State Geological and

Natural History Survey

of Connecticut

# THE BEDROCK GEOLOGY OF THE MIDDLETOWN QUADRANGLE With Map

Open Map

Open Plate II

By

ELROY P. LEHMANN, PH.D.

QUADRANGLE REPORT NO. 8

1959

STATE GEOLOGICAL AND NATURAL HISTORY SURVEY
OF CONNECTICUT

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# THE BEDROCK GEOLOGY OF THE MIDDLETOWN QUADRANGLE

by

ELROY P. LEHMANN, PH.D.

## ABSTRACT

The Middletown quadrangle is principally underlain by Triassic rocks of the Newark group, but a small area of pre-Triassic Bolton schist is exposed southeast of the Eastern Border Fault, which crosses the southeast corner of the map area. In this area the Newark group is divided into seven formations which in geochronologic order are as follows: New Haven arkose, Talcott basalt, Shuttle Meadow formation, Holyoke basalt, East Berlin formation, Hampden basalt, and Portland arkose. Of these formational names, Shuttle Meadow and East Berlin are new.

With the exception of the New Haven arkose, all the formations of the Newark group are well exposed within the quadrangle. The weaker sedimentary rock units generally underlie the valleys; they are mainly gray-red, but the Shuttle Meadow and East Berlin formations each contain one or more gray to black mudstone and shale sequences. The coarser Portland arkose (principally arkose and granule to pebble conglomerate) ranges in color from gray and gray-green to red-brown. Syngenetic sedimentary structures of various types are described from all the sedimentary formations of the Newark. A preliminary study of paleostream senses within the area suggests that an intensive study of all paleostream indicators, as well as other paleogradient indicators such as tilted pipe vesicles at the base of the basalts, on a regional and stratigraphic basis may be useful in providing data on the Triassic sedimentary patterns and environments.

The basalt formations of the Newark group are the topographically prominent units of the Triassic and are abundantly exposed along the scarp faces of structurally controlled ridges. The basalts are fine grained, gray to green- or blue-gray in color, vesicular and amygdaloidal near the upper surfaces of the flows, and exhibit in varying degree the structures commonly found in basaltic lava flows (e.g., pillows, columnar jointing).

Structurally the Newark group rocks are a homoclinal prism dipping about 15 degrees to the east-southeast. The homocline is cut by numerous faults, which are predominantly oblique normal faults, with the downthrown side mostly on the northwest, although conjugate normal faults appear to be present also. Strike-slip faults are exposed in some outcrops of basalt, whereas some outcrops of sedimentary rocks show evidence for bedding-plane faults. A gently plunging anticlinal structure with very small vertical closure is inferred in the area on the basis of the map pattern. Jointing is well developed in some parts of the quadrangle; generally three sets compose the joint system. The general agreement of the orientation of the joint system in the quadrangle with the joint systems observed in two areas to the east and southeast in the pre-Triassic rocks suggests that a careful analysis of jointing on a regional basis might yield significant information on the tectonic history of the region.

# INTRODUCTION

## Location

The Middletown 7½ minute quadrangle is located near the center of Connecticut along the eastern border of the Connecticut Valley Lowland (figure 1). The area is principally in Middlesex County (towns of Cromwell, Haddam, Middletown, Middlefield, and Portland) but includes parts of Hartford County (town of Berlin) and New Haven County (town of Meriden). The principal city of the area is Middletown, located on the southwest bank of the Connecticut River, which cuts across the northeast corner of the quadrangle.

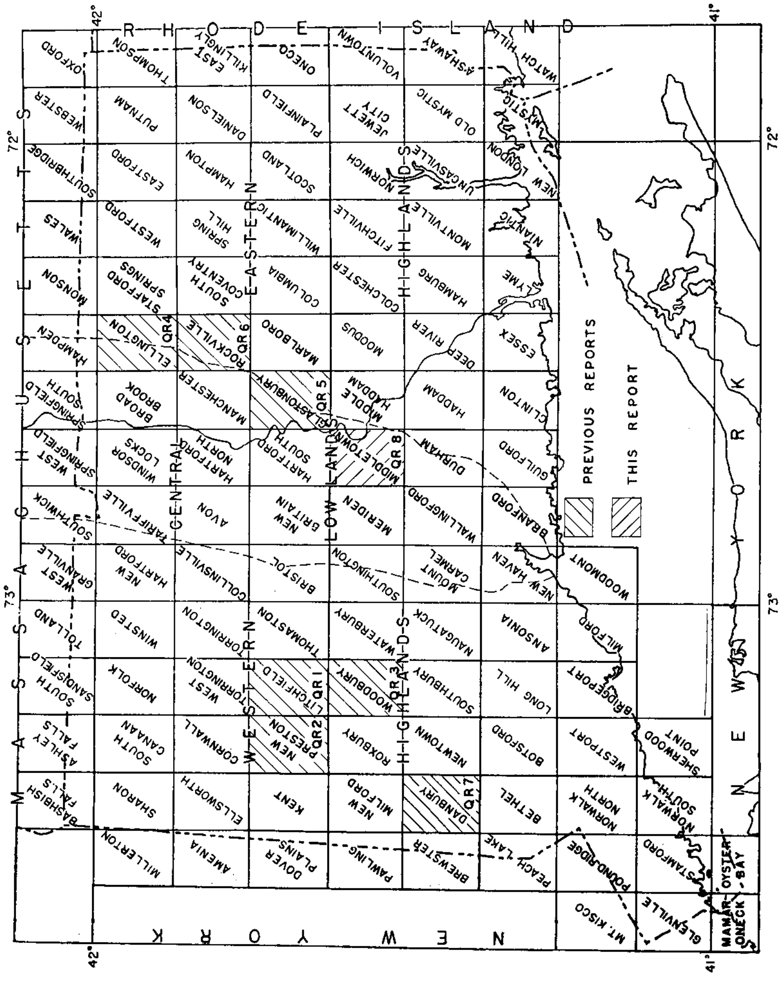


Fig. 1. Index map of Connecticut showing areas covered by previous quadrangle reports and location of the Middletown quadrangle.

## Purpose of Report

The Middletown quadrangle was studied in an attempt to determine in greater detail the stratigraphic and structural pattern of the bedrock of the area and its probable relations to the geologic history. Detailed studies of and searches for outcrops were made in the hope of establishing criteria for the recognition of more rock units than have heretofore been recognized in the sedimentary rocks in the Connecticut Valley Lowland, which would then allow a more precise structural interpretation.

## Method of Study

Field work in the Middletown quadrangle was done chiefly in 1955, with some further work during the spring of 1956. Aerial photographs (stereopairs) taken in October, 1941, and August, 1951, and a 1:24,000 scale blue-line print of the 1945 edition of the U. S. Geological Survey topographic map were used as field maps for locating outcrops and plotting contacts, faults, etc., in the field. The area was covered by traverses which ran principally parallel to the grain of the topography. All stream valleys were thoroughly investigated as well as all roads, railroads, and trails; the generally north-south trending slopes of the hills were traversed.

In view of the very high quality of the topographic base map and the aerial photographs, it is felt that all outcrops are located on the map with reasonable accuracy. Except for the area underlain by the Holyoke basalt, for which only the major outcrops or those showing contacts with the overlying or underlying rock units are shown, the great majority of actual rock outcrops are shown on the accompanying map.

All locations in the text are made with reference to the 10,000-foot grid based on the Connecticut grid system. As the grid guide markers on the map are spaced at 10,000-foot intervals, and in order to facilitate use and recording, the decimal point in the coordinate numbers has been moved four places to the left, so that a point with the coordinates 254,600 feet North and 615,500 feet East would be recorded as 25.46 N-61.55 E.

Unless otherwise indicated, all rock descriptions are based on field descriptions of hand specimens at the outcrop. The range of size of the clastic particles was determined by means of a comparison card that contained samples of clastic material of the class sizes of the Wentworth system. Color names are those used in the Rock Color Chart published by the National Research Council in 1948 (Goddard, 1948), with the code designations of the Munsell system.

## Acknowledgments

Grateful acknowledgment is made for the financial support of the Connecticut Geological and Natural History Survey under the directorship of John B. Lucke. The writer is appreciative of the critical reading of the manuscript and map and the helpful suggestions of John Rodgers. Special thanks are given to Joe Webb Peoples for suggesting the project and encouraging the writer to undertake the work. Informal discussions of numerous aspects of the geology of the quadrangle and adjacent areas

with R. E. Deane, Gordon P. Eaton, and John L. Rosenfeld have been most helpful to the writer. The writer also expresses gratitude for the editorial and secretarial services of Mrs. Elspeth N. Cowie, and the encouragement and assistance of his wife, Dolores.

## Previous Work

Although no detailed geologic map of the Middletown quadrangle or any part thereof has ever been published, a great deal of geologic literature since the early nineteenth century discusses some aspects of the geology of the area. The earliest references known to the writer to any phase of the geology of the Middletown quadrangle are articles by Brongniart (1821) and Silliman (1821), which describe the fossil fish locality of the Westfield area. The first published geologic map to include the Middletown quadrangle was the map accompanying "The Report on the Geology of Connecticut" by J. G. Percival in 1842. Considering the poor quality of the base maps on which he worked, Percival's geologic map of the state is amazingly accurate even today. In a sense, his map is purely descriptive, as he made no attempt to interpret the geology, i.e., to indicate stratigraphic or structural relations except in very broad terms. In terms of map accuracy, subsequent bedrock geologic maps that include the Middletown quadrangle are simply refinements, but some of them give structural and stratigraphic interpretations of the bedrock geology.

After a series of many preliminary papers concerning the lithology, stratigraphy, and structure of the Triassic rocks of the Connecticut Valley Lowland, W. M. Davis in 1898 published his classic work, "The Triassic Formation of Connecticut." In this comprehensive volume and the accompanying map (two miles to the inch) and sections, the stratigraphy and the structure of the Triassic sequence of the Connecticut Valley Lowland are given a full interpretation, which is basically the same as that accepted today.

Shortly after the turn of the century, the newly founded (1903) Connecticut Geological and Natural History Survey published two bulletins describing the geology of the state. The first of these, "Manual of the Geology of Connecticut" by W. N. Rice and H. E. Gregory (Bull. 6, 1906), discusses the geology of the Middletown region. The maps accompanying this bulletin are those of H. E. Gregory and H. H. Robinson (Bull. 7, 1907) for the pre-Triassic areas of the Eastern and Western Highlands, whereas the geologic map of the Connecticut Valley Lowland is a slightly altered version of the map published by Davis in 1898.

Bulletin 7 ("Preliminary Geological Map of Connecticut") by Gregory and Robinson (1907), presents a geologic map for the entire state based on various maps (published and manuscript) available at that time. As in the "Manual of the Geology of Connecticut," the area of the Triassic sequence of rocks is mainly the Davis map of 1898 but shows none of the fault lines. This bulletin presents an excellent brief history of the geologic investigations of the state by federal and state surveys as well as by individuals up to its date of publication.

More recent geologic studies of various aspects of the Triassic of Connecticut have been accompanied by geologic maps, but they did not include the Middletown quadrangle (Wheeler, 1937), or were of such small scale as to be of no real assistance in this area (Russell, 1922; Wheeler, 1939), or were small-scale restatements, with slight changes, of the Davis map of 1898 (Rice and Foye, 1927; Krynine, 1950).

In 1953 R. E. Deane mapped the surficial geology of the Middletown 7½ minute quadrangle, and his map shows the location of rock outcrops according to basic rock types — basalt, sedimentary, or metamorphic (ms in press). R. J. Ross, Jr., in 1950 undertook a revision of the geologic map of the Connecticut Triassic Lowland, basing his work on previously published (and many unpublished) maps along with "critical area" field investigations and topographic and aerial photograph interpretation. The results are incorporated in the "Preliminary Geological Map of Connecticut, 1956" by Rodgers, Cameron, Gates, and Ross.

## GEOGRAPHY

With the exception of a very small triangular area in the very southeast corner of the quadrangle, the entire map area is within the Connecticut Valley Lowland physiographic province. Elevations within the quadrangle range from less than ten feet above mean sea level along the Connecticut River and in the marshes at the confluence of the Mattabesset and Coginchaug Rivers in the northeastern part of the quadrangle, to 892 feet near the north end of Higby Mountain. Except for Beseck and Higby Mountains on the southwestern edge of the quadrangle, which show 300 to 400 feet of relief, the general relief of the area is in the neighborhood of 100 to 200 feet, the summit elevations of the rounded, north-south-trending hills ranging from 200 to 500 feet.

Again with the exception of Beseck and Higby Mountains, the area displays gently rounded, low-lying hills trending north to slightly east of north. This topography is the combined result of the north-south orientation of more resistant ridges of basalt flows and various sedimentary rocks and of glacial ice movement parallel to the resulting topographic grain. Indeed, the orientation of the bedrock ridges probably controlled to a large degree the direction of ice flow within the Connecticut Valley Lowland.

Primarily because the structure of the area is a homocline striking generally north and dipping east, the basalt flows and the various sedimentary rocks crop out as west-facing, north-trending exposures of variable height. Occasional outcrops trend east-west, forming sections parallel to the dip, where artificial exposures of various kinds have been made as well as where discordant streams have cut into bedrock. Scattered outcrops are found on the dip slopes of many of the hills, particularly in the outcrop area of the Holyoke basalt.

