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GRAVITY FLOW INTRODUCTION OF SHALLOW WATER MICROFAUNA INTO DEEP WATER DEPOSITIONAL ENVIRONMENTS

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ABSTRACT

The depositional environment of the Shubuta Member of the Yazoo Formation has been interpreted as being either marginal marine or outer neritic in literature over the previous twenty years. New evidence suggests that marginal, inner neritic and outer neritic to bathyal faunas occur in juxtaposition. Three levels of inhomogeneity, sporadic one-cubic inch blebs of shell debris, one-half inch thick layers of shell coquinas, and three- to four-foot thick layers of matrix-supported shell concentrations, occur within the pure clay of the Shubuta Member.

Extremely high percentages of planktonics (55-60%), low dominances, and a majority of genera that prefer deep environments suggest that the fine-grained clay was deposited in outer neritic to bathyal conditions. Lower planktonics, higher dominances, lower diversities, and large shallow water components suggest that at least the larger-scale inhomogeneities contain inner neritic faunas. Both small-scale gravity flow and the more dramatic turbidity flow appear to have contributed significant beds of shallow water faunas to the deposition of the outer neritic to bathyal clays of the Shubuta Member of the Yazoo Formation.

INTRODUCTION

Offshore hydrocarbon exploration and production from the upper Eocene in the Gulf Coast Province has rejuvenated interest in environmental models of outer neritic to bathyal depositional systems. One problem exploration paleoecologists have encountered is the apparently random occurrence of shallow water faunas in what appears to be a deep water depositional environment. The upper Yazoo Formation of west-central Mississippi was selected as an analogous depositional model. This surface analog allows controlled sampling and the direct correlation of lithology and proposed environments of deposition. Finite sampling methods and close correlation with lithology should provide an accurate depositional model of Eocene fine-grained sediments.

Approximately one hundred feet of the Shubuta Clay sequence have been uncovered at the Cynthia clay pit by the Jackson Ready-Mix Concrete Company, Miss Lite Division. This large excavation permits easy access to a broad lateral and vertical

* Order of authorship decided by a game of one-on-one basketball.

exposure and offers one of the premier localities for observation and sampling of fresh, unaltered Shubuta Clay (Dockery and Zumwalt, 1986). The site is located in the southeast quarter of the southwest quarter of Section 25, Township 7 North, Range 1 West, Hinds County, Mississippi, approximately five miles northwest of Jackson. Foraminiferal preservation is excellent at this locality, with little or no post-depositional alteration.

The Gulf Coast Province is recognized as a region ideally suited for micropaleoecologic research. Many works on stratigraphic and sedimentologic relationships, paleoecology, and modern foraminiferal ecology have been completed in this province, creating a strong scientific foundation for the micropaleoecologic interpretation of the Shubuta Clay.

Previous stratigraphic and sedimentary studies of the upper Yazoo suggest that it was deposited in a middle to outer neritic environment. The Yazoo Formation is composed of four members. In ascending order they are the North Twistwood Creek Clay Member, Cocoa Sand Member, Pachuta Marl Member, and the Shubuta Clay Member. The Cocoa Sand Member and the Pachuta Marl thin and eventually pinch out in a westward direction from the Mississippi-Alabama state line (Dockery, 1982). However, an overall thickening of this formation is also observed due predominantly to an increase in the Shubuta Clay Member (Dockery and Siesser, 1984; Rainwater, 1968). This thickening of the inundative Shubuta Clay and loss of the clastic Cocoa Sand Member in the Cynthia clay pit region corresponds generally with the axis of the depositionally-active Mississippi Embayment. Slow but continual clay sedimentation allowed for thickening in the central portion of the basin where higher subsidence and relatively deeper water were located. This stratigraphic and sedimentologic evidence suggest that the Cynthia locality represents a middle to outer neritic depositional environment.

The paleontologic literature on the upper Eocene, while providing a strong taxonomic base, has had significant difficulty in assigning a consistent environment of deposition to the upper Yazoo. Excellent foraminiferal preservation and dedicated taxonomic work by authors such as Bandy (1954), Deboo (1965), and Loeblich and Tappan (1964) have established a strong taxonomic understanding of the upper Eocene Gulf Coast microfauna. Macrofaunal reconstructions by Elder and Hansen (1981) suggest that the Yazoo represents the deep water component (outer neritic) of a large scale transgressive sequence. In a recent stratigraphic study, Dockery and Siesser (1984) suggest that the Shubuta Clay at the Cynthia Quarry site was deposited in shallow water. This shallower depth estimate was based on the presence of a shallow coccolith fauna.

