma ray, density, neutron, sonic) data. The core features and core analyses will be calibrated to the well log patterns, and electrofacies will be identified for mapping and modeling. A numerical code system will be established so that these data can be entered into the digital database for comparison with the core analysis data and well log measurements and used in the 3-D reservoir model.

Graphic logs were constructed describing each of the six available whole cores from Womack Hill Field (Figures 4-9). The graphic logs show rock types and colors, mineralogy percentages, grain size, bedding and structures, fossil abundances and types, visual porosity estimate, and types of pores. Depositional facies were determined from the core descriptions and conclusions regarding water depth during upper Smackover deposition have been made. It was found that the upper Smackover cycles (Figure 10) generally consist of a mudstone or wackestone base and an oolitic, oncolitic and/or peloidal grainstone top. The tops of each cycle are found to be more dominantly dolomitized and have higher porosity and permeability, although dolomitized porous and permeable zones can be found throughout the entire upper Smackover.

Based on the core descriptions, 118 sample points were selected. The samples represent all rock types/facies established from the core descriptions. Samples were also selected for zones where it appears diagenetic changes have occurred. All reservoir grade rocks were extensively sampled in order to establish pore systems in these zones. Samples consist of thin sections and permeability plugs at all 118 points. Fewer plugs for porosity and capillary pressure analysis were taken from among the 118 sample locations.

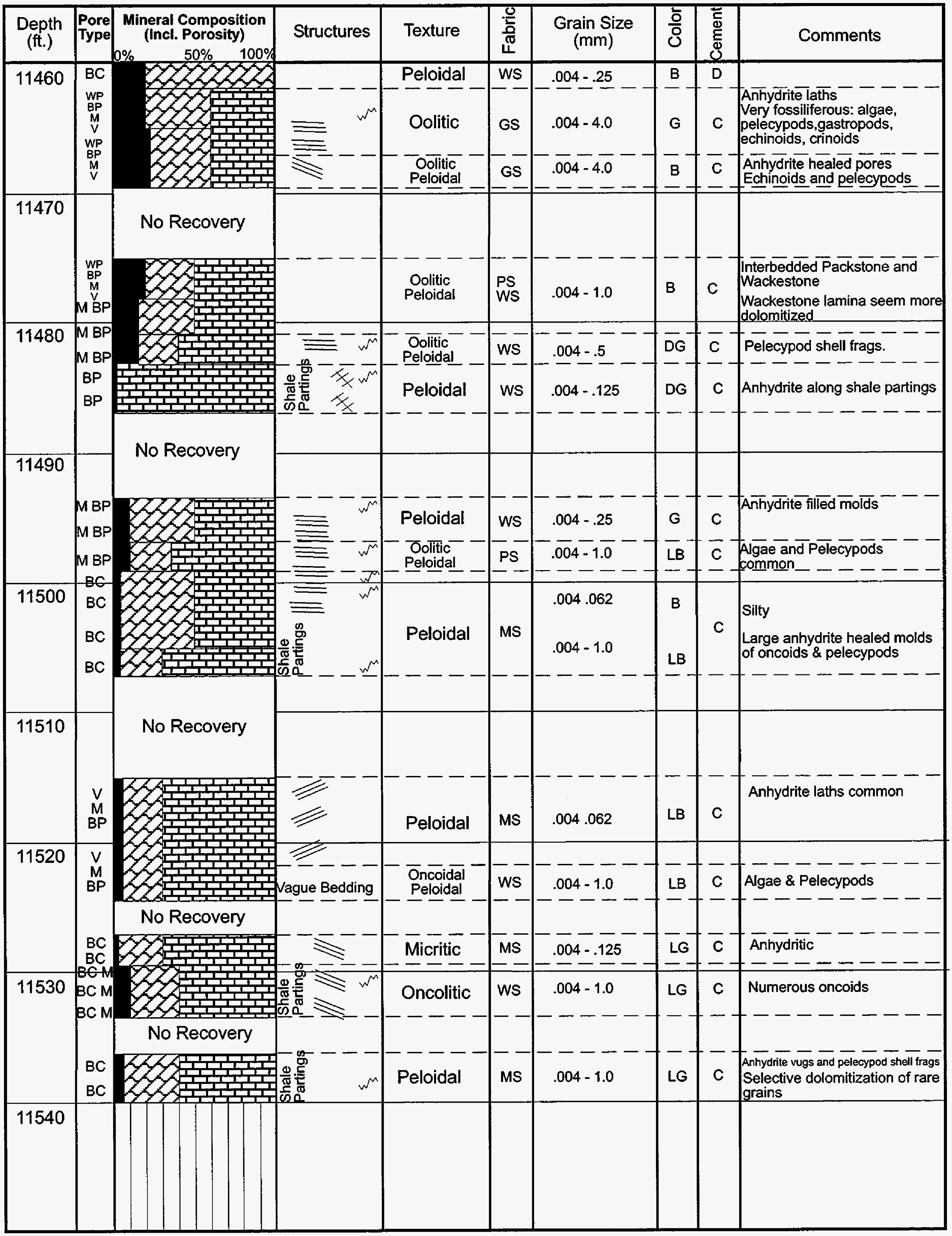
Subtask 2 is the link between core/well log analysis and 3-D reservoir modeling. This subtask involves the preparation of cross sections to illustrate structural growth, lithofacies and reservoir geometry, and depositional systems tract distribution. Maps are prepared to illustrate lithofacies and electrofacies distribution, stratigraphic and reservoir interval thickness (isolith and isopach maps), and stratal structural configurations. These cross sections and maps, in association with the core descriptions, will be utilized to make sequence stratigraphic, environment of deposition, and structural interpretations. Standard industry software, such as StratWorks and

Well: Counselman 18-12

Logged By: W. A. Tedesco

Stratigraphic Interval: Smackover Formation 11460 - 11540

Date: January 10, 2001



Depth (ft.)	Pore Type	Mineral Composition (Incl. Porosity) 0% 50% 100%	Structures	Texture	Fabric	Grain Size (mm)	Color	Cement	Comments
11460	BC			Peloidal	WS	.004 - .25	B	D	
	WP BP M V			Oolitic	GS	.004 - 4.0	G	C	Anhydrite laths Very fossiliferous: algae, pelecypods,gastropods, echinoids, crinoids
	WP BP M V			Oolitic Peloidal	GS	.004 - 4.0	B	C	Anhydrite healed pores Echinoids and pelecypods
11470		No Recovery							
	WP BP M V M BP			Oolitic Peloidal	PS WS	.004 - 1.0	B	C	Interbedded Packstone and Wackestone Wackestone lamina seem more dolomitized
11480	M BP M BP			Oolitic Peloidal	WS	.004 - .5	DG	C	Pelecypod shell frags.
	BP BP		Shale Partings	Peloidal	WS	.004 - .125	DG	C	Anhydrite along shale partings
		No Recovery							
11490	M BP M BP			Peloidal	WS	.004 - .25	G	C	Anhydrite filled molds
	M BP			Oolitic Peloidal	PS	.004 - 1.0	LB	C	Algae and Pelecypods common
11500	BC BC BC BC		Shale Partings	Peloidal	MS	.004 .062 .004 - 1.0	B LB	C	Silty Large anhydrite healed molds of oncoids & pelecypods
11510		No Recovery							
	V M BP			Peloidal	MS	.004 .062	LB	C	Anhydrite laths common
11520	V M BP		Vague Bedding	Oncoidal Peloidal	WS	.004 - 1.0	LB	C	Algae & Pelecypods
		No Recovery							
	BC BC			Micritic	MS	.004 - .125	LG	C	Anhydritic
11530	BC M BC M BC M		Shale Partings	Oncolitic	WS	.004 - 1.0	LG	C	Numerous oncoids
		No Recovery							
	BC BC		Shale Partings	Peloidal	MS	.004 - 1.0	LG	C	Anhydrite vugs and pelecypod shell frags Selective dolomitization of rare grains
11540									

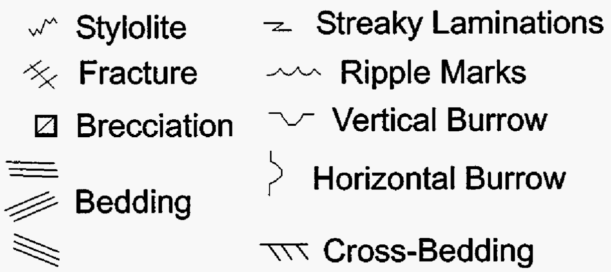
Figure 4. Graph of the core for the 18-12 well.

KEY

Mineral Composition

■ Porosity
▤ Calcite
▨ Dolomite
▦ Anhydrite

Structures



Colors

G - Gray
B - Brown
W - White

Color Modifiers

L - Light
D - Dark
M - Mottled
VD - Very Dark

Pore Types

BP - Interparticle
WP - Intraparticle
BC - Intercrystalline
M - Moldic
F - Fenestral
FR - Fracture
V - Vuggy

Carbonate Fabrics

MS - Micrite
WS - Wackestone
PS - Packstone
GS - Grainstone

Cements

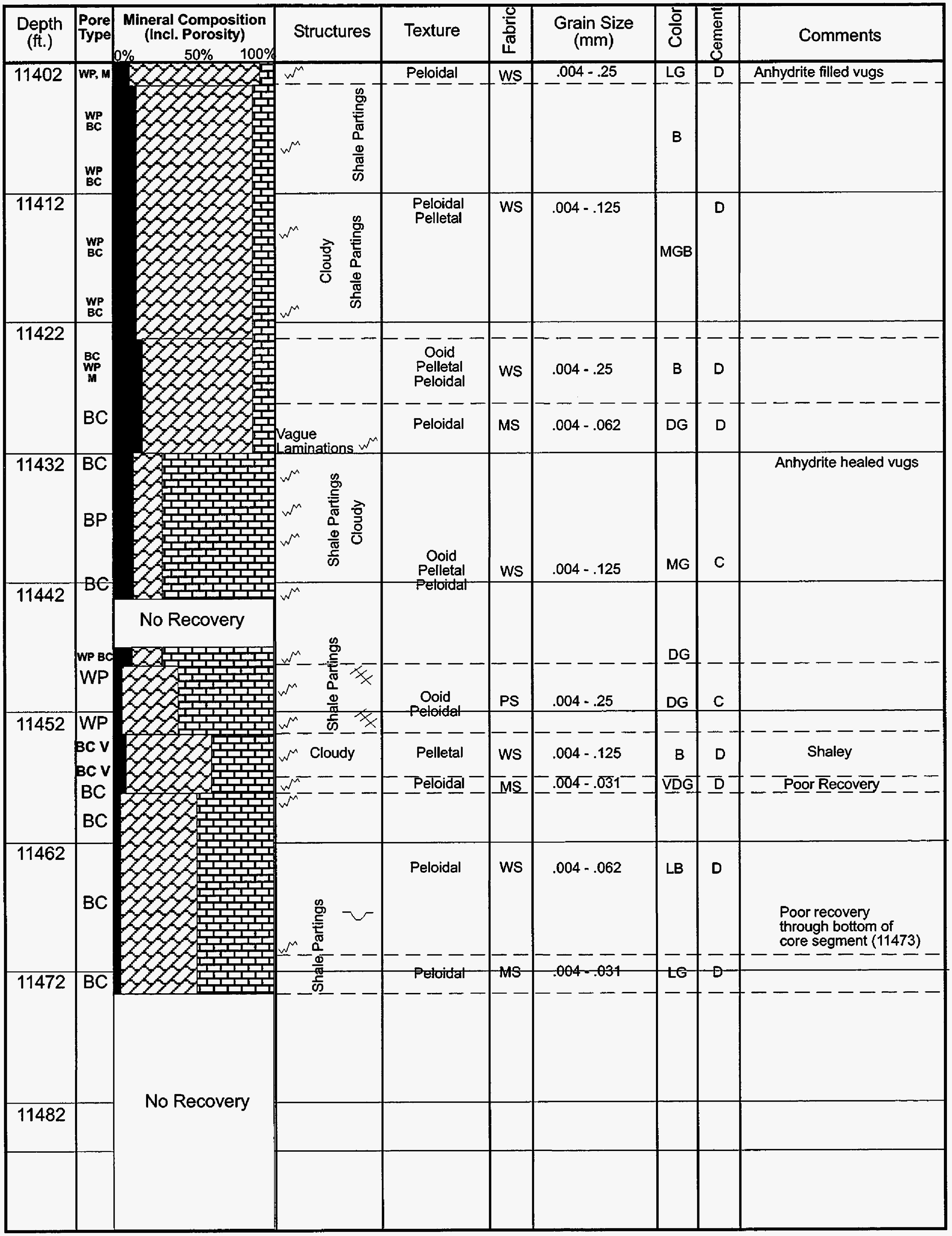
C - Calcite
D - Dolomite
A - Anhydrite

Well: Scruggs, Parker, Norton 9-14

Stratigraphic Interval: Smackover Formation, 11402 - 11555

Logged By: W. A. Tedesco

Date: August 15, 2000



Depth (ft.)	Pore Type	Structures	Texture	Fabric	Grain Size (mm)	Color	Cement	Comments
11402	WP, M		Peloidal	WS	.004 - .25	LG	D	Anhydrite filled vugs
	WP BC WP BC	Shale Partings				B		
11412	WP BC WP BC	Cloudy Shale Partings	Peloidal Pelletal	WS	.004 - .125	MGB	D	
11422	BC WP M		Ooid Pelletal Peloidal	WS	.004 - .25	B	D	
	BC	Vague Laminations	Peloidal	MS	.004 - .062	DG	D	
11432	BC BP BC	Shale Partings Cloudy	Ooid Pelletal Peloidal	WS	.004 - .125	MG	C	Anhydrite healed vugs
11442	WP BC	Shale Partings				DG		
	WP		Ooid Peloidal	PS	.004 - .25	DG	C	
11452	WP BC V	Cloudy	Pelletal	WS	.004 - .125	B	D	Shaley
	BC V		Peloidal	MS	.004 - .031	VDG	D	Poor Recovery
	BC BC							
11462	BC	Shale Partings	Peloidal	WS	.004 - .062	LB	D	Poor recovery through bottom of core segment (11473)
11472	BC		Peloidal	MS	.004 - .031	LG	D	
11482								

Figure 5. Graph of the core for the 9-14 well.

Well: Scruggs. Parker. Norton 9-14

Stratigraphic Interval: Smackover Formation 11402 - 11555

Logged By: W. A. Tedesco

Date: August 15, 2000

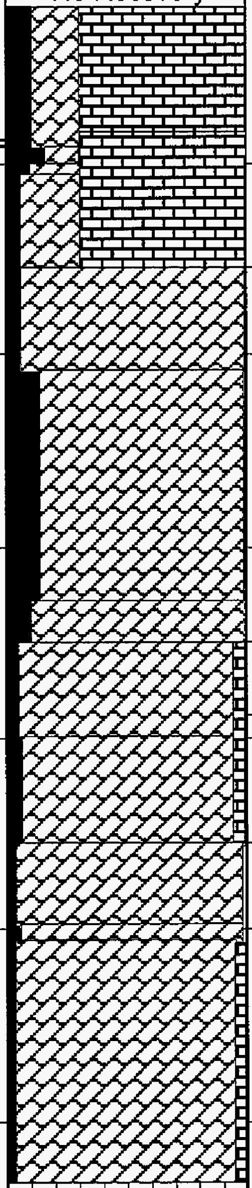
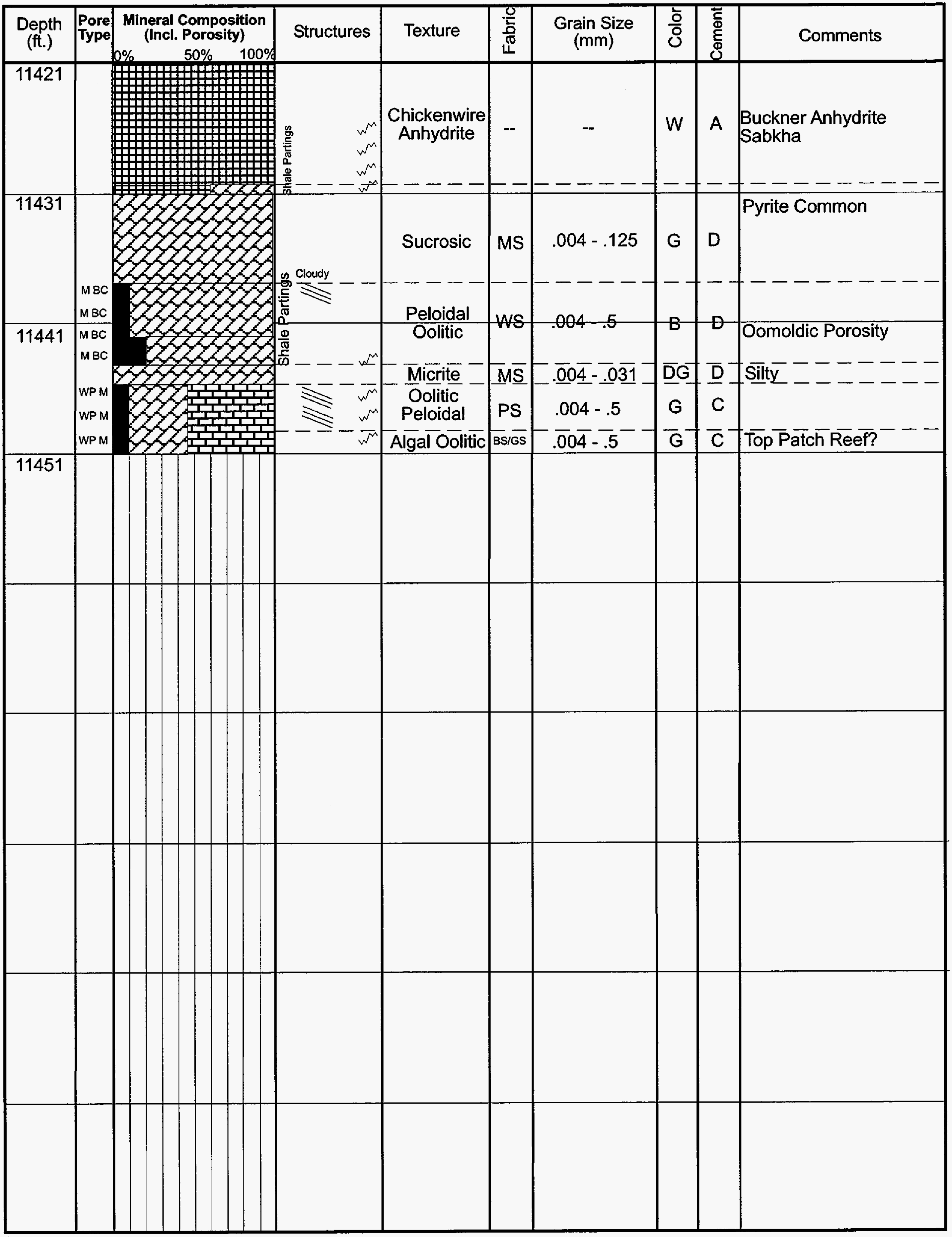
Depth (ft.)	Pore Type	Mineral Composition (Incl. Porosity) 0% 50% 100%	Structures	Texture	Fabric	Grain Size (mm)	Color	Cement	Comments
11492	BC BC, F	No Recovery 	Shale Partings	Peloidal	WS	.004 - .062	DG	C	Very Shaley Increasing Organics
11502	BP			Ooid Peloidal Pelletal	WS	.004 - .062	DG	C	Crumbly till top of cored segment (11495)
	BC		Shale Partings	Pelletal	WS	.004 - .062	LB	D	
11512	BC BC		Shale Partings Vague Laminations	Pelletal	WS	.004 - .125	DB	D	Significant Oil Stain
11522	BC		Vague Laminations	Pelletal	WS	.004 - .125	DB	D	Interbedded brown/gray laminations
	BC		Vague Laminations	Peloidal	MS	.004 - .031	LG	D	
11532	BC		Shale Partings Vague Laminations	Peloidal	WS	.004 - .125	LB	D	Shaley, vague laminations
	BC		Shale Partings Vague Laminations	Peloidal Pelletal	WS	.004 - .062	DG	D	Shaley, vague laminations
11542	BC		Shale Partings Vague Laminations	Peloidal Pelletal	WS	.004 - .125 .004 - .062	G G	D	Shaley, vague laminations
11552									
11555									

Figure 5 (continued). Graph of the core for the 9-14 well.

Well: Turner 13-25 Logged By: W. A. Tedesco

Stratigraphic Interval: Buckner Anhydrite / Smackover Formation 11421 - 11448 Date: August 16, 2000



Depth (ft.)	Pore Type	Mineral Composition (Incl. Porosity) 0% 50% 100%	Structures	Texture	Fabric	Grain Size (mm)	Color	Cement	Comments
11421			Shale Partings	Chickenwire Anhydrite	--	--	W	A	Buckner Anhydrite Sabkha
11431				Sucrosic	MS	.004 - .125	G	D	Pyrite Common
	M BC M BC		Cloudy Shale Partings	Peloidal Oolitic	WS	.004 - .5	B	D	
11441	M BC M BC								Oomoldic Porosity
				Micrite	MS	.004 - .031	DG	D	Silty
	WP M WP M			Oolitic Peloidal	PS	.004 - .5	G	C	
	WP M			Algal Oolitic	BS/GS	.004 - .5	G	C	Top Patch Reef?
11451									

Figure 6. Graph of the core for the 13-25 well.

