WRENCH-STYLE DEFORMATION IN ROCKS OF CRETACEOUS AND PALEOCENE AGE, NORTH CAROLINA COASTAL PLAIN

By

P. M. Brown, D. L. Brown,
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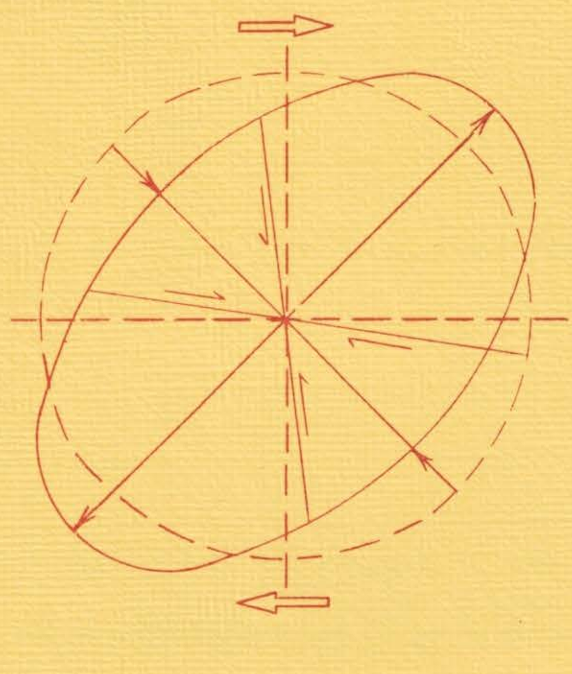
PREPARED COOPERATIVELY BY THE GEOLOGICAL SURVEY, UNITED STATES DEPARTMENT OF THE INTERIOR



NORTH CAROLINA
DEPARTMENT OF NATURAL AND ECONOMIC RESOURCES
DIVISION OF EARTH RESOURCES
GEOLOGY AND MINERAL RESOURCES SECTION

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COVER PHOTO: SHEAR DIAGRAM SHOWING THEORETICAL EFFECTS OF TENSIONAL AND COMPRESSIONAL FORCES.

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Stephen G. Conrad, State Geologist and Director

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GEOLOGY AND MINERAL RESOURCES SECTION

The Geology and Mineral Resources Section shall, by law ". . .make such examination, survey, and mapping of the geology, mineralogy, and topography of the state, including their industrial and economic utilization, as it may consider necessary."

In carrying out its duties under this law, the section promotes the wise conservation and use of mineral resources by industry, commerce, agriculture, and other governmental agencies for the general welfare of the citizens of North Carolina.

The Section conducts a number of basic and applied research projects in environmental resource planning, mineral resource exploration, mineral statistics, and systematic geologic mapping. Services constitute a major portion of the Section's activities and include identifying rock and mineral samples submitted by the citizens of the state and providing consulting services and specially prepared reports to other agencies that require geological information.

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ELDON P. ALLEN, CHIEF

CONTENTS

ILLUSTRATIONS

TABLES

WRENCH-STYLE DEFORMATION IN ROCKS OF CRETACEOUS AND PALEOCENE AGE, NORTH CAROLINA COASTAL PLAIN

By

P. M. Brown[1/], D. L. Brown[1/], T. E. Shufflebarger, Jr.[2/], and J. L. Sampair[3/]

ABSTRACT

In parts of Craven and Lenoir Counties, in the central part of the inner North Carolina Coastal Plain, tilted, partially-exposed blocks of Navarroan, Midwayan, and Claibornian sedimentary rocks comprise a structural mosaic of horst, graben, and half graben that are arranged in a right-handed, en echelon pattern. The relative positioning of the blocks is established chiefly from variance in the relative vertical and horizontal positioning of flat-lying, indurated mudstones (volcaniclastics) and from the relative vertical positioning of a disconformable contact between the mudstone of Midway age and underlying clayey sand of Navarro age at outcrops and in shallow core holes.

On the basis of their relative vertical and horizontal positions and analysis of their fracture geometry, the blocks and their bounding slip planes are judged to coincide with an inactive northeast-striking wrench zone, herein designated the Graingers wrench zone. It is characterized by a sense of relative left-lateral displacement. It is judged to be a wrench zone of the second order and to be associated with a second-order compressive stress axis that strikes about N. 22° W. Synthesis of a mechanical origin for the Graingers wrench zone suggests that its genetic roots go back to a regional primary stress axis with a meridional alignment and to a first-order, left-lateral wrench zone.

INTRODUCTION

The wrench fault, a type of high-angle strike-slip fault, forms in response to the action of horizontal couples operating within the earth's crust. The principal stress axis is horizontal as is the direction of easiest relief. By tacit association, a wrench zone is a linear geographic area that is being or has been subjected to wrenching and which contains structures genetically related to wrenching. As determined from experimental modeling and substantiated by field observation in many areas, basic structures associated with and considered diagnostic of wrench faulting may include en echelon folds, en echelon conjugate strike-slip faults, en echelon normal faults, and a main wrench

[1/] U.S. Geological Survey, Raleigh, N. C.

[2/] Pennsylvania Glass Sand Corp., Berkeley Springs, W. Va.

[3/] North Carolina Division of Earth Resources. Raleigh, N. C.

fault or wrench-fault zone (Wilcox, Harding, and Seely, 1973, p. 77).

Based on fracture analysis and the presence of what we interpret to be wrench-related structure (a locally developed mosaic of horst, graben and half-graben wedges or slices arranged en echelon), we believe that an inactive northeast-striking wrench zone is present in parts of Craven and Lenoir Counties (fig. 1). Within the wrench zone the relative sense of horizontal displacement is left lateral. As interpreted from the spatial distribution of the contacts between essentially flat-lying Navarroan, Midwayan, and Claibornian rocks observed at exposures and in shallow cored sections, vertical displacements in the zone are predominantly up to the northwest. Less commonly, the displacements are reversed and are up to the southeast.

A demonstrable field-scale example of a wrench zone and its structures in the North Carolina Coastal Plain should serve as a model for recognizing similar zones in other parts of the Atlantic Coastal Plain as well as in adjacent provinces. Because the presence of such a zone would influence the manner in which the coastal region is being prospected for its mineral resources and evaluated for its potential for underground waste storage, it was decided to describe its structural-sedimentary geometry.

ACKNOWLEDGMENTS

This study was undertaken as part of the subsurface waste-storage program of the U.S. Geological Survey to evaluate the potential for the occurrence of natural traps in the Atlantic Coastal Plain. The Pennsylvania Glass Sand Corporation, Berkeley Springs, West Virginia, approved the participation of their Chief Geologist in the project and furnished material and data from their core library. Project participation by the Division of Earth Resources, North Carolina Department of Natural and Economic Resources, was arranged for and approved by Stephen G. Conrad, State Geologist and Director.

Among Geological Survey colleagues, Robert R. Bennett and Robert L. Wait assisted in field investigations and took the photographs used in the report. Harlan R. Bergquist and Druid Wilson participated during part of the field study and coring program. Eugene Shuter and Robert R. Pemberton of the U.S. Geological Survey's research drilling group, Denver, Colorado, devised special drilling procedures for local conditions and operated the core-drilling equipment. Richard N. Benson and Frederick M. Swain, U.S. Geological Survey, prepared micropaleontologic reports used in project work. James C. Coffey, Geologist, N.C. Division of Earth Resources, and Teresa C. Windisch, Physical Science Aid, U.S. Geological Survey, assisted in the field investigations.

Vertical elevations of drill holes and of key exposures were determined by plane-table methods under the field supervision of party chief, Larry W. Akers, Director, North Carolina Geodetic Survey. The E. I. DuPont de Nemours and Company furnished locations and data concerning the nature of material

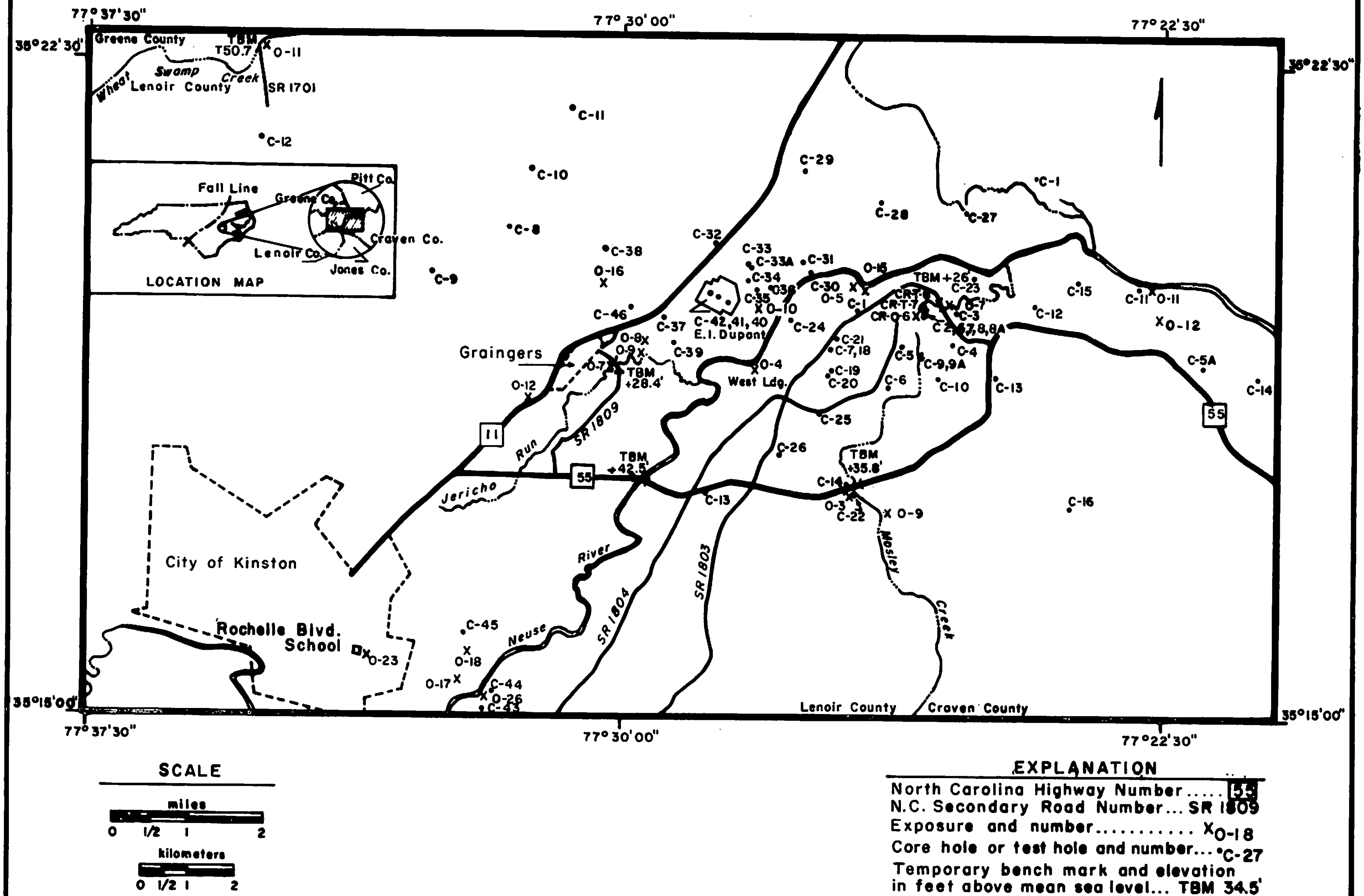


Figure I. Geographic locations of exposures and project boreholes in parts of Lenoir, Craven and Pitt Counties, North Carolina.

penetrated in test borings at their Kinston works located near Graingers, N. C.

LOCATION OF AREA

The rocks and structures described herein are located in parts of Lenoir and Craven Counties, N. C., in an area that lies along the inner margin of the central coastal plain and which is located about 25 miles (40 km) southeast of the Piedmont-Coastal Plain physiographic boundary (fig. 1).

The rocks and structures are located within and help define the approximate boundaries of a northeast-trending linear zone of tectonic uplift and subsidence, hereafter referred to as the Graingers wrench zone. The wrench zone is about 15 miles (24 km) wide and its structural axis lies athwart the Neuse River near Graingers, N. C. Because the zone plunges to the northeast and becomes obscured beneath a covering blanket of surficial material, its length is indeterminate from the data presently available.

EVIDENCE FOR WRENCHING

In a region such as the Atlantic Coastal Plain, characterized by sediments that are poorly consolidated and non-resistant mechanically and by flat low-lying topography, the presence of any or even many of the deformational structures indicative of wrenching may not be readily apparent. Instead, the initial evidence for wrenching may comprise subtle linear trends reflected by the topography and drainage patterns or by minor patterns of geometric discordance in sediment distribution patterns. For example, and in the area described herein, the presence of a wrench zone first was suggested to us by the alternate occurrence of juxtaposed Navarroan and Midwayan rocks in narrow northeast striking bands, an apparent en echelon arrangement of the bands, abrupt lateral changes in sediment types and energy levels of deposition that were inconsistent with respect to regional norms (Brown and others, 1972, pls. 14, 15, and 17) and, locally, anomalous variance in the elevations of essentially flat-lying rocks that crop out in a restricted area. Subsequently, and as a result of additional field reconnaissance to more clearly define the structural-sedimentary geometry in outcrop and prior to initiating a coring program, well developed intersecting fracture sets were recognized, a pronounced fault scarp was located, and the relative vertical and horizontal displacement of comparative exposed sections was noted and estimates made of its magnitude.

Interpretation of gross elements of the structural and sedimentary geometry present in outcrop and in some shallow core holes previously drilled by commercial interests suggested a preliminary wrench model (fig. 2), comprising horst, graben and half graben, with the following general characteristics: (1) A principal shear aligned NE.-SW. and plunging NE. (2) Subsidiary shears that lie en echelon and essentially parallel to a principal shear. (3) A relative sense of left lateral displacement for opposite sides of the shears. (4) A relative sense of vertical displacement across

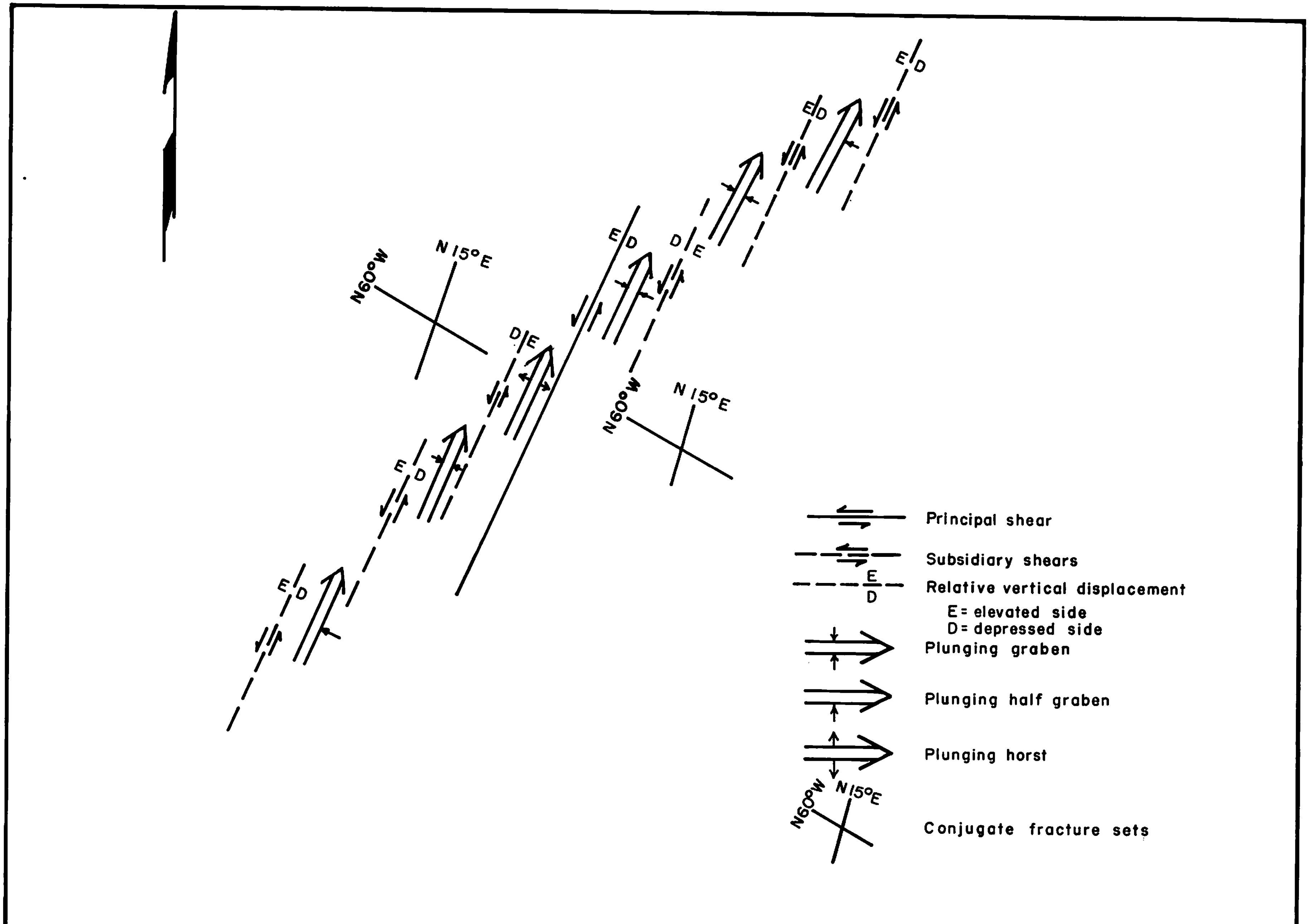


Figure 2. Schematic preliminary wrench model, Graingers area, North Carolina.

both the principal and subsidiary shears, that predominantly is up to the NW. and less commonly up to the SE. and (5) Systematic conjugate fracture sets that strike about N. 15° E. and N. 60° W., respectively.

