GEOLOGY FOR ENVIRONMENTAL PLANNING IN THE RUTLAND-BRANDON REGION, VERMONT

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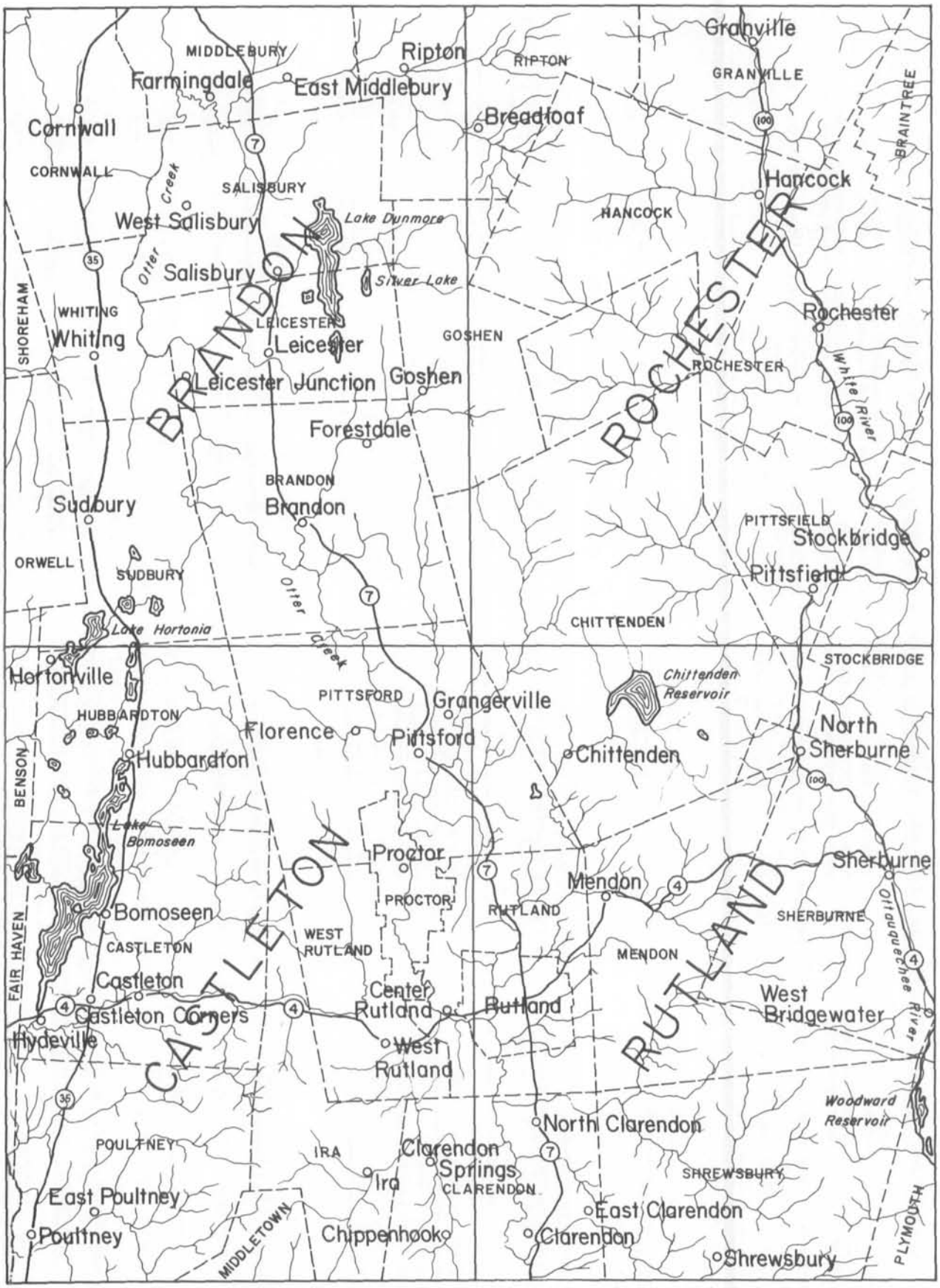

Figure 1. Index map showing the location of quadrangles, townships, cities and villages in the Rutland-Brandon region. Scale: One inch equals approximately four miles.

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INTRODUCTION

Activities of the Vermont State Government, particularly the administration and legislature, promoting programs and enacting legislation relating to environmental problems have recently received national attention (Walsh, 1971; Fales, 1971). The state government and the people realize that substantial growth and development are bound to occur during the decade of the 70's and efforts are being made to prepare for this growth through environmental planning. There is evidence, even at this early date, that some are beginning to lose interest in environmental activities and others, it seems, withdrew after taking a second look at the cost. On the whole, however, the citizens of Vermont are becoming more conscious of environmental problems and are supporting efforts to plan for the future.

This is the second in a series of environmental geology studies sponsored by the Vermont Geological Survey. The field work for the project was completed by the writer, assisted by Terry M. Kramer, during the summer of 1971. The purpose of this report is to describe the geology of the Rutland-Brandon region as it relates to environmental planning.

The Rutland-Brandon region was selected for the second study because of its present population, the projected growth during the next decade and the complex nature of the geology. The region encompasses four topographic quadrangles, namely, the Rutland, Brandon, Castleton and Rochester (Figure 1). The Brandon Quadrangle has a population centered mostly in the village of Brandon with small concentrations in and around the villages of East Middlebury, Salisbury, Cornwall, Whiting and Sudbury. The Rochester Quadrangle has a mountainous topography and is populated only along the White River and three of its tributaries chiefly in the villages of Rochester, Granville, Hancock, Stockbridge and Pittsfield. The Castleton Quadrangle also has a rather rugged topography and the population is clustered mostly in the valleys of the Castleton and Poultney rivers and Otter Creek in the villages of Pittsford, Proctor, West Rutland, Center Rutland, Castleton and Poultney. The population of the Rutland Quadrangle is mostly in the City of Rutland and to the north and south of it in the Vermont Valley. Recently there has been development on the Green Mountains particularly along U.S. Route 4 and the Killington Ski area (Figure 1). There has been a general increase in home building in higher areas along mountain slopes and on high hills, apparently because people want to get up high enough to enjoy the view and away from the congested cities.

Geology adds the third dimension to environmental planning inasmuch as the geologist looks below the surface to ascertain the composition, structure and other characteristics of both the bedrock and the loose, unconsolidated material above it. Knowledge of the subsurface is necessary, among other things, to determine the probability of ground water, the suitability of a site for a sanitary landfill or a septic tank installation. Construction conditions are also determined by the surface material as well as the structure, slope and drainage of the area. These and other problems require specific information of a geological nature. The State Environmental Board and the district commissions do not have geologists on their staffs, and planning agencies generally do not have funds to purchase equipment to probe

below the surface. This report, therefore, is to supply geological information to assist planners involved in environmental problems in the Rutland-Brandon region.

SOURCE OF MATERIAL

The data that were used in the preparation of this report were collected and assimilated from many sources of materials. As a general rule, there is much scientific material available relating to environmental problems that is either too technical for planners or it is not known to exist. In Vermont, material is available from the Vermont Geological Survey, the Vermont Water Resources Department and the regional offices of the United States Conservation Service and, in the area of this study, from the Rutland Regional Planning Commission.

The surficial geology of the Rutland-Brandon region was mapped during the program that produced the *Surficial Geologic Map of Vermont* (Stewart and MacClintock, 1970). The writer mapped the Rutland Quadrangle and the eastern half of the Castleton Quadrangle, MacClintock mapped the Rochester and the western half of the Castleton, and Connally (1970) mapped the Brandon Quadrangle. The surficial maps were checked in the field and adapted for environmental use. The explanations of these maps were simplified to some extent and the descriptions of the materials were modified to include properties that are directly applicable to the environment (Plate I).

Percolation tests were made at irregular intervals all over the four quadrangles to determine the texture, relative permeability and other water-related properties of the top three feet of the surface material. A four-inch auger mounted on the back of a jeep was used to auger holes to a depth of three feet. The holes were filled with water, and the drop in the water level in a given time interval was measured. These tests were made to determine the relative properties of the surface material and attempts were not made to calculate absolute values for porosity or permeability.

Water-well records, on file at the Water Resources Department, were studied to ascertain water potentials. These data were compared with and used to modify existing ground water favorability maps (Hodges and Butterfield, 1967, 1968a, 1968b). The logs were also used to determine, where possible, the depth of the water table, the thickness of the surficial material above bedrock, the sequence of unconsolidated sediment, particularly in the stream valleys, and to assist in determining desirable locations for seismic study. This information was necessary to construct a ground water potential map (Plate III).

Sand and gravel deposits were studied to determine the quality of the material as well as the reserves available. The slate and marble belts were mapped and environmental problems associated with these were noted.

Existing solid waste disposal sites were evaluated in reference to the geology of the area in which they were located. Sewage disposal practices for domestic installations (septic tanks, dry wells, etc.) were studied (Plates IV and V).

Twelve localities were selected for seismic study to ascertain ground water characteristics. The seismic work was done by the Weston Geophysical Engineers, Inc. of Weston, Massachusetts. The twelve-point seismic refraction method was employed using a portable twelve-channel seismograph. The refraction method is an indirect means of determining the depth to bedrock and the depth to seismic discontinuities (contacts between layers of different properties) caused by water saturation and textural changes in the unconsolidated sediment above bedrock. The profiles reproduced in this report are those made by the Weston Geophysical Engineers during the seismic work (Weston Geophysical Engineers, 1971).

EXPLANATION OF THE PLANNING MAPS

A series of maps has been prepared to illustrate the geology and environmental conditions in the Rutland-Brandon region. Plates I through VII in the pocket at the end of this report are planning maps showing the surficial material, the bedrock, the suitability of the areas for various uses and the distribution of sand and gravel deposits. The color schemes on the maps (Plates III, IV, V and VI), green for go, yellow for caution and red for stop, were copied in modified form from the Illinois Geological Survey (Hackett and McComas, 1969; Jacobs, 1971). Areas shown in green are interpreted as offering only minor problems and slight limitations. Areas shown in yellow have moderate to severe limitations, but the problems are, in general, controllable. These areas require detailed study to ascertain the limitations and to determine the necessary controls. Areas mapped in red have severe limitations and many problems that are impractical to overcome. These areas should be avoided in most cases. Where two different symbols are used for the same color, for example r-1 and r-2, it is to show different conditions, but not necessarily more (or less) severe limitations.

The map of the surficial material, Plate I, and the bedrock map, Plate II, show the distribution of the various types, since each different kind of rock and surficial material has different characteristics in so far as the environment is concerned.

GEOLOGIC SETTING

The Rutland-Brandon region includes parts of four geomorphic provinces that contain three distinctly different kinds of rocks and structures. The

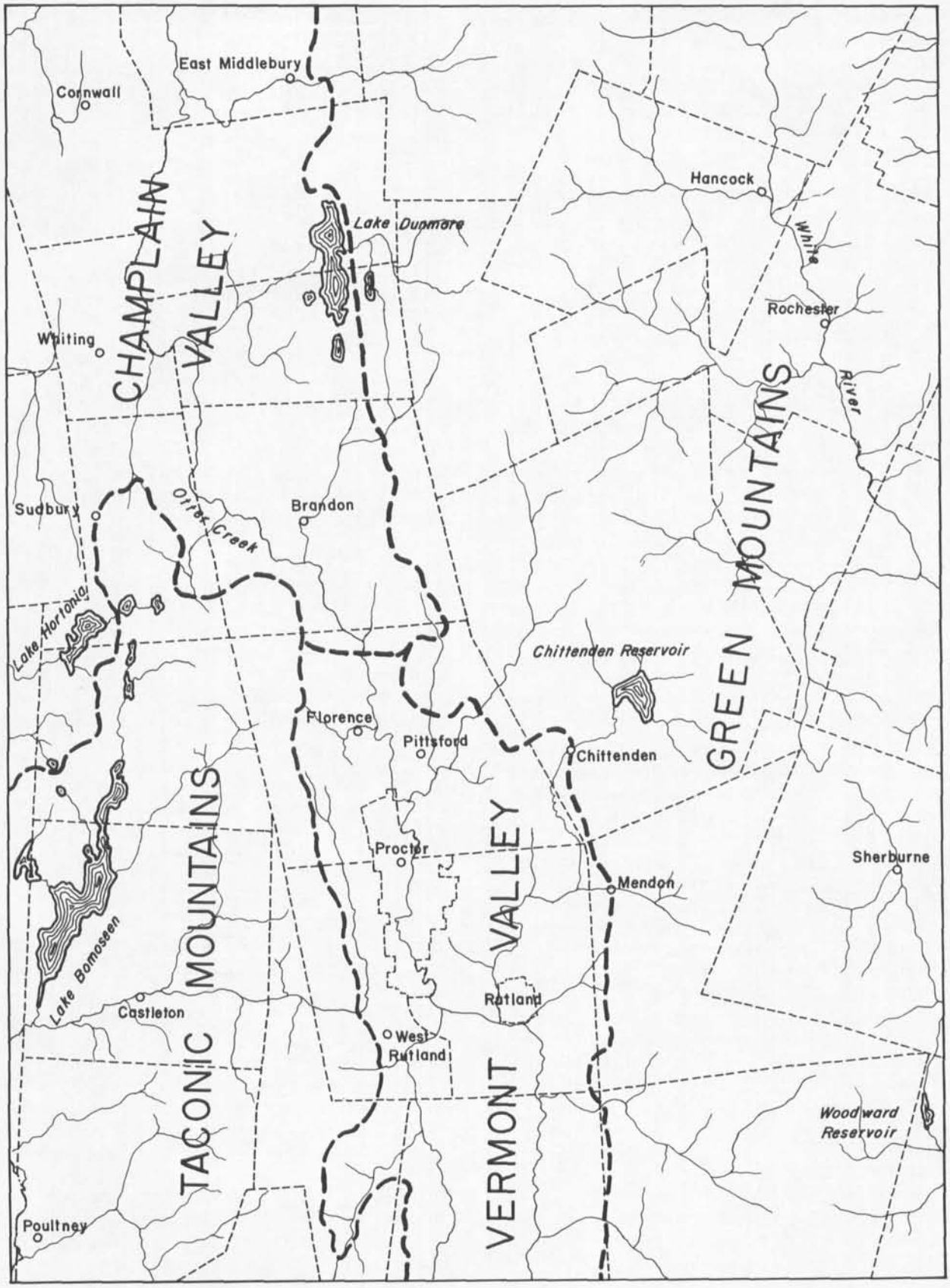

Figure 2. Geomorphic subdivisions of the Brandon-Rutland Region. Scale: One inch equals approximately four miles.

Green Mountains comprise a major portion of the Rutland and Rochester quadrangles; the Taconic Mountains occupy the western two-thirds of the Castleton Quadrangle and the southwestern corner of the Brandon; the Vermont Valley lies between the Green and Taconic mountains; and the Champlain Valley covers the Brandon Quadrangle west of the Green Mountains (Figure 2). Geologically speaking, the Vermont Valley is a continuation of the Champlain Valley down the deep depression between the mountains inasmuch as the bedrock and structure are the same in both. Jacobs (1950), however, designated the 85 mile long valley a separate geomorphic unit.

The Green Mountains form the backbone of the topography of Vermont, particularly in the southern part of the state where they are wider and more complex. In the Rutland-Brandon region, the western slopes of the mountains form a bold, steep front, up to 1500 feet high, on the eastern side of the Vermont and Champlain valleys. This front trends generally north-south along a line that is about two miles east of Rutland and Brandon and immediately to the east of Lake Dunmore and East Middlebury. Structurally the mountains are a huge anticlinorium comprised of three anticlines (Brace, 1953) that was compressed and uplifted. Precambrian basement rock (Mount Holly Complex) forms the mountain core. Erosion has exposed the basement rock in the southern part of the mountains and the exposed portion extends northward into the Rutland and Rochester quadrangles (Plate II).

In the Rochester Quadrangle, the Green Mountains consist of three north-south trending ridges, two of which cross the Rutland Quadrangle. The westernmost ridge, with summit elevations between 1700 and 3200 feet, forms the steep western slopes of the mountains with relief 500 to 1500 feet above the lowlands to the west (Osberg, 1952). The western ridge includes Bald, East, Blue Ridge, Chaffee, Moosalamoo mountains and Chandler Ridge. The middle ridge is the central crest of the Green Mountains that, in the Rutland-Brandon region, forms the divide between the Champlain and Connecticut River drainages. It forms the highest peaks throughout the state including Jay Peak, Mt. Mansfield, Camels Hump and Lincoln Mountain to the north and Stratton, North and Haystack mountains to the south. In the area of the present study, the higher summits of the ridge, from north to south, include Battell (2044), Breadloaf (3823), White Rocks (3307), Cape Lookoff (3298), Goshen (3266), Pico (3967), Killington (4241) and Shrewsbury (3737). The eastern, or third, range is the more or less continuous ridge that is known as the Worcester Mountains in the Montpelier Quadrangle, the Northfield Mountains in the Barre and Lincoln Mountain quadrangles and Braintree Mountain in the Rochester Quadrangle. The ridge leaves the eastern boundary of the study area southeast of Rochester village and ends north of the White River in Stockbridge (Randolph Quadrangle). The summits of the ridge, in the Rochester Quadrangle, range from 2600 to 3000 feet in elevation (Figure 3).

The Taconic Mountains are erosional remnants of a former very large overthrust sheet that was pushed westward or north-westward from root areas now assumed to be buried under the Green Mountains (Hawkes, 1941). The mountains extend from the vicinity of Brandon southward into Massachusetts and New York almost to the Catskills. Erosion has long since separated the thrust sheet (or allochthon) from its roots, and the assumption that the thrusting was from the east is based on the fact that no roots have been found in any area to the north, west or south of it. The rocks of these mountains are the same age as those of the adjacent valleys, but the kinds of rock in the two regions are of such different depositional environments that the sediments that formed them must have been deposited in different basins or different parts of the same basin (Hawkes, (1941). The central one-third (north-south) of the Castleton Quadrangle and the extreme south-central part of the Brandon Quadrangle are occupied by the higher mountains with summits up to 2700 feet elevation, and twelve or fifteen "hills" have crests above the 2000-foot contour. The highest point in this section is Herrick Mountain, northwest of Ira, which has an elevation of 2727 feet. The western one-third of the Castleton Quadrangle is occupied by the Taconic foothills that is also known as the slate belt. Here the rocks are true slates that are less intensely metamorphosed than those in the section to the east, just described, where the rocks are more accurately termed phyllites.

The topography of the Taconic Mountains is quite irregular and in some areas rather rugged. The topography is a reflection of the underlying bedrock with higher areas either composed of more resistant rocks or thrust sheets and the valleys formed in the weaker rock. The Castleton River cuts transversely through the mountains in a deep valley, whose walls rise abruptly from the valley floor (Figure 4).

The Champlain Valley occupies the region west of the Green Mountains and north of the Taconic Mountains. It is a rolling country made up of north-south trending low hills and mountains that are thrust blocks with their steep slopes to the west (Jacobs, 1950) or resistant rock layers that have been left higher by erosion of less resistant rock around them (Figure 5). In the Rutland-Brandon region, the lowland, covering approximately two-thirds of the Brandon Quadrangle, has a very irregular surface with hills dominating the landscape except along the course of Otter Creek. Structurally, the rocks of this region are contained in the Middlebury synclinorium and most of the rocks are part of the

Figure 3. The crests of the Green Mountains in the Rochester Quadrangle. Hancock Mountain in the foreground.

Figure 4. Looking north across the Castleton River valley, two miles west of West Rutland.

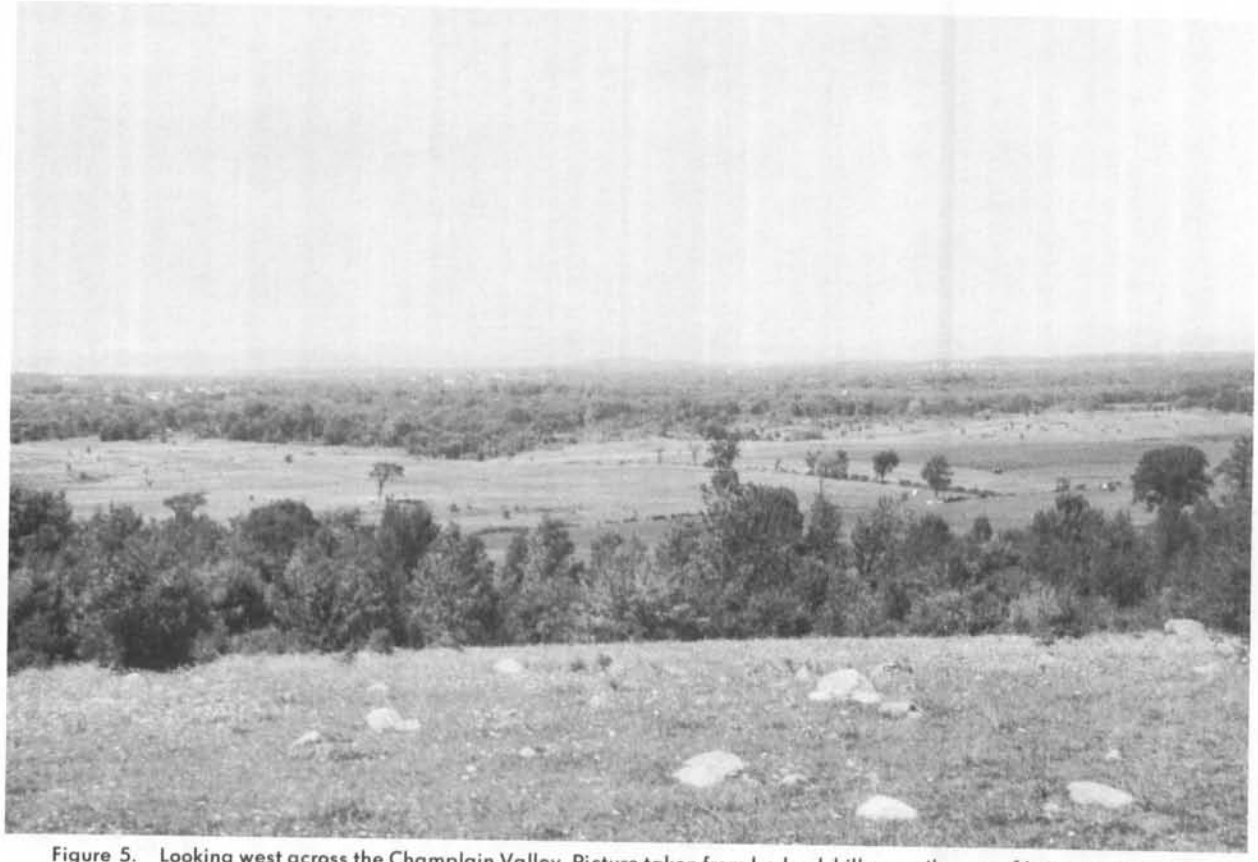

Figure 5. Looking west across the Champlain Valley. Picture taken from bedrock hill one mile east of Leicester Junction.