Well: Turner 13-5

Stratigraphic Interval: Smackover Formation 11318 - 11500

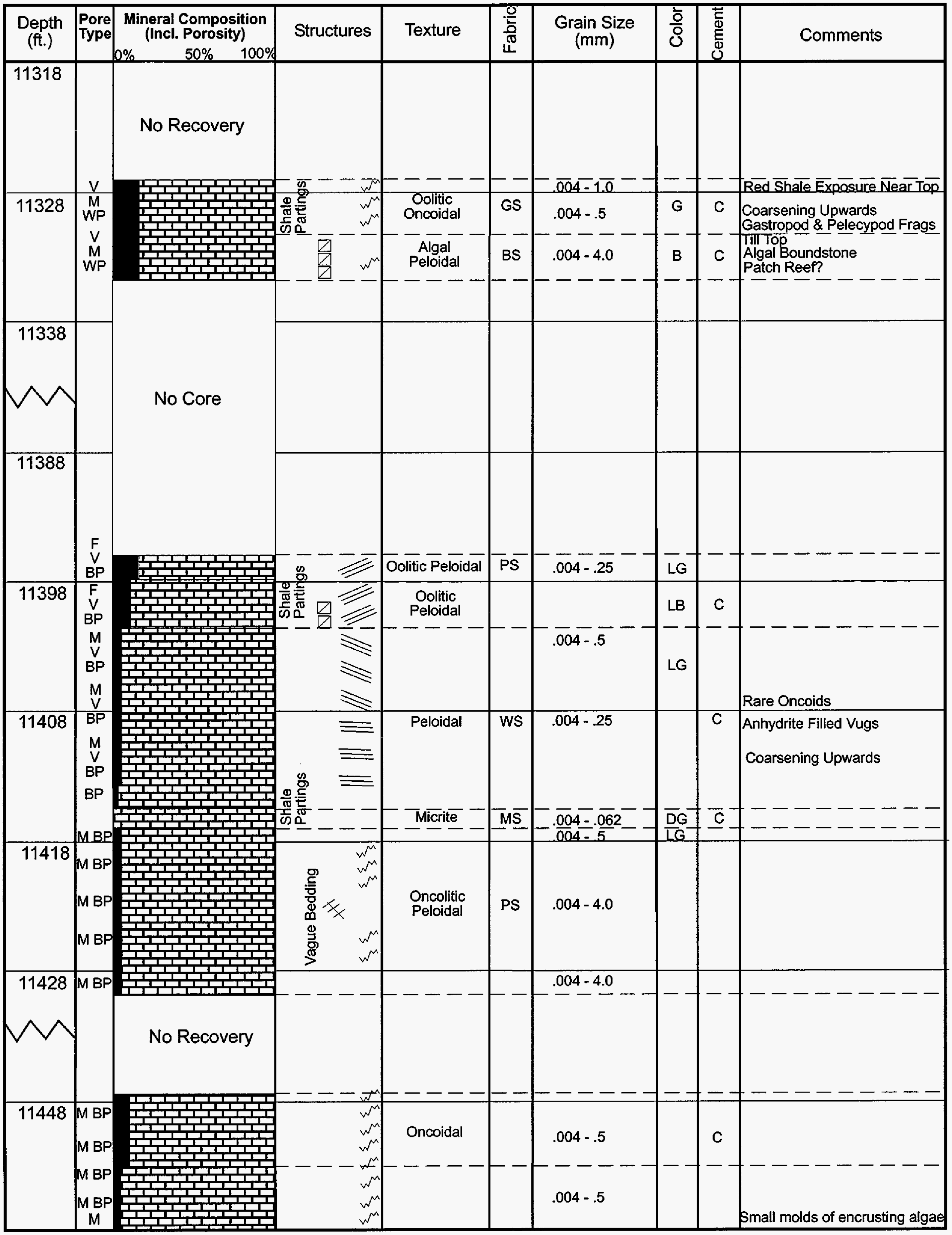
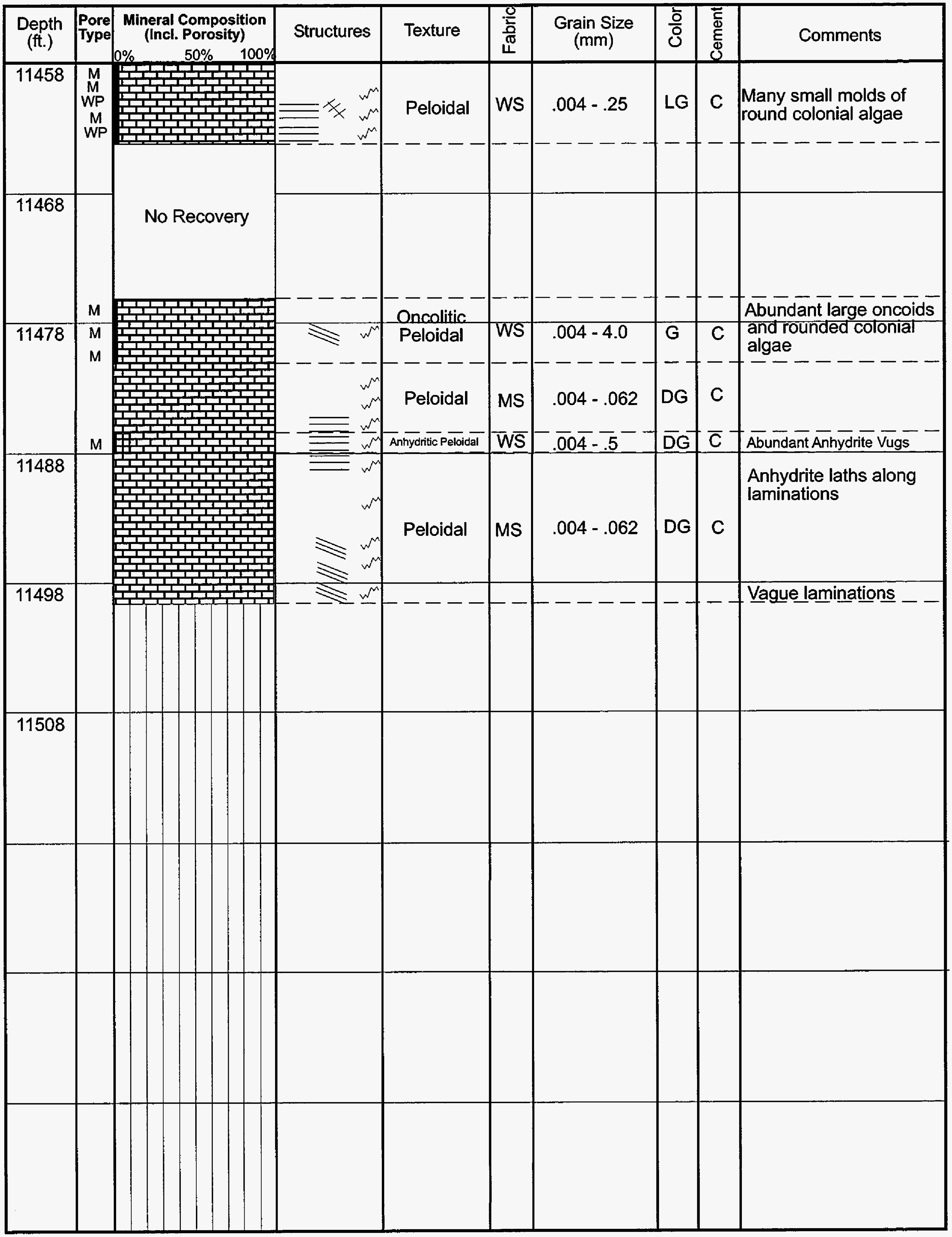


Figure 7. Graph of the core for the 13-5 well.

Well: Turner 13-5 Logged By: W. A. Tedesco

Stratigraphic Interval: Smackover 11318 - 11500 Date: August 16, 2000



Depth (ft.)	Pore Type	Mineral Composition (Incl. Porosity)	Structures	Texture	Fabric	Grain Size (mm)	Color	Cement	Comments
11458	M M WP M WP			Peloidal	WS	.004 - .25	LG	C	Many small molds of round colonial algae
11468		No Recovery							
11478	M M M			Oncolitic Peloidal	WS	.004 - 4.0	G	C	Abundant large oncoids and rounded colonial algae
				Peloidal	MS	.004 - .062	DG	C	
	M			Anhydritic Peloidal	WS	.004 - .5	DG	C	Abundant Anhydrite Vugs
11488				Peloidal	MS	.004 - .062	DG	C	Anhydrite laths along laminations
11498									Vague laminations
11508									

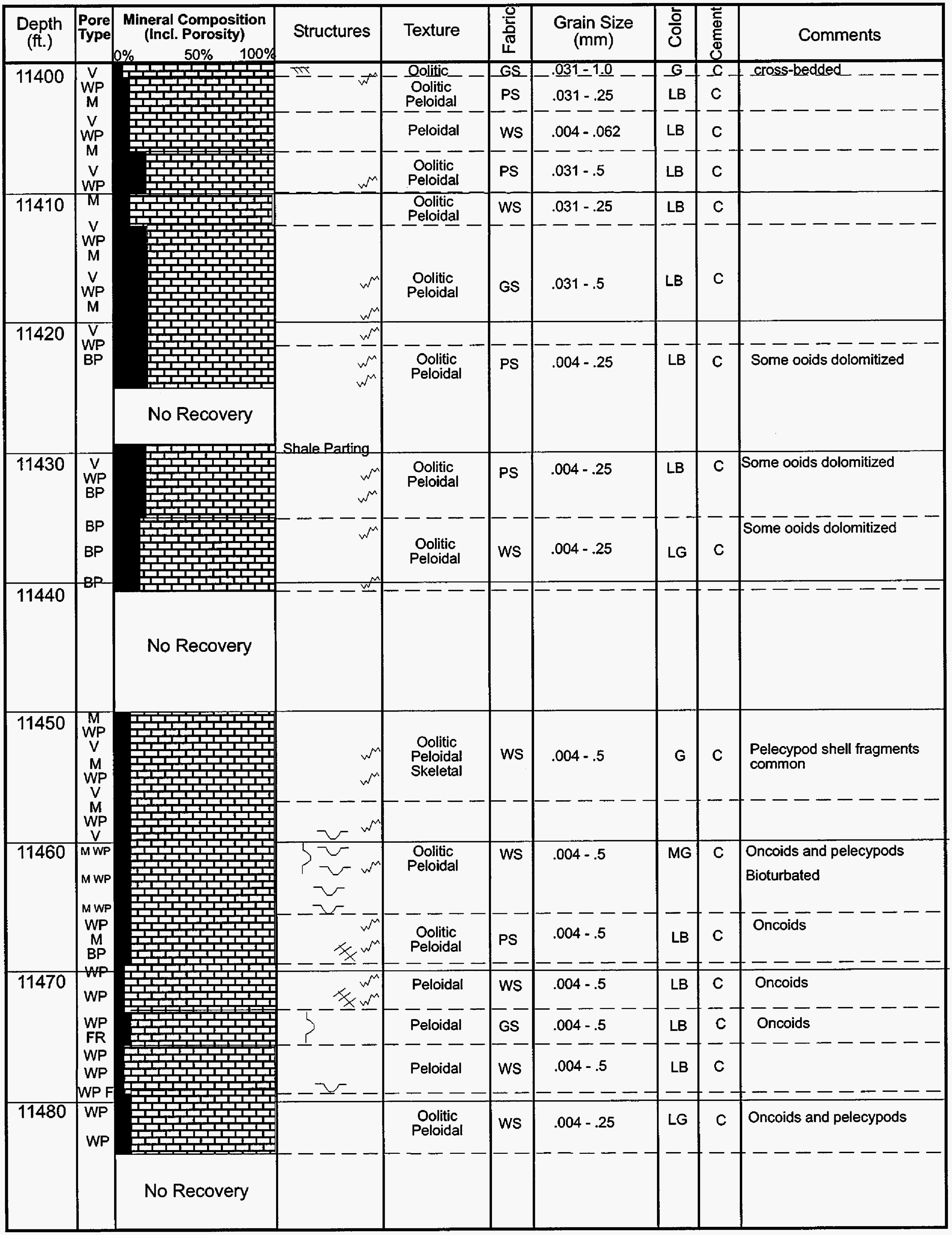
Figure 7 (continued). Graph of the core for the 13-5 well.

Well: Turner 13-6

Logged By: W. A. Tedesco

Stratigraphic Interval: Smackover Formation 11400 - 11525

Date: August 15, 2000



Depth (ft.)	Pore Type	Mineral Composition (Incl. Porosity) 0% 50% 100%	Structures	Texture	Fabric	Grain Size (mm)	Color	Cement	Comments
11400	V			Oolitic	GS	.031 - 1.0	G	C	cross-bedded
	WP M			Oolitic Peloidal	PS	.031 - .25	LB	C	
	V WP M			Peloidal	WS	.004 - .062	LB	C	
	V WP			Oolitic Peloidal	PS	.031 - .5	LB	C	
11410	M			Oolitic Peloidal	WS	.031 - .25	LB	C	
	V WP M V WP M			Oolitic Peloidal	GS	.031 - .5	LB	C	
11420	V WP BP	No Recovery		Oolitic Peloidal	PS	.004 - .25	LB	C	Some ooids dolomitized
11430	V WP BP		Shale Parting	Oolitic Peloidal	PS	.004 - .25	LB	C	Some ooids dolomitized
	BP BP BP			Oolitic Peloidal	WS	.004 - .25	LG	C	Some ooids dolomitized
11440		No Recovery							
11450	M WP V M WP V			Oolitic Peloidal Skeletal	WS	.004 - .5	G	C	Pelecypod shell fragments common
	M WP V								
11460	M WP M WP			Oolitic Peloidal	WS	.004 - .5	MG	C	Oncoids and pelecypods Bioturbated
	M WP WP M BP			Oolitic Peloidal	PS	.004 - .5	LB	C	Oncoids
11470	WP WP			Peloidal	WS	.004 - .5	LB	C	Oncoids
	WP FR			Peloidal	GS	.004 - .5	LB	C	Oncoids
	WP WP WP F			Peloidal	WS	.004 - .5	LB	C	
11480	WP WP			Oolitic Peloidal	WS	.004 - .25	LG	C	Oncoids and pelecypods
		No Recovery							

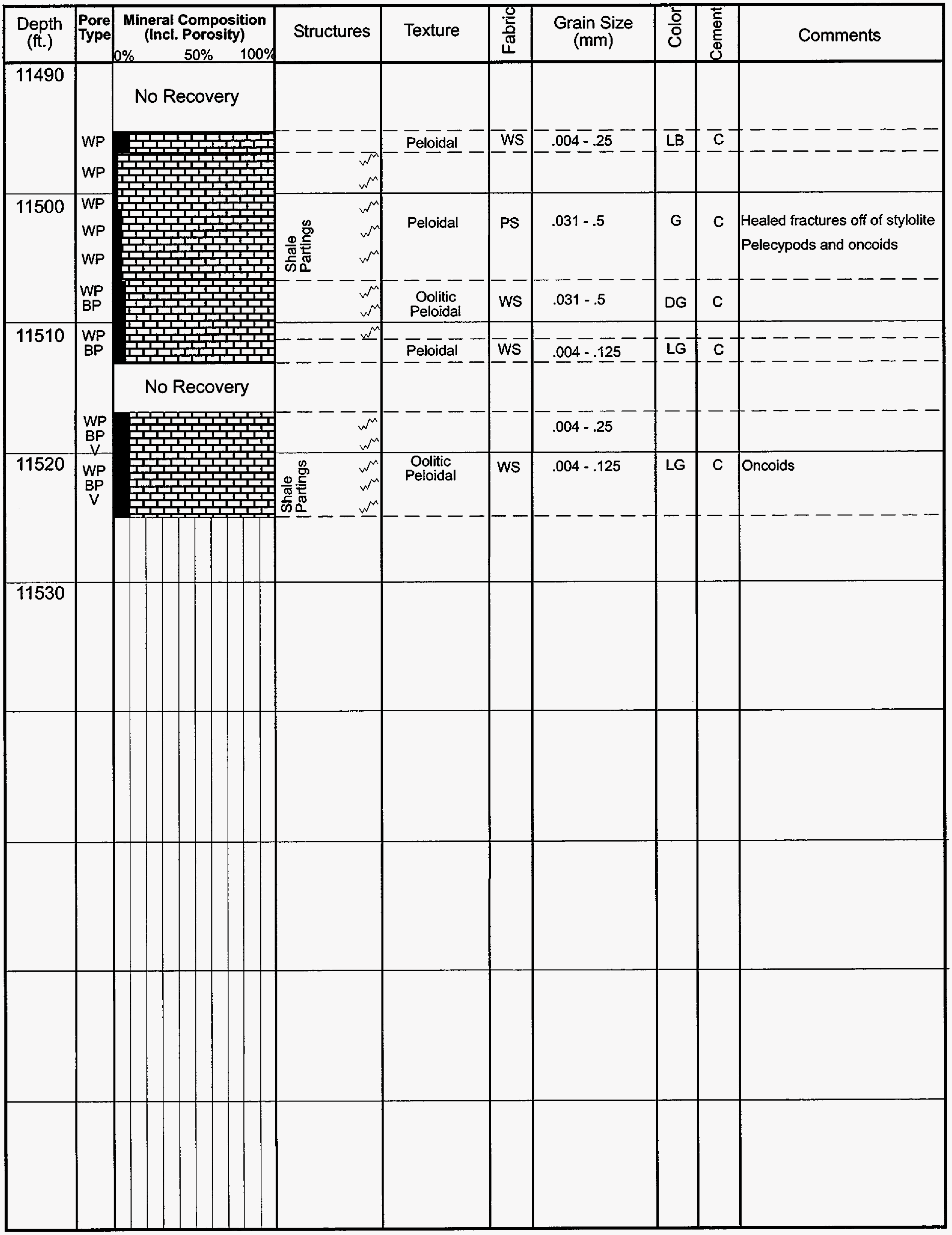
Figure 8. Graph of the core for the 13-6 well.

Well: Turner 13-6

Logged By: W. A. Tedesco

Stratigraphic Interval: Smackover Formation 11400 - 11525

Date: August 15, 2000

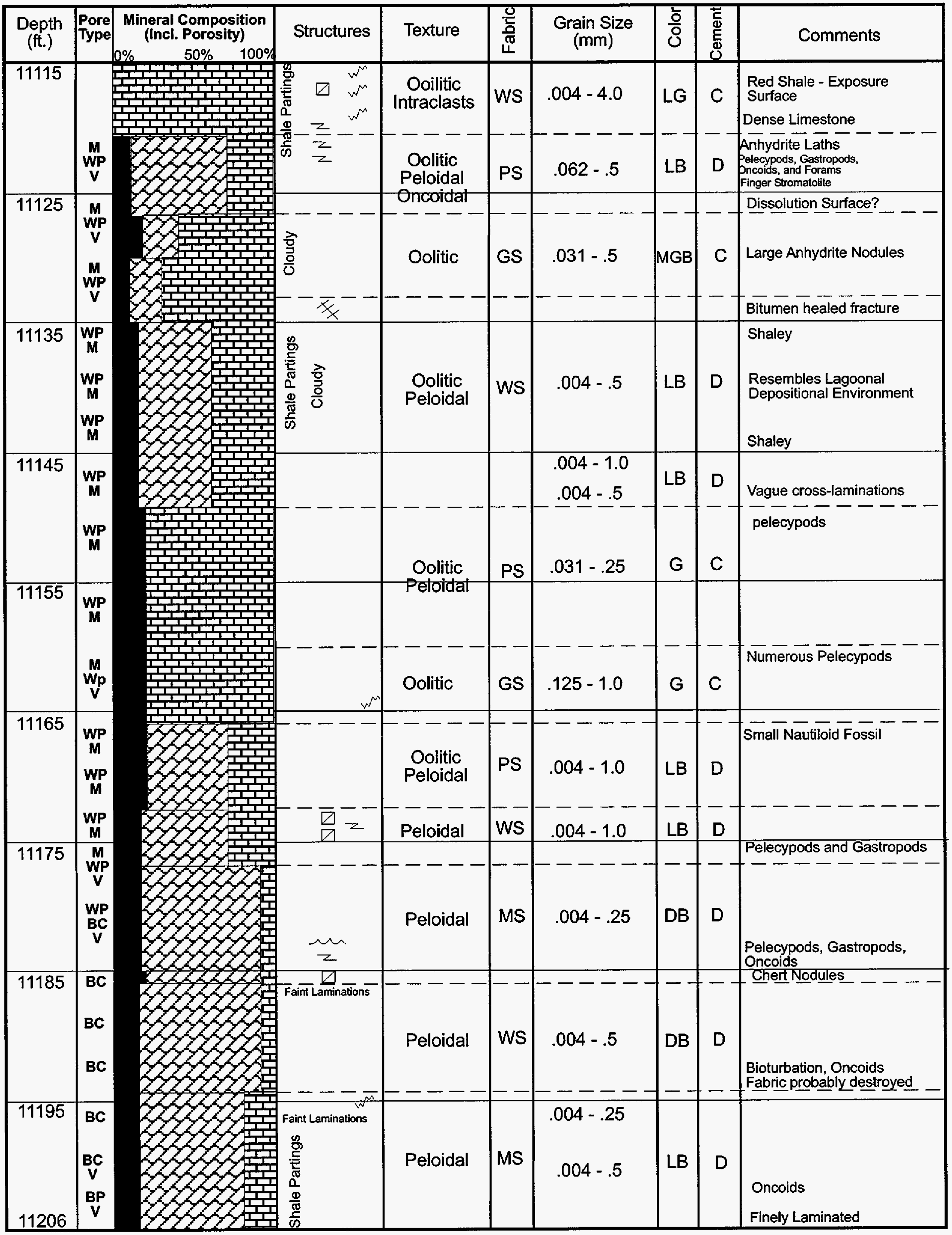


Depth (ft.)	Pore Type	Mineral Composition (Incl. Porosity) 0% 50% 100%	Structures	Texture	Fabric	Grain Size (mm)	Color	Cement	Comments
11490		No Recovery							
	WP			Peloidal	WS	.004 - .25	LB	C	
	WP		∿ ∿						
11500	WP WP WP		Shale Partings ∿ ∿ ∿	Peloidal	PS	.031 - .5	G	C	Healed fractures off of stylolite Pelecypods and oncoids
	WP BP		∿ ∿	Oolitic Peloidal	WS	.031 - .5	DG	C	
11510	WP BP		∿	Peloidal	WS	.004 - .125	LG	C	
		No Recovery							
	WP BP V		∿ ∿			.004 - .25			
11520	WP BP V		Shale Partings ∿ ∿ ∿	Oolitic Peloidal	WS	.004 - .125	LG	C	Oncoids
11530									

Figure 8 (continued). Graph of the core for the 13-6 well.

Well: Womack Hill Field Unit 14-5 #2
Logged By: W. A. Tedesco

Stratigraphic Interval: Smackover Formation 11115 - 11206
Date: August 14 - 15, 2000



Depth (ft.)	Pore Type	Structures	Texture	Fabric	Grain Size (mm)	Color	Cement	Comments
11115		Shale Partings	Oolitic Intraclasts	WS	.004 - 4.0	LG	C	Red Shale - Exposure Surface Dense Limestone
	M WP V		Oolitic Peloidal Oncoidal	PS	.062 - .5	LB	D	Anhydrite Laths Pelecypods, Gastropods, Oncoids, and Forams Finger Stromatolite Dissolution Surface?
11125	M WP V M WP V	Cloudy	Oolitic	GS	.031 - .5	MGB	C	Large Anhydrite Nodules Bitumen healed fracture
11135	WP M WP M WP M	Shale Partings Cloudy	Oolitic Peloidal	WS	.004 - .5	LB	D	Shaley Resembles Lagoonal Depositional Environment Shaley
11145	WP M				.004 - 1.0 .004 - .5	LB	D	Vague cross-laminations
11155	WP M WP M		Oolitic Peloidal	PS	.031 - .25	G	C	pelecypods
	M Wp V		Oolitic	GS	.125 - 1.0	G	C	Numerous Pelecypods
11165	WP M WP M		Oolitic Peloidal	PS	.004 - 1.0	LB	D	Small Nautiloid Fossil
	WP M		Peloidal	WS	.004 - 1.0	LB	D	
11175	M WP V WP BC V		Peloidal	MS	.004 - .25	DB	D	Pelecypods and Gastropods Pelecypods, Gastropods, Oncoids Chert Nodules
11185	BC BC BC	Faint Laminations	Peloidal	WS	.004 - .5	DB	D	Bioturbation, Oncoids Fabric probably destroyed
11195 11206	BC BC V BP V	Faint Laminations Shale Partings	Peloidal	MS	.004 - .25 .004 - .5	LB	D	Oncoids Finely Laminated

Figure 9. Graph of the core for the 14-5 #2 well.

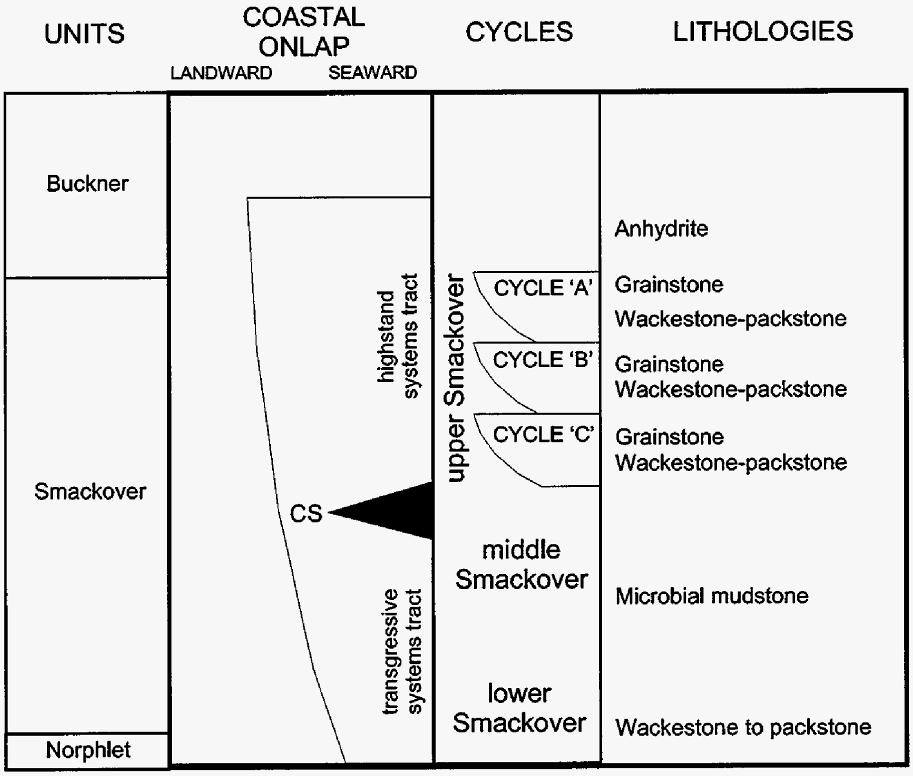


Figure 10. Generalized Smackover high frequency sequence stratigraphy.

