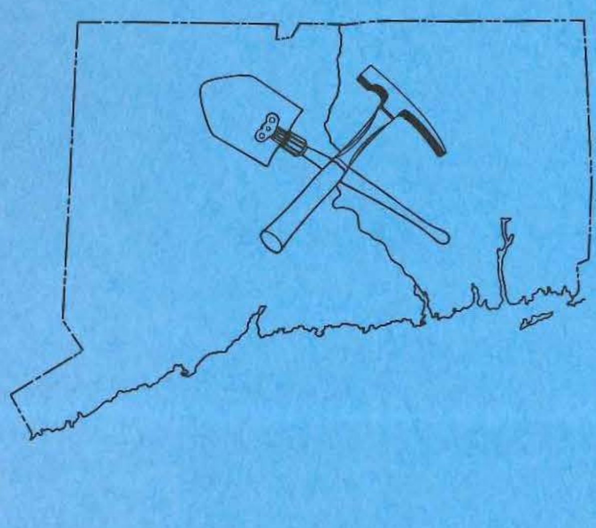
Stratigraphy and Structure of the Triassic Strata of the Gaillard Graben, South-Central Connecticut

JOHN E. SANDERS



STATE GEOLOGICAL AND NATURAL HISTORY SURVEY
OF CONNECTICUT

A DIVISION OF THE DEPARTMENT OF AGRICULTURE
AND NATURAL RESOURCES

1970

GUIDEBOOK NO. 3

STATE GEOLOGICAL AND NATURAL HISTORY SURVEY
OF CONNECTICUT

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AND NATURAL RESOURCES

HONORABLE JOHN N. DEMPSEY, *Governor of Connecticut*

JOSEPH N. GILL, *Commissioner of the Department of Agriculture and Natural Resources*

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A DIVISION OF THE DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES

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JOHN E. SANDERS

Barnard College

Columbia University

1970

GUIDEBOOK NO. 3

Foreword

This guidebook describes Trip C-4 in Connecticut Geological and Natural History Survey's Guidebook No. 2, *Guidebook for Fieldtrips in Connecticut,* New England Intercollegiate Geological Conference held in New Haven in October 1968. The manuscript was received too late to be included in the guidebook which contains only an abstract of this trip. It is published at this time because of the general interest in the area and because many groups may wish to visit some or all of the localities. For general discussion of Triassic geology in Connecticut and for other field trips in the Connecticut Valley the reader is referred to Trips C-1, C-2, C-3, and C-5 in Guidebook No. 2.

The previous warning is repeated:

The fact that a locality is described in this guidebook does not imply that the public has access to the locality. In certain cases the stops are on limited access highways. In other instances stops on private property require permission of the owner. Stops on limited access highways are forbidden by a recent regulation of the State Traffic Commission which prohibits all vehicles to stop or park on any part of the highway. These regulations also prohibit pedestrians on any limited access highway. In some cases the fieldtrip feature on the highway can be viewed from other ground. Anyone planning to go on one of these fieldtrips should check carefully the suggested stops.

Use of the Connecticut Coordinate System

All stop locations have been given both in terms of geographical or cultural features and the Connecticut coordinate system. The Connecticut coordinate system uses a reference point located to the south and west of the state. All 7½ minute topographic quadrangle maps and most geologic quadrangle maps have guide marks on the margin at 10,000 foot and 1000 meter intervals (black tickmarks indicate 10,000 foot grid, blue tickmarks indicate 1000 meter grid). Any point in the state can be located in feet north and east of the reference point. Interpolation between grid marks for 1/24,000 scale maps is easily done using an ordinary ruler because 5 inches=10,000 feet. 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 288,200 feet NORTH, and 603,300 feet EAST, would be recorded as 28.82 N–60.33 E.

JOE WEBB PEOPLES, *Director*
State Geological and Natural
History Survey of Connecticut

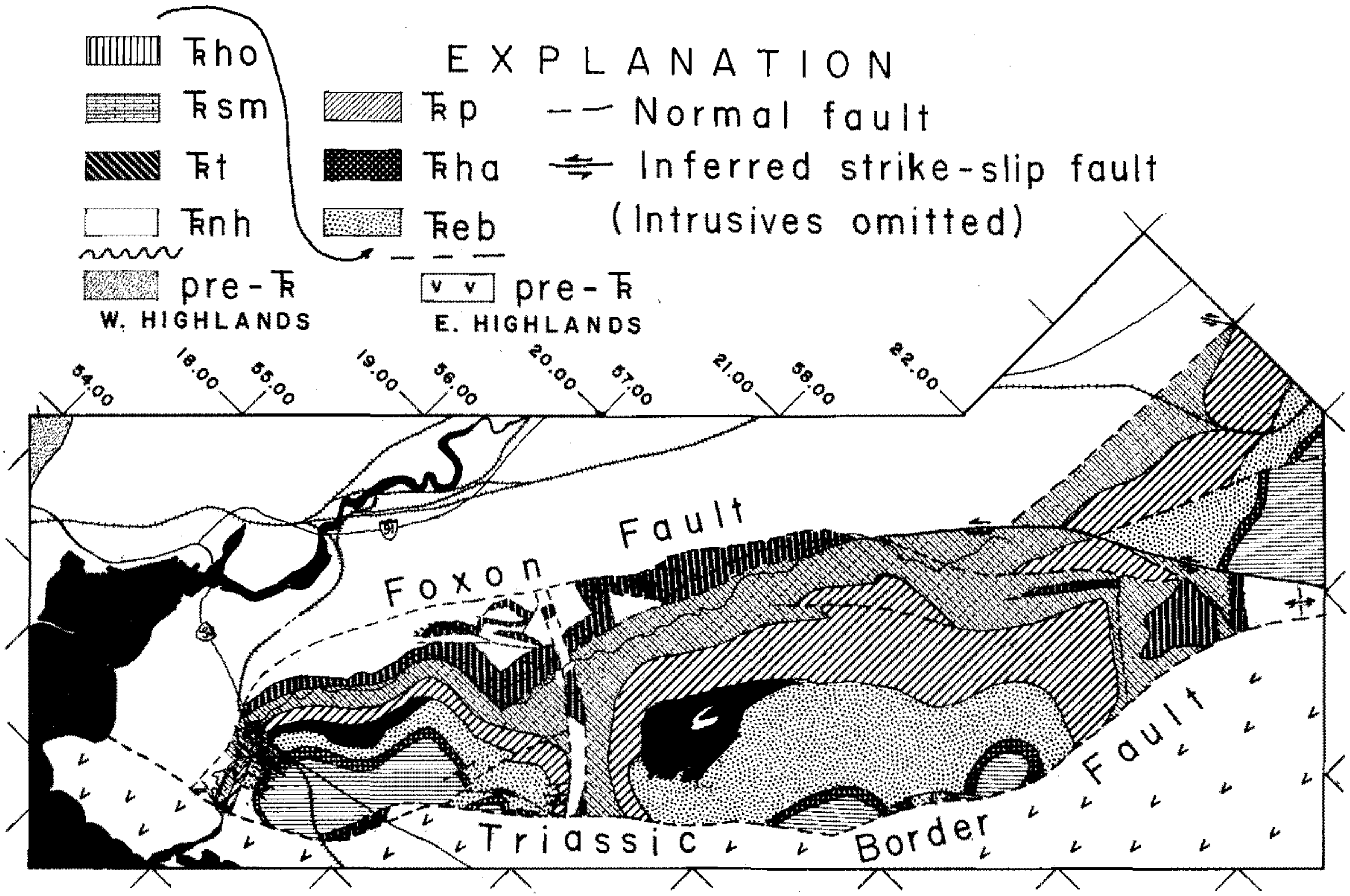


Plate 1. Geologic map of Gaillard Graben and vicinity, Branford, New Haven, Wallingford, Guilford, and Durham 7½ minute quadrangles, Connecticut. Geology by John E. Sanders, based on detailed mapping in Branford, New Haven, and Wallingford quadrangles (from Mikami and Digman, 1957). Intrusives and numerous minor faults omitted. Black areas are water (lakes and Long Island Sound).

Stratigraphy and Structure of the Triassic Strata of the Gaillard Graben, South-Central Connecticut

by

John E. Sanders

ABSTRACT

The Gaillard graben includes a stratigraphic succession, about 6,000 feet thick, ranging from the upper New Haven Arkose into the basal Portland Formation. The Talcott Formation, 1,000 feet thick, is especially well displayed; it consists of 4 volcanic units and 3 sedimentary units.

The strata have been deformed into two major synclines (Saltonstall and Totoket) separated by a faulted anticline (North Branford). Numerous faults cut the folded strata.

The purpose of the trip is to demonstrate the stratigraphic succession, particularly of the Talcott Formation, and to study lateral changes in the sedimentary units both parallel and perpendicular to the Triassic Border fault.

Special emphasis is placed on the spectacular pillows and volcanic breccias of the upper Talcott units and on the relationships between the folds and faults.

INTRODUCTION

For more than 150 years the Triassic strata of southern Connecticut have been studied at various levels of detail and written about by some of America's most distinguished geologists. In addition, these strata are examined each year, perfunctorily at least, by countless undergraduates and graduate students of geology. As a result of this vast expenditure of effort, the general relationships of the Triassic strata have become well known and these strata have become enshrined among the venerable classics of American geology. Descriptions of the geology of the Triassic rocks appear in nearly all introductory textbooks of geology.