Extensive modern foraminiferal ecology studies of the Gulf of Mexico and the Atlantic coast form a strong neontologic base for micropaleoecologic reconstructions. Extensive sampling in deep water (Pflum, Frerichs, and Sliter, 1976; Phleger, 1960; Murray, 1973) and shallow water environments (Parker, 1954; Poag, 1981) provides multiple representations of a wide cross section of benthic marine environments.

METHODS AND MATERIALS

A continuous column of Shubuta clay was carved from the northwest wall of the Cynthia Quarry. This column was taken to the paleontology laboratory at Louisiana Tech University, where it was dissected. Samples were collected to evaluate the differences in the environment of sedimentation represented by inhomogeneities in the clay column. Each sample set includes a subsample of the inhomogeneous layer and a subsample of the clay both above and below the inhomogeneity.

The eleven samples were prepared by heating to 250° F in an oven and quenching in boiling 3% hydrogen peroxide. The disaggregated samples were then washed through a 200 mesh sieve. Dried samples were split with a mechanical microsplitter and placed on a gridded counting tray. All foraminifera were counted until a total of three hundred benthic foraminifera were seen.

A type collection was identified using Loeblich and Tappan (1964), Bandy (1954), and Deboo (1965). Generic identifications were verified by Roy Enrico and staff members from the Mobil Applied Stratigraphy Laboratory in Dallas, Texas. Representative samples were photographed using the Scanning Electron Microscope. The negatives of the photomicrographs and the type collection are stored in the paleontologic collections of the Department of Geosciences of Louisiana Tech University, Ruston, Louisiana.

RESULTS

Point counts conducted on the eleven samples are given in Table 1. Planktonic and benthic forms were counted and are described in Table 2 as a percentage of the total fauna. Paleoecologic trends in the generic populations of benthic foraminifera were found using the statistical parameters of dominance, diversity, and faunal variability (95%), and are displayed in Table 2. Dominance is expressed as a percentage of the population comprised of the two most common genera. Diversity was recorded by two measures: first, simple diversity, which is the total number of genera identified in the sample, and second, faunal variability, which is a weighted measure based on the number of most common genera that constitutes 95% of the fauna.

Table 1. Frequency of benthic foraminifera in the Shubuta Clay samples.

Sample #	1	2	3	4	5	6	7	8	9	10	11
INNER NERITIC											
Discorbis	1	7	3	5	7	1		1	3	3	3
Eponides								2			
Glanulina		2									
Massiliina							2				
Siphonina	10	1	10	37	15	55	79	52	87	54	61
Spiroloculina							1				
Textularia	5	1	4	2			3	2			1
Total	16	11	17	44	22	56	85	57	90	57	65
MIDDLE NERITIC											
Concris								3			
Cibicides	79	54	42	96	128	79	51	79	66	82	62
Fissurina				1					1	1	1
Guttalina										1	1
Globulina			2	1	1				1		
Lagena		3	2	1				1		1	
Lenticulina	28	1	9		9	9	5	7	10	2	7
Loxostomoides	21	56	62	10	17	14	32	10	25	18	16
Nonion									2		
Nonionella	10	24	14	3	6	2	2	5	1	5	3
Nonionellina	2	3	1					1		2	
Total	140	141	132	112	161	104	90	106	106	112	90
OUTER NERITIC											
Angulogerina				1			12		15	2	2
Bolivina	136	121	132	89	85	101	68	90	53	64	76
Brizalina							8		11	4	1
Bulimina		5		1	1			2			3
Dentalina	1	3	6	3	2	1	1	2		4	5
Gyroidina	3	17	4	13	13	11	46	4	25	33	31
Melonis				1	2					1	
Nodosaria				2			4	3	2		1
Robertina	1	7		2	1	1		1		2	2
Uvigerina	5	2	6	37	23	30	21	33	14	38	42
Virgulina	1	10	7	8	3	8	11	6	9	16	14
Total	147	165	155	157	130	152	171	141	129	164	177

Table 2. Statistical measures of foraminiferal distributions in the Shubuta Clay samples.

