Phase Stability Determinations of DWPF Waste Glasses

by

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PHASE STABILITY DETERMINATIONS OF DWPF WASTE GLASSES (U)

by

C. A. CICERO, S. L. MARRA, AND M. K. ANDREWS

Defense Waste Processing Technology
Westinghouse Savannah River Company
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ABSTRACT

Liquid high-level nuclear waste will be immobilized at the Savannah River Site (SRS) by vitrification in borosilicate glass. The glass will be produced and poured into stainless steel canisters in the Defense Waste Processing Facility (DWPF). Eventually these canistered waste forms will be sent to the Civilian Radioactive Waste Management System (repository) for final disposal. In order to assure acceptability by the repository, the Department of Energy has defined requirements which DWPF canistered waste forms must meet. These requirements are the Waste Acceptance Product Specifications (WAPS). The WAPS require DWPF to develop time-temperature-transformation (TTT) diagrams. To fulfill this requirement, glass samples of seven projected DWPF compositions were heat treated at various times and temperatures. The glasses were characterized by x-ray diffraction and scanning electron microscopy to identify and quantify the crystalline phases present. The Product Consistency Test (PCT) was performed on the heat-treated glass samples to determine the durability. These results will provide guidance to the repository program about conditions to be avoided during shipping, handling and storage of DWPF canistered waste forms.

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PHASE STABILITY DETERMINATIONS OF DWPF WASTE GLASSES (U)

INTRODUCTION

Approximately 130 million liters of high-level radioactive waste are currently stored in underground carbon steel tanks at the Savannah River Site (SRS). This high-level radioactive waste will be immobilized in a durable borosilicate glass and poured into stainless steel canisters in the Defense Waste Processing Facility (DWPF). The canistered waste forms will eventually be sent to the Civilian Radioactive Waste Management System (repository) for final disposal. The Department of Energy has defined requirements which these canistered waste forms must meet to be acceptable for disposal in the repository. These requirements are the Waste Acceptance Product Specifications (WAPS).¹ Specification 1.4 of the WAPS requires that time-temperature-transformation (TTT) diagrams be developed for each of the DWPF projected high-level waste glass compositions. The TTT diagrams identify temperatures and the duration of exposure at these temperatures that cause significant changes in phase structure, or phase composition. The effects of crystallization on durability were also determined. This information will provide guidance about conditions to be avoided during shipping, handling, and storage of DWPF canisters.

Seven DWPF glass compositions have been projected and are described in the DWPF Waste Form Compliance Plan (WCP).² Four of these compositions have been projected from existing high-level waste inventory while three of them are hypothetical glass compositions. The three hypothetical glasses are the Blend waste which represents the design-basis, high aluminum (HM) waste which represents the upper design limit of glass viscosity, and Purex (high iron) waste which represents the lower design limit of glass viscosity.² The Purex composition is based on: maximum precipitate feed rate, minimum sludge feed rate and minimum removal of soluble salts during sludge processing. Thus, the Purex represents a possible worst-case composition.

In order to provide the necessary information required by the WAPS, Corning Engineering Laboratory Services (CELS) was contracted to supply large quantities of the seven simulated waste glasses described in the WCP.² During fabrication, the Group A waste components listed in the WCP were added to the glass as MoO_3 . The Group B waste components listed in the WCP were added to the glass in the ratio of 2:1 as Nd_2O_3 and ZrO_2 . All of the sodium, calcium, and barium compounds were added as their oxide equivalents for simplicity. Since uranium and other minor components have little effect on devitrification, these components of the WCP glasses² were omitted and the glass compositions renormalized. However, reference amounts of the minor Ru component were added as RuO_2 since RuO_2 can act as a nucleating agent for crystalline phases.³ The CELS analysis of the seven glass compositions as fabricated is shown in Table 1.

Table 1 - DWPF Projected Compositions*

Glass Components Wt %	Blend	HM	Purex	Batch #1	Batch #2	Batch #3	Batch #4
Al ₂ O ₃	4.16	7.15	2.99	4.88	4.63	3.44	3.43
B ₂ O ₃	8.05	7.03	10.33	7.78	7.88	7.69	8.14
BaO	0.18	0.11	0.20	0.15	0.16	0.18	0.25
CaO	1.03	1.01	1.09	1.22	1.08	0.99	0.84
Cr ₂ O ₃	0.13	0.09	0.15	0.11	0.13	0.14	0.14
Cs ₂ O	0.08	0.06	0.06	0.06	0.02	0.06	0.09
CuO	0.44	0.25	0.42	0.40	0.42	0.40	0.45
Fe ₂ O ₃	10.91	7.78	13.25	12.84	11.12	11.71	11.71
K ₂ O	3.68	2.21	3.41	3.33	3.38	3.40	3.86
Li ₂ O	4.44	4.62	3.22	4.43	4.50	4.51	4.29
MgO	1.41	1.49	1.41	1.42	1.42	1.42	1.43
MnO ₂	2.05	2.15	2.07	2.11	1.73	1.87	3.11
MoO ₃	0.15	0.22	0.08	0.11	0.17	0.12	0.20
Na ₂ O	9.13	8.56	12.62	9.00	9.21	9.01	9.16
Nd ₂ O ₃	0.22	0.55	0.06	0.15	0.26	0.17	0.39
NiO	0.89	0.41	1.19	0.75	0.90	1.05	1.06
RuO ₂	0.03	0.04	0.01	0.02	0.04	0.03	0.05
SiO ₂	51.90	55.80	46.50	50.20	52.10	52.60	50.10
TiO ₂	0.89	0.56	0.68	0.68	0.69	0.68	1.03
ZrO ₂	0.14	0.33	0.05	0.10	0.17	0.12	0.22
Total	99.91	100.42	99.79	99.74	100.01	99.59	99.95

* Glasses produced and analyzed by Corning Engineering Laboratory Services (CELS) as a Level 1 procurement, CELS Report 11988-027 (DPSTN-4771 and WSRC-NB-90-392).