Therefore, is there anything left to do but to rehash familiar themes? As time passes, even in classic areas, new maps are published, new exposures appear and old ones disappear, and geologic theory advances. Any and all of these can provide the bases for new insights into old relationships. When the present writer began his studies of the classic Triassic terrain in 1955, he was armed with new and modern topographic maps on a scale of 1:24,000 with 10-foot contour intervals, and in 1957, during construction of the Connecticut Turnpike, encountered significant new exposures. When the classic rocks were re-examined in light of modern geologic theory and based on new maps and exposures not available to previous workers, previously unstated stratigraphic and structural relationships became apparent. These relationships formed the basis for a revised geologic history set forth by the present writer and some of his former undergraduate students (Sanders, 1958, 1960, 1963; Sanders, Guidotti, and Wilde, 1963). Recently the writer has summarized the geologic evidence that many of the Triassic sedimentary strata were deposited in ancient lakes (Sanders, 1968).

This fieldtrip is intended to permit the participants to examine the strata and structures lying close to the Triassic Border fault within a structural unit named the Gaillard graben (Sanders, 1960; Sanders, Guidotti, and Wilde, 1963). The order in which the localities will be visited has been selected not for any particular geologic reason, but rather for economy of travel.

Southeast and east of the Gaillard graben are pre-Triassic gneisses, quartzites, schists, and granitic rocks of the Eastern Highlands province of Connecticut. Northwest and west of the graben are strata of the New Haven Arkose, the basal formation of the Triassic succession (table 1). Within the Gaillard graben all formations of the Triassic succession are exposed along the scarp slopes of ridges capped by resistant sheets of extrusive igneous rocks. The ridges and exposures of sedimentary strata are the results of differential erosion on inclined strata having varied resistance to erosion. The inclined strata are parts of transverse open folds whose axes plunge southeastward, at right angles to the faults bounding the graben. This trip includes parts of the following major folds (from southwest to northeast): Saltonstall syncline, North Branford anticline, Totoket syncline, and Durham anticline. In addition several smaller folds within the Saltonstall and Totoket synclines will be visited.

Because of these folds within the Gaillard graben, eastward dips, which are so common elsewhere in the Triassic of Connecticut, are more the exception than the rule. In many places within this graben the strata strike at right angles to the Triassic Border fault and dip parallel to it. Therefore by moving along the

Table 1

Names, abbreviations, descriptions and thicknesses of Upper Triassic strata, southern Connecticut (names of formations as in Rodgers, Gates, and Rosenfeld, 1959)

	Name	Abbreviation	Description	Thickness (ft)
	Portland Formation	Ŧ p	Conglomerates, coarse sandstones, and fine-grained, well-bedded maroon, gray and black strata; top eroded	1,600+
Meriden Group	Hampden Formation	Ŧ ha	Extrusive basalt; locally two sheets with about 40 ft of sedimentary strata between	200
	East Berlin Formation	Ŧ eb	Sedimentary strata; sandstones and siltstones away from border fault; conglomerates near fault	1,500
	Holyoke Formation	Ŧ ho	Extrusive basalt; at least two extrusions represented	450
	Shuttle Meadow Formation	Ŧ sm	Sedimentary strata; fine sandstones and siltstones away from border fault; conglomerates (including vesicular basalt clasts) near border fault	900
	Talcott Formation:	Ŧ t		
	Upper breccia member	Ŧ tb	Massive basalt breccia; some fragments of crystalline rocks; matrix contains quartz and feldspar up to coarse sand size	200
	Upper sedimentary member	Ŧ tsu	Coarse pebbly arkose at base; siltstone and carbonate rocks in upper part	250
	Pillowed and brecciated member	Ŧ tpb	Pillowed extrusive basalt in lower of two sheets; breccia in upper sheet	200
	Middle sedimentary member	Ŧ tsm	Coarse grained pebbly arkose	60+
	Lower massive member	Ŧ te	Fine-grained extrusive basalt; well-developed columnar joints	100
	Lower sedimentary member	Ŧ tsl	Coarse-grained pebbly arkose	40
	Basal member	Ŧ tba	Fine-grained extrusive basalt; locally brecciated and amygdaloidal	150
	New Haven Arkose	Ŧ nh	Coarse and fine arkose; base not exposed	5,000+
			Total	10,650+

Triassic Border fault one can examine strata through a stratigraphic range extending from the top of the New Haven Arkose through the lower thousand feet or so of the Portland Formation, a thickness of approximately 5,500 ft (1,680 meters). Accordingly, one of the two chief stratigraphic variables, distance from the Triassic Border fault, can be kept constant while studying the effects of the other chief variable, position within succession. By following the sedimentary strata on the scarp slope of a strike ridge, one can keep position in the succession constant and examine the effects of distance from the border fault. In the Gaillard graben strata can be examined from points adjacent to the Triassic Border fault through distances as much as 5 mi. (8 kilometers) distant from this fault.

The noteworthy stratigraphic features to be examined are the volcanic and sedimentary members of the Talcott Formation (lowest of the three volcanic formations) and the changes of facies within the sedimentary strata interbedded with and overlying the volcanic formations (a general coarsening of particles with approach to the Triassic Border fault).

Structural features to be examined include the large and small transverse folds, Triassic Border fault, Foxon fault, and many unnamed faults. The recognition of 6 previously unmapped stratigraphic units within the Talcott Formation has provided stratigraphic control for inferring many previously unrecognized faults.

The trip proceeds around the Gaillard graben in a counterclockwise direction, beginning near the south end (fig. 1). During the northeastward leg along the southeast side of the graben the trip encounters mostly formations lying above the Holyoke Basalt. At Durham, where the line of travel bends southwestward, the trip includes chiefly formations lying below the Holyoke Basalt. At the southwest end of the Gaillard graben the line of travel is northward to study special

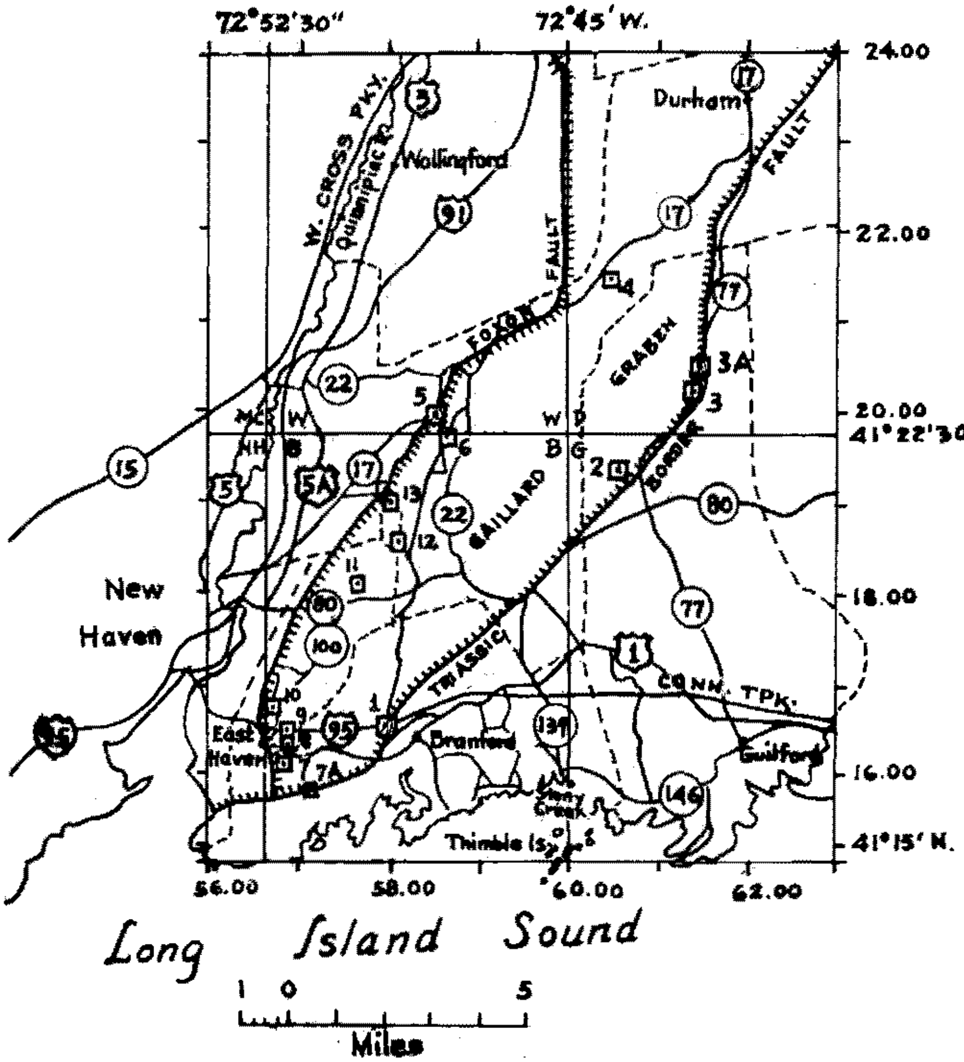


Fig. 1. Index map of chief roads showing town boundaries and trip stop locations. Base from Preliminary Geological Map of Connecticut (Rodgers and others, 1956).

features of several formations and to examine the relationships of faults to gaps in Saltonstall Ridge and the role of faults in repeating various members of the Talcott Formation.

