# Vermont Bedrock and its Potential for Sequestration

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# Carbon Dioxide

by

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VERMONT BEDROCK AND ITS POTENTIAL FOR SEQUESTRATION OF CARBON DIOXIDE

Introduction

Carbon sequestration is a possible strategy to reduce greenhouse gas emissions and mitigate global climate change. Assessment of potential sequestration sites in Vermont affects future energy use in the United States. More specifically, the ability to sequester $CO_2$ has implications for continued use of fossil fuels as well as economic development.

Geologic sequestration involves capture of $CO_2$, generally at the source, and storage in the subsurface in geological formations. $CO_2$ sequestration is being investigated for terrestrial systems and for a variety of geologic environments including deep saline geologic formations, unmineable coal seams, oil and gas reservoirs, organic shales, and mineral sequestration in ultramafic rocks. As part of the National Geologic Carbon Dioxide Sequestration Assessment (COTSA), the U.S. Geological Survey is assessing potential saline formations (reservoirs and seals) and oil and gas traps that can be utilized for geologic carbon dioxide ($CO_2$) sequestration in the United States. The assessment is mandated by the Energy Independence and Security Act (EISA) of 2007 (PL 110-140, Sect. 711) and further requires the USGS to “consult with State geological surveys and other relevant entities to ensure, to the maximum extent practicable, the usefulness and success of the assessment.” The USGS requested a short report on the geology of Vermont focused on specific formations and state maintained data sets and/or aerial and structure maps and geologic cross-sections of potential saline formations (reservoirs and seals) and oil and gas traps that can be utilized for geologic carbon dioxide ($CO_2$) sequestration in Vermont. It should be noted that at present there are no point sources of high $CO_2$ emissions in Vermont (see National Carbon Sequestration Database*), therefore making $CO_2$ capture and sequestration a less likely scenario in Vermont.

* http://www.netl.doe.gov/technologies/carbon_seq/natcarb/index.html

In Vermont there are no depleted oil and gas reservoirs, unmineable coal seams, or expanses of porous basalts to be considered as sequestration targest. Sequestration in Enhanced Gas/Oil Recovery (EGR, EOR) projects, requiring replacement of methane gas by $CO_2$ in organic rich shales, remains largely theoretical (NYSERDA, 2006). Although Vermont has no known gas fields to be coupled with EGR, potential sequestration in shales may become an option in the future. At this time, the primary areas of interest for $CO_2$ sequestration in Vermont are potential deep saline formations and mineral carbonation in ultramafic rocks. Mineral carbonation in Vermont’s ultramafic rocks was most recently evaluated by Krevor and others (2009), Doria (2005), Goff and others (2000, 1997), and Goff and Lackner (1998). The reader is referred to these reports for information. The present report focuses on potential deep saline formations in Vermont.

## Deep Saline Formations

As defined by EISA, a sequestration formation is "a deep saline formation, unmineable coal seam, or oil and gas reservoir that is capable of accommodating a volume of industrial carbon dioxide" (Brennan and others, 2010). "Saline formations are natural salt-water bearing intervals of porous and permeable rocks that occur beneath the level of potable groundwater" (Wickstrom and others, 2005). The USGS methodology for use of saline formations uses a 2008 U.S. Environmental Protection Agency (EPA) proposed limit of >10,000 ppm total dissolved solids (TDS) for $CO_2$ storage (Brennan and others,2010) because water with less than 10,000 ppm TDS is a potential drinking water supply. A saline formation contains very salty undrinkable water. In addition, for the saline formation to serve as a storage formation for $CO_2$ it must be porous and permeable, have adequate thickness, and be capped by an impermeable seal (Cooper, 2006) so that the $CO_2$ remains trapped or sequestered.

$CO_2$ occurs as solid, liquid, gas or supercritical phase which acts as both a gas and liquid. In the supercritical phase, $CO_2$ will fill space like a gas but have the density of a liquid so that more $CO_2$ can be stored in the same amount of space. For example, one ton of $CO_2$ at the surface occupies roughly 18,000 $ft^3$ and only 50 $ft^3$ when in the supercritical phase at depths greater than 2600 feet (Wickstrom and others, 2005). To maintain $CO_2$ in a supercritical state a minimum temperature of 87.8 F (31.1C) and minimum pressure of 7.38MPa (72.8 atm) is required. These temperatures and pressures occur at depths greater than 2500 feet. Therefore, the saline formation must be at least 2500' deep and have adequate pore volume and permeability. Although $CO_2$ could be stored at shallower depths, it would occupy a much greater volume (NYSERDA, 2006). The USGS assessment methodology recommends depth limits of 3,000'-13,000'. The lower depth of 13,000' is based on current engineering constraints.

Once $CO_2$ is injected under pressure into the saline formation, it displaces and mixes with the water, fills the pore spaces and is trapped within the rock matrix, provided there is an impermeable stratigraphic or structural seal. $CO_2$ may be retained in the subsurface through buoyant trapping storage and/or residual trapping in pore spaces through which the larger plume migrated. Factors to consider include geological and geomechanical constraints such as porosity, permeability, potential rates of injection, stress fields, fracture and fault geometries, and formation lithology and thickness. Leakage of injected $CO_2$ along fractures and faults is a concern in the deformed rocks of Vermont and needs to be considered when evaluating any potential structural or stratigraphic seal.

## Geologic and Geographic Settings

Vermont is positioned between the New York promontory and the Quebec re-entrant along the Northeast-trending Appalachian Mountain system, east of the Adirondack Highlands of New York (Figure 1). The rocks record a sequence of rift clastic and volcanic rocks deposited on Grenville basement, development of a continental platform which marks the ancient margin of eastern North America in the Cambrian and Ordovician, Ordovician accreted rocks, and Silurian-Devonian rocks of the Connecticut Valley trough. A variety of metasedimentary, metavolcanic and serpentinized ultramafic rocks are associated with the collapse of the continental margin during the Ordovician Taconian Orogeny. Deformation associated with the Devonian Acadian Orogeny and with eventual Mesozoic rifting to form the current Atlantic Ocean adds complexity to the geologic history. Taconian thrust faults associated with an island arc-continent collision were re-activated during the Acadian Orogeny when the Iapetus Ocean closed and the eastern portion of New England collided with Laurentia. The resulting supercontinent of Pangea began to break up around 200 million years ago; Mesozoic dikes and high angle faults in western Vermont are coincident with that event.

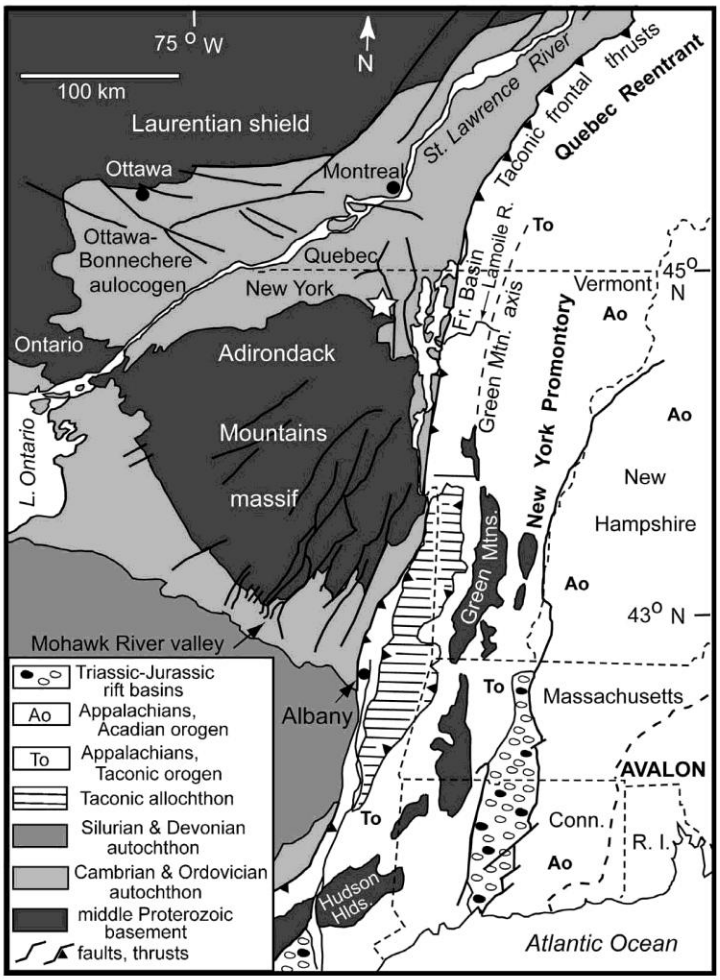


Figure 1. General geologic setting of Vermont (from Landing and others, 2009).

Vermont is divided into 6 physiographic regions (Figure 2). The Vermont Lowlands/Champlain Valley is an area of flat to low-lying hills bounded on the west by Lake

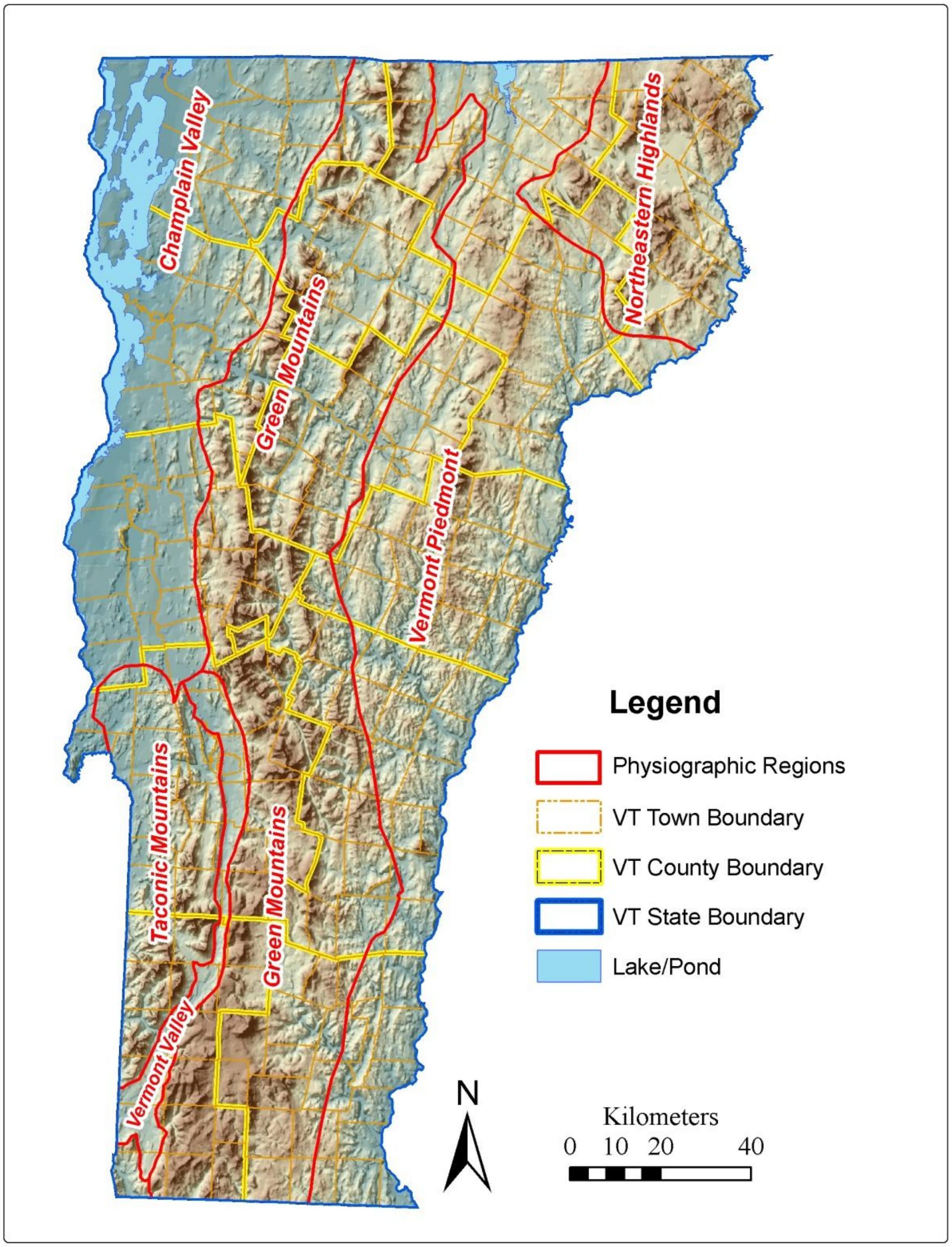


Figure 2. Physiographic regions of Vermont: the Vermont Lowlands/Champlain Valley, the Vermont Valley, the Green Mountains, the Taconic Mountains, the eastern Vermont Piedmont and the Northeast Highlands.

Champlain and the Adirondack Mountains and bounded on the east by the Green Mountains. The lowlands and the Vermont Valley further south are comprised of sandstones, carbonates and shales, the Paleozoic rocks of the ancient Laurentian margin. The Taconic Mountains are a series of peaks in southwest Vermont, many rising above the lowlands to 3,000 feet. The rocks are slates and phyllites which were faulted onto the underlying platform rocks. The Green Mountains run roughly north-south the length of Vermont and are home to Vermont's tallest peak, Mt. Mansfield. The mountains are predominantly Precambrian gneisses (southern Vermont) and overlying Cambro-Ordovician metamorphosed sedimentary, volcanic and oceanic rocks. The Vermont Piedmont is east of the Green Mountains and runs the length of the state from the Canadian border to Massachusetts. The rocks are predominantly Silurian-Devonian metasedimentary rocks and Devonian granitic intrusive rocks. The piedmont area is low to moderate rolling hills. The Northeast Highlands, rugged peaks in the northeast, are mainly composed of igneous intrusive rocks.

## BEDROCK GEOLOGY

The geology of Vermont (Figure 3) is characterized by lithotectonic packages with defined fault boundaries and mappable internal stratigraphy. Most of the bedrock in Vermont is metamorphic crystalline rock without primary or intergranular porosity. Secondary fractures plus partings parallel to the foliation afford some secondary porosity and permeability at shallow depths and are the primary conduits for groundwater flow. In addition to the lack of intergranular porosity, most of the secondary openings are likely closed at depth and consequently, the majority of rocks east of the Champlain Valley are not considered as potential reservoirs for $CO_2$ sequestration. The bedrock is briefly summarized below, followed by a more detailed discussion of the sedimentary rocks in the Champlain Valley and data from 6 oil and gas test wells in northwestern Vermont.

### Proterozoic Rocks

Authochthonous Proterozoic rocks of the Laurentian margin underlie the sedimentary rocks in western Vermont on the lower plate of the Champlain Thrust and are exposed northwest of Whitehall, New York. Faulted Late Proterozoic gneisses, quartzites, marbles and amphibolites are exposed in the core of the Green Mountain Anticlinorium, in the Lincoln Massif and in the Chester and Athens domes of southeastern Vermont (Fig 2). The rocks underlie thin to thick sections of metamorphosed sedimentary and volcanic rocks which record a transgressive Proterozoic to Upper Ordovician rift, shelf and basin sequence. Aleinikoff (2010) reported ages ranging from 0.95 – 1.39 Ga for Proterozoic metaigneous rocks and correlated the ages with four regional orogenic events. Structural repetition of the rocks is due to folding and faulting.

### Cambro-Ordovician rocks of the Taconic allochthons

The Taconic Allochthons are comprised of Late Proterozoic to Middle Ordovician metasedimentary rocks of continental slope origin thrust-emplaced onto the carbonate platform during the Taconian Orogeny. The imbricate slices are comprised of a variety of slates, quartzites, wackes, conglomerates, limestones and dolostones.

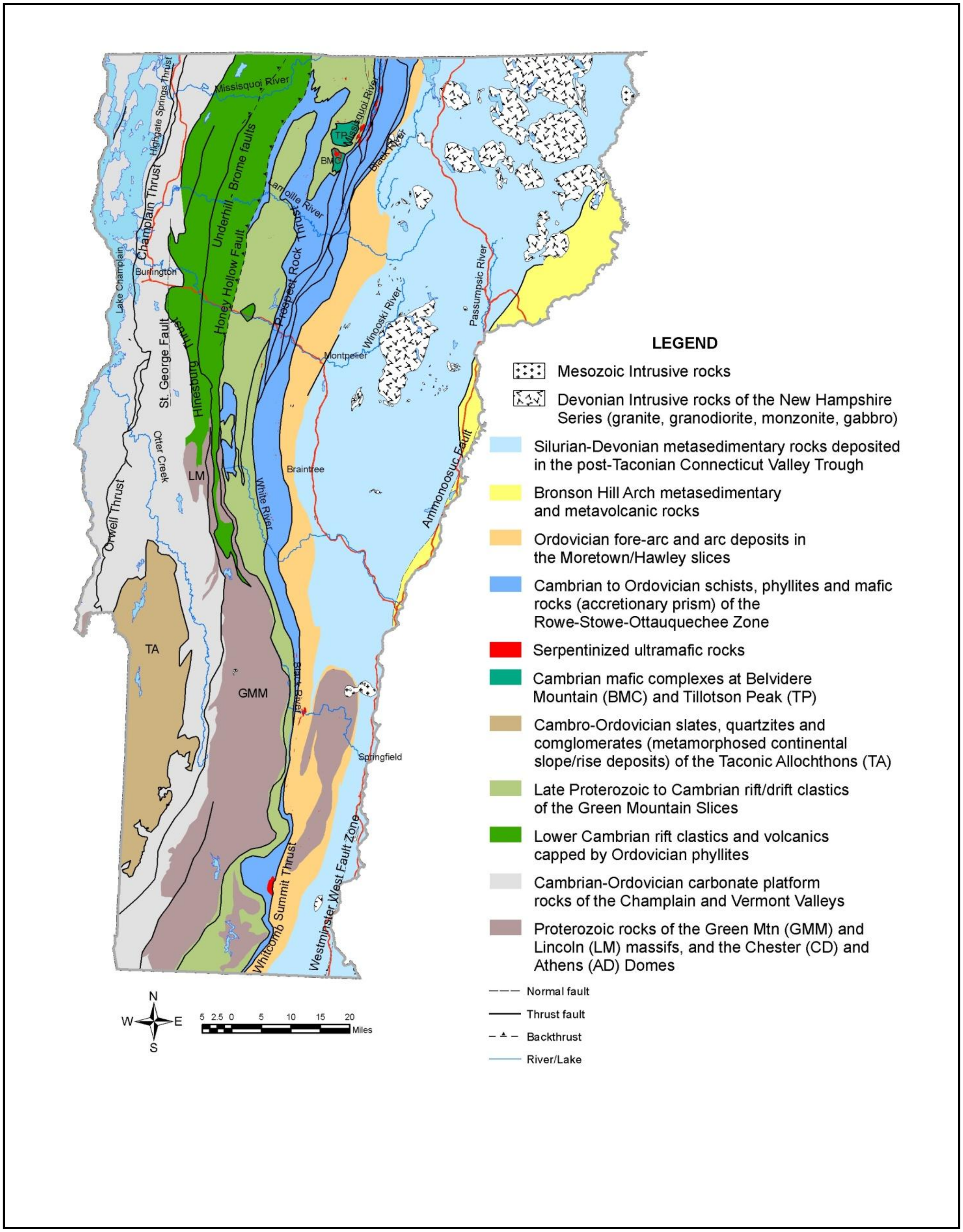


Figure 3: Generalized geologic map of Vermont.

Late Proterozoic to Cambrian rift/drift clastics

The Proterozoic basement complexes are overlain by Proterozoic to Cambrian rift clastics and interbedded volcanic rocks which thicken considerably (> 3 km) in northern Vermont. The Tibbit Hill volcanic age of 554 +4/-2 (Kumarapeli and others, 1989) from southern Quebec provides age control for this western cover section of Pinnacle/ Fairfield Pond/ Underhill rift clastics and Tibbit Hill rift volcanics. The overlying earliest drift stage deposits (shallow marine) are represented by the gray quartzite of the Cheshire Fm. The rift rocks are predominantly silvery green quartz-sericite-chlorite schists, schistose greywacke and conglomerate, and albite-actinolite-chlorite-epidote greenstone. The section is capped by the West Bridgewater Fm. (Ratcliffe and others, 1999), black phyllites with dolomitic pods containing Middle Ordovician conodonts.

East of the Green Mountain Massif, age control for the eastern cover section is provided by a U-PB zircon age of 571+/-5 Ma from a metafelsite (water-lain tuff) in the Pinney Hollow Formation (Walsh and Aleinikoff, 1999). The Pinney Hollow Fm. is thrust over the rift clastics and the West Bridgewater Fm. along its western contact, although north of the Green Mtn. Massif an intervening slice of black (Hazens Notch Fm.) and green (Fayston Fm.) albitic schists occurs immediately below the Pinney Hollow Fm. in fault contact with it. Together these rocks comprise the Green Mountain slices which span from east to west across the Green Mountain anticlinorium. The metamorphic rocks are mainly quartz-sericite-albite-chlorite schists and phyllites, some with garnet, quartzite, amphibolite and actinolitic greenstone. Common features are transposed bedding, compositional layering co-planar with schistosity, two generations of tight to isoclinal Taconian folds overprinted by tight to open Acadian folds and multiple Taconian to Acadian faults. The fault history is recorded in west-directed thrusts and overturned folds. A transition occurs from south to north in which faults are west-directed, then steepen and are cut by backthrusts (Brome and unnamed faults) which are folded over the Green Mountain anticlinorium (Colpron, 1990; Thompson and Thompson, 2003; Gale et al., 2010). Development of a cleavage fan on the west limb of the anticlinorium accompanies this transition.