Z-Map, are used in the preparation of the cross sections and subsurface maps. The burial (Figure 11) and thermal (Figure 12) histories are determined using standard industry software, such as BasinMod. Breaks in depositional and sedimentation patterns are recorded.

Electrical and geophysical well logs were obtained and analyzed for 42 oil and gas wells (Tables 3 and 4) within and immediately adjacent to Womack Hill Field (37 field wells). Log types studied include resistivity, compensated neutron porosity, formation bulk density, compensated density porosity, gamma ray, SP, and sonic. Compensated neutron porosity, gamma ray, SP, formation bulk density, compensated density porosity and resistivity logs were used to pick and distinguish the Smackover, Buckner, and Norphlet Formations (Table 5). Three upward-shoaling cycles in the upper Smackover Formation (labeled A, B, C) were also determined and picked on all logs (Figure 13). These picks were correlated across the field (Figure 3) and used to create stratigraphic cross-sections (Figures 14-17). Core descriptions were also added to the logs, allowing correlation of rock types, facies, and reservoir units across the field.

Apparent porosity values from compensated neutron and compensated density porosity logs were calculated for the wells in the field. The values from each log type in each individual well have been cross-plotted to estimate the dominant mineralogy (calcite, dolomite, anhydrite, or quartz) in the well. Preliminary relationships between mineralogy and porosity percent were established from these cross-plots. Porosity calculations from the logs were used to establish porous and non-porous zones in the wells. It was noted that the three cycles have higher porosity and are more dolomitized at the top of each cycle.

Several different subsurface maps of Womack Hill field have been constructed to aide with analysis of production controls in the field. Structure maps of the Smackover Formation (Figure 18) and Buckner Anhydrite Member of the Haynesville Formation (Figure 19) have been made using depths determined from the geophysical logs. The trace of the major fault along the southern margin of the field is located based on 2-D seismic data and GeoSec software interpretation. Isopach maps of the upper Smackover Formation (Figure 20), Buckner Anhydrite

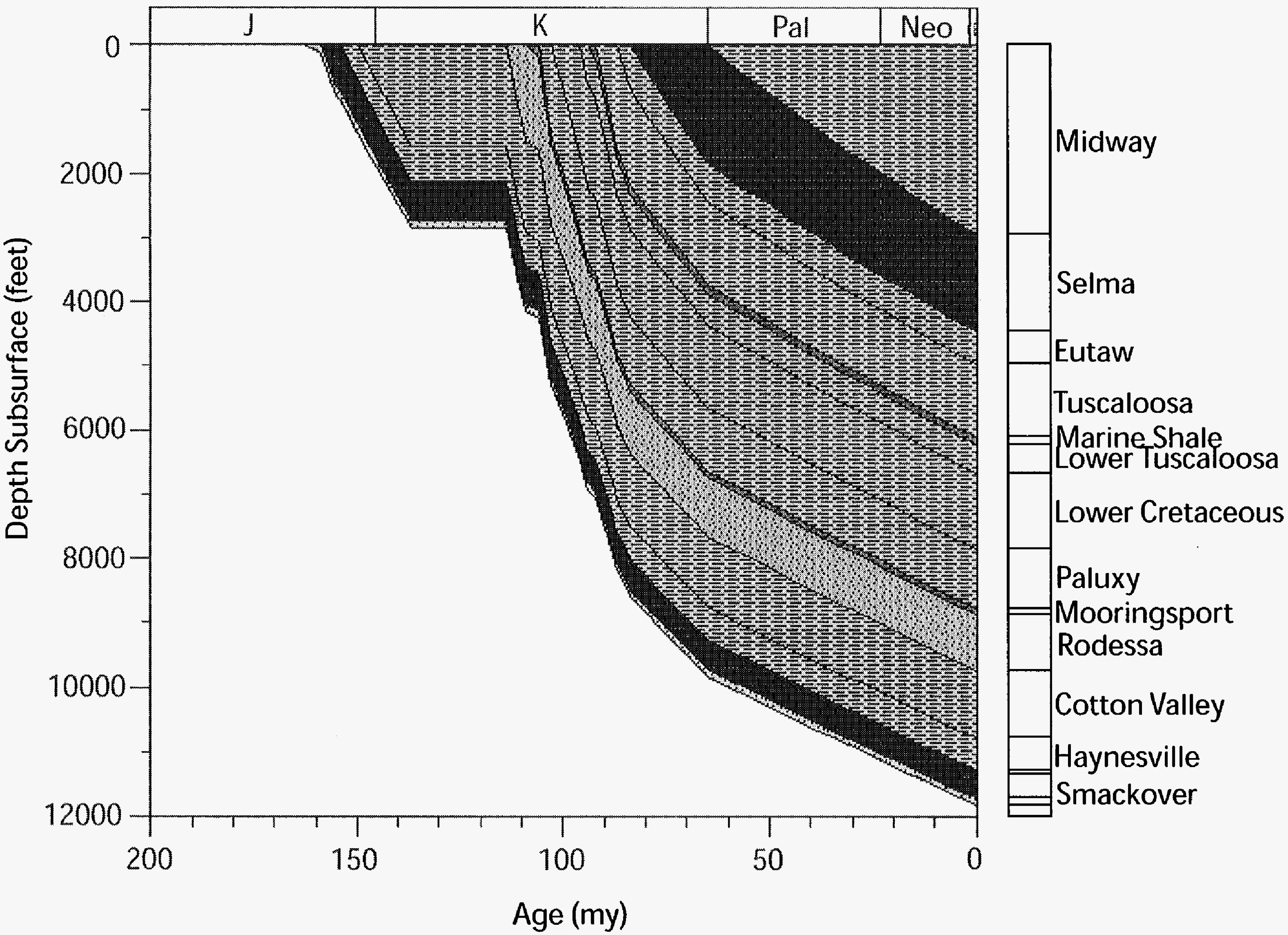


Figure 11. Burial history plot of the 9-15 well.

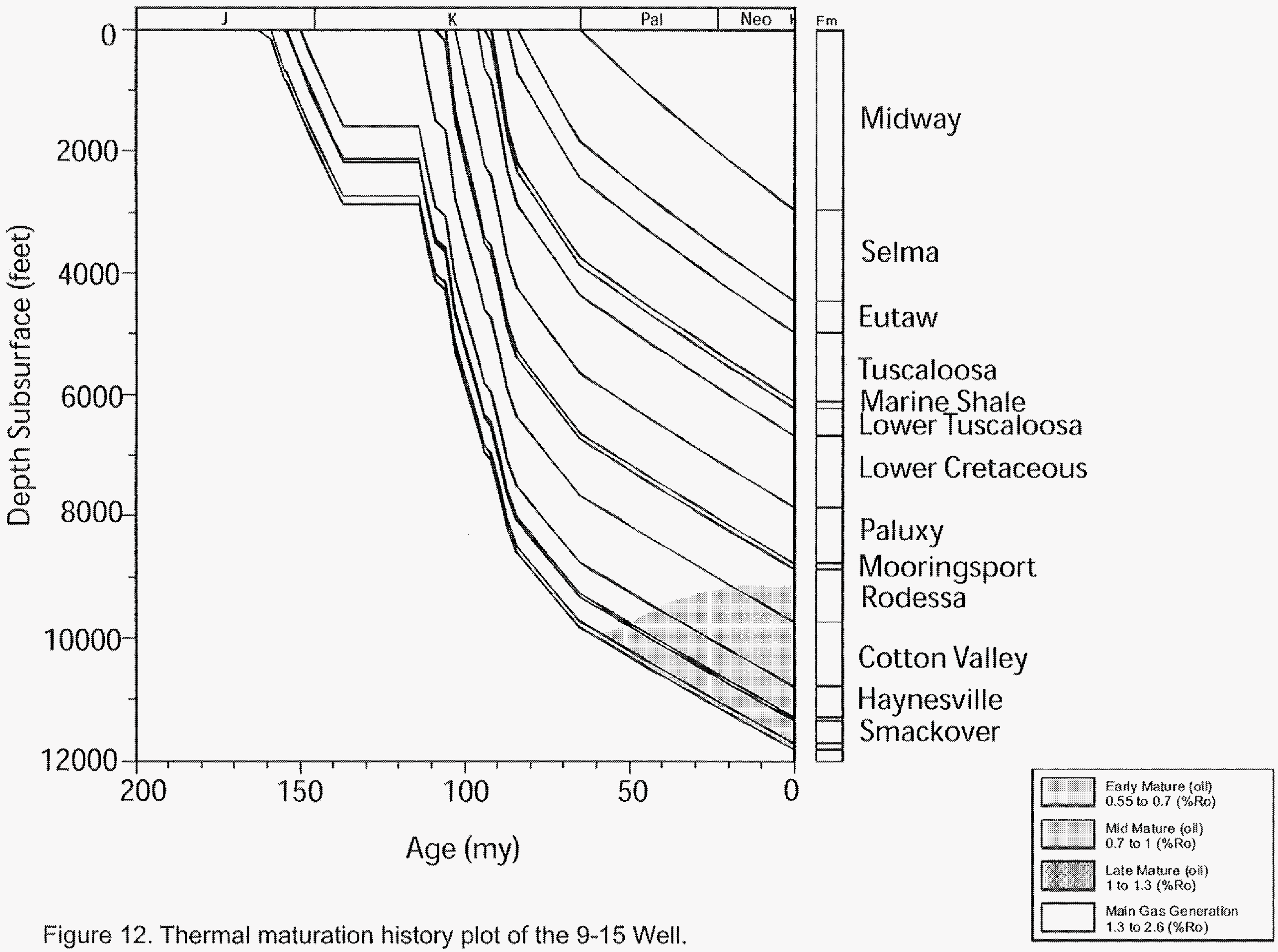


Figure 12. Thermal maturation history plot of the 9-15 Well.

Table 3
Project Information

<table>
<tr><td colspan="3">Field name: Womack Hill</td><td colspan="3">Basin name: Mississippi Interior Salt Basin</td></tr>
<tr><td colspan="2">Field location: State: AL</td><td colspan="2">County: Choctaw/Clarke</td><td colspan="2">Texas RRC District: N/A</td></tr>
<tr><td colspan="3">Field discovery date: 1970 Carlisle Unit 16-4 #1
(P.N.1573)</td><td colspan="3">Total number of wells drilled in field: 44</td></tr>
<tr><td colspan="3">Reservoir name: Smackover</td><td colspan="3">Producing formation: Smackover</td></tr>
<tr><td colspan="3">Reservoir area (Acres): 1,770</td><td colspan="3">Average reservoir depth: -11,270</td></tr>
<tr><td colspan="3">Average reservoir porosity: 20.3%</td><td colspan="3">Average reservoir permeability: 5 md</td></tr>
<tr><td colspan="3">Average reservoir net pay: 90 feet</td><td colspan="3">Initial reservoir pressure: 5,433 psia</td></tr>
<tr><td colspan="3">Initial oil saturation: 82%</td><td colspan="3">Reservoir dip (Angle/Direction): 8° North</td></tr>
<tr><td colspan="3">Depth gas/oil contact: N/A</td><td colspan="3">Depth oil/water contact: -11,360</td></tr>
<tr><td colspan="3">Current number producing wells in reservoir: 12</td><td colspan="3">Current number injection wells in reservoir: 7</td></tr>
<tr><td colspan="3">Primary drive mechanism: Solution gas and water</td><td colspan="3">Estimated primary recovery factor %: 29.2%</td></tr>
<tr><td colspan="3">Secondary recovery project (Mechanism/dates):
Fresh/salt water injection / 1/1/75</td><td colspan="3">Estimated secondary recovery factor %: 39.8%</td></tr>
<tr><td colspan="3">Tertiary (EOR) recovery projects:
(Mechanism/dates): N/A</td><td colspan="3">Estimated tertiary (EOR) recovery factor %: N/A</td></tr>
<tr><td colspan="3">Horizontal/high angle wells: 8 total; 3 active</td><td colspan="3">Number of observation or disposal wells: 2</td></tr>
<tr><td colspan="3">Project area operator, address:
Pruet Production Co.
217 West Capitol St., Suite 201
Jackson, MS 39201</td><td colspan="3">Project location (section/township/range):
Secs. 8, 9, 10, 15, 16, 17, T.10N., R.2W.
Secs. 11, 13, 14, T.10N., R.2W.
Sec. 18, T.10N., R.1W.</td></tr>
<tr><td colspan="3">Cumulative project area production (Date): (11/2000)
30,519,402 BO; 15,103,491 MCF; 43,496,557 BW</td><td colspan="3">Project area (Acres): 3,422.5</td></tr>
<tr><td colspan="3">Active number production wells in project area: 12</td><td colspan="3">Active number injection wells in project area: 3</td></tr>
<tr><td colspan="6">Producing formation lithology, diagenesis, structural style: Producing formation is the Smackover Formation, a Jurassic age limestone and dolostone producing from carbonate shoals; diagenesis includes compaction, cementation, dissolution and dolomitization; structural style is faulted, salt anticline.</td></tr>
<tr><td colspan="6">Surface facilities in project area: All producing wells produce by hydraulic jet pump. Each well is equipped with the following: 1 Triplex pump 150 to 166 HP, 1 500 Bbl power oil tank, at least 2 oil storage tanks ranging from 300 to 500 bbls. Pressure Maintenance Water Injection System. 2 National J-165 Triplex pump 165 hp each. Saltwater Disposal System. 1 60 hp injection pump, 1 horizontal surface installed ESP, 4 - 500 bbl tanks.</td></tr>
</table>

Table 4

Engineering and Geologic Data Availability in Proposed Project Area

Number of each data type: **A** (currently available); **P** (acquisition planned before or during project)

Seismic surveys—include date, 2-D miles, 3-D areal coverage, VSP

A—18 seismic surveys in field area; all 2-D group shoots and spec data: approximately 100 line miles of data; all pre-1990.

P—3-D areal coverage of entire field planned during project.

Other geophysical surveys—aeromagnetic, gravity, and the like

A—Gravity investigations

1. Gravity map of Clarke County, Alabama, by R.G. McWilliams and T.J. Joiner, Geological Survey of Alabama, Special Map 78, 1969.
2. Gravity survey of Clarke County, Alabama, by R.G. McWilliams and Thomas J. Joiner, Geological Survey of Alabama Circular 54, 1970, 73 p.
3. Gravity anomaly map of the U.S. exclusive of Alaska and Hawaii, compiled by the Society of Exploration Geophysicists Ad Hoc Gravity Anomaly Map Committee, 1982.

A—Magnetic investigations

1. Magnetic investigations in southwest Alabama by J. Brian Eby and E.G. Nicar, Geological Survey of Alabama Bulletin 43, 1936, 41 p.

Open hole logs (pre-1980)

gr/resistivity	A-35
neutron/density porosity	A-24
neutron log	A-3
formation density log	A-8

Other:

DIP	A-16	CBL	A-9	TDT	A-2	SL	A-1
DIR	A-16	SONIC	A-3	MD	A-1		
CA	A-27	SWSA	A-4	COR	A-2		

Open hole logs (post-1980)

P—2 wells during project with full open hole log suites including fracture identification logs (FIL)

GR/resistivity	A-7
Neutron/density porosity	A-7
Acoustic	A-5

Other:

DIP	A-4	DIR	A-5	RTS	A-2	TR	A-1
SONIC	A-5	CBL	A-1	TDT	A-1	EPT	A-1

Table 5. Formation and Event Horizon Picks

API	Permit No.	Buckner	Smackover	A	Ap	ApNp1	Anp	AnpP1	AnpP2	B	Bp	BpNp1	BpNp2	Bnp	BnpP1
102320064	1573-WI-69	11370	11431	11431	11431	0	11440	11468	11484	11490	11490	0	0	11560	0
102320068	1591-WI-77-1	11310	11380	11380	11380	0	11424	0	0	11435	11435	0	0	11472	0
102320075	1635	11424	11510	11510	11510	11519	11552	0	0	11562	11562	0	0	11594	0
102320077	1639	11260	11324	11324	11324	11332	11400	0	0	11406	11406	0	0	11449	0
102320081	1655	11172	11252	11252	11252	11274	11304	0	0	11312	11312	0	0	11338	0
102320083	1667	11232	11286	11286	11286	0	11322	0	0	11344	11344	0	0	11361	0
102320087	1678-WI-93-8	11230	11302	11302	11302	0	11346	0	0	11352	11352	0	0	11414	0
102320092	1697	11425	11518	11518	11518	0	11524	0	0	11530	11530	0	0	11560	0
102320099	1720-WI-77-2	11266	11341	11341	11341	0	11349	0	0	11355	11355	11373	11381	11416	0
102320104	1748-B	11230	11296	11296	11296	0	11311	0	0	11318	11318	11322	0	11350	0
102320158	2109	11155	11213	11213	11213	0	11222	0	0	11226	11226	0	0	11250	0
102320165	2168-WI-72	11528	11612	11612	11612	0	11632	11637	0	11668	11668	0	0	11744	0
102320169	2183	11782	11862	11862	11862	0	11881	0	0	11886	11886	0	0	11918	0
102320182	2251	11850	11914	11914	11922	0	11936	0	0	11944	11944	0	0	11950	0
102320183	2257-B	11270	11339	11339	11339	0	11383	0	0	11390	11390	0	0	0	0
102320234	2737-B	11492	11600	11600	11600	0	11609	0	0	11616	11616	0	0	0	0
102320243	2836	11922	12012	12012	12013	0	12054	0	0	12060	12060	0	0	12080	12084
102520021	1579	11356	11434	11434	11434	0	11442	0	0	11468	11468	0	0	11506	0
102520026	1713-SWD-74-24	11456	11532	11532	11532	0	11542	0	0	11568	11568	0	0	11582	0
102520029	1732-B	11481	11528	11528	11528	0	11536	11541	0	11550	11550	0	0	11604	0
102520033	1760	11234	11308	11308	11308	0	11318	0	0	11328	11328	0	0	11373	0
102520037	1781	11300	11372	11372	11372	0	11380	0	0	11396	11396	0	0	11440	0
102520040	1804	11098	11152	11152	11152	0	11158	0	0	11170	11170	0	0	11243	0
102520041	1811-A-SWD-75-104	11426	11496	11496	11496	0	11510	0	0	11516	11516	0	0	11544	0
102520043	1825	11174	11236	11236	11236	0	11250	0	0	11274	11274	0	0	11326	0
102520044	1826	11179	11231	11231	11231	0	11246	0	0	11254	11254	11284	0	11302	0
102520047	1847	11314	11382	11382	11382	0	11397	0	0	11406	11406	0	0	11437	0
102520054	1890-SWD-83-3	11311	11394	11394	11394	0	11405	0	0	11420	11420	11430	0	11455	0
102520055	1899	11378	11454	11454	11454	0	11468	0	0	11474	11474	0	0	11488	0
102520078	2130-B	11256	11310	11310	11310	0	11318	0	0	11322	11322	0	0	11328	0
102520095	2248-B	11228.201	11305	11305	11305	0	11316	0	0	11322	11322	0	0	11387.271	0
102520097	2263-SWD-85-5	11216	11282	11282	11282	0	11296	0	0	11308	11308	0	0	0	0
102520105	2327	11346	11424	11424	11427	0	11438	11442	0	11452	11452	0	0	0	0
102520107	2341	11180	11232	11232	11232	0	11260	0	0	11269	11269	0	0	0	0
102520130	2916	12410	12497	12497	12497	0	12510	0	0	12518	12518	0	0	12538	0
102520150	3452	11187	11236	11236	11236	0	11256	0	0	11270	11270	0	0	11282	0
102520155	3657	11247	11314	11314	11314	0	11322	0	0	11332	11332	0	0	0	0
102520172	4335-B	11064	11120	11120	11120	0	11158	0	0	11166	11166	0	0	11222	0
102520179	4575-B	11079	11119	11119	11119	0	11124	0	0	11144	11144	0	0	11160	0
102520187	4805-B	11154	11203	11203	11203	0	11234	0	0	11238	11238	0	0	11277	0
102520188	4852-B	11362	11412	11412	11412	0	11430	0	0	11437	11437	11449	0	11460	0
102520189	4860	11405	11471	11471	11471	11476	11496	11504	0	11516	11516	0	0	11550	0

Table 5. (Continued)

C	Cp	CpNp1	Cnp	CnpP1	MSmack	LSmack	Norphlet	API
11591	11591	0	11628	0	11640	11811	11846	102320064
11476	11476	11536	11557	0	11562	11720	11776	102320068
11600	11600	0	11606	0	11624	0	11912	102320075
11454	11454	0	11480	0	11504	11656	11717	102320077
11350	11350	0	11388	0	11420	11608	11674	102320081
11390	11390	0	11414	0	11430	0	11593	102320083
11444	11444	0	11474	0	11500	11602	11676	102320087
0	0	0	0	0	11562	11838	11898	102320092
11422	11422	0	11431	0	11480	11626	11704	102320099
11360	11360	0	11376	0	11424	11630	11690	102320104
11254	11254	11265	11286	0	0	0	0	102320158
11754	11754	0	11770	0	0	0	0	102320165
11926	11926	0	0	0	11968	12060	12252	102320169
11964	11964	0	11982	0	11984	12094	12212	102320182
0	0	0	0	0	0	0	0	102320183
0	0	0	0	0	0	0	0	102320234
12090	12090	0	12114	0	12133	12186	12422	102320243
11512	11512	0	11586	0	11590	11618	0	102520021
0	0	0	0	0	11592	11650	11752	102520026
11626	11626	0	11638	0	11650	11834	0	102520029
11376	11376	0	11396	0	11400	11560	11620	102520033
11454	11454	0	11458	11468	11489	11606	11672	102520037
11247	11247	0	11266	0	11272	11514	11530	102520040
11560	11560	0	11600	0	0	0	0	102520041
11330	11330	0	11348	0	11352	11500	11562	102520043
11310	11310	0	11348	0	11356	11490	0	102520044
11442	11442	0	11451	0	11504	11536	11640	102520047
11470	11470	0	11492	0	11495	11532	0	102520054
11520	11520	0	11543	0	0	0	0	102520055
11332	11332	0	11344	0	0	0	0	102520078
11395.03	11395.03	0	11410.549	0	11436.932	0	0	102520095
0	0	0	0	0	0	0	0	102520097
0	0	0	0	0	0	0	0	102520105
0	0	0	0	0	0	0	0	102520107
12542	12542	0	12553	0	0	0	0	102520130
11290	11290	0	0	0	0	0	0	102520150
0	0	0	0	0	0	0	0	102520155
0	0	0	0	0	11226	11278	11350	102520172
11176	11176	11182	11191	0	11228	11402	11439	102520179
11282	11282	0	11297	0	11300	11462	11510	102520187
11484	11484	0	11493	0	11495	11642	11700	102520188
11556	11556	0	11559	0	11570	11754	11780	102520189