EXPERIMENTAL

Heat Treatment

In order to develop TTT diagrams, the WCP glasses were heat treated as follows. Approximately 70 grams of glass were placed in covered high purity (99.8%) alumina crucibles. The crucibles were placed in a Lindberg programmable furnace and melted at the DWPF melt temperature of 1150°C for four hours. For heat treatment at temperatures of 900°C and below, the crucibles were then transferred to preheated Thermolyne muffle furnaces. For heat treatment at temperatures above 900°C, the crucibles remained in the Lindberg. The glass samples were heat treated at temperatures of 500, 600, 700, 800, 900, 1000, or 1100°C for times of 0.75, 3, 12, 48, 192, or 768 hours. Each glass sample was heat treated at a unique time and temperature. The 500 and 1100°C temperatures were chosen for conservatism. No crystals were expected in the samples heat treated at these temperatures because the 500°C temperature is just above the glass transition temperature and the 1100°C temperature is just above the liquidus temperature. Some samples were heat treated at 400°C to serve as controls, while others were heat treated at 650°C to provide additional information. A few glass samples were not exposed to the full heat treatment time that was intended, but the x-ray diffraction results of these glasses were used to better define the TTT diagrams.

Earlier studies on sludge-only glasses^{4,5} heat-treated samples to only 192 hours. For this experiment with coupled feed glasses, some of the glass samples were annealed for 768 hours. This upper time limit was chosen to maximize crystallization. Maximum crystallization was monitored using parabolic curves.⁶ After a given time period the volume percent crystallization reaches a maximum and then remains constant as a function of time.

In order to simulate quenched glass to be used as a base-line, the seven as-received glass compositions from Corning were remelted and quenched. Approximately 70 grams of each of the seven DWPF projected compositions was placed in a covered high purity (99.8%) alumina crucible. The crucibles were placed in the same Lindberg furnace discussed above and melted at 1150°C for four hours. After melting, the glasses were removed from the furnace and air cooled rapidly to room temperature.

X-ray Diffraction and Scanning Electron Microscopy Analysis

Quantitative x-ray diffraction (XRD) was performed on all glass samples to determine the type and amount of each phase present. Previously developed calibration curves⁷ were used for the quantitative examination. Scanning electron microscopy (SEM) coupled with energy dispersive analysis by x-ray (EDAX) was used on several of the glass samples to confirm the x-ray identification and chemical composition of the crystalline phases present in the glasses. SEM analysis was also used to verify the presence of RuO₂ and its role in nucleating crystalline phases.

Product Consistency Test

The heat-treated glass samples and the seven as-quenched glass samples were subjected to the Product Consistency Test (PCT)⁸ to assess the effects of heat treatment on durability. During the performance of the PCT, glass is crushed to 100-200 mesh and immersed in ASTM Type I water for 7 days at 90°C. Three and a half grams of glass and 35 grams of ASTM Type I water were leached in Teflon[®] vessels for each test. Tests containing ASTM Type I water but no glass samples were run simultaneously with all the glasses as "blanks." The use of blanks ensures that test vessel preparation was adequate and that the sample leachates can be corrected for elemental variation occurring independently of the glass-solution interactions. A standard glass, ARM-1, was used as a control standard to eliminate long term bias in the experimental analysis and in the analytical data. For several of the tests the Environmental Assessment (EA) glass⁹ was also run and used as a benchmark.

Following the seven day exposure, the leachates were filtered with a 45 μm filter to remove colloids and/or particulates. The leachates were analyzed for pH and the elemental concentration of the glass species of interest. The normalized releases of B, Na, and Li from the heat-treated samples were compared to the average normalized releases of B, Na, and Li from the EA glass.

The leachate concentrations are reported as normalized elemental mass losses, NC_i , released from the glass in grams of glass per liter of leachant. The measured release concentrations of the leachate in parts per million are normalized by the weight fraction of that element present in the glass.

The expression below for normalized elemental mass loss, NC_i , has been used in this study.

$$\text{NC}_i = \frac{C_i}{F_i}$$

where NC_i = normalized elemental mass loss ($\text{g}_{\text{glass}}/\text{L}$)

C_i = mass of element "i" in the solution corrected for the average mass of element "i" in the blanks (g/m^3)

F_i = fraction of element "i" in the glass ($\text{g}_i/\text{g}_{\text{glass}}$)

Redox

The $\text{Fe}^{+2}/\text{Fe}^{+3}$ ratio of several of the heat-treated and all of the quenched glass samples was measured to verify the redox of the glass samples. For these tests, glasses were melted under oxidizing conditions.

