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PETROLOGY OF NORTH MISSISSIPPI BAUXITE:
A CASE FOR DEPOSITIONAL BAUXITE AND KAOLIN

BY

CHARLES NELSON THOMPSON

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PETROLOGY OF NORTH MISSISSIPPI BAUXITE:
A CASE FOR DEPOSITIONAL BAUXITE AND KAOLIN

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INTRODUCTION

Bauxite was originally defined by Berthier (1821) as aluminum rich material exposed in the vicinity of Les Baux, France. At this time, the term bauxite identified a mineral with the compositional system Al_2O_3-SiO_3-H_2O. Subsequent investigations, however, have shown bauxite to be more of a rock composition containing varying amounts of hydrated alumina (gibbsite, boehmite, or diaspore), Kaolinite and amorphous material (Fig. 1).

The term bauxite is now used to describe a wide range of potentially valuable materials (Table 1) of different mineral composition, physical appearance, and mode of occurence used for the production of alumina, aluminum, and high refractory materials. Bauxite deposits, therefore, can not be authenticated unless mineralogic and compositional analyses are combined with field observations.

Bauxite deposits in Mississippi were first described by Hilgard (1860, p. 14) in the vicinity of Toccopola, Mississippi. The Toccopola deposits were initially described as puddingstone (pisoform iron) by Hilgard (1860), but later recognized as bauxite by P.F. More (1923). Previous stratigraphic studies (Table 2) have placed the bauxite deposits in various time stratigraphic positions ranging from the Upper Paleocene Midway Group through the Lower Eocene Wilcox Group.

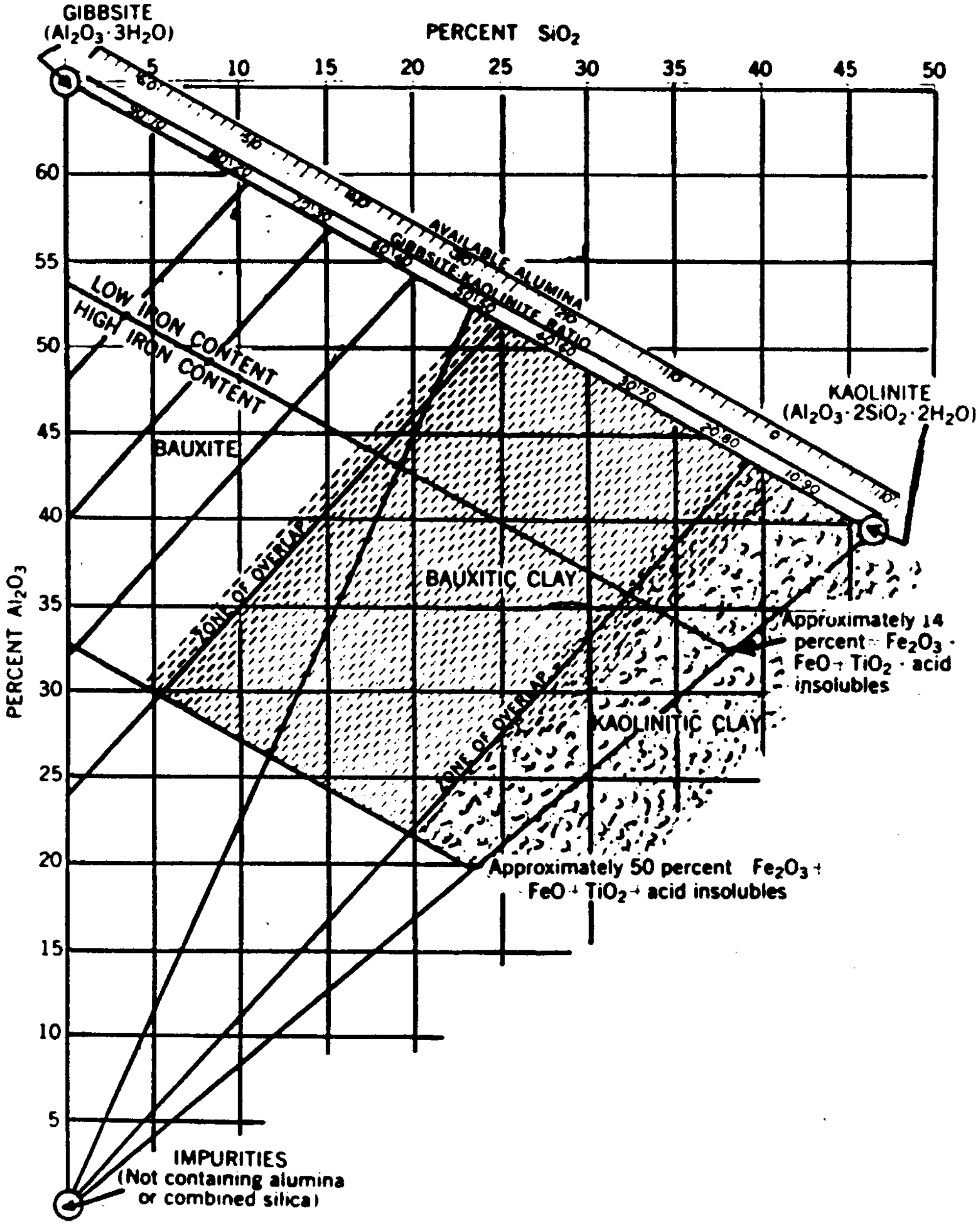
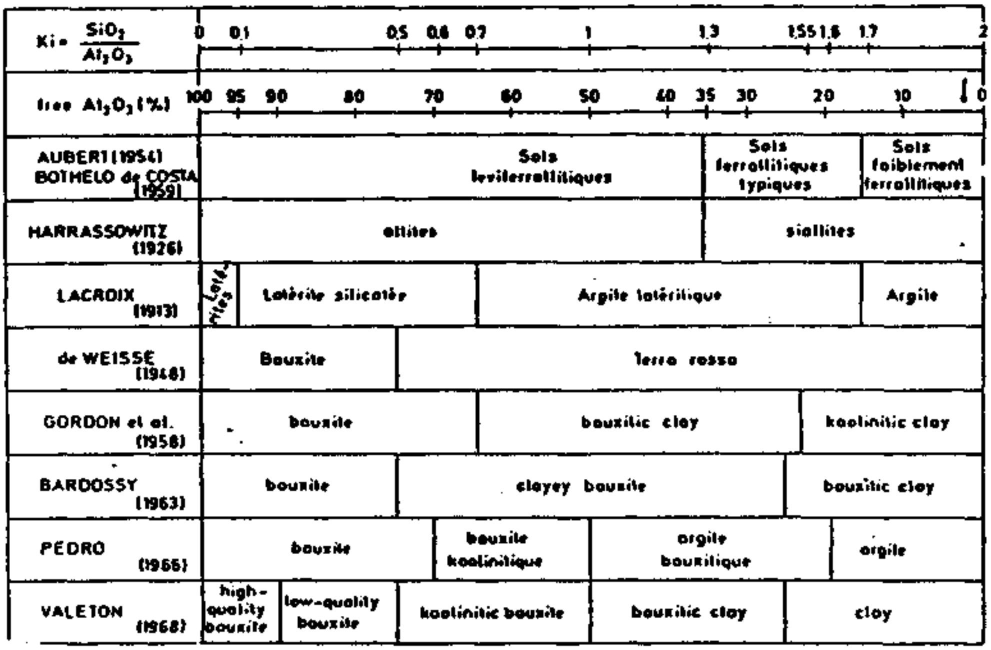


Fig. 1 Bauxite is an economic term having a wide range of variations in mineralogy (Gordon, M. and Tracey, J. I., 1958).



$Ki = \frac{SiO_2}{Al_2O_3}$	0	0.1	0.5	0.6	0.7	1	1.3	1.55	1.6	1.7	2		
free Al_2O_3 (%)	100	95	90	80	70	60	50	40	35	30	20	10	0
AUBERT (1954) BOTHELO de COSTA (1959)	Sols leviferrallitiques	Sols ferrallitiques typiques	Sols faiblement ferrallitiques										
HARRASSOWITZ (1926)	allites	siallites											
LACROIX (1913)	Latérites	Latérite silicatée	Argile latéritique	Argile									
de WEISSE (1948)	Bauxite	terra rossa											
GORDON et al. (1958)	bauxite	bauxitic clay	kaolinitic clay										
BARDOSSY (1963)	bauxite	clayey bauxite	bauxitic clay										
PEDRO (1966)	bauxite	bauxite kaolinitique	argile bauxitique	argile									
VALETON (1968)	high-quality bauxite	low-quality bauxite	kaolinitic bauxite	bauxitic clay	clay								

Table 1 The variations in bauxite nomenclature (Valeton, I., 1972).

			Hilgard 1860	Crider & Johnson 1906	Lowe 1915	Morse 1923	Lowe 1933	Grim 1936	Mellen 1939	Lusk 1956	Hughes 1958	Parks 1961	Rainwater 1964	Tourtelot 1964	Duplantis 1975
TERTIARY PERIOD	EOCENE EPOCH	CLAIBORNE GROUP	Northern Lignitic	Tallahatta	Tallahatta	Meridian Sand	Meridian Form.	Meridian Form.	Meridian Form.	Meridian Form.	Tallahatta	Meridian Form.	Tallahatta	Tallahatta	Tallahatta
				Wilcox	Grenada	Hatchetigbee	Grenada West east Hatch	Hatchetigbee	Hatchetigbee	Ackerman	Tuschoma	Wilcox Undifferentiated	Hatchetigbee	Ackerman	Meri. Sand
		WILCOX GROUP				Bashi	Bashi				Nanafalia		Tuschoma		Upper Wilcox
					Holly Springs	Holly Springs	Holly Springs	Holly Springs	Holly Springs				Nanafalia		
					Ackerman	Ackerman	Ackerman	Ackerman	Ackerman (restricted)	Fearn Springs				Fearn Springs	Lower
									Fearn Springs						
	PALEOCENE EPOCH	MIDWAY GROUP		Porter's Creek	Tippah Sand	Tippah Sand	Tippah Sand	Naheola	Betheden Naheola	Bethedan Naheola	Naheola	Naheola	Naheola	Tippah Sand	Porter's Creek
					Porter's Creek	Porter's Creek	Naheola	Porter's Creek	Porter's Creek	Porter's Creek	Matthews Landing Marl	Porter's Creek	Matthews Landing Marl	Matthews Landing Marl	
							Porter's Creek				Porter's Creek		Porter's Creek	Porter's Creek	
				Clayton	Clayton	Clayton	Clayton	Clayton	Clayton	Clayton	Clayton	Clayton	Clayton	Clayton	Clayton
CRET. PERIOD	GULFIAN EPOCH	SELMA GROUP	Ripley Group	Ripley		Ripley	Ripley	Ripley	Prairie Bluff						Owl Creek Prairie Bluff

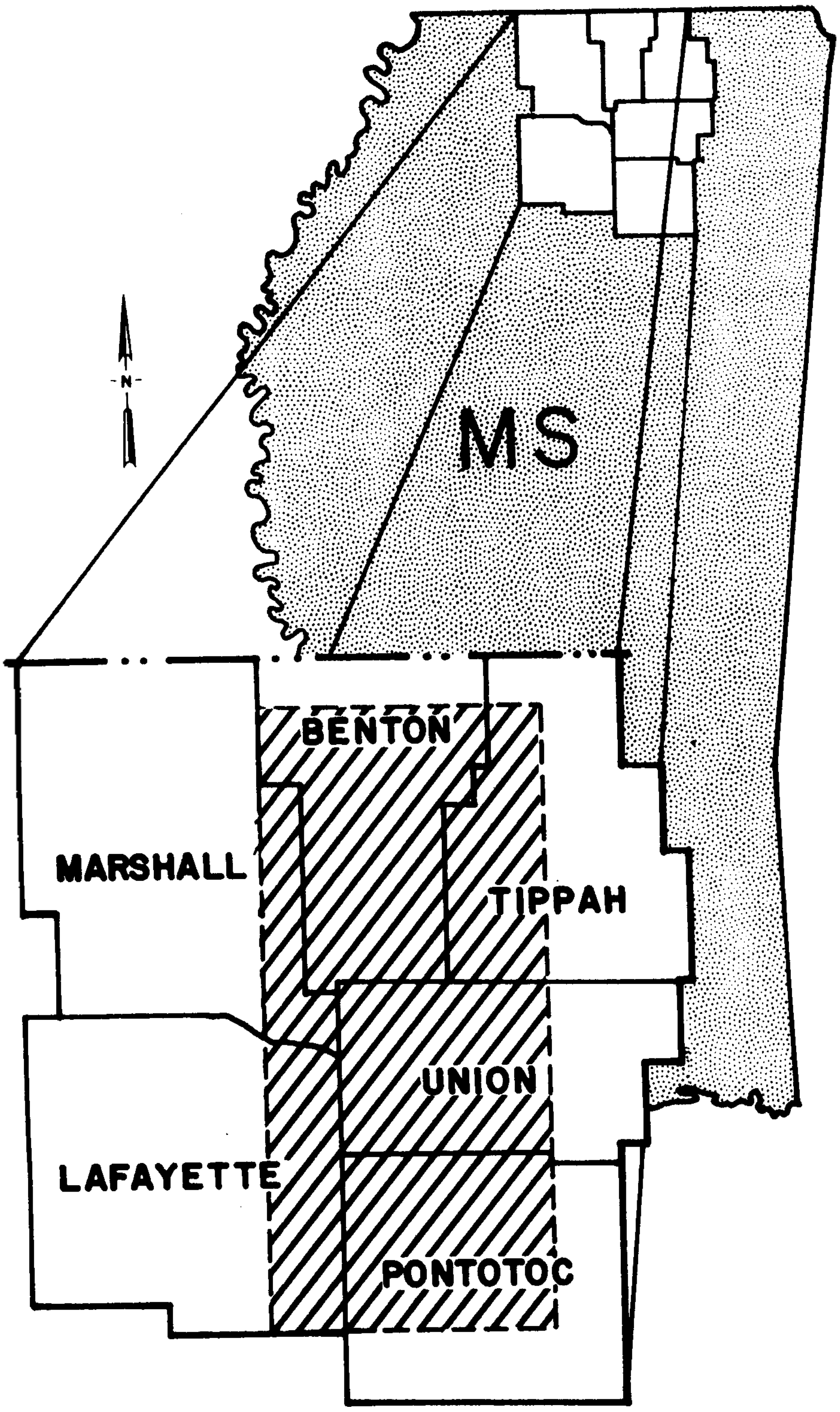
Table 2 Stratigraphic nomenclature of the Lower Tertiary of Mississippi (Modified after Dupplantis, M. J., 1975).

STUDY AREA

The main bauxite deposits of Mississippi are located in Pontotoc, Union, Benton, and Tippah Counties (Fig. 2). Deposits are transitional, with the outcrop boundary between the Upper Paleocene Midway Group and the Lower Eocene Wilcox Group. Exposed deposits occur within an area about 60 miles in length and approximately 2 miles in width (Fig. 3).

The Pontotoc Hills, Flatwoods, and North Central Hills are well-defined, physiographic areas entending north and south throughout the study area. (Hilgard, E.W., 1860). The western margin of the study area is within the North Central Hills, and is underlain by sands, silts, and clays of the Lower Wilcox Group, (Fig. 3), with the highest ridges reaching elevations of 425 to 560 feet above sea level. Near the eastern edge of the North Central Hills, Wilcox sediments cap hills that are often supported by underlying bauxite.

The major portion of the study area is within the Flatwoods belt, which is underlain by the Porters Creek clay. The Porters Creek strata offers nearly uniform resistance to weathering, producing wide stream valleys and broad, low, rounded hills, reaching elevations from 275 to 450 feet. The eastern portion is bordered by the Pontotoc Ridge, which consists of alternating sand, chalk, and limestone beds of the Clayton, Ripley and Prairie Bluff Formations (Conant, L.C., 1965; and Tourtelot, H.A., 1964).



LOCATION OF STUDY AREA

Fig. 2 Index map of the study area (hatched lines).

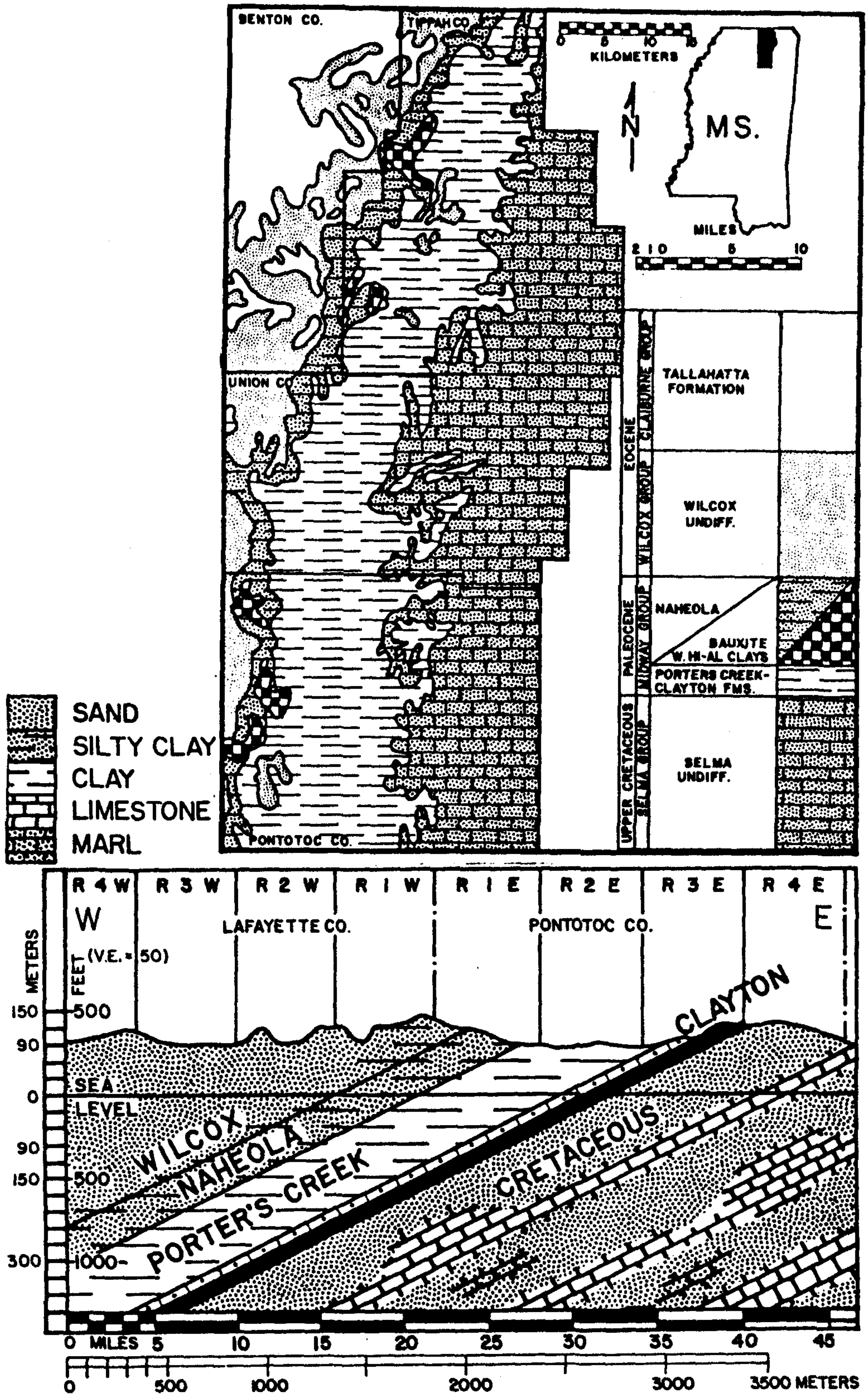


Fig. 3 Generalized surface map and cross section of the study area.

PURPOSE AND OBJECTIVES

In the past 55 years, there has been considerable debate over the stratigraphic position, genesis, and economic value of northeast Mississippi bauxite. The aluminum rich deposits are unlike most deposits (Fig. 4) found around the world. The deposits are associated with 200-300 feet thick marine to nonmarine clays overlain by feldspar poor, fluvial-deltaic sediments. The possible source areas are composed of limestone, marls, sand, and muds ranging in age from Late Cretaceous to Late Paleocene (Fig. 5). These factors prohibit the direct application of previous theories derived from studies outside Mississippi. The deposits, therefore, can not be considered a textbook example of bauxite formation.

To explain the Mississippi deposits the following 3 questions must be answered: [1) how is aluminum supplied to a sedimentary basin, 2) what type of sedimentary environment allows the accumulation of aluminum, and 3) is aluminum distribution related to the paleogeography]. The objective of this study is to answer the questions by describing the mineralogy, mapping the surface distribution, and mapping the shallow subsurface distribution of the aluminum rich deposits. By combining the stratigraphic and petrographic observations with present geochemical theories on aluminum, it may be possible to establish the mode of origin for northeast Mississippi's bauxite.

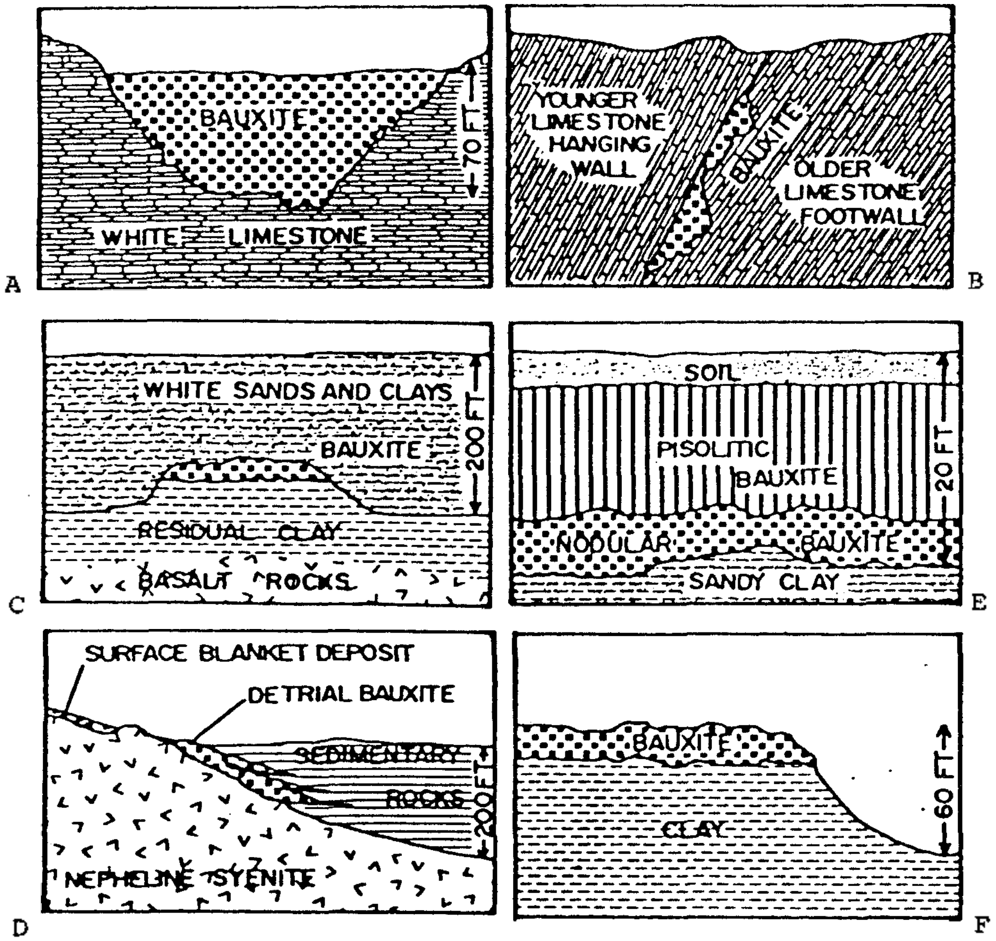


Fig. 4 Six examples of bauxite deposits from around the world: A) Jamaica pocket deposit, B) Guyana interlayered blanket deposit, C) Australia surface blanket deposit, D) Arkansas U.S.A. blanket detrital deposits, E) and F) Surinam's blanket deposits associated with sapralite deposits (Modified from Patterson, S.H. and J. R. Dyni, 1973).

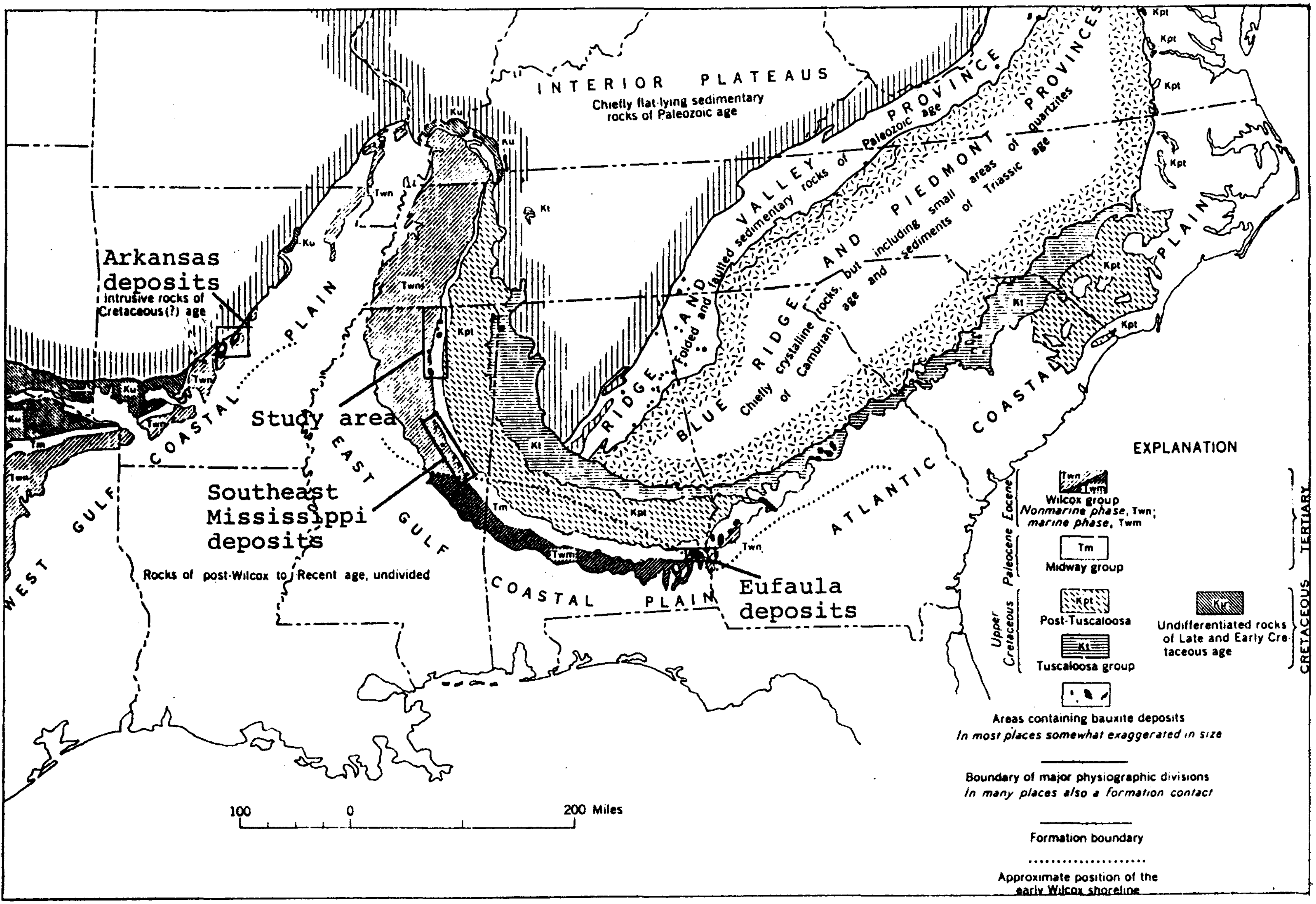


Fig. 5 Regional geology of U.S. bauxite deposits (Gordon, M. and J. I. Tracey, 1958).

PREVIOUS INVESTIGATIONS

Since 1910 the Mississippi Geological Survey and the U.S. Bureau of Mines have made intermittent attempts to ascertain the quality and quantity of bauxite ore. Previous studies have determined these deposits to be thin and too sparse for commercial value. Also, a large variation in composition has been indicated by data collected. This would indicate that the term bauxite, meaning a mineable source of aluminum, is not appropriate for north Mississippi deposits.

The age and stratigraphic position of these aluminum deposits has also been a source of controversy. This is partially due to the complex changes in stratigraphy from southern to northern Mississippi (Table 3). Field description of the numerous deposits range from residual soil to transported sediment (Table 4). The above inequities arise from the ill-defined Midway-Wilcox contact, which has been described as being both conformable and unconformable.

There are two basic theories which have been suggested for the genesis of north Mississippi deposits. The common explanation is that a soil process took place during a major regional unconformity (of about a million years) which separates the Upper Porters Creek from the Lower Wilcox. F. F. Mellen (1939), first proposed this explanation from studies of small deposits in Winston County 60 miles south of Pontotoc County. P.F. More (1923) and E.F. Burchars (1924) conducted the first major studies of the deposits in northern Mississippi.

			Mississippi (Northern)	Mississippi (Eastern)		Alabama (Western)		
LOWER TERTIARY	LOWER EOCENE	WILCOX	Wilcox Group Undifferentiated	Hatchetigbee Formation		Hatchetigbee Formation		Interbedded sands, clays, carbonaceous clays, fissile shales, and lignites.
					Bashi Marl Member		Bashi Marl Member	Glauconitic, fossiliferous, sandy marl. Some lignite.
				Tuscahoma Formation		Tuscahoma Formation	Bells Landing Marl Member	Sands, thinly laminated locally, clays, and fissile shales. Lignites are common. Locally at the base are large angular to rounded blocks of bedded silt.
							Greggs Landing Marl Member	
				Nanafalia Formation		Nanafalia Formation	Grampian Hills Member	Clayey sand, silty clay, and clay - shales. Numerous lignite beds. Thin fossiliferous beds in Kemper and Lauderdale Counties near middle of section.
							Middle Member Ostrea thirsae Beds	
					Fearn Springs Member		Gravel Creek Sand Member	Laminated, silty, micaceous clay, and fine sand; thin lignites, and reworked bauxitic material.
	PALEOCENE	MIDWAY	Naheola Formation			Naheola Formation	Coal Bluff Marl Member	Sand, carbonaceous clay - shales, laminated silts and clays. Kaolinitic and bauxitic clay found locally near the top.
							Oak Hill Member	
			Porters Creek Formation	Porters Creek Formation	Matthews Landing Marl Member	Porters Creek Formation	Matthews Landing Marl Member	Glauconitic, sandy clay. Sparingly fossiliferous. Limonite concretions.
								Blocky clay, with slightly glauconitic, micaceous sand lenses. Siderite concretions. Tippah Sand Lentil recognized in northern Mississippi as lenticular sands, clays, and sandstones.
			Clayton Formation			Clayton Formation	McBryde Limestone Member	Glauconitic, laminated clays, marls, and sands. Locally fossiliferous.
				Chalybeate Limestone Member			Pine Barren Member	Glauconitic, fossiliferous, sandy limestone, with interbedded fossiliferous marl.