The Connecticut River follows the Connecticut Valley Lowland from northern Massachusetts for approximately 80 miles until it enters the quadrangle and reaches Middletown. Just east of Middletown, however, it leaves the quadrangle and the Connecticut Valley Lowland and cuts discordantly across the structure of the Eastern Highlands to empty into Long Island Sound at Old Saybrook. The Connecticut and its tributaries, the southeast-flowing Mattabesset River and the northeast-flowing Coginchaug River, provide the drainage for most of the quadrangle. A small narrow strip, including the west-facing scarps of Higby and Beseck Mountains, drains to the west and south into the Quinnipiac River, which continues in the Connecticut Valley Lowland to the south and empties into Long Island Sound at New Haven. The irregularly scattered swamps of the area, with the possible exception of those at the confluence of the Mattabesset and Coginchaug Rivers, are the result of the disruption of the pre-Pleistocene drainage system by glacial debris.

## STRATIGRAPHY

### History of Nomenclature

The sedimentary rocks and interbedded lava flows that comprise the bedrock of all but a very small area of the quadrangle are part of the widespread Triassic redbed sequence in eastern North America that was designated the Newark group by Redfield (1856, p. 357). The history of the stratigraphic nomenclature applicable to these rocks in eastern North America was reviewed by I. C. Russell in 1878.

The first subdivision of the rock unit now called the Newark group was that made by Percival, who separated in the Connecticut Valley Lowland (1842, p. 432): " . . . three distinct sections of ranges, namely a Western Sandstone, a Middle Shale and an Eastern Sandstone range." He further subdivided the basalt ridges into several "ranges." Davis, in his exhaustive report (1898), unfortunately applied the cumbersome stratigraphic nomenclature suggested by Percival, and the terms "lower sandstone, anterior trap, anterior shales, main trap, posterior shales, posterior trap, and upper sandstones" have been perpetuated to the present time, with some modifications, in the geologic literature of the Connecticut Valley Lowland. Emerson, in the U. S. Geological Survey Holyoke Folio 50, 1898, proposed the currently recognized, less cumbersome nomenclature for the three lava flows of the Newark group, naming them in ascending order: Talcott diabase, Holyoke diabase (first proposed by Emerson in 1891), and Hampden diabase. Krynine in 1936 (1950, p. 31) proposed three formations in the Newark group, in ascending order: the New Haven arkose, Meriden formation, and Portland arkose, which correspond to the basic threefold division of Percival. Unfortunately, Krynine chose to employ the unwieldy terminology of Percival and Davis for the lava flows and sedimentary rocks of the Meriden formation, which he considered members although Emerson had long before given acceptable rock-stratigraphic names to the three lava flows. With regard to the Meriden formation, Krynine states that it is best exposed in the Meriden-New Britain area (1950, p. 58), just west of the Middletown quadrangle.

### Rock-stratigraphic Nomenclature

The various members of Krynine's Meriden formation are as readily mappable in the field as his Meriden formation or the other formations of the group; consequently the term Meriden formation is not used in this report, and the rock units involved are here given formational status as follows.

The formational names, New Haven arkose and Portland arkose, as proposed and designated by Krynine (1950), are employed in this report.

The three lava flows of the Triassic in the Middletown quadrangle are given the acceptable names (as formations) proposed by Emerson (1891 and 1898) for their undoubted rock-stratigraphic equivalents in southern Massachusetts and northern Connecticut. In geochronologic order they are here called the Talcott basalt, Holyoke basalt, and Hampden basalt.

Inasmuch as Krynine designates the exposures on the southern shore of Shuttle Meadow Reservoir between Meriden and New Britain as the type locality for the sedimentary rocks overlying the Talcott basalt and underlying the Holyoke basalt (called the Lower lava flow and Middle lava flow, respectively, by Krynine), it is here proposed that these sedimentary rocks be called the Shuttle Meadow formation. The Shuttle Meadow Reservoir sections as described by Krynine (1950, p. 58, 60-61) are hereby designated the type sections for the formation.

For the sedimentary rocks overlying the Holyoke basalt and underlying the Hampden basalt (Upper sedimentary division of Krynine), Krynine (1950, p. 58) designated as the type locality "a quarry on a country road in Kensington, 1½ miles south of Berlin (loc. 27)." In conjunction with this quotation, it should be noted that Krynine apparently mixed the two geographic names, for the locality referred to is actually in Berlin, 1½ miles south of Kensington. Subsequent to Krynine's field work in the area, excavations for highway rebuilding have exposed an excellent section of this part of the Newark group on Connecticut Highway 72 in the northwest corner of the Middletown quadrangle, just northeast of the town of Berlin and west of the village of East Berlin. As Krynine's type locality for this part of the Newark group and the extensive new exposure referred to above are both in the town of Berlin, and because of the roadcut's proximity to East Berlin, it is here proposed that the sedimentary rocks of the Newark group that conformably overlie the Holyoke basalt and conformably underlie the Hampden basalt be designated the East Berlin formation. Inasmuch as the Highway 72 exposure of the East Berlin formation exposes the upper contact with the overlying Hampden basalt as well as 230 feet of section through a stratigraphic interval of about 325 feet (three gaps in the section – 50, 25, and 26 feet), it is designated as the type section for the East Berlin formation rather than the Kensington quarry section. For a description of the stratigraphic sequence at the Highway 72 exposure of the East Berlin formation, see pages 17-22.

Table I compares the rock-stratigraphic nomenclature used in this report with that used by previous authors.

## TABLE 1

### Rock Stratigraphic Nomenclature Applied by Various Authors to the Triassic Newark Group Rocks in Massachusetts and Connecticut

| J. G. Percival<br>1842<br>Connecticut | W. M. Davis<br>1898<br>Connecticut<br>Valley | B. K. Emerson<br>1898 + 1917<br>Connecticut<br>Valley of Mass. | P. D. Kryine<br>1950<br>Central<br>Connecticut | M. E. Willard<br>1951 + 1952<br>Northern<br>Massachusetts | E. P. Lehmann<br>(this report)<br>Middletown<br>Quad., Conn. |
|---|---|---|---|---|---|
| Secondary formation | Triassic formation | Newark group — units in part contemporaneous | Newark group | Newark group | Newark group |
| Eastern sandstone<br><br>Middle shale<br><br>Western sandstone | Upper division<br><br>Middle division:<br>Posterior trap sheet<br>Posterior shales<br>Main trap sheet<br>Anterior shale and sandstone<br>Anterior trap sheet<br><br>Lower sandstone | Chicopee shale<br>Granby tuff<br>Hampden diabase<br>Longmeadow sandstone<br>Holyoke diabase<br>Talcott diabase<br>Mount Toby conglomerate<br>Sugarloaf arkose | Portland arkose<br><br>Meriden formation:<br>Upper lava flow<br>Upper sedimentary division<br>Middle lava flow<br>Lower sedimentary division<br>Lower lava flow<br><br>New Haven arkose | Mount Toby conglomerate<br>Turner Falls sandstone<br>Deerfield diabase<br>Sugarloaf arkose (correlation of this section with that of Conn. uncertain) | Portland arkose<br>Hampden basalt<br>East Berlin formation<br>Holyoke basalt<br>Shuttle Meadow formation<br>Talcott basalt<br>New Haven arkose |

# LITHOLOGY

## General

The following descriptions of the bedrock of the Middletown quadrangle are presented in geochronologic order for the rock units present in the quadrangle. For a detailed treatment of the petrography and mineralogy of the Newark group sedimentary rocks based on selected specimens, the interested reader is referred to Krynine's "Petrology, Stratigraphy, and Origin of the Triassic Rocks of Connecticut" (1950). Krynine presents data on relative percentages of composing minerals in various specimens of the different lithologies found, descriptions and illustrations of some thin sections, quantitative data on heavy mineral suites (mineralogic composition and relative concentration), and color characteristics and variability, all in terms of the stratigraphic sedimentary rock units of the Newark group in Connecticut.

## Pre-Triassic Metamorphics — Bolton Schist

The Bolton schist crops out in a very small triangular area in the extreme southeast corner of the Middletown quadrangle; the only good exposures are along a brook flowing northwestward into Sumner Brook. Here the Bolton schist is well exposed for approximately 1000 feet transverse to the foliation of the metamorphic rock.

The Bolton in this corner of the Middletown quadrangle is atypical of the rock unit in other areas to the north, east, and south. It is here principally a poorly foliated, quartzitic, micaceous schist, predominantly medium gray (N5), commonly mylonitized. The outcrops in the Middletown quadrangle are cut by numerous breccia zones and quartz veins, most of them undoubtedly related genetically to the Eastern Border Fault of the Connecticut Valley Triassic Lowland, which is very near.

The western contact of the Bolton schist with the geologically much younger Portland arkose is not exposed within the area. That it is a fault contact as shown on the map is deduced from the field relations of the two rock units, from the physiography, from the attitudes of stratification in the Portland arkose, and from the existence of numerous minor faults in the Portland arkose to the west. The foliation, although poorly developed throughout much of the Bolton exposed, strikes approximately N 30° E and dips 25° to 30° NW.

Percival (1842) in the "Report on the Geology of the State of Connecticut" and more recently Herz (1955, p. 7) noted the very common occurrence of atypical mylonitic Bolton schist near the Triassic Valley Eastern Border Fault. Herz (p. 7-8) describes the mylonitic Bolton, as seen in thin sections, as follows: " . . . a fine sericite mat . . . advanced alteration of biotite to chlorite and of feldspar to sericite . . . in each [slide] mylonite comprises well over half. The proximity of the Triassic border fault and the lateness of the deformation, as indicated for example by garnet that has been deformed and altered to chlorite rather than biotite . . . suggest a cataclastic origin in Triassic movement for this rock type."

## New Haven Arkose

The New Haven arkose, the oldest formation of the Triassic Newark group, underlies and is exposed in a small area along the central part of the west margin of the map. The only good exposure of the New Haven in the quadrangle is found on the northwest slopes of a low ridge at 26.445 N-60.0675 E between about 290 and 300 feet above sea level.

At this locality about 10 feet stratigraphically are exposed. The rocks exposed are moderate orange pink (10R7/4) and moderate red (5R4/6), generally coarse-grained arkose, with irregular lenses and beds of fine-grained arkose as well as arkose conglomerate containing pebbles up to four inches in the longest exposed diameter. The conglomerate pebbles and cobbles are principally quartzose. At the low point in the dip slope to the southwest of this outcrop, before the low scarp face of the conformably overlying Talcott basalt is reached, numerous large boulders (outcrops?) of an arkosic pebble conglomerate are found.

## Talcott Basalt

The Talcott basalt is stratigraphically the lowest lava flow in the Middletown quadrangle; it crops out along low ridges trending east of north along the west margin of the map area. Of the three basalts, the Talcott basalt is the least conspicuous ridge-former. Numerous outcrops (dip-slope surfaces) are found along Preston Avenue in the unimproved roadway and along the small west-facing scarp face west of the road southwest from 26.535 N-60.19 E to the west edge of the quadrangle. The exposures along Preston Avenue are of highly vesicular trap, which weathers readily to form a surface covered with many small, heavily weather-stained, quite angular, pebble-sized fragments of basalt.

The calculated stratigraphic thickness of the Talcott basalt is approximately 150 feet in the area west of the north end of Higby Mountain.

The Talcott basalt is characterized by being more highly vesicular at the top and throughout the unit than either of the other basalts of the Newark group. The lower part of the Talcott locally has very well developed pillow lava (not well exposed in the Middletown quadrangle, but found in the Meriden quadrangle to the west): pillows are very uncommon in the other basalts. The Talcott basalt is very fine grained throughout and generally dark bluish gray (5B3/1) to medium dark or dark gray (N4-3). Locally the basalt is amygdaloidal, the amygdales being composed principally of calcite, chlorite or a chlorite-like mineral, prehnite, and some zeolites.

The Talcott basalt is not sufficiently well exposed in the area to determine whether it represents a single lava flow or multiple flows. The contact of the Talcott basalt with the underlying New Haven arkose is not exposed in the Middletown quadrangle. At four outcrops the contact of the Talcott basalt and the overlying Shuttle Meadow formation is exposed. The nature of these contacts and the highly vesicular and amygdaloidal character of the upper part of the Talcott conclusively prove the extrusive nature of the Talcott basalt. These four outcrops have the following locations: 1) 26.475 N-60.18 E; 2) 25.985 to 26.00 N-60.06 E; 3) 25.89 N-60.06 E; 4) 25.80 N-60.045 E. The first two of these have the contact best exposed. At both of these outcrops some of the vesicles in the vesicular upper surface of the Talcott basalt are filled with sedimentary material similar to that in the overlying Shuttle Meadow. The overlying mottled yellowish gray (5Y7/2) to pale brown (5YR5/2) principally medium- and fine-grained feldspathic sandstone contains abundant clasts of quartz and muscovite and also some angular fragments of the underlying basalt.