RESULTS AND DISCUSSION

X-ray Diffraction and Scanning Electron Microscopy Analysis

The phase standards and reflections recommended in the task plan¹⁰ for x-ray diffraction analyses were used except where noted. The trevorite (311) reflection was used in most analyses rather than the (440) reflection because of the interference with (440) from an unknown peak, possibly acmite. For the analyses of some of the 600-800°C heat-treated glass samples, the (311) reflection was interfered with by acmite and the (111) reflection had too high of a detection limit, so the (220) reflection was used. This inability to accurately detect trevorite was considered when developing the TTT curves. Similarly, the acmite (121) reflection was used, rather than the (110) or the (221) reflection as recommended, since it was free from spectral interference. Due to its higher peak intensity and the appearance of a different form of acmite, the acmite (310) reflection was used for some of the 800°C heat treated glass samples. The nepheline (201) reflection, as recommended in the task plan, was used for most of the glass samples because it was free from spectral interference, except in the Purex 800°C heat treated glass samples. The (202) reflection was used to detect the nepheline in these samples.

To correct for instrument drift in the XRD analyses, 10% silicon was added to each sample as an internal standard. Duplicate samples were submitted to control the precision of the analyses. The accuracy of the XRD analyses was within 10% for trevorite but was closer to 20% for acmite since the composition of the acmite in glass samples was different than the composition of the acmite standards. When the crystalline content of the samples approached the detection limits, the accuracy decreased even more. Table 2 shows the detection limits for the different phase reflections.

Table 2 - XRD Detection Limits

Phase	Nominal Composition	Reflection	Detection Limit(%)
Trevorite	NiFe ₂ O ₄	311	0.5
		220	1.0
Acmite	NaFeSi ₂ O ₆	121	0.4
		310	0.4
Nepheline	NaAlSi ₃ O ₈	201	0.2
		202	0.2
Lithium Metasilicate	Li ₂ SiO ₃	111	0.3

Trevorite, acmite, lithium metasilicate, and nepheline crystals were found by XRD in all of the seven glass compositions. The only exception was the lack of lithium metasilicate in the Purex glass. RuO₂ was detected in the HM glass samples, while Mg-Al-O, a metastable spinel intermediate, was detected in the Purex glass samples annealed at higher temperatures. Tables of the quantitative and qualitative XRD results for the duplicate samples can be found in Attachment I, along with the standard deviation.

No detectable crystallization was found in the quenched glasses. In the glasses heat treated at 400, 500, 1000, and 1100°C, very few crystals were detected. In those samples where crystals were detected, generally a maximum of 1.5 vol% trevorite was the only phase found in all compositions except Purex. However, the Purex glass samples contained nepheline in the 768 hour heat treated glasses at 500 and 1000°C, and the quantity of crystals was as much as 3.5 vol%. In the Blend glass sample heat treated at

500°C for 768 hours, trevorite was not detected, but 0.8 vol% acmite was found. The Batch 3 glass sample heat treated at 500°C for 768 hours contained 0.3 vol% nepheline in addition to the trevorite. Trevorite was also the only phase found in the 900°C heat treated glasses except for Purex, which once again contained nepheline. Various combinations of trevorite, acmite, nepheline, and lithium metasilicate in much larger quantities were found in the 600, 700, and 800°C heat-treated glass samples, with the majority of the trevorite present in the 800°C glasses. The 600°C heat-treated glasses contained the largest quantities of crystals for all compositions except Purex, which contained the largest quantity of crystals in the 700°C heat treated glasses.

When compared to the other glass compositions, the Purex glasses have higher amounts of iron oxide and lower amounts of alumina (see Table 1). The Purex glasses tended to interact with the aluminum in the crucibles that were used to melt the glasses. The interaction layer was included with the sample for analysis, which explains the larger quantities of nepheline (NaAlSiO_4) found in the Purex samples. It also explains the presence of crystals at shorter annealing times (see Attachment 1). In addition, the Purex composition represents the lower design limit of glass viscosity. Lower viscosity glasses tend to crystallize more quickly since diffusivity (which controls crystallization) is more rapid in low viscosity glasses.

The SEM results are presented in Table 3, along with the corresponding XRD results. SEM micrographs and EDAX spectra are shown in Figures 1-6. Acmite, trevorite, traces of nepheline, and RuO_2 were detected using SEM. The presence of lithium metasilicate can not be determined since SEM can not detect lithium. Only trace amounts of nepheline were found since nepheline is harder to detect due to the small amounts present and the difficulty in distinguishing it from other phases and the glass matrix.

The trevorite detected in most of the glass samples was close in composition to the nominal NiFe_2O_4 composition and tended to be enriched in chromium and manganese. It was detected in some glasses by SEM, although it was not detected by XRD, due to the acmite peak interference and the XRD detection limit. The acmite detected by SEM was composed mostly of calcium, iron, sodium and silicon. RuO_2 was detected in all glass compositions by SEM, except Purex, but when XRD was used it was only detected in the HM glasses due to problems with the detection limit. In most of the glass samples, individual and clustered RuO_2 particles served as nucleating sites.³ The RuO_2 not only served as a nucleating site for trevorite, but also for an acicular nickel-rich iron silicate compound, which seemed to act as a host nucleus for massive acmite formation.³

Table 3 - Phase Identification by Scanning Electron Microscopy and X-Ray Diffraction