Cambrian to Ordovician phyllites, schists, and serpentinized ultramafic rocks of the Rowe, Stowe, Ottauquechee Zone

Black and green phyllites and schists of the Rowe, Stowe, and Ottauquechee formations structurally overlie the rift/drift clastic sections (Green Mountain slices). These rocks are the Rowe section of the Rowe-Hawley Belt of Stanley and Ratcliffe (1985). The rocks occur on the upper plate of the Prospect Rock fault (Thompson and Thompson, 2003). The flat-lying Taconian thrust slices span the Green Mountain anticlinorium in the north and dip steeply in narrow fault zones on the east limb of the Green Mountain anticlinorium throughout Vermont. The rocks are primarily quartz-chlorite-albite schists and phyllites +/- garnet, +/- biotite, +/- staurolite, graphitic, sulfidic schists and phyllites, greenstone, and amphibolite.

Nested between the Prospect Rock fault and the Green Mountain slice are two structural and metamorphic complexes: the Belvidere Mtn Complex (Gale, 1980) which is a rootless, fault-emplaced ultramafic complex with a sheared metamorphic sole and the Tillotsen Peak Complex (Bothner and Laird, 1999) which is a blueschist-eclogite high pressure metamorphic complex. The ultramafic rock at Belvidere Mountain and the waste piles associated with asbestos mining at the site were evaluated for CO2 sequestration through mineral carbonation reactions by Krevor and others (2009), Doria (2005), Goff and others (2000, 1997), and Goff and Lackner (1998).

Ultramafic rocks occur throughout the northern Appalachians into Quebec and Newfoundland, where complete ophiolite sequences (fragments of oceanic crust) are observed. There are no complete ophiolites in Vermont, but the ultramafic rocks occur within highly sheared metamorphosed Cambrian schists and phyllites, and commonly occur along fault zones. Most of the ultramafic rocks in Vermont are dark green serpentinized peridotite and most contain some talc. The margins of the ultramafic rocks are frequently a punky-weathering talc-carbonate rock. The ultramafic rocks are composed primarily of pyroxene, olivine and hornblende altered to serpentine and talc. The rocks are considered to be slivers of ocean crust emplaced into metasediments in the accretionary prism during the Taconian Orogeny (Doolan and others, 1982; Stanley and others, 1984).

Cambrian - Ordovician fore-arc and arc deposits (Moretown of the Rowe-Hawley Belt)

Metasedimentary and metavolcanic rocks of the Moretown and Cram Hill formations occur east of the Rowe belt and are in fault contact with the Stowe, Rowe and Ottauquechee formations. The rocks are predominantly gray green pinstriped granofels and schist, gray and rusty schists, and quartzites. Ratcliffe and others (1997) reported Cambrian to Ordovician U-Pb zircon ages of 496 – 462 Ma from arc-related tonalite and trondhjemite gneisses in the Moretown Formation. The section is intruded by Silurian (419-423 Ma) diorite, trondhjemite, and granite near Newport and Braintree, as well as east of the Connecticut Valley Trough (Ratcliffe, 2010; Aleinikoff and others, 2010).

Silurian-Devonian metasedimentary rocks of the Connecticut Valley Trough

Silurian-Devonian metasedimentary rocks deposited in the post-Taconian Connecticut Valley Trough and metamorphosed during the Acadian orogeny include phyllites, sandy marble, calcareous quartzites, and quartz-muscovite schist. At a higher metamorphic grade, the rocks may contain garnet, biotite, diopside, kyanite, or staurolite. Throughout most of Vermont, the contact of Silurian –Devonian rocks with the underlying Ordovician section is mapped as an unconformity. Acadian offset of the unconformity was mapped locally in the Braintree and Montpelier areas (Martin, 1994; Kim and others, 2003; Walsh and others, 2010). A fault contact between the Middle Ordovician to Silurian rocks of the Bronson Hill arch (arc volcanics) and the CVT occurs in eastern Vermont.

Although the calcareous schists develop porosity during weathering due to dissolution of carbonate, the fresh rock is massive without primary porosity.

Devonian granitic plutons in eastern Vermont

The granites of Vermont are assigned to the Devonian New Hampshire pluton series. The series occurs throughout the eastern portion of Vermont with the most prominent exposures of granitic rock located north and east of Montpelier. The granites of Vermont were emplaced following the deformation of the Lower Devonian sediments during the Acadian Orogeny.

Autochthonous and para-autochthonous rocks of the foreland in western Vermont

Most of Vermont is composed of crystalline metamorphic and igneous rocks which lack intergranular porosity and in which connectedness of fractures and secondary porosity at depth is difficult to predict. Sedimentary rocks, some of which may be more porous and permeable, occur in northwestern and west-central Vermont west of the Green Mountain anticlinorium. These autochthonous and para-autochthonous sections in Vermont represent a transgressive marine section deposited on Precambrian basement and is comprised of Cambrian sandstones and dolostones of the Potsdam, Ticonderoga and Clarendon Springs formations overlain by Ordovician dolostones and limestones of the Beekmantown group, limestones and dolostones of the Black River Group, and predominantly limestones and black shales of the Trenton Group.

The Champlain Thrust Fault (Figure 4), exposed in western Vermont along the shores of Lake Champlain, extends from Canada south to the Catskill Plateau in New York, a distance of approximately 199 miles. The thrust is a late Taconian, east-dipping fault which places older Cambrian rocks on top of deformed Middle Ordovician shale, with an estimated throw of 8,850' and estimated displacement of 35 to 50 miles (Stanley, 1987). The base of the upper plate is the Lower Cambrian Dunham Dolostone, a resistant carbonate rock exposed throughout the Champlain Valley. The youngest unit on the lower plate of the fault is the Middle Ordovician Iberville Formation (Trenton Group), a dark gray shale with white calcite veins. Additional thrust faults such as the Highgate Springs in the north and the Orwell to the south, below and west of the Champlain thrust, result in imbrication of the para-autochthonous platform section. The sedimentary rocks on the lower plate of the Champlain thrust are the rocks of interest as possible sequestration targets.

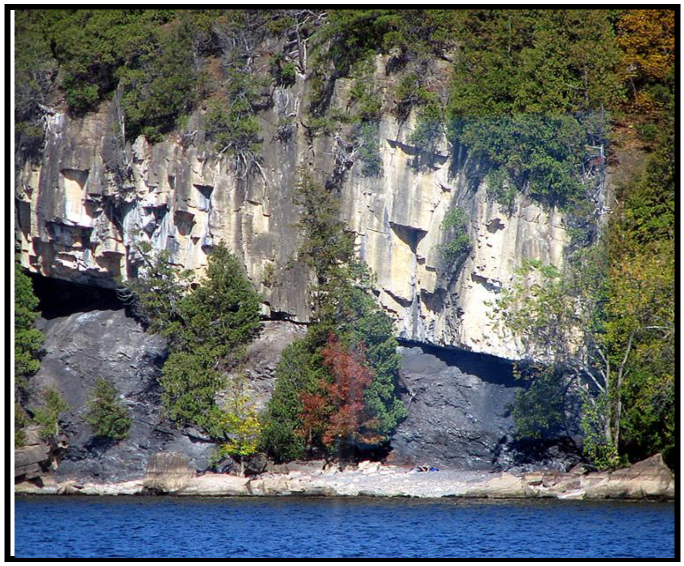

Figure 4. Champlain Thrust at Lone Rock Point, Burlington, VT.

AUTOCHTHONOUS ROCKS AND OIL AND GAS TEST WELL REPORTS

Based on analyses of the autochthonous rocks exposed in New York (DOE, 2008), the Potsdam sandstone was identified as a formation of interest as a sequestration target. The Potsdam occurs below the Champlain Thrust and below thick sections of shale (potential seal) and other impermeable rocks. The Cambrian Potsdam Fm. and the correlative Danby Fm. are overlain by dolomite of the Clarendon Springs Fm. (Little Falls correlative) and Ordovician carbonates. The stratigraphy and lithologies are summarized in Figures 5 and 6, a cross-section along the Winooski River at the latitude of Burlington is given in Figure 7, and comparative New York stratigraphy is given in Figure 8.

Potsdam Formation and Danby Formation (Keith, 1932)

Sandstones assigned to the Potsdam Fm. are exposed over considerable areas in New York State and in Quebec; the correlative Danby Fm., a sandy dolostone, is exposed in Vermont on the upper plate of the Champlain Thrust. The Potsdam itself thins to the east and is part of the transgressive sequence deposited on the lower Cambrian rift clastics; to the west in New York the Potsdam is above the Altona Fm. (Landing, 2009) which sits nonconformably on Precambrian basement. The maximum thickness of the Potsdam in northern Vermont is predicted to be 500 meters and it thins dramatically to the south. Estimates are based on inferred depth to basement and mapped stratigraphic sections. Landing (2009) notes that the Potsdam thickens (to 750 m) north of the Adirondack Massif, coincident with the Ottawa- Bonnechere aulocogen, and thins to less than 50 m or is absent to the south and east of the Adirondacks. Trilobite fossils indicate an early to middle Cambrian age for the Altona Fm. and a middle to

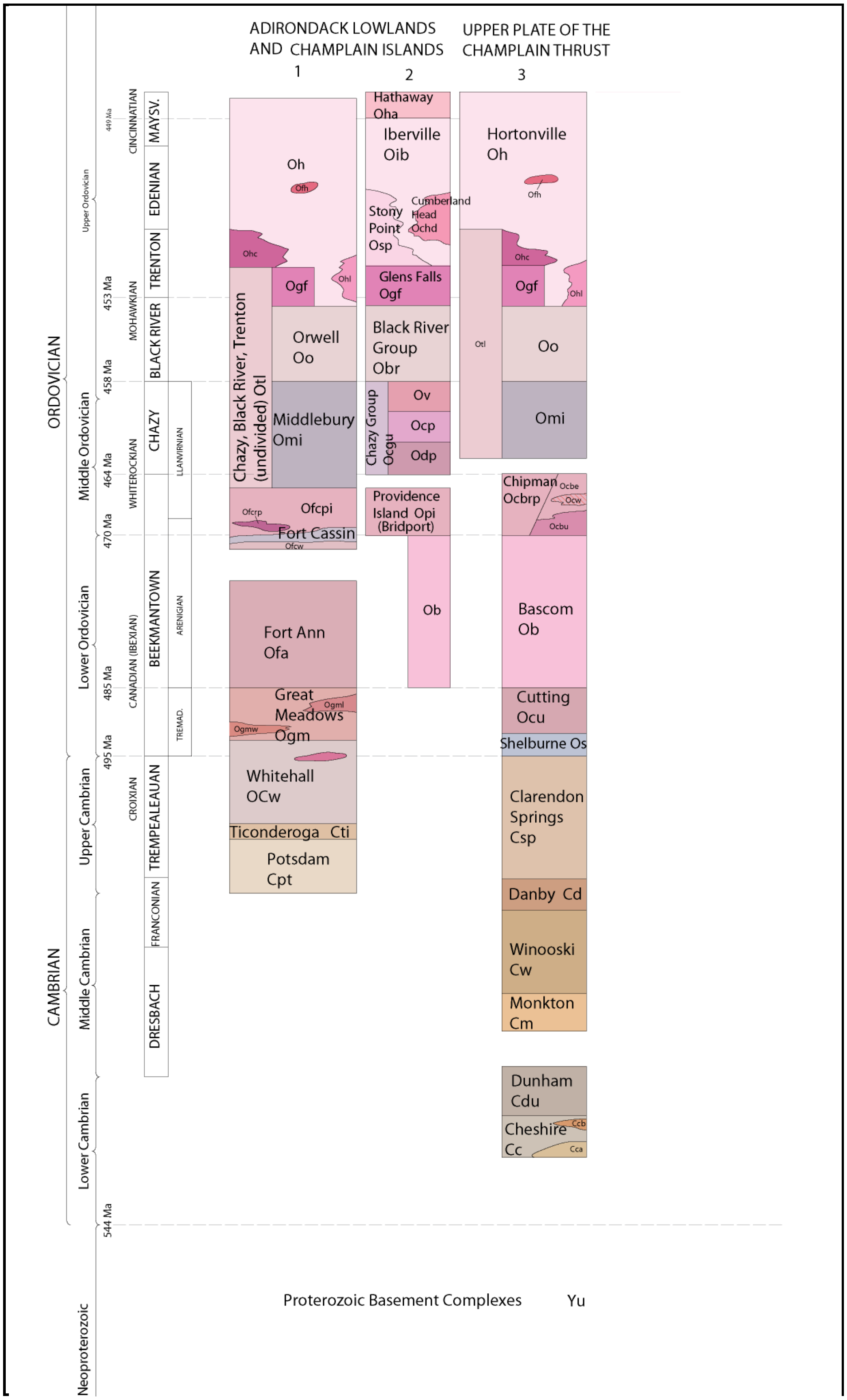


Figure 5. Vermont stratigraphy (from Ratcliffe and others, 2011).

Figure 6. Formation names, thicknesses and major lithologies for the Champlain Islands and Western Vermont on the lower plate of the Champlain Thrust.

| Age and Formation | Thicknesses from Cady (1945), Hawley (1957), Welby (1961), Fisher (1968), Landing (2009) | Description |
|---|---|---|
| **ORDOVICIAN** | | |
| **Trenton Group** | | |
| Hathaway Fm. | 100+ | Limestone, dolostone, sandstone and chert clasts within beds of black shale and chert |
| Iberville/Stony Point Fms. Hortonville Fm. | 1000’-2000+ | Dark gray calcareous and non-calcareous shale with thin beds of dolomitic siltstone |
| Cumberland Head Fm. | 140’+ | Interbedded limestone, calcareous shale and laminated shale |
| Glens Falls Fm. | 30’-500’ | Thin bedded, dark blue gray, fossiliferous limestone and shaly limestone |
| **Black River Group** (includes Orwell limestone) | 35’-75’ | Dolostone, fine grained, dark gray limestone, and sandy dolostone |
| Middlebury Limestone | <600’ | |
| **Chazy Group** | <250’-800’ | Gray limestone and calcareous sandstone |
| Valcour Fm. | 120’-180’ | Gray fossiliferous limestone |
| Crown Point Fm. | 50’-250’ | Massively bedded gray fossiliferous limestone |
| Day Point Fm. | 40’-300’ | Thin to massively bedded sandstone and fossiliferous limestone |
| **Beekmantown Group** | 225’-925’ | Limestone, fossiliferous limestone and dolostone |
| Bridport member of the Chipman Fm./Providence Island dolostone | <700’ | Massive to thick bedded, fine grained, dark gray dolostone with thin beds of fossiliferous limestone |
| Bascom Fm. | 250’-400’ | Interbedded dolostone and limestone with thin beds of calcareous sandstone |
| Cutting Fm. | 350’+ | Gray, thinly bedded dolomitic sandstone and massively bedded dolostone |
| Great Meadows Fm. | 350+ | Light gray, medium grained, bedded dolostone and cherty dolostone, cross-bedded sandstone, and sandy dolostone |

| | | |
|---|---|---|
| Tribes Hill Fm. | 210’ | Fine to medium grained, light gray dolostone, sandy dolostone, and dolostone breccia; chert nodules are common. |
| Shelburne Fm. | 120’-300’ | Light gray limestone, white marble, and dolostone |
| **CAMBRIAN** | | |
| Whitehall Fm. (OC) | 120’-300’ | Light gray dolostone and cherty dolostone with some limestone beds |
| Clarendon Springs/ Little Falls Fm./Ticonderoga Fm. | 50’-300’+ | Interbedded, massive gray dolostone, quartzose dolostone, dolomitic quartzite and breccia |
| Potsdam Fm. | 700’+ | Light gray, tan and dark gray well bedded pebbly quartzite, cross bedded vitreous quartzite and conglomerate |
| Keeseville Member* | | Pinkish-gray to very pale orange regular bedded, clay-deficient, quartz-sandstone, only slightly feldspathic. |
| Ausable Member* | | Highly cross laminated orange-pink to pale red very coarse to medium grained arkose with quartzose green shale seams and conglomeratic lenses |
| Basal Member* | | Maroon, hematitic, feldspathic, micaceous, quartzose sandstone; some shale interbeds |
| Altona Fm.** | 275’ | Red and purple mudstone with feldspathic quartz arenites and dolostones |

*Not mapped in Vermont; Description from Fisher, 1968, for rocks near Cooperville, New York
** Not mapped in Vermont; Description from Landing and others, 2009

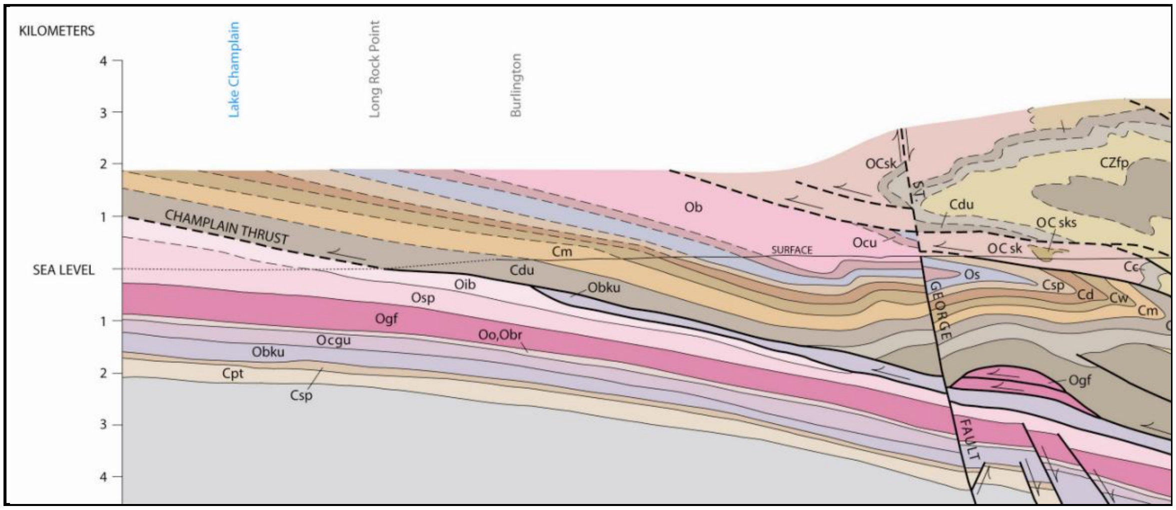


Figure 7. The Winooski River section shows gently east-dipping Proterozoic basement (Yu) overlain by Potsdam (Cpt) and Clarendon Springs (Csp) formation below the Champlain Thrust in the 3,000'-13,000 foot depth interval.  Units are projected above the land surface for interpretive purposes. For legend and descriptions see Figures 5 and 6.

upper Cambrian age for the Potsdam Fm. (Landing and others, 2009). Stratigraphy from Landing and others (2009) for the New York section is shown in Figure 8.

The upper section of the Potsdam Formation is exposed at Mt. Independence in Orwell, Vermont (Mango, 2002). The cross-bedded sandstone is a fine to coarse grained, quartz-cemented sandstone with thin shaly layers. Smooth rounded quartz grains are visible in hand specimen, although recrystallized grain boundaries are evident (triple point junctions) in thin section. Mango reported no visible porosity in thin section (pers. comm., 2011). The Potsdam with ripple marks, cross-beds, and worm burrows has been interpreted as a shoreline deposit limited to intertidal or subtidal zones. This is in contrast to the dolomitic sandstone of the Danby Fm. which represents intertidal to platform edge deposits (Mehrtens, 1985). The Potsdam Fm. is in gradational contact with the overlying sandy dolomite of the Ticonderoga Formation in New York (Selleck, 1997) although Mango (2002) describes an erosional surface at this contact at Mt. Independence.