Stop 1 (16.54 N–57.98 E) Branford quadrangle. Roadcuts in Branford, along Connecticut Turnpike west of Todds Hill Road overpass and at Interchange 54. From the bridge carrying Todds Hill Road over the Connecticut Turnpike three rock faces are visible:

Face A (16.51 N–57.94 E) South side of Turnpike, west of Todds Hill Road overpass (fig. 2)

Face B (16.55 N–57.98 E) North side of Turnpike, west of Todds Hill Road overpass (fig. 2)

Face C (16.56 N–58.02 E) North side of westbound approach road of Interchange 54 onto Connecticut Turnpike (fig. 3)

These three rock faces expose volcanic rocks belonging to a linear belt of extrusive rocks paralleling the Triassic Border fault and extending north-northeastward for 0.95 mi. (1.55 kilometers), from the Triassic Border fault at the intersection of U.S. Routes 1 and 1A, west of Branford Center (16.53 N–57.84 E) to a point 0.07 mi. (0.1 kilometer) north of the intersection of Todds Hill Road and a short road leading to Brushy Plain Road (16.65 N–57.97 E).

Percival (1842, p. 325) designated this belt as the "Second Posterior Range" (P.2 of his map). Since the time of W. M. Davis (1898, p. 128; fig. 31) the volcanic rocks of this belt have been assigned to the upper extrusive sheet (Hampden Formation of modern terminology). Davis inferred that the volcanic rocks had been dragged upward by movement along several smaller faults paralleling the Triassic Border fault. The Davis interpretation (shown in the lower part of fig. 4) has been followed by all subsequent workers. In the absence of any other compelling evidence to the contrary, this interpretation satisfied the dictates of the rule of simplicity: if there must be a fault, prefer the alternative that requires the least displacement. The Davis cross section of the 1898 report was not drawn to scale; I have tried to re-create it along a profile based on the modern topographic map of the Branford quadrangle (lower part of fig. 4). Davis' geologic map did not show as many faults as he sketched on his cross section.

Assignment of the volcanic rocks of this belt to the Hampden Formation implies a minimum displacement of 1,400 ft (420 meters) on the fault lying to the west. According to the present writer's stratigraphic interpretation (evidence for which will be seen elsewhere on this trip), the volcanic rocks belong to the Talcott Formation. Assignment of these volcanic rocks to the Talcott Formation increases the number of faults from 1 (or 3, according to Davis) to at least 10, and increases the stratigraphic displacement on the fault lying to the west by 3,000 ft (920 meters) to a value of 4,400 ft (1,340 meters).

Face A. The rocks exposed in the main part of Face A are nearly flat-lying and include a lower pillowed basalt, at least 25 ft (8 meters) thick with base not exposed, a sedimentary parting, 6 to 12 in. (15 to 30 centimeters) thick, and an upper brecciated and vesicular basalt at least 55 ft (17 meters) thick with top eroded. Careful examination discloses that two thin sedimentary partings are present (not shown on fig. 2). These are interpreted to be the result of faulting of a single sedimentary parting. A fanlt parallel to the face is inferred to have dropped the north side by a few meters, thus repeating the sedimentary parting. These volcanic rocks are assigned to the pillowed and brecciated member of the Talcott Formation, which elsewhere (for example, Connecticut Turnpike cuts through Mullins Hill west of Saltonstall Ridge, 16.40 N–56.66 E) consists of two sheets of extrusive rock, a lower pillowed sheet and an upper sheet that contains columnar joints and/or a distinctive breccia that W. L. Russell (1922ms) named the "ball and socket" breccia. A more accessible face exposing the "ball and socket" breccia is located at the rear of the drive-up hamburger stand at the junction of U.S. Route 1 and 1A (16.53N–57.84 E). The "balls" evidently are tiny pillows or broken pillows; the "sockets" are formed by thin layers of clay, silt, and fine-grained tephra.

Face B. The west end of Face B displays the contact between maroon siltstone and brecciated basalt. The siltstone is noteworthy because this close to the Triassic Border fault such fine-grained strata are rare. The best explanation to account for the deposition of such fine-grained strata in localities where coarse fan debris generally prevails suggests that within the lowland receiving sediment during Late Triassic time, large, deep lakes appeared and that their waters submerged the fans and their shores lapped against the marginal highland block to the east (Sanders, 1968).

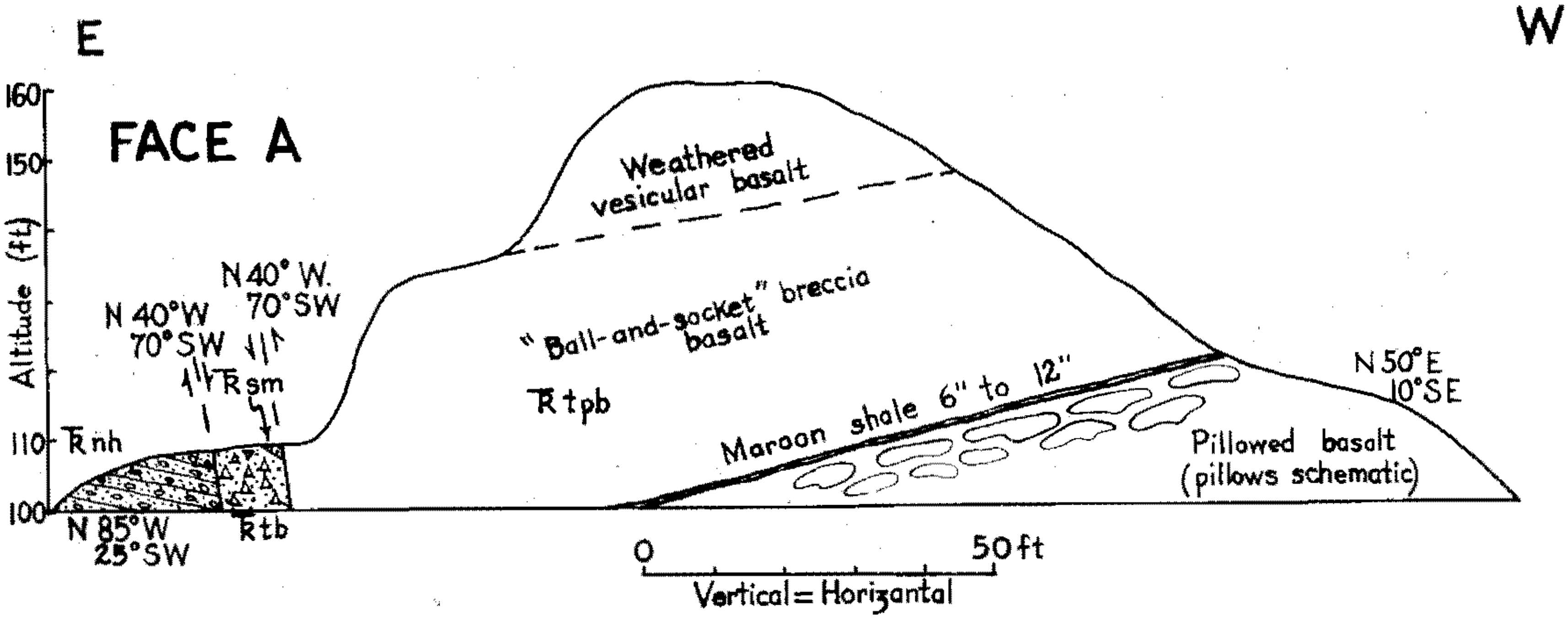
Ellipsoidal bodies of gray, altered basalt, 6 to 12 in. long, are isolated within the upper 2 ft of the siltstone.

The basal 4 to 5 ft of the volcanic unit consist of altered volcanic rock mixed with maroon sediment. Higher up the volcanic rock is not altered but includes angular blocks of basalt in a matrix that includes coarse sedimentary debris and a few large "erratics" of sedimentary and metamorphic rocks. Toward the top of the middle of Face B is the largest of these "erratic" blocks. Here a platy chunk of feldspathic sandstone, 8 ft long and 3 ft thick, has been cut through by a fault having a displacement of 2 ft up on its east side.

At the east end of Face B the distinctive breccia of this member extends to road level. The largest block of basalt seen here measured 2 by 3 ft; the dimensions of many are 1 by 2 ft, but most of them measure 6 to 8 in. across. All blocks show chilled margins with the coarse sandy matrix.

On the top surface of breccia just west of the bridge pier are glacial striae oriented N 15° E–S 15° W.

