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Stratigraphy and Structure of West Central Vermont and Adjacent New York

GUIDEBOOK

for

THE FIFTY-FIRST ANNUAL MEETING

of the

NEW ENGLAND INTERCOLLEGIATE

GEOLOGICAL CONFERENCE

STRATIGRAPHY and STRUCTURE of WEST CENTRAL VERMONT and ADJACENT NEW YORK

E-an Zen, Editor

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STRATIGRAPHY AND STRUCTURE OF WEST-CENTRAL VERMONT AND ADJACENT NEW YORK

STATEMENT OF THE PROBLEM

By: E-an Zen

Precambrian gneisses form the core of the Green Mountain anticlinorium in the vicinity of Rutland. These gneisses are overlain unconformably on the west limb of the anticlinorium by fossiliferous Lower Cambrian sedimentary rocks, which pass westward into Middle Ordovician rocks. Except for the basal Mendon series (Brace, 1953), these overlying rocks are largely carbonates and clean quartzites, and the sequence contains no obvious stratigraphic break below the black mid-Trenton phyllite, the "Hortonville formation". This west-dipping and west-facing section is the east limb of the Middlebury Synclinorium, which is the structural complement to the Green Mountain anticlinorium (Cady, 1945). The stratigraphy of the west limb of the Middlebury Synclinorium corresponds to that of the east limb, except that the Upper Cambrian Potsdam formation, rather than Lower Cambrian units, rests directly on the Precambrian of the Adirondack massif with profound unconformity (Rodgers, in Rodgers, et al., 1952, p. 34). The plunge of the Middlebury Synclinorium is to the south.

The east limb of the Middlebury Synclinorium is complicated by two facts. The first is a mid-Trenton regional unconformity, which also marks a distinct departure in the sedimentary regime. The "Hortonville formation", above the unconformity, rests on units as old as the Precambrian gneisses, thus indicating a considerable hiatus. The second complicating fact is the presence of a zone of faults, both reverse and normal, which extends from northwest of Rutland (the Pine Hill thrust, Brace, 1953) at least as far south as the north slope of Dorset Mountain (Thompson, in Rodgers et al., 1952, Pl. 4). In several areas along this zone, Precambrian rocks are brought to the surface, abutting younger units.

In the area extending from the town of Sudbury and south to the Catskill quadrangle (Ruedemann, 1942), New York, the mid-Trenton black slate is overlain by a sequence of fossiliferous Lower Cambrian to Middle Ordovician argillites, with minor arkoses, greywackes, quartzites, and carbonates. These rocks constitute the Taconic sequence and, though lithologically distinct from the carbonate-orthoquartzite sequence of the Middlebury Synclinorium, the sequence is continuous with that of the Synclinorium in metamorphic grade; indeed the "Hortonville formation" appears, in west-central Vermont, to grade upwards into the Taconic sequence lithologically.

Accepting the abundant and well-studied fossil evidence, the Taconic sequence clearly occupies an anomalous position. The two prevalent explanations for this problem are: (1) that the Taconic sequence is in fact in the core of an anticlinorium. A rapid sedimentary facies change is envisaged to account for the lithological contrasts with the Synclinorium sequence, and the "Hortonville formation" is thought to lie unconformably upon the Taconic sequence. Though local complications due to marginal faults and overturning of the structure are allowed, no major displacement of the rocks is thought to exist. At least part of the phyllite of the main Taconic

Range is regarded as younger than, and in normal succession with, the "Hortonville formation" (MacFadyen, 1956). On the other hand, advocates of (2) the Taconic-klippe hypothesis hold that the entire Taconic sequence, including the phyllites of the Taconic Range, had been moved into the present position through a major thrust fault. The site of deposition of these rocks is thought to be in the present Green Mountains or even farther east, where rocks of like nature and perhaps comparable age are found. Deformation and metamorphism of the rocks subsequent to the emplacement then account for the gradational contact between the Taconic and the Synclinorium sequences.

Trips A and I (Zen) will study the detailed stratigraphy and internal structure of the Taconic sequence at its north end, as well as the relations between the two Sequences. Evidence for a Taconic thrust will be presented. Trip G (Theokritoff, Berry, and Shumaker) will demonstrate the continuation of the stratigraphic succession in areas immediately to the south. Recent discoveries of crucial graptolites from this area have done much to elucidate the Ordovician stratigraphy of the Taconic sequence. Trip H (Thompson) will study the relations of the two Sequences in the Wallingford-Danby-Dorset area, as well as of the faulted Precambrian with the younger units. Trip B (Kay) will study some of the structural complications in the Middlebury Synclinorium immediately north of the Taconic sequence, in the area of the Sudbury Thurst which Zen has shown to be structurally an integral part of the Taconic sequence. Trip C (Welby) studies the stratigraphy in the less deformed rocks of the Middlebury Synclinorium, and Trip F (Osberg) studies some stratigraphic and structural problems of the basal Cambrian units in the Green Mountain Front, which in the vicinity of Coxe Mountain is offset several miles to the west, bringing it close to the Taconic rocks. Trips D (Bain) and E (Theokritoff) are largely of economical interest, and are devoted to the study of marble and slate quarries, respectively, in west-central Vermont.

REFERENCES

Brace, W. F., 1953, The geology of the Rutland area, Vermont. Vermont Geol. Survey Bull. no. 6, 124 p.

Cady, W. M., 1945, Stratigraphy and structure of west-central Vermont. Geol. Soc. America Bull. v. 56, p. 515-558.

MacFadyen, J. A., Jr., 1956, The geology of the Bennington area, Vermont. Vermont Geol. Survey Bull. no. 7, 72 p.

Rodgers, J., Thompson, J. B. Jr., and Billings, M. P., 1952, Geology of the Appalachian highlands of east-central New York, southern Vermont, and southern New Hampshire. Geol. Soc. America Guidebook for field trips in New England, p. 1-71.

Ruedemann, R., 1942, Geology of the Catskill and Kaaterskill quadrangles. Part 1, Cambrian and Ordovician geology of the Catskill quadrangle. New York State Museum Bull. 331. 188 p.

Trips A and I STRATIGRAPHY AND STRUCTURE AT THE NORTH END OF THE TACONIC RANGE AND ADJACENT AREAS

Leader: E-an Zen

STRATIGRAPHY

Rocks of the Taconic sequence range from Early Cambrian to Middle Ordovician in age. Rocks of the Synclinorium sequence, included in Pl. A-1, range from Early to Middle Ordovician in age. These are briefly described, from the oldest to the youngest formations:

Taconic Sequence

Biddie Knob formation

This formation consists of purple and green, chloritoid-bearing slate and phyllite, with subsidiary quartzite and rare thin limestone beds. Typical mineral assemblage: muscovite-chlorite-chloritoid-quartz-rutile, with subsidiary paragonite and hematite.

Bull formation

This consists of five members:

METTAWEE MEMBER: Purple and green slate, mudstone, and phyllite, distinguised from the Biddie Knob formation by the lack of chloritoid, which reflects primary compositional differences. This member constitutes the bulk of the formation. A typical mineral assemblage is muscovite-chlorite-albite-quartz-rutile.

BOMOSEEN GREYWACKE MEMBER: Olive-drab, massive greywacke, weathering grey to brick-red. A typical mineral assemblage is stilpnomelane-chlorite-muscovite-albite-microcline-quartz. West of Lake Bomoseen (Pl. A-3), this is the lowest exposed unit and underlies the Mettawee member; however east of Lake Bomoseen and north of the Pine Pond thrust, it is demonstrably within the Mettawee member (stop 4). The Bomoseen greywacke west of Lake Bomoseen conceivably belongs to a lower horizon, stratigraphically relacing the Biddie Knob formation; on the other hand, it may merely be part of a thickened section of the Bull formation, still underlain by the (unexposed) Mettawee member.

ZION HILL MEMBER: This is a massive greywacke or subgreywacke, ranging from 0 to 100 feet thick. The rapid variation in thickness suggests that it may be a shoestring sand, and occurs as discontinous beds confined in general to the middle part of the Bull formation. The base of the rock may be a pebble conglomerate, with load-casting features (stop 3), whereas the top may be a mudstone. Graded bedding is common. The Zion Hill is thus a crucial unit in working out the sense of the stratigraphic succession.

MUDD POND MEMBER: A white, vitreous, medium-grained orthoquartzite with rare dolomitic pods (concretions?). The thickness ranges up to 20 feet; at places two quartzite beds may occur separated by green slate

(stop 4). The Mudd Pond member may not always be present, but occurs near the top of the Bull formation.

CASTLETON CONGLOMERATE MEMBER: A limestone-pebble, slate-matrix, intraformational conglomerate (stop 1). The pebbles carry the Early Cambrian Elliptochephala fauna. It is probably no more than 20 feet thick, and the ratio of pebbles to matrix varies. It occurs near the top of the Bull formation, just above the Mudd Pond member (stop 4).

West Castleton formation

This formation consists largely of grey siltstone and black fissile slate, with rare beds of quartzite, pebble conglomerate, and rusty-weathering dolostone. Near the base of the unit is a black limestone, the Beebe limestone, which is massive but discontinuous. It yields the Early Cambrian Elliptocephala fauna. This formation was called the Hooker by Keith (1932) and the Schodack by Ruedemann (1914), Kaiser (1945), and Fowler (1950). This latter name, however, was incorrectly applied, as pointed out by Theokritoff (1957).

Poultney River Group

This is a large, and undivided rock group, ranging in age from of Upper Cambrian to Middle Ordovician. In the writer's area, six rock types have been recognized; the following is a tentative chronological listing, from the oldest to the youngest:

1. A white-weathering, black argillite with ribbon limestone and cherty beds (stop 1). (Schaghticoke lithology)

2. A limestone-matrix, limestone-conglomerate.

3. White-weathering, green, grey, black, and rarely red argillite, with interbedded thin, buff-weathering quartzite. Typical mineral assemblage: quartz-muscovite-chlorite-albite-microcline (stop 1). ("Poultney slate")

4. A black slate with interbedded brown-weathering, ankeritic, massive black quartzite with edgewise conglomerate (stop 1). Graded bedding and channel filling are abundant. ("Hatch Hill" lithology)

5. A soft red slate with thin dolomitic and quartzose beds. ("Indian River")

6. A black slate with massive black greywacke beds, commonly showing graded bedding and containing angular rock fragments. (Unnamed)

Units 1 and 3 are Dale's "Hudson white beds" (1898, p. 185). Unit 4 is Larrabee's "Zion Hill quartzite" (1939, p. 51). Unit 5 is Keith's Indian River formation (1932, p. 403), and unit 6 is Dale's Hudson grits (1898, p. 187).

A major unconformity probably separates the West Castleton formation from the Poultney River group. This conclusion is based on overlap relations as well as gaps in the stratigraphy. At least another unconformity exists in the Poultney River group, below unit 6.

The thicknesses of the various formations cannot be stated because of the intense deformation. The Lower Cambrian units are probably no more than 2000' thick, however, and the Poultney River group perhaps no more than 1000'.

Synclinorium Sequence

Rocks of the Synclinorium sequence have been described by various authors (Cady, 1945; Fowler, 1950). On the map (Pl. A-1), the following units are shown:

1. The Beekmantown limestone, consisting, in the map area, of the Bascom formation (Cady, 1945, p. 542) and the Chipman formation (Cady and Zen, 1959). A sugary-textured, grey, massive variety of the Bascom has been mapped in part by Fowler as the Whipple marble (1950, p.32); its reinterpretation will be the subject of an optional Sunday afternoon trip.

2. The Chazy-Trenton limestones, consisting of the Middlebury, Orwell, and Glens Falls formations (Cady, 1945).

3. The black "Hortonville formation" overlying the Glens Falls, perhaps unconformably. This is a black slate or phyllite which resembles the West Castleton formation and also some of the black slate of the Poultney River group. The age of the type Hortonville is subject to question (Zen, 1959), and the writer now suggests reviving Keith's name Ira formation (1932, p. 398) for the belt that runs from Florence (Pl.A-3) south towards Dorset Mountain, a belt that cannot be traced into the type Hortonville with certainty. The name Ira is appropriate, as the writer, in 1958, has found Middle Ordovician fossils in limestone lenses in the phyllite near Ira village.

STRUCTURE

Rocks of the Taconic sequence constitutes a series of imbricate thrust plates (Pl. A-3). Each thrust plate has its intricate internal structure, which however may be obscured by later, transverse, and more open folds that affected all the plates alike, and developed during the formation of the Middlebury Synclinorium. Although each plate has its characteristic stratigraphy, the rock units are broadly similar and there is little problem in correlating the formations.

In the east-central part of the map (Pl. A-1), there is a large, boomerang-shaped tract of Biddie Knob formation, and a half-moon shaped area of the West Castleton formation and the Poultney River group immediately to the northwest. These are the Giddings Brook - Taconic Range anticline and the Ganson Hill syncline, respectively. Taken together, they illustrate the structural motif of the area. (Pl. A-4).

The anticline is interpreted as a recumbent fold, overturned from the east, now lying on its side with nearly horizontal axial plane and nearly north-south axis. Digitations on this anticline are responsible for the Pine Pond thrust and for the areas of Biddie Knob formation to the north and northeast of the boomerang-shaped area. The Ganson Hill syncline is the structural complement of the anticline. East of the crest line of the

Taconic Range, the axial plane of the anticline has been turned beyond the horizontal position so that beds on the under limb of the anticline now actually dip gently west (sections A-A' and B-B', Pl. A-2, also Pl. A-3). Tracing of the units, including the Mudd Pond and the Zion Hill members, from the vicinity of Lake Bomoseen, where primary tops-and-bottoms evidence exists, to the east flank of the Taconic Range (stop 5), conclusively demonstrates that the rocks on the east flank of this Range are Lower Cambrian and are upside-down.

Due to the superposed, later structure of the Middlebury synclinorium, the nearly-horizontal axial plane of the Taconic Range - Giddings Brook anticline dips with a southerly component. This is believed to be responsible for the east-west strike of the beds between the Taconic Range and Lake Bomoseen (stop 4), and for the resulting map pattern. In the field, the large-scale structures are obscured by later folds with north-south axes, and east-dipping axial planes. These folds may be hundreds of feet across and may be the only structures readily observed in individual outcrops. The excellent axial plane cleavages of these later folds render useless cleavage-bedding relations in determining regional stratigraphic sense (stop 4).

The writer's mapping has shown that the Sudbury thrust (Cady, 1945) does not root locally in the Middlebury Synclinorium; instead the trace of the fault disappears under the Taconic sequence. The sequence in the Sudbury thrust slice may be normal rather than inverted; structurally the thrust slice is part of the Taconic sequence and may be a sliver under the main thrust.

In the vicinity of Florence, the Lower Ordovician Bascom formation extends westward abnormally far into the black phyllite terrane. Fowler (1950) interprets this extended area as Whipple marble interbedded with Trenton "Hortonville" formation; the marble however is indistinguishable from undoubted Bascom found a few hundred feet to the east. The marble overlies rather than interbeds with the phyllite, and the contact is sharp. Farther west, a kidney-shaped area of identical marble, mapped by Fowler as type Whipple, is also re-interpreted as Bascom. It is in a syncline underlain on all sides by black phyllite, with minor complications due to thrust faults. Immediately west of here, the black phyllite extends abnormally far up the slope of the Taconic Range, all the way to the summit of Biddie Knob (Pl.A-3). The marble itself extends to an elevation of 1250' up the slope, and is strongly lineated down dip, shown by colour streaking. Taken together with the outcrop relationships near Florence, the structure is interpreted as a nappe of Bascom formation, back-folded into the east edge of the Taconic sequence (section A-A', Pl. A-2). It shows the continuation of intense deformation in this area after the emplacement of the Taconic sequence.

EMPLACEMENT OF THE ALLOCHTHONE AND REGIONAL RELATIONS

The discovery that the Lower Cambrian Taconic sequence, in the east flank of the Taconic Range north of the Castleton River, is upside-down, demonstrates that the Taconic sequence does not constitute an ordinary anticline. Through detailed mapping of the formational contacts, the major structures within the Taconic sequence, as exemplified by the

Giddings Brook - Taconic Range anticline, are as a whole shown to be integral parts of the Middlebury Synclinorium. These structures were folded as part of the south-plunging Synclinorium after the development of the large-scale recumbent folds and thrust faults.

At the north end of the Taconic Range, therefore, the evidence for a Taconic allochthone is overwhelming. Though the trace of this fault can be located on the west side of the area, its location east of the Taconic Range is still conjectural. The gradational contact between the green and black phyllites, and the presence, in the black phyllite southwest of Brandon, of rock units characteristic of the Taconic sequence, however, show that part of the black phyllite east of the Taconic Range must be allochthonous.

The discovery of exotic blocks of Lower Cambrian Taconic rocks in the black slate north and east of Forbes Hill (Pl. A-3; stop 2) and elsewhere along the periphery of the Taconic sequence suggests an explanation for the mechanics of emplacement. (One mile north of Forbes Hill, a 6-inch black limestone carrying Ordovician fossils is interbedded with black slate traceable into outcrops of the "Forbes Hill conglomerate". Moreover, near Sunset Lake a similar rock is found, closely associated with a fossiliferous Middle Ordovician limestone conglomerate). The Taconic sequence, perhaps as soft unconsolidated material, is believed to have moved into a Trenton sea in which black mud was depositing. The allochthonous black argillite and the mud became so intimately commingled that a contact surface, in the ordinary sense, ceased to exist. The continuing deposition of black mud after this diastrophic event would result in local unconformities of Trenton slate over the Taconic sequence, as reported by Bucher (1957) at the south end of the slate belt. The emplacement of the Taconic sequence is thus a Late Trenton event, which tallies with the fact that the youngest rocks in the Taconic sequence is dated as Late Normanskill.

The Taconic sequence may have been moved in from the site of the present Green Mountains. Available fossil evidence suggests a correlation of at least the upper part of the Poultney River group with the Moretown - Cram Hill sequence (Thompson, in Rodgers, et al., 1952). The Moretown - Cram Hill sequence of eastern Vermont is thick and contains much volcanic material, in contrast to the Poultney River group which is relatively thin and free of volcanics. This change seems to fulfill the paleogeograghical requirements for rocks deposited at the site of the present Green Mountains, as the Moretown - Cram Hill, as well as the underlying rocks, are units typical of eugeosynclinal deposits, and somehow these must pass westward into the typical miogeosynclinal deposits of carbonates and orthoquartzites characterized by rocks of comparable age and found in the Middlebury Synclinorium.

REFERENCES

Bucher, W. H., 1957, Taconic klippe - a stratigraphic-structural problem. Geol. Soc. America Bull. v. 68, p. 657-674.

Cady, W. M., 1945, Stratigraphy and structure of west-central Vermont. Geol. Soc. America Bull. v. 56, p. 515-558.

----, and Zen, E., 1959, Stratigraphic relationships of the Lower Ordovician Chipman formation in west-central Vermont. Amer. Jour. Sci. v. 257, p.

Dale, T. N., 1898, The slate belt of eastern New York and western Vermont. U. S. Geol. Survey Ann. Rept. 19, Part 3, p. 163-307.

Fowler, P., 1950, Stratigraphy and structure of the Castleton area, Vermont. Vermont Geol. Survey Bull. no. 2, 83 p.

Kaiser, E. P., 1945, North end of the Taconic thrust sheet in western Vermont. Geol. Soc. America Bull. v. 56, p. 1079-1098.

Keith, A., 1932, Stratigraphy and structure of northwestern Vermont. Wash. Acad. Sciences Jour. v. 22, p. 357-379; 393-406.

Larrabee, D. M., 1939, The colored slates of Vermont and New York. Engr. and Mining Jour. v. 140, no. 12, p. 47-53.

Rodgers, J., Thompson, J. B. Jr., and Billings, M. P., 1952, Geology of the Appalachian highlands of east-central New York, southern Vermont, and southern New Hampshire. Geol. Soc. America guide-book for field trips in New England, p. 1-71.

Ruedemann, R. (Cushing, H. P., and), 1914, Geology of Saratoga Springs and vicinity. N.Y. State Museum Bull. 169, 177 p.

Theokritoff, G., 1957, Use of the term "Schodack formation" in Washington County, New York (abstract). Geol. Soc. America Bull. v. 68, p. 1804-1805.

Zen, E., 1959, Problem of the "Hortonville formation" in western Vermont (abstract). Geol. Soc. America Annual Meeting in Pittsburgh.

SUGGESTED TOPOGRAPHIC SHEETS FOR TRIPS A AND I

Castleton, Vermont - 15 minutes, scale 62,500
Thorn Hill, Vermont - New York - 7½ minutes, scale 24,000 (stop 1)
Benson, Vermont - New York - 7½ minutes, scale 24,000 (stop 2)
Bomoseen, Vermont - 7½ minutes, scale 24,000 and 31,680 (stops 3 and 4)
Proctor, Vermont - 7½ minutes, scale 24,000 and 31,680 (stop 5)

Trip A Road log

0.0 West end of Municipal parking lot in front of Hotel Bardwell. Head west on Evelyn Street left of Killington Bank.

0.1 Turn left (west) onto West Street.

0.2 Traffic light; go straight ahead.

0.9 Bear left on Route 4 (Columbian Avenue) beyond railraod tracks. BEWARE OF TRAFFIC! Stay on Route 4 for the next 16 miles.

2.6 Upper Cambrian Danby dolostone with quartzite beds in roadcut; beds dip west.

2.7 Mid-Trenton black phyllite overlying the dolostone.

3.8 West Rutland.

4.8 Main quarries and mills of Vermont Marble Company to the right and behind; quarries are in Upper Canadian marbles. Steep hills to right and ahead are in the green phyllite of the Taconic sequence, dipping gently west.

6.2 Road cut in the Lower Cambrian Biddie Knob formation.

6.6 View of Bird Mountain; cliffs are in the "Bird Mountain grit", correlative of the Zion Hill quartzite. Surrounding low areas are underlain by the Biddie Knob formation.

10.1 Lower Cambrian Mettawee slate (Bull formation) in pastures to the left.

11.5 Village of Castleton; continue ahead.

13.1 Castleton Corners; continue ahead.

14.7 Bomoseen greywacke on the right; this is the type locality.

15.6 Quarry in Castleton conglomerate (Bull formation), here at the nose of a north-plunging syncline.

16.1 Bear left with Route 4. Town of Fair Haven.

16.5 Turn right on Route 22A and follow it for 500 feet. Then go straight ahead (West Street) where Route 22A turns right, by the Methodist Church.

18.0 Bridge over Poultney River; STOP 1

Stratigraphy in the upper part of the Taconic sequence. Immediately under the bridge the purple and green slate of the Lower Cambrian Bull formation (Mettawee member) is exposed. A minor syncline here contains a black slate of unknown classification. The next group of out-

crops downstream along the river shows the Mettawee slates again, in addition it shows the Castleton conglomerate member. Here, the "conglomerate" ranges from true pebble conglomerate to thin bedded limestone, demonstrating that the conglomerate is in fact intraformational. This is significant, because many Early Cambrian fossils in the Taconic sequence were found in the "pebbles". The next large outcrop, west of the river, shows "unit 1" of the Poultney River group. Notice the hard, "glazed" appearance of the jet black slate, and the ribbony limestone. Delicate cross-bedding in the latter indicates a top-west sense. The cherty beds are rather unusual. The last group of outcrops in the river bed shows the rock types in units 3 and 4 of the PRG. Notice the abundant graded bedding and channel-filling, all indicating top-west sense. At the north end of the outcrops, a minor fault is exposed. The significance of the disharmonious folds in unit 3 here is uncertain; they may represent slump structures.

Climb out of the river channel and walk west to a north-south gravel road. Follow the road south. Cuts along the road expose units 3 and 4 again. Turn left at road junction and back to car.

Turn around and return to Fair Haven.

19.4 Turn left (north) onto Route 22A; same corner as mileage 16.6.

20.7 Bomoseen greywacke to the right.

21.2 Castleton conglomerate; the limestone beds show all gradations between good beds and pebbles. The matrix here is a greenish grey silty slate; locally however it is a black calcareous grit, the "Eddy Hill grit".

21.6 Slate and ankeritic quartzite of the Poultney River group; west (normal) limb of the syncline whose east limb was examined at STOP 1.

22.5 Bomoseen greywacke.

22.8 Mudd Pond quartzite (Bull formation) to the right by the school house.

23.0 Turn left on West Haven road. Outcrops to the east of Route 22A here are the West Castleton formation at the base of the ledges and Bull formation (green slate) on top; section is inverted.

23.2 Beginning of wide area of outcrops of Lower Ordovician carbonates, including the Bascom and Chipman formations.

24.4 Bridge over Hubbardton River; black slate west of the bridge. This slate is mid-Trenton in age.

25.1 Bear right onto gravel road.

25.6 STOP 2

Forbes Hill "conglomerate".

Notice the character of the "blocks" in the black slate matrix:

gray vitreous quartzite, punky-weathering dolomitic sandstone, and green slate. All these types can be matched with units in the Taconic sequence (Mudd Pond, units in the West Castleton, and Mettawee, resp.) immediately east. The blocks are all angular and randomly oriented; their sizes seem to correlate with rock hardness. Although the age of the matrix slate is unknown here, a similar rock (even more spectacular but less accessible) about 1/2 mile northwest of here has been traced into an outcrop containing interbedded fossiliferous Ordovician limestone. The matrix is thus presumably Ordovician.

Forbes Hill, west of the road, is underlain by Lower Ordovician Chipman formation dipping gently east but much folded. To the east, the wooded knoll in the valley is underlain by the Bomoseen greywacke. The valley itself is underlain by the weak Mettawee slate. The line of scarp in the distance is the Great Ledge, whose base is of Mettawee slate but whose face is of Bomoseen greywacke, dipping gently east. To the south of the outcrop, the wooded knobs in the middle distance are made up of Ordovician black slate, including more of the "conglomerate".

PLEASE REFRAIN FROM HAMMERING THE OUTCROP. THIS OUTCROP CAN BE POUNDED OUT OF EXISTENCE BY A GROUP OF THIS SIZE; IT IS TOO CRITICALLY IMPORTANT HOWEVER TO SUFFER SUCH AN EARLY DEATH. ALL THE RELEVANT FEATURES CAN BE SEEN, AND SEEN BETTER, ON THE NATURAL SURFACES. SO PLEASE COOPERATE - THANK YOU.

Turn around and proceed back towards Fair Haven.

28.4 Turn right onto Route 22A (same corner as mileage 23.0)

31.4 Turn left for short cut to Route 4.

32.0 Junction with Route 4; proceed straight ahead (same corner as milage 16.1).

33.9 Castleton Corners (same corner as mileage 13.1); turn left onto Route 30, going north.

34.3 Hills to the right are the Sunset Hill, underlain by the black slates of West Castleton formation. Kootenia fordi (Walcott) has been found here.

37.5 View across the lake (Lake Bomoseen) towards the abandoned quarry of Cedar Mountain. The bluff face is the keel of a recumbent syncline, overturned to the west and plunging south. Mettawee slate; top of the Bull formation.

38.0 Green Mettawee slate to the left of road.

38.6 A thrust fault is exposed on the cliff. Black West Castleton slate overridden by green Mettawee slate; the black slate is badly crumpled here and is in normal succession to the green slate of mileage 38.0.

38.7 Black West Castleton slate and Beebe limestone member, in normal succession above the green slate of mileage 38.6, lying above the thrust fault.

39.5 Purple and green Mettawee slate to the right.

40.1 Turn left onto gravel road.

40.3 STOP 3.

Primary sedimentary features in the Zion Hill member.

Almost the entire peninsula is made up of the Zion Hill quartzite, dipping gently east. The green colour of the quartzite on a fresh surface is due to chlorite. Spots of limonitic stain is also common. The rock is medium-grained and fairly well sorted, with subrounded grains of quartz and feldspar. At water's edge on the west side, one outcrop shows load-casting features against the underlying green slate. The individual grains are 1 cm. or less across here; in other outcrops they range up to 15 cm. and include slate and limestone. The load-casting feature and graded bedding as a whole indicate that the unit is right-side up; these features have been used extensively in the areal mapping and give consistent stratigraphic sense.

Across the lake, a rocky prominence, Page Point, can be seen. It is underlain also by the Zion Hill quartzite, showing graded bedding on the east side (upside-down), and gradation into mudstone on the west side. Drag folds also show that the section is upside-down. These two belts thus define an overturned anticline; this is cored by the Biddie Knob formation which follows the valley of Giddings Brook from Hubbardton on east. This anticline swings south near Biddie Knob, and the Zion Hill quartzite, with its primary sedimentary sense, shows that the east flank of this structure south of Biddie Knob, corresponding to the belt of Zion Hill west of Lake Bomoseen at Page Point, is upside-down.