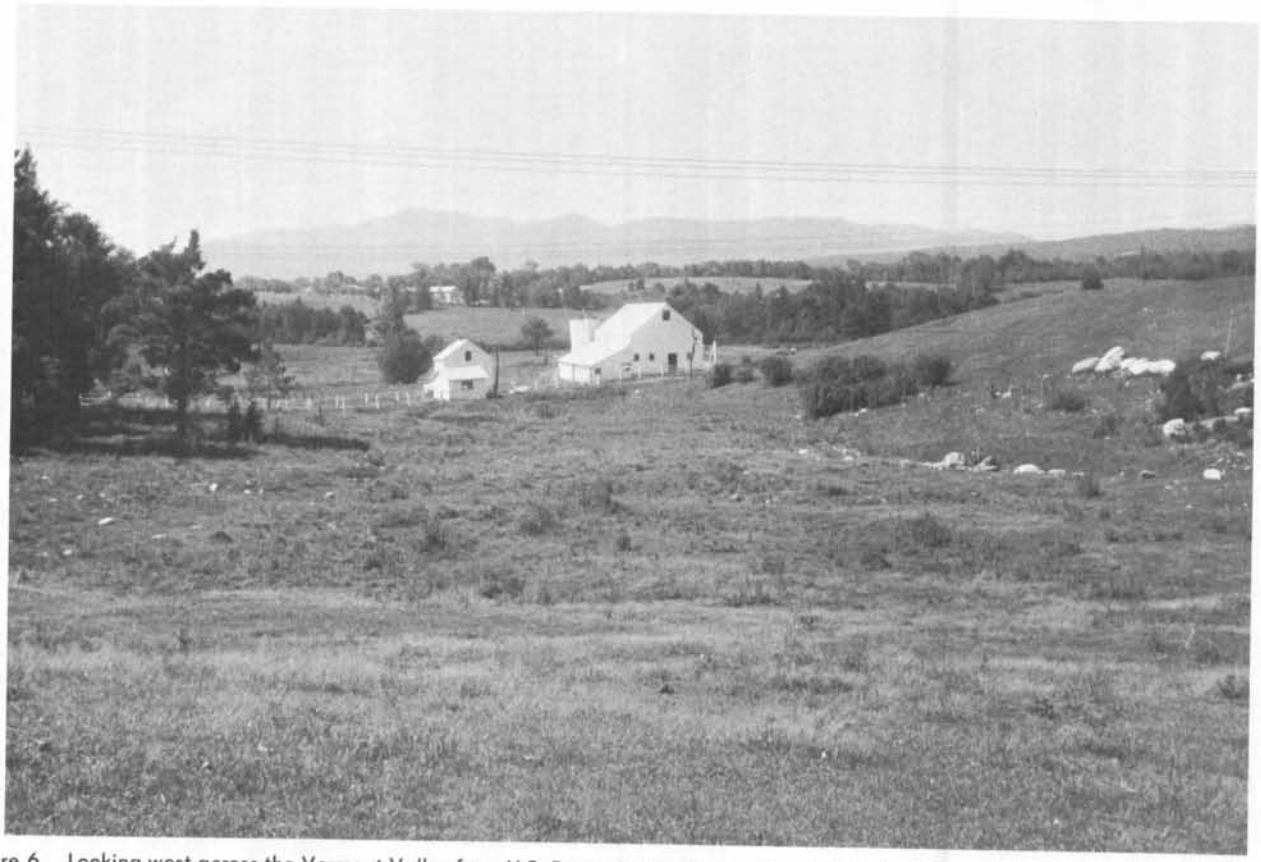

Figure 6. Looking west across the Vermont Valley from U.S. Route 4 two miles northeast of Rutland. Taconic Mountains in the background.

steeply dipping western limb of that structure. Therefore the rocks dip generally to the west, except in the western part of the Brandon Quadrangle along the axis of the basin structure (Cady, 1945). The hills in this area are formed on the upturned edges of the more resistant rock. Lake Dunmore is said to occupy a syncline adjacent to the Lake Dunmore thrust.

The Vermont Valley, as already stated, is the continuation of the Champlain Lowland southward between the Green and Taconic mountains. The east limb of the Middlebury synclinorium is traceable down the valley showing that the Taconic allochthon covers the central portion of the structure (Cady, 1945). In the Rutland area, the valley is interrupted by Pine Hill, east of Proctor, and Boardman Hill south of Center Rutland, which are formed by the Pine Hill thrust. A second hill occurs between the Castleton River and Otter Creek, north of West Rutland. The Vermont Valley in that area therefore includes Otter Creek, Castleton River and Clarendon River valleys. The topography of the valley is irregular due to these structures and the differential hardnesses of the rock (Figure 6).

DRAINAGE

The drainage patterns of the Rutland-Brandon region are complicated by the diverse geology (structure, topography and bedrock) and the effects of glaciation. A divide that separates the westward drainage into Lake Champlain from the eastward drainage into the Connecticut River crosses the region in a north-south direction following the crests of the Green Mountains (Figure 7). Divides also separate the drainage directly into Lake Champlain from that flowing into Otter Creek.

Otter Creek enters the region south of Rutland and flows northward to Rutland where it turns westward for a mile or so to continue northward again through Proctor and Florence to Brandon (Figure 8). The valley floor in that distance is generally one-half to three-fourths mile wide, except at Center Rutland, Proctor and Florence where bedrock constrictions narrow the valley to approximately 100 yards or less, causing falls and rapids in the stream. From Brandon the river flows northwestward and then north through a low, flat, poorly drained valley generally one to two miles wide (Figure 9). As a rule, the bedrock valley is deep, except in the restricted areas, and is filled with lake or glacial sediment. Tributary streams that flow from the Green Mountains into Otter Creek are relatively short (10 to 16 miles), with steep gradients and high velocities. These streams include the Mill River that enters Otter Creek at Clarendon, Cold River at Cold River Station, East Creek at Rutland, Furnace Brook north of Florence, the Neshobe River at Brandon, the Leicester River north of Leicester Junction and the Middlebury River west of Farmingdale. Most of these streams follow bedrock valleys to the point where they reach the lowland, beyond which they are on sediment. The only stream of significant size to enter Otter Creek on the west side is the Clarendon River that drains the southeast corner of the Castleton Quadrangle south of West Rutland. Otter Creek, it should be noted, is one of the major streams that drain the Vermont Valley and the southern part of the Champlain Valley. It is 75 miles long, the longest stream in the state, and it flows into Lake Champlain in Ferrisburg.

The Castleton River heads at the north end of the West Rutland valley and flows southward through that valley to West Rutland, where it turns west to follow a course transverse through the Taconic Mountains to enter the Poultney River west of Fair Haven. In spite of its short length, the river and its tributaries drain most of the Taconic Mountains in the northern part of the Castleton Quadrangle (Figure 7). Lake Bomoseen drains southward into the Castleton River and several small ponds to the north and west of Bomoseen drain into the lake. North Brittain Brook drains the area east of Lake Bomoseen.

The Poultney River and its tributaries drain the southwest corner of the region mapped (Figure 7). Although the river's course swings only into the extreme southwest corner of the area, the tributary streams fan out to drain a relatively large area on the west slopes of the Taconic Mountains. The Poultney River flows in a narrow bedrock valley to East Poultney where the valley is wider and deeper and filled with lake sediment. The Hubbardton River, a tributary of the Poultney River, heads in the vicinity of Hortonville in a group of lakes and ponds that include Lake Hortonia (at Hortonville), Black and Roach ponds (west of Hubbardton) and Burr, Hinkum and Huff ponds (southeast of Sudbury). This small network of streams and ponds drains the north end and west slopes of the Taconics in that region.

The Lemon Fair River, a northward flowing tributary of Otter Creek, rises in Johnson Pond, two and one-half miles south-southeast of Sudbury and, from its head, it flows north approximately seven miles to leave the map area west of Whiting and to return at the extreme northwest corner of the Brandon Quadrangle. This stream drains the western margin of the region, west of a divide that runs north-south through Sudbury, Whiting and Cornwall (Figure 7). The area drained by the Lemon Fair is a low, flat valley filled with lake clays and silts.

The east side of the Green Mountains is drained by the headwaters of the White and Ottauquechee rivers. The Ottauquechee River heads north-northwest of Sherburne and flows southward through Sherburne to West Bridgewater where it turns east and leaves the region. An unnamed tributary stream that enters the river at West Bridgewater drains Woodward Reservoir and Black Pond. These streams

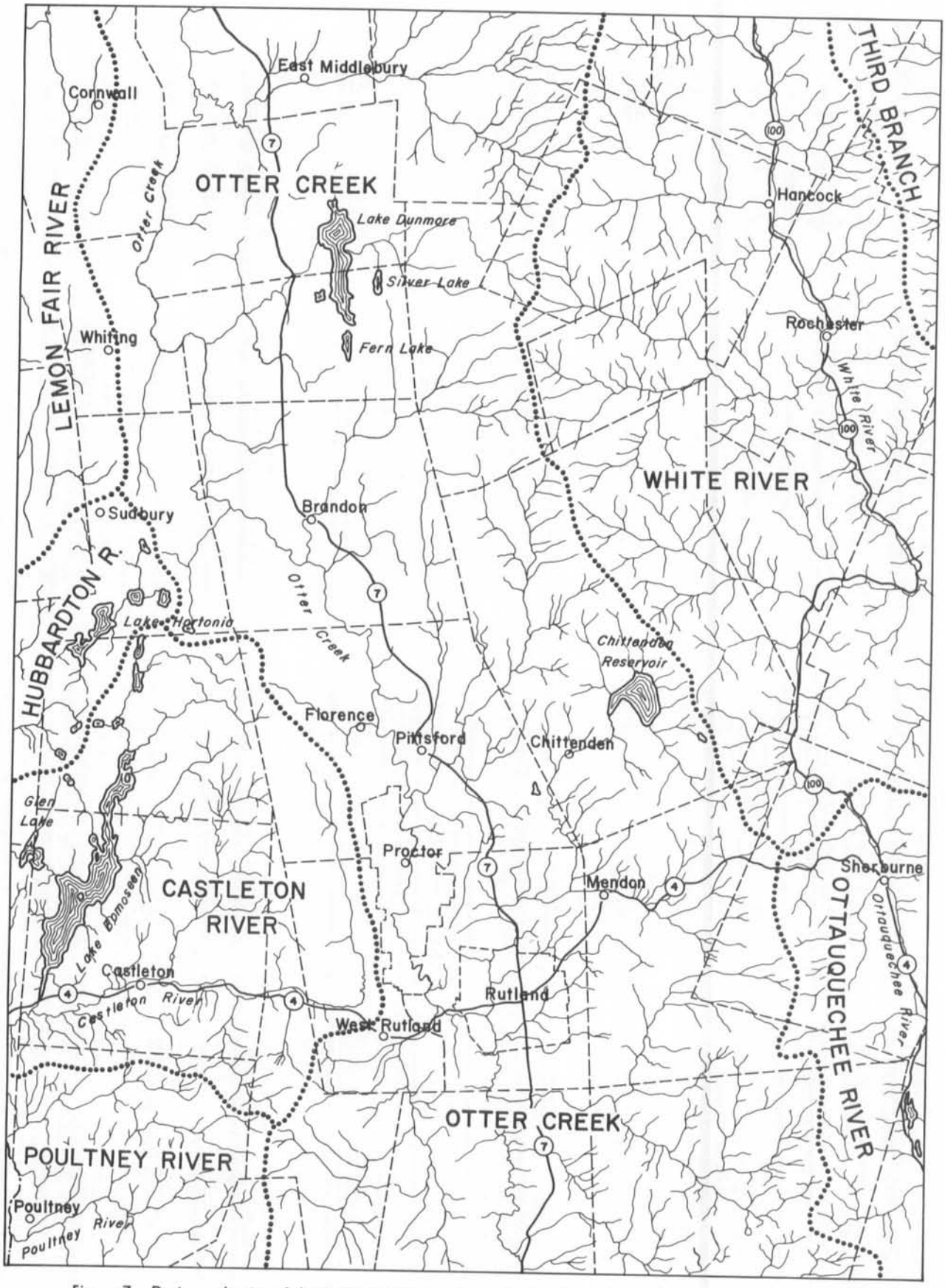

Figure 7. Drainage basins of the Rutland-Brandon region. Scale: One inch equals approximately four miles.

Figure 8. The Otter Creek valley south of Rutland. Picture taken looking north one mile north of Clarendon.

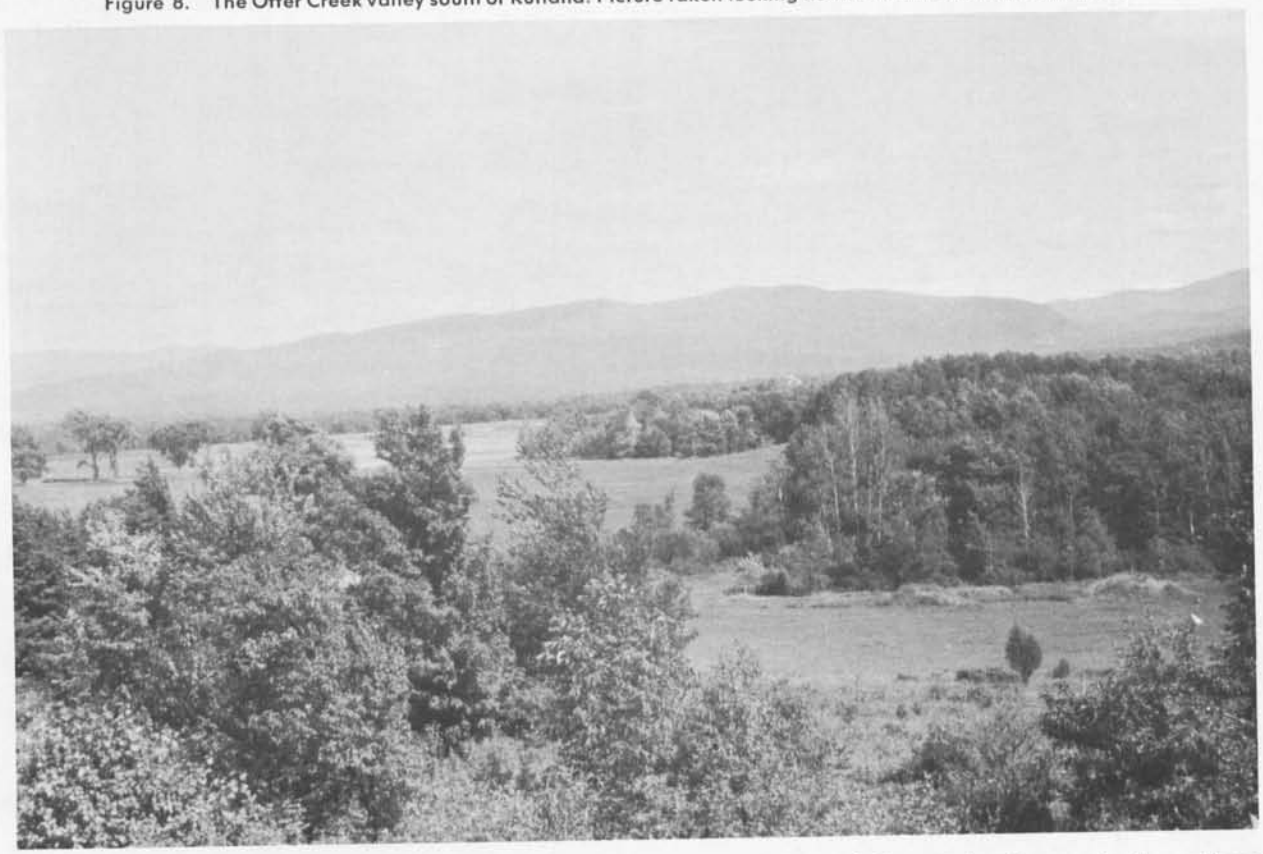

Figure 9. Looking east across the Otter Creek valley. Green Mountains in the background. Picture taken from west valley wall one mile south of Cornwall.

and their tributaries drain the east slopes of the Green Mountains south of North Sherburne (Figure 7).

The White River heads on the east slope of the main ridge of the Green Mountains west of Granville. It flows southward from Granville in a deep valley, between the main ridge on the west and Braintree Mountain on the east, through Hancock and Rochester to Stockbridge. Two major tributaries, Hancock and West Branch, flow eastward from the slopes of the mountains. The Tweed River, a tributary of the White, heads near North Sherburne and flows north to Pittsfield and thence to the White River at Stockbridge. Thus the White River and its tributaries drain the eastern part of the Green Mountains north of North Sherburne (Figure 7).

BEDROCK

The rocks of the Rutland-Brandon region include three distinctly different sequences of the Precambrian, Cambrian and Ordovician systems. The stratigraphy is complicated by the mountain building episodes that have deformed, faulted, fractured and metamorphosed the originally sedimentary strata. For this report, it is necessary to greatly simplify the stratigraphy to render it useful to those for which this report is intended. The most simplified map of the region is probably that published by Hawkes (1941) that merely shows that the Taconic Mountains are composed predominantly of a sequence of Cambrian and Ordovician slates; the Champlain and Vermont valleys of Cambrian and Ordovician carbonate rock and the Green Mountains of Precambrian, Cambrian and Ordovician gneisses, phyllites and schists. Although this map is generally correct, and illustrates adequately what it was intended to show, these generalizations give neither the basic differences among the various strata of the sequences nor their stratigraphic relationships. A geologic map showing the distribution of the rocks and the three stratigraphic sequences is included here to show the different kinds of rock and their stratigraphic relationships (Plate II). These data have been simplified by combining the rock layers into groups wherever it is possible to do so. The information is chiefly modified from the Centennial Geologic Map of Vermont (Doll, Cady, Thompson and Billings, 1961).

The overthrust sheet that forms the Taconic Mountains, as stated above, is composed chiefly of a sequence of slates of Cambrian and Ordovician age. The most widespread of the rock units is the St. Catherine Formation that comprises the bulk of the rock outcropping in the Taconics (Plate II). This formation contains three members of different lithologies. The most common member is the Mettawee that contains the purple, gray-green and variegated slates of the western foothills and the slightly more metamorphosed phyllites of the eastern part of the range. The second member is the Bomoseen graywacke (sandstone) that outcrops in scattered, higher areas west and north of Lake Bomoseen and around the Government Hill area east of Sudbury. The Zion Hill quartzite member outcrops in the Bird Mountain region and in the Zion Hill-Wallace Ledge-Barker Hill area east of Lake Bomoseen. The St. Catherine Formation is lower Cambrian in age. The Brezee Formation, also lower Cambrian, is older than the St. Catherine but its extent is more restricted. This formation is predominantly a dark gray to black phyllite with layers of marble and quartzite also occurring in it. It is found at the northern end of the Taconics, along the eastern margin north of the Castleton River and to the southeast in the Chippenhook-Ira region. The Hatch Hill and West Castleton formations (undifferentiated) are grouped together because the Hatch Hill quartzite is relatively thin and occurs under the West Castleton slate. The Hatch Hill is a a gray, calcareous quartzite that is usually crossed by white quartz veins. The West Castleton is a gray to black slate that is siliceous in places and contains pyrite. These formations occur in thin bands on the map (Plate II) trending north-south in the Lake Bomoseen region but curving eastward to the north. They also occur in an east-west band north of the Castleton River between Hooker Hill and West Rutland. The Ordovician strata include the Mount Hamilton and Pawlet formations that occur only in the southwest corner of the region in the vicinity of Poultney.

The rocks of the Champlain and Vermont valleys are a series of mostly carbonate rock composed of both dolomitic and limestone marbles with occasional quartzite members in the lower part of the section (Plage II). The ages of the lowland formations are the same as those of the Taconic Mountains, but, as noted above, they were deposited in quite different geologic environments. It was the close association of the argillaceous rocks of the Taconic allochthon and the carbonate rocks of the Champlain and Vermont valleys that suggested overthrusting to the early investigators of that region.

The lower Cambrian series of the valleys contains the largest number and the greatest thickness of siliceous formations of the whole section. The basal Dalton Formation is a schistose quartzite rock containing pebbles of feldspar and blue quartz. The Cheshire Quartzite Formation, above the Dalton, is a massive, white to tan, very resistant siliceous rock. The Dunham Dolomite is a multicolored, mostly pink and cream, that weathers to a buff color. The Monkton Quartzite is quite resistant. It has a red color but is usually interbedded with thin white and buff layers. The Winooski Dolomite is pink, buff, or gray in color, but it is usually weathered to buff. It contains thin layers of siliceous rock that are more resistant to weathering than the dolomite. These lower Cambrian formations outcrop along the western slopes of the Green Mountains the entire length of

the Rutland-Brandon region except in the Pittsford-Chittenden area where they have been displaced by thrust faulting. The Dalton Formation is the only exception, as it occurs in the Rutland area and is not found north of Pittsford. The Cheshire quartzite, the oldest formation except the Dalton, outcrops along the base of the Green Mountains and the other formations parallel it in stratigraphic sequence; that is, the rocks become progressively younger away from the mountains (Plate II).

The Danby Formation of middle Cambrian age is composed of interbedded quartzite and dolomitic marble that grades westward into a massive, white to pink dolomite. The Clarendon Springs Formation is upper Cambrian in age, and is a massive, gray dolomite that contains masses of chert near the top. The exposures of the Danby and Clarendon Springs formations parallel the lower Cambrian rocks and occur immediately to the west of them. Their outcrop is narrow since the formations are of intermediate thickness and have a steep dip.

The lower part of the Ordovician system is comprised of several formations that make up the Beekmantown group. All of the formations are light colored, gray, white or buff; most of them weather to a tan or buff and are all limestone and/or dolomitic marbles with occasional layers of calcareous sandstone, slate or phyllite. These formations form the central portion of the Middlebury synclinorium north of the Taconics, but only the lowest of them is traceable down the Vermont Valley. Other than this, the occurrence of these rocks south of Brandon is scattered and the areas of outcrop are small.

The Chazy group is composed predominantly of limestones and occurs only in the Whiting-Cornwall region in the northwestern part of the Brandon Quadrangle. The limestones are dark, blue-gray, granular in texture and contain thin interbedded slate layers. The Chazy formations are middle Ordovician in age.

The most prominent formation of the upper Ordovician Trenton group is the Hortonville which is a black, carbonaceous slate and phyllite. The Hortonville is exposed in a wide strip immediately east of the Taconic Mountains between Chippenhook and Florence, and also north and west of the Taconics between Hubbardton and Cornwall.

