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THE WACCAMAW AND CROATAN DEPOSITS OF THE CAROLINAS

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INTRODUCTION

FUNDS DERIVED FROM A NATIONAL SCIENCE FOUNDATION GRANT HAVE MADE POSSIBLE INITIATION OF A DETAILED STRATIGRAPHIC-PALEOECOLOGIC STUDY OF SOME OF THE MARINE NEOGENE DEPOSITS OF COASTAL NORTH AND SOUTH CAROLINA. SPECIAL EMPHASIS HAS BEEN PLACED ON THE WACCAMAW AND CROATAN FORMATIONS. MUCH OF THE SUMMER OF 1959 WAS SPENT EXAMINING OUTCROPS AND MAKING EXTENSIVE COLLECTIONS. FIELD WORK IN THE AREA WILL BE RESUMED DURING THE SUMMER OF 1960.

IT IS HOPED THAT AS A RESULT OF THIS STUDY A MORE ACCURATE PICTURE CAN BE CONSTRUCTED OF THE MUTUAL STRATIGRAPHIC AND AGE RELATIONSHIPS OF THE VARIOUS NEOGENE FORMATIONS IN THE REGION, AND THAT DETAILS OF THE DEPOSITIONAL ENVIRONMENTS CAN BE DETERMINED.

IT IS DESIRABLE THAT THIS STUDY BE COORDINATED WITH THOSE OF OTHER INVESTIGATORS WORKING CONCURRENTLY ON SLIGHTLY DIFFERENT ASPECTS OF THE SAME GENERAL PROBLEM, THUS MAKING POSSIBLE A MUCH MORE ACCURATE ACCOUNT OF THE NEOGENE HISTORY OF THE COASTAL PLAINS OF THE CAROLINAS AND SUBSEQUENTLY ALL OF THE SOUTHEASTERN SEABOARD.

RESUME OF PAST WORK

THE WACCAMAW FORMATION WAS NAMED BY WILLIAM H. DALL (1892, P. 209) FOR FOSSILIFEROUS MARINE DEPOSITS EXPOSED ALONG THE BANKS OF THE WACCAMAW RIVER IN Horry COUNTY, SOUTH CAROLINA. DALL (1892, P. 209) NAMED THE CROATAN FORMATION FOR FOSSILIFEROUS MARINE SEDIMENTS EXPOSED ALONG THE BANKS OF THE NEUSE RIVER EAST OF NEW BERN, NORTH CAROLINA. HE REFERRED BOTH OF THE FORMATIONS TO THE FLORIDAN GROUP (PLIOCENE) ALONG WITH THE CALOOSAHATCHEE MARL OF FLORIDA.

PRIOR TO THE TIME OF DALL'S STUDY THE WACCAMAW AND CROATAN FORMATIONS WERE GROUPED BY MOST GEOLOGISTS WITH OTHER NEOGENE DEPOSITS OF THE CAROLINAS INTO THE "CAROLINIAN BEDS", CONSIDERED AT THE TIME TO BE MIOCENE IN AGE. TUOMEY AND HOLMES (1857) PLACED THE WACCAMAW AND CROATAN DEPOSITS IN THE PLIOCENE.

DALL CONCLUDED (1892, P. 202-203) THAT THE FAUNA DESCRIBED BY TUOMEY AND HOLMES IN THEIR "PLEIOCENE FOSSILS OF SOUTH CAROLINA" (1857) WAS ACTUALLY A MIXTURE OF SEVERAL HETEROCHRONOUS FAUNAS INCLUDING SOME OF MIOCENE AND SOME OF PLIOCENE AGE. HE CONSIDERED THAT THE MIXTURE WAS NOT ATTRI-

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BUTABLE TO CARELESS FIELD WORK, BUT RATHER THE RESULT OF MIXING BY RUNNING WATER, EARTH FLOWS AND OTHER NATURAL PHENOMENA. DALL CONFINED HIS STUDY TO THE WACCAMAW AND NEUSE RIVER AREAS BECAUSE HE CONSIDERED THE FAUNAS THERE TO BE STRATIGRAPHICALLY IN PLACE.