SAMPLE NUMBER	PLANKTONIC PERCENT	DOMINANCE	DIVERSITY	FAUNAL VARIABILITY
11	37.9	46.0	19	9
10	50.7	48.7	19	10
9	31.3	51.0	16	9
8	38.3	56.3	19	9
7	45.2	49.0	16	9
6	25.4	60.0	12	6
5	54.5	71.0	15	8
4	50.9	61.7	19	8
3	39.8	64.7	15	9
2	54.3	60.3	17	8
1	39.8	71.7	14	7

DISCUSSION

Shell concentrations within extremely fine clay are relatively rare in depositional systems. Three basic models are consistent with observed sedimentologic data. First, storm deposits in a shallow interdeltaic sedimentary sequence could explain the low levels of shell concentrations in a low energy depositional environment. This environmental system would result in a microfauna dominated by Textulariina and miliolids with relatively few benthic or planktonic rotalids. Expected population trends include very high dominance ratings and low diversity.

A second model that is consistent with the observed sedimentary data is a middle neritic depositional environment with periodic large storms creating significant high energy lag deposits. The microfauna in this system would be dominated by benthic rotalids that preferred moderate depth and relatively stable marine conditions. Population trends would also be expected to display relatively more planktonics than a shallow water environment but moderate percentages relative to outer neritic or deeper depths. Both diversity and dominance would be moderate. The shell hash should consist of relatively few smaller organisms with larger individuals of the middle neritic remaining. This depositional system should contain relatively few deep water or shallow water organisms.

The final depositional model that is consistent with the sedimentary data is an outer neritic environment, below wave base, with intercalated deposits of gravity flow material. The microfauna that would characterize this system should be recognizably different. Outer neritic environments receive relatively high concentra tions of planktonics. The benthic fauna is dominated by hyaline rotalids. Dominances are low and diversity measures high. Finally, the fine-grained material should be dominated by benthic genera that prefer deeper water, extremely stable, marine conditions. The coarse material in this model would be significantly different. It should contain a fauna from