Table 3 Stratigraphic nomenclature of the lower Tertiary of Mississippi (Williamson, D. R., 1976).

PREVIOUS INVESTIGATION OF MISSISSIPPI BAUXITE

NAME	DATE	PROPOSED THEORY AND PROCESS
BURCHARD	1924	IN SITU MARSH-SWAMP DEPOSITS SIMILAR TO PRECIPITATION OF BOG ORE.
MELLEN	1939	IN SITU RESIDUAL DEPOSITS REPRESENTING A MAJOR REGIONAL UNCONFORMITY BETWEEN THE EOCENE AND PALEOCENE. PRODUCT OF MILLION YEARS OF SUBAERIAL LEACHING OF PORTERS CREEK CLAY (DESILICATION).
PRIDDY	1943	LOCALIZED LEACHING PRODUCED RESIDUAL DEPOSITS.
COULTER	1948	CHANNEL SHAPED GEOMETRY PRODUCED BY UNKNOWN PROCESSES.
MAC NEIL	1952	DETRITAL KAOLINITE TRANSPORTED INTO SWAMPS.
REED	1952	CHANNEL AND LAGGONAL FEATURES RESULTING FROM SHAOLING OF THE MIDWAY SEA. UNKNOWN PROCESS PRODUCED CLAYS.
TOUTELOT	1964	DETRITAL KAOLIN TRANSPORTED AND DISTRIBUTED IN A NARROW PATTERN. CLAYS ERRODED FROM RESIDUUM THEN TRANSPORTED BY A NARROW DISPERSAL SYSTEM AND THEN DEPOSITED IN A NARROW BELT OF SWAMPS.
CONANT	1965	SAME AS TOURTELOT BUT WITH EMPHASIS ON CHANNEL SHAPED GEOMETRY.
VELTON	1972	ENVIRONMENT CONTROL OF DISTRIBUTION. BAUXITE AND KAOLIN RESTRICTED TO SHOREWARD FACIES OF THE UPPER PORTERS CREEK FORMATION.
PANDYA	1973	IN SITU RESIDUAL DEPOSITS REPRESENTING A MAJOR REGIONAL UNCONFORMITY BETWEEN THE EOCENE AND PALEOCENE. PRODUCT OF MILLION YEARS OF SUBAERIAL LEACHING OR PORTERS CREEK CLAY (DESILICATION).

Table 4

Both researchers believed the overlapping lenses of siderite, lignite, and lignitic clays indicated a marsh or swamp environment, and thus a formation process similar to that of bog ore. These early works, however, have been largely ignored because the acceptable view in the late 1930's favored residual accumulation of bauxite.

Mellen (1939, p. 26) found no evidence of feldspar or a major source material rich in feldspar within the bauxite region. He concluded, therefore, that the parent material was the montmorillonitic (smectite) material of the Porters Creek Formation. He suggested that bauxite could form from such a parent only by prolonged leaching during subaerial weathering. To this proposed residuum he gave the name Betheden Formation. The initial Wilcox sedimentation that followed, Mellen reasoned, eroded much of the residuum and formed the Fearn Springs Formation. This concept has been challenged, however, by several investigators, (Conant, L.C., 1948 and MacNeil, F.S., 1951), and since 1951 the term Betheden has been dropped from the nomenclature. The theory for a major regional unconformity separating the Midway from the Wilcox Group has also been dismissed as unlikely (Dupplantis, M.J., 1975).

An investigation in Pontotoc County demonstrates the difficulty of explaining bauxite development in Mississippi. The major problems facing earlier workers were the scattered distribution of the deposits and their relationship to unweathered or unaltered parent material. Priddy (1943) concluded that such a distribution indicates that laterization was incomplete or interrupted in areas where silt is interbedded with onset of accumulation of peat. The sediments deposited and eroded in these coastal swamps represent the Betheden and Fearn Springs Formations. MacNeil (1951, p. 1063), therefore, considered parts of the two formations to be contemporaneous. The close relationship of the bauxite to the Betheden Formation would make the aluminum deposits contemporaneous with the accumulation of peat in the swamps.

From extensive drilling and quality data, Reed (1952) concluded that many deposits of kaolin and bauxite occupy ancient channels or lagoonal environments which resulted from shoaling of a Late Paleocene sea. Drilling downdip from known deposits revealed no new deposits. Reed (1952) suggested that this paucity was due to a downdip change to a more marine environment. Although Reed suggested such environmental controls, he was not able to explain the mechanism which produced the bauxite.

Studies of Benton and Tippah County's deposits (Tourtelot, H.A., 1964) indicate that the bauxite is associated with a zone of transitional sediments between the marine clays of the Lower Wilcox Group. Tourtelot (1964) proposed that the bauxite deposits were derived from detrital kaolin. The bauxite locations, therefore, would be controlled by the limits of the dispersal pattern and the geometry of the small basins (swamps) in which the detritus was deposited. No explanation, however, was given on how pisolitic bauxite developed from a detrital kaolinitic deposit.

The first indication of a possible precipitational origin for north

Mississippi bauxite was given by Burchard (1924). It is important to note that in the early 1900's many European geologists suggested bauxite could be the result of active precipitation in lakes and swamps (Fisher, E.C., 1955). Theories dealing with precipitational origins for bauxite were replaced in the 1930's by theories supporting soil or residual origins for bauxite. This change in theory was due to the discovery of extensive deposits of high quality ore on or near feldspar-rich rocks. The geologist of the 1930's concluded that such bauxite deposits developed in situ (residual) due to the inertness of aluminum to chemical reactions. Residual origin has been the only exceptable theory for bauxite deposits until the late 1970's.

The most extensive description of exposed Mississippi bauxite deposits is found in the work of More (1923) and Burchard (1924). The average deposit, according to these investigations, is a few inches to a few feet in thickness and covers an area of several acres. Both More (1923) and Burchard (1924) noted the deposits are associated with lignitic clays, lignite, and variegated sands of the basal Wilcox Group. Irregular shapes and common interbedded kaolinitic clays seem to reflect a series of overlapping lenses which are commonly gradational. This geometry, Burchard (1924) suggested, is similar to chemical sediments formed within swampy depressions. The above theory is also favored by Berry's (1916) indication that associated iron carbonate beds (siderite) are good evidence of a paludal environment.

Burchard (1924 and 1925) proposed that it is possible that streams flowing over Cretaceous and Paleocene uplands to the east carried glauconitic and bentonitic clays (montmorillonite or similar forms of smectite) in a finely divided state (colloidal?) and iron - aluminum salts in solution He further suggested that these streams entered swamps along the coast and that within these swamps organic acids affected both iron and aluminum hydroxide, causing precipitation.

Velton (1972) compiled an extensive amount of information as a result of studies of bauxites around the world. She noted that most bauxite deposits were not associated with clastics. For this reason, she took special note of the deposits along the Midway Group in Mississippi and Alabama. There the main parameters were the distribution and size of the deposits. The Eufalia district (less than 12 miles long) occurs in the extreme southeastern corner of Alabama and is within the same stratigraphic position as the Mississippi deposits (Warren, W.C., and Clark, L.D., 1965). Velton (1972) noted that between the Eufalia (fig.5) deposits and the first sign of bauxite in Kemper County, Mississippi (about 180 miles) there exists no evidence of bauxite ever being present. Rather, there exist sediments suggestive of shallow water marine environment such as a large bay. Velton (p. 147) also suggests that the Eufalia and Kemper County deposits developed along the margins of this large bay, and that the absence of bauxite between these two areas is probably due to a difference in the clays within the upper part of the Porters Creek Formation. Again, Velton (p. 147) suggests that this difference is due to the depositional environment, where the portion of the formation where bauxite occurs represents a shoreward mud facies of the

Porters Creek Formation.

The influence of environment has been suggested by several of the above researchers. If these deposits rich in aluminum did form within the active margin of the Late Paleocene coast, it is very possible that accumulation was influenced by environmental changes along strike. This study, therefore, will concentrate on interpretation of the environments present during formation and their probable effect on the genesis of bauxite.

STRATIGRAPHY

Recent stratigraphic studies indicate that the Midway and Wilcox Groups of Mississippi are a complete fluvial-deltaic sequence which prograded into an arm of the Gulf Coast Embayment (Dupplantis, M.J., 1975). The sequence indicated consists of a steady continental transgression of deltaic deposits over the thin carbonates and thick muds of the Lower Midway Group. The net sand and percent sand maps produced by Duplantis (1975) show a close relationship between the Lower Wilcox and Upper Midway dispersal systems. From this, Duplantis (1975) concluded that it is not possible to use the Midway-Wilcox lithologic contact to define a time stratigraphic boundary or a time unit boundary to separate the Paleocene and Eocene series. Subsidence contemporaneous with progradation is believed to be the cause for the overlapping of sediments and the development of the Midway-Wilcox system.

Localized unconformities, possibly formed by storm surges, splays, and channel incisions, are found along the contact of the Midway-Wilcox Groups. There is little evidence to suggest a regional unconformity between the Upper Midway and Lower Wilcox. Previous investigators based the theory of a regional unconformity on the sparce occurrence of bauxite in the outcrop. In the late 30's many geologists believed that bauxite formation on clays could occur only after millions of years of subaerial exposure (Mellen, F. F., 1939). Recent studies of iron, kaolin, and ferruginous pisolities indicate that such deposits may form in active depositional systems. A good example is the deposition of kaolinite within the outer perimeters of modern deltas in the Gulf of Mexico (Snowden, J.O., 1976; Brooks, R.A., 1976; and Griffin, G.M., 1964). Studies of modern and ancient deposits similar to the Midway and Wilcox Groups suggest that localized unconformities can occur simultaneously with depositional processes. (Fig. 6). The fact that sand and clay are in sharp contact does not necessarily indicate a major regional unconformity. Extensive studies of modern and ancient deltaic environments have concluded that time lines often do cut across such lithologic boundaries, depending on the variations in ratios between rate of deposition and rate of subsidence. (Fig. 7).

In northern Mississippi, shallow marine sediments (upper Porters Creek or Naheola equivalent) grade upward into swamp deposits which in turn grade upward into fluvial-deltaic deposits. Roux (1958) and Rainwater (1964) found sufficient evidence to show that eustatic sea level changes did not occur in the Lower Tertiary, and therefore, deltaic sedimentation rates and depth of water were responsible for regressions and transgressions. Consequently, a variety of coastal environments could exist simultaneously along the depositional strike of a series of small prograding delta systems.

PORTERS CREEK FORMATION

In the southernmost extent of the Porters Creek Formation (Kemper County), there is a distinct separation between the overlying Naheola Formation and the Matthews Landing Marl (Hughes, R.J., 1958). But

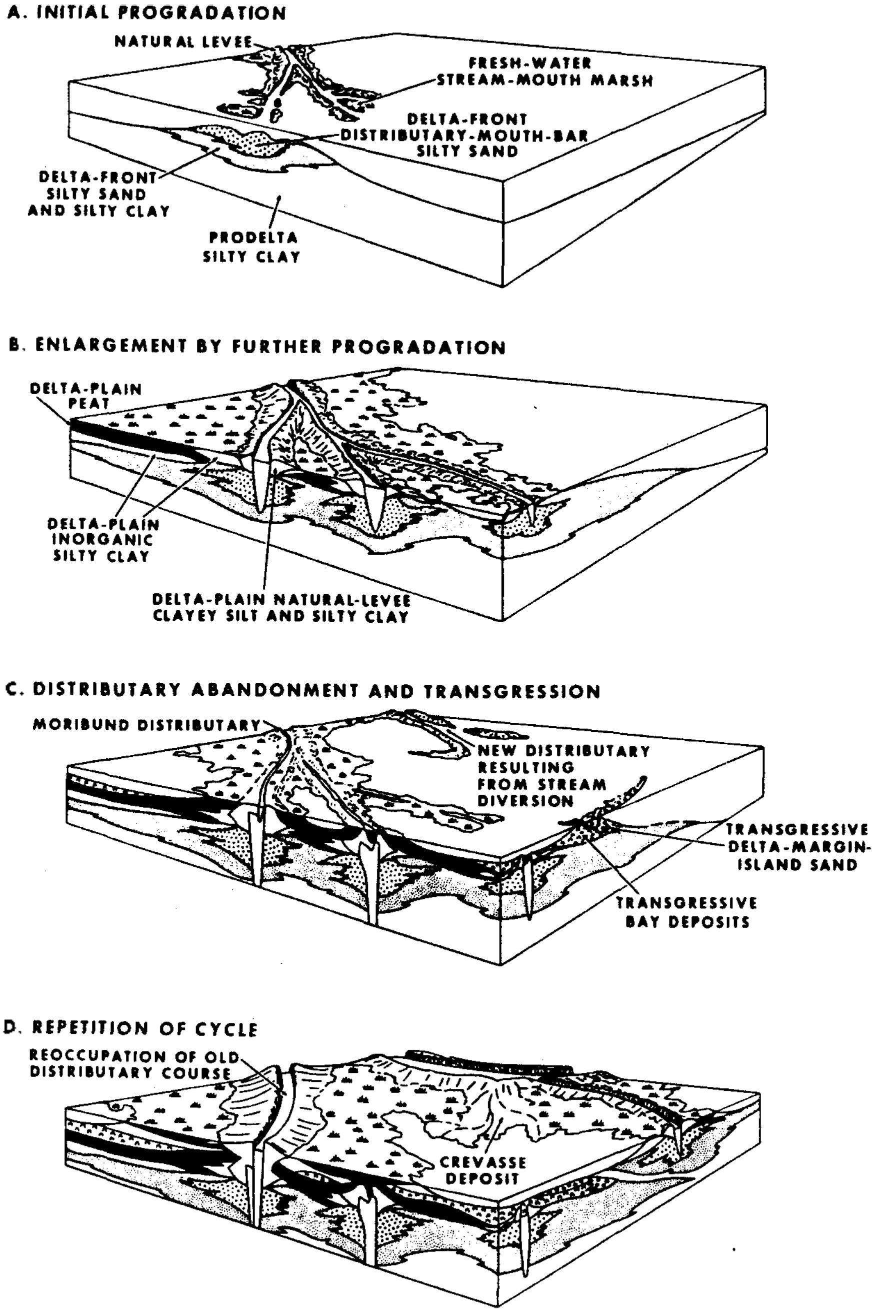


Fig. 6 Evolution of an interdistributary bay fill (Frazier, D. E. and A. Osanik, 1973).

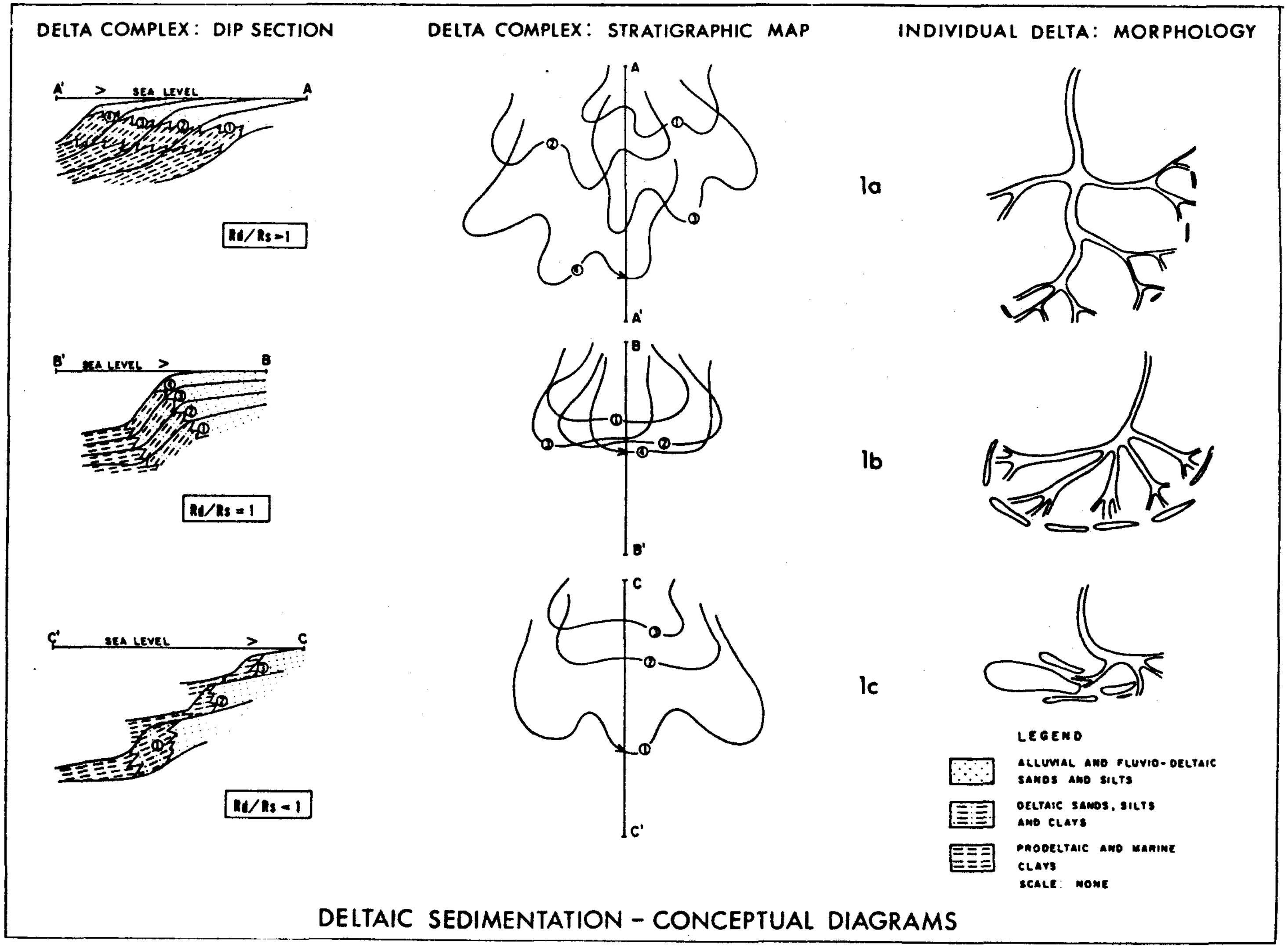


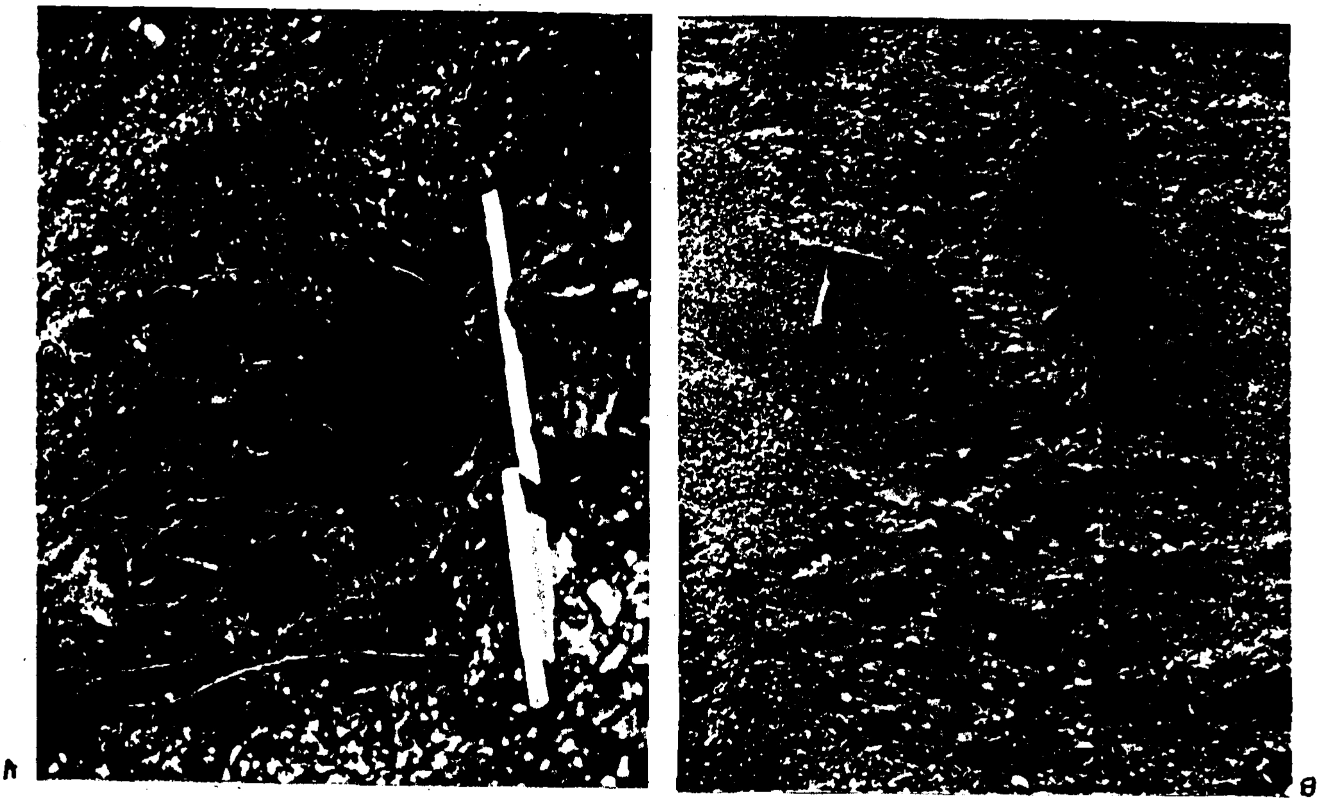
Fig. 7 Conceptual diagram of variations in rate of deposition and rate of subsidence (Rd/Rs) in a delta complex (Curtis, D. M., 1970).

northward along the strike, this marker bed is lost and the separation of Porters Creek and Naheola is made only on the basis of lithology and stratigraphic position. Lithologically, the Porters Creek Formation can be divided into three parts: basal, typical middle, and upper laminated members. The upper laminated phase has also been suggested to be equivalent to the Naheola Formation. (Table 3)

Exposure of the Porters Creek Formation and the Naheola equivalent are few, and generally poor due to the low resistance and uniform weathering. (Fig. 8). Where exposed, the Porters Creek formation typically consists of light brown-gray clays in the fresher sections. The typical phase (middle) consists primarily of finely and sparsely muscovitic, tough to slightly plastic, jointed, conchoidally fracturing clay (Fig 8). The unit has been described as massive, but when it is studied closely by thin section and continuous core samples, faint laminations and siltier portions are revealed.

TIPPAH SAND MEMBER

Exposures of marine sand bodies are found within the study area in the northern portion of Tippah County. (Fig. 3). The bodies have been described by previous investigators as the Tippah Sand Member. These sand bodies have been shown in Tennessee (Whitlatch, 1936) and Mississippi (Conant, L.C., 1941) to consist of several beds of marine sands interstratified with the upper portions of the typical Porters Creek clay. The thickness, length, distribution, and general appearance suggest that they may be part of a barrier beach system that extended from southwest



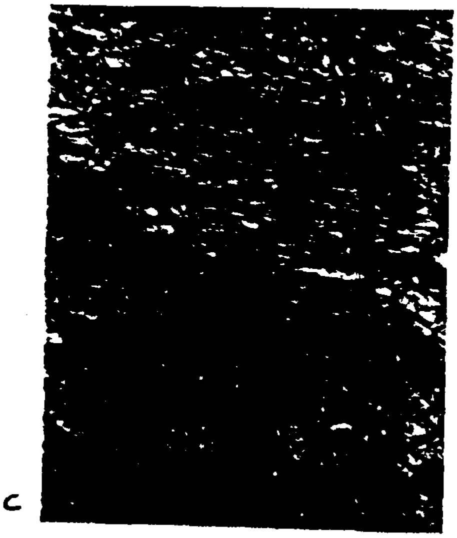


Fig. 8 Exposures of the three typical phases of the Porters Creek Formation. (A) exposure of basal phase in northern Tippah County near Hurricane Creek R. 3 E. T. 2 S., Sw. 1/4 , Sw. 1/4 of Sec. 12 (see x-ray patterns 31 and 32 in appendix C. (B) middle or common phase of the Porters Creek south of Myrtle on hwy. 78 R. 2 E., T. 6 S., Se 1/4 Sec. 20. (C) upper phase or Naheola Formation R. 1 E. T-6 S., Nw 1/4 Nw 1/4 Sec. 16 (see x-ray pattern 30 in appendix C.

Illinois to Tippah County in northern Mississippi.

From northern Tippah County southward, these sands give way to laminated, silty, and sandy sediments, probably Naheola-equivalent. Apparently, initial delta building of the Late Paleocene in northern Mississippi cut short the longshore drift and other conditions favorable for barrier bar and beach building. Close study of the Tippah outcrop in northern Tippah County reveals both these conditions plus features which appear to represent tidal deposition. (Fig. 9).

NAHEOLA FORMATION

Previous investigators have provided many conflicting statements on the Naheola equivalent sediments in northern Mississippi (Table 2.). The definition or separation of the Naheola in north Mississippi is complicated by the lack of marine marker beds, the scarcity of fossils, and the similarity to the upper portion of the Porters Creek Formation.

Exposures of the Naheola outcrop are occasionally found in roadcuts and streams in southeastern Benton County, northwest Union County, Pontotoc County, and almost the entire eastern half of Calhoun County, Mississippi. Where the Naheola Formation is well exposed (Fig. 10). the contact with the underlying Porters Creek Formation is obscure. This contact is difficult to pick from drill cuttings because of the close similarities in clay and silt content of the two formations. When continuous cores are taken, however, changes in silt content, muscovite content, and bedding structures can be observed.

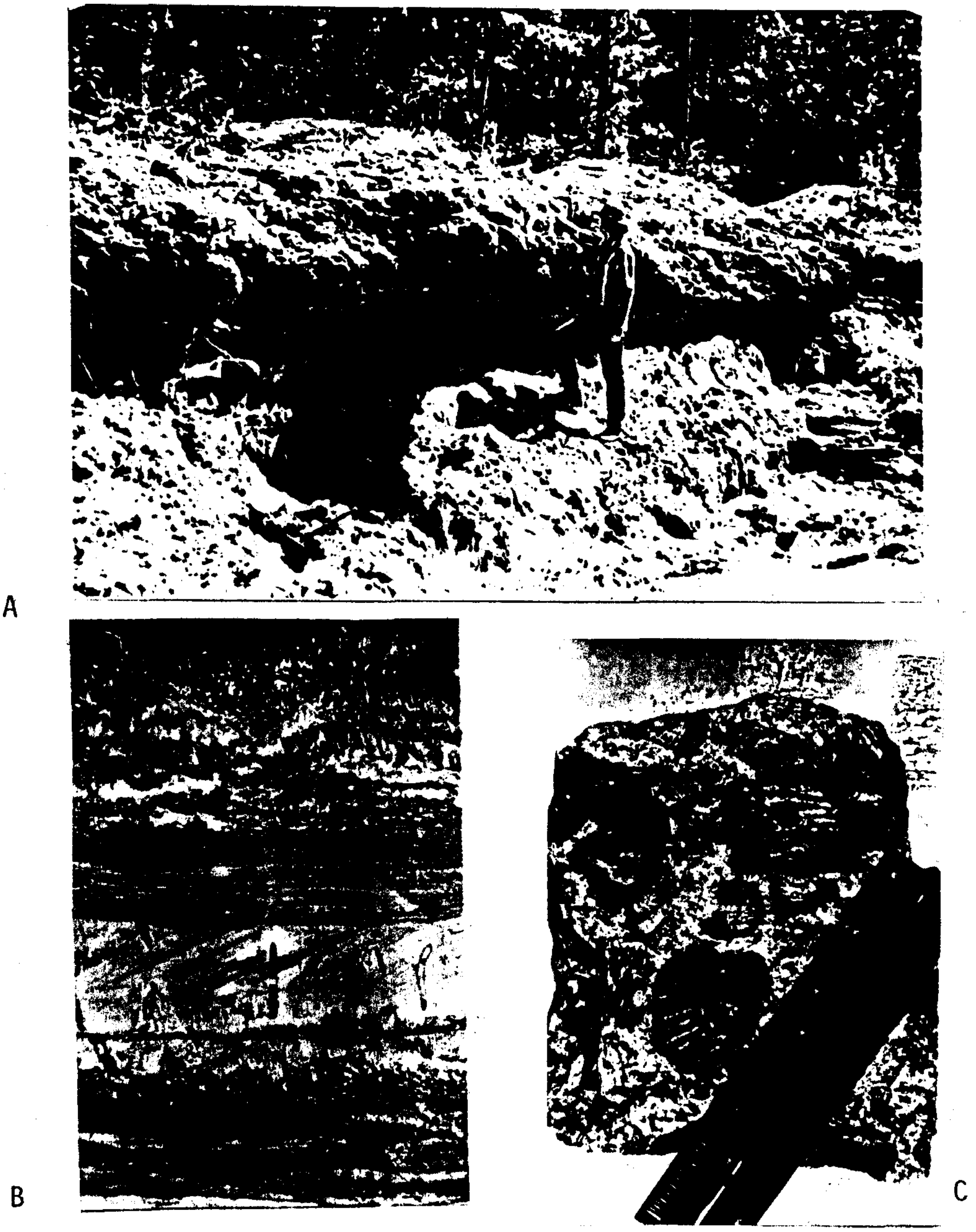
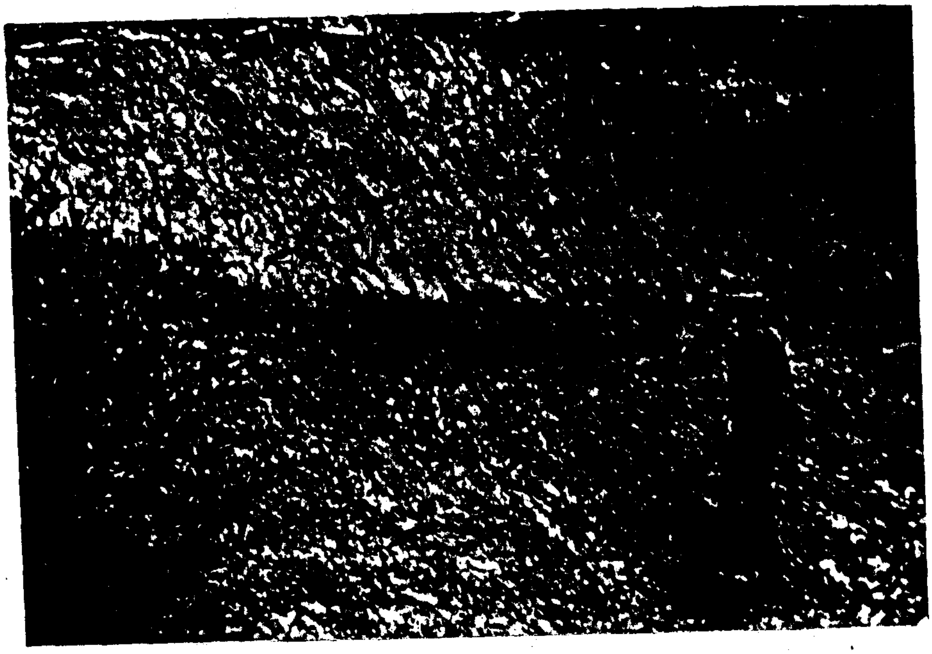


Fig. 9 Exposures of the Tippah Sand Member in northern Tippah County near Hurricane Creek on Odell Jones property Se. 1/4 Sw. 1/4 of Sec. 12, T. 2 S., R. 3 E.
(A) fossiliferous sands form indurated ledges of lenticular bodies within the Porters Creek Formation, (B) bedded and burrowed sands below the ledge suggest a barrier beach origin, and (C) fossil molds forming the indurated ledge.