Face C. Face C displays both sedimentary and volcanic strata dipping 30° to 35° eastward. The sedimentary strata include boulder-bearing conglomerates, in layers 2 to 10 ft thick, interbedded with pebbly and shaly poorly sorted silty sandstone (course variety of "redstone" facies of Krynine, 1950), in layers 2 to 20 ft thick. These strata are repeated by faults dipping about 30° westward. Subtracting for these repetitions and including a covered interval next to the fault lying west of the exposures, a tape-and-compass traverse



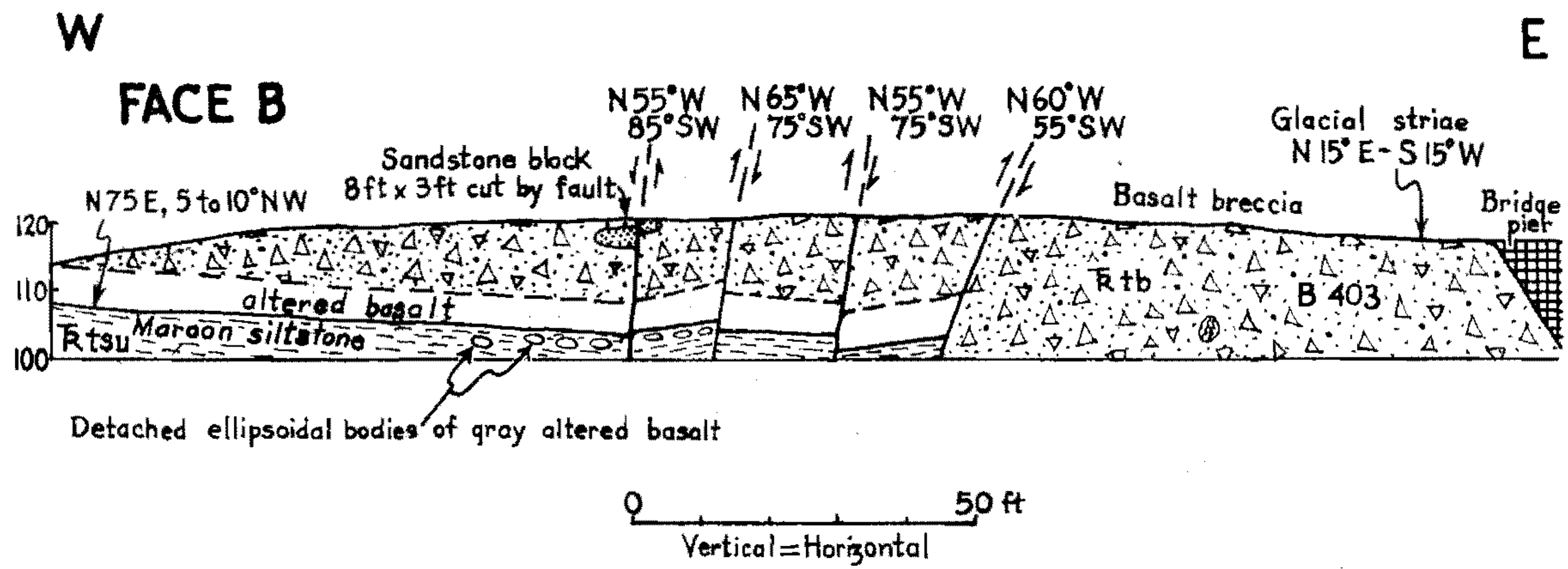


Fig. 2. Sketches of geologic relationships in cuts on Connecticut Turnpike west of Todds Hill Road overpass, Branford. Face A, south side of turnpike (16.51 N–57.94 E). Face B, north side of turnpike (16.55 N–57.98 E).

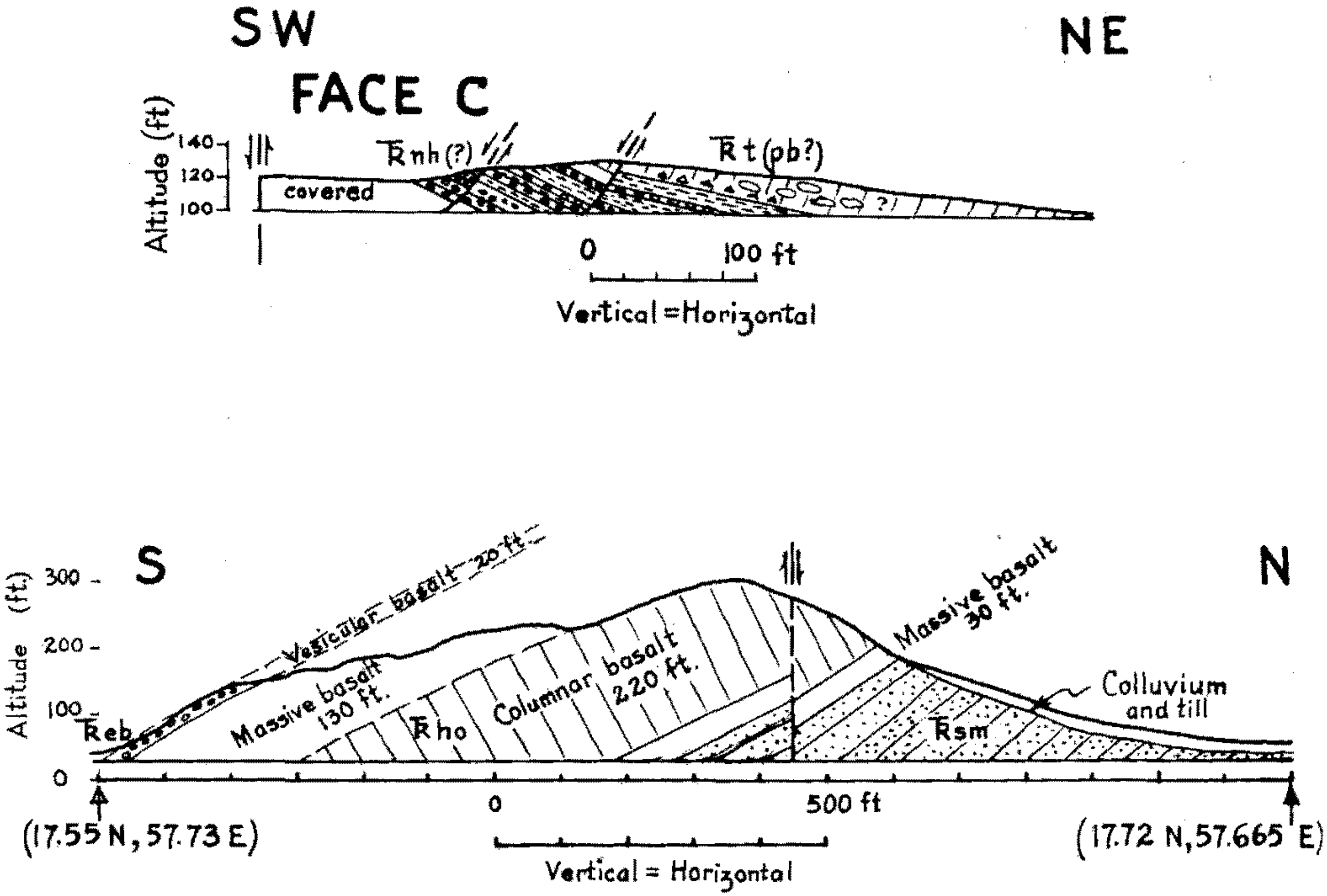


Fig. 3. Sketches of geologic relationships exposed in cut on north side of westbound approach road of Interchange 54, Branford (16.56 N–58.02E), above, and in New Haven Water Company's tunnel through Saltonstall Ridge at north end of Saltonstall Lake, below, (after C. R. Longwell).

