

Marble, Granite and Slate Industries of Vermont

**Isle LaMotte to Graniteville, Vermont
July 20–22, 1989**

Field Trip Guidebook T362

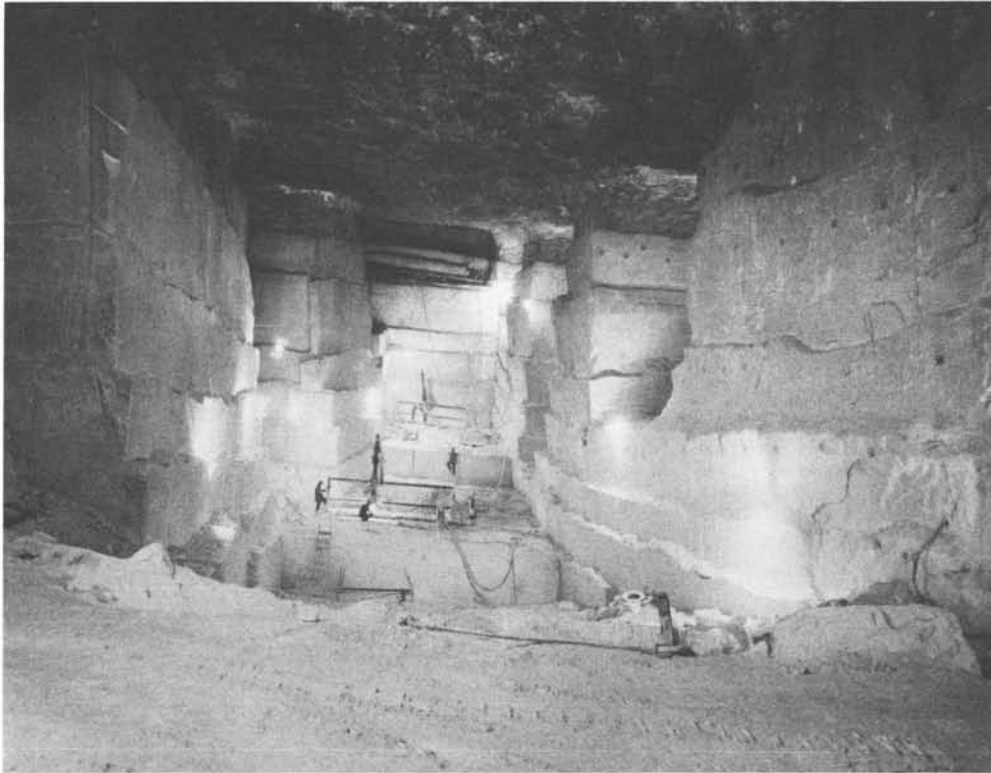
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COVER Imperial Underground Quarry, Danby, Vermont.

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**IGC FIELD TRIP T362:
MARBLE, GRANITE AND SLATE
INDUSTRIES OF VERMONT**

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INTRODUCTION

Five (5) physiographic provinces are recognized in Vermont. They are (from west to east) the Taconic Highlands, the Champlain and Vermont Valley, the Green Mountains, the Piedmont, and the Northeast Highlands (Figure 1-1). Our travels will include stops in all but the Piedmont. The geology and non-metallic mineral industries of these provinces will be briefly described. Quarrying of “true marbles” occurs today only in the Champlain and Vermont Valley province, whereas “verde antique marble” is found and quarried in the Green Mountains province. Slate, although once quarried extensively in the eastern Piedmont, is produced exclusively from rocks of the Taconic Highlands. Granitic plutons are primarily confined to the Northeast Highlands and thus the granite industry is located within this province. Scenery along the way will be enjoyed as a bonus as the field trip proceeds.

Our journey on this first day will include three (3) scheduled stops to see the old Fisk and Goodsell quarries that produced the Vermont “black” marbles. We will also visit one of the oldest limestone reefs (bioherm) in the world. Stops 4 and 5 are optional and will only be visited if time permits. Rocks exposed in highway road cuts are described in the following road log and will be discussed in more detail as we proceed on the field trip. You can follow our route on your geologic map of Vermont.

CHAMPLAIN VALLEY AND VERMONT VALLEY

The Champlain Valley and Vermont Valley are composed of sedimentary rocks of shallow marine origin. They record a history of depositional and deformational events ranging from Cambrian through Ordovician age. The Cambrian/Ordovician shelf sequence (Champlain Valley Sequence) is made up of carbonate and siliciclastic deposits. Dorsey et al. (1983, Figure 1-2) show this shelf sequence grading eastward into shales, turbidites and slump breccias of a deeper marine slope/basin environment. This Cambrian/Ordovician sequence records a major westward transgression of marine shelf/slope/basin environments. The sequence has been deformed by folds and thrust faults of Taconian age. The Champlain thrust fault carried Lower Cambrian sedimentary rocks over Middle Ordovician shales (Figure 1-3). This thrust fault is the dominant and most impressive structure in the Champlain Valley province. Mesozoic dikes of mafic composition are common in the Champlain Valley province.

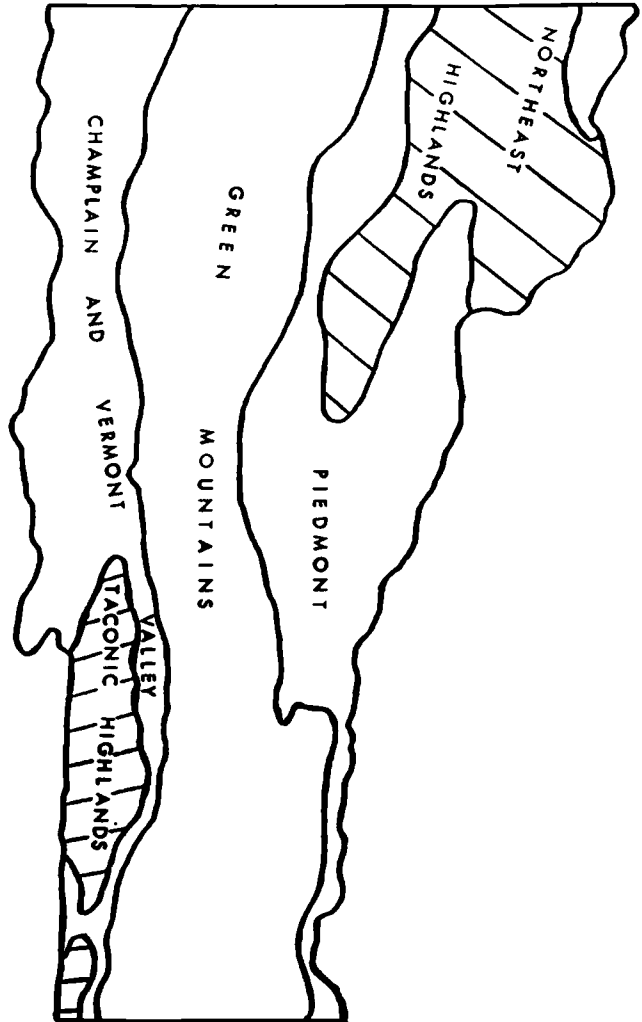


FIGURE 1-1 Generalized map of physiographic provinces of Vermont.

Much of the Vermont marble industry is located within the Champlain Valley and Vermont Valley physiographic province. Here carbonate sediments have been transformed into low grade metamorphic marbles. Tight folding has thickened the limbs of folds adding significant dimension to ore grade deposits.

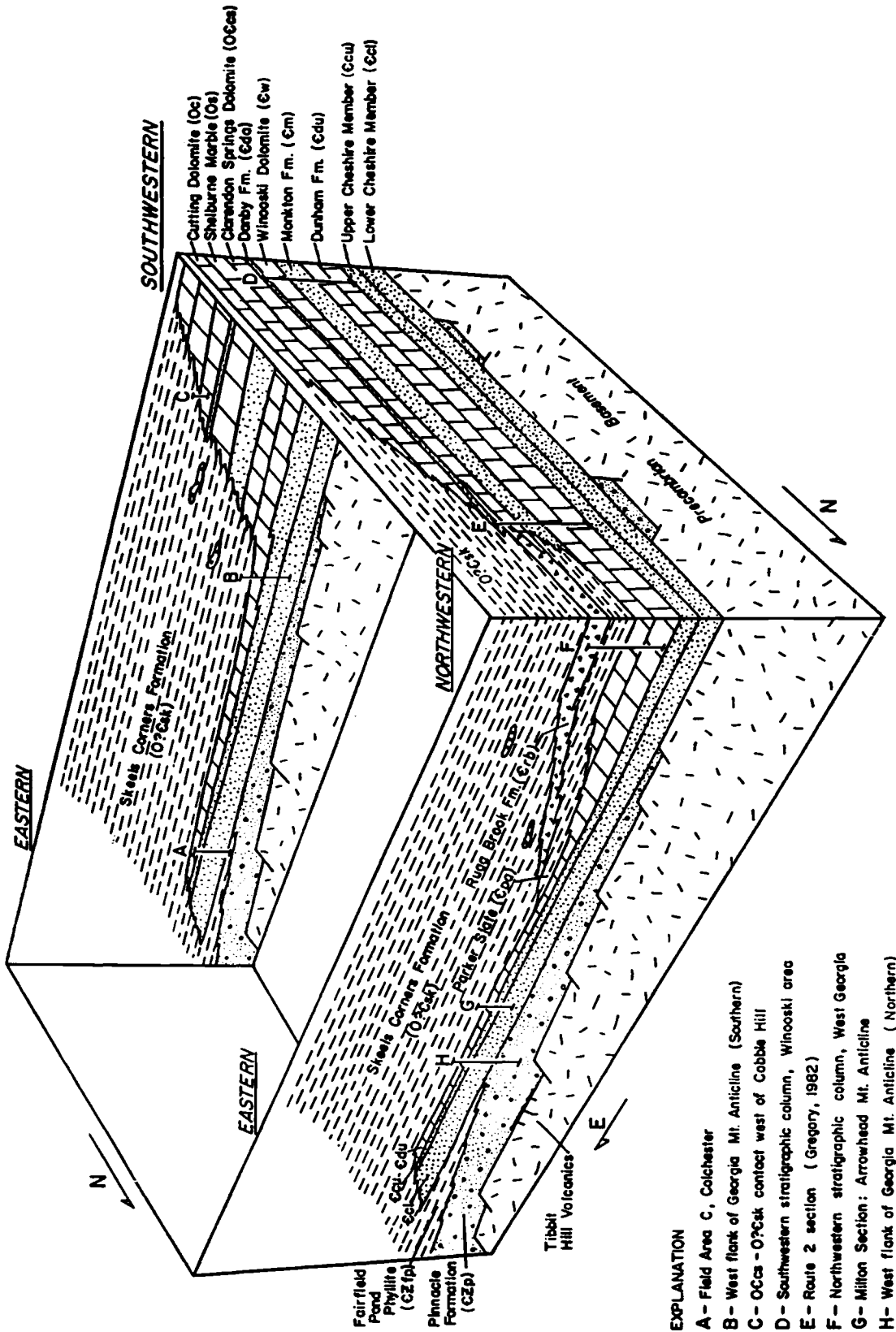


FIGURE 1-2 Block diagram (from Dorsey et al., 1983) illustrating the eastward and northward transition of shelf facies to deeper marine slope/basin facies.