A

B

Fig. 10 Exposure of laminated silty clays of the Naheola Formation in a road cut south of Hickory Flats and east of Cornersville R. 1 E. T. 6 S., Nw 1/4 Nw 1/4 Sec. 16 (See x-ray pattern 30 in appendix C).

BAUXITE AND HIGH ALUMINUM CLAYS

Beds of bauxitic material, where exposed, are most often resistant, irregular in shape, discontinuous, and varying in thickness over short distances. Because of the limited areal extent and discontinuous nature, it is difficult to interpret a deposits' relationships with others unless closely spaced saturation drillings (500 foot or 153 meters centers) are used. The present investigation indicates that the bauxitic deposits could actually be part of the Naheola Formation. This interpretation is based on the occurrence of carbonaceous, laminated, silty clays in close contact with bauxite deposits.

Exposures of indurated bauxite (Fig. 13) are most common in Western Pontotoc County mainly in the areas of Randolph, Toccopola, and Smoky Top-Waldrop (Fig. 11). A few scattered occurrences are also found commonly overlying softer bauxitic material and kaolinites in southwestern Tippah and southeastern Benton Counties. An example of indurated bauxite (Fig. 13 and 14) is the Randolph Road metal pit located about 2 miles (3.2 km) northeast of Randolph, Pontotoc County. Here detailed drilling, measured sections, x-ray diffraction, and petrographic observations helped establish good control for the study area (Fig. 12). Field observation at Randolph indicates that the highly pisolitic cap rock appears to have low angle cross beds. (Fig. 13) Similar cross bedding was noted by Pandya (1973, p. 39) in a deposit in Oktibbeha County, about 90 miles (145 km) south of Pontotoc County.

Bauxite deposits are south of Tippah Sand exposures and are separ-

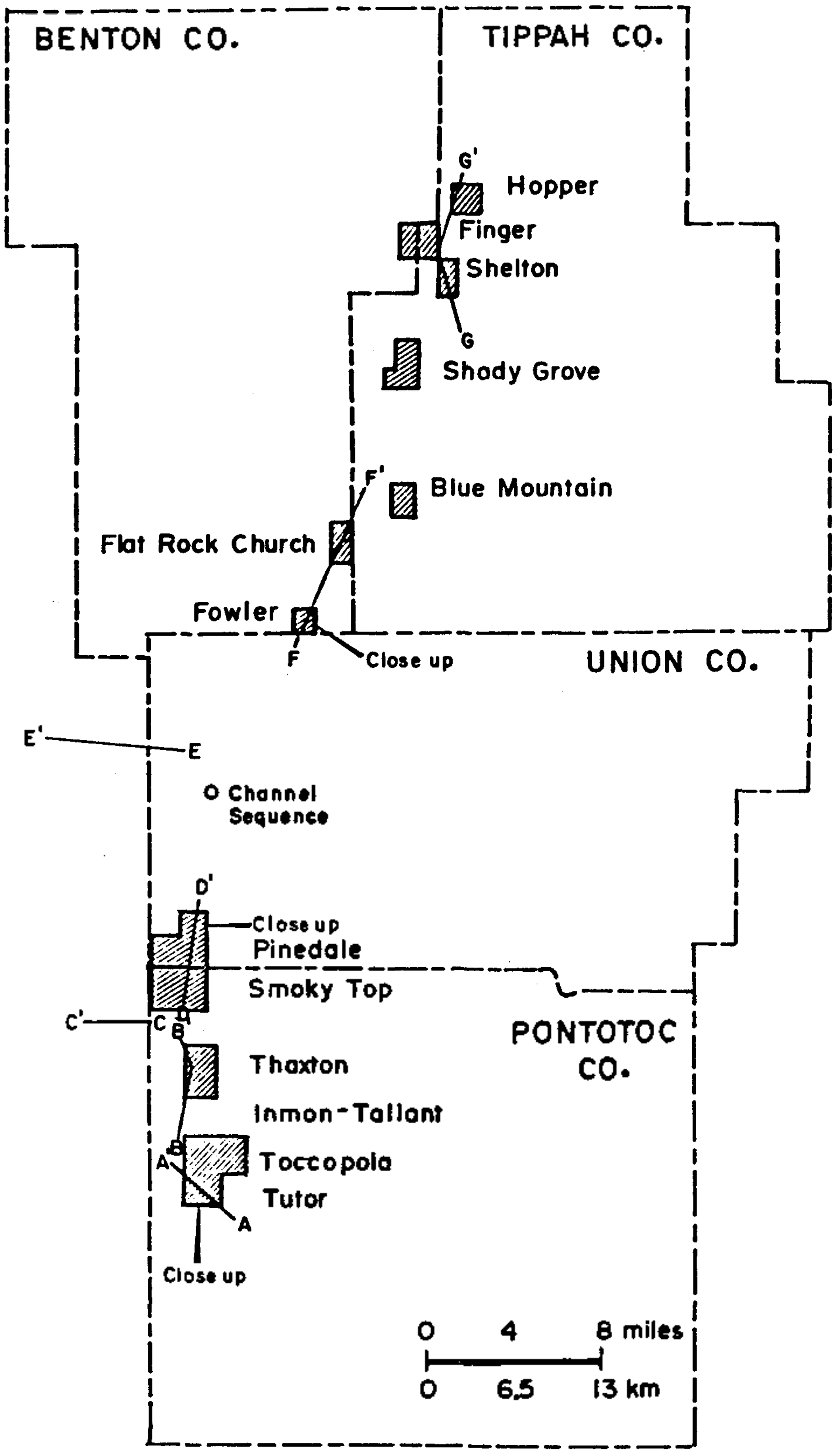


Fig. 11 Index map of cross sections and major deposits.

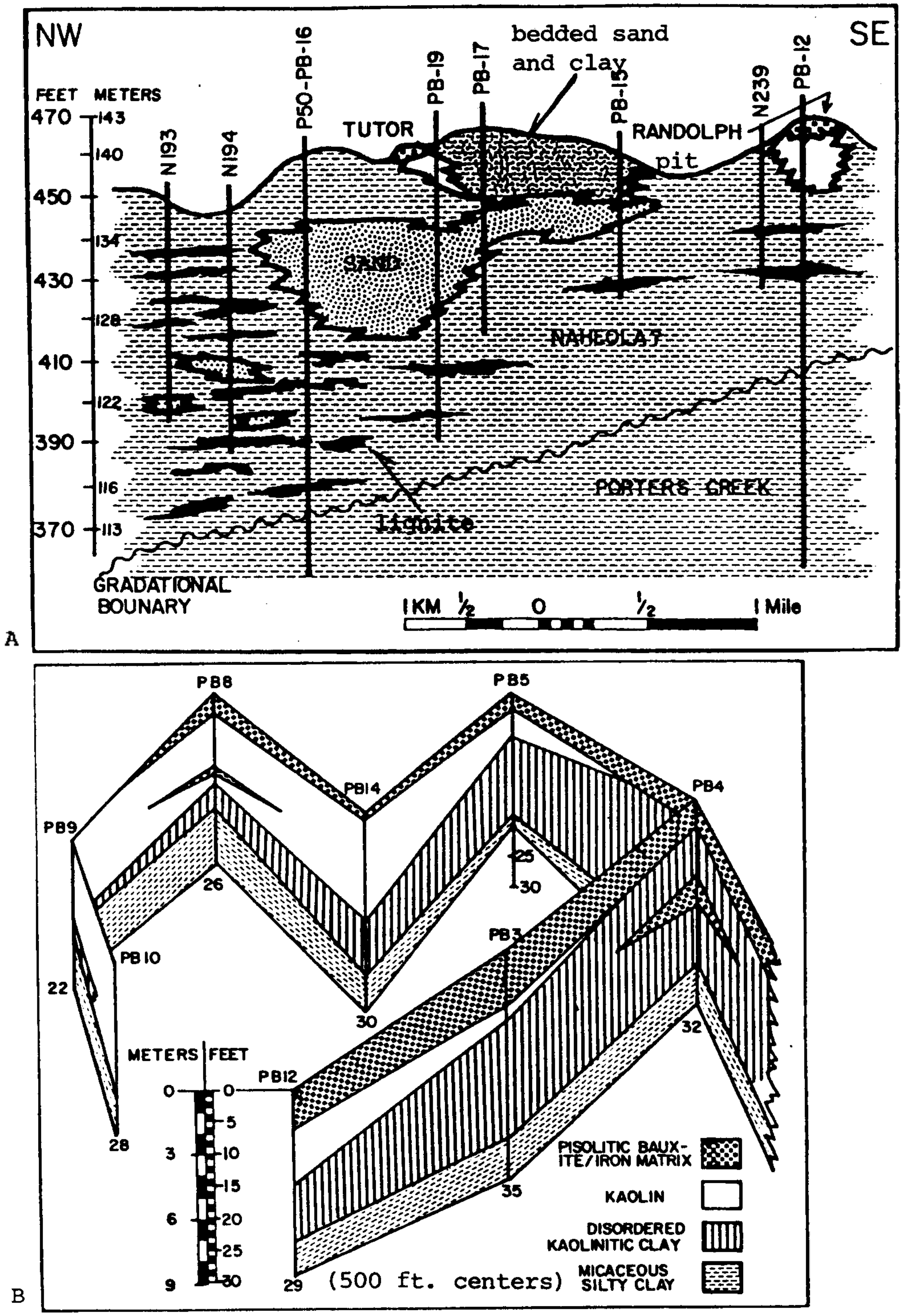


Fig. 12 Part (A) cross section A-A' and Part (B) Randolph road metal pit in southern Pontotoc Co (Appendix A, B, and C).

Fig. 13 Bauxite pit located near Randolph in Pontotoc County. The above photo shows the possible low angle cross bedded bauxite. The exposure consists of an iron enriched cap, a broken and cross bedded pisolitic oolitic zone, a soft pisolitic zone with a clay matrix, and a basal zone of kaolinitic clay (see Appencix A, B, and C).

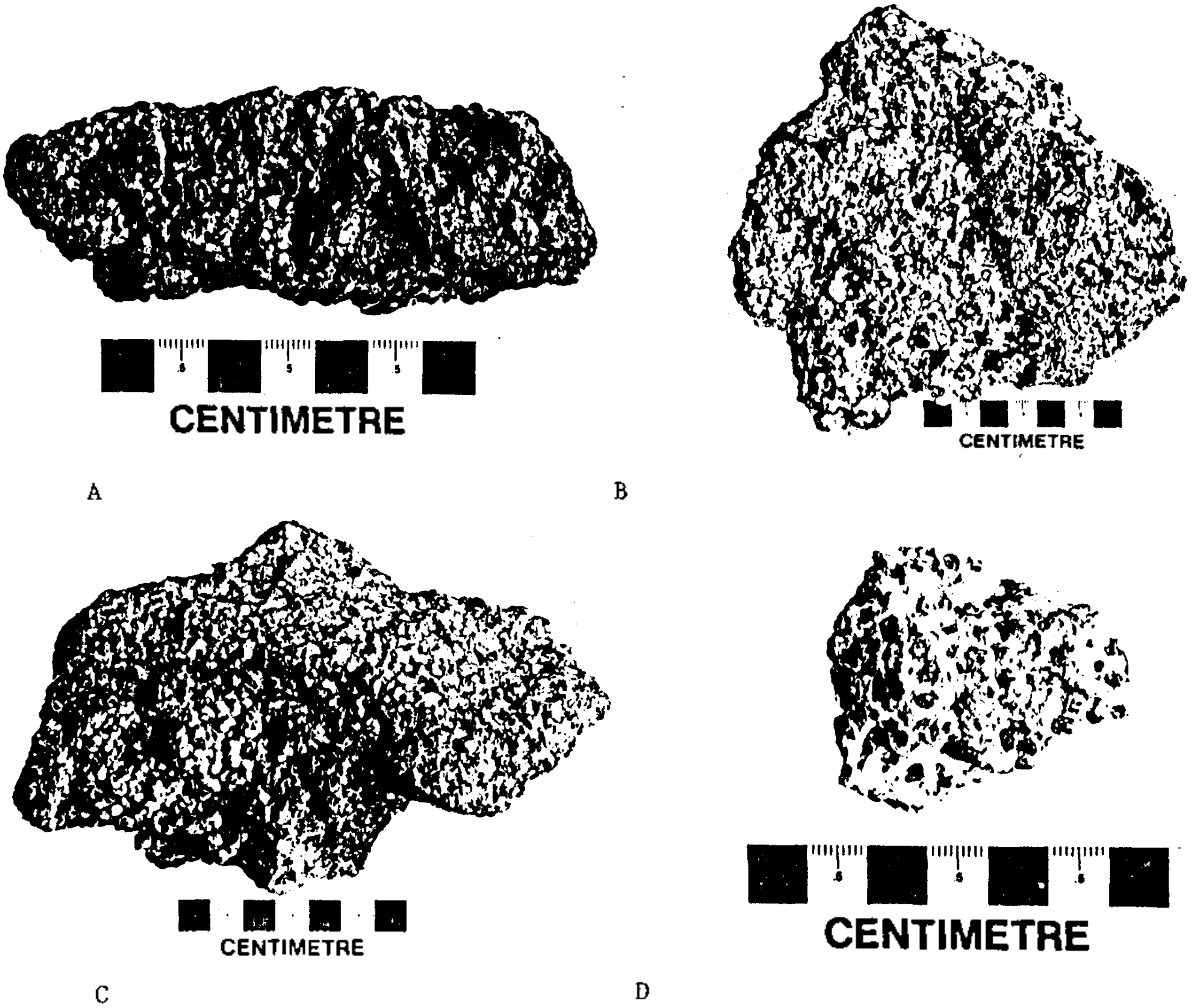


Fig. 14 Bauxite handsamples from the 4 major zones exposed within the Randolph road metal pit in southern Pontotoc County(Fig. 13). (A) upper cap rock hard iron rich, (B) Cross bedded zone, (C) concretionary zone within the cross bedded pisolitic zone, and (D) soft pisolitic kaolinitic clay form the basal contact between the bauxite and kaolin.

ated from their southern counterpart by thick Naheola Formation in Calhoun County, and are north of the marine Paleocene-Eocene Formations in Kemper County, Mississippi, and the Alabama line (Fig. 5). This may indicate an indirect relationship of deltaic and near shore sediment movement to the loci of bauxite formation. Also, a change in mineralogy of deposits is noted northward along strike within the study area. Kaolinitic clays are dominant in the northern half, while the indurated gibbsitic deposits are dominant in the southern half of the study area.

There are two types of bauxite deposits within northern Mississippi. The more common surface deposits are hard pisolitic, ferruginous, and gibbsitic, at times referred to as curiasse. The second variety, subsurface, consists of soft kaolinitic clays with occasional large pisolites and traces of gibbsite. This latter variety is encountered along the strike at depths up to 60 feet (18 meters). Overburden averages 30 to 40 feet, (9-12 meters), and consists of fine-grained quartz sands and carbonaceous muds (Fig. 15). Occasionally, such deposits are found to consist of clay breccia (Fig. 16) within a clay matrix, indicating possible surge forces during the deposition of this material, such as would occur during channel incision, storm surge, or splaying.

Northward from Pontotoc County the first major change occurs at Pinedale in southern Union County. The Pinedale deposit is unique in appearance bacause core sections (Fig. 16) indicate that part of the deposit was the result of a single surge event, splay, or storm.

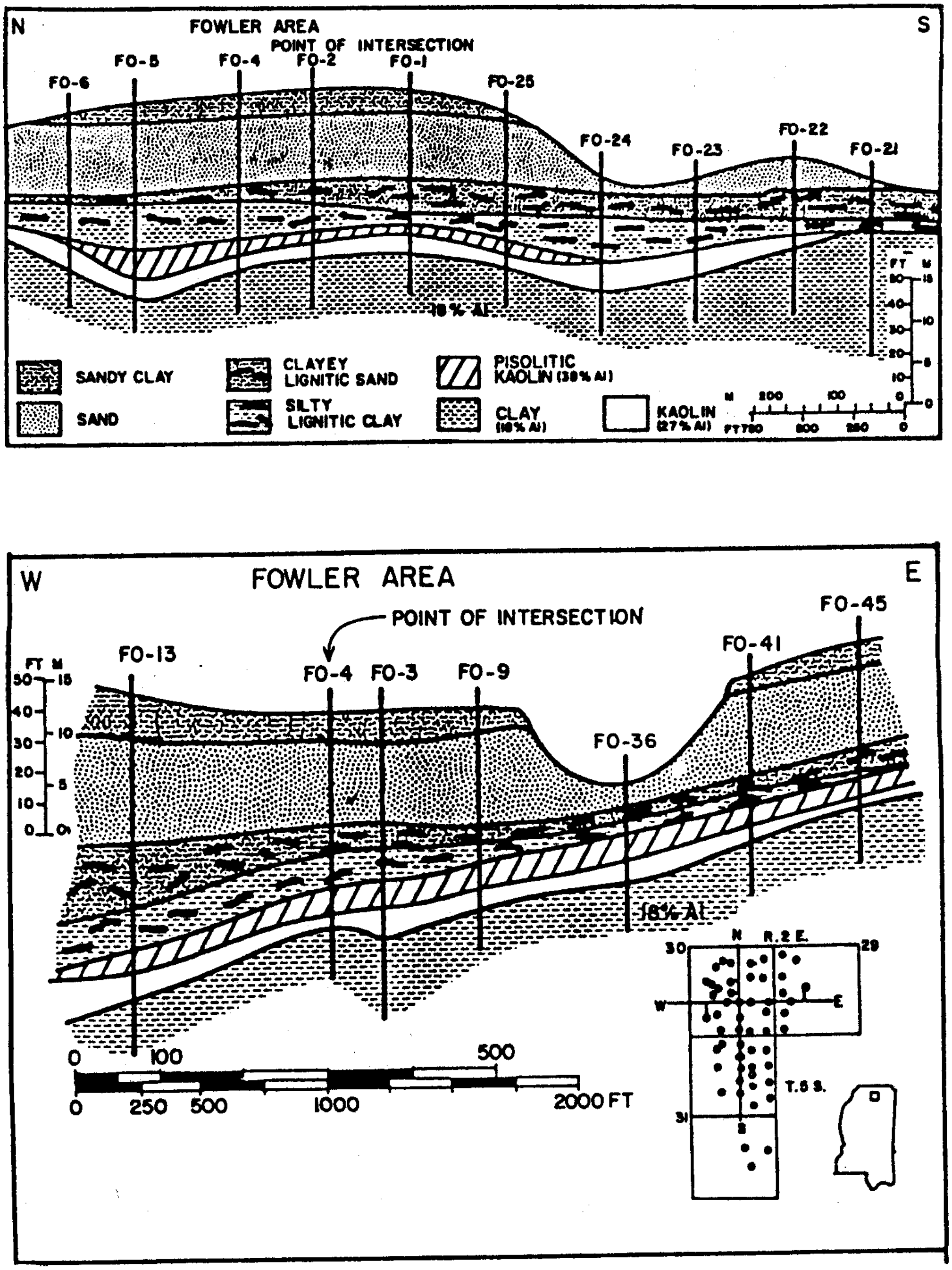


Fig. 15 Detailed cross section of the Fowler deposit in Benton County. Thin sections, quality, and x-ray diffraction can be found in Appendix C.

Fig. 16 Photographs of a typical core from the Pindale deposit.

Assuming this is actually a splay deposit, the surge event was then followed by ponding, or the forming of a swamp or marsh in which peat accumulated. This is indicated by the thinly laminated lignitic clays which grade downward into an interformational conglomerate, which in turn is composed of kaolinitic clays in a kaolinitic mud matrix. Closer inspection reveals that the conglomerate overlies thin remains of pisolitic kaolin very similar to the type found in the Fowler area. Conant's (1965) corss section (Fig. 17) indicates that the deposit was closely related to an ancient channel deposit. It is now suggested that this deposit could represent an interdistributary depression, and that such depressions were the loci for bauxite and kaolin formation. Later, the major channel abandoned the course in favor of a new route which resulted in covering and reworking part of the bauxite deposit.

Additional indication of supratidal marshes or interdistributary environments is found in the close relationship of sandy to silty shales with lignites. It is possible that, in active environments, meandering distributaries could migrate laterally across these pre-existing deposits. The overlapping lenses of siderite, lignitic clays, and occasional lignite seams also to indicate ponding (Fig. 18). The presence of lakes, swamps, or marshes within the same stratigraphic sequence as the aluminum rich deposits suggest a possible relationship between deposition environment and mineralogy. This relationship is revealed in exposures three miles west of Thaxton, and about one mile south of the

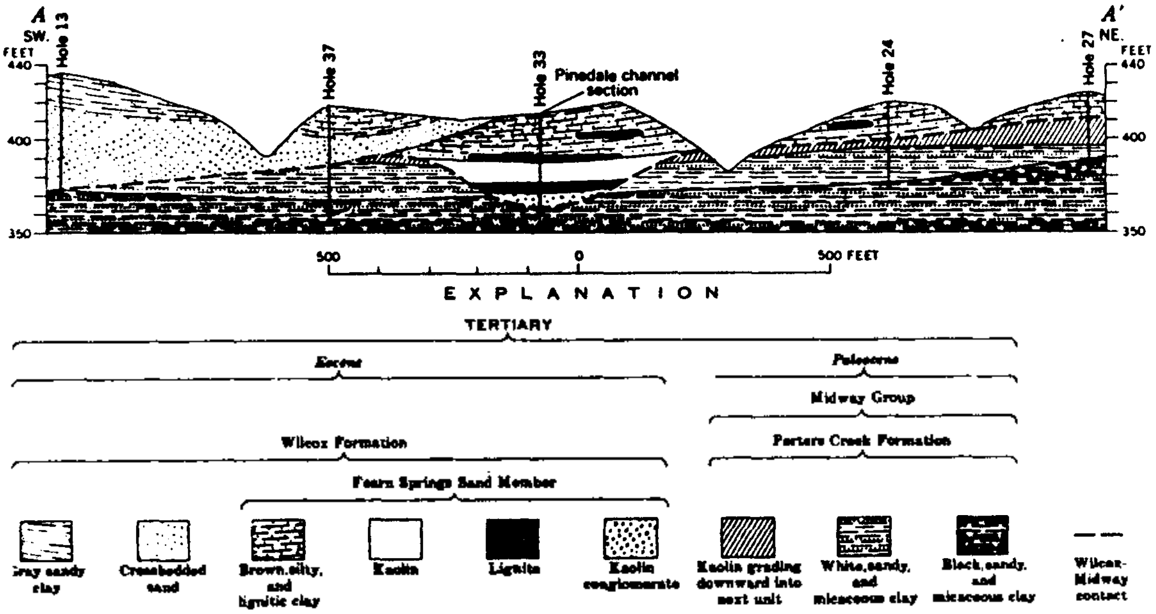


Fig. 17 Cross section of the Pinedale deposit, Union County, located 12 miles north of Randolph and 14 miles south of Fowler. This section is located on the southern flanks of a major channel sequence trending east-west. Core P-22 (Fig. 16) is located 0.5 miles north of P-33 in the above cross section (Appendix A).

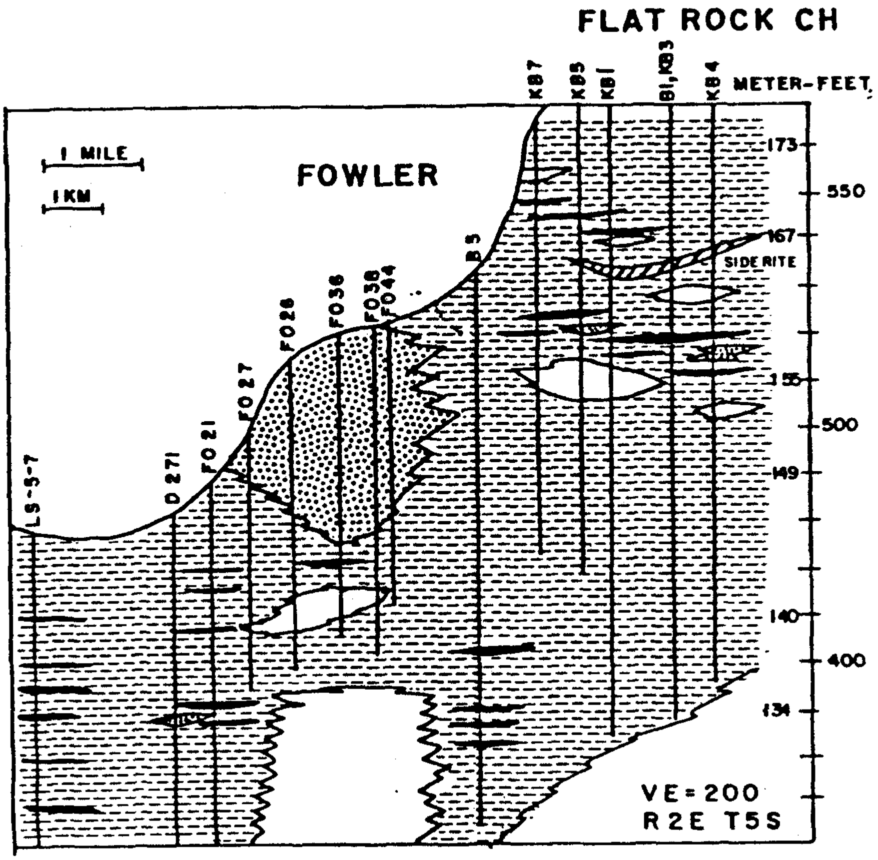


Fig. 18 Cross section F-F' shows the relationship between sand channels, lignite, iron (siderite), and aluminum rich clays (blanks) in the Upper Midway Group. The above figure suggests a lateral relationship of aluminum clays to channels. Such a relationship suggest lacustrine or paludal environments.

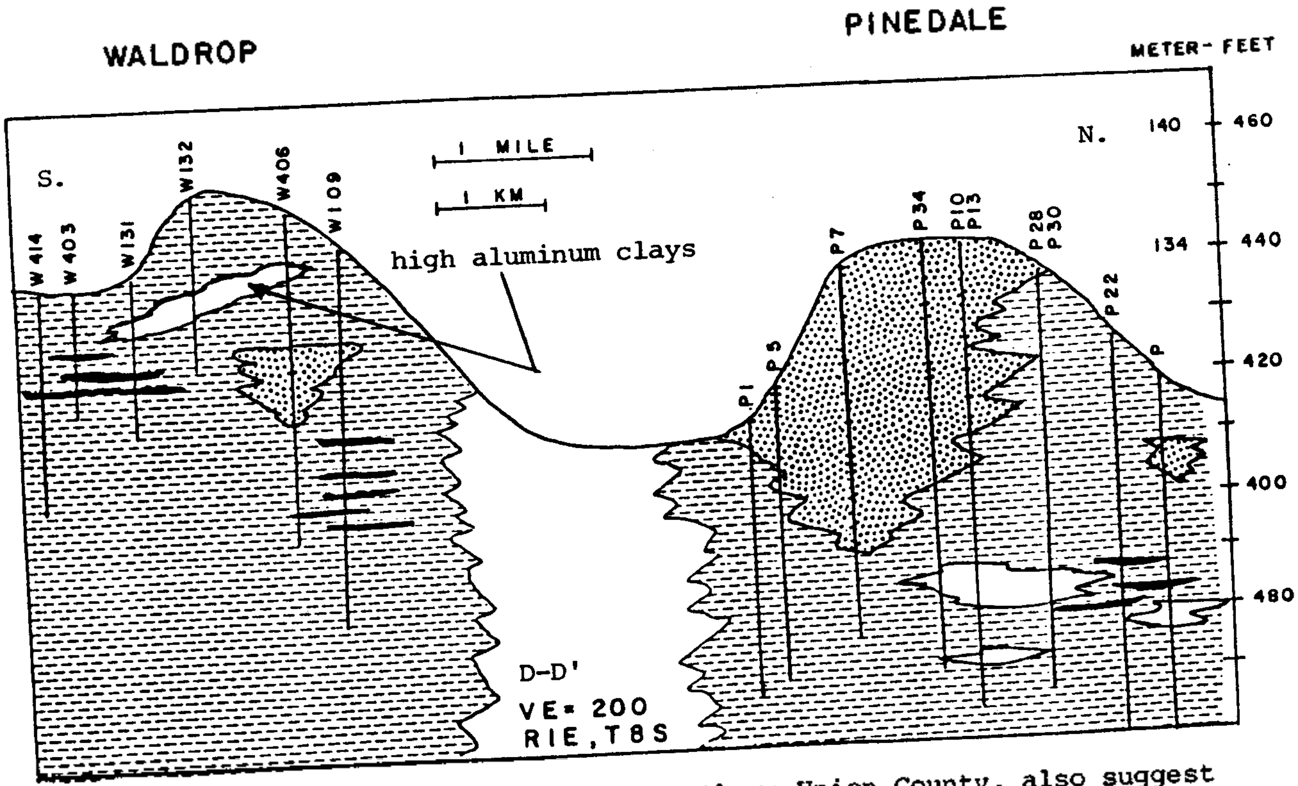


Fig. 19 Cross section D-D' located in southern Union County, also suggest a close relationship between the location of channels and bauxite deposits.

Smokey Top bauxite deposit in Pontotoc County (Fig. 20). The lithology, as exposed here, has a close resemblance to the Naheola equivalent, which in the past has been mapped as Lower Ackerman (Table 2). The same laminated clays are found in exposures 3/4 of a mile (1.2 km) southwest of LaFayette Springs, or two miles (3.2 km) west of the Thaxton exposure. Again, here is an example of how easily Naheola and Lower Wilcox can be confused.

The Thaxton exposure consists of kaolinitic clays interbedded with thin lignite seams (Fig. 20A) and two distinct iron-rich strata. Above is a three dimensional liesegang structure composed primarily of siderite and some limonite (Fig. 20B and C). The base of this exposure is a lense of oolithic to spheroidal sideritic mud (Fig. 20D). The upper iron unit possibly represents the seasonal fluctuations of plant growth and diffusion of iron. The liesegang structure probably was developed by finely layered algal fixing of iron concentrated about on the roots and stems of large reed-or grass-like aquatic plants.