In order to test this preliminary field model, exposures in the area were re-examined in more detail for evidence of structure and some shallow core holes were drilled to further examine, three dimensionally, the structural character of the suggested wrench zone. At exposures, the presence of nonsystematic fractures that form arcuate and wedge-shaped patterns, the presence of "ball and socket" horizontal jointing and the presence of cataclastic breccia, wherein rock materials, rearranged in the form of stress loops, are preserved, provide compelling evidence of action of torsional forces operative in a horizontal plane. The internal geometry of the cores, including the presence of twisted striae (relict signatures of plastic deformation) breccia, and low-angle slickensides provide further evidence of wrenching. These and other physical data associated with fracture analysis are described and interpreted on pp. 20-30.

When presently juxtaposed and dissimilar lithic sections are restored to their approximate geographic position at time of deposition, it suggests that a relative and cumulative left-lateral displacement of about 4 miles (6.4 km) has taken place within the Graingers wrench zone, normal to the trend of its structural axis.

Similarly, a maximum vertical displacement of about 80 feet (24 m) between relatively up and down segments is recognized within the wrench zone. Recognition is based on the altitude, relative to mean sea level, of the Navarroan-Midwayan contact as determined at numerous exposures and in shallow core holes.

At the surface, Navarroan and Midwayan rocks are the principal rocks displaced. The youngest rocks displaced by faulting may be Claibornian judging from the distribution of their erosional remnants in the area.

Due to the absence of folds or of a recognizable fault geometry more complex than that associated with the scissoring that has taken place along the bounding shear planes of the individual slices and wedges in the structural mosaic, we assume that relative lateral movement within the Graingers wrench zone was parallel, as in simple wrenching, and that it probably did not involve either convergent or divergent wrenching.

PREVIOUS WORK

In 1973, field investigations of several days duration were conducted in Craven and Lenoir Counties, N. C. to determine the distribution of exposures of Paleocene rocks, previously described as the Beaufort Formation in the subsurface (Brown, 1959) and first described by Wilson and others (1972, p. A129) as cropping out along Mosley Creek where it forms a boundary between the two counties.

The writers, together with Harlan Bergquist and Druid Wilson, U.S. Geological Survey, delineated an outcrop pattern for Navarroan, Midwayan and Clairbornian rocks that suggested the presence of a wrench zone.

In 1973-74, the Pennsylvania Glass Sand Corporation, Berkeley Springs, West Virginia, drilled eighteen shallow core holes in parts of Craven and Lenoir Counties to evaluate the distribution, thickness and sorptive properties of the mudstone. The company kindly made the cores available to the writers for use in this study.

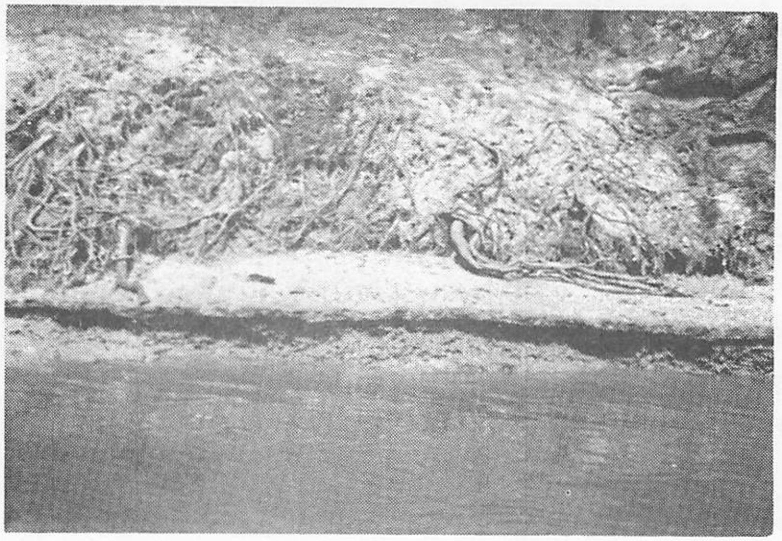
Stephenson (in Clarke and others, 1912, p. 157-58) apparently was the first to recognize and describe the occurrence of thin-bedded shales overlying the Cretaceous in the Kinston-Mosley Creek area and he considered the shale at one locality . . . "to occupy a basin-like depression in the undulating surface of the Cretaceous." Richards (1950, p. 16), with apparent reference to the same section and locality described by Stephenson, referred to the shale as somewhat resembling "Fullers earth". Previously, a shale section was logged between the depths of 4 and 32 feet (1.2 and 9.8 m) in a water well at the E. I. DuPont de Nemours and Company plant near Graingers (Brown, 1958, p. 31) and was included in the Upper Cretaceous. Subsequently, shale has been penetrated in other water wells and in foundation borings at the plant site (see table 2, p. 47).

Swift and Heron (1969, p. 229, fig. 23) recognized siliceous mudstone at one exposure (West Landing, Neuse River) in the Graingers area. They considered it to be a small outlier of the Black Mingo Formation, a South Carolina stratigraphic unit, in part (Gardner and Bowles, 1939, p. 194) of Paleocene age. However, the section described and illustrated by Swift and Heron is not the section exposed at West Landing (fig. 3). Instead, it most probably is downstream from West Landing and at or near the location of the section described previously by both Stephenson (1912, p. 157-58) and Richards (1950, p. 16), judging from its description and from its position relative to the water level in the river.

In previous work it was recognized that the structural alignments shown in figure 2 mirror many of the basic structural alignments of a regional structural configuration recognized and described previously by Brown and others (1972, pl. 1). In effect, the local structural configuration appeared to represent a modified field-scale example of the regional configuration associated with a first-order tectonic stage. In both cases, the genetic association was with wrenching and with relative left-lateral displacement along northeast trending shear zones having an en echelon arrangement.

From previous work we had determined that, in part, the Midwayan rocks comprise black- to light-gray, massive- to thin-and sometimes rhythmically-bedded siliceous mudstone. The mudstone, indurated and of relatively low density in contrast with other rock types that crop out locally, was physically distinct. The mudstone was a marine volcaniclastic. It consisted of volcanic ash admixed with clastics and with marine biogenic elements. The mudstone comprised a readily identifiable "marker"

a.



b.

Figure 3. West Landing, southeast bank of Neuse River, Lenoir County, N. C. Locality: NC-LEN-O-4-73.

a. Siliceous mudstone ledge, Jericho Run Member of the Beaufort Formation; view is upriver.

b. Indurated siliceous mudstone and conglomerate (Jericho Run Member of the Beaufort Formation) in disconformable contact with underlying friable sandy clay (Peedee Formation). Contact is one foot (0.3 m) above water level and 7.5 feet (2.2 m) above mean sea level.

horizon that could be used to map structure. As determined by chemical analysis and light microscopy, the mudstone contained a high percentage of opaline silica (disordered cristobalite, oral commun., F. M. Swain, 1975) and locally had the sorptive properties of "Fullers earth". The presence of disordered cristobalite suggested that the rock was similar lithologically to that described by Wise and others (1974) in the southeastern states. A chemical analysis of a representative sample of the mudstone is given in Table 1.

Table 1. Chemical analysis of siliceous mudstone, Beaufort Formation, Lenoir County, North Carolina. Locality No. NC-LEN-0-5-73 (fig. 1).
(Analyzed by the North Carolina State University Minerals Research Laboratory, Asheville, N. C.)

SiO_2	89.0	percent
Al_2O_3	4.8	
Fe_2O_3	0.54	
CaO	0.56	
MgO	0.25	
Na_2O	0.29	
K_2O	0.31	
TiO_2	0.26	
Mn	0.002	
LOI	3.95	
Total	99.962	

STRATIGRAPHY

When stratigraphic data from drilling by the Pennsylvania Glass Sand Corporation was interpreted as providing additional evidence for the presence of a wrench zone, a more detailed core drilling program was conducted by the U.S. Geological Survey in cooperation with the North Carolina Department of Natural and Economic Resources. Thirty-eight shallow sections were cored and geophysical logs obtained for the core holes in a program designed to further delineate the wrench zone and its diagnostic structures.

In the Graingers area, recognition of structural patterns is dependent, in part, on recognition and interpretation of anomalous stratigraphic associations and their spatial distribution. The following discussion is limited in scope to the level required for recognition of local stratigraphic associations and interpretation of the structural concepts presented herein.

Rocks of Navarroan, Midwayan and Claibornian age are exposed discontinuously along the Neuse River and along Mosley Creek and other tributaries of the Neuse in the Graingers area. The Navarroan rocks are overlain unconformably by Midwayan rocks. They, in turn, are overlain unconformably by Claibornian rocks. These rocks are designated locally as the Peedee Formation (Upper Cretaceous, Navarroan), the Beaufort Formation (Paleocene, Midwayan) and the Castle Hayne Limestone (Eocene, Claibornian). The three formations have contrasting lithologies, and, thus, are readily recognized and separated in the field. Patterns of variance in their spatial distribution help to establish and delimit the wrench zone. Fluvial surficial deposits form a thin discontinuous blanket throughout the area.

Peedee Formation

The Peedee Formation is composed chiefly of olive-gray (5Y4/1) calcareous quartz sand, very fine- to medium-grained, angular to subrounded and moderately sorted, in a clayey silt matrix. Commonly, the accessories include mica, lignite, marcasite, glauconite and phosphorite. In combination, the occurrence of these accessories was estimated to range from a trace to about 25 percent in some 20 samples of about 250 grams each that were obtained from a number of exposures and examined. The formation usually contains scattered shells. Locally, the shells may be concentrated in indurated layers that are intercalated with limy sand or sandy-lime lenses and pods. Less commonly, comminuted shell material may be present in sufficient quantities so that the rock is a friable shell hash. In general and following the classification of Paull (1962), the rock would be classed as moderately hard, but it can range from extremely hard to very friable locally.

In the Graingers area, the Peedee Formation has a maximum thickness of about 25 feet (7.6 m) at the surface and a combined surface and subsurface thickness of about 120 feet (36.6 m). The subsurface distribution and thickness of the Peedee Formation in North Carolina is incorporated in regional maps that show the distribution and thickness of Unit A, the subsurface Navarroan chronostratigraphic unit that includes the Peedee Formation in the middle Atlantic States (Brown and others, 1972, pl. 14).

Exogyra costata Say and *Flemingostrea subspatulata* Forbes, considered by Stephenson (1923, p. 48) to be a species restricted to the Peedee Formation (Navarroan) in the Carolinas, occur commonly at key exposures of this formation in the project area. Also, and according to Druid Wilson (oral commun., 1975) the age definitive Cretaceous oyster common at the DuPont airstrip locality (NC-LEN-O-10-73) is *Pycnodonte mutabilis* (Morton), (as *Gryphaea vesicularis* Lamark by Stephenson). In addition, representative Ostracoda and Foraminifera listed by Brown and others (1972, p. 45) as being characteristic of Unit A of Navarroan age in the subsurface, occur abundantly to commonly in the Peedee Formation both in surface exposures and in cored sections.

Richard Benson studied the planktonic and benthonic foraminiferids obtained at one locality (NC-CR-0-7-72) which is described in this report (p. 35) and judged by us to be representative of the Peedee Formation in the Graingers area. According to Benson's preliminary analysis of the planktonic foraminiferal assemblage present in a sample from this locality (unpublished micropaleontologic project report, 1975), the assemblage . . . "is consistent with that of the Rugotruncana subpennyi Zonule (early Navarroan) of the R. subcircumnodifer Subzone of the Globotruncana fornicata-stuartformis Assemblage Zone" . . . of Pessagno (1967).

Rocks judged to be representative of the Peedee Formation in the Graingers area are exposed at the following localities (fig. 1) described in the basic data section of this report:

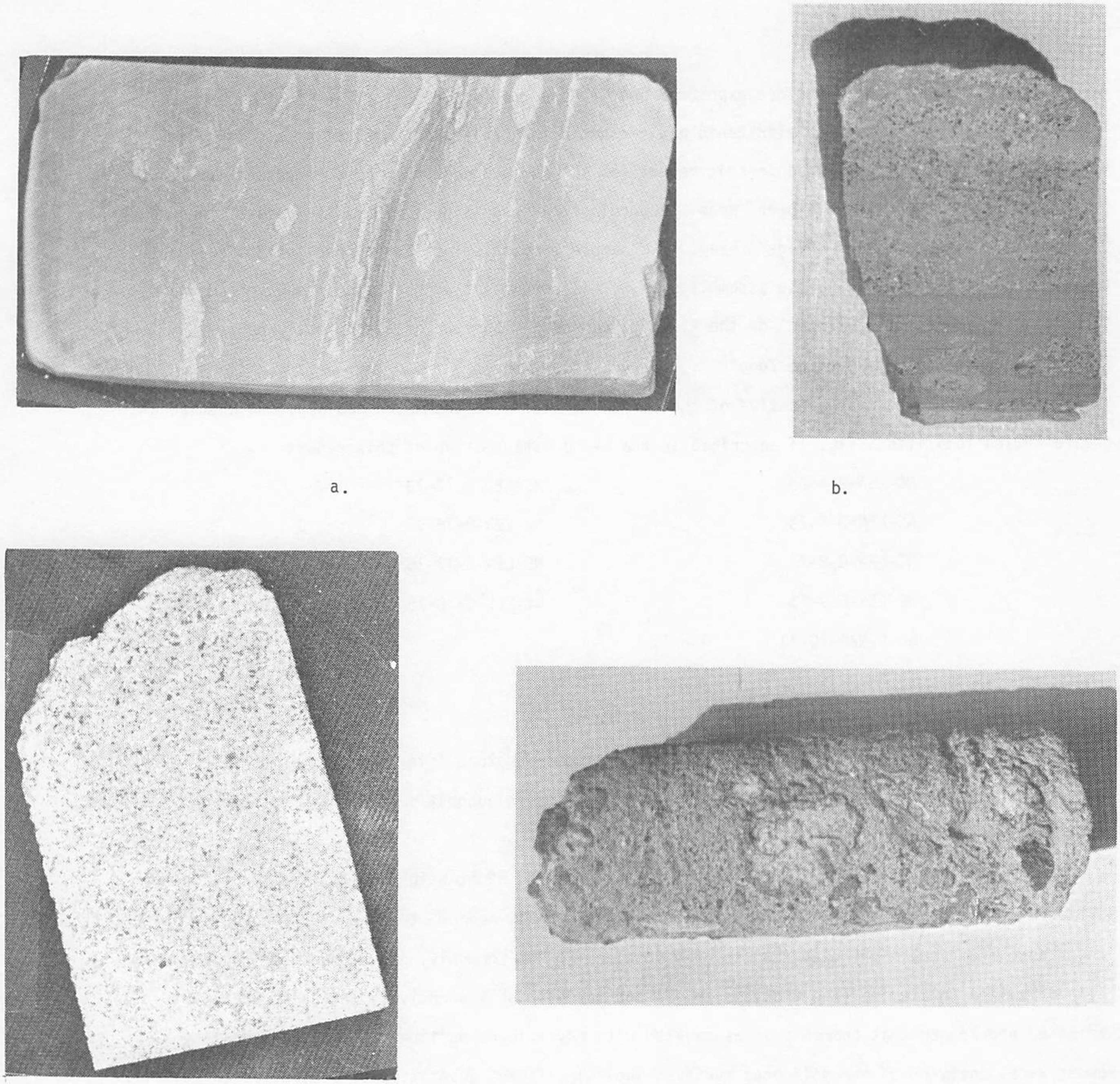
NC-LEN-0-4-73	NC-LEN-0-12-73
NC-LEN-0-7-73	NC-LEN-0-15-75
NC-LEN-0-8-73	NC-LEN-0-17-75
NC-LEN-0-9-73	NC-LEN-0-26-76
NC-LEN-0-10-73	

Beaufort Formation

In the Graingers area the Beaufort Formation includes mudstone (fig. 4a) that intergrades with chert, mudstone-chert intercalated with sandstone (fig. 4b), glauconitic sand (fig. 4c) and phosphatic conglomerate (fig. 4d).

Mudstone is the predominant rock. It is a fine-grained, light-weight silicic rock containing scattered coarse quartz grains of uncertain origin, is chiefly medium- to dark-gray (N4) in color but ranges also from very light gray (N8) to grayish black (N2). Commonly, it is characterized by a high ratio of silica to alumina (see analysis, p. 9) and may be highly sorptive. It has a varved or laminated appearance that commonly is associated with rhythmic deposition. It may be micritic. Powder x-ray analyses of the siliceous mudstone show significant quantities of disordered cristobalite (F. M. Swain, oral commun., 1975). Locally, the mudstone has been altered and transposed to dense vitreous chert, apparently by processes that included the dissolution of silica and its reprecipitation as a cementing agent. Numerous examples of mudstone intergradational with and transitional to chert are present in the field. Following the classification of Paull (1962), the mudstone-chert sequence ranges from extremely hard rock, with a hackly or conchoidal fracture, to friable, fissile-like rock.