In addition to the limited exposure at Mt. Independence, the Potsdam was mapped 3-4 miles west of Vermont in Cooperstown and Champlain, New York by Fisher (1968). Fisher mapped two members of the Potsdam: the Ausable Member and the Keeseville Member. The Ausable Member is a medium to thick bedded, cross-bedded, tan to pink feldspathic sandstone (arkose) with green quartzose shale layers and quartz-pebble conglomerate lenses. The Keeseville Member (Emmons, 1841) is a thin to medium bedded, ripple marked, white to buff

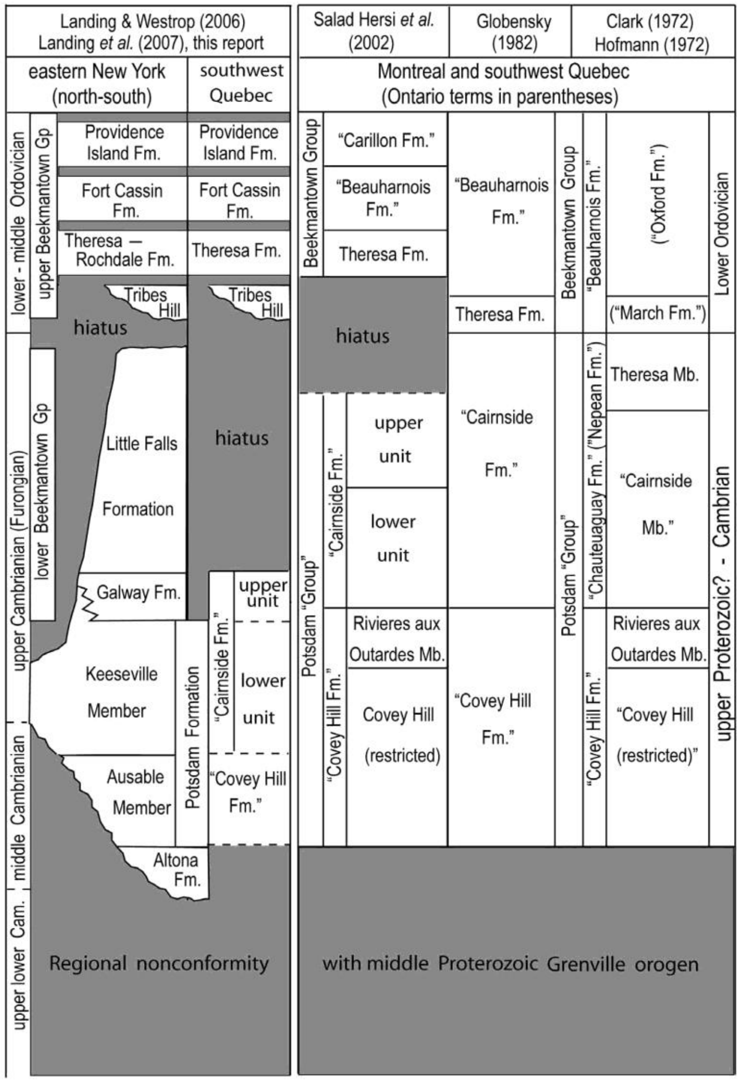


Figure 8. Correlation of Potsdam Fm. and overlying Ordovician units for New York and Quebec (from Landing and others, 2009).

quartz sandstone with frosted sand grains; feldspar is generally less than 10%. The basal member of the Potsdam was not mapped by Fisher, nor was the Altona Fm. Selleck (1997) reported late Devonian to early Carboniferous hydrothermal alteration of the basal Potsdam and underlying Proterozoic basement in New York.

The Danby Formation (Potsdam correlative) is a light gray, medium grained, vitreous quartzite interbedded with light gray to cream dolomite and, near the upper portions, sandy dolomite. Beds are one to several feet thick and the contact with the overlying Clarendon Springs Formation is gradational. The sandy dolostone is commonly cross-bedded with frosted quartz grains (Figure 9). The unit is as much as 700’ thick in the Castleton area but thins to the west to 350’ or less (Rodgers, 1937).

Figure 9. Danby Formation (Potsdam correlative), Charlotte, VT

Data related to porosity, pore volume and permeability would be required for any evaluation of the Potsdam and/or Danby as sequestration targets. Jacobi et al (2010) recently published an estimate of 10% porosity in the Potsdam in Waterford Township, PA. However, where exposed in west-central Vermont, the Potsdam has no porosity (Mango, 2011, pers. comm.). Data held at the VGS provides depth and descriptive information about the Potsdam Fm. in Vermont from oil and gas test wells, but does not include porosity or permeability data.

Ticonderoga, Little Falls, and Clarendon Springs Formations

Ticonderoga/Little Falls is a light to dark gray, silty to sandy dolomite marking the transition from a shoreline to sandy marine environment. The Ticonderoga/Little Falls share some common features such as a general thinning of beds and increase in sand and silt content towards the top of the formation. Ticonderoga at Thompson’s Point in Charlotte is less sandy and contains more chert than the type section on Mt. Hope in Ticonderoga, NY. The dolostone is a fine to medium grained, dark gray to blue gray dolostone with interlocking grains and a dolostone breccia with thin sandy laminae and some sandy cross-beds; carbonate beds contain as much as 15% quartz silt (Welby, 1961). Dark blue chert occurs as lenses, nodules and angular fragments. Intraformational conglomerates and breccias plus filled channels in the massive dolostones are common (Figure 10). Vuggy porosity occurs locally. Formation thickness is estimated to be 200-400’.

The Clarendon Springs Formation (Keith, 1932), correlative with Little Falls (Rodgers, 1937), is mainly a massive gray dolomite with intraformational dolomite breccias. Dark chert nodules occur locally as do quartz-lined cavities and veins. Most fractures are filled.

Figure 10. Dolomite breccia at Thompsons Point, Charlotte, VT.

Oil and Gas Test Wells in Vermont

The VGS reviewed reports for six test wells drilled in Vermont between 1957 and 1984 (Figure 11 and Table 1). The six test wells were drilled to depths of 2306' to 6968'. Five of the wells are interpreted to have penetrated the Cambro-Ordovician section of black shales, carbonates and Potsdam sandstone lithologies; the 6$^{th}$ well (Burnor well) penetrated the rift clastic section further to the east. The well data was obtained through pages of a report(s) by Earle Taylor of Taylor and Associates, Inc. in Houston Texas, through scanned images of well logs, and through transcribed well logs. Taylor and Associates was retained by Cambrian Corp. of Rutland, VT to conduct a geological study of oil and gas resources in Vermont and pages of the report are on file at the VGS. While most of the reports seem to agree with mapped geology, a detailed descriptive log labeled as Alburg #1 does not match either the mapped geology or the Alburg #1 summary in terms of depth intervals and units. The log appears to be mislabeled and is likely the Yandow #1. That well is labeled as the "suspect well" in the attached excel spreadsheet (Appendix A). Also, the scanned report for the E.S. Baker well contains a map which shows additional well locations, perhaps proposed locations which were never drilled.

**Yandow #1:** St. Albans, Vermont

The Yandow #1 well was drilled to a reported depth of 4,500 feet in St. Albans, VT during 1956-1957. Some methane gas was encountered (Khouri, 1977). VGS may/may not hold well log or descriptive information for this well. Based on location, the well was drilled on the lower plate of the Highgate Springs thrust in a thick section of Iberville and Stony Point calcareous and non-calcareous shales with interbedded limestones and dolostones. Elevation of the well site is 180'-190'. The Yandow #1 well may be the "suspect well" in the Appendix A.

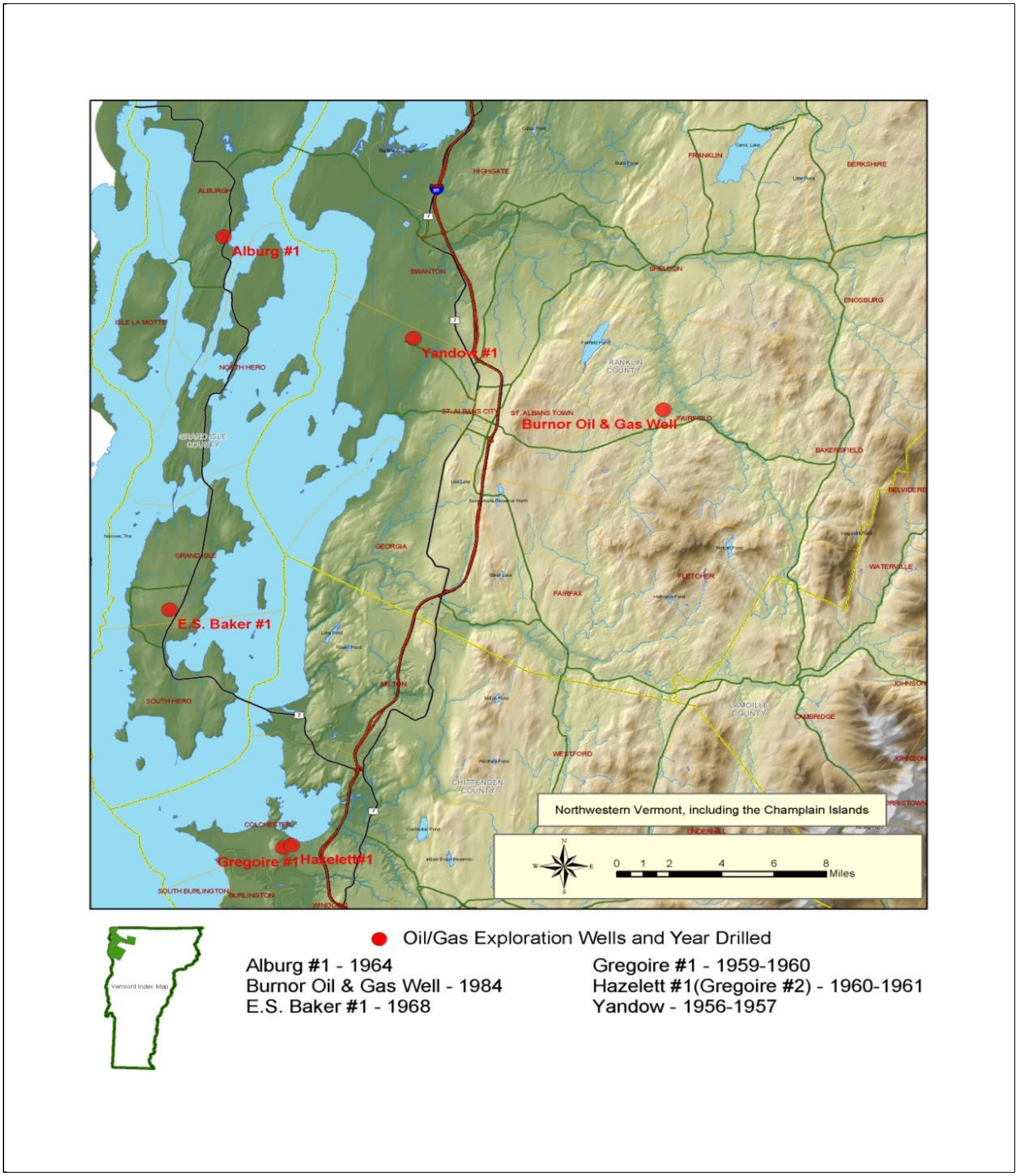


Figure 11. Oil and gas test well locations, northwest Vermont.

| WELL NAME | LOCATION | YEARS DRILLED | DEPTH (FT) | SPONSORING AND DRILLING COMPANY |
|---|---|---|---|---|
| Yandow #1 | Franklin County, St. Albans | 1957 | 4500’ | Maquam Oil & Gas Development Corp. & Henderson Oil Co. API# 44-011-00001-0000 |
| Gregoire #1 | Chittenden County, Colchester | 1959-1960 | 5075’ | Vermont Gas & Mineral Corp. API# 44-007-00001-0000 |
| Hazelett #1 (Gregoire #2) | Chittenden County, Colchester | 1960-1961 | 2306’ | Vermont Gas & Mineral Corp. API# 44-007-00002-0000 |
| Alburg #1 | Grand Isle County, Alburg | 1964 | 5120’ | American Petrofina & Falcon Seaboard Drilling Co. API# 44-013-00001-0000 |
| E.S. Baker | Grand Isle County, Grand Isle | 1968 | 3500’ | Cambrian Corp. API# 44-013-00002-0000 |
| Burnor #1 | Franklin County, Fairfield | 1984 | 6968’ | Columbia Gas Transmission Co. & Delta Drilling API# 44-011-20001-0000 |

Table 1: Name, location and depth of test wells in northwest Vermont. API: American Petroleum Institute.

**Gregoire #1:** Colchester, Vermont

The Gregoire #1 well was drilled in Colchester, VT in 1959-1960 on the upper plate of the Champlain thrust. The well site elevation, based on the location on the topographic base map, was 150’-160’. The scanned descriptive well log is provided as a pdf (Appendix B) and transcribed to an excel spreadsheet (Appendix A). Based on the well descriptions, the well penetrated 318 feet of Dunham Dolomite and reached the base of the Champlain thrust. The well then penetrated a 4757’ thick section of Trenton/Black River limestones and black shales, plus interbedded dolostone near the base, finishing at 5075’. Some pockets of gas were penetrated but the well was abandoned and capped (Doll, 1974, Khouri, 1977).

The Trenton section is interpreted to be structurally thickened. Where exposed in northern Vermont, the shales are extensively folded and cut by numerous low-angle faults with little displacement. However, Stanley (1990) in a study of the Cumberland Head Formation in the Champlain Islands, recognized the cumulative effect of small bedding plane thrusts and calculated total shortening of 11% -16% along predominantly northwest-directed imbricate faults. He also noted the abundance of calcite slickensides, formed by injection of calcite-rich fluids along the fault planes. The Gregoire #1 well intersected numerous slickenside surfaces and calcite veins, an indicator of bedding plane thrusts although the amount of displacement is unknown.

The thick sections of fine-grained black shales (Figure 12) may be a potential seal for a $CO_2$ sequestration site, although detailed subsurface data would be required to fully evaluate the thickness, fractures, faults, and permeability of the rocks. The most complete descriptions and measured sections for the black shales and interbedded limestone in the Champlain Islands are provided by Hawley (1957). Where shales are exposed in the Champlain Valley, shear along bedding planes is common, calcite–filled en echelon fractures occur locally, and two generations of cleavage were recognized by Stanley (1990). Minor folds, overturned to the west, generally strike north-northeast and dip moderately to steeply east. Multiple fractures cross-cut pre-existing fabrics. Earle and others (2010) documented fold, cleavage and vein formation in thick and thin bedded shales below the Champlain thrust (Figure 13) and this style of deformation is pervasive in the Champlain Valley. The intensification of deformation in the shales near bedding plane thrusts, coupled with the fold history and likely variation in depth in basement due to high angle faults all require significant work to understand regional and site specific structures in order to evaluate $CO_2$ sequestration sites.

Figure 12. Bedding/cleavage in Stony Point shale below the Champlain Thrust, Rte. 7, Charlotte

**Hazelett #1** (Gregoire #2): Colchester, Vermont

The Hazelett #1 (Gregoire #2) was drilled roughly 540’ northeast of Gregoire #1 in 1960-1961. The well site elevation is estimated as 150’-160’. The scanned descriptive well log is provided as a pdf and transcribed to an excel spreadsheet in Appendix A. Based on the well descriptions, the well penetrated 465 feet of Dunham Dolomite and reached the base of the

Champlain thrust. The well then penetrated a 1310' thick section of Trenton (Iberville and Stony Point Fms.) black calcareous and non-calcareous shales, stopped sampling at 1775' and ended at 2306'. The hole intersected slickensides (see Gregoire #1) and some dolomitic beds; the log also noted that carbon content was low in the black shales.

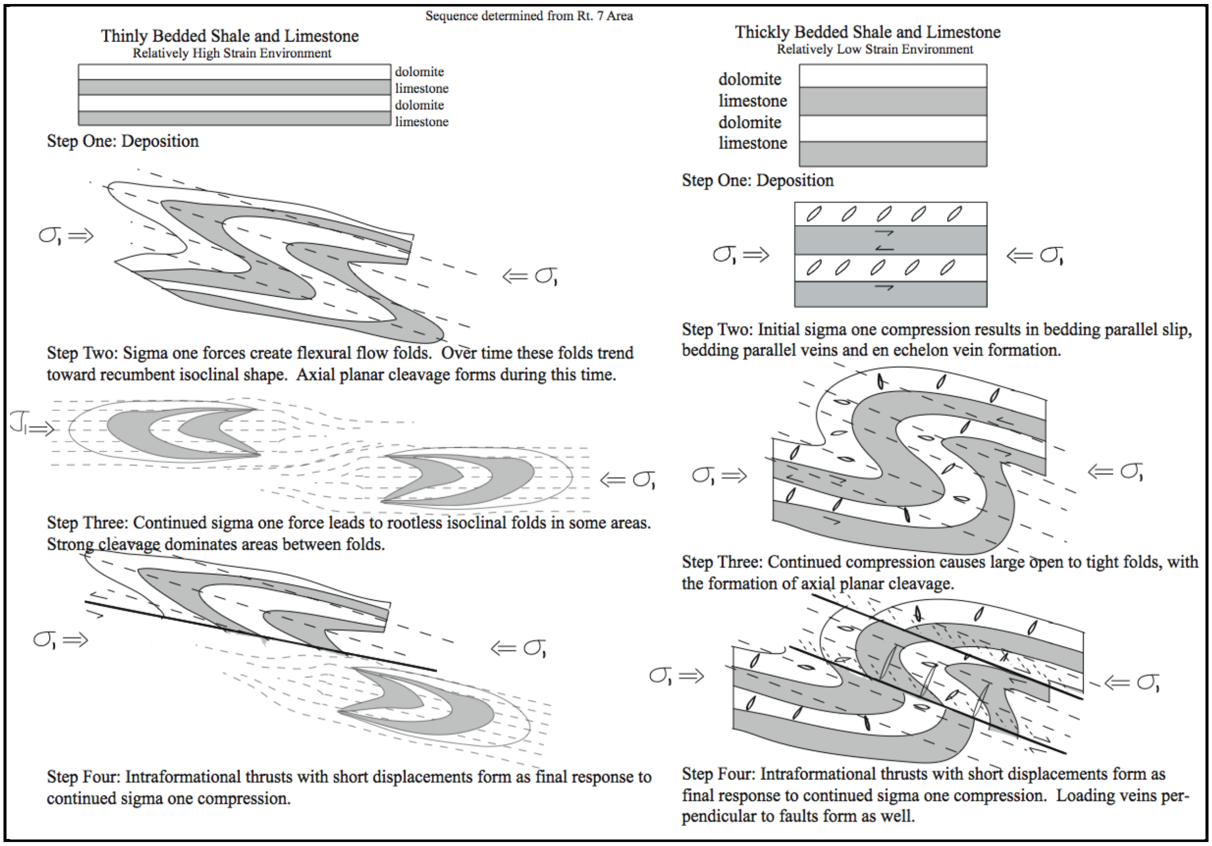


Figure 13. Shale deformation, Rte. 7, Charlotte (Earle and others, 2010).

**Alburg #1**/American Petrofina: Alburg, Vermont

The Alburg #1 site is just west of an un-named west-directed thrust (Fisher, 1987) within the Ordovician black shales of the Stony Point Formation. The well, drilled in 1964, penetrated 3320' of shale, then intervals of limestone, dolomite, sandstone, shale, conglomerate (3715') and reached sandstone at 4290'. Elevation of the well site is 120'-130'. The well was capped (Khouri, 1977). The descriptive well summary is provided in Appendix A. Unfortunately, there appear to be discrepancies between the detailed description and the summary: the depth intervals in the summary do not match depth intervals in the detailed description and rock types listed in the summary are not reported in the detailed description (ex. conglomerate at 3715-3722 is not in the detailed log). We have chosen the well summary to represent the Alburg #1 well because it is in agreement with the geology and stratigraphy as mapped by Fisher, 1968. The detailed log is provided in Appendix A and is labeled “suspect well”. The detailed log seems to correspond with geology as expected in the Yandow #1 well and ends close to the reported 4500’ depth.

The stratigraphy in the Alburg #1 well is compared with the E.S. Baker well and the stratigraphic section from Fisher (1968) in Figure 14. Tops are given for Beekmantown Group and Potsdam. The base of the Potsdam was not reached in any of the test wells. However, thicknesses interpreted in the Quebec seismic data from Q118 (Sejourne and others, 2003) support a 500 meter thickness (Figure 15).

**E.S. Baker:** Grand Isle, Vermont

Drilling of the E.S. Baker test well in an anticline in Grand Isle, Vermont was completed in 1968. Schlumberger subsequently ran several logs, not in the VGS files, of the 3500’ well: Dual induction from 912’-3490’; Sidewall Neutron Porosity Log from 912’-3490’; and Compensated Formation Density Log (Gamma-Gamma) from 100’-3490’. Schlumberger also provided a descriptive log from 1104’-3478’, an interval which showed some porosity. The descriptive log is in Appendix A and an interpretive stratigraphic column is presented in Figure . Well site elevation is estimated between 200’-220’.

The well reportedly penetrated Chazy limestones to 1050’, then sandstone to 1104’. This is a considerable thickness of Chazy as compared to a maximum thickness of the Chazy from Fisher (1968) of 780’ and an average thickness from Welby (1961) of 165’. Taylor and Associates also noted the occurrence of numerous oolitic and sandy zones within the Chazy limestones which may have porosity. The Manager of Exploration for Cambrian Corporation put the top of the Beekmantown at 1126’ and suggested that the Chazy thickens dramatically to the east as compared with limestones further west. Since details of the 0-1050’ interval are not available, one could speculate that either the dip steepens or there is some structural repetition. The Chazy occurs in numerous fault slices below the Champlain thrust. Fisher (1968) mapped a steep fault west of the drilling site which would account for doubling the thickness of the Chazy section.

Thickness of the Beekmantown Group was reported as 1756’-1824’, also much thicker than that mapped by Fisher (1968) and again, details are not reported. The well summary actually reported greater thicknesses in all units as compared to mapping by Fisher. It is likely that some units do thicken but also likely that detail was omitted and there may be some structural repetition.