Upland of such marshes are apparent lacustrine muds of the Upper Porters Creek (typical phase) which include remnants of larger plants such as petrified hickory. Studies by Warter (1965) on the palynology of the Lower Wilcox lignites suggested that the Early Eocene of Mississippi was subtropical and humid. A coastal plain dominated by lowland swamp flora and the inland foothills supporting forests of a more temperate climate aspect was typical. The early works of Berry (1916) also suggested that there were flora inhabiting tidal and fresh water lowlands and that iron deposits within the Midway and Wilcox were of palustrine origin.

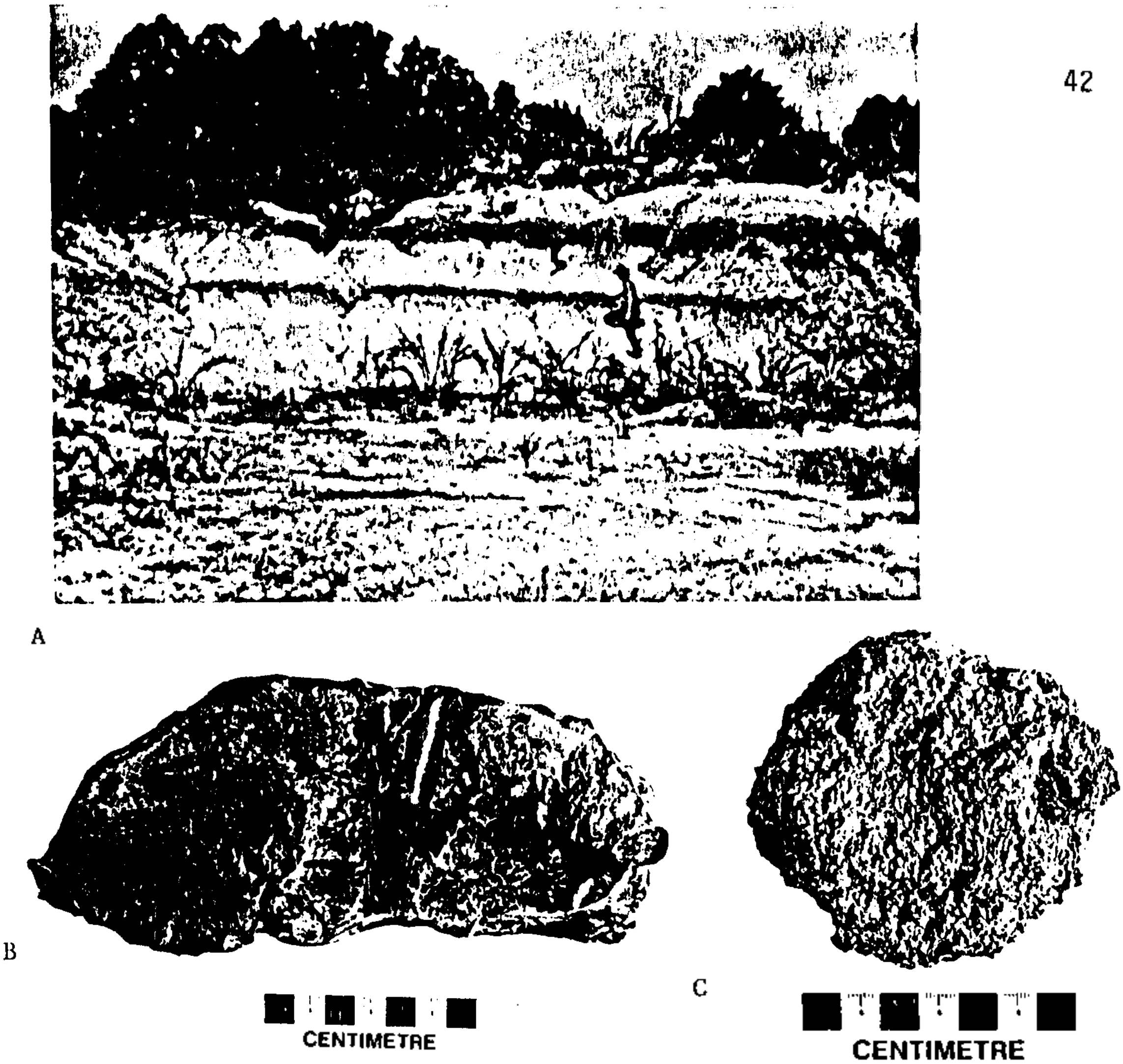


Fig. 20 The Thaxton kaolin pit exposed in the Ne. 1/4, Ne. 1/4 Sec. 7, T. 9 S., R. 1 E. The pit contains two unique iron stones, and lignite seams. Figure B and D represent the upper ironstone cap, which consists of liesegang banded tubular concretions. Figure C represents the lower ironstone located on the floor of the pit. The lower ironstone consist of lenticular beds of oolitic concretions.

Environments in which peat (lignite) is forming today are present along the coast of Louisiana and part of Mississippi. Peat commonly occurs in small coastal basins between distributary channels, in broader inland flood basins, and interfingering laterally with inorganic natural-levee deposits (Fig. 6).

Between the Pinedale and Fowler areas (Union County), core and outcrop data is meager (Appendix A). This area, is presently occupied largely by the flood plain of the Upper Tallahatchie River. Previous investigations indicate that the region has been a main axis of sediment transport since Late Paleocene (Dupplantis, M.J., 1975). The majority of the data for Union County were derived from well log data downdip in Marshall County and a few outcrops along and north of highway 30 near Enterprise, Mississippi (Appendix A).

The dip section through Marshall County (Fig. 21) shows large amounts of shale within what has been interpreted to be Lower Wilcox (Ackerman or Fern Springs) or Upper Midway (Naheola). This presents problems in field interpretations, however, since some cross sections have shown areas where there is a major Lower Wilcox facies change from sand to clay. In most cases, previous investigators relied solely on the occurence of kaolin or bauxite to separate the Upper Midway from the Lower Wilcox. The cross section (Fig. 18) of the Flat Rock Church area (one mile north of Fowler deposit) shows shales above the iron stone and kaolin considered by Kern (1962) to be Wilcox. These deposits also show a close resemblance to the exposures of Thaxton deposits in Pontotoc. It is

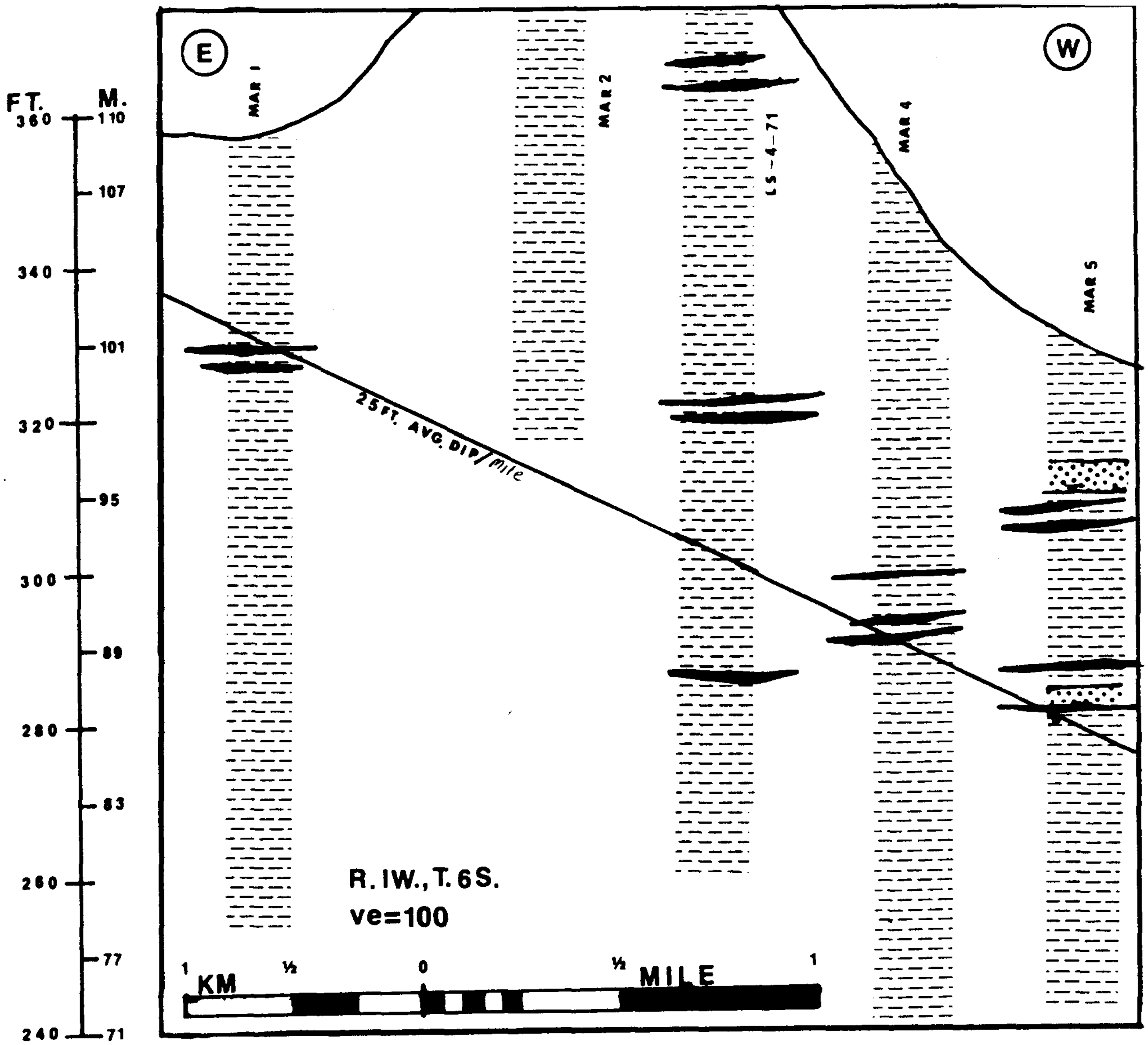


Fig. 21 Cross section E-E' is a dip section located 1 mile west of the channel sequence in Union County, on Highway 30. This portion of eastern Marshall County is possibly Naheola or Upper Porters Creek Formation.

possible, therefore, that such deposits were formed within swamps or marshes lateral to the main axis of sand transport (west central Union).

Several exposures (base map in Appendix A) in the northwestern corner of Union County have aided in explaining the absence of bauxite and kaolin within the county. The first of these exposures (Fig. 22), near Highway 30 about 0.2 of a mile (0.3 km) east of the Tallahatchie River bridge, shows crossbedded sands overlaying silty, thin-bedded clays. A similar exposure can be seen 0.3 of a mile (0.48 km) north on a road paralleling Highway 349. Large channel deposits are found at higher elevations about 0.4 of a mile (0.64 km) east of Highway 30 in an old sand pit (Fig. 22A and B). At this location, planar and tabular cross bed units are stacked in a 24-feet (7.3 meters) high exposure. This exposure consists of an orthoquartzose sand with occasional clay balls at its base.

Naheola-like sediments were found north of the Gallway Enterprise channel sequence. Here a series of exposures north of Enterprise, south of Hickory Flats, and east of Cornersville (Fig. 10) represent the laminated silty clays of the prodelta and delta front facies, which are lateral to the major axis of transport. Vestal (1954, p. 22) suggested that this area be mapped as Naheola rather than Ackerman.

The gradational nature of the Porters Creek (typical phase) with the laminated silty clays can be seen near Oak Grove Church north of Enterprise, Mississippi. Typical Porters Creek clays are found along Highway 78 south of Myrtle, about 1.5 miles (2.4 km) to the east (Fig. 8B). Larger exposures of Naheola are found north of Oak Grove Church about

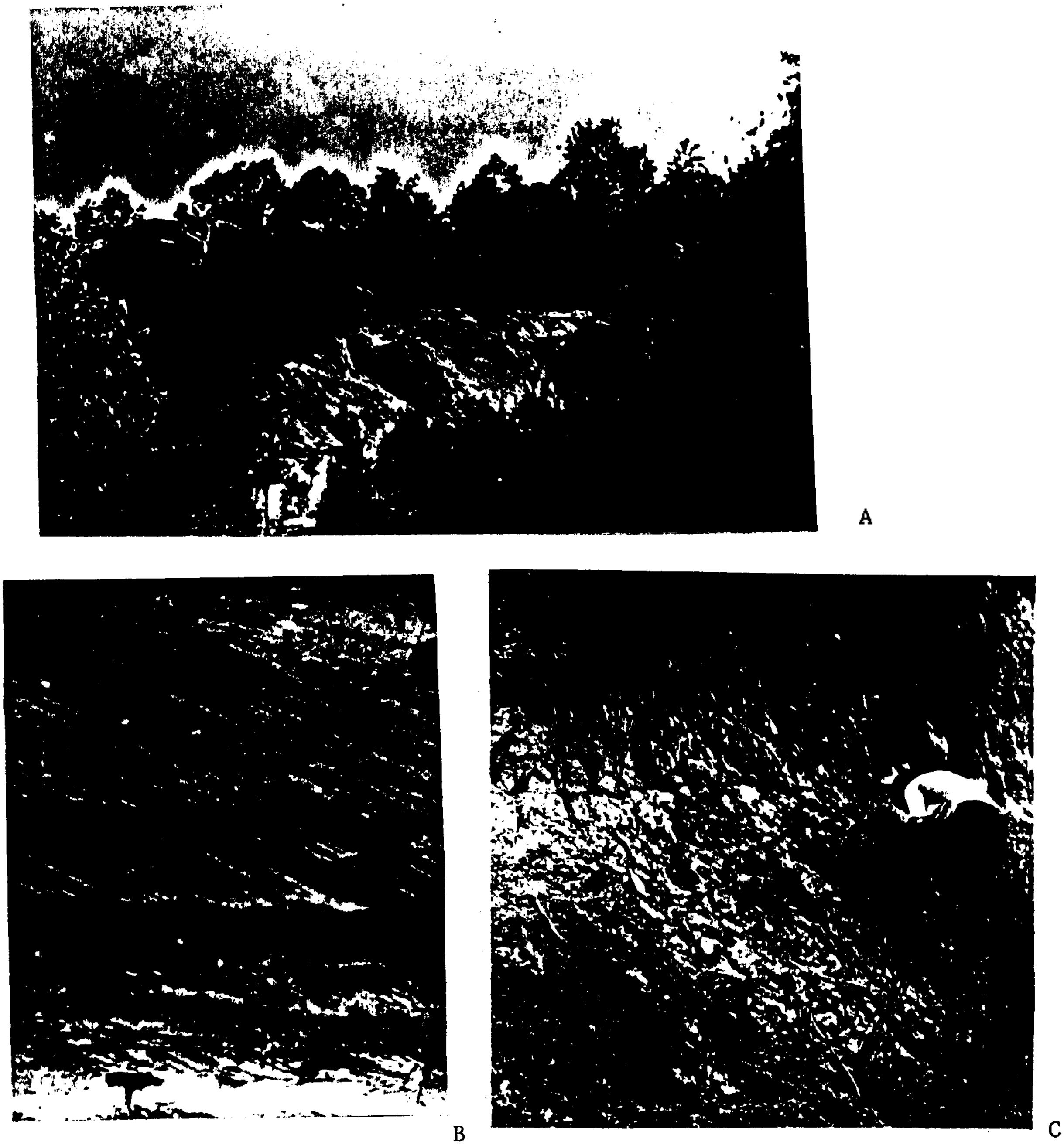


Fig. 22 Sand pit located off Highway 30 near the Tallahatchie River Se 1/4 Se 1/4 Sec. 8, T. 7 S., R. 1 E. (See Appendix A). The above channel sequence has been traced into the subsurface by Dupplantis (1975) and Cleaves (1979).

1.5 miles southeast of Hickory Flats and about one mile west of the Fowler area. This area has been mapped in the past as Ackerman. However, during this investigation no extensive sands were found to separate the laminated silty clays from the thin bedded to massive conchoidal clays of the typical Porters Creek Formation.

In the subsurface, the nature of the contact is still not clear. The sections were aided by outcrop work, which found massive conchoidal Porters Creek clays in exposure at Hell Creek about 1-2 miles (1.6-3.2 km) east of Fowler (Fig. 8A). Also, the section's exposure near Hickory Flats, where Naheola and possibly Wilcox outcrop, about 1 mile (1.6 km) west of Fowler. These field studies indicate that the aluminum rich clays were sandwiched between the silty laminated clays of the Naheola and the massive conchoidal clays of the Porters Creek Formation. Therefore, the deposits at Fowler are within the Naheola-Porters Creek contact and not the Wilcox-Midway Group contact.

The Pinedale, Fowler, and Flat Rock Church deposits yield a good representation of the aluminum rich clay deposits that can be found in the shallow subsurface. The size, distribution, composition, and lithologic relationships of these deposits indicate the possibility of their formation contemporaneously with the laminated silty clays and sands of the Naheola. However, the absence of aluminum clays and bauxite in most of Union County may be due to a different environmental process being present at the time of formation. The more active shallow water areas probably had too high a sedimentation rate, so their active channel systems would not allow accumulation. Therefore, the processes and environments lateral to this distributary system provided areas of ponding (interdistributary depressions, swamps, fresh water marshes, and abandoned splays) along a slowly subsiding shoreline.

North of Flat Rock Church drilling data becomes limited (Fig. 11). The three main deposits in western Tippah County are in the Shady Grove, Shelton, and Finger area. Data for these deposits was sufficiently represented by Reed (1952). In his mapping of the geometry of these deposits, he found that their geometry most closely resembles channel deposits.

Three to four miles west of Shady Grove, at Clemmer Hill near highway 4, are a series of exposures of the Upper Midway and Lower Wilcox. Similar exposures are also found along highway 5 near its junction with the Tippah River (Appendix A). During drilling in Benton County, bauxite was not found more than 0.5 of a mile from a known exposure. The deposits near Clemmer Hill did have very large mud chip conglomerates of silty, laminated clay at the base of a course sand contact. However, this exposure is not typical of the contacts found along highway 5. The exposures off highway 5 contain fine sands with reverse graded bedding. Mud chips were not found at the base of the sand contact. Previous investigators over-emphasized the importance of the mud chip conglomerates. During this study, it was noted that gradational contacts are most often represented as uniform weathering surfaces which yield fewer exposures. However, channel incisions and point bar sequences offer more resistance and yield steeper exposures of the outcrop.

The Middle and Lower Porters Creek are exposed in and near Hurricane

Creek, in northern Tippah County (Fig. 11). At the exposure (Fig. 9) the Tippah is a tidal flat deposit characterized by lenticular and flasher bedding. The next area is two miles northwest of Walnut, Mississippi; here the Tippah Sand becomes fossiliferous and glauconictic. Underlying the indurated ledges of fossiliferous material (Fig. 9) is sand, in part cross bedded, burrowed, and bioturbated, probably indicative of a barrier beach environment. This interpretation is supported by the geometry, lateral discontinuousness, fossil assemblages, and calanasid burrows found in northern Mississippi and southwestern Tennessee. (Whitlatch, G.I., 1936).

The Tippah Sand Member may possibly be contemporaneous with the bauxite, kaolin, laminated silty clays, and channel sequences to the south. If this is true, a good explanation for the lack of kaolin and bauxite in the extreme northeastern portions of the study area would be the presence of a dominantly marine environment. This is similar to the sequence found separating the Eufaula Bauxite District in Alabama from the Kemper County District in Mississippi. Velton (1972, p. 147) suggests that a large marine embayment separated and would not allow the deposition of bauxite within this region. Thus, the shallow bay controlled the distribution of gibbsite.

The data points to fresh water environments along a coast which was occupied by many areas of tidal influence. The areas which the aluminum clays and bauxite occupy may once have been part of an active process within an interdistributary environment. The exact nature of the environment and the depositional processes which were at work are still not well defined. The data, however, indicates a region that was closely related to palustrine-lacustrine environments. (Fig. 23).

Both outcrop and subsurface data revealed that the aluminum deposits nearly always grade updip into either or a combination of argillaceous lignitic sands, light gray kaolinitic clay often with lignite seams, or black highly carbonaceous kaolinitic clay (Fig. 15). Downdip the high aluminum deposits grade into dark gray muds (silty-clay or clayey-silt) with extensive lenticular and occasional flaser bedding (Fig. 9). These extensive muds are subsequently overlain by and may even grade further downdip into lignitic sands and alluvial clays of the Wilcox Group.

From the above data, it can be concluded that the aluminum rich deposits are localized within a facies of more extensive lignite-bearing kaolinitic clays. Downdip this facies grades into tidal flat and prodelta muds, a series of units normally not associated with bauxite deposits. Lateral and updip of the deposits are prodelta and lacustrine muds; laterally and downdip are tidal flat muds, while overlying are fluvial deltaic and delta plain sands.

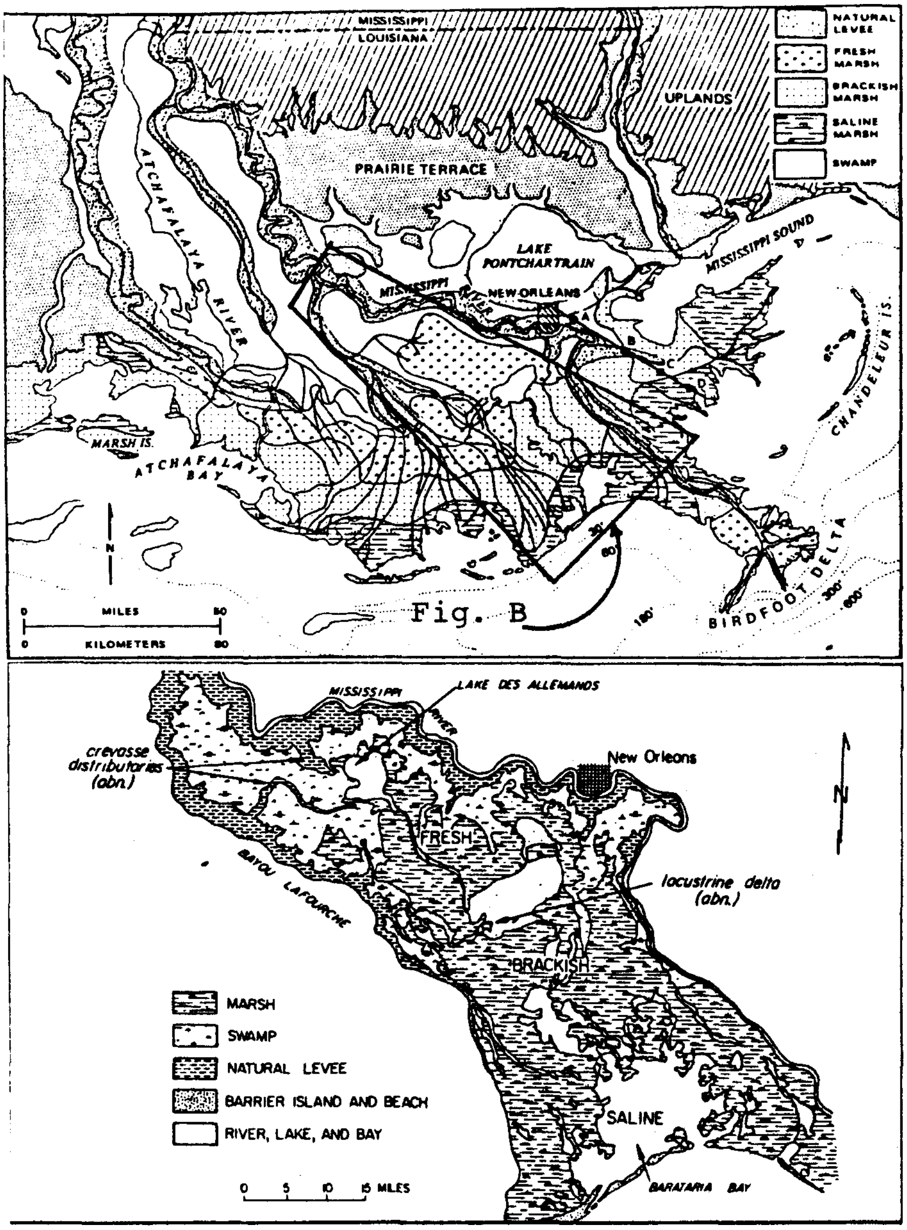


Fig. 23 An example of coastward zonation of marsh to fresh water swamp with interconnected lakes. The Barataria Basin lies between levee and meanderbelt deposits formed by the modern and older Mississippi River course (23a modified after Gould, H. R., 1969 and 23b Gagliano, S. M. and van Beek, J. L., 1970).

DESCRIPTIVE MINERALOGY

Deposits of pisolitic bauxite are often at the surface, and therefore are often assumed to be of a lateritic origin. Such surficial deposits, however, may be the result of a greater resistance to erosion as compared to the surrounding strata. It has been suggested that the textural appearances of many bauxites may explain the physical and environmental conditions of formation (Jones, H.A., 1965, p. 838). Petrographic studies, therefore, must be conducted to complement other data before a genetic interpretation can be made.

The Mississippi Geological Survey, U.S. Geological Survey, and U.S. Bureau of Mines have conducted numerous studies to ascertain the quality and quantity of bauxite ore of north Mississippi. These studies have indicated the deposits to be too thin and too widespread for commercial value in today's market. Studies have concentrated mainly on description of texture, color, extent, and percentage oxides. Such studies, however, have contributed very little information pertaining to the mineralogy of the bauxite, associated lithologies, and possible source areas.

Bauxite is an economic term meaning a mineable source of aluminum and has no definite mineralogical or textural implications. Because of the lack of mineralogic and chemical data, identification of bauxite in northern Mississippi has often been incorrect. Perhaps, a better choice of terms might include high aluminum clay, high silica bauxite, or aluminous laterite.

The deposits of aluminum in north Mississippi range from soft, silty kaolin to hard, ferruginous, gibbsitic strata. Most are contaminated in varying proportions by fine sand, silt, iron, and mica. The kaolin deposits are of local extent, often sinuous, locally pisolitic, commonly brecciated, and occasionally resemble surge deposits (channel cuts, storm surges, or splays). The ferruginous gibbsitic deposits are of local extent; they are very pisolitic and oolitic, have an upward increase in iron content, and are most often exposed as a resistant cap rock. Data from extensive drilling conducted in the past by the Bureau of Mines (Reed, R.F., 1962) indicate that the kaolin deposits have a maximum size of one mile in length and a few hundred feet in width. Deposits, however, on the average rarely reach these proportions; commonly they occupy less than 4 acres.

X-ray diffraction was the principal method of determining the mineralogy of samples. The dominant clay size (1/256 mm) made it necessary for positive identification. Mineralogic interpretations were based on 64 thin sections, coupled with 98 diffractograms from a wide range of samples: Flat Rock Church, Finger, Pinedale, Randolph Road Metal Pit, Tutor, Fowler, and Thaxton iron stone deposit (Fig. 11).

PETROGRAPHY

Microphotographs were made by a 35 mm camera with a Leitz Cambiphot automatic system attached to a Leitz orthopol petrographic microscope. The quality of the microphotographs obtained was good but was complicated by (1) the necessity of long exposures (up to 20 seconds) under high magnification of near opague minerals; (2) the extremely fine grain nature (most clay size) of many samples; and (3) the inability to represent true mineral hues. Standard petrographic procedures were also complicated due to (1) the fine grained, unconsolidated nature, which required repeated vacuum impregnation of samples with epoxy compounds, (2) the predominant clay composition, which hampered grinding to accurate thickness for petrographic analysis; and (3) the unconsolidated matrix in many pisolitic samples, which hampered polishing.

X-RAY ANALYSIS

X-ray analysis was accomplished by using a Phillips-Norelco x-ray diffractometer and copper K radiation with scans of 1° 2 θ per minute averaging 45° to 55° per sample. Some semiquantative determinations were made using a Phillips scaler timer and an external standard (quartz). Basic sample preparation techniques, however, were employed, since the thrust of the data was to determine the presence of kaolin, gibbsite, and iron species. The samples were dried, when necessary, at 25 C for a minimum drying period of 48 hours, then ground in an agate mortar and stored in air-tight vials in a constant temperature-and-humidity-controlled x-ray lab until analyzed. Identification was based on conversion of 2 θ values to d-spacing values, relative peak intensity, and the form peaks when present (Appendix C).

Selective analysis by heat treatment, glycolation, and crystallinity calculations were not employed for this study. The x-ray work, therefore, was undertaken to supplement data previously collected (oxides, DTA). The x-ray data helped clear up misinterpretations regarding the composition of many of the locations studied. A list of the common minerals found within the samples is provided in (Appen. C) A series of x-ray diffractograms has been selected as representative and placed in Appendix C.

GEOCHEMISTRY

Bureau of Mines chemical analyses were used to establish the percentage of oxides within sampled areas. Although no new chemical data was generated, the application of the older data was expanded. This was accomplished by sampling the same cores at the same intervals (U.S. Bur. Mines Cores at the University of Mississippi Geology Dept.) Close inspection of the oxide percentages showed that many locations have a sharp increase in aluminum and decrease in silica at the base of each deposit (Appen. C) Most core samples were continued through what was considered the Porters Creek clay. Previous investigators considered such deposits to be residual in origin (Mellen, F.F., 1939; and Pandya, D.N., 1973). Review of Reed's work (1952) however, indicates that there are many wide variations within the deposits.

The result of using previous data coupled with thin sections of x-ray samples has provided a better indication of the deposits' origin. This was accomplished by relating cross-sections, measured sections, x-ray diffractograms, oxide percentages, and thin sections to the same sampled interval as often as possible. Such areas as Fowler and the Randolph Road Metal Pit are given as examples within this text.

GENERAL MINERALOGIC INTERPRETATIONS

The following interpretations have been based on hand sample, thin section, and x-ray diffraction analysis. The author combined this with cross sections and geochemical data in an attempt to better understand the genesis. There are many more samples and locations which could be mentioned; however, the limits of this study do not permit such voluminus data. Instead, typical areas or samples have been chosen to represent the samples within the study area.

The Porters Creek interval was sampled from both outcrops and cores. The three phases were studied by observations in the field, by x-ray diffraction, and thin section. The Lower Porters Creek clay is observed to be thinly bedded and to break with a conchoidal fracture. Close inspection by x-ray diffraction indicated that samples (Appendix C) from Myertle and Hurricane Creek are predominantly smectite and opal-ct (low cristobalite, Reynolds, W.R., 1970). The Middle Porters Creek samples were obtained primarily from cores. A good vertical profile can be seen in the x-ray diffraction patterns from well PB-12 to a depth of 170 feet (Appendix C). The x-ray diffraction, thin section, and continuous cores taken near the Randolph pit indicate a distinct difference from the type of clays described by previous workers as being the parent material. Thin sections of cored material reveal thin to laminated bedding with distinct layers of silt-size quartz mixed with dark brown organic fragments (Fig. 24). Samples from core hole PB-16, when x-rayed, indicated that kaolinitic-rich samples are not always white and can occasionally be black. The Upper Porters Creek clays or Naheola equivalent were sampled near the bauxite region. These thinly laminated silty and sandy clays consist of a mixture of mica, quartz, smectite, and small amounts of kaolin. Close comparison of these three phases indicates that division can be made on the basis of their mineralogic composition by x-ray diffraction. Such a process could be useful in subsurface exploration when cores are taken.