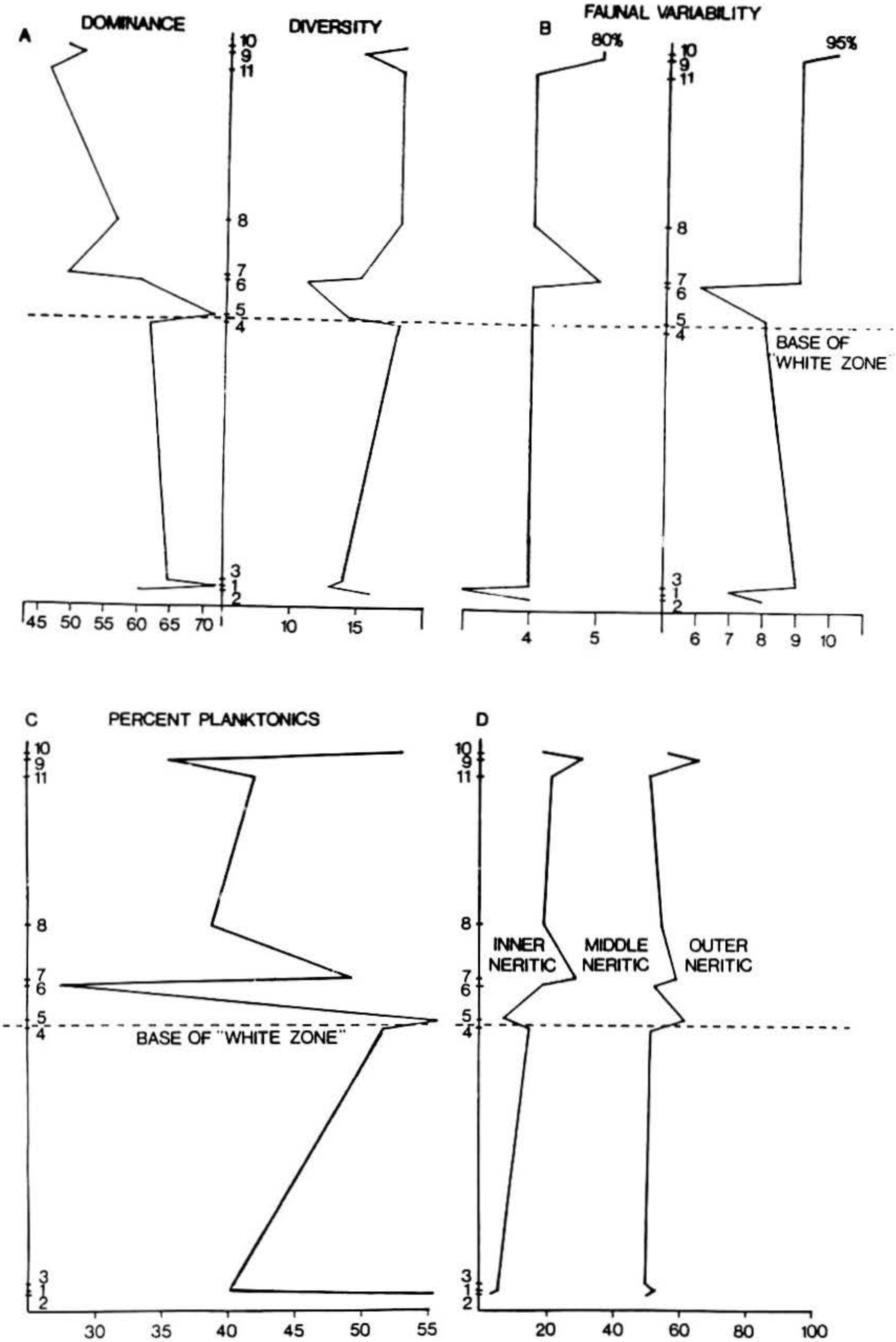

Figure 1. Summary of the statistical measures of faunal change in the Shubuta Clay samples: A-Dominance and Diversity, B-Faunal Variability, C-Percent Planktonics, D-Habitat Preference.

shallower depths. These fauna could come from either marginal marine fauna or nearby middle neritic environments. Either of these fauna would be characterized by lower diversities and proportionately higher dominances. Planktonics would be winnowed out by high energy environments. Finally, gravity flow phenomena should result in the introduction of genera which prefer more marginal marine environments.

Point counts of foraminiferal genera from the Cynthia Quarry indicate that the majority of the stratigraphic column contains approximately 50 percent planktonic forms (Figure 1C). However, samples 1, 6, and 9 have some of the lowest planktonic percentages in the sampled interval at 40.1, 27.4, and 35.6 percent respectively. This graph is perhaps the most clear-cut example of the intercalating relationship of deep water and shallow water samples. The high percentages of planktonic forms, ranging in excess of 55%, precludes a shallow interdeltaic depositional environment. Moreover, these high percentages are indicative of outer neritic to bathyal water depths (Douglas, 1979). Samples 1, 6, and 9, which average 34 percent planktonic forms, however, are indicative of shallower depths.

The extensive prominence of hyaline benthonics suggests a middle to outer neritic environment of deposition. The almost complete lack of Textulariina and the low miliolid frequency also support a deeper environment of deposition. Conversely, the presence of miliolids and Textulariina predominantly in the shell layers suggests a shallower water provenance for these sediments. The lack of complex Textulariina contradicts a bathyal to hadal depositional environment. The distribution of test wall structure is consistent with a middle to outer neritic environment of deposition.

The Cynthia Quarry samples display a well-developed, inversely proportional relationship between diversity and dominance (Figure 1A). The decrease in diversity and increase in dominance in the shell layers suggest that these originated in a less stable habitat. The prominence of inflated *Siphonina* to *Bolivina* in the shell layers and the prominence of *Uvigerina* and flattened *Bolivina* in the clay samples support a deep water depositional environment with allochthonous shallow water elements.