## Shuttle Meadow Formation

The Shuttle Meadow formation is exposed in a narrow belt along the southern half of the west margin of the quadrangle. Generally, the few outcrops of the Shuttle Meadow in the quadrangle are small in lateral extent as well as in stratigraphic interval spanned. Of the total calculated stratigraphic thickness of about 310 feet, only about 50 feet are exposed, but the stratigraphic position of the outcrops ranges from the base of the unit to its upper contact with the overlying Holyoke basalt.

Lithologically, the Shuttle Meadow formation as exposed in the Middletown quadrangle is variable. The predominant rock type appears to be grayish red to dark reddish brown (10R4/2 to 10R3/4) shale with occasional mudstone of a similar color. Coarse to very fine arkose, mottled very pale orange and grayish orange (10YR8/2 and 10YR7/4), as well as grayish red and dark reddish brown (10R4/2 and 10R3/4), are also found. Very minor amounts of coarse to fine, yellowish gray (5Y7/2) and pale brown (5YR5/2) coarse- to fine-grained, feldspathic sandstone also occur in the Shuttle Meadow. Near the base of the Shuttle Meadow, in a small stream bed and its banks, at 26.5 N-60.25 E, are small outcrops of fissile, grayish black to dark gray (N2 to N3) shale from which were recovered the fossil fish of the Higby area described by Davis and Loper (1891). Pieces of grayish black shale float found in the stream bed show fragments of carbonized fossil fish (mainly scales) on the bedding surfaces, but none of the bedding surfaces of the associated "sandstones" were found to contain the large footprints (dinosaur?) reported by Davis and Loper (1891, p. 426).*

At 25.79 N-60.04 E on the banks of a minor stream a very small outcrop exposes highly sheared and deformed grayish black to dark gray (N2 to N3) shale with numerous slickensided surfaces.

The contact of the Shuttle Meadow with the underlying Talcott basalt is basically conformable, but the presence of small angular fragments of basalt in the Shuttle Meadow immediately above the Talcott suggests minor erosion.

The contact of the Shuttle Meadow with the overlying Holyoke basalt is well exposed at one outcrop in the area, and three others very nearly expose it. The outcrop of the Shuttle Meadow-Holyoke contact is at 26.71 N-60.545 E and exposes a total stratigraphic thickness of about

*Material collected by students on a field trip of one of Dr. Lehmann's classes made in May 1958 has recently been identified by Dr. Joseph T. Gregory of Yale University as sandstone clasts of dinosaur bones. Additional material has been collected by Dr. Gregory and others. The locality is at 60.12 E, 25.31 N. The horizon is the Shuttle Meadow formation near the base of the Holyoke basalt. This find represents the first known occurrence in Connecticut of dinosaur bones below the Portland formation.

18 feet; approximately the lower 16 feet are interbedded mudstone, shale, arkose, and feldspathic to quartzose sandstone. The quartzose sandstone immediately underlying the basalt has apparently undergone very little alteration as compared to the alteration found elsewhere, where the immediately underlying lithology is a red shale or mudstone.

At several locations in the Black Pond area the contact of the Shuttle Meadow with the Holyoke can be quite precisely located in the field, e.g., at the following locations: 25.305 N-60.115 E, 25.29 N-60.213 E, and 25.308 N-60.18 E.

Syngenetic sedimentary structures found in the Shuttle Meadow rocks in the area are principally rather profuse shrinkage (mud) cracks, current ripple marks, and cross-bedding. The rocks of the Shuttle Meadow show stratification in varying degree. Some of the shales and sandstones are very finely laminated, the individual laminae being a fraction of a millimeter; elsewhere there are massive beds of mudstone. Small-scale aqueous cross-bedding is found in the outcrops at the following locations: 24.875 N-60.053 E and 26.71 N-60.545 E.

## Holyoke Basalt

The thick Holyoke basalt crops out extensively along the west edge of the quadrangle in a belt from 3000 to 5000 feet wide, trending slightly east of north. The steep west-facing scarps of the gently arcuate Beseck, Higby, and Lamentation Mountains are nearly continuous outcrops of the heavily fractured and jointed Holyoke. The lower west slopes of these mountains are basalt talus slopes that are generally heavily overgrown in timber and brush; although those along the east edge of Black Pond are fairly clear of vegetative cover and well displayed. On the more gentle dip-slopes on the east sides of the mountains basalt crops out widely along the steep-walled valleys of high-gradient streams and as scattered, glacially smoothed and striated surfaces. Relative to the area it underlies, the Holyoke basalt is the best exposed rock unit in the quadrangle. On the accompanying geologic map only the major or critical outcrops of the Holyoke are indicated.

The stratigraphic thickness of the Holyoke basalt was calculated to be 450 to 500 feet in the Middletown quadrangle. The Holyoke basalt represents two successive lava flows, the second flow being the thinner. The double-flow character of the Holyoke is not readily observed in the Middletown quadrangle, although it is suggested in the massive appearance of the upper part of the west-facing cliffs of basalt in Beseck and Higby Mountains. In the Meriden and New Britain quadrangles, to the west and northwest respectively, the evidence for two flows in the Holyoke is clearly visible in several trap-rock quarries.

Davis first recognized the two flows in the Holyoke basalt in a paper describing the trap-rock quarries of Meriden (1896). In his classic work on the Triassic of Connecticut, Davis (1898, p. 70-71) describes the contact of the two flows and illustrates it with a photograph. The quarries he described are not marked as quarries on the new 7½ minute Meriden topographic map of the area; the northernmost quarry described by Davis is presently flooded and is marked as a lake at the following location: 26.48 N-58.75 E, but comparison of the topographic map with the panoramic drawing of Davis (1896, p. 8) quickly establishes the location of the quarries. Davis (1896, p. 9-10) describes the two flows and their relationships in the Meriden quarries as follows: "The deepest part of the lower flow now exposed is in the back of the southern one of the new quarries. . . . Here it is of a bluish gray color, fine-grained and dense, rarely vesicular. Nearer its surface it becomes red or purplish, with an increasing proportion of vesicles. . . . The color is often so strong near the upper surface that this part of the trap might easily be mistaken for baked sandstone. . . . The lower bed nowhere exhibits any distinct columnar structure, but has on the other hand a tendency to split into slabs four or five feet thick, along weathered joints parallel to its surface. . . .

"The upper bed, as far as exposed in the quarries, is unlike the lower in many respects. The color of its deeper joint planes, where not affected by weathering, is dark steel-gray, greenish or bluish; the fresh broken rock is dark gray or greenish, without any of the bright reds or purples of the lower flow. The texture is dense throughout, vesicles and cavities being very unusual; but by following the quarry ridge to the northeast about a third of a mile, one may find the ordinary vesicular structure of the upper part of the bed there exposed on its back slope. . . . The columnar jointing of the upper bed is fairly well developed at many parts of the quarries, but it nowhere produces columns of notable regularity. Near the base of the upper bed, the rough joint columns are of small dimensions: half a foot to a foot in diameter. Some fifteen or twenty feet above the base the columns are often two, three, or four feet in diameter. The weathered joints in the rocks near the surface of the ridge are yellowish in the upper bed, but brownish in the under bed."

Basically the same rock types and relationships are found in the quarries (locations: 30.54 N-57.85 E and 30.6 N-57.99 E) on the north side of Cooks Gap at Plainville in the New Britain quadrangle. The basalt of the northwest wall of the larger lower quarry at Cooks Gap exhibits well the "tendency to split into slabs four or five feet thick" that Davis indicated as characteristic of the lower flow. In the upper quarry, at 30.59 N-58.03 E, the quarry wall exposes the contact of the two flows of the Holyoke basalt and all the features described by Davis at the Meriden quarries are well displayed. These features of the Holyoke basalt in the Cooks Gap quarries were brought to the writer's attention by H. E. Simpson, Geologist, U. S. Geological Survey, on a field excursion in the area, which is currently being mapped by Simpson.

The Holyoke basalt is generally very fine grained and tough except in the highly vesicular and amygdaloidal upper part of the flows. The color of the basalt ranges from dark greenish gray (5G3/1) or grayish olive green (5GY3/2) to dark bluish gray (5B4/1) or dark gray (N3). The basalt is mostly very fine grained, but the central parts of the Holyoke are coarser and diabasic. Amygdales of calcite, a chlorite-like mineral, prehnite, zeolites, and some quartz are common.

The basalt is normally heavily jointed and fractured, as shown by the small blocky character of the material comprising the talus below the cliffs of basalt. Contraction (cooling) joints are variably developed at different stratigraphic levels as well as geographic locations, as described by Davis (1896, p. 10).

On the weathered basalt surfaces exposed on dip-slopes, some of the roughly hexagonal to polygonal cooling joints are etched in relief, forming thin narrow ridges up to 1/4 inch high. Although not checked in thin section, field evidence seems to indicate that the cooling joints of the basalt were healed principally by quartz or, less likely, a zeolite mineral during the very late cooling stages of the flows, or at some later time; thus strengthened, they are etched in relief by weathering. A system of tectonic joints appears fairly well developed throughout the area; it is discussed below under structure.

The contact of the Holyoke basalt with the overlying East Berlin formation, which is exposed at three outcrops, is in every respect similar to the Talcott basalt-Shuttle Meadow contact. At all the outcrops where the contact is exposed, the upper surface of the Holyoke basalt is highly vesicular, and some of the vesicles are filled with the overlying clastic material, which commonly contains angular, generally small clasts of basalt. The best exposure of the Holyoke-East Berlin contact is in the bed and rock walls of Spruce Brook at the base of the gentle east slope of Lamentation Mountain at 27.9 N-60.3 E. This locality was well described and illustrated by Davis (1898, p. 69, fig. 11). The overlying sedimentary rock here is grayish red (10R4/2) muscovitic mudstone, containing clasts of basalt just above the contact. The two other outcrops exposing this contact are quite small and lie at the base of the east slope of Higby Mountain. One is in the bed of Fall Brook at 26.44 N-60.81 E; here the overlying East Berlin formation is grayish red (10R4/2) sandy mudstone containing some small angular fragments of basalt. The other outcrop is near the west bank of Mount Higby Reservoir at 26.035 N-60.72 E on the south bank of a very small stream flowing into the reservoir. The outcrop is just west of the small reservoir road bridge crossing the small stream. Here the sedimentary rocks overlying the basalt are mottled yellowish gray (5Y7/2) and light olive-gray (5Y5/2) muscovitic, medium-grained to slightly coarse-grained arkose with very minor amounts of clastic basalt.

## East Berlin Formation

The East Berlin formation is well exposed in the western half of the Middletown quadrangle. Generally the best outcrops are to be found in the northwest corner of the quadrangle, the best along Connecticut Highway 72 and the northern edge of the map. The area of possible outcrop of the East Berlin is generally elongate slightly east of north and varies in width between approximately 2600 feet and 3000 feet. This variability is here interpreted as the results of a broad open plunging anticline, which is discussed in the section on structure.

Natural outcrops occur as low scarps trending slightly east of north with the steep face and outcrop on the west, or in the beds and banks of small streams flowing parallel to the strike of the rocks (slightly east of north).

Krynine reported a total thickness of 750 ± to 900 ± feet (1950, p. 32) for the East Berlin formation (his Upper Sedimentary division) in

Central Connecticut. On the basis of calculations along three cross sections in three different fault blocks, the East Berlin formation in the Middletown quadrangle is found to vary between 550 and 600 feet in thickness.

Lithologically, the East Berlin is principally fine-grained clastics — shale and mudstone — predominantly grayish red (10R4/2).

The sand-sized clastic sedimentary rock of the East Berlin is principally arkose, although feldspathic sandstone is nearly as common in its occurrence. The arkose is predominantly medium grained although it ranges from very coarse to very fine grained; it varies considerably in color. Generally the arkose, particularly the coarser phases, is mottled by the color contrast between the grains of feldspar and the finer matrix of clay (hematitic?) and quartz grains. The coloring in the coarse arkose is usually mottled very pale orange (10YR8/2) and pale yellowish brown (10YR4/2) or light brown (5YR5/5) and pinkish gray (5YR8/1). Colors of the same hues (5YR and 10YR) predominate in the fine-grained arkose with value (lightness) ranging from 3 to 8 and chroma (saturation) from 1 to 6. The feldspathic sandstone is mainly medium grained to fine grained, but all variations from very coarse-grained to very fine-grained feldspathic sandstone occur in the East Berlin. Its prevailing color is varying values of gray — ranging from dark gray (N3) to very light gray (N8). The color of some feldspathic sandstone is of hues 5YR and 10YR with value from 3 to 6 and chroma from 1 to 4.

A medium gray (N5) quartz sandstone (orthoquartzite?) forms a bed 14 inches thick in the East Berlin formation at the Highway 72 roadcut (Unit 24). The rock is distinctive, for the quartz clasts are so thoroughly cemented that the rock might be called an orthoquartzite, and many quartz grains are quite clear, yet non-angular, and give a glassy appearance to the rock.

The rocks composed of particles of silt and clay size are dominant in the East Berlin formation, probably comprising well over half the exposed section. Those with fissility are called shale, whereas those without fissility, being generally massive, are called mudstone.