The Green Mountains of the Rutland-Brandon region, except for the easternmost range, are composed chiefly of the Precambrian Mount Holly complex and the formations of the Camels Hump group. The Mt. Holly complex is the Precambrian basement that was uplifted to form the core of the mountains. It is the most highly metamorphosed rock of the whole region inasmuch as it has been subjected to two or more episodes of mountain building. Many geologists now believe the Mt. Holly is a correlative of the Grenville series of the Adirondacks. It is a complex mixture of schists and gneisses with large areas of quartzite and small concentrations of calcite and dolomite marble. The mineralogy is complicated because of the new minerals formed as a result of metamorphism. The Camels Hump group includes, in this region, the Tyson, Hoosac and Pinney Hollow formations. They are mostly schists and phyllites with minor amounts of greenstones, quartzites and dolomites. Braintree Mountain, the eastern range, is underlain by the Ottauquechee and Stowe formations of Cambrian and Ordovician age respectively. Both formations are phyllites and schists and the Ottauquechee also has interbedded quartzite.

SURFICIAL MATERIALS

The surficial materials in the Rutland-Brandon region (Plate I) are composed of transported sediments that were deposited by glaciers or by meltwater streams or in lakes associated with glaciation. The one exception is the recent alluvium that is found forming a thin veneer on the floor of most of the valleys. The surficial material is associated with two different ice advances, the Burlington (younger) and the Shelburne (Stewart and MacClintock, 1969). As the ice retreated from the region, lakes were formed in the valleys, since the glaciers were blocking drainage to the north, and much sediment (sand, silt and clay) was deposited in the lakes.

Till is unsorted glacial debris deposited directly from melting ice. The material contains a wide variety of particle sizes ranging from clay through large boulders. The tills in the Rutland-Brandon region vary in composition, and in general, they contain more sand and less clay than do average tills. Because till is unsorted, containing all particle sizes, it has a low permeability, but because of the low clay – high sand content it is capable of transmitting fluids at a slow rate. Till covers the uplands as a thin veneer generally less than 10 feet thick, and is much thicker in the valleys. Tills in the southern part of the region are older than those to the north, but deeper weathering of the older till compensates for its loose, sandy texture and the physical characteristics of the two tills are essentially the same insofar as environmental problems are concerned.

Outwash is stratified glacial drift that was deposited by meltwater streams flowing from diminishing glaciers. It usually contains a high content of sand and gravel that is extremely well sorted. Outwash has a high permeability and is a very good water-bearing material (aquifer). It is also a good source of groundwater. Kame terraces are outwash deposits formed along valley walls or along the slopes of a mountain. The deposits were made in contact with ice and can usually be identified by slumping structures formed when the ice supporting them melted (Figure 10). Kames are rounded hills of outwash that were also deposited in contact with ice. A valley train deposit is horizontally bedded

Figure 10. Gravel pit in kame terrace deposit at Clarendon Springs.

Figure 11. The surface of the lake clay of the Champlain valley. Bedrock hill in background. Picture taken looking northwest from State Route 74 two miles west of West Cornwall.

outwash that was deposited in a stream valley by streams flowing from a melting glacier. All of these types of outwash deposit are found in the Rutland-Brandon region. Their distribution is somewhat scattered but the greatest concentration is along the eastern side of the Vermont and Champlain valleys at the base of the Green Mountains.

Lacustrine (lake) sands and gravels, including beach gravel and deltas, are shallow water lake deposits that are usually well sorted although sorting is not as complete as in outwash. These have a medium to high permeability depending upon the amount of silt contained in them. The gravel, in general, is much thinner than the sand and both commonly occur above silts and clays. The water-bearing characteristics of the lake sands and gravels depends on the thickness of the deposit, the texture and the underlying material.

Lacustrine silts and clays are fine-grained lake bottom sediment. They may have a relatively high porosity and be capable of holding much water, but the permeability is quite low because of the small grain sizes. Lake clay is not a good foundation material because it has poor internal drainage and high plasticity. The thickest deposits of lake silts and clays in the area studied are found in the western part of the Brandon Quadrangle where the thickness often exceeds 200 feet (Figure 11).

Recent alluvium is post-glacial stream deposited sediment that covers the valley floor. Alluvium generally varies in thickness from 5 to 25 feet. It is a poor foundation material that must be removed for heavy construction.

Peat and muck designate marshy, poorly drained areas in the Rutland-Brandon region. Most of these are small, shallow depressions with little or no peat. The Otter Creek valley west and north of Brandon, however, contains extensive areas of swampland on the valley floor. Some of these may be deep and contain accumulations of plant material.

SURFACE WATER

The Rutland-Brandon region is one of the few areas that still has a potentially good surface water supply. The surface water, mostly in the higher sections of the Green Mountains, could be developed for municipal and/or industrial use. Just how long this water potential will remain clean and uncontaminated is a moot question, and the region should be carefully studied to ascertain sections that should be set aside for future water development. In view of the limited ground water supply in this region, the surface water potential should be considered a vital resource, and, since development of the mountains has already begun, time is of the essence.

The development of the surface water on the Green Mountain slopes would be a rather expensive task inasmuch as it is assumed that the demand for the water would be mostly in the lowlands. Water catchment and water storing facilities would have to be constructed and pipelines would, of necessity, have to carry the water to areas of use. Admittedly, the expense of such installations would exceed the cost of drilling wells adjacent to the area where water is needed, but there are many localities in the region where an adequate supply of ground water is not available.

The City of Rutland has a water system that is an excellent example of an efficiently operated supply from a surface source. The city owns a large acreage approximately one mile east of Mendon along one of the headwater branches of East Creek. The water from this watershed is stored in two reservoirs located about one and one-half miles west of Mendon. The old reservoir has a capacity of only five million gallons, but a new reservoir stores 95 million gallons of water. Water is piped from the reservoirs to the city. The watershed is inspected regularly, and debris of all kinds is removed to prevent contamination. The village of Proctor also has a surface water supply that is piped from Chittenden Township.

Streams that seem to have surface water potential are those heading on the west side of the central ridge of the Green Mountains that flow westward to Otter Creek. The headwaters of Cold River in the towns of Shrewsbury and Mendon, the Neshobe River in the town of Goshen and the Middlebury River in the town of Ripton are the most likely possibilities to the west. On the eastern side of the Green Mountains, the headwaters of the White River in the town of Granville, Robins Branch in Hancock and West Branch in Rochester, tributaries of the White River, have good apparent potential. In the town of Chittenden the headwaters of West Branch, a tributary of the Tweed River, also has good water possibilities. Fortunately, parts of some of these streams are now in the Green Mountain National Forest where development is not permitted and the watersheds will be protected.

The lakes and ponds of the Rutland-Brandon region should be a potentially good reserve of surface water. Lake Bomoseen and Lake Dunmore, the two largest in the region, could supply a large volume of water. Developments along these lakes, however, have proceeded to the point that potable water is not now available, and contamination will soon render the water unfit for use. Regulations are sorely needed to control waste disposal so that developments for recreation, vacation and tourism are possible without the eventual pollution of the water in natural surface reservoirs.

Another possible source of water that needs study is the water contained in the many abandoned marble quarries that are scattered over parts of the Brandon-Rutland region. Many of these are quite large and deep, and most of them are filled with water (Figure 12). To the writer's knowledge, there have been no

Figure 12. Abandoned marble quarry reportedly over 200 feet deep filled with water. Five miles north of West Rutland.

investigations to determine the source, rate of recharge or quality of the water in these reservoirs. It is assumed that much of the water drains off the surface with lesser amounts supplied by ground water. It is doubtful that the quantity of water is enough to supply a city system, but it might well be used for a supplement to a city supply or for small villages or industry. Some of the quarries that are not now being worked are in reserve for future use, but this might not be a problem to their development for water. It is doubtful that future quarrying would be hindered by the water operation, or that quarry work would necessarily render the water unfit for use. Most of the quarries are located near Otter Creek valley between Leicester Junction and Clarendon Springs.

GROUND WATER

Data collected during this study relating to the ground water supply came from several sources. The basic data came from water-well records on file at the Water Resources Department that have been required of all drillers since 1966. The information supplied by these records assisted in the determination of such geologic conditions as the thickness and type of material above bedrock, the depth of wells in each locality, the amount of water produced by each well, the depth to bedrock and the location of buried valleys. These records are on open file and available to all planning agencies.

Seismic studies were made at 12 different locations where well-log and geological data indicated water possibilities. Seismic data supplies important information pertaining to ground water in that it gives the depth, width and shape of the valley, the depth to the water table and a generalized profile of the sedimentary layers. In the Rutland-Brandon region, seismic studies were made to supply information about the unconsolidated sediment in stream valleys. Using seismic data alone, materials may be placed into broad classifications based on the velocities of the seismic wave transmitted through them. Each velocity does not, however, have a unique material correlation, but most bedrock and sediment has a particular velocity range.

Bedrock has a high seismic velocity because of its density, generally above 12,000 feet/second. The seismic velocities of unconsolidated sediment are much lower. Dense, unsaturated till commonly has a velocity range of 3,500 to 4,000 feet/second but compact till, with high density, may have velocities of 6,000 to 8,000. Loose till ranges between 2,000 and 4,000 feet/second. Alluvium (stream sediment) on the floodplains of streams has seismic velocities ranging between 800 and 2,000 feet/second. Unconsoli-

dated sediment with seismic velocities ranging between 4,500 and 5,500 feet/second is usually saturated with water. Ground water in sufficient quantity for a municipal water supply has been found only in materials with velocities between 4,800 and 5,300 feet/second. Materials with velocities below 4,800 are usually not saturated and those above 5,300 are too compact and dense to be of sufficient permeability to yield large quantities of water (Weston Geophysical Engineers, 1971). The seismic profiles reproduced in this report are those made by the Weston Geophysical Engineers during the seismic study.

The *Ground Water Favorability Map* (Hodges, 1967; Hodges and Butterfield, 1968a and 1968b) of each stream system was studied to ascertain available data at the time they were published. These maps show the most favorable areas for ground water based on the information available at that time. They also locate wells of high yield and indicate the type of water aquifer. Highway Department drill-hole records are also located and described. It is not the intention of this report to supersede the favorability maps with the *Ground Water Probability Map* of this report. The favorability maps have been most useful to this study and the data they contain are quite accurate. The probability map of this report merely utilizes more recent data and the seismic profiles.

A few highway department bore-hole records were used to give information concerning the sediment in Otter Creek valley south of Rutland. These records were made available by Mr. Frank Lanza, Geologist, Vermont Highway Department.

Ground water is a limited resource in the Rutland-Brandon region and its management poses one of the most important and critical aspects of environmental planning. As already discussed, a surface water reserve is still available in the region, but the protection of this supply requires immediate action to prevent development of the watersheds, restrictions on lake usage and controls to prevent pollution of the surface water. In the event these precautions are not taken, ground water will be the most readily available reserve and, in view of the fact that the demand for water will increase, the most likely to be utilized.

Ground water in this region has three major modes of occurrence: in the fractures in the bedrock, in solution cavities of the limestones and dolomite and in the unconsolidated sediment in stream valleys. Of these, the sediment probably offers the largest reserve that can be produced with the least amount of expense.

Water is available in the fractures of the bedrock since, as has already been noted, most of the rocks are metamorphosed, recrystallized, broken and fractured (Figure 13). The rock contains little or no pore space

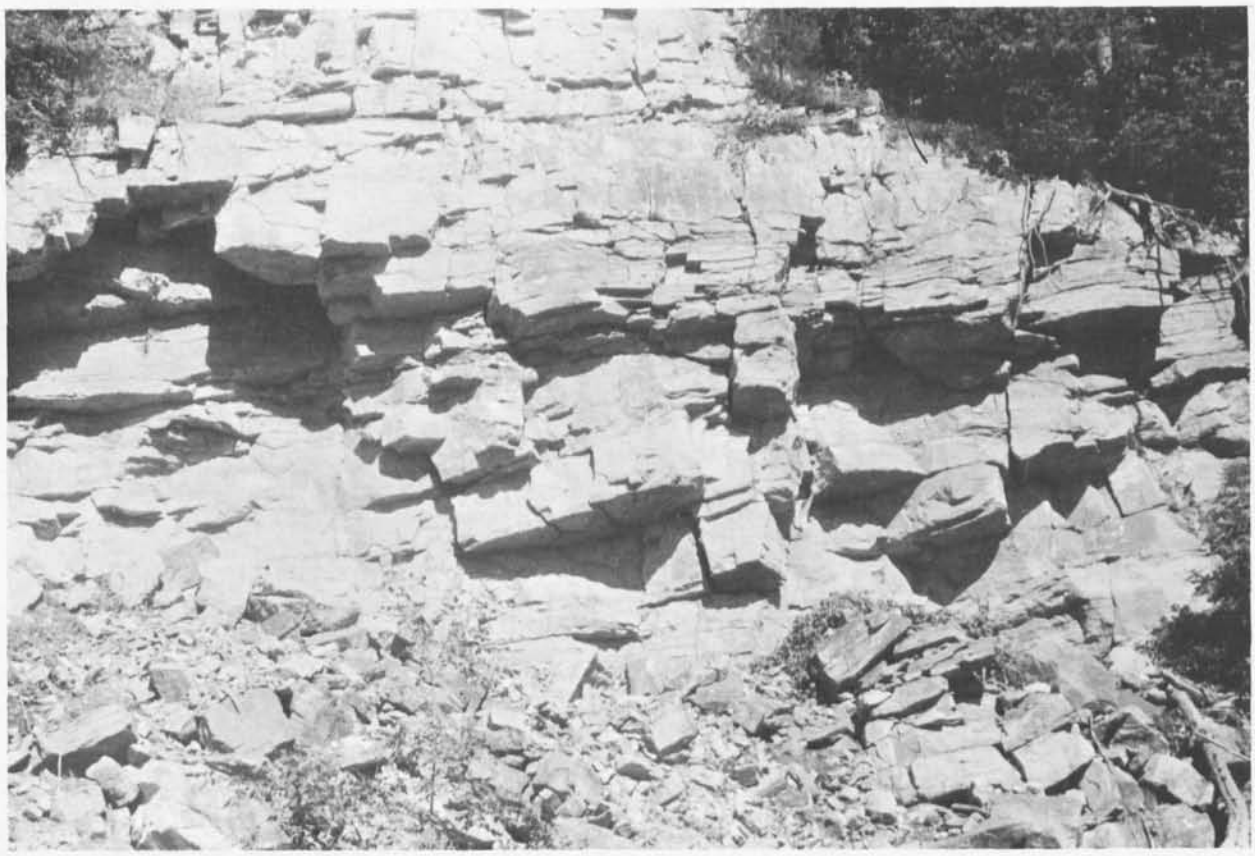

Figure 13. Fractured limestone bedrock exposed along the Lemon Fair River one and one-half miles west of West Cornwall.

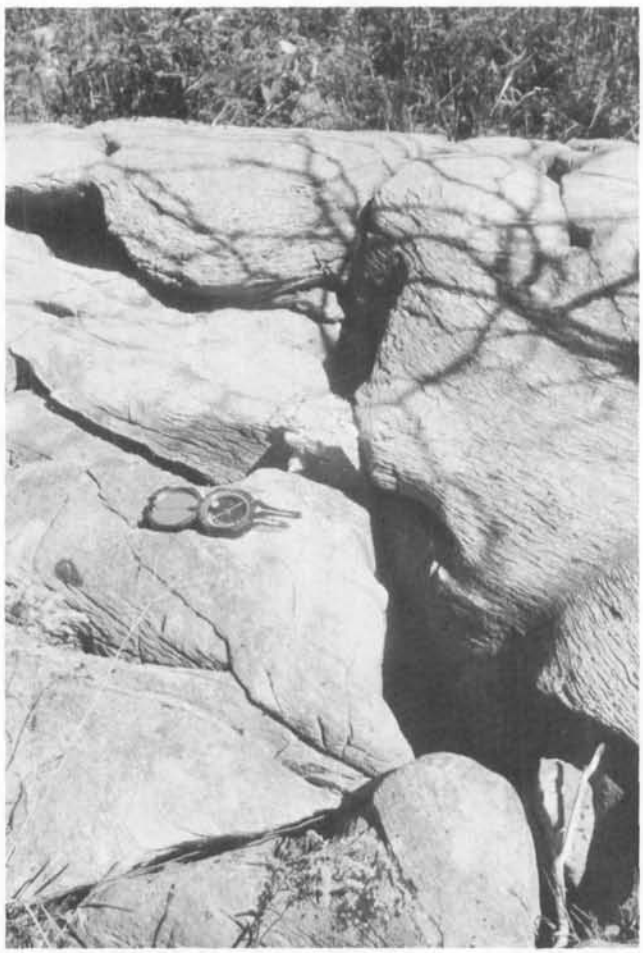

Figure 14. Solution cavities in limestone bedrock one mile south-southeast of Leicester Junction.

between the grains to hold water and through which the water can readily move. The fractures are open at the surface and their width decreases downward. At depth below 400 feet, the fractures are usually so tight that they either contain little or no water or the water contained in them is held by capillary action. The fractures in the rock trend in all directions and they intersect at all depths. For this reason, the water is usually under hydrostatic pressure and commonly rises in the well. Bedrock water wells, as a general rule, have very low yield, ranging between 2 and 10 gallons of water per minute with an occasional well with a yield of 50 or 60 gallons per minute. Inasmuch as the Taconic and Green mountains are veneered with a thin mantle of till with low permeability, the fractures in the bedrock are the only source of water.

The limestone and dolomitic marble of the Champlain and Vermont valleys is also highly fractured. The carbonate rock, however, is solvable in acidic water and is dissolved enlarging the fractures and forming cavernous channelways in the rock (Figure 14). These channels carry water from the surface downward and form openings in which the water can be stored. The Vermont Marble Company reported finding gravel in a well near Florence at a depth of 120 feet. This gravel had been moved downward by water from the surface of the land. The marble company drilled three wells in the vicinity of Florence that yield water from solution cavities in the rock. The total water yield of the three wells is about 150 gallons of water per minute. The solution channels are not so numerous as fractures and few wells intercept the cavities. Therefore most wells in the marble belt produce water from the fractures and the yield is approximately the same as noted above for the Taconic and Green mountains.

The water that occurs in fractures and solution cavities in the rock is most susceptible to contamination (Hodges, 1967). Whereas organic contamination in water would be removed in a short distance of filtration through sand or other sediment, it might travel for miles through rock fractures or solution cavities without removal. Once contamination occurs, control and abatement are very difficult.

An area that apparently has one of the highest ground water potentials of the region includes all of the kame, outwash and lake sand and gravel, deposits occurring along the western base of the Green Mountains. This belt, trending north-south, extends from the southern border of the region, south of East Clarendon, through Mendon to Chittenden in the Rutland Quadrangle and from the Brandon area through Forest Dale, Lake Dunmore and East Middlebury to the northern border of the area mapped in the Brandon Quadrangle (Plate III). These deposits need some further study, but available information, mostly well records, indicates water-bearing surficial materials. Regrettably, no seismic work was done in this area because a limited budget did not permit such long traverses as would have been necessary to obtain diagnostic results.

Well records show that the kame deposits in the southern part of the Rutland Quadrangle vary in thickness from 40 to 185 feet. A single well south of the latitude of Rutland, however, is the only one that produces water from unconsolidated sediment. The kame material in this section is very sandy and resembles lake sand in texture, but the structure indicates ice contact deposition. East of Rutland and northward to the village of Mendon the kame gravel, in many areas, extends down to depths as great as 215 feet. Several wells in this section produce water from gravel aquifers, but the yield is generally low (10-25 gallons/minute) for this kind of sediment.

Between Mendon and Chittenden the kame deposit is thin (up to 90 feet) and the gravel is of lower quality. The kame sediment in this section is not well sorted, contains much silt, and is composed of a high percent of angular rock. It appears to be gradational between the average, well sorted kame gravel and unsorted till. The water potential in this section is much lower than to the south in the areas described above.

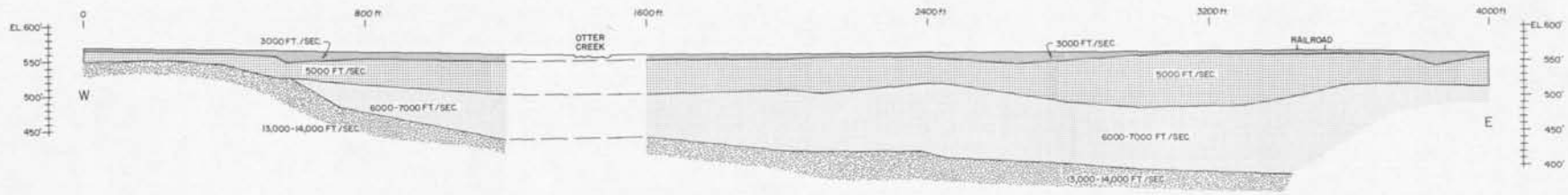

Figure 15. East-west seismic profile across Otter Creek valley three-fourths mile south of Rutland City limits.

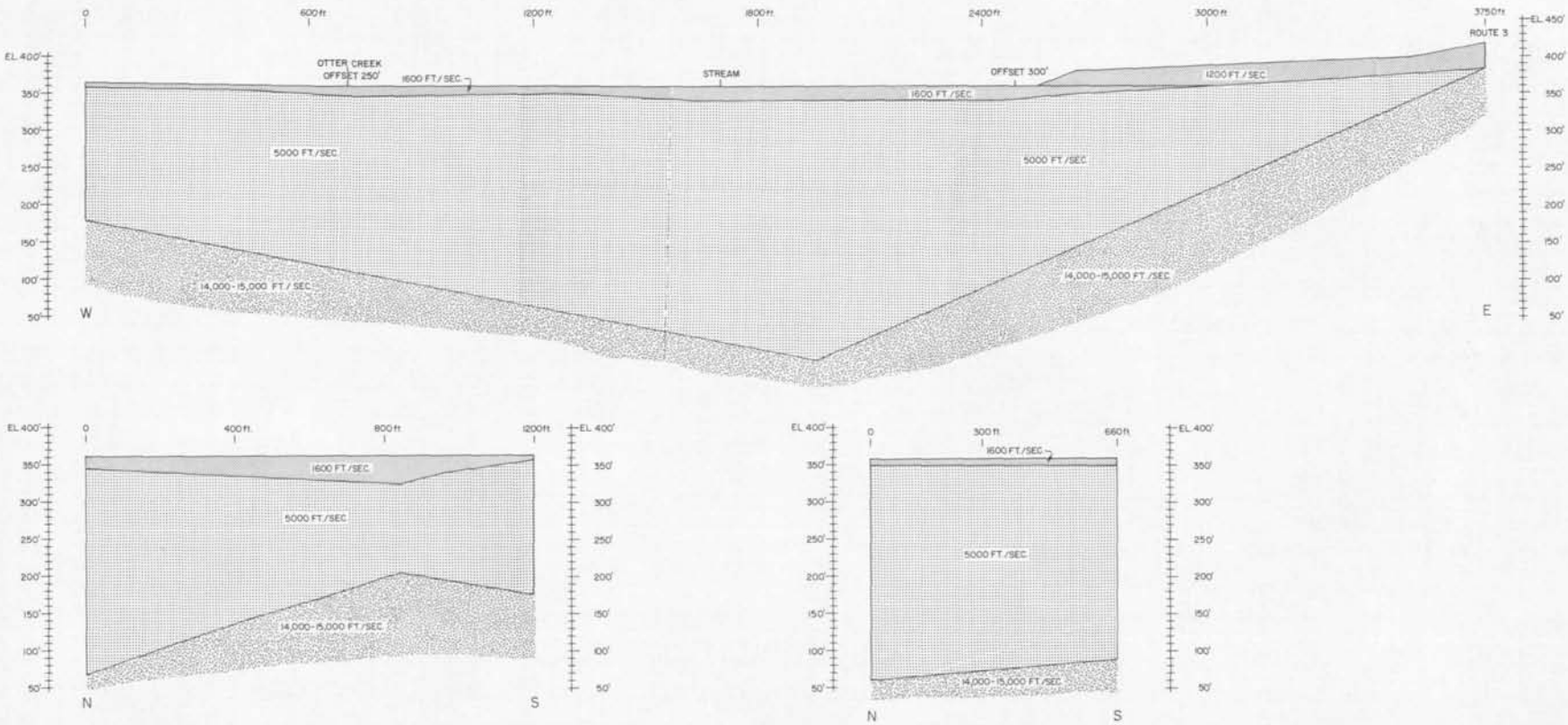

Figure 16. East-west seismic profile across Otter Creek three-fourths mile north of the falls at Proctor.