West of Page Point, the Zion Hill is followed by the Mettawee slate, and eventually, at Cedar Mountain and Neshobe Island, by the West Castleton formation in the center of a recumbent syncline visible in the Cedar Mountain quarry. East of Stop 3, the Mettawee slate visible on the road is followed by black West Castleton slate (fossiliferous, Lower Cambrian) in the wooded hills visible from the road.

LUNCH STOP. THIS IS PRIVATE PROPERTY; WE ARE PERMITTED TO BE HERE BY THE COURTESY OF THE OWNER. PLEASE DO NOT POUND THE ROCK INDISCRIMINATELY AND DO NOT LEAVE ANY LITTER BEHIND! BRING IT BACK TO THE CAR AND DUMP IT IN ONE OF THE ROADSIDE TRASH CANS - WE WILL COME TO ONE SHORTLY. ALSO, BEWARE OF POISON IVY. THEY ARE THICK HERE.

Turn around and return to Route 30.

40.5 Route 30; turn left and continue on north.

41.3 Zion Hill quartzite (Bull formation) on the normal limb of the Giddings Brook fold. A minor thrust fault is exposed.

42.6 Village of Hubbardton. Turn right onto gravel road.

43.3 Bridge over Giddings Brook. Mettawee slate on the inverted limb of the Giddings Brook fold.

43.6 Turn left.

43.7 Quartzites to the right of the road are the Zion Hill member on the normal limb of the Giddings Brook fold.

44.2 Sharp cobble ahead held up by the Zion Hill quartzite.

44.9 Biddie Knob formation; return to the reverse limb of the Giddings Brook fold.

45.1 Two small recumbent anticlines in the Zion Hill quartzite are exposed in the road cut to the right.

45.4 STOP 4

Stratigraphy in the lower part of the Taconic sequence. The recumbent folds of the Giddings Brook and Ganson Hill area.

The pasture east of the farmhouse, south of the brook, is purple and green Biddie Knob formation - notice the tiny, sparkling cleavage flakes of chloritoid in the rock. Contact with the younger Bull formation is at the north end of the pasture, just south of the foot bridge. North of the bridge, Zion Hill quartzite dips under the Mettawee slate. Knobs to the north show the typical appearance of the quartzite.

Go southwest down from these knobs, follow lumber trail west, then north, around the south end of wooded hill. In the pasture: Zion Hill quartzite and Mettawee slate. Sharp, wooded knob to the southwest is a recumbent syncline of these same units. In the valley: Biddie Knob formation.

Where the trail branches near a ravine, stick to the east side of the gully. In the gully: green Mettawee slate. Continue on trail to a small pasture. First outcrop is Mettawee slate; at the northwest corner is a flat-lying outcrop of black limestone. This same limestone is seen a short distance north to underlie the green slate; it is the Beebe limestone, basal to the younger West Castleton formation. The section thus must be inverted; the cleavage-bedding relation is a later feature and cannot be trusted.

200 feet northwest, in another pasture, the black West Castleton formation is exposed. The contact of West Castleton and Bull can be traced in detail to yield an upside-down and gently south-dipping section.

Follow the overgrown pasture north-northeast. The trail nearly follows the Bull-West Castleton contact. At the end of clearing, go east into woods. A few poorly exposed Castleton conglomerate exist here. The quartzite beds, soon to be encountered, are Mudd Pond. Two beds exist, separated by green slate. Continue east to top of 1330' knob in the open. Notice the dolomitic pods in the quartzite; notice the structure, with the quartzite beds keeling over at the north end - apparently here is the nose of a major fold barely preserved. Notice the attitude of the slaty cleavage swinging over with the structure. The structure is in fact an inverted syncline, with older beds in the center. It has a north-south axis and

southerly plunge; it is formed during a second deformation (contemporaneous with the formation of the Middlebury Synclinorium?) superposed upon the already-existing inverted section. The slaty cleavage presumably belongs to the first deformation.

At the northeast side of the top, notice the Castleton conglomerate with extreme deformation of the pebbles - these are b-lineated relative to the second folding. Time and interest permitting, a short trip south, along the ridge of the hill, will encounter the Bomoseen greywacke, both underlain and overlain by green Mettawee slate; it is not exposed along the trail whence the group ascended the hill. Unfortunately, the best outcrops are not readily accessible from this hill.

Go north from the hilltop. In the woods, the black West Castleton is seen to underlie the Bull. Continue north to transverse gully; follow it east to farmyard. Go across dirt road up sharp knob. Poultney River (?) slate near the core of the Ganson Hill syncline. Ganson Hill is the group of knobs to the west.

Go east across stout barb-wire fence. BEWARE OF BLACK ANGUS BULLS! KEEP IN CLOSE FILE. Black slate up to the sharp ridge; on the east side Beebe limestone outcrops.

On the shore of Mudd Pond the quartzite bearing the same name dips very gently south. Section is normal; we are on the north limb of the Ganson Hill syncline. North of the pond, Bomoseen greywacke holds up the outlet, underlain to the north by purple Mettawee slate and finally more Biddie Knob formation. Go south in pasture. Green slate above the Mudd Pond, with cleavage-bedding relation again indicating a normal section although the sequence is exactly the reverse of that southwest of the 1330' hill. Continue south in pasture; green slate followed by black slate and several large outcrops of Beebe limestone. A last outcrop is the Mudd Pond quartzite again, in two beds; this is the same belt that was studied on the 1330' hill and on the reverse, south limb of the Ganson Hill syncline.

Walk south along dirt road to road junction; Biddie Knob formation in the gully to the south. Walk west to car.

Continue east.

45.9 Road cut is in Biddie Knob formation.

47.0 View of Biddie Knob (2008'); top of the knob marks the contact between black phyllite to the east and green phyllite (Bull) to the west. Biddie Knob formation begins at 1800' level on the west slope and continues to the road. This formation crosses to the east side of the Taconic skyline at the col south of Biddie Knob. Small wooded hill to the left and ahead is held up by Zion Hill quartzite on the normal limb of the Giddings Brook fold.

47.4 Zion Hill quartzite in woods to the right.

48.7 Zion Hill to the right. Cliffs are held up by Zion Hill quartzite.

51.0 Road cut in Biddie Knob formation of the Pine Pond thrust slice.

54.6 Hooker Hill to the right; type locality of Keith's Hooker formation, now called the West Castleton.

55.0 Road cut in purple and green Mettawee slate, including a poor outcrop of the Castleton conglomerate. The strata strike east-west and dip vertically. East (left) of the valley this sequence is masked by a higher tectonic unit, the Bird Mountain thrust slice, which makes up the hills to the east and south.

55.5 Route 4. Turn left (east) and continue to Rutland. End of itinerary.

Trip I Road Log

Mileage

0.0 Junction of Routes 3 and 7 just east of Pittsford Mills. Proceed west on Route 7.

2.2 View of Coxe Mountain ahead to the right. The ledges on the lower slopes are Lower Cambrian Cheshire quartzite dipping east and overturned; the mass of the mountain is underlain by Lower Cambrian (?) Mendon series.

2.3 Turn left on secondary paved road.

2.9 Outcrops north of road are Lower Cambrian Dunham dolostone.

3.0 Crossing Otter Creek.

3.1 Middle Cambrian (?) Winooski dolostone in road cut; section is inverted.

3.3 Turn left (south). Hamlet of Florence.

3.7 Turn right just before the second underpass.

3.9 Bear right, follow gravel road.

4.0 Road cut in Lower Ordovician (?) Shelburne marble; commercially this is the most important marble unit in western Vermont.

4.3 Lower Ordovician Bascom formation in pasture left of road.

4.6 Bascom marble resting on black phyllite south (left) of road; marble in the knolls and phyllite to the west.

5.0 Bear left.

5.4 Road cut in black phyllite; probably Middle Ordovician Ira formation.

5.5 Outcrops in fields to the right are black phyllite; either West Castleton or Ira. Taconic fault must be nearby although it is concealed. Hills to the northwest are in the Bull and Biddie Knob formations.

5.6 Bear left.

6.1 Flat-lying Bascom formation to the right, resting on black phyllite.

6.6 Bascom marble resting on black phyllite left of road.

6.9 Turn right. USE LOW GEAR!

7.1 STOP 5.

Stratigraphy and structure at the east flank of the Taconic Range.

PLEASE NOTE. THIS IS A ROUND-TRIP WALK OF NEARLY 3 MILES AND A CLIMB

OF OVER 1000 FEET, MUCH OF WHICH IS BUSHWHACKING. PLEASE MAKE SURE YOU ARE PREPARED FOR THIS. PLEASE DO NOT GO OFF ON YOUR OWN; THERE IS A MAZE OF LUMBER TRAILS ON WHICH ONE CAN GET LOST EASILY. STAY WITH THE GROUP.

Start on footpath by the hunting lodge, el. 820'; follow it west. Outcrops along the trail are black Ira or "Hortonville" formation. The black phyllite near the western margin of this rock type, however, may be Taconic; the contact is hidden.

1090' elevation. Trail forks. Bear left on overgrown branch.

1150'. Leave trail, go up slope. Black phyllite. At 1450', near top of steep slope, ledges of grey to green, massive, silty rock with visible porphyroblasts of albite up to ½ mm. across. This rock is typical of the green-black contact along the east flank of the Taconic Range at its north end. At 1480', this rock passes gradationally into green, fine, micaceous phyllite, directly traceable into the Mettawee slate south of Mudd Pond (stop 4). At 1510;, in open meadow on top of knoll, there is a ten-foot white quartzite with dolomitic pods. This rock is like the Mudd Pond member and occupies a similar position relative to the green-black contact as at the type locality.

Continue northwest up the knob in the woods, elevation 1650'. Keep WNW to the next knob, el. 1710'. Notice the green phyllite is without chloritoid.

Go west down. At 1650' there are two large outcrops of a white-weathering, vitreous, pale green, limonite-stained quartzite which resemble the Zion Hill. To the west, the phyllite begins to acquire chloritoid.

Go south to hit trail in the col; follow trail west to 1470' and see good outcrops of coarsely-grained chloritoid-bearing green Biddie Knob formation.

The succession of rock units are, in reverse order, the same as those seen at stop 4 - Biddie Knob, Mettawee, Zion Hill, Mettawee, Mudd Pond, Mettawee, and black slate. In fact, the same rock units can be traced continuously into the outcrops of stop 4. It will be recalled that at stop 3 primary tops evidence was seen in the Zion Hill member; it was pointed out that at Page Point, across Lake Bomoseen, the Zion Hill was inverted. This same inverted belt was seen at stop 4, and again at the present stop. Thus the stratigraphic correlation is proved by direct tracing, and the east flank of the Taconic Range in the vicinity of Biddie Knob must, therefore, represent an inverted section of Lower Cambrian rocks. This fact of an inverted sequence overlying a normal succession of the Synclinorium sequence cannot be explained by any scheme of simple sedimentary succession, even ignoring the fossil evidence.

Notice also that the chloritoid-bearing strata here occur west of the chloritoid-free green phyllite. Since the grade of regional metamorphism increases eastward, this fact shows that the basis of demarkation of the Biddie Knob and Mettawee, namely the presence of chloritoid in the former, is stratigraphically valid; the difference is not merely due to differences in metamorphic grade.

If the trail were followed westward, the Biddie Knob would be succeeded by purple and green Mettawee, Zion Hill (with graded bedding to show normal sense), Mettawee, Bomoseen, Mettawee, Castleton, and finally West Castleton with basal Beebe limestone. The two limbs of the structure thus correspond closely.

The group, however, will follow the trail east, and thence return to the cars.

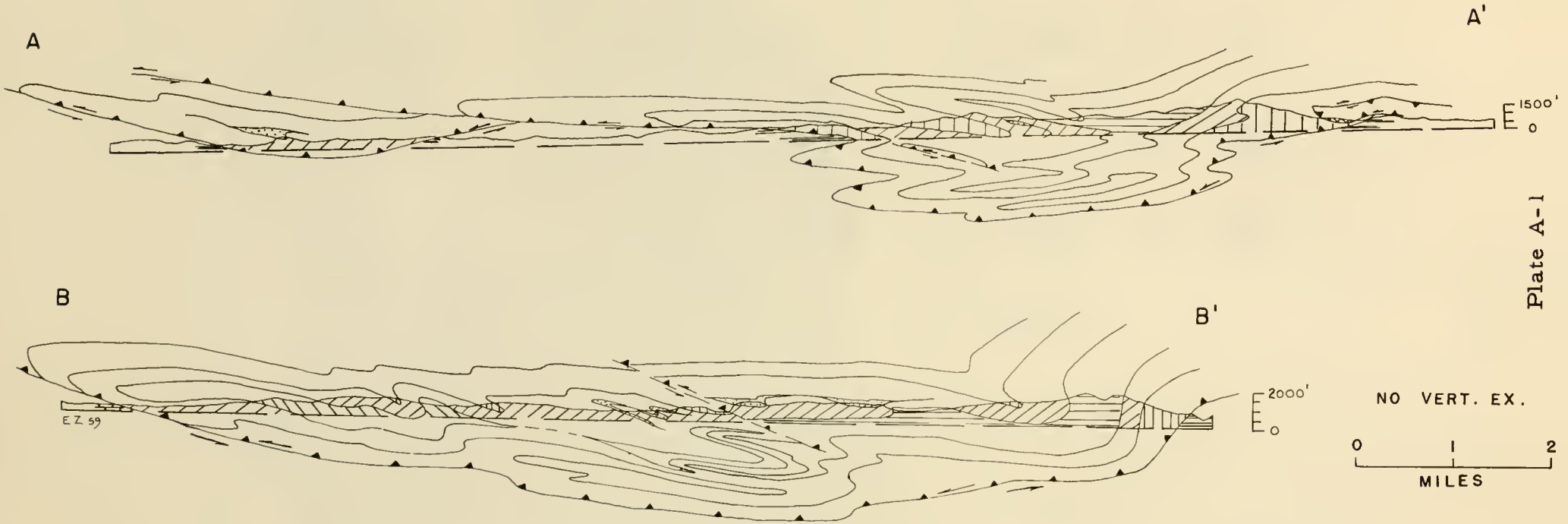
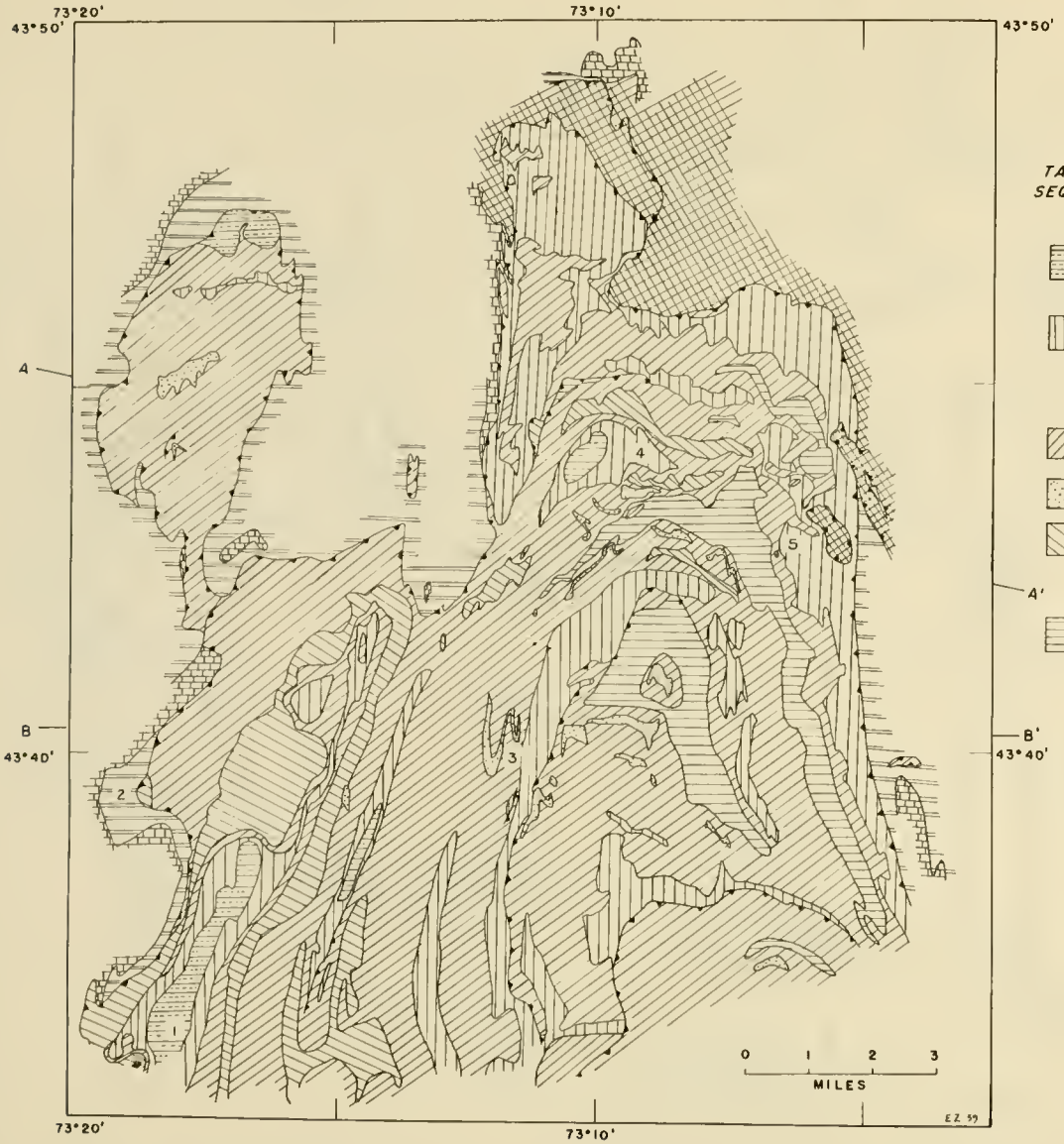


Plate A-1



LEGEND

TACONIC SEQUENCE

- POULTNEY RV. GROUP (U.€.-M.O.)
- WEST CASTLETON FM (L.€.)
- BULL FM (L.€.)
- METTAWEE SL.
- ZION HILL QTZT
- BOMOSEEN GRAYWACKE
- BIDDIE KNOB FM. (L.€.?)

SYNCLINORIUM SEQUENCE

- "HORTONVILLE" FM (M O.)
- UNDIFFERENTIATED M. ORD. LS. (GLENS FALLS, ORWELL, MIDDLEBURY)
- UNDIFFERENTIATED L. ORD. FMS. (CHIPMAN & BASCOM)

- CONTACT
- FAULT (CARATS ON UPFAULTED SIDE)

GEOLOGY BY E. ZEN, 1953 - 1958

Plate A-2

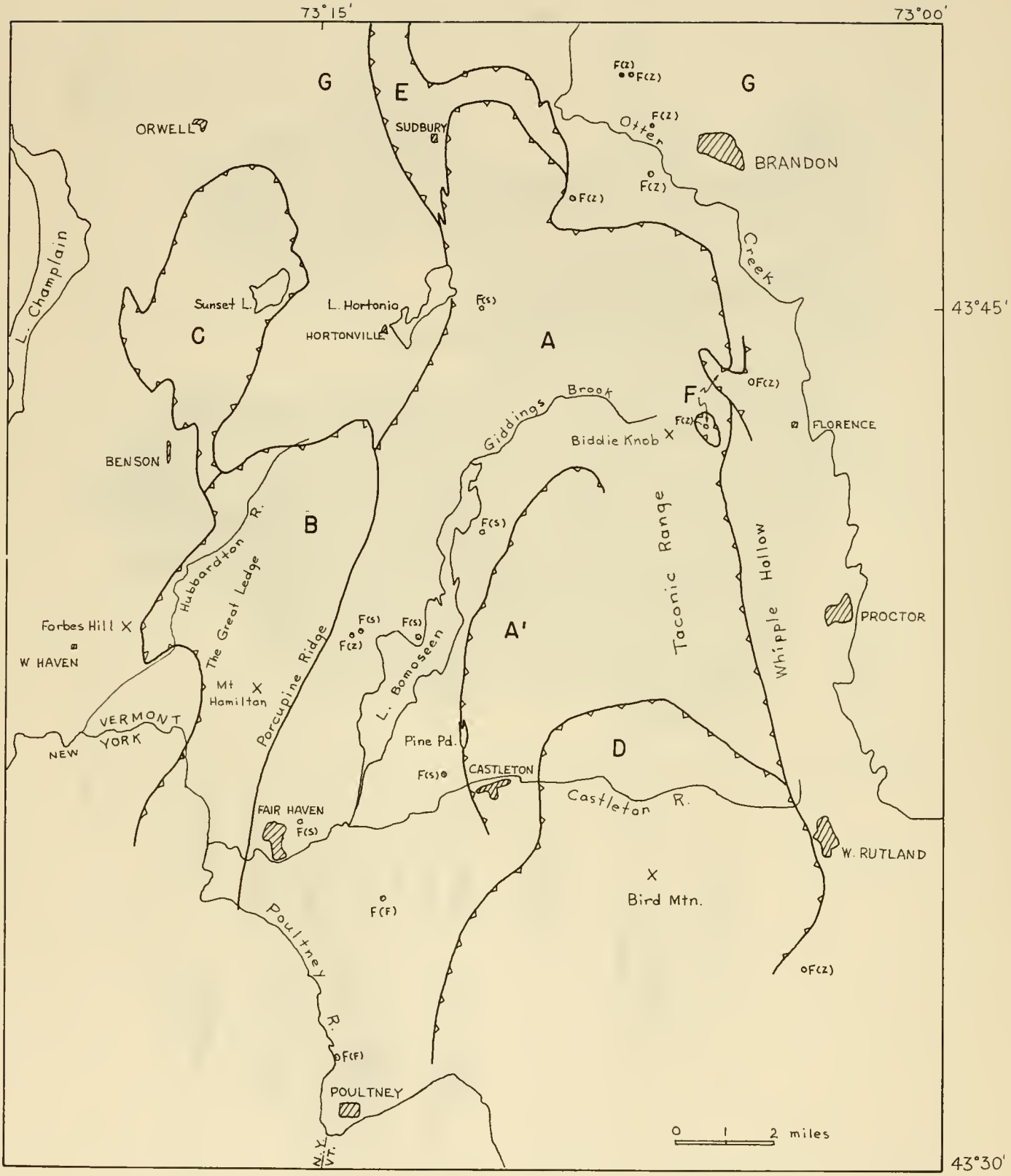
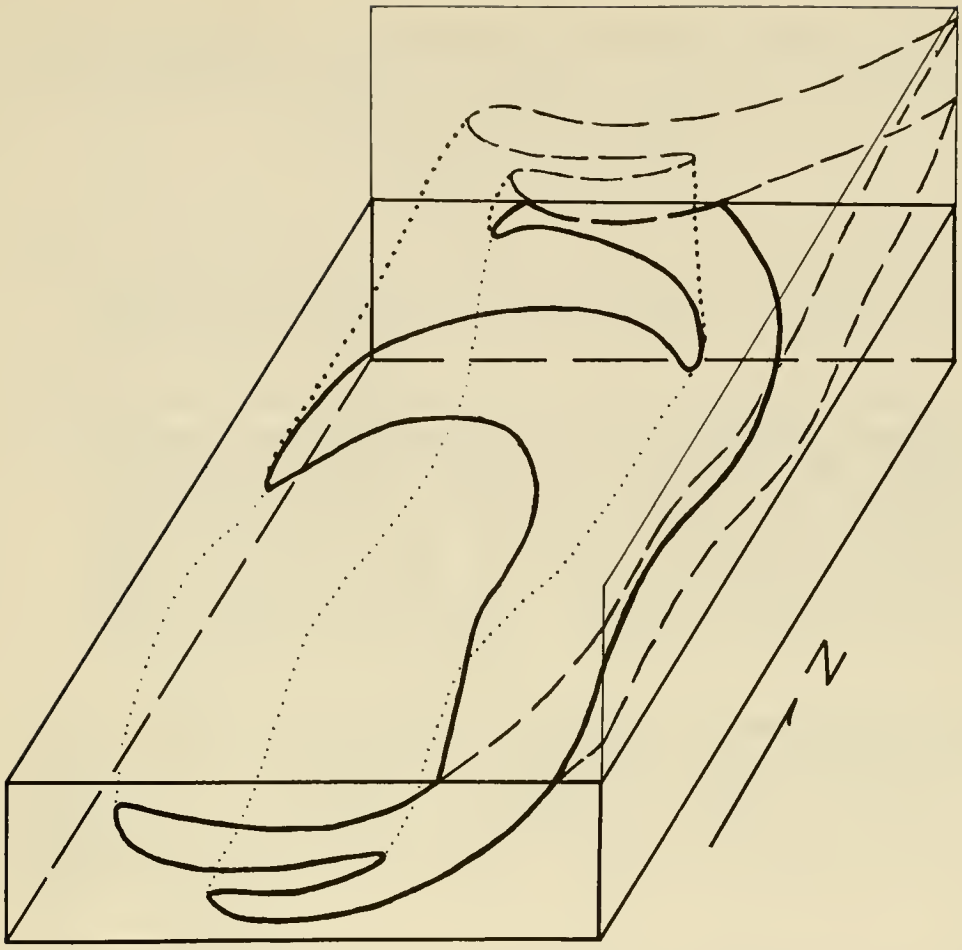

73°15'
73°00'
43°45'
43°30'
G
E
G
ORWELL
SUDBURY
Otter
BRANDON
F(z)
F(z)
F(z)
F(z)
F(z)
L. Champlain
Creek
Sunset L.
L. Hortonia
F(s)
C
HORTONVILLE
A
OF(z)
F
Giddings Brook
F(z)
FLORENCE
Biddie Knob
BENSON
B
F(s)
Taconic Range
Whipple Hollow
Hubbardton R.
The Great Ledge
PROCTOR
Forbes Hill
W HAVEN
F(s)
F(s)
F(z)
A'
Porcupine Ridge
L. Bomoseen
Mt Hamilton
VERMONT
NEW YORK
Pine Pd.
D
F(s)
CASTLETON
Castleton R.
FAIR HAVEN
F(s)
W. RUTLAND
Bird Mtn.
F(F)
Poultney R.
OF(z)
OF(F)
POULTNEY
N.Y.
Vt.
0 1 2 miles

Plate A-3



A: Taconic Range Giddings Brook fold

A': Pine Pond slice

B: Porcupine Ridge - Great Ledge fold

C: Sunset Lake slice

D: Bird Mountain slice

E: Sudbury slice

F: Florence Nappe

G: Middlebury Synclinorium

Trip B EXCURSIONS AT NORTH END OF THE TACONIC RANGE NEAR SUDBURY

SATURDAY AFTERNOON, OCTOBER 17th

Leader: Marshall Kay

Meet at Sudbury church on routes 30 and 73 west of Brandon at noon. We will study the section at nearby Sudbury Pond after lunch, leaving at about one o'clock.

The area has three tectonic layers, separated by the upper Taconic Thrust and the lower, Sudbury Thrust. The trips are concerned with the evidence for the Taconic Thrust, the structure and stratigraphic sequence in the Sudbury Nappe between the thrusts, and the Middlebury Synclinorium that lies below the nappe. The general regional relations have been described by Cady in his paper on West-Central Vermont in the Bulletin of Geological Society of America in 1945. Much of the area has been mapped by plane-table on a scale of 200 feet to one inch by Columbia University parties.

The Taconic Thrust is evidenced by the presence beneath the Taconic slates of divergent structures in the Sudbury Nappe that are cut across by the fault trace, particularly between localities 2 and 3. The section in the nappe will be examined at Sudbury Pond (loc. 1), and the type of structure is beautifully revealed at Recumbent Hill to the northwest (loc. 4).

The Sudbury Nappe lies on the Sudbury Thrust, which cuts across structures in the underlying Middlebury Synclinorium, a southward plunging structure extending for more than 20 miles northward. The marble of the Sudbury Nappe can be seen to lie on the slates of the core of the synclinorium at the base of the bluff south of the road junction just east of Jones Store (loc 7). The rocks of the west limb of the synclinorium will be examined at the Wilson Tupper farm (loc. 5), a mile west of Hyde Manor. A basic dike cuts the Sudbury Nappe at Locality 6.

Locality 1 - Sudbury Pond. Go to the lane west of Road 30. Walk north to the gate, and across the field to the pond. The sketch of the ledges just south and west of the small pond shows the beds and cleavage, from which a structure section can be drawn and the stratigraphic sequence determined. Numbers correspond to those painted on the rocks. The anticline on the west has longitudinal veins and cross joints. PLEASE RETURN THROUGH THE GATE.

Locality 2 - probably omitted as a stop because of parking difficulties. Take the road southeast from Sudbury church for .6 mile to sharp turn with rock cut. Cross the fence and go through the fields to the west and then south along the Taconic Thrust. The marble and interbedded dolomites below the thrust have fine displays of cleavages of several sorts, of intricate folds and boudinage structures. The rocks give evidence of the severe deformation at the sole of the Taconic Thrust fault. Sketch sections north and south of Hyde Manor are between this locality and the next.