The fissility of the shale is principally due to the thin stratification or lamination of the rock, although in some poorly stratified rocks it is due to parallel orientation of the common micaceous minerals. In some, chiefly the dark gray to black shales, the fissility is very even, giving an almost slaty appearance to the rock; but in others, generally the red shales, the fissility is poorly developed and flaky. This general relationship between color of shale and degree of fissility was noted by Ingram (1953, p. 871) and demonstrated experimentally in the laboratory (Ingram, 1953, p. 874).

The shale of the East Berlin is predominantly grayish red (10R4/2), the value ranging from 3 to 6 and the chroma from 2 to 6, producing such colors as dark reddish brown (10R3/4) and moderate reddish orange (10R6/6). Grayish brown and moderate brown (5YR3/2 and 5YR3-4/4) shale is also found, as is grayish black (N2), dark gray (N3), and medium gray (N4) shale rich in organic matter. The predominantly red and reddish brown shale weathers to light brown or yellowish brown, whereas the black and gray shale commonly weathers to pale yellowish orange (10YR8/6) and pale olive (10Y6/2) — also greenish to dark greenish gray (5G6/1 to 4/1); in the process, discernible lamination of the fresh shale is accentuated.

The massive mudstone of the East Berlin is, like the shale, predominantly grayish red (10R4/2); the beds range in thickness from several inches to three or four feet. The range of variability of the red hue 10R (and the brown hue 5YR) is about the same in the mudstone as in the shale. Grayish/red-purple (5RP4/2) and varying values of gray (medium dark gray to medium light gray — (N4 to N6) mudstone is also found. The color of the weathered surfaces of the mudstone is very similar to that of the shale and exhibits about the same variability. Differences in weathering alterations (surface coloration) on the weathered surfaces of some mudstone (just as in some shale) bring out lamination that is difficult to identify on a fresh broken surface. Because of differences in competency under stress, the mudstone has much better developed jointing than the shale. Consequently the mudstone outcrops are characterized by relatively smooth surfaces, whereas the shale outcrops are commonly irregular, the bedding being the principal planar feature. The mudstone generally breaks with a relatively smooth curved fracture, but some is splintery because of closely spaced joints.

The most complete and easily accessible section of the East Berlin formation known to the writer in the Triassic Valley area of Connecticut and Massachusetts is in the roadcut along Connecticut Highway 72 in the Middletown quadrangle. Field descriptions and measurements of this section are presented here.

East Berlin and Hampden Basalt

Highway 72 Roadcut

Location: 28.74 N-60.41 E to 28.83 N-60.29 E

Description begins at top of stratigraphic interval exposed

| *Unit No.* | *Thickness Ft.* | *In.* | *Hampden basalt* |
|---|---|---|---|
| 1 | 160 (cal.) | | Upper 40 to 60 feet of exposed basalt weathers out to small, irregular-shaped blocks with curved surfaces, in strong contrast to underlying part, which is generally very massive. The upper 20 feet (approximately) of the massive basalt is quite vesicular. The basalt is also slightly vesicular just above its base (contact with underlying sedimentary rocks).<br><br>The basalt is cut by many (observed) strike-slip faults (minor?), which have relatively small shear zones. Some of the faults show fault breccia and gouge (mylonite?) and nearly all show well developed slickensiding. The strike-slip faults have two general orientations: one set strikes from true north to N 10° W, dip 65° to 85° SW; the other set strikes from N 40° E to N 70° E, dips 65° to 80° NW.<br><br>Contact with underlying sedimentary rocks of the East Berlin very well exposed showing the conformable relations between the rock types. The basalt has slightly metamorphosed the underlying mudstone. |

| Unit No. | Thickness Ft. | In. | Hampden basalt |
|---|---|---|---|
| 2 | 1 | 2 | Medium gray (N5) to medium dark gray (N4) mudstone with some fine to very fine clastic quartz. Some evidence of recrystallization, particularly in the upper 4 to 6 inches of this unit which is coarser textured. Locally this upper zone has a vesicular appearance (generation of steam —— gas holes — in the water-soaked sediments at time lava flowed out?). |
| 3 | 18 | 4 | Grayish red (10R4/2) shale and mudstone with varying amounts of medium to coarse clastic quartz and muscovite — particularly in upper 6 to 8 feet of this unit, which may be called a feldspathic sandstone or arkose in some beds. Upper 4 to 6 inches of this unit has a very faint bluish hue.<br><br>Attitude: N 17° E, 17° SE on bedding — average of 5 observations. |
| 4 | 50 (approx.) | | COVERED INTERVAL |
| | | | North side of roadcut |
| 5 | | 5 | Light olive-gray (5Y5/2) very fine-grained sandstone or mudstone. |
| 6 | | 10 | Medium dark gray (N4) mudstone, which grades upward into overlying unit. |
| 7 | 2 | | Grayish red (10R4/2), massive mudstone. |
| 8 | 3 | 9 | Light gray (N7) to medium gray (N5), medium-grained to coarse-grained, quartzose sandstone interbedded with thin beds of grayish red (10R4/2) mudstone and shale. |
| | | | South side of roadcut |
| 9 | | 6 | Similar to underlying unit except that the color becomes medium dark gray (N4). |
| 10 | 15 | 4 | Grayish red (10R4/2) massive mudstone, about 10% of the rock near the base of the unit being medium- to coarse-grained clastic quartz and muscovite. Amount of coarse clastic increases upward. Top of unit about 30% clastics which are medium grained to very coarse grained. Some mud cracks are exposed on bedding surfaces in this unit.<br><br>Attitude of bedding: N 30° E, 17° SE<br>Attitude of jointing: N 22° E, 72° NW, and N 65° W, 87° NE |
| 11 | | 6 | Medium gray (N5), fine-grained to medium-grained sandstone. Predominantly clastic quartz. This unit grades upward into overlying unit. |
| 12 | | 9 | Interbedded medium dark gray (N4) mudstone and medium to medium-light gray (N5 to N6) very fine-grained sandstone (feldspathic). Bedding units 1 to 3 inches thick. Some bedding surfaces show mud cracks. |
| 13 | | 9 | Grayish red (10R4/2) massive mudstone with 10 to 20% fine-grained to coarse-grained clastic quartz and muscovite near top of unit. Upper surface mud-cracked. |

| Unit No. | Thickness Ft. | In. | Hampden basalt |
|---|---|---|---|
| 14 | 1 | 10 | Light brownish gray (5Y5/1) fine-grained to coarse-grained feldspathic sandstone. |
| 15 | | 7 | Interbedded (beds 1/4 to 1½ inch thick) feldspathic sandstone and shale like next two units below. |
| 16 | | 6 | Medium to medium dark gray (N4.5), very fine-grained, very compact, feldspathic sandstone, which weathers to dark yellowish brown (10YR3/2). Current ripple on upper surface. Wave length about 1 inch amplitude about 1/4 inch, indicating a current sense toward the NW quadrant. |
| 17 | 4 | 6 | Dark gray (N3); shale and mudstone. Beds generally thick, ranging in thickness from 1 to 10 inches. Quite resistant to weathering. Weathered surface dark greenish gray (5GY4/1) and olive-gray (5Y4/1). Somewhat calcareous. |
| 18 | 1 | | Grayish black (N2) shale, highly crumbly; weathers to small chips. Similar in lithology and appearance of outcrop to fracture-cleaved shale lower in section (Unit 28). Some secondary pyrite cubes found on partings and fractures. Occasional fish scales and other bits of organic debris as carbonaceous films on bedding surfaces. |
| 19 | | 8 | Dark gray (N3) shale, platy, laminated. Laminae weather to dark gray (N3), light gray (N7), and pale yellowish orange (10YR8/6), accentuating the laminar character of the unit. Some pyrite crystals, 1 mm or less on an edge, found disseminated throughout the unit. Occasional fish scales as carbonized films on some bedding surfaces. |
| 20 | 10 | 4 | Interbedded medium gray (N4) fine- to medium-grained feldspathic sandstone (dominant), medium gray (N4) shale (highly fissile), and occasional grayish red (10R4/2) mudstone (beds 1 to 4 inches thick). Abundant quartz and micaceous minerals (clastic) in sandstone. Many bedding planes with thin shale partings, which are mud-cracked. Locally slightly calcareous. |
| 21 | 4 | 9 | Grayish red (10R4/2) massive mudstone. |
| | | | Measurements on north side of road |
| 22 | 3 | 1 | Interbedded medium- to very coarse-grained, medium gray (N4) to medium dark gray (N3) feldspathic to quartzose sandstone; dark gray (N3) shale along partings in the sandstone. Slightly calcareous. |
| 23 | 9 | 6 | Grayish red (10R4/2) massive mudstone. |
| 24 | 1 | 2 | Medium gray (N5), fine-grained, highly quartzose sandstone that is extremely well cemented and tough (orthoquarzite?) Quartz clasts round to sub-round and very transparent. The matrix surrounding the quartz grains is very dark colored, and consequently on first examination the quartz appears to be smoky quartz. |
| 25 | 1 | 8 | Grayish red (10R4/2) mudstone. |
| 26 | 7 | | Dark gray (N3) to medium dark gray (N4) shale. Very similar to unit (29) directly below fracture-cleaved unit stratigraphically lower in section. Lower 4 feet of unit quite massive, weathering to pale yellowish orange |

| *Unit No.* | *Thickness Ft.* | *In.* | |
|---|---|---|---|
| | | | (10YR8/6) for the most part, pale olive (10Y6/2) locally. Upper 3 feet of unit very thinly bedded, non-massive; weathers distinctively to greenish gray (5G6/1) to dark greenish gray (5G4/1). Slightly calcareous. |
| 27 | | 5 | Grayish black (N2), very fissile, thinly bedded, easily weathered shale. |
| 28 | | 10 | Grayish black (N2), highly fractured shale, fracture cleavage well developed with occasional very small drag folds. Fracture cleavage forms an angle of 30° to 40° (to the northwest) with the upper bedding surface of this unit. The shear sense of the fracture cleavage and drag folds indicate that the upper beds have moved relatively down-dip to the southeast. |
| 29 | | 9 | Dark gray (N3), laminated shale, with secondary pyrite. Laminae weather to pale olive (10Y6/2) or pale yellowish orange (10YR8/6), accentuating the lamination. Slightly calcareous. |
| | | | Attitude of bedding: N1° W, 20° NE — average of 5 observations |
| 30 | 4 | | Medium gray (N5) to medium dark gray (N4), highly micaceous, very fine-grained sandy mudstone. |
| 31 | 7 | 10 | Grayish red (10R4/2) mudstone and shale. Quite massive, except for upper 2 feet, which is shaly and weathers out readily. |
| 32 | 3 | | Moderate brown (5YR5/5) to pinkish gray (5YR8/4) and grayish red (10R4/4), medium-grained to very coarse-grained arkose. Basal part of unit is a granule conglomerate locally. Thin stratification; variations in grain size from stratum to stratum. Unit is quite massive in beds 2 to 14 inches thick. Arkose is compact and tough, breaks with somewhat conchoidal fracture. Weathered surface is moderate brown (5YR4/4) to light brown (5YR5/6). |
| 33 | 18 | 6 | Grayish red (10R4/2) to reddish brown (10R4/4) mudstone with a few shale layers. Massive to thinly bedded. Some strata weather-mottled. |
| 34 | 2 | 6 | Grayish red (10R5/2), very fine-grained arkose, very thinly stratified, beds 2 to 12 inches thick, quite tough; breaks with a conchoidal fracture. |
| 35 | 4 | 10 | Grayish red (10R4/2) mudstone with clay shale partings. Mudstone is thinly laminated for the most part. Mud cracks on the shale partings. |
| 36 | 1 | 6 | Grayish red (10R4/2), very fine-grained, massive, thinly stratified arkose. |
| 37 | 6 | 9 | Grayish red (10R4/2), thinly laminated shale and mudstone with occasional thin lenses of medium-grained arkose. Some very small-scale cut-and-fill observable in the arkose lenses. Lustrous appearance on the parting surface — produced by extremely finely divided hematite-rich clay? |
| 38 | | 9 | Grayish red (10R4/2), medium-grained to coarse-grained arkose to feldspathic sandstone. This unit lenses out to a thickness of 1 to 2 inches 20 to 30 feet up the dip from road level. Arkose is very tightly cemented and tough. Weathered surface is pale brown (5YR5/2). |