In the Brandon Quadrangle, lake sediment, mostly sand, occupies a wide strip from the southern border of the map to Forest Dale. Well records show this deposit to exceed 230 feet in depth in some localities and several wells produce water from gravel at depths ranging from 90 to 230 feet. According to Hodges (1968), a well located at Forest Dale, owned by the Town of Brandon, yields 450 gallons of water per minute from a gravel aquifer at a depth of 60 feet. Most of the wells in this area that produce water from gravel, however, have yields of only 4 to 20 gallons per minute.

North of Forest Dale the valley is filled with kame gravel to the vicinity of Lake Dunmore, but there is little information available concerning the water potential. Three wells, located on the east side of the deposit, indicate the gravel is quite deep, extending to over 170 feet. Wells located along the east and north shore of Lake Dunmore penetrate the gravel to depths ranging from 40 to 80 feet, but none of the wells reaches bedrock. In spite of the limited data, it is believed that this section has a high water potential.

North of Lake Dunmore, there is scanty information concerning an outwash deposit that extends northward to East Middlebury. Two wells in this locality produce 10 gallons of water per minute from a gravel aquifer at depth of 70 and 80 feet. Another well penetrates bedrock at 60 feet. Undoubtedly there is a good water reserve in this area. North of East Middlebury, wells yield water from gravel at depths up to 145 feet. Yields are generally low and range up to 30 gallons per minute. The town of East Middlebury has a well in the village of East Middlebury that yields 90 gallons of water per minute from a gravel aquifer at a depth of 40 feet.

A kame gravel area located in the Green Mountains adjacent to U.S. Route 4, one mile east of Mendon, seems to have a potentially good ground water reserve. The area extends for about four miles on either side of U.S. Route 4. Wells in this small area yield water at rates up to 125 gallons per minute from gravel aquifers varying in depth between 50 and 150 feet (Plate III).

The Otter Creek valley south of Rutland is covered with lake sand and alluvium (Plate I). The valley is low and flat and subject to flooding. There are no producing water wells for which records are available. Seismic data (Figure 15) and highway department drilling records, however, indicate that the valley is over 175 feet deep just south of Rutland. The valley fill is till at the bottom that is over 100 feet thick in some sections. Lake silts and clays that overlie the till average approximately 50 feet in thickness with maximum being about 85 feet. The sand and alluvium on the surface are quite thin. This section of the valley does not seem to have a water potential large enough for a municipal or industrial supply. Deltaic deposits of the Mill and Cold rivers, made during the lake stage following glaciation, do seem to have possibilities as water aquifers. Further study of these deposits is warranted.

At Rutland, on the southern side of the city, a well in the Otter Creek valley yields 100 gallons of water per minute from gravel at a depth of 80 feet. This single well indicates that the valley at this point is filled with gravel. The extent of this gravel is not known, and further study is needed to ascertain the composition of the valley fill westward to Center Rutland.

From the falls at Center Rutland to the falls at Proctor, the Otter Creek valley is filled with lake silts, silty clays and clays. Test wells made by the Village of Proctor south of the falls at Proctor indicated 120 feet of clay above bedrock. Possibilities of water in this section are very low.

North of the falls at Proctor the Otter Creek valley has probably the highest water potential of any area in the Rutland-Brandon region. The Village of Proctor has a water well one-fourth mile northeast of the falls. The well penetrates 135 feet of sand and gravel and yields 385 gallons of water per minute. Seismic profiles one-half mile north of the falls (Figure 16) show the valley to be 375 feet at its deepest point along a generally east-west profile. It cannot be stated at this time just how far downstream the gravel fill extends. Kame gravel and sandy lake sediment cover a sizable area from Proctor to Florence and north to Pittsford, but the Otter Creek valley west of Pittsford is floored with lake clay with a veneer of alluvium. It seems, therefore, that the valley is filled with clay in that section, but gravel may underlie the surface sediment as far north as Florence.

North of Florence, Otter Creek flows over a valley filled with lake silts and clays. It is apparent that the water potential is very low and that water in quantity adequate for a municipal or industrial supply is unavailable in the valley sediment.

Tributary valleys of Otter Creek that contain sediment that might yield ground water in quantity are few. As already noted, Mill and Cold rivers, except for deltaic deposits, are not possibilities and East Creek, north of Rutland, has similar valley characteristics. The Clarendon River flows in a wide deep valley, but the valley is filled with lacustrine silts and clays. Two miles north of Rutland, sediment in a small valley and kame terraces along the valley walls do contain water. The area is about one mile wide and three miles long (Plate III). Kame terrace gravel covers the lower slopes of Blueberry Hill and gravel and sand fill the valley at the head of a small stream that flows into Furnace Brook. Seismic data (Figure 17) indicate a valley 150 feet deep is filled with saturated sediment. One well log in this area records 40 feet of fine sand at the top underlain by 112 feet of gravel above bedrock. Inasmuch as these deposits are adjacent to U.S. Route 7 and about halfway between Rutland and Pittsford, they may prove to be important water aquifers.

Furnace Brook, in the vicinity of Pittsford, flows through sandy lake sediment from Grangerville

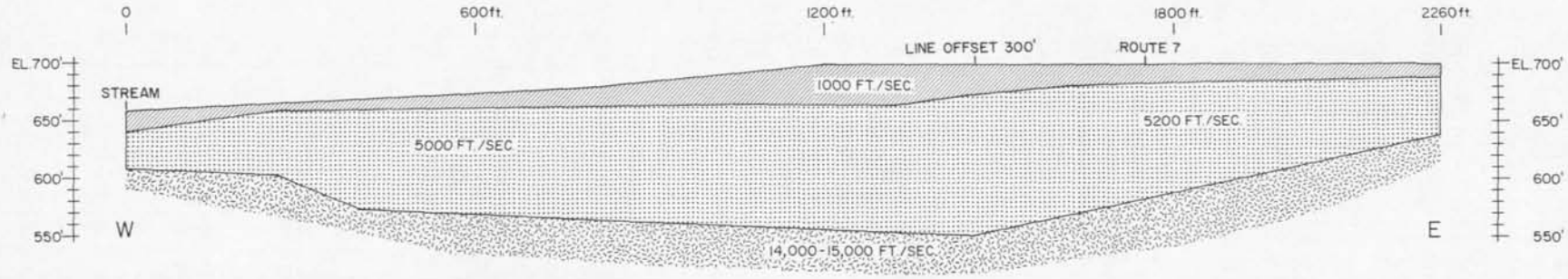

Figure 17. East-west seismic profile across valley of an unnamed tributary of Furnace Brook. Two miles south-southeast of Pittsford Mills.

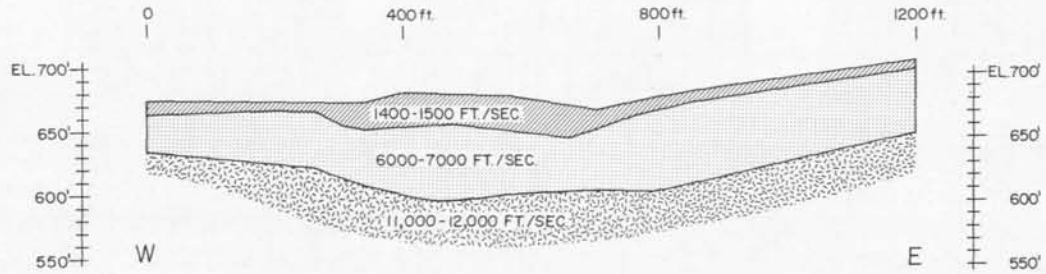

Figure 18. East-west seismic profile across unnamed tributary of Furnace Brook one and one-fourth miles northeast of Pittsford Mills.

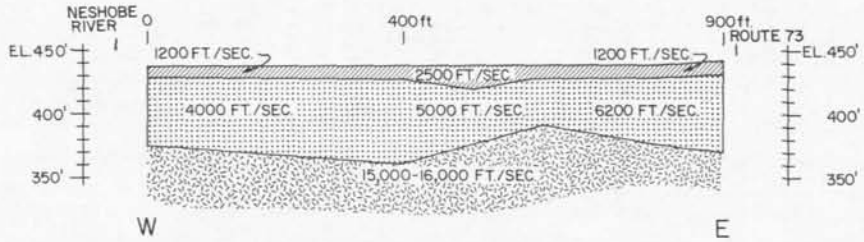

Figure 19. East-west seismic profile across the Neshobe River. Three-fourths mile north-northeast of Brandon.

(north of Pittsford) southward to its confluence with Otter Creek. The sand in this area is thin and covers silt and clay lake sediments, and the water potential is low. North of Grangerville, Furnace Brook flows over till and bedrock, and its tributary streams, except the one already noted, are filled with lake sediment (Figure 18). A small kame area in the vicinity of Grangerville trending east-west for approximately two and one-half miles, may contain water.

Seismic data (Figure 19) shows that the Neshobe River valley north of Brandon is filled with lake clays and silts, and the Leicester River valley southwest of Salisbury is also filled with lake-bottom sediment. The Middlebury River valley west of East Middlebury, according to well records and seismic data, contains sand and gravel up to 150 feet deep (Figure 20). Two wells in the valley, one mile east of U.S. Route 7, yield 5 and 92 gallons of water per minute from a gravel aquifer at depths of 106 and 110 feet. The westward extent of the gravel aquifer is not known, but it is doubtful that it extends beyond Farmingdale, two miles west-southwest of East Middlebury.

The Castleton River valley from West Rutland northward to Butler Pond is low, flat and swampy. Seismic data show the valley is filled with lake clay and therefore not a water aquifer (Figure 21). Lake-bottom sediment and till also fill the valley for two and one-half miles after it turns westward toward Fair Haven. In Castleton Township, however, the valley fill is sand and gravel that is mostly lake sediment with probably some interbedded outwash gravel. Records of wells drilled in the valley east of Castleton show ground water yields at rates of 6 to 30 gallons per minute at depths ranging between 50 and 90 feet. A seismic profile one mile east of Castleton indicates a valley 1,400 feet wide with a maximum depth of 90 feet (Figure 22). The Town of Castleton has two wells just north of the river at Castleton village, 25 and 35 feet deep, that produce 210 and 130 gallons of water per minute from gravel. A seismic profile across the valley one-half mile west of Castleton shows a valley depth of 50 to 95 feet (Figure 23). Well records prove that the valley is wider and deeper to the west between Castleton Corners and Hydeville with some wells in that section yielding 15 to 40 gallons of water per minute from gravel aquifers at depths of 120 to 160 feet. The probability of a large ground water reserve in this section seems assured and additional investigations are warranted to determine the quantity and quality of water. Sand deposits, apparently following a buried valley, that occur between Castleton Corners and Bomoseen are, according to well records, of irregular depth. One well located one and one-half miles north of Castleton Corners is 75 feet deep and yields 30 gallons of water per minute.

The Poultney River, in the southwest corner of the Rutland-Brandon region, flows through a deposit of lake sediment, mostly sand and gravel, between East Poultney and Poultney. The river turns north at Poultney village to follow a wide valley to the New York border. The sediment in the valley varies in depth between 20 and 85 feet, and water is available in the deeper portions. The Town of Poultney has a well in the valley at Poultney village that yields 250 gallons of water per minute from gravel at a depth of 40 feet. A seismic profile one mile north of Poultney shows an irregular valley bottom with saturated sediment from 40 to 80 feet deep (Figure 24).

On the east side of the Green Mountains, the Ottauquechee and White River valleys offer fair to good water potentials. South of West Bridgewater, a tributary valley of the Ottauquechee, containing Woodward Reservoir and Black Pond, has kame deposits of variable thickness and extent. In the vicinity of Woodward Reservoir and Black Pond, two water well records show sand and gravel up to 90 feet deep. One well near the reservoir yields 20 gallons of water per minute from gravel at a depth of 58 feet. A second kame deposit is located in the Ottauquechee valley in the vicinity of West Bridgewater, but no well records are available for this locality. In the Sherburne section of the valley, well records suggest that a moderate reserve of ground water may be available. The section extending from two and one-half miles south of Sherburne to one mile north of it seems to have the best potential. Records of wells recently drilled in this part of the valley indicate sand and gravel 60 to 80 feet deep. Two wells producing water from gravel yield 8 and 16 gallons per minute. Upstream beyond this section, the valley is filled with till and lake sediment (Figure 25).

The White River valley has the best ground water potential in the Town of Rochester. This sector extends from the confluence of Cold Brook, two miles north of Stockbridge, to Cobble Hill, one mile south of Hancock. The sediment in this portion of the valley, according to well record data, is from 50 to 140 feet deep and composed of a mixture of sand and gravel interbedded with some silt and clay. One well, near the confluence of West Branch, is 140 feet deep and yields 25 gallons of water per minute. A seismic profile one-half mile north of Rochester reveals a maximum depth of 95 feet to bedrock (Figure 26).

SOLID WASTE DISPOSAL

The geological problems associated with solid waste disposal are due to the fact that when refuse is saturated with water, even intermittently, it produces a liquid contaminant called leachate. Leachate usually contains a high percentage of dissolved mineral material and, because it is liquid, it acts as a transporting agent for both biological and chemical pollutants. It is imperative, therefore, that these solutions do not seep downward to the water table or move laterally into surface water. Because of the fractures and

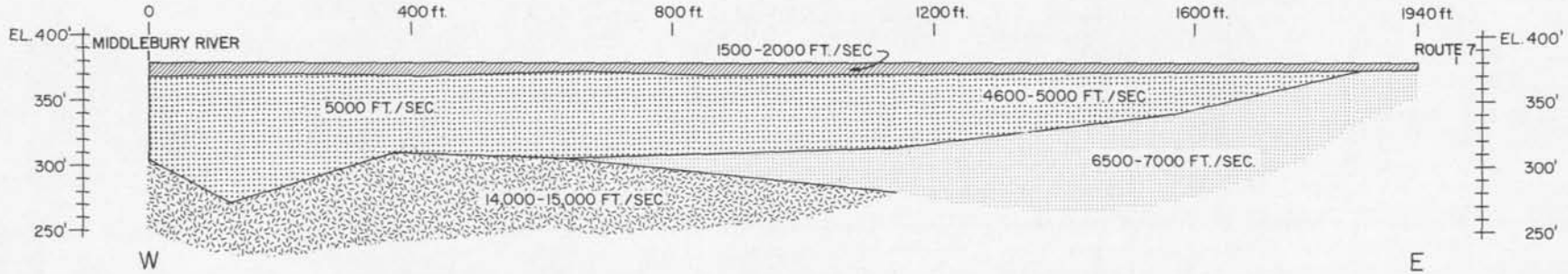

Figure 20. Seismic profile across the Middlebury River valley, one mile southwest of East Middlebury. East half of profile trends east-west, west segment trends southeast-northwest.

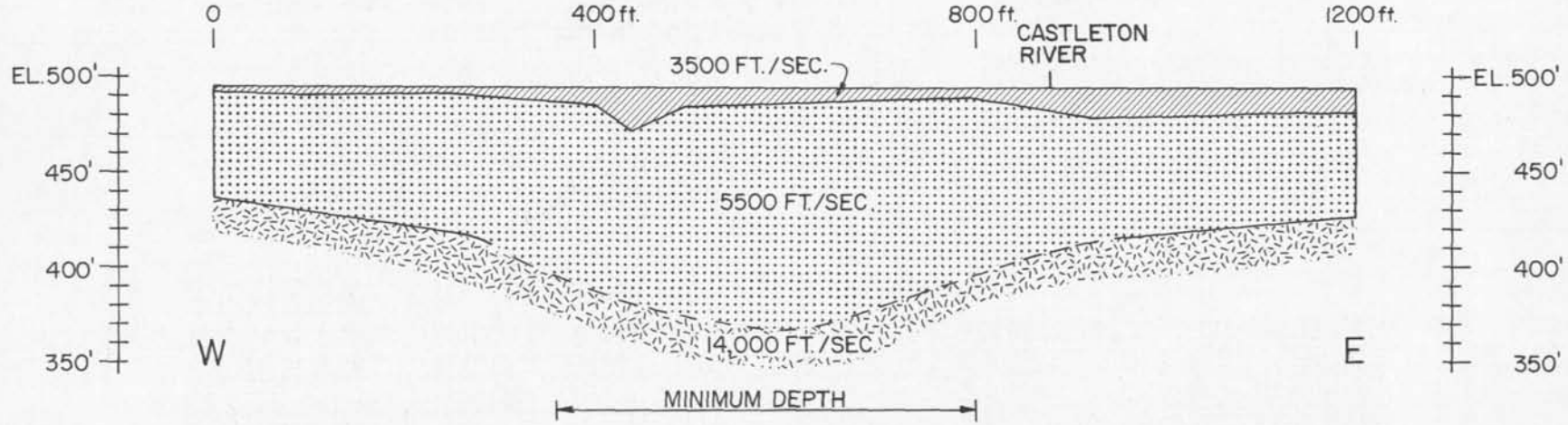

Figure 21. East-west seismic profile across the Castleton River valley one and one-half miles northwest of West Rutland.

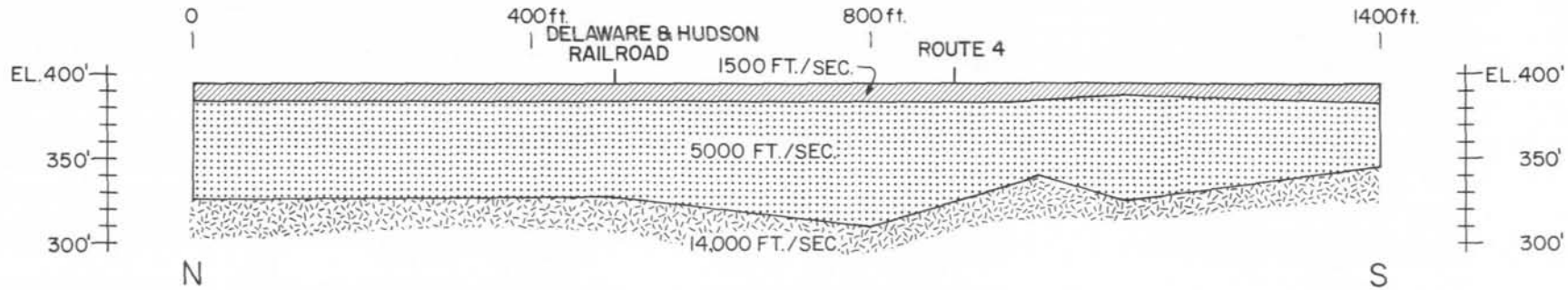

Figure 22. North-south seismic profile across the Castleton River valley one mile east of Castleton.

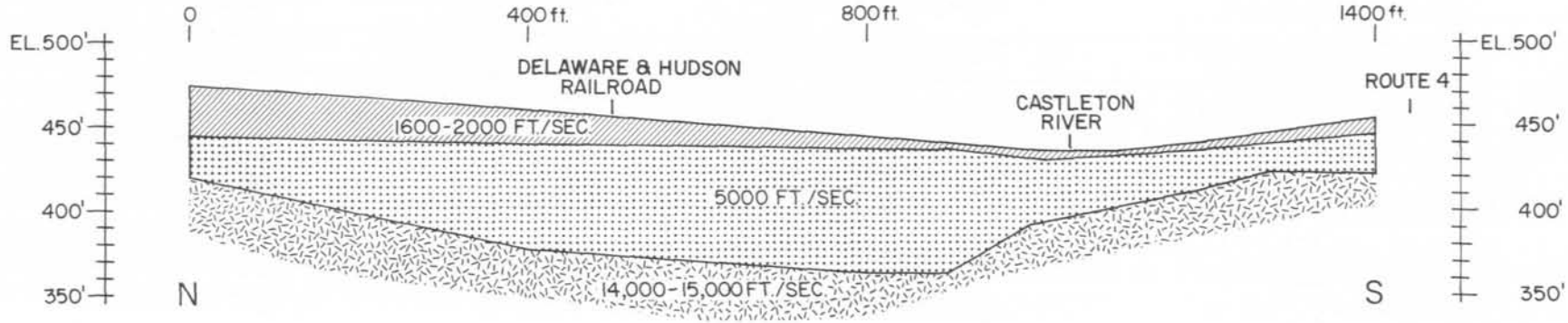

Figure 23. Northwest-southeast seismic profile across the Castleton River valley one-half mile west of Castleton.

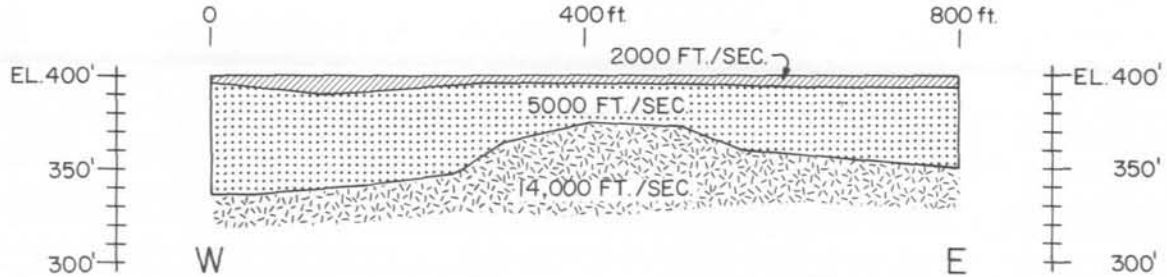

Figure 24. East-west seismic profile across the east (Vermont) side of the Poultney River valley one-fourth mile north of Poultney.