The glauconitic sand is a green-gray (5GY6/1) argillaceous quartz sand in which the occurrence of glauconite, that ranges from dark to light green, is estimated (after Terry and Chilingar, 1955) to comprise 10 to 20 percent of the samples examined. Medium-grained, spherulitic, water-polished,



a. b. c. d.

Figure 4. Beaufort Formation, representative lithologies in cored sections.

a. mudstone.

b. mudstone intercalated with glauconitic sandstone.

c. glauconitic sandstone.

d. phosphatic conglomerate.

light-to dark-brown phosphorite is a usual accessory. Commonly, the sand is intercalated with lenses and pods of vuggy, skeletal-micritic limestone. Following the classification of Paull (1962), the glauconitic sand ranges from moderately to very hard at most exposures and in core holes. Scattered macrofossils or layers of macrofossils are prominent. In some samples foraminiferids are estimated to comprise as much as about 40 percent of washed residues in sample fractions between 120 and 200 mesh.

A phosphatic pebble conglomerate may be present at the base of the Beaufort Formation. Where present, it serves as a readily identifiable key bed. It may contain reworked Navarroan sediments and it marks the disconformable contact between the Beaufort and Peedee Formations. The conglomerate is readily recognized at key exposures in the Graingers area and was present in most, but not all, of the project's core holes. It is judged to be a basal transgressive conglomerate. It is mimicked, somewhat, by local, intraformational phosphatic conglomerates associated with diastems in the upper part of the Beaufort Formation.

In the Graingers area the Beaufort Formation of Paleocene age attains a maximum thickness of about 15 feet (4.6 m) at the surface (NC-LEN-O-23-75). In project core holes it had an average thickness of about 19 feet (5.8 m), but ranged from less than 1 (0.3 m) to more than 85 feet (25.9 m) in thickness. Locally, the formation is essentially flat lying. Regionally, the dip is about 11 feet per mile (2.1 m/km) to the east. The subsurface distribution and thickness of the Beaufort Formation in North Carolina is incorporated in regional maps that show the subsurface distribution and thickness of rocks of Midway age in the middle Atlantic States (Brown and others, 1972, pl. 15).

Based on his study of the planktonic foraminiferids from exposures and core holes in the Graingers area, Richard Benson (unpublished micropaleontologic project report, 1975) places siliceous mudstone occurring in the lower part of the Beaufort Formation in the Globigerina daubjergensis - G. trinidadensis Zone (P1) of Berggren (1972). The dominant foraminiferids present in the mudstone are Globorotalia pseudobulloides (Plummer) and Subbotina triloculinoides (Plummer). Its age is early Midwayan (early Danian) according to Benson.

Glauconitic sand that contains the brachiopod Oleneothyris harlani (Morton), as identified by Wilson and others (1972, p. A129), occurs in the upper part of the Beaufort Formation in the Graingers area. On the basis of planktonic foraminiferids, Benson places this glauconitic sand in the basal part of the Globorotalia pseudomenardi Zone (P4) of Berggren (1972). In the glauconitic sand the dominant foraminiferid is Globorotalia aequa Cushman and Renz. It occurs in association with Globorotalia pusilla pusilla Bolli, G. angulata angulata (White), and Subbotina triloculinoides (Plummer). The age of the glauconitic sand is late Midwayan (Thanetian) according to Benson.

The siliceous mudstone and basal phosphatic conglomerate of early Midwayan (early Danian) age, is described and herein named the Jericho Run Member of the Beaufort Formation. It takes its name from Jericho Run, a small stream, tributary to the Neuse River, and located at the base of the Jericho Run fault scarp near Graingers, Lenoir County, N. C. Adjacent to Jericho Run, the type exposure of the member is designated as Project Locality: NC-LEN-0-8-73 (fig. 5a). The map coordinates and summary geographic lithologic description of this type locality are given on p. 39. Among other representative and key exposures of the member are those at Project Localities: NC-LEN-0-5-73 (fig. 5b); NC-CR-0-6-71 (fig. 5c); and NC-LEN-0-15-73 (fig. 5d).

Rocks judged to be representative of the Jericho Run Member of the Beaufort Formation (early Danian) in the Graingers area are exposed at the following localities (fig. 1) described in the basic data section of this report:

NC-CR-0-6-71	NC-LEN-0-9-73
NC-CR-0-7-72	NC-LEN-0-11-73
NC-LEN-0-4-73	NC-LEN-0-15-75
NC-LEN-0-5-73	NC-LEN-0-16-75
NC-LEN-0-7-73	NC-LEN-0-17-75
NC-LEN-0-8-73	NC-LEN-0-23-75

Rocks judged to be representative of the upper part of the Beaufort Formation (Thanetian) in the Graingers area are exposed at the following localities (fig. 1) described in the basic data section of this report:

NC-CR-0-9-73

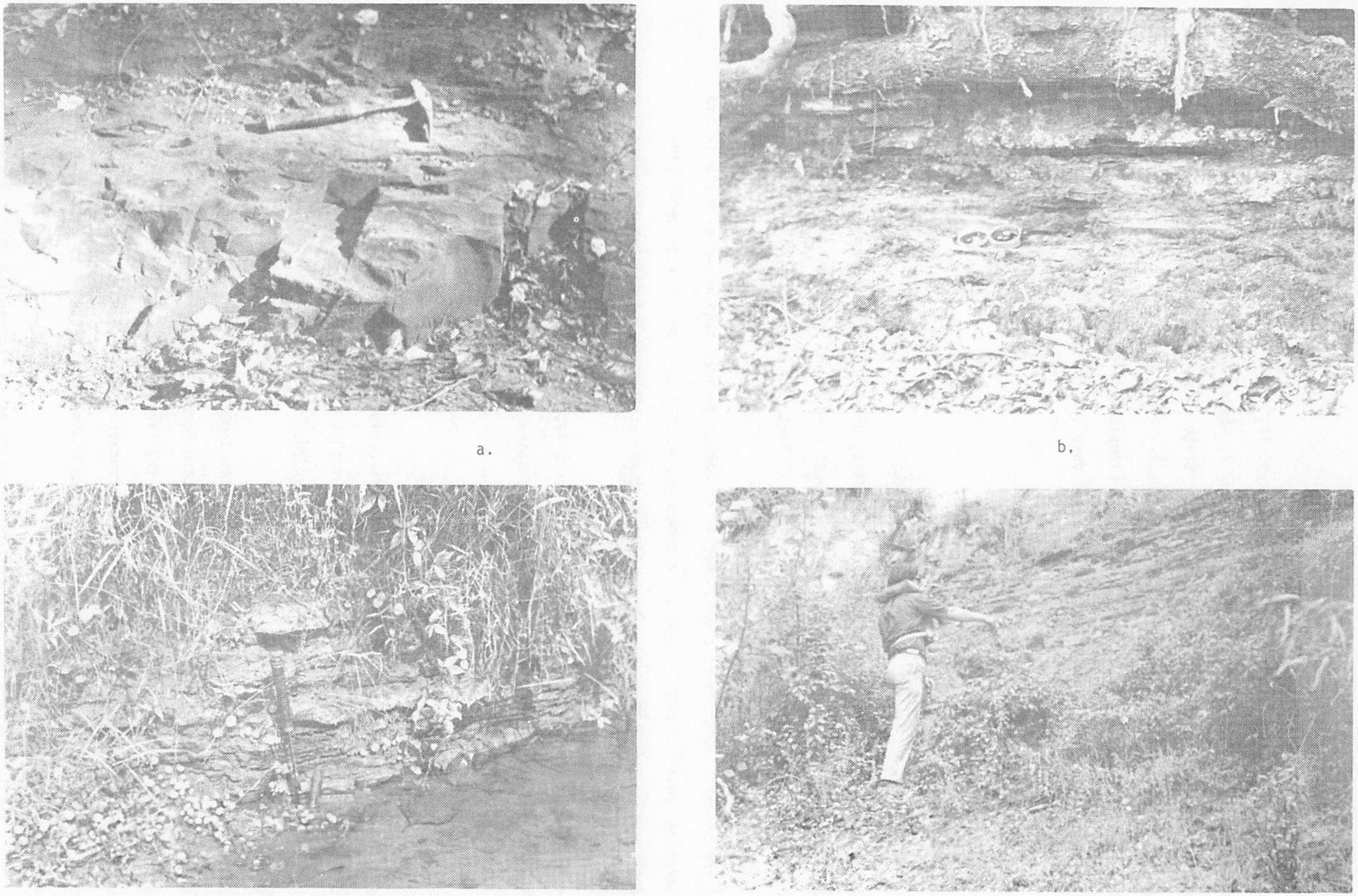
NC-LEN-0-3-72

NC-LEN-0-18-75

Castle Hayne Limestone

Texturally, the Castle Hayne Limestone is a skeletal to micritic-skeletal rock whose color varies from light greenish gray (5GY8/1), to tan (10YR6/1), to buff (10YR8/2). Compositionally, it ranges from a sandy molluscan limestone, consisting of the disarticulated molds and casts of mollusks, set in consolidated or semi-consolidated sandy micrite, to a shell hash, consisting of comminuted bryozoa and molluscan shell debris admixed with quartz sand, clay and micrite. Glauconite and phosphorite, both granular and in the form of moldic and vuggy fillings, are common accessories. Following the induration terminology of Paull (1962), the limestone ranges from friable in some areas to extremely hard in areas where it is silicified.

At the surface in the Graingers area the Castle Hayne Limestone has a maximum recorded thickness of about 8 feet (2.4 m). It may overlie unconformably either the Beaufort Formation or the Peedee Formation. The subsurface distribution and thickness of the Castle Hayne Limestone in the Graingers area is incorporated in regional maps that show the distribution and thickness of rocks of Claiborne



a. b.

c. d.

Figure 5. Representative exposures of flat-lying layers of mudstone of the Jericho Run Member of the Beaufort Formation, in the Graingers area.

a. Locality: NC-LEN-0-8-73

b. Locality: NC-LEN-0-5-73

c. Locality: NC-CR-0-6-71

d. Locality: NC-LEN-0-15-73

age in the middle Atlantic States (Brown and others, 1972, pl. 17).

Species of Ostracoda and Foraminifera listed (op. cit., p. 45) as being characteristic of Clabornian strata in the subsurface in the middle Atlantic States occur commonly in the Castle Hayne Limestone at exposures and in cored sections in the Mosley Creek area.

Rocks judged to be representative of the Castle Hayne Limestone in the Graingers area are exposed at the following localities (fig. 1) described in the basic data section of this report:

NC-CR-0-9-73

NC-CR-0-11-74

NC-CR-0-12-74

Surficial Material

Except in and adjacent to stream valleys where older stratigraphic units are exposed, fluvial surficial deposits blanket the Graingers area. In the project core holes, the material ranged from about 7 to 46 feet (2.1 to 14.0 m) and averaged about 19 feet (5.8 m) in thickness (table 2 and fig. 15).

In general the material consists of clean, coarse- to medium-grained sand mixed with clayey and silty sand. Quartzose gravel or pebble layers are common at or near the contact with underlying units. Buff- (10YR8/2) to tan- (10YR6/6) colored sand that may exhibit graded bedding and cross lamination is dominant.

No fossils indigenous to this unit were recognized. Locally, and adjacent to the contact with underlying marine units the surficial material sometimes contains reworked fossils and clasts of the older units.

STRUCTURE

In the Graingers area the dominant structures are differentially-eroded blocks of sediment. The blocks comprise a structural mosaic of wedges and slices that form graben, half graben and horst. They are arranged en echelon and are judged to be fault bounded. Movements on the faults appear to have combined both translation and rotation.

The discussion that follows consists of two interrelated segments. In the first segment, evidence for faulting in the area is discussed. In the second segment, geometric elements of the structural mosaic are examined and a mechanical origin for the faulting is synthesized. The synthesis, wherein the stresses are inferred from the deformations observed in the field, is based on fracture analysis, the analysis of core-geometry, and on structural interpretation of stratigraphic data obtained from core holes and exposures.

The prevailing structural mosaic in the Graingers area appears to represent a deformational response to rotational forces, operating in a horizontal plane, acting counterclockwise, and having vertical resultants. Wrenching is judged to have occurred in a zone whose axis strikes about N. 25°-30° E. and lies athwart the Neuse River in the vicinity of West Landing (fig. 1).

Evidence for Faulting

In the Graingers area, and as would be expected in relatively unconsolidated sediments located at or near sea level, the evidence for non-current faulting is indirect. Actual slip planes, along which relative movement occurred, have not been recognized at the surface. This is not surprising inasmuch as the slip-plane locales would be expected to comprise highly-erodible zones of relative weakness within the rock framework of the area. As used in this report, slip planes are a pair of planes (surfaces) between which relative movement occurs. The relative vertical positioning of graben and horst blocks is readily discernible in the field on the basis of lateral offsets and of abrupt change in the vertical positioning of a contact between flat-lying Navarroan and Midwayan rocks. We consider the graben-horst terrane in the Graingers area to constitute prima facie geometric evidence of faulting. However, there is other and varied supporting evidence that points to the occurrence of faults in the area.

A NE.-SW. trending scarp borders Jericho Run on the northwest and extends from near the DuPont plant, east of Graingers, to the grounds of the Rochelle Boulevard School in the city of Kinston (fig. 1). In terms of its relative relief, it is the dominant topographic scarp in the Graingers area. At various points on the scarp, where we measured a difference in elevation between its crest and its base, the relief averages 44 feet (13.4 m). From near the DuPont plant, to the site of the Rochelle Boulevard School and its environs, a distance of about 7.5 miles (12 km), the scarp is capped, discontinuously, with interlayered mudstone and sandstone of the Beaufort Formation. The Peedee Formation is exposed intermittently along the scarp face, and in and along Jericho Run, which flows at the base of the scarp along part of its extent. Throughout its extent, the scarp is associated with features that commonly are recognized as being diagnostic of fault scarps. They include:(1) the presence of a key, relatively-uplifted, stratigraphic-marker horizon;(2) triangular faceting (apex up) of the scarp;(3) the development of extensive parallel ravinement normal to the scarp trend, together with a concomitant parallelism of the interravine areas, and;(4) the occurrence of cataclastic breccia in talus and the development of steep talus slopes along the toe of the scarp. These features can be observed intermittently along the scarp and are most highly developed along that segment commencing from where State Road 1809 crosses Jericho Run and intersects the scarp, and continuing northeastward along the scarp for a distance of about 1.8 miles (2.9 km) in the direction of the DuPont plant which is visible from the top of the scarp (fig. 1).

The key, stratigraphic-marker horizon associated with the scarp is the disconformable contact between the Beaufort Formation and the underlying Peedee Formation. The contact is marked by the presence of a basal, transgressive, phosphatic-pebble conglomerate in the Beaufort Formation. The contact is readily identifiable because of the presence of the conglomerate and the physical contrast between the flat-lying interlayered mudstone and sandstone of the Beaufort Formation and the moderately consolidated clayey sand of the underlying Peedee Formation. The contact is exposed intermittently along the scarp and in ravines that extend back from the scarp face. One of the more visible and striking examples of the exposed contact may be seen at the waterfall, at the type locality of the Jericho Run Member, (NC-LEN-0-8-73, fig. 1). Here, the phosphatic-pebble conglomerate at the base of the Beaufort Formation is a flat-lying layer about 4 inches (100 mm) thick. It forms the resistant lip of the falls. Along the sides of the stream immediately adjacent to the waterfall about 4 feet (1.2 m) of exposed mudstone and sandstone overlie the conglomerate. In turn, the conglomerate rests on a perpendicular face of the exposed Peedee Formation, about 8 feet (2.4 m) thick that forms the backdrop for the falls. The elevation of the disconformable Beaufort-Peedee contact at the waterfall and along immediately adjacent segments of the Jericho Run scarp is 42 feet (12.8 m) above mean sea level.

As an example of the vertical displacements, relative to mean sea level, that characterize the wrench zone in the Graingers area, the vertical position of the lower Midwayan-Navarroan contact at the type locality (NC-LEN-0-8-73) may be compared with its vertical position at another nearby locality (NC-LEN-0-4-73), West Landing, on the Neuse River (fig. 1). At West Landing and at the base of a thin mudstone ledge, the basal phosphatic conglomerate of the Jericho Run Member of the Beaufort Formation forms a nearly flat-lying layer, about four inches (100 mm) thick, that is underlain by the Peedee Formation (fig. 3). Here, the elevation of the key stratigraphic-marker horizon, the Beaufort-Peedee contact, is 7.5 feet (2.3 m) above mean sea level. Thus, the elevation of the contact at the Jericho Run type locality is 34.5 feet (10.5 m) higher than its elevation at West Landing.

Similar comparisons with respect to the vertical positioning of the Midwayan-Navarroan contact may be made using other exposures as well as core hole localities described in this report (fig. 15).