| Unit No. | Thickness Ft. | In. | Hampden basalt |
|---|---|---|---|
| 39 | 6 | 6 | Grayish red (10R4/2) shale and mudstone. Four feet from base of unit is a 4-inch bed of current-cross-bedded, medium-grained to coarse-grained arkose or feldspathic sandstone. Angular fragments of the enclosing mudstone and shale are found along the cross-stratification planes. Cross-bedding inclined 23° from major stratification of unit, dipping toward the northwest, indicating a stream sense in that direction. Predominant color of cross-bedded unit the same as that of the next lower unit. |
| 40 | 1 | 4 | Pale brown (5YR5/2) to light brown (5YR6/4), medium-grained, arkosic sandstone. Very small-scale cross-bedding is barely discernible. |
| 41 | 5 | 6 | Grayish red (10R4/2) mudstone and shale. Mud-cracked bedding surfaces. |
| 42 | 3 | | Light pale brown (5YR6/2) at base of unit to pale brown (5YR5/2) at top of unit. Medium-grained arkose with readily discernible clasts of quartz, muscovite, and feldspar. Mud polygons, from underlying mudstone and shale, enclosed in arkose near its base. Mud cracks, which extend several inches into underlying mudstone, are filled with the strongly contrasting arkose and are well exposed in cross section. |
| 43 | 16 | | Grayish red (10R4/2) mudstone, quite massive, becomes sandy near the top. Upper surface extensively mud-cracked; some cracks extend to a depth of 6 inches in the mudstone. |
| 44 | 4 | | Pale yellowish brown (10YR6/2) to moderate yellowish brown (10YR5/4) arkose, fine-grained grading upward to very fine-grained. Some cross-bedding in the lower part. |
| | | | Attitude of bedding: N 21° E, 18° SE — average of 5 observations |
| 45 | 2 | 6 | Medium dark gray (N4), thinly laminated (1/32 inch or less) mudstone, massive despite the thin lamination. Laminae weather to different colors, accentuating the lamination of the mudstone. |
| 46 | 3 | 6 | Grayish red (10R4/2) thinly bedded shale, mudstone in upper part of unit. Shale and mudstone very well indurated, producing small, sharp-edged chips on weathering. |
| 47 | 2 | | Mottled light gray (N7) and medium gray (N5) feldspathic sandstone thinly stratified, 1 to 4 inches thick, cross-bedded on a small scale. Cross-bedded wedges 1 to 3 inches long and 1/2 to 1 inch high, giving the impression of being eolian cross-bedding. Upper part of the unit quite shaly. |
| 48 | 6 | | Grayish red (10R4/4) medium-grained feldspathic, highly muscovitic sandstone with numerous irregular shale partings. The shale partings are not horizontal but convoluted. In some places the shale-sandstone relationship suggests an interformational conglomerate (shale fragments forming the clasts). On weathered surface the unit appears "nodular." |
| 49 | | 8 | Light gray (N7) to pale reddish brown (10R5/4), highly micaceous, medium-grained arkose interbedded with thin shale streaks. One arkose bedding surface exposes well developed oscillation ripple marks; average |

| Unit No. | Thickness Ft. | In. | |
|---|---|---|---|
| | | | wave length 1 inch, average amplitude about 1/10 of an inch. Wave crests and troughs are oriented N 65° W. |
| 50 | 6 | | Grayish red (10R4/2) shale and mudstone, highly micaceous. |
| 51 | 25 (approx.) | | COVERED INTERVAL |
| 52 | 15 (approx.) | | Generally grayish red (10R4/2 — color ranges widely), blocky, massive (3-foot beds) mudstone, thinly bedded shale, and some fine-grained arkose and fine-grained arkosic conglomerate, all interbedded. Mudstone is dominant. |
| 53 | 10 | | Principally medium dark gray (N4), thinly bedded shale, weathers to greenish gray (5GY6/1), abundant, small, sharp-edged chips. |
| 54 | 20 (approx.) | | COVERED INTERVAL |
| | | | South Side of Road Cut |
| 55 | 4 | 6 | Dark yellowish red (10YR6/6) to grayish red (10R4/2) thinly bedded shale and massive mudstone and arkose interbedded, the mudstone dominant. Just below the top is a bed of shale that weathers readily to a distinctive moderate yellowish brown (10YR5/4) or dark yellowish orange (10YR6/6). Mudstone weathers to conchoidal chips, which are very abundant on the outcrop. |
| | | | Attitude of bedding: N 12°E, 16° SE — average of 5 observations |
| | | | Attitude of joint surfaces: N 34° E, 73° NW and N 64° W, 85° NE — average of 5 observations |

Base of exposed section.

324 ft. — Total stratigraphic interval spanned.

Varied sedimentary structures are found in outcrops of the East Berlin formation in the Middletown quadrangle. The commonest are the shrinkage (mud) cracks on the bedding surfaces of the shale and mudstone, especially in the grayish red shale and mudstone, but also in the black to dark gray shale at the Highway 72 roadcut described. Shrinkage cracks filled with the overlying rock are well exposed in cross section in several beds at the Highway 72 roadcut. The shrinkage cracks are highly variable in outline and exhibit various surface configurations ranging from convex upward through flat to concave upward. Those that are convex upward are normally best developed on the thin shale beds overlying sand-sized clastics.

Ripple-marked bedding surfaces of the East Berlin are exposed at several localities; both the oscillation and current varieties occur. Oscillation ripple marks are found near the base of the section at the Highway 72 roadcut (Unit 49) and also at the dinosaur footprint locality south of Baileyville at 24.413 N-60.52 E, where raindrop imprints are also preserved on some of the bedding surfaces exposed. Current ripple marks are found on the bedding surface of a very fine-grained feldspathic sandstone near the middle of the section at the Highway 72 roadcut (Unit 16).

The current ripple marks are of short wave length (1 inch) and small amplitude (1/4 inch) and indicate a current sense toward the northwest quadrant.

Cross-bedding is variably developed in the sand-sized clastics. Generally it is on a small scale. Aqueous cross-bedding is exposed in many beds at the Highway 72 roadcut, at 26.71 N-61.0 E, in several beds at 28.7125 N-61.4275 E five to six feet below the exposed contact with the overlying Hampden basalt, and at 24.6675 N-60.775 E along Ellen Doyle Brook, which drains Beseck Lake. What appears to be small-scale eolian cross-bedding (wedge-shaped units 1 to 3 inches long and 1/2 to 1 inch high is exposed in the Highway 72 roadcut near the base of the section in thinly stratified gray feldspathic sandstone (Unit 47).

A small channel filling about one foot deep and three to four feet long is exposed in the arkose about four feet below the contact with the overlying Hampden basalt at 27.388 N-61.4 E. The channel appears to have been filled by currents flowing generally north, while the unit in which the channel is cut has well developed cross-bedding that indicates a stream sense toward the south (attitude of cross-bedding is N80° W, 25° SW).

Fragments of carbonized fossil fish, mostly isolated fish scales, are found at several outcrops of the East Berlin where the dark gray to black shales are exposed. They were found in the bedding-plane partings in the stratigraphically highest dark gray to black shale exposed in the Highway 72 roadcut and in the gray to black shale exposed in a stream bank at 27.77 N-61.378 E and 27.66 N-61.358 E. The latter two exposures are probably the "posterior shales" at Westfield, which were described by Davis and Loper (1891, p. 427) as "known for many years" and from which numerous fairly complete fossil fish specimens have been obtained. Many of these specimens are currently in the Wesleyan University Museum at Middletown. The very well known fossil dinosaur track locality south of Baileyville on Powder Hill at 24.412 N-60.52 E is the only known occurrence of fossil dinosaur footprints in the East Berlin formation in the Middletown quadrangle. At this location, which is part of the Peabody Museum of Yale University and maintained by the museum, tracks of what were probably three different species of dinosaurs may be seen.

The contact of the East Berlin formation with the conformably overlying Hampden basalt is the best exposed contact of the Newark group in the Middletown quadrangle. The most accessible of the outcrops exposing this contact are found at the extreme north and south margins of the map. At the Highway 72 roadcut in the northwest corner of the quadrangle, the contact is completely exposed on both sides of the highway for a down-dip distance of about 75 feet. The East Berlin mudstone immediately below the Hampden basalt is medium gray to medium dark gray (N5 to N4) and shows some evidence of recrystallization in the four to six inches ~~immediately below the~~ contact. This upper zone of the mudstone locally contains what appear to be vesicles; probably they represent steam holes produced at the time the lava flowed out because of the abundance of water in the muds over which the hot lava flowed. For a thickness of six inches to a foot above the contact, the Hampden basalt is varyingly vesicular; some of the vesicles are elongate "perpendicular" to the contact and are tipped toward the northwest quadrant, suggesting that the lava flowed in that direction.

The other readily accessible East Berlin-Hampden contact is found on the south side of Connecticut Highway 147 going west toward Baileyville at 24.66 N-60.805 E. This outcrop is rather heavily weathered and the contact between the East Berlin and the Hampden basalt is not as readily discerned as in the Highway 72 exposure. At the Baileyville exposure of the contact the immediately underlying sedimentary rocks show no megascopic evidence of contact metamorphism. At the top of the underlying East Berlin is a unit three to four feet thick; the rock is a coarse-grained to very coarse-grained, muscovitic arkose near the contact and grades downward to medium-grained arkose at the base of the bed. The rock is mottled very light gray to medium gray (N7 to N5) with occasional specks and bands (parallel to bedding) several millimeters across in which grayish brown (5YR3/2), hematitic (?) silt is highly concentrated in the arkose. There is some suggestion of current cross-bedding in this arkose unit. For a stratigraphic interval of several feet, the Hampden basalt immediately above the contact has a well developed parting (spaced ½ to 1 inch) parallel to the contact; upon casual observation this parting looks like the stratification of sedimentary rock. This platy jointing is known in the Middletown quadrangle only at this outcrop. The other exposures of the base of the Hampden basalt (or of any of the other basalts) have no such parting developed parallel to the contact. It was first thought that the platy jointing of the basalt at this outcrop developed parallel to the contact with the underlying arkose as a result of the cooling of the lava, the heat transfer being mainly at right angles to the contact and the isothermal surfaces basically parallel to the contact. As platy joints occur at the base of lava flows nowhere else in the area, however, this interpretation is not tenable, for similar thermal gradients obviously obtained at the other contact areas. More probably the platy joints have developed in response to flow banding (Turner and Verhoogen, 1951, p. 51) that had developed in the Hampden basalt in the immediate vicinity of this outcrop.

The East Berlin-Hampden contact is exposed at many other outcrops in the Middletown quadrangle, principally in the north-central part. Several outcrops along the low ridge trending east of north, just east of Westfield, expose it. At the northernmost (27.3875 N-61.40 E to 27.4075 N-61.406 E) of these three exposures lava pillows are found in the lower two feet of the Hampden basalt. The pillows are about two feet in diameter and have well vesiculated outer "shells." At these localities the underlying sedimentary rock is arkose, thinly stratified, generally medium grained, and light olive gray (5Y6/1) to greenish gray (5G7/1) with streaks of gray brown (5YR4/2) parallel to the bedding. This arkose unit is 12 to 16 inches thick and is underlain by finer-grained arkose, mudstone, and shale, generally grayish red (10R4/2). The lighter colors of the arkose immediately below the Hampden basalt are probably the result of metamorphic alteration of the finely divided hematite that produces the red color in the majority of the sedimentary rocks of the Connecticut Valley Lowland.

A series of outcrops on the steep west slope of a low ridge trending east of north, just east of the village of East Berlin, also expose the East Berlin-Hampden contact. The southernmost of these exposures, at 28.38 N-61.285 E, exposes about four feet of the underlying East Berlin formation; characteristic grayish red (10R4/2) shale and mudstone below gives way to a unit about one foot thick, immediately below the basalt, of thinly stratified, medium-grained, micaceous, arkose, pale brown (5YR5/2) with thin bands (1/8 inch or less) of grayish brown (5YR3/2) silt parallel to stratification. Locally in this area, pillows are found through as much as 10 feet of the overlying Hampden basalt. Where the basalt shows pillows, it is generally quite vesicular, whereas the overlying 45 to 50 feet of basalt in these outcrops is very massive and fine grained. Along this same ridge at 28.685 N-61.4 E, the sedimentary rock underlying the Hampden basalt is massive mudstone (2 1/2 feet exposed); it is grayish red (5R5/2) below but changes to blackish red (5R3/2) in the foot next below the basalt and appears to contain very small (1 mm or less) disseminated crystals of a metallic sulfide, probably pyrite or chalcopyrite. At this outcrop and those to the northeast to the edge of the quadrangle, the overlying Hampden basalt is quite vesicular although no pillows are in evidence. The mudstone at the top of the underlying East Berlin formation persists in the outcrops to the northeast that expose the contact, in contrast to the arkose next below the contact to the south. More commonly the underlying mudstone is pale red (5R6/2) or light brownish gray (5YR6/1) rather than blackish red (5R3/2) as at the outcrop just described. The mudstone is not infrequently scoriaceous immediately below the contact, perhaps because of solution and/or differential weathering, or perhaps because the water contained in the mud was converted to steam by the heat of the lava flow. At several of the outcrops exposing the contact along this ridge, the mudstone immediately below the contact is underlain by fine-grained to medium-grained arkose that exhibits small-scale current cross-bedding.

### Hampden Basalt

The Hampden basalt, stratigraphically the highest of the lava flows of the Newark group, is exposed in a series of low ridges trending generally north across the center of the quadrangle and in the northwest corner. Its belt of outcrop has been offset and repeated by faulting. Because the dip is consistently to the east-southeast, and because the Hampden basalt is the youngest of the three basalts within any one structural block, it normally forms the most easterly of the trap ridges of the Connecticut Valley Lowland. The width of the outcrop belt of the Hampden basalt is variable in the area, ranging from about 600 feet in the northwest corner of the quadrangle, where the dip of the Hampden basalt is at a maximum (17° to 20°), to about 3500 feet in the Miramichi area west of Middletown, where the low dip (7° to 8°) of the Hampden and the topography combine to widen the belt.