DALL (1892, p. 215) FOUND THAT 125 OUT OF 180 MOLLUSK SPECIES (OR 80%) FROM THE TYPE WACCAMAW DEPOSITS WERE STILL LIVING, WHEREAS 80 OF 96 SPECIES (OR 83%) FROM THE CROATAN FORMATION WERE REPRESENTED IN THE RECENT FAUNA. CONSIDERING THESE PERCENTAGES AND BY COMPARING THE FAUNA WITH THOSE OF OTHER AREAS AND OTHER FORMATIONS DALL CONCLUDED THAT THE WACCAMAW FORMATION WAS PLIOCENE AND THAT THE CROATAN WAS SLIGHTLY YOUNGER BUT ALSO PLIOCENE IN AGE.

MOST GEOLOGISTS HAVE AGREED SINCE DALL'S PUBLICATION (1892) THAT THE WACCAMAW AND CROATAN FORMATIONS ARE PLIOCENE IN AGE AND THAT THEY ARE CORRELATIVES OF THE CALDOOAHATCHEE MARL (COLE, 1931, GARDNER AND WOODRING, 1943; COOKE, 1936; GARDNER, 1943; MANSFIELD, 1938, 1936; MILLER IN CLARK, 1912, AND RICHARDS, 1950).

MANSFIELD (1928, p. 135) THOUGHT THAT DALL HAD INCLUDED BOTH PLIOCENE AND PLEISTOCENE SPECIES IN HIS CROATAN FAUNAL LIST. MANSFIELD RE-EXAMINED THE TYPE AREA NEAR SLOCUM'S CREEK WHERE HE DECIDED THE TERM CROATAN (PLIOCENE) SHOULD BE RESTRICTED TO THE LOWER FEW FEET OF THE SECTION, WHICH WERE SUPPOSEDLY OVERLAIN UNCONFORMABLE BY FOSSILIFEROUS PLEISTOCENE DEPOSITS. NEITHER RICHARDS (1950) NOR I COULD LOCATE THIS UNCONFORMITY AND JUDGING FROM FIELD RELATIONSHIPS, I HAVE TENTATIVELY CONCLUDED THAT MANSFIELD'S "PLIOCENE" AND "PLEISTOCENE" STRATA ARE ACTUALLY INTERTONGUING FACIES REPRESENTING THE SAME AGE.

RECENTLY BROWN (LEGRAND & BROWN, 1955) HAS CONCLUDED ON THE BASIS OF COMPARISON OF OSTRACODE SPECIES THAT AT LEAST SOME OF THE "WACCAMAW" OUTCROPS IN NORTH CAROLINA REPRESENT A FACIES OF THE LATE MIOCENE DUPLIN FORMATION.

GEOLOGY OF THE WACCAMAW AND CROATAN FORMATIONS

SUPPOSED WACCAMAW AND CROATAN DEPOSITS CROP OUT IN SCATTERED PATCHES ALONG THE EASTERN EDGE OF THE COASTAL PLAIN FROM CHARLESTON, SOUTH CAROLINA TO THE NEUSE RIVER AREA IN NORTH CAROLINA, A DISTANCE OF MORE THAN 200 MILES. ALL THE KNOWN OUTCROPS LIE BELOW THE WICOMICO (100 FOOT SHORELINE). EXPOSURES OF THE CROATAN ARE RESTRICTED TO THE BANKS OF THE NEUSE RIVER EAST OF NEW BERN, NORTH CAROLINA AND TO THE AREA IMMEDIATELY ADJACENT TO THE RIVER.

THE FORMATIONS ARE THIN WHERE OBSERVED, AVERAGING LESS THAN 10 FEET AT MOST OUTCROPS. MILLER (IN CLARKE, 1912, P. 252-253) REPORTS A THICKNESS OF 80-100 FEET FOR THE WACCA-

MAW IN A WELL IN HYDE COUNTY.

LITHOLOGICALLY THE WACCAMAW CONSISTS OF UNCONSOLIDATED SANDY MARLS, ARGILLACEOUS MARLS AND SAND AS WELL AS SOME THIN, RELATIVELY HARD LIMESTONES OR CALCAREOUS MARLS. MOST OF THE OUTCROPPING DEPOSITS ARE BROWNISH IN COLOR ON THE SURFACE, BUT UNWEATHERED MATERIAL IS COMMONLY BLUE-GRAY. IN GENERAL, MEGAFOSSILS, ESPECIALLY MOLLUSKS, ARE ABUNDANT AND FAIRLY WELL PRESERVED.