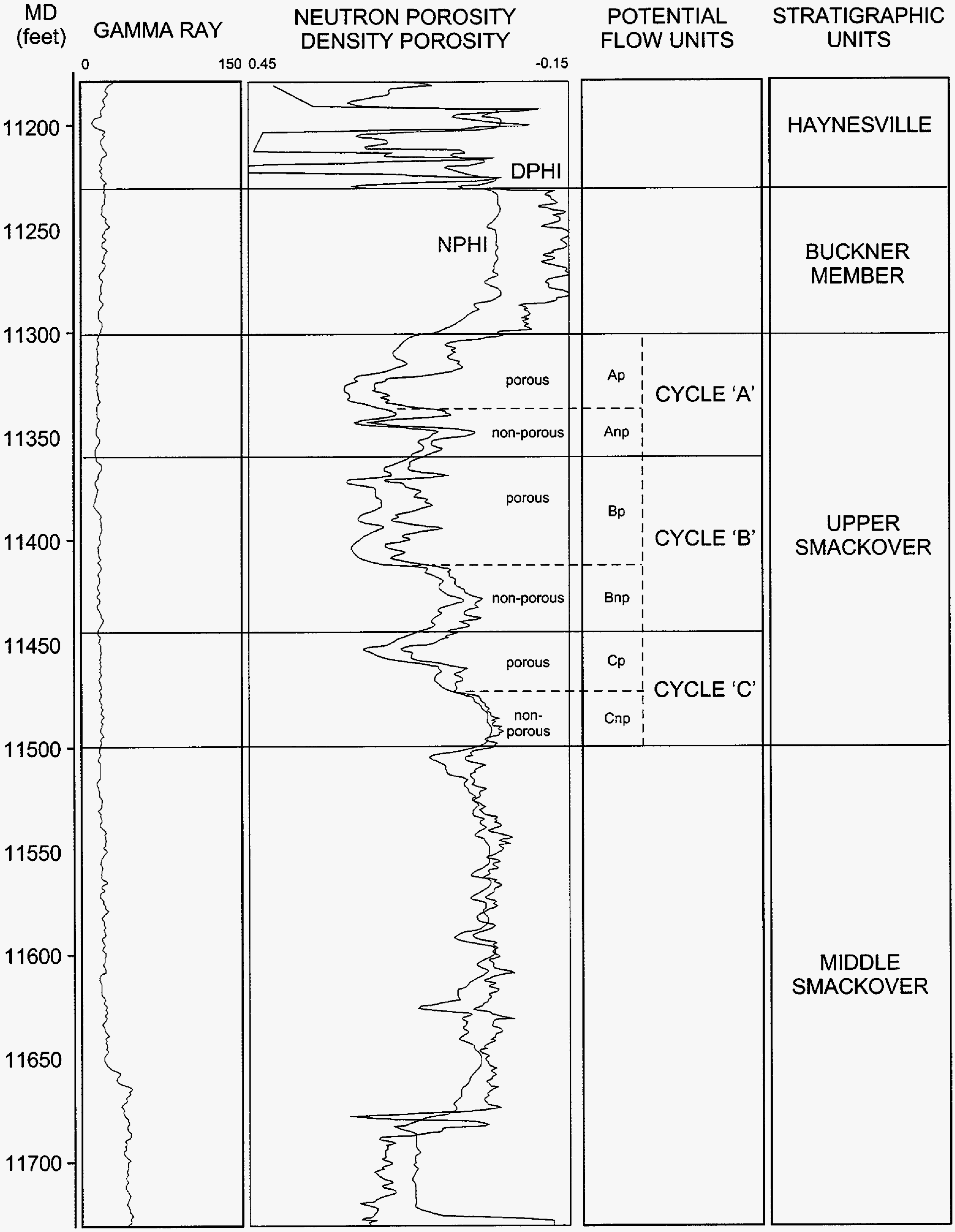


Figure 13. GR-NPHI-DPHI log for the 10-14 well showing Smackover cycles and potential flow units.

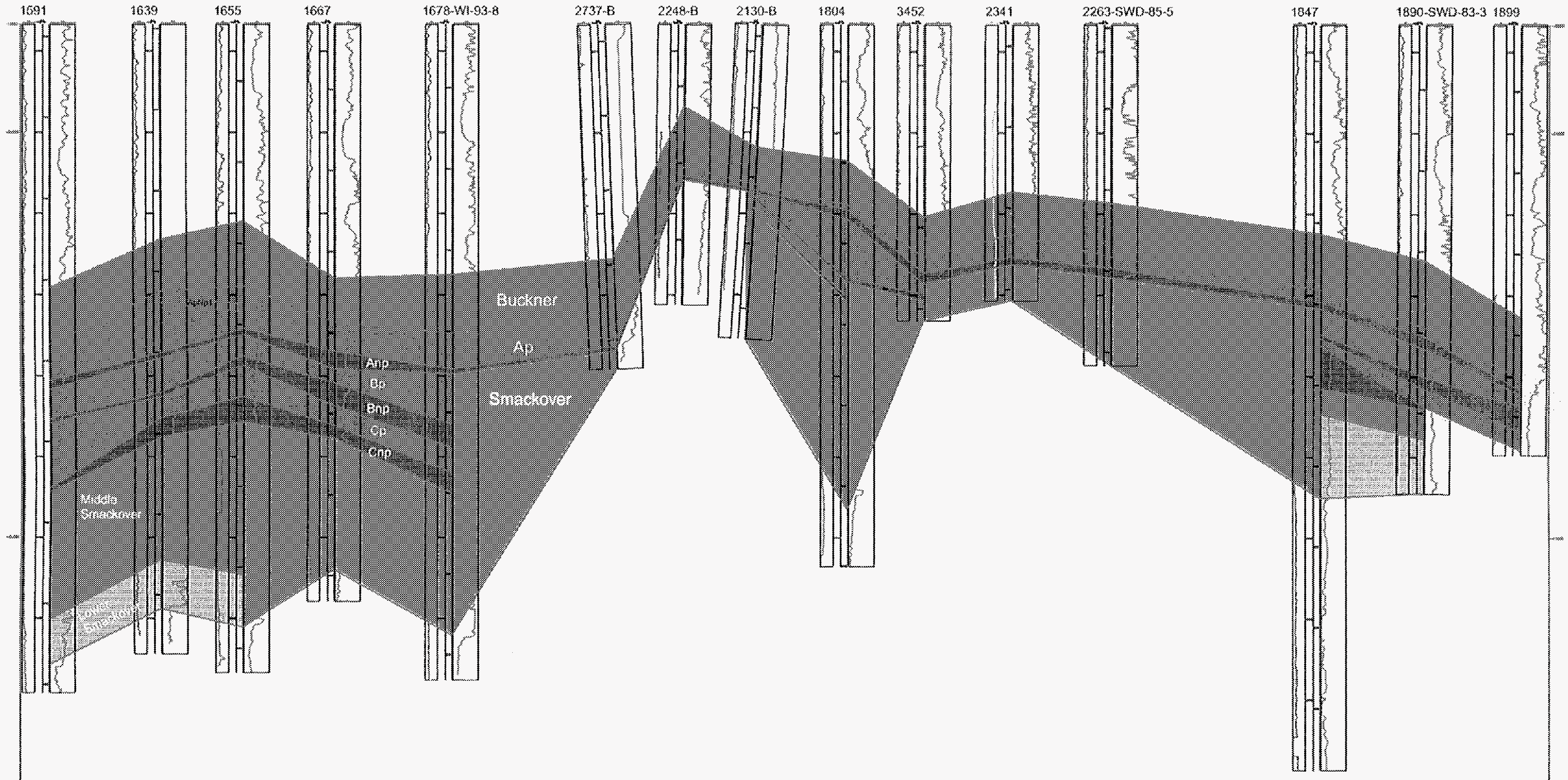


Figure 14. Cross Section A - A'.

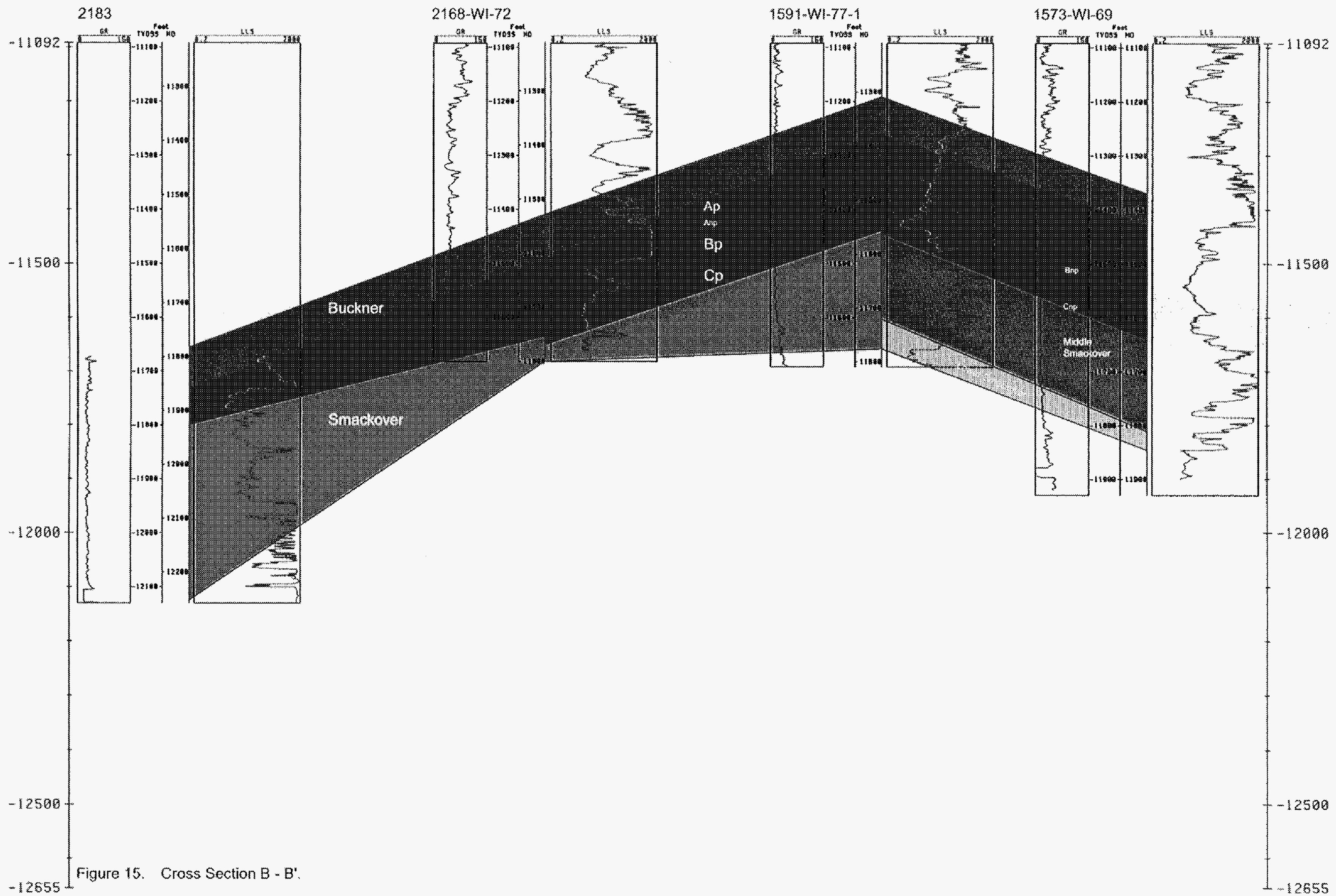


Figure 15. Cross Section B - B'.

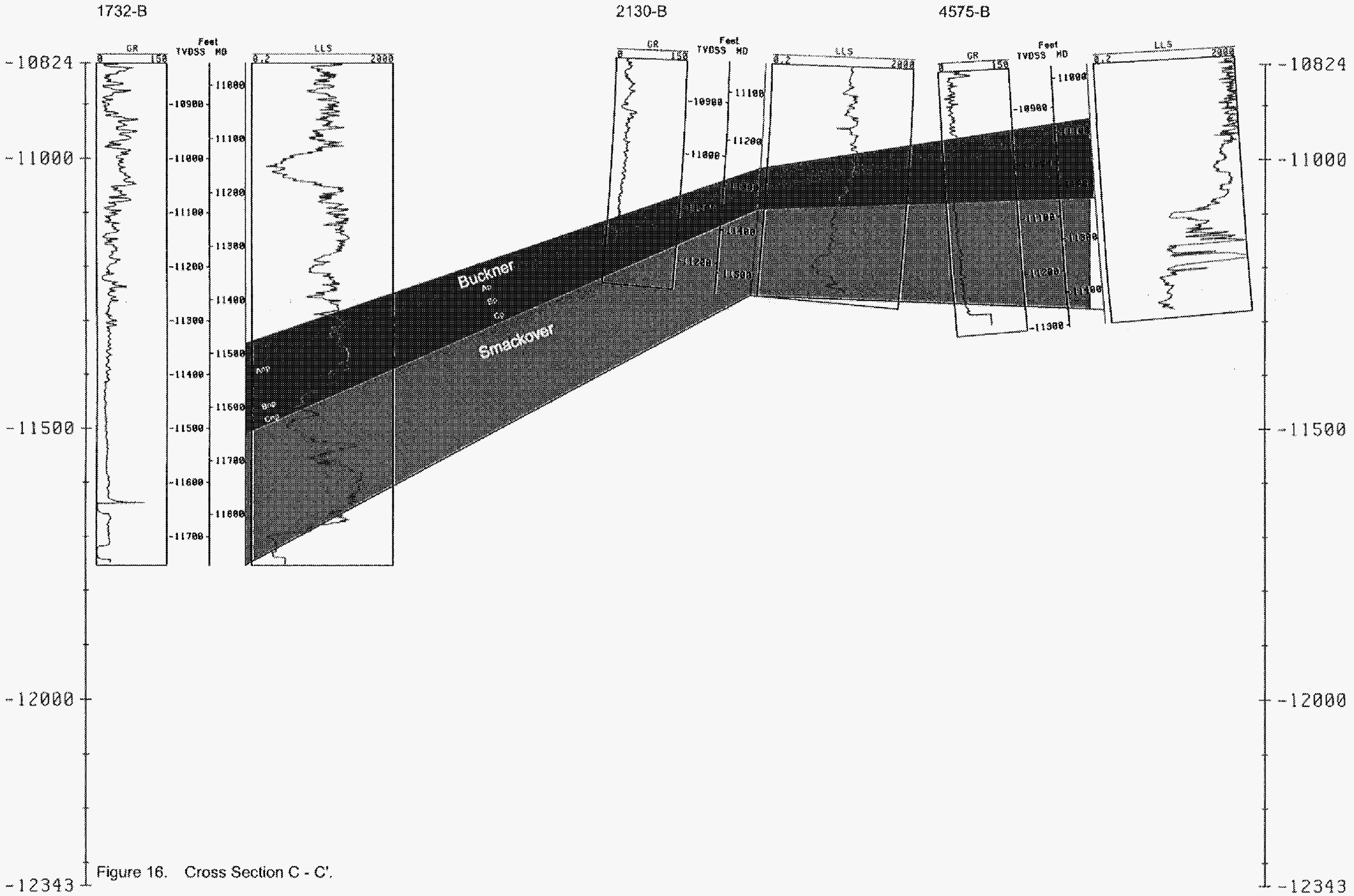


Figure 16. Cross Section C - C'.

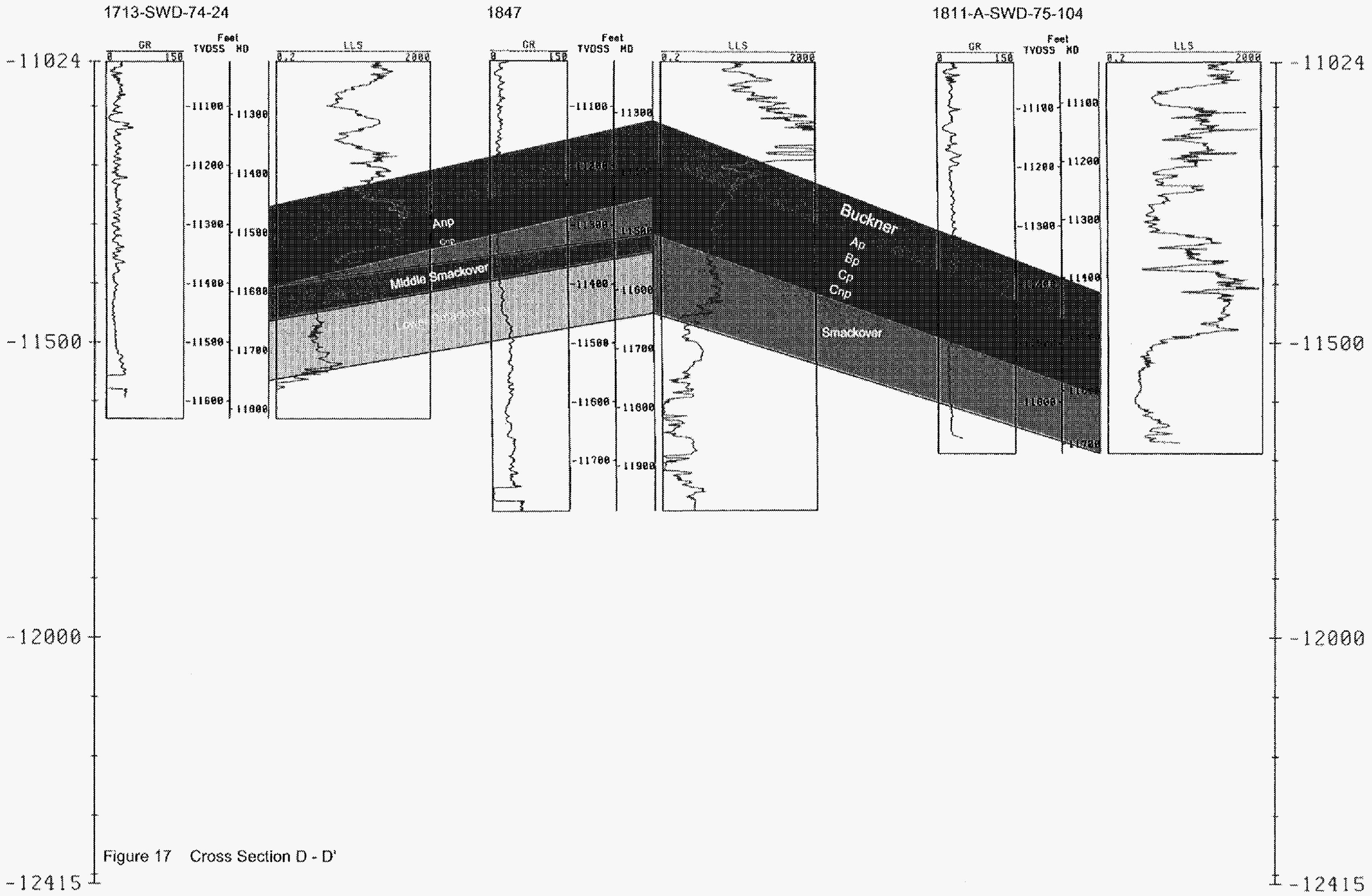


Figure 17 Cross Section D - D'

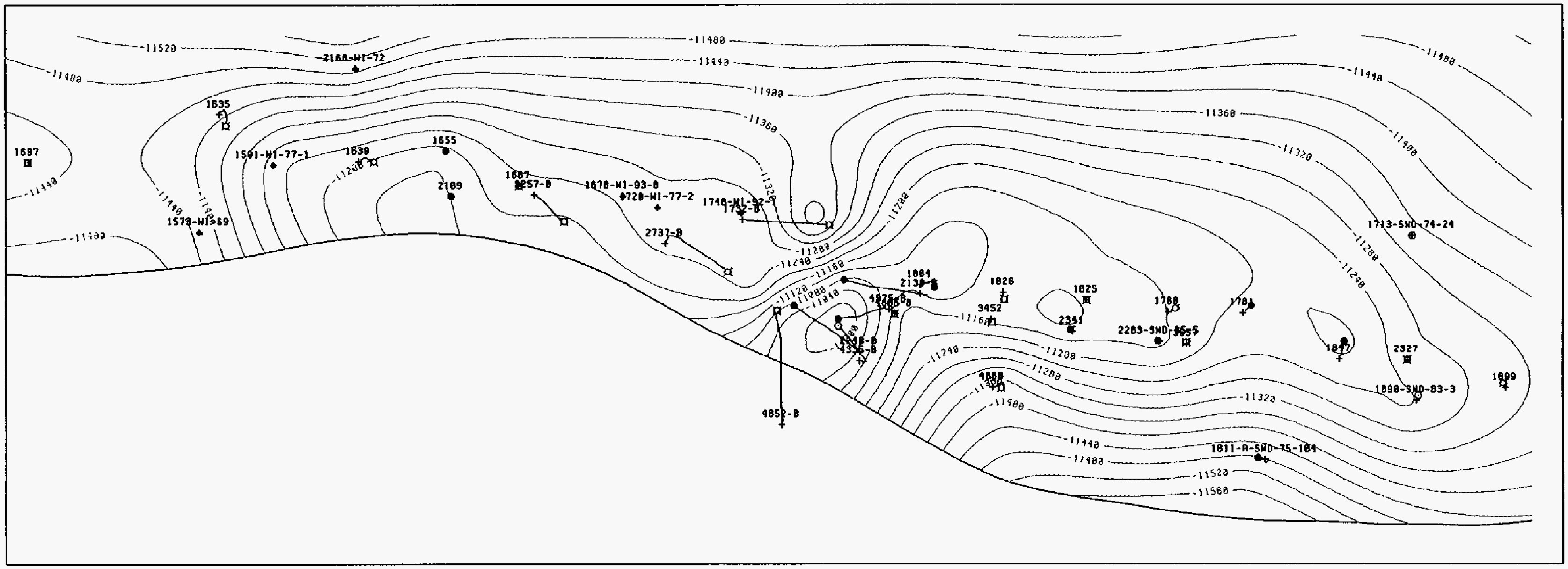


Figure 18. Structure map on top of the Smackover Formation.

Contour Interval = 40 feet

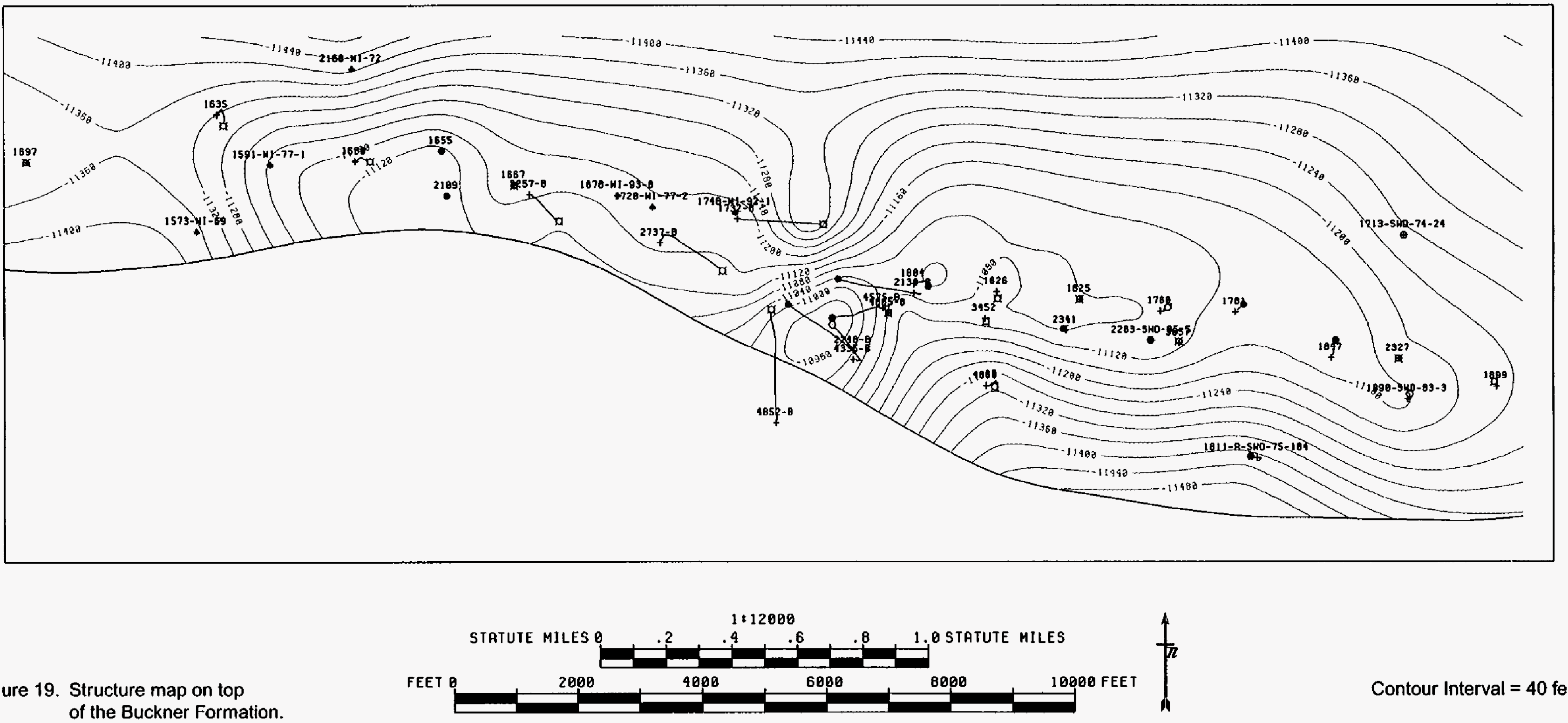


Figure 19. Structure map on top of the Buckner Formation.