The Hampden basalt generally crops out in low, west-facing scarp faces that are discontinuous along the strike, in road and railroad cuts generally transverse to strike, and in the beds and cut banks of the small generally adjusted streams and the larger generally discordant streams (the Mattabesset and Coginchaug).

The stratigraphic thickness of the Hampden basalt is apparently 150 to 160 feet in the Middletown quadrangle. The maximum exposed thickness of the Hampden basalt is at the Highway 72 roadcut at the northwest corner of the quadrangle where calculations based on width of outcrop belt and dip indicate a thickness of about 160 feet. Four structure cross sections on lines along which generally good outcrop control is available indicate a thickness for the Hampden basalt of about 150 feet.

The Hampden is generally massive, dense, tough, fine-grained basalt of grayish olive-green (5GY3/2), greenish gray (5G5/1), dusky yellow-green (5GY5/2), or grayish olive (10Y4/2) color. At three outcrops, which are very near the upper contact stratigraphically, it is grayish red (10R4/2) on fresh fracture surfaces or mottled grayish red (10R4/2) and grayish olive green (5GY3/2) through an exposed thickness of several feet. Two of these exposures are in Wadsworth Falls State Park at 25.27 N-61.5125 E, on the northwest side of the railroad tracks, and at 25.3475 N-61.37 E on the southwest bank of the Coginchaug River. The third exposure is in the north bank of a small intermittent stream at 27.1575 N-61.5875 E.

Many outcrops display well the vesicular and amygdaloidal character of the Hampden; generally they are either within about the upper 20 feet of the flow or within a few feet of its base. The minerals of the amygdales of the Hampden differ from locality to locality, but a chlorite-like mineral predominates and calcite, prehnite, and zeolite also occur. At some localities, such as the abandoned quarry along Highway 72 at 28.02 N-61.69 E, prehnite is the dominant mineral.

The contact of the Hampden basalt with the overlying Portland arkose is exposed at two localities along the Coginchaug River in the south-central part of the quadrangle. At 25.3475 N-61.370 E in the southwest bank of the Coginchaug River, a dip-section outcrop exposes the contact of the Hampden with the overlying Portland for a distance of approximately 100 feet. At this locality the upper several feet of the Hampden basalt is grayish red (10R4/2), whereas the overlying Portland is coarse- to very coarse-grained arkose and arkosic conglomerate containing occasional fragments of angular basalt. To the north, in the north bank of the Coginchaug River at 25.730 N-61.735 E, the contact of the Portland arkose with the older Hampden basalt is nearly exposed and can be dug out. Here the uppermost Hampden basalt does not display the grayish red (10R4/2) color described above but is grayish olive (10Y4/2) to dusky yellow green (5GY5/2) and very amygdaloidal; the amygdales contain predominantly a chlorite-like mineral with some calcite, prehnite, and (rarely) a zeolite mineral. The overlying Portland is here grayish red (10R4/2) fine-grained, highly micaceous arkose and mottled pale brown (5YR5/2) and medium gray (N5) medium- to very coarse-grained, highly micaceous arkose.

### Portland Arkose

Except for the very small area in the extreme southeast corner of Middletown quadrangle where the pre-Triassic Bolton schist crops out, the Portland arkose underlies the entire eastern half of the quadrangle; it also appears in the northwest quarter as the result of faulting.

The nature of the outcrops and the extent of exposure of the Portland arkose are extremely variable in the area. In approximately the northern two-thirds of the eastern half of the Middletown quadrangle, the Portland is generally very poorly exposed; outcrops are almost entirely restricted to the banks of streams, to roadcuts, and to the well known but now abandoned brownstone quarries of Portland and Cromwell. In the southern third of the eastern half, however, the Portland is well exposed. Here near-strike ridges trending generally slightly east of north present numerous west-facing low scarps and cliffs (vertical faces 40 to 60 feet high are not uncommon) of Portland arkose for strike distances over half a mile.

The thickness of the Portland arkose is not directly measurable and can only be approximated. On the basis of approximate structural sections and calculations, the present thickness of the Portland arkose in the Middletown quadrangle appears to be about 3000 to 3500 feet. Krynine (1950, p. 69) reported an estimate for the present thickness of "4000 feet in central Connecticut." As indicated by Krynine (1950, p. 69) and others, the total primary thickness of the Portland was undoubtedly greater than the present thickness, as an undetermined amount has been lost by erosion subsequent to deposition.

The Portland arkose is highly varied, ranging from fanglomerate and coarse, arkosic conglomerate to black shale, mudstone, and highly calcareous arkose.

Fanglomerate crops out very near the Eastern Border Fault on a steep southwest-facing slope of Sumner Brook valley at 24.36 N-63.215 E. This is the only outcrop of an undoubted fanglomerate in the Middletown quadrangle. The rock is polymict and contains boulders up to several feet in diameter with very poor sorting, rounded to highly angular clasts, and virtually no stratification. The rock types among the clasts in the fanglomerate are similar to those in the conglomerate described below.

Conglomerate is abundant in the Portland, particularly as the Eastern Border Fault is approached, although fine-grained arkose, mudstone, and shale are also found in close proximity to the Eastern Border Fault. The conglomerate is polymict and mottled by differences in color of the clasts, matrix, and cement; the colors include moderate orange pink, gray orange pink, and pale brown (5YR8/4, 7/2, and 512) and varied values and chromas of the 10R and 10YR hues. The clasts are highly varied also in rock type, yet few of the rocks cropping out in the metamorphic complex east of the Eastern Border Fault (as known by this writer in the field and from the literature) are positively represented. The predominant rock in the clasts is a lustrous, fine-grained to medium-grained, garnetiferous, gray phyllite. Quartzite, massive quartz, finely foliate quartz-feldspar gneiss, fine-grained schist (biotite and muscovite, rarely chlorite), granite, and (rarely) vesicular or amygdaloidal basalt are also found as clasts in the Portland in the Middletown quadrangle. The rounding of the clasts larger than sand-size in the Portland conglomerate is highly variable within the same conglomerate bed; many pebbles, cobbles, and even boulders are rounded to well rounded while others are definitely angular to sub-angular. The matrix of the conglomerate is in most cases typical "red" arkose of the Portland; the sorting is generally poor and the sand-sized grains of quartz, feldspar, and mica (mostly muscovite) exhibit more angularity than the coarser clasts.

The dominant rock type in the Portland is arkose; it ranges from fine- to very coarse-grained, but the majority falls in the coarser grain sizes. The arkose of the Portland is similar in all other major megascopic respects to the arkoses of the Shuttle Meadow formation and East Berlin formation. The coarser arkose is commonly mottled moderate orange pink, gray orange pink, and pale brown (5YR8/4, 7/2, and 5/2); the medium- to fine-grained arkose is more commonly grayish red (10R4/2) or displays varying chromas and low values generally less than 5 of the 5R, 10R, and the 5YR hues. Arkoses of varying shades of gray to green are found at many stratigraphic levels in the Portland. In the outcrops studied in the Middletown quadrangle there are at least 20 separate units of gray to green arkose and intercalated shale and mudstone in the Portland. Some of these stratigraphic units can be traced approximately two miles on strike through a series of outcrops, while others are apparently represented by single outcrops. The thickness of these units of gray to green sedimentary rocks is quite variable: the thickest exposed section displays a stratigraphic interval of about 25 feet. One unit has an apparent thickness of 75 to 125 feet if the rock does not change between the closely adjacent limiting outcrops. Stratigraphically the gray to green arkoses are found throughout the Portland arkose. The lowest unit is found within 30 feet of the base, and the highest crops out 100 feet or less from the Eastern Border Fault at three localities in the southeast corner of the quadrangle. The predominant color is greenish gray to dark greenish gray (5GY6/1 to 4/1), but other colors occur, such as olive gray to yellowish gray (5Y4/2 to 7/2); greenish gray (5G6/1), which is quite common; grayish to pale olive (10Y4/2 to 6/2); light to medium dark gray (N7 to N4); and, in one instance, grayish blue green (5BG5/2). Quite commonly the gray to green arkose has appreciable amounts of calcite and possibly dolomite as the cement and part of the fine matrix. Part of the stratigraphically lowest gray to green arkose unit is pronouncedly nodular and calcareous.

Feldspathic sandstone occurs throughout the entire Portland arkose and shows all the variations in color and size of constituent clasts just described. Generally, however, the feldspathic sandstones, at least those identifiable in hand specimen, are more commonly varying shades of gray to green than the arkose. They commonly are better sorted than the arkoses with better-rounded clasts and with smaller amounts of matrix and cement, and they are commonly quite fine grained and tough. The feldspathic sandstones are intimately interbedded with the gray to green arkoses of the Portland.

Dusky red (10R4/2) sandy, micaceous, nodular shale showing shrinkage cracks and intertonguing into thinly bedded, well stratified, quite well sorted, yellowish gray (5Y7/2) arkose or feldspathic sandstone, is well exposed in an outcrop at 27.7775 N-62.25 E on the west bank of Chestnut Brook west of Cromwell. At the southern end of the outcrop the shale bed is 8 to 10 inches thick, yet about 25 feet to the north the red shale pinches out and disappears in the yellowish gray arkose or feldspathic sandstone.

The fine-grained clastics, although comparatively less abundant in the Portland than in the Shuttle Meadow or East Berlin formations, occur throughout the entire Portland as exposed in the Middletown quadrangle. They are more abundant in the lower part than in the upper. This probably reflects not a significant change in sedimentation within the stratigraphic interval but simply that the stratigraphically higher parts of the Portland arkose now crop out close to the probable source area to the east (the Eastern Highlands); coarser clastics are generally found near the Eastern Highlands, whatever the stratigraphic interval.

The shale and mudstone of the Portland is generally grayish red (10R4/2), but other colors of low value (5 to 2) and intermediate to low chroma (4 to 2) of the 5R, 10R, 5YR, and 10YR hues are common, such as dark reddish brown (10R3/4), dusky red (5R3/2), grayish brown (5YR3/2), and dusky yellowish brown (10YR2/2). Shale and mudstone colored like the gray to green arkoses and feldspathic sandstones are found associated with them. The shales are typically highly muscovitic, the muscovite being unusually well rounded, in some instances nearly perfect disks, whereas the mudstones are not uncommonly calcareous.

Dark gray to black (N3 to N1) highly fissile shale is interbedded with generally gray feldspathic sandstone, micaceous shale, and calcareous mudstone at two localities in the Portland arkose. Although the lack of stratigraphic and structural control of sufficient accuracy makes it impossible to be sure, quite probably the two localities are stratigraphically equivalent. One locality is near the south margin of the quadrangle in the bed and stream banks of a small stream flowing northward into the Laurel Brook Reservoir at 24.38 N-61.87 E. This outcrop is the well known fossil fish locality of Durham. The other is to the northeast, in the east and south banks of Long Hill Brook, just north of the Pine Grove Cemetery at 25.645 N-62.48 E. To the writer's knowledge no fish fossils have been found at this locality.

A very unusual rock type is found low in the north bank of Chestnut Brook, west of Cromwell at 27.77 N-62.23 E. Here a bed 12 to 20 inches thick is surprisingly poorly exposed on top of a small ledge of compact, light gray (N7), calcareous mudstone. The unusual rock appears to consist of irregular, rounded masses (several inches in each dimension) of mudstone very similar to that below in a groundmass of brownish black (5YR2/1), very compact, tough, glassy-appearing quartz, which on some surfaces appears "scoriaceous," particularly where it is in contact with the calcareous mudstone. Scattered through the quartz are small (¼ to ½ inch diameter) radiating masses of quartz (?) crystals in a rosette pattern. As far as can be ascertained, this bed is conformable to the overlying and underlying rocks. The origin of this unusual lithology is unknown. An aqueous sedimentary origin seems unlikely, as is an intrusive origin. On first examination the rock appears grossly volcanic, although a volcanic origin fails to explain the details as described above. The non-granular character of the quartz strongly suggests crystallization, either with deposition or diagenetic or post-diagenetic. Yet these alternatives make the unaltered appearance of the calcareous mudstone masses difficult to explain. No final conclusion as to the origin of this rock can be presented at this time.

Numerous examples of various syngenetic sedimentary structures are found in the outcrops of the Portland arkose in the Middletown quadrangle. Of these, the most common are aqueous cross-bedding and shrinkage (mud) cracks, found most frequently in the coarse arkoses to pebble conglomerates and the shales or mudstones respectively.

A preliminary study of the paleostream-sense of the cross-bedding in the Portland arkose by Thomas L. Plimpton and Orrin S. Hallock (Wesleyan students working under the direction of Dr. John L. Rosenfeld and Dr. Gordon P. Eaton) during the spring of 1956 indicated that the average direction of transportation was to the northwest. The inferred direction of transportation varies greatly, however, at different outcrops of cross-bedded arkose and conglomerate, and paleostream-senses in all quadrants may be found.

Shrinkage cracks are generally restricted to the lower part of the Portland arkose, like the shales and mudstones in which they typically occur, but even in that part of the Portland they are not as profuse as in the East Berlin formation.