Composition	Temp(°C)	Time(hrs)	SEM	X-Ray Diffraction
Batch 1	600	48	Acmite	Acmite, Li ₂ SiO ₃
Batch 1	700	48	Acmite	Acmite, Li ₂ SiO ₃
Batch 1	800	48	Trevorite, Acmite	Trevorite, Acmite
Batch 1	900	48	Trevorite, RuO ₂	Trevorite
Batch 2	600	0.75	RuO ₂	None detected
Batch 2	600	3	Acmite, RuO ₂	Acmite
Batch 2	600	12	Acmite	Acmite
Batch 2	600	48	Acmite, RuO ₂ , Trev.	Acmite, Li ₂ SiO ₃
Batch 2	600	192	Acmite, RuO ₂	Acmite, Li ₂ SiO ₃ , Neph.
Batch 2	600	768	Acmite, trace Neph.	Acmite, Li ₂ SiO ₃ , Neph.
Batch 3	700	48	Acmite, RuO ₂	Acmite, Li ₂ SiO ₃
Batch 3	700	768	Acmite, RuO ₂	Acmite, Li ₂ SiO ₃ , Neph.
Batch 3	800	3	Trevorite, RuO ₂	Trevorite, Acmite
Batch 3	800	192	Trevorite, RuO ₂	Trevorite, Acmite
Batch 4	500	192	RuO ₂	Trevorite
Batch 4	800	768	Trev., Acmite, RuO ₂	Trev., Acmite, Li ₂ SiO ₃
Batch 4	1000	768	Trevorite, RuO ₂	Trevorite
Batch 4	1100	192	Trevorite, RuO ₂	Trevorite
Blend	600	3	Acmite, RuO ₂	Acmite
Blend	600	48	Acmite	Acmite, Li ₂ SiO ₃
Blend	600	192	Acmite	Acmite, Li ₂ SiO ₃ , Neph.
Blend	700	48	Acmite	Acmite, Li ₂ SiO ₃
Blend	700	192	Acmite, RuO ₂	Acmite, Li ₂ SiO ₃ , Neph.
Purex	600	3	None detected	Nepheline
Purex	600	48	Trace Nepheline	Nepheline
Purex	600	192	Acmite	Acmite, Nepheline
Purex	700	3	Trevorite	None detected
Purex	700	48	Acmite	Acmite, Nepheline
Purex	700	192	Trevorite, Acmite	Acmite, Nepheline
HM	600	3	RuO ₂	None detected
HM	600	48	Acmite, RuO ₂	Acmite, Li ₂ SiO ₃
HM	600	192	Acmite, RuO ₂	Acmite, Li ₂ SiO ₃
HM	700	3	Acmite, RuO ₂	Acmite
HM	700	48	Acmite, RuO ₂	Acmite, Li ₂ SiO ₃ , Neph.
HM	700	192	Trevorite	Acmite, Li ₂ SiO ₃ , Neph.
HM	800	192	Trev., RuO ₂ , Acmite	Trevorite
HM	800	768	Trevorite, RuO ₂	Trev., Acmite, Li ₂ SiO ₃

Figure 1 - Typical Trevorite Crystal found using SEM

Figure 2 - Typical Acmite Crystal found using SEM

Figure 3 - Typical Acicular Acmite Crystal found using SEM

Figure 4 - EDAX Spectra of Trevorite Crystal

Figure 5 - EDAX Spectra of Acmite Crystal

Figure 6 - EDAX Spectra of RuO₂ Nucleating Acmite

The results from the x-ray diffraction and SEM analyses were used to construct parabolic curves for each of the seven waste glass compositions. These parabolic curves were used to monitor the maximum crystallization at a given temperature over time.⁶ It has been shown that crystallization reaches a maximum and remains constant over time, after reaching a steady state at a specific temperature.⁶

The parabolic curves developed for the seven waste glass compositions are presented in Figures 7-13. Only the data from the 600, 700, and 800°C heat treated glasses were plotted, since they contained the most significant amounts of crystals. As shown in the graphs, the volume percent crystals increased with time and then approached steady state between 192 and 768 hours. From these curves it is apparent that the 600°C heat treated glasses contained the largest amounts of crystals for all glass compositions, except for the Purex glasses, which had the greatest amount of crystals present in the 700°C heat treated glasses.

Figures 7, 8 - Parabolic Curves for Batch 1 and 2

Figures 9,10,11 - Parabolic curves for Batch 3, 4, and Blend

Figures 12,13 - Parabolic curves for Purex and HM

For most of the glasses, within the accepted errors of the method, a maximum amount of crystallization, or saturation concentration, was reached at each temperature. This concentration was used to create sigmoidal fractional ingrowth curves for the seven waste glass compositions. Sigmoidal fractional ingrowth curves are developed by plotting fractional ingrowth vs the log of time.⁶ The sigmoidal and parabolic curves together provide an excellent method for monitoring the heat treatment process because any data that is sufficiently deviant will plot outside of the expected limits determined from the graphs.

The sigmoidal fractional ingrowth curves for the seven waste glass compositions are presented in Figures 14-20. Once again, only the 600, 700, and 800°C heat treated data were plotted, since the saturation concentration had to be determined from the parabolic curves. The maximum amount of crystallization was determined from the maximum point of the parabolic curves and was plotted as 100% on the Fractional Ingrowth axis.