Contour Interval = 40 feet

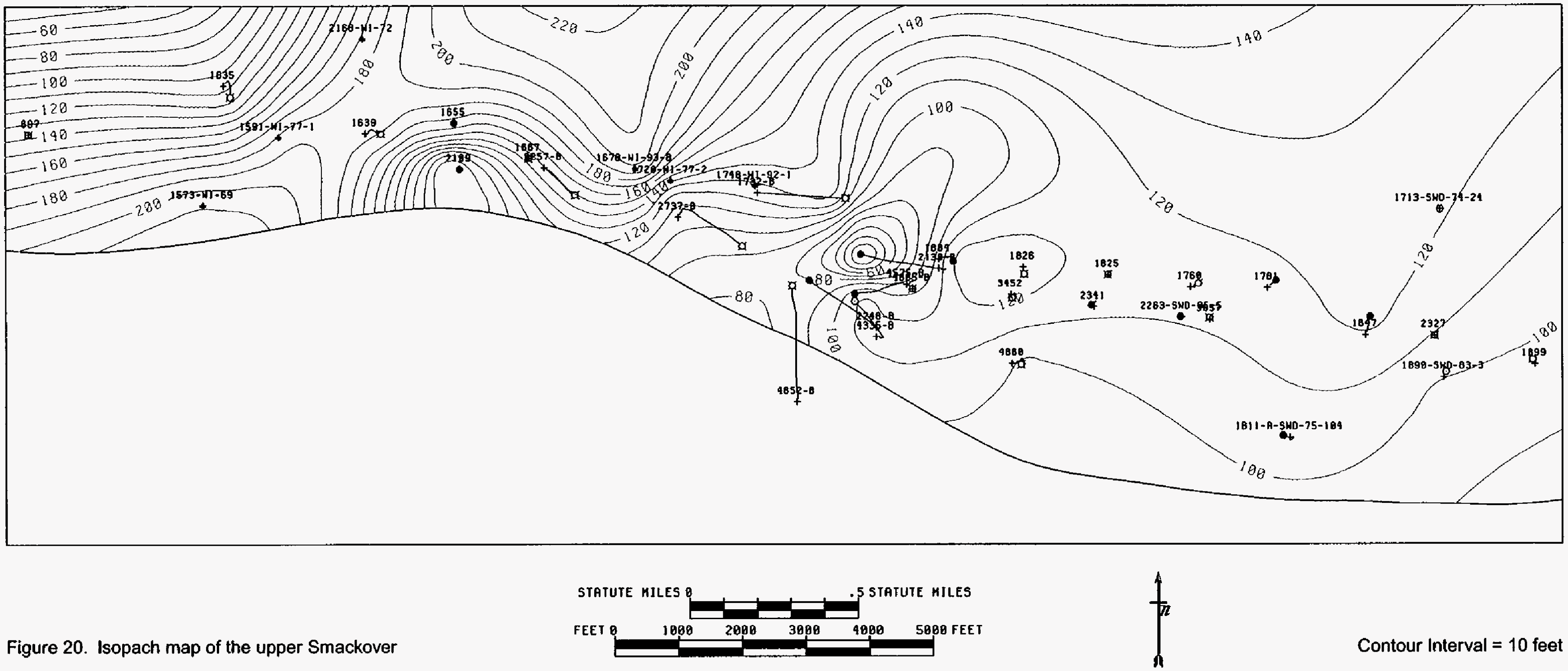


Figure 20. Isopach map of the upper Smackover

Contour Interval = 10 feet

(Figure 21), A cycle (Figure 22), B cycle (Figure 23), C cycle (Figure 24), and the Smackover Formation (Figure 25) have been made using log derived thicknesses.

Subtask 3 encompasses the interpreting of seismic data and performing stratigraphic and structural analysis. Seismic interpretations are guided by the generation of synthetic seismograms resulting from the tying of well log and seismic data and by the comparison of seismic transects with geologic cross sections. Seismic forward modeling and attribute (average frequency, average reflection strength, etc.) characterization are performed in this subtask. Structure and isopach maps constructed from well logs will be refined utilizing the 2-D seismic data. The seismic imaging of the structure and stratigraphy, forward modeling and attribute characterization are accomplished utilizing standard industry software, such as 2d/3d Pak and SeisWorks.

In October 2000, at the Gulf Coast Association of Geological Societies Annual Meeting in Houston, we met with Seismic Exchange, Inc. (SEI) and discussed the availability of seismic reflection data from the Womack Hill Field area. SEI indicated 2-D seismic data were available from the field area. Dave Cate, Pruet Production, reviewed the available data and recommended the purchase of 8 lines (1 W-E and 7 N-S lines across the field). Figure 3 shows the location of these sections. Currently, we are awaiting shipment of the tapes from SEI.

Subtask 4 includes the identification and quantification of organisms, mineralogy, textures (grain, matrix and cement types), pore topology and geometry, and percent of porosity and is performed to support and enhance the visual core descriptions. These petrographic, XRD, SEM and microprobe analyses will confirm and quantify the observations made in the core descriptions. This study provides the opportunity to study reservoir architecture and heterogeneity at the microscopic scale.

Seventy-one thin sections previously available from cores in Womack Hill Field have been described and point counted. Descriptions focused on grain types, cement types, mineralogy (percent calcite, dolomite, anhydrite, and insolubles), percent porosity, pore types, and compaction effects. The descriptions have been used to establish a preliminary diagenetic sequence from sediment deposition through deep burial for the upper Smackover with an emphasis on porosity

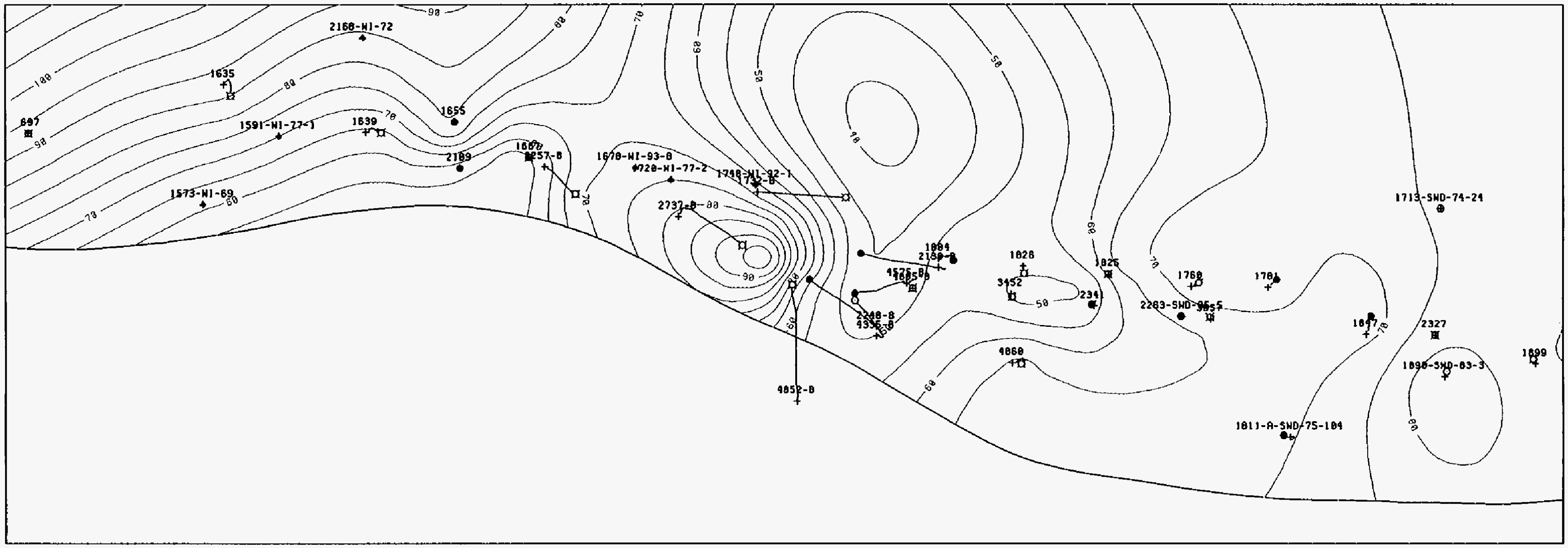


Figure 21. Isopach map of the Buckner Formation.

Contour Interval = 5 feet

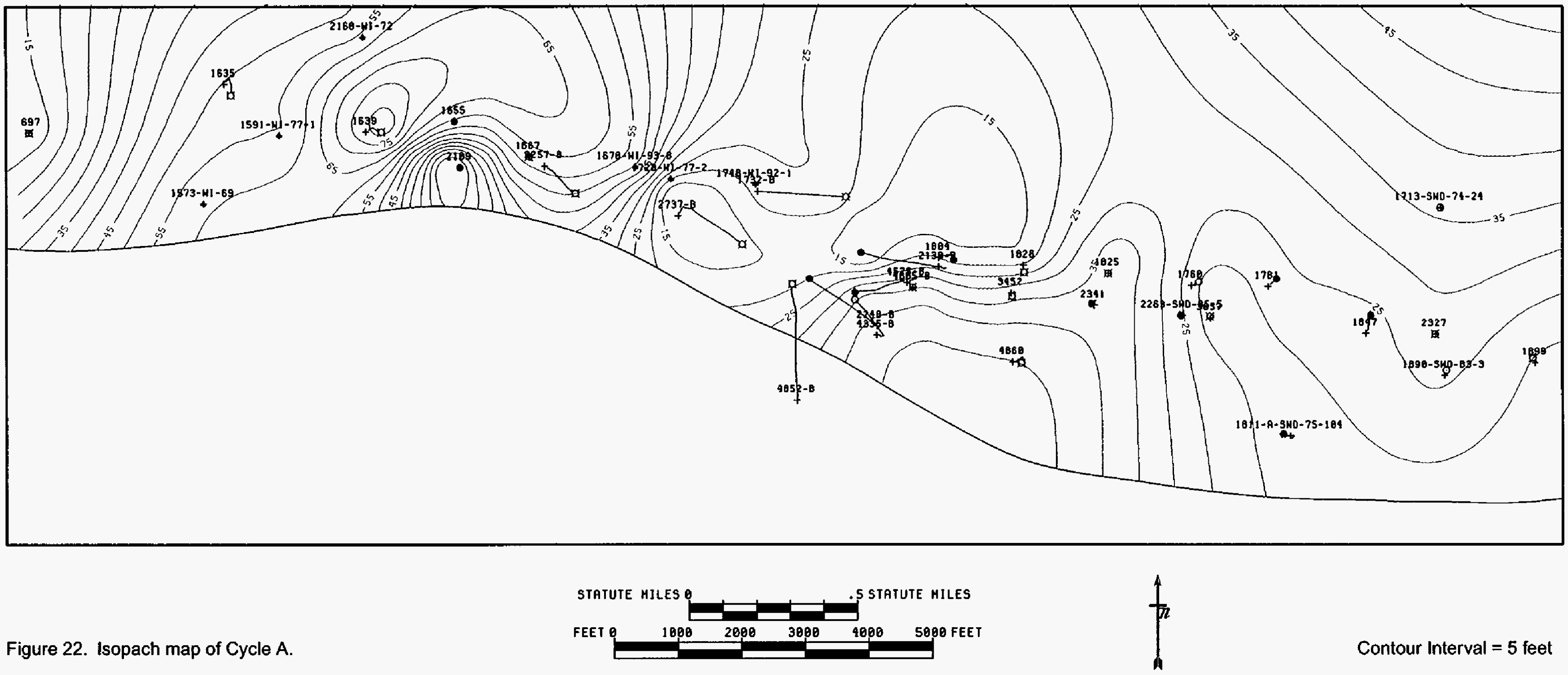


Figure 22. Isopach map of Cycle A.

Contour Interval = 5 feet

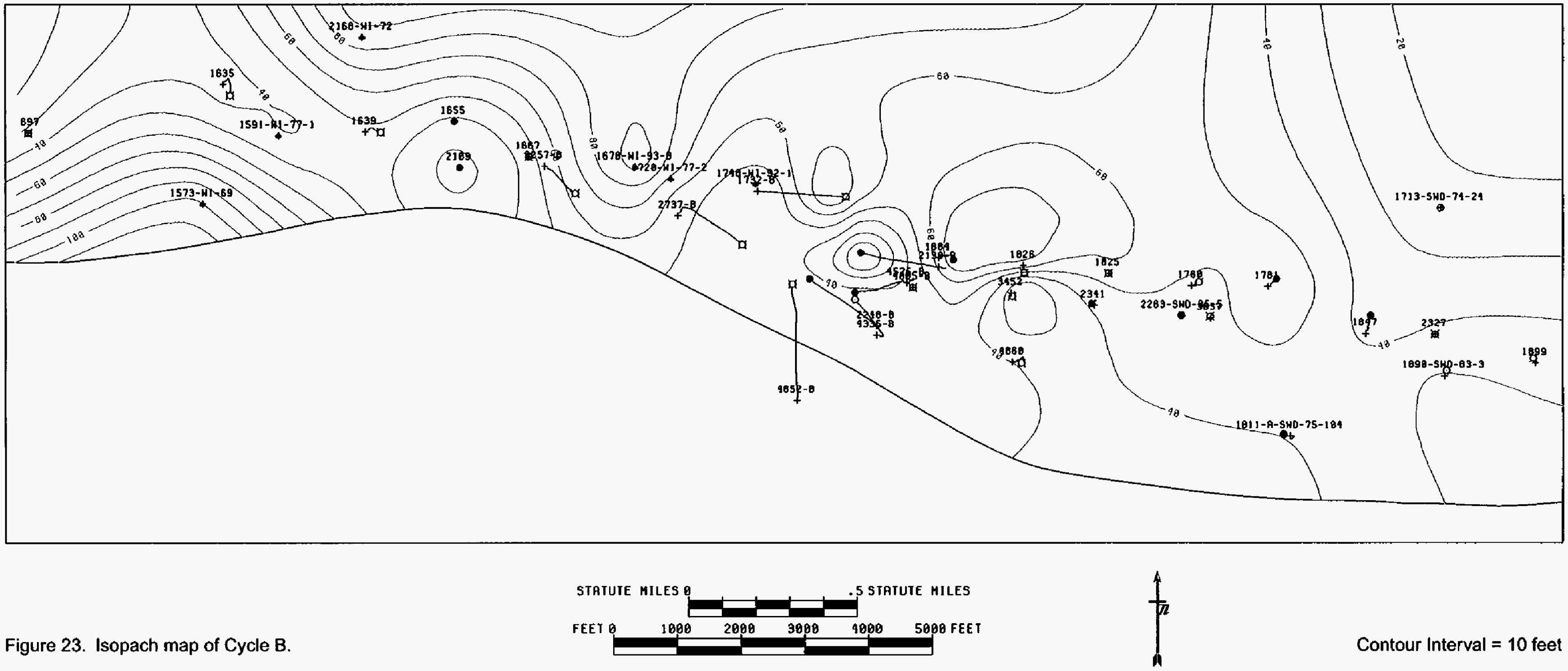


Figure 23. Isopach map of Cycle B.

Contour Interval = 10 feet

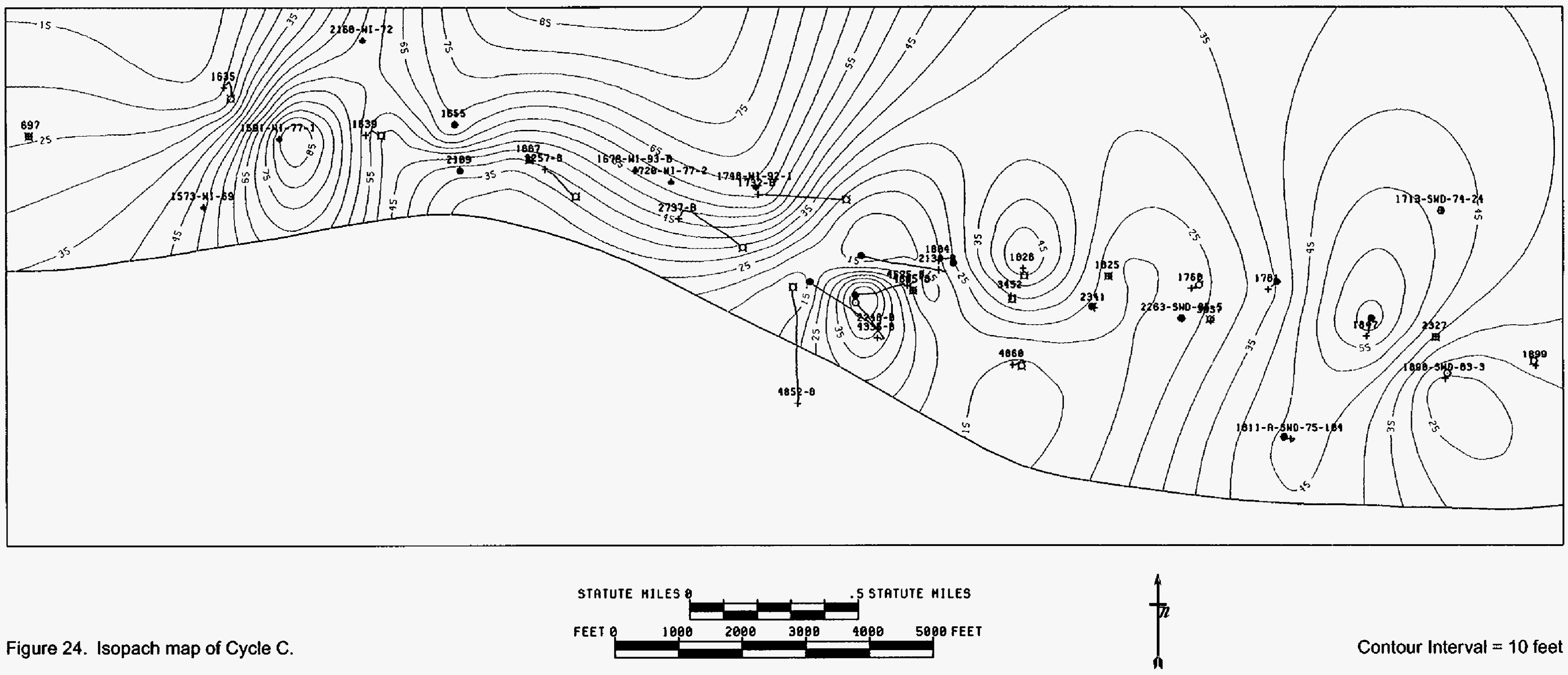


Figure 24. Isopach map of Cycle C.

Contour Interval = 10 feet

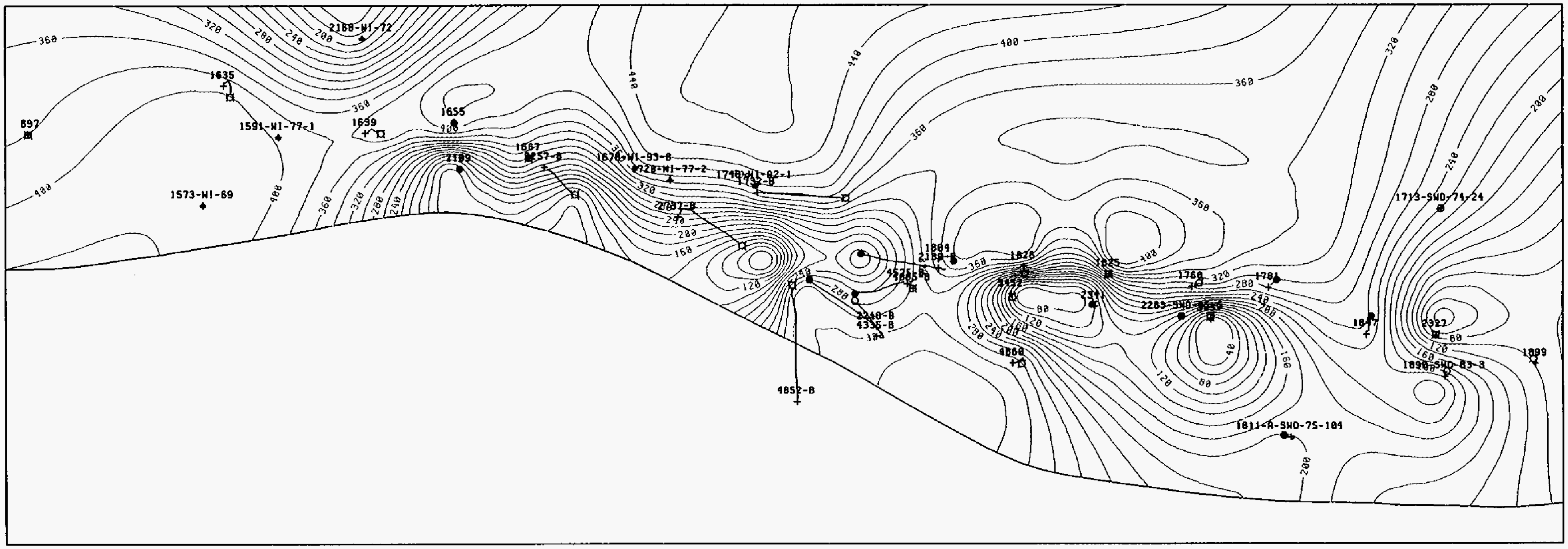


Figure 25. Isopach map of the Smackover Formation.

Contour Interval = 20 feet

destroying or porosity enhancing events. The thin section descriptions have also been used to better fine-tune the reservoir zones and cycle boundaries established from well-log analysis. Point counts of the thin sections allow construction of cross-plots of the different pore types and mineralogy. From these cross-plots porosity relationships have been established and compared with relationships determined previously from well-log analysis and core descriptions. Study of the 118 thin sections is ongoing.