Current ripple marks are found on the bedding surfaces of the arkoses at several localities. Usually the ripple marks are of very small wave length (1 to 2 inches) and amplitude (about 1/4 to 1/2 inch). At the most accessible locality, on the east bank of the Coginchaug River under a bridge at 26.475 N-62.3 E, typical current ripple marks are found. Current ripple marks are not nearly as profuse in the Portland arkose outcrops as cross-bedding structures, but they indicate about the same range of variability in the paleostream-sense as the cross-bedding.

The only fossil plant material (unidentifiable) found in the Newark rocks of the Middletown quadrangle is in a tongue of dusky red (10R4/2) nodular sandy shale of the Portland exposed along Chestnut Brook, west of Cromwell at 27.7775 N-62.25 E. What may be the carbonaceous remains of plant stems or twigs of a tree are found along an exposed bedding plane. The organic material has apparently reduced the ferric oxide of the enclosing sandy shale, and consequently the thin, dark "stem" is bordered by a narrow zone (1/8 to 1/4 inch) in which the red color of the shale is altered to a gray green.

One of the best localities for collecting Triassic fossil fish in the Connecticut Valley Lowland is the Durham fossil fish locality in the lower part of the Portland arkose along the easternmost brook flowing into Laurel Brook Reservoir from the south. It has yielded excellent specimens to collectors since the middle of the last century. Numerous publications discuss the taxonomy of the fossil fish from this locality, and as the writer did not attempt to obtain a collection of specimens from the outcrop or to study the numerous specimens from this locality in the Wesleyan University Museum, no further discussion of the fossil fish is presented here. What may well prove to be the same stratigraphic horizon is also exposed to the northeast, as described above in discussing the black shale in the Portland arkose. No fossil fish specimens, nor indications thereof, were found there, but an intensive search was not made.

Many slabs of arkose from the well known brownstone quarries of Portland have been found to contain numerous, excellent tracks of highly varied species of dinosaurs. No tracks can be seen at these quarries at the present time, although many fine specimens are in the Wesleyan University Museum, the Peabody Museum of Yale University, and other museums of the New England region.

The only dinosaur footprints or trackways seen in a Portland arkose outcrop in the Middletown quadrangle during the present investigation were found west of the village of Cromwell. This outcrop was recently produced when a small dam across Chestnut Brook broke and the stream bed was heavily eroded by flood waters, uncovering bedrock surfaces immediately downstream from the old dam at 27.785 N-62.25 E. The dinosaur tracks found at this locality all belong to the genus *Anchisauripus* Lull. The interested reader is referred to Dr. Richard S. Lull's "Triassic Life of the Connecticut Valley" (1953), for a complete description of the fossil fauna and flora of the Triassic Newark group rocks.

## STRUCTURE

In this section only the epigenetic, tectonic structures in the area of the Middletown quadrangle are discussed. The syngenetic sedimentary structures are discussed above in this report under the description of the particular rock units.

### Regional Structure of the Triassic

The rocks of the Triassic Newark group in the Connecticut Valley Lowland form a prism-shaped body of intercalated sedimentary rocks and basaltic lava flows. Structurally this prism of rock is an eastward-dipping homocline bounded on the east by a normal fault, commonly referred to as the Great Fault (Krynine, 1950; Russell, 1922), although Davis (1889a, p. 73) first used this term for one of the faults within the Triassic (the fault separating the Hanging Hills and Lamentation Mountain blocks). In order to avoid confusion, and following the usage of Digman (1950) and others, this fault is referred to in this report as the Eastern Border Fault.

The contacts of the Newark group with the adjacent metamorphic and igneous rocks to the west and east have been variously interpreted by students of the Triassic of New England. Most generally the eastern margin is interpreted as an irregular, curving, major normal fault (or set of faults) dipping west 30° to 60°, the west margin as the surface on which Triassic sedimentary materials were deposited (an angular unconformity (Davis, 1898; Longwell, 1922; Wheeler, 1939)). The existence and character of the Eastern Border Fault in Connecticut has been demonstrated by artificial exposures at several localities in Connecticut (Digman, 1950, p. 40; Davis, 1898, p. 131).

Faulting within the Triassic area of central Connecticut has been recognized since the work of Davis and his co-workers during the last quarter of the nineteenth century. The major faults recognized are chiefly oblique to the strike of the sedimentary rocks; northeast-trending faults generally dominate in central and southern Connecticut and northwest-trending faults in northern Connecticut and southern Massachusetts. Although rarely exposed in outcrops, these major faults of the central and southern Connecticut areas are interpreted as normal faults, the west or northwest sides of most being downthrown.

The Triassic rocks have also been folded subsequent to deposition. In central and southern Connecticut the folding, or at least the evidence for it, is principally found along the eastern margin of the Triassic Lowland. The most obvious effect of the folding is the crescent-shaped ridges formed by the resistant basalts which serve to delineate the major structure. The folds are mainly basins elongate northeast-southwest and intervening southeast-plunging anticlines – referred to as saucers, dishes, half-boats, etc., by various workers. The mechanics of formation of the incomplete basins has been in dispute for many years. Wheeler (1939) discusses the problem of the basins near the Eastern Border Fault and concludes that the anticlinal and synclinal warps within the Triassic area are due to the mechanics of fault action along the curved fault surface (his interpretation of the form of the Eastern Border Fault), the anticlines being formed by friction against the fault on the salients (Eastern Border Fault deflections into the Triassic basin), and synclines forming in the re-entrants. Field data bearing on this problem appear to be absent in the Middletown quadrangle.

## Structures of the Middletown Quadrangle

Although ideally structure should be elucidated on the basis of stratigraphic information, many of the structural features shown on the accompanying map are inferred from the topography of the area in the light of the general structure of the region as currently known. Thus, for example, the two basalt ridges east of the village of East Berlin in the Middletown quadrangle are shown as Hampden basalt, although it is possible that they expose one of the other basalts of the area if the transecting faults are not normal faults with the northwest or west sides downthrown. Unfortunately, in this area particular outcrops cannot be identified as belonging to particular stratigraphic units of the Newark group with any degree of assurance. The stratigraphy and structure, therefore, must be interpreted concomitantly, using all available evidence.

*Folds.* Aside from the "folding" of the sedimentary rocks where they have been subjected to drag action adjacent to major faults, only doubtful fold structures are present in the rocks of the Middletown quadrangle. Near Wadsworth Falls State Park, the map pattern of the Hampden basalt and the attitudes of the Portland arkose suggest an anticlinal structure of very small vertical closure plunging to the southeast. Such an anticline would partially account for the apparent thickening of the East Berlin formation west of Wadsworth Falls State Park. The orientation of this fold is similar to that of the Rocky Hill

Anticline to the north and of the anticlines separating the "saucers" (or "half-boats," etc.) so well known and clearly defined farther south in the Connecticut Triassic. Like the Rocky Hill Anticline, this broad fold, if indeed it exists, appears to be cut by a transverse fault with the downthrown block to the northwest, judging by the abnormal thickness of the Hampden basalt in the Rockfall area as indicated by water wells and by surface outcrops and their attitudes.

*Faults.* Faults exposed in outcrop are designated on the geologic map by heavy solid lines, generally accompanied by strike-dip symbols giving the attitude of the fault surface as exposed. The inferred continuations of these faults, and those whose existence is quite certain from the topography, stratigraphy, minor structures, and/or field relationships, are indicated by heavy dashed lines. Faults, whose existence and position are inferred less certainly on the basis of topography, minor structures, and/or stratigraphy, are indicated on the geologic map by heavy dashed lines with intermittent question marks.

The great majority of the faults within the Triassic area of the Middletown quadrangle are oblique faults; dip- and oblique-slip normal faults, strike-slip, and bedding-plane faults are exposed and positively identified.

Normal faults are dominant in the Middletown quadrangle. Admittedly some of the stratigraphic and topographic relationships here explained by normal faults could be equally well explained by reverse faults with opposite dip. In this area, however, positive evidence for the existence of reverse faults is completely absent whereas the evidence for normal faulting is abundant – many minor normal faults as well as a few major normal faults are actually exposed. Logical simplicity therefore dictates that the inferred faults also be designated as normal faults. The normal faults, with one minor exception in the northwest quadrant, are apparently oriented in three "sets." The most common set, and the one with the largest apparent displacements, strikes about N 30° E; the second set strikes about N 45° to 60° E, and the third approximately east-west. Only two known faults belong to the third set; both the fault surfaces dip south, the larger about 85° and the smaller 46°.

Although, according to previous structural interpretations of this area, all the faults within the Triassic dip northwest, the field evidence (minor faults exposed in outcrop) and the field relationships show conclusively that some of the faults of the N 30° E and N 45° to 60° E sets are complementary and dip southeast 60° to 85°; graben structures are thus produced.

The Eastern Border Fault of the Triassic barely enters the Middletown quadrangle in the southeast corner of the map. This fault is also interpreted as a normal fault in the area; its strike is approximately N 25° E. The Eastern Border Fault is quite accurately located in the map area by a series of outcrops of the Portland arkose and the pre-Triassic Bolton schist.

The faulting in the area is emphasized by the offsettings and terminations of the resistant basalts, particularly at the north ends of Higby Mountain and Lamentation Mountain. Pronounced drag is found at several places in the sedimentary rocks where cut by faults; in some places the usual southeast dip is completely reversed to a northwest dip. Elsewhere the faulting has produced only slight changes in the attitude of the beds. The gently lobate pattern of the strikes in the southeast corner of the Middletown quadrangle near Crystal Lake is here attributed to a small amount of drag along faults. Particularly good examples of drag adjacent to faults are found at two localities in the northwest quarter of the quadrangle. In an abandoned railroad cut between 27.8925 N-61.3825 E and 27.9025 N-61.4125 E nearly continuous exposures of the East Berlin formation show gradual changes in attitude from N 38° E, 12° NW at the east end to N 42° E, 47° NW at the westernmost outcrop of the East Berlin in this cut, within a few feet of the fault zone which is not actually exposed. About 1500 feet northeast of this exposure, outcrops of the East Berlin formation along the present railroad have an attitude of N 15° W, 12° NE. Similarly drag along the fault that truncates Lamentation Mountain on the northwest can be observed in a traverse down the northward-flowing Spruce Brook, which is just east of the foot of the dip-slope of Lamentation Mountain.

Evidence of strike-slip faulting along nearly vertical surfaces is exposed at several localities. None of the strike-slip faults found is shown on the accompanying geologic map, since all available field evidence indicated that these faults are minor and have no determinable effect on the map distribution of the varying rock units of the Triassic. The most accessible exposures of strike-slip faults are the Highway 72 roadcut in the northwest corner of the quadrangle and an exposure just west of the Wadsworth Falls of the Coginchaug River at 25.24 N-61.46 E. At the latter place a vertical, horizontally slickensided surface in the Hampden strikes N 65° E; the east side has moved relatively south. At the Highway 72 exposure, again in the Hampden, eight strike-slip fault surfaces and/or shear zones are exposed. These appear to occur in two sets as follows. One set, consisting of three faults, strikes N to N 10° W and dips 65° to 85° SW. The slickensides on the one fault oriented north indicate that the east side moved relatively north along slickensides that pitch 8° S. The slickensides are horizontal on one of the other two faults and pitch 16° S on the other; relative displacement could not be ascertained. The second set, comprising the other five faults at the Highway 72 roadcut, strikes N 40° E to N 70° E and dips 65° to 80° NW. In this set apparently the west side moved relatively north along slickensides that are principally horizontal, although on one fault they pitch 10° N. The strain pattern thus indicated could have been produced by compressional stresses oriented northwest-southeast or by tensional stresses oriented northeast-southwest bisecting the obtuse and acute angles respectively of the intersecting fault sets. It is interesting to note that, within the quadrangle, strike-slip faulting is known to occur only in the basalts, probably because of their greater competency relative to the enclosing sedimentary rock.

There is evidence for bedding-plane faulting in the sedimentary rocks at two localities in the Middletown quadrangle. At the well known Durham fossil fish locality, along the brook flowing into Laurel Brook Reservoir from the south at approximately 24.4 N-61.86 E, the bedding surface of a dark grayish black mudstone slab was found to be highly polished and slickensided. The Portland sediments at this locality are at present nearly horizontal. In the section exposed at the Highway 72 roadcut, of the East Berlin formation, at about 28.825 N-60.35 E and stratigraphically approximately 140 feet below the contact with the overlying Hampden basalt, a bed (Unit 28) of grayish black (N2) shale 10 to 12 inches thick shows well developed fracture cleavage and occasional small drag folds. The shear sense of the fracture cleavage and drag folds indicates that the overlying rocks moved relatively down-dip to the southeast. Apparent offsetting of the joints in the enclosing more competent mudstone suggests movement of the order of magnitude of a foot. At each of these places, the bedding-plane slippages probably represent the relief of local stresses accompanying the block faulting of the Triassic rocks of the Connecticut Valley Lowland.

*Joints.* Jointing is variously developed in the rocks of the Middletown quadrangle. Crude columnar cooling joints, as well as the very common, irregularly, broadly curved cooling joints, were noted in the basalt at a few localities. This section is concerned, however, with tectonic joints related to the other tectonic structures of the area. Plate II is a joint-system map of the Middletown quadrangle showing the relative development of the various sets of the system in various parts of the quadrangle. Although jointing is profuse in many of the outcrops of the Middletown quadrangle, no quantitative determination of frequencies, etc., were attempted, nor were joint-orientations determined at all outcrops exhibiting jointing. Thus the joint data may represent a random sampling of outcrops.