Figures 14,15,16 - Sigmoidal Fractional Ingrowth Curve for Batch 1,2 and 3

Figures 17,18,19 - Sigmoidal Fractional Ingrowth Curves for Batch 4, Blend & Purex

Figure 20 - Sigmoidal Fractional Ingrowth Curves for HM

Data for the sigmoidal curves for the Batch 1, Batch 2, Batch 3, and Blend glasses created curves that were "S-shaped", indicating that the data was fairly accurate. The 600 and 700°C Batch 4 and HM heat treated glasses also produced "S-shaped" curves, but the 800°C data did not produce the curves expected. A good explanation for this can be found by examining the XRD data (Attachment I). The Batch 4 800°C heat treated glasses experienced a major volume percent crystal change after 48 hours, whereas, the change for the 600 and 700°C glasses occurred after 12 hours. This resulted in the transition point being off-center on a log time plot, so a nice "S-shaped" curve was not produced. For the HM 800°C heat treated glasses, this volume percent crystal change did not occur until after 192 hours, but the explanation is the same as for the Batch 4 glasses. The Purex data for 700 and 800°C produced "S-shaped" curves, but the lower part of the 800°C curve did not approach zero, which serves to indicate that at 800°C Purex starts to crystallize immediately and stays at a relatively constant crystallization concentration for a short period. The Purex glass composition has a lower viscosity than the other glass compositions. Since lower viscosity glasses tend to crystallize more quickly, a larger volume percent crystals was detected in the Purex samples heat treated for 0.75 hours. The Purex 600°C data was close to producing an "S-shape", but the 192 hour data point was a little low. All data that was considered suspect from these graphs was resubmitted for XRD analyses to ensure that the results were accurate. The analyses of the resubmitted samples were virtually the same as the original samples, so the data was deemed acceptable.

The total volume percent crystals, along with the volume percent of each crystal type, was plotted versus temperature to observe the variation of the rate of nucleation with temperature. In general, a specific crystal type will continue growing until a maximum point is reached, and then the amount of this crystal type will decrease. Since the 768 hour heat-treated glass samples showed the greatest variety of detectable crystals and the maximum amount of crystallization, this data was plotted for each of the waste glass compositions. These plots are given in Figures 21-27.

For the Batch 1, Batch 2, Batch 3, and HM glasses, the maximum point of crystallization for acmite, nepheline, and lithium metasilicate occurred at 600°C, and the maximum point of crystallization for trevorite occurred at 900°C. The Batch 4 glasses reached the maximum point of crystallization for acmite, nepheline, and lithium metasilicate at 600°C, also, but the trevorite reached the maximum at 800°C. The Blend composition waste glasses contained the largest percentage of acmite and lithium metasilicate crystals at 600°C, of nepheline at 700°C, and of trevorite at 800°C. The Purex glasses exhibited nucleation behavior that was different from all other glass types. For the Purex composition, acmite reached a maximum point of crystallization at 700°C, nepheline at 600°C, trevorite at 800°C, and lithium metasilicate was not present. Finally, the total crystallinity plots support the findings presented

Figures 21, 22 - Percentage of Crystals vs Temperature for Batch 1 and 2

Figures 23, 24 - Percentage of Crystals vs Temperature for Batch 3 and 4

Figures 25, 26 - Percentage of Crystals vs Temperature for Blend and Purex

Figures 27 - Percentage of Crystals vs Temperature for HM

After evaluating the XRD data using the curves discussed above, the time-temperature-transformation curves were developed. Qualitative volume percents from the duplicate XRD analyses were plotted on a temperature versus log time graph. All heat-treated glass samples were plotted on the graphs even if no crystals were detected to show which times and temperatures were tested. In some instances, only one sample had detectable crystals. These points were included on the graph but not in the phase regions defined by the contoured phase transformation lines. The location and arrangement of the crystalline phase data points are used to define the phase transformation lines, which indicate the time and temperature where the phase transitions occur. The TTT curves for the seven waste glass compositions are presented in Figures 28-34.

In areas where no crystals were detected, the samples were completely glass which is referred to as the liquid phase. The liquid phase was present by itself and with all the crystalline phases. For simplification, liquid is included in the TTT diagrams but is not included in the descriptions of the diagrams.

Figures 28, 29 - TTT Diagrams for Batch 1 and 2

Figures 30, 31 - TTT Diagrams for Batch 3 and 4

Figures 32, 33 - TTT Diagrams for Blend and Purex

Figure 34 - TTT Diagram for HM

The TTT diagram for the Batch 1 waste glass composition had six different phase regions: trevorite; trevorite + acmite; trevorite + acmite + lithium metasilicate; acmite; acmite + lithium metasilicate; and acmite + nepheline + lithium metasilicate. The trevorite region encompassed the majority of the phase diagram, and was the prevalent crystalline phase at higher temperatures and shorter annealing times. Between 750 and 850°C, acmite began to form with the trevorite. The acmite concentration in this region increased with time, as the trevorite concentration remained constant, until extreme annealing times were reached where lithium metasilicate began to grow and replace some of the trevorite. At temperatures from 550 to 750°C and times greater than 3 hours, trevorite no longer formed and acmite became the primary nucleating phase. In addition, as annealing times increased, lithium metasilicate formed and then nepheline at longer annealing times.

The Batch 2 TTT diagram was similar to the Batch 1 diagram and had the same phase regions. Once again, the trevorite region encompassed most of the TTT diagram, but was not found below temperatures of 650°C. The trevorite + acmite region existed at approximately the same time and temperature as the Batch 1 composition. However, this region started at lower temperatures. The same growth order of acmite, lithium metasilicate, and then nepheline was experienced at temperatures from 550 to 750°C, but they appeared at higher temperatures sooner than they did in the Batch 1 composition.