Locality 3 is along Road 30 one mile south of Hyde Manor at an exposure of sandy limestone on the east of the highway - see the section. The sandy limestone and succeeding beds are of the west limb of an asymmetrical syncline, the east limb being cut out by the Taconic thrust beneath green and maroon slates with many quartz veins. From locality 2 to locality 3, the thrust has cut across structure from the upper Canadian Beldens marble to the middle Trentonian "Hortonville" slate.

Locality 4 has a magnificant exposure of an asymetrical anticline in "Recumbent Hill", reached by the lane north from road 73 one-half mile west of the junction with road 30 south of Sudbury church. The northward extension of this lane through fields is impassable in wet weather. The axis of the fold is of such low inclination that the trace of the axial plane on the topography is on both sides of the hill, and cuts irregularly through the hill to the northwest and the pasture to the east.

Locality 5 is the area of Tupper Farm directly to the south, one mile south of Road 73. Please USE THE GATES at the south end of the hill and across from the farmhouse; close the gates. The map shows the pattern of outcrops but not the names of units and their structure. This is a good place to apply cleavage-bedding criteria to work out the sequence.

A phyllite at the southern fossil star has Dinorthis sp., an elliptical brachiopod whose distortion can be seen. Similar fossils are preserved in the same phyllite at the northern star by the lake on the hill top to the north. Reuschella sp., another orthid brachipod, is common in a calcarenite bed above the phyllite in the axis of the syncline at the southern end of this little pond.

Locality 6 will not be visited. It is a four-foot dike of basic igneous rock that cuts down the hill east of Road 30 one-fourth mile south of Hyde Manor. The strike is N.55°W., and the rock crops out in the roadside ditch between two white posts east of the highway.

Locality 7, south of the road junction east of Jones or Selleck store on road 73, shows the Sudbury Thrust beneath Beldens marble and above "Hortonville" slate of the Middlebury Synclinorium. We will not stop at this locality.

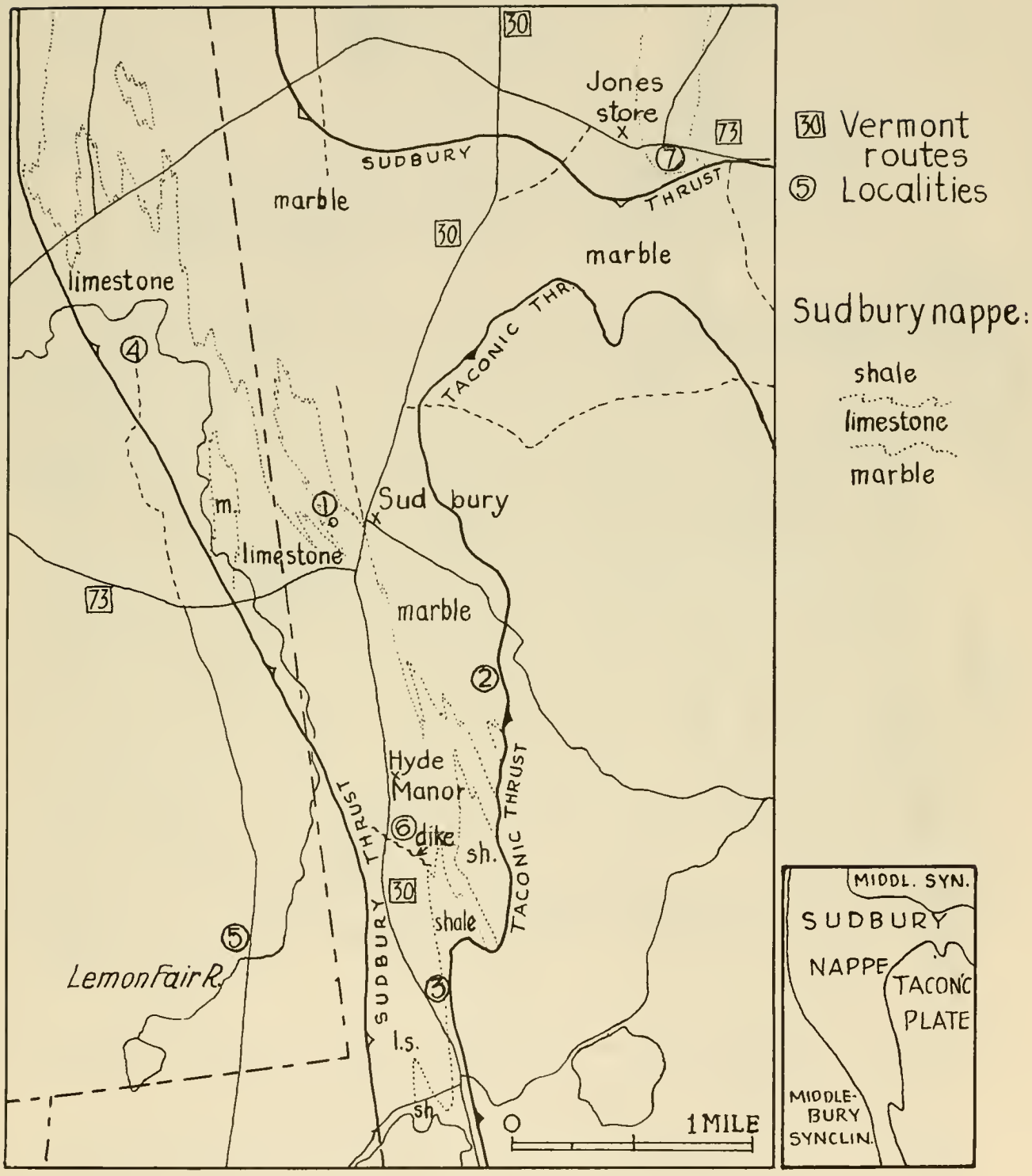
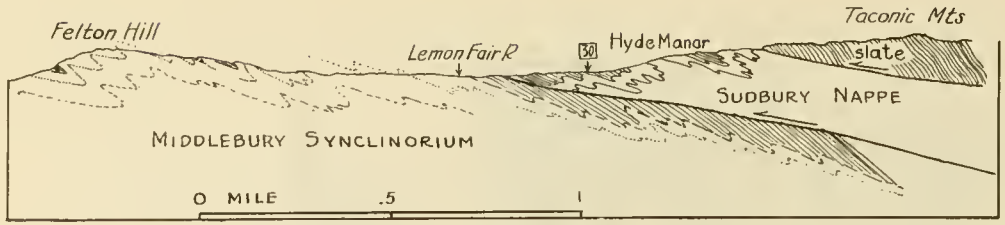
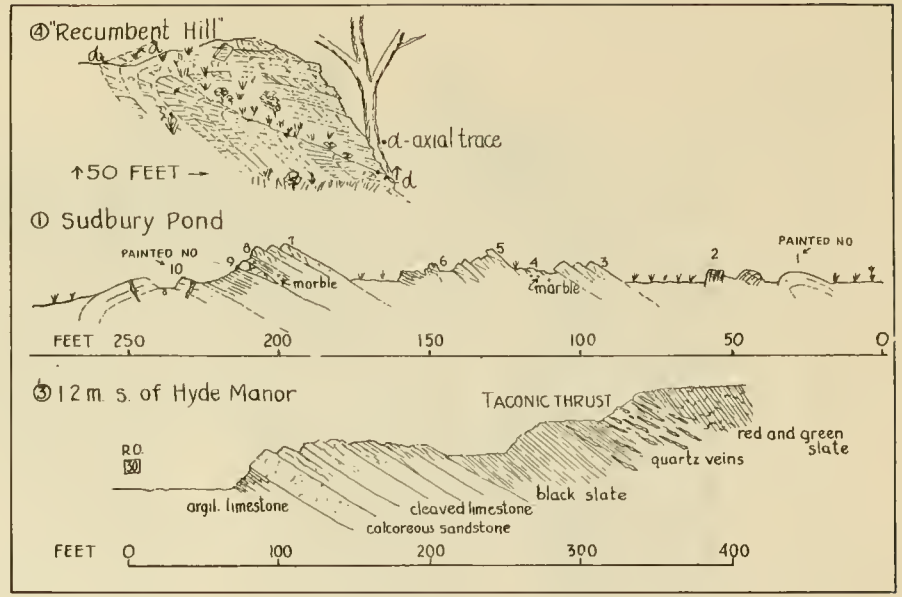

30
Jones store
73
SUDBURY THRUST
marble
30
marble
limestone
TACONIC THR.
m.
limestone
Sud bury
73
marble
Hyde Manor
dike
sh.
TACONIC THRUST
SUDBURY THRUST
30
shale
Lemon Fair R.
l.s.
sh.
1 MILE
30 Vermont routes
⑤ Localities
Sudbury nappe:
shale
limestone
marble
MIDDL. SYN.
SUDBURY NAPPE
TACONIC PLATE
MIDDLEBURY SYNCLIN.

Plate B-1


Felton Hill
Lemon Fair R.
30
Hyde Manor
Taconic Mts
slate
SUDBURY NAPPE
MIDDLEBURY SYNCLINORIUM
0 MILE .5 1


④"Recumbent Hill"
a
a-axial trace
↑50 FEET →
d
① Sudbury Pond
PAINTED NO 10
PAINTED NO 1
marble
marble
FEET 250 200 150 100 50 0
③ 1.2 m. S. of Hyde Manor
TACONIC THRUST
RD 30
red and green slate
quartz veins
black slate
argil. limestone
cleaved limestone
calcareous sandstone
FEET 0 100 200 300 400

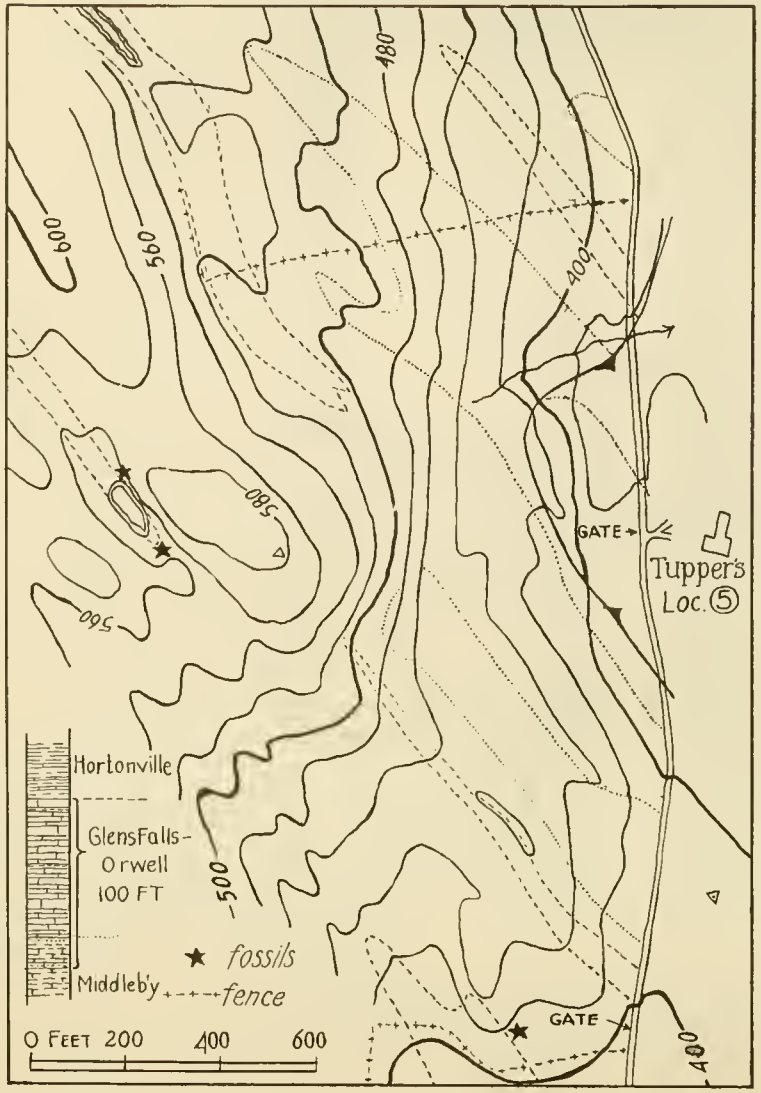
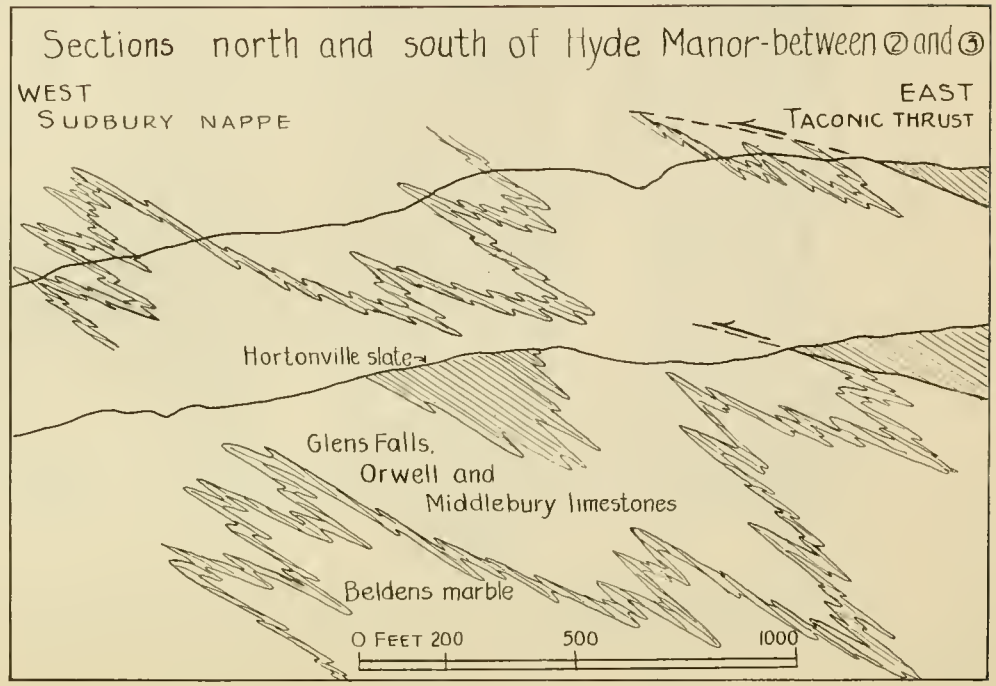

480
600
560
400
580
560
500
GATE
Tupper's Loc. ⑤
GATE
400
Hortonville
Glens Falls-Orwell 100 FT
Middleb'y
fossils
fence
0 FEET 200 400 600

Plate B-2


Sections north and south of Hyde Manor-between ② and ③
WEST
SUDBURY NAPPE
EAST
TACONIC THRUST
Hortonville slate
Glens Falls, Orwell and Middlebury limestones
Beldens marble
0 FEET 200 500 1000

Trip C - Stratigraphy of the Central Champlain Valley

Charles W. Welby
Department of Geology
Trinity College

The work on which this trip is based was sponsored by the Vermont Geological Survey, and the author is grateful to Dr. Charles G. Doll, State Geologist, for permission to use the material prior to publication of the report on the area.

The purpose of the trip is to show some of the typical exposures of the Ordovician and Cambrian rocks which outcrop in the Central Champlain Valley. Two stops will be made for fossil-collecting.

Structurally the area is relatively simple; gentle tilting predominates. However, along the Champlain Thrust and the subsidiary thrusts accompanying it, the structures become more confused. There are overturned, isoclinal folds present in the upper thrust plates, and strong evidence exists to support the concept of post-thrusting cross-faulting. It is not unlikely that evidence for several deformations exists in the faulting if it can be unraveled. On the south slope of Buck Mountain (northeast of mile 67.2) the fault plane of a reverse fault cutting the Champlain Thrust can be seen. North of Vergennes and in Charlotte the presence of transverse faults can be shown. Some of the cross-faulting will be demonstrated in an approximate fashion during the trip. Section AA', Plate C-1 illustrates diagrammatically some of the structural relationships. It should be pointed out that the plane of the fault next to the Champlain Thrust can be seen on Buck Mountain. The stratigraphic relations indicate that the easternmost Orwell-Crown Point-Bridport sequence is the eastern limb of an overturned syncline; however, there is some evidence to suggest that each outcrop belt represents a thrust fault and that the beds have been shoved out in an order reverse to their normal sequence, retaining their topside uppermost. High angle faults which have downdropped the older beds of the overthrust masses against the younger beds of the lower plate exist. One such fault is exposed at the quarry south of Vergennes.

The sequence is of Ordovician age with the exception of the Upper Cambrian Ticonderoga formation, although the area is bordered on the east by the Lower Cambrian Monkton formation lying above the Champlain Thrust.

No attempt is made to explain the regional correlations. Papers in the selected references discuss this aspect, although the author does not necessarily agree with all the conclusions voiced in them. The following table gives a brief resume of the stratigraphy.

Ordovician - Champlainian

Mohawkian Stage

Iberville shale: Black, brittle, non-calcareous, thin-bedded, thin-cleaving, with occasional beds and laminae or orange-weathering dolomitic siltstones and silty dolostones; generally unfossiliferous, although graptolites have been found. The formation is well exposed on Shelburne Point near Burlington, and it appears again south of the south end of Snake Mountain. Thickness is probably in excess of 1000' but no direct measurements have been made.

Stony Point shale: Black, caccareous, splintery shale with occasional beds of olive-gray weathering finely crystalline limestones and dolostones. Some black non-calcareous shale, and a few orange-weathering dolostones and silty dolostones. Within the area of the field trip the dolostones and limestones are rare. The formation grades upward into Iberville through a transition zone of interbedded non-calcareous and calcareous shale with occasional orange-weathering dolomitic beds. Graptolites, occasional brachiopods, and the trilobite Triarthus beckii (Green) are common in places. The formation in the past has been grouped with the Iberville and both correlated with the Canajoharie shale of the Mohawk Valley. The Hortonville east of the thrust belt may correlate with the combined Iberville-Stony Point[1]. Thickness is estimated to be in excess of 500'.

Glens Falls limestone: Highly fossiliferous black argillaceous limestone with thinner shale beds between the 6 to 12 inch beds of limestone. Where the formation is relatively undeformed, it can be broken down into two members: the lower, Larrabee member, and the upper, Shoreham member. Characteristic fossils include: Cryptolithus, Flexicalymene, Isotelus, a variety of ramose bryozoans, Prasopora, Rafinesquina, Reuschella, Sowerbyella, Resserella, Dinorthis, Strophomena, Trematis, Zygospira, Lingula, Doleroides, and Conularia. The layers of fossil fragments are useful in distinguishing between cleavage and bedding.

The top of the formation is gradational into the overlaying Stony Point shale; the transition zone probably correlates with the Cumberland Head formation to the north. 350-400' thick.

Orwell limestone: Black massive beds of sublithographic and lithographic limestone with layers of brachiopod and gastropod fragments common. Characterized by a rectangular scoring-pattern in most exposures and by masses of blue-black chert as well as the dolomitized brachiopod and gastropod fragments. Probably includes both "Lowville" and Isle la Motte limestones auctores. Averages about 40', but in places it attains almost 100'.

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[1] Editor's note: See discussions on the "Hortonville formation" in section of Trip A, however.

Chazyan Stage

Chazy Group. The group correlates with the Middlebury limestone east of the thrust.

Valcour formation: Variable in composition, both vertically and laterally; dolomitic and silty limestones and calcitic dolostones. Many of the limestones are very finely crystalline to sublithographic; others are medium and coarse grained. Pale orangish brown weathering dolostones are common. The beds are notably sandy in places; in other areas the limestones resemble closely the overlying beds of the Orwell while in still other localities the formation is composed of coarse- and medium-grained fossil-fragmental limestones. The formation seems restricted to the western one-half of the area, being replaced in the east by the Crown Point-type lithology. The formation is gradational into the overlying limestones; with few exceptions the lower contact is easily recognizable, although it too is of a gradational nature. Varies from ±20 feet east of the mouth of Otter Creek, north of Vergennes, to possibly as much as 200 feet near Crown Point.

Crown Point limestone: Bluish gray weathering, bluish gray, generally massively bedded limestone; sublithographic to coarse-grained fossil-fragmental limestones. Characterized by black and buff dolomitic silt and silty dolomite partings and laminae which cause a nodular-weathering habit where closely spaced. Average thickness is between 150 and 200 feet. Although not restricted to the formation, the large low-spired gastropod Maclurites magna Leseur characterizes the formation, hence the synonym for it, "Maclurites beds."

Day Point formation: Chiefly a limestone-shale sequence with important quantities of finely crystalline silty dolostones and dolomitic siltstones which are useful in recognizing the formation where the limestone beds closely resemble the overlying Crown Point. Fossil-fragmental limestones are the chief component of the upper one-third of the formation. Olive-colored, non-calcareous shale is an important component in the western exposures. Tough quartz sandstones are found in the formation along the lake. Eastward the formation is a sequence of orange-weathering dolomitic siltstones and silty very finely-crystalline dolostones with interbedded thin-bedded limestones in places. The formation averages 40 to 50 feet thick, but is as much as 150 feet near Long Point, west of North Ferrisburg, and as little as 20 feet near the Champlain Thrust. The formation seems to be consistently present between the Crown Point and the underlying Bridport, a fact which is important in interpreting the structural relations near the thrusts.

A sandy zone which may correspond to the Day Point has been noted by the author at the base of the Middlebury formation in Cornwall; Oxley and Kay (1959) report a sandy zone at its base in Weybridge.

Wherever the contact between the Day Point and the underlying Bridport is exposed, the two formations appear conformable. However, some authors indicate the presence of a disconformity between the two formations, partly on the supposed absence of Day Point in exposures south of the field trip area.

? Disconformity ?

Ordovician - Canadian

----- Stage

Beekmantown Group

Bridport dolostone: The formation is light buff to yellowish orange and light bluish gray weathering, moderately to heavily scored, very finely crystalline dolostone with occasional light bluish gray sublithographic, sheared-appearing limestones and thin beds of non-calcareous shale. Generally in beds 1 to 2 feet thick. Thickness about 450' to 500'. This formation correlates with the Beldens formation east of the thrust.

Cassin limestone: The formation can be divided into two units in the Central Champlain Valley; a lower sandy limestone sequence which characteristically weather dark gray with rust-colored raised ridges of more sandy material and an upper unit which consists of bluish weathering, dark gray sublithographic and lithographic limestones, some of which have significant amounts of black silt partings. These limestones may be easily mistaken for Crown Point beds. The bulk of the Fort Cassin fauna came from the upper unit. Only the upper unit is exposed within the area of the field trip (mile 58.4). East of the thrust belt and south of the Central Champlain Valley both limestones and dolostones underlie the Cassin formation; within the Central Champlain Valley the immediately underlying beds are covered, but it assumed that they are the limestones and dolostones seen elsewhere. The formation corresponds to Brainerd and Seely's (1896) Calciferous D-3 and D-4, and in part with Cady's (1945) Bascom formation. Thickness is between 200' and 250'.

Cutting formation: Finely and medium crystalline dolostone comprises this formation. The exposures in the valley are similar to those at Shoreham. The basal unit with fine-grained, cross-bedded dolomitic sandstone at the base possesses a characteristic basal breccia of intraformational origin. Three other units are recognizable on the basis of variations in the characteristics of the dolostones and the quantity of chert. Away from the Central Champlain Valley a limestone sequence seems to take the place of some of the upper dolostones. The basal sandy unit is rather widespread, apparently. Approximately 325' thick.

Whitehall formation: Dolostone, finely to coarsely crystalline, weathers in various shades of light gray and light bluish gray and is massively bedded. In places the dolostones contain small to moderate amounts of rounded, frosted quartz grains and occasional intraformational breccias. The dolostones become lighter in color upward. Limestone is found in the formation only in one place, approximately 2 miles west of Snake Mountain.

As originally defined at Whitehall, N.Y., (Rodgers, 1937) the formation included beds that are now placed in the under lying

Ticonderoga formation (J. Rodgers, manuscript and personal communication). The formation correlates with the Shelburne limestone lying east of the thrust belt. Approximately 300' thick.

Cambrian - Croixian

Trempealeauian Stage

Ticonderoga formation: J. Rodgers (manuscript, personal communication) has called the dolostones and sandy dolostones lying between the Potsdam sandstone and the Whitehall formation the Ticonderoga formation and has described a type section on Mt. Hope at Ticonderoga, N.Y. The complete description of the type section is to be given in a forth-coming report on the Central Champlain Valley.

Within the area of the field trip the Ticonderoga formation consists of dark-weathering, medium to dark gray, medium and finely crystalline dolostones with interbedded coarse-and medium-grained quartz sandstones. The unit is exposed sporadically south of Vergennes to the latitude of Addison. The best exposures within the Central Champlain Valley are on the west side of Thompson Point. Nowhere is the base exposed. The formation is very similar to the dolostones at Shoreham called Clarendon Springs by Cady (1945) and Calciferous A by Brainerd and Seely (1890). Maximum exposed thickness is approximately 90' at Thompson Point. Outcrop width south of Vergennes suggests a thickness of as much as 350 to 400'.

Dresbachian Stage

Potsdam sandstone: This formation is not exposed within the Central Champlain Valley of Vermont, but it outcrops along the Adirondack border to the west, and south of the area it outcrops on Mt. Independence and east of the Shoreham Thrust in Shoreham, along Rt. 22A. The formation is a white to pinkish weathering, generally tough massively bedded quartzite.

Bordering the area on the east as the upper plate of the Champlain Thrust is the Monkton formation consisting of two recognizable units: (1) a lower dolostone and light-colored pinkish weathering massive quartzite unit, and (2) an upper relatively thin-bedded, brick red quartzite unit. Mapping of these two units has led to the recognition of some of the cross-faults.

SELECTED REFERENCES

Brace, W. F. (1953) The geology of the Rutland area, Vermont: Vermont Geological Surv. Bull. 6, 124 pp.

Brainerd, E.C. (1891) The Chazy formation in the Champlain Valley: Geol. Soc. Am. Bull., vol. 2, p. 293-300.

Brainerd, E. and Seely, H.M. (1890) The Calciferous formation in the Champlain Valley: Am. Mus. Nat. History Bull., vol. 3, p. 1-23.

Brainerd, E. and Seely, H.M. (1896) The Chazy of Lake Champlain: Am. Mus. Nat. History Bull., vol. 8, p. 305-315.

Cady, W.M. (1945) Stratigraphy and structure of west-central Vermont: Geol. Soc. Am. Bull., v. 56, pp. 515-558.

Fowler, P. (1950) Stratigraphy and structure of the Castleton area, Vermont: Vermont Geological Surv. Bull. 2, 83 pp.

Hawley, David. (1957) Ordovician shales and submarine slide breccias of northern Champlain Valley in Vermont: Geol. Soc. Am. Bull., vol. 68, p. 55-94.

Kay, G.M. (1937) Stratigraphy of the Trenton Group: Geol. Soc. Am. Bull., vol. 48, p. 233-302.

Kay, M. (1958) Ordovician Highgate Springs sequence of Vermont and Quebec and Ordovician Classification: Am. Jour. Science, vol. 256, p. 65-96.

Oxley, P. and Kay, M. (1959) Ordovician Chazyan series of Champlain Valley New York and Vermont, and its reefs: Am. Assoc. Petrol. Geol. Bull., vol. 43, p. 817-853.

Quinn, A.W. (1933) Normal faults of the Lake Champlain region: Jour. of Geology, v. 41, pp. 113-143.

Raymond, P.E. (1902) The Crown Point Section: Bull. Am. Paleont., vol. 3, no. 14, 44 pp.

Raymond, P.E. (1906) The Chazy formation and its fauna: Carnegie Mus. Ann., vol. 3, p. 498-598.

Rodgers, John (1937) Stratigraphy and structure in the upper Champlain Valley: Geol. Soc. Am. Bull., v. 48, p. 1573-1588.

Seely, H.M. (1910) Preliminary report of the geology of Addison County: Vt. State Geol., 7th Rept., p. 257-313.

ROAD LOG

The Stratigraphy of the Central Champlain Valley

Quardrangles: Brandon 15', Middlebury 15', Ticonderoga 15' (Bridport 7½') and Port Henry 15'.

The motorcade for Trip C will form in the parking lot of the Grand Union Market at the intersection of U. S. Routes 7 and 4 East (Woodstock Avenue). Departure time will be 8:00 A.M. Bring lunches as there are no food facilities near the lunch stop.

The first part of the trip will follow U.S. Route 7 northward to Brandon for a distance of 16 miles through areas described by Brace (1953), Fowler (1950) and Cady (1945). Road log begins in Brandon.

