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Analysis of kerogen and biostratigraphy of core from the Dummit-Palmer No. 1 well, Deep River basin, North Carolina

by

Eleanora I. Robbins (1) and Daniel A. Textoris (2)

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(1) Reston, VA

(2) University of North Carolina, Department of Geology, Chapel Hill, NC

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INTRODUCTION

During the course of anlyses of organic tissues in the coal beds of the Deep River basin (Robbins and Textoris, 1988), core became available for study from the Dummit-Palmer No. 1 well, courtesy of the North Carolina Geological Survey. The Dummit-Palmer No. 1 well site is located at 35° 32' 45" N, 79° 17' 45" W in Lee County, North Carolina. Red shale of the Sanford Formation (Upper Triassic, Chatham Group, Newark Supergroup) dominates the upper 370 ft of the well. A thick diabase sill occurs from a depth of 370 to 584 ft. Below the sill, black shale and coal of the Cumnock Formation (as above) occur to the bottom of the well at a depth of 953ft 3in. Other thinner diabase sills occur within the Cumnock Formation at 683ft 4.5in to 684ft 6.5in, 751ft 5in to 754ft 7in, and 869ft to 869ft 4in. All coal had been removed from the core; therefore none was available for study.

This report presents the results of our research on 13 samples of core from the Dummit-Palmer No. 1 well. Samples were selected for two purposes. The uppermost two samples were used to analyze the effect of igneous intrusion on the organic tissues; the lower 11 samples were selected for their relationship to coal beds. Specifically, we wanted to know the depositional environment of organic-rich rocks that are directly above and below the coal beds. Analyses resulted in data on types of kerogen or organic tisses, thermal alteration, biostratigraphy, total organic carbon, distribution of opaque sulfide minerals, and clay mineralogy.

MATERIALS AND METHODS

Samples were taken from black and gray lithologic units (Table 1). The presence of siderite was determined petrographically. A red color was observed after treatment of the sample with HCl, a reaction that is consistent with Fe being released from a carbonate mineral.

Ten grams of rock were crushed in a mortar and pestle to pea-sized pieces and then subjected to acid extraction procedures for kerogen (Robbins and Traverse, 1980). Kerogen is a word with several meanings; in this paper it is defined as organic matter that is insoluble in HCl and HF. The rock pieces were processed through 10 or 30 percent HCl to remove carbonate minerals. This procedure was followed by extraction in 50 percent HF to remove silicate minerals. The residues from acid processing were fixed onto microscope slides with glycerin jelly and are available for examination in the Branch of Coal Resources in Reston, VA.

The residues of organic matter and acid-resistant minerals were analysed palynologically. Percent recovery of acid insoluble residues was noted by comparing water-settled residues to a standard volume. The residues were then sieved through a standard set of screens chosen for palynological analysis. The "clay" fraction represents the component that passes through a 25um sieve. The "sand" fraction does not pass through a 125um sieve and consists of particles too big to mount on microscope slides. The "silt" fraction, which is greater than 25 and less than 125um, contains the component that can be most easily interpreted using palynological analysis.

Total organic carbon (TOC) was determined on sample splits. The analysis was performed by ARCO Exploration and Technology, courtesy of Gerald R. Baum.

The identity of organic tissues was determined by comparison with tissues of known organisms. The kerogen fraction therefore represents the remains of bacteria, plants, algae, and microscopic animals. The thermal alteration index (TAI) for each sample was analysed on thin-walled bisaccate pollen grains. Where such pollen is not present, the color analysis was performed on amorphous tissues. The color data were then quantified by comparison with Pearson (1981).

Opaque sulfide minerals are commonly present in such palynological preparations and were therefore studied for content, distribution, and crystal form.

X-ray diffraction (XRD) anlyses were performed on nine samples to determine the mineralogy of the fraction that could not be determined using microscopic methods. Quartz was present in all samples and is not reported any further.

DATA

The content of acid resistent components in the rocks is shown in Table 2. Volume percent recovery through acid processing ranged from 45 to 100 percent. The highest values are from organic rocks that have very little inorganic matrix. These recovery data can be compared with TOC values on Table 3. The distribution by size is also shown on Table 2.