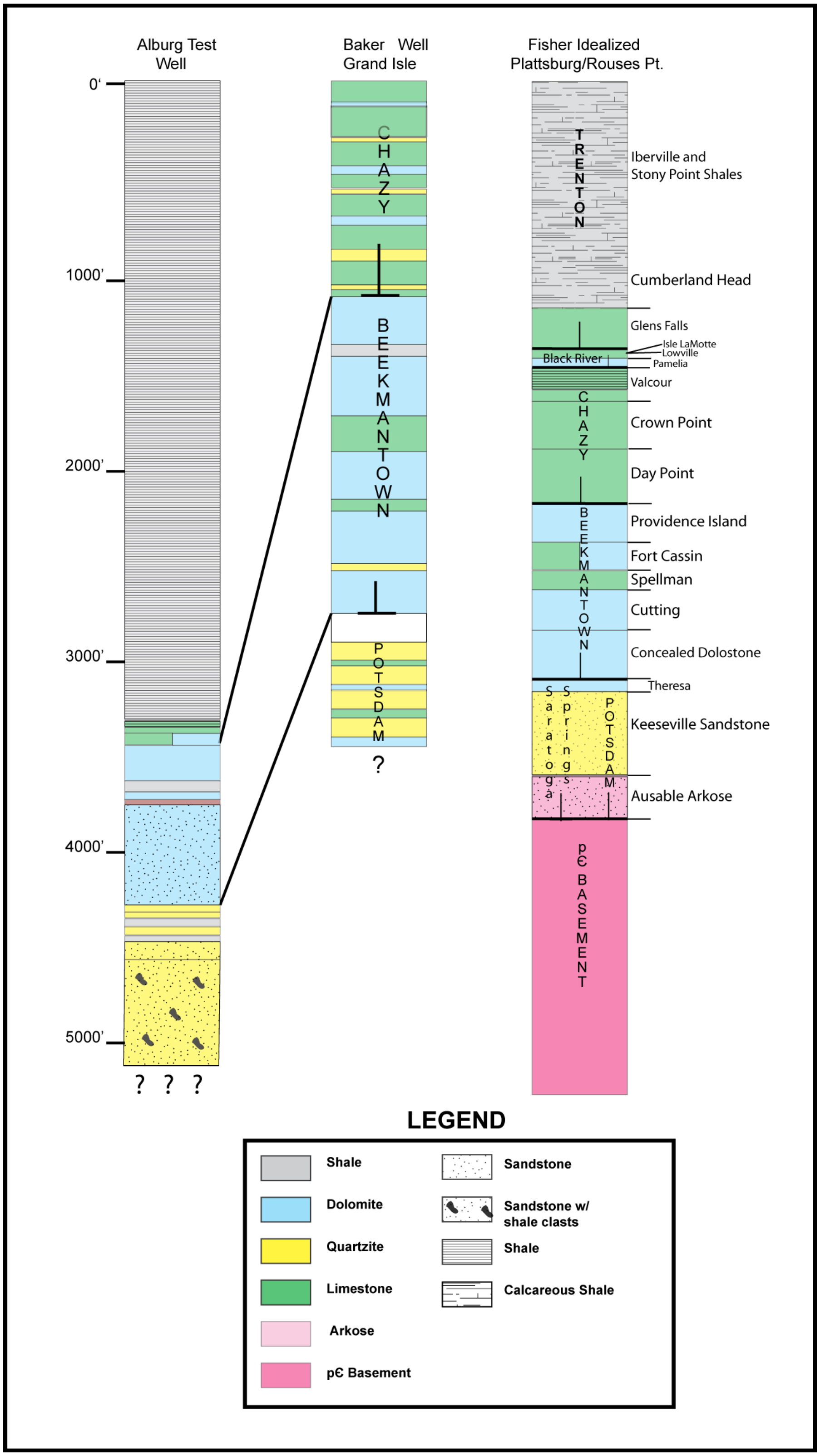


Figure 14. Comparison of stratigraphy interpreted from test wells with the idealized stratigraphy from Fisher, 1968 (modified after Becker and others, 2006).

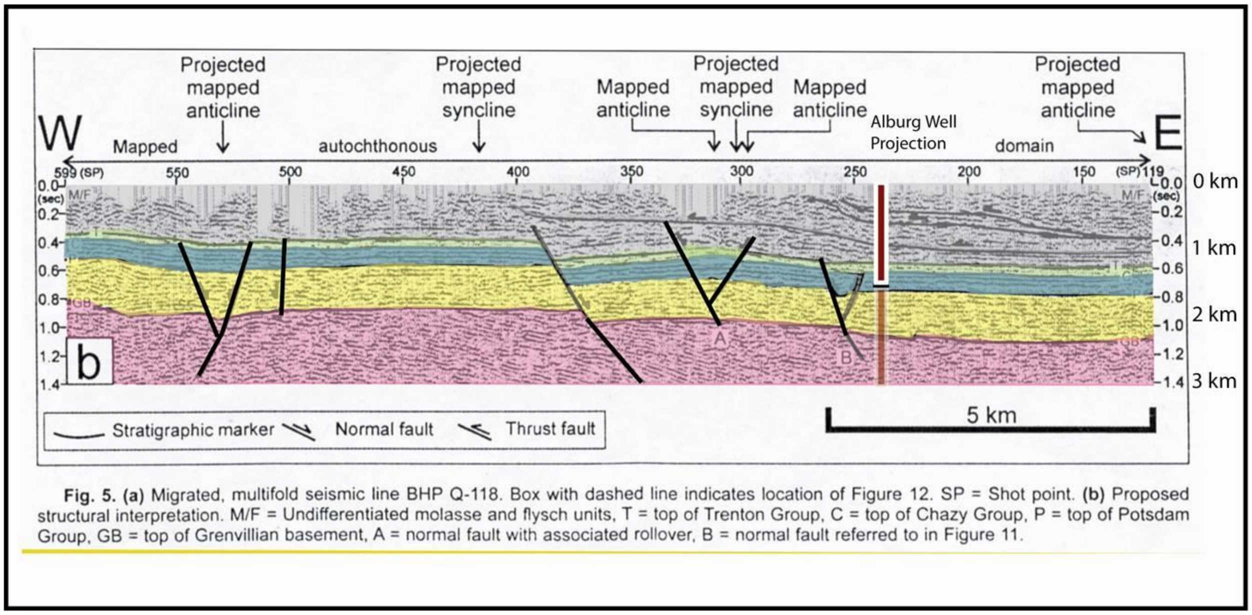


Figure 15a.

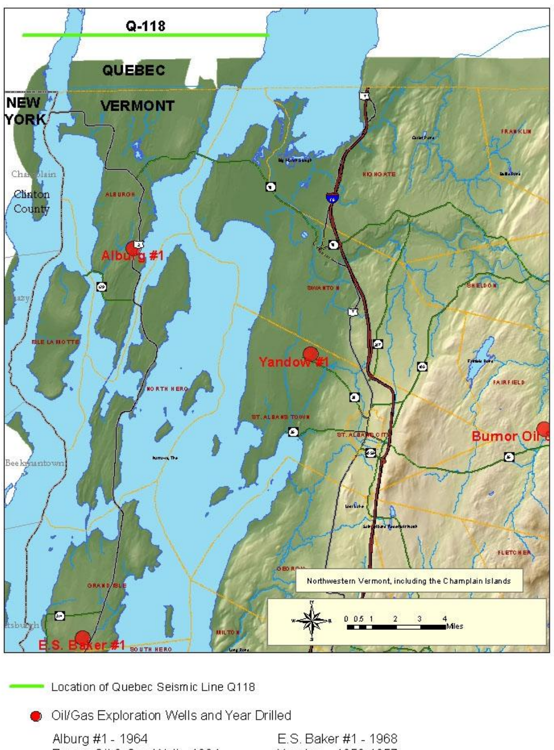


Figure 15a and 15b. Sejourne and others (2003) interpreted the seismic data in Quebec seismic line Q118 (Fig. 15a) which is located just north of the Vermont border (Fig. 15b). The Alburg #1 well is projected onto the seismic line and shown penetrating Trenton, Chazy and Beekmantown lithologies. Colors are also keyed to Figure 14.

The Potsdam was described as more calcareous than that in outcrops to the west which is to be expected as the sandstone transitions to the dolomitic sandstone of the correlative Danby Fm. The Potsdam was described as a fine to coarse grained, angular to sub-round, brown to gray in color, loosely consolidated to well cemented sandstone with interbeds of calarenite and dolomite (especially near the top). The well penetrated 550-694 feet of Potsdam depending on where one picks the top of the Potsdam or the base of the Beekmantown and finished in the Potsdam Fm.

**Burnor #1:** Fairfield, Vermont

The Burnor #1 test well was drilled to a depth of 6968’ in hopes of penetrating the Champlain thrust. The well failed to reach the thrust. The well site elevation is estimated at 150’-160’ based on topographic location although the elevation is listed as G.L. = 480.8’ in the log. The well penetrated 550’ of phyllites of the Fairfield Pond Formation, then remained in a thick section of interbedded graywackes, quartzites and meta-volcanic rocks of the Tibbit Hill and Pinnacle formations to the bottom. Cherichetti and others (1998), estimated that the rift deposits could be as thick as 3.5 km in northern Vermont, associated with a deep basin, then thin dramatically to the north across the Missisquoi transfer zone of Doolan and others (1987) or Missisquoi transform of Allen and others (2003). The thickening of the rift section in Vermont corresponds to a greater depth to basement which is reflected in cross-sections as compared to the seismic profiles from southern Quebec (Q118, Figure 15).

Representative Cross-Sections for the Champlain Valley

The VGS correlated the test well log information and logger’s descriptions of materials with Vermont and New York stratigraphy and with that of the Quebec seismic line (Q118) to generate an interpretation of depth and thickness of the Potsdam Fm. in northwest Vermont (Figure 14, 15). The Potsdam Formation is projected in cross-sections and identified in well reports to occur in the depth interval of interest (3,000’ – 13,000’). The projection of the Potsdam Fm. in map pattern, based on these cross-sections is shown in Figure 16. The highly interpretive map highlights possible areas to explore if $CO_2$ sequestration were to become a serious option for Vermont. Lastly, cross-sections for northwest Vermont, based on the following information, are provided as guidance:

- One unprocessed seismic line from Colombia Gas Company, 1980s
- COCORP seismic data from Brown and others (1983)
- Seismic data from Quebec seismic line Q118 (Figure 15 ) as reported by Sejourne and others (2003)
- Test well data from 6 wells drilled between 1957 and 1984 (Appendix A, B and main text)
- Bedrock geologic mapping and inferred cross-sections (1960s-2011; Ratcliffe and others, 2011)

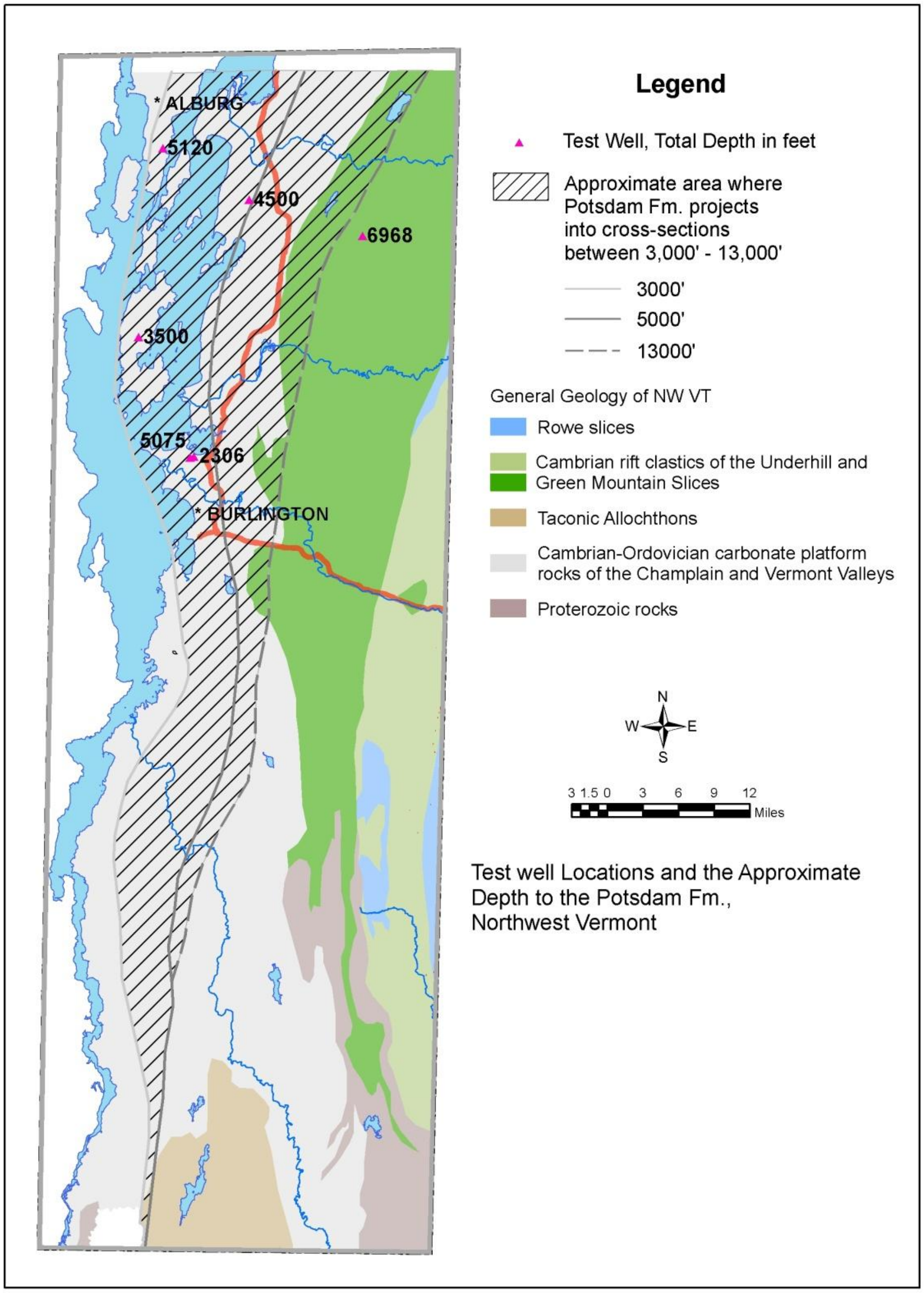


Figure 16. Based on the oil and gas test well data points, plus geologic mapping and interpretation, the occurrence of the top of the Potsdam in the 3,000’ -13,000’ depth interval is estimated in map plan.

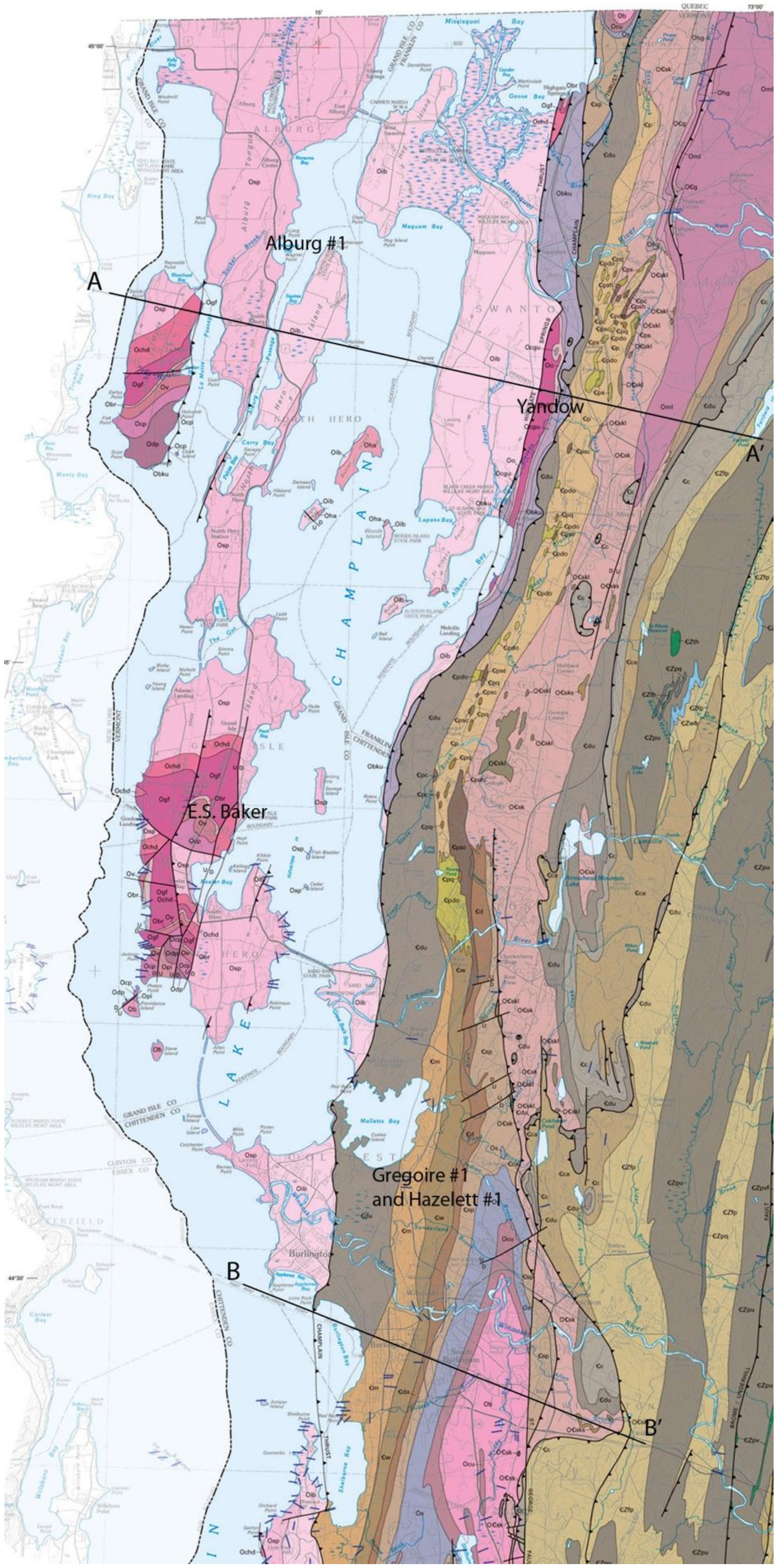


Figure 17: Location of cross-sections A-A' and B-B'. For legend see Figure 5.

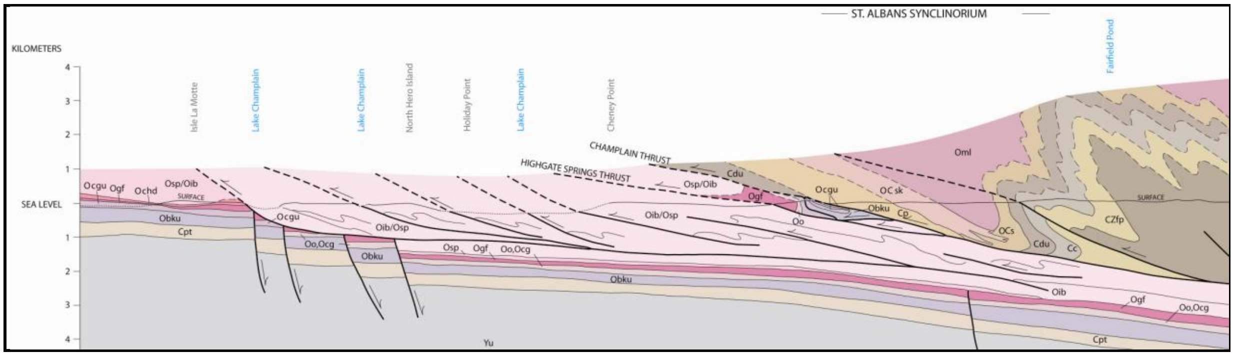


Figure 18. Champlain Islands section (A-A’, Fig. ) shows gently-dipping Proterozoic basement overlain by Potsdam and Beekmantown Group. Structurally thickened sections of Ordovician shales may act as seals. Faults in the basement and under Lake Champlain are schematic. Note increased thickness of the shale section as compared with cross-sections B-B’ and C-C’.

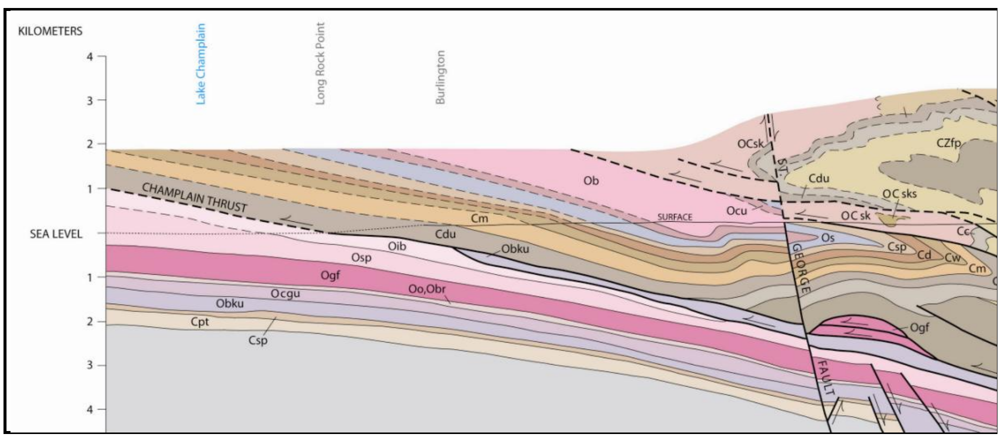


Figure 19. The Winooski River section (B-B’) shows gently east-dipping Proterozoic basement (Yu) overlain by Potsdam (Cpt) and Clarendon Springs (Csp) formation.  Shales (Osp, Oib) are dramatically thinner as compared with cross-section A-A’.

