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LOWER TUSCALOOSA "ASH" — A MISNOMER

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ABSTRACT

The "ashy" units in the Stringer Member of the Lower Tuscaloosa Formation are a misnomer. "Ash" units (beds) are authigenic detrital clays of illite, chlorite, and kaolinite composition which often completely occlude the intergranular pore spaces within a sand body and eliminate all effective reservoir permeability. The spontaneous potential and resistivity readings measured from electric logs are consistent and indistinguishable from equivalent oil-producing horizons.

The sonic log appears to be an excellent tool for determining net effective sand and for differentiating the permeable sand from clay-plugged sand.

INTRODUCTION

The unexpanded Lower Tuscaloosa (Upper Cretaceous) trend of southwestern Mississippi is a major oil producer from low resistivity sandstones (.2 ohms). Successful exploration of the trend began in the mid 1940's and has continued through the present (Figure 1).

The trap style is predominantly stratigraphic, with some fields having a structural component. The trend has produced 229 MMBO from approximately 1000 productive wells. The Lower Tuscaloosa of southwestern Mississippi has produced this large

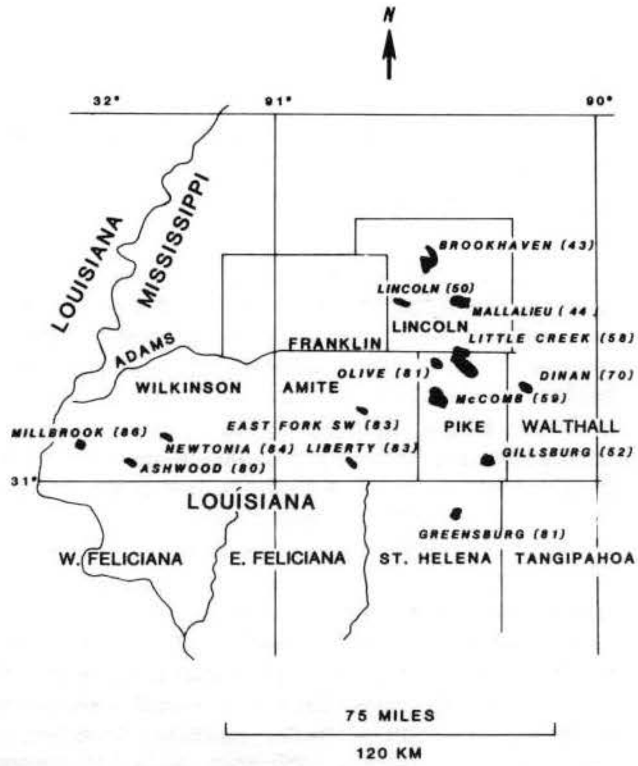

Figure 1. The Tuscaloosa trend of southwestern Mississippi.