Triangular faceting of the Jericho Run scarp, coupled with extensive ravinement, is evident from field inspection. The individual triangular facets (apex up) are separated by deep, relatively narrow ravines that lie essentially parallel and stand normal to the northeasterly trending scarp. They commence at the base of the scarp and slope steeply up to its top. In a distance of less than 2 miles (3.2 km) along that portion of the scarp, extending from State Road 1809 to the DuPont plant (fig. 1), eight such ravines are present. In the ravines and, intermittently, along the toe of the scarp, talus and talus slopes are present. In addition to containing slabs of Midwayan mudstone and sandstone the talus contains some cataclastic (fault) breccia (see fig. 10c).

The presence of a relatively uplifted stratigraphic-marker horizon in the scarp face, the triangular faceting of the scarp, together with the geometry of its ravinement, the presence of cataclastic breccia in the talus and the development of steep talus slopes provide compelling evidence that the Jericho Run scarp is a fault scarp.

On both sides of the Neuse River there is additional evidence of faulting as well as of a particular style of vertical displacement. On the opposite side of the river from the Jericho Run fault scarp, the evidence includes the change that occurs in the relative vertical positioning of the Beaufort-Peedee disconformity at exposures along the river as related either to the water level or to mean sea level. For example, this may be seen by comparing its relative positioning at two localities along the river: NC-LEN-O-4-73 (fig. 3 and p. 38) and NC-LEN-O-15-75 (fig. 5d and p. 43). As may be observed from a comparative visual inspection of these and other key exposures along and adjacent to the Neuse River, the flat-lying disconformity will be exposed for up to a mile (1.6 km) or more and will then be abruptly cut off and terminated. Some distance downstream it will reappear abruptly, be flat-lying, have either a relatively uplifted or depressed attitude with reference to both upstream and downstream exposures, and again extend for a distance of up to a mile (1.6 km) or more before terminating abruptly. Although no slip planes are visible at these abrupt cut-off or terminating points, the stratigraphic relations dictate their presence beneath the soil cover. The style of vertical displacement is step-like. It is characteristic of block faulting in horst-graben terrane. Although many earlier workers have referred to the Cretaceous surface as being undulating and, thus, implied that its relief was wave-like, we see no evidence to support this interpretation in the Graingers area with respect to the geometry of the Navarroan-Midwayan contact. In fact, the presence of a well developed transgressive conglomerate at the base of the overlying Beaufort Formation argues against such an interpretation. Instead, the presence of the transgressive conglomerate, whose deposition required a relatively long period of geologic time, supports the concept of a long-term planing action by the Beaufort sea that would have leveled the top of the soft underlying Cretaceous rocks.

In the Graingers area the style of vertical displacement is judged to be step-like and not wave-like. Additional evidence for this style of vertical displacement can be seen along Mosley Creek where flat-lying mudstone at locality NC-CR-O-6-71 (fig. 5c) terminates abruptly and is replaced in outcrop a short distance downstream by clayey sands of the Peedee Formation at locality NC-CR-O-7-72 (fig. 1). Surficial material occupies the downstream interval between the two exposures. Similarly, the flat-lying Midwayan mudstone, as recorded at locality NC-CR-O-6-71, extends upstream along Mosley Creek for a distance of about a mile (1.6 km) where it again is terminated abruptly and is replaced a short distance upstream by an exposure of clayey sand of the Peedee Formation. Again, surficial material occupies the upstream interval between the two exposures. Interpretation of core drilling data indicate that the slip planes, judged to lie at either end of the mudstone layer exposed along Mosley Creek, strike about N. 30° E.

To further illustrate the nature and magnitude of the relative vertical displacements that characterize the Graingers wrench zone locally, the depth, relative to mean sea level, and the thickness of stratigraphic units encountered in project boreholes are listed and plotted (table 2 and fig. 15) in the basic data section of the report.

Currently (1977), the Division of Earth Resources, North Carolina Department of Natural and Economic Resources, is preparing structure maps, isopachous maps and structural sections as part of an economic mineral survey of the siliceous mudstone in the Graingers area. The maps, sections and other interpretive data of economic interest will be published in a forthcoming State report.

Fracture Analysis

Fracture analysis is a useful tool for evaluating the possible nature of external forces that produce deformations observed in the field. In part, inferences and conclusions drawn from such analyses are derived from comparison with the action of directed forces and the resultant deformations observed in the laboratory. Because fractures and wrench zones occur together in predictable geometric association (Wilcox and others, 1973, p. 79) the field presence of one may be used to predict a location for the other.

At most exposures where the Midwayan mudstone crops out in the Graingers area, it is highly fractured. The fractures are tectonic and are of two general types; a systematic type that has parallel linear expression and a nonsystematic type that has both linear and arcuate expression (fig. 6).

Among the systematic linear fractures observed, two intersecting sets appear dominant. From field measurements, we judge their average strike to be about N. 15° E. and N. 60° W., respectively. Both sets appear to be of the same age. On balance, neither set appears to have developed preferentially, even though one set or the other may appear to have done so when viewed at a single exposure (for example, the northwest set at NC-LEN-0-4-73 and the northeast set at NC-LEN-0-8-73). The linear systematic sets (fig. 7a) are especially well defined in the mudstone ledge exposed at West Landing (NC-LEN-0-4-73, fig. 1) where one fracture from each set forms the X-pattern (conjugate wedge) characteristic of intersecting fractures (fig. 7b).

The two sets are judged to be conjugate shear fractures, Riedels and conjugate Riedels, respectively. Where measured in the field, the dihedral angle (conjugate shear angle) has an average value of about 75 degrees. The bisector of the dihedral angle, the maximum compressive stress axis, has a strike calculated to be about N. 22° W.; a strike that is consistent with that of a third less-pronounced set of linear fractures recognized in the mudstone, and which we consider to be

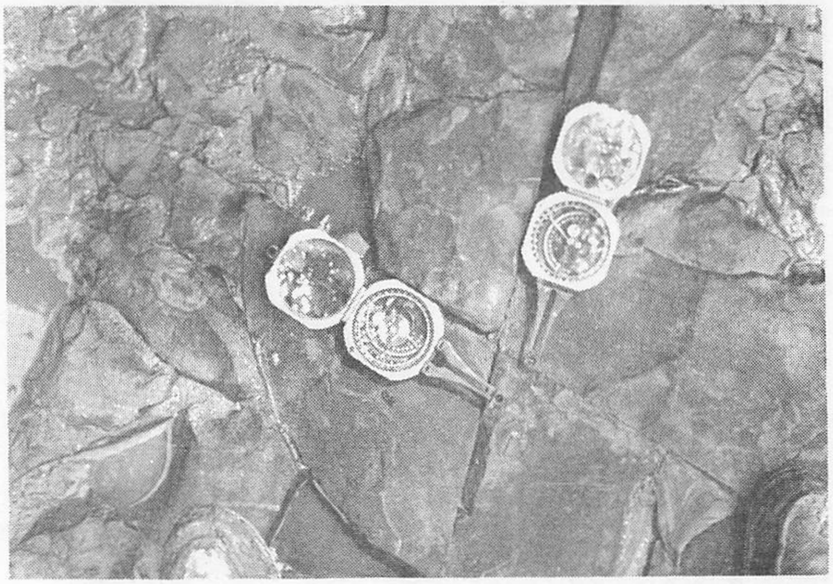


Figure 6. Linear and arcuate fractures in siliceous mudstone.

Locality: NC-LEN-0-4-73

a.

b.

Figure 7. Fracture patterns, West Landing. Locality: NC-LEN-0-4-73

a. linear fracture sets.

b. conjugate "X" formed by intersecting fracture sets.

extension fractures. The observed fracture geometry could have developed in response to straight compression, to tension, or to the action of either right-lateral or left-lateral couples. However, when the fracture geometry is considered in conjunction with the right handed en echelon arrangement of juxtaposed Navarroan and Midwayan rocks in alternate, narrow, northeast-striking bands in the Mosley Creek area, only a couple that exhibits a relative sense of left lateral displacement in a zone trending N.E.-S.W., will satisfy both the fracture geometry and the observed en echelon pattern. Consistent with the relative sense of lateral displacement recognized in the area, the northeast striking fractures are judged to be low-angle (synthetic) Riedels, whereas the northwest striking fractures are judged to be high-angle conjugate (antithetic) Riedels.

Assuming that a low-angle synthetic fracture set would intersect a wrench zone at an angle of between 10° and 30° (Wilcox and others, 1973, p. 79), the synthetic set that strikes N. 15° E. should intersect a wrench zone whose strike lies between N. 25° E. and N. 45° E. (fig. 8a). Assuming that the high-angle antithetic fracture set would intersect a wrench zone at an angle of between 70° and 90° (op. cit., 1973, p. 79), a antithetic set that strikes N. 60° W. should intersect a wrench zone whose strike lies between N. 10° E., and N. 30° E. (fig. 8b). Insofar as the fracture geometry is concerned and if both assumptions are satisfied equally, a wrench zone associated with the synthetic and antithetic fracture sets present in the Mosley Creek area should have a strike of between N. 25° E. and N. 30° E. (fig. 8c). This was one of the factors considered in determining the location of the core holes that were drilled to help define the geometry of the wrench zone.

If the maximum compressive stress axis (N. 22° W.), that bisects the dihedral angle formed by the dominant intersecting fracture sets in the Graingers area, is considered a reoriented stress axis (a second-order derivative of a meridional stress axis), a synthesis of mechanical relations may be diagrammed (fig.9) that incorporates local structural elements with published concepts of regional tectonics and structure. The synthesis utilizes McKinstry's (1953) concept of the derivation of shears of the second order. It incorporates the concept of a N-S alignment of regional stress, the alignment for a primary compressive-stress axis inherent in the Moody and Hill (1956) wrench-fault hypothesis. It is compatible with and incorporates the geometry of the tectonic-structural model (first-order tectonic stage) for the Atlantic Coastal Plain proposed by Brown and others (1972, pl. 1). Our diagram is similar in nature to that drawn by Badgley (1965, fig. 7-8), who, incorporating the concepts of McKinstry (1953), diagrammed a reorientation of stress so as to generate second-order shears in an adjoining block in connection with discussion of Precambrian strike-slip faulting, Yellowknife district, Northwest Territory, Canada.

In our diagram the strike of the Graingers wrench zone and the sense of relative lateral displacement that characterizes it are dependant upon the orientation of a second-order stress axis whose strike, calculated by means of fracture analysis is about N. 22° W. The orientation of the

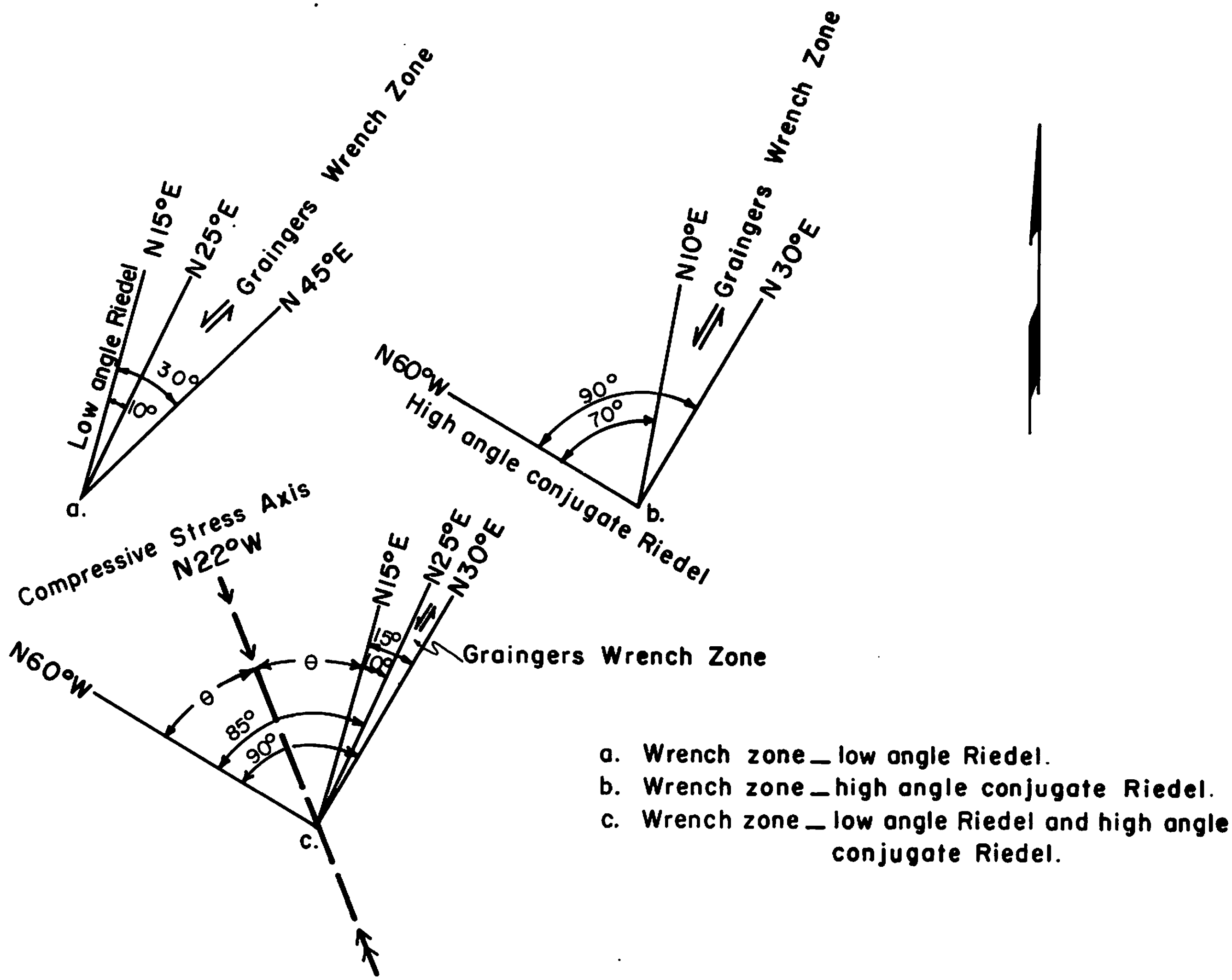


Figure 8. The suggested orientation of the Graingers wrench zone derived from fracture analysis.

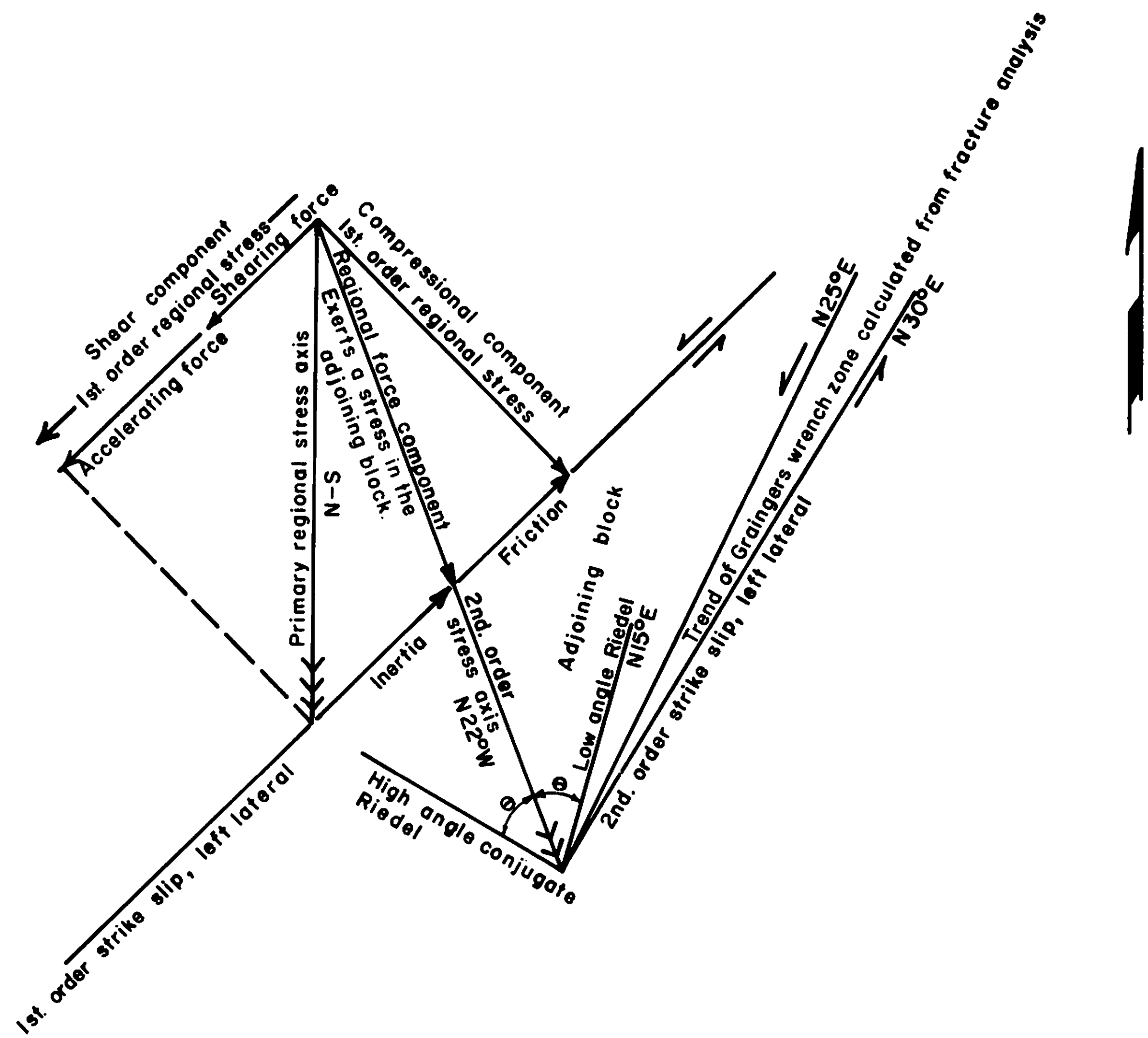


Figure 9. Synthesis of the mechanical origin of the Graingers wrench zone.

second-order stress axis in the adjoining block is derived from the orientation (N-S) of a regional primary stress axis and from the relative values of inertia and friction along a first-order left-lateral shear zone that stands at an angle of about 40 to 45 degrees to the primary stress axis. This alignment for shear zones of the first-order in the Atlantic Coastal Plain was suggested by Brown and others (1972, pl. 1) following study of the geometry of the regional sediment mass.