THE CROATAN DIFFERS FROM THE WACCAMAW IN BEING SANDIER, MORE ARGILLACEOUS AND LESS CALCAREOUS.

BOTH THE WACCAMAW AND CROATAN FORMATIONS UNCONFORMABLY LIE ON OLDER FORMATIONS. THE WACCAMAW RESTS ON DEPOSITS WHICH RANGE IN AGE FROM CRETACEOUS TO LATE MIOCENE. WHERE OBSERVED THE CROATAN FORMATION RESTS ON THE TRENT FORMATION (EARLY MIOCENE).

BOTH THE WACCAMAW AND CROATAN ARE UNCONFORMABLY OVERLAIN BY PLEISTOCENE SANDS AND CLAYS.

STRATIGRAPHIC AND AGE RELATIONSHIPS

AS MENTIONED ABOVE, THE WACCAMAW AND CROATAN FORMATIONS ARE AT PRESENT GENERALLY CORRELATED WITH THE CALOOSAHATCHEE MARL OF FLORIDA, AND THESE THREE FORMATIONS COLLECTIVELY HAVE BEEN CONSIDERED TO REPRESENT THE MARINE PLIOCENE OF EASTERN UNITED STATES. RECENTLY, STUDIES BY MYSELF (1958A, 1958B, AND 1958C) AND OTHERS (PURI AND VERNON, 1959) HAVE CONCLUSIVELY DEMONSTRATED THAT THE CALOOSAHATCHEE MARL IS A PLEISTOCENE DEPOSIT. IN ADDITION, THE TAMAMI FORMATION, ONCE REGARDED AS A PLIOCENE FACIES OF THE CALOOSAHATCHEE, IS NOW CLASSIFIED AS LATE MIOCENE IN AGE (PARKER, 1951).

ALL MARINE PLEISTOCENE STRATA OF FLORIDA YOUNGER THAN THE CALOOSAHATCHEE MARL, WHICH CONTAINS MARINE FOSSILS, LIE BELOW THE PAMLICO SHORELINE (30 FEET ABOVE SEA LEVEL). PROBABLY ALL THESE YOUNGER PLEISTOCENE DEPOSITS, WHICH INCLUDE THE FT. THOMPSON, ANASTASIA, MIAMI OOLITE AND KEY LARGO FORMATIONS, ARE MORE OR LESS CONTEMPORANEOUS WITH THE PAMLICO FORMATION OF THE CAROLINAS (TABLE 1). IT IS THOUGHT BY ME THAT ALL OF THESE FORMATIONS, INCLUDING THE PAMLICO, WERE DEPOSITED AT A TIME WHEN THE WISCONSINAN GLACIERS RETREATED AND SEA LEVEL STOOD APPROXIMATELY 25-30 FEET HIGHER THAN TODAY.

IT IS PROBABLE THAT ONE OR MORE OF THE FLORIDA PLEISTOCENE SHORELINES ABOVE THE PAMLICO WERE FORMED BY THE CALOOSAHATCHEE SEA. PALEOECOLOGICAL AND PALEO GEOGRAPHICAL EVIDENCE (DU BAR, 1958A, P. 152) SUGGESTS THAT THE HIGHEST STAND OF THE CALOOSAHATCHEE SEA CORRELATES WITH THE MAKING OF THE WICOMICO SHORELINE (100 FEET ABOVE SEA LEVEL).

TABLE 1
CORRELATION OF NEOGENE DEPOSITS OF SOUTHERN FLORIDA
Cooke, Gardner and Woodring, 1943

Present study

		Wisconsinan	Peorian Iowan	Lake Flirt marl Pamlico sand	Present study			
					Lake Flirt marl Pamlico sand Fort Thompson fm.	Anastasia fm.	Miami oolite	Key Largo ls.
Pleistocene	Sangamonian	Fort Thompson fm.	Miami oolite	Key Largo ls.	Anastasia fm.	Talbot fm. Penholoway fm. Wicomico fm.	Caloosahatchee marl	Talbot fm. ? Penholoway fm. Wicomico fm.
	Illinoian						No record	
	Yarmouthian				Sunderland fm.		No record	
	Kansan						No record	
	Aftonian						No record	
	Nebraskan			No record			No record	
Pliocene	Upper (Astian)	Bone Valley fm.	Caloosahatchee marl		Tamiami limy sandstone facies		No record	
	Lower (Plaisancian)			Buckingham marl member		No record		
Miocene	Upper (Sahelian?)		No record			Tamiami fm.	Bone Valley fm.?	