Environmental preferences of foraminiferal genera are by necessity more general than species preferences, but even these generalities are useful in comparing the samples from Cynthia Quarry. While many of the 28 genera found have some representation in all shelf environments, each was assigned to a general environment of preference (Table 1). These environmental interpretations were based on a literature search relying heavily on Bandy and Arnel (1960), Boersma (1980), Crouch (1955), Douglas (1979), Gernant and Kesling (1966), Phleger (1960), Poag (1981), Tipsword et al. (1966), and Walton (1964). While no one genus is necessarily indicative of a specific environment, cumulative preferences can be used in conjunction with other parameters to interpret the environment of deposition.

Figure 1D is a cumulative graph of genera counted in each sample relative to their environmental preferences. The first line from the left is the total percentage of the fauna represented by organisms which prefer inner neritic environments. The second line is a total of the fauna which prefer the inner and middle neritic. The remaining fauna, which plot to the right of the second line, are those organisms which prefer outer neritic to bathyal depths.

Two generalities appear to be consistent throughout the Cynthia Quarry data. First, the fauna of each of the clay samples was composed of forty to fifty percent organisms which prefer outer neritic environments. The median depth preference then was outer neritic. This high prominence of deep water forms coupled with the low likelihood that deep water forms could be worked on shore suggest that the clay was deposited at depths that were at least equivalent to the inner outer neritic.

The second generality that can be made from the environmental preference data is that the two large scale shell concentrations have significantly larger representation of shallow water elements. The high percentage of fauna that prefer deep water is inconsistent with either the marginal or middle neritic, wave base model. The high percentage of deep water organisms in the clay and the increased elements of shallow water fauna is consistent with the deep water/gravity flow model.

Stratigraphic studies (Rainwater, 1968; Murray, 1961) suggest that the Shubuta Clay Member of the upper Yazoo Formation, Jackson Group, represents middle to outer neritic deposition. Observations of the sedimentology at the Cynthia clay pit substantiate this suggestion with strong evidence including the abundance of marine clays and the absence of coarse, terrigenous clastics such as compose the Cocoa Sand Member. This member pinches out in a westward direction across Mississippi (Dockery, 1982), from lands-edge toward deeper water in the central portion of the subsiding Mississippi Embayment. In this regional stratigraphic setting it can be stated with relative confidence that the fine-grained marine silts and clays at Cynthia represent fairly deep water. The question centers squarely on the enigmatic shell hash layers. These layers have several prominent sedimentologic characteristics: they contain disarticulated, imbricated, shallow water macrofauna shells and shell hash; they have sharp, bounding contacts; and they are matrix-supported. The disarticulated nature of the shells in these layers indicates that the material has not been preserved in place, and the imbricated fabric of the deposit suggests unidirectional transportation.

Sharp bounding contacts between the shell hash layers and the fine-grained marine clays also suggest a rapid emplacement event, where the sediment supply was short-lived. A final prominent sedimentary observation is that the layers are matrix-supported. This would eliminate winnowing by large storms as a depositional mechanism for the shell layers. Compiling all observable sedimentary information in conjunction with the regional stratigraphic setting, the data would suggest a downslope gravity flow model.

The foraminiferal trends seen at Cynthia Quarry support a deep water environment of deposition. The high planktonics, lack of Textulariina or Miliolina, and the preponderance of deep water genera preclude any shallow water or inner neritic depositional system. A middle neritic environment is also contradicted by the high planktonic and high preponderance of deep water forms. A deep water offshore environment is supported by the high percentage of planktonic foraminifera and the high preponderance of deep water forms.

Gravity flow introduction of coarse-grained shell material is supported by several lines of evidence. The large scale fluctuations in planktonics between the shell concentration and clay samples are consistent with a gravity flow model. The decrease in diversity and concomitant increase in dominance also suggest that the shell concentrations came from a shallow environment. Finally, the presence of shallow water forms such as *Massalina*, inflated *Siphonina*, and *Nonionellina* supports a shallow middle neritic provenance.

CONCLUSION

The sedimentary and micropaleontologic data support a sedimentary model which includes deep water sedimentation and the introduction of shallow material by gravity flow phenomena. The data also strongly preclude both a deltaic depositional model and a middle shelf with storm deposits model. We then suggest:

1. The fine clay of the upper Shubuta was deposited in an outer neritic environment.
2. The white layer represents a large scale gravity flow or turbidity current.
3. The smaller shell hashes represent laminar gravity flow phenomena that resulted in the introduction of shallow faunal elements into a deep water depositional system.