In each outcrop, the degree of development of the joint sets relative to each other was qualitatively evaluated and recorded as very well developed, well developed, or poorly developed, depending on such features as the straightness of the joint(s), smoothness of surface, continuity through the outcrop, and spacing. In Plate II the relative length of the strike lines of a particular joint set indicates the degree of development of the set; that is, the longer line represents the better developed joint set of the system in the outcrop(s) of the region of the map in which the pattern is located.

Jointing appears to be better developed in the fine-grained clastic rocks and the basalt than it is in the coarse arkose and conglomerate. Consequently there are few observations on the jointing of the arkose and conglomerate of the Portland in the southeast corner of the quadrangle. In addition, many of the fractures in this southeast corner display definite evidence of relative movement, and hence they are not classified as joints, although they are surely part of the tectonic fracture pattern of the area. The orientations of these faults are shown on the geologic map. Since the great majority of the joints observed in outcrop are very nearly vertical, only the strike of the joint surface was read at most outcrops.

The joints, in some outcrops, are mineralized, the minerals being principally calcite, quartz, some barite, and possibly ankerite (ferrous dolomite). Generally, however, most of the joint surfaces are nonmineralized and open. The most mineralization in the area is found on the joints (and also the strike-slip faults) in the Highway 72 roadcut in the northwest corner of the quadrangle.

The concentration of joint-system symbols of the map in Plate II into two roughly parallel belts trending approximately N 35° E is not necessarily significant; it is principally a function of outcrop distribution in the quadrangle, as an examination of the accompanying geologic map demonstrates.

It is of interest to note, however, the generally persistent strikes of the joint system throughout the quadrangle. The dominance of the approximately N 35° E set of the system is strikingly shown, particularly in the west-central and north-central parts of the map. The control of the course of the Coginchaug River by the joint system is well demonstrated on the map. The orientation of the joint system in the Middletown quadrangle appears, however, to be of minor importance in determining the grain of the topography, which is apparently primarily related to the attitude of the interbedded basalts and sedimentary rocks.

The joint system depicted cannot be resolved, however, in terms of the orientation of the producing stresses. The parallelism of the major joint set — the N 35° E set — with the major normal faults of the area, which are in all probability the result of tension oriented NW-SE, suggest that the major joint set is also tensional in origin, although varied stress patterns or couples could result in tension of this orientation.

Fig. 2. View looking northeast across Sumner Brook 25.865 N-63.0425 E at large-scale cross-bedding in the Portland arkose. Attitude of major stratification is N 21 W, 23 NE. Cross-bedding indicates a generally north stream sense at this outcrop.

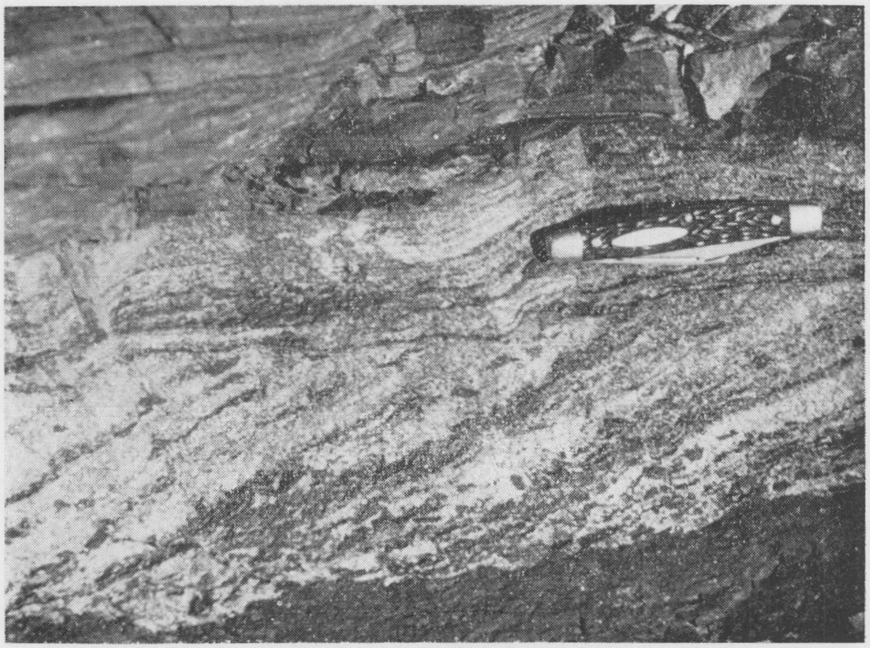

Fig. 3. Small-scale cross-bedding in the East Berlin formation on the north side of the Highway 72 roadcut. Unit (39) is about 120 feet stratigraphically above the base of the exposed section. Pen knife is two and five-eighths inches long. Note angular clasts of material similar to underlying grayish red mudstone concentrated along bedding surfaces and the base of the cross-bedded unit. View looking northeast.

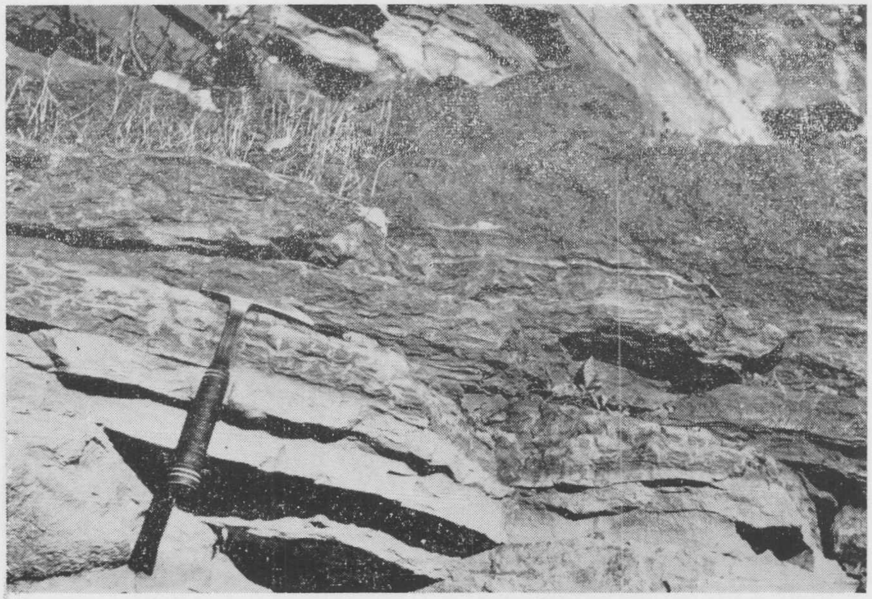

Fig. 4. East Berlin formation — gray, slabby, feldspathic sandstone (behind hammer handle) overlain by a sedimentary breccia composed of fairly large angular clasts (mud-crack polygon fragments ?) of dusky red mudstone in a matrix of light gray red muscovitic arkose (best exhibited to the left of the hammer at the margin of the photograph). Highway 72 roadcut (Unit 48).

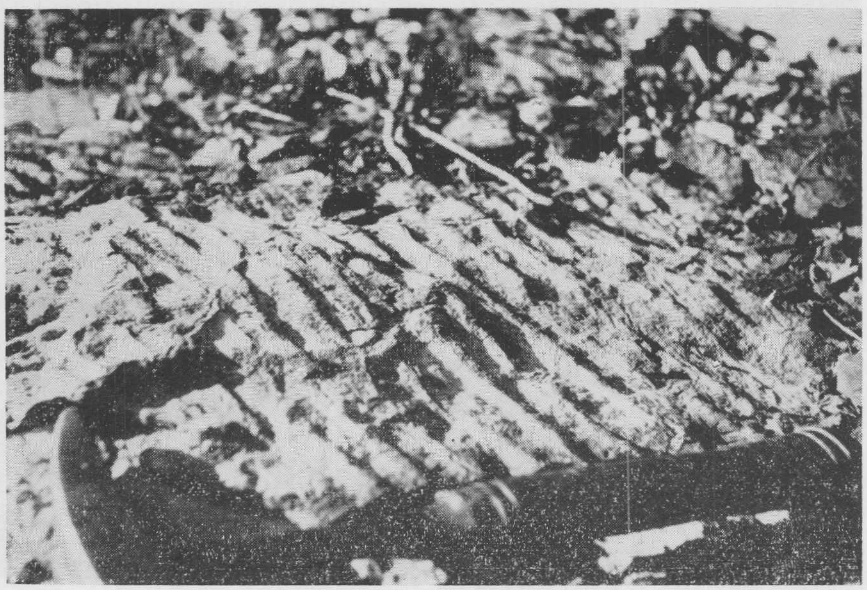

Fig. 5. Oblique view, looking northwest, of small oscillation ripple-marks, with crests oriented N 65 W, on bedding surface of gray, feldspathic sandstone of the East Berlin formation just to northwest and up-dip from location of figure 4 (Unit 49).

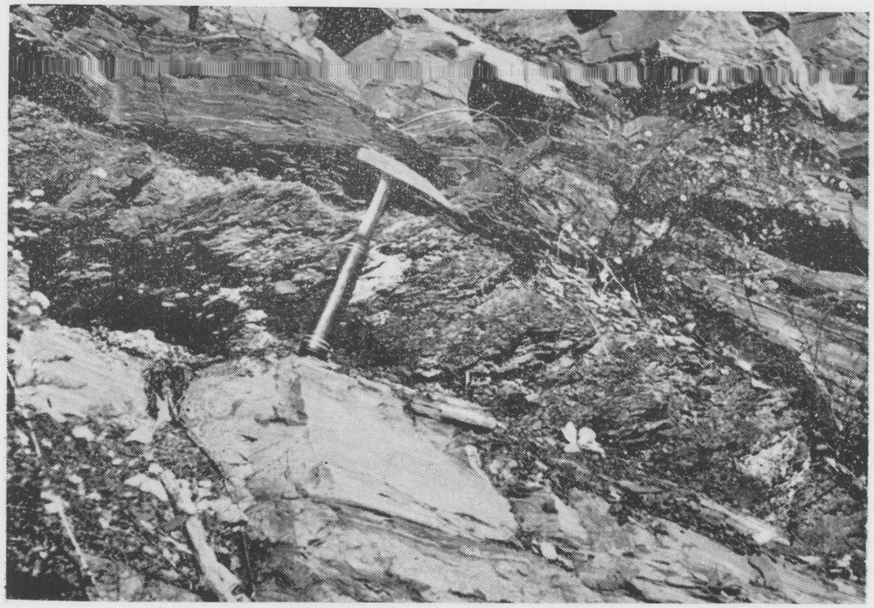

Fig. 6. Gray to black fissile shale and laminated mudstone of the East Berlin formation; bed behind hammer shows well developed fracture cleavage indicating that the upper rocks moved relatively down-dip to the southeast. View looking northeast on north side of Highway 72 roadcut (Unit 28) at 28.825 N-60.345 E.

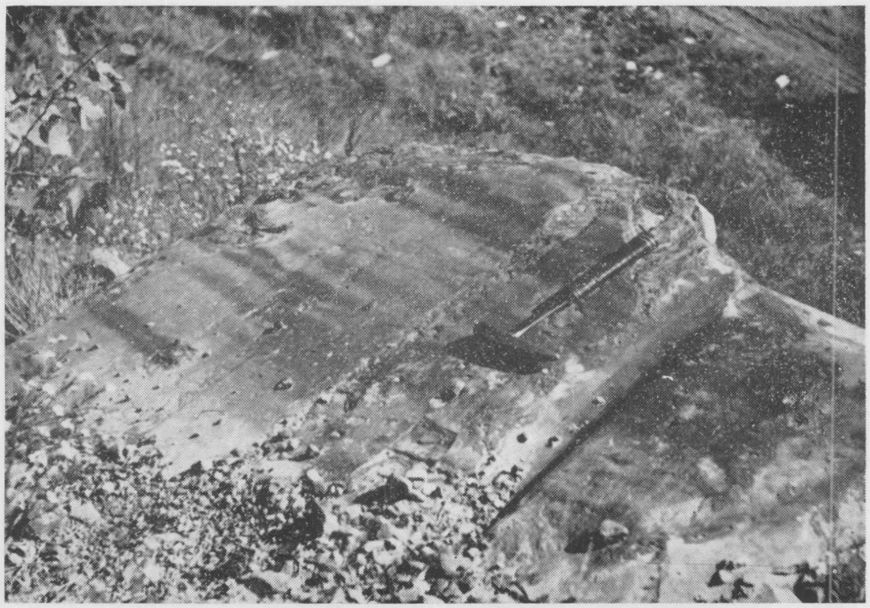

Fig. 7. Oblique view, looking southeast, of bedding surface of massive, very fine-grained sandstone of the East Berlin formation showing glacial polishing and grooving. Ice moved from lower left of photograph toward the upper right (approx. south). North side of Highway 72 roadcut at 28.82 N-60.355 E.

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