CONSIDERING ALL AVAILABLE EVIDENCE, ESPECIALLY THAT DERIVED FROM VERTEBRATE FOSSILS, I (DU BAR, 1958B, P. 136-142) ASSIGNED THE CALOOSAHATCHEE MARL TO THE SANGAMONIAN INTERGLACIAL. NEITHER OLDER MARINE PLEISTOCENE NOR MARINE PLIOCENE DEPOSITS IN FLORIDA ARE NOW DEFINITELY RECOGNIZED BY ME.

SEVERAL FACTORS HAVE BEEN GIVEN MUCH WEIGHT BY GEOLOGISTS WHO ASSIGN THE WACCAMAW AND CROATAN DEPOSITS TO THE PLIOCENE. THREE OF THE MOST IMPORTANT CRITERIA ARE DISCUSSED BELOW:

1. UNDOUBTEDLY THE "PLIOCENE SCHOOL" HAS BEEN INFLUENCED BY THE ASSUMPTION THAT IN PLACES THE WACCAMAW IS SUPPOSEDLY OVERLAIN BY EARLY PLEISTOCENE SEDIMENTS, AND THAT THE YOUNGEST ROCKS WHICH ARE KNOWN TO DIRECTLY UNDERLIE THE WACCAMAW ARE ASSIGNED TO THE LATE MIOCENE DUPLIN MARL. THIS WOULD NARROW THE POSSIBLE AGE FOR THE WACCAMAW AND CROATAN FORMATIONS TO THE RANGE BETWEEN LATE MIOCENE AND EARLY PLEISTOCENE, THUS VIRTUALLY FORCING THEM INTO THE PLIOCENE.

2. USING THE LYELLIAN METHOD OF PERCENTAGE OF LIVING MOLLUSCAN SPECIES CONTAINED IN THE FAUNAS BOTH THE WACCAMAW AND CROATAN FORMATIONS SEEM CLEARLY TO FALL INTO A PLIOCENE CLASSIFICATION.

3. BY COMPARISON OF THE FAUNAS WITH THOSE OF OTHER NEOGENE FORMATIONS, IT WAS SHOWN THAT, CONSIDERING DIFFERENCES ATTRIBUTABLE TO LATITUDE, THE WACCAMAW AND CROATAN FAUNAS ARE MOST SIMILAR TO THAT OF THE CALOOSAHATCHEE MARL. FROM THIS OBSERVATION IT WAS DEDUCED THAT THE WACCAMAW AND CROATAN DEPOSITS REPRESENT A COOLER WATER FACIES OF THE TROPICAL CALOOSAHATCHEE FORMATION. THE LATTER CONCLUSION IS STRENGTHENED BY THE FACT THAT THE CALOOSAHATCHEE MARL OF NORTHEASTERN FLORIDA WAS APPARENTLY DEPOSITED IN WATER WITH A TEMPERATURE RANGE INTERMEDIATE BETWEEN THAT FOR THE TYPE CALOOSAHATCHEE AND THAT FOR THE WACCAMAW AND CROATAN FORMATIONS.

BELOW THE PAMLICO SHORELINE THE WACCAMAW IS NEARLY EVERYWHERE OVERLAIN BY THE LATE PLEISTOCENE PAMLICO FORMATION. PLEISTOCENE DEPOSITS OLDER THAN THE PAMLICO WHICH CONTAIN MARINE FOSSILS, HAVE NOT BEEN DEFINITELY RECOGNIZED ANYWHERE IN EASTERN UNITED STATES (RICHARDS, 1936, 1938, 1950). WHERE THEN ARE THE FOSSILIFEROUS DEPOSITS CORRESPONDING TO THE HIGHER, OLDER SHORELINES? COULD THE WACCAMAW AND CROATAN FORMATIONS REPRESENT OLDER PLEISTOCENE DEPOSITS?