Cumulative Mileage	
0.0	Junction of U. S. 7 and Vermont 73 from right at monument, Brandon. Brandon Inn straight ahead on U. S. 7. Follow U. S. 7.
0.4	Left turn onto Vt. 73 west (Champlain Street). Stephen A. Douglas birthplace, white house north of church on right. The first 20 miles of the trip lies in the folded belt of Cambrian and Ordovician beds of the south end of the Middlebury synclinorium which are bordered on the west and separated from the Champlain Valley sequence by "Logan's Line". While the Taconic disturbance caused intense shearing and metamorphism of the rocks east of "Logan's Line" in some places, in others the rocks are relatively unaffected by metamorphism, and they closely resemble their stratigraphic equivalents west of the main belt of thrusting. Emphasis is placed upon this statement for the rocks of the uppermost Cambrian (Clarendon Springs = Ticonderoga) and the rocks of the Beekmanton group particularly.
1.4	Road from right.
1.5	Railroad overpass.
1.7	Enter valley of Otter Creek.
3.55	Brandon-Sudbury town line.
4.0	Cross Otter Creek.
6.45	Stop sign. Junction with Vermont Route 30. Turn right. Junction is in the Hortonville formation which probably can be correlated with part of the Stony Point and the Iberville formation west of the belt of thrusting. The Hortonville represents the youngest of the Ordovician formations in the Middlebury synclinorium.

7.3 Sudbury-Whiting town line and Rutland County-Addison County line.

8.9 Railroad crossing--prepare to make left turn.

9.2 Road junction in Whiting. Turn left. Approximate position of Orwell-Glens Falls contact with Hortonville lying to the west of the Glens Falls.

9.8 Hortonville in low outcrop in road cut on left.

10.0 Road from left; continue straight ahead on dirt road.

10.5 Abandoned railroad; Shoreham-Whiting town line. Approximate position of axial line of Middlebury synclinorium.

11.35 Road from right. Junction marks approximate position of Glens Falls-Hortonville contact on east limb of Middlebury synclinorium.

11.6 Creek. Road begins to climb. Stratigraphically the route is going down in the section. To the north approximately 1 mile Bridport (= Beldens to east) outcrops on the eastward sloping hills followed to the west (down stratigraphically) by the Bascom formation (Calciferous D of Brainerd and Seely; upper part = Cassin formation restricted) at its type locality.

11.85 Road from right follows the contact between the Bascom to the east and the Cutting to the west. On slopes of hill to the northwest is the type area of the Cutting formation (Cutting Hill). The four divisions of the Cutting that can be recognized here are recognizable in the Central Champlain Valley of Vermont and probably to the south and west in New York state also. This locality is slightly south of Brainerd and Seely's (1896) southeastern Shoreham section.

12.15 Road from left. Junction near center of Cutting. Outcrop on left.

12.3 Cemetery left. Shelburne (correlates with Whitehall formation west of thrust; basal formation of Beekmantown group) outcrop in woods to right.

12.5 Clarendon Springs dolostone (correlates with Ticonderoga formation west of thrust) in road out; fine-grained dolostone. Contact with overlaying Shelburne lies to the east $\pm$ 30 yards.

12.85 Entrance to Richville Dam Fishing Access Area.

13.1 Road from right followed by Danby (= Potsdam of New York state) in road out.

13.15 Left turn across bridge. Pinnacle Thrust which places Danby of west limb of the Middlebury synclinorium over Clarendon Springs dolostone to west lies west of the west end of bridge.

13.2 Turn right. Danby outcrop in road cut on left.

13.4 Danby in cut on left.

14.4 Clarendon Springs in hills to left and in road cut on right.

15.5 Stop sign. Junction with Route 22A. Turn right.

15.85 Junction with Route 74 from west (left) continue on Route 22A.

16.35 Junction with Route 74 right (east), continue on Route 22A. To the right is the locale of Brainerd and Seely's (1896) Shoreham section which was visited during the 1955 N.E.I.G.C. meetings. Outcrop to west of Route 22A is Clarendon Springs. Route 22A crosses thrust fault placing Orwell over the Clarendon Springs a short distance north of the quarry and gravel storage area north of the barn ahead.

17.05 Road from right. Mutton Hill to the northeast is on the lower plate of the thrust fault just crossed and is underlain by the Danby (Potsdam) through the middle part of the Bascom (Brainerd and Seely's Calciferous D-2)

17.80 Danby on right.

18.80 Bascom outcrops on slopes to left. John Rodgers (personal communication) reports Lower Canadian fossils from near the top of the Cutting formation on the hill to the west.

18.90 Halfway House and cross-roads.

19.40 Shoreham-Bridport town line. Bascom in outcrop.

21.8 Road from left; prepare to turn right.

21.9 Road from right; turn right onto dirt road.

22.25 Quarry in Iberville shale. Both cross-bedding and cleavage-bedding relations indicate that the Iberville is overturned here, "dipping" to the east.

22.40 Small Iberville outcrop on the left is right side up.

22.70 Iberville in quarry; right side up.

22.90 Iberville right side up.

23.0 Top of small rise. Glens Falls in bushes to left and hill to right. Fault contact between Glens Falls and Iberville near west base of rise. Stony Point is faulted out by what appears to be a high angle reverse fault.

23.1 Bridport dolostone (= Beldens to east) of overthrust block on right, lying on Glens Falls. Thrust fault lies in the small

valley to the west. This is the Orwell thrust of Cady, although its position is east of that shown by Cady (1945) and work to the north indicates the presence of a number of small slices on either side of it.

23.15 Junction, turn left.

23.25 Glens Falls outcrops adjacent to the road; massive dolostones capping ridge are Bridport above the Orwell thrust.

23.30 Iberville. Fault crossed between 22.90 and 23.0 miles crossed again. Continue in Iberville. The trace of the fault is about halfway up the hillside.

23.60 STOP 1 - 20 MINUTES. Please pull cars off road and forward as far as possible.
Iberville formation: Typical outcrop of this formation. Black, non-calcreous shale with thin beds and laminae of orangish-weathering, cross-laminated and very fine-grained sandstone. The outcrops here are lithologically identical with the Iberville of the islands at the northern end of Lake Champlain (Hawley, 1957). The Iberville outcrops westwart to Route 22A. Cross-bedding and cleavage-bedding relations indicate overturning. The axial line of the overturned syncline would seem to lie about 500 feet west of the road.
In general the formation is flexed into a series of small, gentle folds; however near the zone of thrust faulting some of these folds are overturned. Fragmentary pieces of graptolites have been found in a quarry approximately half a mile west-northwest from this stop.
To the east, above the quarry, the Glens Falls outcrops in fault contact with the Iberville. Higher on the slope the Orwell thrust brings the Bridport over the Glens Falls. Above the thrust plane the Bridport is folded into an overturned isoclinal syncline with the Day Point and Crown Point formations of the Chazy group in the core of the fold.
The westward offset of the Glens Falls-Iberville contact and road junction at 23.15 miles suggests the presence of a small west-northwest trending zone of faulting.

24.05 Stop sign. Junction with Route 125. Turn right.

24.30 Road from right.

24.40 Glens Falls in road cut on left. Small outcrop of Iberville in field to west at base of hill. Reverse fault between Glens Falls and Iberville crosses Route 125 near the base of hill and is offset to the east of the fault trace on the hill to the southwest (Stop 1) of Route 125. The relationship suggests the presence of another west-northwest trending zone of faulting. Similarly the axial line of the overturned isoclinally-folded syncline in the upper thrust plate is offset to the east on the hill east of this point when compared with its position on the

hill at Stop 1.
The massive Bridport dolostones seen on the hill to the right form the lower limb of the overturned isoclinal syncline. The Glens Falls beds dip gently to the west in this and immediately succeeding exposures. Cleavage, which is easily mistaken for bedding wherever the Glens Falls is deformed, dips at an angle of ± 60° in a general easterly direction.

24.6-24.8 Glens Falls. Fault contact between Glens Falls and Iberville crosses the hill approximately 600 feet north of the road.

24.9 Signal for left turn.

25.05 Sharp left turn onto dirt road.

25.10 Approximate position of Orwell thrust coming down slope from right.

25.20 Fault between Glens Falls and Iberville observed near Stop 1 intersects road coming from right, striking approximately north. Same fault strikes southwest as it crosses hill to left (southwest); the contact from the left intersects the road near the beginning of the dip ahead. The offsetting of the Glens Falls-Iberville contact together with structural complications in the Bridport on the hill to the northeast suggests strongly that the Orwell thrust and associated faults are cut by a zone of faulting trending approximately parallel to the road (northwest).

25.30 Enter Iberville formation.

25.45 Iberville formation in quarry. Formation is contorted and several small overturned folds appear here.

26.30 Cross-road; continue straight ahead.

26.40 Iberville in quarry.

27.20 Typical rolling knobs of Iberville covered by thin layer of lake and glacial deposits.

27.40 Stop sign. Junction with Route 22A. Approximate position of Iberville-Stony Point contact. Continue across Route 22A.

27.80 Road Junction. Turn left.

28.45 Road Junction; continue straight ahead.

28.85 Bridge across Potash Creek. Prepare to stop.

29.0 STOP 2 - 20 MINUTES. Pull cars to extreme right. Walk back to bridge and down into creek. Outcrop of Stony Point shale. Bedding dips gently (± 5°) to the east and northeast

while the cleavage dips between 35° and 45° in the same direction. Where the formation is deformed, the cleavage is the more dominant feature and may easily be mistaken for bedding.

29.25 Road junction; turn left.

29.65 Stop sign at junction with Route 22A. Turn left.

30.60 Junction with Route 125 from right; continue northward.

31.0 Signal left turn.

31.15 Turn left onto Route 125. The route for the next 7 miles crosses the flat and gently rolling floor of the Champlain Valley. Occasional outcrops to the north and south of the route suggest that the Stony Point is succeeded westward by the Glens Falls. In addition the information available indicates the presence of a belt of folding and possible faulting succeeded westward by a virtually undeformed zone with prevailing westerly and northwesterly low angle dip (± 5°). It is likely that these two zones are truncated to the north, in the latitiude of the north end of Snake Mountain, by an east-west trending zone of rupture.

38.10 Prepare to turn right.

38.30 Turn right (north) for junction with Route 17.

38.70 Cross Hospital Creek. Small quarry on right contains sandy limestones of the Valcour formation (Upper Chazy).

38.80 Prepare to turn left.

38.90 Turn left into driveway and continue to shore.
STOP 3 - 1-1/4 HOURS. A total thickness of 315 feet of fossiliferous Glens Falls limestones outcrops along the shore on the south side of Crane Point. In the pasture to the southeast Orwell (Isle la Motte) outcrops beneath the Glens Falls with the Larrabee member of the Glens Falls overlying it. All of the outcrops along the shore belong to the Shoreham member. Near the northwest corner of the farm house and southwest of the barn are outcrops of the sandy and dolomitic Valcour. However, the best exposure of this formation is in the small quarry near Hospital Creek.

The complete Chazy sequence (Day Point, Crown Point, Valcour) is present on Crown Point across the lake.

38.9 Turn cars around and return to driveway and milage 38.9

39.6 Turn left at Route 17.

40.4 Road junction. Leave Route 17 and continue northward on the dirt road to the left (west) of the store.

40.9 STOP 4 -30 MINUTES. Owls Head Harbor turn left and drive to end of road. Walk down to beach. Outcrops along shore on south side of cabins represent the upper part of the Glens Falls formation. Northward the limestones become more argillaceous and are eventually replaced by shale of the Stony Point about 1000 feet north of the last cabin. These upper shaly limestone beds represent the transition from the Glens Falls to the overlying Stony Point. The transition beds are recognizable over a wide area in the Central Champlain Valley, and probably they correlate with the Cumberland Head formation of the northern part of the Lake Champlain region. In the central Champlain Valley they have been mapped with the Glens Falls since it is almost impossible to separate them from the Glens Falls in areas of poor exposures and extreme deformation. They can usually be differentiated from the Stony Point shale because of the presence of fragments of "Glens Falls fossils," especially Cryptolithus tesselatus Green, and because of the association with them of fragments of argillaceous limestones of the Glens Falls type.

40.9 Return to road junction at 40.9 miles and turn left (north).

42.50 Slow.

42.60 Stony Point outcrops along lake shore.

42.80 Stony Point in small quarry to right and road cut to left.

43.05 Road junction; continue straight ahead.

46.6 Bear right on paved road.

47.0 STOP 5 - 25 MINUTES. Walk south along ridge approximately 1/4 mile. At this stop the uppermost beds of the Day Point and the lower beds of the Crown Point formations are exposed. The contact is gradational and seems best placed at the crest of the west-facing escarpment. A few boulders of very pale yellowish brown dolomitic siltstones and silty dolostones typical of the Day Point can be found, although these beds are covered by talus from the limestones. The Day Point-Crown Point beds contact is placed where the limestones change from 4-6" thick beds with very few black or buff silty partings to 3-4" beds with such partings as a common feature. Also the bluish-gray coloration of the limestones seems to change slightly, the upper beds seeming to be more bluish-tinted. The ridge to the west is Bridport dolostone.

47.4 Valcour outcrop in road cut on left.

47.45 Road junction; turn left.

48.05 Panton Four-corners, continue north.

48.10 Orwell outcrops on left side road and on hill to right.

48.50 Road junction; bear right.

48.60 Orwell to left in dip slopes.

49.50 STOP 6 -35 MINUTES. Walk westward across pasture. Outcrops adjacent to road are Glens Falls. These are succeeded westward by typical Orwell, massive, black, fossiliferous limestones. At this locality the upper part of the Valcour closely resembles the Orwell, and the contact is placed only with great difficulty. Farther south, the Valcour contains much quartz sand, and lenses of cross-bedded quartz sandstone are present, the exposures resembling those in the Crown Point area. The contact between the Valcour and the underlying Crown Point is placed near the top of the west-facing escarpment where the bluish gray, sublithographic and fine-grained fossil-fragmental limestones give way to coarse and medium grained, very light gray to almost white fossil fragmental limestones. The Valcour is approximately 50 feet thick at this stop, but it expands rapidly to more than 150 feet south of Panton.
While fossils are difficult to extract from the limestones here, some good specimens may be obtained.

50.35 Road from left, continue straight ahead.

51.25 Road junction. Turn right toward Vergennes. The route now follows Otter creek to Vergennes where MacDonough built his fleet during the War of 1812.

53.9 Road junction and stop sign. Turn left.

55.25 Stop sign; junction with Route 22A. Turn left.

55.4 Signal for left turn.

55.5 Turn left on Canal Street between the two wooden buildings. STOP 7 - 15 MINUTES. Whitehall (= Shelburne east of thrust belt) lies on Stony Point shale. As exposed in the ditch north of the road the fault plane seems to have a high angle of dip, and it may be dipping to the west. Away from the fault the Whitehall dips gently eastward; the Stony Point here and in exposures north of Otter Creek. The fault displayed here continues southward to the latitude of Addison where it either dies out or is offset by a zone of rupture with strikes in a general east-west direction. Turn cars around and return to intersection of Canal Street and Route 22A and mileage 55.5.

55.5 Canal Street and Route 22A. Turn right on Route 22A.

55.8 Whitehall formation in road cut on right. Basal Cutting breccia exposed in driveway of barn on left. Prepare to turn left.

55.9 Turn left onto dirt road (Hopkins Road).

56.05 STOP 8 - 25 MINUTES. Climb hill behind oil tanks for exposure of breccia at base of Whitehall formation. This breccia and the basal unit of the Whitehall are better exposed at Thompson Point

about 7 miles north and west of Vergennes. After viewing breccia walk eastward across road to visit the top of the basal unit of the Cutting exposed in the west face of the ridge and the two succeeding units of the Cutting. The fourth unit is not exposed here, but four are recognizable at Thompson Point as well as on Cutting Hill in Shoreham (see mile 11.85).

56.35 Quarry. Ticonderoga formation (= Clarendon Springs) with Whitehall overlying it at the top of the quarry face. One or more small cross-faults cause the exposure of the Ticonderoga here. For the most part it is exposed along the west-facing escarpment of the ridge west of the quarry.

56.60 STOP 9 - 15 MINUTES. Walk across ridge to west of road to view the Whitehall formation and the upper part of the Ticonderoga formation. Ticonderoga exposures along Route 22A display sandy dolostone and medium-grained sandstones.

58.1 Road junction; turn left.

58.4 Hill to left is part of the basal unit of the Cutting. South of the low tree-covered ridge to right are limestones lithologically similar to limestones in the upper part of the Cassin formation and containing similar fossils.

59.7 View of the north end of Snake Mountain. The Champlain Thrust crosses at the base of the steep slope approximately one-quarter of the way down from the top. The three knobs on the east slope are capped by Monkton quartzite and dolostone and are offset along small cross-faults which apparently post-date the development of the Champlain Thrust. Beneath the main thrust there are several small thrust faults which bring Crown Point and Bridport beds over the younger Stony Point shale. These thrusts are also cut by the cross-faults. About in the middle of the west face of Snake Mountain there is a band of non-calcareous shale surrounded by calareous shale. The present interpretation is that it represents a lens in the Stony Point, isoclinally folded, overturned syncline beneath the thrust.

61.8 Outcrop of Stony Point in pit on left.

61.95 Junction with Route 17. Turn left after stop.

62.3 Slow to observe thrust.

62.4 Thrust fault beneath main Champlain Thrust. Bridport on Stony Point. This is one of the thrusts beneath the main Champlain Thrust, which is exposed on the knob south-southeast of this spot (lowest of the 3 knobs mentioned at mile 59.7) and near the top of the hill almost due east across Otter Creek. The southward continuation of this fault lies beneath the cover of the slopes to the south of the road and seemingly at a lower elevation than the exposure north of Route 17. The relationships here and on a regional scale suggest the presence of an east-west

trending zone of rupture.

62.7 Junction with Route 23. End of log.

Route 7 to Rutland may be reached by following Route 23 to Middlebury or by continuing on Route 17 to New Haven Junction. It will take approximately an hour to reach Rutland from this point.

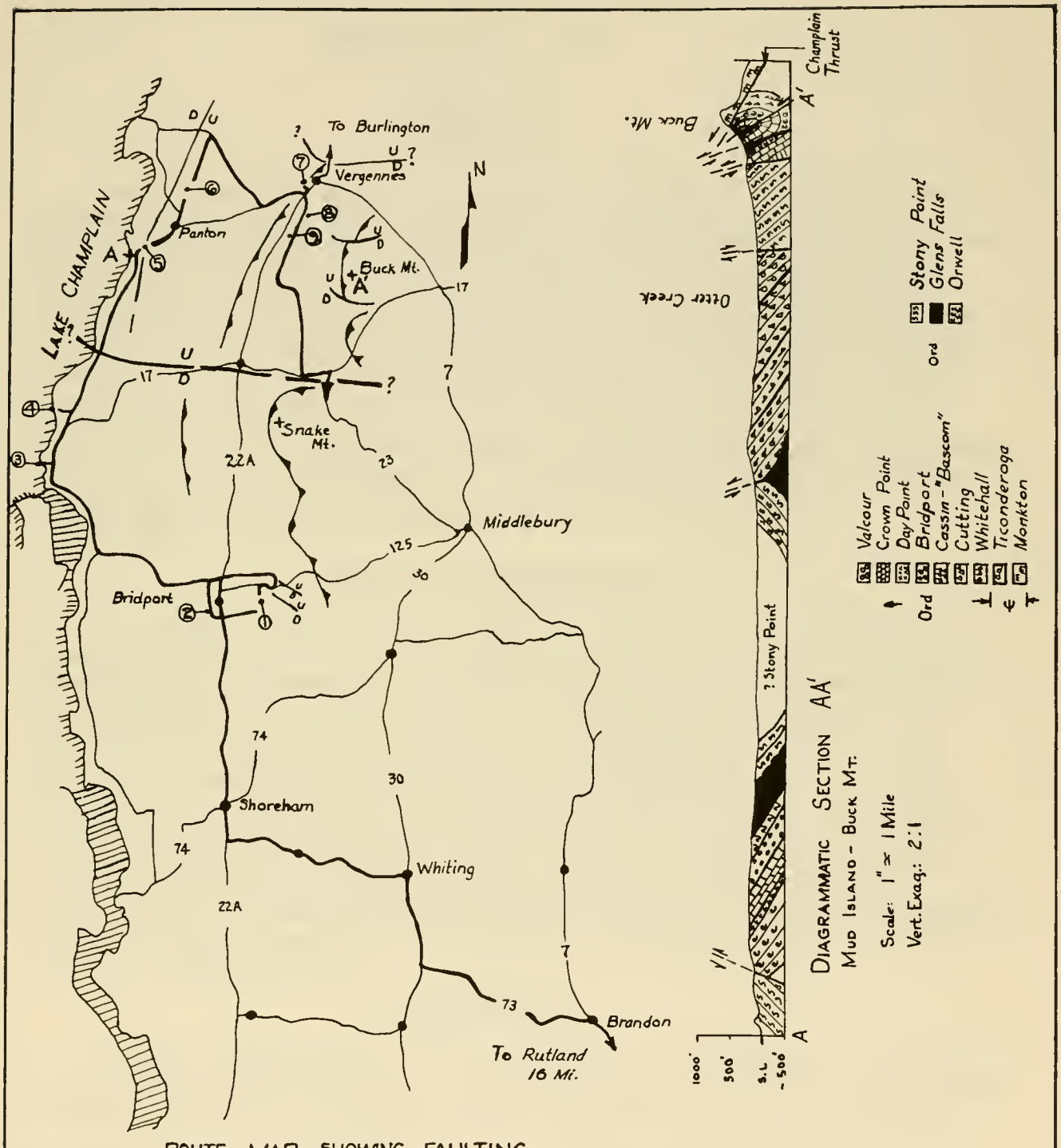

PLATE 1 – TRIP C

N.E.I.G.C. MEETING, RUTLAND, VT.

OCT. 17-18, 1959

C.W. Welby

7/7/59

TRIP D GEOLOGY OF THE MARBLE DEPOSITS NEAR RUTLAND.

Leader: George W. Bain.

August 1959.

INTRODUCTION

The tour of the marble belt will show geological occurrence of the marble strata, metamorphic transformations of the original rocks, influence of these upon the structure of the original materials, and fabrication of stone for use. The general geological structure will be seen during the drive from Rutland to West Rutland, the detailed stratigraphy of the bottom of the marble belt will be seen at Proctor and the surface expression of the complex internal fabric will be very obvious at Pittsford Valley. The initial transformation of limestone with middle Ordovician fossils to white marble and of dolomite to green silicate bands is displayed best at West Rutland where those who wish may go into the Main Quarry #2 of the Vermont Marble Company. Carving and sawing of marble will be seen in the Center Rutland Shop. The variety of products is displayed in the marble exhibit at Proctor which may be done at leisure or in lieu of one of the other units of the trip.

GEOLOGY OF THE MARBLE BELT

The marble occurs in lower and middle Ordovician strata between thick bedded gray dolomite (Clarendon Springs dolomite) below and a black phyllite (Canajoharie or Hortonville slate) above. The Clarendon Springs dolomite (200 feet thick) is underlain by the crossbedded zone (Danby quartzite of some authors) which is the key horizon for identifying structure. All marbles have suffered close folding and flowage and have a major thrust fault along their east margin (Figure D-1). Metamorphism has been partly mechanical with development of good glide fabrics and partly hydrothermal attended by recrystallization of dolomite to ferromagnesian silicates and removal of graphitoid coloring matter. Distension joints strike E.W. and some are occupied by Monteregian dikes which have caused "fish-scale" flakes for up to twenty feet distant; chill borders and vesiculated centers of some dikes indicate that the rocks were cool and at relatively shallow depth at intrusion time.

Stratigraphy

Relevant stratigraphy of the marble belt is restricted to the strata between the crossbedded zone and the "Canajoharie" phyllite, except insofar as identification of the thrust faults is concerned. It is as follows:[1]

Middle and Upper Ordovician	Canajoharie phyllite
	True Blue marble

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[1] Readers who are unfamiliar with the correlation of Professor Bain's stratigraphic nomenclature with the standard names, used elsewhere in this Guidebook, may find the following chart helpful.

Bain	Elsewhere
Canajoharie phyllite	"Hortonville", Ira
True Blue marble	Whipple in part
Chazyan (?) West Rutland marble	
Blue marble and dolomite	Burchards (Chipman fm.); Upper Canadian
Westland marble	Beldens (Chipman fm.)
Upper Deposit	Beldens
Main Deposit	Beldens
West Blue marble	Bascom fm. (Upper to Middle Canadian)
Blue marble and dolomite	Bascom fm.
Beekmantown	
Columbian marble)	
Intermediate dolomite)	Shelburne formation
Sutherland Falls marble)	
Lower Dolomite (Clarendon Springs)	Clarendon Springs; Upper Cambrian
Crossbedded zone (Danby quartzite?)	Danby formation; Upper Cambrian
Cambrian	
Rutland formation	Winooski, Monkton, and Dunham fms.; Middle to Lower Cambrian
Cheshire quartzite	Cheshire quartzite
Pre-Cambrian Mendon Series.	Mendon series; Cambrian? Precambrian?

For references on correlation, see, for example, Cady (1945), Fowler (1950), Thompson (1952), Cady and Zen (in preparation); these are all given in connection with Trip A.

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* * * * *

	West	Blue marble and dolomite
	Rutland	Westland marble
Chazyan?	Marble	Upper deposit
		Main deposit
		West Blue marble
		Blue marble and dolomite

	Columbian marble
	Intermediate dolomite
Beekmantown	Sutherlands Falls marble (Shelburne marble)
	Lower dolomite (Clarendon Springs)
	Crossbedded zone (Danby quartzite?)

Rutland formation Pittsford Valley dolomite

Cambrian	Cheshire quartzite	Florence dolomite Clarendon dolomite
Pre-Cambrian	Mendon Series	

The CROSSBEDDED ZONE is a dolomitic feldspathic sandstone characterized by crossbedding throughout its 250 feet of thickness in the area of study. It thins to 10 feet at E. Dorset and is thicker near Middlebury. Beds are generally less than 5 inches thick. The sand grains are subspherical and include principally quartz, microcline, albite and obigoclase but rock fragments, zircon, tourmaline and vesuvianite have been recognized.

The LOWER DOLOMITE or Clarendon Springs dolomite is gray weathering gray dolomite in beds about 8" thick and it contains very little detrital matter. Total thickness is 160 to 200 feet. Locally a disconformity separates it from the crossbedded zone. It is a folded, very brittle rock, but shows no flowage effects.

The SUTHERLAND FALLS MARBLE or Shelburne marble is a 90 foot, creamy white colored zone with contorted chains of gray dolomite grains across almost any surface. It has a single central silicate band (Henhawk layer). The entire zone is thinned to inches locally and at other places is thickened to more than 300 feet.

The INTERMEDIATE DOLOMITE is thick bedded, light gray weathering gray dolomite about 200 feet thick. A silicified band occurs near the mid section at most places; this is due to groundwater and the formation contains less than 15 per cent arenaceous matter.

The COLUMBIAN MARBLE is 500 to 600 feet thick but flowage locally thins this to inches and at other places increases it to over 1000 feet; even where thickness is average some layers are thickened locally serveralfold and others thinned..The lower 50 feet of this marble is dolomitic like the Sutherland Falls marble but the dolomite chains are not so contorted. Green silicate and white or light gray marble continue stratigraphically upward to a thick dolomite bed at the base of the West Rutland group of marbles; no dolomite beds are know within the Columbian marble. All Columbian marble weathers white with dark lines and within our tour area is characterized by "S" tectonite fabric.

The WEST RUTLAND MARBLE ZONE extends from the dolomite at the top of the Columbian marble through the dolomite at the base of a dark blue gray marble adjacent to the phyillite. The zone is intimately and finely crumpled so that the stratigraphic thickness has not been measured. Dolomite beds alternate with blue marble and are deformed to folds with much cross fracturing, or are stretched out into boudins; fractures are filled with calcite veins or flowage masses of blue marble. Locally deformation is on a sightly larger scale and there hot solutions have entered along fractures to bleach the gray marble; bleaching is displayed in West Rutland at Main Quarry #1 (stop) and silication is shown in the Sherman Quarry and Main Quarry #2 (stop).

Most of the blue marble is mixed too intimately with dolomite to be recoverable and is shown in a tunnel and drill core westward from Main Quarry #1. The upper part of the lower blue marble (West Blue layers) has fossil gastropods resembling Maclurea. This marble is separated from the West Rutland deposit by a thick dolomite. Most operations are in the Main West Rutland deposit (stratigraphy given in tour stops). The Green Mountain Marble Corporation works the Upper Deposit. This is overlain by blue marble with turritelliform and planiform gastropods and crinoid stems. A part of it is bleached to make the Westland deposit.