Although no direct crystallinity values were calculated, the general intensity of the peaks were noted. In many samples, there was a distinct broadening of the peak. Such broadening of the basal spacing intensity may not be entirely a function of degradation but instead may be due in part to dilution by amorphous silica and alumina residues. Evidence of excess silica has been indicated by the percentage of oxide, and the presence of opal-ct (Reynolds, W.R., 1970). Further evidence of possible excess silica has been indicated by silicous concretions found in the kaolin clays located near Thaxton. The presence of so much excess silica may be an important factor in the interpretation of the genesis of such clays.

Not only is the Thaxton pit the location of siliceous concretions, but it also contains a unique sequence of lithologies (Fig. 20). The

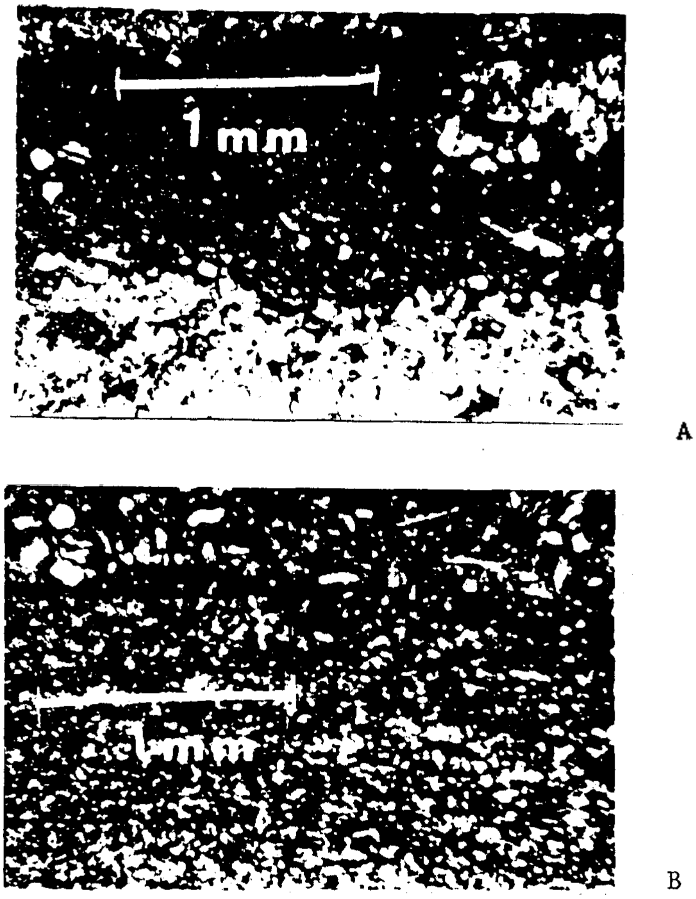


Fig. 24 Photomicrograph (A) is taken from a depth of 30' in core PB-12. Photomicrograph (B) was taken from a depth of 35' in the same core. The core was taken in the floor of Randolph's road metal pit in Pontotoc County. The thin sections above give a close examination of the laminated clays and silts within the upper Porters Creek Formation. It is doubtful that such clays and silts are the parents of the overlying bauxite (see Appendix C).

sequence revealed in the pit may explain the genesis of bauxite deposits nearby. The base of the pit contains kaolin, with lenses of oolitic iron ore (Fig. 20) consisting of siderite. The walls of the pit consist of kaolin with two thin lignitic seams; the silicous concretions are found within and near these seams. These features are unusual, but an even more unusual find was the presence of a liesegang-banded iron stone cap (Fig. 20). The cap consists primarily of goethite in vertical tubes of concentric banded geothite and limonite (Fig. 20B and C). It is possible that such an iron stone could have developed in a bog where reed-like plants were growing. The iron was present in solution and may have been attached to the plant stems by algal material. (Oborn, E.T., 1960)

Detailed measured sections (Fig. 13) and x-ray diffraction data (Appendix C) indicate that gibbsite is found only in the upper 5-7 feet of the Randolph Road Metal Pit. Hand samples shown in Figures 14A, and B give good representations of the vertical change in composition. A diagram constructed from the data shows some correlation between the lithologic appearance and mineralogic composition (Fig. 12). Within the pit, the wedge of minerals indicated seems to represent a lense shaped body. The gibbsite and better crystalline kaolinite occur in the center and upper portion of the pit. The pisolitic material pinches outward laterally and downward into disordered kaolin, quartz, and mica. The poor quality of materials probably represents the unweathered sediments which formed the small basin in which the kaolin and pisolitic clays were deposited.

Continuous core samples, x-ray diffraction, and petrographic data collected in the Randolph pit indicate the possibility that the underlying material is not the parent. Core samples revealed that the underlying lithology consists of laminated silts and carbonaceous clays (Fig. 10). Petrographic examination also indicates the laminations and the presence of silt quartz and organic matter (Fig. 24). This observation was also confirmed by the mineralogic identification made from the diffraction patterns (Fig. 10, some are in Appendix C). If the overlying clays and pisolitic bauxite formed from such a parent material, there should be similar bedding features. This is not the case for the Randolph pit. The overlying kaolin is massive and homogenous. The bauxite-like material which overlies the kaolin is pisolitic and has what appears to be low-angle cross bedding. The lack of brecciated structure in the kaolin indicates that it probably was not transported as detritus. It is possible, however, that such a homogenous body could have formed from solution in a single event. The overlying pisolitic material does have sedimentary features which suggest shallow water with gentle currents.

The mechanism which forms iron or aluminum pisolites is still controversial. Important factors which have been suggested include: groundwater circulation, electrolyte phenomena, properties of colloids, and the effect of organic material on mobilization of both iron and aluminum. Description of textures of oolitic and pisolitic deposits, including shape and internal structure, may provide evidence on their mode of formation and their physical state during growth.

TEXTURE

Most outcrop and subsurface deposits of bauxite have a pisolitic texture. The bauxite exposed in outcrops is highly pisolitic and oolitic ranging in size from 1 mm to 5 mm. The pisolitic and oolitic composition is varied, with some composed entirely of gibbsite and other composed of a combination of gibbsite with siderite or goethite. The proper term for some of the structures may be pisoliths or ooliths (McFarlane, 1976) Most, however, are banded pisolites ranging in shape from spherical to ellipsoidal. The matrix varies between the surface and subsurface samples. The smaller pisolites are common in the outcrops and are composed of gibbsite and kaolin in varying amounts with a sheath of iron (Fig. 25). Some of the pisolites and oolites have no distinct internal structure, and these are usually made of pure gibbsite. Others, however, are concentrically laminated with alternating layers of gibbsite and siderite and occasionally goethite (Fig. 25). Still other pisolitic strucures have an interior that is packed with minute siderite and gibbsite oolites which are enveloped by either a gibbsite and siderite, gibbsite and geothite, or geothite casing (Fig. 25) The pisolite matrix is composed of varying amounts of kaolinite and goethite.

The pisolites within Mississippi deposits are of three types: (1) seed variety, consisting of gibbsite or goethite nucleated around a quartz or mica grain; (2) compound variety, consisting of minute clustered gibbsite and kaolin oolites enveloped by a geothite layer; (3) a binary variety, consisting of a gibbsite nucleus surrounded by alternating geothite,

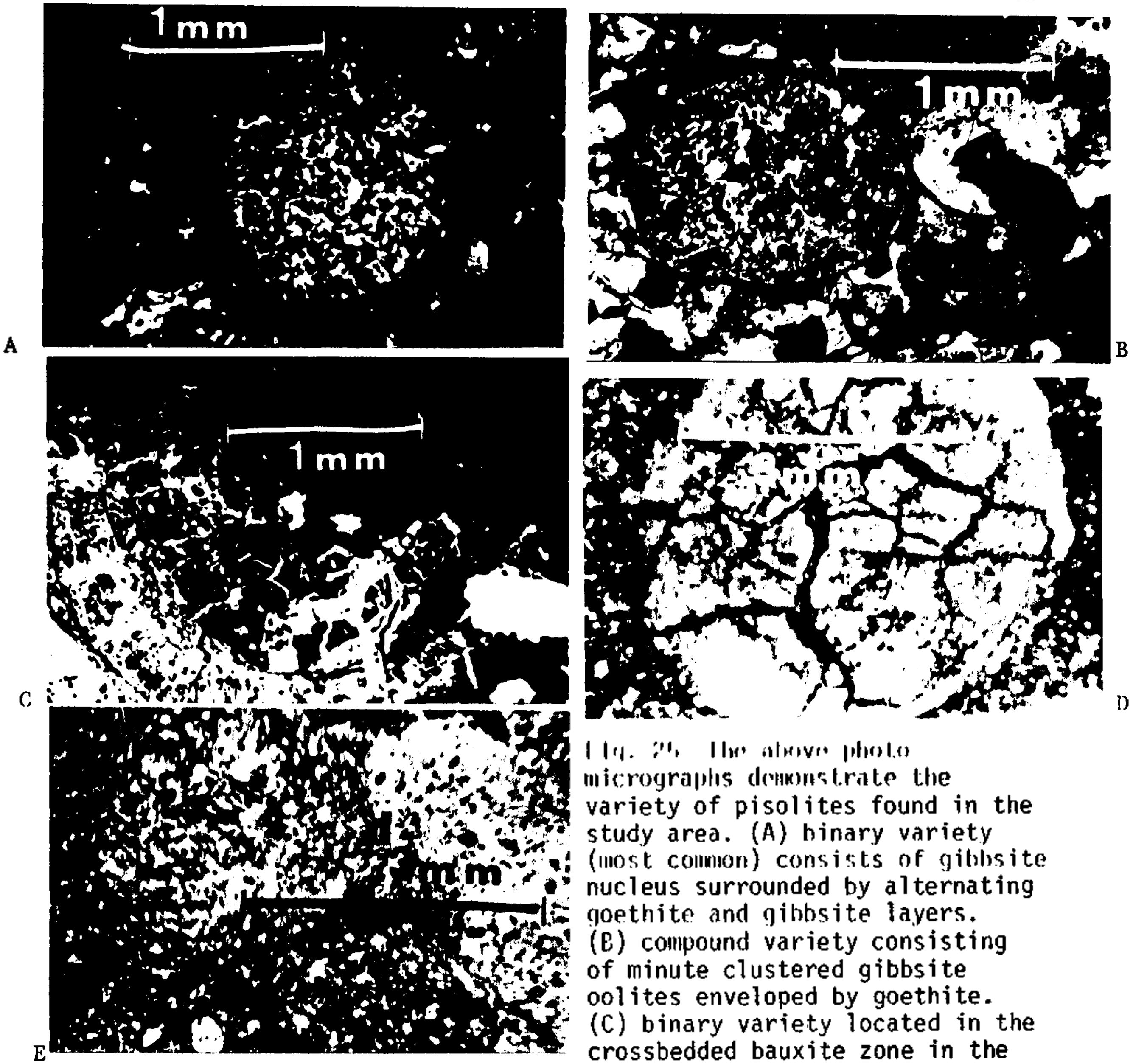


Fig. 26. The above photo micrographs demonstrate the variety of pisolites found in the study area. (A) binary variety (most common) consists of gibbsite nucleus surrounded by alternating goethite and gibbsite layers. (B) compound variety consisting of minute clustered gibbsite oolites enveloped by goethite. (C) binary variety located in the crossbedded bauxite zone in the Randolph road metal pit in southern Pontotoc County. (D) soft pisolite from the subsurface kaolinitic clays at Fowler. The cracks in slide D could have been the result of resilication of gibbsite. (E) grain or seed variety located in the soft kaolinitic clays of Pinedale. Slide E consists of kaolin or gibbsite nucleated around a quartz or mica grain. (A) sampled from core PB-11 at 5', (B) sampled from PB-11 at 5', (C) sampled from PB-14 at 8', (D) sampled from core FO-2 at 50', (E) sampled from core P-22 (Fig. 16) at 71'.

kaolin, and gibbsite layers. These pisolites are suggestive of a depositional origin, rather than the soil katamorphic origin commonly suggested for bauxite.

Orientation of pisolites in the matrix at the Randolph pit suggest the presence of low angle cross bed (Fig. 13). The only previous notation of cross bedding in the surface bauxite deposits was made by Pandya (1973, p. 39) in the Oktibbeha County deposits far south of the Pontotoc County deposits. However, Pandya suggested the cross bedding represented a festoon structure similar to that which is found in channel deposits.

There are problems in initial field interpretations due to modification of textures resulting from redistribution of ferric hydroxides after consolidation and exposure of the rock. This redistribution commonly results in the formation of knots, lenses, and large irregular masses in the upper zone of the deposits (Fig. 14). Also in natural exposures oxidation often obscures the sedimentary structures.

Similar internal structures were noted in the Ratcliffe mine of Arkansas (Gordon, M., 1958, p.121). Pisolites at Ratcliffe were found to have oolites within their interiors and are surrounded by accretionary layers often cut by a network of cracks. The Ratcliffe deposits are considered by Gordon (1958) to be stratified and the result of deposition of detritus. The parent bauxite from which the detritus was derived consists of unbanded pisoliths. The deposits downdip, however, are banded and occasionally compound pisolites. No explanation was given for how pisolites were derived from pisoliths. Also of interest is the fact that the Ratcliffe deposits are cross bedded with rare lignite and carbonaceous layers at their base. Gordon (1958, p. 102, 120) concluded that the origin for such deposits was detrital deposition within a swamp.

The pisolites in Mississippi's surface deposits consisted of whole, cracked and parts of pisolites cemented within the same deposit. Many of these features suggest that the pisolites had been agitated (Jones, H.A., 1965, p. 841; Curtis and Spears 1968, p. 269). In addition to these features the surface deposits have a higher amount of iron within their matrix. This has been suggested in the past as secondary iron enrichment. The previous investigators point to a gradational contact with underlying kaolin. Transport and/or sedimentary features within these iron rich pisolitic caps are contradictions to the residual origin theory.

Not unlike the surface deposits, the subsurface deposits have pisolitic structure. The soft, friable kaolinitic clays have relatively larger pisolites on an average (5 to 10 mm or 0.19 to 0.39 in.). On close microscopic inspection, the matrix, and internal structure, consists of small oolitic kaolin (compound variety) occasionally with silt-size quartz and mica. Commonly, ooliths or spheroidal siderite occurs in abundance within many kaolin deposits. It does not seem possible that these deposits could ever yield a ferruginous, highly pisolitic cap rock with sedimentary features. The subsurface deposits have been exposed to the same ground water, climate, and interstitial waters as the surface deposits, yet they have little or no gibbsite present.

There has been little agreement about the formation of aluminous and ferruginous pisolites and oolites. If such structures are analogous with carbonate pisolites and oolites, then they may have developed under similar physical conditions. This would suggest that banded pisolites and oolites formed in shallow water and were agitated by gentle currents. Many researchers have studied ancient deposits; each has postulated a different origin (Table 5). Only in the last several years has research been undertaken to study environments and conditions where active formation of ferruginous oolites occur.

V.T. Allen (1952, p. 660) complied a list of suggested theories for the origin of oolitic structures in clays: direct precipitation of suspensoids in the basin of deposition as aggregates with concentric structure; (2) rearrangement and adjustment of colloidal particles around a point during or shortly after deposition; (3) differential shrinkage of the area of the future oolite with respect to the surrounding clay, from which it differs in mineral composition, particle size, stacking of the molecular sheet, and plasticity; and (4) incorporation of fragments which were derived from older clay formation and rolled about until round.

Some geochemists, however, did not believe Allen (1952) covered all the possibilties. Curtis and Spears (1971, p. 223-224) suggested a theory based on the diagenetic development of kaolin from gibbsite. In general, the physiochemical difference exists between the depositional waters and the water entrapping the sediments. They postulate that once gibbsite is in a confined system, metasomatic reactions increase the silica content and generate oolitic textures in the same way igneous rock

Origin of Pisolitic and Oolitic Structures in Kaolin, Bauxite, and Iron Deposits

1924	Burchard	Miss.	Solutions enter bogs and swamps where organic compounds chaleate and precipitate.
1937	Fedorov	USSR	Transport solution in streams (colloids?) to lake where acidity change results in precipitation and formation of Pisolites.
1952	Allen	USA	Direct precipitation of colloidal material, differential shrinkage occurs upon maturity.
1964 1976	Keller	USA USSR	Desilication of Kaolin colloid transported to swamp or marsh where alteration and eventual recrystallization occur in Situ.
1971	Curtis	USA	Metasomatic reaction causes resilication of Gibbsite conversion to Kaolinite post depositional alteration results in reduced porosity following expansion due to addition of Silica this expansion results in Oolitic structures.
1960	Dunham	England	Petrographic evidence (banded and compound Oolites) supports interbanding structure is due to degregation during crystallization. The initial precipitate was a Colloidal Gel of variable composition. Segregation during crystallization not necessary for Eh fluctuation to form bands. The presence of Kaolin and Opal mean excess Silica and Aluminum in initial precipitate.

(continued on part B)

Part A

Table 5

1965	Jones	Nigeria	Accretionary growth around separate nuclei in a high energy environment. Soil pisoliths textural difference in irregular shape and lack of internal structure (bands).
1968	Curtis	England	Oolitic Ironstone accumulated in shallow marine environment where mixing of gel precipitate occurred. Later crystallization resulted in cracks in bands formed during diagenesis. Followed by diagonetic alteration and formation of matrix due to excess iron.
1973	Lemoalle	Chad (active)	Colloidal iron transported by river to lake where reactive iron coprecipitates with silica. Shallow water and active wind cause Oolitic (banded) structure to form around a montmorillonite nuclei.
1976	McFarland	Africa	Pisoliths and Ooliths (unbanded and irregular) form from both soil and ground water. The shape is dependent on the maturity and errosion (reworked).
1979	Kimberly		Most oolitic iron formations are transgressive and overlain by mud or argillaceous sandstone. Postulated that during regression aragonitic oolites form then deltaic muds cover the deposits. These muds produce ferriferous leachates which permeate the oolite resulting in ferruginized oolites. This replacement theory suggests banded oolites formed in shallow water with little terrigenous sediment under aigation.

Table 5 Part B

weather to spheroidal texture. The silica causes a development of kaolinite which in turn reduces the porosity resulting in spheroidal texture. The occasional bending would be the result of gibbsite preservation in the centers. Such a theory has some application to the aluminum rich clays found in the subsurface. The pisolites in the Fowler area consist of compound structures (Fig. 24D) and often have cracks which may indicate expansion due to resilication of gibbsite (Curtis, C.D. and D.A. Spears, 1971). Cracks in pisolites, however, could also be due to shrinkage from the gel state to the solid state (Lindgren, W., 1925).

Deposits in Mississippi vary from a composition of soft kaolin to hard ferruginous exposures. Similar features have been noted in iron-bearing oolites actively forming in Lake Chad, Africa (Lamoalle and Dupont, 1973). The Chad basin allowed close monitoring in time and space of the different steps of erosion, transportation, and sedimentation of both dissolved and particulate elements. This closed basin is fed by the Chari River which produces a small delta at its mouth within the lake. During the period of 1970-1971, weekly measurements of the Chari River before its confluence allowed accurate measurements of reactive iron in solid load (page 174). After nearly four years of continuous study, it was concluded that the oolitic iron was not derived from pre-existing deposits, but rather the result of active precipitation near the mouth of the Chari River.

Petrographic,chemical, and x-ray diffraction analysis indicated that the nuclei consists of montmorillonite surrounded by goethite and silica. The chemical analysis of the oolites indicates they consist of

40-49% Fe_2O_3. The oolites vary in size from .25 to .50 mm and vary from polished to cracked grains. The layers of oolites reach a maximum thickness of 40 cm (16 inches), often having clay intercalations and always are found lying on clay bottoms. Similar features are reflected in the deposits of Mississippi. Iron and aluminum, therefore, may have been transported by various means to aqueous environments along the Midway shoreline where they were deposited in their present form.

MODERN AND ANCIENT COUNTERPARTS

The principle of uniformitarianism suggests that geologic processes and natural laws now operating have acted in the same regular manner througout geologic time. This principle has become an important tool in reconstructing processes and environments which produced the geology of a region. Uniformitarianism has been used extensively in the last ten years to develop modern and ancient analogue (counterpart) theories. Such theories suggest that ancient sedimentary structures, mineral suites, and sequence of strata can be correlated to modern regions where similar features are forming. The conditions under which these modern features formed are commonly documented. Applying the principle with caution can aid in collection of circumstantial evidence to prove a hypothesis or define the history of a region.

There are no true counterparts for the north Mississippi high aluminum material. However, there are modern and ancient deposits which contain either kaolin or bauxite as their main constituent. It would be difficult to find a counterpart which could resemble the size, shape, depth, and complexity of the Mississippi Embayment of the Late Paleocene and Early Eocene. Stratigraphically there are features which are shared by several deposits. By comparison of the following counterparts (Table 6), some generalities can be brought out about facies, environment, and processes involved in the formation of bauxite and kaolin in north Mississippi.

THEORETICAL ORIGINS FOR ANCIENT DEPOSITS	
SMOOT 1960 Pre-Pennsylvanian shales of the Illinois Basin.	Fluvial transported kaolin, colloidal, and suspended, deposited in large quantities near the mouth and periphery of a delta. Kaolin rich facies location and occurrence is controlled by the sedimentation rate and salinity.
WILLIAMS 1968 Pennsylvanian underclays of western Pennsylvania.	Occurrence of hi-aluminum clay facies is controlled by the chemistry of the depositional environment. The flint clay facies was produced by flocculation of colloidal gel in electrolytic solution. Differential colloidal fractionation caused concentration and distribution. Kaolinitic clays were deposited in paludal-lacustrine environments fringing the sea.
BURST 1972 Eocene bauxite and kaolin of Eufaula Alabama.	Kaolin and bauxite facies may represent meanders in fresh water swamps and tidal flats. Hi aluminum content is the result of migration through and separation from degraded clay lattices trapped in meanders within a swamp or tidal flat. Degraded clay lattices have low resistance to chemical attack.
MODERN OBSERVATIONS OF ACTIVE FORMATIONAL PROCESSES	
THEOBALD 1963 Deer Creek and the Snake River, Summit County, Colorado.	Occurrence of iron and aluminum rich deposits along and at the junction of rivers. Extreme pH differential between streams above their junction resulted in difference in precipitates formed on streambeds. Aluminum rich (60%) deposits occur at the junction of two rivers where pH neutralization occurred and produced precipitation by hydrolysis.
LAMONALLE 1973 Lake Chad, Africa	Iron rich oolite facies within a lake. Fluvial transported reactive iron, colloidal, and absorbed, precipitated at the mouth of a small delta within the lake. Several stages of oolite development were noted and considered to be the result of shallow water with gentle agitation during concentration.
BROOKS 1976 Mississippi River at SW Pass to 150 miles west on the continental shelf.	Fluvial transported kaolin, colloidal, and suspended, is deposited near the mouth and on the continental shelf of Louisiana. The kaolin makes up 30-45% of the clay fraction near the mouth of the modern Mississippi River delta. Kaolin rich facies produced by the influence of coarse grained material and salinity variations at the marine-fresh water interface.

Table 6 Six examples of possible counter parts for North Mississippi.

KAOLINITE

Studies of the clay content of the Modern Mississippi and Pearl River Deltas have shown localized high concentrations of kaolinite. Extensive x-ray diffraction analyses of suspended sediment, channel cores, and lower delta cores of the Pearl River show that, except in the lower delta, the clay mineral suite is nearly equal (50%) amounts of kaolinite and smectite. In the lower delta, where the waters mix with the saline Gulf of Mexico water, there is an increase (60%) in the kaolinite content of the channel sediments. The increase is only noted above the mouth; below the kaolinite decreases seaward to about 30% of the clay fraction. Changes in the clay mineralogy have been postulated to be the result of differential flocculation and settling of kaolin in brackish water of the lower delta (Snowden and Forsthoff, 1976).

Clay samples collected near Southwest Pass to about 150 miles west of the Modern Mississippi River have shown similar kaolin ratios. Near the mouth of Southwest Pass kaolin content reaches 56%, however, there is a 16% decrease west of the river mouth (Brooks and others, 1976). Two reasons for this decrease have been suggested: (1) decreased kaolin may be due to differential transportation whereby kaolinite settles out of suspension more rapidly than illite or montmorillonite, and/or (2) kaolin's decrease in total cation exchange capacity (Brooks and others, 1976).

The origin and stratigraphic application of clay mineral zones within the Mississippi River Delta has been investigated (Griffin, G.M. and

B.S. Parrott, 1964). This research has indicated that clay mineral zones may develop by occasional migration of a delta. As an active delta migrates, a series of locally derived regressive and transgressive clay mineral zones will be built up. Griffin and Parrott (1964) conclude that such distinct clay zones exist within the seven deltas (5,000 years) of the Mississippi River. Kaolin rich clays that are present now at the mouth of the Pearl and Mississippi River; therefore, could become local zones as the deltas migrate. It is possible, therefore, that the kaolin rich zones in the Upper Midway of Mississippi were the result of a similar process.

Studies conducted by Brooks (1976), Snowden (1976), and Griffin (1964), indicate that clay mineral zones can develop on the margins of deltas and be segregated by migration. The results of these modern studies are also reflected in the interpretations of clay mineral facies of the Illinois Basin (Fig. 26). T.W. Smoot (1960) compared samples from various facies in a Pre-Pennsylvanian formation within the Illinois Basin. The results indicated that the rate of sedimentation and salinity of the waters resulted in a high kaolinite facies close to the mouth of rivers feeding sediments into the basin. It is possible that an intermediate phase of the Modern Mississippi River and the Ancient Pre-Pennsylvanian Deltas formed the Upper Midway bauxite deposits.

Studies of the Pennsylvanian Pottsville and Allegheny Formations of Pennsylvania reveal areas where kaolinitic clays are dominant (35% Al_2O_3, 40-60% SiO_2, 1-5% Fe_2O_e). The clays have a similar chemical composition

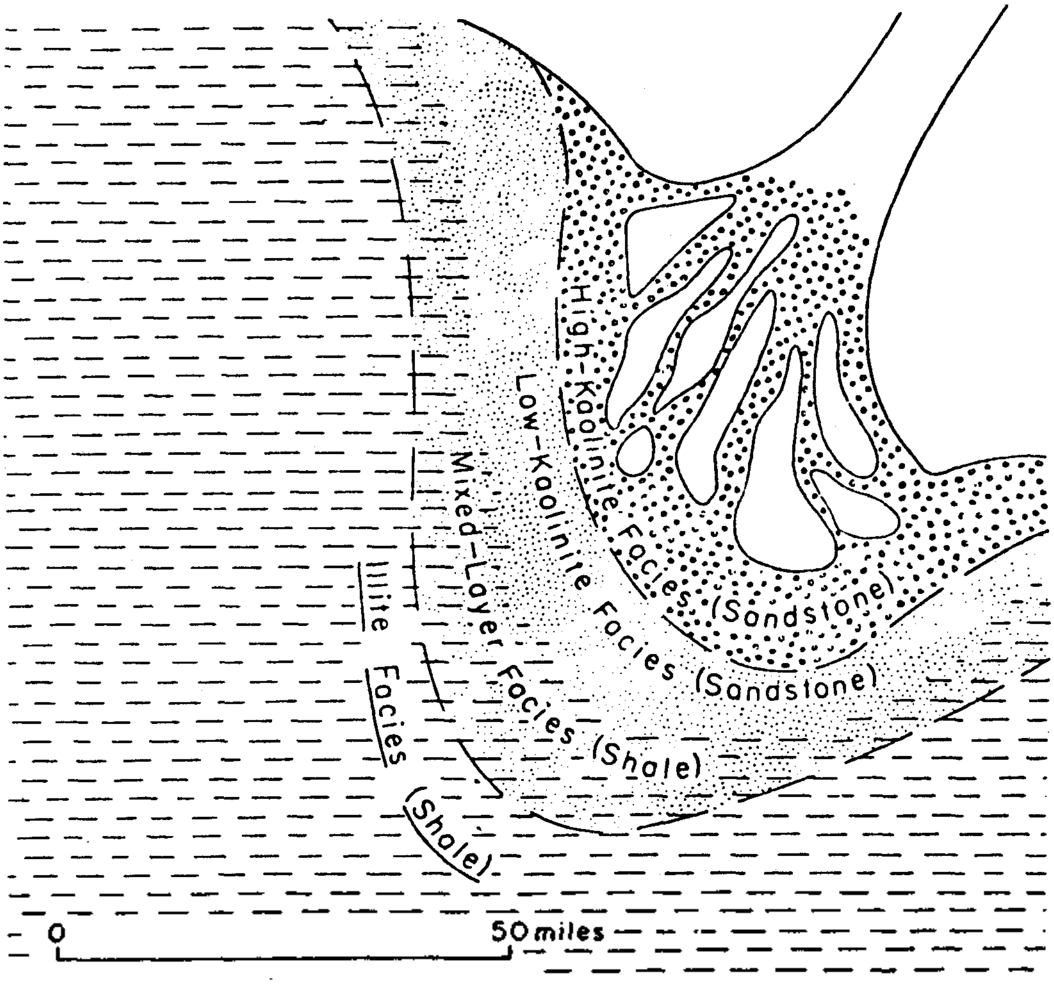


Fig. 26 Idealized relation between clay mineral facies of the Pre-Pennsylvanian sandstone and shales of the Illinois Basin. The above figure is an example of how sedimentary environments, sedimentation rates, salinity and river transported clays can produce a kaolinite rich facies within the destributary system of a delta. This chemical and physical sorting of clay minerals could have produced localized areas of aluminum rich clays in the Upper Midway Group of Mississippi (Smoot, T. W., 1960).

as the high aluminum clays of north Mississippi. The Pennsylvanian clays occur approximately at an ancient shoreline whose pattern is controlled by paleotopography development on an underlying deltaic clastic wedge. Kaolinitic clays in some localities are underlain by black carbonaceous siltstone and overlain by gray siltstone which grades upward into plastic clay (Williams and Bergenback, 1968).

Researchers postulate that differential colloidal fractionation produced the mineralogical character of the kaolin clay and the composition and distribution of insoluble residue in the laterally equivalent marine deposits. The kaolinitic clay most likely occurs in areas where pH changes range from acid to basic; such an area would be the swamps and lakes. Williams and Bergenback (1968, p. 1190) concluded that these paludal-lacustrine environments which fringed the sea varied enough in pH and electrolyte concentration to permit selective colloidal precipitation of clays and syngenetic removal of soluble bases and silica. A similar theory is suggested for the aluminum rich clay pods within the Upper Freeport Coal of Pennsylvania (Clark, 1979, p. 31).