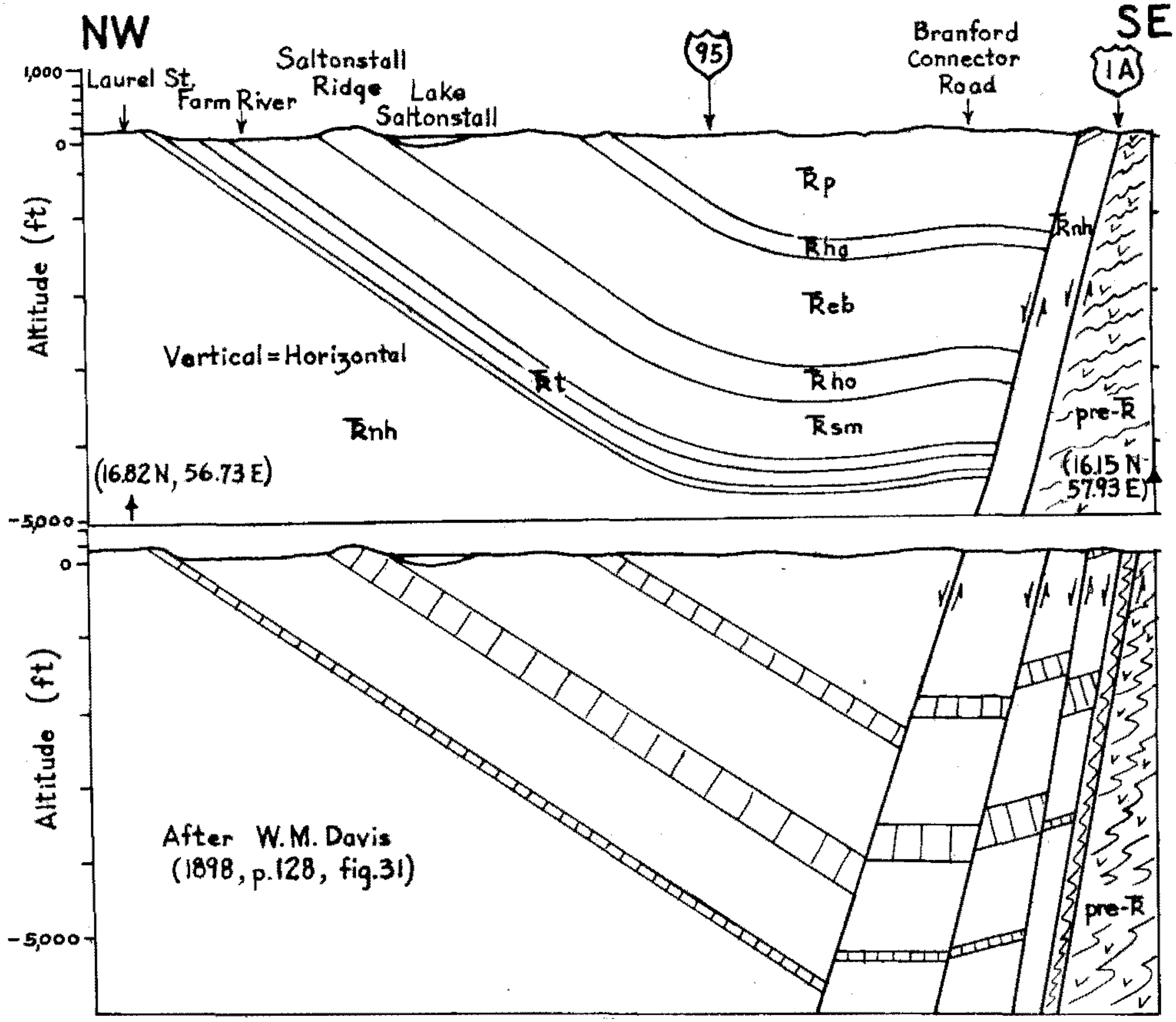


Fig. 4. Two versions of geologic structure section across Saltonstall syncline, Branford (Connecticut coordinates shown on figure for points at each end). Upper section shows upfaulted extrusive rock to be part of Talcott Formation. Lower section (after W. M. Davis, 1898, fig. 31) shows upfaulted extrusive rock to be part of Hampden Formation.

along the side of the road suggests a thickness of 114 ft of strata beneath the volcanic rock.

In the conglomerate layers cobbles and boulders of greenschists, feldspathic quartzites, granitic rocks, and gneisses are abundant. The dominant clasts, feldspathic quartzites, probably were derived from the Plainfield Formation. Many of the platy greenschist clasts are imbricated with their long axes steeply inclined in the downdip direction. This suggests stream flow in the updip direction, directly away from the Triassic Border fault.

The abnndance of schist clasts is emphasized because this abundance contrasts with the observations of Kryniue (1950) and of Fritts (1963) that in the New Haven Arkose north of New Haven schist clasts become notably less abundant upward in the succession.

The basal part of the volcanic rock capping the knoll at the east end of Face C is a breccia with mineral-filled cavities. Breccia with mineral-lined cavities occurs at the base of the pillowed and brecciated member of the Talcott Formation, the upper part of which forms Face A.

According to the present writer, therefore, the rocks in the three faces may be summarized as follows:

Face A. Formations: Talcott and (?) New Haven
- Stratigraphic position: pillowed and brecciated member (main part of cut), upper breccia member, Shuttle Meadow Formation, and (?) New Haven Arkose (or one of lower sedimentary members of Talcott)
- Distance from border fault: 0.12 mi.
- Particle sizes of sedimentary strata: silt, sand, and cobbles
- Attitude of strata: pillowed basalt: N 50° E, 10° SE
  conglomerate: N 85° W, 25° SW
- Structural setting: Saltonstall syncline; upfaulted block along Triassic Border fault

Face B. Formation: Talcott
- Stratigraphic position: lower part of upper breccia member and basal contact with upper sedimentary member
- Distance from border fault: 0.17 mi.
- Particle sizes of sedimentary strata: clay, silt, and very fine sand
- Attitude of strata: N 75° E, 5° to 10° NW
- Structural setting: Saltonstall syncline; upfaulted block along Triassic Border fault

Face C. Formation: Talcott
- Stratigraphic position: middle sedimentary member (or New Haven Arkose) and pillowed and brecciated member
- Distance from border fault: 0.05 mi.
- Particle size of sedimentary strata: course sand to coarse boulders
- Attitude of strata: N 60° W, 30° to 35° NE
- Structural setting: Saltonstall syncline; upfaulted block along Triassic Border fault

If these assignments are correct, then each face is separated from the other faces by one or more faults. Two sets of faults are inferred, the principal one striking N 25° W and a subordinate one striking N 60° E. These two sets are in addition to the main fault lying west of the belt of volcanic rock, which strikes N 10° E. The oldest strata are exposed in Face C and at the eastern end of Face A; the youngest strata (Shuttle Meadow Formation) occur near the east end of Face A.

Stop 2 (19.34 N–60.54 E) Guilford quadrangle. Cut on west side of Great Hill Rd., 0.34 mi. (0.55 kilometer) southwest of Melissa Jones School, North Guilford.
- Formation: East Berlin
- Stratigraphic position: about 100 ft below top
- Distance from border fault: 0.5 mi. (0.8 kilometer)
- Particle sizes of sedimentary strata: coarse sand and cobbles
- Attitude of strata: EW, 30° S
- Structural setting: SW limb of small transverse anticline within Totoket syncline

Stop 3 (20.24 N–61.35 E) Durham quadrangle. Conn. Route 77, west side of Lake Quonnipaug, 0.7 mi. NNE of southwest end of the lake, North Guilford.
- Formation: Portland
- Stratigraphic position: about 500 ft above base
- Distance from border fault: 0.05 mi. (0.08 kilometer)
- Particle sizes of sedimentary strata: up to boulders
- Attitude of strata: N 60° E, 25° SE
- Structural setting: NE limb of Quonnipaug Mountain syncline, the northern of two small synclines within the Totoket syncline

Stop 3A (20.48 N–61.40 E) Durham quadrangle. Conn. Route 77, east end of Quonnipaug Mountain, west side of Lake Quonnipaug, 0.25 mi. (0.4 kilometer) south of the north end of the lake, North Guilford.
- Formations: East Berlin aud Hampden
- Stratigraphic position: lower part of Hampden, contact, and upper few hundred feet of East Berlin Formation
- Distance from border fault: 0.05 mi. (0.08 kilometer)
- Particle sizes of sedimentary strata: up to boulders
- Attitude of strata: N 70° E, 30° SE
- Structural setting: NE limb of Quonnipaug Mountain syncline

The contact is well exposed about 100 ft up the steep slope, but no attempt should be made to examine it at close range with a large gronp. The talus is an active one and cannot be ascended without kicking loose many large pieces of the sliderock. The exposnre is worth the climb, but only with small gronps.

Stop 4 (21.54 N–60.39 E) Durham quadrangle. Old Coe quarry, in what is now a housing subdivision, 0.3 mi. due east of the point where Conn. Route 17 crosses the New Haven-Middlesex County line, North Branford.
- Formation: not certain; Talcott or Shnttle Meadow
- Stratigraphic position: Immediately overlies a sheet of amygdaloidal basalt ("Anterior" of

Percival, 1842, p. 316, 344; now part of the Talcott Formation). If the basalt is the upper breccia member of the Talcott, then the limestone belongs in the basal part of the Meriden, (now the Shuttle Meadow Formation), as assigned by Krynine (1950, p. 59, 107). If, however, the basalt is the pillowed and brecciated member of the Talcott, then the limestone belongs in the upper sedimentary member of the Talcott Formation.

Distance from border fault: 1.9 mi. (3.04 kilometers)

Particle sizes of sedimentary strata: fine, medium, and coarse sand (insoluble residue)

Attitude of strata: N 30° E, 30° SE

Structural setting: near NE end of Totoket syncline; on SW limb of Quonnipaug Mountain syncline

Stop 5 (19.94 N–58.42 E) Wallingford quadrangle.

Cut on Conn. Route 17, 1.25 mi. southwest of junction of Conn. Routes 17 and 22 (Northford), North Branford.

Formation: New Haven Arkose

Stratigraphic position: unknown; presumably near top

Distance from border fault: 4 mi. (6.4 kilometers)

Particle sizes in sedimentary strata: up to 261 mm (small boulders)

Attitude of strata: N 5° E, 20° E

Structural setting: just NW of Foxon fault that bounds the Gaillard graben on its NW side.

A pace-and-compass traverse along the highway indicates a total exposed thickness of 115 ft (assuming no faults are present). Three pebble zones occur; the distances indicate their stratigraphic position above the base of the exposure: (1) A layer about 1.5 ft thick at 70 ft; (2) a zone of scattered large pebbles at 90 ft; and (3) a pebbly zone 9 ft thick at 98 ft.

