DISTRIBUTION OF MAJOR AND TRACE ELEMENT GEOCHEMISTRY OF TILL, **MONTPELIER 1:100,000 SHEET, CENTRAL VERMONT**

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Abstract

A study of major and trace element geochemistry of glacial till has been undertaken by the Vermont Geological Survey (VGS) in order to explore the connection between till chemistry and surface water and groundwater chemistry. Of specific interest is the distribution in till of arsenic, uranium and other metals, phosphorus, and their spatial relationship to bedrock sources. The study area includes samples from multiple geologic domains from the Green Mountains to the Connecticut Valley Trough.

A total of 94 till samples were collected from 67 sites, including stream banks, road-cuts, excavations and a strong effort was made to access unweathered samples. Sites were sampled within a grid of 10 x 10 km squares that covered the Montpelier one-degree sheet. Data includes clast %, color, grain size, reaction to HCl, and pH. Clast lithology counts were undertaken at a subset of sites. Samples were air-dried, split, sieved to < 2 mm, and split for chemistry by ICP-AES, ICP-MS and bulk mineralogy using quantitative XRD techniques.

Till pH differs notably across the major lithotectonic boundary known as the Richardson Memorial contact (RMC), the boundary between Cambrian and Ordovician transitional margin and accreted rocks of the Rowe-Hawley zone to the west and post-Taconian Silurian and Devonian (SD) rocks of the Connecticut Valley Trough to the east. Tills derived from SD metasedimentary rocks often contain calcite which serves to buffer pH to 7-8, whereas tills derived from CO phyllitic rocks west of the RMC and Devonian granitoids east of the RMC lack calcite and have pH < 6.

This study confirms the strong link between bedrock lithology and the composition of till derived from it. Our results confirm the idea that the background geochemistry of soils, surface water, and groundwater in this area will vary as the composition of the till varies. This, in turn, has been extensively shaped by the lithologies of the bedrock and bedrock-derived sediments that have served as the source materials for the till.

Introduction

Late Wisconsinan till blankets most of the landscape in Vermont and the surrounding region (Figure 1a). In general, the till has a composition reflecting local and up-ice bedrock compositions. A lithochemical map of the study area is shown in Figure 2. Samples locations are indicated on this map. Each sample represents approximately 100 km², a density that corresponds to a regional-scale study as defined by Kauranne and others (1992). This study assumes that lodgement or basal tills are homogenous in their vertical and lateral extent such that a single sample from a 10 km grid is representative of till composition.







Figure 1. Surficial geologic map of Vermont. Till (salmon color) is the predominant material over much of the land surface. Study area outlined in red.



Figure 2. Lithochemical Units of the Montpelier sheet. The bedrock units shown on the 2011 Bedrock Geologic Map of Vermont have been grouped together into units having a similar bulk geochemistry.

Methods

Considerable effort was made to obtain fresh samples. Most sites were on eroded stream banks or in roadside ditches. Typical exposures are shown in Figure 3. Pits were excavated into each face to remove surface material. Multiple samples were collected at some of the sites, with at least one sample at each site being taken from below the visibly weathered zone. Care was taken to avoid contaminating the matrix through crushing of till clasts.

Samples were dried and sieved to separate the < 2mm fraction prior to digestion for ICP analysis. The choice of the < 2 mm fraction was made to allow comparison with the study in Connecticut by Brown and Thomas (2014) and the USGS study of soil geochemistry in the lower 48 states by Smith and others (2013).

Analyses were conducted by ACT Labs of Ancaster, Ontario for 55 elements using Inductively Coupled Plasma Optical Emission Spectrometry and ICP-Mass Spectrometry, plus Loss-on-ignition. ACT Labs reports the method as follows: "(f)used sample is diluted and analyzed by Perkin Elmer Sciex ELAN 6000, 6100 or 9000 ICP/MS. Three blanks and five controls (three before sample group and two after) are analyzed per group of samples. Duplicates are fused and analyzed every 15 samples. Instrument is recalibrated every 40 samples."