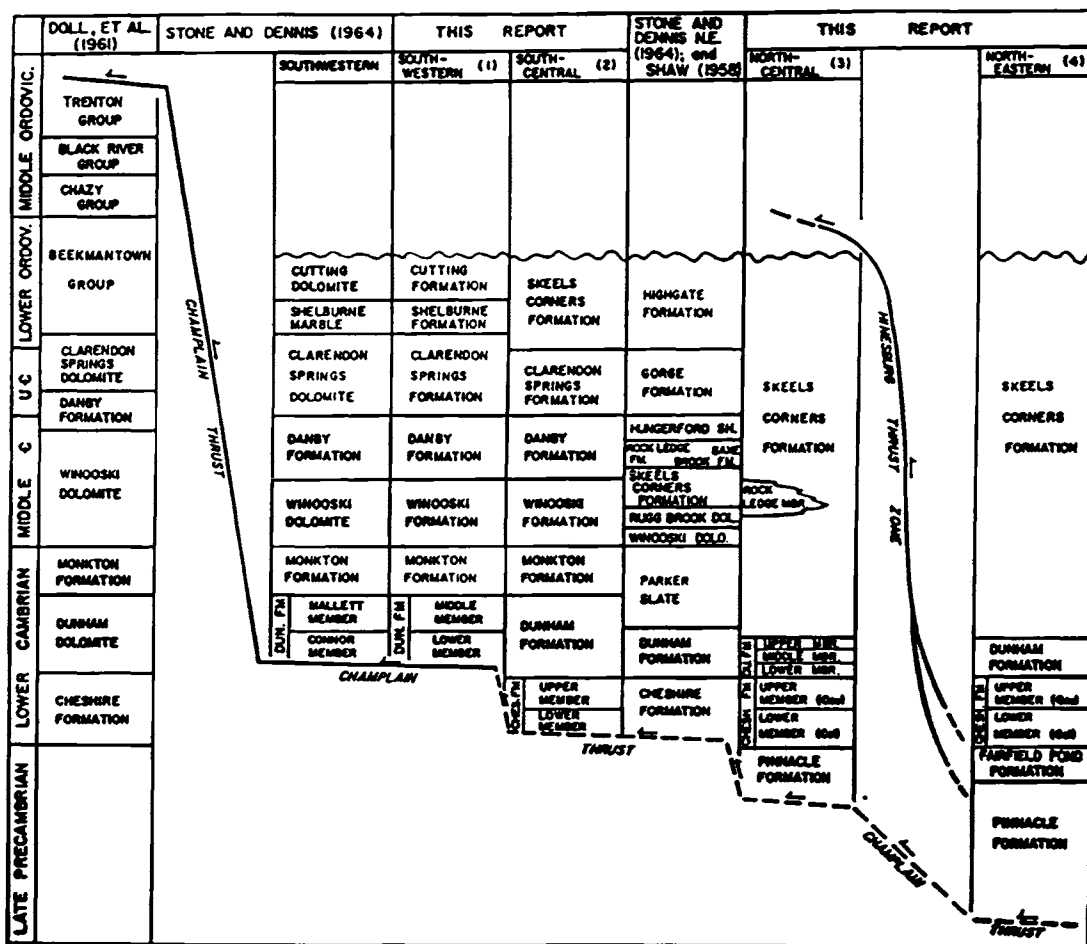


FIGURE 1-3 Correlation chart (from Dorsey et al., 1983) showing several stratigraphic interpretations of the Champlaine Valley Sequence and eastern facies. The relative positioning on the Champlaine and Hinesburg Thrusts is illustrated. This interpretation applies only to northwestern Vermont. The Champlaine thrust fault cuts upward into higher stratigraphic units to the south.

ROAD LOG FOR DAY ONE

Mileage*

00.0	Start at the entrance to the Econo Lodge, Williston Road, South Burlington, Vermont. Turn right (west) on Williston Road (U.S. Route 2).	03.3	Winooski Formation (dolostone) in roadcut.
00.3	Turn right (north) at entrance ramp to Interstate highway, I-89 North (Interchange 14).	03.8	Dark red-maroon quartzite of the Monkton Formation (€m). The Monkton Formation is composed of interbedded quartzites and sandy dolomites. Lower Cambrian fossils have been found in the Monkton Formation. The Monkton Formation is part of the shelf sequence.
01.6	Highway passes over the Winooski River Gorge (look to your right). The walls of the gorge are composed of gray dolostone of the Winooski Formation (€w)**. The Winooski Formation here is relatively flat-lying and is part of a continental shelf sequence of clastic and carbonate strata that grade northeasterly into shales and conglomerates that accumulated in a deeper basinal sequence (Figure 1-2).	05.3 to 06.6 06.9	Monkton Formation. Arrowhead Mountain (look off to the northeast) was interpreted by Stone and Dennis (1964) as an outlier (klippe) of Lower Cambrian Cheshire quartzite (€c) lying above the younger Dunham dolomite (€d) and Middle Cambrian Skeels Corner shale (€ssm) along the Hinesburg thrust fault. More recent workers in the area (Dorsey et al., 1983) after large scale, detailed mapping recognize Arrowhead Mountain geology as a shear zone (Arrowhead thrust fault) located within the recumbent limb of an anticline overturned to the west. Thus a com-

*Mileage is given in cumulative miles.

**Abbreviations are from the Centennial Bedrock Map of Vermont (Doll et al., 1961) and entered only at the first introduction of a formation name.

- bination of folding and shearing of the Cambrian sequence is the preferred explanation for the position of older strata lying above younger units of the Cambrian sequence.
- 0.74 Monkton Formation. These upper beds of the Monkton Formation are massive; the uppermost beds include two or three inch layers of yellowish weathering arenaceous shale. These top beds display mud cracks and markings that suggest trails of crawling organisms. The Monkton is interpreted as representing supra-tidal, inter-tidal and sub-tidal deposition. Other primary sedimentary structures such as ripple marks, cross-bedding, and swash-marks are common throughout the formation.
- 08.0 Lake Champlain (Malletts Bay Estuary) to the west.
- 08.5 Monkton Formation.
- 09.4 Interstate I-89, take the Exit at Interchange 17; Winooski Formation gently east-dipping.
- 09.7 Turn right onto U.S. Route 2 West.
- 10.4 Monkton Formation. Note yellowish coloration in quartzite.
- 12.9 Road parallels the Champlain thrust fault. High bluffs to the east are composed of dolostone of the Dunham Formation. Here the Dunham Formation has been thrust westward and now overlies the shales of the Stony Point (Osp) and Iberville (Oi) Formations.
- The Dunham Formation documents a transgressive sequence in this area. Dorsey et al. (1983) present the following description. A lower member consists of a stromatolitic dolomicrospar with thin shale partings and intermittent sandy dolospar beds. This lower member represents peritidal flat deposition. A middle member consists of massively bedded, highly bioturbated dolospar. Horizontal and vertical burrows are present as are occasional intraformational (rip-up) clasts. This middle member represents subtidal shelf deposition. The upper Dunham is a dolomicrospar containing channelled dolomitic quartzites, polymictic dolomitic breccias, shaley dolomites, shales and sporadically graded beds of gray and black dolomitic siltstone. These upper beds have been interpreted as representing deposition in a shelf-shelf edge-slope environment.
- 13.9 Fresh water wetlands and bird sanctuary.
- 14.5 Sand Bar State Park—Causeway connecting mainland to South Hero Island in Lake Champlain.
- 14.6 On the causeway, view to the left (south) Adirondack Mountains (in New York State), a large Precambrian massif.
- 15.9 Quarry (on left) in Stony Point shale.
- The Stony Point Formation is the dominant bedrock in the Champlain Islands. It consists of black, calcareous shale. The shales are characteristically thin bedded, slickensided and highly fissile. Thin, white calcite veins are common throughout the formation.
- 16.8 Trilobite and graptolite fossils have been found in the Stony Point shales.
- to Outcroppings and road cuts in Stony Point shale.
- 17.3
- 18.0 Town of South Hero, Vermont.
- 18.9
- to Stony Point shale, with thrust faults.
- 19.1
- 19.3 Town of Keeler Bay, Vermont.
- 24.2 Town of Grand Isle, Vermont.
- 26.6 Outcroppings of Stony Point shale.
- 27.2 Drawbridge connecting South Hero and North Hero Islands.
- 30.8 Town of North Hero, Vermont.
- 31.7 Outcroppings of Stony Point shale.
- 32.5 Cary Bay to the left (west).
- 36.2 Bridge over Alburg Passage.
- 36.5 At Town of South Alburg turn left (west) on VT Route 129 to Isle La Motte.
- 37.6 Stony Point shale outcroppings.
- 39.2 Turn left (still on VT Route 129) to Isle La Motte.
- 39.4 Bridge to Isle La Motte and Town of Isle La Motte.
- 41.8 VT Route 129 ends; go straight through this intersection.
- 43.3 Chazy (Ordovician) limestones, Valcour member (Omiv), Crown Point member (Omic), and the Day Point member (Omid). Portions of these limestones are highly fossiliferous and are considered to be representative of some of the oldest limestone biohermal reefs in the world.
- 43.6 Historical Society marker; go straight at this road intersection.
- 44.2 Bear right onto dirt road (pavement ends).
- 44.7 Small outcrops of Crown Point limestone (Omic).
- 45.1 Fisk quarry on right (approximately one (1) hour travel time to this point). Go to the second entrance road on the right.
- 45.2 Second entrance road to Fisk quarry on the right. Fisk Point on left where old loading docks once existed.
- STOP 1. THE FISK QUARRY, ISLE LA MOTTE, VERMONT**
- History and Production**
- Perhaps the oldest quarry in Vermont is the Fisk quarry. It was first operated in 1664 for production of lime (CaO) by burning (Dale, 1914). In 1788 the quarry began producing building stone. Quarry blocks were shipped by boat to the Barney Marble Company in Swanton, Vermont. The finished product was marketed as “Fisk black” and “Fisk gray”. Several other quarries have operated off and on since the middle of the 19th century. The best known are the Goodsell, Fleury and Hill quarries. Ver-

mont Marble Company purchased the Fisk and Goodsell quarries in 1901.

