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Chemical and Mineralogical
Composition of the Lockport
and Rochester Formations,
Smithville, Ontario
By
Greg. S. Bickerton

NWRI Contribution No. 97-130

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of the Lockport and Rochester Formations,
Smithville, Ontario

by

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NWRI Contribution # 97 - 130

MANAGEMENT PERSPECTIVE

Title: Chemical and Mineralogical Composition of the Lockport and Rochester Formations, Smithville, Ontario

Author(s): Greg S. Bickerton

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Citation:

EC Priority/Issue:

This report presents the results of a bedrock sampling program undertaken in February 1997 as part of ongoing GWRP studies at Smithville Ontario. A total of 32 samples of rock core were collected for chemical and mineralogical analysis. The samples were selected to maximize both aerial and stratigraphic coverage of the study area. The purpose of this investigation was to provide an indication of the regional distribution of rock composition for the stratigraphic units underlying the Smithville area. These data provide necessary information required to evaluate the groundwater geochemistry, regional flow and groundwater evolution in the Smithville area. In addition, the results will also assist in the interpretation of diffusion and dissolution experiments currently being conducted in related studies. The work is unique in developing techniques for effectively characterizing the geochemistry of fractured rock systems and in the detailed nature of the investigation.

The results showed that three principal minerals were found in the samples provided. These minerals were dolomite, quartz and gypsum. The composition of the stratigraphic units was found to be variable. However, all samples ranged between 86-98% (by weight) dolomite, 2-15% quartz and 3-8% gypsum (when detected). Examination of the whole-rock chemistry suggested that clay minerals may also be present in significant quantities (0.3-13.1%).

This works supports EC priorities under COA Stream 1.6 (groundwater) and Stream 1.4 (contaminated sites). Additionally, it supports GWRP deliverables under Toxics Result #3.

Current Status:

The report is intended to be released as a NWRI contribution and will be incorporated into a journal manuscript later in the year after the completion of further field work and interpretation.

Next Steps:

Additional sampling is not planned, however, further XRD analyses on selected samples may be attempted to investigate the nature and content of clay minerals in the samples. The results of this survey will be used to support other studies at the Smithville site and will lead to a journal manuscript.

Executive Summary

A total of 32 samples of rock core were collected from the Smithville, CWML site for chemical and mineralogical analysis. The samples were obtained from existing core, drilled during the Fall of 1995 and Spring of 1996. The samples were selected to maximize both aerial and stratigraphic coverage of the study area. The samples were submitted to the Analytical Chemistry Laboratories of the Geological Survey of Canada for preparation, whole rock analysis and x-ray diffraction (XRD) analysis.

The results of the XRD analyses showed that three principal minerals were found in the samples provided. These minerals were dolomite, quartz and gypsum. The composition of the stratigraphic units was found to be variable. However, all samples ranged between 86-98% (by weight) dolomite, 2-15% quartz and 3-8% gypsum (when detected). Examination of the whole-rock chemistry suggested that clay minerals may also be present in significant quantities. Using a normative mineral calculation approach, it was estimated that clay minerals may account for 0.3-13.1% of the rock. Normative calculations for carbonates were generally consistent with the XRD analysis. However, the abundance of several accessory minerals detected in the XRD analysis, appear to be significantly overestimated when reconciled against the corresponding chemical analysis. Therefore, it is suspected that the XRD values for dolomite and quartz may slightly overestimate the actual amounts present. In general, the Eramosa and Goat Island members were found to have a more uniform, dolomite rich and clay poor composition. The Rochester formation showed an opposite trend and the composition of the remaining units was found to lie between these groups.

It is recommended that Phase II of the proposed study be abandoned. It is believed that the proposed additional sampling would provide limited additional information. However, further XRD analyses on selected samples may be warranted to further investigate the nature and content of clay in the samples.

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Introduction

The purpose of this investigation was to provide an indication of the regional distribution of rock composition for the stratigraphic units underlying the Smithville area. These data will provide necessary information required to evaluate the groundwater geochemistry, regional flow and groundwater evolution in the Smithville area. In addition, the results will also assist in the interpretation of diffusion and dissolution experiments currently being conducted in related studies.

A total of 32 samples of rock core were selected for chemical and mineralogical analysis. The samples were collected from existing drill core, recovered from the bedrock during the Fall of 1995 and Spring of 1996. The samples were selected with the intent of maximizing both aerial and stratigraphic coverage of the study area. Appendix A provides the details of the samples analyzed, including: the borehole number, elevation above sea level and the stratigraphic unit from which the samples were collected. All samples were submitted to the Analytical Chemistry Laboratories of the Geological Survey of Canada (GSC) for preparation, whole rock analysis and x-ray diffraction (XRD) analysis and interpretation. Table 1 illustrates the number of samples collected from each stratigraphic unit.

Table 1: Stratigraphic distribution of samples.

Stratigraphic Unit	Number of Samples
Eramosa	5
Vinemount Unit2	3
Vinemount Unit 1	6
Goat Island	6
Gasport	7
Decew	1
Rochester	4

Preparation of each sample was accomplished by crushing the material to 1.5 cm, sub-sampling and pulverizing the result in a Bico ceramic disc grinder, followed by reduction to < 100 mesh powder in a ceramic ball mill. The whole rock analyses of the samples were conducted using a variety of methods. The major elements (SiO_2, TiO_2, Al_2O_3, Cr_2O_3, MnO, Fe_2O_3 Total, MgO, CaO, Na_2O, K_2O and P_2O_5) and trace elements (Ba, Nb, Rb, Sr and Zr) were determined by wavelength dispersive x-ray fluorescence (XRF) on fused discs. Ferrous iron (FeO) was determined using the Wilson method (titrimetric), H_2O Total, CO_2 Total, and S Total were determined using combustion followed by infra-red spectrometry and loss on ignition (LOI) was found gravimetrically at 900 °C. Identification of the mineral phases, present in the samples, was accomplished using XRD analysis.

Only bulk XRD scans were requested for the initial phase of sampling. Although this approach makes the detection of clay minerals difficult, especially when these minerals occur at relatively

low concentrations, it avoids the larger costs associated with clay mineral identification. The bulk XRD approach was selected, with the intention of using the results of the initial whole rock and XRD study, to identify future candidates for a more detailed XRD analysis.

Results and Discussion

The results of both the whole rock and XRD analyses are tabulated in Appendix A. The chemical composition of the rock samples are reported, by convention, in terms of oxides. These oxides are generally not present in the form reported, rather they are usually bound with other oxides in various mineral phases. However, some of a given oxide may also occur in a uncombined state, a common example is quartz (SiO_2). The convention of reporting rock constituents as oxides is also based on the assumption that individual elements are combined with oxygen. This assumption however, is not always valid. For example, iron present in pyrite (FeS_2) would be combined with iron found in other minerals and expressed as Fe_2O_3 $_{Total}$. The mineralogical composition of the samples were determined using a semi-quantitative interpretation of x-ray diffractograms. In this approach the entire sample is assumed to be composed of the detected mineral phases. The proportions of these are then based on the relative peak-areas of the respective minerals.