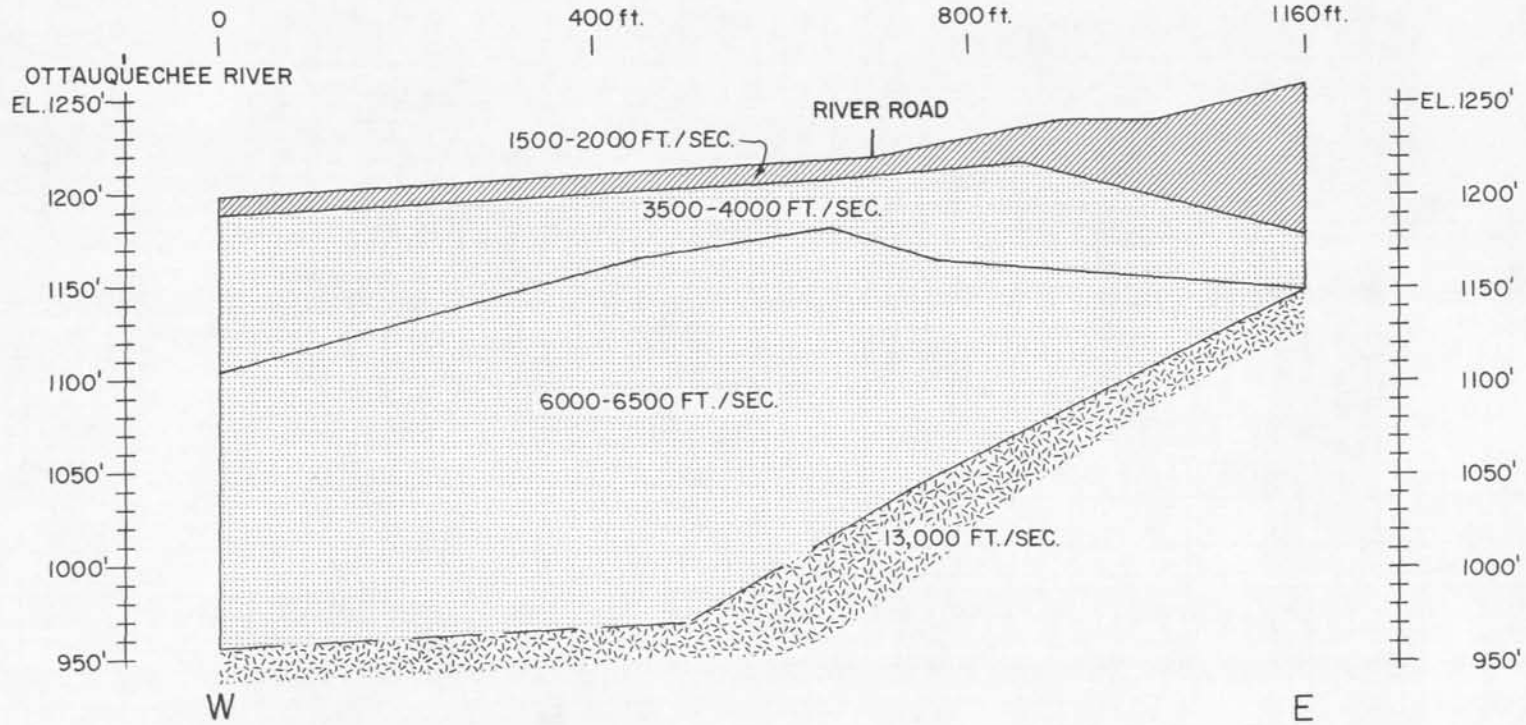

Figure 25. Northeast-southeast seismic profile across the Ottauquechee River valley one and one-half miles north of Sherburne Center.

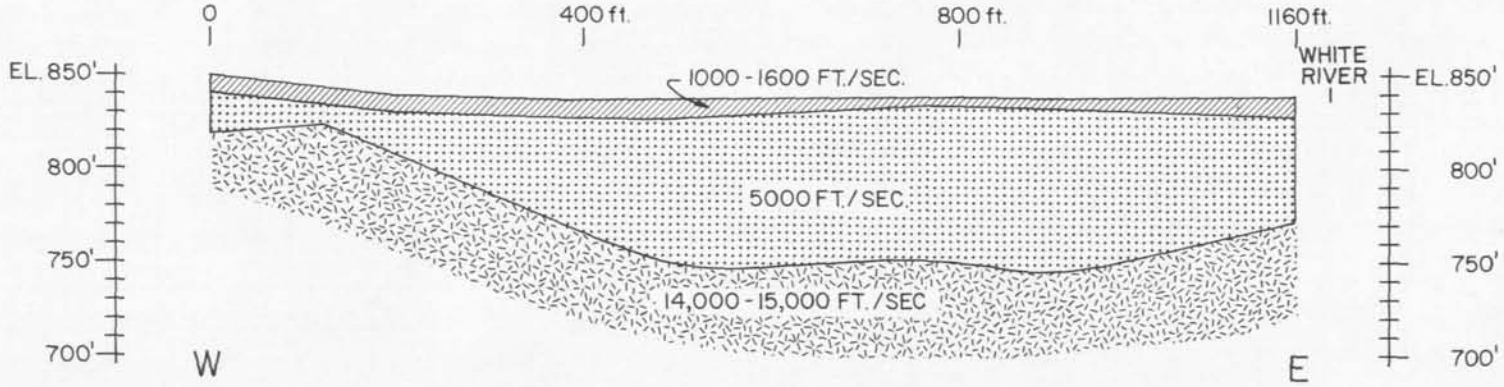

Figure 26. Seismic profile trending north-northwest across the White River valley one-fourth mile north of Rochester.

solution cavities in the bedrock of the Rutland-Brandon region, it is necessary to contain the leachate above bedrock inasmuch as the fractures and cavities allow free passage of liquids.

Two precautions must be taken to decrease the amount of leachate produced and to restrict its movement to a small area above bedrock. In the first place, a site must be selected where the surficial material is low in permeability and of sufficient thickness to contain the leachate. Secondly, the material used for cover must also be nonpermeable to prevent surface water (precipitation) from entering. These precautions prevent the migration of the leachate beyond the area of the fill and the resulting contamination. In the Rutland-Brandon region, materials with low permeability that are suitable for sanitary landfill sites are the glacial tills and the lacustrine silts and clays (Plate I). According to the Illinois Geological Survey (Cartwright and Sherman, 1969; Hughes, London and Farvolden, 1971) a 30-foot minimum thickness of impermeable material is necessary to prevent the escape of leachate and the Geological Survey of Alabama suggests 50 feet (Riccio and Hyde, 1971). Inasmuch as surficial material in Vermont is similar to that in Illinois, this thickness is recommended as a minimum in the Rutland-Brandon region.

A proper cover material for a sanitary landfill is important for three reasons. First, the amount of surface water entering the fill determines, in a general way, the decomposition that takes place and therefore the amount of leachate formed. Second, excess water causes the formation of ground-water mounds. Such mounds form when precipitated water that infiltrates the refuse is so restricted in its lateral flow that the water builds up in and along the sides of the fill. The water often seeps out along the margins of the landfill site when the ground-water mound builds up high enough to intersect the surface (Hughes, London and Farvolden, 1971). A third reason for an impermeable cover, especially in Vermont, is to prevent freezing and thawing of water in the refuse during the winter months. Since the material containing the fill is of low permeability, water that infiltrates will collect and freezing and thawing will occur. If, however, the cover prevents water penetration this effect will be minimized. Freezing and thawing of water causes frost heaving that loosens and dislocates the compacted refuse allowing more water to enter. Drainage of surface water away from the landfill site can be accomplished by compacting and sloping the surface of the fill.

The above discussion of favorable geologic conditions for landfill sites precludes the use of sand and gravel deposits for that purpose. It has long been a practice in Vermont to use abandoned sand and/or gravel pits for solid waste and garbage. Such practices are most undesirable since sand and gravel have high permeability and the leachate moves freely in any direction. Many of these deposits have high water tables because of the water they contain. The cover used at these sites is usually sand and/or gravel that does not prevent the infiltration of water through the refuse. Even well sorted, very fine sand is too permeable for such use.

The solid waste conditions map included in this report (Plate IV) gives a generalized classification of the surficial materials as they relate to solid waste disposal. The areas outlined on the map have been so designated because of the type and thickness of materials and their permeability. The map is intended as a guideline in selecting landfill sites, but it does not eliminate the necessity for a detailed study of each individual site to be used.

The areas designated r-1 on the map are sand and gravel deposits with permeabilities too high for solid waste disposal. These include kame, outwash, and lake deposits composed predominantly of sand and/or gravel. Surface characteristics, well records and seismic data indicate these deposits are of considerable thickness with consistent textures. Use of these areas for solid waste would require costly sealing materials and techniques to restrict the movement of the leachate. In some areas, there are already solid waste disposal operations located in these deposits that should be relocated to more suitable locations.

The r-2 legend on the map locates swampy and poorly drained localities. The larger and more extensive of these are in the Otter Creek valley, particularly north of Brandon, where clay in the valley prevents internal drainage and flooding is common due to the low relief. It is impossible to prevent contamination of the surface water under such conditions.

Till areas are yellow (y) on the map. Many areas of these till deposits are suitable for solid waste disposal inasmuch as the till has low permeability and only the thickness is a limiting factor. As already stated, research in other regions has determined that at least 30 feet thickness is necessary for a landfill. Environmental agencies need equipment to determine thickness and to perform simple permeability tests.

The green sections (g) on the map are covered with till and lake clay with thicknesses in excess of 30 feet. There are no apparent restrictions to using these areas for sanitary landfills.

SEWAGE DISPOSAL

This report is not particularly concerned with municipal or industrial sewage disposal inasmuch as these facilities are controlled primarily by rigorous state and federal regulations. The Vermont Department of Water Resources and the former State Water Conservation Board have maintained a continuous study of the surface streams of the state and staff

reports are available for most stream systems. These reports have noted sources of surface water pollution and efforts have been continually made to eliminate the sources. It suffices for this report to point out that some municipalities, mostly small villages, do not have adequate sewage disposal systems. State law should prohibit dumping of raw sewage by any individual or group, public or private, into any surface water. Public sentiment runs high against an industrial facility that pollutes surface water, but the same public is reluctant to vote levies, taxes and bond issues to build, expand or maintain publicly owned sewage systems that pollute the same water.

This report is much concerned with the domestic sewage problem in the Rutland-Brandon region. Environmental State Board Chairman, Benjamin Partridge, has recently stated that he believed single unit vacation home construction may pose as great a threat to Vermont's environment as large vacation home developments (Coffin, 1971). Although Mr. Partridge was speaking specifically about the adverse effects of vacation homes on small parcels of land not controlled by state law, this report agrees that single-unit, rural dwellings, and not just vacation homes, pose a real threat because of domestic sewage regulation and control. Domestic sewage disposal, chiefly by septic tanks, the writer believes, is a problem that has not been fully realized by state agencies. The Vermont Water Resources Department publishes, in pamphlet form, very complete and easily understood directions on the proper installation of septic tanks, but the enforcement of regulations is a local government responsibility and here the system breaks down.

In spite of the inadequacies of the septic tank as a domestic sewage system, it is still the most desirable for a single-unit dwelling. Housing subdivisions and multiple dwellings, however, are a different situation and require more sophisticated systems. The desirability of the septic system results from the bacterial action that takes place in the tank. But, from a geological point of view, the leaching field is of prime importance because it distributes the affluent (liquid from the septic tank) over a large area. The leaching field is a network of tile that is installed near the surface where the surficial material is loose and permeable. The tile, which has small holes to allow the affluent to escape, is laid in a trench with a flat bottom, and gravel fills the trench above and below the tile. The efficiency of the leaching field, particularly in material of low permeability, can be controlled by the length of pipe used as well as by the width of the trench. Dry wells, cesspools, lagoons and similar methods are less desirable because they concentrate the affluent in a smaller area and they are deeper where the surficial material is more compact and less permeable. The geologic problem with the septic tank and leaching field is similar to solid waste inasmuch as the affluent should be contained above bedrock and therefore the thickness of the sediment covering bedrock is an important factor. The affluent from a septic tank, however, contains chiefly biological contaminants that are more easily removed by seepage than the chemical contaminants from solid waste.

In the Rutland-Brandon region, the practice of using dry wells with septic tanks is widespread regardless of the type and thickness of the surficial material above bedrock. The sewage system pictured in Figure 27 has a dry well deeply buried in compact till covered with coarse, crushed stone. In spite of the large circumference of the excavation, and therefore a fairly large seepage surface, the till at that depth is too compact to transmit a large amount of affluent. As a result, the excess liquid will rise in the well and may come to the surface. This installation would have been more efficient with a 200-foot long leaching field located within three feet of the surface.

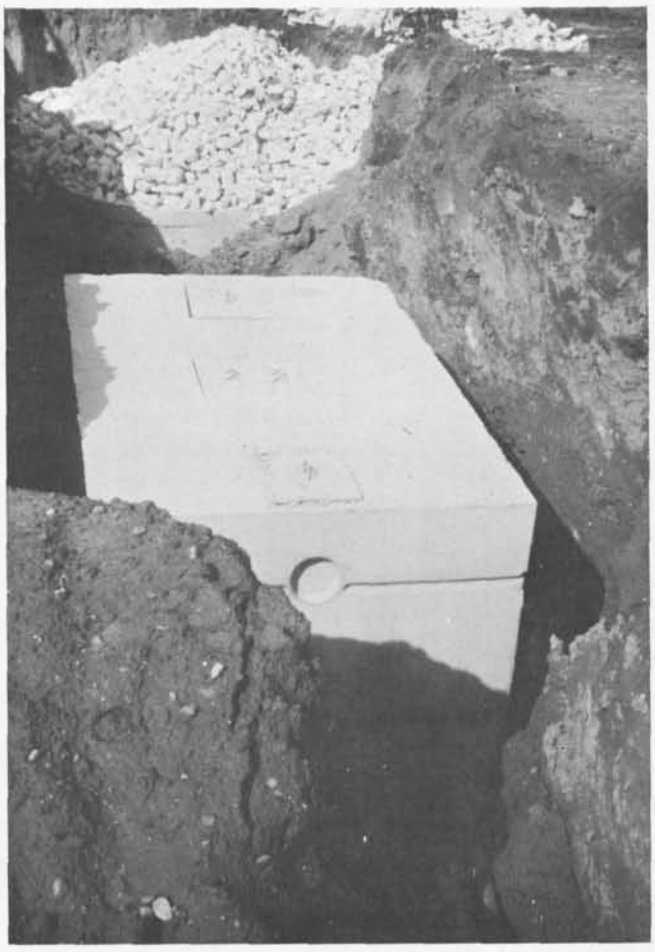

Figure 27. Septic tank installation with dry well covered by coarse, crushed stone. This is a common type installation in the Rutland-Brandon region.

The septic tank conditions map (Plate V) delineates the characteristics of the surficial material as they relate to domestic sewage, particularly septic tanks. The wide use of yellow and red as compared to small

patches of green suggests that there are few localities in the region that do not have limitations for septic tank use. The areas designated r-1 are low, poorly drained stream bottoms covered with alluvium and/or swamps. The surface material is poorly drained, often wet, frequent flooding occurs in the spring and during heavy rains and the permeability of the sediment is generally quite low. Under these conditions septic tanks would operate at best only during periods of dry weather.

Areas with considerable thicknesses of lake silts and clays are legend r-2 on the map. These areas are so designated because of the extremely low permeability of the lake sediment and septic tanks as they are normally installed will not function properly in such material. Building, of course, will no doubt continue in these sections and special specifications for sewage disposal systems is imperative. This report recommends the use of mechanically operated tanks, seepage fields with gravel fill at least three feet wide and two feet deep and at least 200 feet of tile for each leaching field.

Till areas are designated y-1 on the map. The use of septic tanks in these regions depends on the slope of the land and the thickness of the till covering bedrock. As a general rule, 10 to 12 feet of till cover should be sufficient to prevent the affluent from reaching bedrock before purification. Steep slopes are problems inasmuch as the fluid added to the soil causes movement down slope. Usually this movement is very slow but slumping and sliding (rapid movement) may occur. As stated before, there is a general movement of people to the higher regions of Vermont, and this trend is quite apparent in the Rutland-Brandon region. On most steep slopes, the mantle covering bedrock is thin and these conditions complicate proper installation of a sewage system.

Areas designated y-2 on the map have permeable sand and gravel surface deposits. These localities are suitable for septic tank use only if the deposit is over 15 feet in thickness and the water table is over 25 feet below the surface. Many of these sections are covered with lake sand, often above silt and clay of low permeability. The silt and clay, below sand and/or gravel, will normally prevent the passage of the affluent.

The green areas on the septic tank conditions map are those that are known to have till cover of sufficient thickness for septic tank installation.

Housing developments in areas where municipal sewage is not available should have a single sewage system. Developments that require a separate sewage system for each housing unit only compound the septic tank problems. Regulations for subdivisions relating to the thickness of sediment covering bedrock do not take account of the varying permeabilities of surficial materials and assume an impervious bedrock. Contamination from housing developments is therefore always a possibility. Multiple-unit housing should also have sewage systems that are specifically designed for the whole unit to accommodate the total capacity of the housing.

SKI DEVELOPMENT

In recent years, ski developments have expanded greatly in size and number in Vermont and two of the largest ski areas are located in the Rutland-Brandon region. The Killington ski area is by far the largest development in the region, but the Pico Peak area is also of considerable size. Much development has taken place in the surrounding countryside. The ski developments, of course, are centered around localities where ski slopes and ski lifts have been constructed either by state or private funds or both. The ski slopes and lifts are as a general rule well maintained and pose little or no environmental problems. Associated with the ski areas, however, are developments for vacation and permanent housing. The housing developments do create environmental problems because of the intensity of the development, the steepness of the slopes, the thinness of the bedrock cover, and the problems of water and sewage.

In the Killington ski area a network of roads for housing developments has been made adjacent to the ski trails and the roads pass through sections where hillside slopes vary from 30° to 70° (Figure 28). The land bordering these roads has been divided into half-acre lots and both vacation and permanent housing has been started and continues. No sewage or water has been arranged by the developer, so each individual lot requires an independent water supply and sewage system. In much of this region, however, the slope of the land is at a high angle, the till covering the bedrock is only 4 to 8 feet thick, the till surface is very bouldery and the bedrock below the till is highly fractured. Water wells already drilled in this section vary in depth between 125 and 475 feet and most wells yield between 1 and 4 gallons of water per minute.

Septic tank sewage systems in this development are an acute problem. There is not enough level ground for an adequate leaching field, the till is not thick enough to contain the affluent and is not permeable enough for infiltration to occur. As a result, the sewage systems are inadequate and often of makeshift design (Figures 29 and 30). Under these conditions it seems likely that as building continues, and by the time a fair percentage of the lots have been developed, sewage disposal will create problems both on the surface and in the water supply.

This report contends that developments for vacation and permanent dwellings in remote, hillside locations should have a sewage system, similar to a municipal system, installed by the developer before building is commenced. Ski developments in other

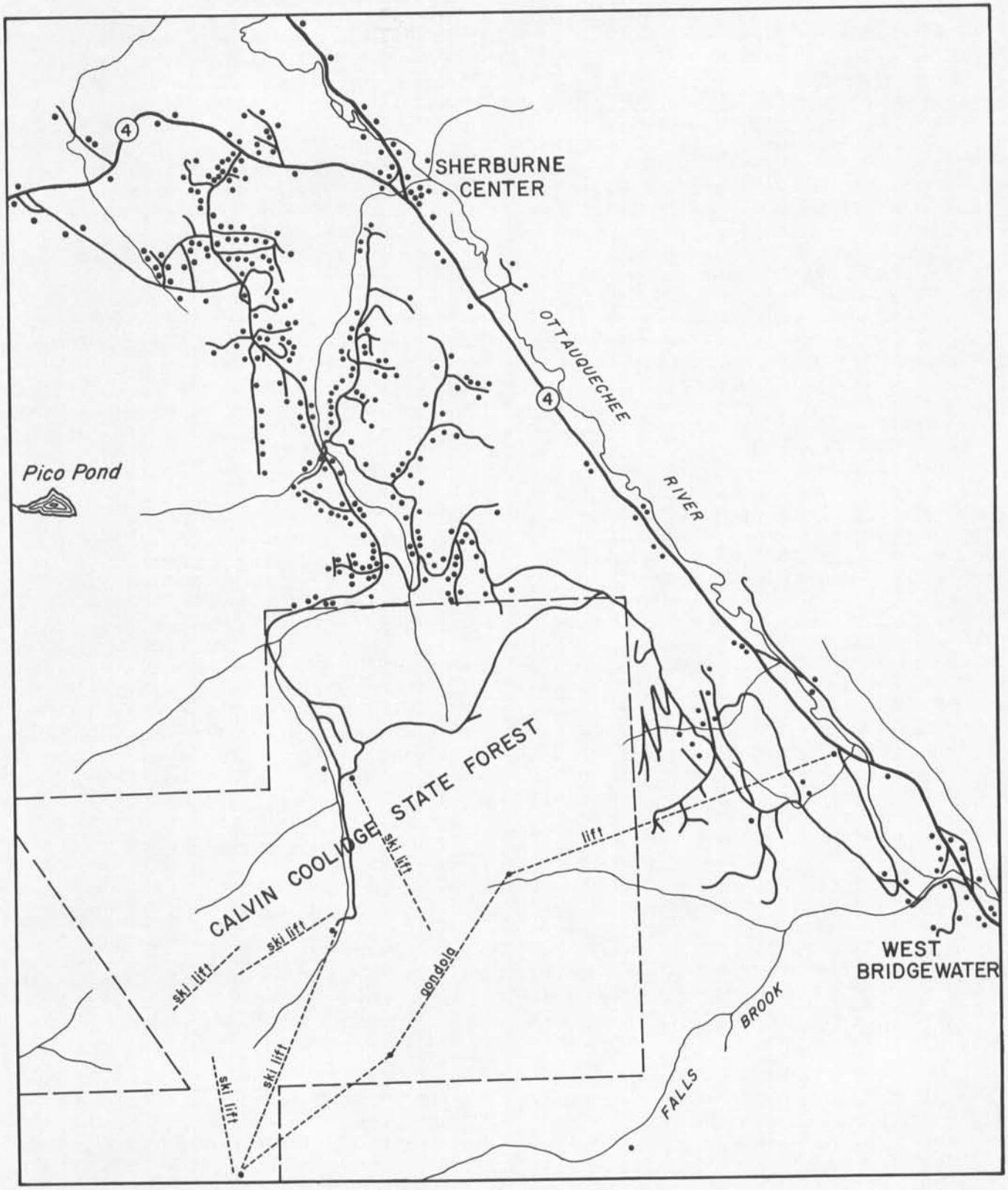

Figure 28. Development in the Killington Ski Area. Scale: One inch equals six and one-half miles.

regions of Vermont bear out the conclusion that single-unit sewage systems do not function properly under conditions normally found in those areas.