Production today (1988) comes only from the Goodsell quarry. Current production figures indicate an average 34,000 cubic feet were quarried annually from 1962 to 1973 (excluding the no production years of 1965 and 1966, and the no record year of 1971). Typically about 50% of the total volume quarried is of marketable quality. The Goodsell quarry was last active in 1987. Quarried blocks in reserve are expected to meet demands until 1990.

Black marble from these quarries is used primarily as an interior decorative stone. It has been used in buildings such as Radio City Music Hall in New York City, The National Gallery of Art in Washington, DC, and the Vermont State Capital in Montpelier, Vermont.

Geologic Setting

The quarry produces rock from the Fisk/Goodsell beds (Bain, 1934) within the Middle Ordovician (Chazyan) Crown Point limestone. The Fisk/Goodsell horizon ranges in thickness from 0-40 feet. Beds are massive, dark blue-black limestones characterized by masses of *Stromatocarium lamottense*. The weathered surface of this massive limestone is typically a light to dark-gray color. Rock quarried from these beds produces a "marble" which has a brilliant dark-gray to black luster when polished. It is now sold commercially as "French Gray", or "Champlain Black" marble.

In addition to *Stromatocarium lamottense* the following fossils have been identified as being common in the Fisk/Goodsell beds (Erwin, 1957):

Orthoceras vagum
Maclurites magnus
Rafinesquina incrassata
Zygospire acutirostra

A brief description of two fossils easily found and recognized in the Fisk quarry are presented below (from Welby, 1962):

COELENTERATA

Stromatoporoidea

Stromatocarium lamottense Seely

Chazyan (L. Ordovician) rocks of Isle La Motte

Calcareous Algae Colonies: Consist of layers of calcium carbonate laminae separated by short (less than 1 mm), vertical (pillar-like) structures. The colonies are massive or encrusting, ranging from a few inches up to several feet in diameter. In cross-section the light-colored laminae stand out, the darker material being a lime mud filling between laminae.

MOLLUSCA

Gastropoda

Maclurites magnus Lesueur

This large gastropod is easily recognized in Chazyan rocks. It occurs dominantly in the Crown Point limestone, but is found occasionally in both the Day Point and Valcour limestones.

Maclurites magnus Lesueur is distinguished from other subspecies by the subtriangular cross-sectional shape of the outer whorl, and the characteristic flat base as seen when the aperture is held facing the observer.

STOP 2. THE CROWN POINT REEF (BIOHERM) DEPOSIT, ISLE LA MOTTE, VERMONT, (from Erwin, 1957).

The deposit forms a low ridge, ellipsoidal in outcrop and has a northeast-southwest trend. It is about 2300 feet long and 1100 feet maximum width. Rocks of the bioherm all seem to plunge beneath the surface.

The surface of the bioherm is generally a flat, pavement-like surface with the stromatoporids and channel deposits well displayed in plan view. *Stromatocarium lamottense* and *Stromatocarium eatoni* are abundant. Nautiloids, gastropods (*Raphistoma* and *Maclurites*) and a few brachiopods are other common fauna. Fauna of the bioherm are also found in the Fisk/Goodsell beds and are considered to be contemporaneous.

STOP 3. THE GOODSELL QUARRY, ISLE LA MOTTE, VERMONT.

This is a brief stop to see the most recently active quarry. Return to Burlington, VT by returning via VT Route 129, U.S. Route 2 and Interstate I-89. At Interchange 13 take exit to South Burlington and I-189 to U.S. Route 7 South to Middlebury, VT. Destination: Rutland, VT (70 miles) Howard Johnson Motor Lodge.

ROAD LOG FOR DAY ONE. . . continued

Mileage (reset mileage)

- | | |
|------|---|
| 00.0 | Junction of Interstate connector highway, I-189, and U.S. Route 7. Turn left (south) on U.S. Route 7 toward Shelburne, VT. |
| 04.0 | Outcroppings in road cut on both sides of the highway are Winooski dolomite. |
| 04.2 | Road cut on left (east) exposes Monkton quartzite. Note the reddish color. |
| 04.7 | Town of Shelburne, VT. Continue south on U.S. Route 7. |
| 05.4 | Famous Shelburne museum on the right (west). |
| 06.6 | View to the left (east) of the Green Mountain range. |
| to | The prominent mountain in the centerground is |
| 07.8 | Camel's Hump, elevation 4,083 feet. Looking to the right (west) across Lake Champlain you will see the Adirondack Mountains in New York State. The highest elevation in the Adirondacks is Mt. Marcy, elevation 5,344 feet. |
| 08.2 | Directly ahead is Jones Hill with Pease Mtn. beyond and to the left (east). Both mountains are outliers (klippen) on the upper plate of the Champlain thrust fault. These features will be discussed at Stop 4. |
| 08.8 | On the left (east) is Monkton Formation thrust over |
| to | shales of the Iberville Formation. Note the highly contorted shales (Iberville) in the lower plate of the |
| 09.4 | Champlain thrust fault. |

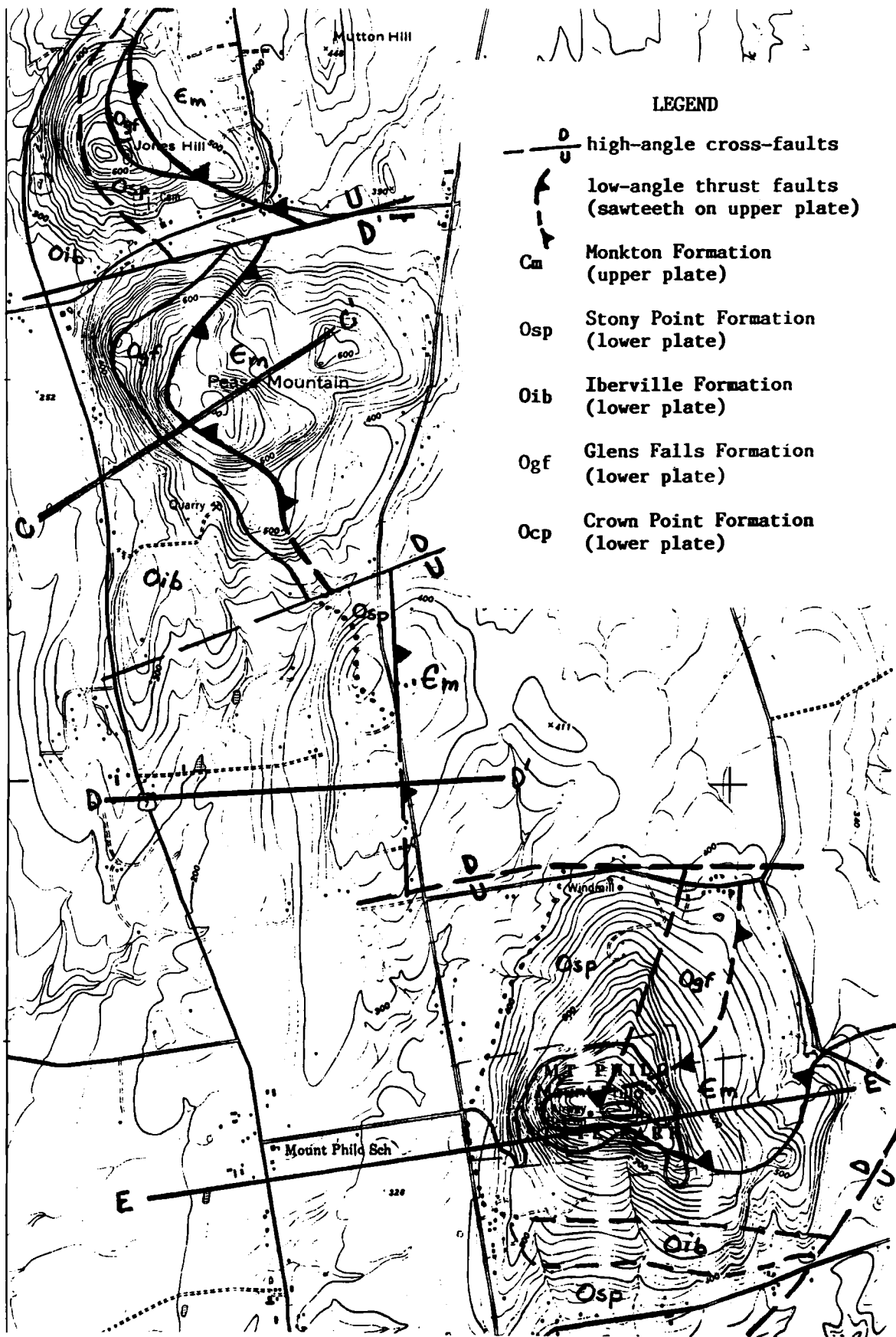


FIGURE 1-4 Portion of geologic map (modified from Welby, 1961) showing Mt. Philo and vicinity.

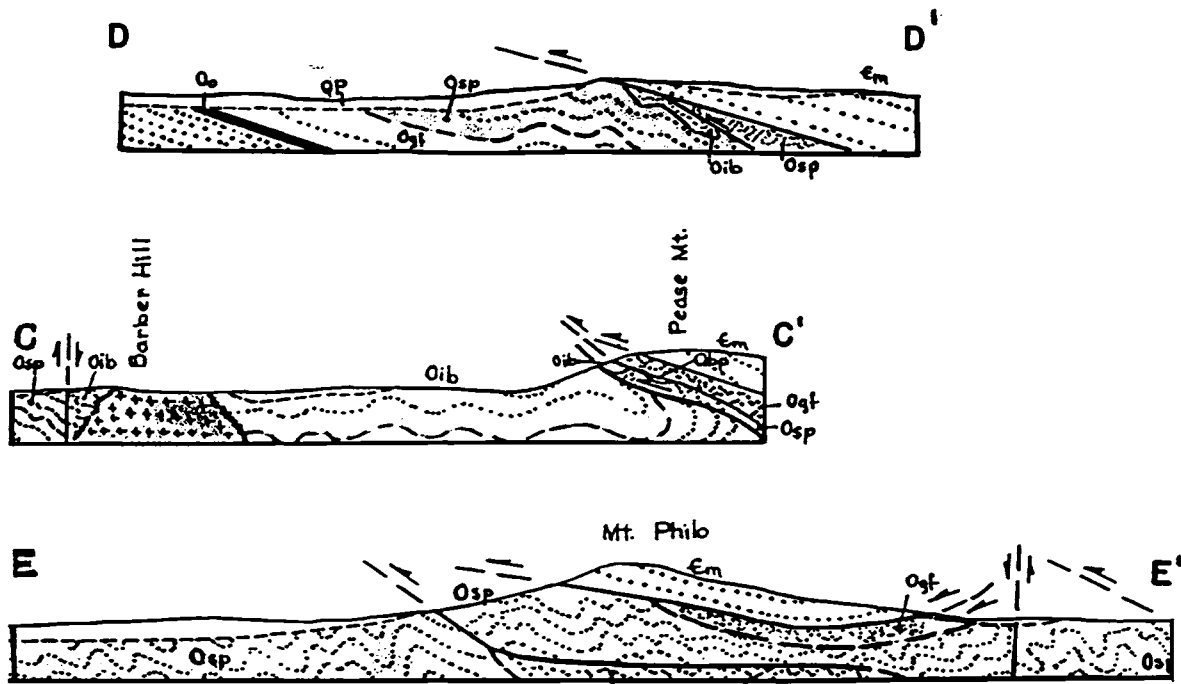


FIGURE 1-5 Cross-sections associated with Figure 1-4 (from Welby, 1961).