The identity of the components in the "clay" and "silt" fractions is shown on Tables 3 and 4. The "clay" fraction is composed of broken pieces of larger plant tissues and a fine amorphous fluff. In the top two samples, this fine fraction represents most of the acid residue. The "sand" fraction in samples 1123 and 1125 represents most of the acid residue. The "silt" fraction in the core samples ranges from 3 to 25 percent of the acid residues. Table 3 shows the analysis of the "silt" sized fraction in each of the rocks. The coaly samples contain mostly wood cells. The two upper samples from the core are rich in pollen and spore content. Sample 1129, which had a low value for TOC, dominantly consists of minerals. Amorphous organic matter in the form of algal sheets and balls and fecal pellets dominates samples 1122 and 1126. Table 4 shows the identity of the amorphous component in each of the rocks. The amorphous component in the lowermost samples is primarily composed of vascular plant parts. The uppermost samples contain the typical amorphous component that is best identified as algal balls and zooplankton fecal pellets.

The colors of the organic tissues are shown on Table 5. Colors range from medium brown (TAI 3) to very dark brown (TAI 4). The thermal anomaly in the vicinity of the sill is obvious from the data.

The result of a biostatigraphic analysis of the samples is shown on Table 6. Among the identifiable palynomorphs are trilete spores, monosaccate and bisaccate pollen, and monosulcate and plicate pollen. The suite of palynomorphs dates this section of the Cumnock Formation to the middle Karnian stage of the Late Triassic. Patinasporites densus is diagnostic in that it does not range below the Karnian (Cousminer and Manspeizer, 1977).

The anlaysis of opaque sulfide minerals in the "clay" and "silt" sized fractions are shown on Table 7. Pyrite undoubtedly dominates this fraction which is brassy yellow in color under reflected light. Sample 1123 has the highest content of pyrite. The pyrite varies in its distribution; in most samples, crystals are dispersed. In some of the samples, the pyrite is physically enmeshed in the tissues. Crystal forms are generally framboids and octahedrons. Masses of octahedrons are present in some samples also. Sample 1125 has sheets of a brassy opaque sulfide mineral; this form is not typical of pyrite.

Clay mineralogy of the samples is shown in Table 8. The dominant clay is kaolinite. Illite is common, and chlorite and an illite-smectite interlayer clay follow in abundance. Siderite is present in all samples in varying amounts, as is an apatite mineral that matches x-ray characteristics of dahllite.

INTERPRETATIONS AND CONCLUSIONS

All of the data collected in this study can be used to infer the environments in which the sediments and organic matter were deposited (Table 3). The coal, which can be interpreted as the swamp facies, was not available for study. Several samples had greater than 90 percent recovery after acid processing. The same samples had total organic carbon greater than 10 percent, and the organic tissues were dominated by wood cells. These data suggest that the carbonaceous shale samples 1123, 1125, and 1127 represent a swamp or a marshy swamp that may have been dominated by bushy plants. A marsh facies can be defined from samples whose organic tissues are a mixture of aquatic organisms and plant tissues. TOC is less than 10 percent in such samples as 1121 and 1124. A lake facies in which the bottom waters were anoxic can be inferred in samples having a lithology of black shale, and organic matter that is dominated by aquatic organisms such as algae and zooplankton. A soil facies can be interpreted in the claystone samples 1129 and 1131 on the basis of lithology and the abundance of acid-resistant minerals. The pyrite content is relatively high in sample 1131, which is a variegated claystone; these data suggest this soil layer that underlies a coal bed was saturated and served as an aquitard.

The pyrite content of most of these rocks is generally small, which suggests that sulfur-bearing source rocks were not weathering in the watershed during the time of deposition. The pyrite is dominated by octahedrons and framboids, which are the two crystal forms known to be formed by bacteria. Thermally derived cubes and pyritohedrons are not present in these rocks (Robbins and others, 1988).

The organic tissues in these rocks are generally dark in color. A comparison with Staplin (1977) suggested these rocks have been buried to a temperature of 110 to 150^{o}C.

The effects of the diabase sill can be seen by the dark colors of the tissues in the rocks in contact with it. The tissues are much more degraded in sample 1120, which directly underlies the sill. Although palynomorphs are abundant in this sample, they are so degraded that none could be identified.

Palynomorphs are abundant and well preserved in sample 1119. This sample should be made available to all scientists working on Karnian floras.

Kaolinite clays which are known to form in acid waters, and siderite and apatite (dahllite) which form authigenically in reducing environments, were not unexpected. These minerals are consistent with deposition in euxenic lake-marsh-swamp environments. Based on petrographic study, the other clays appear to be detrital in origin.