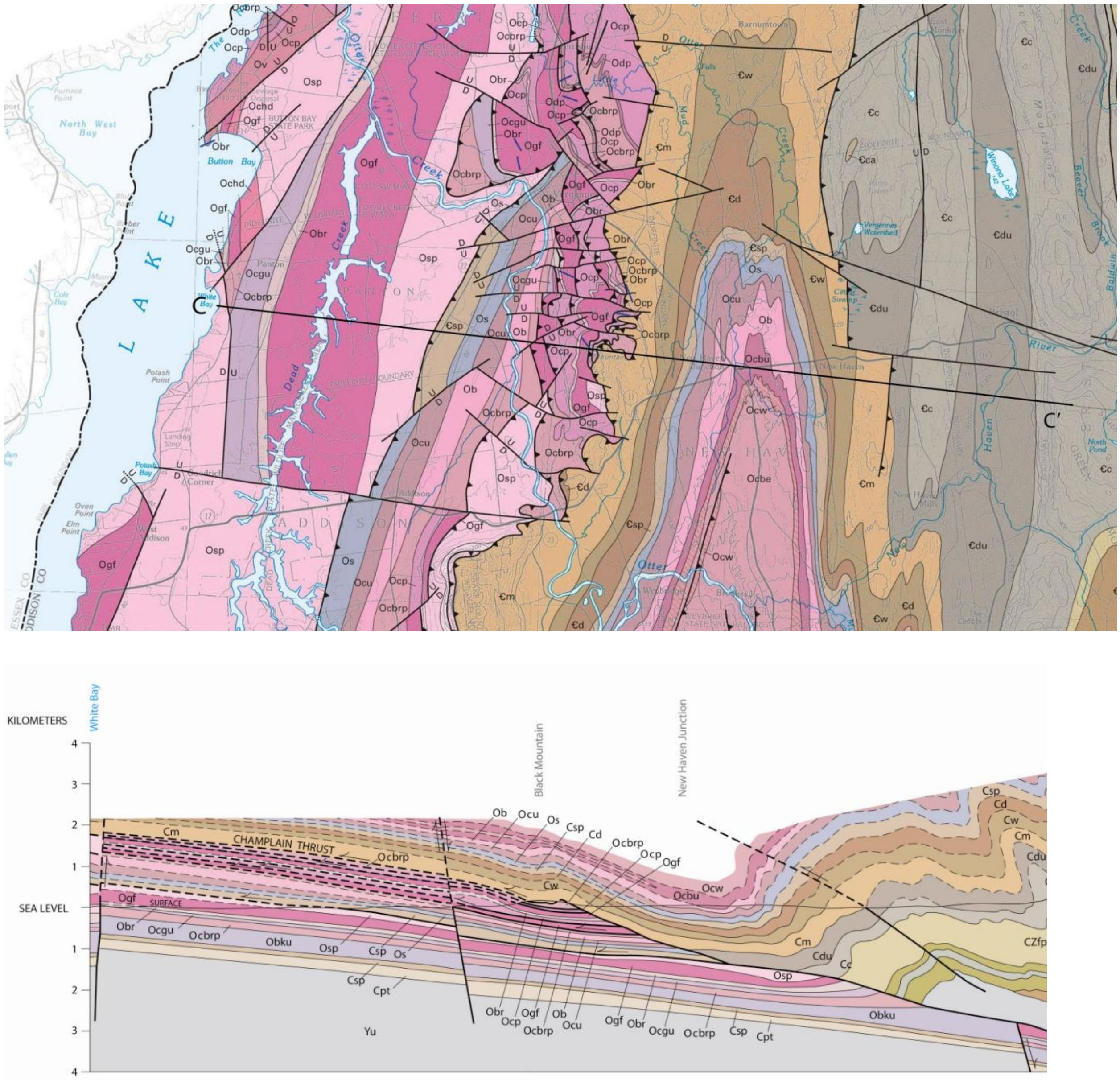


Figure 20. The Middlebury synclinorium section (C-C' ) shows gently east-dipping Proterozoic basement (Yu) overlain by Potsdam (Cpt), Clarendon Springs (Csp), and Beekmantown Group lithologies on the lower plate of the Champlain thrust. Again, shales are considerably thinner than the A-A' section. Potsdam is thinner to the east and replaced by Danby Fm. (Cd) on the upper plate of the Champlain Thrust. The units occur in the depth of interest below the Champlain and Orwell thrusts. Faults in basement (far east) are schematic.

## CONCLUSIONS

The USGS requested a short report on the geology of Vermont, a focus on specific formations, and a review of state maintained data sets and/or aerial and structure maps and geologic cross-sections of potential saline formations (reservoirs and seals) and oil and gas traps that can be utilized for geologic carbon dioxide ($CO_2$) sequestration in Vermont. A review of the files at the Vermont Geological Survey was conducted to search for data relevant to $CO_2$ sequestration in Vermont.

Most of the bedrock in Vermont is metamorphic crystalline rock without primary or intergranular porosity. Secondary porosity and permeability are primarily due to fractures plus partings parallel to the foliation. However, the Potsdam and overlying Ticonderoga or Clarendon Springs formations were identified as possible sequestration formations in New York and these formations are shown at depth in interpretive cross-sections in west-central and northwestern Vermont. Control for the cross-sections is provided by limited seismic data and by 6 oil and gas test well reports. Seismic data in Quebec shows numerous steep faults extending into basement and these types of faults likely also occur in western Vermont. Additional data would be needed to characterize the subsurface structures in Vermont.

The test well data also provides more specific constraints on the subsurface. Porous, permeable formations may exist in Vermont at the appropriate depths, but extensive data collection is needed in order to generate lithology, porosity, permeability, and injectivity information. Oil and gas test well data is provided in an Excel spreadsheet and as pdf files. A shapefile with well locations is attached.

Vermont may be a less likely area of the United States for $CO_2$ sequestration, particularly if one considers that there are currently no large point sources of $CO_2$ emissions in the state. However, the potential for sequestration in Vermont from a geological perspective remains an option that could be further investigated.

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NOTE: There are unexplained discrepancies between this summary and the data as provided in the detailed decritpive well log. Depth intervals summarized here do not correspond to depth intervals reported in the log.

| Depth Interval | DescriptionA | DescriptionB | DescriptionC | Formation Interpreted | Field1 |
|---|---|---|---|---|---|
| 0'-3320' | Shale, gray to black, calcareous (percent of carbonate 40.8 minimum to 78.4 maximum, averaging 60 percent), hard, sometimes silty and micaceous. Pyrite is always present and can be abundant. | Calcite is disseminated throughout the entire interval and sometimes is abundant: 10 to 20 percent from 1014 to 1029; 10 percent at 1685. Slickensides also frequently observed in shales. Thin beds of shaly limestone occur, especially toward the base. | | Trenton | |
| 3320' - 3364' | Shale and shaly limestone as above; also limestone, dark gray to bluish black, micro-crystalline with some brown limestone, medium grained with very coarse calcite crystals (recrystallized fossils 1) and some coarse, well-rounded quartz grains. | Three fragments of Brachiopoda and one of recrystallized Bryozoan were found in this interval. | | Trenton/Glens Falls | 70' of Ogf is a little thin - likely there is some in section above |
| 3364'-3390' | Mostly limestone as above. No fossils. | | | Trenton | |
| 3390'-3420' | Limestone as above and dolomite or dolomitic limestone with coarse quartz grains. | | | Beekmantown? | 300' of dolostones |
| 3420'-3630' | Dolomite, white micro to finely crystalline; gray brown, fine to medium crystalline; black and white (coarse recrystallization of a black microcrystalline matrix), some thin bedded gray dolomite; | some sandy dolomite with coarse, well-rounded qtz grains; some shale inclusions. Pyrite frequent and abundant 3550 - 3580. Some traces of fossils (3520-3530 & 3560), (probably dolomitized coquinoidal ls). | Two intercalations of shale (electric log) at 3610 and 3626 to 3630. Calcite is abundant from 3600 to 3630. | Bridport? | |
| 3630'-3680' | Mainly black, calcareous and/or dolomitic shale, hard, with some intercalations of dolomite. | | | Clarendon Springs?? | |
| 3680'-3715' | Dolomite -white micro to finely crystalline then gray, fine to medium crystalline then sandy with coarse, well-rounded quartz grains | Becomes more sandy toward the base, and grading into dolomitic sand¬stone below 3700. Intercalations of dolomitic black shale. Pyrite frequent. | | Clarendon Springs? | |
| 3715'-3722' | Conglomerate -with slightly dolomitic coarse sandstone matrix; pebbles not contiguous at top of the interval; very compact to¬ward the base; diameters up to 2 inches near the top; from 1/8 inch to 1/2 inch near the base; | pebbles angular near the top, less angular toward the base. | Composition of pebbles: Conglomerate; Dolomite -white, pure, finely crystalline; Dolomite -white, sandy (well-rounded quartz); Dolomite -brown, medium crystals; some fragments show bedding. | Clarendon Springs | |
| 3722'-4290' | Sandstone, dolomitic matrix, clear to frosted, sub-round to well-roWlded; medium to coarse grains, white to translucent. Some black inclusions (shale 1) toward the base. | Dolomite -sandy to very sandy, medium to coarse quartz grains, gray color. The percentage of dolomite diminishes-toward the base, and the white sandstone becomes quartzitic. | White soft clay (kaolinite 1) always present --averaging 5 to 10 percent; slickensides. Several intercalations of black shale (3788 to 3796, 3810 to 3812, 3872 to 3876, 3900 to 3950). | Potsdam/Danby | |
| 4290'-4330' | Sandstone, white, quartzitic, gray with black in¬clusions; slightly to non-dolomitic; fine to coarse grained; 10 percent of kaolinite (1). | Intercalations of black calcareous shale. Sandstone same as above. Black shale same as above. Kaolinite | Shale -gray-black, very micaceous, non-calcareous (5~) Sandstone -red-brown, dolomitic; grading into sandy dolomite (20~ at 4350); diminishing toward the base. | | |
| 4330'-4470' | Sandstone, black shale, kaolinite, shale- gray black micaceous non-calcareous, red dolomitic sandstone grading into sandy dolomite, diminishing toward base | | | Potsdam/Danby | |
| 4470'-4580' | Sandstone -white to translucent, quartzitic, slightly to non-dolomitic; rounded to well-rounded; fine to coarse. Sandstone, gray as above, but with black inclusions(Shale 1) | Dolomite, dolomitic sandstone or sandy dolomite; reddish brown.Kaolinite (1) Black shale | | Potsdam/Danby | |
| 4580'-5120' | Sandstone, quartzitic, slightly to non-dolomitic; fine to coarse grained; rounded to well-rounded; clear to frosty; white or gray with black inclusions (slate 1). | Traces of black calcareous shale. | | Potsdam/Danby | |

Town: Grand Isle, County: Grand Isle, State: VT, Operator: Cambrian Corp, Well Name: ES baker, year: 1968

| Depth (FT) START | Depth (FT) END | Description | RockTypeA | RockTypeB | Formation | Comment |
|---|---|---|---|---|---|---|
| 1 | 1050 | limestone interbedded with clastics and dolomite | Limestone | dolomite | Chazy | |
| 1050 | 1104 | sandstone, mostly | sandstone | | Chazy and/or Beekmantown | base of Chazy estimated in report between 1050' and 1126' |
| 1104 | 1126 | sandstone, mostly | sandstone | | Chazy and/or Beekmantown | top of Beekmantown picked at 1126' (Quebec Nat. Gas Co. Mgr) |
| 1126 | 2806 | carbonate-magnesium sequence with interbedded clastics | carbonate-magnesium sequence with interbedded clastics | sandstone and calcarenite | Beekmantown | base of Beekmantown picked from Schlumberger Electric log |
| 2806 | 2950 | carbonate-magnesium sequence with interbedded clastics | carbonate-magnesium sequence with interbedded clastics | sandstone and calcarenite | Beekmantown and/or Potsdam | base of Beekmantown based on sample study |
| 2950 | 3500 | clastic sediment with siliceous sandstone, fine to coarse grained, brown to gray, angular to sub-rounded, loosely consolidated to well cemented | sandstone | calcarenite and dolomite | Potsdam | 2976-3070 contains black sticky masses of asphaltic material |

Town:Fairfield, County: Franklin, State: VT, Operator: Columbia Gas Transmission Company, Well Name: Burnor #1, Year: 1984, Well plugged and abandoned