If kaolinitic clay assemblages occur and are localized within the Pearl and Mississippi River, then such differences could occur in ancient coastal sequences. This has been demonstrated in the Pennsylvanian kaolinitic clays (Smoot, T.W., 1960; and Williams and Bergenback, 1968). For these reasons it seems likely that the Midway Group of Mississippi could have inherent clay mineral facies prior to weathering or diagenesis. It is possible, therefore, that kaolin rich deposits along the strike of the Upper Midway Group were deposited within similar environments along the Late Paleocene coast of north Mississippi. Weathering could be considered as a secondary enrichment process but not the primary producer of such deposits.

No one has actually observed bauxite actively forming, however, a possible incipient deposit has been observed by Theobald (1963) in Colorado. Precipitation of aluminum, iron, and manganese at the confluence of Deer Creek and the Snake River in Summit County, Colorado, may be a natural mechanism for the formation of bauxite.

The aluminum rich deposit (54-64% Al) occured below the confluence where the pH stabilized near a neutral value (7 to 9). A sharp decrease in the concentration of iron also occured below the confluence. This was traced to precipitation of the iron in large bogs upstream.

Theobald and Lakin (1963) postulate the bauxite could form by the hydrolysis of aluminum from sulfate-rich waters. They further infer that sulfate-rich waters are potential carriers of dissolved aluminum, and the formation of aluminous clays accordingly follows a geochemical sequence of: (1) oxidation of pyrite releasing sulfuric acid, (2) decomposition of clays by this acid releasing aluminum, and (3) precipitation of the aluminum by hydrolysis when the acidic and aluminum-bearing waters are neutralized. This is similar to neutralization of the water discharge into a standing body of fresh water such as a lake downstream. Again, fluvial transport and paludal-lacustrine deposition of kaolin and bauxite materials have been suggested. Paludal-lacustrine environments did (Fig. 23) exist along the Late Paleocene coast (Upper Midway) of north Mississippi and kaolin and bauxite-like material occured along the strike of the Upper Midway.

SUMMARY

Petrographic, stratigraphic, and geochemical investigations have aided in the development of explanations for genesis of north Mississippi bauxite and/or kaolin of the Upper Midway Group. Most of the data points toward an origin involving a coastal environment. The formation of the aluminum and iron rich deposits appears to have taken place between the deposition of the prominent shallow shelf typical Porters Creek muds, and the deposition of Upper Porters Creek-Naheola incipient deltaic sands and muds.

Mississippi deposits are not associated with known volcanic, igneous, metamorphic, or sedimentary rocks containing feldspar. The uplands are composed of limestone, shale, and sands of Early Paleocene and Late Cretaceous age. During the Late Paleocene, the sources supplied are predominantly silt and clay size material. The bauxite commonly overlying prodelta muds is overlain by fluvial deltaic muds and sands, downdip grades into tidal flat and prodelta muds, and is commonly localized within a facies of more extensive carbonaceous kaolin. The above represents a series of units normally not associated with bauxite deposits. The above also rules out almost all previous theories on bauxite genesis (terra rossa or lateritized igneour and/or saprolite complex). A new and relatively unsupported theory, therefore, must be postulated to explain the development of bauxite on an aluminum poor, silica rich clay.

It is difficult to resolve the genesis of north Mississippi bauxite using a genetic soil model. If these high aluminum deposits are the product of soil genesis, then they are the only soil catina (facies) among intertidal, and fluvial-deltaic sediments.

If soil processes are not the primary processes, then the process or catalyst which produced the bauxite must have been short-lived. The data indicates that the process was related to very low gradient deltas and sluggish contributary systems draining across clayey formations. Previous research and the present study have indicated that swamps, lakes and marshes located with interdistributary areas of subsidence are also related. One hypothesis is that the bauxite process could be similar to the formation of nonclastic carbonate. If the bauxite were a chemical precipitate, it would be effected by processes which also effect the formation of nonclastic limestone. For example, if the sediment content increases and progradation begins, the result would bury and/or disturb the chemical precipitate preventing formation. Increase in sediment load would also result in dilution of the precipitate. If the above postulation can be proven, then the transporting agent and depositional environments chemical conditions would be the most important factors controlling the location of bauxite deposits.

Although previous investigators point to the presence of bauxite and high aluminum clays of the same age in Arkansas and Alabama as evidence of a widespread residual process, there has been little explanation of the paucity of deposits of the same age in southeast Mississippi, and most all of south Alabama. One explanation for the lack of extensive aluminum rich deposits is that greater erosion in these areas resulted in removal of the deposits. Environmental and/or facies changes also occur in the areas of paucity. This shoreline occurance in Alabama has been noted by Velton (1972), however, no one has suggested the same for northeast Mississippi.

In the review of geochemical research of aluminum rich clays, the works of Curtis and Spears (1971), along with Huang and Keller (1972), are most applicable. Their work indicates that a large amount of kaolinite in the world developed at the expense of gibbsite through resilicification. This would allow for the precipitation of gibbsite with simultaneous deposition of kaolinite by flocculation in other areas. The result would be larger volumes of kaolinite resulting from both conversion of gibbsite and primary deposition. The problem of how aluminum is supplied to these sedimentary basins has been answered by Huang and Keller (1972). Aluminum ions may become mobile in localized areas of low pH and low solubilized silica and transported by organic complexes and reprecipitated.

The mobility data seems to be accurate in very general ways. The reason for only general application is the effects of organic content, anions, and sediment rate have not been taken into account. In the case of kaolinite, it has been shown in previous sections that large areas of kaolinite occur on the shallow parts of the Louisiana continental shelf near the mouth of the modern Mississippi River and several kaolinite zones occur near the mouth of the Pearl River (Brooks, R.A., 1976; Snowden, J.O., 1976; and Griffin, G.M., 1964).

Transportation of aluminum and iron by streams has been suggested by several researchers (Keller, W.D., 1964, p. 140, Beck and others, 1974, p. 360). Many of the pisolitic and nodular high aluminum clays of the U.S.S.R., Pennsylvania, and Missouri have been suggested to be the result of muddy and colloidal suspensions transported to their present site by slow, quiet streams. One theory suggests that pH was the major control of transport and deposition.

High concentration of organic matter can contribute significantly to the mobilization of metals. In the downstream reaches of a river, the important factors are those which result in flocculation or precipitation. In the case of iron, experiments have shown that it is resistant to precipitation over a wide range of Eh and pH. The goal, therefore, is to find the conditions under which aluminum could be separated from the other metal organic complexes.

The pisolitic characteristic of many north Mississippi high aluminum deposits suggests a sedimentary origin with rapid accumulation in shallow, still, and/or agitated waters. Although little research has been conducted on the origin of aluminum rich pisolites, some correlations to non-aluminum pisolites can be made. Sedimentation of aluminum and iron rich pisolites probably occured where natural electrokinetics initially produced colloidal synaresis, then finally pisolites and oolites. (Thompson, C.N. and Reynolds, 1978). Periodically the dissolved silica content within this system would be elevated at which time kaolinite was formed and deposited along with organic and terrigenous clastics. Precipitation of gibbsite with small amounts of kaolinite and iron probably took place within the more dynamic system of the tidal channels where sedimentation in response to a natural dorm potential would be strong, particularly during periods of flushing.

It is possible that variation and migration of depositional environments resulted in much of the stratigraphic variation in the composition of the kaolinitic clays. This conclusion is supported by the previous studies which have shown no significant source area changes occurred. It could be possible that simple pH changes between fluvial and paludal environments caused the selective precipitation and/or differential flocculation of high aluminum clays and iron. Following removal in solution or colloidal suspension, it is postulated that these components were transported and subsequently precipitated in or near swampy coastal environments. This would suggest that bauxite, bauxitic clays, kaolin, lignitic clays, and iron deposits formed contemporaneously in a laterial series of interrelated environments (Fig. 27).

A model suggested for the genesis of aluminum rich deposits in northeast Mississippi must be based on stratigraphy. The aluminum rich clays are positioned in the Late Paleocene during the deposition of the Upper Porters Creek and Lower Naheola Formations. Data indicates that con-

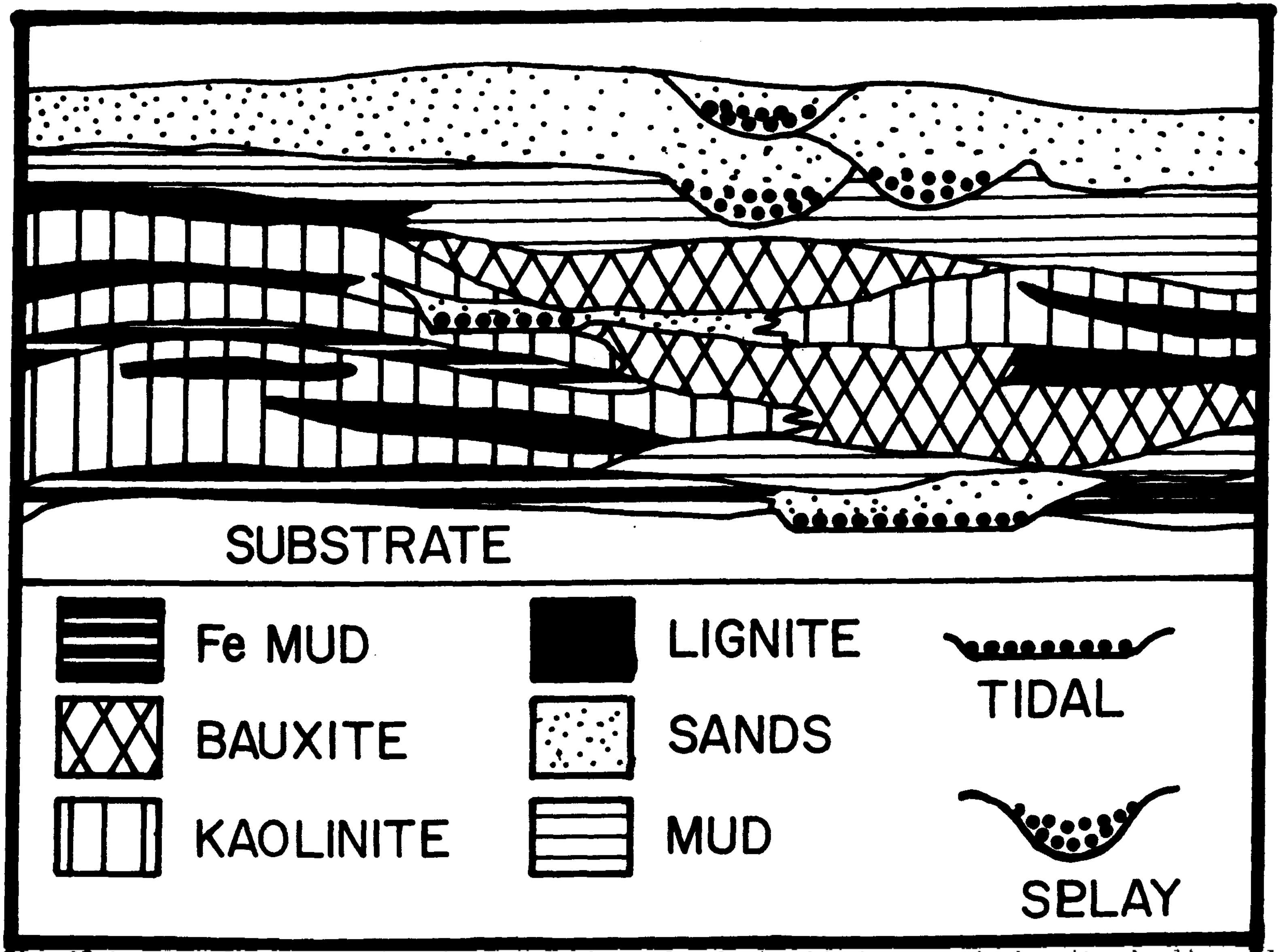


Fig. 27 Conceptual cross section showing the lateral relationship between the bauxite, kaolin, and iron.

tributary systems began exerting influence over the tidal flat-marine shelf environment of the Upper Porters Creek Formation. It is at this time the high aluminum deposits appear to have accumulated. The cycle of deposition started with the build up of sediment within swamps and lakes. In addition to this, clays and iron began accumulating in the supratidal marsh system. It is within the supratidal marsh areas the initial amorphous silica deposition occured. This was followed by the fixation of iron by algae; in some cases this is shown as accumulation around plant stems. With slight changes in geochemical parameters, (Fig. 28) kaolinite with some gibbsite could be deposited within the more stagnant shallow waters.

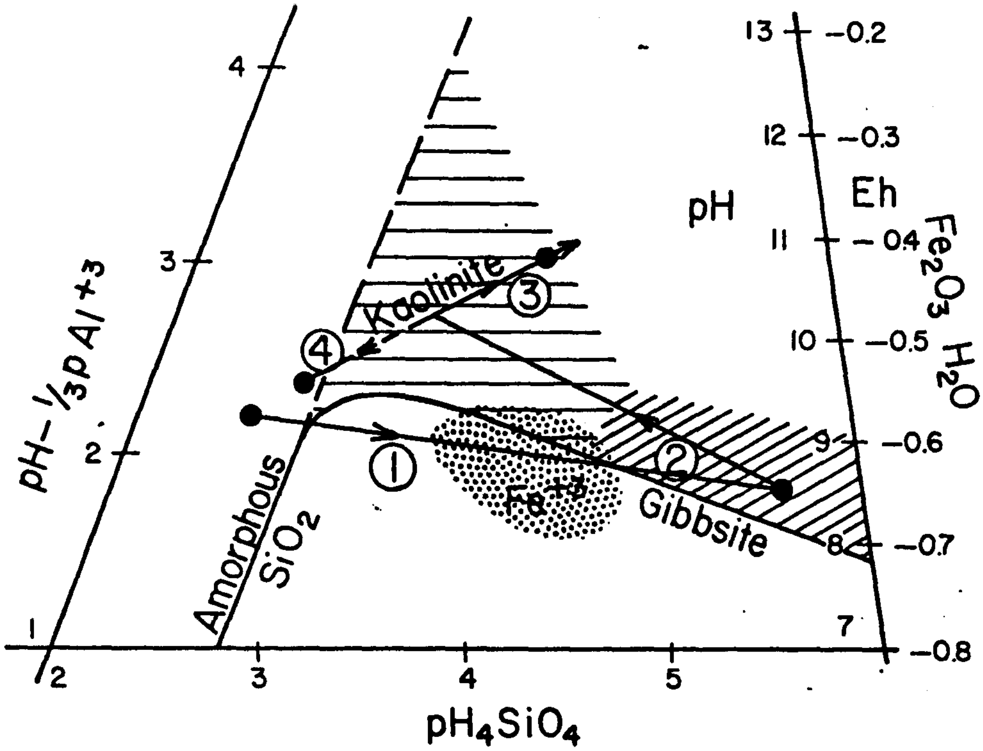


Fig. 28 Geochemical phase diagram showing the chemical parameters which could have segregated the minerals thus forming the localized deposits laterally of each other (Reynolds, W. R., 1977). Streams draining into the interdistributary regions contained high concentrations of aluminum, iron, and silicon ions plus colloidal material. Selective precipitation of gibbsite, kaolin, and siderite occurred when the streams entered static coastal marsh systems where the suspended ions reacted to the change in chemical parameters.

CONCLUSIONS

It has been difficult from the beginning to resolve the genesis of north Mississippi high aluminum clays (bauxite-kaolin). The majority of the information obtained seems to involve a coastal environment. The formation of north Mississippi high aluminum clays took place within a facies trap between the time of deposition of prominent marine-shelf muds (Porters Creek) and the time when Upper Midway (Naheola) incipient delta systems began a westward progradation.

It is possible that variation in depositional environments resulted in the stratigraphic variation in the composition of the high aluminum deposits. This conclusion is supported by previous investigations which have shown no significant source area changes occured and that post depositional leaching did not alter most of the Upper Midway Group clays. Variation in the chemistry of the depositional environment, therefore, controlled the variation and distribution of high aluminum material along the strike of the Upper Midway Group. This does not mean that some variation in source area composition and post depositional leaching did not effect local composition such as iron content (cap rock). High aluminum clay distribution when compared to paleogeographic data appears to be perpendicular to the Upper Midway shoreline. Some aspect of environment, therefore, is reflected by the high aluminum deposits.

Paucity of deposits of high aluminum clays in the southeastern counties may be the result of environmental conditions varying along strike of the Upper Midway. The environment conducive for genesis, therefore, was more prominent in the northeast. The most prominent change occurs in the southeast where marine influence was greater during the Late Paleocene. The large distances which separate deposits that do occur in the southeast suggest that a gradual dilution occured in the environment in which the high aluminum clays formed.

Reconstruction of the paleogeography is basically conceptual with some factual backing. It is postulated that during the Late Paleocene (Upper Midway Group) contributary systems began to exert influence over the heretofor tidal flat-shallow shelf environment. This series of widely dispersed contributary system of low gradient streams meandered across the clayey Upper Midway deltaic plain. Westward (front of the incipient deltas) prodelta muds of the Porters Creek and Naheola Formations continued to accumulate. A series of broad interlobate regions consisting of tidal, supratidal, fresh water lakes and swamps developed within and between the small wave dominated incipient deltas. Streams draining into these small basins contained high concentrations of aluminum, iron, and silicon ions plus colloidal material derived from the erosion of the weathered uplands (Lower Porters Creek Fm., Clayton Fm., and several Upper Cretaceous Fms.). These sluggish acidic streams drained into static coastal waters where selective precipitation and/or differential flocculation of kaolin, gibbsite, and iron minerals occured as a result of changes in chemical and/or physical parameters (organic content, anions, pH, and salinity).

Deposition of the Lower Wilcox (Early Eocene) sediments closely followed the deposition of Late Paleocene incipient deltas. The entire Midway system was then covered and in many areas locally incised by the larger fluvial-deltaic system prograding westward over the slowly subsiding shelf in the northern extremities of the Mississippi Embayment. This period of delta building continued through the Eocene after which time the upper portions of the Mississippi Embayment was completely covered by continental sediments. Deep erosion again exposed the updip portions of the Midway Group which contained the high aluminum deposits. As a result, portions of the high aluminum (kaolin and bauxite) outcrop were eroded and exposed resulting in partial conversion to duricrust (iron cap) while other portions remained covered by Naheola or Lower Wilcox sediments.

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APPENDIX A

CROSS SECTIONS AND BASE MAPS

Cross Section	Well No.	County	Source			
			Organization	Pub. No.	Author	Date
A-A'	N193	Pontotoc	Miss. Geol. Survey	Bull. 54	Priddy, R.R.,	1943
	N194					
	N239					
	P-50		U.S. Bur. Mines	R.I. 4235	Reed, D.F.,	1952
	PB-16		Univ. of Miss.	Thesis	Thompson, C.N.,	1980
	PB-17		Bauxite Project see Appendix for log records			
	PB-15					
	PB-12					

(see figure 12, page 31)

Cross Section	Well No.	County	Source			
			Organization	Pub. No.	Author	Date
B-B'	N194	Pontotoc	Miss. Geol. Survey	Bull. 54	Priddy, R.R.,	1943
	N261					
	N262					
	N202					
	N204					
	N275					
	N270					
	N288					
	Kaolin Pit		Univ. of Miss. Thesis		Thompson, C.N.,	1980
			Bauxite Project see Figure 20.			

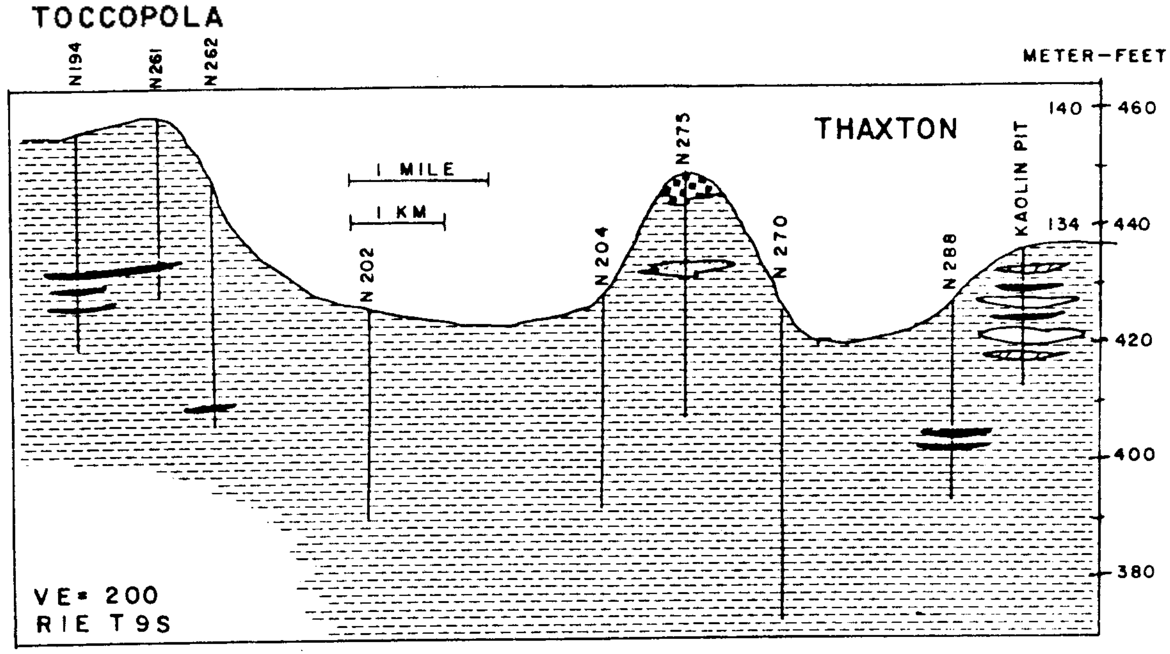
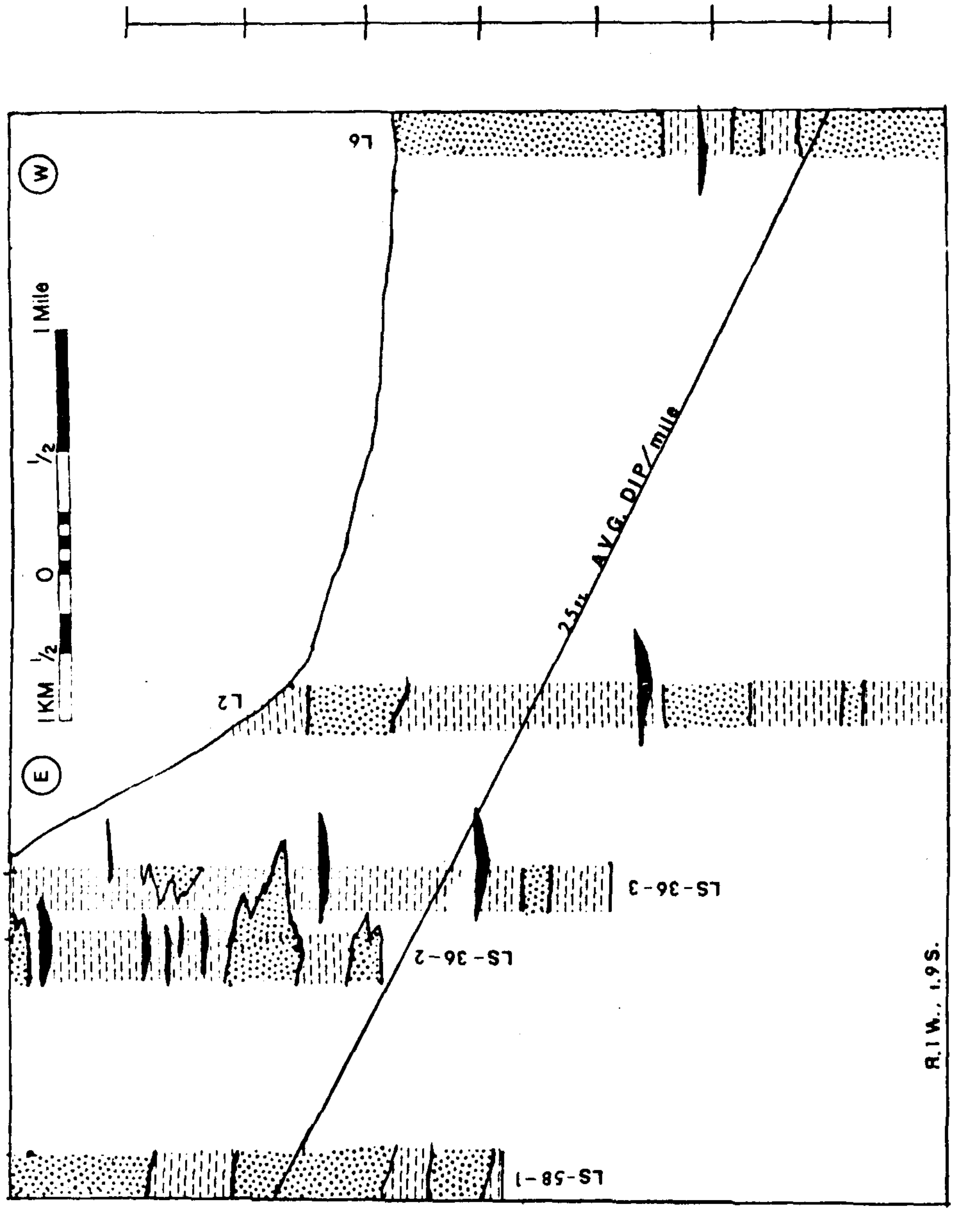


Fig. 29 Cross section B-B'

Cross Section	Well No.	County	Source			
			Organization	Pub. No.	Author	Date
C-C'	LS-58-1	Pontotoc	Miss. Geol. Survey	MGS-74-1	Williamson, D.R.,	1976
	LS-36-2	LaFayette				
	LS-36-3					
	L2		Miss. Geol. Survey	Bull. 71	Attaya, J.S.,	1951
	L6					


E
W
1 KM
1/2
0
1/2
1 Mile
L2
L6
LS-36-3
LS-36-2
LS-58-1
25ft. AVG. DIP/mile
R.1W., 1.9S.

Cross Section	Well No.	County	Source Organization
D-D'	W414	Pontotoc	U.S. Bur. Mines
	W403		
	W131		
	W132		
	W406		
	W109		
	P1	Union	
	P5		
	P7		
	P34		
	P10		
	P13		
	P28		
	P30		
	*P22		

(see figure 19, page 40)

Pub. No.	Author	Date
R.I. 4827	Reed, D.F.	1952

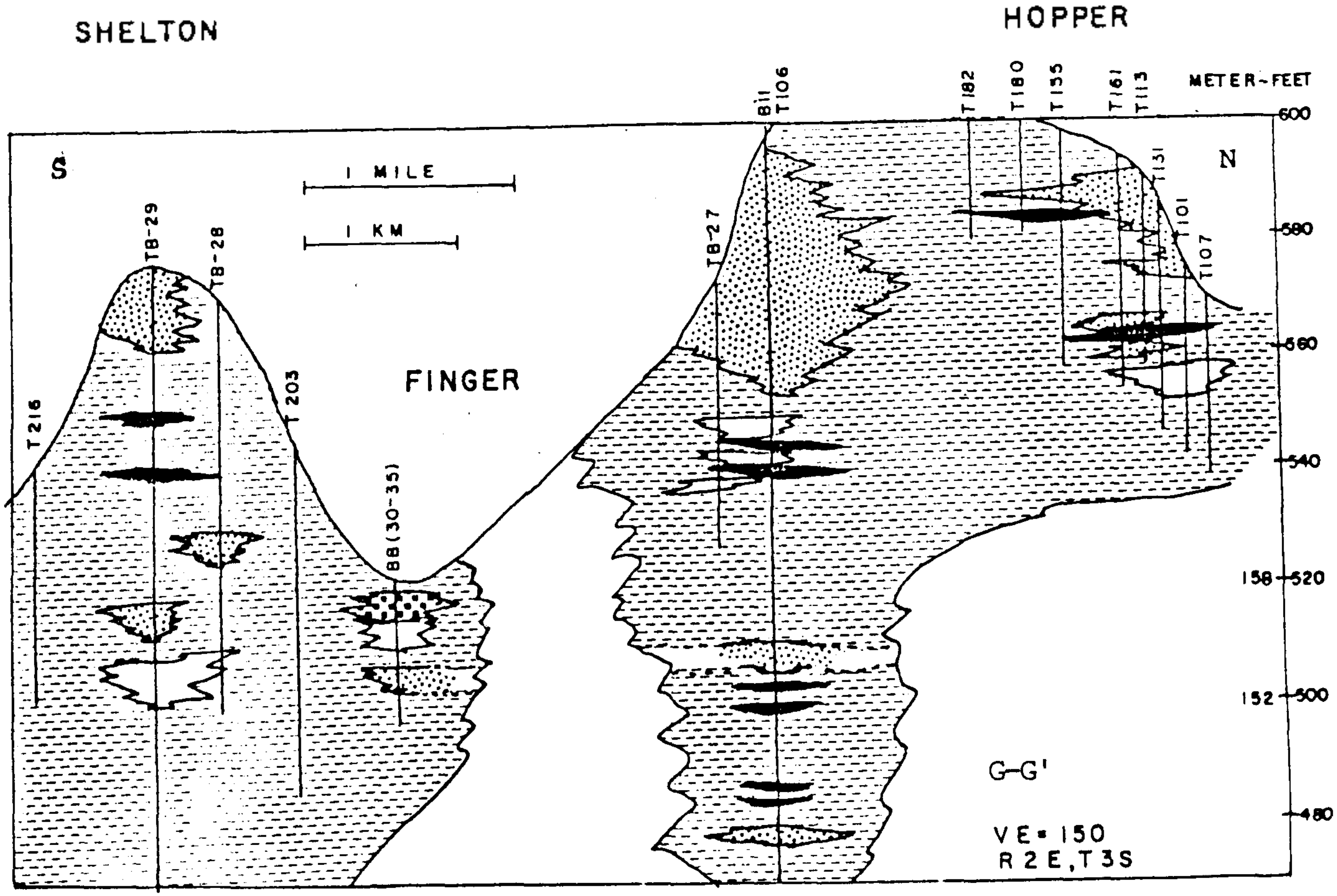
Cross Section	Well No.	County	Source			
			Organization	Pub. No.	Author	Date
E-E'	MAR1	Union	Miss. Geol. Survey	Bull. 78,	Vestal, F.E.,	1954
	MAR2	Marshall				
	MAR4					
	MAR5					
	LS-4-71		Miss. Geol. Survey	MGS-74-1,	Williamson, D.R.,	1976

(see figure 21, page 44)

Cross Section	Well No.	County	Source Organization	Pub. No.	Author	Date
F-F'	D271	Union	Miss. Geol. Survey	Bull. 45	Conant, L.C.,	1942
	F021	Benton	U.S. Bur. Mines	R.I. 4287	Reed, D.F.,	1952
	F027					
	F026					
	F036					
	F038					
	F044					
	KB-7	Benton	Miss. Geol. Survey	Bull. 101	Kearn, M.K.,	1963
	KB-5					
	KB-1					
	KB-3					
	B-1		Miss. Geol. Survey	Bull. 80	Lusk, T.W.,	1956
	B-5					

(see figure 18, page 39)