Batch 3 was also similar to the Batch 1 TTT diagram and produced the same phase regions, plus an additional trevorite + nepheline region. The trevorite region encompassed most of the diagram at higher temperatures and shorter annealing times. The trevorite + acmite region was identical to Batch 1. Both acmite and lithium metasilicate began to appear at shorter annealing times in the 550 to 750°C region, which can probably be attributed to the higher lithium concentration in the waste composition. This higher lithium concentration combined with the lower alumina concentration in the glass composition attributed to the growth of nepheline at low temperatures and long annealing times in the trevorite + nepheline region. The acmite + lithium metasilicate + nepheline phase region was the same as Batch 1.

The TTT diagram for the Batch 4 composition was similar to the previous diagrams, but contains a few extra data points which better define the phase regions. The six phase regions found were trevorite, trevorite + acmite, trevorite + acmite + lithium metasilicate, acmite, acmite + lithium metasilicate, acmite + nepheline + lithium metasilicate. Once again, the trevorite phase region encompassed most of the diagram, and was even detected at lower temperatures for longer times. Its presence at shorter times in the middle temperature range produced a larger trevorite + acmite phase region. However, an extra point for the Batch 4 composition heat treated at 800°C verified that the lithium metasilicate started growing earlier than predicted in other diagrams at these temperatures. The growth pattern of acmite, lithium metasilicate, and nepheline between 550 and 750°C was repeated, except that nepheline did not start growing in the upper temperatures of this region until extreme annealing times had been reached.

The Blend composition TTT diagram was similar to the Batch 1 - 4 diagrams, and also contained the same six phase regions. As with the Batch 1 - 4 diagrams, the trevorite phase region was the predominant phase of the diagram, but it was only present at higher temperatures. Acmite began to form with the trevorite from 750 to 850°C above 0.75 hour annealing times and led to the ingrowth of lithium metasilicate at extreme annealing times, consistent with the other TTT diagrams. The normal growth procession of acmite, lithium metasilicate, then nepheline occurred in the absence of trevorite at the lower temperatures.

Due to the fact that Purex glass samples tend to crystallize nepheline at lower temperatures, its TTT diagram was different than any of the diagrams discussed earlier. This tendency to crystallize alkali silicate phases (nepheline) at lower temperatures can be correlated to the interaction between the glass and the alumina crucibles and the increase in $(\text{Li}_2\text{O} + \text{Na}_2\text{O})/(\text{SiO}_2 + \text{Al}_2\text{O}_3)$ ratio compared to the other compositions. The five phase regions discovered in the Purex TTT diagram were trevorite, trevorite + nepheline, trevorite + acmite + nepheline, acmite + nepheline, and nepheline. The trevorite region was the predominant phase at higher temperatures, while the nepheline region was the predominant phase at lower temperatures. A combination of the phases, trevorite + nepheline, existed in the middle temperature range. At extreme time durations in the 750 to 850°C temperature range, acmite began to grow with the trevorite and nepheline to form the trevorite + acmite + nepheline region. Acmite was also present when the glass composition was heat treated for longer times in the lower temperature region, but only with nepheline and not trevorite or lithium metasilicate.

The HM composition produced a TTT diagram which varied even more than the previous diagrams. No crystals of any type were detected at 0.75 hour annealing times because the diffusivity of the more viscous HM glass is slower, so crystallization is slower. The HM glass contained six phase regions, which were trevorite, trevorite + acmite, trevorite + acmite + lithium metasilicate, acmite, acmite + lithium metasilicate, and acmite + nepheline + lithium metasilicate. The largest region was the trevorite region, which was the predominant phase at temperatures above 750°C. Acmite was found coexisting with the trevorite only at times greater than 192 hours in the 750-850°C range. Lithium metasilicate began to grow at extreme times in this temperature region as it had in Batch 1 - 4 glasses. Acmite formed between 550 and 750°C at times greater than 0.75 hours, but was only found above this temperature at extreme annealing times. Lithium metasilicate and nepheline still followed the same growth pattern as the other glasses, but the acmite + nepheline + lithium metasilicate phase region was larger than in the other diagrams and also started to form at shorter annealing times. The acmite + lithium metasilicate phase region was only found in the 550-650°C range, not from 650-750°C as in the other diagrams.

To obtain the TTT diagrams, the seven glass compositions were heat treated at times and temperatures that are not expected during normal canister cooling or storage. Earlier experimentation, however, did subject the seven glass compositions to the worst case temperatures expected during canister cooling. These glasses did not have significant crystallization and were more durable than the EA glass.⁷ Figures 35-41 show the TTT diagrams with a curve representing the expected centerline cooling temperature. This curve was determined by measuring the temperature at a height of 51" during the cooling of three full scale DWPF canisters in the Scale Glass Melter Campaigns.¹¹ This height is where the canister cools the slowest, making it the worst case scenario since slower cooling yields higher crystallization.

**Figures 35, 36 - TTT Diagrams with Cooling Curve
Information for Batch 1 and 2**

**Figures 37, 38 - TTT Diagrams with Cooling Curve
Information for Batch 3 and 4**

**Figures 39, 40 - TTT Diagrams with Cooling Curve
Information for Blend and Purex**

**Figure 41 - TTT Diagram with Cooling Curve
Information for HM**

Product Consistency Test

The durability of the heat-treated glass samples was assessed by leaching them according to the PCT protocol.⁸ The blanks and standard glasses run simultaneously with the heat-treated glasses showed that no significant errors occurred during the testing. The average PCT results (in ppm and in g/L) for all of the heat-treated glasses are shown in Attachments II and III, respectively.