A count of 100 clasts picked at random out of the 9-ft zone near the top of the exposure showed the following distribution of rock types (based on megascopic identification in the field):

Rock type	Proportion (per cent)
Quartzites (pink and gray)	35
Gneisses (several varieties)	23
Granitic rocks (pink alaskite, pink and gray granites)	14
Pegmatites	13
Schists	5
Others (calc-silicates, garnet-quartz rocks, green altered rocks)	10

The longest diameters of the clasts were distributed as follows:

Names of particles	Limiting diameters (mm.)	Proportion (percent)
Coarse pebbles	16 to 32	5
Very coarse pebbles	32 to 64	46
Small cobbles	64 to 128	40
Large cobbles	128 to 256	8
Small boulders	256 to 512	1

The kinds of particles in the New Haven Arkose of the Route 17 cut contrast with those found in a count of 50 clasts from the East Berlin Formation in a cut along the northwest side of Conn. Route 80 (18.19 N–59.72 E), 0.1 mi. northeast of the jnnction of Route 80 and the gravel road to City Mission Camp, in which the following were identified (megascopically in the field):

Rock type	Proportion (per cent)
Chloritized basalt	38
Quartzite	26
Chlorite schist	24
Mica schist	6
Others (gneiss, mylonite, pegmatite)	6

The point of this comparison is to emphasize that in the Branford and Wallingford quadrangles schist pebbles are extremely abundant even at stratigraphic levels much above the lower part of the New Haven Arkose. The chloritized basalt and chlorite schist of the Route 80 cut are noteworthy for their similarity to the volcanics now exposed only between Allingtown and Milford in the Western Highland province. Nevertheless these green pebbles, derived from the Eastern Highland, suggest the former presence of altered basaltic volcanic rocks and greenschists on the east side of the Triassic outcrop.

The Foxon fault passes between the Route 17 cut of Stop 5 and the wooded knoll to the south (19.90 N–58.41 E).

Stop 6 (19.59 N–58.62 E) Branford quadrangle.

Cut on Idlewood Drive, North Branford, on west side of hill east of Village Street, 0.25 mi. north of junction of Village Street and Totoket Road.

Formation: Talcott

Stratigraphic position: somewhere in the upper breccia member

Distance from border fault: 3.5 mi. (6.5 kilometers)

Attitude of strata: N 15° E, 15° SE

Structural setting: Totoket syncline; one of many fault blocks along the northwest side of the Gaillard graben.

This exposure displays the distinctive volcanic breccia of the upper member of the Talcott Formation of the present writer's classification. The breccia contains angular fragments of basalt np to several feet in diameter and a few "erratic" particles of metamorphic rocks from the Eastern Highland. The matrix includes quartz and feldspar particles of coarse sand size.

The breccia was noticed by Percival (1842, p. 342); he described it as "a peculiar dark green Trap conglomerate," or "a peculiar ferruginous amygdaloidal conglomerate." W. M. Davis (1898, p. 62-63) described this breccia as "tuffaceous" or "ashy" trap. Davis remarked that west of Totoket Mountain the "highly scoriaceous or ashlike trap" inclndes crystalline pebbles "in greater or less proportion through the ash," and that the unit varied from "dense trap" to a rock with "so largely increased a share of pebbles as to gain the appearance of an ordinary conglomerate" (p. 68). W. L. Russell (1922ms) and C. R. Longwell (1922 and in Longwell and Dana, 1932) apparently classified the breccia as volcanic agglomerate and thought that it indicated proximity to the vent(s).

Following the suggestions of R. V. Fisher (1958, 1960, and 1961), the present writer designates this distinctive rock as volcanic breccia. The origin of the breccia is not certain, but chilled margins observed on nearly all volcanic particles larger than 1 cm in diameter suggest that brecciation occurred while the volcanic material was still hot. The present writer (Sanders, 1968) has suggested that the breccia originated by the interaction of hot lava and lake water. Presumably the original product was a lava flow. The exotic large particles of nonvolcanic rocks could have been derived from the walls of the vent. If so, the lava may have issued from the Triassic Border fault where it would have had access to coarse particles which had already been deposited on Triassic fans. After reaching the surface, the lava and its included large nonvolcanic particles are thought to have flowed into water. Instead of forming pillows, the lava broke into countless large and small angular fragments which then formed chilled margins against the cool sediment matrix.

Whatever its origin, this breccia appears to be a widespread stratigraphic unit having a uniform thickness of 200 ft. It has been found in so many localities that its absence elsewhere is ascribed to the effects of faulting.

Stop 7 (16.04 N–56.88 E) Branford quadrangle. Parking lot of Branford Trolley Museum east of East Haven village green. Walk across bridge over East Haven River (16.05 N–56.90 E) and board trolley. Get off at Bera Brae Station and walk south to picnic grounds on small wooded knoll (15.86 N–56.94 E). Reboard trolley and ride to the end of the line, (15.75 N–57.12 E), opposite an abandoned trap rock quarry in the Holyoke Formation (north of the tracks) and a low hill composed of sheared white granitic gneiss on the south side of the tracks (15.73 N–57.12 E). Walk back to Bera Brae Station, studying hillside exposures of conglomerates in the Shuttle Meadow Formation en route (at 15.74 N–57.08 E, 15.75 N–57.07 E, and 15.78 N–57.06 E). Reboard trolley for return to bridge by parking lot.

Formations: Talcott (at picnic grounds)
Holyoke and sheared Branford Gneiss (at end of trolley tracks)
Shuttle Meadow (on hillside east of tracks)
Stratigraphic position: Talcott (member not identified)
Holyoke (lower half)
Shuttle Meadow (top 200 ft)
Distance from border fault: picnic grounds (0.4 mi.)
end of line (on fault)
hillside east of tracks (up to 0.1 mi.)
Attitude of strata: (Shuttle Meadow: N 20° W; 75° NE)
Structural setting: Saltonstall syncline and its intersection with Triassic Border fault

The Talcott Formation underlying the wooded knoll (picnic area) is much-weathered vesicular basalt. It is part of a narrow outcrop belt of basalt that reappears north of the trolley tracks opposite the Bera Brae Station (15.94 N–56.94 E) and continues northward to the bend in the East Haven River where the outflow of Saltonstall Lake joins the Farm River (16.09 N–56.92 E). In the bank of the river the basalt is overlain by micaceous sandstone.

The Triassic Border fault can be closely located at the end of the trolley tracks (Stop 7A). The fault passes between the south end of Beacon Hill (quarry side) and the low knoll south of the tracks that is underlain by sheared white gneiss (15.72 N–56.12 E). Just north of the trolley track (15.72 N–57.10 E) is sheared quartz rock similar to that marking the border fault in other localities. If this quartz rock is in place, then the Triassic Border fault here lies north of the trolley tracks. The shearing effects seen in the basalt of the Holyoke Formation in the abandoned quarry resulted from faulting.

The exposures of the Shuttle Meadow Formation near the southwest end of Beacon Hill are noteworthy because angular clasts of vesicular basalt up to 1 ft in diameter are present (15.78 N–57.06 E). A field estimate of the proportion of rock types iu the conglomerate is:

Rock type	Proportion (per cent)
White vein quartz	30 to 40
Plainfield quartzite	10 to 20
Schist	15
Feldspar and pegmatites	10
Gneiss	10
Vesicular basalt	5

The clasts compose an estimated 50 percent of the volume of the rock. Many boulders of granitic rock attain diameters of a foot or so; the most numerous sizes are 4 to 6 inches.

Presumably either the Talcott Formation formerly extended across the Triassic Border fault or else the fault block seen at Stop 1 was actively uplifted. Either alternative could make basalt available to form clasts that could be mixed with other rock types and sedimented into the Shuttle Meadow Formation. No basalt clasts have yet been found that would permit assignment to one of the members of the Talcott Formation.

Stop 8 (16.18 N–56.93 E) Branford quadrangle. Cut on north side of U.S. Route 1, East Haven, at junction with western end of loop made by Conn. Route 142. This is the southern of two large gaps in Saltonstall Ridge.

Formation: Shuttle Meadow
Stratigraphic position: Highest strata exposed are approximately 200 ft below top, but exact location is not known.
Distance from border fault: 0.85 mi.
Particle sizes of sedimentary strata: silt up to boulders
Attitude of strata: N 43° W, 55° NE
Structural setting: Totoket syncline; limb offset by numerous faults striking nearly E-W; gaps have formed as a result of fault-displacement of the resistant Holyoke Formation underlying the ridge.

A tape-and-compass traverse of this cut indicates that about 190 ft of strata are present; there are numerous small faults, but nevertheless the succession seems to be fairly straightforward. The lower 80 ft are interbedded sandstone and siltstone with a few pebbly layers. Two prominent conglomerates occur: a unit

20 ft thick at 80 ft above the base of the exposure, and a unit 18 ft thick at 130 ft above the base of the exposure. The sandstones at the top of the exposure may correlate with those exposed north of the New Haven Railroad tracks in the next gap to the north, but this is not certain.

A count of 400 pebbles in the lower (20-ft) conglomerate unit showed the following distribution of long diameters:

Names of particles	Limiting diameters (mm.)	Proportion (percent)
Fine pebbles	4 to 8	2.5
Medium pebbles	8 to 16	16.8
Coarse pebbles	16 to 32	36.7
Very coarse pebbles	32 to 64	29.4
Small cobbles	64 to 128	13.5
Large cobbles	128 to 256	1.0

The kinds of rocks were distributed as follows:

Rock type	Proportion (per cent)
Quartzite	60
Granitic rocks and pegmatites	20
Schists	8
Limestone and carbonate rocks	6
Sandstones (?)	4
Gneisses	2

The noteworthy feature of the composition of the clasts is the large proportion of quartzite (presumably from the Plainfield Formation) and the presence of limestones and carbonate rocks. These carbonate rocks form disks and blades; several kinds are present and all were derived from nonmetamorphosed source rocks. The whereabouts of such source rocks in the Eastern Highland province is a complete enigma. One possibility is that they were derived from the carbonate rocks of the Talcott and basal Shuttle Meadow formations. If so, then these Triassic carbonate rocks were deposited in lakes that extended at least locally across the Triassic Border fault. It is not known whether any Triassic carbonate rocks were present on the fault block seen at Stop 1.