The percentage of the two most commonly detected minerals from the XRD analysis, dolomite and quartz, are presented in Figure 1a and 1b respectively. In this, and subsequent figures, the upper and lower bounds of the rectangular correspond to the arithmetic mean plus and minus one standard deviation, respectively. The vertical line represents the full range of values encountered. Several other mineral phases were also detected using XRD. However, unlike dolomite and quartz, these minerals were not found in every sample. Gypsum was detected in 8 samples; however, it was not found in any of the samples collected from the Eramosa or Rochester. When detected, the concentration of gypsum was found to be between 3.4% and 7.7%. The remaining minerals were detected only once: calcite (3.8%) and garnet (13.0%) were found in the Eramosa; hematite (7.0%) was detected in the Gasport (7.0%) and pyrite (13.5%) and chloritoid (7.0%) were identified in the Rochester.

Selected results from the chemical analyses for the major oxides are presented in Figures 2a to 2i. Two general trends, which are negatively correlated, were observed in the concentration data of these oxides. When considered as a function of the stratigraphic unit, the concentration data for MgO, CaO and CO_2 $_{Total}$ illustrates one of the these patterns and SiO_2, Al_2O_3, Fe_2O_3 $_{Total}$, K_2O, H_2O $_{Total}$ and S $_{Total}$, the other. The concentrations of the trace elements (Ba, Nb, Rb, and Zr) and TiO_2 were also found to behave in a manner similar to SiO_2. The results for MnO and Sr appear to indicate an approximately constant mean with only the ranges of concentration varying between the stratigraphic units. The data for P_2O_5 behaves in a similar fashion, with the exception of elevated concentrations in both the Vinemount Unit 2 and Rochester. Of the remaining oxides, Na_2O and Cr_2O_3 were not detected in any samples and reliable determinations of FeO could not be obtained.

Figure 1a: Dolomite composition of the bedrock in weight percent.

Figure 1b: Quartz composition of the bedrock in weight percent.

Figure 2a: CaO composition of the bedrock in weight percent.

Figure 2b: MgO composition of the bedrock in weight percent.

Figure 2c: CO_2 composition of the bedrock in weight percent.

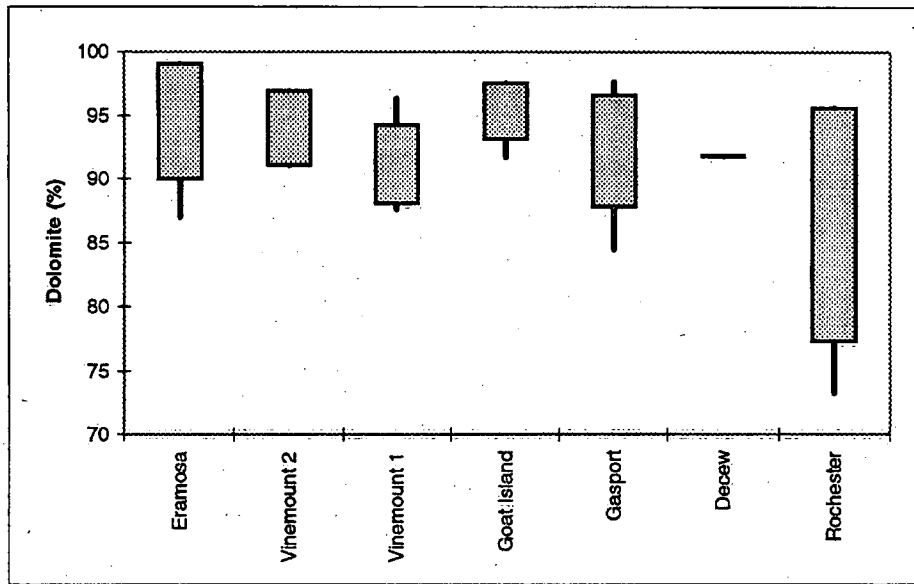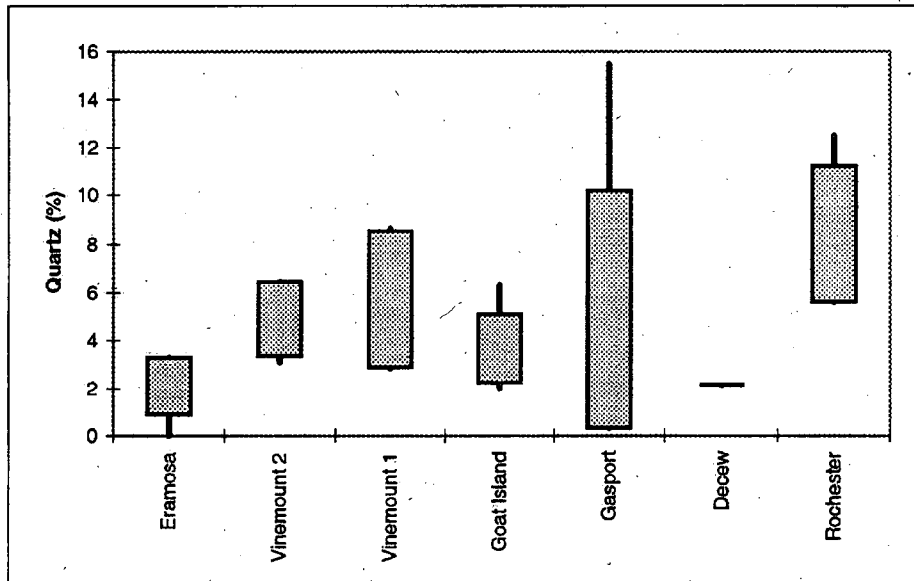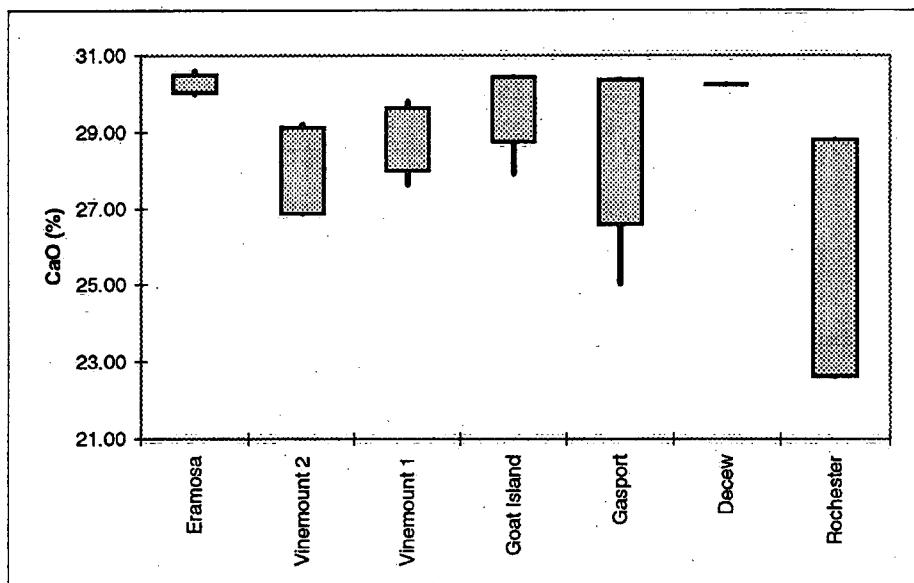Figure 2d: SiO_2 composition of the bedrock in weight percent.