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"Here, like elsewhere, when science transcends the limits of the perceptible and the domain of experience, venturing into the dark field of the unknown, the investigator must ultimately be guided by an ingenious use of the imagination; of that wondrous faculty which, left to ramble uncontrolled, leads us astray into a wilderness of perplexities and errors, a land of mists and shadows; but which, properly controlled by experience and reflection, becomes the noblest attribute of man, the source of poetic genius, the instrument of discovery in sciences, without the aid of which Newton would never have invented the fluxions, or Davy have discovered the earths and alkalis, nor Roentgen the X rays, nor Columbus have found another continent."

Augustin Gattinger
1901

OIL AND GAS EXPLORATION IN MISSISSIPPI - FIRST HALF OF 1987

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Exploration activity in Mississippi lagged behind development drilling during the first half of 1987. This is reflected in the slight addition to Mississippi's reserve base from new wildcat discoveries while the more significant completions were found in or near existing fields. There were five wildcat discoveries found in the shallow producing trends of the Eocene-age Wilcox Formation, of southwestern Mississippi, and in the Paleozoic sediments of the Black Warrior Basin, northern Mississippi. The largest oil and gas producers completed during the first half of the year, however, were found at intermediate depths from the Jurassic-age Smackover Formation in Nancy Field and the Cretaceous-age Rodessa Formation in Oak Grove Field.

The Wilcox discoveries include two in Franklin County: Guernsey Pet. Corp. No. 1 Scarbrough et al., located in Section 10, T.6N., R.3E., and James B. Furrh, Jr. No. 1 U.S.A. 27-1, located in Section 27, T.5N., R.1E.; and two more in Adams County: Cardneaux No. 1-A Craig, located in irregular Section 79, T.7N., R.2W., and David New Operating Co. No. 1 Haynes Unit, located in Section 31, T.6N., R.2W. These wells each tested from 45-80 barrels of oil per day (BOPD) at depths ranging from approximately 6000 feet to 6400 feet. The single Black Warrior discovery during this period is the Morrow Oil & Gas Co., Inc. No. 1 McCain 16-3, located in Section 16, T.3S., R.5E., Chickasaw County. It tested 210 thousand cubic feet of gas per day (MCFGPD) from the Sanders Sand (without stimulation) through an 8/64" choke with tubing pressure of 585 pounds. Perforations are at depths of 2238-2244 feet.

Mississippi's largest producing oil well was a development well in Nancy Field, brought in by Esenjay Petroleum Company. The No. 1 Menasco 11-4, located in Section 11, T.1N., R.14E., Clarke County, tested 2346 BOPD (10 hour test) and 2.3 MMCFGPD through a 30/64" choke with tubing pressure of 1084 pounds and no formation water. Production is from the Brown Dense Member of the Smackover with perforations at 13,976-14,004 feet. The gravity of the oil is 41.4 degrees, GOR is 980-1, and hydrogen sulfide is about 15%. This new reservoir is 600 feet deeper than established Smackover production in the field. Total depth for the well is 14,512 feet.

The largest gas producer completed during this time was also a development well, the Ka-Lyn Oil & Gas, Inc. No. 1 Berry 35-5, located in Section 35, T.10N., R.19W., Oak Grove Field in Simpson County. Total depth for the well is 14,500 feet. The Rodessa "A" sand was perforated at 13,565-13,578 and 13,583-13,590. The zone tested 7.5 MMCFGPD, 32 BOPD, and 12 barrels water per day (BWPD) through a 22/64" choke with tubing pressure of 1500 pounds.

With the price of oil stabilized for the past several months at the $20/barrel level, the second half of 1987 should see more exploration activity in Mississippi. The weekly rig count ranged from 7-15 and it too should increase in the latter half of the year.