The exposures in this cut and those in the cuts in the next gap to the north (16.30 N–56.84 to 56.90 E) are instructive in that they completely disprove the idea, championed by W. M. Davis (1898), that gaps resulted from zones of weakness along fanlts. Davis mapped one fanlt along the axis of each gap; he thought the gap-forming faults had a strike of NE-SW.

The present writer's interpretation of the fanlts is shown in figure 5. Although many of the details may be difficult to see clearly in the black-and-white drawing, the important points are obvious. In particular, each gap has resulted from the dislocations on four fanlts striking N 85° E, not from one fault striking NE-SW, as Davis supposed.

Two faults can be pinpointed in the U.S. Route 1 cut; these are shown by the solid lines in figure 5. The perpendicular distance between these two faults (based on tape-and-compass survey) is 57 ft. Along the northern of these two faults the base of the Holyoke Formation has been displaced from a presumed position at road level (on side road west of the hill) to a point on the hillside where it dips 45°. Assuming a 45-degree dip on both sides of the northern fanlt, then the vertical component of slip is 65 ft relatively up on the south side.

The southern of these two faults is by far the larger. Along it, the base of the Holyoke Formation has been displaced at least 450 ft eastward south of the fault. Assuming a dip of 55°, then the vertical component of slip is 643 ft up on the south side. The base of the Holyoke Formation on the block south of this fault has not been precisely located. Borings for the highway where it crosses the outlet of Lake Saltonstall reported only conglomerate and sandstone bedrock. The present writer's best guess is that the base of the Holyoke Formation lies nearly opposite the line formed by the top of this formation on the block north of the two faults being described. The other two faults shown south of U.S. Route 1 are based on indirect evidence. No direct confirmation is available for the presence of the Holyoke Formation in the lowland south of the highway (as shown on the map); it is thought to be there because only sedimentary strata occur on the northern slope of the knoll at the south edge of figure 5.

Stop 9 (16.30 N–56.84 to 56.90 E) Branford quadrangle.

Cuts on New Haven Railroad and Connecticut Turnpike, East Haven, in artificial gap west of Saltonstall Lake. This is the northern of the two large gaps in Saltonstall Ridge.

- Formations: Shuttle Meadow, Holyoke, East Berlin
- Stratigraphic positions: Shuttle Meadow (base and top 174 ft)
  Holyoke (most of it, including base and top)
  East Berlin (basal few feet)
- Distance from border fault: 1.25 mi (2.0 kilometers)
- Particle sizes of sedimentary strata: silt, sand, and fine pebbles
- Attitude of strata: (varies; in cut on north side of New Haven Railroad tracks: N 20° W, 40° NE)
- Structural setting: faulted limb of Saltonstall syncline

The large gap accommodating the railroad and the Connecticut Turnpike is, evidently, the work of man. Percival (1842) mentions that the crest of Saltonstall Ridge extended unbroken from the gap through which Saltonstall Lake overflows (Stop 8) to its northeastern extremity. The location of one of the faults is known exactly and the positions of the other three can be bracketed within narrow limits.

To begin with, the Shuttle Meadow strata in the railroad cut consist largely of sandstone and siltstone in beds 1 to 3 ft thick; a tape-and-compass traverse indicates 174 ft of strata are present from the bridge abutment on the north side of the tracks to the western limit of the exposure. The contact between Shuttle Meadow sandstone and Holyoke basalt was exposed during construction of the bridge in the middle of the nineteenth century; the stones of the bridge pier conceal it now.

The top of the Holyoke sheet is present just east of this bridge, on both the north and south sides of the tracks. The horizontal distance between the base and

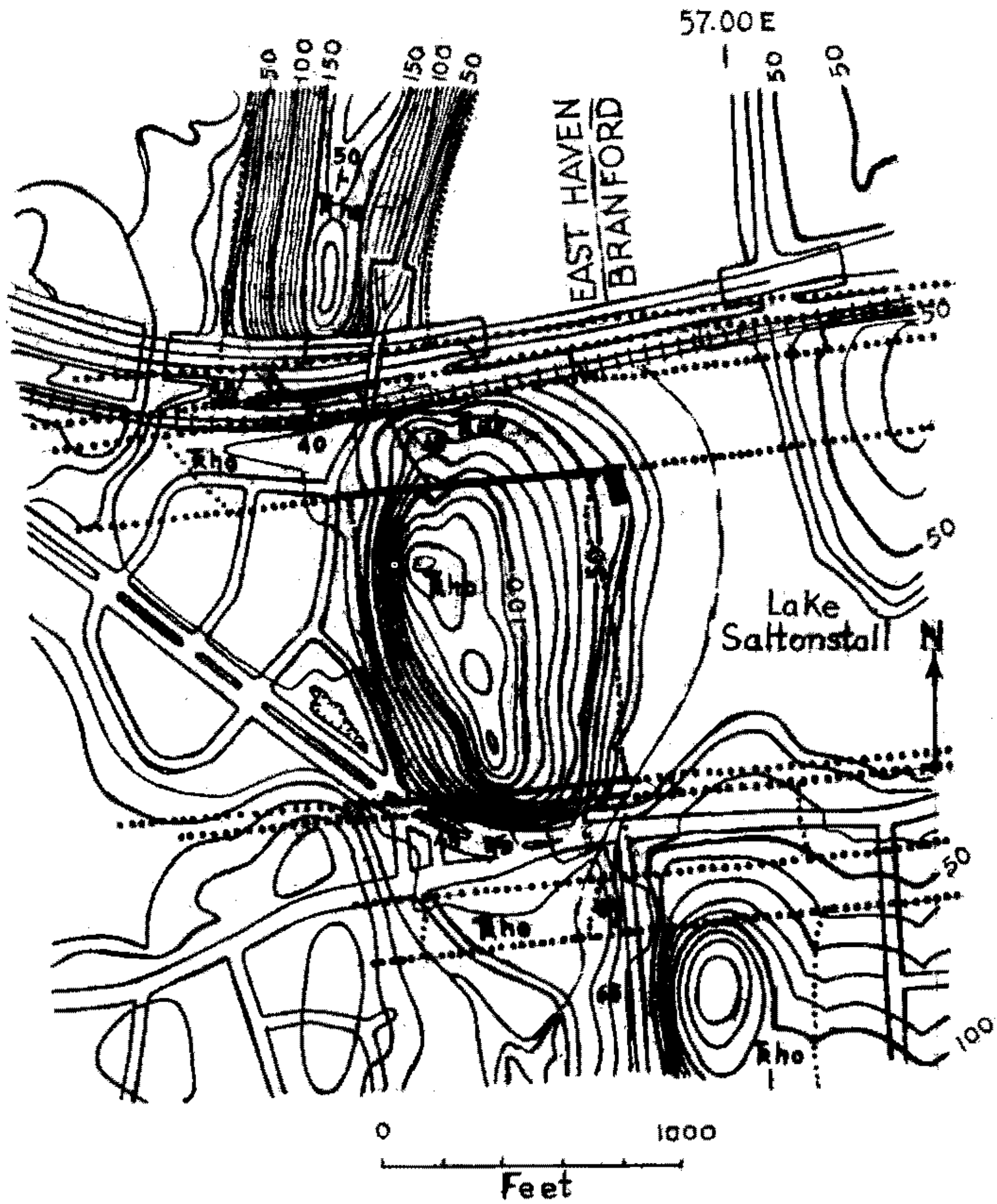


Fig. 5. Geologic sketch map of faults and gaps in Saltonstall Ridge, Branford quadrangle, Connecticut. Contours (10-ft interval) from U.S. Geological Survey topographic map. Geology by J. E. Sanders.

top of the sheet is 110 ft; assuming a dip of 45° this indicates a vertical component of slip equal to about 700 ft. About 1 ft above the base of the overlying East Berlin Formation is a limestone bed 1 ft thick; it is visible in the cut on the south side of the railroad and east of the bridge (16.17 N–56.93 E).

The bridge over the railroad, therefore, spans the fault marking the north side of a graben 750 ft wide. The Holyoke Formation in the graben is largely covered. The Holyoke-East Berlin contact can be followed part way up the hill to the fault on the south side of the graben. Along this fault the East Berlin Formation has been shifted 560 ft eastward to the pump house along the west shore of Lake Saltonstall; with dip of 45° (and assuming strike is perpendicular to the faults, which is not quite true), the vertical component of displacement is also 460 ft.

By crossing over the tracks on the bridge and turning left onto the small hill separating the railroad and the Connecticut Turnpike, it is possible to pinpoint a fault separating Holyoke basalt and Shuttle Meadow sandstone and to see the contact at the base of the Holyoke Formation. The fault extends down the center of this small hill; it is only 31 ft north of the fault at the north side of the graben we have just seen. Along the fault at the north side of this thin fault block, the base of the Holyoke Formation has been shifted relatively downward on the north so that it is displaced from the bridge abutment to the cut along the south side of the Connecticnt Turnpike (16.32 N–56.84 E). The indicated vertical component of slip is 172 ft.