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Figure 2e: Al_2O_3 composition of the bedrock in weight percent.

Figure 2f: K_2O composition of the bedrock in weight percent.

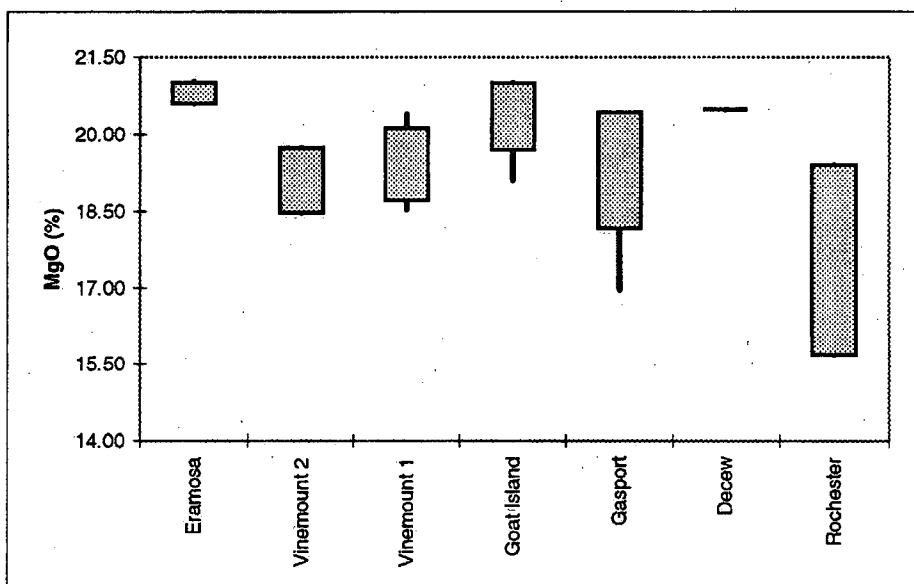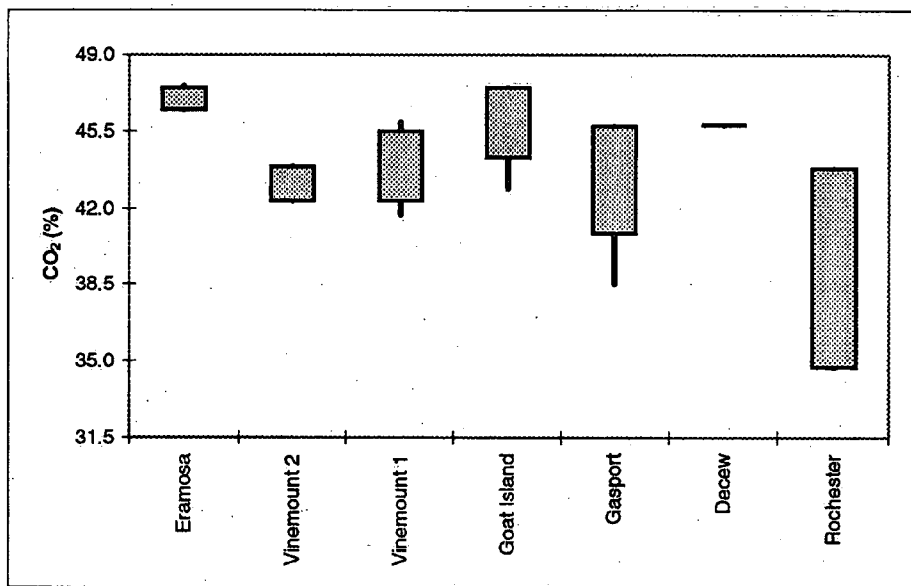