Task RC-2. Petrophysical and Engineering Property Characterization

Description of Work.--This task is designed to focus on the characterization of the reservoir rock, fluid, and volumetric properties. These properties can be obtained from petrophysical and engineering data. This task will assess the character of the reservoir fluids (oil, water, and gas), as well as quantify the petrophysical properties (rock type, grain density, porosity, permeability, electrical properties, etc.) of the reservoir rock. In addition, considerable effort is devoted to the fluid-rock behavior (i.e., capillary pressure and relative permeability). The production rate and pressure histories are cataloged and analyzed for the purpose of estimating reservoir properties such as permeability, well completion efficiency (skin factor), average reservoir pressure, as well as in-place and movable fluid volumes. A major goal is to assess current reservoir pressure conditions and develop a simplified reservoir model (i.e., drive mechanism). New pressure and tracer survey data are scheduled to be obtained in Year 2 to assess communication within the reservoir fieldwide, including among and within the various pay zones in the Smackover. This work will both serve as a guide and provide bounds for the reservoir simulation modeling.

Rationale.--Petrophysical (core, well logs, etc.) and engineering data (production rate and pressure histories, pressure tests, well completion data) are fundamental to the reservoir characterization process. Petrophysical data are often considered static (non-time dependent) measurements, while the engineering data are considered dynamic. The reservoir characterization concept is (almost by definition) the coupling or integration of these two classes of data. The data are analyzed to identify fluid flow units (reservoir-scale flow sequences), barriers to flow, as well as reservoir compartments. The petrophysical data are essential for defining the quality of the reservoir rock, and engineering data (performance data) are crucial for assessing the producibility of the reservoir. Coupling these concepts, via reservoir simulation or via simplified analytical models, allows for the interpretation and prediction of reservoir performance under a variety of conditions.

Subtask 1 involves the review, cataloging, and analysis of available core measurements and well log data. This information will be used to classify porosity, permeability, oil and water saturations, grain density, hydrocarbon show, and rock type for each foot of core. Core data are correlated to the well log responses, and porosity-permeability relationships will be established for each rock type (or depositional unit) evident in the available data.

The engineering efforts for the project began in January 2001 and have consisted of data gathering, interpretation, cataloging, and implementation for future use in the proposed simulation program. While data collection has been very successful thus far, its generation and reporting are considered to be interactive throughout the project life as warranted. Gaps in data have been seen primarily as a result of multiple operators of the Unit, and additional testing may be necessary to bridge these gaps.

The Womack Hill Unit has been effective since 1974, which is both advantageous and problematic from a data collection perspective. The long operating life of the Unit has allowed the accumulation of plentiful data of all types, but the same duration has seen four operators of record. The change of operator invariably brings a different emphasis on the care of the well file system for the Unit, and gaps will occur in the timely collection of data. Further, the Unit production decline coupled with the oil price dip in the late 1990's halted testing activities that had formerly occurred on a regular basis.

To date, core, well log, and well completion data have been acquired and cataloged (core data and well completion data were originally in paper form, well log data are in digital form). An initial attempt has been made to correlate core and well log data in selected cases, and this effort will be extended to all of the wells where such data are abundantly available (Figures 26-31). The issues remaining to be resolved in this work are:

1. Quality Control—Much of the core data is sparsely sampled and there are concerns that these samples may not represent the overall geologic flow behavior of the system. Similarly, all of the core and well log data must be "depth shifted" to a common datum for each well. In general, the core data are given at measured depths, and the well logs have been converted to true vertical depths.
2. Correlation Models—Our initial attempts at a "core-log" correlation were derived using non-parametric regression of these data (which gives a correlation of the data on a point-by-point basis, but does not yield a functional relationship) and from "polynomial surface" models developed using standard non-linear regression techniques.
3. Spatial Correlation of Porosity and Permeability—Once we have achieved representative correlations of permeability for each well, we will then develop spatial correlations of porosity and permeability for the entire Womack Hill Field.

All of the production and injection data have been acquired, cataloged, plotted and several preliminary analyses have been made. The remaining issues are an absence of initial pressure data as well as flowing pressure data. We have identified a number of potential sources for these data, and continued efforts will be made to acquire or estimate relevant pressure information.

Subtask 2 involves the measurement of basic relative permeability and capillary pressure relations for the Womack Hill Field reservoir from existing cores. These data will be compiled and analyzed and then used for reservoir simulation and secondary/tertiary recovery calculations.

A rock plug suitable for measuring permeability was cut from the thin section points (Figure 32). Permeability measurements were run using a laboratory permeameter on 117 samples. Both vertical and horizontal permeabilities were measured on nearly all samples. Except in very rare cases, there was not a significant difference between the vertical and horizontal permeabilities within an individual sample.

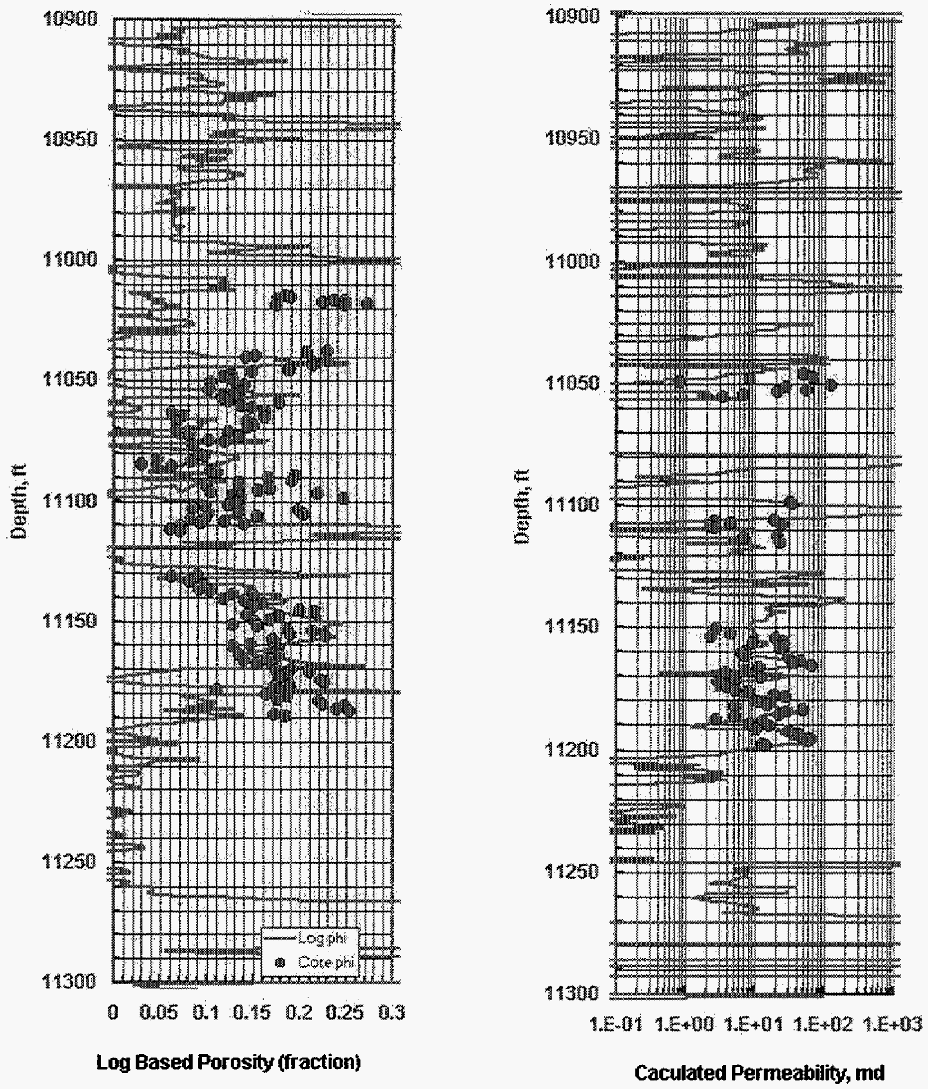


Figure 26. Calculated permeability for the 9-14 well.

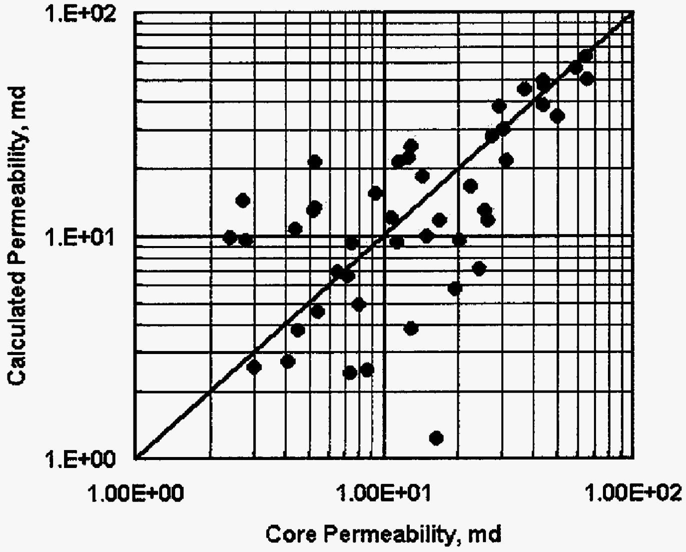


Figure 27. Comparison of core permeability and calculated permeability for the 9-14 well.

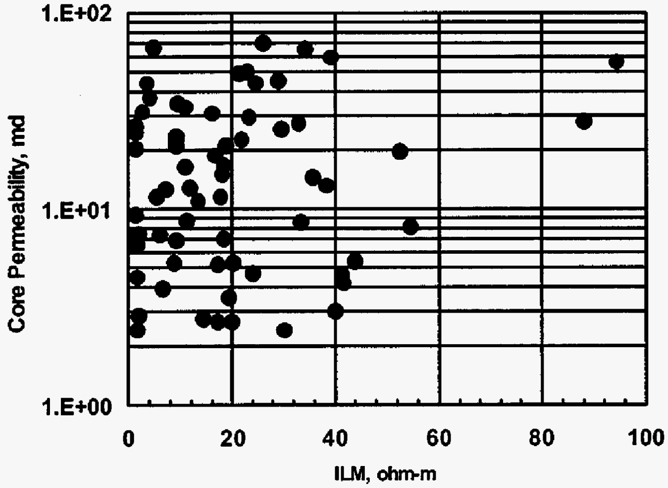


Figure 28. Core permeability versus ILM well log response for the 9-16 well.

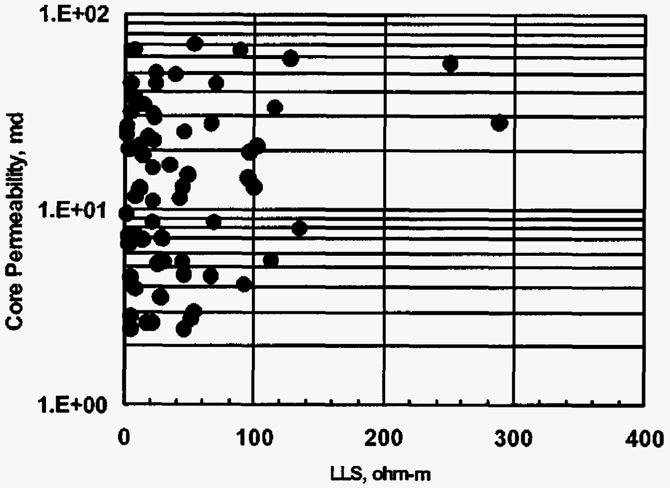


Figure 29. Core permeability versus LLS well log response for the 9-14 well.

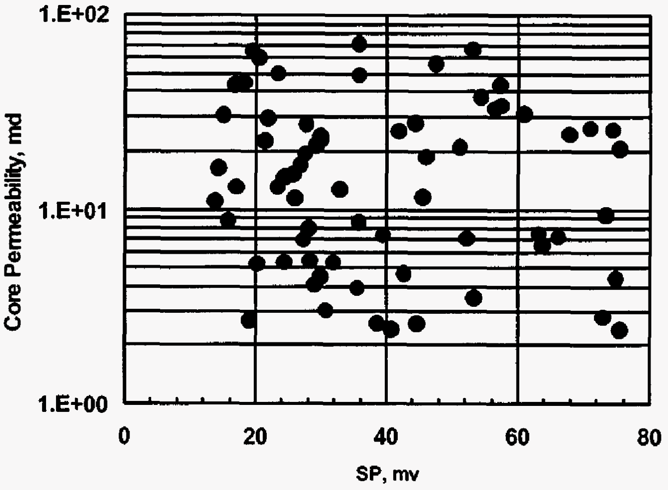


Figure 30. Core permeability versus SP well log response for the 9-16 well.

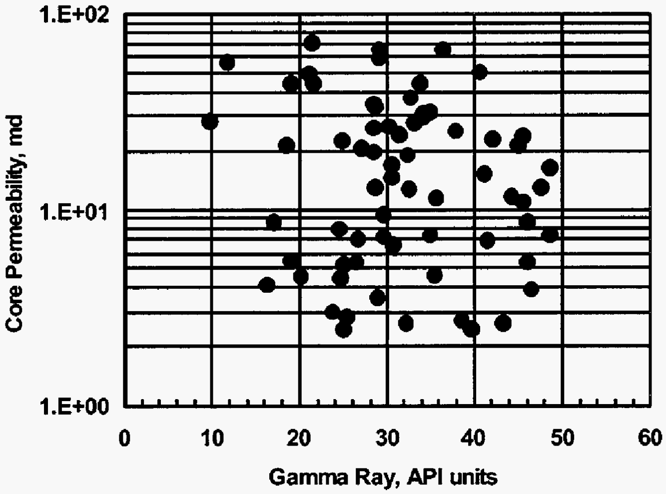


Figure 31. Core permeability versus GR well log response for the 9-14 well.

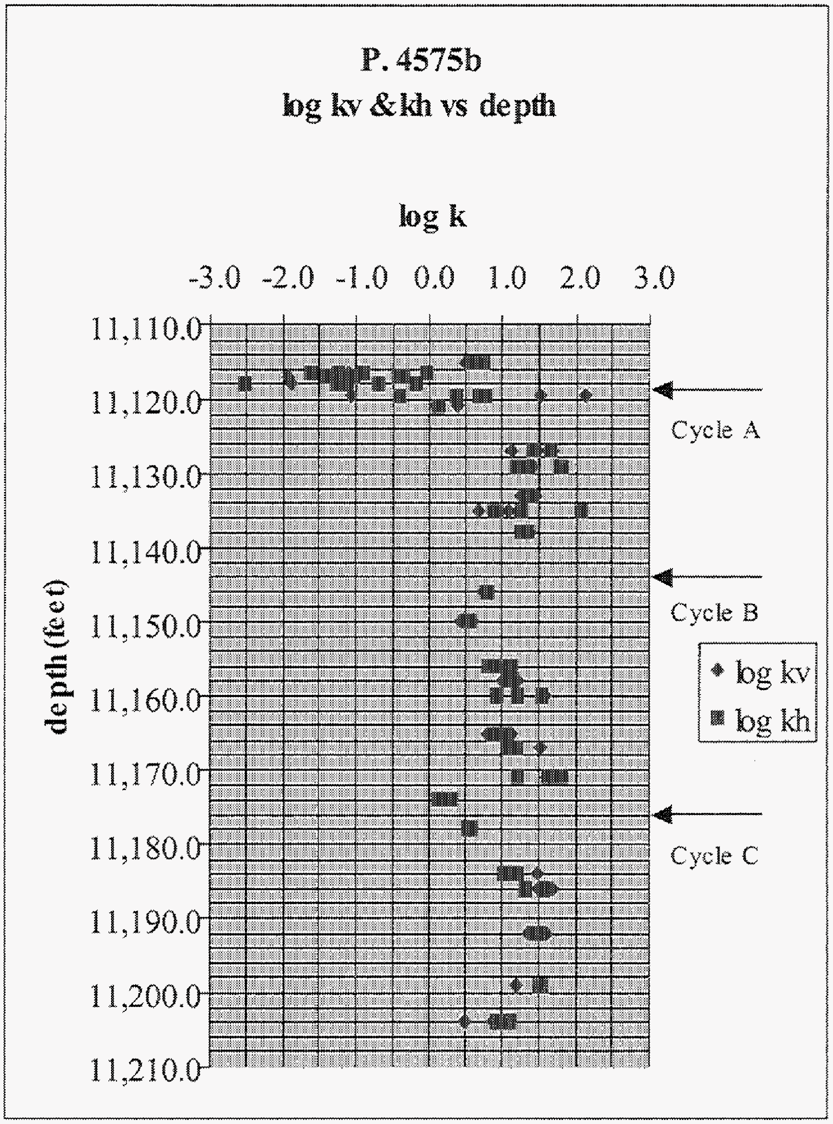


Figure 32. Plot of log permeability (both horizontal and vertical) over depth for the 14-5 #2 well.

Representative samples will be chosen from each A, B, C cycle; a total of approximately 15 samples will be used for Nuclear Magnetic Resonance (NMR) testing. Tests will include determinations of T1, T2, and surface relaxation times. Pore size distributions will be identified from these tests. In addition, approximately 6 of the 15 samples will first be run on a porosimeter, then tested with NMR. Because NMR is non-invasive, these same samples will then be subjected to mercury-injection capillary pressure testing. This will allow for a direct comparison of the different methods and variations between the results. This not only permits statistical variation analyses, but also judgments in cost effectiveness. There is a great disparity between the costs of NMR and mercury-injection capillary pressure. If NMR tests yield similar results, future tests could be run on a greater number of samples, resulting in a greater sampling coverage and therefore a more accurate field model.

Subtask 3 focuses on the collection and cataloging of fluid property (PVT) data. In particular, basic (black oil) fluid property data are available for Womack Hill Field, where these analyses include standard measurements of gas-oil-ratio (GOR), oil gravity, viscosity, and fluid composition. The objective of the fluid property characterization work is to develop relations for the analysis of well performance data and for reservoir simulation.

A conventional "black oil" fluid report developed by Core Laboratories, Inc. (9-15 Well, P-1639) in 1972 has been obtained and processed for use in reservoir engineering calculations and reservoir simulation. In particular, these data have been used to compute oil formation volume factor and solution gas-oil ratio. Gas viscosity and gas formation volume factor data were not available from this report, but these quantities have been estimated using standard industry correlations based on gas gravity, temperature, and pressure.

The preliminary review of the production and injection data for Womack Hill Field has shown that little or no flowing pressure data are available for the production wells. However, there is a considerable body of injection pressure data available, typically tied to the monthly (or daily) injection rate. The primary issue affecting production and injection data analyses is the lack of pressure data; but in addition, we also need to assess the availability of reservoir and fluid property data (e.g., reservoir thickness, formation volume factors, rock and fluid compressibilities, etc.). Figures 33 and 34 depict pressure history for the fields. Figures 35-38 illustrate production history, estimated ultimate recovery and decline type curve analysis for the 9-14 Well (P-1591). Figures 39-42 depict injection history, ultimate recovery and decline type curve analysis for the 15-1 Well (P-1748).

Bottom Hole Pressure (BHP) data have been taken continually but not continuously throughout the producing life of the Unit. These data have been taken when necessary to support a petition to the Alabama State Oil and Gas Board or when it was thought necessary to support an initiative of the operator. As a result, BHP data were found in petition hearing files and to a lesser extent in well files.

BHP's for Unit wells ranged from 4,100 psig to 5,150 psig in the early 1970's. Records show a rapidly decreasing BHP such that the need for enhanced recovery was apparent only two years after field discovery. Core Laboratories estimated that the BHP would have declined to 3,250 psi at the beginning of 1976 if injection had not begun.

BHP tests have been sporadic throughout the field. One operator ran BHP tests almost monthly during the late 1980's, but in general, these data were taken in the 1970's at the outset of unitization, during the late 1980's, and only occasionally to date. BHP's are estimated as being around 1,800 psi at the present time.

The 14-5#2 Well (P-3656-B) shows a history of BHP data that indicates that the pressure has not followed a monotonic decrease. The following data from the 14-5#2 suggest that the BHP can increase or decrease according to injectivity or other reasons. All data are from the late 1980's and early 1990's in this sequence. The predecessor well, the Unit 14-5 Well, also had BHP data taken in the early 1970's and again in the 1980's onward.

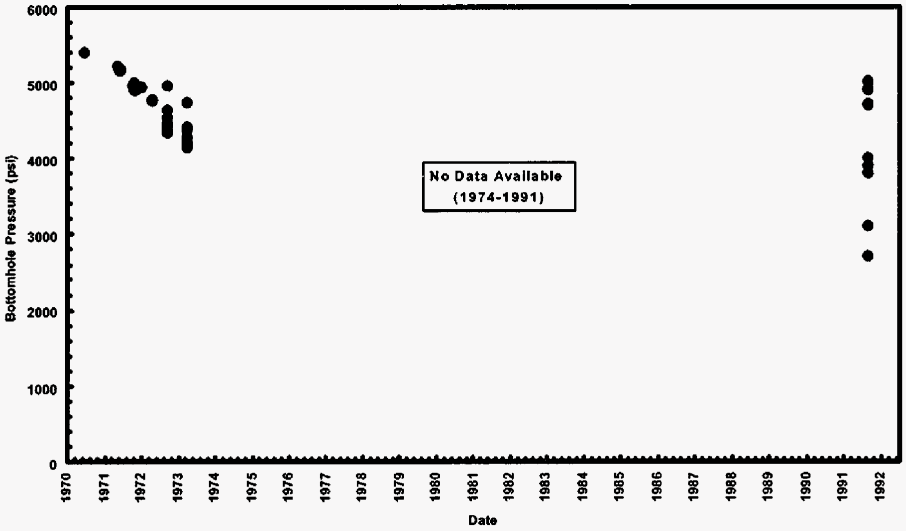


Figure 33. Pressure history for Womack Hill Field (as a function of date).

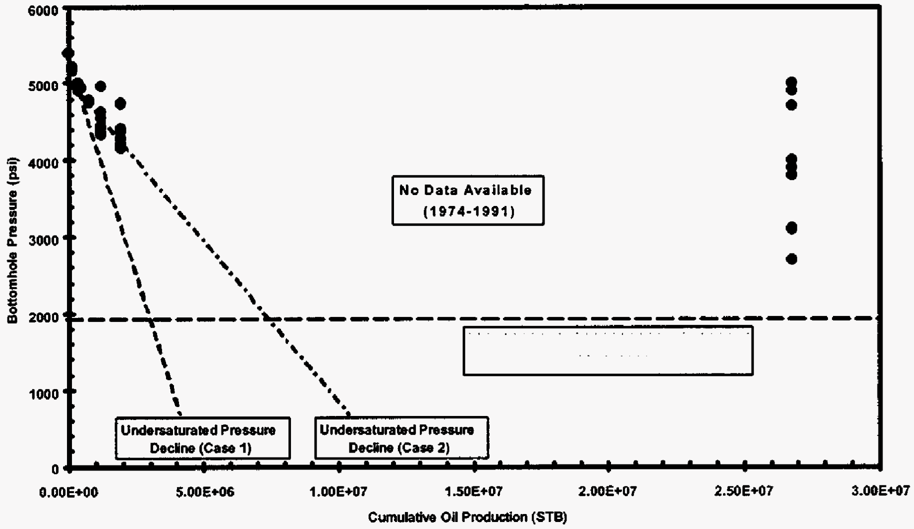


Figure 34. Pressure history for Womack Hill Field (as a function of cumulative oil production).

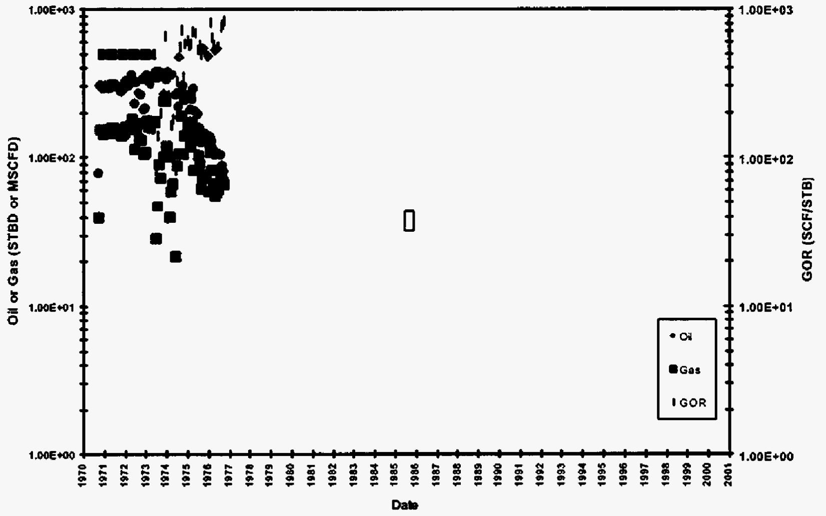


Figure 35. Production history for the 9-14 well.