FOUNDATION MATERIAL

Foundation and building conditions in the Rutland-Brandon region are not as critical as other environmental aspects already discussed. The criteria for desirable construction sites concern such geological factors as slope, drainage, plasticity and strength of the surface material, the availability of water and accessibility of building material. In the area of this study, special planning and some limitations are necessary because of the poor drainage of the lake silts and clays and to some extent the tills, the plasticity of the clay, the flooding and poor drainage of stream bottomlands, the steep slopes and the strength of stream alluvium covering the valley floors. The floodplains of some streams, particularly Otter Creek, are too low and too poorly drained for any kind of construction (Plate VI).

The floodplains of most streams are veneered with a stream-deposited clastic sediment called alluvium that varies between 5 feet and 25 feet in thickness. The alluvium is a very undesirable foundation material since it is usually poorly drained; flooding is a serious, although seasonal, problem, and the strength of the alluvium is too low for heavy construction. If these bottomlands are to be used for industrial or other types of heavy construction, the total thickness of the alluvium should be removed.

Sand and gravel deposits offer favorable construction sites inasmuch as they have adequate strength, good drainage, and they usually contain large reserves of ground water. These deposits usually have economic value, however, and this factor should be taken into account when zoning such an area for use. It is recommended that good quality sand and gravel reserves should be set aside until after the sand and gravel have been removed. Most abandoned sand and gravel pits are suitable construction sites after a minimum of filling and grading. Lacustrine sands and gravels that overlie silts and clays require special study inasmuch as the plasticity of the clay may cause movement such as slumping, sliding or flowing. In these cases, the thickness of the sand and/or gravel should be ascertained as well as the physical characteristics of the underlying sediment.

Lake clay, as a general rule, has a high plasticity and is subject to flow. Large areas of the Rutland-Brandon region, particularly the northwestern part, contain lake clay at the surface that in some places is over 200 feet deep. The internal drainage of the clay is very low requiring that building specifications include detailed provisions for drainage. Steep slopes should definitely be avoided to assure that flowage does not undermine foundations. Tests to determine the plasticity and bearing strength are recommended for each site.

Steep slopes are common along the valley walls in most sections of the region. Slumping, sliding and creeping are common along these slopes, particularly those containing lake clay. Buildings should not be located on these slopes, on the top near the break of the slope, or in the valley near the base. Problems associated with building in the high mountains have, in part, already been discussed. In addition to slope in these areas, the characteristics of the bedrock are also important inasmuch as the sedimentary cover is thin or completely absent.

The general construction conditions map (Plate VI) classifies the surficial material according to its suitability for foundation material. The areas shown in green (g) are sand and gravel deposits. This designation includes lake sands and gravels which, as noted above, should be checked to ascertain the underlying material. Most of these deposits have considerable thickness and this minimizes the influence of the underlying sediment. The sections designated y-1 are areas of lake sediment composed predominantly of clay and silt. These localities are poorly drained. Many of the valleys are filled with the lake sediment.

Till regions are designated y-2 on the map and building conditions vary greatly from place to place due mostly to variations in the till thickness. In most areas, the till is so thin the excavation of the underlying rock is necessary, but the rock is usually fractured, weathered and soft enough so that it can be removed without difficulty. Areas designated r-2 are stream valley bottoms covered with alluvium. The undesirable characteristics of these sections are described above. Red sections marked r-1 are poorly drained swampy localities that cannot be used for any kind of construction.

GEOLOGIC RESOURCES

According to Fowler (1957, p. 78), the rocks of the Castleton and Brandon quadrangles are among the most valuable in the state because the slate and marble belts extend into that area. In addition, sand and gravel deposits are scattered over the Rutland-Brandon region. Clay has not been developed as a geologic resource but it is believed that clay of quality to be used for brick and tile occurs in the region.

Slate

The western part of the Castleton Quadrangle lies in the colored slate belt of New York and Vermont that stretches from Greenwich, New York, to the northwest side of Lake Bomoseen (Figure 31). The region has had a long history of slate production and several slate quarries are still active in the towns of Poultney, Castleton, and Fair Haven. Slate production in former years has extended as far north as the area between Lake Bomoseen and Glenn Lake,

Figure 29. Makeshift sewage system for private dwelling in ski area.

Figure 30. Sewage disposal system for eight-unit condominium in ski area. Cement box in lower right is dry well for all units.

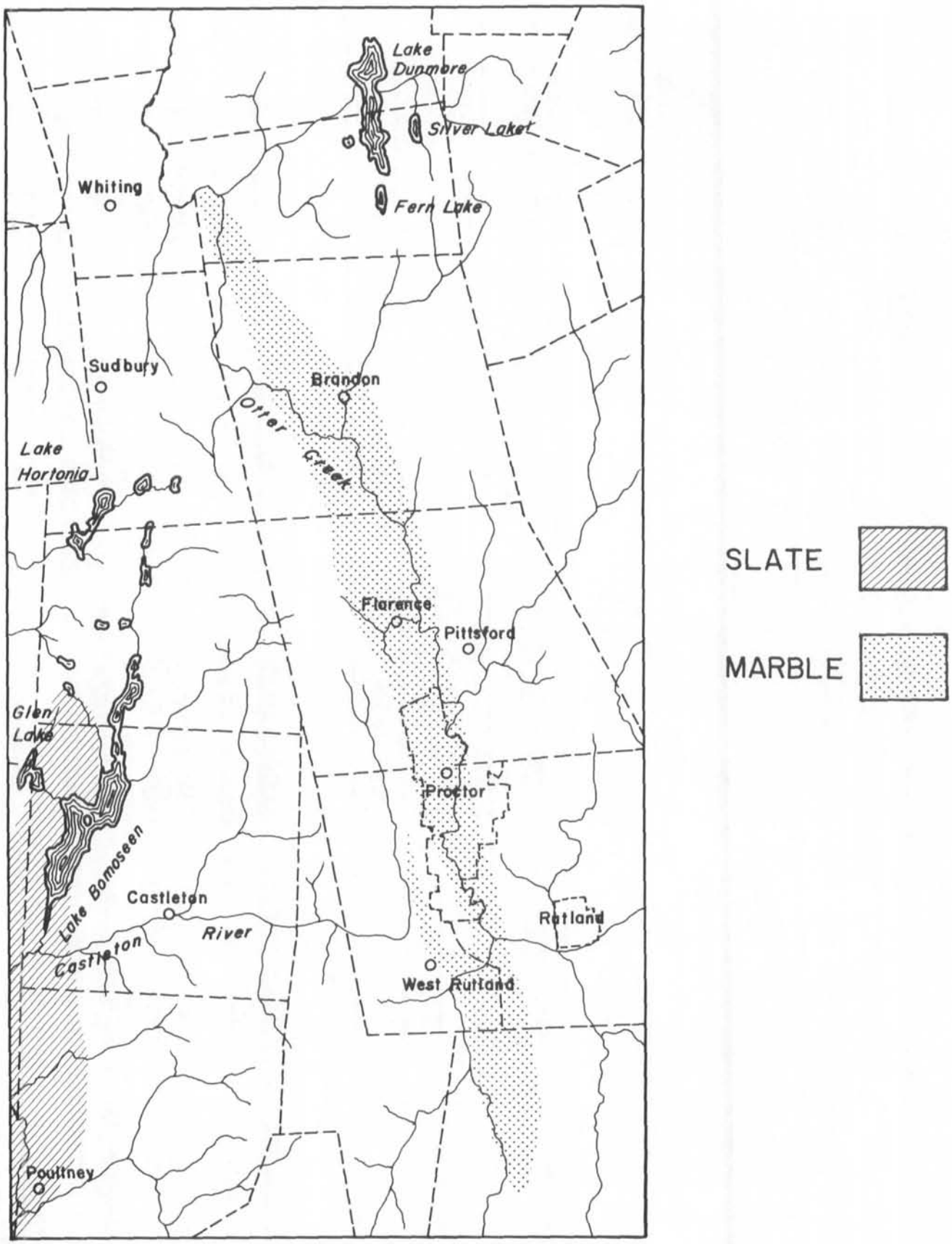

Figure 31. The slate and marble belts of the Rutland-Brandon region. Scale: One inch equals three and one-fourth miles.

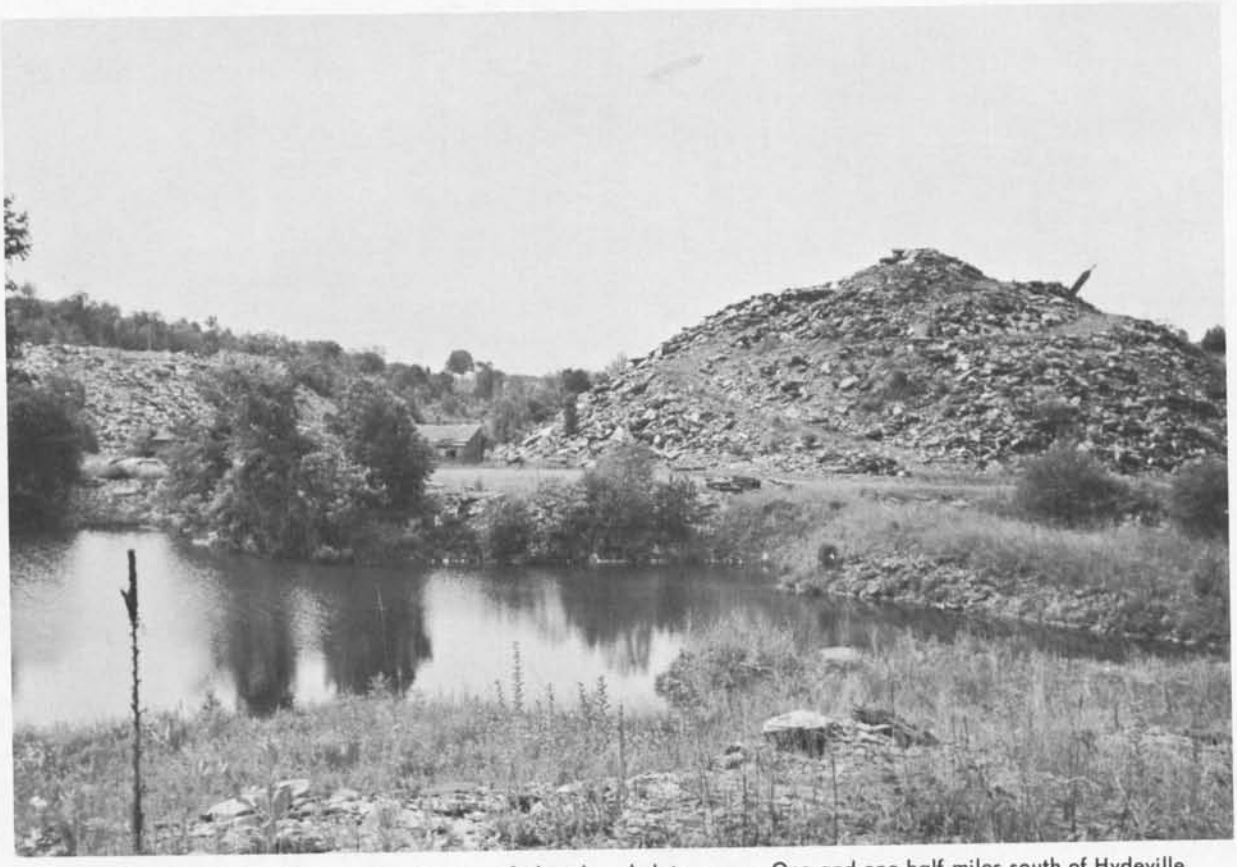

Figure 32. Spoil pile and water-filled quarry of abandoned slate quarry. One and one-half miles south of Hydeville.

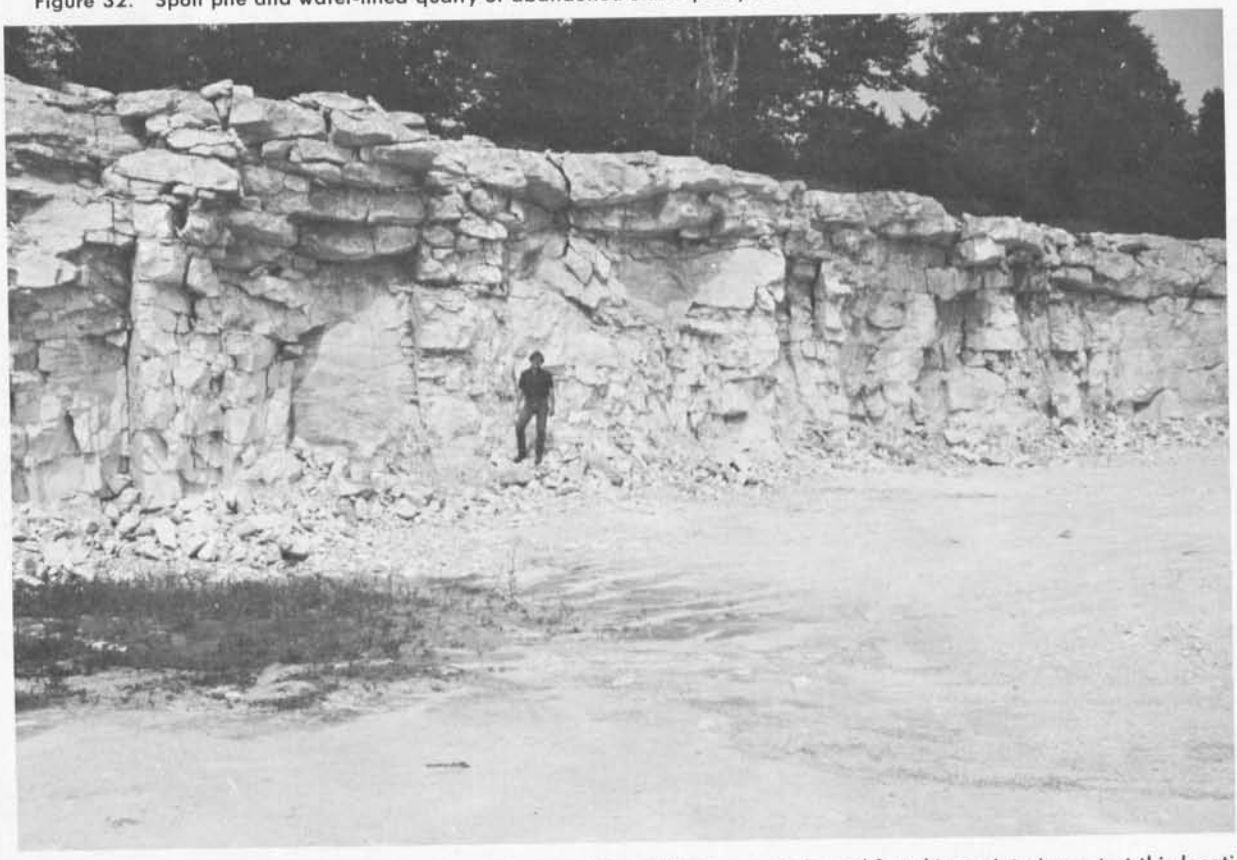

Figure 33. Quarry in Bascom Formation two miles northwest of East Middlebury. Rock used for white paint pigment at this location.

north of the village of West Castleton, but present operations are located south of the Castleton River. Total output at this time is from the Mettawee slate member of the St. Catherine Formation of Cambrian age (Plate II). Large reserves of slate still exist in this section and production will no doubt continue for as long as the demand continues.

Numerous spoil piles of present and former slate quarries dot the landscape of the slate belt and many abandoned quarries are now filled with water (Figure 32). From an environmental point of view, land reclamation of these areas would be possible if the material in the spoil piles was transferred to the abandoned quarries. Quarrying practices of active operations could be modified to the extent that waste rock would be dumped in the already abandoned portion of the quarry.

Marble

The eastern one-third of the Castleton Quadrangle and a much smaller portion of the south-central part of the Brandon Quadrangle lies in the marble belt that extends from Danby at the south to Leicester Junction at the north (Figure 31). As a general rule, the carbonate rocks north of Brandon have grain sizes that are so small that the rocks are more correctly called limestones. Rock units that have been quarried for marble in this region include the Boardman and Bascom formations of the Beekmantown group, the Burchard and Beldens of the Chazy, and the Orwell and Whipple of the Trenton. At the present time, most marble comes from the Columbian Formation of the Beekmantown group and from several green-streaked marbles at West Rutland of the Chazy group that Fowler (1950, p. 79) collectively called the Beldens Formation. Some Whipple and Columbian marbles are quarried at Clarendon Springs and production at Florence is from the Sutherland and Bascom (both Beekmantown) formations. The so-called green Marble has been mined one and three-quarter miles southeast of Hancock. This rock, more correctly called *Verd Antique,* is composed chiefly of the mineral serpentine formed by the metamorphism of a dark-colored, basic igneous intrusion.

In addition to marble for dimension and decorative stone, calcareous rock is also used for agriculture lime, crushed stone and white paint pigment. Years ago the Beldens Formation (Chazy) was used for agricultural and burnt lime and two large quarries and plants were located at Leicester Junction. Some of the ruins of these operations still stand, but production stopped some years ago. The Bascom Formation is quarried two miles northwest of East Middlebury for white paint pigment (Figure 33).

Sand and Gravel

The sand and gravel map prepared during this survey (Plate VII) classified the deposits as to quality and estimated reserves. There is no sand or gravel in the region that meets standard specifications for cement and therefore the highest rank is good. The gravel deposits are scattered over the region and most deposits have a high sand content. An adequate reserve for the near future is available.

The largest reserves of sand and gravel occur along the western base of the Green Mountains in the region already delineated in the section of this report concerning ground water. The kame deposits along the mountain slopes south of U.S. Route 4 in the Rutland Quadrangle are very sandy at the surface and some sections seem to be composed predominantly of sand. The sand and gravel are quite deep, however, and subsurface investigations are needed to ascertain the quality of the deposits at depth. In the East Pittsford-Chittenden-Chittenden Reservoir section, the gravel is quite angular with a high content of silt and an irregular stratification. Use of these deposits would require crushing, screening and probably washing to remove the silt. The quality of the gravel produced, however, would be good inasmuch as the stone in the gravel is hard and resistant to wear.

In the Brandon Quadrangle, large reserves of sand and gravel apparently occur between Forest Dale and the south end of Lake Dunmore and between Lake Dunmore and East Middlebury. The Forest Dale-Lake Dunmore section has not been excavated enough to determine the reserve and quality, but the type of deposit suggests considerable reserve. Kame terraces in the vicinity of Proctor and adjacent to U.S. Route 7 southeast of Pittsford also have considerable reserves of good gravel.

Sand deposits are scattered all over the Rutland-Brandon region. These are mostly lake sands and their thicknesses vary greatly. The largest reserves of sand are along the Castleton River between Hydeville and Castleton, the Proctor-Pittsford area, the region around Brandon and the kame terraces north and south of East Clarendon.

Clay

To the writer's knowledge, no studies have been made in the Rutland-Brandon region to determine the quality of the clay deposits. In many areas, the clay and silty clay are quite thick and testing to see if they could be used for brick and tile is advisable. The northwestern corner of the region seems to have the best possibilities.

Kaolin, a white clay deposit formed by the weathering of bedrock or by hydrothermal processes, was formerly mined one and one-half miles south of Forest Dale.

METALS

There has been no actual production of metallic minerals in the Rutland-Brandon region, with the exception of some low-grade iron ore in the past. Mineral exploration in the Forest Dale area, however, has located lead and zinc concentrations about two miles west of the village. The size of the deposit is not known to the writer.

ACKNOWLEDGMENTS

Dr. Charles G. Doll, the Vermont State Geologist, directed and arranged the financing of the project that resulted in this report. The writer appreciates his continued support, assistance and encouragement. Terry M. Kramer, graduate student at Miami University and field assistant, contributed much to the summer's work, and did most of the drafting for the planning maps. Walter Coppinger, graduate student at Miami University, drafted the maps appearing in the text and the geologic map of the Rutland-Brandon region. The writer also notes the assistance of Mr. Frank Lanza, Geologist, Vermont Highway Department, Mr. Arthur Hodges, Geologist, United States Geological Survey and Mr. David Butterfield, Geologist, Vermont Water Resources Department.