Comparisons of lab duplicates and field duplicates are shown in Figure 4. The small variation between field duplicates suggests that the matrix of the till has a limited variability over distances of a few meters.



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-Mean of Lab

Duplicate

Absolute

Differences

— Lower 95% Cl







Analysis of Duplicate Samples Analyses of duplicate samples were undertaken in order to understand the variability of the materials and the accuracy and precision of the laboratory work (Figures 4a and b below). 1.20 — Upper 95% Cl 4a. Comparisons of 5 1.00 Pairs of Lab % 0.80



(Below, left) Dense silt-matrix till derived from Waits

Plainfield. C (Above) Sand-matrix till derived from Knox

River and Gile Mountain Formations, Great Brook,

Mountain Granite, Groton State Forest.

Figure 4a. Comparison of 5 pairs of lab duplicates. This figure shows the variability in major oxides observed in 5 splits from samples. The plots show the means of the absolute values of the differences between splits. Note that the variability is low, with only silica and alumina exceeding 0.2 wt %. The 95 % confidence intervals suggest that the lab analyses will be consistent to within less than 0.2 wt % for most elements.



Figure 4b. Comparison of 6 Pairs of Field Duplicates. This figure shows the variability observed in pairs of samples taken from the same site and at the same stratigraphic level. Three pairs are from the same shovel hole and three are from 5 to 10 meters apart. Although the variability is higher than with the lab samples, they still agree within well under 0.5 w %. This suggests that the matrix is relatively homogeneous at the scale of a few meters.





and others (2003). Transport direction (SE) is consistent with glacial striations. Granitic intrusions shown in dark gray.



Figure 6. Variation of pH of till across the study area. Values are generally low to the west of the RMC and high to the east of the RMC, except where till is derived

Figure 7a. Concentration of Fe2O3 in till (weight %).

Figure 7b. Concentration of CaCo3 in till (weight %). Only unweathered till sites are plotted.



Figure 7c. Concentration of TiO2 in till (weight %).







Figure 8c. Tills derived from Waits River and Gile Mountain Formations in central part of area to the east of the RMC. Somewhat lower CaO values than in Fig. 8b.

RO3A

RO3B1

RO3B2

RO3C2

RO3C2

RO1A

RO2B

NFLD-1

NFLD2A

-----NFLD3A

These samples have low CaO and relatively high Na2O and K2O.

Figure 8b. Tills derived from Waits River and Gile Mountain Formations in northeast of area. Note high CaO values.

Figure 8d. Tills derived from phyllitic and quartzose rocks just to the west of the RMC. CaO values are considerably lower than in Figures 8b and

These differ both in pH and major element concentrations (particularly Calcium). These are:

- Tills derived from Siluro-Devonian rocks east of the RMC.
- Tills derived from Cambro-Ordovician rocks to the west of the RMC.
- Tills derived from the Devonian granitic intrusive rocks to the east of the RMC.

Bivariate plots such as CaO versus TiO2 (Figure 11) may turn out to be useful in discriminating tills derived from distinct bedrock lithologies Statistical analysis of the data is just getting underway. Preliminary Mann-Whitney tests indicate that the major elements do indeed have statistically significant

Acknowledgements

differences across the RMC.

- Funding supplied by the Vermont Geological Survey.
- Thanks to Peter Gale, Ethan Thomas, and Colin Dowey for help with field work and sample preparation.
- Colin Dowey of the Vermont Geological Survey produced the box and whisker plots
- Thanks to Rick Dunn of Norwich University for his support and encouragement and his insistence on diving deeper into the variability of glacial till.
- Thanks to the following students from Laurie Grigg's GIS class at Norwich University for compiling data from Fred Larsen and his students: Jack Dallmeyer, Joel Morin, Jake Nichols, and Joseph Vallo.

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