In addition to the presence of linear, systematic shear and extension fractures, non-systematic fractures that form arcuate as well as wedge-shaped patterns (fig. 10) are present in siliceous mudstone and sandstone of the Jericho Run Member of the Beaufort Formation at a number of exposures. One of the more striking examples of this type of fracture pattern (fig. 11) occurs at the type locality of the member (NC-LEN-O-8-73), and may be seen in the floor of the flume about 100 feet (30 m) above the falls. Key elements of this fracture pattern, shown in figure 11, are diagrammatically illustrated in figure 12. Similar patterns are present in cores that have been recovered from the Jericho Run Member.

The diagram (fig. 12), which may appear complex in detail, is relatively simple in principle. It combines the effects of failure in compression, and consequent failure in torsion, with failure in simple loading as follows:

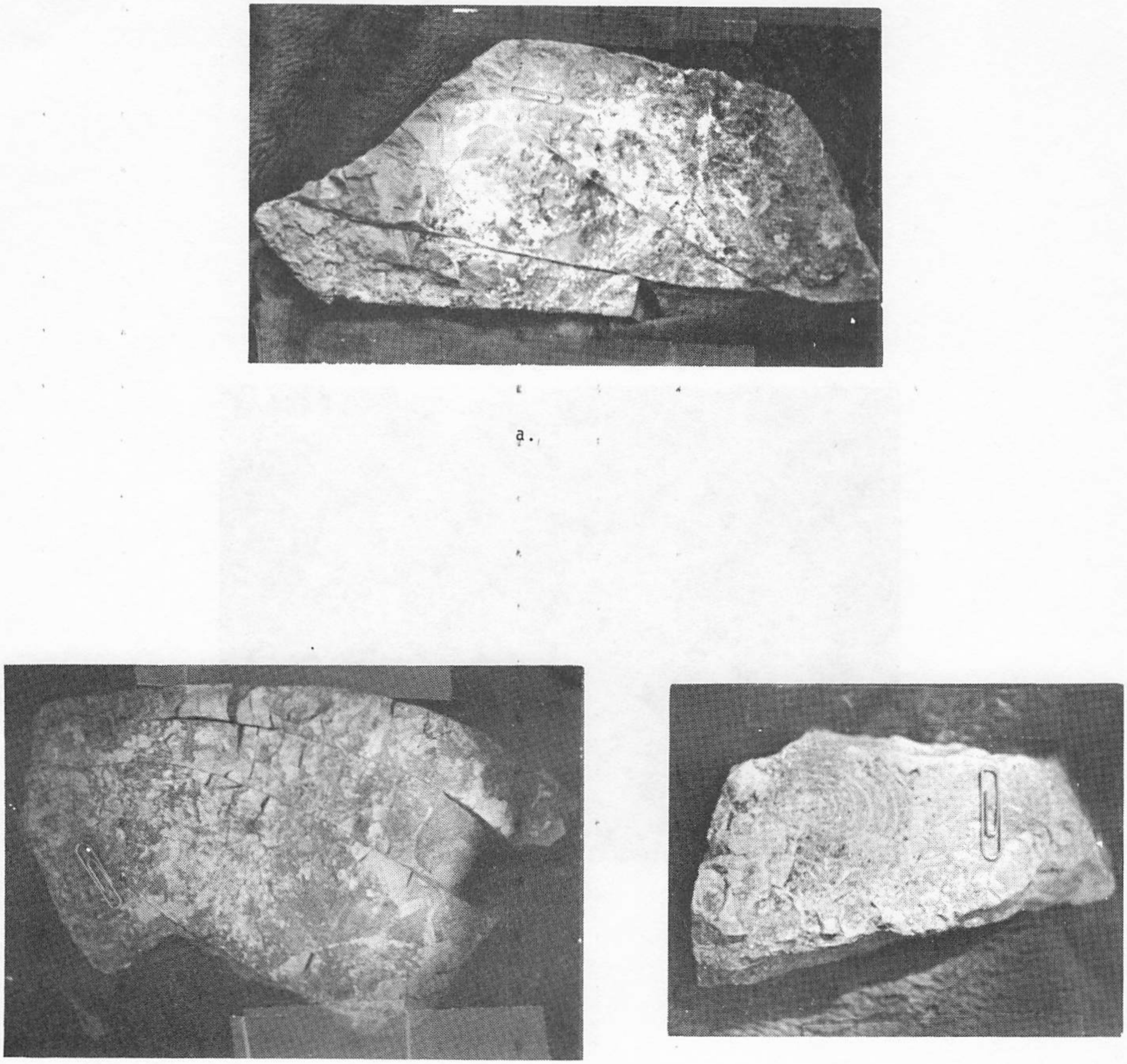
1. The arc- and wedge-shaped fractures developed in response to failure in compression and (or) counterclockwise rotation, and consequent failure in torsion.

2. The second-order force component (regional load) and the high angle conjugate Riedel (local load, Graingers wrench zone) may be considered line loads; fracture analyses suggest that both have operated as such.

3. The sets of arcuate fractures that abut a common plane of shear (or shear-direction) at points of maximum inflection and which terminate, individually, along parallel tension fractures suggest failure in simple loading. The sets of arcuate fractures approximate the form of a stress envelope. Subsequent to failure, counterclockwise rotation has resulted in right-lateral slip along the high angle conjugate Riedels, as shown by offsets at the apices of the arcs. In response to rotation and compression-wedging, fractures aligned in the direction of the high angle Riedels become sine-shaped locally and approximate a hysteresis pattern.

4. Regional rotation about a vertical axis results in deformation of the low angle faults. Manifest in such deformation and for left lateral movement, are S-shaped fault or fracture patterns, the arcs of the "S" pointing toward the direction of displacement. Continued movement along the synthetic faults has resulted in attenuation of the S-shaped patterns and, finally, their separation by shear. The magnitude of deformation ranges from a few millimetres to field-scale.

Some cores of indurated mudstone exhibit an arrangement of crests and troughs (figs. 13a and 14a) that we believe to indicate a shifting in the position of constituent material subsequent to



a.

b.

c.

Figure 10. Arcuate and wedge-shaped fracture patterns preserved in rocks from the Jericho Run Member of the Beaufort Formation.

a. glauconitic sandstone, Locality: NC-LEN-0-17-75

b. siliceous mudstone, Locality: NC-LEN-0-5-73

c. cataclastic breccia, Locality: NC-LEN-0-9-73

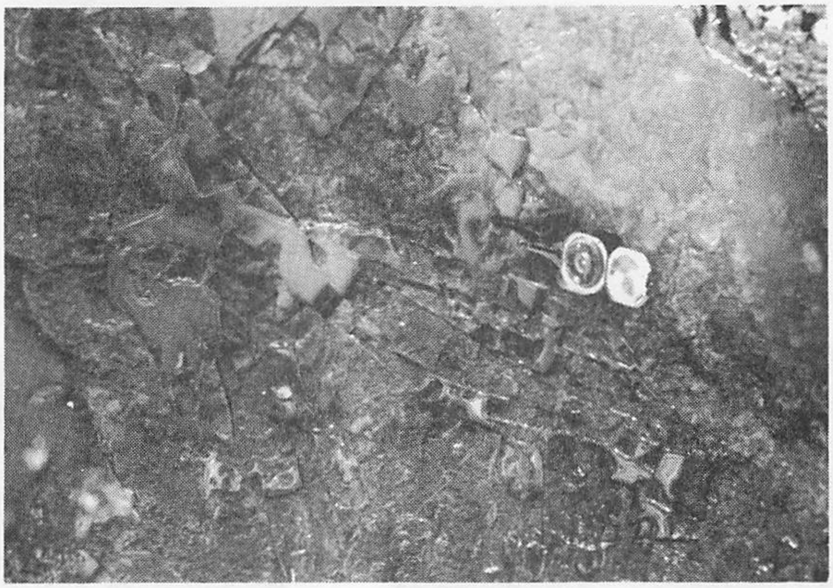


Figure 11. Arcuate and wedge-shaped fractures preserved, in situ, in the Jericho Run Member of the Beaufort Formation.

Locality: NC-LEN-0-8-73

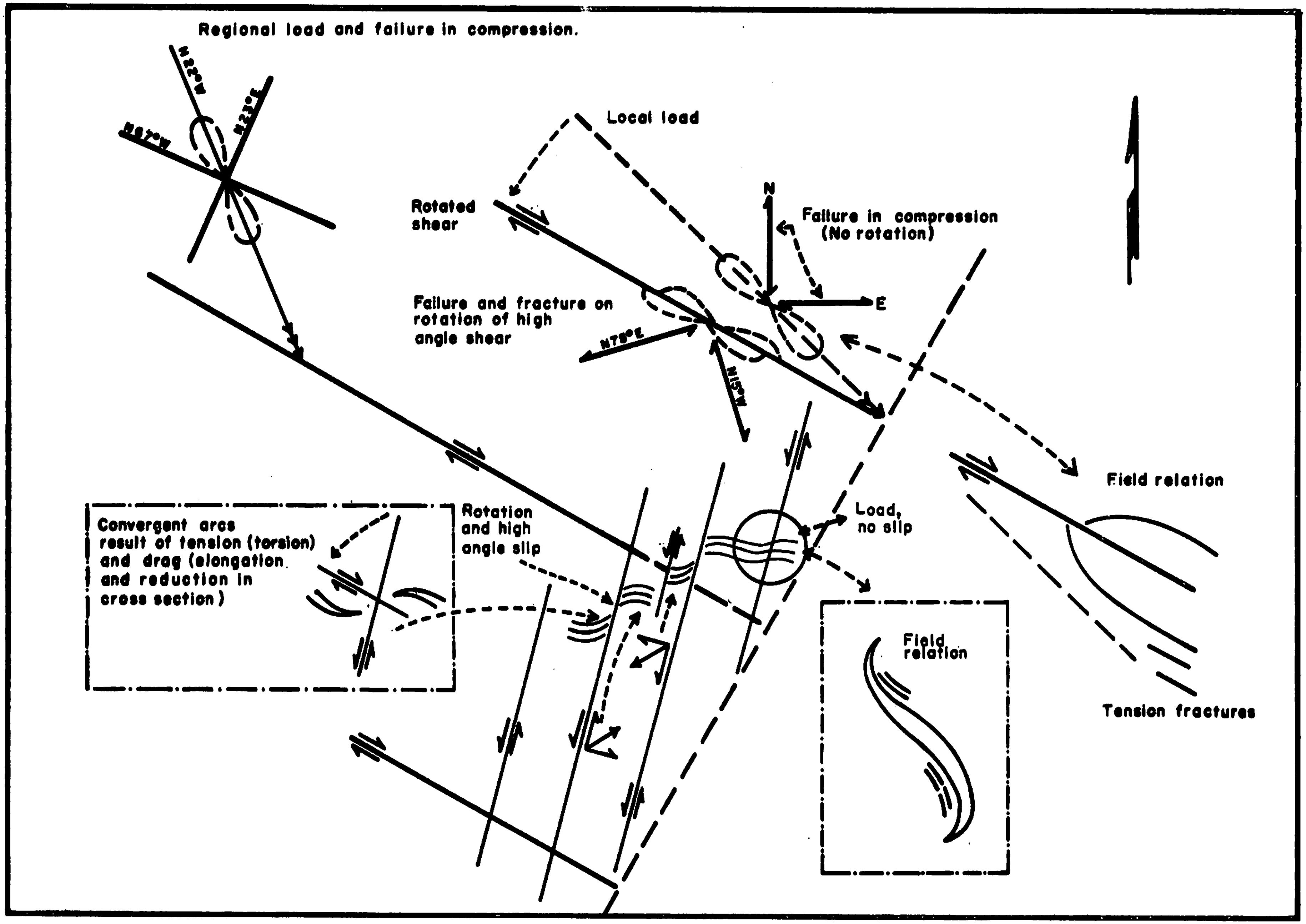


Figure 12. Diagrammatic sketch and analysis of fracture pattern shown in Figure 11.

deposition (plastic flow). In many cases the crests and troughs form arcuate and wedge-shaped patterns analogous to the fracture patterns that occur in outcropping sections of the Jericho Run Member. We consider the geometric arrangement of the crests and troughs, or twisted striae (figs. 13a and b and 14a and b), to be prima facie evidence of rotation, failure in torsion, and consequent shear. Displacement of the striae (offset of individual crests and troughs), the development of "ball and socket" horizontal joints, jamming of the S-shaped or arcuate striae, and the presence of wedge-like arc ends are considered deformational signatures of wrenching and diagnostic of a wrench zone in the Graingers area.

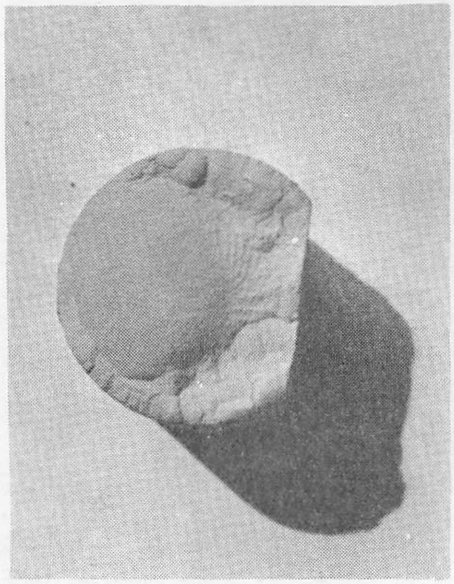
The occurrence of brecciated or shattered mudstone in cored sections as well as in outcrop is common in the Mosley Creek area. Such sections are present in core holes located on both sides of the Neuse River. For example, a brecciated mudstone occurred between the depths of +19.5 and -4.5 feet (+5.9 and -1.4 m) (MSL) in a core hole (NC-LEN-C-24-74, fig. 1) located on the R. E. L. Johnson, Jr. farm south of the river. Similarly, brecciated mudstone was penetrated between the depths of +53.0 and +23.5 feet (+16.2 and +7.2 m) (MSL) in a core hole (NC-LEN-C-37-74, fig. 1) on the Mrs. Ruby McArthur property north of the river. In addition, and at several core-hole locations, such as NC-LEN-C-33-74 (fig. 1) the ground was so highly fractured that, during drilling, fluid was returned to the surface in an area six feet (1.8 m) or more in circumference surrounding the core hole.

Low-angle (nearly horizontal) slickensides are present in the core obtained from one drill hole (NC-CR-C-13-74, fig. 1). The slickensides occur in cores of moderately consolidated sandy clay of Navarroan age recovered from between the depths of -13.5 and -18.5 feet (-4.1 and -5.6 m) and -18.5 and -23.5 feet (-5.6 and -7.2 m) (MSL). The Midwayan-Navarroan contact in this core hole is at -11.5 feet (-3.5 m) (MSL).

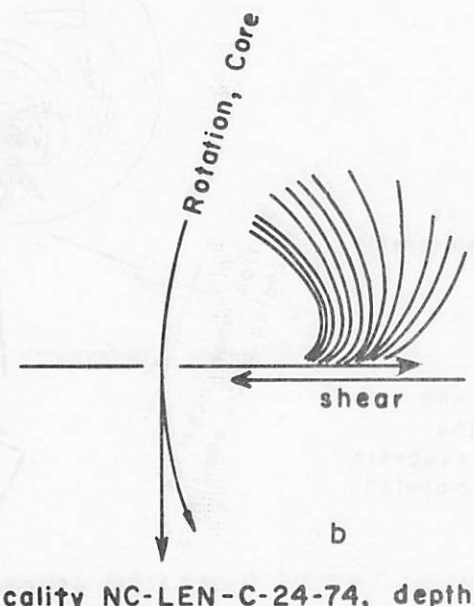
The twisted striae which occur in the cores, the zones of brecciated mudstone and the occurrence of low-angle slickensides are compelling evidence of the torsion and subsequent failure by shear that we judge to have occurred in a wrench zone.

CONCLUSIONS

Interpretation of surface and shallow-subsurface structural and stratigraphic data indicates that a northeast-trending, linear shear zone of tectonic uplift and subsidence, about 15 miles (24 km) wide, is present near Graingers, Lenoir County, N. C. The zone is characterized by a structural mosaic of wedges and slices (horst, graben and half graben) of Navarroan, Midwayan and Claibornian sedimentary rocks that are bounded by high-angle slip planes. The relative lateral and vertical positioning of the wedges and slices, the manner in which they exhibit discordant sediment distribution patterns and the geometry of their fracture patterns constitute deformational evidence that



a.
View of core segment is downhole.