- 09.4 Jones Hill to the left (east).
- 09.9 Pease Mtn. to the left (east).
- 10.2 Iberville shale to the left (east).
- 11.3 Mt. Philo to the left (east) is a klippe on the Champlain thrust fault.
- 12.2 At the flashing yellow traffic light turn left (east) to Mt. Philo Road.
- 12.8 Enter Mt. Philo State Park and drive to the park at the top of the mountain.

STOP 4. MT. PHILO STATE PARK.

Observation points on Mt. Philo provide a spectacular view of the Lake Champlain valley and west across Lake Champlain to the Adirondack Mountains in New York State.

The Adirondack Mountains are composed of an elevated Precambrian (1300 Ma) massif, a complex of metamorphic and igneous rocks. Early Paleozoic (Cambrian, Ordovician) sedimentary rocks flank the eastern Adirondacks and dip gently east beneath the Champlain valley. Within the Champlain valley, these early Paleozoic rocks have been involved in major tectonic events associated with the Taconian mountain building that occurred late in Ordovician Period.

The isolated mountains that dot the landscape of the Champlain valley locate the Champlain thrust fault. These mountains are as follows: To the north (of Mt. Philo) Pease Mtn. and Jones Hill, to the south are (in order of increasing distance) Shellhouse Mtn.*, Buck Mtn.*, and Snake Mtn.*. All are erosional remnants of the Monkton quartzite resting on the Champlain thrust fault. The trace of this fault has been mapped at or near the base

*These mountains are south of Figure 1-4 and therefore not shown.

of each of these prominent features (Figure 1-4). Strike of the fault is generally north and dip is to the east. Strata in the allochthon dip gently east (Figure 1-5) and are occasionally folded into isoclinal recumbent folds (Welby, 1961). East striking cross-faults which are believed to be nearly vertical have helped to further isolate these mountainous features into tilted fault blocks (Figure 1-4). Welby (1961) has considered the Jones Hill-Pease Mtn. block, the Shellhouse Mtn. block, and the Snake Mtn. block to be grabens, while the Mt. Philo and Buck Mtn. blocks are horsts [see Figures 1-4 and 1-5 from Welby (1961)]. Welby (1961) postulates as much as 2000 feet of vertical displacement at the north end of Snake Mtn. and 1700 feet north of Mt. Philo. Coney et al. (1972) attribute an undulating fault plane as being responsible for the "offset" rather than cross-faults.

- 16.5 Return to U.S. Route 7, turn left (south).
- 17.4 County line, Chittenden Co. (north)/Addison Co. (south).
- 18.5 Highway (U.S. Route 7) crosses Lewis Creek; Iberville shale in creek bed.
- 20.2 Shale exposed in roadcut on left (east). This is probably Stony Point shale. Shellhouse Mtn. can be seen to the left (east).
- 21.5 Town of Ferrisburg, VT.
- 22.1 Highway (U.S. Route 7) crosses Little Otter Creek.
- 22.6 Railroad Crossing. Buck Mtn. and Snake Mtn. can be seen ahead on the horizon.
- 23.8 City of Vergennes, VT to the right (west) was once claimed to be the smallest *city* in the world.
- 25.5 Reddish quartzite exposed in hill to the right

- (west) is the Monkton Formation allochthonous in the Buck Mtn. sequence. Here the Monkton Formation overrides younger limestones [Crown Point (Ocp)*, Glens Falls (Ogf)*, etc.].
- 26.5 Bristol Water Gap to the left (east) with high peaks of the Green Mountains in the distance. Mt. Abraham (elev. 4052 feet) is the prominent peak.
- 28.4 New Haven Junction, VT. Junction of former Rutland Railroad (now Vermont Railway System) and the now defunct Bristol Railroad. Also, U.S. Route 7 (N-S) and Vermont Route 17 (E-W) join at this location. The OMYA, Inc.-White Pigment Corporation mills and shipping facilities are located here. This facility produces finely ground CaCO₃ (white marble). The marble is quarried at the Foote Street quarry in East Middlebury (STOP 5).
- 30.8 Pike Industries Incorporated crushed rock (highway aggregate) plant and quarries to the right (west).
- 31.3 Dog Team Road (north end).
- 32.0 Blue-gray limestone outcroppings in road cuts are the Beldens Member of the Chipman Formation (Ocb). These limestones are east of the Champlain Thrust Belt and occur within the major fold known as the Middlebury Synclinorium.
- 32.6 Highway (U.S. Route 7) crosses New Haven River.
- 33.1 Dog Team Road (south end).
- 34.2 New Haven/Middlebury Town Line.
- 36.1 Town of Middlebury, VT. Home of Middlebury College. Stay on U.S. Route 7 south through Middlebury.
- 38.9 Turn left (east) on Cady Road just before Foster Motors.
- 39.2 Turn left (north) on dirt road (Foote Street).
- 40.5 Turn right at intersection of Foote Street and Schoolhouse Road.
- 40.7 Turn right (east) at entrance to Foote St. quarry.
- 44.3 Return to Schoolhouse Rd. and turn left to junction with U.S. Route 7. Turn left (south) toward Brandon, VT.
- 50.5 Road cut on left (east) exposes Dunham dolomite.
- 54.6 Smokerise Marble quarry (OMYA, Inc.) on the left (east). This quarry also supplies white marble for the plant in Florence, VT. The quarry is hidden from view by a high berm intended to maintain more aesthetically pleasing scenery, and to subdue the noise and dust related to the quarrying process.
- 56.5 Abandoned marble quarry on left (east).
- 56.9 Town of Brandon, VT.
- 57.7 Abandoned marble quarry on left (east).
- 58.7 Marble exposed in highway road cuts and cliff faces both east and west of the highway.
- 59.7
- 61.2 The marble processing mills for the ground products at Florence, VT can be seen to the right, in the valley ahead.
- 63.3 Trucking route to Florence on the right (west).
- 64.4 Town of Pittsford, VT.
- 70.1 Roadcut on the left (east) exposes Dunham dolomite.
- 72.3 Junction of U.S. Route 7 (N-S) and U.S. Route 4 (E-W). Town of Rutland, VT.

END OF DAY ONE FIELD TRIP

DAY TWO

TACONIC HIGHLANDS

Traveling south from Rutland, VT on U.S. Route 7 the broad Champlain Valley narrows and becomes the Vermont Valley portion of the Champlain Valley and Vermont Valley physiographic province. Highlands to the east (left) are part of the Green Mountains physiographic province whose core is a large Precambrian massif. To the west (right) is the Taconic Highlands physiographic province. The highlands are capped by rocks of the Taconic allochthon known as the Taconic Sequence (Doll et al, 1961; Zen, 1964; Shumaker and Thompson, 1967; Baldwin and Raiford, 1988). This allochthon is a complex mass containing several thrust slices emplaced during Late Middle Ordovician and Late Ordovician time. Particulars concerning mode of emplacement, full dimensions, origin, and the roots of the Taconic allochthon continue to be revealed as new, more detailed investigations are conducted. This portion of the Taconic allochthon is composed of deep-water argillites containing interbeds of sandstone, graywacke and limestone. These sediments are believed to have been deposited on the distal edge of the proto-North American continental slope and rise. Approximately 450 million years ago the closing of the proto-Atlantic ocean initiated the Taconic orogeny. During this orogeny the deep-water

STOP 5. THE FOOTE STREET QUARRY, EAST MIDDLEBURY, VT.

The Foote Street quarry is operated by the OMYA, Inc.- Vermont Marble Company. This quarry supplies white marble from the Columbian Member of the Shelburne Formation (Os) for the ground products industry. Mills that process this rock for marketing are located in Florence, VT (approx. 25 miles to the south) and New Haven Junction, VT (approx. 12 miles to the north). The mill at New Haven Junction is operated by the White Pigment Corporation (see mile 28.4).

*Symbols from Welby (1961) see Figures 1-4, 1-5.

TABLE 2-1 Several interpretations of the Taconic Sequence stratigraphy.

	Baldwin & Raiford, 1988) (mod. from Rowley, 1983)	(Shumaker and Thompson, (1967)	(Zen, 1964)	(Doll et al., 1961)
MIDDLE ORDOVICIAN	WILLARD MT. GROUP			
	Pawlet Formation Mt. Merino Form.	Pawlet Greywacke and Black Slate	Pawlet Formation	Pawlet Formation (Opa)
LOWER ORD.	MT. HAMILTON GROUP			
	Indian River Slate	Indian River Slate	Indian River Slate	Mt. Hamilton Formation(Omh)
UPPER CAMBRIAN	Poultney Slate	Poultney Slate	Poultney Slate	
	Hatch Hill Formation	Hatch Hill and West Castleton Formations (undif) Hatch Hill Formation		
MIDDLE CAMBRIAN	West Castleton Formation	West Castleton and Hatch Hill (undivided) West Castleton Formation	West Castleton Formation	Hatch Hill and West Castleton Formation (€hw) (undif)
	“transition zone” Middle Granville Slate			
LOWER CAMBRIAN	Brown's Pond Formation			
	NASSAU GROUP	St. Catharine Formation	Bull Formation	St. Catherine Formation (€sc)
	Bull Formation		Metawee Slate	Bomoseen Gwacke
	Truthville Slate		Zion Hill Qtzite	Zion Hill Qtzite
	Mudd Pond Quartzite	Netop Formation	Bomoseen Greywacke	Breeze Formation
	Bomoseen Member		Biddie Knob Formation	(€br)
	Zion Hill Member			

sediments (Taconic Sequence) were thrust westward in several slices that were emplaced on the carbonate sediments of the shallow-water continental platform (Champlain Valley Sequence). Table 2-1 illustrates progressively more detailed attempts at interpreting the stratigraphy of the Taconic Sequence.