HUGHES EASTERN PETROLEUM

#1 ROBERTSON

SEC. 40-5N-3E

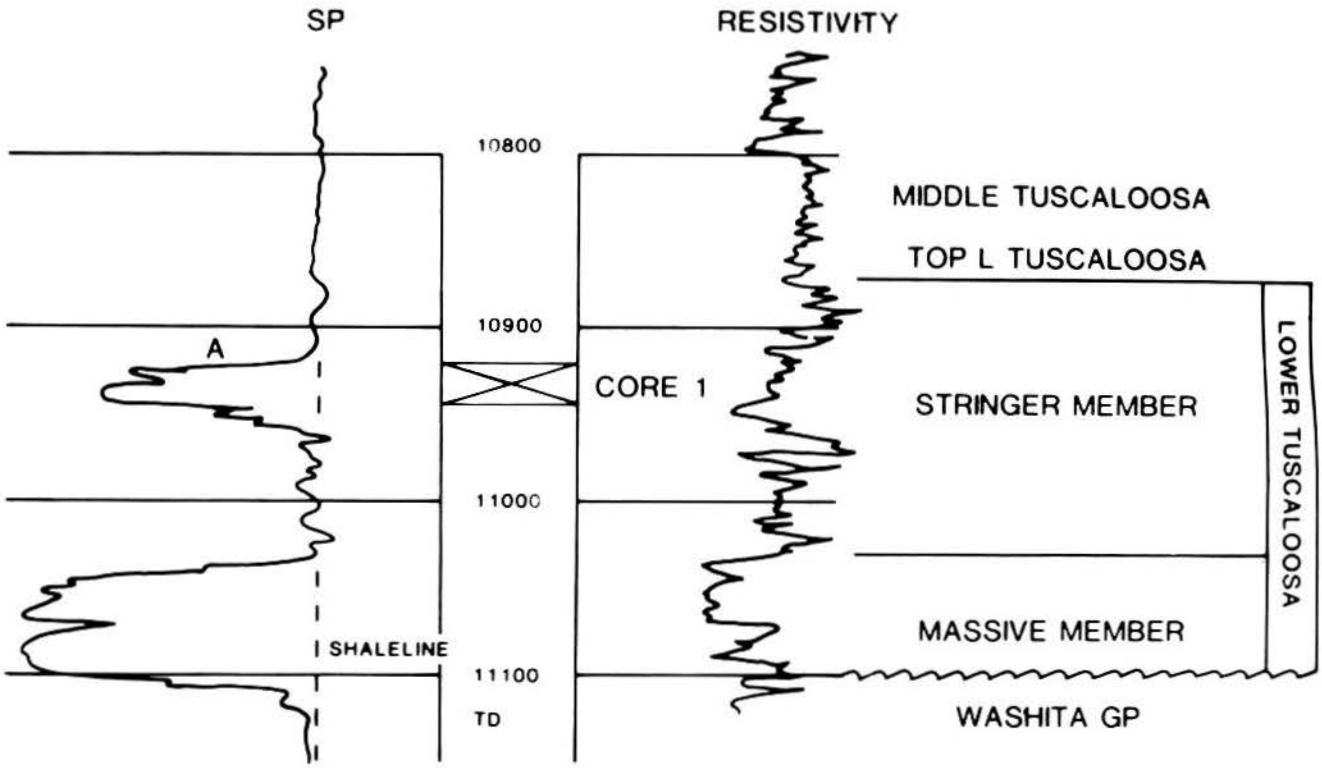

Figure 2. Type log showing Lower Tuscaloosa Formation and core interval.

quantity of oil from thinly bedded sands (30 feet or less in thickness). Identification of these potential reservoirs and their projection updip is the explorationist's task (Hersch, in press).

The Stringer Member of the Lower Tuscaloosa Formation is predominantly fluvial in origin, with marine and near marine deposits also being present. Inspection of conventional core reports and drill cutting descriptions in the Lower Tuscaloosa reveals numerous descriptions of "ash". This "ash" is not a genetic term. The Lower Tuscaloosa "ash" is a descriptive term used to describe clay zones within the objective Stringer Sand horizon (Figure 2). The term does not refer to fine-grained pyroclastic material. The origin of the clayey zones is diagenetic alteration of detrital volcanic rock fragments (Stancliffe and Adams, 1986).

REGIONAL SETTING AND STRATIGRAPHY

Regionally, the top of the Lower Tuscaloosa dips 1° to 2° gently to the southwest with subsea-level depths ranging from 9500 feet (2900m) near Brookhaven Field, Lincoln County, Mississippi, to 13,500 feet (4115m) in southwestern Amite County, Mississippi. Regional dip is interrupted by three prominent structural features (the Brookhaven Dome, the Mallalieu Dome, and the Gillsburg structural nose). The trend is dominated by stratigraphic traps with combination structural-stratigraphic traps also being important.

For exploratory purposes the Upper Cretaceous (Cenomanian) Lower Tuscaloosa Formation of southwestern Mississippi may be subdivided into two main members. The basal sands (Massive Member) lie unconformably on Lower Cretaceous (Comanchean) rocks. The objective section conformably overlies the Massive Sand and is referred to as the "Stringer Sand Member" (Mississippi Geological Society, 1957). The "Stringer Sand Member" consists of interbedded lenticular sandstones and shales predominantly of fluvial and near marine origin. Conformably overlying the "Stringer Sand Member" is the Middle Tuscaloosa, which is predominantly a transgressive marine shale and the most likely hydrocarbon source for the Lower Tuscaloosa fields.