A thin band of TRUE BLUE MARBLE lies immediately below the black graphitic Canajoharie phyllite. Everywhere layers and boudins of dolomite appear within the blue marble. Only locally is it thickened adequately to make a commercial deposit and at each place it has an infolded syncline of the phyllite. At the True Blue Quarry, the phyllite syncline was squeezed off as a sock shaped enclave within the marble.

The CANAJOHARIE PHYLLITE is very black and graphitic adjacent to the marble but becomes dark and micaceous at over 100 feet above. This upper part is not easily distinguishable from the Mendon Series in the overthrust slices to eastward.

Major Structure

The Taconic disturbance caused the sub-marble sequence to be overthrust on the marble along Boardman Hill, through Center Rutland, along the west face of Pine Hill in Proctor and near Coxe Mt. Cheshire quartzite and mylonite rests on dolomite in the Otter Creek at Center Rutland and mylonitized Mendon Series transgresses Sutherland Falls marble Lower Dolomite, and the Crossbedded Zone near the Proctor town line. A very complex klippe covers the marble from Boardman Hill to Danby but otherwise no great thrust planes enter the marble zone to be visited.[2]

"Overfolds" on the Lower or Intermediate dolomite, approaching nappes in size, are attended by development of flowage folds in the Sutherland Falls and Columbian Marble. Flowage off the main arch folds in the West Rutland Valley develop local thickening or flowage folds on their east limbs. They will be seen in the Main Quarries.

[2]Editor's Note:
See Also the descriptions given by Thompson, Trip H.

Trip D Road Log

This tour is planned for four hours and a departure time of 8:15 a.m. is assumed.

Assemble at the north end of the Municipal Parking Lot to leave by Evelyn Street. Turn left on West St. and proceed west through the traffic light at Pine St. cross the Rutland R.R. and enter Route U.S. 4 after recrossing the Rutland R.R.; distance 0.8 mi. Clarendon dolomite outcrops behind the houses to right (north).

Mileage

1.3 Route Vt. 3 turns right to Proctor. Continue on U.S. 4.

1.5 Cross Otter Creek. Note Cheshire quartzite outcropping falls at left. This is part of the upper plate of the Pine Hill-Boardman Hill thrust.

2.15 Intermediate dolomite outcropping to right.[3] Sutherland Falls marble is concealed from Proctor line to Boardman Hill. To westward the Intermediate dolomite, Columbian and Blue marble zones are squeezed down to inches thickness.

2.2 Black Canajoharie phyllite north of the highway. This rock continues to outcrop for the next 0.8 miles to the railroad crossing.

3.4 Route Vt. 3 comes in on left; continue on U.S. 4 to traffic light.

3.5 Traffic light; turn right and continue past D & H. R.R. station at 3.9 miles, across C & P. R.R. at 4:05 miles.

4.2 Leave paved highway by gravel road to right; take first left after V.M. Co. stock room and proceed north to Main Quarry #1.

4.45 Main Quarry No. 1.. 8:30 stop #1. 5 minutes.

The roof layers separating the West Rutland Main deposit from the upper deposit are gray in the north end of the roof and white at the south. Thin green silicate bands form the axis of the bleaching: this is the second stage in transformation of limestone to marble.. (See Bain 1, p. 137).

4.6 Main Quarry No. 2. 8:40, stop #2; duration one hour. By courtesy of the Vermont Marble Company the party will be lowered by derrick to the main floor at 156 feet below. Departure time 9:45.

The Main Deposit is on a flowage fold which carried the Hard Layer forward from a 20° slope eastward to be vertical for 86 feet as seen in the south wall of the shaft; a perspective diagram (fig. D-2) shows this structure. The roof layers continue at nearly uniform dip eastward and in consequence the intermediate marble is thickened. The sequence of marble layers is as follows:

Thin Statuary - in roof; is mainly blue here
Green silicate layer (thin)

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[3] Editor's note: Fresh road cuts revealed quartzite beds in this outcrop and is now mapped by Zen as Danby formation. See road log to Trip A.

Green strip	
	Green silicate layer (thin)
Monumental	
Statuary	
White average	
Brocadillo thin	green stripes uniform over a wide zone
Crinkly layer	
	Mainly irregular green stripe with mixed white
Smith layers	
	5" dark green stripe
Jackman	
Striped Smith	
Hard layer	
	Dolomite with some silication
Double belt two	4" green silicate layers separated by up to 2' of white
Rutland Italian	
Bottom Blue	
Dolomite	

Proceeding to the south tunnel, a 9 foot Monteregian dike, with chilled border, is exposed. (See polished slab in Proctor Marble exhibit.) The dike follows a distension joint system. Only slight displacement of strata occurs across its width. Thermal effects have produced "fish scale" checks in the marble for 20' on either side and have rendered the stone worthless.

South of the dike, a tunnel to eastward follows the deposit down dip past the flowage fold responsible for most metamorphism and thickening.

Return to cars.

Retrace route past Proctor road to Center Rutland shops.

8.3 Turn off right (south) to Center Rutland shops. Stop #3. Arrival time 9:55, departure time 10:25. This will afford an opportunity to see some carving, turning and various fabrication work on architectural marble. (For some problems see Bain 2.)

8.9 Turn right on Vt. 3 to Proctor.

9.7 Phyllonite of thrust plane outcrops on right (east) for 0.1 miles.

10.1 Sutherland Falls marble quarry dump visible on hillside ahead and slightly to right. Cheshire quartzite above thrust plane appears in cliffs to right.

11.1 Small area of Intermediate dolomite on right and in railroad cut to left. Sutherland Falls marble in quarries to east.

11.3 Abandoned Riverside Quarry in Columbian Marble is just west of the railroad on the left (west).

11.5 Crossbedded zone on right. Lower dolomites from here to Proctor.

13.3 Turn left from Route Vt. 3 to cross Marble bridge over Otter Creek and follow signs to marble exhibit at 13.5. Continue to near 13.7.

13.7 C & P R.R. tracks. Stop, #4. Time 15 minutes, departure 10.55. The Crossbedded zone is exposed west of this crossing and the strata are inverted. Farther west is the Lower Dolomite; beyond it is the original Sutherland Falls Quarry and birthplace of the Vermont Marble Company. The Hen Hawk layer can be seen dividing the deposit into the East layers (poor) and West layers. Return to cars and depart to right following Brandon road; keep left after crossing C & P tracks.

14.0 Sutherland Falls marble on left.

14.1 Intermediate Dolomite.

14.3 Columbian Marble found in drill holes. No exposures. The ridge to westward is the Canajoharie phyllite. The entire marble zone is thinned here by an overfold of the dolomites.

15.3-15.5 Marbles in Columbian Marble on the left or north. Note straight lining on marble outcrop just east of the quarries.

16.5 Abandoned Florence Plant. White pigment operations carried out on Sutherland Falls deposit to left (west).

19.7 Turn left off paved road to go to Pittsford Valley quarries.

20.2 Crossbedded zone on left.

20.4 Pittsford Valley Quarries. Stop #5. Departure 12:00.

The Pittsford Valley quarries extract the lower layers of Columbian Marble and east of them is a 200 foot deep glacial gorge which presents a few problems. Pittsford Valley Quarry No. 7 is the northernmost of the series and its light gray marble is between two yellowish silicate bands (See Fig. D-3). The north wall of the quarry shows the west wall band encroaching eastward toward the bottom of the quarry. The east wall band is within three feet of the west band at the northwest corner and descends for seven floors before turning up to the roof and striking diagonally southeast; this band forms another syncline at the beginning to the tunnel roof, rises on an arch and then drops down at the cliff face. This accordion folding or flowage folding is responsible for the thickening of 3 feet to 100 feet of marble at this section.

The quarry shows the appearance of a flowage fold in cross section. The outcrop on the top of the hill shows it in plan and the west wall and east wall silicate bands can be followed in detail on the stripped hill top (Figure D-3).

This marble has well developed shear fabric which renders it almost as stress anisotropic as Colorado Yule. Sonder's glide lines of "a" axes are displayed on the cliff four feet north of the tunnel wall. These pitch northward at the angle of the thickened body of marble. The "ab" plane is a plane of near foliation in this homogeneous rock. Slabs cut on the "ab" plane are extremely resistant to weather and for this reason you will see many glacial striations on the cliff face. Surfaces at right angles to the "ab" plane are less resistant to weather as you may note on the hilltop. These S tectonite marbles have extremely low porosity, very high elasticity, and low inter-granular pore width.

To join your next tour, return to within 1/2 mile of Florence and turn left on a dirt road by the "Covered Bridge" to U.S. 7. Turn right on U.S. 7 and continue to Pittsford and Rutland.[4]

BIBLIOGRAPHY

Bain, G.W. 1. Calcite marble. Econ. Geol., V.29, pp. 121-134, 1934.

2. Geological, chemical and physical problems in the marble industry. A.I.M.E., Trans. V.144, pp. 324-339, 1941.

3. The Central Vermont Marble Belt. Guidebook. 34th Field Trip, N.E. Intercoll. Geol. Assn., 1938.

Brace, W.F. Geology of the Rutland Area, Vermont. Vt. Geol. Sur., Bull 6, 124 pp., 1953.

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[4] Editor's note: Those who wish to join Professor Kay's Trip B should follow Route 7 north to Brandon, then take Rte. 73 west to Rte. 30. Take Rte. 30 south (left) to Sudbury.

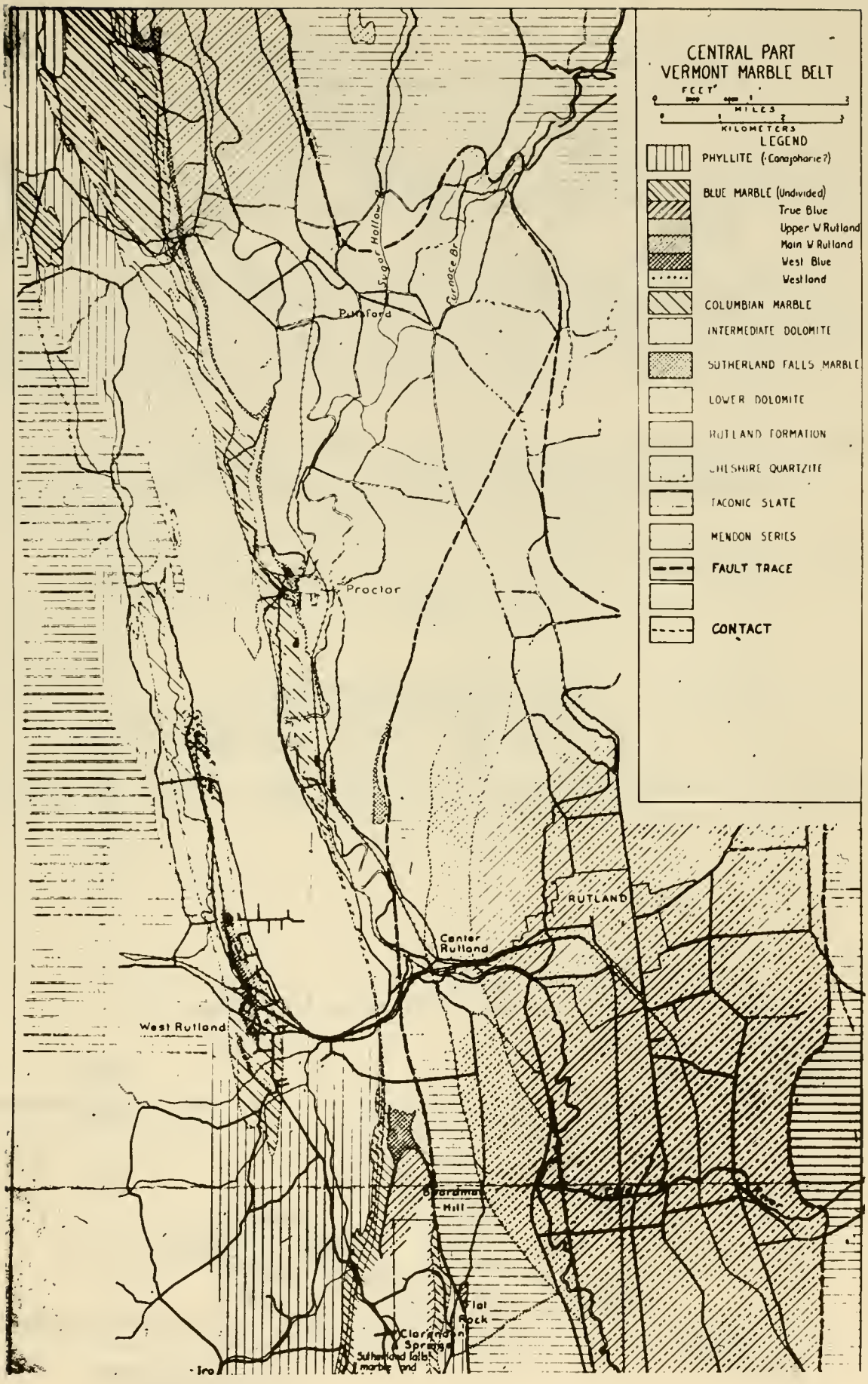


Plate D-1 Geology of the northern part of the Marble belt.

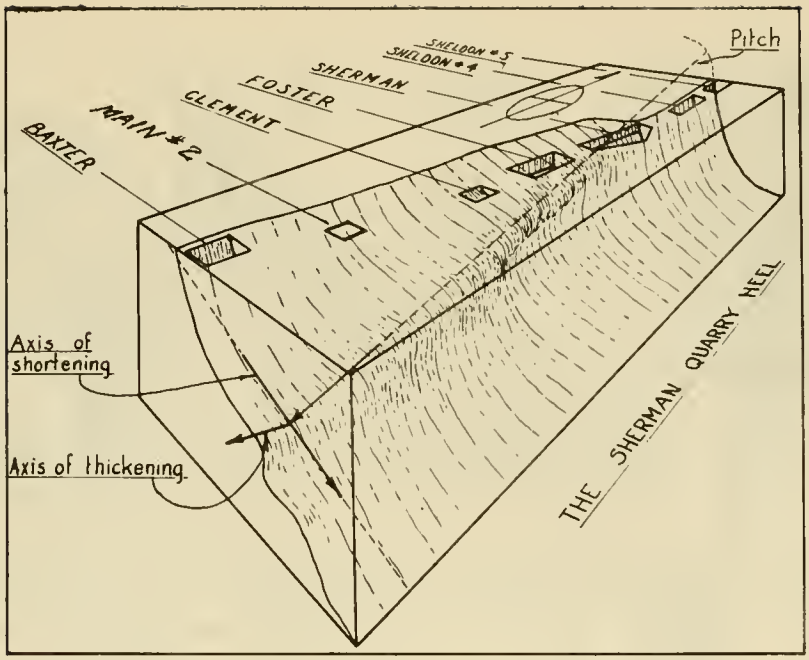


Plate D-2. Flowage fold in West Rutland Main Quarry. Deposit near Main #2 quarry.

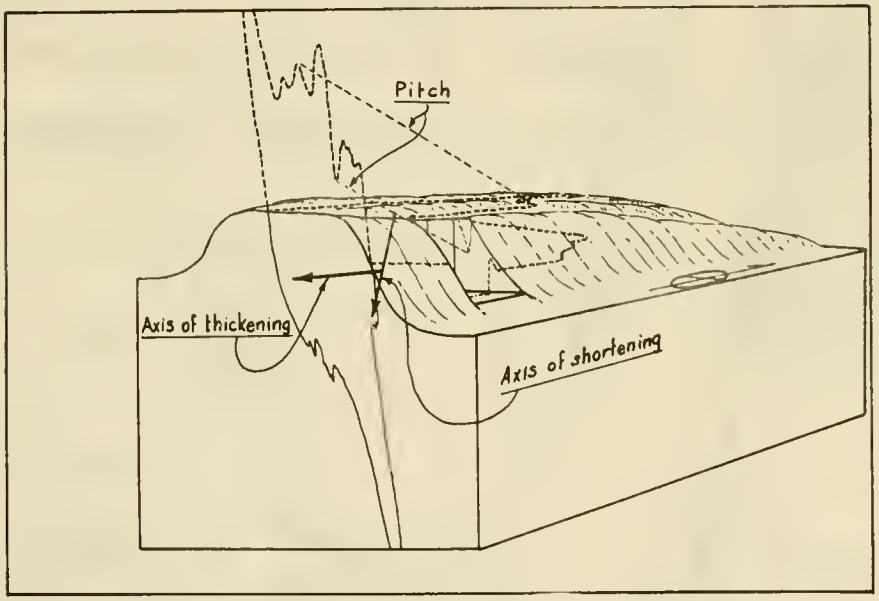


Plate D-3. Flowage fold at Pittsford Valley Quarry #7.

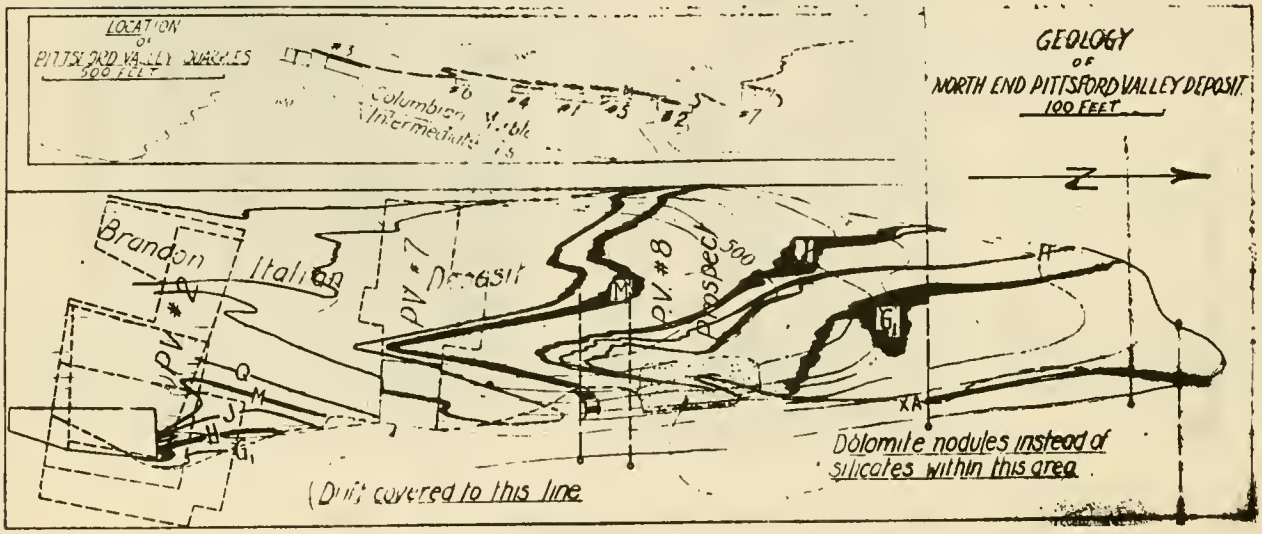


Plate D-4. Intercept of flowage bands of silicates with surface above Pittsford Valley #2 Quarry.

Trip E ECONOMIC GEOLOGY OF SLATE

Leader: George Theokritoff

Meet in front of the office of the Vermont Structural Slate Company, near junction Routes 4 and 22A south of Poultney River in Fair Haven. 9 a.m., Saturday, October 17.

Within the Slate Belt of New York and Vermont, flagstone and slate are quarried from three rock-units; the Mettawee slate member of the Bull formation, the Poultney slate and the Indian River formation. The Mettawee yields purple, green, and more rarely, grey slates, the Poultney grey-green slates as in the vicinity of Granville, New York, and the Indian River red and blue-green slates.

Dale (1899) has described the petrography of the several slates encountered in the Slate Belt. Larrabee (1939-40) has discussed the application of the principles of structural geology to flagstone and slate quarrying.

The purpose of the trip is to demonstrate the quarrying as well as the processing of flagstone and slate.

Bibliography

Dale, T.N. 1899, "The Slate Belt of Eastern New York and Western Vermont," U. S. Geol. Survey An. Rept. 19 pt. 3, pp. 153-307.

Larrabee, David M. 1939-40, "The Colored Slates of Vermont and New York," Eng. and Min. Journ. vol.140, no. 12, pp. 47-53, vol. 141, no. 1, pp. 48-52

Trip F THE STRATIGRAPHY AND STRUCTURE OF THE COXE MOUNTAIN AREA, VERMONT

Leader: P.H. Osberg

Date: Saturday, October 17, 1959

Assembly point: Arch Street, just north of bridge at Pittsford Mills

Time: Trip leaves assembly point at 8:30 A.M.

Quadrangles: Brandon, Vt., 1948
Proctor, Vt., 1946
Rochester, Vt., 1915
Rutland, Vt., 1893

GENERAL STATEMENT

The location of the Coxe Mountain area is shown in Figure F-1. The rocks underlying this area are dominantly quartzites, carbonates, and light gray, light green, and black phyllites and schists. Their stratigraphic sequence is presented in Table 1. The Mount Holly group (Whittle, 1891) containing rocks of distinctive tectonic style and middle to high metamorphic grade, are the oldest rocks exposed in the Green Mountains and are Pre-Cambrian in age. The Pinnacle (Clark, 1934), Forestdale (Keith, 1932), and the Moosalamoo (Keith, 1932) are a conformable sequence of questionable age. This group lies on the Mount Holly with pronounced unconformity and is in turn unconformably overlain by the Cheshire. Their tectonic style and grade of metamorphism are essentially the same as that of the overlying rocks, yet they have yielded no undoubted Cambrian fossils. The Cheshire (Emerson, 1892) is the oldest unit containing Early Cambrian fossils and forms the base of an apparently conformable sequence of quartzites and carbonates of Cambrian and Ordovician age.

Table 1.

FORMATIONS FOR THE COXE MOUNTAIN AREA

	(Thickness in feet)
Lower Ordovician	
Shelburne marble	500 - 600
Upper part: white marble with dolomitic "curdling" and thin gray partings.	(250)
Intermediate part: massive gray, slightly limy dolomite.	(200)
Lower part: white marble with dolomitic "curdling" and thin gray partings.	(50 - 100)
Upper Cambrian	
Clarendon Springs dolomite	70 - 100
Massive gray, slightly limy dolomite.	

Danby formation ---------- 500-700
Gray, slightly limy dolomite with beds of dolomitic sanstone and white, vitreous quartzite.

Middle or Lower Cambrian

Winooski dolomite ---------- 900-1000
Buff and gray dolomite in beds up to one foot with beds of dolomitic sandstone and quartzose phyllite.

Lower Cambrian

Monkton quartzite ---------- 50-100
Gray-green quartzite interbedded with dolomite, dolomitic sandstone and thin beds of gray-green or black phyllite.

Dunham dolomite ---------- 900-1000
Upper part: buff dolomite and cross-bedded dolomitic sandstone. (50-100)
Lower part: massive gray and buff dolomite. (800-900)

Cheshire quartzite ---------- 900-1200
Upper part: massive, white, vitreous quartzite. (400)
Intermediate part: mottled gray and white quartzite, massive white quartzite, and black phyllite. (500-700)
Lower part: dolomitic sandstone and conglomerate. (50-100)

Pre-Cambrian (?)

Moosalamoo phyllite ---------- 0-200
Gray to black quartzose phyllite.

Forestdale dolomite ---------- 0-300
Upper part: white and buff dolomite in beds up to one foot thick (0-160)
Intermediate part: dolomitic sandstone and gray-green phyllitic quartzite, cross-bedded sandy dolomite. (0-10)
Lower part: white dolomite with pink mottling. (0-100)

Pinnacle formation [1] ---------- 20 - 700
Light gray Qtz. Musc. Ab. Biot. schist and Qtz. Ab. Biot. gneiss, light green Qtz. Musc. Chlor. mg. schist, conglomerate.

Pre-Cambrian

Mount Holly group ---------- unknown
White, vitreous quartzite, light gray Mic. Qtz. Biot. Olig. musc. gneiss.

Structurally the rocks of the Coxe Mountain area lie in the west flank of the Green Mountain anticlinorium and in the south-plunging Ripton anticline (Figure F-1). All of the rocks are autochthonous. They are found in overturned folds having normal limbs that dip gently east and inverted limbs that dip steeply east. The resulting areal distribution of formations is shown in Figure F-2, and the structure sections are shown in Figure F-3. Most minor folds are compatible with the major folds, but a few are sufficiently overturn to be recumbent. For the most part the axial traces parallel the trend of the Green Mountain anticlinorium. The abnormal trend of the anticline two miles northeast of Pittsford may be controlled by the tectonic behavior of the basement or may be due to a recumbent "bulge". The fault east of Pittsford is inferred from stratigraphic data. It is interpreted to be a normal fault with the relatively upthrown block to the west.

BIBLIOGRAPHY

Bain, G.W. (1926) Geological history of the Green Mountain front. Rept. Vt. State Geol., pp. 222-241.

Brace, W.F. (1953) The geology of the Rutland area, Vt. Vt. Geol. Survey, Bull. 6, 119 p.

Cady, W.M. (1945) Stratigraphy and structure of west-central Vermont. G.S.A., Vol. 56, pp. 515-558.

Clark, T.H. (1934) Structure and stratigraphy of southern Quebec. G.S.A., Vol. 45, pp. 1-20.

Emerson, B.K. (1892) Outlines on the geology of the Green Mountain region in Massachusetts. U.S. Geol. Survey, Geol. Atlas, Hawley Sheet.

[1] Although the names Mendon (Whittle, 1891) and Nickwaket (Keith, 1932) have been used for the rocks included in the Pinnacle of this report, their use is questionable. The name, Mendon, is not sufficiently definitive, and the name, Nickwaket, is inapplicable because the rocks exposed on Mount Nickwaket (allegedly the type locality) belong to the Cheshire.

Fowler, P. (1950) Stratigraphy and structure of the Castleton area, Vt. Vt. Geol. Survey, Bull. 2, 83 p.

Gordon, C.E. (1920) Studies in the geology of western Vermont. Rept. Vt. State Geol., pp. 188-200.

Keith, A. (1932) Stratigraphy and structure of northwestern Vermont. Jour. Wash. Acad. Sci., Vol. 22, pp. 357-379, 393-406.

Osberg, P.H. (1952) The Green Mountain anticlinorium in the vicinity of Rochester and East Middlebury, Vt. Vt. Geol. Survey, Bull. 5, 127 p.

Whittle, C.L. (1891) The occurrence of Algonkian rocks in Vermont and the evidence for their subdivision. Jour. Geol., Vol. 2, pp.396-429.

Trip F Road Log

Mileage

0.0 Assembly point: Arch Street, just north of bridge at Pittsford Mills. Proceed northwest along Arch Street.

0.5 Exposures of Pinnacle under bridge.

0.8 Pittsford. Arch Street rejoins Route 7. Travel north on Route 7.

2.8 Exposure of massive, vitreous, white quartzite belonging to the upper unit of the Cheshire on the right. Coxe Mountain beyond.

6.0 Turn right off Route 7 at Al and Bell's Restaurant.

7.2 Turn right on dirt road.

9.0 Park cars for stops 1,2,3,4,5, and 6.

Stop 1. Contact between the intermediate and lower units of the Cheshire. The vitreous, white quartzite marks the base of the intermediate unit and the dolomitic feldspathic sandstone and sandy dolomite belong to the lower unit.

Stop 2. Contact between the Moosalamoo phyllite and Forestdale dolomite. The dolomite is in the core of a small anticline with phyllite both east and west.

Stop 3. Intermediate unit of the Forestdale dolomitic quartz sandstone.

Stop 4. Pinnacle formation. Gray weathering, white Qtz. Musc. Feld. gneiss containing relict grains of quartz and feldspar. Schistosity and bedding are nearly parallel; both are cut by a later cleavage. A large quartz vein cuts the gneiss.

Stop 5. Exposures of Pinnacle and Forestdale formations. Light gray Qtz. Musc. Biot. Feld. schist and light green Qtz. Musc. Chlor. mg. schist of the Pinnacle formation have a foliation that dips east. Dolomitic quartz sandstone of the intermediate unit and white dolomite of the upper unite of the Forestdale exhibit bedding that dips gently east.

Stop 6. Contact between the Moosalamoo phyllite and the lower unit of the Cheshire. Gray Qtz. Musc. graph. phyllite overlain by five feet of light gray quartzose phyllites which in turn are overlain by conglomeratic and dolomitic feldspathic sandstones. Bedding dips gently east. Cleavage dips steeply east and is bent adjacent to bedding planes. The intersection of bedding and cleavage plunges gently north.

Return to cars. Continue along dirt road.

12.1 Stop 7. Contact between Pinnacle and Forestdale formations. Light gray Qtz. Musc. Feld. gneiss containing relict grains of quartz and feldspar and overlying light green Qtz. Musc. Chlor. mg. schist in contact to east with gray and white dolomite. The dolomite to the east lies in a syncline. The slightly phyllitic sandstone represents the intermediate unit of the Forestdale. Cross-bedding indicates that this bed lies in the east limb of the syncline. The intermediate unit is not exposed in the west limb of syncline. Proceed along dirt road.