| Depth(FT)Start | Depth(FT)End | Description | RockTypeA | RockTypeB | CommentInLog | Formation | Remark_2011_VGS |
|---|---|---|---|---|---|---|---|
| 0 | 110 | Null | | | | | |
| 110 | 190 | Phyllite (greenschist) with quartz veins, green gray, moderately hard, poorly sorted, fine grained, cleavage bands prominent; quartz, chlorite, muscovite, magnetite, albite, pyrite, carbonate | Phyllite | | | Fairfield Pond Fm | Fairfield Pond Fm: lower Cambrian, pale green to light gray, quartz-sericite-chlorite phyllite+/- magnetite. Commonly the logger refers to coarse and fine to describe the cutting itself, not the texture of the rock |
| 190 | 260 | as above with euhedral chlorite in quartz veins | Phyllite | | | | |
| 260 | 310 | as above with trace feldspathic-quartz siltstone | Phyllite | | | | |
| 320 | 330 | as above with abundant magnetite and druzy pyrite | Phyllite | | | | |
| 330 | 340 | as above with abundant globular and crystalline chlorite | Phyllite | | | | |
| 340 | 350 | as above, cuttings-platy-phyllite, angular quartz | Phyllite | | | | |
| 350 | 360 | as above, water flow into hole | Phyllite | | went to drilling on foam | | |
| 360 | 400 | as above, cuttings much larger, foliation more prominent | Phyllite | | | | |
| 400 | 440 | as above, phyllite matrix, well sorted fine grained, banded | Phyllite | | | | |
| 440 | 450 | as above, fracture fill 10% quartz, minor carbonate | Phyllite | | | | |
| 450 | 490 | as above, 10%-20% very fine grained graywacke; quartz-chlorite-sericite-albite | Phyllite | Graywacke | | | |
| 490 | 500 | as above, increasing vein quartz with abundant chlorite | Phyllite | Graywacke | | | |
| 500 | 540 | as above, 10% graywacke | Phyllite | Graywacke | | | |
| 540 | 550 | as above, increasing to 40% graywacke, fine grained quartz-sericite-schist, slightly calcareous, abundant chlorite, minor feldspathic metasandstone | Phyllite | Graywacke | | | |
| 550 | 560 | as above with 10-20% phyllite | Graywacke | Phyllite | | | near contact with Pinnacle |
| 560 | 570 | as above, quartz-chlorite-magnetite-albite | Graywacke | Phyllite | | | |
| 570 | 580 | as above, interbedded phyllite and meta-feldspathic sandstone | Graywacke | Phyllite | | | |
| 580 | 590 | as above, very abundant quartz, chlorite and magnetite in matrix | Graywacke | Phyllite | | | |
| 590 | 600 | as above | Graywacke | Phyllite | | Pinnacle Fm | Pinnacle Fm: Proterozoic to Cambrian quartz pebble conglomerates, graywackees and schists with interbedded feldspathic, amphibolitic and calcareous meta-volcanic rocks |
| 600 | 610 | meta-feldspathic sandstone, quartz-chlorite-magnetite-albite | Meta-feldspathic sandstone | Phyllite | | Pinnacle Fm | |
| 610 | 620 | quartz vein 40-50% of sample | Meta-feldspathic sandstone | Quartz vein | | | |
| 620 | 640 | meta-feldspathic sandstone, 20% vein quartz | Wackestone | Feldspathic sandstone | doubled drilling rate from 20 to 40 minutes per foot | | |
| 640 | 650 | as above, slickensides | Wackestone | Feldspathic sandstone | | | slickensides |
| 650 | 660 | as above, slickensides | Wackestone | | | | slickensides |
| 660 | 670 | meta-feldspathic sandstone, wackestone with interbedded phyllite (10%-20%), 10%-20% quartz vein | Meta-feldspathic sandstone | | | | |
| 670 | 680 | Hornblende, muscovite, chlorite, quartz schist with tourmaline, calcite, pyrite accesoory mins, greenschist | Hornblende schist | | | | |
| 680 | 870 | as above | Hornblende schist | | | | |
| 870 | 910 | chlorite, muscovite, quartz schist, generally fine grained with occassional large angular quartz, greenschist, some micaceous concentrations | Schist | | | | |
| 910 | 960 | as above, slight increase in grain size | Schist | | | | |
| 960 | 1010 | as above, slight increase in amount of quartz and decrease in degree of schistosity | Schist | | | | |
| 1010 | 1050 | chlorite-muscovite-quartz schist/greenschist, red to purple transluscent garnet, fine to medium grained | Schist | | | | |
| 1050 | 1080 | as above, trace pyrite | Schist | | | | |
| 1080 | 1150 | garnet-chlorite-quartz-muscovite schist, abundant anhedral garnet, less quartz | Schist | | | | |
| 1150 | 1200 | garnet-quartz-chlorite-muscovite schist, increase of quartz to 60%, | Schist | | | | |
| 1200 | 1220 | garnet, quartz, muscovite, chlorite schist, fine to medium grained, possible pink feldspar, cuttings hard to brittle | Schist | | | | |
| 1220 | 1250 | as above with decreasing schistosity | Schist | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1250 | 1270 | feldspar, garnet, quartz, chlorite, muscovite gneiss (semi phyllite), fine grained with coarse quartz clean to milky | Schist | | | | |
| 1270 | 1290 | as above, quartz 30% | Schist | | | | |
| 1290 | 1310 | chlorite-quartz-muscovite-quartz gneiss (semi schist), very fine grained, some angular shards of milky quartz, chlorite 10%-15% | Gneiss | | | | |
| 1310 | 1330 | as above, abundant quartz, abundant vitreous metallic graphitic soft dark gray material | Gneiss | | | | |
| 1330 | 1340 | as above, quartz becoming clear to opague, increasing % | Gneiss | | | | |
| 1340 | 1360 | metaquartzite, very coarse clear to opague angular interlocking grains 60%, 20% dark gray graphitic soft mineral, 10% red earthy mineral | Metaquartzite | | | | |
| 1360 | 1390 | metaquartzite, milky to transluscent, fine to coarse, unconsolidated to interlocking aggregates, 70% quartz, 30% other mins | Metaquartzite | | | | |
| 1390 | 1440 | metaquartzite, hard, coarse grained, sub rounded to angular, high comcentration of magnetite, iron stained quartz, graphitic inclusions, 10%-20% phyllite | Metaquartzite | Phyllite | | | |
| 1440 | 1450 | as above, quartz grains with inclusions of rutile, pyrite, magnetite | Metaquartzite | | | | |
| 1450 | 1460 | as above, quartz grains sub-rounded to angular | Metaquartzite | | | | |
| 1460 | 1480 | as above, metaquartzite | Metaquartzite | | | | |
| 1480 | 1490 | as above, cuttings are green to greenish gray | Metaquartzite | | | | |
| 1490 | 1500 | as above, quartzite 80%, some green phyllite, trace garnet | Metaquartzite | | | | |
| 1500 | 1510 | as above, quartzite with 20-25% fracture or vein fill quartz | Metaquartzite | | | | |
| 1510 | 1520 | graphitic metaquartzite, 10-15% graphite | Metaquartzite | | | | |
| 1520 | 1540 | metaquartzite, some reddish grains | Metaquartzite | | | | |
| 1540 | 1560 | metaquartzite/gneiss plus chlorite, magnetite, graphite | Metaquartzite | Gneiss | | | |
| 1560 | 1600 | metaquartzite (80%) and green phyllite (40%) | Metaquartzite | Phyllite | | | |
| 1600 | 1610 | as above with trace garnet | Metaquartzite | | | | |
| 1610 | 1640 | as above | Metaquartzite | | | | |
| 1640 | 1650 | as above with trace pyrite | Metaquartzite | | | | |
| 1650 | 1660 | as above | Metaquartzite | | | | |
| 1660 | 1670 | as above, gneiss - quartz schist, increase muscovite | Metaquartzite | Gneiss | | | |
| 1670 | 1690 | schist to phyllite, increase mica to 50% plus albite, chlorite, quartz | Schist | Phyllite | | | |
| 1690 | 1700 | as above, schist, phyllite, increase albite to 20% | Schist | Phyllite | | | |
| 1700 | 1770 | greenschist, quartz, albite, chlorite, muscovite, magnetite | Chlorite schist | | | | |
| 1770 | 1790 | as above, albite 20%, quartz increase, chlorite, rutile and/or tourmaline inclusions | Chlorite schist | | | | |
| 1790 | 1810 | as above with 10-20% clear to milky quartz, fracture and vein filling | Chlorite schist | | | | |
| 1810 | 1820 | as above, no more vein quartz | Chlorite schist | | | | |
| 1820 | 1830 | as above,very fine grained | Chlorite schist | | | | |
| 1830 | 1850 | as above | Chlorite schist | | | | |
| 1850 | 1880 | quartz-chlorite-albite-magnetite-graphitic schist/greenschist with slickensides | Chlorite schist | | slickensides | | |
| 1880 | 1892 | as above with chlorite-magnetite-graphite inclusions in quartz | Chlorite schist | | | | |
| 1892 | 1908 | as above, slickensides and gouge, graphitic slickensides | Chlorite schist | | slickensides | | |
| 1908 | 1930 | quartzite, light green to white, minor schistosity, slickensides, slightly calcareous | Quartzite | | slickensides | | |
| 1930 | 1950 | as above, well sorted, medium grained | Quartzite | | | | |
| 1950 | 1970 | schist, quartz, graphite, chlorite, magnetite, light green foliated, 10-15% magnetite, 5-10% albite, quartz vein fill | Schist | | | | |
| 1970 | 1990 | as above | Schist | | | | |
| 1990 | 2000 | as above, schist to phyllite, dark green chlorite, quartz vein fill | Schist | | | | |
| 2000 | 2010 | dark green foliated schist | Schist | | | | |
| 2010 | 2050 | quartzite with interbedded chlorite schist and phyllite | Quartzite | Chlorite schist | | | |
| 2050 | 2100 | quartzite with interbedded chlorite schist and phyllite, trace of cross-bedding, some frosted quartz grains subangular to rounded | Quartzite | Chlorite schist | | | |
| 2100 | 2150 | quartzite and chlorite-muscovite phyllite | Quartzite | Phyllite | | | |
| 2150 | 2180 | quartzite as above, medium- coarse grains, 20-25% magnetite-graphite-chlorite, slightly calcareous siltstone, 10% phyllite | Quartzite | Phyllite | possible thrust ? | | |
| 2180 | 2200 | as above, 20-25% quartz vein fill, trace amethyst, minor slickensides | Quartzite | | | | slickensides |
| 2200 | 2210 | quartz vein material | Quartz vein | | | | |
| 2210 | 2230 | quartzite, 85-90% quartz, transluscent to frosted, sub rounded, minor chlorite,albite, andmagnetite | Quartzite | | color change, no slickensides | | |
| 2230 | 2240 | as above, minor graphite | Quartzite | | | | |
| 2240 | 2260 | as above, porly sorted grains, quartz, hematite, graphite, minor chlorite, albite, slight schistosity, trace calcareous | Quartzite | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2260 | 2270 | as above, dirty, pinkish greenish tan gray | Quartzite | | color change due to presence of albite and no magnetite, no iron stain | | |
| 2270 | 2280 | as above, 20-25% hematite stain | Quartzite | | | | |
| 2280 | 2290 | as above | Quartzite | | | | |
| 2300 | 2320 | as above | Quartzite | | | | |
| 2320 | 2330 | as above, cleaner | Quartzite | | | | |
| 2330 | 2350 | as above | Quartzite | | | | |
| 2350 | 2360 | as above quartzite, dirty increasing iron stain, increasing magnetite graphitic and albite accessories | Quartzite | | quartzite has undergone recrystallization with overgrowths and foliation | | |
| 2290 | 2300 | as above 80-85% quartz, transluscent- yellow-milky white | Quartzite | | | | |
| 2360 | 2390 | as above quartzite with pink albite, green chlorite and black magnetite, iron stained (yellowish) quartz, sub angular to sub rounded frosted grains, recrystallized grains | Quartzite | | | | |
| 2390 | 2400 | as above | Quartzite | | trace slickendsides with graphitic gouge | | |
| 2400 | 2420 | as above | Quartzite | | | | |
| 2420 | 2430 | as above cuttings beach sand grain size sub angular to sub rounded | Quartzite | | | | |
| 2430 | 2440 | as above | Quartzite | | | | |
| 2440 | 2450 | as above cutting size coarse, blocky-angular | Quartzite | | | | |
| 2450 | 2500 | as above quartzite with blue metallic magnetite, slight schistosity | Quartzite | | | | |
| 2500 | 2590 | as above quartzite, 10-15% light green phyllitic schist | Quartzite | Phyllite | | | |
| 2590 | 2610 | as above quartzite 60%, light green phyllitic schist 40%, garnet accessory | Quartzite | Phyllite | | | |
| 2610 | 2630 | as above quartzite, 5-10% quartz vein material | Quartzite | | | | |
| 2630 | 2640 | as above slight schistosity | Quartzite | | | | |
| 2640 | 2660 | quartzite as above, tr garnet, increasing albite, quartz, magnetite and chlorite | Quartzite | | | | |
| 2660 | 2720 | quartzite, clear to clear opague, some greenish tint, some yellow tint, some graphite | Quartzite | | | | |
| 2720 | 2740 | quartzite, general increase in chloritic nature, abundant fine to medium grained semi-schist to gneissose fragments- muscovite, chlorite,quartz, 10% graphite, tr calcite | Quartzite | | | | |
| 2740 | 2760 | phyllite- quartz, chlorite, muscovite phyllite, quartzite 30% to 60% of sample | Phyllite | quartzite | | | |
| 2760 | 2830 | quartzite, clear to milky grains, matrix of chlorite, muscovite and quartz with minor graphite | Quartzite | | | | |
| 2830 | 2850 | phyllite 60%, quartz-muscovite-chlorite, quartzite 40% | Phyllite | quartzite | | | |
| 2850 | 3080 | phyllite- quartz, chlorite, muscovite phyllite with occasional milky to clear quartz, occassional calcite | Phyllite | | | | |
| 3080 | 3100 | phyllite- quartz, chlorite, muscovite phyllite, vitreous green to silver luster, abundant free calcite | Phyllite | | | | |
| 3100 | 3450 | phyllite- quartz (50%-80%), chlorite, muscovite phyllite with occasional milky to clear quartz, occassional calcite | Phyllite | | | | |
| 3450 | 3510 | phyllite- quartz (20%-30%), chlorite, muscovite phyllite | Phyllite | | | | |
| 3510 | 3520 | phyllite- quartz (70%), chlorite, muscovite phyllite | Phyllite | | | | |
| 3520 | 3530 | phyllite- quartz (50% - 60%), chlorite, muscovite phyllite | Phyllite | | | | |
| 3530 | 3540 | phyllite- quartz (80%), chlorite, muscovite phyllite | Phyllite | | | | |
| 3540 | 3550 | phyllite- quartz (60%), chlorite, muscovite phyllite | Phyllite | | | | |
| 3550 | 3560 | phyllite- quartz (50%), chlorite, muscovite phyllite | Phyllite | | | | |
| 3560 | 3570 | phyllite- quartz (40%), chlorite, muscovite phyllite | Phyllite | | | | |
| 3570 | 3590 | phyllite- quartz (20% - 30%), chlorite, muscovite phyllite | Phyllite | | | | |
| 3590 | 3640 | phyllite- quartz , chlorite, muscovite phyllite | Phyllite | | | | |
| 3640 | 3680 | phyllite- quartz , chlorite, muscovite phyllite, gradual increase in grain size | Phyllite | | gradual change from phyllite to schist | | |
| 3680 | 3730 | schist- muscovite, chlorite schist with dark accessory minerals, occassional yellow tint | Schist | | | | |
| 3730 | 3740 | schist- muscovite, chlorite schist | Schist | | cuttings are magnetic | | |
| 3740 | 3770 | schist- gray green muscovite, chlorite schist, yellow mineral (epidote increases to 20% | Schist | | | | |
| 3770 | 3790 | schist- muscovite, chlorite schist | Schist | | | | |
| 3790 | 3800 | schist- musc chlorite scist, yellow mineral decreases to 10%as above | Schist | | | | |
| 3800 | 3820 | schist- green, gray green, occ purple tint, generally speckled fragments, inc muscovite gives inc foliation (green from chlorite-serpentine?)as above | Schist | | yellow green mineral is epidote | | |
| 3820 | 3840 | schist- greenschist, sample contains identifiable rods of serpentine, yellow green mineral in aggregates | Greenschist | | yellow green mineral is epidote | | questionable occurrence of serpentine |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3840 | 3860 | schist- greenschist | Greenschist | | | | questionable occurrence of serpentine; likely amphibole |
| 3860 | 3890 | schist- various mineral crystals in random distribution, soft fibrous (serpentine), yellow fine xtl aggregates, occassional dark purple xtls, milky quartzas above | Greenschist | | cuttings continued magnetic | | |
| 3890 | 3900 | schist- quartz, garnet (?), serpentine schist | Greenschist | | | | likely Pinnacle volcanic amphibolitic member |
| 3900 | 3930 | schist - greenschist as above, dark green to gray green chlorite-muscovite-quartz schist, tr pyrite, tr magnetite, yellow-green bands throughout (epidote), calcite vein fill | Greenschist | | | | |
| 3930 | 3940 | schist- greenschist as above, trace serpentine (elongated fibers) | Greenschist | | | | likely amphibolite |
| 3940 | 3950 | as above, trace slickensides | Greenschist | | | | slickensides |
| 3950 | 3960 | as above, 20% quartz vein fill, minor epidote-quartz aggregates | Greenschist | | | | |
| 3960 | 3978 | as above, traceserpentine -epidote | Greenschist | | | | questionable occurrence of serpentine |
| 3978 | 3986 | greenschist - medium-dark green, soft to hard depending on quartz content, quartz-muscovite (sericite)-chlorite-magnetite, minor grpahite andpyrite, quartz vein fill | Greenschist | | cuttings magnetic | | |
| 3986 | 4020 | schist - more phyllitic, increasing muscovite, minor quartz silts with calcareous cement | Phyllitic greenschist | | cuttings magnetic | | |
| 4020 | 4034 | as above, trace pyrite-epidote, abundant chlorite, trace black tourmaline | Phyllitic greenschist | | | | |
| 4034 | 4040 | as above, trace serpentine, 20% slickensides | Phyllitic greenschist | | possible fault due to increasing slickensides | | |
| 4040 | 4050 | as above, phyllitic greenschist | Phyllitic greenschist | | | | |
| 4050 | 4070 | schist -quartzose, decreasing chlorite | Schist | | | | |
| 4070 | 4096 | schist - graphitic and quartzose, 10% slickensides, calcareous matrix and vein fill, minor chlorite-muscovite phyllite | Schist | Phyllite | change - sharp decrease in chlorite | | slickensides |
| 4096 | 4100 | graphitic quartzite | Quartzite | | | | |
| 4100 | 4130 | graphitic phyllitic quartzite and gray phyllite, trace slickensides | Phyllitic quartzite | | | | slickensides |
| 4130 | 4160 | quartzite | Quartzite | | | | |
| 4160 | 4180 | limy quartzitic schist: greenish gray, possible pseudomorphs of calcite and dolomite, very calcareous | Calcareous schist | | possible thin beds of limestone more like dolomite | | calcareous volcanic member of the Pinnacle? |
| 4180 | 4200 | limy light green schist, chlorite-quartz-mica-calcite | Calcareous schist | | | | calcareous volcanic member of the Pinnacle? |
| 4200 | 4222 | quartzite -schistose, coarse to med grained with trace of calcite, magnetite, pyrite, graphitic slickensides | Quartzite | | | | |
| 4222 | 4230 | schist with minor quartzite, 80% greenschist with slickensides | Schist | Quartzite | | | slickensides |
| 4230 | 4240 | phyllitic schist as above, 15% calcite vein fill | Schist | | | | |
| 4240 | 4260 | as above schist 80%, quartzite 20% | Schist | Quartzite | | | |
| 4260 | 4270 | as above quartzite 60%, schist 40% | Quartzite | Schist | | | |
| 4270 | 4280 | massive quartzite - minor chlorite and tr calcite vein fill | Quartzite | | | | |
| 4280 | 4330 | quartzite | Quartzite | | | | |
| 4330 | 4340 | as above quartzite, 20-30% greenschist | Quartzite | Greenschist | | | |
| 4340 | 4370 | greenschist - dark green to greenish gray, well foliated, quartz, chlorite, magnetite, banded | Greenschist | | change | | |
| 4370 | 4380 | as above, trace maroon fine grained quartz silt, 10-20% slickensides | Greenschist | | | | slickensides |
| 4380 | 4400 | as above greenschist- phyllitic, 20-25% slickensides, quartz (chert) and calcite veining | Greenschist | | possible fault, possible fault gouge | | slickensides |
| 4400 | 4410 | quartzite 50%, grayish greenschist 50% | Quartzite | Greenschist | change | | |
| 4410 | 4430 | quartzite, silica and calcite matrix, graphitic, magnetite | Quartzite | | | | |
| 4430 | 4440 | quartzite as above, tr pyrite, tr phyllite, tr slickensides | Quartzite | | | | slickensides |
| 4440 | 4450 | as above quartzite | Quartzite | | | | |
| 4450 | 4460 | schist (greenschist) 70%, quartzite 30% | Greenschist | Quartzite | change | | |
| 4460 | 4470 | schist and quartzite, calcareous matrix and calcite vein fill | Schist | | | | |
| 4470 | 4480 | as above, quartzose greenschist, tr epidote- aggregates | Schist | | | | |
| 4480 | 4490 | as above, schist (greenschist) quartz, sericite, chlorite, magnetite, tr ab and epidote | Schist | | | | |
| 4490 | 4500 | as above, schist - quartzose with veins and massive chert-bedding(?), banded with graphite and magnetite | Schist | | | | |
| 4500 | 4510 | as above, schist - quartzose with tr crystalline dolomite | Schist | | | | |
| 4510 | 4520 | as above, schist (greenschist) quartz, sericite, chlorite, magnetite, ab and tr epidote, quartz vein with serpentine | Schist | | | | |
| 4520 | 4530 | as above, schist - quartzose with 2% epidote | Schist | | | | |
| 4530 | 4540 | as above, quartzose schist, trace garnet | Schist | | | | |
| 4540 | 4550 | as above, quartzose schist, trace pyrite | Schist | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4550 | 4560 | as above, quartzose schist | Schist | | | | |
| 4560 | 4580 | as above, quartzose schist, dark green, decreasing quartz, 2% epidote | Schist | | | | |
| 4580 | 4620 | schist - dark green gray chlorite-muscovite-magnetite-albite | Schist | | change, magnetic | | |
| 4620 | 4650 | schist as above 50% of sample, 50% quartz vein, 20% epidote, slickensides | Schist | | change, large increase in epidote | | |
| 4650 | 4680 | schist as above, quartz-epidote vein fill | Schist | | | | |
| 4680 | 4690 | phyllitic schist, dark gray, non-calcareous, fissile | Phyllitic schist | | change, cleavage/bedding intersection 25-30 degrees | | |
| 4690 | 4730 | phyllite- dark greenish gray phyllite, sericite, magnetite, graphite, chlorite with minor quartz | Phyllite | | change | | |
| 4730 | 4820 | phyllitic schist, dark grayish green, chlorite, quartz, sericite, some calcite and quartz vein material | Phyllitic schist | | | | |
| 4820 | 4900 | schist- calcite, quartz,epidote, chlorite, muscovite schist, green to gray green | Schist | | | | |
| 4900 | 4910 | schist - calcite, quartz,epidote, chlorite, muscovite schist, green to gray green, slickensides | Schist | | | | |
| 4910 | 5120 | schist- calcite, quartz,epidote, chlorite, muscovite schist, green to gray green | Schist | | | | |
| 5120 | 5180 | schist- calcite, quartz,epidote, chlorite, muscovite schist, green to gray green, free quartz increases to 30% | Schist | | | | |
| 5180 | 5270 | metaquartzite, conchoidal fractures,abundant free chlorite and magnetite | Metaquartzite | | | | |
| 5270 | 5280 | schist, metaquartzite, decrease amount of quartz and magnetite, increase chlorite | Schist | Metaquartzite | | | |
| 5280 | 5290 | schist, gray green chlorite, quartz, muscovite, epidote, some magnetite | Schist | | | | |
| 5290 | 5420 | schist, gray green epidote, quartz, chlorite, muscovite, | Schist | | | | |
| 5420 | 5430 | schist, gray green epidote, quartz, chlorite, muscovite, abundant calcite | Schist | | | | |
| 5430 | 5460 | schist, gray green epidote, quartz, chlorite, muscovite, | Schist | | | | |
| 5460 | 5480 | schist, epidote, quartz, chlorite, muscovite schist, calcite 20% | Schist | | | | |
| 5480 | 5490 | schist, epidote, quartz, chlorite, muscovite schist, calcite 10% | Schist | | | | |
| 5490 | 5500 | schist, epidote, quartz, chlorite, muscovite schist, calcite 5% | Schist | | | | |
| 5500 | 5520 | schist, epidote, quartz, chlorite, muscovite schist | Schist | | | | |
| 5520 | 5530 | schist, epidote, quartz, chlorite, muscovite schist, abundant calcite | Schist | | | | |
| 5530 | 5600 | schist, epidote, quartz, chlorite, muscovite schist | Schist | | | | |
| 5600 | 5640 | schist, epidote, quartz, chlorite, muscovite schist, abundant calcite | Schist | | | | |
| 5640 | 5780 | schist, epidote, quartz, chlorite, muscovite schist | Schist | | | | |
| 5780 | 5800 | schist, epidote, quartz, chlorite, muscovite schist, quartz increase to 60 -70% | Schist | | | | |
| 5800 | 5850 | schist, epidote, quartz, chlorite, muscovite schist | Schist | | | | |
| 5850 | 5860 | schist, epidote, quartz, chlorite, muscovite schist, calcite <10% | Schist | | | | |
| 5860 | 5990 | schist, gray green epidote, quartz, chlorite, muscovite schist | Schist | | | | |
| 5990 | 6000 | schist, gray green epidote, quartz, chlorite, muscovite schist becoming phyllitic | Schist | | gradual change from schist to phyllite | | |
| 6000 | 6020 | phyllite, chlorite-quartz-muscovite phyllite, green gray, silky luster, hard | Phyllite | | | | mainly describing interlayered gray graphitic phyllites and green schists |
| 6020 | 6040 | phyllite, dark gray, chlorite-quartz-muscovite phyllite with graphitic inclusions | Phyllite | | | | |
| 6040 | 6050 | phyllite, chlorite-quartz-muscovite phyllite, quartz inc to 30% | Phyllite | | | | |
| 6050 | 6070 | phyllite, chlorite-graphite, muscovite, quartz phyllite, green to green gray, green fibrous serpentine, 40% quartz | Phyllite | | | | |
| 6070 | 6100 | schist, green gray, graphite, chlorite, epidote, muscovite, quartz | Schist | | | | |
| 6100 | 6130 | schist, chlorite, epidote, muscovite, quartz | Schist | | | | |
| 6130 | 6150 | schist, green gray, graphite, chlorite, epidote, muscovite, quartz | Schist | | | | |
| 6150 | 6170 | dark green graphitic schist, chlorite-quartz-graphite-muscovite-trace epidote, pyrite, 5% graphitic phyllite | Schist | Graphitic phyllite | | | |
| 6170 | 6180 | as above greenschist with minor slickensides with graphitic faces | Greenschist | | | | slickensides |
| 6180 | 6190 | as above, greenschist with increasing quartz, trace calcite | Greenschist | | | | |
| 6190 | 6210 | as above, greenschist and graphitic phyllite | Greenschist | Graphitic phyllite | | | |
| 6210 | 6240 | as above, greenschist and phyllite, trace pink garnet, 5-10% quartz siltstone | Greenschist | | | | |
| 6240 | 6250 | as above, greenschist | Greenschist | | | | |
| 6250 | 6260 | as above, greenschist, phyllite 30%, 5-10% vein quartz and calcite | Greenschist | Phyllite | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 6260 | 6270 | as above, greenschist, more graphitic, 20-25% calcite with chert and quartz vein fill, 20-30% quartz siltstone chloritic to hematitic | Greenschist | Siltstone | change | | |
| 6270 | 6290 | as above, greenschist | Greenschist | | | | |
| 6290 | 6300 | as above, greenschist, very fine grained quartz siltstone, chloritic, graphitic | Greenschist | Siltstone | | | |
| 6300 | 6310 | as above, greenschist, more schistose, graphitic, 10-20% vein quartz and calcite | Greenschist | | | | |
| 6310 | 6340 | as above, greenschist and quartz siltstone with graphitic matrix | Greenschist | | | | |
| 6340 | 6350 | as above, greenschist, trace epidote, graphitic schist, 10% quartz and cal vein fill | Greenschist | | | | |
| 6350 | 6360 | as above, greenschist, trace pink garnet, slickensides, iron staining | Greenschist | | | | |
| 6360 | 6370 | as above, greenschist quartzose graphitic, 5-10% phyllitic chlorite muscovite | Greenschist | | | | |
| 6370 | 6380 | as above, greenschist increasing pure chlorite | Greenschist | | | | |
| 6380 | 6400 | as above, greenschist, 20-25% calcite vein fill | Greenschist | | | | |
| 6400 | 6410 | as above, greenschist, quartzose, graphitic | Greenschist | | | | |
| 6410 | 6420 | as above, greenschist, calcite/quartz/chert vein material, quartz crystalline growth outward indicates possible open fractures | Greenschist | | quartz crystalline growth outward indicates possible open fracs | | |
| 6420 | 6450 | as above, greenchist quartzose abundant chlorite inclusions | Greenschist | | | | |
| 6450 | 6460 | as above, greenschist -5% slickensides 6430'-6450' with graphitic or Fe oxidized faces | Greenschist | | | | slickensides |
| 6460 | 6500 | as above, greenschist | Greenschist | | microfractures in quartz/chert vein are calcite filled | | |
| 6500 | 6510 | as above greenschist, trace epidote, microfractures are calcite filled | Greenschist | | | | |
| 6510 | 6570 | as above, greenschist | Greenschist | | | | |
| 6570 | 6600 | as above, greenschist, phyllites are silver gray to black, highly graphitic | Greenschist | | | | |
| 6600 | 6640 | as above, greenschist | Greenschist | | | | |
| 6640 | 6670 | greenschist decreasing, 40% graphitic phyllite | Greenschist | Phyllite | phyllite beds | | |
| 6670 | 6710 | greenschist with 30% quartz siltstone graphitic | Greenschist | Siltstone | fine grained graphitic quartz siltstones | | |
| 6710 | 6740 | greenschist- greenish gray abundant chlorite, quartz, muscovite, graphite, 10-20% phyllite, trace siltstone | Greenschist | Phyllite | | | |
| 6740 | 6750 | greenschist as above, quartz siltstone inc to 20-30% | Greenschist | Siltstone | increasing fine grained quartz siltstone | | |
| 6750 | 6830 | as above, greenschist with quartz siltstone | Greenschist | Siltstone | | | |
| 6830 | 6840 | greenschist with epidote vein | Greenschist | | decreasing siltstone | | |
| 6840 | 6910 | greenschist | Greenschist | | | | |
| 6910 | 6968 | greenschist, green gray, abundant chlorite, quartz, muscovite,trace graphite, trace epidote, assoc with quartz and calcite veins; 10-15% phyllite, silver gray slightly graphitic dominantly muscovite with trace chlorite | Greenschist | Phyllite | | | |
| 6970 | 6970 | Total Depth LTD (logging tool recorded depth); 6968 DTD (driller recorded depth) | | | | | |