"ASH" — ARGILLACEOUS FACIES

The "ash" facies of drillers' logs and core descriptions is a misnomer. The term originated early in the trend's drilling history (1940's) when rotary drilling penetrated argillaceous zones within the Stringer Sand interval. Personal communication with numerous operators and personal inspection of various core reports suggest that the resulting cuttings were essentially clays of the illite, chlorite, and kaolinite groups. The agglomeration of clay, silt, and fine sand was termed "ash". The term is in common usage today and identification of the clay zone from sonic logs has exploration significance.

METHODS OF LITHOLOGY DETERMINATION

The areal distribution of reservoir sands and their projection updip is essential for Lower Tuscaloosa stratigraphic exploration. Conventional cores are the best method of determining reservoir-quality sands.

The Hughes Eastern Petroleum #1 Robertson, Section 40, T5N, R3E, Franklin County, Mississippi, is an excellent example of an SP (spontaneous potential) log indicative of a permeable formation (Schlumberger, 1972; Figure 2). Deflection of the SP away from the shale base line in the Stringer Sand interval is often interpreted to result from permeable sands. This assumption may be a critical error in the Tuscaloosa trend of southwestern Mississippi. The conventional core descriptions from the interval 10,923' - 10,950' are "very ashy with poor porosity and permeability." Sidewall core analysis shows horizontal permeabilities never exceeding 4.56 millidarcys. This "ash" zone (8% chlorite) is obviously a poor reservoir even though the SP and resistivity readings are similar to nearby productive oil wells. In the absence of core data, the explorationist would be prudent to secure sonic logs on critical "prospect" wells before finalizing an

TEXACO
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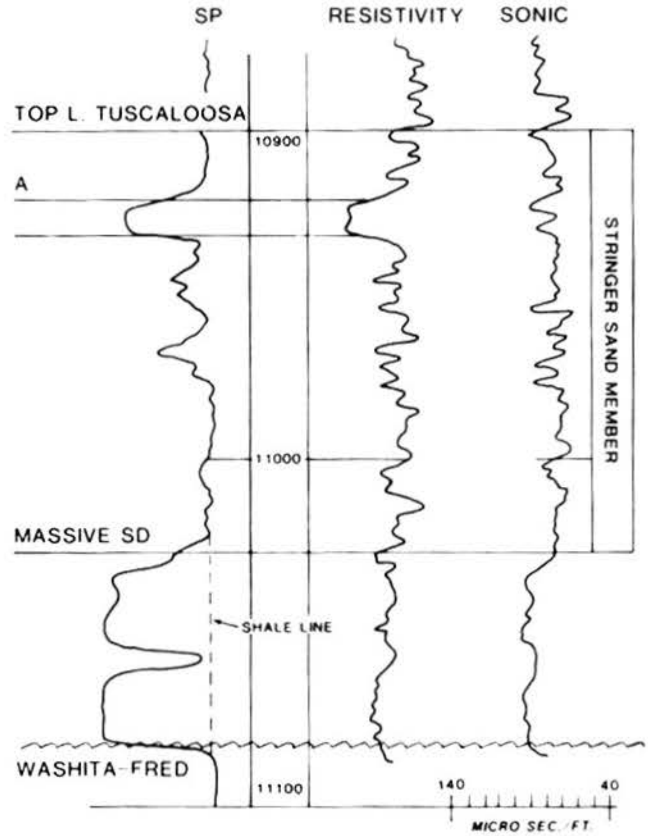

Figure 3. Well log suite illustrating typical log response in a Lower Tuscaloosa "ash" horizon.

exploratory lead. This would avoid the possibility of projecting a potential reservoir sand updip, only to find the prospect's key wells to contain an "ash" sand not of reservoir quality.

The Texaco #1 Robertson, Section 37, T5N, R2E, Franklin County, Mississippi, is an example of the sonic log response in a tight "ashy" zone (Figure 3). The Texaco #1 Robertson is offset 1/3 mile from the Hughes Eastern #1 Robertson (Figure 2).

The sonic log (Figure 3) is reading approximately 85 microseconds per foot in the "A" interval. The SP response over this interval exhibits an SP reflection away from the shale base line indicative of a permeable horizon. The sonic log at 85 microseconds/foot is essentially the same reading as the surrounding shales. Core descriptions from the interval 10,916' - 10,928' have porosities of 7.5 percent or less and no permeability. The significant

Stringer Sand reservoirs often have an excellent sonic response. Sonic velocities often differ by several thousand feet per second between sands and shales. Permeable reservoirs have slower velocities (feet/second) than the enclosing shales. This low velocity effect is critical for net permeable sand determination and seismic stratigraphic purposes.