13.8 Turn left on tar road.

13.9 Stop 8. Contact between Cheshire and Pinnacle. Exposures of white and gray quartzite in contact with conglomeratic and dolomitic feldspathic sandstone overlying light gray Qtz. Biot. Feld. musc. schist and gneiss. Bedding is nearly vertical.

14.9 Turn left on tar road.

16.4 Stop 9. Exposures of Forestdale and Pinnacle formations. Gray weathering, white, sandy dolomite exhibiting cross-beds which indicate right side up. Interbedded is a 3 to 5' bed of dolomitic quartz sandstone belonging to the intermediate unit of the Forestdale. Bedding dips gently northeast. Dolomite to the west belongs to the lower unit of the Forestdale. The calcareous, light green Qtz. Musc. Chlor. mg. schist in the brook is the uppermost Pinnacle. Outcrops to west are light green Qtz. Musc. Chlor. mg. chist underlain by light gray Qtz. Musc. Biot. Feld. schist and gneiss.

Return to cars and continue north on road.

18.6 Stop 10. Exposures of Forestdale and Pinnacle formations. Dolomitic quartz sandstone of the intermediate unit of the Forestdale. Bedding is nearly vertical. Dolomite to east belongs to the lower unit of the Forestdale. Small hill to east contains a small anticline of light green Qtz. Musc. Chlor. mg. schist with interbeds of marble belonging to the Pinnacle. The anticline is asymmetrical to the west, and the minor folds have the appropriate shear sense and plunge to be in harmony with the larger structure.

Turn cars around and drive south on road.

19.0 Stop 11. Minor folds in the Pinnacle formation. Interbedded light green Qtz. Musc. Chlor. mg. schist and marble. A doubly plunging syncline is exposed in the top of the outcrop. The south face of the outcrop shows a recumbent fold with gentle northeast plunge. In the core both limbs tend to be folded together. Higher beds in the normal limb are tightly folded, whereas the higher beds in the overturned limb are folded with two shear senses. Cleavage is not axial plane and cuts both limbs in the core of the fold.

Return to cars.

20.6 Turn left on tar road.

21.4 Village of Holden.

21.9 Turn right on dirt road.

23.2 Stop 12. Cheshire quartzite. Exposures of black phyllite and white quartzite of the intermediate unit. Pebbly beds may belong to the lower unit. Bedding strikes northwest and dips moderately south.

Return to cars and drive south on tar road.

24.0 Turn left.

25.4 Turn left on Route 7.

25.9 Stop 13. Shelburne marble. White marble with gray partings and dolomitic "curdling". Beds are steeply dipping. Mafic dike cuts marble.

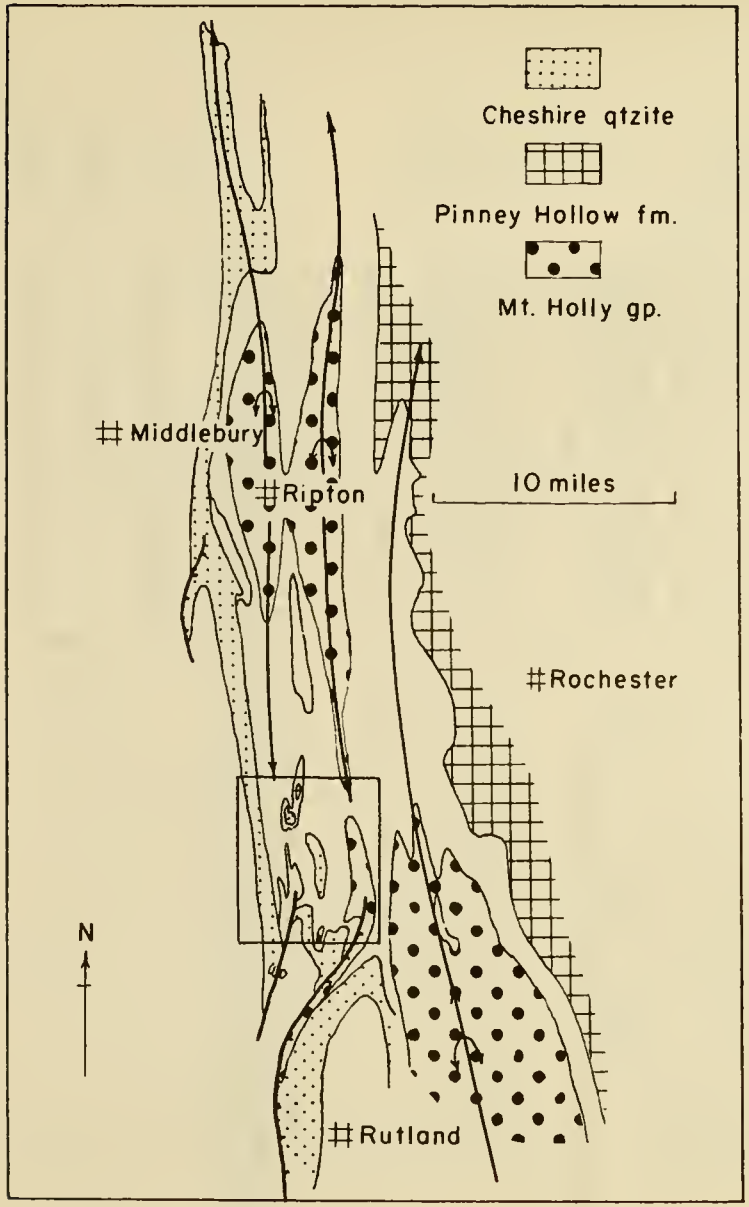
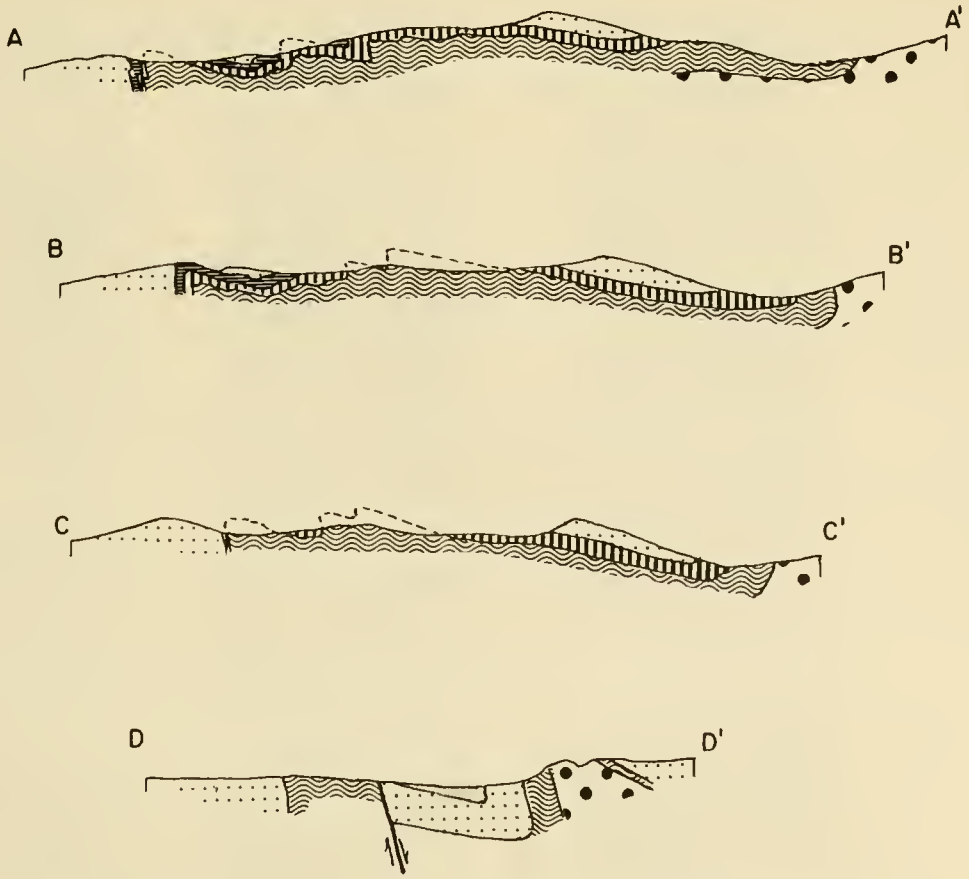
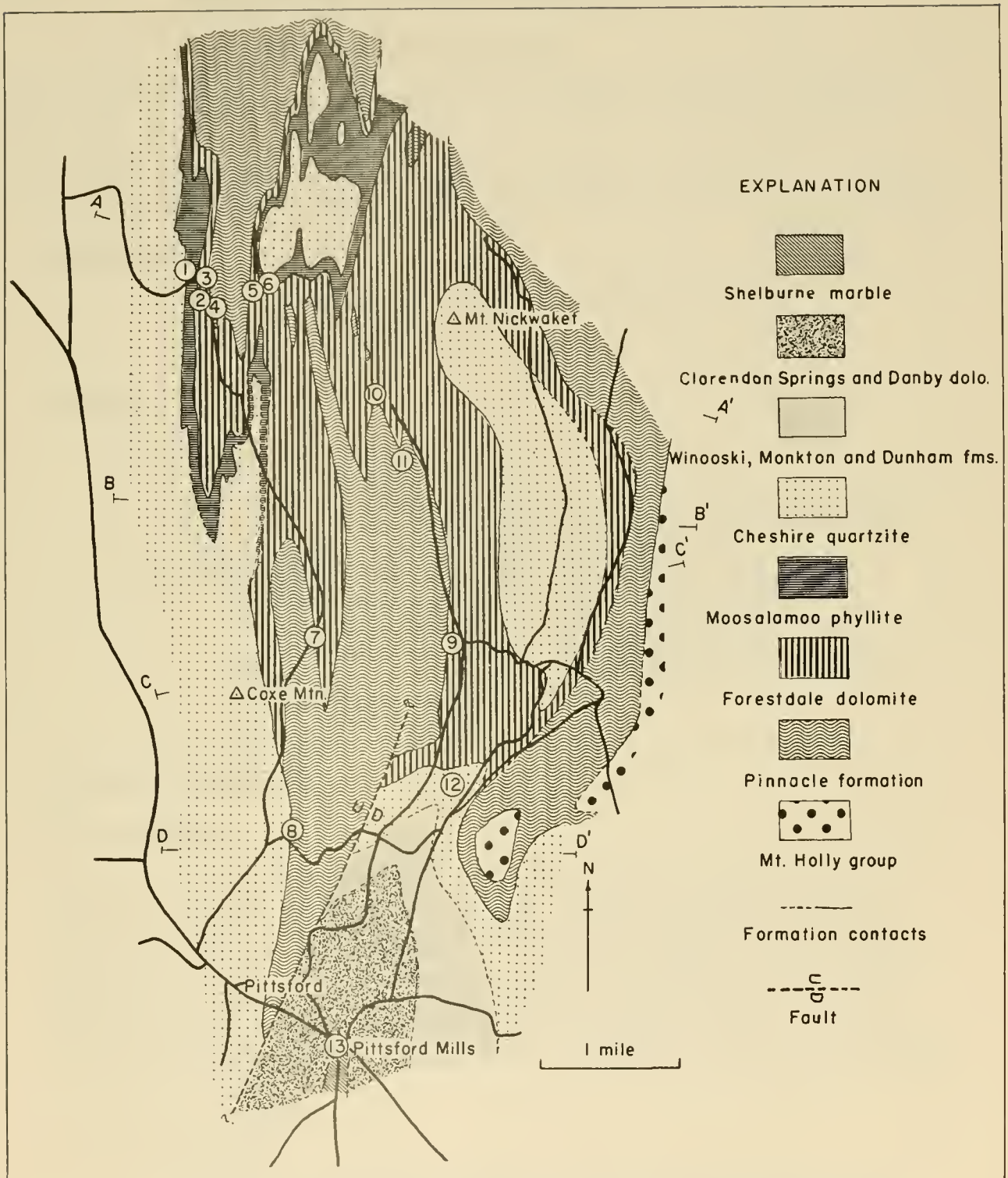


Plate F-1 · Teconic map of a part of the Green Mtns. showing location of the Coxe Mtn. area.



F-3. Structure sections. Patterns for formations and horizontal and vertical scales same as for F-1.



PRELIMINARY GEOLOGICAL MAP OF THE COXE MTN. AREA

Plate F-2

Trip G Part 1 STRATIGRAPHY AND STRUCTURE OF THE TACONIC SEQUENCE IN THE THORN HILL AND GRANVILLE QUADRANGLES

Leader: George Theokritoff

Meet at corner of Main and College Streets, Poultney. 8:45 a.m., Sunday October 18.

In the Taconic rocks of Washington County, New York, the following sequence is now recognized: -

ORDOVICIAN

Unnamed Normanskill greywackes and black shales
Indian River formation
Poultney formation

CAMBRIAN

Hatch Hill formation
-----Supposed Hiatus-----
West Castleton formation with two Lower Cambrian assemblages; an upper named the Paedeumias fauna and a lower named the Elliptocephala underlain asaphoides fauna.
Bull formation with associated Zion Hill quartzite
Mettawee slate member with lenses of limestone-conglomerate locally near the top named Castleton conglomerate and bearing the Elliptocephala asaphoides fauna.
Bomoseen grit member

CAMBRIAN STRATIGRAPHY

Bull formation

The Bull formation in Washington County consists of two members; an upper member essentially of purple and green slates with limestone locally and named the Mettawee slate member, and a lower member essentially of greywacke and subordinate green slates named the Bomoseen grit member. Their mutual contact is gradational and since green slates appear locally in the Bomoseen which differ from green Mettawee slates only in that they contain spangles of mica, the Bomoseen and the Mettawee are here considered to be members of a formation named the Bull formation.

Bomoseen grit member.

The lowest rock-unit exposed in the Taconic sequence in Washington County consists essentially of greywacke with subordinate green slates and orthoquartzite. It was named "the olive grit" by Dale (1899, pp. 179-180).

The Bomoseen grit consists typically of dark olive-green laminated grit containing spangles of mica. Its weathered surfaces generally show a ribbed appearance and are characteristically,

although rarely, brick-red in colour. It is locally fine-grained and is distinguishable from the green slates of the overlying member in containing mica spangles. Thin beds and lenses of orthoquartzite occur locally in the grit. A purple colour may be developed locally.

Dale's "olive grit" was named the "Bomoseen grit" by Ruedemann (1914, p. 69) and this name has been used in the same sense by all subsequent workers who have recognized it. This same usage is retained here.

Throughout the area mapped in Washington County, the Bomoseen grit occurs in the cores of anticlines. It is apparently unfossiliferous.

Mettawee slate member.

With the exception of the western part of the area mapped, the Bomoseen grit member is overlain by purple and green slates which were named "the Cambrian roofing slates" by Dale (1899, p. 180) and the "Mettawee slate" by Ruedemann (1914, p. 69). The Mettawee slate member consists essentially of purple and green slates, the purple being confined to the upper half of the unit where it is frequently associated with green slate. The purple and green colours locally follow bedding planes, but more usually occur as a mottling effect. Chemical analyses published by Dale (1899, p. 264) indicate that the colour-differences can be correlated with the relative proportions of ferric and ferrous iron.

Locally, a bed of orthoquartzite, usually 10 feet or so in thickness but reaching a maximum of 80 feet, occurs within the Mettawee slate member.

Thin beds of limestone and lenses of limestone-conglomerate occur locally near the top of the Mettawee. The limestone-conglomerates have been named the Castleton conglomerate by Zen (Ms.) and are the equivalent of the type Schodack. They yield fossils of the Elliptocephala asaphoides fauna which indicate a position at the top of the Lower Cambrian. The Elliptocephala asaphoides has recently been described by Lochman (1956).

Zion Hill quartzite.

A fine greenish to brownish quartzite weathering whitish to light grey occurs in the Bull formation. It is correlated with the Zion Hill quartzite in Vermont on the basis of lithological similarity and stratigraphical position. Unifortunately, Dale (1899, p. 184) correlates the quartzite of Zion Hill with quartzites "between the Cambrian black shales (Horizon D) and the Ordovician black shales (Horizon G)." He named this unit "the Ferruginous quartzite" and included in it the quartzites at Zion Hill as well as the quartzites developed at higher horizons.

Ruedemann later (1914, p. 69) named Dale's Ferruginous Quartzite the "Zion Hill quartzite" but the quartzites included in this unit which occur at the higher horizons are here referred to a higher unit assigned to the Upper Cambrian and named the Hatch Hill formation.

West Castleton formation.

The Bull formation is overlain by a black shale unit which rests on the Mettawee slate member throughout the area mapped, except locally along its western margin, where the black shale units rests on the Bomoseen grit member. This black shale unit has been named the "Cambrian black shale" by Dale (1899), the "Schodack shales and limestones" by Ruedemann (1914, p. 69), and the "Hooker" formation by Swinnerton (1922, p. 74) and Keith (1932, pp. 361, 402). Zen (Ms.) has named this unit the "West Castleton formation."

Theokritoff (1957) rejected the use of the term Schodack in Washington County on the grounds that Ruedemann's designated type-section in columbia County cannot be compared with the beds which have been named Schodack in Washington County.

The West Castleton formation consists essentially of dark gray or black shales which usually show a dark bluish tinge on weathered surfaces. Locally, it contains several beds of a fine dark bluish-gray limestone-conglomerates yield fossils of the Elliptocephala asaphoides fauna, and at one locality, fossils of an overlying Paedeumias fauna with Paedeumias sp., Agnostids, Bonnia sp., Calodiscus lobatus, Fordaspis nana, Hyolithellus micans and brachopods. Both these faunas indicate a position at the top of the Lower Cambrian.

Locally, the West Castleton formation contains lenses of a dark-gray calcareous grit with conspicuous rounded quartz grains. Dale (1899) named such beds "the Black Patch grit."

Hatch Hill formation.

The name Hatch Hill is applied here for the first time to a unit consisting of sooty black pyritic rusty-weathering shales interbedded with rotten-weathering bluish dolomitic sandstones, locally cross-bedded, and characteristically traversed by numerous quartz veins. The type locality is Hatch Hill in the Thorn Hill quadrangle where the formation can be seen outcropping on its western flank. This unit was included by Dale (1899) with other quartzites in which was later renamed the Zion Hill quartzite by Ruedemann (1914).

The Hatch Hill formation has yielded graptolites identified by Dr. W.B.N. Berry as species of Callograptus, Dendrograptus, and rarely Dictyonema. He considers this fauna to be Upper Cambrian.

This sandstones in the Hatch Hill formation may well prove to occur at the same stratigraphical position as the Egle Bridge quartzite. (Prindle and Knopf, 1932, p. 277).

ORDOVICIAN STRATIGRAPHY.

Poultney formation.

The name "Poultney slate" was applied by Keith (1932, p. 403) to the lowest Ordovician formation after "good exposures in the town of Poultney at the boundary of New York 7 miles southwest of Castleton." It was described as "mainly of gray slate which becomes lighter or even white on exposure. The most prominent feature of the formation is white or light gray chert which appears in very thin seams or in massive beds a foot or so thick. The formation resists erosion and it outcrops abundantly, making hills of considerable height. The normal succession of these beds following the Cambrian is well shown in a shallow syncline in New York just west of Poultney."

The Poultney formation is here understood to include the beds of the Ordovician section up to the overlying red and bluish-green slates named Indian River. The Poultney formation is variable unit consisting typically of bluish-gray waxy-looking banded argillites, locally with indigo coloured patches replacing the banding. There are local developments, near the base, of the finger-thick green and greenish-weathering black argillites and brown sandstones, and also of black shales with limestone-conglomerates and thin ribbon-limestones. This lithological development is similar to that of the type Schaghticoke section in the Hoosick River. Massive quartzite beds with angular fragments of limestone occur locally in the Poultney formation.

The Poultney formation has yielded Lower Ordovician and Normanskill graptolites (*Nemagraptus gracilis* zone).

Indian River formation.

The Poultney formation grades conformable into red and bluish-green slates, glazed in appearance, with some interbedded cherts locally. This unit was named the "Indian River slate" by Keith (1932, p. 403).

Unnamed Normanskill greywackes and black shales.

Greywackes with interbedded black shales bearing Normanskill graptolites overlie the Indian River formation, apparently unconformably.

BIBLIOGRAPHY.

Dale, T.N. 1899, "The Slate Belt of Eastern New York and Western Vermont," U.S. Geol. Survey An. Rept. 19, pt. 3, pp. 153-307.

Keith, Arthur 1932, "Stratigraphy and Structure of Northwestern Vermont," Wash. Acad. Sci. Journ. vol. 22, pp. 357-379, 393-406.

Lochman, Christina 1956, "Stratigraphy, Paleontology and Paleogeography of the *Elliptocephala asaphoides* strata in Cambridge and Hoosick Quardrangles, New York, "G.S.A. Bull., vol 67, pp. 1331-1396.

Pringle, L.M., and Knopf, E.B., 1932, "Geology of the Taconic Quadrangle rangle", Amer. Jour. Sci. 5th ser., vol. 24, pp. 257-302.

Ruedemann, R. 1914 in Cushing, H.P. and Ruedemann, R. 1914, "Geology of Saratoga Springs and Vicinity," New York State Mus. Bull 560.

Swinnerton, A.C. 1922, "Geology of a portion of the Castleton, Vt., quadrangle," Unpublished Ph. D. thesis, Harvard University.

Theokritoff, Geroge 1957, "Use of the term 'Schodack formation' in Washington County, New York," abstract, G.S.A. Bull. vol. 68, pp. 1804-1805.

Zen, E-an, Ms. "Stratigraphy and Structure at the North End of the Taconic Range in west-central Vermont," G.S.A. Bull..

Trip G Part 2 PAWLET QUADRANGLE

Leader: Robert Shumaker

The stratigraphic section of the western half of the Pawlet Quadrangle is nearly identical to that found in Washington County, New York, and at the north end of the Taconic Range. All units mentioned in the sequence for this trip have been recognized except for the Bomoseen grit member of the Bull formation. It is noted however that exposures of the West Castleton formation, the Hatch Hill formation, and the Castleton conglomerate of the Bull formation are limited in extent. The unnamed greywacke and its basal bleck slate member are significant units within the Pawlet Qadrangle. The basal black slate is fossiliferous, and has yielded graptolites of the Nemagraptus gracilis zone from a dozen localities in the western part of the quadrangle.

As one proceeds eastward, the effects of increased metamorphism tend to mask the identity of the units, and primary sedimentary features and fossils are exceedingly scarce. The units remain identifiable within the sequence, however, so that rocks once mapped by Dale (1899) as Berkshire Schist (Ordovician) within the Pawlet Quadrangle have now been subdivided into the Cambro-Ordovician units given above.

Even though Trip G uses the stratigraphic section given above, two distinct sequences can be recognized in the field. The term "low Taconic sequence" applies to rocks of the lower areas, whereas the term "high Taconic sequence" applies to those of the high Taconic Range occupying the area between Trip G and Trip H. A brief discussion of the relationships between the two sequences within the Pawlet Quadrangle follows.

On the east, the "high Taconics" overlie Cambrian and Ordovician carbonates and phyllites. Although the fact that these rocks overlie phyllites and carbonates with Trenton fossils suggests that they are younger than Trenton in age, they are, nevertheless, lithologically very similar to units within the "low Taconics". This similarity is apparent if one inverts the "low Taconic sequence" and applies the resulting sequence to the "high Taconics": capping the hills should be the lowest Lower Cambrian formation, the Biddie Knob (Zen, 1959), as indeed is the case. A coarse conglomerate, occasionally green (Zion Hill?), has been found within the green phyllites now underlying the Biddie Knob formation, and a lenticular limestone (Castleton conglomerate?) occurs in the same phyllite, near the contact with the underlying black phyllites. These black graphitic phyllites, containing a dark blue limestone (Beebe?), lie topographically above limy phyllites and quartzites which have characteristic quartz veins (very similar to the Hatch Hill formation). Black and green phyllites occuring below the quartzites might belong to the Poultney formation.

Although the stratigraphic similarity is striking, there is not complete identity between the two sequences. Proof and final comprehensive acceptance of any correlation between them possibly rest upon fossil finds within the "high Taconic sequence".

References

Dale, T.N., 1899, The slate belt of eastern New York and western Vermont, U. S. Geol. Survey Ann. Rept. 19, pt. 3, p. 153-307.

Zen, E., 1959, This guidebook, Trips A and I.

Trip G Part 3 GRAPTOLITE FAUNAS OF THE NORTHERN PART OF THE TACONIC AREA

Leader: William B.N. Berry

Department of Paleontology, University of California
Berkeley, California

Until the recent collections made by Platt, Shumaker, Theokritoff, and the writer in the Castleton, Granville, Hartford, Pawlet, and Thorn Hill quradrangles, the occurrence of graptolites in the northern part of the Taconic area has only been mentioned with little reference to specific names or stratigraphic signifigance by Dale (1899) and Keith (1932). Graptolites have been found in the region in the Hatch Hill formation, the Poultney slate, the Indian River formation, and the shale and greywacke unit above the Indian River formation. Table 1 shows the correlation of these formations with the classic New York state graptolite-bearing units, the Schaghticoke, Deepkill, Normanskill, and Snake Hill shales, with the complete sequence of Ordovician graptolite zones delimited by the writer (in press) in the Marathon region, Texas, and with the stages and series of the Ordovician.

HATCH HILL FORMATION

Graptolites have been found in the Hatch Hill formation at one locality three and one-half miles north of Truthville, New York in the Granville quadrangle. The forms are exclusively dendroids with genera Callograptus and Dendrograptus abundant and Dictyonema rare. The writer considers the fauna to be Late Cambrian in age.

POULTNEY SLATE

Species of Clonograptus and Adelograptus which characterize graptolite zone 2 have been collected from the lower part of the Poultney slate on Rascal Mountain in the Hartford quadrangle and from three and one-half miles north of Truthville, New York in the Granville quadrangle. Graptolite assemblages diagostic of zones 3 and 4 have been obtained from the lower and lower-middle parts of the Poultney slate two miles southwest of Hampton, New York in the Thorn Hill quadrangle.

No identifiable graptolites have been found in the middle or upper parts of the formation except some from the highest beds. These belong in either the zone of Nemagraptus gracilis or that of Climacograptus bicornis. They come from a roadcut exposure on New York Route 22A, two and one-fourth miles south of Hampton, New York. Because the formation is apparently a continuous lithologic unit and no readily mappable division of it has as yet been made, it is correlated as shown on the correlation chart. It is interpreted by the writer as the product of continuous deposition throughout the Early and part of the Middle Ordovician. Representiative collections of more graptolite zone should be found in the formation with further collecting.

INDIAN RIVER FORMATION

The Indian River formation has yielded graptolites which are diagnostic of the zone of Climacograptus bicornis from several localities. Two part-.

icularly fossiliferous exposures are in quarries - one is one and one-fourth miles north of North Granville, New York in the Granville quadrangle and the other is 0.9 miles south of Hampton, New York in the Thorn Hill quadrangle. All graptolites collected from this formation are common in the zone of C. bicornis.

SHALE AND GREYWACKE UNIT

Assemblages of graptolites characteristic of the zone of C. bicornis have been obtained from several exposures of the shale and greywacke unit which overlies the Indian River formation in the Pawlet and Granville quadrangles. This shale and greywacke unit overlies older rock units with angular unconformity in the northern part of the Taconic area (Shumaker and Zen, 1959, oral communications; also the writer's own observations). However, beds immediately above and below the unconformity in one exposure yield graptolites clearly diagnostic of the same zone.

CONCLUSIONS

The fossil record indicates that deposition was apparently continuous from Late Cambrian into Middle Ordovician in the northern part of the Taconic area. Then, a relatively short interval of intense folding took place, followed by further sedimentation for a brief time.

The sequence of Lower Ordovician graptolite zones in the lower and lower-middle parts of the Poultney slate is the only one known in the eastern part of the United States.

REFERENCES

Berry, W.B.N., (In Press), Graptolite faunas of the Narathon region, West Texas: Univ. Texas Publication.

Dale, T.N., 1899, The slate belt of eastern New York and western Vermont: U.S. Geol. Survey, 19th Ann. Rept. pt. 3, p. 153-307.

Keith, A., 1932, Stratigraphy and structure of northwestern Vermont: Washington Acad. Sci. Journal, v. 22, p. 357-379, 393-406.

Trip G Road Log

Stratigraphy and Structure of the Taconic Rocks of the Thorn Hill, Granville and Pawlet Quadrangles.

00.00 Start at intersection of Main and College Streets in Poultney, Vt..Proceed north on College Street.

00.20 Stop sign: College and York Streets. Proceed left onto York Street.

00.70 Outcrops of type Poultney in field to left.

00.80 Cross bridge over Poultney River into Washington County, New York. Turn Right. Outcrops of Poultney slate in left roadside and in field on left.