Cross Section	Well No.	County	Source			
			Organization	Pub. No.	Author	Date
G-G'	T216	Tippah	Miss. Geol. Survey	Bull. 42	Conant, L.C.	1941
	T203					
	T182					
	T106					
	T180					
	T155					
	T161					
	T113					
	T131					
	T101					
	T107					
	B-11		Miss. Geol. Survey	Bull. 80	Lusk, T.W.	1956
	TB-29		Univ. of Miss. Thesis		Thompson, C.N.	1980
	TB-28		Miss. Bauxite Project			
	BB (30-34)					


SHELTON
HOPPER
FINGER
S
N
1 MILE
1 KM
METER~FEET
600
580
560
540
158 520
152 500
480
T216
TB-29
TB-28
T203
BB(30-35)
TB-27
B11
T106
T182
T180
T155
T161
T113
T131
T101
T107
G-G'
VE = 150
R 2 E, T 3 S

DRILL HOLE LOCATION CHART (NOT KEY TO EXPOSURES)

■	LAFAYETTE COUNTY: BULLETIN 71 (1951)
◓	PONTOTOC COUNTY: BULLETIN 54 (1943)
●	UNION COUNTY: BULLETIN 45 (1942)
○	BENTON COUNTY: BULLETIN 80 (1956) (WITH E-LOGS)
△	TIPPAH COUNTY: BULLETIN 42 (1941)
□	MARSHALL COUNTY: BULLETIN 78 (1954) (WITH E-LOGS)
▲	UNIVERSITY OF MISSISSIPPI (1974)
✪	LIGNITE STUDY (1976) M.G.S. SERIES 74-1 (WITH E-LOGS)
◎	IRON ORE STUDY (1963) BULLETIN 101 (WITH E-LOGS)
◉	WATER WELL OR OIL WELL (E-LOG ONLY)
⬤	U.S. BUREAU OF MINES R.I. 4827
·······	ESTIMATED FORMATIONAL CONTACTS BASED ON M.G.S. DATA (ARBRITRARY)
▨	SATURATED DRILLING AREA SEE U.S. BUREAU OF MINES R. I. 4827

Fig. 32 Index for drill hole location base map

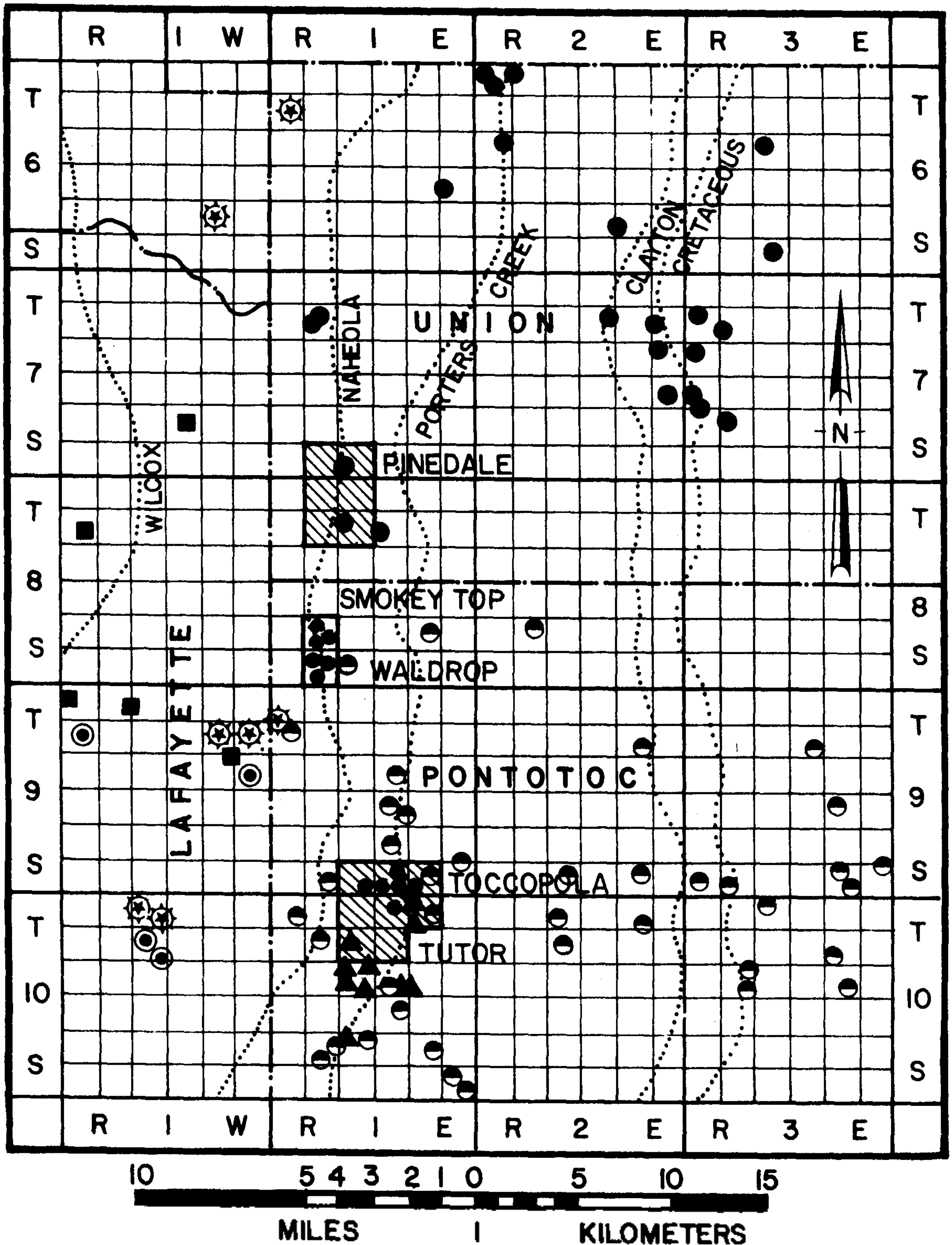


Fig. 33 Part (A) of drill hole location base map

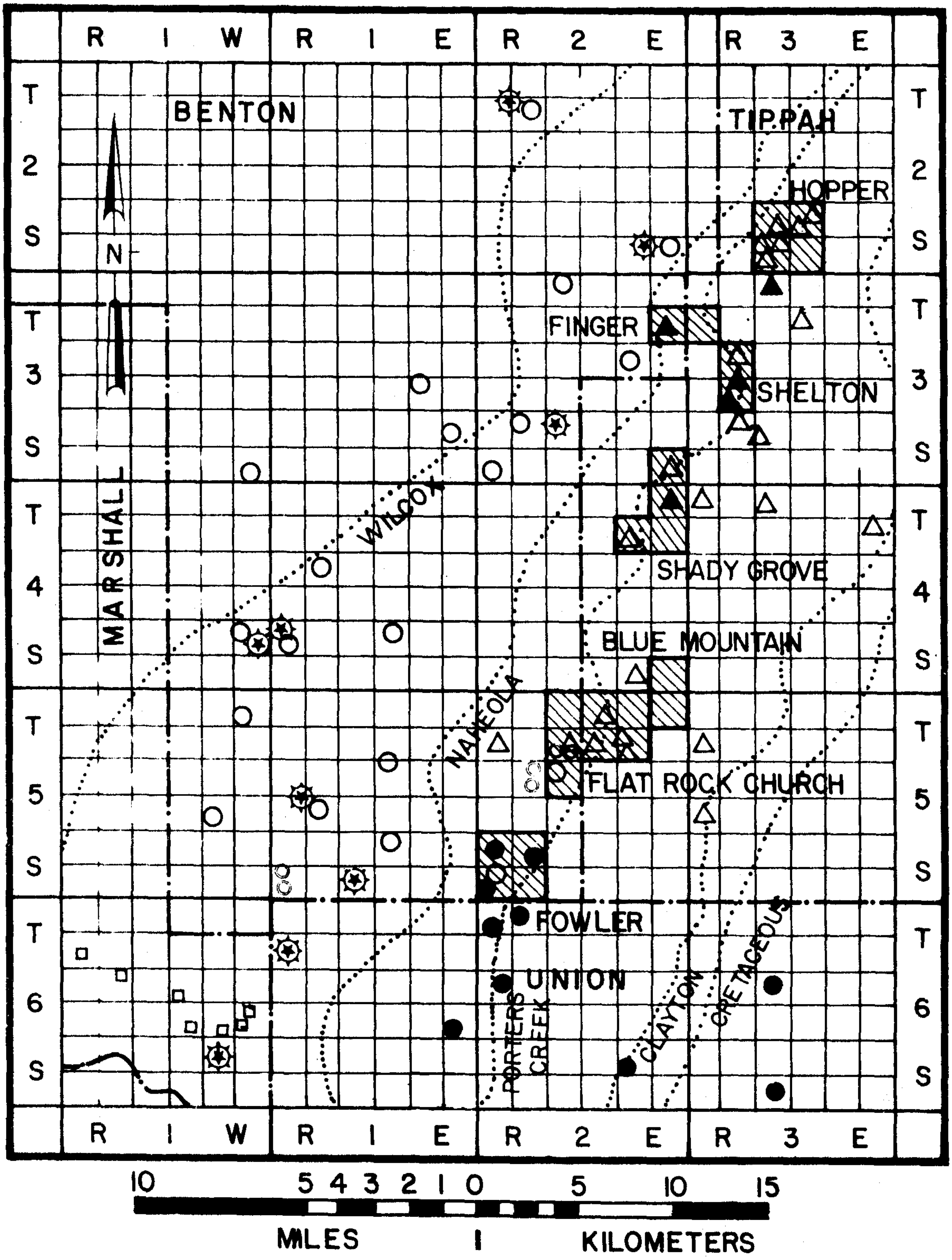


Fig. 33 Part (B) of drill hole location base map.

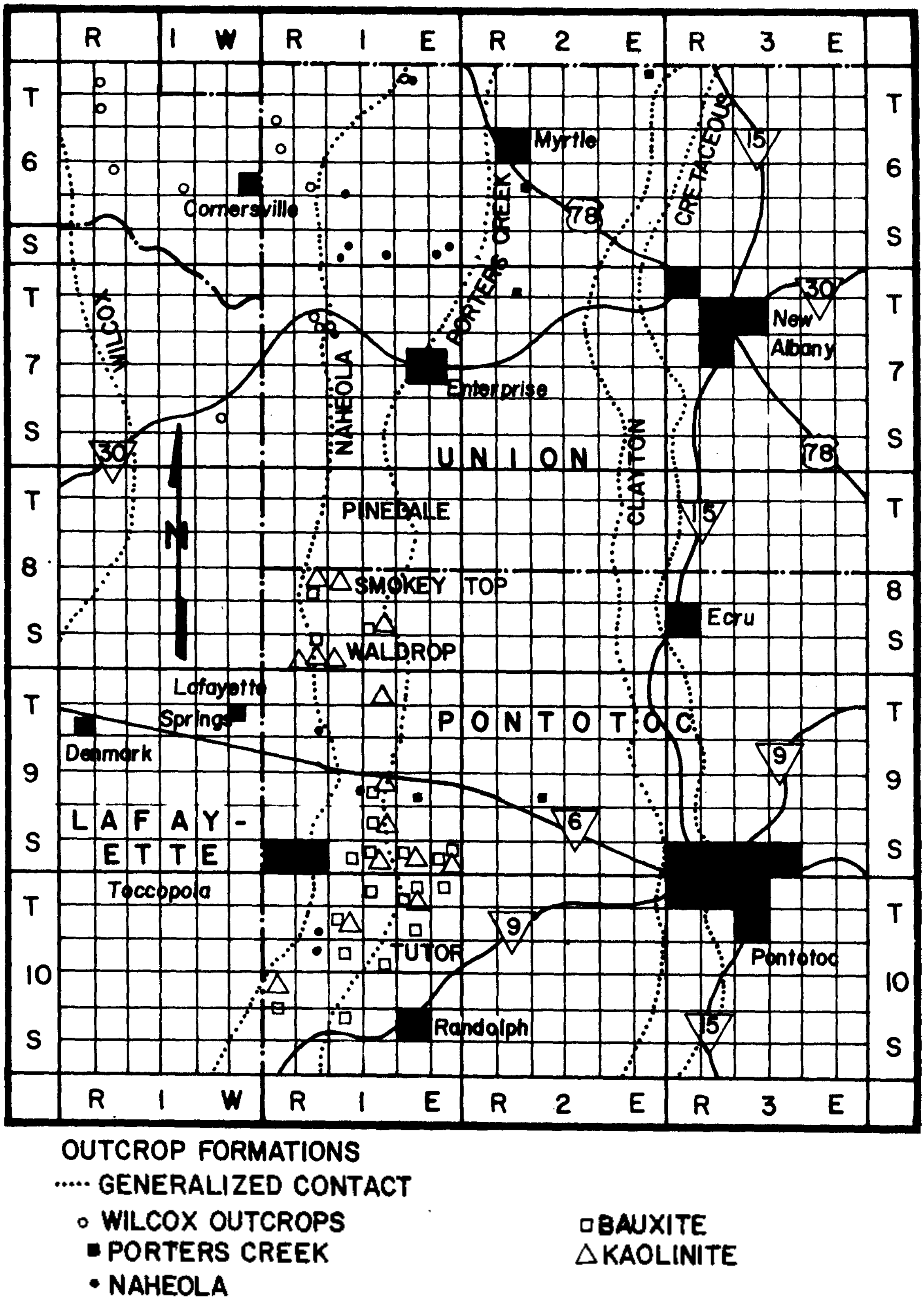


Fig. 34 Part (A) of outcrop exposure base map.

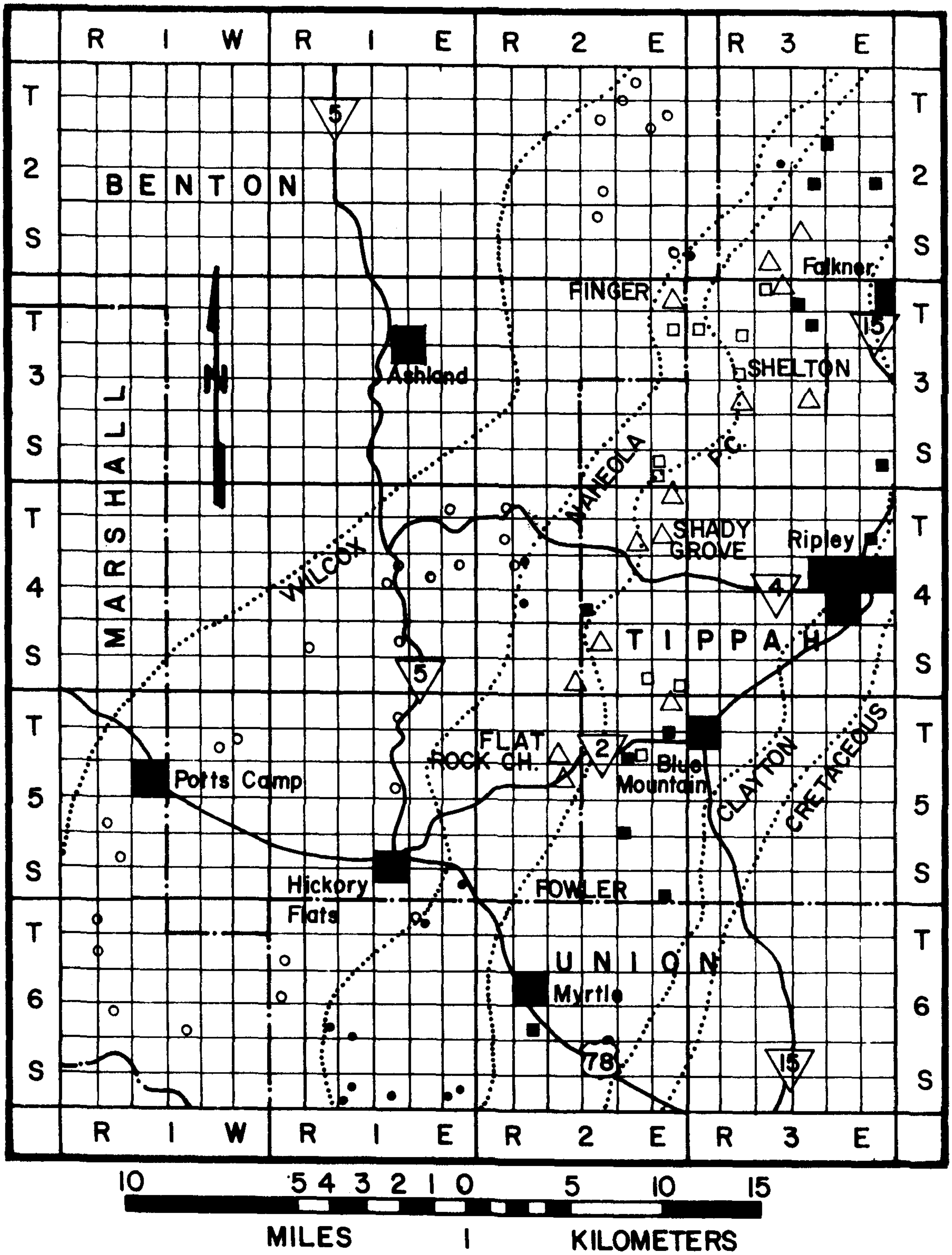


Fig. 34 Part (B) of outcrop exposure base map.

APPENDIX B

DRILL LOG RECORDS

Core No. PB1 County Pontotoc Date 1976

Section SW ¼, SW ¼, Sec. 14 T. 10 S. R. 1 E.
Elevation 481 feet Total Depth 39 Ft. 11.9 M.

Bottom	Thickness Feet Meters	East of Randolph Road Metal Pit
13.0'	3.9	V.F. sand to silt, mottled, beige to rust, clay matrix probably Kaolinitic.
22.0'	2.7	V.F. sand to silt, slightly mottled, light gray, clean, well sorted, trace of Mica.
28.0'	1.8	Fine sand, light gray, few small Lignite (1/5") fragments, trace small rock fragments possibly volcanic glass, increase in mica flakes.
30.0'	0.6	Medium to fine sand, light gray, small Lignite (3/10'-4/10') fragments, clean with trace of clay.
32.0'	0.6	Silty clay, Light gray to gray, few fragments of white clay (prob. Kaolinitic), few small Lignite (1/5") fragments.
33.0'	0.3	Silty clay, white, micaceous, probably Kaolinite
34.0'	0.3	Clay, Light gray, highly Micaceous
36.0'	0.6	Clay, Light gray-gray, Conchoidal break, many thin partings of 75% Mica, very brittle.
37.0'	0.3	Sandy clay, fine sand, gray clay, few small Lignite fragments, some small white clay fragments, note some white clay surrounds small Lignite fragments.
39.0'	0.6	Clay, gray, Conchoidal break, many thin bottom parting of 75% Mica, very brittle.

Bottom

Core No. PB-2 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 E.
Elevation 471' Total Depth 40' Ft. 12.2 M.

Bottom	Thickness		On partially mined surface
	Feet	Meters	In Randolph Road Metal Pit
7.5'	7.5'	2.3	Bauxite, Pisolitic, Hard, ferruginous matrix note pisolites appear to decrease in size downward.
			Contact, hard, ferruginous, pisolitic Bauxite with yellow gibbsitic Kaolinic clay.
9.5'	2.0'	0.6	Clay, yellow, trace iron, probably gibbsitic and Kaolinic clay, note few 2.0 mm hard pisolites, increase in Goethite at bottom, possible contact zone, it is continous horizonally through the core at 9.5', an ocherous staining through interval.
13.5'	4.0'	1.2	Clay, white, low iron content, presence of what appears to be thin undulating beds with faint ocherous stain, increase in stain downward, probably Kaolinite.
14.5'	1.0'	0.3	Clay, mottled appearance, highly undulated color pattern, (pink, yellow, and white) appears more brittle than sample from above, few (1.0-0.5mm) piselites. Trace of brown goethite in cracks. Grades down into white clay.
17.0'	2.5'	0.8	Clay, white, w/large gray ghost (1/2"-1") also note few small pellets (1.0-2.0mm) close inspection are gray clay balls, trace ocherous stain. (Probably Kaolinite)
21.0'	4.0'	1.2	Clay, white-gray, highly undulated to mottled appearance, white & gray clay pisolites, ocherous stain throughout interval, appears to be more brittle than clay. Above, grades downward into gray clay where any (4.0 mm) white clay pisolites, trace of siderite towards bottom.

25.0'	4.0'	1.2	Clay, Lt. gray-white, silt site siderite, Kaolinite, many white ghost of clay with gray matrix, even what appears to be a white clay burrow or root ghost. (Note at 24.5 thin (1"-2") bed of siderite continous horizonally)
30.0'	5.0'	1.5	Clay, white-gray, 30% silt site siderite, Kaolinite, appears to have a pisolitic texture, increase in mica downward & Siderite.
32.0'	2.0'	0.6	Clay, white to Lt. gray, salt & pepper Siderite (About 1.0 mm size), some mica present. (Probably Kaolinite)
34.0'	2.0'	0.6	Clay, gray, 15-20% Mica, faint appearance of thin laminations, salt & pepper Siderite 30% appears to have low silt content., mottled texture w/occ. traces of white clay (Kaolinite) ghost.
36.0'	2.0'	0.6	Clay, white-lt. gray, decrease in Mica & Siderite, probably Kaolinite, some ocherous staining *Special note--Layer of 50% Mica 40% 0.25 mm Siderite pellets 10% Kaolin about 1" thick at 35' mark *Special note--Layer 1/2" thick of very fine sand and mica at 35'8" mark.
40.0'	4.0'	1.2	Clay, silty, gray to black, conchoidal break, thin partings of 75% mica, massive no definite bedding or lamination grades into black laminated clay w/some V.F. sand lenses

Bottom

Core No. PB-3 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 E.
Elevation 471.0' Total Depth 35.0' Ft. 10.7 M.

Bottom	Thickness Feet	Meters	Just below bauxite seam In Randolph Road Metal Pit
1.0'	1.0'	0.3	Clay, multi color, thin laminations of white and pink clay, probably Kaolin, appears silt free, friable, some mica present, iron staining.
3.0'	2.0'	0.6	Clay, white w/ocherous staining, some pisolite ghost about (2.0 mm size), clay appears mottled, grade down into a purple stain clay w/occ siderite pellets.
4.0'	1.0'	0.3	Clay, lt. brown-reddish brown, pisolitic, soft, Kaolinitic, mottled texture, friable.
5.0'	1.0'	0.3	Clay, lt. brown-white, very pisolitic (4.0 mm size), soft, friable, w/ocherous staining.
10.0'	5.0'	1.5	Bauxite, appears weathered and friable, brown, with low iron content.
20.0'	10.0'	3.0	Clay, lt. gray to white, friable in upper section, silt size siderite throughout increasing downward to about 35% w/occ (4.0 mm size) pellets. Clay probably Kaolinite, w/occ areas of mottling.
22.0'	2.0'	0.6	Clay, lt. brown to white, with spotty red staining throughout section, some mica present, red stain appears to be mottling texture, possibly burrowing ghost, appears to have low siderite & silt content.
29.0'	7.0'	2.1	Clay, white to lt. gray, salt & pepper siderite (0.50 mm size avg.) about 20%, note heavy siderite at 24' mark, some mica present (10%), clay probably Kaolin, clay grades downward into a gray-black clay.
35.0'	4.0'	1.2	Silty clay, gray to black, Micaeous, Conchoidal break, becomes laminated toward bottom, increase in parting of silt & mica.

Bottom

Core No. PB-4 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 I.
Elevation 476.0' Total Depth 33.0' Ft. 10.1 M.

Bottom	Thickness Feet	Meters	Just below mined seam in Randolph Road Metal Pit
4.0'	4.0'	1.2	Clay, orange to lt. brown, friable, mottled appearance, ocherous staining, soft, probably Kaolin, few iron pellets (2.0 mm size), note 1" thick iron bed at 3½' mark, the section appears silt free.
6.5'	2.5'	0.8	Clay, gray, silt size siderite about 15%, mottled appearance, appears silt free probably Kaolin.
12.0'	5.5'	1.7	Clay, white-lt. gray, 50% silt size Sederite from 6½ to 8' mark decrease downward to about 25%, some Mica present, note another 50% Siderite zone from 11' to 12' mark, clay appears silt free, probably Kaolin.
18.0'	6.0'	1.8	Clay, white to lt. brown, 15% Mica, appears siderite free, and silt free.
25.0'	7.0'	2.1	Clay, white to lt. brown, salt & pepper siderite about (0.50 mm size) 30%, micaeous, note 2" thick 75% siderite bed at 22½' mark, increase in silt downward.
26.0'	1.0'	0.3	Clay, gray-black, gradational contact, note several thin fine sand lenses, increase in silt & mica.
33.0'	7.0'	2.1	Silty clay, gray-black, laminated, many thin parting of mica & silt.

X-Ray and thinsections

Core No. PB-5 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 E.
Elevation 471.0 Total Depth 30.0' Ft. 9.2 M.

Bottom	Thickness Feet	Thickness Meters	On Partially mined surface in the Randolph Road Metal Pit
4.0'	4.0'	1.2	Bauxite, weathered texture, friable, pisolotic texture with high clay matrix low iron content, lt. brown, most iron pisolites 2.0 mm size.
11.0'	7.0'	2.1	Clay, lt. brown, w/iron staining, low siderite content, low silt content, Micaeous.
20.0'	9.0'	2.7	Clay, lt. brown-lt. gray, w/iron stain, salt & pepper siderite silt size to 0.50 mm, most Siderite 25% some small intervals higher content, micaeous increasing downward, increase in silt downward, grades down into black clay.
30.0'	10.0'	3.0	Silty clay, gray-black, massive to laminated, many thin lenses of mica & fine sand.

Core No. PB-7 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 E.

Elevation 471.0' Total Depth 32.0' Ft. 9.8 M.

Bottom	Thickness		On mined surface below seam
	Feet	Meters	In Randolph Road Metal Pit
4.0'	4.0'	1.2	Clay, white w/ocherous stain, soft, friable, silt free, probably Kaolin.
12.0'	8.0'	2.4	Clay, yellow brown to lt. brown, mottled to pisolitic texture, some iron pisolites present, many pisolitic ghost structures (clay pisolites white within brown clay matrix) may have gibbsite & Kaolin.
14.0'	2.0'	0.6	Clay, lt. brown to white, increase in goethite, goethite in crack filling & one 4" thick laminated bed of goethite at 13' mark.
19.0'	5.0'	1.5	Clay, white w/ocherous stain, thin vertical vain of goethite runs through the section, soft clay, probably Kaolin, appears massive.
25.0'	6.0'	1.8	Clay, white to lt. gray w/siderite stain, decrease in goethite increase in siderite content, salt & pepper siderite silt size to 0.50 mm, 5% mica, siderite varies 5-30%.
27.0'	2.0'	0.6	Clay, lt. gray-white, slightly silty, micaeous 10%, probably Kaolin w/some silt.
			Contact, lt. gray to white clay w/gray silty clay, contact appears about 2" thick, contact point composed of fine sand & mica.
32'	5.0'	1.5	Silty clay, gray to black, laminated, many thin lamination of fine sand & mica, increase in mica downward.

Bottom

Core No. PB-8 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 E.
Elevation 471.0' Total Depth 25.0' Ft. 7.6 M.

Bottom	Thickness Feet	Meters	Below bauxite outcrop in Randolph Road Metal Pit
2.0'	2.0'	0.6	Clay (Kaolinite??) Purple to brown, many small iron concretions.
3.0'	1.0'	0.3	Clay (Kaolin or Gibbsite), brown 2" bed of small concretion at bottom.
11.0'	8.0'	2.4	Clay (Kaolinite) white with red streaks (marble effect) w/occ thin filling of Goethite
12.0'	1.0'	0.3	Clay, (Kaolinite?), brown, many iron concretions, increasing in mica & silt.
14.0'	2.0'	0.6	Clay, (Kaolinite), white to gray
18.0'	4.0'	1.2	Clay, (Kaolinite), white to gray, with red stain, salt and pepper, (small iron concretions)
25.0'	7.0'	2.1	Clay, gray to black, mica, and silt present increase downward, note thin (½") bed of mica & Goethite 50-50 mix no clay at 22' 2", note mica concentrated in bands throughout, thin varbed bedding through this section

Bottom

Core No. PB-10 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 E.
Elevation 471.0' Total Depth 28.0' Ft. 8.5 M.

Bottom	Thickness Feet	Meters	Mined surface in the Randolph Road Metal Pit.
7.0'	7.0'	2.1	Clay (Kaolin & Gibbsite??) white to red marbled in color, 1' to 2" layers of Goethite (4', 4.5', 5', 6')
11.0'	4.0'	1.2	Clay (Kaolin) white with red marbling
21.0'	10.0'	3.0	Clay (Kaolin) white, salt & pepper concretions throughout, with heavy concentration at 11.5' to 12.5' and 14.5', 16.0', 17-17.5'.
28.0'	7.0'	2.1	Clay, gray to black, thin bedding mica increasing downward 20%.

Bottom

X-Ray and Thinsections

Core No. PB-11 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 E.

Elevation 471.0' Total Depth 40.0' Ft. 12.2 M.

Bottom	Thickness Feet	Meters	On Bauxite outcrop in Unmined section of Pit
9.0'	9.0'	2.7	Bauxite (Pisolites),
10.0'	1.0'	0.3	Clay (Kaolinite) white with some streaks of red, some ghost of former pisolite structures
22.0'	12.0'	3.7	Clay (Kaolinite) white-lt. blue, some white pisolites or ghost structures (Pure Kaolin), 18' to 22' iron concretions (2-5 mm) increase toward bottom.
25.0'	3.0'	0.9	Clay (Kaolinite) white to lt. gray, no iron concretions.
31.0'	6.0'	1.8	Clay (Kaolinite) white with red streaks, salt & pepper size iron specks 30%.
36.0'	5.0'	1.5	Clay (Kaolinite ??), white to gray, fine sand & mica content increase downward.
40.0'	4.0'	1.2	Clay, black to gray, thin beds of mica & sand with thin beds of black clay.

X-Ray and Thinsections

Core No. PB-12 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 E.
Elevation 471.0' Total Depth 270.0' Ft. 82.4 M.

Bottom	Thickness Feet	Meters	500 feet from PB-11 In Randolph Pit
21.0'	2.0'	0.6	Clay- lt. gray-brown-orange, mottled Kaolinitic in appearance, some Goethite.
6.0'	4.0'	1.2	Clay (Kaolinite) lt. gray to white, v. clean and massive a 6" bed of iron stained clay at 4' mark.
13.0'	7.0'	2.1	Clay (Kaolinite?) lt. gray-lt. brown mottled, w/occ. iron (Goethite) concretions throughout w/occ. mica flakes.
14.0'	1.0'	0.3	Clay (Kaolinite?) lt. gray-white, mottled, w/occ iron (Goethite) concretions, (2-4 mm), w/occ white balls (10-20 mm) of v. clean Kaolinite, w/occ mica flakes
15.0'	1.0'	0.3	Clay (same as 6'-13')
17.0'	2.0'	0.6	Clay, white to lt. gray, iron stained, with 25-30% V. fine sand, mottled and undulating appearance
23.0'	6.0'	1.8	Clay, lt.-gray with iron stain, thin bedded, (salt & pepper) many small iron concretions avg. 30%, many flakes of muscovite presence, w/occ silt size quartz, clay appears to be kaolinitic.
24.0'	1.0'	0.3	Clay, white to lt. gray grading downward into darker gray clay, increase in mica downward.
270.0'	146.0'	44.5	Clay, lt. gray-dk. gray, massive, micaeous, w/occ thin sandy clay beds (less than 6"), Lignite (1") bed at 48' mark. see X-Ray samples) See (Fence diagram)

Bottom

Core No. PB-13 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10 S. R. 1 E.
Elevation 471.0' Total Depth 30.0' Ft. 9.2 M.