The cores from the Dummit-Palmer No. 1 well are therefore extremely useful for the determination of both depositional and diagenetic changes in organic sedimentation in the Deep River basin. Two intervals, 868ft 11in and 949ft 10in, are particularly rich in palynomorphs and should be subject to more detailed biostratigraphic study.

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Table 1. Lithology of rock samples from Dummit-Palmer No 1 well.

Lab No.	Core Depth	Lithology from laboratory analysis
1119	868'11"	black laminated shale
sill		
1120	869'8"	black siderite
1121	883'6"	black sideritic carbonaceous shale
1122	894'8"	black sideritic massive shale with slickensides
1123	898'0"	black sideritic impure coal
1124	899'0"	black massive siderite
		coal
1125	902'7"	black sideritic impure coal
		coal
1126	907'6"	black sideritic massive shale
		coal
1127	909'6"	black laminated shale
1128	920'8"	black impure coal
1129	949'10"	light gray massive clayey shale
1130	952'2"	dark gray claystone
		coal
1131	952'10.5"	black and gray variegated claystone

Table 2. Volume percent recovery after acid treatment and size distribution of acid residues.

Lab No.	Core Depth	Volume percent recovery	Size distribution of acid residues (normalized to 100%)		
			clay <25um	silt 25-125 um	sand+ >125 um
1119	868'11"	95	94	3	3
sill					
1120	869'8"	45	90	5	5
1121	883'6"	80	25	25	50
1122	894'8"	80	63	25	12
1123	898'0"	97	7	10	83
1124	899'0"	70	50	21	29
coal					
1125	902'7"	95	5	11	84
coal					
1126	907'6"	60	75	8	17
coal					
1127	909'6"	100	45	10	70
1128	920'8"	90	44	12	44
1129	949'10"	55	72	10	18
1130	952'2"	67	60	10	30
coal					
1131	952'10.5"	55	72	10	18

Table 3. Total organic carbon (TOC), dominant organic tissues in silt fraction, and inferred depositional environment.

Lab No.	Core Depth	TOC	Dominant organic tissues in silt fraction	Depositional environment
1119	868'11"	--	50% pollen-25% wood-25% amorphous	--
sill				
1120	869'8"	--	60% wood-50% pollen	--
1121	883'6"	6.25	50% amorph-50% wood	marsh
1122	894'8"	1.81	70% amorph-30% wood	lake
1123	898'0"	33.62	50% wood-50% amorph	swamp/marsh
1124	899'0"	4.38	50% wood-50% amorph	marsh
coal				
1125	902'7"	15.29	50% wood-50% amorph	swamp/marsh
coal				
1126	907'6"	1.65	80% amorph-20% wood	lake
coal				
1127	909'6"	11.31	50% wood-50% amorph	swamp/marsh
1128	920'8"	12.56	90% wood & plant tissues-10% other	swamp
1129	949'10"	0.73	50% minerals-30% wood-10% tissues-10% pollen	soil
1130	952'2"	5.36	80% wood-20% plant tissues	swamp/marsh
coal				
1131	952'10.5"	2.24	80% wood-20% plant tissues & minerals	saturated soil

Abbreviations: amorph-amorphous, wood-wood cells

Table 4. Types of amorphous kerogen (in order of abundance).

Lab No.	Core Depth	"Clay" fraction	"Silt" fraction
1119	868'11"	fluffy	sheets, balls, fecal pellets
sill			
1120	869'8"	fluffy	fecal pellets
1121	883'6"	fluffy, broken plant parts	fecal pellets, balls
1122	894'8"	fluffy	balls, fecal pellets
1123	898'0"	broken plant parts	unspecified plant parts
1124	899'0"	balls	fecal pellets, balls
coal			
1125	902'7"	broken plant parts	unspecified plant parts
coal			
1126	907'6"	balls	fecal pellets, balls
coal			
1127	909'6"	balls	balls, fecal pellets
1128	920'8"	fluffy, broken plant parts	unspecified plant parts
1129	949'10"	broken plant parts	unspecified plant parts
1130	952'2"	broken plant parts	unspecified plant parts
coal			
1131	952'10.5"	fluffy, broken plant parts	unspecified plant parts

Table 5. Thermal alteration indices (TAI) as used by Pearson (1981) .