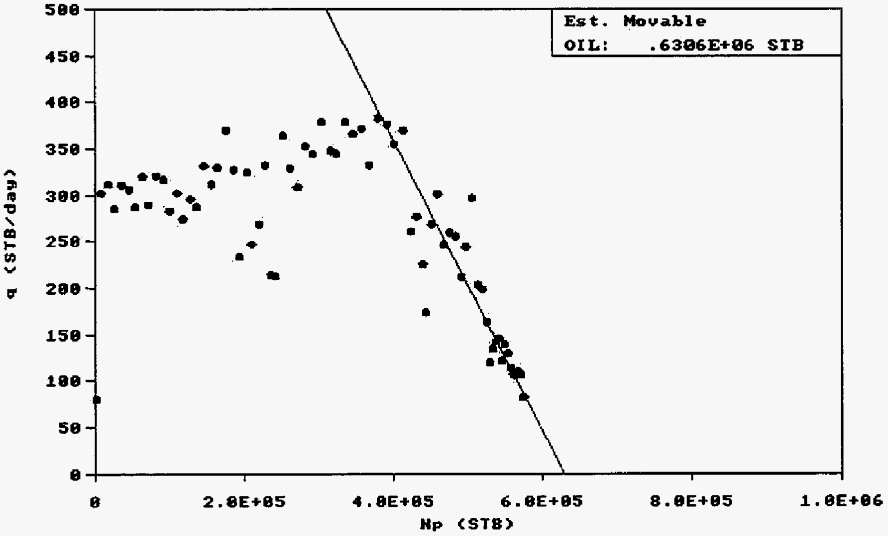


Figure 36. EUR plot for the 9-14 well (movable oil).

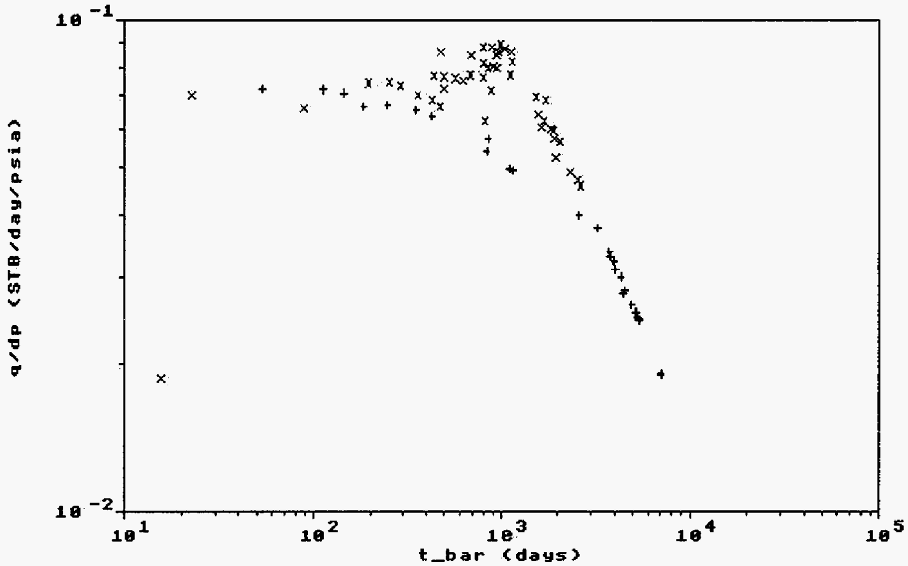
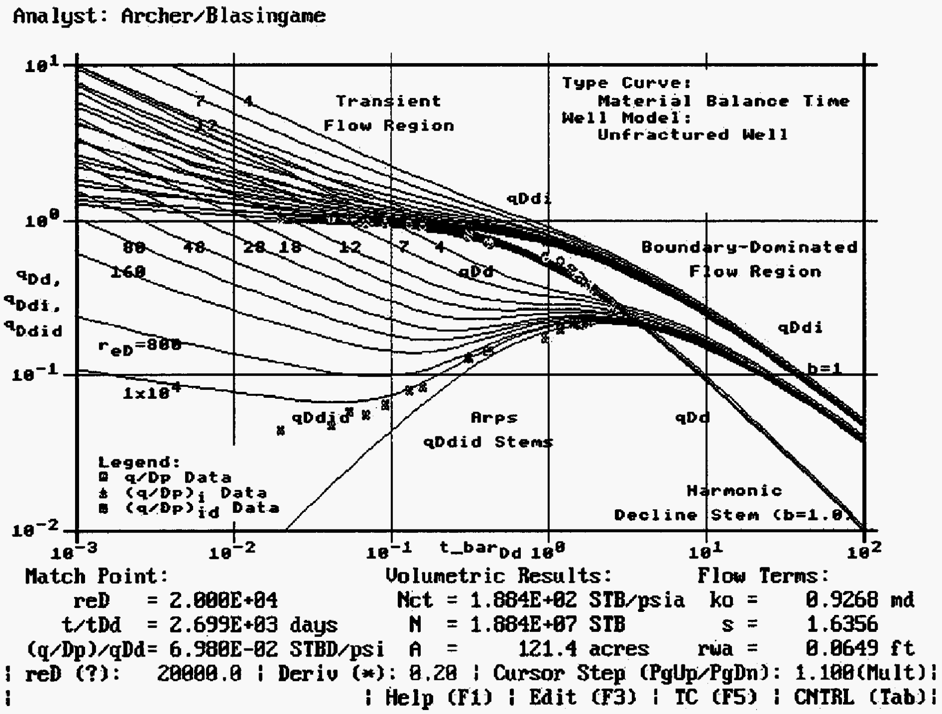


Figure 37. Data editing plot for the 9-14 well.



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Match Point:                    Volumetric Results:        Flow Terms:
    reD    = 2.000E+04           Nct = 1.884E+02 STB/psia  ko =    0.9268 md
   t/tDd   = 2.699E+03 days       N  = 1.884E+07 STB         s =    1.6356
 (q/Dp)/qDd= 6.980E-02 STBD/psi  A  =      121.4 acres     rwa =    0.0649 ft
| reD (?):   20000.0 | Deriv (*): 0.20 | Cursor Step (PgUp/PgDn): 1.100(Mult)|
|                                | Help (F1) | Edit (F3) | TC (F5) | CNTRL (Tab)|
```

Figure 38. Decline type curve analysis plot for the 9-14 well.

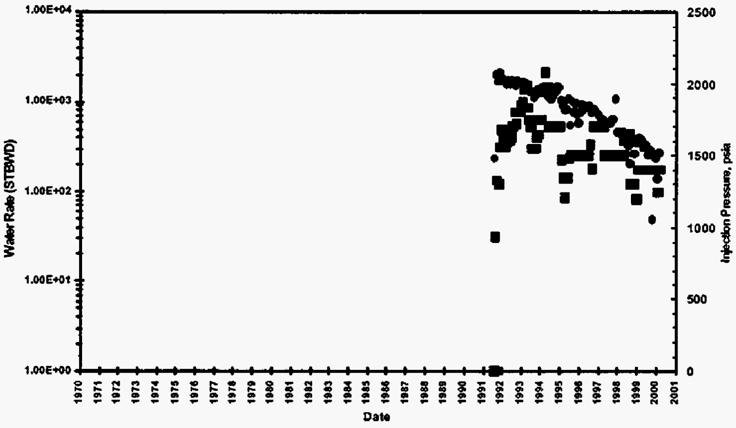


Figure 39. Injection history for the 15-1 well.

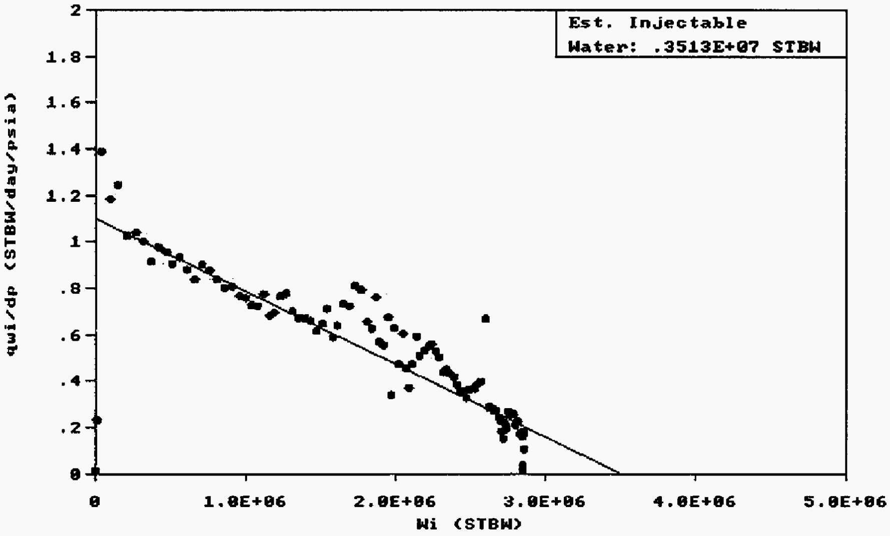


Figure 40. EUR plot for the 15-1 well ("injectable" water).

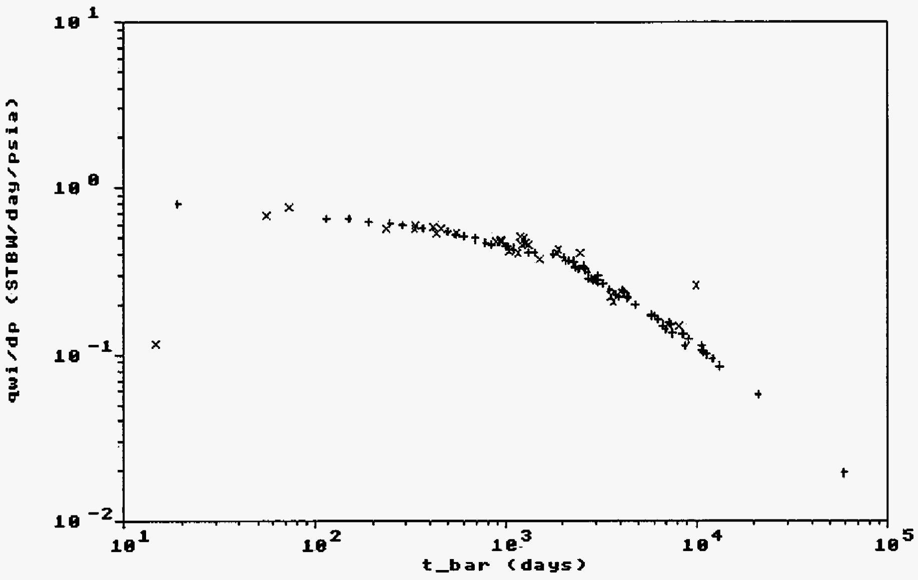
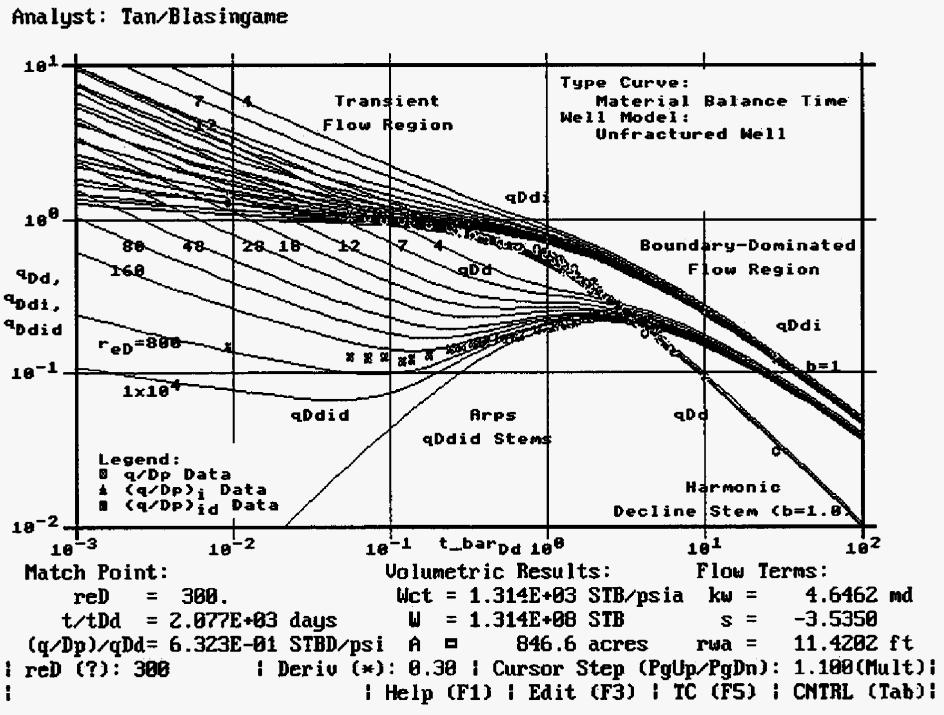


Figure 41. Data editing plot for the 15-1 well.