CONCLUSIONS

1) The "ash" of the Lower Tuscaloosa is a descriptive rather than a genetic term.
2) The SP log often does not differentiate between "ash" zones and permeable reservoirs.
3) In the absence of core data, the sonic log may substitute for net effective porous sand determinations.

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"The geologist by training, perhaps more than any other scientist, is expected to be a skillful observer, an accurate recorder, a lucid writer, and, above all, an innovative synthesizer of conflicting incomplete data to form a coherent picture."

A. K. Turner and D. M. Coffman
1973

RB-SR AGE OF GLAUCONITE FROM THE EOCENE MOODYS BRANCH FORMATION, HINDS COUNTY, MISSISSIPPI

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ABSTRACT

Five, hand-picked, little-evolved glauconitic smectites (4-6 percent K_2O) from the Moodys Branch Formation at the hypostratotype, Jackson, Mississippi, yield a Rb-Sr glauconite isochron age of 39.2 ± 3.2 Ma. The interpreted initial $^{87}Sr/^{86}Sr$ ratio of 0.70784 ± 70 agrees well with the suggested initial $^{87}Sr/^{86}Sr$ ratio of Eocene seawater determined from carbonate. Evaluation of the Rb-Sr data, using the model age technique and the appropriate seawater initial $^{87}Sr/^{86}Sr$ ratio, results in five model ages that average 40.8 ± 1.6 Ma. Though the isochron age has a moderately large uncertainty, and the model ages exhibit some scatter, the Rb-Sr data suggest that the Moodys Branch Formation at the hypostratotype is between 39 and 41 Ma old. Glauconite ages on carefully selected pellets provide a direct mechanism of placing age constraints on sedimentary rocks and the standard geologic time-scale.

INTRODUCTION

Sand-size, green grains common in sedimentary rocks are called glauconite; however, the term is also applied to a specific mineral species that may or may not comprise the green grains. Recognizing this confusion, Odin and Matter (1981) suggested that glaucony (pl. glauconies) should be used for the field description or facies, and glauconitic smectite or glauconitic mica for end-members of the mineral family. In this paper glauconite is used for both end-members of the mineral family as well as mixtures of the two. Glauconite, either a dioctahedral illite or smectite, is commonly used to date sedimentary rocks. Although the mineral contains K and Rb, in recent years most ages have been determined by the K-Ar dating method, and many investigators (e.g., Owens and Sohl, 1973; Odin et al., 1978) believe that carefully selected samples give reliable K-Ar ages. On the other hand, glauconite ages have been criticized by some workers as being unreliable for determining the time of sediment deposition (e.g., Obradovich, 1964; Berggren et al., 1978; Berggren et al., 1985). Nevertheless, glauconite is a common chronometer that is relied upon for calibrating parts of most numerical time scales (Berggren, 1969, 1972; Hardenbol and Berggren, 1978; Odin, 1982a, 1982b; Harland et al., 1982; and Palmer, 1983).

Since the early days of K-Ar and Rb-Sr geochronology (1950's), there have been few attempts to systematically evaluate Rb-Sr ages of glauconite, especially those obtained by the isochron technique. In this paper, we present a new Rb-Sr isochron age for Jacksonian age rocks in Mississippi, and a discussion of stratigraphically similar age strata.

PREVIOUS INVESTIGATIONS

Early attempts to date glauconite by the K-Ar method were first reported by Lipson (1956), Wasserburg et al. (1956), and Amirkhanov et al. (1957); the Rb-Sr technique was first applied to glauconite by Cormier (1956) and Cormier et al. (1956). Although these investigations proved that both dating techniques could be applied, their results were disappointing as many ages seemed to be too young relative to dated igneous rocks. Subsequent studies by Herzog et al. (1958), Kazakov and Polevaya (1958), Lipson (1958), and Goldich et al. (1959) provided the impetus for Hurley et al. (1960) to conclude that K-Ar and Rb-Sr ages are approximately 10-20 percent younger than the time of sedimentation. Because of these early studies, glauconite commonly has been considered unsuitable for use in time-scale calibration studies. In a review of K-Ar and Rb-Sr studies of glauconite done over the last 25 years, Keppens and Pasteels (1982) concluded that if glauconites are altered by metamorphism, weathering, or deep burial diagenesis, radiometric ages on them in most cases would be too young. On the other hand, if glauconites have never been deeply buried, most of them would yield K-Ar and Rb-Sr model ages that are in good agreement. They also suggested the likelihood of resetting glauconite ages is greater for the K-Ar system than the Rb-Sr system.