Town: Colchester, County: Chittenden, State: VT, Operator: VT Gas and mineral Corp., Well name: Gregoire #1, Year: 1959-1960

| Depth(FT)START | Depth(FT)END | Description | RockTypeA | RockTypeB | Formation | Comment |
|---|---|---|---|---|---|---|
| 180 | 184 | Dolostone, light gray, white, light pink; scattered black dolomitic chips (cavings) less than 5% | Dolostone | | Dunham Dolomite | |
| 184 | 188 | as above as above, minor sandy textures | Dolostone | | | |
| 188 | 192 | as above | Dolostone | | | |
| 192 | 197 | as above | Dolostone | | | |
| 197 | 202 | as above | Dolostone | | | |
| 202 | 227 | Sample gap | Null | | | |
| 227 | 228 | Dolostone, buff to pink, more crystalline than above | Dolostone | | | |
| 228 | 230 | Dolostone as above, 30% black and qray chips | Dolostone | | | |
| 230 | 238 | as above | Dolostone | | | |
| 238 | 246 | as above | Dolostone | | | |
| 246 | 248 | as above, becoming redder | Dolostone | | | |
| 248 | 250 | Dolostone, red to pink, sugary | Dolostone | | | |
| 250 | 254 | as above | Dolostone | | | |
| 254 | 258 | Dolostone, buff to pink, as above | Dolostone | | | |
| 258 | 262 | as above | Dolostone | | | |
| 262 | 268 | as above, with white dolostone also | Dolostone | | | |
| 268 | 271 | as above | Dolostone | | | |
| 271 | 275 | Dolostone, light gray to pink | Dolostone | | | |
| 275 | 283 | Dolostone, light gray | Dolostone | | | |
| 283 | 290 | Dolostone, light pink, 20% gray as above | Dolostone | | | |
| 290 | 297 | Dolostone, white and pink banded bedding, crystalline | Dolostone | | | |
| 297 | 302 | as above | Dolostone | | | |
| 302 | 305 | as above | Dolostone | | | |
| 305 | 308 | as above | Dolostone | | | |
| 308 | 313 | Dolostone as above, 20% siltstone, trace conglomerate (breccia) (dolostone pebbles, shale matrix) | Dolostone | | | |
| 313 | 318 | as above | Dolostone | | | |
| 318 | 329 | Limestone, white, thin-bedded, with black shale partings, disturbed | Limestone | | Stony Point/Iberville Fm. | Champlain Thrust. Stony Point shale and Iberville shale are both calcareous in this area in Vermont. |
| 329 | 344 | Shale, black, calcareous, 30% limestone as above | Shale | Limestone | | |
| 344 | 368 | as above, trace slickensides | Shale | Limestone | | slickensides |
| 368 | 386 | as above, no slickensides | Shale | Limestone | | |
| 386 | 406 | as above | Shale | Limestone | | |
| 406 | 411 | as above, white limestone content decreasing | Shale | Limestone | | |
| 411 | 431 | Shale as above, white calcite veinlets as fracture fill, occasional shale fragments in white calcite | Shale | | | |
| 431 | 438 | as above, trace slickensides | Shale | | | slickensides |
| 438 | 445 | as above, trace slickensides | Shale | | | slickensides |
| 445 | 452 | as above | Shale | | | |
| 452 | 459 | as above | Shale | | | |
| 459 | 478 | as above, trace slickensides, white calcite veinlets increasing | Shale | | | slickensides |
| 478 | 498 | as above | Shale | | | |
| 498 | 523 | as above, trace slickensides | Shale | | | slickensides |
| 523 | 543 | as above, trace slickensides | Shale | | | slickensides |
| 543 | 553 | as above, white calcite decreasing | Shale | | | |
| 553 | 566 | as above, white calcite decreasing | Shale | | | |
| 566 | 593 | as above, white calcite decreasing | Shale | | | |
| 593 | 615 | as above | Shale | | | |
| 615 | 629 | Shale, black, silty, slightly dolomitic (loss of shale carbonate content) | Shale | | | |
| 629 | 643 | as above | Shale | | | |
| 643 | 658 | as above | Shale | | | |
| 658 | 660 | Sample gap | Null | | | |
| 660 | 698 | Shale, black, calcareous, about 20% white calcite vein fill | Shale | | | |
| 698 | 740 | as above | Shale | | | |
| 740 | 840 | as above | Shale | | | |
| 840 | 934 | as above | Shale | | | |
| 934 | 944 | Sample gap | Null | | | |
| 944 | 948 | Shale as above, slightly calcareous, becoming fissile | Shale | | | |
| 948 | 950 | as above, 20% white calcite veinlets, 10% quartz grains, clear (rounded to angular) | Shale | | | |
| 950 | 955 | as above, some appears silty, some calcite is fibrous, white calcite content decreasing | Shale | | | |
| 955 | 962 | as above | Shale | | | |
| 962 | 968 | as above, loss of clear quartz grains | Shale | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 968 | 974 | as above, 5% white calcite, trace shale, gray, soft | Shale | | | |
| 974 | 982 | as above | Shale | | | |
| 982 | 995 | as above | Shale | | | |
| 995 | 1002 | as above | Shale | | | |
| 1002 | 1020 | 2 Sample bags missing | Null | | | |
| 1020 | 1033 | Shale, black, slightly calcareous, 5% white calcite vein fill | Shale | | | |
| 1033 | 1041 | Sample gap | Null | | | |
| 1041 | 1049 | Shale, very dark gray to black, carbonate content variable, trace quartz, clear grains, iron stained | Shale | | | |
| 1049 | 1059 | as above | Shale | | | |
| 1059 | 1068 | as above | Shale | | | |
| 1068 | 1088 | Sample gap | Null | | | |
| 1088 | 1098 | Shale as above, softer, decrease in calcite content of shale, fissile | Shale | | | |
| 1098 | 1110 | Sample gap | Null | | | |
| 1110 | 1125 | as above | Shale | | | |
| 1125 | 1135 | as above, increase in white calcite veinlets | Shale | | | |
| 1135 | 1145 | as above | Shale | | | |
| 1145 | 1187 | as above, trace slickensides | Shale | | | slickensides |
| 1187 | 1199 | as above | Shale | | | |
| 1199 | 1224 | as above, white calcite decreasing | Shale | | | |
| 1224 | 1239 | as above, 5% white calcite | Shale | | | |
| 1239 | 1250 | Shale, black,moderately fissile, trace white calcite, variable carbonate content in shale | Shale | | | |
| 1250 | 1261 | as above | Shale | | | |
| 1261 | 1276 | as above | Shale | | | |
| 1276 | 1290 | as above, 10% white calcite | Shale | | | |
| 1290 | 1310 | as above, some shale, dark gray | Shale | | | |
| 1310 | 1333 | as above, all shale, black | Shale | | | |
| 1333 | 1343 | as above | Shale | | | |
| 1343 | 1353 | Shale, dark gray, moderately fissile, slightly calcareous | Shale | | | |
| 1353 | 1363 | as above | Shale | | | |
| 1363 | 1374 | as above | Shale | | | |
| 1374 | 1389 | as above, shale carbonate content variable | Shale | | | |
| 1389 | 1404 | as above, very dark gray to black, shale, carbonate content variable | Shale | | | |
| 1404 | 1420 | as above | Shale | | | |
| 1420 | 1433 | as above | Shale | | | |
| 1433 | 1443 | as above, 5% white calcite | Shale | | | |
| 1443 | 1454 | as above | Shale | | | |
| 1454 | 1466 | Shale, black, moderately fissile, shale carbonate content variable (appears less calcareous than above) | Shale | | | |
| 1466 | 1477 | as above | Shale | | | |
| 1477 | 1489 | as above | Shale | | | |
| 1489 | 1504 | as above, remains slightly calcareous | Shale | | | |
| 1504 | 1517 | as above, 20% white calcite veinlets | Shale | | | |
| 1517 | 1536 | as above, 10% white calcite veinlets, shale carbonate content variable | Shale | | | |
| 1536 | 1550 | as above | Shale | | | |
| 1550 | 1567 | as above | Shale | | | |
| 1567 | 1586 | Shale as above, 5% white calcite veinlets, smaller carbonate content | Shale | | | |
| 1586 | 1599 | Sample gap | Null | | | |
| 1599 | 1610 | as above | Shale | | | |
| 1610 | 1626 | as above | Shale | | | |
| 1626 | 1640 | as above | Shale | | | |
| 1640 | 1655 | Shale as above, 5% white calcite veinlets, shale very slightly calcareous | Shale | | | |
| 1655 | 1663 | as above | Shale | | | |
| 1663 | 1675 | Sample gap | Null | | | |
| 1675 | 1702 | Shale, dark gray and black, 55% black as above; 40% dark gray shale, silty, calcareous; 5% white calcite veinlets | Shale | | | |
| 1702 | 1721 | as above | Shale | | | |
| 1721 | 1732 | as above, shale carbonate content increasing | Shale | | | |
| 1732 | 1755 | as above, shale carbonate content decreasing, trace white calcite | Shale | | | |
| 1755 | 1763 | as above, shale carbonate content very low, trace white calcite | Shale | | | |
| 1763 | 1775 | as above | Shale | | | |
| 1775 | 1783 | as above, shale carbonate content variable, 5% white calcite | Shale | | | |
| 1783 | 2010 | Large sample gap | Null | | | |
| 2010 | 2030 | Shale, black, moderately calcareous, trace white calcite veinlets | Shale | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2030 | 2041 | as above | Shale | | | |
| 2041 | 2055 | as above | Shale | | | |
| 2055 | 2067 | as above | Shale | | | |
| 2067 | 2079 | as above | Shale | | | |
| 2079 | 2097 | as above | Shale | | | |
| 2097 | 2129 | as above | Shale | | | |
| 2129 | 2140 | as above, trace pyrite | Shale | | | |
| 2140 | 2152 | Shale as above | Shale | | | |
| 2152 | 2161 | as above | Shale | | | |
| 2161 | 2171 | as above | Shale | | | |
| 2171 | 2180 | as above | Shale | | | |
| 2180 | 2194 | as above | Shale | | | |
| 2194 | 2210 | as above | Shale | | | |
| 2210 | 2226 | as above | Shale | | | |
| 2226 | 2236 | as above | Shale | | | |
| 2236 | 2238 | as above, shale carbonate content increasing | Shale | | | |
| 2238 | 2251 | as above | Shale | | | |
| 2251 | 2261 | as above | Shale | | | |
| 2261 | 2271 | as above | Shale | | | |
| 2271 | 2284 | as above | Shale | | | |
| 2284 | 2296 | as above | Shale | | | |
| 2296 | 2308 | Shale, black, moderately fissile, shale carbonate content variable, trace calcite | Shale | | | |
| 2308 | 2321 | Shale, black, moderately fissile, calcareous, trace calcite | Shale | | | |
| 2321 | 2331 | as above | Shale | | | |
| 2331 | 2343 | as above | Shale | | | |
| 2343 | 2353 | as above | Shale | | | |
| 2353 | 2365 | as above | Shale | | | |
| 2365 | 2380 | as above | Shale | | | |
| 2380 | 2390 | Sample gap | Null | | | |
| 2390 | 2412 | Shale as above | Shale | | | |
| 2412 | 2425 | as above | Shale | | | |
| 2425 | 2438 | as above | Shale | | | |
| 2438 | 2440 | as above | Shale | | | |
| 2440 | 2448 | as above | Shale | | | |
| 2448 | 2463 | as above | Shale | | | |
| 2463 | 2470 | as above | Shale | | | |
| 2470 | 2495 | Sample gap | Null | | | |
| 2495 | 2510 | Shale as above | Shale | | | |
| 2510 | 2521 | as above | Shale | | | |
| 2521 | 2531 | as above | Shale | | | |
| 2531 | 2535 | as above | Shale | | | |
| 2535 | 2542 | Shale, black, moderately fissile, 5% calcite veinlets, slickensides, shale carbonate content variable | Shale | | | slickensides |
| 2542 | 2553 | Shale, calcareous as above, 5% white calcite | Shale | | | |
| 2553 | 2563 | Shale as above, trace white calcite veinlets | Shale | | | |
| 2563 | 2575 | as above | Shale | | | |
| 2575 | 2587 | as above | Shale | | | |
| 2587 | 2598 | as above | Shale | | | |
| 2598 | 2618 | as above | Shale | | | |
| 2618 | 2633 | as above | Shale | | | |
| 2633 | 2649 | as above | Shale | | | |
| 2649 | 2662 | as above, shale carbonate content variable | Shale | | | |
| 2662 | 2672 | Shale, black, more fissile, calcareous, trace white calcite | Shale | | | |
| 2672 | 2683 | as above | Shale | | | |
| 2683 | 2691 | as above | Shale | | | |
| 2691 | 2700 | as above | Shale | | | |
| 2700 | 2709 | as above | Shale | | | |
| 2709 | 2717 | as above | Shale | | | |
| 2717 | 2729 | as above | Shale | | | |
| 2729 | 2739 | as above | Shale | | | |
| 2739 | 2746 | as above | Shale | | | |
| 2746 | 2757 | as above | Shale | | | |
| 2757 | 2765 | as above | Shale | | | |
| 2765 | 2775 | as above | Shale | | | |
| 2775 | 2789 | as above, slickensides (in the shale, not in calcite) | Shale | | | slickensides |
| 2789 | 2803 | as above | Shale | | | |
| 2803 | 2819 | as above | Shale | | | |
| 2819 | 2829 | as above | Shale | | | |
| 2829 | 2840 | as above | Shale | | | |
| 2840 | 2848 | as above | Shale | | | |
| 2848 | 2860 | as above | Shale | | | |
| 2860 | 2868 | Shale, black, fissile, calcareous, 10% white calcite veinlets | Shale | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2868 | 2874 | Shale as above, 5% white calcite | Shale | | | |
| 2874 | 2887 | as above | Shale | | | |
| 2887 | 2897 | as above | Shale | | | |
| 2897 | 2907 | as above | Shale | | | |
| 2907 | 2917 | as above | Shale | | | |
| 2917 | 2927 | as above | Shale | | | |
| 2927 | 2932 | Shale as above, trace white calcite | Shale | | | |
| 2932 | 2943 | Shale as above, 5% white calcite | Shale | | | |
| 2943 | 2952 | Shale as above, trace white calcite | Shale | | | |
| 2952 | 2960 | Shale as above, 10% white calcite | Shale | | | |
| 2960 | 2965 | Shale as above, 5% white calcite | Shale | | | |
| 2965 | 2973 | Sample gap | Null | | | |
| 2973 | 2993 | Shale as above, trace white calcite | Shale | | | |
| 2993 | 3009 | as above | Shale | | | |
| 3009 | 4001 | Large sample gap | Null | | | 992' sample gap |
| 4001 | 4010 | Shale, black, calcareous, fissile, trace white calcite vein fill | Shale | | | |
| 4010 | 4021 | as above | Shale | | | |
| 4021 | 4034 | as above | Shale | | | |
| 4034 | 4046 | as above | Shale | | | |
| 4046 | 4056 | as above | Shale | | | |
| 4056 | 4070 | as above | Shale | | | |
| 4070 | 4085 | as above | Shale | | | |
| 4085 | 4100 | as above | Shale | | | |
| 4100 | 4110 | as above | Shale | | | |
| 4110 | 4127 | as above | Shale | | | |
| 4127 | 4147 | as above | Shale | | | |
| 4147 | 4157 | Shale as above, shale carbonate content increasing | Shale | | | |
| 4157 | 4167 | Shale, black, very calcareous, moderately fissile, trace white calcite | Shale | | | |
| 4180 | 4190 | as above | Shale | | | |
| 4190 | 4209 | as above | Shale | | | |
| 4209 | 4219 | as above | Shale | | | |
| 4219 | 4231 | as above | Shale | | | |
| 4231 | 4241 | as above | Shale | | | |
| 4241 | 4253 | as above | Shale | | | |
| 4253 | 4267 | as above | Shale | | | |
| 4267 | 4272 | as above | Shale | | | |
| 4272 | 4287 | Shale as above, 5% white calcite veins | Shale | | | |
| 4287 | 4296 | Shale as above, trace white calcite veins | Shale | | | |
| 4296 | 4306 | as above | Shale | | | |
| 4306 | 4322 | as above | Shale | | | |
| 4322 | 4336 | as above | Shale | | | |
| 4336 | 4356 | as above, trace slickensides | Shale | | | slickensides |
| 4356 | 4367 | Shale, black, very calcareous, moderately fissile, trace white calcite | Shale | | | |
| 4367 | 4379 | as above | Shale | | | |
| 4167 | 4180 | as above | Shale | | | |
| 4379 | 4388 | as above | Shale | | | |
| 4388 | 4398 | as above | Shale | | | |
| 4398 | 4410 | as above | Shale | | | |
| 4410 | 4422 | as above | Shale | | | |
| 4422 | 4432 | as above | Shale | | | |
| 4432 | 4452 | as above | Shale | | | |
| 4452 | 4465 | as above | Shale | | | |
| 4465 | 4471 | Shale as above, 10% whire calcite, only slightly fissile | Shale | | | |
| 4471 | 4478 | Shale as above, 20% white calcite, only slightly fissile | Shale | | | |
| 4478 | 4485 | Shale as above, 5% white calcite, only slightly fissile | Shale | | | |
| 4485 | 4497 | as above, trace slickensides | Shale | | | slickensides |
| 4497 | 4503 | as above, trace slickensides | Shale | | | slickensides |
| 4503 | 4508 | Shale, black, very calcareous, slightly fissile, trace white calcite | Shale | | | |
| 4508 | 4515 | as above | Shale | | | |
| 4515 | 4531 | as above | Shale | | | |
| 4532 | 4540 | as above | Shale | | | |
| 4540 | 4550 | as above | Shale | | | |
| 4550 | 4564 | as above | Shale | | | |
| 4564 | 4575 | as above | Shale | | | |
| 4575 | 4585 | as above | Shale | | | |
| 4585 | 4605 | as above | Shale | | | |
| 4605 | 4614 | as above | Shale | | | |
| 4614 | 4655 | Sample gap | Null | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4655 | 4660 | Shale, black, very calcareous, slightly fissile, trace white calcite, 5% combination hematitic arkose & (trace) pink dolostone | Shale | | | |
| 4660 | 4662 | as above, trace pyrite | Shale | | | |
| 4662 | 4666 | Shale as above, trace arkose and dolostone (as above), trace pyrite | Shale | | | |
| 4666 | 4668 | Shale as above, trace dolostone, trace white calcite veinlets | Shale | | | |
| 4668 | 4673 | Shale, black,very calcareous, slightly fissile, trace white calcite (a few chips per bag) | Shale | | | |
| 4673 | 4686 | as above | Shale | | | |
| 4686 | 4689 | as above | Shale | | | |
| 4689 | 4702 | as above | Shale | | | |
| 4702 | 4713 | as above | Shale | | | |
| 4713 | 4914 | as above, Note: this interval represents 16 sample bags | Shale | | | |
| 4914 | 4926 | 50% shale as above, 50% dolomite, white with a green tint, crystalline, trace pyrite, trace slickensides | Shale | Dolomite | | |
| 4926 | 4934 | 80% shale as above, 20% dolomite as above | Shale | Dolomite | | |
| 4934 | 4944 | Shale, as above, 5% white calcite vein fill | Shale | | | |
| 4944 | 4962 | as above | Shale | | | |
| 4962 | 4972 | as above | Shale | | | |
| 4972 | 4978 | 75% shale as above, 25% white dolomite | Shale | Dolomite | | |
| 4978 | 4986 | Sample gap | Null | | | |
| 4986 | 4992 | Shale, black, very calcareous, slightly fissile, trace white calcite, trace slickensides | Shale | | | |
| 4992 | 5006 | Shale as above, 5% white calcite | Shale | | | |
| 5006 | 5014 | as above | Shale | | | |
| 5014 | 5020 | 70% shale as above, 10% shale, dark gray, moderately calcareous, 10% wht. calcite, 10% dolomite, white as above | Shale | | | |
| 5020 | 5030 | Shale, black as above | Shale | | | |
| 5030 | 5036 | Shale as above, 20% dolomite as above | Shale | Dolomite | | |
| 5036 | 5052 | Shale as above, 2% white calcite, trace dolomite as above | Shale | | | |
| 5052 | 5067 | shale as above, trace white calcite | Shale | | | |
| 5067 | 5071 | as above | Shale | | | |
| 5071 | 5075 | as above, trace pyrite | Shale | | | |
| 5075 | 5075 | END, total depth 5075' | Shale | | | |