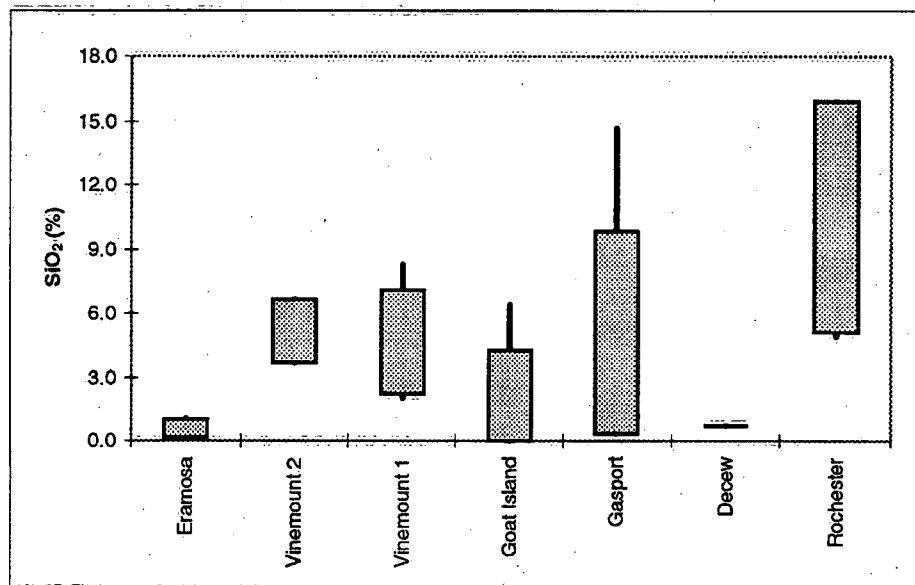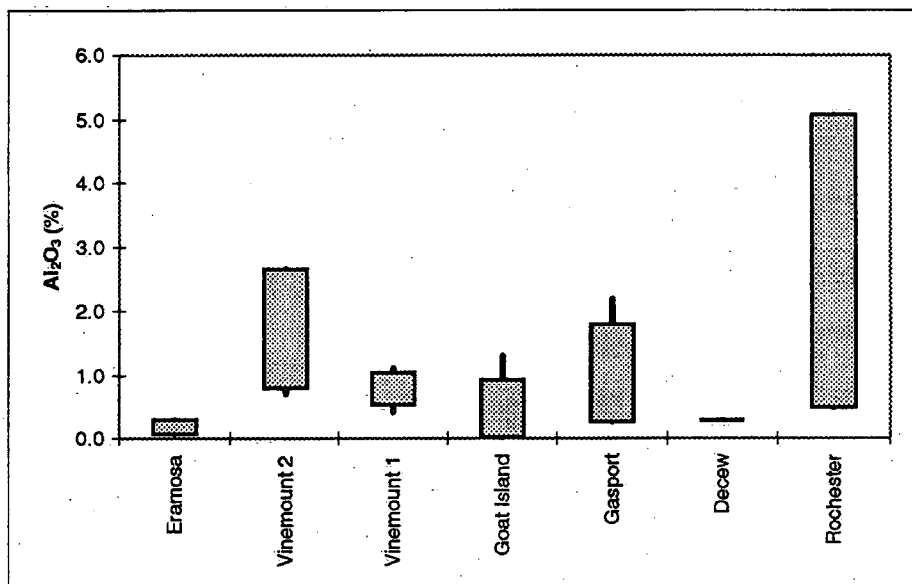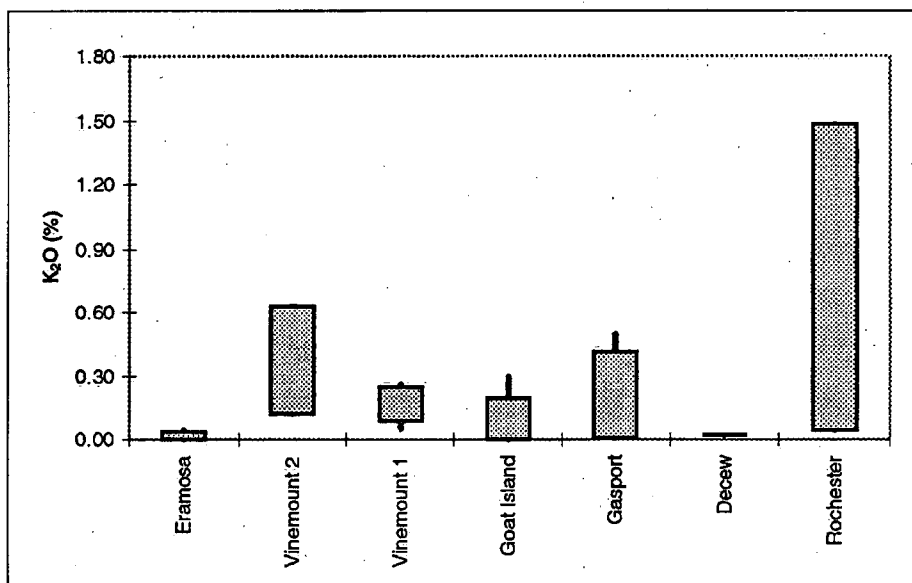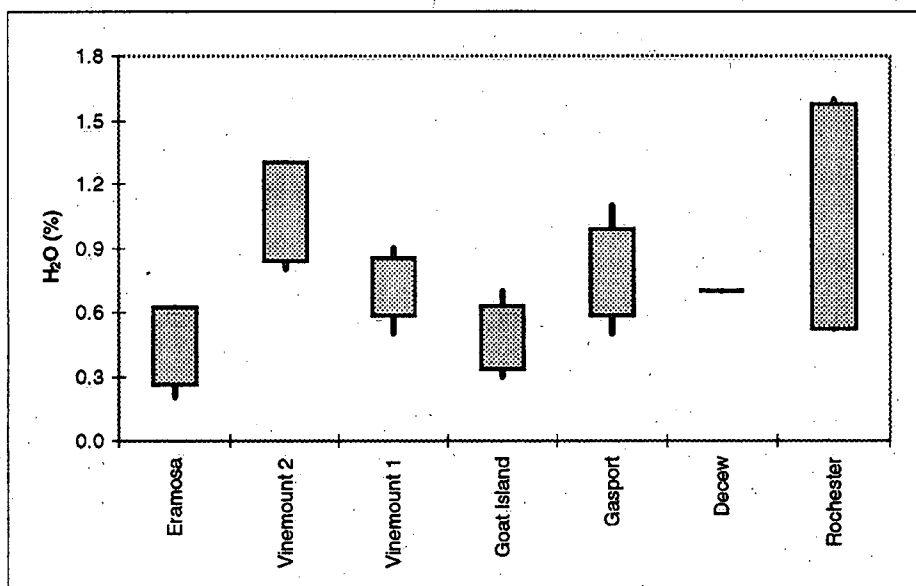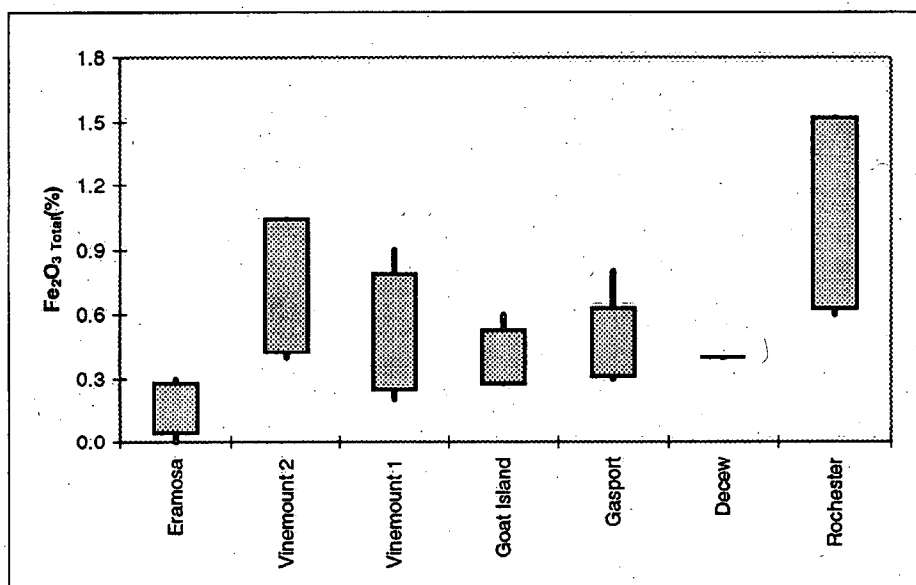Figure 2g: H₂O composition of the bedrock in weight percent.