In recent years relatively few investigators in the United States have determined glauconite ages. Those investigators using the Rb-Sr method include Harris and Bottino (1974); Harris (1976, 1982); Harris and Baum (1977); Fullagar et al. (1980); Harris and Zullo (1980); Laskowski et al. (1980); Morton and Long (1980, 1984); Montag and Seidemann (1981); Harris and Fullagar (1982a, 1982b); and Harris et al. (1984). Investigators using the K-Ar method include Ghosh (1972); Owens and Sohl (1973); Laskowski (1982); Foland et al. (1984); and Grant et al. (1984). In Europe numerous K-Ar glauconite ages have been determined and many of these are reported or summarized by Odin (1975, 1982a), and Odin et al. (1978); however, few Rb-Sr glauconite ages have been determined (for summary, see Keppens and Pasteels, 1982). Although some studies have resulted in anomalous ages, most of the above investigators have suggested that in relatively shallowly buried Cretaceous and Paleogene sediments, stratigraphically accurate glauconite ages can be determined.

Ghosh (1972), Harris and Fullagar (1982b), and Siesser and Fitzgerald (1985) have provided the only radiometric ages of Tertiary sediments and rocks in the Gulf Coastal Plain. Ghosh (1972) used glauconite and in some cases mica from bentonite to date several Upper Cretaceous and Tertiary units in Texas, Mississippi, and Alabama. Harris and Fullagar (1982b) reported a preliminary Rb-Sr glauconite isochron age for the Moodys Branch Formation at the hypostratotype, near Jackson, which forms the basis for this paper. Siesser and Fitzgerald (1985) reported an anomalous Rb-Sr model age of 51.4 $\pm$ 4.8 Ma for glauconite from the Moodys Branch Formation at Riverside Park, Jackson, Mississippi. According to their sample location data, this sample was collected about 1 to 1.5 m above the dated sample reported here.

MOODYS BRANCH RB-SR ISOCHRON AGE

The Moodys Branch Formation at its type locality, Jackson, Mississippi, is a greenish-gray, calcareous, clayey, glauconitic, fossiliferous sand. The unit is basal Jacksonian in age, and contains a calcareous nannoflora indicative of zone NP 17 (Siesser, 1983; Siesser et al., 1985). The formation was sampled at Riverside Park, Jackson, Hinds County, 1.2 m above the contact with the Claibornian Cockfield Formation. Very fine to coarse sand-size, dark to light apple green, mammillated to lobate, fossil replacement, earthy, and vermicular glauconite pellets comprise the sample. Dark green, mammillated to lobate types with well-developed external morphologies comprise greater than 90 percent of the total glauconite fraction. Five size fractions, corresponding to coarse medium sand (MG1-140), medium medium sand (MG1-150), fine medium sand (MG1-160), coarse fine sand (MG1-180), and fine fine sand (MG1-1120) were separated for radiometric dating.