PETRIFIED PALM "WOOD" FROM THOMPSON CREEK, YAZOO COUNTY, MISSISSIPPI

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Mississippi Bureau of Geology

INTRODUCTION

Petrified palm "wood" occurs frequently in the stream gravels of southern Mississippi south of a line connecting Vicksburg, Jackson, and Waynesboro. This "wood" is associated with the Late Oligocene-Early Miocene Catahoula Formation outcrop belt and is generally assumed to have been derived from that formation. The gravel with which the "wood" occurs is derived from the Pliocene-Pleistocene Citronelle Formation or, near the Mississippi River valley wall, the Pleistocene pre-loess gravels. These later units also contribute petrified wood to the local streams, but only hardwoods and conifers from temperate forests and not tropical petrified palm.

North of the Catahoula and Citronelle outcrop belts petrified wood occurs commonly in streams crossing the loess hills bordering the Mississippi River Valley. Here only hardwoods and conifers have been reported. These woods of Pleistocene age are often observed in situ within the pre-loess gravels in gravel pits and along local streams. Blackwell and Dukes (1981) reported four different petrified hardwoods and one conifer in the reworked pre-loess gravels of Thompson Creek in Yazoo County. Recently John D'Isepo made an unusual discovery of two pieces of petrified palm (Figure 1) in the channel of Thompson Creek at low water. This discovery poses a problem in theory with what would be predicted for the Ice Age flora of the Pleistocene pre-loess gravels.

SOURCE OF THE THOMPSON CREEK PETRIFIED PALM

Several possibilities must be considered before interpreting the meaning of the Thompson Creek palm occurrence. One possibility that would immediately eliminate the problem is that the creek was accidently or purposely salted with petrified palm from another locality. This possibility is not considered likely as the find was along a remote part of the creek and not near any roads. A collector looking to fill a sack with weighty pieces of petrified wood is not likely to enter Thompson Creek with the sack partially filled from another locality.

The petrified palm might have been derived from older "bedrock" units cropping out along the creek. Underlying the pre-loess gravels along Thompson Creek are the fossiliferous marine sands and clays of the Eocene Moodys Branch and Yazoo formations. Fossil wood does occur in these formations, but the numerous occurrences seen by the writer have all been lignitized rather than petrified and contained borings of the marine clam *Teredo*. It is very unlikely that the petrified palm was derived from either of these "bedrock" units.

A third possibility is that the palm was deposited in the Thompson Creek stream system or perhaps even the pre-loess gravels at an earlier time when the Catahoula Formation cropped out in the area. The Catahoula outcrop belt and the accompanying hilly terrain of the Piney Woods Physiographic Province have retreated southward through time due to uplift and erosion. An occurrence similar to that proposed was observed along the Chickasawhay River north of Waynesboro, Mississippi. Terrace sand of the Chickasawhay River alluvial plain disconformably overlies the Red Bluff Formation at MGS locality 34 in the NW/4, Section 28, T.10N., R.7W., Wayne County. In the base of the terrace sand resting above the Red Bluff clay are limestone boulders from the Marianna-Glendon carbonate sequence. The nearest limestone outcrop to this locality at present is 3.5 miles to the south at MGS locality 73 on the Chickasawhay River in the SE/4, Section 9, T.9N., R.7W., Wayne County. Since the time the limestone boulders were introduced into the ancient (Late Pleistocene ?) Chickasawhay River system and came to rest on the Red Bluff clay, over a hundred feet of section, including the upper Red Bluff, Forest Hill, Mint Spring, Marianna, and Glendon formations, were removed from the area by erosion.

A fourth possibility is that the petrified palm came from the pre-loess gravels and occurs there along with hardwoods and conifers. The palm could have inhabited the region during interglacial periods in the Pleistocene when the climate was warmer than the present. As palm specimens are rare (only two known) in Thompson Creek while hardwoods are common, it must be assumed that palms were uncommon in the region during the Pleistocene (if they occurred at all).

CONCLUSIONS

Further studies of the palm specimens themselves may provide the answer to their origin. Blackwell et al.

x 0.8
546 grams

x 0.9
175 grams

Figure 1. Petrified palm "wood" from Thompson Creek, Yazoo County, Mississippi.

(1983) noted the mixed occurrence of temperate hardwoods and tropical palm in Bayou Pierre and White Oak creeks in Copiah and Claiborne counties (southern Mississippi). Here the palm was identified as *Palmoxylon*, and its source was attributed to the Catahoula Formation. Thin-section analysis of the Thompson Creek palm specimens may provide information as to their geologic age and thus their probable origin.

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