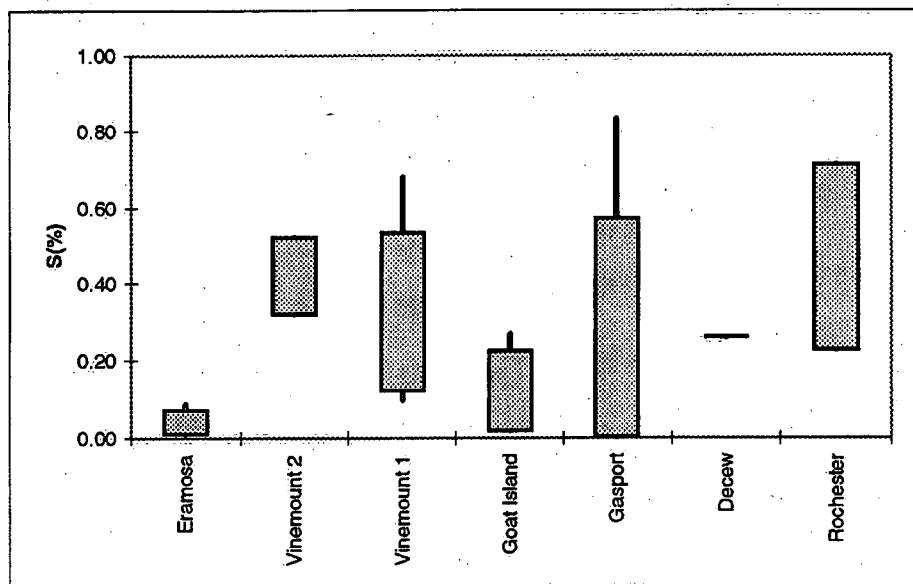Figure 2h: Total Fe (expressed as Fe_2O_3) composition of the bedrock in weight percent.

Figure 2i: S composition of the bedrock in weight percent.

The results for both FeO and Fe_2O_3 (Fe_2O_3 is calculated from the measured values of FeO and Fe_2O_3 $_{Total}$) have been omitted because an accurate determination of FeO could not be obtained. Each analysis for FeO was found to be greater than the total iron (Fe_2O_3 $_{Total}$). This is believed to be related to the presence of trace sulfide minerals in the rock matrix. Sulfur is known to provide an FeO enhancement when present in the form of acid-decomposable sulfide minerals (*personal communication, P. Belanger, GSC*, 1997). Although no sulfide phases were detected in the XRD analysis (except for SMV59), several of these minerals (ie. pyrite, galena and sphalerite) were visually identified in the rock core during the logging process. These minerals were found to occur in trace concentrations only, possibly explaining why they were not detected using XRD. However, for rocks with low iron contents, such as those sampled, the enhancement effect is more pronounced (*personal communication, P. Belanger, GSC*, 1997). Therefore, only a small amount of sulfide is required to adversely effect the FeO and Fe_2O_3 analyses. Additional support for the occurrence of an enhancement effect is provided by the positive correlation between S and FeO (Figure 3) and the failure to detect other known interferences such as tramp iron (from sample preparation) and organic carbon.

Although clay minerals were detected in only one sample (SMV59), examination of the whole rock data suggests that clay minerals may be present in most samples. Typically, the aluminum and potassium found in sedimentary rocks are associated with either clay minerals found in shale-rich horizons, feldspars (detrital or authigenic) or both (*Brownlow*, 1979). The most probable of these minerals can often be inferred based on the interrelationships between the various chemical analysis. To investigate this, correlation analysis was used (eg. *Davis*, 1973 or *Miller et al.*, 1990). This approach allows a statistical measure of the degree of interrelation between random variables that is independent of the units of the variables. The correlation coefficients (r) were calculated for each pair of rock constituents. A correlation coefficient ranges from -1 to +1, where +1 indicates a perfect direct relationship between two variable and -1 indicates a perfect

inverse relationship. A 0 implies that the variables are independent of each other. The square of the correlation coefficient (r^2) indicates what proportion of the variation observed in one variable can be directly attributed to the other.
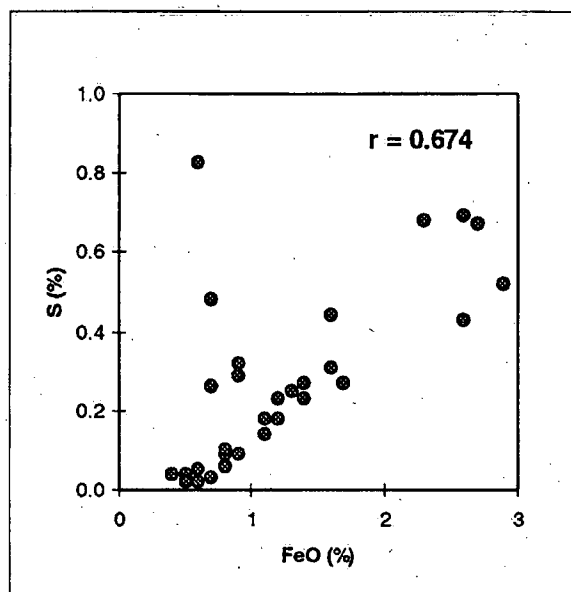
Figure 3: Correlation between S and FeO.

Figure 4 illustrates the relationship between Al_2O_3 and selected constituents for all 32 samples. Figures 4a and 4c illustrate distinct, positive correlations between the pairs Al_2O_3-SiO_2 and Al_2O_3-K_2O. This supports the contention that a potassium-rich alumino-silicate (eg. feldspars and/or clay minerals) phase is present in the bedrock. A near-perfect correlation is observed in Figure 4c. This would be expected for two constituents occurring in the same mineral phases (due to stoichiometric constraints). Figure 4a can be interpreted in a similar manner. Although the correlation in Figure 4a is weaker than that observed in 4c, this can be explained by considering that the mineral quartz (SiO_2) was detected in every sample during the XRD analysis. Therefore, the correlation between Al_2O_3 and SiO_2 would be less pronounced if SiO_2 was associated with both and aluminum and an aluminum-free phase. The uncombined silica occurs as chert (visually identified in core) and possibly detrital and/or authigenic quartz as well. The presence of the aluminum and potassium were interpreted as an indication of clay minerals rather than feldspar on the basis of the correlations displayed in Figure 4b and Figures 4d to 4f. Shales, which are rich in clay-minerals, are generally found to be enriched in most trace elements (eg. Ti, Rb and Ba) compared to other sedimentary rocks (*Brownlow*, 1979). Thus, it is expected that stratigraphic horizons rich in clay minerals should also show enrichment of these elements. The majority of the trace elements in shale-rich horizons are concentrated there because of adsorption or ion exchange occurring on the clay mineral surfaces (*Brownlow*, 1979). In addition, minor substitutions for major elements are also common in many clay minerals. For example, Rb and Ba for K in glauconite (an iron-bearing illite) and Ti for Al and Rb for K in illite (*Klein and*

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Figure 4: Correlations of selected constituents and Al_2O_3.