01.10 Stop sign: intersection with Route 22A. Pull off road on right just beyond Stop sign.

STOP 1. Road cut along west side of Route 22A. The most northerly exposures in this cut consist of rotten-weathering bluish-grey dolomitic sandstones with characteristic veining interbedded with dark blue-grey shales. This unit is referred to the Hatch Hill formation.
The next outcrops to the south are of limestones-conglomerates with interbedded black shales. The limestone pebbles are angular and are of fine grained dark grey limestone.
Further south, there are black carbonaceous shales which are succeeded by banded greenish-grey and black argillites with thin interbeds of dolomitic sandstone.

Note that these exposures are on strike with the type Poultney.

In this roadcut, all those beds that overlie the Hatch Hill formation are referred to the Poultney slate.

Return to cars and proceed north. Turn around at "Trucks lettered."

01.20 Turn right onto Route 22A, bear right at intersection (sign to Granville), proceed south on Route 22A.

01.85 Bear Right at intersection just beyond Sunoco Station towards Whitehall.

02.70 Quarry in Mettawee slate on left.

03.30 Outcrops of Mettawee slate on right roadside. Note purple and green colour.

03.55 and 03.60. Outcrops of Bomoseen grit on left roadside.

04.10 Intersection.

04.22 House on right.

STOP 2. Proceed to barn just east of house and enter field. Proceed east across field to outcrops of Bomoseen grit just beyond power-line pole. Note characteristic brown skin and ribbed appearance of weathered surface.
Extending from power-line pole to the road intersection is a 20 food thick bed of orthoquartzite which is situated within the Bomoseen grit. This quartzite is referred to the Zion Hill quartzite.

Return across field to barn.

Mettawee slate outcrops on roadside 10 feet east of barn. Note purple and green colour.

Return to cars and proceed west along highway.

04.40-04.80. Note outcrops of black shales in left roadside.

05.50 Outcrops of Bomoseen grit.

06.20 East Whitehall. Turn left (south) towards Granville.

06.50 Outcrops of shales and thin ribbon-limestones, possibly in basal part of Poultney slate.

07.30 STOP 3. Outcrops of black shales with thin limestone interbeds in stream to left (east) of road.

Proceed a few yards south along road to outcrops on right (west) roadside. These outcrops consist of dark-grey banded argillites with a few thin dolomitic sandstone layers.

The lithological assemblage seen at Stop 3 is similar to that in the type-section of the Schaghticoke in the Hoosick River.

Return to cars. Proceed south. Outcrops of Poultney slate along roadside at top of hill.

07.95 Turn right (west) onto dirt road. Outcrops of Poultney slate on left.

08.10 STOP 4. Magenta and bluish-green siliceous argillites, glazed in appearance. These beds are referred to the base of the Indian River formation and occupy the centre of a syncline at this locality. Green and dark grey banded argillites referred to the Poultney slate occur a few yards to the west and east and their gradation into the Indian River may be observed. Note the light buff weathering characteristic of the Poultney slate in the outcrops on the north side of the road west of the Indian River outcrop.
Note the development of cleavage across the centre of the syncline.

Return to cars. Proceed west along road.

08.35 Note outcrops of black shale with thin limestone interbeds on right roadside. These probably belong to the basal part of the Poultney slate.

08.95 Intersection.
STOP 5. Enter field on southeast corner of intersection. Proceed south. Outcrop of fossiliferous limestone-conglomerate in Mettawee slate in trees. Outcrop of fossiliferous limestone-conglomerate in black shales which are referred to the West Castleton formation a few yards south.

Return to cars. Turn left (south) at intersection.

09.30-09.45. Outcrops of Bomoseen at left roadside.

09.80-10.00. do.

10.10 Intersection. Proceed left (south) on pavement.

10.50 Intersection. Turn left (east) onto dirt road. The rise ahead is underlain by Bomoseen grit. The knoll immediately south of the farm marks an outcrop of fossiliferous Castleton conglomerate.

11.20 Intersection. Bear left.

11.40 STOP 6. Walk back to outcrops on bend in road near intersection. Rusty-weathering sooty black shales with rotten-weathering bluish dolomitic sandstones named Hatch Hill formation. The shales have yielded Callograptus sp., Dendrograptus sp., and rarely, Dictyonema sp. . These are considered to be of Late Cambrian age.

Proceed easterly along road to outcrop on south (Right) side of road of greenish-grey banded argillite with a few thin quartzite interbeds referred to the Poultney slate. This locality has yielded graptolites indicative of early Canadian (late Tremadoc) age.

Return to cars. Proceed west on dirt road.

11.50-11.60 Outcrops of Poultney slate on right roadside.

11.70 Indian River outcrops (red and bluish-green argillites)

12.30 Note quarry and waste dumps in Indian River to right.

12.30-12.46 Section from Indian River through Poultney slate into Hatch Hill formation.

12.46 STOP 7. (Park cars in gear and with brakes set)
Outcrops of sandstones with interbedded black shales referred

to the Hatch Hill formation. Note easterly dip and cross-bedding indicating inversion at this locality.

Return to cars. Proceed west along dirt road.

12.60 Mettawee slate in right roadside.

12.70 Intersection. Turn left (north).

13.35 STOP 8. Outcrop on left roadside of fossiliferous limestone-conglomerate in Mettawee slates named Castleton conglomerate. This locality has yielded Serrodiscus speciosus, Fordaspis nana, Helcionella subrugosa, Stenothecoides elongata, Hyolithes sp., Hyolithellus micans, Coleoloides prindlei and brachiopods.

Return to cars. Proceed north.

Outcrops of Mettawee slate along roadside.

14.45 Intersection. Turn sharp right onto pavement. Proceed south. Outcrops of Mettawee slate along roadside.

14.70-14.90 Bomoseen outcrops.

15.00 Mattawee outcrops on left roadside.

15.60-15.70 Hatch Hill on right roadside.

15.90 Black shales with thin interbedded limestones and limestone conglomerates, probably in basal part of Poultney slate, on right roadside.

16.20-16.40 Banded argillites of Poultney slate on left roadside.

16.60-16.80 Indian River on left roadside.

16.90 Poultney slate on left roadside.

17.80 Note Indian River dumps on right.

18.70 Cross Mettawee River. Note quarry in Indian River on right.

18.90 Stop sign. Intersection with Route 22A. Proceed south towards Granville.

20.60 Note dumps of Mettawee slate on right.

20.90] Middle Granville. Stop sign. Intersection with Route 22. Proceed on Route 22 south across Bridge (Mettawee River) towards Granville.

23.10 Granville. Traffic signal. Turn right onto Main Street.

23.25 Cross Railroad tracks.

23.30 Cross Mettawee River

23.40 Bear left; follow Route 22 (Quaker Street)

24.40 Intersection with Route 149. Follow Route 22 straight across.

25.10 Pull off right side of highway onto widened shoulder.
STOP 9. Cross road, walking east thru field across Poultney to small red slate quarry. Note sequence in quarry; characteristic weathered and fresh-appearance of the Indian River formation. Fracture cleavage in the competent cherty beds is nearly vertical.

Continue east across field to gate leading across railway track into adjoining field. Enter field, heading southeast approximately 200 yards, crossing black slate (Nemagraptus gracilis zone) believed to be the basal unit of the unnamed greywacke. The top of the second ridge affords the best exposures of this greywacke with interbedded black slate. This formation is believed to be the highest unit in the sequence described herein, lying unconformably over the older unit.

Return to railroad, turn south proceeding along the track approximately 40 yards to another exposure of basal black slate of the unnamed greywacke formation. Some of the graptolites identified from the locality by Berry are: Nemagraptus gracilis (zone), N. exilis, Decellograptus sextans, D. gurleyi, D. intortus, D. divaricatus, Climacograptus parvus, Dicranograptus spinifer, Glyptograptus teretiusculus, Cryptograptus tricornus, Orthograptus calcartus var. acutus, Hallograptus mucronatus, etc.....

Lunch, 45 minutes .....

25.30 Proceed south on route 22, crossing Indian River.

25.40 Turn left (east) onto dirt road.

25.50 Cross Indian River. Note small quarry of red Indian River slate on right side of road.

25.80 Greywacke and black slate exposed in field to left.

25.90 Bear left on main dirt road.

26.10 Entering Pawlet, Vermont 15-minute quadrangle. Note dumps of gray slate probably from the Poultney formation (?).

26.60 Intersection: continue straight ahead. Cambrian purple and green slates to left (Mettawee).

26.80 Cross road: bear right (south) on high level terrace.

27.10 Valley on right is probably an abandoned proglacial drainage channel cut into high level terrace. Note reversal of drainage as indicated on topographic map.

27.50 Intersection: bear left onto paved road.

27.90 Cross Mettawee River, bear right (east) after crossing bridge onto dirt road. Cambrian purple and green roofing slate (Mettawee) exposed in stream on right.

28.10 Greywacke of Normanskill age under terrace, exposed in stream to south.

28.60 STOP 10. Pull cars over far to right. Exposure of red and green Poultney slate with characteristic quartzite stringers.
Red and green portion of the Poultney is believed to be near the top of the formation. Note the axial position of the cleavage in relation to the minor folds. These folds indicate older units to the west while in fact the highest unit in the section is found just to west.

29.10 On left, waxy green and red slates with quarztite stringers (probably upper Poultney).

29.20 View oblique right toward Haystack Mountain, which is composed primarily of Mettawee (Cambrian) slates.

29.60 Stop sign: Across road are outcrops of green Mettawee. Bear right onto route 30. Bull formation units exposed on hills either side of road.

30.20 On left, just beyond farm with two silver silos and near fence at base of hill, is a small fold in Bull formation overturned slightly toward the west with axial plane cleavage. Slow down for stop 11.

30.30 STOP 11. Pull over far right, dangerous location. Walk along road eastward to road cut. These rocks have been assigned to the Poultney formation. On hill a few hundred feet above are exposures of the Bull formation. Hallograptus?, Glyptograptus teretiusculus ? and some pieces looking like a dicellograptid or didymogrptid were found a few hundred yards to the north behind the Esso station. At least three "s" surfaces can be seen at this exposure: bedding, low and high angle cleavage. Note the effect of cleavage and drag on the quartzite beds. Walk down to the eastern-most stream exposure. Observe the variance in dip of apparent compositional changes, brought out by differential weathering. Several directions of dip may be caused by cleavage banding and deformed, carbonate-filled fractured. True dip of the bedding may be seen by examining large brown-weathering limy quartzite beds. This exposure is more typical of the Poultney formation than the rock at the road cut. Now walk westward along the stream about 50 yards to the next outcrop. After deciding the direction and amount of dip look at the sheared drag folds of limy quartzite exposed on the joint face next to the stream. The bedding is horizontal in the long limb of folds and the short limb is sheared off. Boudons indicate dip to be nearly vertical. This is apparently an anticlinal structure with Cambrian Bull formation overlying Poultney.

30.60 Turn left at Esso station onto dirt road.

31.20 On right (south) in distant field: Bull, West Castleton and Poultney contacts.

31.80 On left (north) behind farm on hill top: Indian River outcrops.

31. 90 Unexposed along road: greywacke-Indian River contact.

32.30 On left in field: contact of Poultney and greywacke.

33.10 Intersection with route 3. Across valley oblique right (southwest) is Woodlawn Mountain. "High Taconic sequence" overlying Valley marbles. Turn left onto route 3.

33.50 Poultney formation on the left.

34.10 Turn left (west) at red barn, just before red gasoline pump, onto dirt road.

34.60 STOP 12. Turn left into field after passing old sugar house. Make wide swing for turn around in field.

Cross north over road going to far northwestern corner of field by pine tree. Cross the small creek, staying on west side of wire fence. Walk north along low ridge of limy greywacke for 60 yards. At the base of the hill walk west along tree line for another 60 yards. Outcrops uphill in the woods are exposures of greywacke and interbedded slate. Note the graded bedding, angle of the cleavage in slate as compared to cleavage angle in the greywacke, and identity of greywacke with that seen at stop 9.

Return to cars and return to route 3.

35.00 Poultney formation on hill to left.

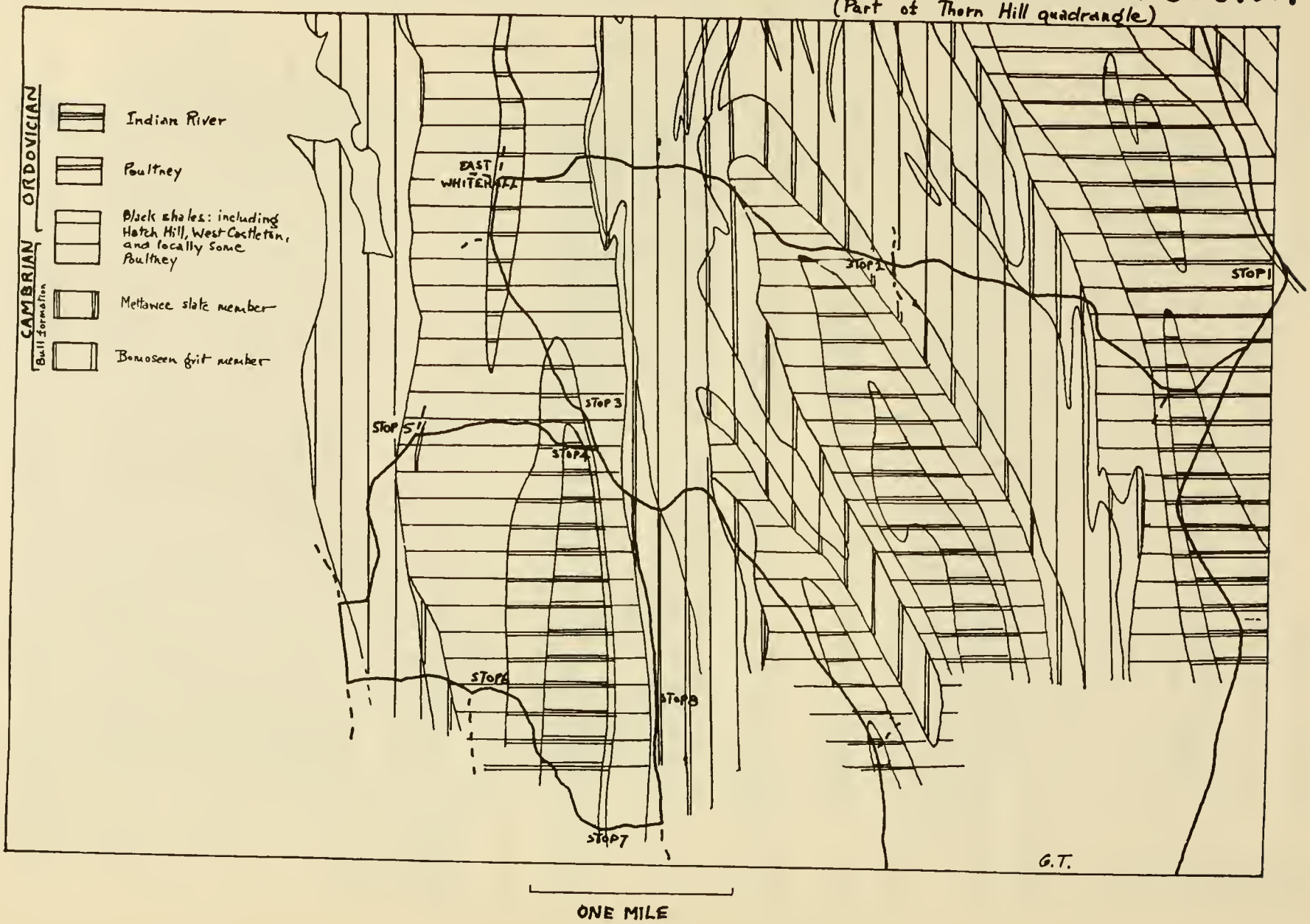
35.20 Turn left (north) onto route 3.

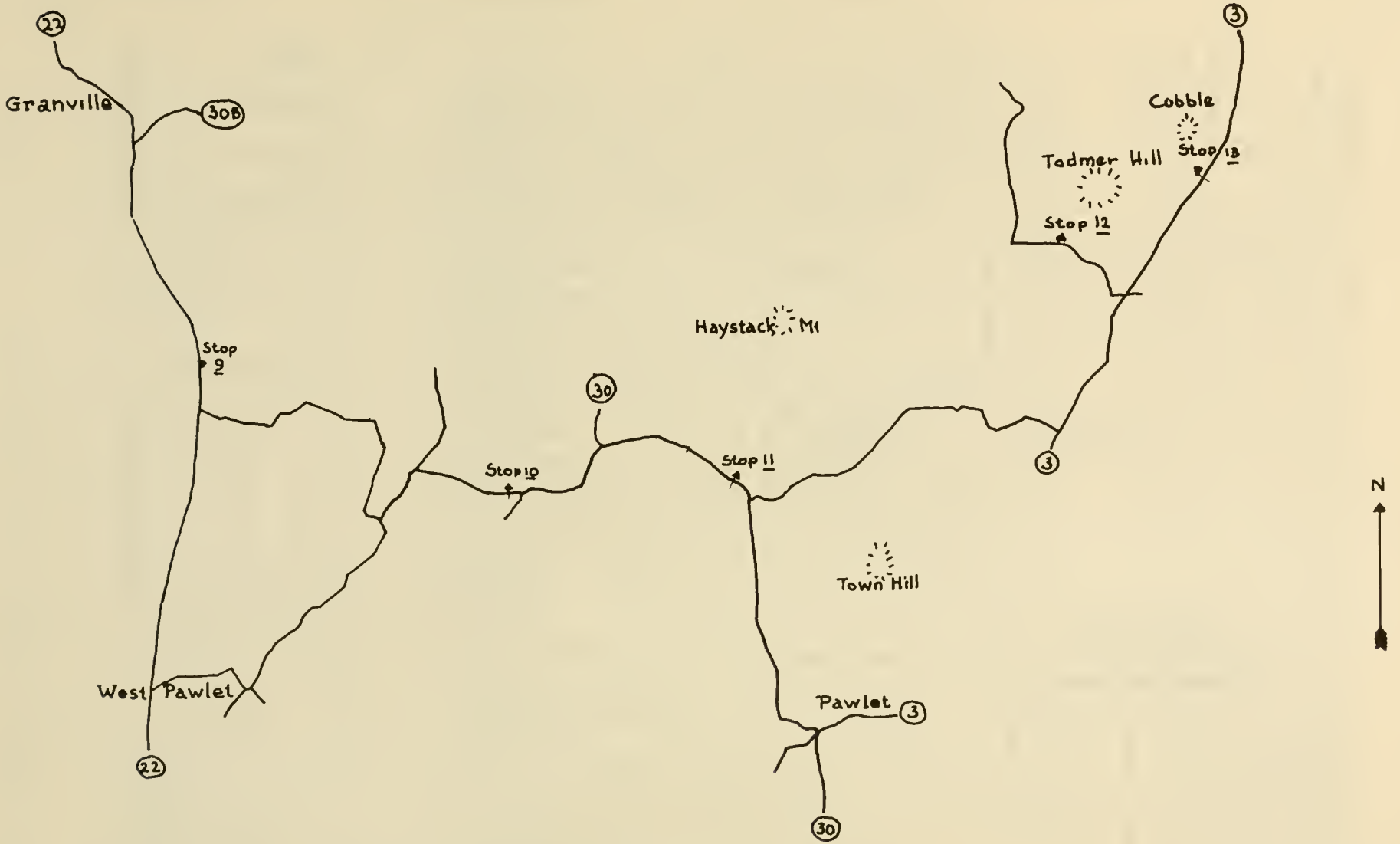
36.10 STOP 13. Park in farm yard of red barn on left side of road. Walk west up valley behind barn to notch between hill on right (Cobble) and hill ahead (Tadmer). Blue and green pin-stripe Poultney exposed in the notch and on Tadmer Hill to west. West Castleton formation outcrops at the base of the slope on the west side of the Cobble. Follow the West Castleton-Bull contact along the south side of the Cobble. Exposure on the southeastern side of the hill shows a fold of West Castleton with Beebe limestone and Bull formation with Castleton conglomerate. Directly across the valley are exposures of Lower Ordovician-type marbles (Burchards and Beldens lithology). These units are overlain by "High Taconic sequence" phyllites. (end of trip)

Route 3 leads north to Middletown Springs and south to Pawlet.

TRIP G GEOLOGICAL MAP OF PART OF WASHINGTON COUNTY

(Part of Thorn Hill quadrangle)





TRIP G ROUTE CONTINUED

Table 1. Correlation chart of graptolite-bearing units in the Taconic area.

	STAGES		GRAPTOLITE ZONES	CLASSIC UNITS	NORTHERN TACONIC AREA
UPPER ORDOVICIAN	Richmond	15	Dicellograptus complanatus		
	Maysville Eden	14	Orthograptus quadrimucronatus		
MIDDLE ORDOVICIAN	Trenton	13	Orthograptus truncatus var. intermedius	Snake Hill	
	Wilderness	12	Climacograptus bicornis	Normanskill	Shale and greywacke unconformity Indian River
	Porterfield	11	Nemagraptus gracilis		Poultney
	Ashby	10	Glyptograptus terediusculus		
	Marmor	9	Lasiograptus etheridgei	Deepkill (beds 6 & 7)	
	Whiterock	8	Isograptus		
		7	Didymograptus bifidus		
LOWER ORDOVICIAN	Canadian Series (Stages not yet recog-nized)	6	Didymograptus protobifidus	Deepkill (beds 1-5)	
		5	Tetragraptus fruticosus 3 & 4 br.		
		4	Tetragraptus fruticosus 4 br.		
		3	Tetragraptus approximatus		
		2	Clonograptus		
		1	Anisograptus	Schaghticoke	? - ? - ?
CAMBRIAN					Hatch Hill

Trip H STRATIGRAPHY AND STRUCTURE IN THE VERMONT VALLEY AND THE EASTERN TACONICS BETWEEN CLARENDON AND DORSET

Leader: James B. Thompson, Jr.

The pre-Cambrian rocks in the core of the Green Mountain anticlinorium are overlain to the west with profound unconformity by quartzites, dolomites and calcite marbles of Cambrian and Early Ordovician age (see Table H-1). These, in turn, are overlain with angular unconformity by limestones and phyllites of mid-Ordovician age which may be found resting upon any of the older formations including the pre-Cambrian gneisses.

Above the Middle Ordovician limestones and phyllites, at least in structural position, though possibly older, are the phyllites and schists, with minor carbonate rocks and quartzites, forming the most easterly and highest range of the Taconic Mountains.

The Cambrian and Lower Ordovician carbonate rocks are notably less resistant than either the pre-Cambrian gneisses to the east or the schists and phyllites of the Taconic Mountains to the west. Hence they are found mainly in the Vermont valley although in many places the basal quartzites extend high on the western face of the Green Mountains in spectacular dip-slopes as at White Rocks, east of Wallingford or on Mount Tabor east of Danby.

Through much of the area here considered the Vermont valley is a double valley consisting of the main valley on the east, extending from Rutland through Wallingford, Danby, and East Dorset to Manchester (the route of U.S. highway 7), and the Tinmouth valley on the west, extending from Clarendon Springs through Tinmouth to Danby Four Corners where it is truncated abruptly by the imposing massif of Dorset Mountain (el. 3,804'). The floor of the main valley rises from about 550 feet above sea level at Rutland to 800 feet at East Dorset, and that of the Tinmouth valley from 700 feet at Clarendon Springs to 1,400 feet at Danby Four Corners. The ridge between the two valleys also increases in elevation southward, though breached by the valley of Baker Brook in Danby, with elevations rising from 1,315 feet on Boardman Hill in Clarendon to 3,060 feet on Clark Mountain in Tinmouth and 2,112 feet on Danby Hill. Pine Hill (1,445') northwest of Rutland is on the continuation of this ridge north of Otter Creek. This ridge between the Green Mountains and the Taconics is terminated abruptly on the south, as is the Tinmouth valley, by the massif of Dorset Mountain, an eastward extension of the Taconic Mountains. The complex geologic structure of this ridge and of the surrounding areas has long been the concern of geologists (see T.N. Dale, 1894, 1912; C.E. Gordon, 1921, 1925; G.W. Bain, 1931, 1933, 1938; P. Fowler, 1950, and W.F. Brace, 1953) and is the principal concern of the present study which has occupied portions of the summers of 1951, 1952, 1958 and 1959.

The rocks of both the Tinmouth valley and the main valley to the east may be regarded, though complicated by overthrusting toward the west, as essentially homoclinal, westward-dipping sequences with pre-Cambrian gneisses on the east succeeded westward by Cambrian and Lower Ordovician quartzites, dolomites, and calcite marbles. The unique feature of the Tinmouth valley is the truncation eastward of the Cambrian and Lower Ordovician sequence by the Middle Ordovician Ira formation. Along the western side of the Tinmouth valley, the Ira formation rests on Lower Ordovician carbonate rocks. The work of Fowler (1950) at the north end of the Tinmouth valley showed that the Ira formation

(= Whipple marble and Hortonville formation) cuts down eastward at least as far as the Winooski dolomite in the area southeast of Clarendon Springs. The present study has shown that the Ira actually cuts down as far as the Dunham dolomite (Stop #1) in this area and that farther south it may be found resting directly upon the Cheshire quartzite, the Nickwaket greywacke and the pre-Cambrian gneisses. This truncation of the older units is particularly striking northeast of Danby Four Corners and on Clark Mountain. In the main Vermont valley to the east, however, the Ira formation rests on no formation older than the Shelburne even in areas where it rests directly upon pre-Cambrian gneisses within less than a mile west on the Danby Hill - Boardman Hill ridge. At two localities, one on the west side of the main valley a little more than a mile south-southwest of Clarendon village, and the other on the north slope of Dorset Mountain (Stop #7), Lower Ordovician marble and pre-Cambrian gneiss appear in direct juxtaposition with no intervening Ira formation. The best interpretation of the above evidence appears to be that there was faulting in post-Beldens, pre-Ira time (here probably a normal fault with the rocks on the east downthrown relative of those on the west), followed by considerable erosion before the deposition of the Ira formation. The presence of what appear to be metamorphosed volcanic tuffs at the base of the Ira formation in South Wallingford and Danby is consistent with a disturbance of this sort as is the evidence elsewhere in the Appalachian region of unconformity between Lower and Middle Ordovician rocks (see Bucher, 1951).

The main movement on the Pine Hill thrust (Stop #1) and similar thrusts farther east in the main valley (see map, Plate H-1)is believed to be post-Ira, but this cannot be demonstrated conclusively. The Dorset Mountain thrust, however, (Stops # 7, 8, 9, 10) is clearly post-Ira inasmuch as rocks of the Ira formation are overridden by it. As can be demonstrated at Stop #7, all the major structural features of the Tinmouth valley and of the Danby Hill - Boardman Hill ridge are truncated abruptly by the Dorset Mountain thrust. If, as seems perhaps probable, the Berkshire and Greylock schists are a part of the Taconic sequence and not in normal superposition above the Ira formation, then the Dorset Mountain thrust offsets the main Taconic fault although indicating a displacement of much the same kind. The relative age of the Pine Hill and Dorset Mountain thrusts are unknown inasmuch as neither could be traced into the other.

References

Bain, G.W. (1931) Flowage folding, Am. Jour. Sci., 5th Ser., vol. 22, p. 530-530.

_____ (1933) The Vermont marble belt, 16th Int. Geol. Cong. Guidebook 1, p. 75-80.

_____ (1938) The Vermont marble belt. Guidebook for 34th Annual Field Meeting, New England Intercollegiate Geologicial Conference, 22 pp.

Brace, W.F. (1953) The Geology of the Rutland area, Vermont, Vermont Geological Survey, Bull. No. 6, 124 pp.

Bucher, W.H. (1951) Infolded mid-Ordovician limestone on pre-Cambrian north of Peekskill, New York and its bearing on the region's orogeny (abstract), Geol. Soc. Am., Bull., vol. 62, p. 1426-1427.

Cady, W.M. (1945) Stratigraphy and structure of west-central Vermont, Geol. Soc. Am., Bull., vol. 56, p. 515-558.

Dale, T.N. (1894) On the structure of the ridge between the Taconic and Green Mountain ranges in vermont, U.S. Geological Survey, 14th Ann. Rept. Pt. 2, p. 525-549.

_____ (1896) Structural details in the Green Mt. region and in eastern New York, U.S. Geol. Survey, 16th Ann. Rept. Pt. 1, p.543-570.

_____ (1902) Structural details in the Green Mountain region and in eastern New York, (second paper), U.S.Geol. Survey, Bull. 195, p. 10-13.