```
Match Point:                    Volumetric Results:       Flow Terms:
    reD    =  300.                Wct = 1.314E+03 STB/psia  kw =    4.6462 md
   t/tDd   = 2.077E+03 days        W  = 1.314E+08 STB         s =   -3.5350
(q/Dp)/qDd= 6.323E-01 STBD/psi     A  =     846.6 acres      rwa =   11.4202 ft
| reD (?): 300         | Deriv (*): 0.30 | Cursor Step (PgUp/PgDn): 1.100(Mult)|
|                               | Help (F1) | Edit (F3) | TC (F5) | CNTRL (Tab)|
```

Figure 42. Decline type curve analysis plot for the 15-1 well.

DATE	BHP (psig)
10-13-88	2101
07-20-89	1792
07-27-89	1939
08-17-89	1938
09-15-89	1938
12-20-89	1975
03-06-90	2140
04-10-90	2006
10-20-92	2786
04-30-93	2813
10-12-93	2663
05-18-94	2721

These data show that the BHP had decreased to below 1,800 psig in 1989, only to increase to over 2,700 psi by 1994. Evidently, injected fluid was reaching this well.

File data show that PVT data were taken in 1972 prior to unitization. The operator at that time retained Core Laboratories to provide these data. The essence of these initial PVT analyses was as follows:

Reservoir temperature	212° F.
Bubble point pressure	1925 psig
GOR	844 scf/bbl at 60° F.
FVF	1.641 bbl/bbl
Viscosity	0.342 cp at the saturation pressure, to a maximum of 1.210 cp at atmospheric pressure
Gravity	36.5° -42.6° API at 60° F.
Z	0.900

Subtask 4 is used to develop a performance-based reservoir characterization of the Womack Hill Field. This subtask focuses exclusively on the analysis and interpretation of well performance data (production/injection rates and pressures) as a mechanism to predict recoverable fluids and reservoir properties. This analysis is dominantly focused on the production data, but any other well performance data will also be considered, in particular, pressure transient test data, injection data, and well completion/stimulation data will also be analyzed and integrated into the reservoir

description. Historical pressure data will be compared to new pressure and tracer survey data for both unit and field wells obtained as part of this subtask.

Presently, the following Unit wells are active:

Producing		**Water Injection**	
Unit 14-5#2	P-3656-B	Unit 10-14	P-1678
Unit 9-16	P-1655	Unit 15-2	P-1720/1720-WI-77-2
Unit 9-16A	P-2109	Unit 15-1	P-1748-WI-92-1

The Turner 14-6 Well is in the Unit reservoir. The 15-1 WIW well is located near the Tombigbee River and is on a scour shore. As a result, the river has encroached to within 50 ft of the wellhead. This well is scheduled for abandonment in 2001. Injectivity tests have shown that the water injected in this well is at a relatively low rate and has not had a discernible effect on waterflood performance.

All wells in the Unit, regardless of status, were investigated to determine workover history and dates of status changes. At all status changes, the perforation configuration was studied to determine if meaningful change occurred. For example, several wells had the Smackover perforation interval lengthened upward. Typical of these wells was the 14-4A Well (P-2130), a producer since December 1975. Originally perforated at 11,394-11414 ft, the perforation interval was extended upward to 11,374 at an unknown date. These perforations were sealed by squeeze cementing in January 1997 and reperforated at 11,320-11,340 ft, considerably uphole. The new perforated interval has not been productive and the well is now shut in. In like fashion, the 15-8 Well (P-2248B) was originally perforated at 11,331-11,352 ft, but these perforations were sealed in May 1996 and the new perforated interval at 11,306-11,316 ft has not been economic. The well is now shut in.

All Unit wells were included in a spreadsheet to show sequential well status changes. An example of this spreadsheet notation is shown below.

Well	Original Status	Workovers	Current Status
WHFU 15-1	Producer	Converted To WIW	WIW
Permit 1748	09-72	12-91	
	pf 11,296-11,311	pf 11,298-11,312	
		pf 11,344-11,374	

An interesting aspect of fluid flow in the Smackover emerged that will be considered in the model. The WHFU 15-8#1 Well produced an anomalous water cut consistent with its structural location. This is suspected to have resulted from a later well, also designated as the 15-8 Well drilled to the Norphlet but abandoned during the drilling process by stuck drill string. The upper Smackover is thought to be open in the latter well, thereby permitting flow out of the Norphlet into the Smackover. A workover was proposed in 1992 to recomplete the Unit well in a Smackover interval thought to be isolated from the Norphlet invasion. At that time, it was thought that the Norphlet had a 5,500 psi BHP vs. the relatively lower 2,600 psi in the Smackover. This workover was approved and completed, but the well never regained its former production rate and was temporarily abandoned in 1996.

Task RC-3. Microbial Characterization

Description of Work.--This task is designed to determine whether *in-situ* microorganisms are present in the Smackover carbonate reservoir at Womack Hill Field and will determine through laboratory experiments the ability of these microbes to produce a single by-product (acid) by supplying them with only enough nutrients to sustain the cells but not enough to support cell proliferation.

Rationale.--Researchers at Mississippi State University have demonstrated the cost-effectiveness of utilizing the growth of indigenous microbes in enhancing the efficiency of an active waterflood for the recovery of incremental oil. The technology involves injecting a regulated stream of nutrients into a sandstone reservoir at a subsea depth to stimulate indigenous microbe growth. Cell proliferation by these microorganisms acts to reduce the flow of injected water in more permeable zones of the reservoir by selective plugging, thereby diverting the water to other areas of the reservoir. This diversion and altering of flow patterns in the reservoir serve to enhance the sweep efficiency of the waterflood. This technology will be expanded upon in this study by using the ability of these microbes to produce a single by-product (acetic acid).

This immobilized enzyme technology is scheduled to be applied to the carbonates at a depth of 11,300 ft in Womack Hill Field. It is anticipated that the acetic acid will act to break down the Smackover reservoir through dissolution thereby creating enhanced reservoir connectivity.

Subtask 1 includes characterizing the microflora present in the core material and/or produced fluids for the Womack Hill Oil Field Unit in terms of their ability to act as a source of enzymes that convert alcohols to acids and to determine the nutritional requirements to maintain the cells in a metabolically active state with minimal replication. When microbial cells are operating in an immobilized enzyme mode they are not reproducing but rather they are serving as an enzyme holder for enzymes to carry out a specific reaction—namely the conversion of ethyl alcohol to acetic acid in the current project. The cells will perform only a limited amount of repair during this time and virtually no reproduction will take place in the absence of a supply of nitrogen. Therefore, only a small periodic addition of a nitrogen source to the injection water will be required for cell maintenance in order to maintain enzymatic activity. The key to success will be to supply a sufficient amount of nitrogen to the cells for repair, and perhaps a small amount of reproduction, but not enough to allow vigorous growth. Therefore, experiments will be conducted to determine the concentration and amount of potassium nitrate to satisfy the above requirements.

Orthophosphate is the usual source of phosphorus for microbial growth but it could react with constituents in the reservoir to such an extent that it would become unavailable to the microorganisms. Therefore, some experiments will involve adding measured amounts of crushed core material to different concentrations of a sodium dihydrogen phosphate solution and measuring a loss of phosphate from the solution. If the loss of phosphate is not significant, work will proceed to the next series of experiments. If most of the phosphate is lost, another source of phosphorus will be tested for its ability to serve as a source of phosphorous for the microorganisms and not react with reservoir constituents.

Ethanol is a protein-denaturing agent and therefore it is critical to supply the microflora with the ethanol at a concentration below that which will harm the cells. Obviously, the greater the amount of ethanol added, the greater the amount of acid produced and thus experiments will be conducted to determine the concentration of ethanol that results in the production of the greatest amount of acid.

All experiments will be conducted anaerobically at the reservoir temperature. On the basis of the results from the above studies, a tentative program for the amounts of chemicals to be utilized in the field demonstration and the schedule for their addition will be formulated.

On September 21, 2000, two core samples were taken from the Womack Hill Field Unit 14-5 #2 Well. This core was obtained from the field in 1985. Although the probabilities of finding viable organisms in the samples are remote, their presence was possible since any organisms in the core would unquestionably be in a dormant state (e.g. as ultramicrobacteria).

Two small samples (1-inch diameter) were obtained from the cores, crushed under a nitrogen atmosphere, and each core sample used to inoculate 12 VOA vials, each containing 20.0 ml of simulated injection water. Four samples of each core sample were prepared with 1.0 g/l of KNO_3 as a nitrogen source and 0.38 g/l of K_2HPO_4. Four samples were prepared with 0.1 g/l of KNO_3 and 0.038 g/l K_2HPO_4 and four with 0.01 g/l of KNO_3 and 0.0038 g/l of K_2HPO. Two samples of each set were prepared with oxygen and two were gassed with nitrogen to create anaerobic conditions. All the samples were incubated at 93°C and observed for growth.

Four water samples from the Womack Hill Turner 13-6 Well were received in December of 2000. Two samples were fresh water and two were salt water. Twenty ml of mineral salts medium (MSM) were transferred to a 60 ml VOA capped with a 24 mm Mininert valve. The atmosphere of the vial was replaced with nitrogen. Five ml of crude oil was transferred into the vial and the atmosphere was again replaced with nitrogen. Four samples were prepared. Two were inoculated with salt water sample #3 and two with salt water sample #4. The sediment at the bottom of the sample was used as the inoculum. The samples then were incubated at 93°C and observed for growth.

Enrichment cultures were also prepared with the Womack Hill oil samples. Three ml of the sample was transferred into a 60 ml VOA vial containing 20.0 ml of simulated injection water. Sodium nitrate (0.12%) was added as a nitrogen source and sodium phosphate (0.03%) was added as a phosphorous source. The atmosphere of each sample was replaced with nitrogen and the samples incubated at 93°C and periodically observed for growth.

The MSM employed above was prepared by adding 1.0 g of KNO_3, 0.38 g K_2HPO_4, 0.2 g $MgSO_4 \cdot 7\ H_2O$, and 0.05 g $FeCl_3 \cdot 6\ H_2O$ to 1.0 l of distilled water. The pH was adjusted to 7.0 with 10% KOH.

The simulated injection water employed above was prepared by combining 10.9 g $CaCl_2$, 2.71 g $MgCl_2$, 4.57 $BaCl_2$, 1.48 Na_2SO_4, and 147.8 g NaCl with 50.0 l of distilled water. The pH was adjusted to 7.0 with 10% HCl or with 10% KOH.

To date, none of the above enrichment samples has shown any evidence of growth, but it is not unusual for such cultures to take months before growth will become evident. All samples are still being incubated and observed periodically.

Arrangements have been made to obtain live core material from a well being drilled into the same formation (Smackover) that is producing in the Womack Hill Oil Field Unit and situated within five miles of it. It is expected that microorganisms will be isolated from these samples and will be characterized as to their nutritional requirements to convert ethanol to acetic acid.

Sample preparation and imaging procedures for confocal and scanning electron microscope (SEM) are being developed. Samples of the Lower Cretaceous Walnut Formation with similar mineralogy, texture, and pore geometries as the Smackover Formation have been inoculated with bacteria and fed in order to approximate the rock and organic samples from the Womack Hill reservoir. The purpose of these experiments is to develop and evaluate techniques that preserve the organic textures and allow study of the relationships between the organic material and the porosity and rock matrix.

Several sample preparation procedures for SEM analysis are being evaluated. Most involve primary fixation of organic matter by glutaraldehyde. Experiments are being performed in order to evaluate the importance of subsequent ethanol and acetone dehydration, and critical point and freeze drying. Samples prepared by these different techniques will be analyzed by SEM in order to determine which procedure best preserves the *in situ* bacterial and microfilm textures. The chosen procedures will be used for SEM analysis of the Womack Hill samples. SEM analysis allows high-magnification investigation of organic/inorganic samples using low-energy electrons which are unlikely to cause textural damage to the samples.

Larger-scale organic/inorganic relationships will be studied using standard petrographic and confocal microscopy. Different fluorescent stains (such as cell wall, live vs. dead, biofilm, etc.) are being tested on Walnut and other samples for conoscopic study. Ultra-thin flat samples will be produced by low-viscosity vacuum impregnation and diamond microtoming. These samples also will be studied using the confocal microscope.

Work Planned in Year 2

The work planned for Year 2 includes the following.

Task RC-1.--Geoscientific Reservoir Characterization

Description of Work.--This task will characterize reservoir architecture, pore systems and heterogeneity based on geological and geophysical properties (Tables 1 and 6).

Rationale.--Reservoir characterization is fundamental to determining reservoir architecture, pore systems, and heterogeneity. It is critical in the design of a cost-effective fieldwide reservoir management strategy and for making sound operational decisions. Deformational (structural), depositional, and diagenetic processes exert the major influences on reservoir quality and evolution and produce heterogeneities at various scales. To predict accurately changes in reservoir quality, heterogeneity, and producibility in interwell areas, it is crucial to characterize and understand the processes that produce carbonate rock textures and the diagenetic fluid-rock interactions that have altered the primary rock fabric and pore system.

Subtask 5 is a continuation of studying reservoir architecture and heterogeneities at the microscopic scale. Diagenesis is believed to be a key to the producibility of the Smackover reservoir at Womack Hill Field. This study involves determining the paragenetic sequence for the

Table 6
Milestone Chart—Year 2

Tasks (Phase I)	M	J	J	A	S	O	N	D	J	F	M	A
Reservoir Characterization												
Geoscientific	▨	▨	▨									
Petrophysical and Engineering	▨	▨	▨	▨	▨	▨						
Microbial	▨	▨	▨	▨	▨	▨						
Data Integration	▨	▨	▨	▨	▨	▨	▨	▨	▨			
Recovery Technology Analysis												
3-D Geologic Modeling									▨	▨	▨	▨

Work Planned ▨
Work Accomplished xx

Smackover reservoir in this field. This subtask includes determining the pore types and their nature, the origin of primary and secondary porosity, the timing of compaction and cementation, the cement types, the nature and timing of carbonate dissolution, the nature and timing of dolomitization (seepage reflux or mixed water), and the timing of hydrocarbon migration.

Subtask 6 involves the study of pore systems in the Smackover reservoir at Womack Hill Field, including pore types and throats through SEM analysis. This subtask will examine the pore shape and geometry and the nature of the pore throats in the reservoir at Womack Hill Field to determine the features of the pore systems that are affecting reservoir producibility. The nature (interparticulate, shelter, moldic, intercrystalline, vuggy) and origin (depositional, dissolution, dolomitization) of the pore systems will also be studied.

Task RC-2. Petrophysical and Engineering Property Characterization

Description of Work.--This task focuses on the characterization of the reservoir rock, fluid, and volumetric properties. These properties can be obtained from petrophysical and engineering data. This task will assess the character of the reservoir fluids (oil, water, and gas), as well as quantify the petrophysical properties (rock type, grain density, porosity, permeability, electrical properties, etc.) of the reservoir rock. In addition, considerable effort will be devoted to the fluid-rock behavior (i.e., capillary pressure and relative permeability). The production rate and pressure histories will be cataloged and analyzed for the purpose of estimating reservoir properties such as permeability, well completion efficiency (skin factor), average reservoir pressure, as well as in-place and movable fluid volumes. A major goal is to assess current reservoir pressure conditions and develop a simplified reservoir model (i.e., drive mechanism). New pressure and tracer survey data will be obtained to assess communication within the reservoir fieldwide, including among and within the various pay zones in the Smackover. This work will both serve as a guide and provide bounds for the reservoir simulation modeling.

Rationale.--Petrophysical (core, well logs, etc.) and engineering data (production rate and pressure histories, pressure tests, well completion data) are fundamental to the reservoir characterization process. Petrophysical data are often considered static (non-time dependent) measurements, while the engineering data are considered dynamic. The reservoir characterization concept is (almost by definition) the coupling or integration of these two classes of data. The data are analyzed to identify fluid flow units (reservoir-scale flow sequences), barriers to flow, as well as reservoir compartments. The petrophysical data are essential for defining the quality of the reservoir rock, and engineering data (performance data) are crucial for assessing the producibility of the reservoir. Coupling these concepts, via reservoir simulation or via simplified analytical models, allows for the interpretation and prediction of reservoir performance under a variety of conditions.

Subtask 1 involves the review, cataloging, and analysis of available core measurements and well log data. This is a continuation of Year 1 work. Core data will continue to be correlated to the well log responses, and porosity-permeability relationships will be established for each rock type (or depositional unit) evident in the available data.

Subtask 2 involves the measurement of basic relative permeability and capillary pressure relations for the Womack Hill Field reservoir from existing cores. These data will continue to be compiled and analyzed in Year 2 and then used for reservoir simulation and secondary/tertiary recovery calculations.

Subtask 4 to develop a performance-based reservoir characterization of the Womack Hill Field will continue into Year 2. Historical pressure data will be compared to the new pressure and tracer survey data for both unit and field wells obtained as part of this subtask.

Task RC-3.--Microbial Characterization

Description of Work.--This task will determine whether *in-situ* microorganisms are present in the Smackover carbonate reservoir at Womack Hill Field and will determine through laboratory experiments the ability of these microbes to produce a single by-product (acid) by supplying them with only enough nutrients to sustain the cells but not enough to support cell proliferation.

Rationale.--Researchers at Mississippi State University have demonstrated the cost-effectiveness of utilizing the growth of indigenous microbes in enhancing the efficiency of an active waterflood for the recovery of incremental oil. The technology involves injecting a regulated stream of nutrients into a sandstone reservoir at a subsea depth of -2,300 ft to stimulate indigenous microbe growth. Cell proliferation by these microorganisms acts to reduce the flow of injected water in more permeable zones of the reservoir by selective plugging, thereby diverting the water to other areas of the reservoir. This diversion and altering of flow patterns in the reservoir serve to enhance the sweep efficiency of the waterflood. This technology will be expanded upon in this study by using the ability of these microbes to produce a single by-product (acetic acid).

This immobilized enzyme technology will be applied to the carbonates at a depth of 11,300 ft in Womack Hill Field. It is anticipated that the acetic acid will act to break down the Smackover reservoir through dissolution thereby creating enhanced reservoir connectivity.

Subtask 1 to characterize the microflora present in the core material and/or produced fluids for the Womack Hill Oil Field Unit in terms of their ability to act as a source of enzymes that convert alcohols to acids and to determine the nutritional requirements to maintain the cells in a metabolically active state with minimal replication will continue into Year 2 using the fresh samples obtained from a new Smackover core.

In order for microorganisms to carry out the activities needed to enhance oil recovery from the Womack Hill reservoir they must be able to grow at the temperature that exists in the reservoir (93°C). Thus, the indigenous microflora in the reservoir would be primarily extremophiles and it is essential that these unique organisms be studied in regard to their nutritional requirements since they may differ significantly from mosophiles and even thermophiles. It is highly unlikely that extremophiles could be obtained from normally available sources. Furthermore, the indigenous extremophiles should be able to grow on crude oil as a carbon and energy source and our studies have shown that essentially all microorganisms isolated from petroleum reservoirs can metabolize oil. Therefore, obtaining cores from the formation under investigation, in order to isolate and study oil-degrading extremophiles, is essential to the success of this project.

Subtask 2 is the validation of the program for chemical additions for the field demonstration using a sandpack methodology. These studies are conducted in sandpacks. The Plexiglas sandpacks will be 6" x 6" by 0.125" and have a total internal volume of 41.49 ml. The sandpack is fitted with a No. 17 hypodermic needle in each of two opposite corners to serve as a means of introducing liquids into the sandpack and collecting the effluent. The total liquid volume in the sandpack is approximately 18 ml. On one side of the sandpack 100 holes are to be drilled 1/4" in diameter. One layer of thin see-through plastic is placed beneath the side with 100 holes to contain formation materials inside the sandpack. On the opposite side of the sandpack one hole is drilled, 1" in diameter, to be used for filling the sandpacks. The 1" diameter plug is glued on a 1 1/2" x 1 1/2" Plexiglas baseplate and, after filling up the sandpack, this hole is closed and then secured with methylene chloride.

The sandpacks are prepared as follows. A paste of oil, production water, microbial inoculum, and formation material is used to fill the sandpack through the opening provided for this purpose, while the sandpack is held on a vortex. The sandpack is packed uniformly and the entry port closed and sealed.

The flow pattern in the sandpack is determined by injecting production water containing 140 µci Cl-36. To determine the location of the injected water, radioactivity measurements are performed at each of the sandpack holes (total of 100 holes/pack) using a Ludlum Model 2200 Scaler Ratemeter. From these measurements, the path of water through the sandpack is determined. The sandpack is then flushed with production water without Cl-36 until the effluent contains no more radioactivity.

Next, the sandpack is subjected to treatment with production water containing nutrients according to the program formulated in Subtask 1. After treatment, deviations in flow pattern is assessed by the biweekly addition with Cl-36 (as described above). Control packs do not receive nutrients but are tested with Cl-36 to determine if abiotic changes in flow pattern occur.

All experiments are carried out under anaerobic conditions at reservoir conditions. The parameters monitored include pH, microbial numbers, orthophosphate, calcium carbonate, carbon dioxide and gas chromatography profile, in addition to the radioisotope analysis. Based on the above studies, changes or modification of the chemical addition plan are made where necessary.

Task RC-4. Integration of Data

Description of Work.--This task will integrate the geological, geophysical, petrophysical and engineering data for the Womack Hill Field into a single comprehensive digital database for reservoir characterization, 3-D geologic and seismic modeling, 3-D reservoir simulation, cost-effective field management, and for making operational decisions in the field.

Rationale.--This task serves as a critical effort to the project because the construction of a digital database is an essential tool for the integration of large volumes of data. This task also serves as a means to begin the process of synthesizing concepts. The database also provides a mechanism for quality control in that core and log data can be compared to geophysical, petrophysical and engineering data. These measured and calculated data are utilized in developing predictive algorithms for calculating variable values for interwell areas. The database serves as an archival record that can be updated in the future. The database is built using a spreadsheet approach. The data are accessed, managed, and analyzed by using standard industry software. The goal is to develop a relevant and transportable database.

Subtask 1 involves entering geologic core, log, petrographic, diagenetic and pore system data and merging these data with geophysical imaging information. Individual well logs serve as the standard from which the data are entered and compared. The data are entered at one-foot intervals. All well logs in the fields are utilized. The researchers will resolve any apparent inconsistencies among data sets through an iterative approach.

Subtask 2 involves entering petrophysical data, rock and fluid property data, production data, including oil, gas and water production, and well completion data, including perforated intervals, completion parameters, well stimulation information, etc. A validation effort is conducted to resolve any apparent inconsistencies among data sets through an iterative approach. These data can be voluminous and validation and archiving tasks represent a major effort.

Subtask 3 utilizes an innovative approach, known as data mining, to predict lithofacies and petrophysical properties of reservoirs (porosity and permeability). Researchers at The University of Alabama have used data mining (knowledge discovery in databases) to predict porosity and permeability values for Smackover wells at Appleton Field. Data from a typical Smackover well with a core analysis at Womack Hill Field is used as a training set to extract the rules and data for other wells in the field without core data. This approach is used to assign porosity and permeability values to reservoir intervals in wells where cores were not taken or where porosity logs are not available. These data are used in the 3-D modeling of the reservoir at Womack Hill Field.

Task RTA-1. 3-D Geologic Model

Description of Work.--This task involves using the integrated database which includes the information from the reservoir characterization tasks to build a 3-D stratigraphic and structural model of the Womack Hill reservoir. Previous reservoir models constructed for the Smackover and for the Permian carbonate shoal reservoirs in West Texas and the depositional modeling of modern ooid sand shoals of the Great Bahama Bank are used as analogs in building the 3-D stratigraphic and structural model for the Smackover shoal reservoir at Womack Hill Field.

Rationale.--This task provides the framework for the reservoir simulation model. Sequence stratigraphy in association with structural interpretation forms the framework for the model for Womack Hill Field. The model incorporates data and interpretations from the core and well log analysis, sequence stratigraphic, depositional history and structural studies, petrographic analysis, and diagenetic, pore system, and petrophysical and engineering studies. The purpose of the 3-D stratigraphic and structural model is to provide an interpretation for the interwell distribution of systems tracts, lithofacies, and reservoir-grade rock. This work is designed to improve well-to-well predictability with regard to reservoir parameters, such as primary depositional lithologies, diagenetic features, pore types and systems, porosity and permeability values, and heterogeneity. This layer-based model is built utilizing data mining and associated neural networks to populate and distribute property and attribute data. Key data include structural features, physical surfaces, depositional sequences, stratigraphic event beds, sedimentary structures, carbonate textures and mineralogy, diagenetic features, pore types and throats, and porosity and permeability. Geologic modeling sets the stage for reservoir simulation and for the recognition of flow units, barriers to flow and flow patterns in the respective fields. The reservoir model and integrated database become effective tools for cost-effective reservoir management for making decisions regarding operations in the field. Accepted industry software, such as Stratamodel and GeoSec are used to build the 3-D geologic model. GeoSec software is used in the 3-D structural interpretation and Stratamodel software is used to construct the geologic model.

RESULTS AND DISCUSSION

The Project Management Team and Project Technical Team are working closely together on this project. Members of the Project Management Team met on April 11, 2001, at the offices of Pruet Production Co. in Jackson, Mississippi to review progress on the project and to resolve certain issues related to the project. Members of the three disciplines working groups met several times during the year. The Geoscientific Reservoir Characterization Group met in Tuscaloosa, Alabama three times in the fall of 2000 and winter of 2001. Members of this group also met with the Microbial Characterization Group in Tuscaloosa in the fall of 2000. Members of the Petrophysical and Engineering Characterization Group met in College Station, Texas, Jackson and Tuscaloosa during the winter and the spring of 2001. The meeting in Tuscaloosa was a joint meeting with members of the Geoscientific Reservoir Characterization Group. This close coordination has resulted in a fully integrated research approach and the project has benefited greatly from this approach. For example, a discussion among members of the Geoscientific Reservoir Characterization and Petrophysical and Engineering Characterization Groups regarding the apparent flow barrier in the field resulted in a reevaluation of Smackover cycle picks by the geoscientific group in the vicinity of the eastern boundary of the Womack Hill Field. Further discussion about this barrier has revealed that the pressure differential in the field is actually east (east of the 14-6 well) of the Unit boundary. This finding will be incorporated into the flow model for the Smackover reservoir.

Geoscientific Reservoir Characterization

Geoscientific Reservoir Characterization is essentially on schedule. Subtask 1 has been completed. Graphic logs have been constructed for available whole cores from the field. Core samples (118) have been selected and thin sections have been made from these samples. Study of the thin sections is in progress. The graphic logs have been compared to the respective core analysis for these wells, and the core analyses have been calibrated to the well log patterns. Electrofacies have been identified and are being used for correlation within the field. These data have been entered into the digital database for the field.

Subtask 2 has been completed. Electrical and geophysical logs (42) and core analysis data (28) have been digitized and entered into the field database. Formation tops and key event horizons (3 high-frequency cycles, including porous and non-porous intervals) have been identified using the graphic core logs and electrofacies (Figures 10 and 13). The porous intervals in these cycles have the potential to serve as vertical and lateral flow units, while the non-porous intervals separating the porous intervals have the potential to act as vertical and lateral barriers to flow. Thus, potentially there are three reservoirs within the field. Cross sections (Figures 14-17) have been drawn to illustrate these sequence stratigraphic relationships. Isopach maps of each of these cycles (Figures 22-24) and field structure maps (Figures 18 and 19) have been prepared. Burial (Figure 11) and thermal maturation history (Figure 12) plots for wells in the field have been constructed and show that the oil at Womack Hill Field was sourced from outside the field area.

Subtask 3 has commenced and 2-D seismic reflection data are being acquired.

Subtask 4 has been initiated through the study of existing thin sections (71) from Smackover cores in Womack Hill Field. Work will continue on petrographic analysis of the newly acquired thin sections (118).

Subtasks 5 and 6 are being initiated and are scheduled for completion at the end of the first quarter of Year 2. Petrographic work in Subtask 4 continues and is scheduled for completion in August 2001. Seismic interpretation in Subtask 3 is dependent upon receipt of the data from SEI, but this work is also scheduled for completion by the end of the summer of 2001.

All acquired field data have been entered into the digital database for the Womack Hill Field; therefore, Task RC-4, Data Integration, is ahead of schedule. Also, work has begun on building the 3-D geologic model for Womack Hill Field, so Task RTA-1, 3-D Geologic Model, is also ahead of schedule.

Petrophysical and Engineering Characterization

Petrophysical and Engineering Characterization is on schedule. All four subtasks have been initiated and are progressing. Most of the critical data has been acquired and entered into the digital database for the field. Also, initial ultimate recovery and decline type curve analysis for certain field wells has been performed. Work on the reservoir simulation model has commenced.

Initial correlation of permeability appears representative as a function of depth (Figures 26 and 27). No single correlation of core permeability with ILM, LLS, SP or GR well log responses is evident (Figures 28-31). Work in early Year 2 will focus on a generalized correlation of core and well log data, such as permeability.

Because the modeling of reservoir performance requires reasonable estimates of flowing and shut-in reservoir pressures as a function of time, a concerted effort for the first six months of Year 2 will be to search files for additional pressure data for the Womack Hill Field reservoir. Preliminary analyses (Figures 33 and 34) have shown that pressure data quality and quantity is an issue for the field. Also, acquisition of additional water production records for the field is important as shown from the preliminary well analyses (Figures 35-38). On the other hand, preliminary well analyses (Figures 39-42) indicate that the injection data for the Unit are excellent.

To resolve remaining questions regarding the flow barrier in the eastern part of the field, work in Year 2 will include a sequence of tracer and pressure transient tests within the Womack Hill Field. An apparent correlation of production and injection exists as observed from data from the 10-14 Well (P-1678), 15-2 (Well (P-1720), and 15-1 (P-1748) injectors and 14-6 Well (P-1804) and 14-8A (Well P-2341) producers. The testing sequence is designed to confirm or dispute the flow barrier in the Womack Hill Field, to assess the permeability (flow thickness) in the drainage/injection area of the reservoir for a particular well, and to evaluate the near-well damage (or stimulation) for these wells.

To provide additional and recent pressure data for the reservoir, work in Year 2 will include the evaluation of conducting pressure buildup test sequences for certain wells in the Womack Hill Field, including the 9-16 Well (P-1655), 9-16A Well (P-2109), and 14-6 Well (P-1804).

Microbial Characterization

Microbial Characterization is on schedule although no microbial growth has yet been observed in samples from old core samples, produced water, or oil from the Womack Hill Field reservoir. Microflora characterization will be enhanced as a result of the acquisition of a new Smackover core in the early part of Year 2. These new core materials will also be used in Subtask 2 which involves the validation of the program for chemical additions for the field demonstration using the sandpack methodology.

CONCLUSIONS

Pruet Production Co. and the Center for Sedimentary Basin Studies at the University of Alabama, in cooperation with Texas A&M University, Mississippi State University, University of Mississippi, and Wayne Stafford and Associates are undertaking a focused, comprehensive, integrated and multidisciplinary study of Upper Jurassic Smackover carbonates (Class II Reservoir), involving reservoir characterization and 3-D modeling and an integrated field demonstration project at Womack Hill Oil Field Unit, Choctaw and Clarke Counties, Alabama, Eastern Gulf Coastal Plain.

The principal research effort for Year 1 of the project has been reservoir characterization, which has included three (3) primary tasks: geoscientific reservoir characterization, petrophysical and engineering property characterization, and microbial characterization. In the first year, the research focus has been primarily geoscientific reservoir characterization. This work was scheduled for completion in Year 1. Petrophysical and engineering property and microbial characterization were initiated in the last six months of Year 1.

Geoscientific Reservoir Characterization is essentially on schedule. Subtask 1 has been completed. Graphic logs have been constructed for available whole cores from the field. Core samples (118) have been selected, and thin sections have been made from these samples. Study of the thin sections is in progress. The graphic logs have been compared to the respective core analysis for these wells, and the core analyses have been calibrated to the well log patterns. Electrofacies have been identified and are being used for correlation within the field. These data have been entered into the digital database for the field. Subtask 2 has been completed. Electrical and geophysical logs (42) and core analysis data (28) have been digitized and entered into the field database. Formation tops and key event horizons (3 high-frequency cycles, including porous and non-porous intervals) have been identified using the graphic core logs and electrofacies. The porous intervals in these cycles have the potential to serve as vertical and lateral flow units, while the non-porous intervals separating the porous intervals have the potential to act as vertical and lateral barriers to flow. Thus, potentially there are three reservoirs within the field. Cross sections have been drawn to illustrate these sequence stratigraphic relationships. Isopach maps of each of these cycles and field structure maps have been prepared. Burial and thermal maturation history plots for wells in the field have been constructed and show that the oil at Womack Hill Field was sourced from outside the field area. Subtask 3 has commenced and 2-D seismic reflection data are being acquired. Subtask 4 has been initiated through the study of existing thin sections (71) from Smackover cores in Womack Hill Field. Work will continue on petrographic analysis of the newly acquired thin sections (118).

Petrophysical and Engineering Characterization is on schedule. All four subtasks have been initiated and are progressing. Most of the critical data has been acquired and entered into the digital database for the field. Also, initial ultimate recovery and decline type curve analysis for certain field wells has been performed. Work on the reservoir simulation model has commenced. Because the modeling of reservoir performance requires reasonable estimates of flowing and shut-in reservoir pressures as a function of time, a concerted effort for the first six months of Year 2 will be to search files for additional pressure data for the Womack Hill Field reservoir. Preliminary analyses have shown that pressure data quality and quantity is an issue for the field. Also, acquisition of additional water production records for the field is important as shown from the preliminary well analyses. On the other hand, preliminary well analyses indicate that the injection data for the Unit are excellent. To resolve remaining questions regarding the flow barrier in the eastern part of the field, work in Year 2 will include a sequence of tracer and pressure transient tests within the Womack Hill Field. An apparent correlation of production and injection exists as observed from data from the 10-14 Well (P-1678), 15-2 (Well (P-1720), and 15-1 (P-1748) injectors and 14-6 Well (P-1804) and 14-8A (Well P-2341) producers. The testing sequence is designed to confirm or dispute the flow barrier in the Womack Hill Field, to assess the permeability (flow thickness) in the drainage/injection area of the reservoir for a particular well, and to evaluate the near-well damage (or stimulation) for these wells.

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