ALL THE KNOWN WACCAMAW AND CROATAN DEPOSITS OF THE CAROLINAS LIE BELOW THE WICOMICO SHORELINE, THOUGHT TO BE SANGAMONIAN IN AGE (DU BAR, 1958A). ALL THE SPECIES OF THESE TWO FORMATIONS COULD HAVE LIVED IN WATER LESS THAN 100 FEET IN DEPTH. THUS IT IS POSSIBLE THAT THE WACCAMAW-CROATAN SEA COULD HAVE FORMED THE WICOMICO SHORELINE DURING THE PLEISTOCENE. IF THIS IS TRUE, THEN UNFOSSILIFEROUS SANDS

OVERLYING THE WACCAMAW AT ELEVATIONS BETWEEN 30 AND 100 FEET WOULD BE LATE PLEISTOCENE RATHER THAN EARLY PLEISTOCENE IN AGE.

THE LYELLIAN PERCENTAGE METHOD HAS BEEN LONG DISCREDITED AS A PRECISE METHOD OF DETERMINING THE AGE OF A CENOZOIC FORMATION (DALL, 1892, P. 215). FACTORS OF LOCAL DEPOSITIONAL ENVIRONMENTS, RATE OF DISPERSION, EFFECT OF GEOGRAPHIC AND ECOLOGIC BARRIERS, AND INCREASING KNOWLEDGE OF FOSSIL AND RECENT FAUNAS ALL CONTRIBUTE TO THE INVALIDATION OF LYELL'S CONCEPT. AT BEST IT IS A METHOD WHICH MUST BE USED WITH EXTREME CAUTION. IT IS UNLIKELY, HOWEVER, THAT A MIOCENE FORMATION WOULD CONTAIN 80-83% RECENT SPECIES OF MOLLUSKS; ON THE OTHER HAND, IT SEEMS QUITE POSSIBLE THAT OLDER PLEISTOCENE DEPOSITS MIGHT CONTAIN 17-20% EXTINCT SPECIES.

COMPARATIVE ANALYSES OF THE FAUNAS SUCH AS THAT BY DALL (1892, P. 215-216) SEEM TO BE A MORE RELIABLE APPROACH TO DETERMINATION OF THE RELATIVE AGE OF THE WACCAMAW AND CROATAN FORMATIONS THAN THE LYELLIAN METHOD. HOWEVER, EVEN COMPARATIVE STUDIES MAY ENCOUNTER SERIOUS PITFALLS.

DALL LISTED (1892, P. 215) THE FOLLOWING GEOLOGIC RANGE DATA FOR 180 MOLLUSCAN SPECIES FROM THE TYPE WACCAMAW.

MIOCENE	2 SPECIES
MIOCENE-PLIOCENE	16 SPECIES
PLIOCENE	17 SPECIES
NEW SPECIES	7 SPECIES
DOUBTFUL RANGE	13 SPECIES
PLIOCENE-PLEISTOCENE	1 SPECIES
RECENT	51 SPECIES
PLIOCENE AND RECENT	64 SPECIES
RECENT	9 SPECIES

SUCH A FAUNA, IF THE DATA WERE ACCURATE, WOULD INDEED APPEAR TO BE PLEISTOCENE IN AGE. HOWEVER, THE PLEISTOCENE PART OF ALL THE RANGES LISTED BY DALL WERE BASED ON THE RECORD OF THE SPECIES IN THE CALOOSAHATCHEE MARL, INCORRECTLY JUDGED TO BE A PLEISTOCENE FORMATION. NONE OF THE SO-CALLED "PLEISTOCENE GUIDE FOSSILS" IN THE WACCAMAW AND CROATAN ARE RESTRICTED ELSEWHERE TO UNQUESTIONED PLEISTOCENE DEPOSITS. THERE IS NO REASON TO ASSUME THAT THE TWO "MIOCENE SPECIES" LISTED BY DALL, OR THE 13 "MIOCENE-PLIOCENE SPECIES" COULD NOT HAVE SURVIVED INTO THE EARLY AND MIDDLE PLEISTOCENE. SIMILAR EVIDENCE PRESENTED BY DALL AND OTHERS FOR THE PLEISTOCENE AGE OF THE CROATAN FORMATIONS SEEMS EQUALLY UNCONVINCING.