Our first stop will be at the Vermont Marble Company—OMYA, Inc., Imperial quarry in Danby, Vermont. The productive horizon in the Imperial Marble quarry is in the Shelburne Formation. This formation lies below the Taconic allochthon and is considered to be, therefore, within the Champlain Valley Sequence. Rocks of this Sequence, as indicated earlier (DAY ONE), were complexly folded during the Taconic orogeny.

Our second stop on this field trip will be at the Vermont Structural Slate Company Eureka quarry in Fair Haven, Vermont. The quarry is located in the Vermont/New York slate belt. These rock formations form a coherent stratigraphic sequence now recognized as part of the Taconic allochthon and are thus included in the Taconic Highlands physiographic province.

ROAD LOG FOR DAY TWO

Mileage

0.00	Leave Howard Johnson's Motor Lodge, Rutland, VT and proceed south toward Danby, VT.
04.8	Bridge crosses the Mill River. Rock exposed in the road cut and median is dolomite of the Dunham Formation.
05.3	
07.2	Outcroppings of Dunham dolomite on the left (east).
07.8	Town of Wallingford, VT.
08.3	Small building on left (east) constructed of dolomite blocks from the Dunham Formation.
09.8	White cliffs and talus slopes in the distance on the left (east) are steep, westerly dipping beds of Cheshire Formation. Major rock falls and rockslides have occurred here in late and post Pleistocene time. The area is now preserved as the White Rocks National Monument in the Green Mountain National Forest.

- 10.3 Large, fresh road cut on the right (west) is Dunham dolomite. This fresh exposure clearly displays the cream colored beds of dolomite.
- 11.8 Little village of South Wallingford, VT.
- 12.8 Large quarry on the right (west). This quarry is owned by the OMYA, Inc.-White Pigment Corp. The quarry supplies the ground products industry with 30 to 50 thousand tons of selected high calcium, white marble from the Columbian Member of the Shelburne Formation. The dark colored overlying marbles are used for crushed highway aggregate.
- 13.8 Scenery is a typical view of the narrow Vermont Valley physiographic province. The Green Mountain front to the east (left) is buttressed by the highly resistant quartzites of the Cheshire Formation. The high Taconics are illustrated by Dorset Mountain to the right (west). Tightly folded beds and perhaps thin fault slices of the Champlain Valley Sequence underlie the narrow Vermont Valley.
- 16.2 Thin-bedded carbonate rocks of the Danby Formation (Єda) exposed on the right (west).
- 17.0 Danby, VT. Turn right to center of town.
- 17.2 Center of small village of Danby, VT, turn left (south) to the Imperial Marble quarry.
- 17.8 Turn right to quarry road.
- 18.4 Turn right again to quarry road. This is a narrow, steep road to the quarry entrance.
- 19.3 Entrance to the Imperial Marble Quarry.

STOP 1. IMPERIAL QUARRY, DANBY, VERMONT

Brief History and Geology

The Imperial quarry is located on the east flank of the northern part of Dorset Mountain in the town of Danby, Rutland County, Vermont. The entrance to this quarry (claimed to be the largest underground marble quarry in the world) is 1,350 feet above sea level. The quarry tunnel was begun in 1903 by Vermont Marble Company of Proctor, Vermont. The quarry has been in continuous operations since that time. According to Dale (1914, page 103) the original tunnel was driven into the mountain from its east flank and directed N70° W for 160 feet and then N10° E a distance of 45 feet to reach production quality stone. The present entrance to the underground quarry enters directly on the productive horizon and is directed southerly, down the plunge of the fold structure that contains the high-quality marble layers.

The Imperial layers vary in thickness from 30 to 75 feet and lie in a broad trough that plunges 8 degrees to the south. The layers belong to the Columbian Marble Member of the Shelburne Formation of Lower Ordovician age (Figure 2-1). The marble is massive, white, and medium textured. Green and dark streaks and mottlings contain pyrite, chalcopyrite, muscovite and chlorite. Gold and bronze streaking is due to the presence of sericite and phlogopite. The productive layers are consistent in physical character throughout the quarry and are identified by the let-

ters A through H (Figure 2-2). Each layer is also given an identifying/marketing name such as "Royal", "Imperial", "Montclair", "Highland", etc. These names are also shown on Figure 2-2.

The size of the present quarry area is over 20 acres. The underground opening (room and pillar construction) averages 500 feet wide, is 2600 feet in length and averages 40 feet in height.

It is appropriate here to mention a few of the prominent buildings where marble from the Danby, Vermont quarry was used:

- Washington, DC—Old Senate Office Building—1905
- Washington, DC—Jefferson Memorial—1939
- New York, NY—United Nations Building—1955
- Tiawan—Chiang Kai-Shek Memorial—1979
- Saudi Arabia—Sama Bank Building—1983

Return to U.S. Route 4 (West) south of Rutland, Vermont by returning north on U.S. Route 7.

The Vermont/New York Slate District

The geology of the Taconic klippe (allochthon) has challenged mapping and interpretive skills of the geologic profession for years and debate continues with regard to structural detail, timing and method of emplacement, and location of the roots of the allochthon. A special field trip offered at this International Geological Congress (Zen, Field Trip No. T-359) will devote much of its attention to this area and the questions proposed.

The Fair Haven, Vermont area and the Vermont/New York Slate Mining District lie fully within the Taconic allochthon. We will visit Vermont Structural Slate Company's Eureka quarry and milling operations. Slate in the Eureka quarry represents the typical green and purple colored slates for which Vermont is famous.

ROAD LOG FOR DAY TWO . . . continued

Mileage (reset mileage)

- 0.00 Junction of U.S. Route 7 (N-S) and U.S. Route 4 (E-W). Head west toward Fair Haven, VT on U.S. Route 4.
- 03.8 For the first 5-7 miles U.S. Route 4 crosses the Champlain Valley and Vermont Valley physiographic province underlain by folded and faulted Cambrian and Ordovician limestones (marble), dolomites and quartzites of the Champlain Valley Sequence.
- 04.0 Towns of Center Rutland and West Rutland, Vermont. The main quarries and mills of the Vermont Marble Company once flourished in these communities. In the 1970's the company concentrated its operations with milling of dimension stone in Proctor, Vermont, 6 miles north, and ground products at Florence, Vermont, 10 miles north. The quarries and mills in West Rutland are now idle.
- 05.0 View to the west. Highway follows the Castleton River Water Gap. High elevations to the left (south) are Bird Mountain (elev. 2216') and Herrick Mountain (elev. 2726') far left; to the right (north) is Grandpa Knob (elev. 1976').

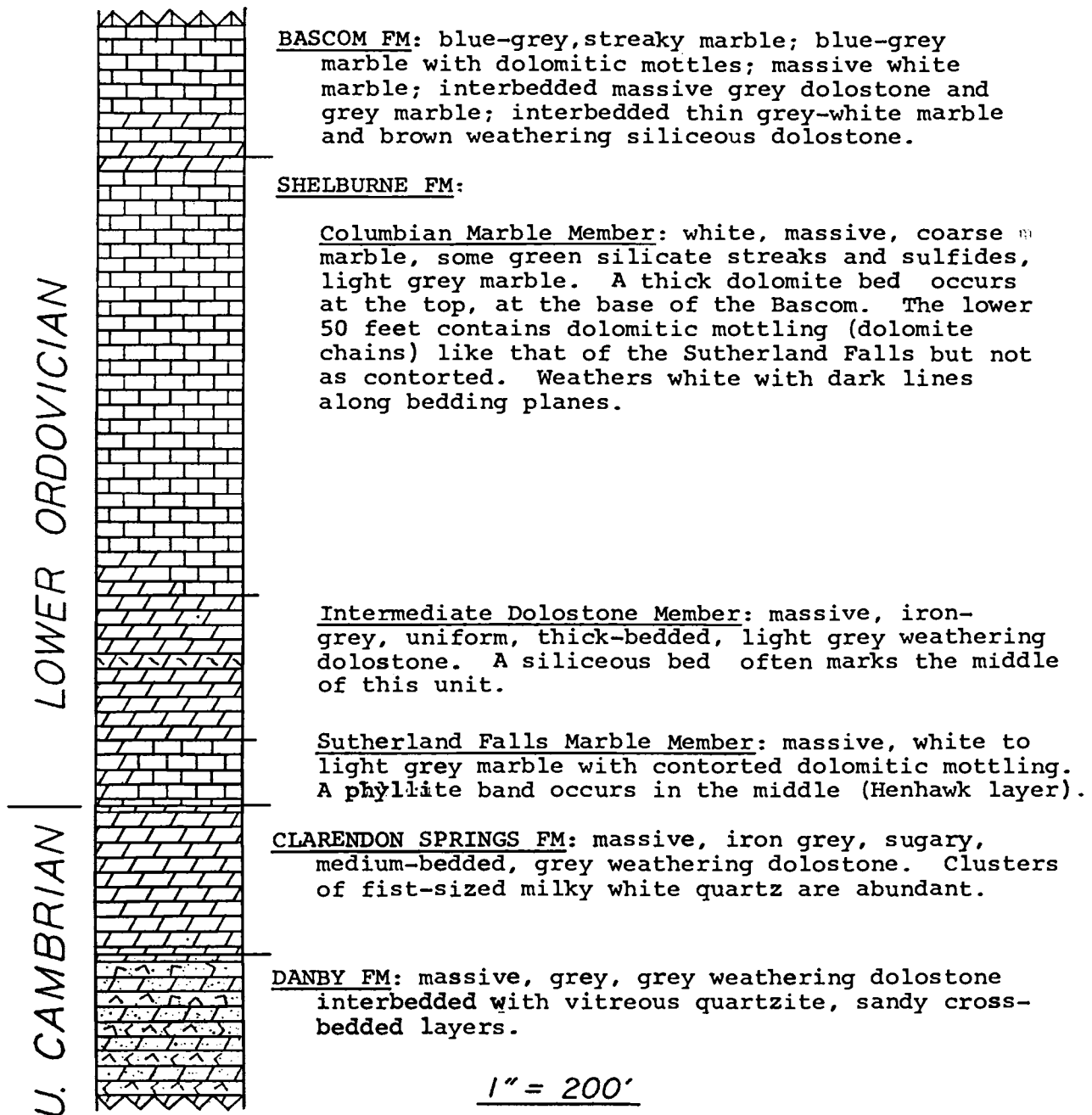


FIGURE 2-1 Columnar section of the Vermont marble layers.

06.0	Road cuts are all in the St. Catherine Formation to (€sc)*. Note in particular the green and purple	12.2
12.0	Slate (Mettawee Slate Facies of the Bull Formation, see below*).	12.3

*The St. Catherine Formation (€sc) shown on the Centennial Bedrock Geology Map of Vermont (Doll, 1961) has more recently been renamed the Bull Formation and is considered to be Lower Cambrian in age (Zen, 1964). This formation will be discussed in more detail at STOP 2, The Eureka Quarry. Also see Table 2-1.