SAMPLE PREPARATION AND ANALYTICAL PROCEDURES

Each size fraction was washed with distilled or demineralized water and concentrated using a magnetic separator. Although we have not systematically evaluated the suitability of different fractions, we have noted that mammillated to lobate shapes, or replaced fossils, seem to produce good isochrons. Fractions were further processed by hand-picking until approximately 100 mg of 100 percent glauconite pellets were available. Small amounts of visible carbonate commonly adhere to the pellets. All pellet fractions were washed in 0.1N HCl, usually three times for one minute each, then rinsed with demineralized water and reagent-grade acetone after each washing. This treatment removed all obvious carbonate. Some investigators have washed samples with more concentrated acids for much longer periods of time. While this process removes obvious carbonates, it could alter the radiometric age of the glauconite by removing radiogenic ^{87}Sr, or possibly by changing the Rb/Sr ratio of the sample. Kralik (1984) reviewed the effects of leaching on illites and similar minerals, including glauconites, and suggested that the limited data available indicate that leaching for very short periods of time with dilute HCl (e.g., O.1N) does not significantly affect the radiometric age of glauconites, especially those that are relatively young and have simple histories (see for example, Clauer, 1982; Keppens and Pasteels, 1982). This treatment essentially shifts data points along an isochron away from the origin by removing the Sr in the carbonate; removal of common Sr from the glauconite would have the same effect. In cases where the Sr isotopic composition of the leachate has been measured (e.g., Laskowski et al., 1980; Clauer, 1982; Keppens

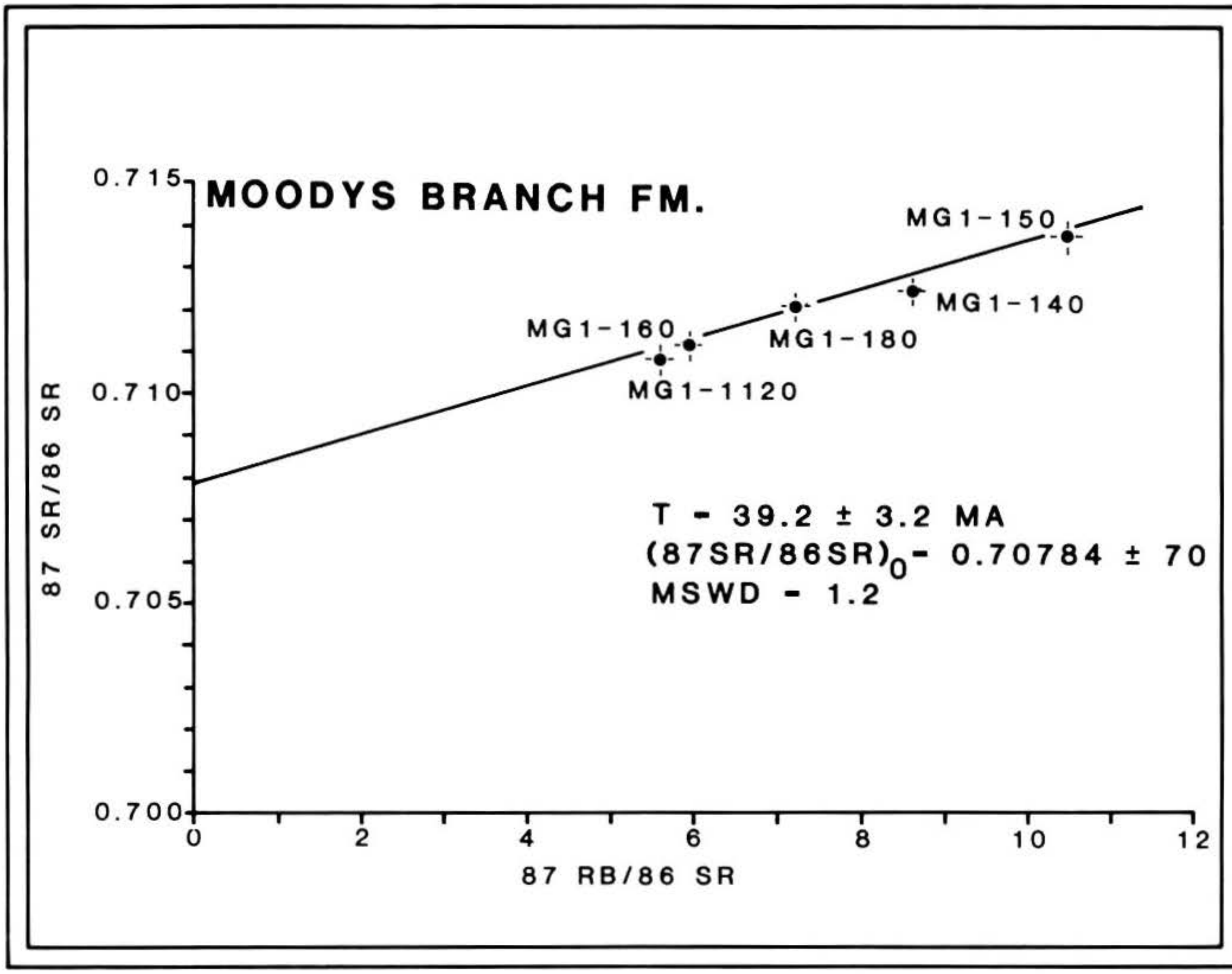

Figure 1. Plot of $^{87}Rb/^{86}Sr$ for glauconitic smectite from the Moodys Branch Formation, Hinds County, Mississippi.