Bottom	Thickness Feet	Meters	
3.5'	3.5'	1.1	Clay, white-lt. brown w/ocherous stain, some Goethite present.
7.0'	3.5'	1.1	Soft Bauxite, low iron, weathered appearence more clay pisolites than iron pisolites, ocherous stain, lt. brown to white matrix.
11.0'	4.0'	1.2	Clay, white-ash gray, very friable, mottled to pisolitic texture, appears to be made of many small white clay pisolites (1-2 mm). Siderite appears towards the bottom.
26.0'	15.0'	4.6	Clay, white 2/siderite stain, salt & pepper Siderite silt size to 1.0 mm, micaeous, (note) several small none sideritic unites at: (16' mark 4" bed, 17" mark a varved kaolin bed 6" thick and at 19' mark a 7" bed and finally one small varved bed at 21' mark) Siderite varies from 10% to 40%.
28.0'	2.0'	0.6	Clay, white to ash gray, several thin beds of fine Kaolinic sand, micaeous, most appear to be Kaolin.
			Contact, core data poor, appears to be a sharp contact with a gray micaeous clay.
30'	2.0'	0.6	Silty clay, gray, micaeous, lam~~m~~inated, many thin lammated laminations of silt & mica.

Bottom

Core No. PB-14 County Pontotoc Date 1976

Section SW ¼, SE ¼, Sec. 15 T. 10.S. R. 1 E.

Elevation 471.0' Total Depth 30.0' Ft. 9.2' M.

Bottom	Thickness Feet	Meters	On Partially mined surface in Randolph Road Metal Pit
1.0'	1.0'	0.3	Bauxite, brown, low iron, weathered friable.
3.6'	2.6'	0.8	Clay, white w/ocherous stain, massive friable, soft, silt free, probably Kaolin.
8.0'	4.4'	1.3	Clay, white to lt. brown w/ocherous stain, traces of mica, friable to hard.
18.0'	10.0'	3.0	Clay, white w/brown Goethite stain, three intervals of Siderite salt & pepper with Mica (1) at 12' mark 5" thick (2) at 13'8" mark 2" thick (3) at 16.4' mark 3" thick Each unit above 40% Siderite 15% Mica and 45% Kaolin, some Goethite in section. * Special note: Many Rootlets & Lignite throughout the section, dense pattern of root system within Kaolin, roots and Lignite decrease at 14' mark and Mica and Silt increase downward. Contact: 1" layer of light gray micaeous silty clay grades downward into black clay.
30.0'	12.0'	3.7	Silty clay, gray-black, micaeous, laminated, many thin layers of orange fine sand and mica.

Bottom

Core No. PB-15 County Pontotoc Date 1976

Section SE ¼, NE ¼, SE ¼, Sec. 16 .T. T. 10. S.R. 1 E.

Elevation 465.0' Total Depth 23.0' Ft. 7.0 M.

Bottom	Thickness Feet	Meters	Near Road Side
2.5'	2.5'	0.8	Sandy Clay, orange-red, fine sand to silt, mottled texture, traces of white clay, matrix probably Kaolin, section is hard, decreasing in clay downward.
10.0'	7.5'	2.3	Clayey sand,orange to red, fine sand, some mica, some thin layers more clayey than most, friable.
12.0'	2.0'	0.6	Fine sand, some clay, lt. brown, possible low angle x-beds at 10'6" mark, increase in clay downward.
13.8'	1.8'	0.5	Clay, white to gray, much medium sand mixed between layers of clay, 2 main beds of clay each 4" thick. Note from 13'4" bed of medium sand with A 1" thick clay layer at 13'8".
15.0'	1.2'	0.4	Sandy clay, brown-gray w/thin parting of orange sand, medium size sand, micaeous
18.0'	3.0'	0.9	Medium to coarse sand, orange to brown, some clay, becoming clayey at bottom grading into gray clay
23.0'	5.0'	1.5	Silty clay, gray, massive to laminated many parting of silt & mica.

Bottom

PB-16
Core No. P-50 County Pontotoc Date 1976

Section NW ¼, SW ¼, SW ¼, Sec. 9 T. 10 S. R. 1 E.
Elevation 490.0' Total Depth 108.0' Ft. 33.0 M.

Bottom	Thickness Feet	Meters	P-50 is a U.S. Bur. Mines Core-Twin on Road Side
1.5'	1.5'	0.5	Clay, silty, w/ocher stain, appears to have varves.
13.0'	11.5'	3.5	Clay (prob. Kaolin), slightly silty w/mica, several thin parting of silt at 3', 5', 8', and 9'.
43.0'	30.0'	9.2	Sand, fine slightly silty, micaceous at top
44.0'	1.0'	0.3	Clay and lignite, black stain, lignite about 1" thick possible Goethite and Kaolin pisolites with clay matrix (may be distruction of a bauxite)
52.0'	8.0'	2.4	Clay, Lignite stain, several thin lignite beds and many fragments throughout section. (Note 3" bed of lignite at 51')
P-50			
108.0'	56.0'	17.1'	Clay & Lignite, lt. gray-blacks, w/occ. lignite and micaceous layers, (note x-ray shows clay to be Kaolin)

Lignite layers occur at:

6" lignite to	52'	Note 90' to 103' missing	
6"	59'	3" Lignite to	104'
6"	61'	6"	105'
3"	62'	4"	106'
3"	67'		
8"	69'		
3"	85.5'		

Bottom

Core No. BB-30 County Tippah-Benton Date 1976

Section NE ¼, NE ¼, Sec. 7 T. 3 S. R. 2 E.
Elevation Total Depth 26.0' Ft. 8.0 M.

Bottom	Thickness Feet	Meters	Finger Outcrop Area
2.0'	2.0'	0.6	Sand; Clay matrix, friable, lt. brown w/occ. iron conccretions towards the bottom (0.125 mm sand)
3.6'	1.6'	0.5	Clay; Silty, lt. brown-gray, few iron concretions
4.9'	1.3'	0.4	Sand; (0.07 mm sand), friable, lt. orange-brown,
5.6'	0.7'	0.2	Clay; silty, lt. orange-gray
9.9'	4.3'	1.3	Sand (0.07 mm), silty, lt. orange-lt. purple-lt. brown.
19.0'	9.1'	2.8	Clay; silty, lt. gray, clay content increases towards bottom
26.0'	7.0'	2.1	Clay; lt. gray-black

Bottom

Core No. BB-31 County Tippah-Benton Date 1976
5 foot intervals
Section NE ¼, NE ¼, Sect. 7 T. 3 S. R. 2 E.
Elevation ______ Total Depth 50.0' Ft. 15.2 M.

Bottom	Thickness Feet	Meters	Finger Outcrop Area
5.0'	5.0'	1.5	None - lost sample
10.0'	5.0'	1.5	Sand (0.5 mm); lt. gray, w/occ clay concretions
20.0'			Sand (1.0 - 0.5 mm); lt. gray, poor sorting Angular-sub-angular quartz
35.0'			Sand (0.5 - 0.25 mm) few Lignite fragments w/occ clay balls
40.0'	5.0'	1.5	Sand (1.0 - 0.5 mm); A~~n~~rgillaceous w/occ concretions of clay
50.0'			Clay; silty, gray-black, w/occ. Iron concretions.

Bottom

Auger No. BB-32 County Tippah-Benton Date 1976
2 foot intervals
Section NE ¼, NE ¼, Sec. 7 T. 3 S. R. 2 E.
Elevation Total Depth 40.0' Ft. 12.2 M.

Bottom	Thickness		Finger Area Outcrop
	Feet	Meters	In Creek Bottom near Bauxite
5.0'	5.0'	1.5	Sand (1.0 mm - 0.5 mm); lt. brown w/occ clay concretions, few small iron concretions
16.0'	11.0'	3.4	Clay, silty, lt. brown, some iron stains
16.0'			Out
16-18'	2.0'	0.6	(Bauxite??) Clay; w/occ small round concretions, lt. brown few iron concretion
18'-20'	2.0'	0.6	Clay; lt. gray, many small concretions, some iron concretions also present.
20'-22'	2.0'	0.6	Clay; (Bauxite??) lt. gray, many small concretions (yellow & red).
22'-24'	2.0'	0.6	Clay, (Bauxite) white (Kaolin like), many pea size concretions
24'-26'	2.0'	0.6	None (Lost Sample)
26'-28'	2.0'	0.6	Sand (1.0 mm - 0.5 mm), lt. gray, many fragments of iron concretions, few white clay concretions, few fragments of lignite.
28'-30'	2.0'	0.6	Sand (0.5 mm-silt), many lignite fragments, few clay concretions
30'-32'	2.0'	0.6	Silty clay, lt. gray, w/occ lignite fragments, few clay concretions.
34.0'	2.0'	0.6	Silty clay, gray-black
38.0'	4.0'	1.2	Clay, gray-black
38'-40'	2.0'	0.6	Clay, gray-black, few pea-size concretions

APPENDIX C

X-RAY DIFFRACTION

NAME	CHEMICAL COMPOSITION	2θ VALUE STRONGEST	ANGSTROMS	INTENSITY
1. KAOLINITE	$Al_2Si_2O_5\ (OH)_4$	12.4, 20.4, 24.9	7.17, 1.49, 3.58	100, 90, 80
2. KAOLINITE (B-AXIS DISORDERED)	$Al_2Si_2O_5\ (OH)_4$	12.4, 24.8, 62.5	3.58, 7.18, 1.49	100,100, 100
3. GIBBSITE	$Al_2(OH)_3$	18.3, 20.3, 37.7	4.85, 4.37, 2.39	100, 50, 27
4. DIASPORE	$Al_2(OH)_3$	22.3, 38.8, 42.5	3.99, 2.32, 2.13	100, 56, 52
5. GOETHITE	$FeO(OH)$	21.3, 33.3, 36.7	4.18, 2.69, 2.45	100, 30, 25
6. SIDERITE	$FeCO_3$	32.2, 52.9, 24.8	2.79, 1.73, 3.59	100, 80, 60
7. HEMATITE	Fe_2O_3	33.3, 54.3, 35.8	2.69, 1.69, 2.51	100, 60, 50
8. QUARTZ	SiO_2	26.7, 20.8, 50.1	3.34, 4.26, 1.82	100, 35, 17
9. LOW CRISTOBALITE (OPAL CT)	SiO_2	21.95, 36.1	4.05, 2.49	100,20
10. MUSCOVITE	KAl Si AlO (OH)	8.85, 26.7, 17.8	9.97, 3.33, 4.99	100,100,53
11. SMECTITE: (Montmorillonite)	$(Ca/2,Na)_{.3}\ Al_{2-x}Mg_x(Si_4O_{10})\ (OH)_2 \cdot n\ H_2O$			
		Main: 5.9, 19.7, 17.8	15.0, 4.5, 5.0	100, 80, 60
		Form: 29.6, 35.2, 61.8	3.0, 2.6, 1.5	

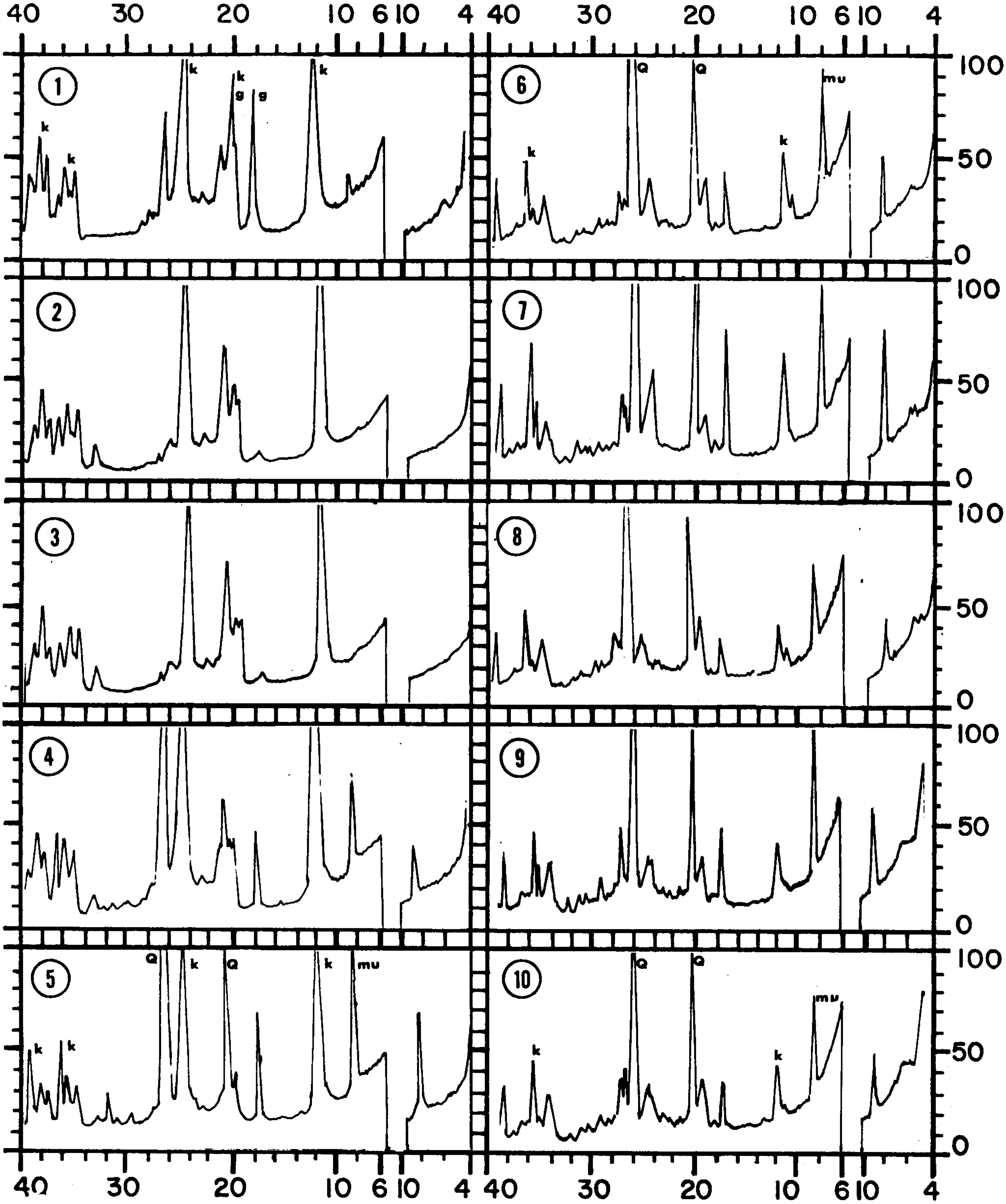
CORE - DRILL SAMPLE RECORDS
FOR FOWLER AREA
D.F. REED 1952 U.S. BUR. MINE

Hole No.	Depth	Al_2O_3	Insol. $Si\ O_2$	Fe_2O_3	TiO_2	Ig. loss
Fo-1	58.6 to 62.0	34.9	44.1	4.0	1.9	14.5
Fo-1	62.0 to 67.0	28.2	40.2	19.4	1.5	15.9
Fo-1	67.0 to 72.0	26.5	37.0	16.1	1.3	17.1
Fo-1	72.0 to 77.0	21.8	61.8	4.5	1.0	9.4
Fo-1	77.0 to 79.2	16.1	74.4	.9	.9	5.7
Fo-2	54.8 to 58.8	36.5	46.4	1.0	1.9	13.8
Fo-2	58.8 to 63.8	33.9	43.1	5.2	1.7	14.4
Fo-2	63.8 to 68.8	23.5	41.8	14.7	1.1	15.5
Fo-2	68.8 to 71.9	21.9	64.0	2.5	1.0	8.5
Fo-3	51.7 to 53.9	35.3	46.6	2.4	1.7	14.1
Fo-3	53.9 to 57.8	36.8	47.2	.7	1.9	13.4
Fo-3	57.8 to 62.8	24.9	49.7	8.5	1.3	13.1
Fo-3	62.8 to 67.8	28.7	44.4	8.4	1.1	14.7
Fo-3	67.8 to 72.8	19.6	68.8	1.8	.8	7.6
Fo-4	53.7 to 56.0	37.9	40.6	1.0	2.2	15.5
Fo-4	56.0 to 60.0	41.4	39.3	.8	2.0	16.0
Fo-4	60.0 to 65.0	29.0	35.6	14.6	1.5	16.5
Fo-4	70.0 to 74.5	19.1	71.5	.7	.8	6.7
Fo-5	59.8 to 64.8	34.8	34.8	3.4	2.1	14.6
Fo-5	64.8 to 69.8	37.2	44.9	.7	2.5	13.9
Fo-5	69.8 to 74.8	35.8	42.7	2.6	2.7	14.2
Fo-5	74.8 to 79.8	26.2	43.5	11.0	1.7	14.6
Fo-5	79.8 to 81.7	16.9	67.2	4.2	.2	7.7
Fo-6	46.9 to 51.9	32.8	44.6	5.4	1.9	14.4
Fo-6	51.9 to 56.9	38.1	44.7	.6	1.7	14.1
Fo-6	56.9 to 61.9	25.6	54.3	6.8	1.2	11.0
Fo-9	51.5 5o 54.1	33.7	49.0	1.1	1.4	13.7
Fo-9	54.1 to 59.1	36.6	45.5	1.2	1.9	14.0
Fo-9	59.1 to 64.1	26.5	39.4	14.5	1.8	16.2
Fo-9	64.1 to 69.2	21.4	39.2	18.4	1.2	16.9
Fo-9	69.2 to 74.5	19.7	67.2	2.0	.9	7.7

INDEX FOR THE FOLLOWING 38 X-RAY DIFFRACTION PATTERNS

K . . . . . .KAOLINITE
G . . . . . .GIBBSITE
Q . . . . . .QUARTZ
MU . . . . .MUSCOVITE
MT . . . . .MONTMORILLONITE

1. CORE PB-12 sampled at 5 ft.
2. 10 ft.
3. 15 ft.
4. 20 ft.
5. 25 ft.
6. 30 ft.
7. 35 ft.
8. 40 ft.
9. 45 ft.
10. 50 ft.
11. 60 ft.
12. 70 ft.
13. 80 ft.
14. 90 ft.
15. 100 ft.
16. 110 ft.
17. 120 ft.
18. 130 ft.
19. 140 ft.
20 190 ft.
21.Outcrop samples from the Randolph road metal pit starting at the base.
22.S-5 see figure 14 for additional information.
23.S-7
24.S-8
25.S-9
26.S-10
27.S-12
28.S-14 ....the cross bedded zone.
29 S-15 ....the iron cap zone.
30.Sample of the Naheola Formation see figure 10 for additional information.
31.Sample of the Lower Porters Creek Formation see figure 8.
32.Sample of the middle or typical phase of the Porters Creek Formation.
33.Core PB-16 sampled at 45 ft.
34.Outcrop sample from Flatrock Church.
35.Core PB-11 sampled at 5 ft. see also figure 25.
36.Core PB-5 sampled at 15 ft.
37.Core FO-6 sampled at 55 ft.in the Fowler deposit.
38.Core FO-9 sampled at 52 ft.in the Fowler deposit.
39.
40.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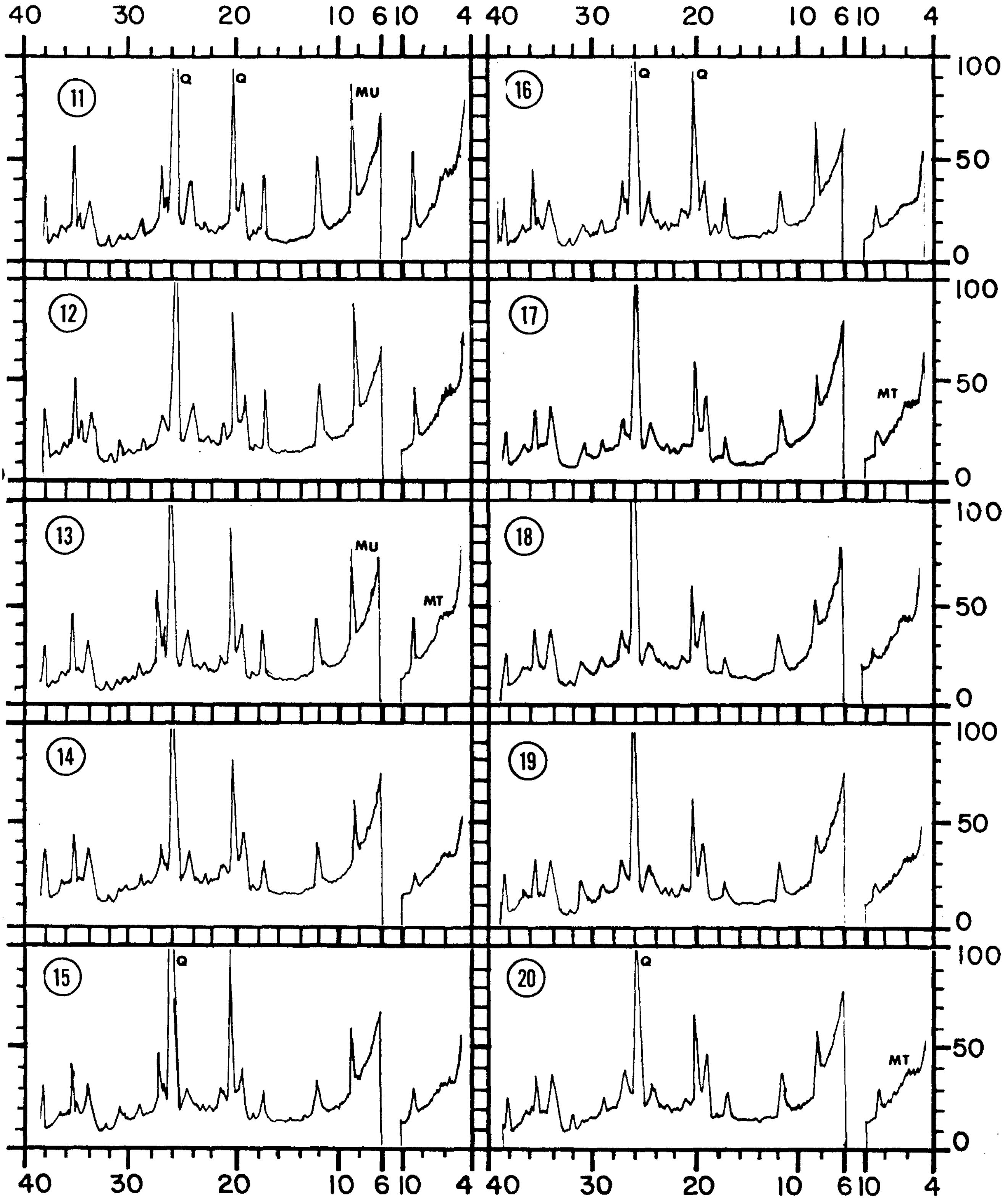
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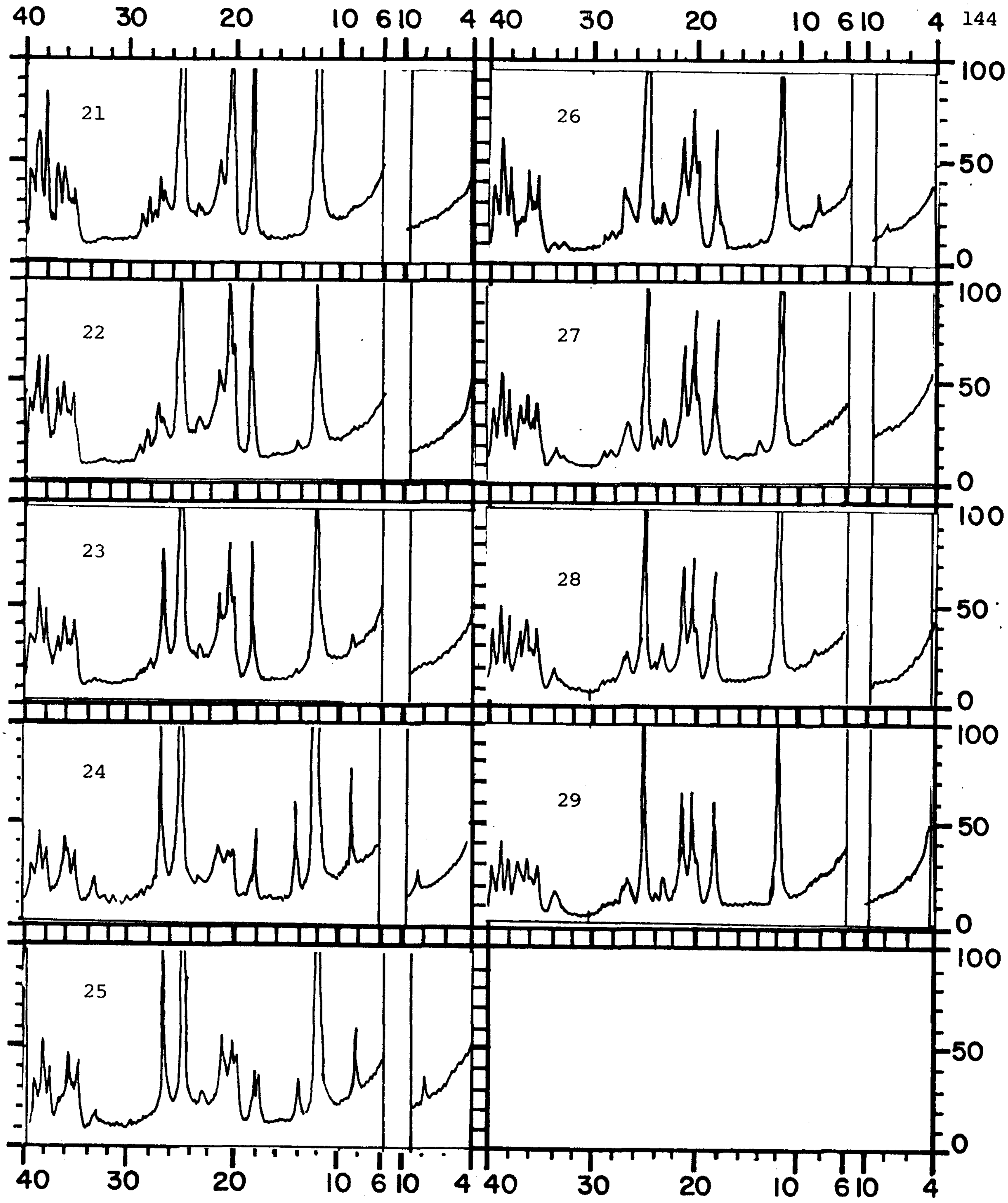
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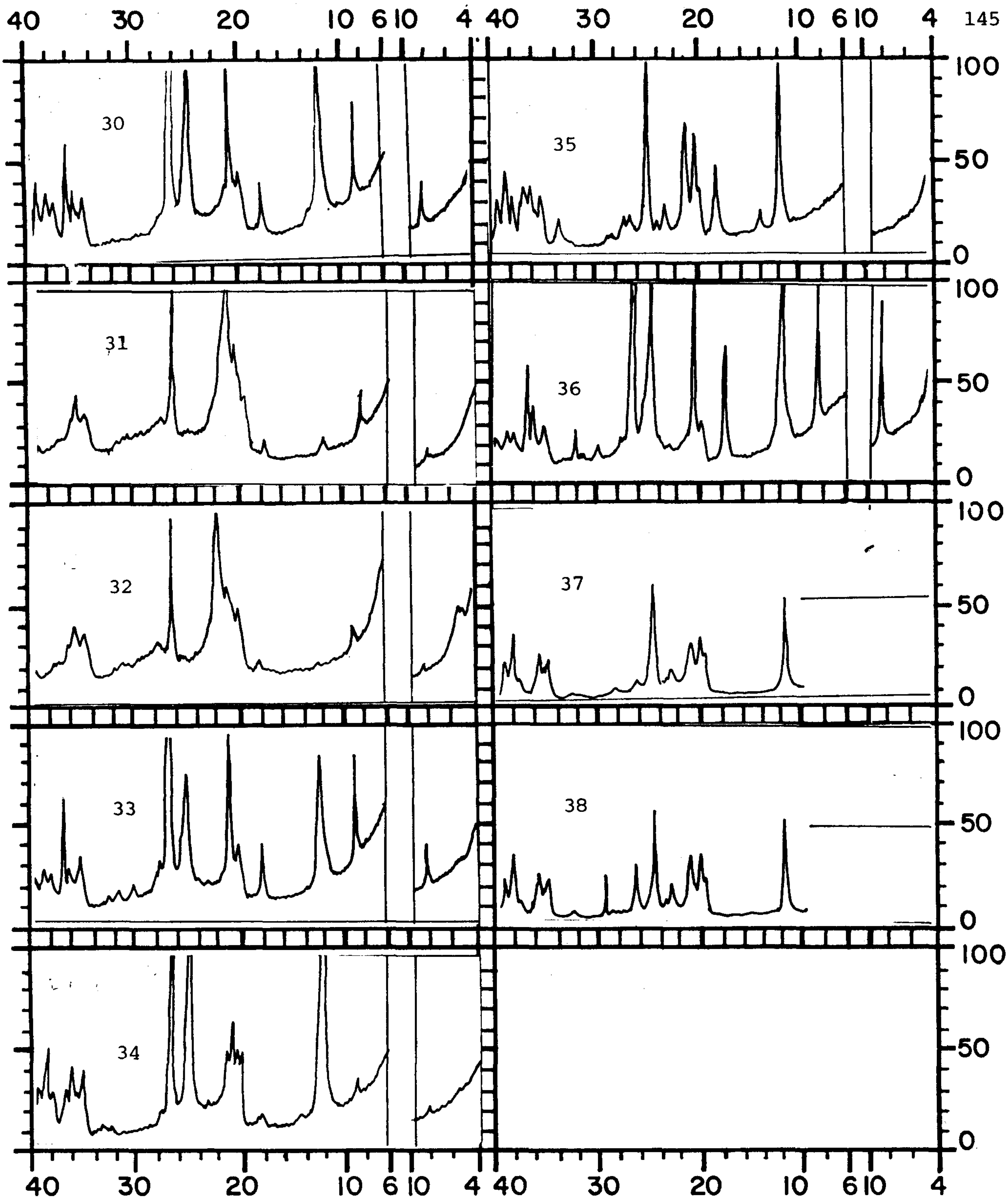
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