Still another fault lies somewhere under the Connecticut Turnpike; along it the base of the Holyoke Formation shifts westward to the base of Saltonstall Ridge. A tape-and-compass traverse of the Holyoke Formation along the cut north of the Turnpike yielded a thickness of 434 ft, with neither base nor top exposed. This is 34 ft more than the thickness Longwell found in the New Haven Water Company's tunnel through Saltonstall Ridge at the north end of Saltonstall Lake (fig. 3).

In summary, the four faults that strike E-W through Saltonstall Ridge at the gap cut for the railroad and Turnpike have resulted in a general left-lateral offset of the ridge, just as in the gap followed by U.S. Route 1. In each case, the topographic low point appears to have resnlted from the effects of the shift of the resistant sheet of extrusive rock. The natural gap followed by U.S. Route 1 has cut through at the point where the base of the resistant layer has been shifted opposite its top on the opposite side of the fault.

Stop 10 (16.96 N–56.86 E) Branford quadrangle. Hillside east of Weeping Willows Restaurant, east of Laurel Street, East Haven.

Formations: Talcott and (?) New Haven

Stratigraphic position: Base of pillowed and brecciated member of Talcott and underlying pebbly coarse sandstone. (If no other Talcott flows lie below the sandstone, it presumably belongs in the New Haven Arkose. If other Talcott flows occur below the sandstone, then it belongs in the middle sedimentary member of the Talcott Formation.)

Distance from border fault: 2 mi. (3.2 kilometers)

Attitude of strata: N 15° E, 30° SE

Structural setting: limb of Saltonstall syncline

This exposure resulted from excavation of till and the effects of subsequent rainstorms. The pillows of the pillowed and brecciated member of the Talcott Formation are strikingly displayed. The effect of a Pleistocene glacier on the pebbly sandstone is also well displayed here. This is a good spot for comparing the scratches and striations created by a glacier with those resulting from a large power shovel used in excavating the till.

Stop 11 (17.98 N–57.64 E) Branford quadrangle. Deer Run School, Foxon (Town of East Haven).

Formation: Talcott

Stratigraphic position: basal basalt member

Distance from border fault: 2 mi. (3.2 kilometers)

Attitude of strata: EW, 30° S

Structnral setting: limb of Saltonstall syncline, near axial plane (see fig. 6)

The basalt behind the school building belongs to the basal basalt member of the Talcott Formation of the present writer's classification. The ridges east of the school expose the basal basalt member and two of the other overlying basalt members. The npper breccia member is not exposed at Foxon; presnmably it lies beneath either Route 80 or the outwash sands of the Farm River valley.

Stop 12 (18.60 to 18.70 N–58.06 to 58.10 E) Branford qnadrangle.

Hillside east of Barberry Road, northern panhandle of Town of East Haven.

Formation: Talcott

Stratigraphic position: pillowed and brecciated member, upper sandstone member, and upper breccia member

Distance from border fault: 2.5 mi (4 kilometers)

Attitude of strata: NS, 10° to 20° E

Structural setting: Totoket syncline; faulted blocks along northwest side of Gaillard graben

The west face of the wooded knoll east of Barberry Road and north of the junction with Thompson Street

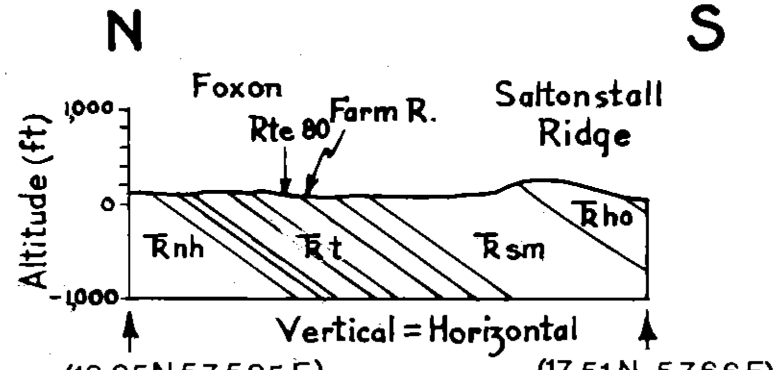


Fig. 6. Profile and section on limb of Saltonstall syncline near Deer Run School, Foxon. This is one of the few localities where the Talcott Formation has not heen extensively faulted.

exposes the pillowed and brecciated member of the Talcott Formation. The upper sedimentary member of the Talcott Formation underlies the cleared field on the lower slope just north of the woods; higher up this slope are exposures of the upper breccia member. Faults striking N-S limit this outcrop belt of the Talcott Formation; on the block between these two fanlts, the strata have been cut by faults striking NE-SW, and have been shifted up and down. Accordingly, the apparent stratigraphic displacement on the eastern of the two north-south faults decreases from 550 ft (lower profile and section of fig. 7) to only 150 ft within a very short distance (upper profile and section of fig. 7). Along a steep bluff (18.77 N–58.10 E) about 0.1 mi. N 30° E of the large barn, carbonate rocks are exposed near the top of the upper sedimentary member of the Talcott Formation.

Stop 13 (18.95 N–57.97 E) Branford quadrangle. Wooded knolls on opposite sides of Clintonville Road, northern panhandle of Town of East Haven.

Formation: Talcott
Stratigraphic position: three upper members
Distance from border fault: 3 mi. (4.8 kilometers)
Attitude of strata: varies; in many exposures the strata are nearly horizontal
Structural setting: complex of fault blocks near northwest border of Gaillard graben

Three sets of faults are present in this vicinity; a master set striking NW-SE, a N-S set, and a set striking NE-SW. A N-S fault follows Clintonville Road. The upper breccia member of the Talcott Formation is east of it, occupying the south half of the large knoll. The overlying Shuttle Meadow Formation is at the crest of the knoll. The northern half of the knoll is underlain by the pillowed and brecciated member of the Talcott Formation, dipping about 35° SE.

On the west side of Clintonville Road, a group of small rounded knolls exposes nearly flat-lying sedimentary and volcanic strata. The author has not revisited these localities since working out the stratigraphy of the Talcott Formation (Sanders, 1961).

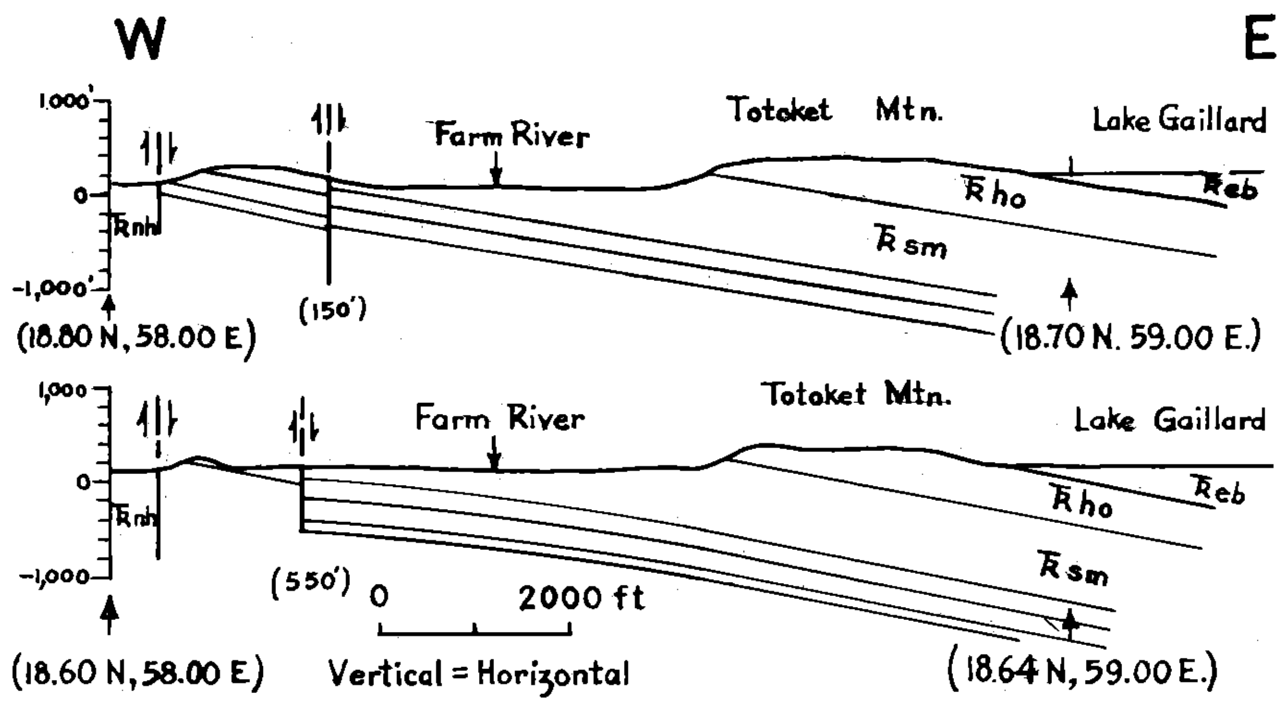


Fig. 7. Profiles and sections on limb of Totoket syncline between points indicated by arrows and coordinates of the Connecticut system.

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