and Pasteels, 1982) there has been no evidence of removal of significant radiogenic ^{87}Sr from the glauconites. However, Marshall and DePaolo (1983) suggest that glauconite ages can be severely affected by sample treatment with various acids resulting in ages older and younger than the stratigraphic age. Morton and Long (1980; 1984) conducted leaching experiments with HCl, acetic acid (HOAc), ammonium acetate (NH_4OAc), and Na-EDTA. Based on these investigations, they suggest treating glauconite pellets with NH_4OAc prior to determining the Rb-Sr age.

Based on microscopic examination, samples showing evidence of re-working, alteration, or mineral impurities were discarded. X-ray diffraction analysis was used to identify glauconite plus foreign grains. Samples we have analyzed are disordered glauconite as defined by Bentor and Kastner (1965) or little-evolved glauconitic smectite (less than 6 percent K_2O) using Odin's (1982a) x-ray diffraction technique to estimate K_2O percent. Odin (1982a) and Keppens et al. (1984) have noted that glauconites containing less than 6 percent K_2O may give spurious K-Ar and Rb-Sr ages. Glauconite samples from the Moodys Branch Formation contain between 4 and 6 percent K_2O.

The glauconite pellets were analyzed by standard mass spectrometric techniques. All $^{87}Sr/^{86}Sr$ values are reported relative to a value of 0.70800 for the Eimer and Amend Sr isotope standard. Thirteen recent analyses of this standard give an average $^{87}Sr/^{86}Sr$ ratio of 0.70803 ± 5 (one-standard deviation). NBS K-feldspar standards 70a and 607 have been suggested as Rb-Sr age standards; 21 analyses in our laboratory give an average age of 1377 ± 6 Ma (one-standard deviation) using λ 1.42 ±

TABLE 1. Rb-Sr Analytical Data for the Moodys Branch Formation, Riverside Park, Jackson, Hinds County, Mississippi.

Sample	Rb (ppm)	Sr (ppm)	87Rb/86Sr	87Sr/86Sr [1]	Model Age (Ma) [2]
MG1-140	148.5	49.74	8.64	0.71243	38.7
MG1-150	149.8	41.13	10.54	0.71377	40.7
MG1-160	143.3	69.08	6.00	0.71119	41.2
MG1-180	147.6	58.68	7.28	0.71214	43.1
MG1-1120	146.5	79.94	5.66	0.71092	40.3
					AVERAGE 40.8 ± 1.6

1 Ratios normalized so that $^{86}Sr/^{88}Sr = 0.11940$.

2 Model ages are determined using an initial $^{87}Sr/^{86}Sr$ ratio of 0.70768; this is the average value of five Bartonian Eocene Sr seawater ratios reported by Koepnick et al. (1985).

$10^{-11}yr^{-1}$ as the ^{87}Rb decay constant, and assuming an initial $^{87}Sr/^{86}Sr$ ratio of 0.710. All $^{87}Rb/^{86}Sr$ values have been determined by isotope dilution analyses. The analytical uncertainties and MSWD value in Figure 1 (York, 1969) were calculated using errors of 1 percent and 0.025 percent for $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios, respectively. Rb-Sr data are presented in Table 1. An isochron age of 39.2 ± 3.2 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70784 ± 70 was determined from the five size fractions (Figure 1). The MSWD value for this isochron is 1.2. This value indicates that the data points exhibit a relatively small amount of scatter.