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APPENDIX A

MAPS SHOWING FIELD LOCATIONS OF SEISMIC PROFILES

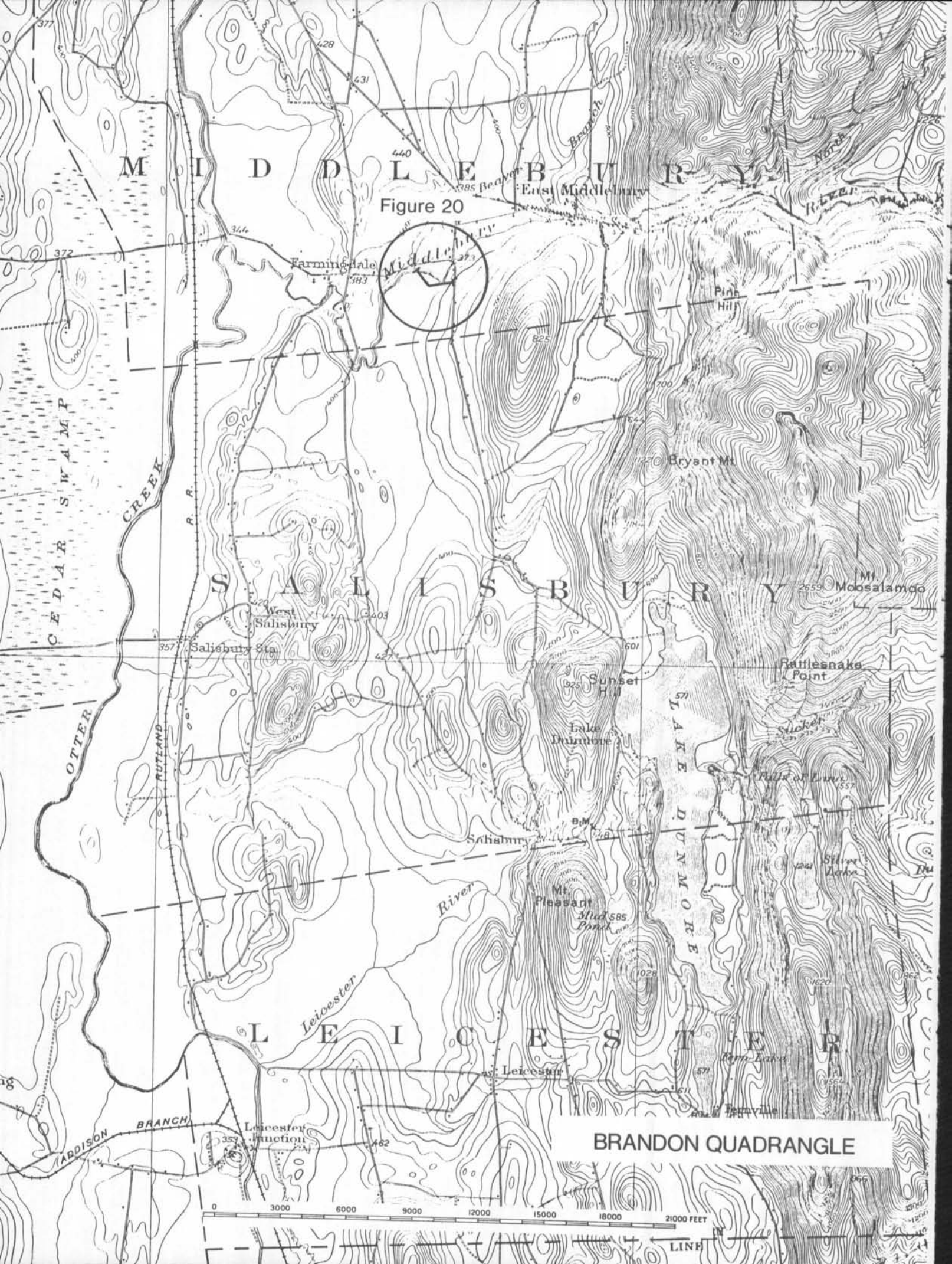
Figure 20
MIDDLEBURY
East Middlebury
Beaver Branch
North River
Farmingdale
Middlebury
Pine Hill
Bryant Mt
CEDAR SWAMP
OTTER CREEK
RUTLAND R. R.
SALISBURY
West Salisbury
Salisbury Sta
Mt Moosalamoo
Rattlesnake Point
Sunset Hill
Lake Dunmore
LAKE DUNMORE
Sucker
Falls of Lunn
Salisbury
Mt Pleasant
Mud Pond
River
Leicester
LEICESTER
Leicester
Leicester Junction
ADDISON BRANCH
Ferrisville
BRANDON QUADRANGLE
0 3000 6000 9000 12000 15000 18000 21000 FEET
LINE

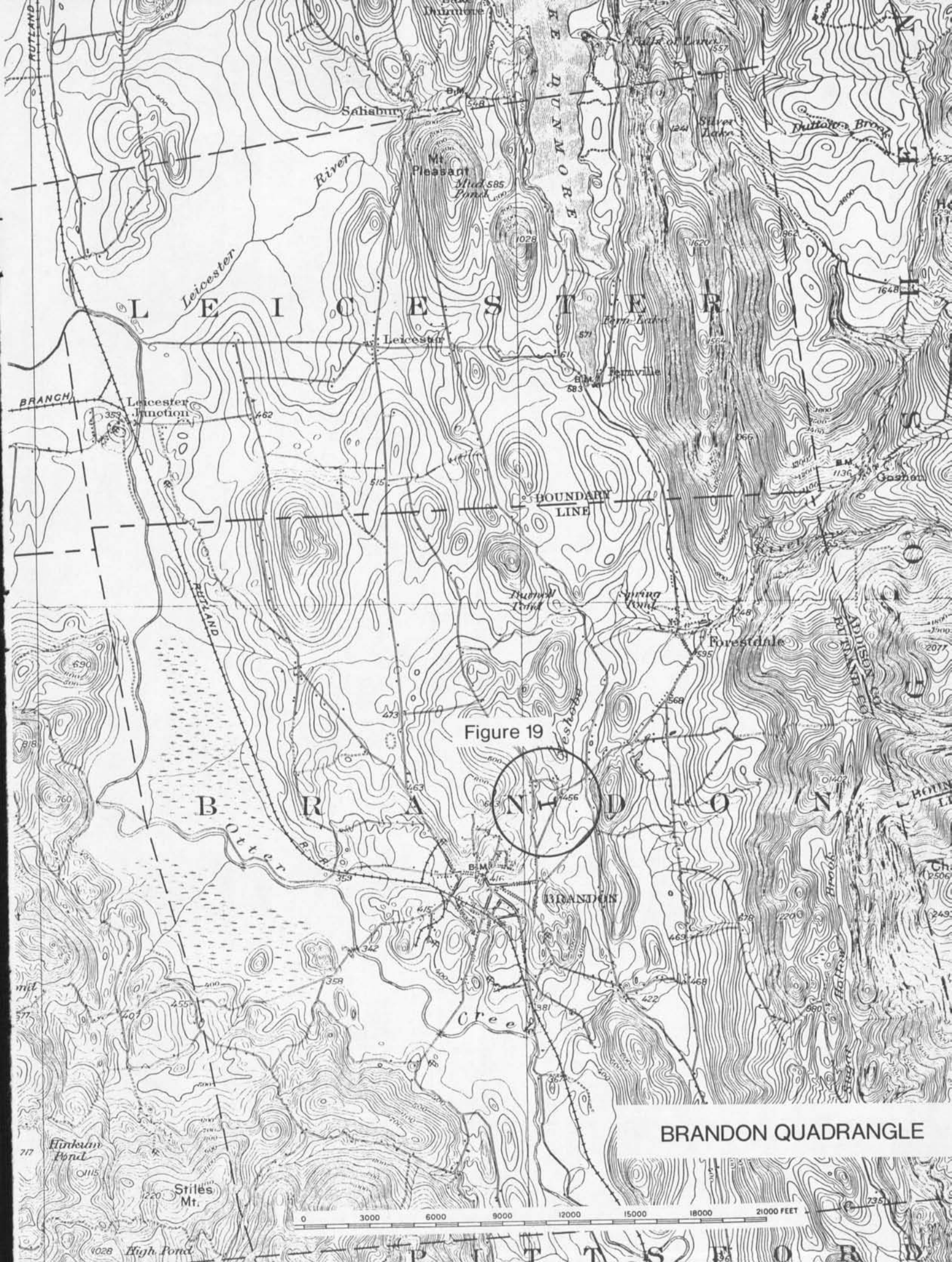
Figure 19
BRANDON QUADRANGLE
L E I C E S T E R
B R A N D O N
Salisbury
Mt. Pleasant
Leicester
Leicester Junction
Ferrisville
Forestdale
BRANDON
BOUNDARY LINE
Leicester River
Otter Creek
Mud Pond
Farm Lake
Silver Lake
Dutton's Brook
Falls of Dunmore
Thomas Pond
Spring Pond
Hinkum Pond
Stiles Mt.
High Pond
RUTLAND
BRANCH
ADDISON CO.
RUTLAND CO.
0 3000 6000 9000 12000 15000 18000 21000 FEET


Figure 26
ROCHESTER QUADRANGLE
Texas School
Gillespie Mtn
South Hollow School
Hancock Mtn
Texas Falls
Hancock
Branch School
Thunder Head
North Hollow School
Cobble Hill
Pine Gap
Philadelphia Pk
Hancock Tunnel
Mt Cushman
Randolph Gap
Rochester
Austin Hill
Corner School
Maple Hill School
Little Pico Mtn
Robinson
Talcville
South Hollow School
Brunch School
Emerson
Rogers Pk
Jerusalem School
Corporation Mtn
Garland Camp
Little Wilcox Pk
BOUNDARY LINE
ADDISON CO
WINDSOR CO
WHITE RIVER
HANCOCK
ROCHESTER
BETHEL
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

Figure 18

Figure 17

RUTLAND QUADRANGLE


Figure 25
RUTLAND QUADRANGLE
0 3000 6000 9000 12000 15000 18000 21000 FEET
Sable Mt.
N M O U N T A I N
E N D E N
S T O C K B R I D G E
N A T I O N A L
F O R E S T
South Pond
North Sherburne
WINDSOR CO
RUTLAND CO
BOUNDARY LINE
Sherburne
East Mt.
S H E R B U R N E
Pico Pond
Pico Peak
Little Pico
Killington
Little Killington


Figure 21
Figure 15
CASTLETON QUADRANGLE
RUTLAND QUADRANGLE
PROCTOR
WEST RUTLAND
RUTLAND
Proctor
West Rutland
Center Rutland
Clark Hill
Boardman Hill
Herrick Mountain
Cold River Sta.
North Clarendon
Clarendon Springs
Flat Rock
Ira
Clarendon
East Clarendon
Cold River
Otter Creek
East Creek
Tenney Brook
Moon Brook
Castleton River
Ira Brook
RUTLAND CITY LINE
BENNINGTON
RAILROAD
CENTRAL
0 3000 6000 9000 12000 15000 18000 21000 FEET


Figure 16
CASTLETON QUADRANGLE
Coxe Mt.
Grangerville
Biddie Knob
Florence
Pittsford Mills
Butler Pond
Zion Hill
Berker Hill
Hinesburgville
Proctor
Castleton
Castleton River
Otter Creek
Furnace Brook
Sugar Hollow Brook
Lake Bradley Brook
Hubson
Brook
0 3000 6000 9000 12000 15000 18000 21000 FEET

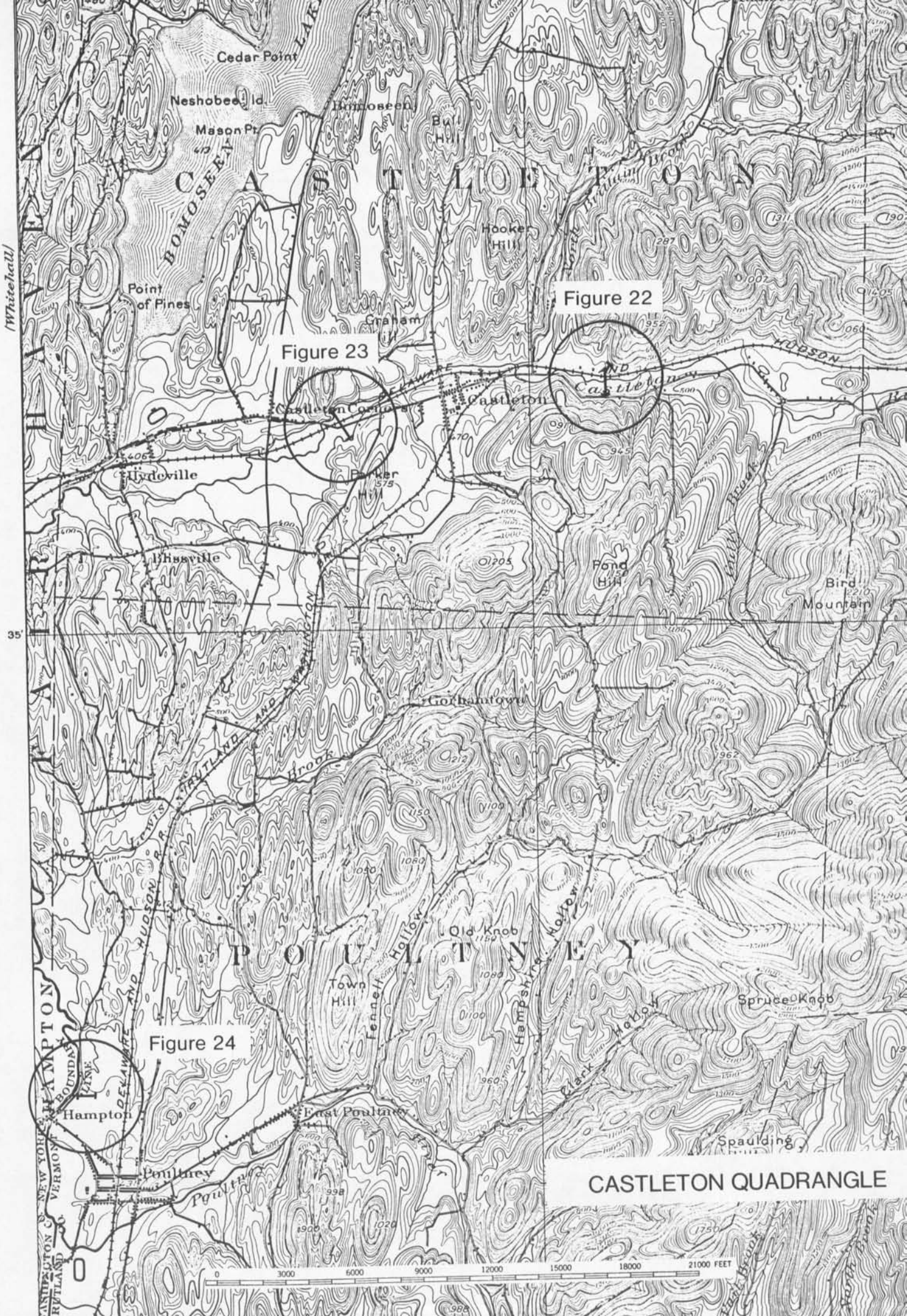
Figure 22
Figure 23
Figure 24
CASTLETON QUADRANGLE
Cedar Point
Neshobe Id.
Mason Pt.
Bomoseen
Burl Hill
CASTLETON
Hooker Hill
Point of Pines
Graham Hill
Castleton Corners
Castleton
Hydeville
Parker Hill
Fassville
Pond Hill
Bird Mountain
Gorhamtown
POULTNEY
Old Knob
Town Hill
Spruce Knob
Hampton
East Poultney
Poultney
Spaulding
0 3000 6000 9000 12000 15000 18000 21000 FEET

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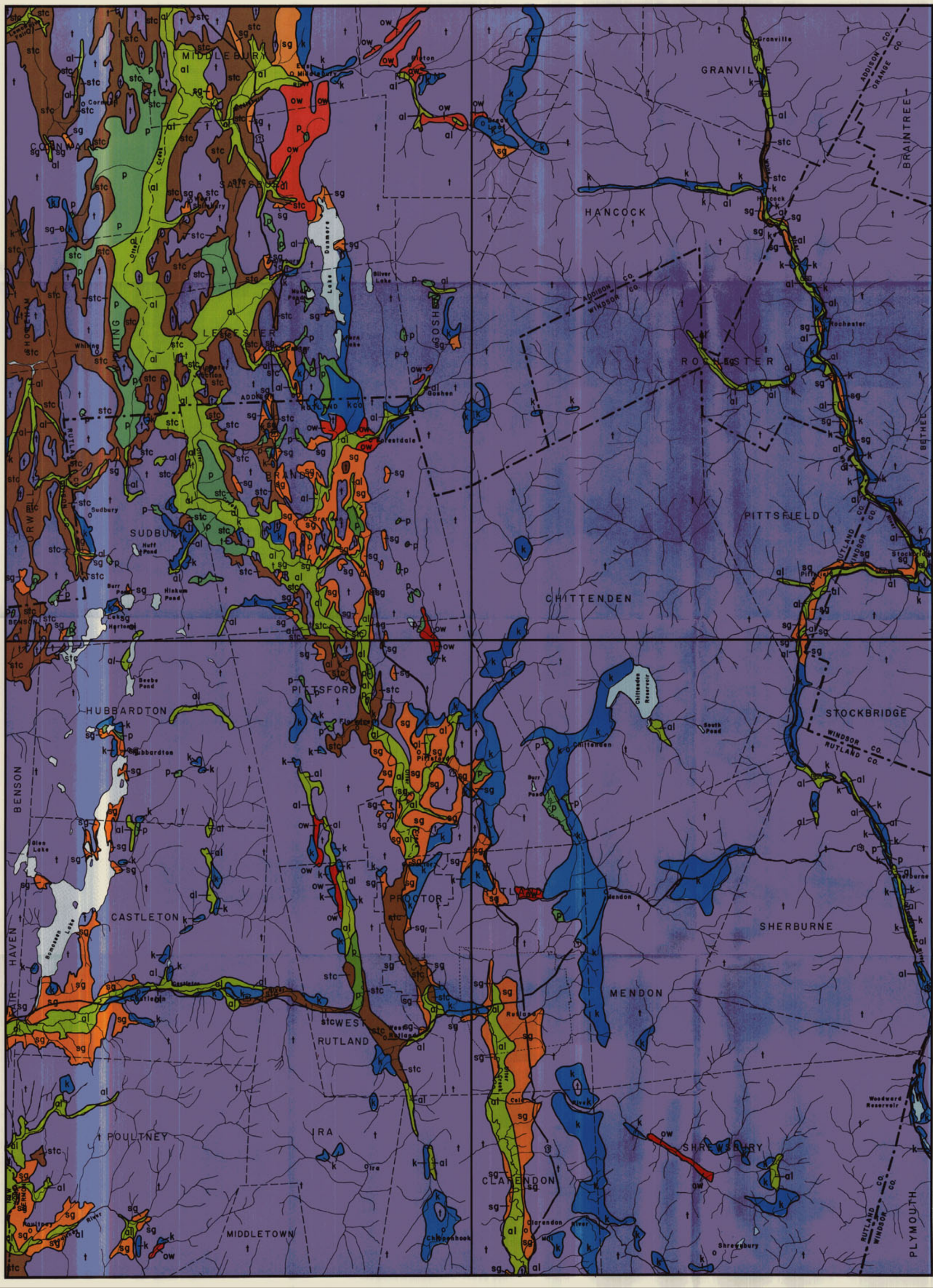
Environmental Geology 2

SURFICIAL MATERIAL OF THE RUTLAND-BRANDON REGION

Plate I



LEGEND

t

Glacial Till - generally thin over bedrock, much bedrock exposed, poorly drained, bouldery surface. Low water potential.

k

Ice Contact Gravel, mostly kame terraces - good gravel source, well drained above water table. High water potential below water table.

ow

Outwash and Fluvial Gravel - in stream valleys, well drained. Fair to good water potential.

sg

Lacustrine Sands and Gravels - predominantly sands and pebbly sand, good source for sand, good drainage above water table. Moderate to high water potential below water table.

stc

Lacustrine Clays and Silts - poorly drained, medium to high plasticity. Low water potential.

p

Peat and Muck - swampy, poorly drained areas.

al

Recent Stream Alluvium - thin covering valley floor, poor foundation material. Fair to moderately well drained.

1 1/2 0 1 2
miles

true north

Modified by the author from the Surficial Geologic Map of Vermont by David P. Stewart and Paul MacClintock; Brandon Quadrangle mapped by G. Gordon Connally; Rochester and western half of Castleton quadrangle by Paul MacClintock; Rutland and eastern half of Castleton quadrangle by David P. Stewart.

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Published 1972

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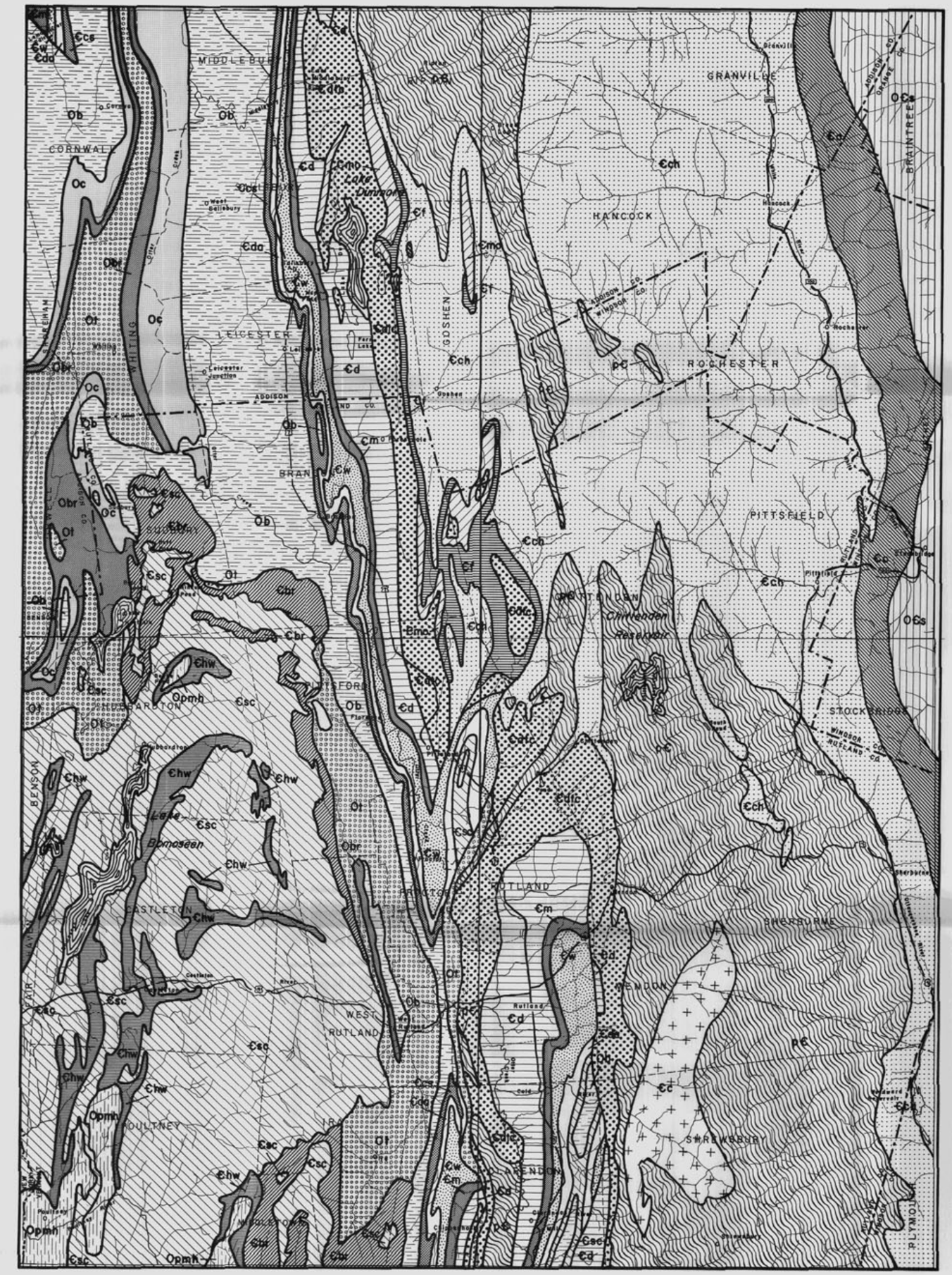
Environmental Geology 2

BEDROCK GEOLOGY OF THE RUTLAND-BRANDON REGION

Plate II



EXPLANATION

	TACONIC MOUNTAINS	CHAMPLAIN & VERMONT VALLEYS	GREEN MOUNTAINS
Ordovician	Opmh — Pawlet and Mt. Hamilton formations	Ot — Trenton group	OCs — Stowe formation
		Obr — Black River group	
		unconformity	
		Oc — Chazy group	
		Ob — Beekmantown group	
	unconformity		
Cambrian	Chw — Hatch Hill and West Castleton fms.	Ccs — Clarendon Springs, Ticonderoga, Rock River dolomites; Gorge fm.	Co — Ottauquechee formation
		Cdo — Danby and Potsdam formations	
		Cw — Winooski dolomite	
	Csc — St. Catherine formation	Cm — Monkton quartzite	Cch — Camels Hump group
		Cd — Dunham dolomite	
		unconformity	
		Cdtc — Dalton and Cheshire quartzites	
	Cbr — Brezee formation	Cmo — Moosalamoo phyllite	Cc — Cavendish formation
		Cf — Forestdale marble	
		unconformity	
Precambrian			pЄ — Mt. Holly complex

Modified by the author from the Centennial Geologic Map of Vermont.