Take exit ramp at Interchange 3 to West Castleton Road. Turn left to Fair Haven, Vermont. Town of Fair Haven, Vermont. Pass by the village green (on your right-west) and drive south on Vermont Route 22A, which dips downhill, crosses the Castleton River, crosses the railroad tracks and goes immediately uphill. U.S. Route 4A bears to the right. Turn left (east) onto Bolger Road. Fork in the road, bear left. Entrance to the Eureka quarry of the Vermont Structural Slate Company.

DANBY QUARRY
SECTION SHOWING LAYERS
AND VARIETIES

MARCH 15, 1965

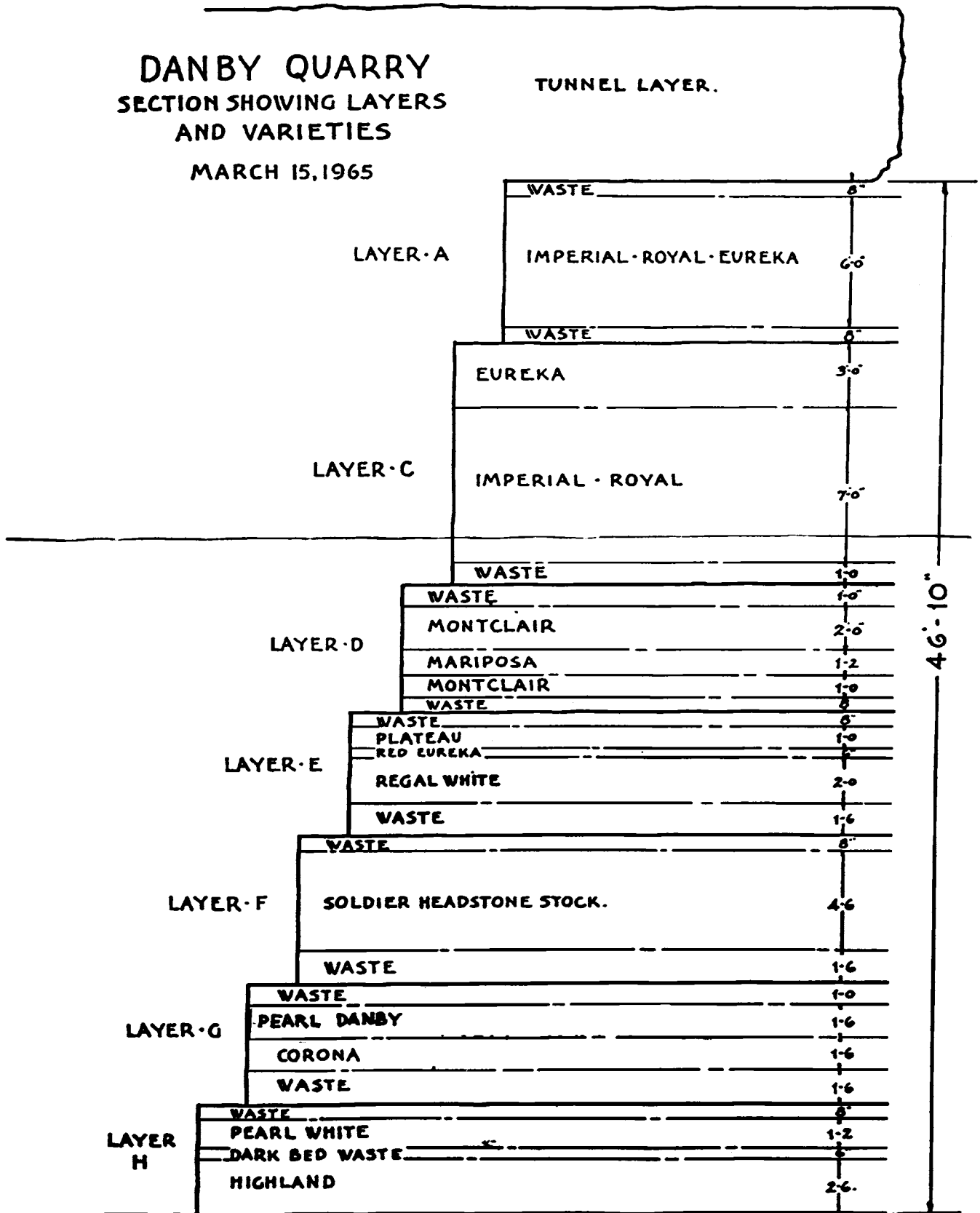


FIGURE 2-2 Descriptive section of layers and commercial varieties of marble, Danby, Vermont.

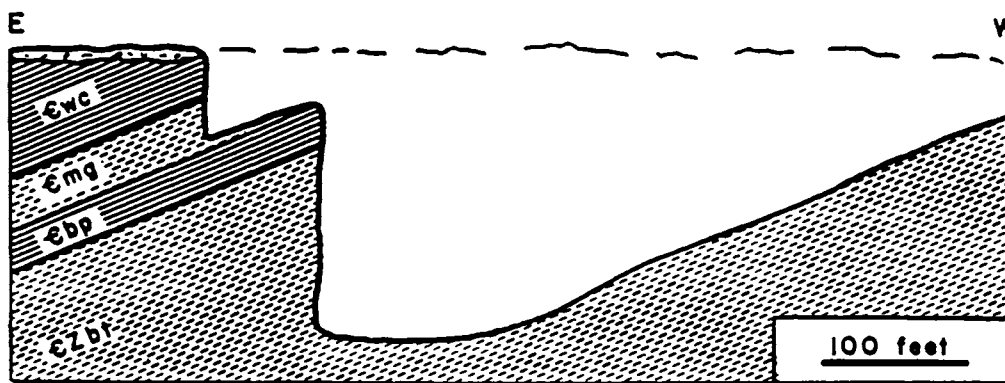


FIGURE 2-3 Cross-section and stratigraphy of the Eureka quarry. €Zbt, Truthville, Slate; €bp, Brown's Pond Formation; €mg, Middle Granville Slate; €wc, West Castleton Formation (see Table 2-1). The green and purple slates are quarried from the Truthville and Middle Granville. Black slates in this quarry are not considered of commercial quality.

STOP 2. THE EUREKA QUARRY, VERMONT STRUCTURAL SLATE COMPANY.

Geology

The following description and Figure 2-3 are modified from the presentation in Baldwin and Raiford, 1988, page G7.

The Eureka quarry exposes the east-dipping, upright sequence of the upper part of the Nassau Group and the lower part of the Mount Hamilton Group (Table 2-1 and Figure 2-3). The main quarry is in the Truthville Slate Member (€Zbt) of the Bull Formation, and the Brown's Pond Formation (€bp) constitutes the top 15 feet of the main quarry wall. This part of the section must be viewed from the north rim, near the splitting shed.

In the upper quarry, the lower 20 or 30 feet is the Middle Granville Formation (€mg). The upper half of the upper quarry face is black slate and thin limestone of the West Castleton Formation (€wc). A fault, about parallel to the contact, extends along the quarry face.

Quarrying and Milling (modified from Watson et al, 1980).

Slaty cleavage of the Vermont/New York slate beds characteristically has high angles of dip (30° to 90°). The beds also are broken by joints and faults. Veining and quartz clustering and other mineral discolorings are not uncommon. The slate splits readily parallel to the cleavage and also splits less readily along the "grain". This results in problems of finding consistently large areas of high quality slate from which uniform blocks can be quarried. This fact has an important influence on the method of quarrying. Although, various quarrying techniques (drilling and broaching, wire saw) have been attempted, essentially all of the quarries produce their blocks by drilling and blasting followed by manual splitting.

Quarry slabs or blocks are loaded onto haul trucks either by power shovel or front-end loaders. Some quarries use a crane or power boom. The block of slate is loaded into a bucket or secured in a wire sling and lifted from the quarry. Quarry blocks are unloaded in front of the roller conveyor at the intake end of the mill. In the early fall quarry blocks are stockpiled in a storage shed for processing during winter months when quarrying ceases.

Roofing Slate. The quarry block is cut by diamond saws and sculpted to the correct thickness of an "eighter" by the block-maker. An "eighter", when split, will yield eight roofing slates of standard thickness.

The eighters are then transported by conveyor to the splitting stations. The splitter uses a splitting knife or wedge and hammer and first splits the eighter in half. Each half is split in half until eight roofing slates (shingles) are created.

The shingles are then individually trimmed to the exact width and length desired on a dressing machine. This machine is a long rotating blade which is driven by a motor or is operated manually with a foot treadle.

Finally, the shingles are punched for mounting holes. The punching machine is driven by a foot pedal. The finished roofing slates are stored on transportation pallets ready for delivery to the customer.

Flooring Tile and Flagging. Quarry blocks are inspected for quality and marked for either floor tile or flagging. A multi-bladed diamond saw then cuts the blocks into the desired width, after which they are hand split into the desired final thickness. At this point flagging is a finished product.

To produce floor tile each tile must conform in thickness and requires gauging. The tiles are run through a planer which reduces the tiles to a uniform thickness.

Structural Slate. All slate products except those discussed above are considered "structural" slate. These would include fireplace mantles, electrical panels, window sills, etc. Production of each product will vary somewhat in the production method. Sawing, splitting, polishing etc. will be accomplished by making the proper adjustments to the various mechanized equipment to be used.

Each of the above operations will be visited at the Vermont Structural Slate Company quarry and mill.

Return to U.S. Route 4 East. Exit at West Rutland, Exit 6. At the end of Exit 6 ramp turn right (east) on U.S. Route 4A.

Go 2 miles to VT Route 3 north. Turn left (north) onto VT Route 3. Go approximately 5 miles to Proctor, Vermont. Follow signs to Marble Exhibit.

STOP 3. THE VERMONT MARBLE EXHIBIT (optional/time permitting).

END OF DAY TWO FIELD TRIP

DAY THREE

GREEN MOUNTAINS

Introduction

The Green Mountains are the dominant topographic feature in central Vermont, often referred to as the “backbone” of the State (Figure 1-1). This mountain range consists of several high, nearly parallel ridges and peaks with narrow intervening valleys. The ridges and valleys are oriented approximately north-south and extend the entire length of the State, approximately 160 miles. The Green Mountains are a part of the Appalachian Mountain System, and are a northern extension of the Eastern (North American) Overthrust Belt. The width of the mountain range averages approximately 25 miles. The highest peak in the Green Mountains is the “Chin” at Mt. Mansfield (4,393’). Other prominent mountain peaks we will see on this field trip are Camel’s Hump (4083’) and Pico Peak (3967’).