DISCUSSION AND CONCLUSIONS

Rb-Sr glauconite ages are reported as model ages or as isochron ages. Model age calculations rely upon an estimate of the initial $^{87}Sr/^{86}Sr$ ratio of the sample, and usually only one to perhaps three samples from the same unit are analyzed. To establish an isochron age, five or more samples from the same unit usually are analyzed, and the initial $^{87}Sr/^{86}Sr$ ratio is calculated rather than assumed; thus the accuracy of the age is improved as several samples from the same unit are analyzed. In addition, if the calculated initial $^{87}Sr/^{86}Sr$ ratio is different than the value of seawater at the time the glauconite formed (see, for example, Peterman et al., 1970; Palmer and Elderfield, 1985; DePaolo and Ingram, 1985; Koepnick et al., 1985), this suggests that the glauconite was chemically or isotopically altered after formation and deposition. Thus an isochron age obtained from samples with an initial $^{87}Sr/^{86}Sr$ ratio different from the seawater composition during the time that the glauconites formed would be suspect as the glauconite should have formed in Sr isotopic equilibrium with the seawater in which it crystallized and was deposited. The Moodys Branch Formation isochron indicates an initial $^{87}Sr/^{86}Sr$ ratio that is analytically identical to the Sr isotopic composition suggested for Jacksonian seawater. Therefore, glauconite used to date the Moodys Branch Formation has not experienced obvious isotopic exchange with groundwater.

Acceptable isochrons are those with both relatively low age uncertainties and MSWD values of about 3 and lower. Though the MSWD value for the Moodys Branch Formation is low (1.2), the age uncertainty is moderately high. Limited range of $^{87}Sr/^{86}Sr$ values accounts for at least some if not all of the large age uncertainty. Although glauconites from the Moodys Branch Formation may not yield a good isochron, the age obtained is reasonable when compared to recent Eocene time-scales.

Calcareous nannofossil zone NP 17, which is assigned to upper Bartonian age strata, has a suggested age range of about 40 - 42.3 Ma (Berggren et al., 1985), 39.4 - 41.4 Ma (Haq et al., 1986), or 37.0 - 39.0 Ma (Odin, 1982b). Therefore, considering analytical uncertainty, our age for the Moodys Branch Formation is in agreement with recent time-scales. In addition, the isochron age is analytically identical to the K-Ar age of 38.3 $\pm$ 1.2 Ma determined on low K_2O glauconite from the Moodys Branch Formation by Ghosh (1972).

Another way to evaluate the Rb-Sr data is to calculate model ages for the Moodys Branch Formation samples using an appropriate $^{87}Sr/^{86}Sr$ initial ratio based on seawater analyses (Koepnick et al., 1985); these values are given in Table 1. The five model ages average 40.8 $\pm$ 1.6 Ma (one-standard deviation). Deletion of the two extreme values gives an age of 40.7 $\pm$ 0.5 Ma.

Keppens and Pasteels (1982) observed that many Precambrian and Paleozoic glauconites have K-Ar and Rb-Sr ages that have been reset, probably due to alteration at elevated temperatures of deep burial or in response to tectonic stress. They note that burial seems to affect Rb-Sr ages less than K-Ar ages. Morton and Long (1984) suggested that Paleozoic glauconites from the Llano Uplift of Texas that have been disturbed but not deeply buried gives ages corresponding to times of regional emergence above sea level. Many Cenozoic glauconites, such as our samples from the U.S. Coastal Plain, have not been subjected to deep burial, tectonism, or other obvious disturbance. It is difficult to rule out the possibility that these sediments had their radiometric ages altered, perhaps due to leaching by ground waters or percolating fresh waters, a condition observed in the North Sea and on Spitsbergen by Smalley et al. (1986) for Triassic and Miocene glauconites.

Glauconite that gives spurious ages commonly displays one or both of the following:

1. inconsistent model ages for samples from the same unit plus an isochron with both large age uncertainty and high MSWD value, or
2. initial $^{87}Sr/^{86}Sr$ ratios significantly different than seawater values at the time of formation and deposition of the glauconites.

Though the isochron age has a moderately large uncertainty and the model ages exhibit some scatter, our Rb-Sr data indicate that the Moodys Branch Formation is 39-41 Ma old. Glauconite ages on carefully selected pellets provide a direct mechanism of placing age constraints on sedimentary rocks and the standard geologic time-scale.

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LOCALITY REGISTER

Moodys Branch Formation- Sample collected 1.2 m above Cockfield Formation, Riverside Park, Jackson, Hinds County, Mississippi.

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