Lab No.	Core Depth	TAI 2 med yw	2+ dk yw	3– lt-lt med bn	3 med bn	3+ dk med bn	4– dk bn	4 v dk bn	5 black
1119	868′11"							x (x)	
sill									
1120	869′8"							x (x)	
1121	883′6"						(x)		
1122	894′8"				(x)				
1123	898′0"					(x)			
1124	899′0"							(x)	
coal									
1125	902′7"							(x)	
coal									
1126	907′6"						(x)		
coal									
1127	909′6"				(x)				
1128	920′8"					(x)			
1129	949′10"					x (x)			
1130	952′2"						(x)		
coal									
1131	952′10.5"						(x)		

Abbreviations: bn-brown, dk-dark, lt-light, med-medium, v-very, yw-yellow
Symbols: x =analysis done on thin-walled bisaccate pollen
(x)=analysis done on amorphous tissues

Table 6. Biostratigraphic analysis of rock samples from Dummit-Palmer No. 1 well.

Lab No.	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131
TRILETE SPORES													
Cyclogranisporites oppressus	-	-	-	-	-	-	-	-	+	-	-	-	-
Dictyophyllidites mortoni	-	-	-	-	-	-	-	-	-	-	+	-	-
unidentified spores	+	-	-	-	-	-	-	-	+	-	-	-	+
MONOSACCATE, CIRCUMPOLLOID, & INAPERTURATE POLLEN													
Patinasporites densus	+	-	-	-	-	-	-	-	-	-	+	-	-
unidentified round grains	+	+	+	+	+	-	-	-	+	-	+	-	-
BISACCATE POLLEN													
Alisporites ovatus	+	-	-	-	-	-	-	-	-	-	-	-	-
A. parvus	+	-	-	-	-	-	-	-	+	-	-	-	-
A. sp.	+	-	-	-	-	-	-	-	-	-	+	-	-
Colpectopollis ellipsoideus	+	-	-	-	-	-	-	-	+	-	-	-	-
Klausipollenites gouldii	+	-	-	-	-	-	-	-	-	-	+	-	-
Pityosporites sp.	+	-	-	-	-	-	-	-	-	-	-	-	-
Triadispora sp.	+	-	-	-	-	-	-	-	-	-	-	-	-
unidentified bisaccates	+	+	-	-	+	-	-	-	+	+	-	-	-
MONOSULCATE & PLICATE POLLEN													
Cycadopites deterius	-	-	-	-	-	-	-	-	-	-	+	-	-
C. sp.	+	-	-	-	-	-	-	-	+	?	-	-	-
Ovalipollis ovalis	-	-	-	-	-	-	-	-	+	-	-	-	-
unidentified prolate grains	+	-	-	-	-	-	-	-	-	-	-	-	-
GRAINS DEGRADED BEYOND RECOGNITION	-	-	+	-	+	+	-	-	+	-	-	+	-

Symbols: - absent, + present, ? uncertain about identification

Table 7. Content and crystal form of opaque sulfide minerals (probably pyrite).

Lab No.	Core Depth	Estimated pyrite content	Distribution of pyrite	Form of pyrite
1119	868′11"	1%	detrital	fram
sill				
1120	869′8"	5%	detrital	fram, octa, masses of octa
1121	883′6"	2.5%	detrital, enmeshed	octa
1122	894′8"	tr	detrital, enmeshed	masses of octa, octa
1123	898′0"	7.5%	detrital	masses of octa, octa
1124	899′0"	1%	detrital	octa
coal				
1125	902′7"	5%	detrital	octa, masses, sheets (?)
coal				
1126	907′6"	1%	detrital, enmeshed	octa, masses of octa
coal				
1127	909′6"	tr	detrital, enmeshed	octa
1128	920′8"	1%	enmeshed, detrital	masses, fram
1129	949′10"	tr	enmeshed	octa
1130	952′2"	5%	detrital, enmeshed	fram, masses
coal				
1131	952′10.5"	5%	detrital, enmeshed	fram, masses, octa

Abbreviations: fram-framboids, octa-octahedrons

Table 8. XRD analysis of selected core depths. (Quartz not included.)

Lab No.	Core Depth	Dominant clay mineral	Secondary clays	Other
	sill			
8836	883′6"	kaolinite	illite	siderite, dahllite
8948	894′8"	kaolinite	chlorite, illite	siderite
8980	898′0"	illite	--	dahllite
	coal			
1568	902′6"	--	--	siderite, dahllite
	coal			
	coal			
1567	909′6"	kaolinite	illite-smectite, illite, chlorite	dahllite
1566	920′8"	kaolinite	illite	dahllite
9490	949′10"	kaolin[illegible]	[illegible]	dahllite, siderite
1564	952′2"	kaolinite	illite	dahllite
1565	952′10.5"	kaolinite	illite	dahllite