IT APPEARS FROM THE ABOVE DISCUSSION THAT AT LEAST THE TYPE WACCAMAW AND CROATAN FAUNAS COULD BE PLEISTOCENE IN AGE. CERTAINLY THE PLEISTOCENE AGE DETERMINATION IS OPEN TO SERIOUS QUESTION, AND THERE SEEMS PRESENTLY TO BE LITTLE EVIDENCE SUPPORTING CLAIMS OF A MIOCENE AGE FOR EITHER THE WACCAMAW OR CROATAN FORMATIONS. IT IS QUITE POSSIBLE, HOW-

EVER, THAT OUTSIDE THE TYPE AREAS OUTCROPS ASSIGNED TO THE WACCAMAW AND CROATAN FORMATIONS COULD HAVE BEEN MISIDENTIFIED AND SOME OF THESE ARE PERHAPS ACTUALLY OLDER THAN THE TYPE DEPOSITS, BEING CORRELATIVES OF THE DUPLIN MARL (LATE MIOGENE).

IN SHORT, THE EXACT STRATIGRAPHIC AGE, PALEOECOLOGICAL AND PALEO GEOGRAPHICAL RELATIONSHIP AMONG THE LATE NEOGENE DEPOSITS OF THE CAROLINAS IS NOT CLEAR AND THE RELATIONSHIP OF THESE FORMATIONS WITH THOSE OF AREAS TO THE SOUTH, NORTH, AND WEST HAS NOT BEEN DEFINITELY ESTABLISHED.

FUTURE WORK

THE LATE NEOGENE DEPOSITS OF THE CAROLINAS NEED TO BE SERIOUSLY RE-EVALUATED IN THE LIGHT OF NEW INFORMATION AND IDEAS CONCERNING APPARENTLY CORRELATIVE DEPOSITS IN FLORIDA AND ELSEWHERE. FUTURE WORK IN THE REGION SHOULD BE BOTH MORE COMPREHENSIVE AND MORE DETAILED THAN IN THE PAST. TOTAL ASPECTS OF ALL FAUNAL, FLORAL AND SEDIMENTOLOGICAL CHARACTERISTICS NEED CAREFUL EXAMINATION SO THAT ALL POSSIBLE EVIDENCE CAN BE BROUGHT TO BEAR ON THE SOLUTION OF PROBLEMS CONCERNING STRATIGRAPHIC POSITION, RELATIVE AGE, DEPOSITIONAL ENVIRONMENT, AND PALEO GEOGRAPHY. THIS WILL ENTAIL STUDY OF ALL KNOWN NEOGENE EXPOSURES AS WELL AS THE ACCUMULATION OF AS MUCH SUBSURFACE DATA AS IS POSSIBLE. IN ADDITION, ULTIMATE SOLUTION OF THE DIVERSE PROBLEMS DEMANDS THE COOPERATIVE EFFORTS OF THE VARIOUS SPECIALISTS CONCERNED WITH THE NEOGENE HISTORY OF OUR ATLANTIC COASTAL PLAIN.

IT WILL NOT SUFFICE TO RESTRICT EXAMINATION TO THE SHALLOW MARINE DEPOSITS NEAR THE PRESENT SHORE AND SUCH DOWN-DIP DATA AS WE SHALL BE ABLE TO ACQUIRE. STUDIES ALSO NEED TO BE DIRECTED TO THE NON-MARINE FACIES FOUND GENERALLY WESTWARD FROM THE MARINE FACIES. GEOMORPHOLOGICAL INVESTIGATIONS SHOULD BE ENCOURAGED AND DETAILED MAPPING OF PLEISTOCENE SHORELINE FEATURES IS ESPECIALLY DESIRABLE.

MORE WORK NEEDS TO BE DONE IN FLORIDA. AS YET THE CALOOSAHATCHEE MARL AND CHARLTON FORMATIONS OF NORTHEASTERN FLORIDA ARE NOT WELL ENOUGH UNDERSTOOD. THE STRATIGRAPHIC ASPECTS AND DEPOSITIONAL ENVIRONMENTS OF THE VARIOUS FLORIDA MIOGENE FORMATIONS NEED MORE STUDY. THE SAME COMMENTS ARE PERHAPS APPLICABLE, TO A LESSER DEGREE, TO THE MIOGENE FOUND NORTH OF NORTH CAROLINA.

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