Geology

The Green Mountains constitute a belt of complexly folded and faulted metasedimentary and metavolcanic rocks of Precambrian and Early Paleozoic age. The metamorphic history of these rocks is complex. Pre-Paleozoic metamorphism probably reached sillimanite grade. The rocks were later subjected to lower-grade metamorphism during the Taconian and Acadian orogenies. The pelitic rocks now record post-peak metamorphism with chlorite, albite and muscovite as prominent minerals. Garnet and biotite porphyroblasts are not uncommon. Quartz is ubiquitous (O’Loughlin and Stanley, 1986, p. 9). The central Green Mountains contain many lenses of serpentized ultramafic rocks that yield talc, soapstone, asbestos, and verde antique. These serpentinite bodies form a zone that trends northerly to the large asbestos deposits at Thetford Mines in Quebec, Canada. Along with associated pillow basalts, cherts and argillites, these rocks constitute a slice of ancient oceanic crust, emplaced as an accretionary mass on the margin of an ancient continent (Baldwin, 1982). Table 3-1 describes the stratigraphy of the Green Mountains as presented by Doll et al., (1961).

ROAD LOG FOR DAY THREE

Mileage

0.00 Junction of U.S. Route 4 and U.S. Route 7. Go east on U.S. Route 4.

- 01.2 The first 4 to 5 miles cross Lower Cambrian Formations (members of the Champlain Valley Sequence) i.e., Dunham dolomite, Monkton quartzite, Winooski dolomite, Cheshire quartzite and Dalton Formation (€dt). The rock exposed near the athletic field on the right is Winooski dolomite.
- 03.5 Cheshire quartzite on right.
- 03.7 Cheshire quartzite grades into the quartzites and schists of the Dalton Formation.
- 04.8 Sheared and jointed Cheshire/Dalton Formations near the Cambrian/Precambrian unconformity. U.S. Route 4 for the next 6 miles crosses undifferentiated schist, quartzite, marble, and gneiss of the Precambrian massif. These rocks are all included in what has been called the Mount Holly Complex (p€m). Some of the higher peaks in the state are composed of these Precambrian rocks.
- 08.5 Pico Peak (elev. 3967’) can be seen off to the right (south). A major ski resort occupies the north and west slopes of this mountain. We are now entering the Green Mountain physiographic province often referred to as the “backbone” of the State of Vermont.
- 10.5 Entering the Town of Sherburne, VT. Junction of U.S. Route 4 and VT Route 100. Turn left (north) on VT Route 100.
- 13.0 Contact (unconformity) between Precambrian (Mt. Holly) and Cambrian (Dalton Fm.? Tyson Formation, Ct?) on the east flank of the massif, predominantly quartzites.
- 14.5
- 15.3 Hoosac Formation (€ho) on right (east); black carbonaceous phyllite.
- 16.7 Pinney Hollow Formation (€ph) on right (east); silver-green chlorite schist.
- 18.3 Town of Pittsfield, VT.
- 19.5 Ottauquechee Formation (€o), on left (west); black carbonaceous schists.
- 20.2 Ottauquechee Formation.
- 21.2 Junction of VT Route 100 and VT Route 107. Bear left on VT Route 100.
- 21.5 Stowe Formation (O€s) on left (west); chloritic schist.
- 21.7
- 21.9 Sharp right turn onto bridge that crosses the White River. The high ridge ahead and to the left (west) is made up of black carbonaceous phyllite and schist of the Ottauquechee Formation. Two old, abandoned verde antique and/or talc quarries are located on this ridge.
- 22.3 Sharp left turn in village of Stockbridge, VT.
- 23.6 Road-cut on the right (north) exposes black carbonaceous schist of the Ottauquechee Formation.
- 24.4 Rochester/Stockbridge Town line.

TABLE 3-1 Stratigraphy of the Green Mountains and Northeast Highlands.

Middle Devonian	}	New Hampshire Plutonic Series, nhu. (undifferentiated granitic rocks)
		Gile Mountain Formation, Dg. (grey micaceous quartzite, quartz-muscovite schist, micaceous crystalline limestone).
Lower Devonian	}	Waits River Formation, Dw, Barton River Member, Dwb. (grey quartzose, micaceous crystalline limestone which weathers to a distinct brown earthy crust interbedded with grey quartz-muscovite phyllite or schist).
		Northfield Formation, DSn. (dark grey to black quartz-sericite slate or phyllite).
Upper & Middle Silurian	}	Missisquoi Formation, Moretown Member, Omm. (quartzite, quartz-plagioclase granulite with thin "pin-stripe" partings of muscovite, chlorite, and epidote.)
Ordovician		Stowe Formation, OEs. (quartz-chlorite-sericite schists with greenstone and amphibolite).
Cambrian	}	Ottauquechee Formation, Eo. (black carbonaceous phyllite or schists).
		Pinney Hollow Formation, Eph. (pale green quartz-chlorite-sericite phyllite or schists).
		Hoosac Formation, Eho. (quartz-sericite-albite-chlorite schist).
Precambrian	}	Tyson Formation, Et. (feldspathic quartz-sericite schist with chlorite, biotite and carbonate).
		Mt. Holly Complex, pEm. (undifferentiated gneiss, quartzite, and calcsilicates).

- 24.6 to 24.8 Greenstone of the Pinney Hollow Formation.
- 27.1 Pinney Hollow Formation. Talcville, abandoned talc mines in hills to the east. Prospered until the flood of 1927 that washed out railroad bridges.
- 28.7 Intersection with VT Route 73 (west), Brandon Gap road and VT Route 100, proceed north on VT Route 100. Pinney Hollow Formation on right (east).
- 29.7 Town of Rochester, VT.
- 30.5 Fresh road cut in greenstone of the Pinney Hollow Formation.
- 31.5 Quarry Road to the right. Turn right on Quarry Road, 1.5 miles to the Vermont Marble Company—OMYA, Inc. verde antique quarry.
- 32.1 Bear left, continue uphill.
- 33.0 Quarry entrance.

STOP 1. THE ROCHESTER VERDE ANTIQUE QUARRY, ROCHESTER, VT.

Geology of Verde Antique

Verde antique is the commercial name for "marble" derived from highly sheared ultramafic rocks that have been rewelded and metasomatized by the process of serpentinization. Numerous lense shaped serpentinite bodies of varying size occur along the spine of the Green Mountains. These ultramafic bodies are almost exclusively associated with a belt of black carbonaceous schists of the Ottauquechee Formation. However, carbonaceous schists of the Missisquoi Formation (Omc) (Omm), the Hoosac Formation and the Stowe Formation are hosts to several serpentinite bodies. The ultramafic bodies, once thought to be of igneous intrusive origin, are now recognized as segments of ancient oceanic crust occurring as fault slices within the complex geology of an accretionary wedge that became part of the eastern North American continent during the Taconian orogeny. In addition to the production of verde antique, these serpentinized ultramafic rocks are host to valuable talc and asbestos deposits.

Production

Average annual production of verde antique in recent years has been 40,000 cubic feet. Average recovery of mined quarry blocks is 50%. Current reserves are confirmed (by core drillings) as 3.3 million cubic feet or approximately a 65 year supply.

Current production comes from the northern extension area 50'x80'x140' deep (25th floor*), and the western extension area 30'x68'x44' deep (8th floor). The old quarry to the south was quarried to a depth of 148'. Future plans are to quarry in three stages:

1. Stage 1 will excavate to 198' (36 floors).
2. Stage 2 will excavate a southeast block (60'x90") to a depth of 198' (36 floors.).
3. Stage 3 will excavate an eastern block 40'x180' to a depth of 230' (42 floors), and extend Stages 1 and 2 to the 42nd floor.

It should be noted that chromite, $(Mg,Fe)Cr_2O_4$, has been found in significant quantity in this quarry.

Return to Vermont Route 100.

- 34.5 Turn right (north) on VT Route 100.
35.8 Ottauquechee Formation on left (west).
36.6 Town of Hancock, VT.
37.0 Ottauquechee Formation on left (west).
37.6 Pinney Hollow Formation on left (west).
38.4 Pinney Hollow Formation on left (west).
41.0 Town of Granville, VT.
41.3 Ottauquechee Formation on left (west).
42.2
to Granville Gulf. Cliffs on both sides of the road are
44.8 Pinney Hollow Formation.
43.8 Waterfalls.
46.6
to Greenschist of the Pinney Hollow Formation.
51.3
51.5 Town of Warren, VT on right (east).
62.2 Junction of VT Route 100 and VT Route 100 B. Go straight (north) on VT Route 100 B. Ottauquechee Formation/Stowe Formation contact.
62.7 Bridge across the Mad River. River gorge cuts through Stowe Formation.
63.3 Town of Moretown, VT.
65.7 VT Route 100 B crosses road-cuts and exposures of pale green, quartz-sericite-chlorite phyllite and schist, and greenstones typical of the Stowe Formation.
70.1
70.1 Junction of VT Route 100 B and U.S. Route 2. Turn left (west) on U.S. Route 2.
70.5 Turn right (north) to entrance ramp to Interstate Highway, I-89 south.

- 70.6 Turn right (east) on entrance ramp to Interstate Highway, I-89 south.
72.3 Missisquoi Formation, Moretown Member, typical interbedded quartzite, quartz-plagioclase granulate, and quartz-sericite-chlorite phyllite.
73.0
73.8 Missisquoi Formation.
to
74.3
74.6 Missisquoi Formation. Note joint and fault surfaces.
to
74.9
75.3 Prominent horizontal jointing.
75.6 Bridge crosses Winooski River, Capital City of Vermont, Montpelier, VT to the left (north).
75.9 Exit 8 to Montpelier, VT. Stay on Interstate Highway, I-89 south.
76.7 Highly sheared rock on left (north). This represents a major discontinuity between Cambrian/Ordovician rocks to the west and Silurian/Devonian rocks to the east. This is probably a faulted unconformity.
to
76.8
77.2
to Waits River Formation, Barton River Member (Dwb).
77.5
78.1 Waits River Formation, Barton River Member.
78.9 Take Exit 7 (to the right) exiting Interstate Highway, I-89. Exit ramp is cut in the Waits River Formation. Mountains of the Northeast Highlands physiographic province can be seen ahead in the distance.