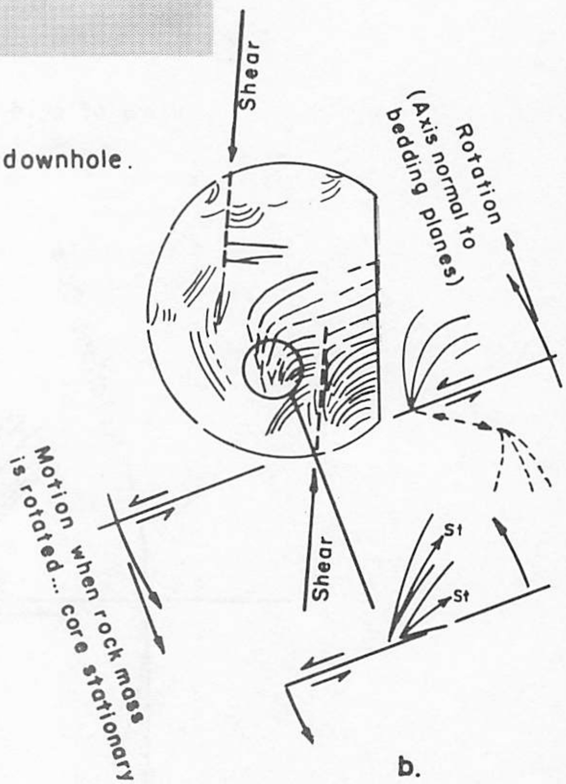
b

a. Core segment (Locality NC-LEN-C-24-74, depth +17 feet (+5.2m) above mean sea level). Note "ball" joint, the result of shear in torsion.

b. Mechanical synthesis.

Figure 13. Deformed core segment of siliceous mudstone and a mechanical synthesis of the stresses that resulted in deformation.

a.
View of core segment is downhole.



b.

NOTES:

a. Core segment (Locality NC-LEN-C-37-74 depth + 49 feet (+14.9 m) above mean sea level).

b. Mechanical synthesis.

1. shape of striae considered priori evidence of rotation.

2. convolved striae have been drawn and jammed in a wedge-like fashion; the "wedging" as well as the "jamming" suggests failure in torsion and folding accompanied by drag in simple shear.

Figure 14_ Deformed core segment of siliceous mudstone and a mechanical synthesis of the stresses that resulted in deformation.

we consider to indicate the presence of a wrench zone.

The geometry of the wrench zone, herein designated the Graingers wrench zone, is characterized by relative left-lateral displacement, by relative vertical displacement, that is predominantly up to the northwest and, less commonly, up to the southeast, and by a right-handed en echelon arrangement of the slices and wedges.

The structural alignments and characteristics of the Graingers wrench zone provide a modified field-scale example that mirrors, and thus supports, the regional tectonic-structural model associated with the first-order tectonic stage described previously by Brown and others (1972, pl. 1).

It is a reasonable geologic assumption that in a region where one wrench zone is present, others exist. Other wrench zones that may be present in the Coastal Plain and contiguous Continental Shelf may have a geometric style similar to that of the Graingers wrench zone. Recognition and study of local as well as regional variance in both the external and internal structural-sedimentary geometry of the regional sediment mass should provide the initial clues to their presence. Because wrench zones comprise linear tectonic zones of uplift and subsidence, they constitute zones that may have significant potential with regard to locating natural traps for the underground storage of waste in sedimentary basins.

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BASIC STRATIGRAPHIC DATA

Localities - Key Exposures

In this report, the county-keyed system of letters and numbers, used to identify key exposures, core holes and stratigraphic tests, is the system used and described previously (Brown and others, 1972, p. 35-36) in regional evaluation of permeability distribution. Locations for the exposures described are shown on figure 1.

Among exposures of the Castle Hayne Limestone, the Beaufort Formation, and the Peedee Formation in the Graingers area, eighteen are considered to be key exposures in that they are judged to have primary or ancillary value for purposes of interpreting local structural conditions. These key exposures are listed and described as follows:

Craven County Exposures

Project Number

NC-CR-0-6-71

Map Coordinates

Lat. 35°19'43" N., Long. 77°25'56" W.

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Land Owner

Mrs. W. B. Pearce

Description: Commencing about one-third mile (0.5 km) upstream from where County Road 1803 crosses Mosley Creek, and extending upstream for about a mile (1.6 km), siliceous mudstone of the Jericho Run Member of the Beaufort Formation crops out at the base of the stream bank along both sides of the channel and is about 1.5 feet (0.5 m) thick. The rock is predominantly a black, thin-layered, siliceous mudstone that contains cherty layers and thin sand partings. It is flat lying, highly fractured, glauconitic in streaks, and ranges from friable to extremely hard. Along this section of the creek, spoil piles thrown by a dragline contain large amounts of the rock that crops out in the dug channel.

Several core holes were drilled along the roadway bordering the segment of the stream channel where the siliceous mudstone crops out. In a representative core hole (NC-CR-C-9A-74, table 2 and fig. 1), the Jericho Run Member has a measured thickness of 17.5 feet (5.3 m), and lies disconformably on the Peedee Formation at an elevation of 12 feet (3.7 m) below mean sea level and is overlain by 17 feet (5.2 m) of surficial material. The planktonic foraminiferid species recovered from the cored mudstone at this drill site indicate that the rock is of early Danian age (early Midwayan) according to Richard Benson (unpublished micropaleontologic project report, 1975).

Project Number

NC-CR-0-7-72

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Peedee Formation

Map Coordinates

Lat. 35°19'47" N., Long. 77°25'36" W.

Land Owner

Mr. J. R. West

Description: Along both sides of the Mosley Creek channel at the Craven-Lenoir County boundary and extending downstream for approximately a half mile (0.8 km) from where County Road 1803 (Lenoir County) and 1475 (Craven County) crosses the creek (fig. 1) as much as an 8 to 10 foot- (2.4 to 3 m) thick section of the Peedee Formation may be exposed at any one time depending upon the level of the water in the channel. The rock is an olive-gray clayey sand that is very fossiliferous. It is glauconitic, phosphatic and friable to moderately indurated.

Disconformably overlying the Peedee Formation and present intermittently along this segment of Mosley Creek are glauconitic clayey sands and siliceous mudstones of the Jericho Run Member up to a foot (0.3 m) or more thick. Overlying the Jericho Run Member of the Beaufort Formation and, where it is absent, the Peedee Formation, are surficial sands and clays that attain a thickness of from 10 to 15 feet (3 to 4.5 m) at places along the creek channel.

Navarroan Ostracoda and Foraminifera, characteristic of the Peedee Formation in the region, are particularly abundant in samples from this locality according to F. M. Swain and Richard Benson (unpublished micropaleontologic reports). Samples from the overlying Jericho Run Member contained a sparse foraminiferid assemblage, of early Midwayan (early Danian) age, and no Ostracoda.

Project Number

NC-CR-0-9-73

Geologic Unit(s)

Surficial material

Castle Hayne Limestone

Beaufort Formation

Map Coordinates

Lat. 35°17'32" N., Long. 77°26'40" W.

Land Owner

Mr. J. H. West

Description: On the northeast (Craven County) side of Mosley Creek and upstream about 0.5 mile (0.8 km) from the point where the State Highway 55 bridge lies athwart the creek, the Castle Hayne Limestone and the Beaufort Formation are exposed along the bank of the creek. The Castle Hayne Limestone, about a foot (0.3 m) thick, lies disconformably on the Beaufort Formation, about 4 feet (1 m) thick, and is overlain by about 9 or 10 feet (2.7 to 3 m) of surficial material.

The Castle Hayne Limestone is predominantly a gray, skeletal-micritic limestone that ranges from moderately to extremely hard. The Beaufort Formation is predominantly a olive-gray, glauconitic clayey sand. The disconformable contact between the units is undulating. It is marked by the presence of a basal transgressive conglomerate in the Castle Hayne Limestone. Phosphorite pebbles up to 1/4 inch (6 mm) in diameter characterize the conglomerate. The elevation of the disconformable contact between the Castle Hayne Limestone and the underlying Beaufort Formation is 22.3 feet (6.8 m) above mean sea level.

At this exposure the Castle Hayne Limestone contains a Claibornian microfauna and the Beaufort Formation, a late Midwayan (Thanetian) microfauna.

Project Number

NC-CR-0-11-74

Geologic Unit(s)

Surficial material

Castle Hayne Limestone

Map Coordinates

Lat. 35°20'01" N., Long. 77°22'47" W.

Land Owner

Mrs. Louise Register

Description: On the south side of the Neuse River, adjacent to the boat landing on the Register property, and extending upstream for a distance of about 200 yards (182 m), the Castle Hayne Limestone crops out intermittently. It is overlain by about ten feet (3 m) of surficial material and extends below river level. Depending upon water level in the river, as much as four feet (1 m) of limestone may be exposed at any one time.

The rock is predominantly a buff-to-tan, skeletal-micritic limestone ranging from moderately to extremely hard. Characteristically, it is riddled with solution channels, some of which are as much as eight inches (200 mm) in diameter. In a core hole (NC-CR-C-11, table 2), located in the field adjacent to the exposure (fig. 1), the Castle Hayne Limestone had a measured thickness of 9 feet (2.7 m) and was in disconformable contact with the Jericho Run Member of the Beaufort Formation at an elevation of 7.5 feet (2.2 m) below mean sea level.

A microfauna, characteristic of the Castle Hayne Limestone in the region, was obtained at this exposure.

Project Number	Map Coordinates
NC-CR-0-12-74	Lat. 35°19'40" N., Long. 77°22'39" W.
Geologic Unit(s)	Land Owner
Surficial material	Mrs. Louise Register
Castle Hayne Limestone	

Description: Boulders, cobbles, and small fragments of Castle Hayne Limestone are scattered around the periphery of a number of abandoned marl pits, now partly filled with surficial material. The pits lie along an unnamed stream in woods that are adjacent, on the left, to a dirt access road that extends from State Highway 55 to a boat landing on the Neuse River.

The exposed rock is predominantly a gray-to-tan bryozoan shell hash. It is sparsely glauconitic and phosphatic and is moderately indurated. A small well-preserved microfauna, characteristic of the Castle Hayne Limestone in the region, was obtained at this exposure.

Lenoir County Exposures

Project Number	Map Coordinates
NC-LEN-0-3-72	Lat. 35°17'41" N., Long. 77°26'47" W.
Geologic Unit(s)	Land Owner
Surficial material	Mr. J. H. West
Beaufort Formation	

Description: Immediately adjacent to the bridge where State Highway 55 crosses Mosley Creek and at the junction of a dug drainage channel and the creek, about 1 to 2 feet (0.3 to 0.6 m) of the Beaufort Formation is exposed along the sides of the creek and along the sides and in the floor of the drainage channel.

The rock is predominantly a olive-gray, glauconitic, clayey sand that is friable to moderately hard in streaks. It contains an abundant microfauna, identified by Richard Benson (unpublished micropaleontologic project report), as late Midwayan (Thanetian) in age.

In a core hole (NC-LEN-C-22, table 2), located immediately adjacent to the exposure (fig. 1), the Beaufort Formation had a measured thickness of 3 feet (0.9 m), was in disconformable contact with the Peedee Formation at an elevation of 17 feet (5.2 m) above sea level, and was overlain disconformably by 11.7 feet (3.6 m) of surficial material.

Project Number

NC-LEN-0-4-73

(West Landing, Neuse River)

Geologic Unit(s)

Beaufort Formation,

Jericho Run Member

(see figs. 3, 7, and 8)

Peedee Formation

Map Coordinates

Lat. 35°19'07" N., Long. 77°28'10" W.

Land Owner

Mr. J. O. Daughety

Description: On the south side of the Neuse River at West Landing, the Jericho Run Member of the Beaufort Formation, the Peedee Formation, and their disconformable contact are exposed where a mudstone ledge (fig. 3), which attains a maximum width of about 16 feet (4.5 m), juts out into and extends along the river for a distance in excess of a quarter mile (0.4 km). The mudstone is a gray-to-black siliceous rock that is moderately to very hard and is generally less than a foot (0.3 m) thick. At its base is a well developed transgressive conglomerate, about 4 inches (100 mm) thick that contains phosphatic pebbles up to one-fourth inch (6 mm) in diameter. The mudstone is characterized by the presence of tectonic fractures, shattered rock and, ubiquitous, "ball and socket" horizontal jointing. The mudstone lies disconformably on olive-gray clayey sand of the Peedee Formation. As much as a one foot (0.3 m) thick section of the Peedee Formation may be exposed at West Landing during a low-flow stage of the Neuse River. At the extreme upstream end of the exposed mudstone ledge, the elevation of the disconformable contact between the Jericho Run Member and the Peedee Formation was determined to be 7.5 feet (2.3 m) above mean sea level.

At this locality the siliceous mudstone of the Jericho Run Member contains a microfauna identified by Richard Benson (unpublished micropaleontologic project report) as being early Danian (early Midwayan) in age. The olive-gray clayey sand, that underlies the phosphatic conglomerate and which is in contact with it, contains an abundant microfauna characteristic of the Peedee Formation (Navarroan) in the region.

Project Number

NC-LEN-0-5-73

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Map Coordinates

Lat. 35°19'54" N., Long. 77°26'52" W.

Land Owner

Mrs. Nina Hill

Description: In a U-shaped ravine extending back from a cut-off meander of the Neuse River, located in woods immediately adjacent to a cleared field and about 500 yards (460 m) directly to the rear of the farmhouse on the Nina Hill property, siliceous mudstone and inter-layered chert of the

Jericho Run Member, crops out on both sides of the ravine and is overlain by about 8 to 10 feet (2.4 to 3 m) of surficial material. In the floor of the ravine and at the upper end of it, the rock forms a series of resistant steps over which the water of two small streams flow. The black to gray rock occurs in flat-lying layers that are alternately soft to extremely hard. About 11 feet (3.4 m) of the siliceous rock is exposed in the ravine and it contains several well-developed sets of tectonic fractures.

In a core hole (NC-LEN-C-1-73, table 2) located immediately adjacent to the farmhouse (fig. 1), the Jericho Run Member has a measured thickness of 14.9 feet (4.5 m), lies disconformably on the Peedee Formation at a depth of 3.1 feet (0.95 m) below mean sea level and is overlain by 22 feet (6.7 m) of surficial material.

Project Number

NC-LEN-0-7-73

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Peedee Formation

Map Coordinates

Lat. 35°19'03" N., Long. 77°30'05" W.

Land Owner

Lenoir County, Road no. 1809, right of way

Description: Where County Road 1809 crosses Jericho Run near Graingers (fig. 1), a combined thickness of about 25-30 feet (7.6-9 m) of the Peedee Formation is exposed in the stream channel at the bridge and in the ditch that borders, on the west, where the road intersects the Jericho Run fault scarp. The formation is a olive-green to grayish-black clayey sand or sandy clay. It is very friable to friable, glauconitic and sparsely phosphatic. The lower third of the exposed section contains comminuted shell fragments as well as an abundant microfauna characteristic of the Peedee Formation (Navarroan) in the region.

Adjacent to the road and in the ditch near the top of the scarp, a layer of light-gray, sandy clay, about 1 to 1.5 feet (0.3 to 0.5 m) thick unconformably overlies greensand of the Peedee Formation. On the basis of its lithology, this clay layer is judged to be a weathered section of the Jericho Run Member.

Project Number

NC-LEN-0-8-73

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Peedee Formation

Map Coordinates

Lat. 35°19'14" N., Long. 77°29'43" W.

Land Owner

Mr. W. T. Hunt

Description: In a ravine extending back from the Jericho Run fault scarp and about 0.5 mile (0.8 km) to the northeast of County Road 1809, the Jericho Run Member of the Beaufort Formation is exposed at and adjacent to a waterfall about 10 feet (3 m) in height. About 3 feet (0.9 m) of surficial material, about 3 feet (0.9 m) of the member and about 10 feet (3 m) of the underlying Peedee Formation are exposed at the fall itself. The member's basal, transgressive, phosphatic conglomerate, about 4 inches (100 mm) thick, forms the resistant ledge at the lip of the fall. Upstream from the fall and for a distance of about 150 feet the Jericho Run Member is exposed along the sides and in the floor of a natural flume where it attains a thickness of about 9 feet (2.7 m). This locality is herein designated the type locality of the Jericho Run Member of the Beaufort Formation.

Downstream from the falls, an additional 15 to 20 feet (4.5 to 6 m) of the Peedee Formation is exposed along and in the stream channel.

At the waterfall, the elevation of the disconformable contact between the Jericho Run Member and the underlying Peedee Formation is 41.7 feet (12.7 m) above mean sea level.

Several feet of surficial material unconformably overlies the Jericho Run Member. The elevation of the disconformable contact between the Peedee Formation and the overlying Jericho Run Member at this exposure is 59.6 feet (18.1 m) above mean sea level.

At this exposure, the Jericho Run Member consists of black to gray, flat-lying layers of siliceous mudstone, intercalated with layers of chert and sandstone, that lie on a basal transgressive phosphatic conglomerate. The mudstone is moderately hard and contains thin sand partings. The chert is extremely hard and breaks with a characteristic conchoidal fracture. The sandstone is moderately to very hard and commonly contains large "floating" quartz grains. Tectonic fractures with linear expression as well as those with arcuate expression are common in the exposed Midwayan section, especially in the floor of the flume above the waterfall.