Hurlbut, 1985). These substitutions and trace element enrichments are not as common or pronounced in feldspar-rich rock. Figure 4d provides additional support to the predominance of clay-minerals over feldspar. The positive correlation observed between Al_2O_3 and H_2O is expected for clay minerals but not for feldspars. This occurs because, unlike clay minerals, feldspars do not contain structural water in their crystal structure.
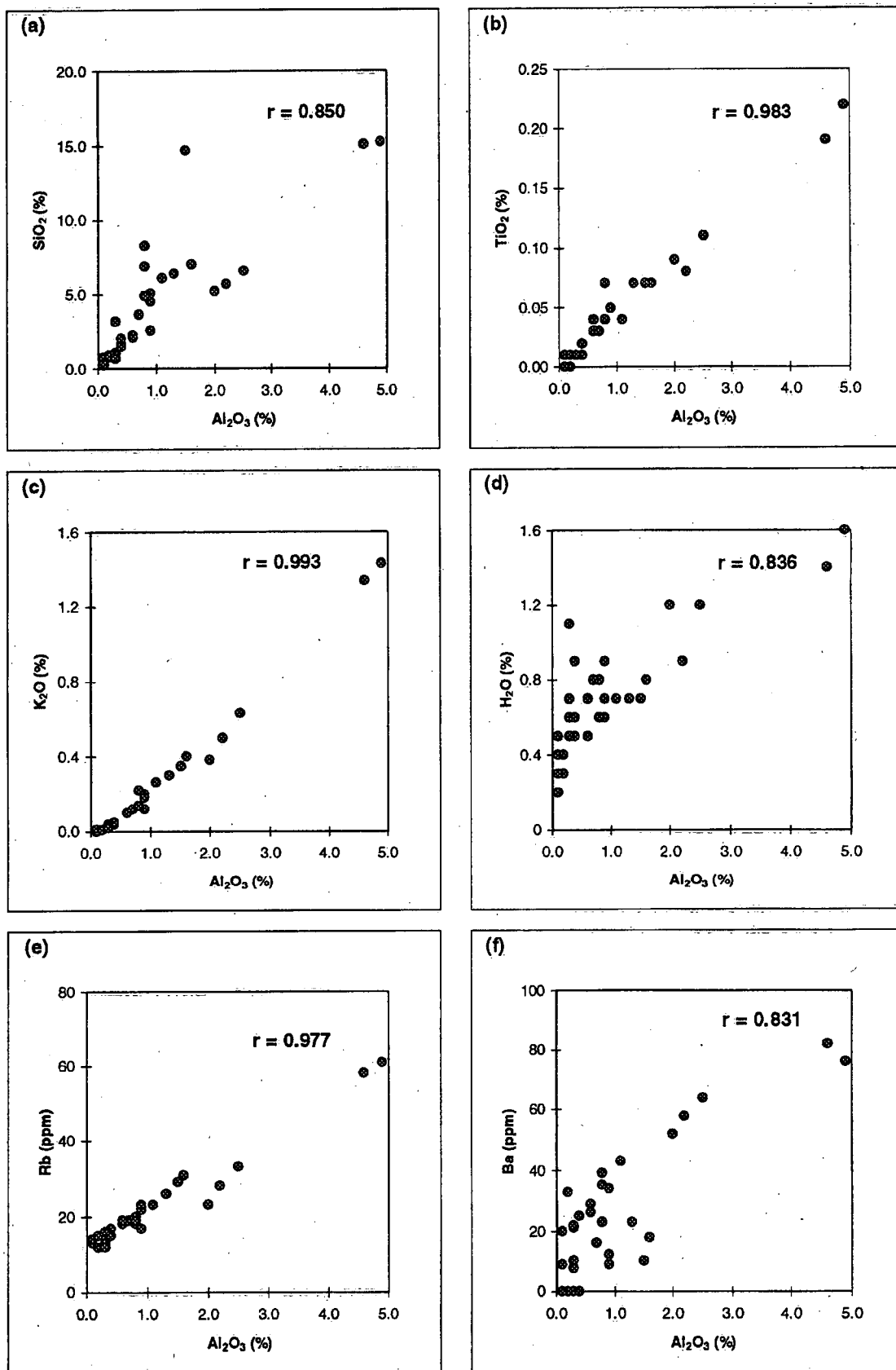
The actual clay minerals present cannot be deduced from rock chemistry alone. However, for sedimentary rocks of Silurian age, the clay minerals are probably composed of 65% to 80% illite and 10% to 35% chlorite (*Weaver*, 1967). Normally montmorillonite would also be present, however, it probably does not occur in significant amounts in the present samples considering no sodium was detected in the whole-rock analyses. An attempt was made to estimate the clay-mineral content of the samples using the rock chemistry available and following the normative calculation procedure outlined in *Garrels and MacKenzie* (1971). The normative minerals selected were illite and chlorite. The calculation involves allocating all Al_2O_3 and K_2O between the two normative minerals, in appropriate molecular proportions with other oxides. Because of the approximate nature of this exercise, the results are presented as an aggregate of the normative minerals in Table 2.

Table 2: Stratigraphic distribution of clay minerals (estimated) in weight percent.

Stratigraphic Unit	Estimated Clay-Mineral Content (%)
Eramosa	0.3 - 0.9
Vinemount Unit2	2.0 - 6.7
Vinemount Unit 1	1.2 - 3.0
Goat Island	0.3 - 3.5
Gasport	0.9 - 6.0
Decew	0.9
Rochester	3.1 - 13.1

Several less common minerals, detected in the XRD analyses, cannot be reconciled with the chemical results, especially when the estimated weight percentages of the minerals are considered. Instead of dolomite as the dominant carbonate phase, ankerite was detected in SMV58. This mineral is the Fe-rich end member of the Mg-Fe solid solution that exists between dolomite and ankerite. Based on the chemistry of SMV58, however, it is unlikely that the sample is 91.2% ankerite. There is insufficient Fe present in the rock to account for such a high proportion of this mineral. A more probable characterization of the mineral is a dolomite slightly enriched in Fe (ie. some substitution of Fe for Mg). Similarly, there in insufficient Fe present for hematite in SMV116 and pyrite in SMV59. In both cases the Fe_2O_3 Total is at least an order of magnitude less than would be required based on the XRD results. Garnet, a common detrital mineral in many sedimentary rocks, was detected in SMV53. Although the presence of this mineral is somewhat unusual, the measured values of Fe_2O_3 Total, Al_2O_3 and SiO_2 are 30 to 40 times less than that required to account for the 13% reported from the XRD analyses. However, the Al_2O_3 present in SMV59 is more than adequate to account for the amount of chloritoid

detected. Normative calculations were also performed to confirm the content of dolomite and quartz reported in the XRD results. In general the normative results agreed with the XRD values within 2% for dolomite. Results for the quartz also compared well, especially for higher weight percentages. However, the normative values often under predicted the XRD results for quartz, up to a factor of two for those samples having smaller weight percents reported. Exceptions were noted between the normative and XRD results for the samples noted above (SMV53, SMV59 and SMV116). In these cases the normative dolomite was generally higher, than the XRD determined value, by approximately the amount attributed to the suspect mineral in that sample.