The normalized releases were compared to the average normalized release of the Environmental Assessment (EA) glass.⁹ (The EA glass was run simultaneously with the glasses during several leach tests.) For the majority of the glasses, the normalized release was significantly less than the EA glass. However, some of the samples heat treated at 600 and 700°C for longer times did exceed the EA normalized release for boron and lithium due to excessive crystallization. It should be noted that previous work by SRTC⁷ has shown that under the conditions expected during cooling of a canister, all of the projected glasses were more durable than the EA glass.

Figures 42-48 show the normalized boron, sodium, and lithium releases as a function of time for each of the seven glass compositions annealed at 600, 700, and 800°C. The other temperatures had lower releases. Also included in these figures are the average normalized releases of boron, sodium and lithium for the EA glass. Batch 1 and HM glasses did not exceed the results of the EA glass even under extreme conditions. A few Batch 2 and Blend crystallized glass samples exceeded the lithium release of the EA glass but all were acceptable for boron and sodium. A few Batch 3, Batch 4 and Purex crystallized glass samples exceeded the boron and the lithium releases of the EA glass.

To determine a baseline release concentration for the glasses, a sample of each glass type was melted under the same conditions but was not annealed. These quenched glasses were subjected to the PCT with the normalized results shown in Table 4. With the exception of the EA glass, the Batch 4 and Purex glass compositions had the least durable baseline because they contain the highest amounts of alkali (which decrease durability) and the lowest amount of glass formers (which increase durability). The higher baseline releases for Batch 4 and Purex contribute to the crystallized glasses exceeding both the boron and the lithium releases of the EA glass (Figures 45 and 47)

Table 4 - Normalized Releases of Boron, Sodium and Lithium in the Quenched and EA Glasses

<u>Glass Type</u>	<u>B</u>	<u>Na</u>	<u>Li</u>
Batch 1	0.64	0.66	0.73
Batch 2	0.54	0.56	0.61
Batch 3	0.74	0.71	0.75
Batch 4	0.83	0.81	0.84
HM	0.42	0.43	0.53
Purex	0.88	0.90	0.84
Blend	0.61	0.62	0.67
EA	15.48	12.85	9.05

Figure 42 - Normalized B, Na and Li Releases for Batch 1 and EA glass

Figure 43 - Normalized B, Na and Li Releases for Batch 2 and EA glass

Figure 44 - Normalized B, Na and Li Releases for Batch 3 and EA glass

Figure 45 - Normalized B, Na and Li Releases for Batch 4 and EA glass

4.

Figure 46 - Normalized B, Na and Li Releases for Blend and EA glass

Figure 47 - Normalized B, Na and Li Releases for Purex and EA glass

Figure 48 - Normalized B, Na and Li Releases for HM and EA glass

As with the Batch 4 and Purex glass compositions, the Batch 3 composition had a higher release for the remelted and quenched glass sample. When heat treated, the Batch 3 glass composition exceeded the lithium release of the EA glass before 12 hours at 700°C. The projected composition of Batch 3 contained more lithium and the heat-treated glasses formed more lithium metasilicate crystals than most of the other glasses (see Table 1 and Figure 23). The crystallization of alkali silicate phases tends to decrease durability,⁴ which explains why the Batch 3 crystallized glass samples were less durable than the EA glass at a shorter heat treatment time than the other glasses.

The devitrification of three different alkali silicate phases, lithium metasilicate, acmite and nepheline, in some glass samples caused additional loss of durability. Figures 49-55 show the normalized boron release for nearly all of the heat-treated glass samples (the 400 and 650°C tests were not included in these graphs since they were not annealed for each of the six time periods). These figures show that the region of lowest durability (the highest release) can be found at the longer heat treatment times at 600 and 700°C. This corresponds to the region where acmite, lithium metasilicate, and nepheline were detected and where the most crystallization was observed in the Percentage of Crystals versus Temperature diagrams (Figures 21-27).

Although crystallization of alkali silicate phases tended to decrease durability, crystallization of trevorite had no effect on glass durability.⁴ In the region of trevorite devitrification, the concentration of boron released was virtually the same as in regions of no crystallization. This effect was also seen in earlier studies.⁵

Redox

Table 5 shows the $\text{Fe}^{+2}/\text{Fe}^{+3}$ ratios and the normalized boron release (g/L) for selected glass samples. The crystallization content for these samples is also given in Table 5. For glass samples annealed at 400, 500, 900, 1000, and 1100°C for short times (0.75 and 3 hours), little change in the $\text{Fe}^{+2}/\text{Fe}^{+3}$ ratio or the boron release was observed and minimal crystallization was detected. However, for the glasses annealed at 600, 700 and 800°C for longer times, an increase in the $\text{Fe}^{+2}/\text{Fe}^{+3}$ ratio, the boron release and the crystallization content was observed. An increase in the Fe^{+2} concentration decreases the durability of the glass because Fe^{+2} acts as a network modifier while Fe^{+3} can be a network former.