The rock under the fall, and also exposed downstream from the fall, is a olive-green to gray, glauconitic, clayey sand that is friable to very hard in streaks. It contains an abundant microfauna characteristic of the Peedee Formation (Navarroan) in the region.

Project Number

NC-LEN-0-9-73

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Peedee Formation

Map Coordinates

Lat. 35°19'11" N., Long. 77°29'45" W.

Land Owner

Mr. J. W. Odham

Description: At a locality along the Jericho Run fault scarp, about 0.6 mile (1 km) east of

County Road 1809 marked by the presence of a large twin-beech tree at the top of the scarp and extensive rock slides on the scarp itself, the Jericho Run Member of the Beaufort Formation and the underlying Peedee Formation are exposed along the face of the scarp for a distance of approximately 100 feet (30 m) (fig. 1). Their disconformable contact is buried beneath slumped rock rubble.

The rock of the Jericho Run Member consists of flat-lying, thin-bedded gray-to-black layers of siliceous mudstone, intercalated with layers of chert and glauconitic sandstone, that overlie a basal phosphatic conglomerate. About four feet (1.2 m) of the rock is exposed along the scarp face. The top of the exposed rock lies at an elevation of 55.2 feet (16.8 m) above mean sea level. Slabs and fragments of a well indurated mudstone-glauconitic sandstone breccia, from the Jericho Run Member are present in the rock rubble near the base of the scarp.

Eight to ten feet (2.4 to 3 m) of fossiliferous olive-gray clayey sand of the Peedee Formation is exposed in the scarp face. It is exposed above the rubble zone as well as along the banks of Jericho Run where the stream flows at the font of the rubble zone.

At this locality the relief on the fault scarp is about 45 feet (13.7 m). Reconstruction of a section, including exposed and rubble-covered rock, would approximate 12 feet (3.6 m) of surficial material, 10 feet (3 m) of the Jericho Run Member, and 23 feet (7 m) of the underlying Peedee Formation all of which would lie above the level of the water in Jericho Run.

Project Number

NC-LEN-0-10-73

Geologic Unit(s)

Surficial material

Peedee Formation

Map Coordinates

Lat. 35°19'44" N., Long. 77°28'10" W.

Land Owner

E. I. DuPont de Nemours Co., Kinston Works

Description: Along a northeast extension of a World War II auxiliary landing strip, aligned NE.-SW. and located adjacent to the southeast corner of the DuPont Company's main facility, as much as 5 to 6 feet (1.5 to 1.8 m) of the Peedee Formation has been exposed by excavation in an area several acres in extent. The rock is a greenish-yellow-to-tan glauconitic sand that is highly weathered and very friable. It contains a well-preserved macrofauna and microfauna both of which are characteristic of the Peedee Formation (Navarroan) in the region. The top of the Peedee Formation lies at an elevation of 55.2 feet (16.8 m) above mean sea level and is overlain by surficial material, about 6 feet (1.8 m) thick, along the southeast side of the excavation.

In contrast to this exposed section is the section present in a nearby core hole (NC-LEN-C-35-74, table 2) about one-fourth mile (0.4 km) from the exposure. In the cored section the Jericho Run Member is 14 feet (4.3 m) thick and is in disconformable contact with the underlying Peedee Formation at an elevation of 36 feet (11 m) above mean sea level and 28 feet (8.5 m) below land surface.

Project Number

NC-LEN-0-11-73

Geologic Unit(s)

Surficial material

Beaufort County, Jericho Run Member

Map Coordinates

Lat. 35°22'38" N., Long. 77°35'08" W.

Land Owner

Lenoir County, Road no. 1701, right of way

Description: Eight feet (2.4 m) of flat-lying siliceous mudstone intercalated with chert is exposed in a roadcut along County Road 1701, about 100 feet (30.4 m) south of the bridge athwart Wheat Swamp at the Lenoir-Greene County line (fig. 1). It is light-to-dark gray, moderately to extremely hard, light weight and highly sorptive in some layers, and breaks with a characteristic conchoidal fracture.

The mudstone is characterized by the presence of linear tectonic fractures as well as by "ball and socket" horizontal jointing. The top of the exposed mudstone-chert section lies at an elevation of 67.9 feet (20.7 m) above mean sea level. Several feet of surficial material overlie the mudstone and scattered slabs and chunks of weathered siliceous sandstone occur as float in the hilly pasture immediately adjacent to the exposure.

Microfossils recovered from the siliceous mudstone at this exposure are preserved as internal molds of silica, and their original calcareous walls have been replaced by silica, according to Richard Benson (unpublished micropaleontologic project report), who, following study of the foraminiferal assemblage, concludes that the poorly preserved Foraminifera from this exposure probably are late Danian (late Midwayan) in age.

Several core holes and (or) water wells drilled in the vicinity of this exposure did not encounter rocks of Paleocene age, suggesting that the exposed siliceous mudstone, the Jericho Run Member of the Beaufort Formation, is an erosional outlier.

Project Number

NC-LEN-0-12-73

Geologic Unit(s)

Surficial material

Peedee Formation

Map Coordinates

Lat. 35°18'37" N., Long. 77°31'18" W.

Land Owner

State Highway Route 11, right of way

Description: In the drainage ditch at the base of the roadcut adjacent to a drive-in theatre on State Highway Route 11, about three feet (0.9 m) of the Peedee Formation is exposed. The rock is a blue-black to dark-gray clayey sand that is friable. It is very micaceous and is glauconitic and lignitic. It is overlain unconformably by about 15 feet (4.5 m) of surficial material and contains a sparse microfauna characteristic of the Peedee Formation (Navarroan) in the region.

Project Number

NC-LEN-0-15-75

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Peedee Formation

Map Coordinates

Lat. 35°19'59" N., Long. 77°26'36" W.

Land Owner

Mrs. Nina Hill - Mr. Reid White

Description: On the south side of the Neuse River along a bluff about 25 feet (7.6 m) high, that lies athwart the Hill-White property line and which extends along the river for a distance of about one-third mile (0.5 km) or so (fig. 1), the Peedee Formation and the Jericho Run Member of the Beaufort Formation, overlain by surficial material, are exposed discontinuously along the length of the bluff. At this exposure, these stratigraphic units may show minor variance in lithologic character but appear to maintain a rather uniform thickness. The following description of the section is a composite summary of the several exposures examined.

Up to a maximum thickness of 12 to 13 feet (3.7 to 4 m) of the Peedee Formation may be exposed along the bluff depending upon the level of the water in the river. It is predominantly a olive-gray-to-green clayey sand. It is glauconitic, micaceous, phosphatic, and contains comminuted shell material as well as dispersed fossils and layers of fossils. Although the rock is generally compact and friable, extremely hard layers of fossil material occur commonly and crop out as resistant ledges. Species of Ostracoda and Foraminifera characteristic of the Peedee Formation (Navarroan) in the region occur commonly at this locality.

The Jericho Run Member overlies the Peedee Formation disconformably and is about 2.5 feet (0.8 m) thick. It is predominantly a black, thin-layered siliceous mudstone with thin sand partings, is intercalated with chert lenses, and has a phosphatic conglomerate about 5 inches (125 mm) thick at its base. The elevation of the disconformable contact with the underlying Peedee Formation is 22.0 feet (6.7 m) above mean sea level.

Overlying the Jericho Run Member is about 10 feet (3 m) of surficial material.

Project Number

NC-LEN-0-16-75

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Map Coordinates

Lat. 35°20'01" N., Long. 77°30'14" W.

Land Owner

Mr. Sam McLawhorn

Description: The Jericho Run Member is exposed about 1 mile (1.6 km) north of Graingers in the floor of a dug drainage ditch and extends for a distance of about 50 feet (15.2 m). The segment of the ditch in which the member is exposed lies directly to the rear of and about 1,200 feet (366 m) west of the farmhouse at a point where a open field and a wood lot are juxtaposed.

The rock is a black siliceous mudstone, with thin sand partings, intercalated with glauconitic sandstone. It is thin bedded, moderate-to-very hard, and fractured. The base of the mudstone is not exposed and it is overlain by about 8 feet (2.4 m) of surficial material. The areal extent and thickness of the siliceous mudstone is thought to be limited in the area of this exposure because of its absence in several nearby core holes (fig. 1 and table 2).

Project Number

NC-LEN-0-17-75

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Peedee Formation

Map Coordinates

Lat. 35°15'24" N., Long. 77°32'18" W.

Land Owner

Thomas Greene Heirs

Description: In a ravine about 0.6 mile (1 km) east of Rochelle Blvd. School, Kinston, that extends back from the Jericho Run fault scarp and over a distance of about 100 feet (30 m), the Peedee Formation and the Jericho Run Member of the Beaufort Formation are exposed as ledges and steps that lie in the bottom and along the sides of a natural flume above a small waterfall about 2.5 feet (0.8 m) high.

About six feet (1.8 m) of the olive-gray clayey sand is exposed at the waterfall and in the ravine below it. It is overlain, disconformably by about five feet (1.5 m) of flat-lying, thin-bedded black-to-gray siliceous mudstone that is intercalated with chert and sandstone and which rests on a basal phosphatic conglomerate, that ranges from 4 to 14 inches (100 to 360 mm) in thickness. The elevation of the Midwayan-Navarroan contact is 36.5 feet (11.1 m) above mean sea level.

The mudstone is moderately hard and contains thin sand partings and lenses. The sandstone ranges in thickness from 3 to 10 inches (75 to 250 mm). Commonly, it contains glauconite and fragments of siliceous mudstone in some layers. Tectonic fractures having both linear and arcuate expression are present in the mudstone.

Project Number

NC-LEN-0-18-75

Geologic Unit(s)

Surficial material

Beaufort Formation

Map Coordinates

Lat. 35°15'52" N., Long. 77°32'04" W.

Land Owner

Felix Harvey - J. Roundtree Heirs

Description: In a small stream, about 0.8 mile (1.3 km) east of Rochelle Blvd. School, Kinston, located at the foot of a small man-made dam and farm pond, and extending downstream for a distance of about 100 yards (91 m), the Beaufort Formation crops out intermittently in the stream channel as well as in a cutbank, about 50 feet (15 m) long, that borders the channel on the west. In addition, large fossiliferous boulders of the Beaufort Formation are visible around the periphery of several abandoned marl pits, located immediately adjacent to and across the stream channel from the cutbank.

About 7 feet (2.1 m) of the Beaufort Formation is exposed in the cutbank. It comprises calcareous olive-gray sand (friable, glauconitic and highly fossiliferous) that contains, near its center, a pod of yellowish-tan calcareous sandstone (moderately hard, glauconitic, phosphatic, and highly fossiliferous) which ranges in thickness from about 0.5 to 2.5 feet (0.15 to 0.8 m).

A well-preserved macrofauna is visible at this locality and it includes numerous specimens of the brachiopod Oleneothyris harlani (Morton) as identified by Druid Wilson (oral commun., 1975). Following a preliminary study of the planktonic foraminiferid assemblage obtained from this locality, Richard Benson (unpublished micropaleontologic project report) considers the Beaufort Formation at this locality to be late Midwayan (Thanetian) in age.

Project Number

NC-LEN-0-23-75

Map Coordinates

Lat. 35°15'41" N., Long. 77°33'38" W.

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Land Owner

Harry Cummings

Description: The Jericho Run Member of the Beaufort Formation crops out in Kinston, N. C., along Secrest Street, at its junction with Cogdell Drive and adjacent to the southeast corner of the Rochelle Boulevard School playground. The member consists of light-gray to grayish-black, moderately hard to hard, thin bedded siliceous mudstone that contains chert layers and intercalated sandstone layers as much as 1 foot (0.3 m) thick. The exposed mudstone section ranges in thickness from about 5 feet (1.5 m) on the west side of Secrest Street to about 15 feet (4.6 m) on its east side. The mudstone dips gently to the northwest, is highly fractured and is capped by surficial material that ranges in thickness from 1 to 6 feet (0.3 to 1.8 m).

The base of the member is not exposed.

Project Number

NC-LEN-0-26-76

Map Coordinates

Lat. 35°15'15" N., Long. 77°81'58" W.

Geologic Unit(s)

Surficial material

Beaufort Formation, Jericho Run Member

Land Owner

E. E. Boyette

Description: About 0.7 mile (1.1 km) east of Rochelle Blvd. School, Kinston, and beginning from where the southwestern corner of the Boyette property and the Neuse River intersect, and extending downstream for about 1,000 feet (300 m) the Jericho Run Member of the Beaufort Formation is exposed in a vertical wall along the southeast bank of the river. The member consists of dark-gray, thin-bedded, flat-lying, moderately hard-to-moderately soft, siliceous mudstone intercalated with light- to medium-gray, moderately hard-to-hard glauconitic sandstone layers up to 8 inches (200 mm) thick. About 6 to 8 feet (1.8 to 2.4 m) thickness of the member is exposed when the river is low. Commonly, slabs of siliceous mudstone and indurated sandstone occur as float along the banks of the river. The covering surficial material ranges from 1 to 4 feet (0.3 to 1.2 m) in thickness. In a core hole (NC-LEN-C-44-76) drilled about 800 feet (240 m) east of the outcrop, 10 feet (3 m) of surficial material, 9 feet (2.7 m) of the Jericho Run Member and 7.5 feet (2.3 m) of the Peedee Formation were penetrated. At the disconformable contact between the Jericho Run Member and the underlying Peedee Formation a basal phosphatic pebble conglomerate, about 6 inches (150 mm) thick, was present.

Project Borehole Data

The location of the project's stratigraphic boreholes are shown on figure 1. Stratigraphic data for these boreholes are given in table 2 and illustrated in figure 15.

The cores, the detailed lithologic description of the cores, the geophysical logs of project boreholes, as well as other analytical and testing data pertaining to nonstructural aspects of the project, are on file in the offices of the State Geologist of North Carolina, Raleigh, N. C.

Temporary Bench Marks

In the present study indirect methods were used to determine the relative vertical positioning of exposures located along rivers and streams and chiefly accessible by boat. Elevation of water level relative to temporary bench marks (T.B.M.) established at area bridges was extrapolated between bridges and downstream to an exposure where it was recorded with reference to time and relative to mean sea level. Thus, the water level at an exposure, recorded at a given time, serves as the reference datum for determining the vertical positioning of the exposed rocks relative to mean sea level.

The bridges used for these measurements with their respective temporary bench mark elevation (see fig. 1) are as follows:

(1) Main bridge on N. C. 55 over the Neuse River - the elevation of the top of the curbing at white stripe in the center of the upstream side of the bridge is 42.5 feet (13.0 m) above mean sea level.

(2) Bridge on County Road 1804 (Lenoir County) over Mosley Creek - the elevation of the top of the curb rail in the center of the downstream side of the bridge is 26.0 feet (7.9 m) above

mean sea level.

(3) Bridge on State Highway 55 over Mosley Creek - the elevation of the highway surface on the upstream side of the bridge is 35.8 feet (10.9 m) above mean sea level.

(4) Bridge on County Road 1809 over Jericho Run - the elevation on the road surface in the center of the downstream side of the bridge is 28.4 feet (8.7 m) above mean sea level.

(5) Bridge on County Road 1701 over Wheat Swamp Creek - the elevation on the top of the curb on the downstream side of the bridge is 50.7 feet (15.5 m) above mean sea level.

Figure 15. Section showing stratigraphic units penetrated in project boreholes.