Conclusions and Recommendations

The results of the XRD analyses showed that only three principal minerals were evident in the samples provided. These minerals were dolomite, quartz and gypsum. The composition of the stratigraphic units was found to be variable. However, all samples ranged between 86-98% (by weight) dolomite, 2-15% quartz and 3-8% gypsum (when detected). The XRD analyses were intended as preliminary and thus were not ideally formatted for the detection of clay minerals. Examination of the whole rock chemistry however, suggested that clay minerals may also be present in significant quantities. Using a normative mineral calculation approach, it was estimated that clay minerals may account for 0.3-13.1% of the rock. Normative calculations for carbonates were generally consistent with the XRD analysis. However, the abundance of several accessory minerals detected in the XRD analysis, appear to be significantly overestimated when reconciled against the corresponding chemical analysis. Therefore, it is suspected that the XRD values for dolomite and quartz may slightly overestimate the actual amounts present. In general, the Eramosa and Goat Island members were found to have a more uniform, dolomite rich and clay poor composition. The Rochester formation showed an opposite trend and the composition of the remaining units was found to lie between these groups.

Because of the relatively small variation in mineralogical and chemical compositions of various samples, it is believed that an additional 30 to 40 samples would not provide enough additional information to justify the expense. Therefore it is recommended that Phase II of the proposed study be abandoned. However, additional XRD analyses on selected samples may be warranted to further investigate the nature and content of clay in the samples. The presence of clay may have an impact on the processes of dissolution and diffusion.

References

Brownlow, A. H., *Geochemistry*, Prentice-Hall Inc., 498 pp., 1979.

Davis, J. C., *Statistical and Data Analysis in Geology*, John Wiley and Sons, 550 pp., 1973.

Klein,C. and C. S. Hurlbut, Jr., *Manual of Mineralogy*, 20th edition, John Wiley and Sons, 596 pp., 1973.

Miller, I., J. E. Freund and R. A. Johnson, *Probability and Statistics for Engineers*, 4th edition, Prentice-Hall Inc., 612 pp., 1990.

Garrels, R. M. and F. T. MacKenzie, *Evolution of Sedimentary Rocks*, W. W. Norton and Company Inc., 397 pp., 1971.

Weaver, C. E., The significance of clay minerals in sediments, in *Fundamental Aspects of Petroleum Geochemistry*, B. Nagy and U. Colombo, editors, Elsevier Publications, 37-76, 1967.

Appendix A

Chemical and Mineralogical
Results

Table A1: Results of XRF analyses for major elements and volitiles

NWRI Sample ID	Borehole	Depth (fbgs inclined)	Elevation (masl)	Formation /Member	SiO_2 (%)	TiO_2 (%)	Al_2O_3 (%)	Cr_2O_3 (%)	Fe_2O_3 Total (%)	MnO (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	H_2O Total (%)	CO_2 Total (%)	P_2O_5 (%)	S (%)
Determination Limit					0.50%	0.02%	0.40%	0.02%	0.10%	0.01%	0.10%	0.10%	0.50%	0.05%	0.10%	0.10%	0.02%	0.02%
SMV95	59	35.00	183.26	Eramosa	1.0	0.01	0.3	0.0	0.1	0.03	20.65	30.17	0.0	0.03	0.6	46.6	0.01	0.04
SMV122	60	65.83	179.87	Eramosa	0.3	0.00	0.1	0.0	0.0	0.05	20.74	30.60	0.0	0.01	0.5	46.6	0.02	0.04
SMV75	54B	58.33	176.06	Eramosa	1.1	0.01	0.3	0.0	0.2	0.06	20.60	30.01	0.0	0.04	0.6	46.7	0.05	0.09
SMV53	53	75.92	171.63	Eramosa	0.2	0.01	0.1	0.0	0.2	0.10	21.02	30.27	0.0	0.00	0.2	47.5	0.01	0.02
SMV106	61	52.17	168.46	Eramosa	0.2	0.00	0.1	0.0	0.3	0.15	20.99	30.22	0.0	0.00	0.3	47.5	0.01	0.02
SMV77	54B	66.75	173.50	Vinemount 2	6.6	0.11	2.5	0.0	1.0	0.07	18.45	27.00	0.0	0.63	1.2	42.3	0.06	0.52
SMV99	59	105.00	165.57	Vinemount 2	5.2	0.09	2.0	0.0	0.8	0.06	19.11	27.77	0.0	0.38	1.2	43.1	0.05	0.43
SMV113	61	167.50	139.66	Vinemount 2	3.7	0.03	0.7	0.0	0.4	0.08	19.71	29.19	0.0	0.12	0.8	43.9	0.04	0.32
SMV123	60	89.33	173.94	Vinemount 1	6.1	0.04	1.1	0.0	0.8	0.09	18.82	28.26	0.0	0.26	0.7	42.8	0.03	0.44
SMV114	62	86.83	172.90	Vinemount 1	2.1	0.04	0.6	0.0	0.4	0.06	19.98	29.65	0.0	0.10	0.7	45.4	0.03	0.23
SMV78	54B	72.83	171.64	Vinemount 1	8.3	0.07	0.8	0.0	0.9	0.14	18.51	27.63	0.0	0.22	0.8	41.7	0.03	0.68
SMV100	59	120.58	161.64	Vinemount 1	4.5	0.05	0.9	0.0	0.4	0.08	19.43	28.81	0.0	0.18	0.9	43.8	0.02	0.29
SMV55	53	123.50	159.47	Vinemount 1	5.1	0.05	0.9	0.0	0.4	0.07	19.34	28.66	0.1	0.20	0.7	43.8	0.02	0.23
SMV108	61	102.17	155.97	Vinemount 1	2.0	0.02	0.4	0.0	0.2	0.06	20.38	29.80	0.0	0.05	0.5	45.9	0.01	0.10
SMV115	62	99.50	169.72	Goat Island	6.4	0.07	1.3	0.0	0.6	0.07	19.08	27.90	0.0	0.30	0.7	42.9	0.02	0.27
SMV80	54B	84.08	168.21	Goat Island	2.3	0.03	0.6	0.0	0.5	0.09	20.20	29.67	0.0	0.10	0.5	45.6	0.03	0.18
SMV125	60	112.25	168.15	Goat Island	0.8	0.01	0.2	0.0	0.3	0.08	20.67	30.09	0.0	0.01	0.4	46.9	0.02	0.05
SMV102	59	136.58	157.59	Goat Island	0.9	0.00	0.2	0.0	0.3	0.11	20.78	30.07	0.0	0.01	0.3	47.0	0.02	0.02
SMV56	53	143.17	154.44	Goat Island	0.8	0.00	0.1	0.0	0.3	0.08	20.79	30.08	0.0	0.01	0.4	47.0	0.02	0.03
SMV110	61	122.92	150.79	Goat Island	1.5	0.01	0.4	0.0	0.4	0.06	20.49	29.82	0.0	0.05	0.6	46.0	0.04	0.18
SMV127	60	128.92	163.93	Gasport	0.8	0.01	0.3	0.0	0.4	0.09	19.91	30.36	0.0	0.02	1.1	44.5	0.01	0.83
SMV116	62	126.00	163.06	Gasport	3.2	0.01	0.3	0.0	0.3	0.08	20.06	29.40	0.0	0.03	0.5	45.7	0.02	0.06
SMV117	62	137.17	160.25	Gasport	14.7	0.07	1.5	0.0	0.8	0.11	16.99	25.06	0.0	0.35	0.7	38.5	0.03	0.31
SMV129	60	161.42	155.72	Gasport	2.6	0.05	0.9	0.0	0.5	0.07	19.99	29.20	0.0	0.12	0.6	44.4	0.03	0.10
SMV84	54B	131.50	153.76	Gasport	5.7	0.08	2.2	0.0	0.5	0.04	19.12	27.65	0.0	0.50	0.9	42.3	0.05	0.14
SMV103	59	160.50	151.55	Gasport	7.0	0.07	1.6	0.0	0.4	0.07	18.85	27.45	0.0	0.40	0.8	42.5	0.03	0.09
SMV58	53	178.50	145.41	Gasport	1.7	0.02	0.4	0.0	0.4	0.10	20.10	30.13	0.0	0.04	0.9	44.8	0.03	0.48
SMV112	61	159.00	141.78	Decew	0.7	0.01	0.3	0.0	0.4	0.07	20.49	30.25	0.0	0.02	0.7	45.8	0.02	0.26
SMV130	60	165.67	154.65	Rochester	6.9	0.04	0.8	0.0	0.8	0.12	18.90	27.98	0.0	0.14	0.6	42.7	0.04	0.27
SMV119	62	165.83	153.05	Rochester	4.9	0.04	0.8	0.0	0.6	0.09	19.39	28.73	0.0	0.14	0.6	43.7	0.04	0.25
SMV86	54B	153.50	147.06	Rochester	15.1	0.19	4.6	0.0	1.4	0.06	16.05	23.18	0.1	1.34	1.4	35.6	0.04	0.67
SMV59	53	194.50	141.32	Rochester	15.2	0.22	4.9	0.0	1.5	0.06	15.84	22.93	0.2	1.43	1.6	35.1	0.04	0.69