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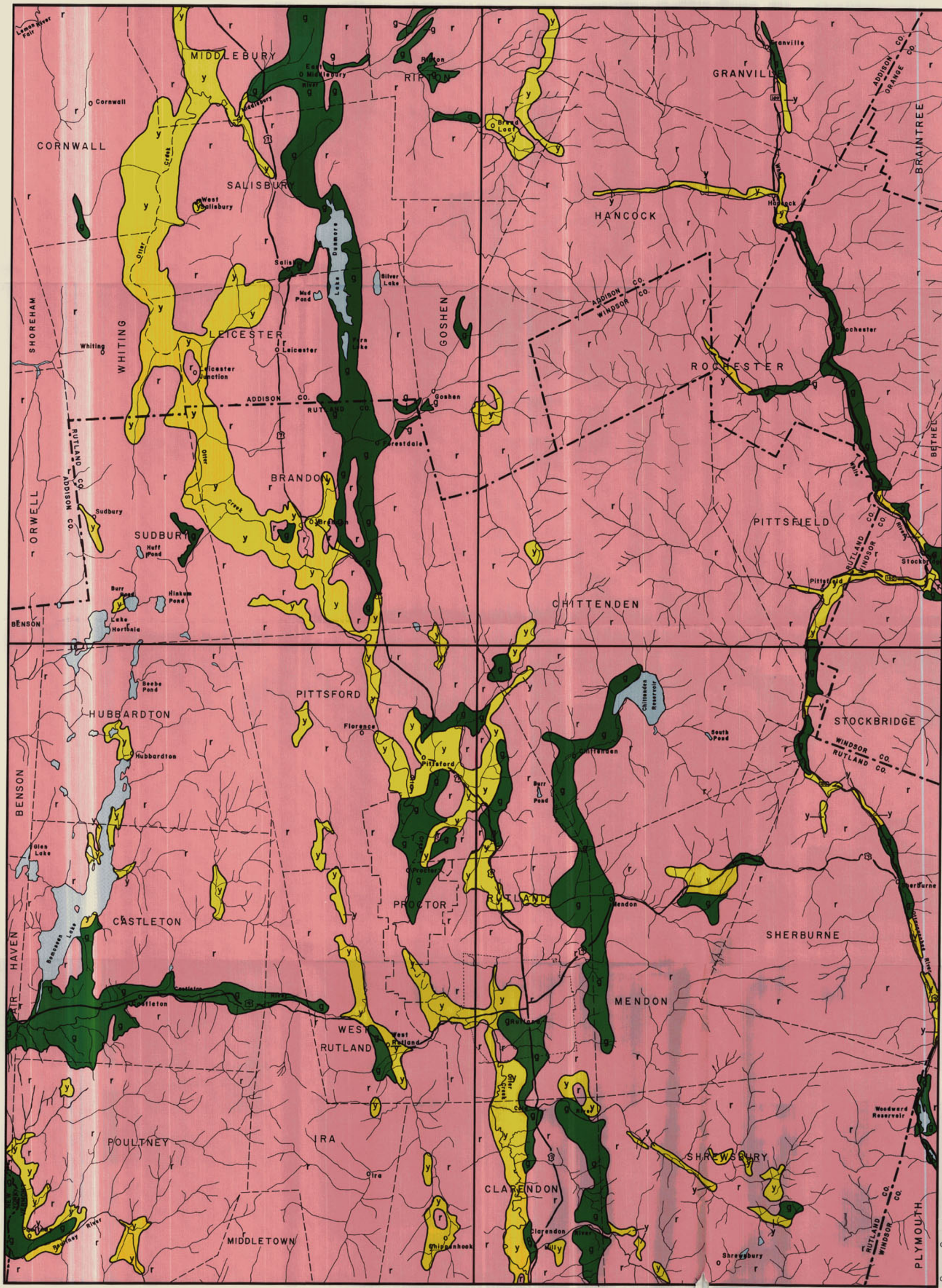
GROUND WATER POTENTIAL OF THE RUTLAND-BRANDON REGION

Plate III



LEGEND

g — Areas of good ground water potential. Water probably available in gravel and sand. Yield medium to high at depths to 200 feet.

y — Areas of moderate ground water potential. Water available from gravels in stream valley or from bedrock below the valley fill. Yield low to medium at depths to 300 feet.

r — Areas of very low ground water potential. Water available in in these areas from low yield, fractured bedrock sources at depths to 300 feet.

1 1/2 0 1 2
miles

true north

Geologic interpretation by David P. Stewart.

Vermont Geological Survey
Charles G. Doll, State Geologist
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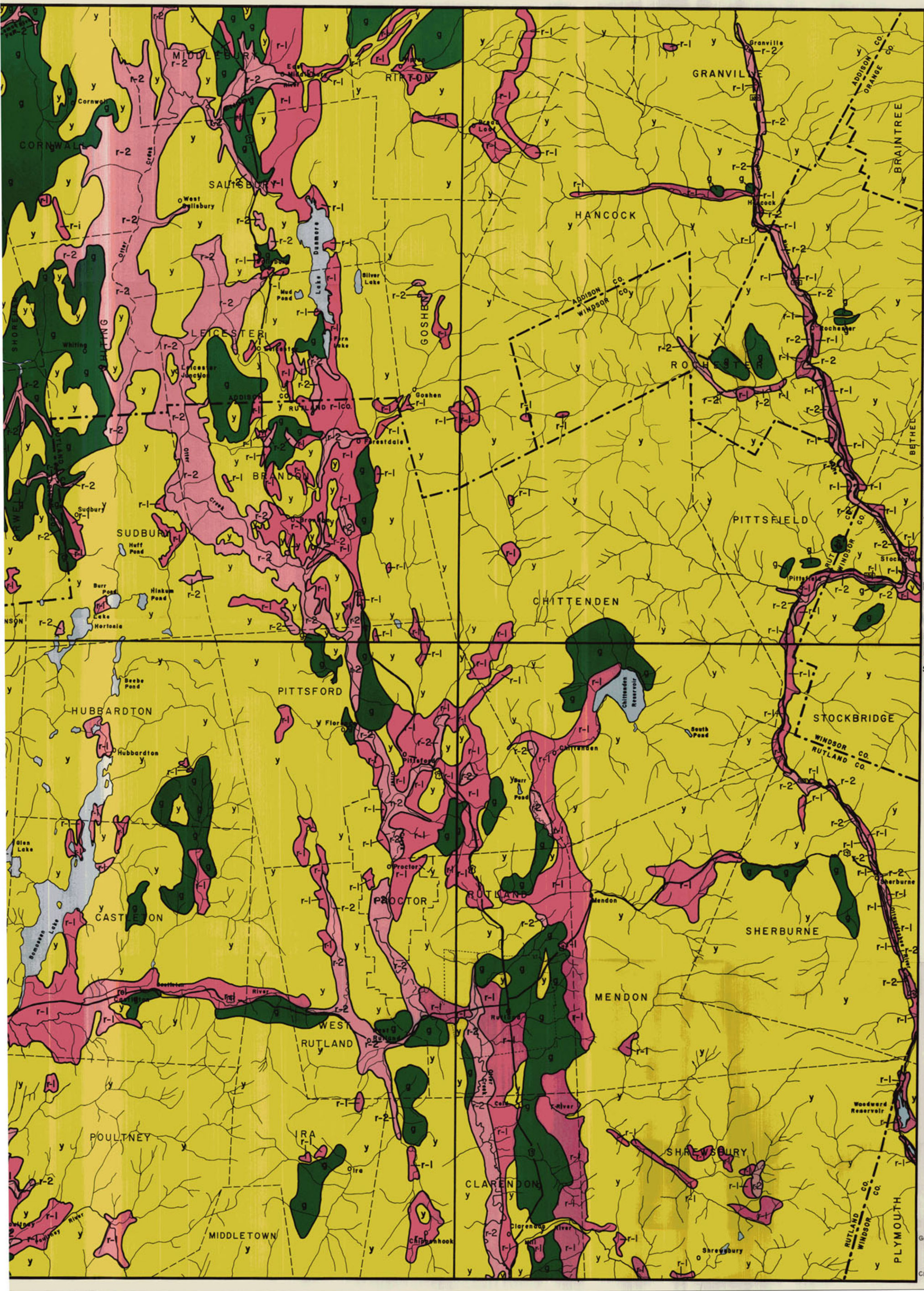
SOLID WASTE DISPOSAL CONDITIONS IN THE RUTLAND-BRANDON REGION

Plate IV



Geologic interpretation by David P. Stewart.

Vermont Geological Survey
Charles G. Doll, State Geologist
Published 1972

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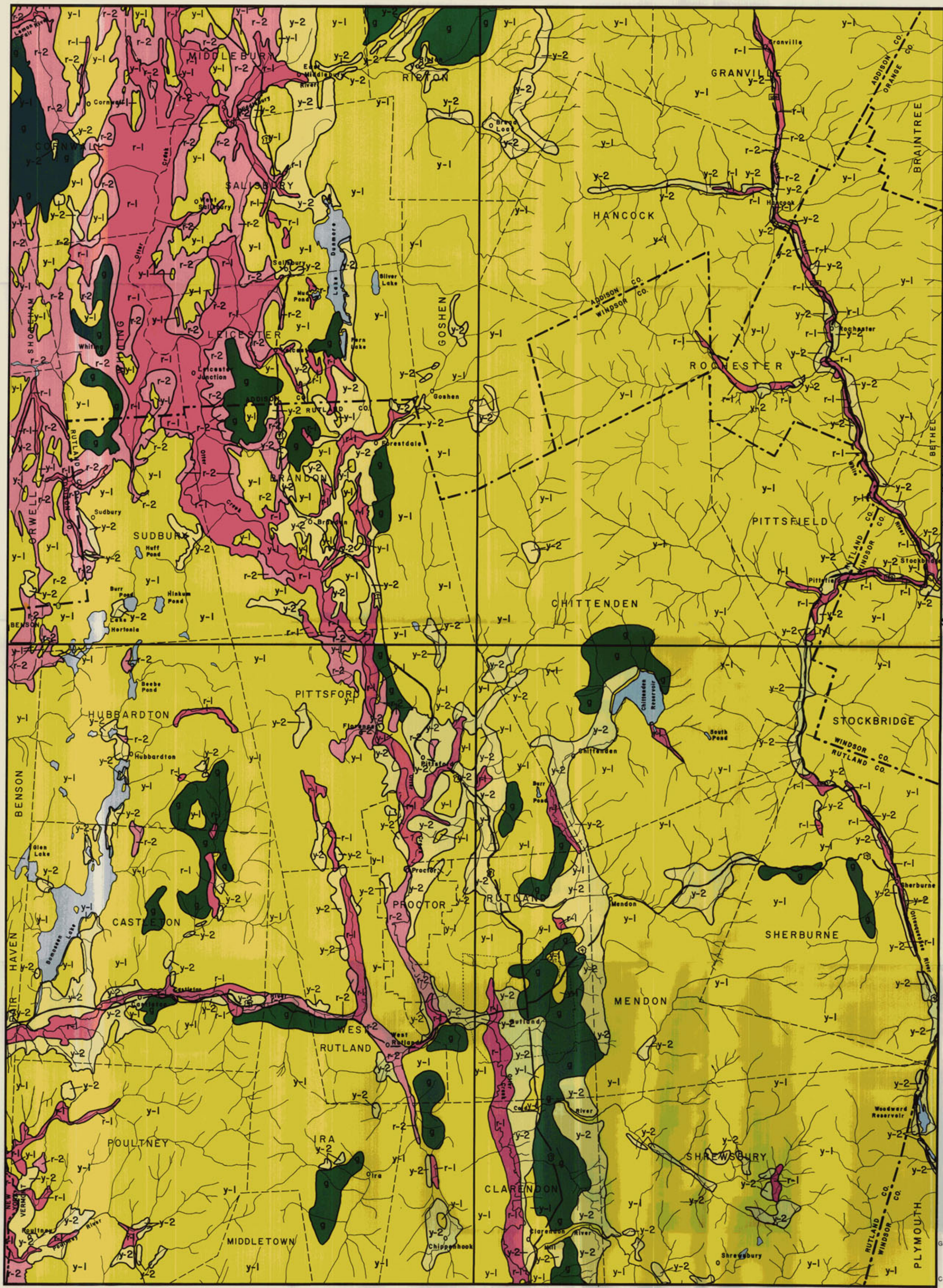
SEPTIC TANK CONDITIONS IN THE RUTLAND-BRANDON REGION

Plate V



LEGEND

g

Areas of till over 25 feet thick. Low permeability but suitable for septic tanks with leaching field at least 200 feet long.

y-1

Areas of thin till over bedrock. Septic tanks with 200 foot leaching field where till is over 10 feet thick.

y-2

Areas of permeable sand and gravel. Suitable for septic tanks if deposit is over 15 feet thick and water table is over 20 feet below the surface.

r-1

Low, poorly drained, frequently flooded stream floodplain covered with alluvium and/or swamps. Also includes small, isolated swamps. Unsuitable for septic tanks.

r-2

Areas of lake silts and clays with very low permeability. Septic tanks cannot properly function in these materials.

1 1/2 0 1 2
miles

true north

Geologic interpretation by David P. Stewart.

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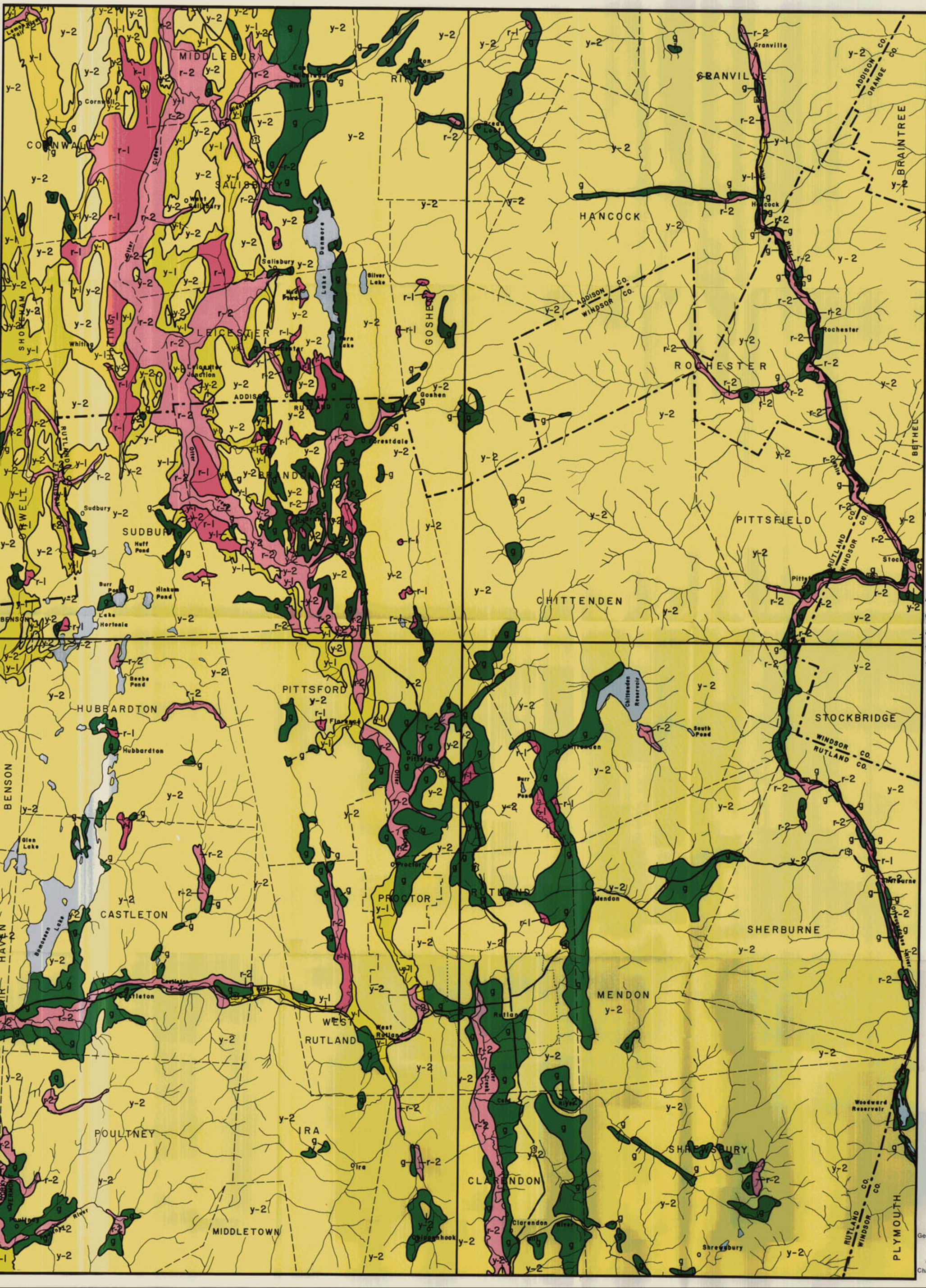
GENERAL CONSTRUCTION CONDITIONS IN THE RUTLAND-BRANDON REGION

Plate VI



LEGEND

g

Areas of thick, well drained sand and gravel deposits with adequate bearing strength.

y-1

Areas of lake sediment composed predominantly of silt and clay. May or may not be capped with sand and/or gravel. Steep slopes common on the outer margins of terraces.

y-2

Areas of till and bedrock. Till cover generally less than 20 feet. Permeability of till very low. Wide areas have bedrock exposed at the surface or bedrock with less than 5 feet of till.

r-1

Areas of poor drainage and swampy conditions. Ground water level near or at the surface. Contains wet, compressible sediment.

r-2

Areas of stream bottom-land covered with 10 to 25 feet of alluvium. Subject of frequent flooding. Alluvium unsuitable for foundations of heavy structures.

1 1/2 0 1 2
miles

true north

Geologic interpretation by David P. Stewart.

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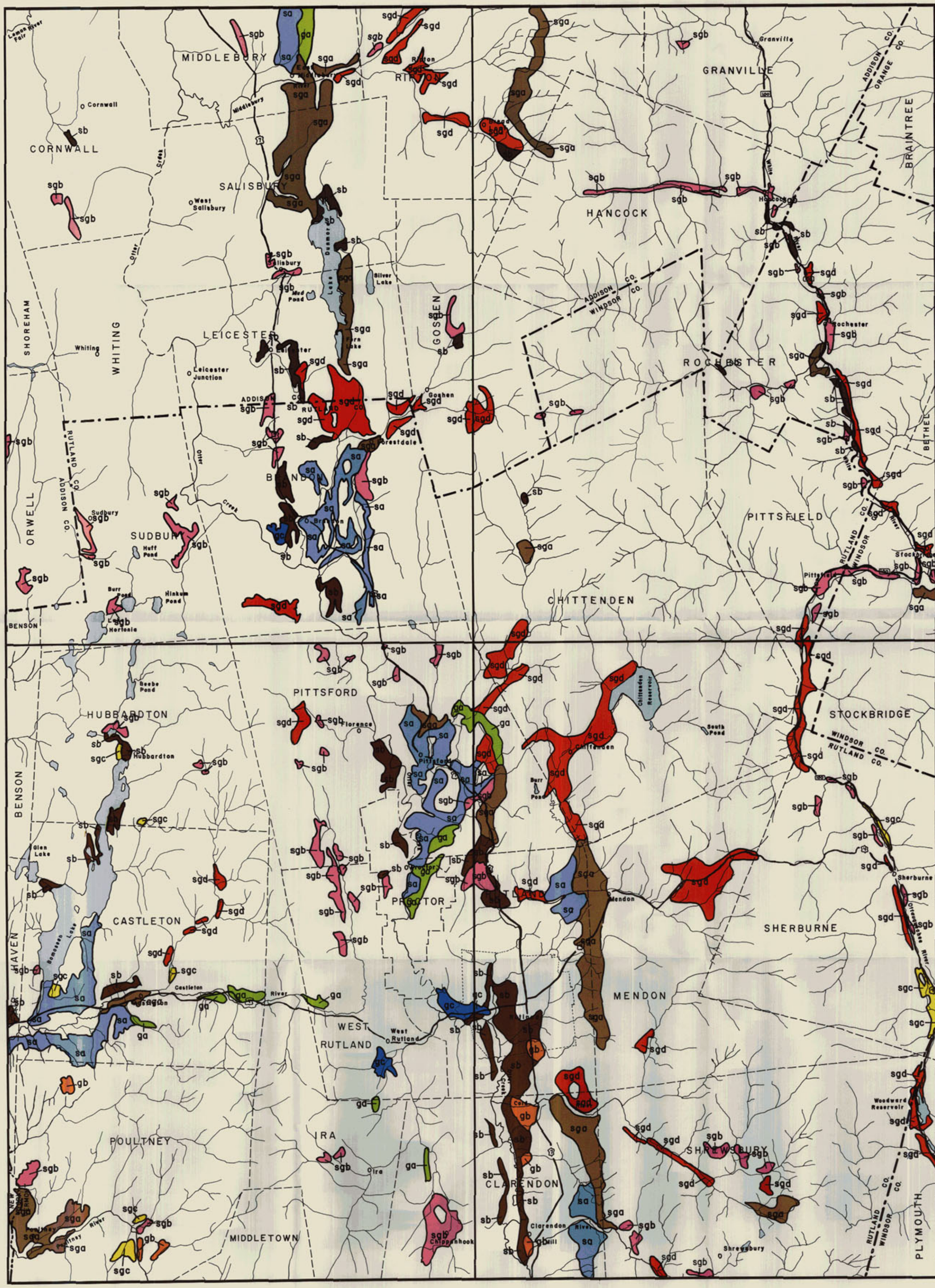
SAND AND GRAVEL RESERVES OF THE RUTLAND-BRANDON REGION

Plate VII



LEGEND

ga

Gravel deposits containing less than 25% sand. Medium to good quality. Large reserve. Less than *one-half the original reserve* depleted.

gb

Gravel deposits containing less than 25% sand. Low to medium quality. Low to medium reserve. Less than one-half original reserve depleted.

gc

Gravel deposits. Medium to good quality. Low to medium reserve. Over one-half of the original reserve depleted.

sga

Sand and gravel deposits of medium to good quality and large reserve. Less than one-half original reserve depleted.

sgb

Sand and gravel deposits of low to medium quality and low to medium reserve. Less than one-half of the original reserve depleted.

sgc

Sand and gravel deposits. Medium to good quality. Over half of the original reserve depleted.

sgd

Sand and gravel deposits of unknown quality and reserve.

sa

Sand deposits containing less than 25% gravel. Medium to good *quality. Large reserve. Less than* one-half of the original reserve depleted.

sb

Sand deposits containing less than 25% gravel. Low to medium quality. Low to moderate reserve. Less than one-half of original reserve depleted.

1 1/2 0 1 2
miles

true north

Geologic interpretation by David P. Stewart.

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