STRATIGRAPHIC DATA

Core Hole No.	Property Owner	Driller	Coordinate Location: Latitude	Coordinate Location: Longitude	Elevation of Core Hole (feet/meters above mean sea level) ft.	m.	Total Depth of Core Hole ft.	m.	NAVARROAN ROCKS: Depth of Top (feet/metres above or below mean sea level) f.	m.	NAVARROAN ROCKS: Thickness (T) or Thickness Penetrated (P) feet/metres f.	m.	MIDWAYAN ROCKS: Depth of Top (feet/metres above or below mean sea level) f.	m.	MIDWAYAN ROCKS: Thickness (T) or Thickness Penetrated (P) feet/metres f.	m.	CLAIBORNIAN ROCKS: Depth of Top (feet/metres above or below mean sea level) f.	m.	CLAIBORNIAN ROCKS: Thickness (T) or Thickness Penetrated (P) feet/metres f.	m.	SURFICIAL ROCKS: Thickness (T) or Thickness Penetrated (P) feet/metres f.	m.	Geophysical Logs	Total Depth f.	m.
Craven County																									
NC-CR-C-2-73	Mrs. W. B. Pearce	Pennsylvania Glass Sand Corp.	35°19'42"	077°25'54"	28.1	8.6	- 4.9	- 1.5	+ 3.6	+ 1.1	8.5(P)	2.5	+15.1	+ 4.6	11.5(T)	3.5	Absent		-		13(T)	4.0			
NC-CR-C-3-73	Mr. J. R. West	do	35°19'40"	077°25'24"	29.0	8.8	+ 5.0	+ 1.5	+10.0	+ 3.0	5(P)	1.5	+22.0	+ 6.7	12(T)	3.7	Absent		-		7(T)	2.1			
NC-CR-C-4-73	Mrs. Myrtle White	do	35°19'19"	077°25'27"	40.4	12.3	-21.1	- 6.4	-15.1	- 4.6	6(P)	1.8	+ 8.4	+ 2.6	23.5(T)	7.2	Absent		-		32(T)	9.7			
NC-CR-C-5A-74	Mr. I. B. Lane	U.S. Geological Survey	35°19'04"	077°21'56"	40.4	12.3	-28.1	- 8.6	-19.6	- 6.0	8.5(P)	2.6	- 1.6	- 0.5	18(T)	5.5	+29.9	+ 9.1	31.5(T)	9.6	10.5(T)	3.2	Electric, Gamma	-27.9	- 8.5
NC-Ck-T-6-74	Mrs. W. B. Pearce	do	35°19'46"	077°25'53"	26.0	7.9	+ 8.0	+ 2.4	+10.0	+ 3.0	2(P)	0.6	Absent		-		Absent		-		16(T)	4.9			
NC-CR-T-7-74	do	do	35°19'44"	077°25'54"	20.4	6.2	-18.1	- 5.5	+ 6.4	+ 2.0	24.5(P)	7.5	Absent		-		Absent		-		14(T)	4.3	Gamma	-18.1	- 5.5
NC-CR-C-8-74	do	do	35°19'43"	077°25'54"	20.4	6.2	-18.1	- 5.5	+ 2.9	+ 0.9	21(P)	6.4	+10.4	+ 3.2	7.5(T)	2.3	Absent		-		10(T)	3.0	Electric, Gamma	-18.1	- 5.5
NC-CR-C-8A-74	do	do	35°19'43"	077°25'54"	20.4	6.2	-13.1	- 4.0	+ 1.9	+ 0.6	15(P)	4.6	+12.4	+ 3.8	10.5(T)	3.2	Absent		-		8(T)	2.4	Electric, Gamma	-13.1	- 4.0
NC-CR-C-9-74	Mrs. Myrtle White	do	35°19'06"	077°25'53"	22.5	6.9	- 3.0	- 0.9	Absent		-		+ 4.5	+ 1.4	7.5(P)	2.3	Absent		-		18(T)	5.5			
NC-CR-C-9A-74	do	do	35°19'06"	077°25'53"	22.5	6.9	-21.0	- 6.4	-12.2	- 3.7	8.8(P)	2.7	+ 5.5	+ 1.7	17.7(T)	5.4	Absent		-		17(T)	5.2	Electric, Gamma	-16.3	- 5.0
NC-CR-C-10-74	do	do	35°18'55"	077°25'38"	38.1	11.6	-20.4	- 6.2	-10.9	- 3.3	9.5(P)	2.9	+ 6.6	+ 2.0	17.5(T)	5.3	Absent		-		31.5(T)	9.6	Gamma	-20.4	- 6.2
NC-CR-C-11-74	Mrs. Louise Register	do	35°19'59"	077°22'47"	22.0	6.7	-26.5	- 8.1	-26.0	- 7.9	0.5(P)	0.2	- 7.5	- 2.3	18.5(T)	5.6	+ 1.5	+ 0.5	9(T)	2.7	20.5(T)	6.3	Gamma	-25.4	- 7.7
NC-CR-C-12-74	Mr. Leonard Brown	do	35°19'45"	077°24'18"	40.4	12.3	-33.1	-10.1	-28.3	- 8.6	4.8(P)	1.5	+ 0.9	+ 0.3	29.2(T)	8.9	Absent		-		39.5(T)	12.0	Gamma	-33.1	-10.1
NC-CR-C-13-74	Mr. Clee Hill	do	35°18'56"	077°24'52"	40.0	12.2	-38.5	-11.7	-11.5	- 3.5	27(P)	8.2	- 6.0	- 1.8	5.5(T)	1.7	Absent		-		46(T)	14.0	Electric, Gamma	-38.4	-11.7
NC-CR-C-14-76	Mr. Roger Johnson	do	35°18'58"	077°21'11"	35.0	10.7	-76.1	-23.2	-64.5	-19.7	11.6(P)	3.5	+ 2.0	+ 0.6	66.5(T)	20.3	+22.5	+ 6.9	20.5(T)	6.3	12.5(T)	3.8	Gamma	-76.1	-23.2
NC-CR-C-15-76	Mr. Rocky Brown	do	35°20'02"	077°23'43"	30.0	9.1	-26.1	- 8.0	-19.5	- 6.0	6.6(P)	2.0	+ 7.0	+ 2.1	26.5(T)	8.1	Absent		-		23.0(T)	7.0	Gamma	-26.1	- 8.0
NC-CR-C-16-76	Mr. A. C. Kilpatrick	do	35°17'26"	077°23'47"	50.0	15.2	-21.1	- 6.4	-19.0	- 5.8	2.1(P)	0.6	+ 8.0	+ 2.4	27.0(T)	8.2	+41.0	+12.5	33.0(T)	10.1	9.0(T)	2.7	Electric, Gamma	-21.1	- 6.4
Lenoir County																									
NC-LEN-C-1-73	Mrs. Nina Hill	Pennsylvania Glass Sand Corp.	35°19'40"	077°26'45"	36.9	11.2	-10.1	- 3.1	- 4.1	- 1.2	6(P)	1.8	+14.9	+ 4.5	19(T)	5.8	Absent		-		22(T)	6.7			
NC-LEN-C-5-73	Mr. Reid White	do	35°19'17"	077°26'10"	34.3	10.5	-10.2	- 3.1	+ 3.8	+ 1.2	14(P)	4.3	+19.3	+ 5.9	15.5(T)	4.7	Absent		-		15(T)	4.6			
NC-LEN-C-6-73	Mrs. Pauline Gates	do	35°18'47"	077°26'21"	36.5	11.1	-10.5	- 3.2	+ 4.5	+ 1.4	15(P)	4.6	+11.5	+ 3.5	7(T)	2.1	Absent		-		25(T)	7.6			
NC-LEN-C-7-73	Mr. R. E. L. Johnson, Jr.	do	35°19'15"	077°27'09"	36.5	11.1	- 5.5	- 1.7	Absent		-		+16.5	+ 5.0	22(P)	6.7	Absent		-		20(T)	6.1			
NC-LEN-C-8-74	Mrs. Lana Langston	do	35°20'37"	077°31'38"	70.3	21.4	+27.3	+ 8.3	+37.3	+11.4	10(P)	3.0	Absent		-		Absent		-		33(T)	10.1			
NC-LEN-C-9-74	Highway Right of Way	do	35°20'07"	077°32'42"	47.3	14.4	+10.8	+ 3.3	+33.3	+10.1	22.5(P)	6.9	Absent		-		Absent		-		14(T)	4.3			
NC-LEN-C-10-74	Mrs. Lana Langston	do	35°21'17"	077°31'19"	74.0	22.6	+22.0	+ 6.7	+28.0	+ 8.5	6(P)	1.8	+33.0	+10.1	5(T)	1.5	Absent		-		41(T)	12.5			
NC-LEN-C-11-74	Highway Right of Way	do	35°21'59"	077°30'46"	72.0	21.9	+28.0	+ 8.5	+62.0	+18.9	34(P)	10.4	Absent		-		Absent		-		10(T)	3.0			
NC-LEN-C-12-74	do	do	35°21'37"	077°35'07"	75.5	23.0	+42.5	+13.0	+62.0	+18.9	19.5(P)	5.9	+63.5	+19.4	1.5(T)	0.5	Absent		-		12.5(T)	3.8			
NC-LEN-C-13-74	do	do	35°17'36"	077°28'53"	30.2	9.2	-15.8	- 4.8	+15.2	+ 4.6	31(P)	9.4	Absent		-		Absent		-		15(T)	4.6			
NC-LEN-C-14-74	do	do	35°17'41"	077°26'53"	33.1	10.1	-11.9	- 3.6	+18.1	+ 5.5	30(P)	9.1	Absent		-		Absent		-		15(T)	4.6			
NC-LEN-C-18-74	Mr. R. E. L. Johnson, Jr.	do	35°19'15"	077°27'09"	36.5	11.1	-11.5	- 3.5	- 4.5	- 1.4	7(P)	2.1	+14.5	+ 4.4	19(T)	5.8	Absent		-		22(T)	6.7			
NC-LEN-C-19-74	do	do	35°19'01"	077°27'08"	38.0	11.6	- 5.0	- 1.5	- 2.2	- 0.7	2.8(P)	0.9	+17.0	+ 5.2	19.2(T)	5.9	Absent		-		21(T)	6.4			
NC-LEN-C-20-74	do	do	35°18'56"	077°27'12"	37.0	11.3	- 6.0	- 1.8	- 3.0	- 0.9	3(P)	0.9	+16.0	+ 4.9	19(T)	5.8	Absent		-		21(T)	6.4			
NC-LEN-C-21-74	do	do	35°19'22"	077°27'04"	36.2	11.0	- 1.3	- 0.4	Absent		-		+18.2	+ 5.5	19.5(P)	5.9	Absent		-		18(T)	5.5			
NC-LEN-C-22-74	Mr. J. H. West	U.S. Geological Survey	35°17'40"	077°26'49"	32.5	9.9	+14.0	+ 4.3	+17.0	+ 5.2	3(P)	0.9	+20.8	+ 6.3	3.8(T)	1.2	Absent		-		11.7(T)	3.6	Gamma	+15.8	+ 4.8
NC-LEN-C-23-74	Mr. J. R. West	do	35°20'05"	077°25'09"	31.0	9.4	- 7.5	- 2.3	+ 2.5	+ 0.8	10(P)	3.0	+16.0	+ 4.9	13.5(T)	4.1	Absent		-		15(T)	4.6	Electric, Gamma	- 7.2	- 2.2
NC-LEN-C-24-74	Mr. R. E. L. Johnson, Sr.	do	35°19'35"	077°27'42"	26.0	7.9	-12.5	- 3.8	- 4.4	- 1.3	8.1(P)	2.5	+19.6	+ 6.0	24(T)	7.3	Absent		-		6.4(T)	1.9	Gamma	-12.5	- 3.8
NC-LEN-C-25-74	Mr. Grover Daughety	do	35°18'31"	077°27'18"	36.8	11.2	+ 8.3	+ 2.5	+14.8	+ 4.5	6.5(P)	2.0	+18.4	+ 5.6	3.6(T)	1.1	Absent		-		18.4(T)	5.6	Gamma	+ 8.8	+ 2.7
NC-LEN-C-26-74	Mrs. Sudie Kilpatrick	do	35°18'02"	077°27'52"	43.5	13.3	+15.0	+ 4.6	+19.0	+ 5.8	4(P)	1.2	+21.5	+ 6.6	2.5(T)	0.8	Absent		-		22(T)	6.7	Gamma	+15.3	+ 4.7
NC-LEN-C-27-74	Mr. Ben Scarborough	do	35°20'52"	077°25'15"	22.0	6.7	-11.5	- 3.5	+ 4.0	+ 1.2	15.5(P)	4.8	Absent		-		Absent		-		18(T)	5.5	Gamma	-11.1	- 3.4
NC-LEN-C-28-74	Mr. S. C. Barwick	do	35°20'56"	077°26'28"	24.0	7.3	- 4.5	- 1.4	+ 4.5	+ 1.4	9(P)	2.7	Absent		-		Absent		-		19.5(T)	6.0	Gamma	- 4.5	- 1.4
NC-LEN-C-29-74	Mrs. Amy Hill	do	35°21'18"	077°27'32"	28.0	8.5	-55.5	-16.9	-10.5	- 3.2	45(P)	13.7	Absent		-		Absent		-		38.5(T)	11.7	Gamma	-49.5	-15.1
NC-LEN-C-30-74	Mr. C. W. Hamilton	do	35°20'08"	077°27'26"	19.0	5.8	- 9.5	- 2.9	0	0	9.5(P)	2.9	Absent		-		Absent		-		19(T)	5.8	Gamma	- 9.5	- 2.9
NC-LEN-C-31-74	do	do	35°20'15"	077°27'33"	26.1	8.0	- 6.9	- 2.1	+ 7.1	+ 2.1	14(P)	4.3	Absent		-		Absent		-		19(T)	5.8	Gamma	- 6.9	- 2.1
NC-LEN-C-32-74	Mr. B. R. Letchworth	do	35°20'27"	077°28'46"	38.0	11.6	+ 9.5	+ 2.9	+17.0	+ 5.2	7.5(P)	2.3	Absent		-		Absent		-		21(T)	6.4	Gamma	+ 9.5	+ 2.9
NC-LEN-C-33-74	Mr. Ernest Johnson (operator)	do	35°20'14"	077°28'19"	36.2	11.0	+27.7	+ 8.4	+27.8	+ 8.5	0.1(P)	.0	Absent		-		Absent		-		8.4(T)	2.6			
NC-LEN-C-33A-74	do	do	35°20'12"	077°28'17"	36.2	11.0	+17.7	+ 5.4	+23.7	+ 7.2	6(P)	1.8	Absent		-		Absent		-		12.5(T)	3.8	Gamma	+17.7	+ 5.4
NC-LEN-C-34-74	do	do	35°20'03"	077°28'20"	65.0	19.8	+12.0	+ 3.7	+40.0	+12.2	28(P)	8.5	+52.5	+16.0	12.5(T)	3.8	Absent		-		12.5(T)	3.8	Gamma	+16.0	+ 4.9
NC-LEN-C-35-74	do	do	35°19'56"	077°28'12"	64.0	19.5	-14.5	- 4.4	+30.0	+ 9.1	44.5(P)	13.6	+50.0	+15.2	20(T)	6.1	Absent		-		14(T)	4.3	Electric, Gamma	-12.9	- 3.9
NC-LEN-C-36-74	do	do	35°19'57"	077°27'59"	28.6	8.7	- 9.6	- 2.9	+14.6	+ 4.5	24.2(P)	7.4	Absent		-		Absent		-		14(T)	4.3	Gamma	- 7.2	- 2.2
NC-LEN-C-37-74	Mrs. Ruby McArthur	do	35°19'36"	077°29'28"	60.0	18.3	+16.5	+ 5.0	+21.5	+ 6.6	5(P)	1.5	+53.0	+16.2	31.5(T)	9.6	Absent		-		7(T)	2.1	Gamma	+17.0	+ 5.2
NC-LEN-C-38-74	Mr. J. C. Langston	do	35°20'23"	077°30'18"	71.8	21.9	+48.3	+14.7	+57.3	+17.5	9(P)	2.7	Absent		-		Absent		-		14.5(T)	4.4	Gamma	+48.8	+14.9
NC-LEN-C-39-74	Mr. J. W. Odham	do	35°19'18"	077°29'20"	70.2	21.4	+26.7	+ 8.1	+29.7	+ 9.0	3(P)	0.9	+56.7	+17.3	27(T)	8.2	Absent		-		13.5(T)	4.1	Gamma	+26.2	+ 8.0
NC-LEN-C-40-74	E. I. DuPont	E. I. DuPont	35°19'47"	077°28'35"	65.6	20.0	+33.1	+10.1	Absent		-		+43.1	+13.1	10(P)	3.0	Absent		-		22.5(T)	6.9			
NC-LEN-C-41-74	do	do	35°19'50"	077°28'43"	64.0	19.5	+40.0	+12.2	Absent		-		+49.0	+14.9	9(P)	2.7	Absent		-		15(T)	4.6			
NC-LEN-C-42-74	do	do	35°20'14"	077°28'19"	64.0	19.5	+20.5	+ 6.2	+45.5	+13.9	25(P)	7.6	Absent		-		Absent		-		18.5(T)	5.6			
NC-LEN-C-43-76	Mr. George Casey	U.S. Geological Survey	35°15'04"	077°31'57"	27.0	8.2	+ 1.9	+ 0.6	+13.0	+ 4.0	11.1(P)	3.4	Absent		-		Absent		-		14.0(T)	4.2	Electric, Gamma	+ 2.4	+ 0.7
NC-LEN-C-44-76	Mr. E. E. Boyette	do	35°15'16"	077°31'49"	33.0	10.0	+ 6.9	+ 2.1	+14.0	+ 4.3	7.1(P)	2.1	+23.0	+ 7.0	9.0(T)	2.7	Absent		-		10.0(T)	3.1	Electric, Gamma	+ 7.2	+ 2.2
NC-LEN-C-45-76	Mr. Felix Harvey	do	35°15'57"	077°32'12"	65.0	19.8	-36.1	-11.0	-29.5	- 9.0	6.6(P)	2.0	+55.0	+16.8	84.5(T)	25.8	Absent		-		10.0(T)	3.0	Electric, Gamma	-36.1	-11.0
NC-LEN-C-46-76	J. C. Rasberry Heirs	do	35°19'43"	077°29'56"	65.0	19.8	+18.9	+ 5.8	+22.0	+ 6.7	3.1(p)	0.9	+49.0	+14.9	27.0(T)	8.2	Absent		-		16.0(T)	4.9	Electric, Gamma	+18.9	+ 5.8
Pitt County																									
NC-PI-C-1-74	Mr. W. A. Gaskins	U.S. Geological Survey	35°21'13"	077°24'14"	26.0	7.9	- 2.5	- 0.8	+ 5.5	+ 1.7	8(P)	2.4	Absent		-		Absent		-		20.5(T)	6.2	Gamma	- 1.1	- 0.3

Table 2.- Location and Stratigraphic Data for Project Core Holes.