Table A2: Results of XRF analyses for trace elements and loss on ignition

NWRI Sample ID	Borehole	Depth (fbgs inclined)	Elevation (masl)	Formation /Member	Ba (ppm)	Nb (ppm)	Rb (ppm)	Sr (ppm)	Zr (ppm)	LOI (%)
Determination Limit										
SMV95	59	35.00	183.26	Eramosa	0	8	13	65	3	45.2
SMV122	60	65.83	179.87	Eramosa	9	4	14	157	0	46
SMV75	54B	58.33	176.06	Eramosa	21	6	13	48	5	45.6
SMV53	53	75.92	171.63	Eramosa	20	8	13	40	0	44.7
SMV106	61	52.17	168.46	Eramosa	0	9	13	34	0	45.2
SMV77	54B	66.75	173.50	Vinemount 2	64	11	33	51	22	41.3
SMV99	59	105.00	165.57	Vinemount 2	52	6	23	136	12	42.3
SMV113	61	167.50	139.66	Vinemount 2	16	10	19	56	11	43.7
SMV123	60	89.33	173.94	Vinemount 1	43	9	23	47	15	41.7
SMV114	62	86.83	172.90	Vinemount 1	29	7	19	62	2	44.8
SMV78	54B	72.83	171.64	Vinemount 1	23	9	20	46	92	40.8
SMV100	59	120.58	161.64	Vinemount 1	12	10	23	57	17	43.2
SMV55	53	123.50	159.47	Vinemount 1	34	11	22	65	29	43.1
SMV108	61	102.17	155.97	Vinemount 1	25	7	17	68	6	45.1
SMV115	62	99.50	169.72	Goat Island	23	11	26	48	38	42.2
SMV80	54B	84.08	168.21	Goat Island	26	8	18	53	4	44.4
SMV125	60	112.25	168.15	Goat Island	33	7	15	55	2	46
SMV102	59	136.58	157.59	Goat Island	0	7	12	43	2	45
SMV56	53	143.17	154.44	Goat Island	0	8	18	50	3	44.9
SMV110	61	122.92	150.79	Goat Island	0	7	15	51	3	45.1
SMV127	60	128.92	163.93	Gasport	10	8	16	64	2	44.8
SMV116	62	126.00	163.06	Gasport	22	8	12	45	4	44.4
SMV117	62	137.17	160.25	Gasport	10	10	29	50	18	38.4
SMV129	60	161.42	155.72	Gasport	9	9	17	57	7	44.9
SMV84	54B	131.50	153.76	Gasport	58	11	28	54	18	42.1
SMV103	59	160.50	151.55	Gasport	18	11	31	43	18	42
SMV58	53	178.50	145.41	Gasport	25	9	17	54	4	44.2
SMV112	61	159.00	141.78	Decew	8	10	12	54	4	45.6
SMV130	60	165.67	154.65	Rochester	35	8	19	45	12	42.6
SMV119	62	165.83	153.05	Rochester	39	8	18	52	11	43.4
SMV86	54B	153.50	147.06	Rochester	82	12	58	58	38	36.2
SMV59	53	194.50	141.32	Rochester	76	10	61	61	48	35.7

Table A3: Results of XRD analyses

Dolomite	Quartz	Gypsum	Calcite	Hematite	Pyrite	Garnet	Choritoid
97.3	2.7						
93.7	2.5		3.8				
97.1	2.9						
87.0						13.0	
97.6	2.4						
94.0	6.0						
96.9	3.1						
91.1	5.5	3.4					
91.6	8.4						
89.3	3.0	7.7					
87.6	8.7	3.6					
89.8	2.8	7.4					
92.4	7.6						
96.3	3.7						
93.7	6.3						
96.7	3.3						
91.7	2.0	6.3					
96.4	3.6						
96.7	3.3						
96.6	3.4						
93.2	2.1	4.6					
90.0	3.0			7.0			
84.5	15.5						
97.6	2.4						
96.3	3.7						
92.1	7.9						
91.2	2.3	6.5					
91.8	2.1	6.2					
92.1	7.9						
93.0	7.0						
87.5	12.5						
73.3	6.2				13.5		7.0

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