_____ (1912) The commercial marbles of western Vermont, U.S.Geol. Survey Bull. 521, 170 pp.

Foerste, A.F. (1893) New fossil localities in the early Paleozoics of Pennsylvania, New Jersey, and Vermont, with remarks of the close similarity of the lithologic features of these Paleozoics, Am. Jour. Sci., 3rd ser., vol. 46, p.435-444.

Fowler, P. (1950) Stratigraphy and structure of the Castleton area, Vermont, Vermont Geological Survey, Bull. No. 2, 83 pp.

Gordon, C.E. (1921) Studies in the geology of western Vermont. Report of the Vermont State Geologist, 1919-1920, pp.114-279.

_____(1925) Studies in the geology of western Vermont. Report of the Vermont State Geologist, 1923-1924, pp. 218-259.

Keith, A. (1932) Stratigraphy and structure of north-western Vermont, Wash. Acad. Sci., Jour., vol. 22, p. 357-379, 393-406.

MacFadyen, J.A,Jr. (1954) The Geology of the Bennington area, Vermont, Vermont Geological Survey, Bull. No. 7, 72 pp.

Prindle, L.M. and Knopf, E.B. (1932) Geology of the Taconic quadrangle, Am. Jour. Sci., 5th ser., vol. 29, p. 257-302.

Pumpelly, R., Wolff, J.E., Dale, T.N. (1894) Geology of the Green Mountains in Massachusetts, U.S. Geol. Survey, Mon. 23, 206 pp.

Whittle, C.L. (1894) The general structure of the main axis of the Green Mountains, Am. Jour. Sci., 3rd ser., vol 47, p. 347-355.

_____ (1894) The occurrence of Algonkian rocks in Vermont and the evidence for their subdivision, Jour. Geol., vol. 2, p. 396-429.

Wolff, J.E. (1891) On the lower Cambrian age of the Stockbridge limestone, Geol. Soc. Am., Bull., vol. 2, p. 331-337.

TABLE I

FORMATIONS OF THE CLARENDON-DORSET AREA*

MIDDLE ORDOVICIAN

	(Approximate thickness in feet)
Ira (Hortonville) formation Gray to black phyllite; beds of blue or blue-gray limestone (Whipple marble) in lower part contain Middle Ordovician fossils (Foerste, 1893). Base of formation contains a variety of rock types, not all present in any one section. These include: blue limestone; dark gray dolomite or dolomite breccia; quartzite, locally with pebbles of blue quartz; and, in Danby and South Wallingford, feldspathic schist and actinolitic greenstone believed to be metamorphosed volcanic tuffs.	400+

LOWER ORDOVICIAN

Beldens formation Blue-gray and white marble alternating with beds of gray- or orange- weathering dolomite that may be several feet thick.	150-200
Bascom formation Blue-gray, locally white, marble characterized by dolomitic mottling and minor beds of gray- or orange- weathering dolomite. Minor rock types include thin beds of black phyllite and cross-bedded calcareous sandstone.	200-250
Shelburne formation	
Columbian marble member; White calcite marble with minor beds of light gray marble.	200-250
Intermediate dolomite member: Light gray calcitic dolomite	150-200
Sutherland Falls marble member: White calcite marble with minor beds of light gray marble. Dolomitic "curdling" is more characteristic of the Sutherland Falls marble than of the Columbian marble.	50-100
(The marbles of the Shelburne formation contain all the important quarries in this area. The only quarries now operating are in the Columbian.)	

UPPER CAMBRIAN

Clarendon Springs formation Light gray calcitic dolomite; lower part has beds, several inches or a foot thick, of cross-bedded sandy dolomite.	200-250

* For further information see Brace (1953), Cady (1945), Fowler (1950), Keith (1932) and Wolff (1891).

(Approximate thickness in feet)

Danby formation — 50-100
Light gray calcitic dolomite interbedded with cross-bedded sandy dolomite or dolomitic quartzite and, in the lower part, beds of pure vitreous quartzite that may be five or six feet thick.

MIDDLE OR LOWER CAMBRIAN

Winooski dolomite — 300-400
Light gray dolomite, typically weathering yellow or orange-red. Beds are commonly several inches thick separated by thin siliceous partings. Minor rock types include dark blue-gray dolomite; rusty-weathering dolomitic quartzite; and greenish schistose quartzite.

LOWER CAMBRIAN

Monkton formation — 300
Beds up to five feet thick of greenish, schistose quartzite, locally containing pebbles of blue quartz several millimeters in diameter, alternating with rusty-weathering dolomitic quartzite and beds of light gray dolomite weathering yellow or orange-red. Minor rock types include dark blue-gray dolomite and green or gray-black phyllite. Quartzite locally shows cross-bedding and ripple marks.

Dunham dolomite — 900
Light gray, yellow-weathering dolomite with thin siliceous partings and minor beds of dark gray dolomite. Upper part (Mallett member) contains beds as much as eight or ten feet thick of sandy dolomite or dolomitic sandstone with conspicuous cross-bedding.

Cheshire formation — 1000-1600
Massive white or blue-gray vitreous quartzite, locally with cross-bedding, ripple marks, and worm tubes (Scolithus). Beds of tan-weathering schistose, feldspathic quartzite, and dark gray to black quartzose phyllite are abundant in the lower two-thirds of the formation. The lower part of the formation corresponds to the upper part of the Mendon series of Whittle (1894b).

Nickwaket greywacke (Dalton formation) — 50-300
Schistose greywacke, conglomerate; minor beds of green chlorite-chloritoid phyllite and impure dolomite in the upper part. (Equivalent to the lower part of the Mendon series of Whittle.)

PRE-CAMBRIAN

(Approximate thickness in feet)

Mount Holly series — Unknown

Gneiss, schist, amphibolite, quartzite, marble, and calc-silicate granulite, with cross-cutting bodies of pegmatite, gneissic granite, and massive amphibolite. The rocks of the Mount Holly series were metamorphosed and deeply eroded before deposition of the Cambrian formations.

FORMATIONS OF UNCERTAIN AGE

Berkshire schist — 400-600

Dark gray to black phyllite, some gray-green and green phyllite. Also includes beds of blue-gray marble, dark gray dolomite, dark gray sandy dolomite and dolomitic sandstone, and massive quartzites up to twenty feet thick containing pebbles of blue quartz. This formation cannot be separated with any certainty from the Ira formation to which it may be in part or wholly equivalent. On the other hand, it contains rock types that appear to be metamorphosed equivalents of the fossiliferous Cambrian rocks of the Taconic slate belt. The "Taconic fault" may thus lie within what has been mapped as Berkshire schist or on either side of it. It is possible that the problem may never be resolved unless diagnostic fossils are found.

Greylock schist — 1000+

Green phyllite, commonly containing abundant plates of chloritoid, with minor beds of gray-green, gray or black phyllite, and white or greenish quartzite containing pebbles of blue quartz. If the Berkshire schist is equivalent to the Ira formation, the Greylock schist may represent rocks that overlie the Ira conformably. On the other hand, the Greylock schist closely resembles the Biddie Knob formation of the Castleton area which is believed to underlie conformably the fossiliferous Cambrian of the Taconic slate belt.

Most of the blue marble is mixed too intimately with dolomite to be recoverable and is shown in a tunnel and drill core westward from Main Quarry #1. The upper part of the lower blue marble (West Blue layers) has fossil gastropods resembling Maclurea. This marble is separated from the West Rutland deposit by a thick dolomite. Most operations are in the Main West Rutland deposit (stratigraphy given in tour stops). The Green Mountain Marble Corporation works the Upper Deposit. This is overlain by blue marble with turritelliform and planiform gastropods and crinoid stems. A part of it is bleached to make the Westland deposit.

A thin band of TRUE BLUE MARBLE lies immediately below the black graphitic Canajoharie phyllite. Everywhere layers and boudins of dolomite appear within the blue marble. Only locally is a thickened adequately to make a commercial deposit and at each place it has an infolded syncline of the phyllite. At the True Blue Quarry, the phyllite syncline was squeezed off as a sock shaped enclave within the marble.

The CANAJOHARIE PHYLLITE is very black and graphitic adjacent to the marble but becomes dark and micaceous at over 100 feet above. This upper part is not easily distinguishable from the Mendon Series in the overthrust slices to eastward.

Major Structure

The Taconic disturbance caused the sub-marble sequence to be overthrust on the marble along Boardman Hill, through Center Rutland, along the west face of Pine Hill in Proctor and near Coxe Mt. Cheshire quartzite and mylonite rests on dolomite in the Otter Creek at Center Rutland and mylonitized Mendon Series transgresses Sutherland Falls marble Lower Dolomite, and the Crossbedded Zone near the Proctor town line. A very complex klippe covers the marble from Boardman Hill to Danby but otherwise no great thrust planes enter the marble zone to be visited.[2]

"Overfolds" on the Lower or Intermediate dolomite, approaching nappes in size, are attended by development of flowage folds in the Sutherland Falls and Columbian Marble. Flowage off the main arch folds in the West Rutland Valley develop local thickening or flowage folds on their east limbs. They will be seen in the Main Quarries.

[2] Editor's Note:
See also the descriptions given by Thompson, Trip H.

Trip H Road Log

Quadrangle maps needed: Rutland, Castleton, Wallingford, Pawlet and Equinox. Most of the stops will be in the Wallingford and Pawlet quadrangles.

Assembly point: The west side of Route U.S. 7 at the Rutland Fair Grounds (0.9 mi. south of the junction of U.S. 7 and U.S. 4 West).

Mileage log:

0.0 Junction of Routes U.S. 7 and U.S. 4 West. Proceed south on U.S. 7.

0.8 Railroad crossing.

0.9 Rutland Fair Grounds; assembly point.

2.2 Turn right on secondary road (paved) at picnic table.

2.5 Rutland-Clarendon town line.

2.9 Cross Cold River.

3.2 Crossroads; proceed straight ahead.

6.2 Turn sharply right, crossing railroad tracks and Otter Creek.

6.8 Crossroads; proceed straight ahead.

7.1 Pre-Cambrian quartzite on left.

7.2 Pre-Cambrian gneiss.

7.4 Stop #1: Cars may pull off to left on dirt road and park. Pre-Cambrian gneiss and pegmatite exposed in road-cut; Pre-Cambrian quartzite, marble and calc-silicate rock exposed several yards south on dirt road.

7.6 Stop #2: Cars may park on right of road. Outcrops on south side of road are lower part of Cheshire quartzite. Walk 0.2 mi. west on road, then approximately the same distance north, following crest of anticline in Cheshire quartzite to contact Dunham dolomite. Proceed 0.1 mi. northeast to crest of ridge where Dunham is overlain unconformably by dark gray phyllite of the Ira formation (mid-Ordovician). A few yards southeast the Ira phyllite is in fault contact with the lower part of the Cheshire quartzite. From here the fault may be followed south to exposures just south of the road where the Dunham dolomite may be seen in fault contact with the lower part of the Cheshire quartzite without any intervening Ira phyllite.

7.8 Enter Castleton quadrangle.

8.0 Ledges of Cheshire quartzite on right; exposures on hill to northwest are upper part of Dunham dolomite.

8.3 Turn left (south) on dirt road.

8.7 - 9.2 Dipslope ledges of Cheshire quartzite across fields on left.

9.6 Enter Pawlet quadrangle.

9.9 Cheshire quartzite exposed in ditch.

10.1 Cheshire quartzite to left of road.

10.2 Clarendon-Tinmouth townline; hill west of road is Monkton formation.

10.6 Junction; proceed straight ahead.

11.3 Ledges of Cheshire quartzite to left of road overlain unconformably by dark phyllites of Ira formation.

11.5 Cheshire quartzite both sides of road.

11.7 (Possible stop.) Ledges west of road are typical "dirty" quartzites of lower Cheshire lying nearly flat on crest of anticline. A few yards to the west the pure white upper quartzites of the Cheshire appear dipping westerly. Farther west, across the fields, are dolomites also may dipping west. East of the road the pure upper quartzites may be seen dipping easterly, overlain to the east, across the pasture, by phyllites of the Ira formation.

12.2 - 12.6 Outcrops of Cheshire quartzite.

12.7 Dunham dolomite on left side of road.

13.0 Dunham dolomite to left of road.

13.3 Junction, turn left (east) on paved road, Route 140.

13.8 Cheshire quartzite on ridge to right.

14.1 Cheshire quartzite on ridge to north and south of road. View west into Tinmouth valley and Taconic Range beyond.

14.3 Phyllites of Ira formation.

14.4 Ira formation in fault contact with Nickwaket greywacke near sugar house north of brook. Nickwaket greywacke rests unconformably on pre-Cambrian gneisses exposed south of the road on the northeast slopes of Clark Mountain. In the pastures north and northeast of the sugar house, phyllites of the Ira formation, east of the fault, rest unconformably on both the Nickwaket greywacke and the pre-Cambrian gneiss.

14.8 Junction, turn sharp left. Road follows townline between Tinmouth and Wallingford for 0.4 mi. with excellent views east across the Vermont valley toward the Green Mountains. The prominent ledge on the Green Mountain front opposite is a dipslope in the Cheshire quartzite known as White Rocks.

Note: Exposures of limestone (Whipple member of the Ira formation) containing Middle Ordovician fossils may be seen by proceeding 1.1 mi. south on the dirt road from 14.8, thence west across hay field to ledges in pasture.

15.5 Enter Wallingford quadrangle.

15.6 - 16.3 Phyllites of Ira formation; views of Vermont valley and Green Mountains across Elfin Lake.

17.2 Cross Otter Creek and railroad tracks. Ledges of Monkton formation in stream. Turn left then right following Route 140 to center of town.

17.5 Turn right (south) on Route U.S. 7 at traffic light.

18.4 - 18.6 Stop #3. Mallet facies of Dunham dolomite and lower part of Monkton formation on hill west of road.

19.0 Dunham dolomite west of road.

19.2 Hill ½ mi. east (Green Hill) is a doubly plunging anticline to Cheshire quartzite.

19.8 Stop #4. Cars may park opposite Filling Station. The exposures in the highway cut are quartzites and dolomites of the Monkton formation. By proceeding west up the hill, it is possible to see a nearly complete section through the Winooski, Danby, Clarendon Springs and Shelburne formations.

20.5 Shelburne formation to right of road.

21.2 Upper (Columbian) marble member of Shelburne formation west of road. Intermediate dolomite member of Shelburne formation east of road.

21.4 Quarry west of road is in Columbian marble.

21. South Wallingford.

22.0 Stop #5. Exposures of Danby formation in Otter Creek to left, mill and quarry on right. Walk south a few yards on Route 7 thence west over a nearly complete section through the Clarendon Springs, Shelburne, Bascom, and Beldens formations, into the lower part of the Ira formation. The south wall of the quarry shows some interesting folds in the Columbian marble. Taken as conventional drag folds, they would indicate top east whereas cross-bedding in both the underlying and overlying formations shows that tops are west.

22.2 Contact between lower (Sutherland Falls) marble member of Shelburne formation and intermediate dolomite member is exposed on west side of road.

22.4 Columbian marble west of road.

22.7 Junction (obscure) with gravel road on right. Exposures of the Beldens formation are succeeded a few yards up the hill to the west by feldspathic schists, believed to be of volcanic origin, at the base of the Ira formation.

Note: Alternate itinerary via Danby Hill starts here.

23.0 Wallingford-Danby townline.

24.0 Monkton formation west of road.

24.2 View of Dorset Mountain ahead.

24.4 Road enters Pawlet quadrangle. On the west side of a gravel pit 0.2 mi. west and 0.2 mi. north on side road is an excellent exposure of folded quartzite and dolomite of the Monkton formation.

25.0 Re-enter Wallingford quadrangle. Contact between Dunham dolomite and Monkton formation is exposed southwest of road.

25.1 - 25.3 Monkton formation west of road.

26.2 Danby formation west of road.

26.6 Danby village. Turn right (west) leaving Route 7.

26.8 Enter Pawlet quadrangle. Gorge on left (south) of road for next 0.3 mi. offers a fine exposure of Danby and Clarendon Springs formations in syncline plunging south-southwest.

26.9 Road forks, bear left.

27.3 Junction; proceed straight ahead.

27.5 Winooski dolomite.

27.7 Bridge.

27.8 Winooski dolomite.

27.9 - 28.0 Winooski dolomite with recumbent fold.

28.2 Junction; turn left on dirt road.

28.3 - 28.4 Dolomite, Clarendon Springs formation.

28.6 Junction; proceed straight ahead.

28.7 Hairpin turn, watch out for water bars.

29.2 Stop #6. At road junction. (Following Stop 6, route will continue left uphill.) Exposures at and south of road junction are pre-Cambrian gneiss. Small open knoll northwest of junction shows the Nickwaket greywacke and the lower part of the Cheshire quartzite resting unconformably on the pre-Cambrian. In the pastures farther northwest are black phyllites of the Ira formation.

29.4 Slow, cattle bar.

29.6 Stop #7. Road bends sharply right (west). The exposure northeast of the corner is pre-Cambrian gneiss. About 100 yards west across the fields are outcrops of the Shelburne formation. The fault between them probably a normal fault, predates the deposition of the Ira formation which rests unconformably on both the Shelburne and the pre-Cambrian north of Mill brook on the eastern slopes of Danby Hill. All of the formations just described are cut off on the south by a major thrust fault here trending east-west. The rocks above the thrust fault belong to the Bascom formation and may be seen cropping out near the buildings northwest of the corner and near the large barn in the fields to the east. High on the slopes of Dorset Mountain the Bascom formation is overlain by Beldens formation and that, in turn, by the Berkshire and Greylock schists on the steep upper slopes.

29.8 Views north of the Tinmouth Valley and Danby Hill.

30.3 Outcrop north of road of the Bascom formation.

30.5 Road bends sharply toward the right.

30.8 Exposures downstream from bridge are limestone and phyllite of the Ira formation. We are now below the fault plane.

31.0 Junction; proceed straight ahead.

31.2 Junction; turn left.

32.6 Junction; turn left.

33.9 Spring; park just beyond for Stop #8. Walk a few yards south on road and east up gully to base of landslide. Lower part of slide is in Beldens formation. Top of slide is in limestone and phyllite, possibly of the Ira formation. Large block at base of slike is a detached piece of the recumbent fold exposed at the top of the slide. The rock of Woodlawn Mountain west of the road belongs to the Berkshire and Greylock schists.

34.4 Stop #9. Outcrop of Beldens formation in small brook east of road is above the thrust plane, and the outcrop of Greylock schist across the small field west of the road is below the thrust plane.

34.6 Danby-Dorset townline.

36.3 Road drops sharply.

36.4 - 36.5 Ledges of Beldens formation east of road.

36.6 We have now dropped through the thrust plane. The ledges in the west of the road are of Greylock schist.

37.1 The ledges in and along the road are of Greylock schist, beneath but close to the fault plane.

37.3 Stop #10. The small knoll in the woods east of the road is a klippe of the Beldens formation resting upon Greylock schist. Farther east across the brook the main fault plane is exposed at several points and may be followed in detail for some distance to the southeast.

37.5 Greylock schist east of road, Beldens formation in distance.

37.8 Junction; turn left on paved road (Route 30)

39.0 Dorset Village.

39.3 Enter Equinox quadrangle.

40.5 Stop #11. Quarry northeast of road in Columbian marble, capped by basal beds of the Bascom formation. The quarries high on the hills to the north are also in the Columbian marble repeated in a large recumbent fold. End of trip.

Alternate Itinerary via Danby Hill

22.7 Turn right off U.S. 7 onto gravel road.

22.8 Feldspathic schist at base of Ira formation to right of road.

22.9 Enter Pawlet quadrangle.

23.0 - 23.1 Gray-black phyllites of Ira formation.

23.2 Phyllites of Ira formation to north in pastures; road turns sharply south.

23.3 Phyllite in brook.

23.4 Wallingford-Danby townline.

23.8 Junction; turn right.

24.0 - 24.4 Phyllites of Ira formation; fossiliferous limestones crop out to north on southeast shoulder of Clark Mountain.

24.5 Junction; bear left.

24.7 - 24.8 Cheshire quartzite.

25.6 Junction; continue straight ahead.

25.8 Junction; turn left (south) toward Danby Four Corners.

26.9 Junction; turn left.

27.2 One-half mile south, at the west base of Danby Hill, the Whipple member of the Ira formation rests unconformably on quartzites and dolomites of the Monkton formation.

27.6 Junction; turn right.

28.0 Danby Hill; fine panorama.

28.2 Quartzose dolomite of Ira formation to right of road.

28.3 - 28.5 Phyllites of Ira formation.

29.2 Phyllite of Ira formation southeast.

29.4 View of Dorset Mountain ahead.

29.7 Phyllite of Ira formation on left; continue straight ahead at junction.

29.8 Fine view of Dorset Mountain, rising 3,200 feet above Route U.S. 7 and 2,500 feet above the level of the Tinmouth valley which it terminates.

30.2 Junction; continue straight ahead

30.3 Junction (just beyond cemetery); bear right.

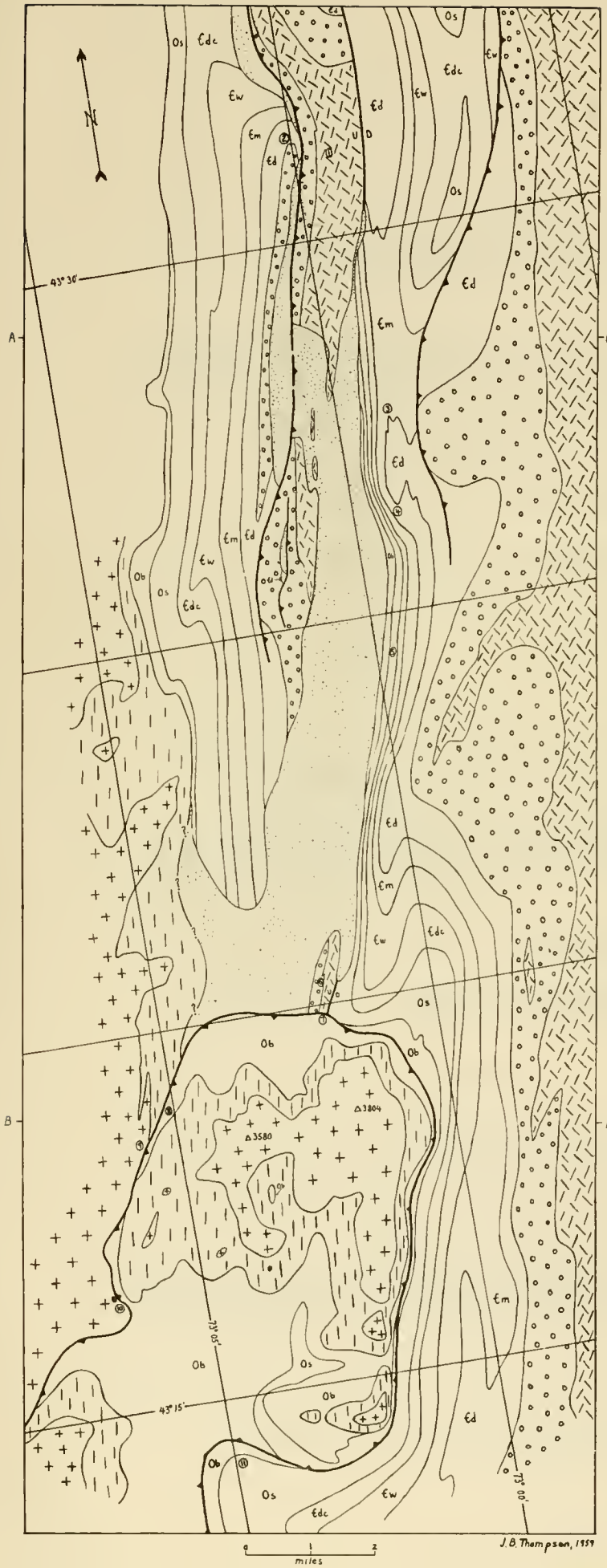
30.6 Bump (water bar).

30.7 Junction; bear right.

30.8 Phyllites of Ira formation on left. Bear left on paved road at junction just below.

30.9 Phyllite and limestone of Ira formation on left.

31.1 Turn right on gravel road at obscure junction just beyond bridge. This point corresponds to mileage 28.2 of the regular itinerary.

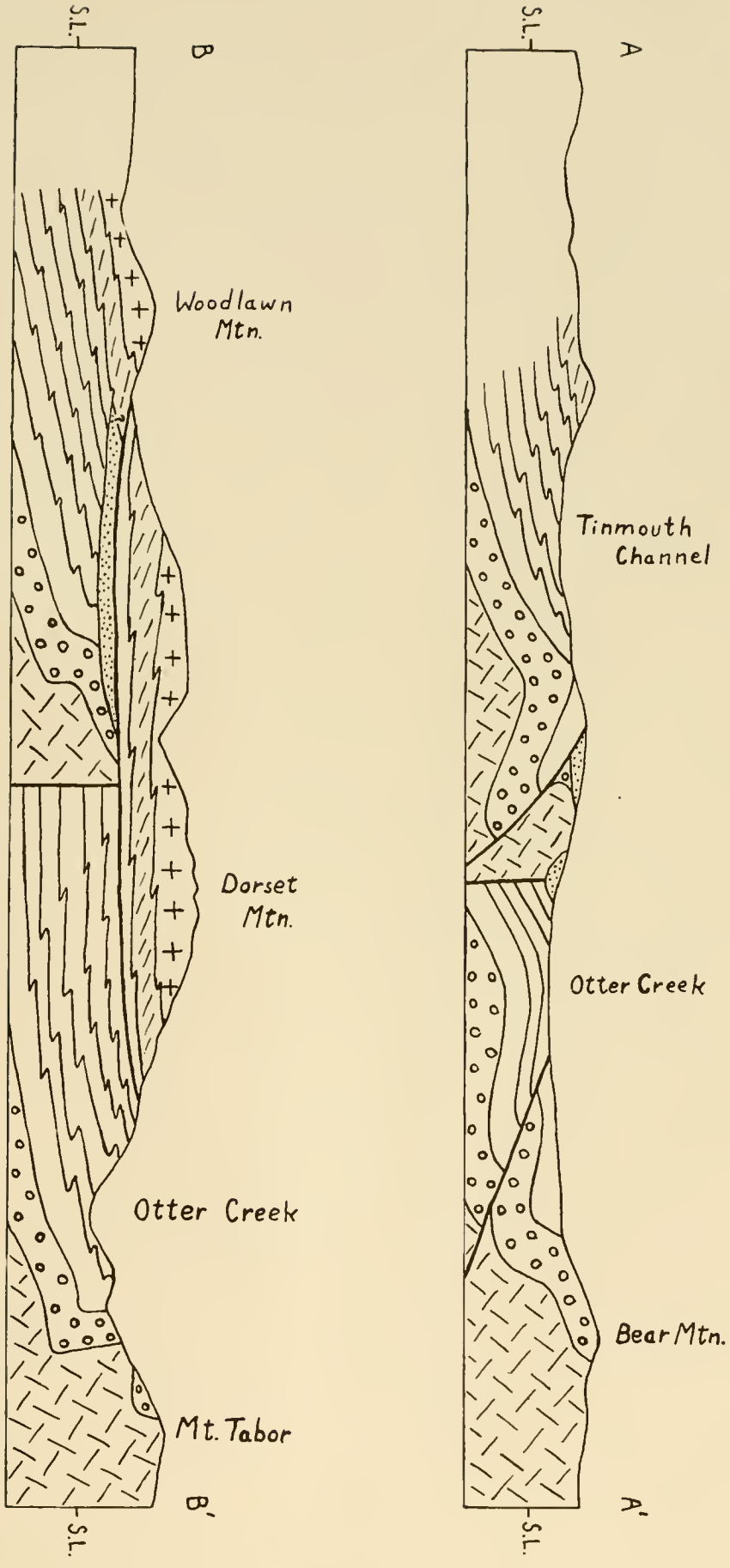


GEOLOGIC MAP OF THE VERMONT VALLEY BETWEEN CLARENDON AND DORSET

Legend:

- +++ Greylock schist
- Berkshire schist
- Ira formation
- Ob Bascom and Beldens formations
- Os Shelburne marble
- Edc Danby and Clarendon Springs formations
- Ew Winooski dolomite
- Em Monkton formation
- Ed Dunham dolomite
- Nickwackett greywacke and Cheschire formation
- Pre-Cambrian

Geology mapped in 1951, 1952, 1958 and 1959 by J. B. Thompson, assisted by G. J. F. Macdonald, S. M. Ornstein, E-an Zen and G. A. Mairs. Area north of 43° 30' modified in part from maps by P. Fowler (1950) and W. F. Brace (1953).


S.L.
B
Woodlawn Mtn.
Dorset Mtn.
Otter Creek
Mt. Tabor
B'
S.L.
S.L.
A
Tinmouth Channel
Otter Creek
Bear Mtn.
A'
S.L.