| Depth(ft)Start | Depth(Ft) End | Description | RockTypeA | RockTypeB | Formation | Comment |
|---|---|---|---|---|---|---|
| 120 | 186 | Dolostone, white to light pink, partly crystalline, trace rock fragment 5% large sand grains, quartz, clear, angular fragments | Dolostone | | Dunham Dolomite | |
| 186 | 196 | Dolostone, as above, scattered pyrite in dolostone, 40% sand, quartz, large grains, frosted to clear, angular to rounded | Dolostone | | | |
| 196 | 210 | as above, 10% sand | Dolostone | | | |
| 210 | 231 | as above, 10% sand | Dolostone | | | |
| 231 | 250 | Dolostone, pink, sandy, finer grained than above, crystalline, orange tint | Dolostone | | | |
| 250 | 275 | Dolostone, white to pink, crystalline, 5% sand as above | Dolostone | | | |
| 295 | 310 | Dolostone, as above, trace sand | Dolostone | | | |
| 325 | 335 | Dolostone, pink to orange, sandy, finer grained | Dolostone | | | |
| 335 | 348 | Dolostone, white to pink, crystalline, 5% sand as above | Dolostone | | | |
| 348 | 365 | Dolostone as above, trace pyrite, no sand | Dolostone | | | |
| 365 | 379 | Dolostone, white to buff, banded, slightly sandy | Dolostone | | | |
| 379 | 388 | Dolostone, white to pink, sandy texture, fine sand, trace pyrite | Dolostone | | | |
| 388 | 395 | as above, less sand | Dolostone | | | |
| 395 | 404 | Dolostone, pink, orange, buff, very silty, trace fossil(?) algae or stem | Dolostone | | | |
| 404 | 407 | Dolostone, white to pink, low sand content, trace pyrite | Dolostone | | | |
| 407 | 412 | Dolostone, white to pink, low sand content, trace pyrite | Dolostone | | | |
| 412 | 416 | as above, getting whiter | Dolostone | | | |
| 416 | 421 | as above, getting whiter | Dolostone | | | |
| 421 | 423 | as above, getting whiter | Dolostone | | | |
| 423 | 465 | Sample gap, seemingly correlating to thrust fault surface | Null | | | Champlain thrust |
| 465 | 468 | Shale, black, calcareous, slightly fissile, 5% white calcite vein filling | Shale | | Iberville/Stony Point Fm. | Calcareous shales occur in both the Iberville and Stoney Point formations. No mappable difference between the two units. |
| 468 | 470 | Shale, black, calcareous, slightly fissile, 5% white calcite vein filling | Shale | | | |
| 470 | 579 | Shale, black, calcareous, slightly fissile, 5% white calcite vein filling (note-interval represents many bags) | Shale | | | overlap of depth in well report |
| 576 | 614 | Shale, as above, trace slickensides | Shale | | | |
| 614 | 682 | Shale, as above, becoming more fissile | Shale | | | |
| 682 | 694 | Sample gap | Null | | | |
| 694 | 720 | Shale, black, calcareous, slightly fissile, 5% white calcite | Shale | | | |
| 720 | 775 | Shale, black, calcareous, slightly fissile, 5% white calcite | Shale | | | |
| 775 | 863 | Shale, as above, trace white calcite | Shale | | | |
| 863 | 967 | Shale, as above, 10% white calcite | Shale | | | |
| 967 | 995 | Shale, as above, white calcite decreasing | Shale | | | |
| 995 | 1055 | Shale, as above, white calcite increasing | Shale | | | |
| 1055 | 1072 | Shale, as above, white calcite almost absent | Shale | | | |
| 1072 | 1113 | Shale, as above, 2% to 5% white calcite | Shale | | | |
| 1113 | 1128 | Shale, as above, influx of shale, dark gray, slightly calcareous | Shale | | | |
| 1128 | 1178 | 70% shale, dark gray, silty, non-calcareous, 30% shale, black as above | Shale | | | |
| 1178 | 1220 | Shale, dark gray, as above, trace white calcite | Shale | | | |
| 1220 | 1224 | Sample gap | Null | | | |
| 1224 | 1236 | Shale, dark gray to black, non-calcareous, 30% dolomite, light gray, sandy | Shale | | | overlap of depth in well report |
| 1224 | 1250 | Shales, interbedded, part slightly calcareous, part non-calcareous, not fissile | Shale | | | |
| 1250 | 1271 | as above | Shale | | | |
| 1271 | 1284 | as above, possible dolomitic component (?) | Shale | | | |
| 1284 | 1295 | Shales, interbedded, very black, mostly non-calcareous | Shale | | | |
| 1295 | 1317 | Shales, interbedded, slightly to moderately calcareous, trace white calcite vein | Shale | | | |
| 1317 | 1395 | as above, Note: this interval represents 3 sample bags | Shale | | | |
| 1395 | 1455 | Sample gap | Null | | | |
| 1455 | 1480 | Shales, interbedded, mostly non-calcareous, some moderately calcareous, some calcareous | Shale | | | |
| 1480 | 1551 | as above, Note: this interval represents 2 sample bags | Shale | | | |
| 1551 | 1566 | as above, 5% white calcite vein fill | Shale | | | |
| 1566 | 1584 | as above | Shale | | | |
| 1584 | 1602 | as above, lots of veins in the shale | Shale | | | |
| 1602 | 1624 | as above, 10% shale, dark gray, calcareous | Shale | | | |
| 1624 | 1641 | as above, variable carbon content, mostly low | Shale | | | |
| 1641 | 1720 | as above, Note: this interval represents 4 sample bags | Shale | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1720 | 1742 | Shale, black, non-calcareous, trace white calcite | Shale | | | |
| 1742 | 1775 | as above, Note: this interval represents 2 sample bags | Shale | | | |
| 1775 | 2306 | No more samples on file | Null | | | |

Town: Alburg; County: Grand Isle; State: VT; Operator: American Petrofina; Well name: Alburg #1; Year:1964. NOTE: does not agree with Alburg#1 well summary; seems to agree with expected Yandow#1 geology.

| Depth(FT)Start | Depth(FT)End | Description | RockTypeA | RockTypeB | Formation | Comment | Remarks_2011_VGS |
|---|---|---|---|---|---|---|---|
| 0 | 1500 | Sample Gap | Null | Null | | | |
| 1500 | 1510 | Shale, black, very calcareous, slightly fissile, soft, trace white calcite vein fill | Shale | Null | Stony Point Fm. and Iberville Fm. | Upper Ordovician, dark gray calcareous and non-calcareous shale with interbedded gray limestone and dolomitic siltstone | |
| 1510 | 1520 | Shale, black, very calcareous, slightly fissile, soft, trace white calcite vein fill | Shale | Null | | | |
| 1520 | 1530 | as above | | | | | |
| 1530 | 1720 | as above; this interval represents 19 sample envelopes | Shale | Null | | | |
| 1720 | 1730 | as above | | | | | |
| 1730 | 1740 | as above | | | | | |
| 1740 | 1750 | as above | | | | | |
| 1750 | 1790 | as above | | | | | |
| 1800 | 1810 | Shale as above trace white calcite vein fill | Shale | Null | | | |
| 1810 | 1820 | as above | | | | | |
| 1820 | 1850 | as above | Shale | Null | | | |
| 1850 | 1860 | as above, trace slickensides | Shale | Null | | slickensides | |
| 1860 | 1870 | Shale and calcite as above | Shale | Null | | | |
| 1870 | 1950 | as above | Shale | Null | | | |
| 1950 | 1960 | Sample Gap | Null | Null | | | |
| 1960 | 2000 | Shale and calcite as above | Shale | Null | | | |
| 2000 | 2500 | Large sample gap | Null | Null | | 500' sample gap | |
| 2500 | 2630 | Shale, black, very calcareous, slightly fissile, soft, trace white calcite; Note: 13 envelopes in this interval | Shale | Null | | | |
| 2630 | 2640 | Sample Gap | Null | Null | | | |
| 2640 | 2690 | Shale and calcite as above, Note: 5 envelopes | Shale | Null | | | |
| 2690 | 2700 | Sample Gap | Null | Null | | | |
| 2700 | 2710 | Shale and calcite as above | Shale | Null | | | |
| 2710 | 2720 | Sample Gap | Null | Null | | 10' missing description in log | |
| 2730 | 3000 | Shale and calcite as above, shale almost pure, only one or two chips of calcite per envelope, Note: 27 envelopes in interval | Shale | Null | | | |
| 3000 | 3300 | Shale as above, no white calcite, (a few have trace white calcite) Note: 30 envelopes in this interval | Shale | Null | | | |
| 3300 | 3340 | Shale as above, trace white calcite vein fill | Shale | Null | | | |
| 3340 | 3350 | Shale as above, trace white calcite vein fill; picking up limestone characteristics | Shale | Null | | | |
| 3350 | 3350 | Limestone, shaley, black, trace crinoid stem | Limestone | Null | | | |
| 3350 | 3370 | Sample Gap | Null | Null | | | |
| 3370 | 3380 | Limestone, gray, crystalline, 20% shale as above | Limestone | Shale | | | |
| 3380 | 3390 | Limestone, dark gray, shaley | Limestone | Shale | | | |
| 3390 | 3400 | 80% shale, black, slightly calcareous | Shale | Limestone | | | |
| 3400 | 3410 | 80% shale as above, 20% limestone as above | Shale | Limestone | | | |
| 3410 | 3420 | 80% limestone as above, 20% shale as above | Limestone | Shale | | | |
| 3420 | 3430 | as above, trace pyrite | Limestone | Shale | | | |
| 3430 | 3440 | Dolostone, dark gray, sandy texture, easily broken, angular crystalline (sand size) grains | Dolostone | Siltstone | | | |
| 3440 | 3450 | as above | Dolostone | Siltstone, dolomitic | | | |
| 3450 | 3460 | 70% Dolostone as above, 30% siltstone, medium gray, dolomitic | Dolostone | Siltstone, dolomitic | | | |
| 3460 | 3470 | 70% Dolostone as above, 30% siltstone, medium gray, dolomitic | Dolostone | Siltstone, dolomitic | | | |
| 3470 | 3480 | 80% Dolostone as above, 20% shale, black, calcareous | Dolostone | Siltstone, dolomitic | | | |
| 3480 | 3490 | as above | Dolostone | Siltstone, dolomitic | | | |
| 3490 | 3500 | as above, shale content increasing to 50% | Dolostone | Shale | | | |
| 3500 | 3510 | as above, shale content increasing to 50% | Dolostone | Shale | | | |
| 3510 | 3520 | as above, shale content increasing to 50% | Dolostone | Shale | | | |
| 3520 | 3530 | 70% shale as above, 30% dolostone as above | Shale | Dolostone | | | |
| 3530 | 3540 | Shale, black, trace white calcite veinlets as above, trace dolostone | Shale | Dolostone | | | |
| 3540 | 3550 | 80% shale as above, 20% dolostone as above | Shale | Dolostone | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3550 | 3560 | 50% shale as above, 50% dolostone as above | Shale | Dolostone | | | |
| 3560 | 3570 | 50% shale as above, 50% dolostone as above | Shale | Dolostone | | | |
| 3570 | 3580 | as above, crystalline dolostones getting finer textures | Shale | Dolostone | | | |
| 3580 | 3590 | as above, dolostone slightly darker, trace pyrite | Shale | Dolostone | | | |
| 3590 | 3600 | 80% shale, black, calcareous, trace white calcite, 20% dolostone, dark gray, crystalline, sandy texture, trace Pyrite | Shale | Dolostone | | | |
| 3600 | 3610 | 90% shale as above, 10% dolostone as above | Shale | Dolostone | | | |
| 3610 | 3620 | as above ; trace slickensides | Shale | Dolostone | | slickensides | |
| 3620 | 3630 | Shale as above, trace dolostone as above | Shale | Dolostone | | | |
| 3630 | 3640 | Shale as above, trace dolostone as above; trace white calcite | Shale | Dolostone | | | |
| 3640 | 3650 | as above | Shale | Dolostone | | | |
| 3650 | 3660 | as above, trace slickensides | Shale | Dolostone | | slickensides | |
| 3660 | 3670 | Shale as above | Shale | Dolostone | | | |
| 3670 | 3680 | 60% shale as above, 40% dolostone, sandy, crystalline, well cemented; Quartz: clear, well-rounded, coarse grained, in dolostone | Shale | Dolostone | | | |
| 3680 | 3690 | as above, dolostone, darker gray | Shale | Dolostone | | | |
| 3690 | 3700 | 80% shale as above, 20% dolostone as above | Shale | Dolostone | | | |
| 3700 | 3710 | 70% dolostone, gray, sandy, crystalline, with quartz, clear, angular; 30 % shale, black, calcareous, trace white calcite, sand grains | Dolostone | Shale | | | |
| 3710 | 3718 | 80 % shale as above, 20% sandy dolomite | Shale | Dolostone | | This does not match the well log summary which has dolomitic conglomerate at 3715'-3722' | |
| 3718 | 3720 | as above | Shale | Dolostone | | | |
| 3720 | 3724 | 90% shale as above; 10% shale, gray dolomitic | Shale | Dolomitic Shale | | | |
| 3724 | 3728 | as above | Shale | Dolomitic Shale | | | |
| 3728 | 3730 | 70% black shale as above, 10% white calcite vein fill, 20% dolostone as above, with well rounded quartz grains | Shale | Dolomitic Shale | | | |
| 3730 | 3731 | as above, trace slickensides | Shale | Dolostone | | slickensides | |
| 3731 | 3740 | 70% dolostone, gray, sandy, with quartz, rounded and angular, well cemented, 30% black shale | Dolostone | Shale | | | |
| 3740 | 3750 | Sandstone, lt gray, dolomitic, sandy texture, quartz increasing sand grains both qtz and dolostone | Sandstone | Null | | 3722-4290: sandstone with dolomitic matrix and clear to frosted sand grains; lesser shale, and gray sandy dolomite | |
| 3750 | 3760 | as above, finer grained, 10% black shale | Sandstone | Null | | | |
| 3760 | 3770 | as above, finer grained, 10% black shale | Sandstone | Shale | | | |
| 3770 | 3780 | as above | Sandstone | Shale | | | |
| 3780 | 3782 | as above | Sandstone | Shale | | | |
| 3782 | 3790 | Sandstone, half becoming clear, 10% black shale as above | Sandstone | Shale | | | |
| 3790 | 3800 | Quartz sandstone, clear dolomitic cement, 10% shale as above | Sandstone | Shale | | | |
| 3800 | 3805 | 80% black shale as above, 20% sandstone as above | Sandstone | Shale | | | |
| 3805 | 3810 | 60% black shale as above, 40% sandstone as above | Shale | sandstone | | | |
| 3810 | 3820 | 80% black shale as above, 20% sandstone as above | Shale | sandstone | | | |
| 3820 | 3830 | 70% sandstone as above, 30% shale as above | Sandstone | Shale | | | |
| 3830 | 3840 | 90% sandstone, lt gray, dolomitic, 10% shale as above | Sandstone | Shale | | | |
| 3840 | 3850 | as above | Sandstone | Shale | | | |
| 3850 | 3860 | as above | Sandstone | Shale | | | |
| 3860 | 3870 | as above | Sandstone | Shale | | | |
| 3870 | 3880 | as above, sandstone becoming clear, quartz grains rounded and angular | Sandstone | Shale | | | |
| 3880 | 3890 | as above | Sandstone | Shale | | | |
| 3890 | 3900 | as above | Sandstone | Shale | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3900 | 3910 | 80% sandstone, clear as above, 20% shale, black, calcareous with white calcite vein fillings | Sandstone | Shale | | | |
| 3910 | 3920 | as above | Sandstone | Shale | | | |
| 3920 | 3930 | as above | Sandstone | Shale | | | |
| 3930 | 3940 | as above | Sandstone | Shale | | | |
| 3940 | 3950 | as above | Sandstone | Shale | | | |
| 3950 | 3960 | as above; trace dolomite, tan | Sandstone | Shale | | | |
| 3960 | 3970 | as above, no dolomite | Sandstone | dolomite | | | |
| 3970 | 3980 | as above | Sandstone | Null | | | |
| 3980 | 3990 | as above, trace tan dolomite | Sandstone | Null | | | |
| 3990 | 4000 | as above, with black shale fragments scattered in clear sandstone | Sandstone | dolomite | | | |
| 4000 | 4090 | Sample Gap | Null | Null | | | |
| 4090 | 4095 | Sandstone, clear, dolomitic, quartz grains both rounded and angular | Sandstone | Null | | | |
| 4095 | 4100 | Sandstone, clear, dolomitic, quartz grains both rounded and angular | Sandstone | Null | | | |
| 4100 | 4110 | Sandstone as above, 10% dolomite, white | Sandstone | dolomite | | | |
| 4110 | 4120 | Sandstone as above, trace dolomite, white | Sandstone | dolomite | | | |
| 4120 | 4130 | as above | Sandstone | dolomite | | | |
| 4130 | 4140 | as above, 5% black shale | Sandstone | Shale | | | |
| 4140 | 4150 | as above | Sandstone | Shale | | | |
| 4150 | 4160 | as above, becoming more quartzitic | Sandstone | Shale | | | |
| 4160 | 4170 | Sandstone as above, 10% black shale | Sandstone | Shale | | | |
| 4170 | 4180 | Sandstone as above, 40% black shale | Sandstone | Shale | | | |
| 4180 | 4190 | Sandstone as above, 10% black shale, 10% white dolomite | Sandstone | Shale | | | |
| 4190 | 4200 | Sandstone as above, 30% black shale | Sandstone | Shale | | | |
| 4200 | 4210 | Sandstone as above, 10% black shale, 10% white dolomite, 5% white calcite | Sandstone | Shale | | | |
| 4210 | 4220 | Sandstone as above, slightly gray, trace black shale, trace white dolomite, trace white calcite vein fill | Sandstone | | | | |
| 4220 | 4230 | Sandstone as above, 10% black shale, trace white dolostone, trace white calcite | Sandstone | Shale | | | |
| 4230 | 4240 | as above | Sandstone | Shale | | | |
| 4240 | 4250 | as above | Sandstone | Shale | | | |
| 4250 | 4260 | as above | Sandstone | Shale | | | |
| 4260 | 4270 | Sandstone, clear, lt gray, dolomitic cement, variable quartzitic, quartz round to angular, 10% black shale as above, trace white dol, trace white calcite | Sandstone | Null | | | |
| 4270 | 4280 | as above | Sandstone | Null | | | |
| 4280 | 4290 | as above, dolomitic cement increasing in black shale content | Sandstone | Null | | | |
| 4290 | 4300 | 60% black shale as above, 40% sandstone as above | Shale | sandstone | | 4290-4330: sandstone with some intercalated shale; Fine to medium grained white sandstone with black inclusions; slightly to non-dolomitic | |
| 4300 | 4310 | as above | Shale | sandstone | | | |
| 4310 | 4320 | 80% sandstone as above, 20% shale as above | Sandstone | Shale | | Potsdam? | |
| 4320 | 4330 | as above, more black shale content in the dolomitic cement | Sandstone | Null | | 4330-4470: White sandstone, black shale, and red sandstone | |
| 4330 | 4340 | as above | Sandstone | Null | | | |
| 4340 | 4350 | 60% black shale as above, 40% sandstone as above; sandstone matrix varies from clear to opague shaley dolomite | Shale | sandstone | | | |
| 4350 | 4360 | 90% sandstone as above, 10% black shale, trace white calcite | Sandstone | Shale | | | |
| 4360 | 4370 | 80% sandstone as above, 20% black shale, trace white calcite | Sandstone | Shale | | | |
| 4370 | 4380 | 60% sandstone as above, 40% black shale, trace white calcite | Sandstone | Shale | | | |
| 4380 | 4390 | 70% sandstone as above, 30% black shale, trace white calcite | Sandstone | Shale | | | |
| 4390 | 4300 | 60% sandstone as above, 40% black shale, trace white calcite | Sandstone | Shale | | | |
| 4400 | 4410 | 90% sandstone as above, slightly finer grain size, trace red in matrix, 10% black shale, trace white calcite | Sandstone | Shale | | | |
| 4410 | 4420 | as above | Sandstone | Shale | | | |

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|---|---|---|---|---|---|---|---|
| 4420 | 4430 | 60% sandstone as above, no red, 30% black shale, 5% white dolomite | Sandstone | Shale | | | |
| 4430 | 4440 | 70% sandstone as above, trace red, finer texture, 20% black shale, 10% milky dolomite | Sandstone | Shale | | | |
| 4440 | 4450 | 70% black shale as above, 25% sandstone as above, 5% milky white dolomite | Shale | Sandstone | | | |
| 4450 | 4460 | 70% sandstone as above, 25% black shale, 5% milky white dolomite | Sandstone | Shale | | | |
| 4460 | 4470 | 60% black shale as above, 35% sandstone, 5% milky white dolomite | Shale | Sandstone | | | |
| 4470 | 4480 | 80% sandstone as above, 10% shale, trace milky dolomite | Sandstone | Shale | | | |
| 4480 | 4490 | 80% sandstone as above, 20% shale, trace milky dolomite | Sandstone | Shale | | | |
| 4490 | 4500 | as above, trace white calcite | Sandstone | Shale | | | |
| 4500 | 4510 | 90% sandstone with distinct red matrix, 10% shale, trace dol, trace cal | Sandstone | Shale | | | |
| 4510 | 4520 | as above | Sandstone | Shale | | | |
| 4520 | 4530 | Sample Gap | Null | Null | | | |
| 4530 | 4540 | 80% sandstone, pink, matrix has increase in black shale content, 20% black shale as above, trace milky white dolomite | Sandstone | Shale | | | |
| 4540 | 4550 | as above | Sandstone | Shale | | | |
| | | | | | | | |