NORTHEAST HIGHLANDS

Jacobs (1950) says "The whole mountainous region is an extension into Vermont of the White Mountain uplift of New Hampshire". Today we know that this physiographic province is composed of several granitic plutons of Middle Devonian age referred to as the New Hampshire Plutonic Series (nhu) and plutons of Mesozoic age referred to as the White Mountain Plutonic Series on the Centennial Geologic Map of Vermont (Doll et al, 1961). For the most part the region is a mountainous wilderness with some 130 individual high hills and mountains, many of which are unnamed (Jacobs, 1950). The area retains evidence of having been heavily glaciated. A textbook example of a glacially scoured trough exists between Mt. Pisgah (elev. 2761') and Mt. Hor (elev. 2648') in the towns of Westmore and Sutton, VT. The trough is occupied by one of the deepest lakes in the State, Lake Willoughby, reported to have a maximum depth of "slightly more than 308 feet" (Mills, 1951).

The granite industry is the main industry in the Northeast Highlands province followed by lumbering, pulp wood and wood products (furniture). The granite industry is centered in the southern part of the province with the principal "Rock of Ages" quarries in Graniteville and Websterville, and finishing/processing facilities in Barre, VT. Several smaller quarrying operations occur in other plutons throughout the Northeast Highlands.

*Note: Floors average 5.5'.

ROAD LOG FOR DAY THREE. . . . continued

Mileage

- 80.1 Go straight through the next 3 sets of traffic lights.
- 80.7 At the third traffic light follow sign to Barre, VT straight ahead.
- 83.1 Granite processing sheds on left.
- 83.5 Traffic light. Go straight through this intersection.
- 84.0 Traffic light. Turn right (south). Follow VT Route 14 south through Barre, VT.
- 84.2 City of Barre, VT.
- 84.4 Bear right. Traffic light.
- 84.5 Traffic light. Go straight on VT Route 14 south.
- 85.1 Waits River Formation on left (east). Go slowly.
- 85.3 Turn left (east) onto Quarry Street. Go slowly, this street is narrow and somewhat hidden. Traffic may be heavy.
- 86.3 Hilltop Restaurant on right.
- 86.7 Road intersection, large cemetery on left, most monuments are made from Barre "Rock of Ages" granite. Go straight through this intersection.
- 87.8 Stop sign. Go left at this road intersection.
- 88.1 Bear left (see QUARRY sign) Village of Graniteville, VT. Post office on the right.
- 88.3 Note large granite waste piles on the left.
- 88.9 Turn right into the "Rock of Ages" Visitor's Center parking lot.

STOP 2. THE BARRE GRANITE, ROCK OF AGES CORPORATION, BARRE, VERMONT (from Richter, 1987)

Dimension stone has been quarried from the granitoid pluton in the Barre district since the 1830's. Cemetery monuments are the primary product manufactured in the Barre district today. Other products include building facings, surface plates, (i.e., precision ground flat tables for machine bases and inspection surfaces) and paper-pulp rolls. The Barre district is one of the major producers of granite products in the United States.

The Barre pluton intrudes Silurian-Devonian metasediments of the Gile Mountain and Waits River Formations. K-Ar ages (Naylor, 1971) taken on primary mica samples from several Vermont granitoid bodies, including the Barre pluton, cluster around 380 Ma.*

Granitic rock of the Barre pluton has a very uniform composition. It is a gray, fine-to medium-grained (1 to 5 mm) granodiorite. Its mineral composition is 35% oligoclase (sericitized), 9% biotite (chloritized), 27% quartz (highly strained), 21% microcline (fresh), 6% muscovite. Accessory minerals include zircon, apatite, sphene, allanite (metamict) and opaques. Peg-

matite dikes occur in the Barre pluton, but are not common. Several lamprophyre dikes (dark dike rocks w/mafic phenocrysts) of Mesozoic ages cut the Barre pluton. Xenoliths are common and occur most frequently near the contacts with the intruded metasediments.

Contacts with the metasediments are mildly to strongly discordant. Metamorphic aureoles are associated with most of the regional plutons, including the Barre pluton. Contact metamorphic mineral assemblages associated with the Barre pluton include quartz, muscovite, biotite, plagioclase, microcline or cordierite (amphibolite facies) (Murthy, 1957).

More than 700,000 cubic feet (20,000 cubic meters) of salable granite blocks are produced in the Barre district annually. This represents 25 to 40 percent of the quarried rock. Five grades are selected depending on variations in color and texture. Blocks are sent to numerous finishing plants in the Barre area for processing into a finished product. Final, total recovery is said to be approximately 15%.

Return to Burlington, Vermont.

END OF DAY THREE FIELD TRIP

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*A Rb/Sr age on biotite separated from the Barre granite was reported by Murthy (1957) as 330 ± 25 Ma.

ROAD LOG FOR DAY THREE. . . . continued

Mileage

- 80.1 Go straight through the next 3 sets of traffic lights.
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- 83.1 Granite processing sheds on left.
- 83.5 Traffic light. Go straight through this intersection.
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- 84.2 City of Barre, VT.
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- 85.1 Waits River Formation on left (east). Go slowly.
- 85.3 Turn left (east) onto Quarry Street. Go slowly, this street is narrow and somewhat hidden. Traffic may be heavy.
- 86.3 Hilltop Restaurant on right.
- 86.7 Road intersection, large cemetery on left, most monuments are made from Barre "Rock of Ages" granite. Go straight through this intersection.
- 87.8 Stop sign. Go left at this road intersection.
- 88.1 Bear left (see QUARRY sign) Village of Graniteville, VT. Post office on the right.
- 88.3 Note large granite waste piles on the left.
- 88.9 Turn right into the "Rock of Ages" Visitor's Center parking lot.

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The Barre pluton intrudes Silurian-Devonian metasediments of the Gile Mountain and Waits River Formations. K-Ar ages (Naylor, 1971) taken on primary mica samples from several Vermont granitoid bodies, including the Barre pluton, cluster around 380 Ma.*

Granitic rock of the Barre pluton has a very uniform composition. It is a gray, fine-to medium-grained (1 to 5 mm) granodiorite. Its mineral composition is 35% oligoclase (sericitized), 9% biotite (chloritized), 27% quartz (highly strained), 21% microcline (fresh), 6% muscovite. Accessory minerals include zircon, apatite, sphene, allanite (metamict) and opaques. Peg-

matite dikes occur in the Barre pluton, but are not common. Several lamprophyre dikes (dark dike rocks w/mafic phenocrysts) of Mesozoic ages cut the Barre pluton. Xenoliths are common and occur most frequently near the contacts with the intruded metasediments.

Contacts with the metasediments are mildly to strongly discordant. Metamorphic aureoles are associated with most of the regional plutons, including the Barre pluton. Contact metamorphic mineral assemblages associated with the Barre pluton include quartz, muscovite, biotite, plagioclase, microcline or cordierite (amphibolite facies) (Murthy, 1957).

More than 700,000 cubic feet (20,000 cubic meters) of salable granite blocks are produced in the Barre district annually. This represents 25 to 40 percent of the quarried rock. Five grades are selected depending on variations in color and texture. Blocks are sent to numerous finishing plants in the Barre area for processing into a finished product. Final, total recovery is said to be approximately 15%.

Return to Burlington, Vermont.

END OF DAY THREE FIELD TRIP

REFERENCES USED AND CITED

- Bain, G.W., 1934, Calcite Marble. *Economic Geology*, vol. 29, no. 2, pp. 121-139.
- Baldwin, B., 1982, Geology of Vermont. *Earth Science*, American Geological Institute, vol. 35, no. 2, pp. 10-14.
- Baldwin, B., and Raiford, A.V., 1988, Taconic Geology near Fair Haven, Vermont. *Vermont Geology*, vol. 5, Guidebook 2, Field Trip Guide G, Vermont Geological Society, Montpelier, VT.
- Coney et al., 1972, *The Champlain Thrust and Related Features Near Middlebury, Vermont*. 64th Intercollegiate Geological Conference Guidebook, pp. 97-115.
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- Doll, C.G., et al., 1961, *Centennial Geologic Map of Vermont*. Vermont Geological Survey, Waterbury, VT.
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- Naylor, R.S., 1971, Acadian Orogeny; an abrupt and brief event. *Science*. vol. 172, pp. 558-560.
- O'Loughlin, S.B., and Stanley, R.S., *Bedrock Geology of the Mt. Abraham-Lincoln Gap Area, Central Vermont*. Vermont Geological Survey, Special Bulletin no.6, Waterbury, VT.
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- Watson, W.I., et al., 1980, *Study of the Slate Mining Industry of Vermont/New York*. Prepared for the U.S. Dept. of the Interior, Bureau of Mines by Arthur D. Little, Inc., Cambridge, MA, Contract no. JO19975, ADL reference C-83918.
- Welby, C.W., 1962, *Paleontology of the Champlain Basin in Vermont*. Vermont Geological Survey, Special Publication no. 1, Waterbury, VT.
- Zen, E-An, 1964, *Stratigraphy and Structure of a Portion of the Castleton Quadrangle, Vermont*. Vermont Geological Survey, Bulletin no. 25, Waterbury, VT.

ROAD LOG FOR DAY THREE. . . continued

Mileage

- 80.1 Go straight through the next 3 sets of traffic lights.
- 80.7 At the third traffic light follow sign to Barre, VT straight ahead.
- 83.1 Granite processing sheds on left.
- 83.5 Traffic light. Go straight through this intersection.
- 84.0 Traffic light. Turn right (south). Follow VT Route 14 south through Barre, VT.
- 84.2 City of Barre, VT.
- 84.4 Bear right. Traffic light.
- 84.5 Traffic light. Go straight on VT Route 14 south.
- 85.1 Waits River Formation on left (east). Go slowly.
- 85.3 Turn left (east) onto Quarry Street. Go slowly, this street is narrow and somewhat hidden. Traffic may be heavy.
- 86.3 Hilltop Restaurant on right.
- 86.7 Road intersection, large cemetery on left, most monuments are made from Barre "Rock of Ages" granite. Go straight through this intersection.
- 87.8 Stop sign. Go left at this road intersection.
- 88.1 Bear left (see QUARRY sign) Village of Graniteville, VT. Post office on the right.
- 88.3 Note large granite waste piles on the left.
- 88.9 Turn right into the "Rock of Ages" Visitor's Center parking lot.

STOP 2. THE BARRE GRANITE, ROCK OF AGES CORPORATION, BARRE, VERMONT (from Richter, 1987)

Dimension stone has been quarried from the granitoid pluton in the Barre district since the 1830's. Cemetery monuments are the primary product manufactured in the Barre district today. Other products include building facings, surface plates, (i.e., precision ground flat tables for machine bases and inspection surfaces) and paper-pulp rolls. The Barre district is one of the major producers of granite products in the United States.

The Barre pluton intrudes Silurian-Devonian metasediments of the Gile Mountain and Waits River Formations. K-Ar ages (Naylor, 1971) taken on primary mica samples from several Vermont granitoid bodies, including the Barre pluton, cluster around 380 Ma.*

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