Table 5 - Fe²⁺/Fe³⁺ Ratios, Boron Concentrations, and Crystallization Content

Composition	Temp(°C)	Time(hrs)	Fe ²⁺ /Fe ³⁺	B*	Crystalliz. (Vol. %)
Batch 1	N/A	N/A	0.072	0.64	None detected
Batch 1	400	0.75	0.035	0.65	None detected
Batch 1	500	0.75	0.053	0.62	None detected
Batch 1	600	0.75	0.066	0.64	None detected
Batch 1	700	0.75	0.049	0.63	0.7
Batch 1	800	0.75	0.050	0.60	1.7
Batch 1	900	0.75	0.050	0.64	0.8
Batch 2	N/A	N/A	0.077	0.54	None detected
Batch 2	600	3	0.059	0.59	1.2
Batch 2	700	3	0.068	0.72	8.5
Batch 2	800	3	0.063	0.57	2.4
Batch 2	900	3	0.078	0.62	1.1
Batch 2	1000	3	0.058	0.53	None detected
Batch 2	1100	3	0.068	0.53	None detected
Batch 3	N/A	N/A	0.052	0.74	None detected
Batch 3	500	12	0.077	0.63	None detected
Batch 3	600	12	0.072	3.87	13.4
Batch 3	700	12	0.108	14.28	23.7
Batch 3	800	12	0.091	0.80	2.4
Batch 3	900	12	0.067	0.73	1.2
Batch 3	1000	12	0.064	0.37	None detected
Batch 4	N/A	N/A	0.045	0.83	None detected
Batch 4	500	48	0.054	0.81	0.3
Batch 4	600	48	0.073	16.64	36.4
Batch 4	700	48	0.079	18.66	25.8
Batch 4	800	48	0.076	0.88	3.3
Batch 4	900	48	0.034	0.87	2.2
Batch 4	1000	48	0.044	0.51	0.7
HM	N/A	N/A	0.083	0.42	None detected
HM	500	192	0.065	0.39	None detected
HM	600	192	0.057	1.31	25.0
HM	700	192	0.039	1.65	27.9
HM	800	192	0.090	0.40	1.8
HM	900	192	0.047	0.39	0.8
HM	1000	192	0.023	0.29	None detected
Purex	N/A	N/A	0.148	0.88	None detected
Purex	500	768	0.038	1.57	1.1
Purex	600	768	0.027	5.63	6.2
Purex	700	768	0.050	19.43	23.0
Purex	800	768	0.008	2.10	5.7
Purex	900	768	0.009	0.99	1.9
Purex	1000	768	0.065	0.22	3.5
Blend	N/A	N/A	0.106	0.61	None detected
Blend	600	0.75	0.059	0.68	None detected
Blend	600	3	0.081	0.60	0.7
Blend	600	12	0.075	1.71	4.9
Blend	600	48	0.080	13.47	30.9
Blend	600	192	0.062	9.00	35.7
Blend	600	768	0.069	9.80	42.7

* Final boron concentration (g/L) in the PCT leach test. Similar trends were observed for Na and Li.

Figures 49, 50 • Normalized Boron Release for Batch 1 and 2

Figures 51, 52 - Normalized Boron Release for Batch 3 and 4

Figures 53, 54 - Normalized Boron Release for Blend and Purex

Figure 55 - Normalized Boron Release for HM

CONCLUSIONS

The TTT diagrams for the seven waste glass compositions, which span the glass compositions that will be vitrified in the DWPF, have been constructed. All glass compositions contained trevorite, acmite, lithium metasilicate, and nepheline in various amounts and combinations, except for the Purex glasses which did not contain any lithium metasilicate. Trevorite was the predominate phase for all times at temperatures from 850-1100°C and for shorter times at temperatures from 650-850°C for most compositions. For the Purex glass composition, the trevorite phase existed only from 950-1100°C and was not found by itself at temperatures below 950°C. The trevorite phase in the HM glass composition was observed at temperatures as low as 750°C, not 850°C as with the other compositions. A combination of acmite and trevorite was the predominant phase for most glass compositions from 750-850°C, except for the Purex and HM waste glasses. For the Purex glass composition, trevorite and nepheline were the predominant phases from 750-950°C and for the HM glass composition in this temperature range, trevorite was the lone phase for times up to 192 hours.

At temperatures from 550-750°C, acmite, along with some combination of lithium metasilicate and nepheline, was the predominant crystalline species, except for the Purex glass composition. Nepheline was the predominant phase at lower temperatures in the Purex glass composition. The largest volume percent of crystals were found when the glasses were heat treated for extremely long times in the 600°C and 700°C temperature range. Purex glasses had the lowest volume percent crystallization compared to all of the other glass compositions. This can be partly attributed to the small amounts of alumina and lithia present in the glass, which tend to increase the rate of devitrification.

From the SEM results, it appears that all crystallization was heterogeneous with RuO_2 serving as the principal nucleating agent. At temperatures above 850°C , the RuO_2 served as a host site for trevorite nucleation, while at temperatures below 850°C , it served as a host site for massive acmite formation. In the $500\text{--}700^\circ\text{C}$ range, acicular acmite began nucleating on the RuO_2 sites, which lead to the massive acmite formations.

The regions of highest crystallization correspond to the regions of lowest durability (as measured by the Product Consistency Test). These are the regions where alkali silicate phases are found. The presence of lithium metasilicate and nepheline significantly reduce durability while acmite by itself had less effect. The presence of trevorite had virtually no effect on the durability of the glass compositions.

Although some of the crystallized glass samples were less durable than the EA glass, these glass samples were produced under conditions that are not expected to be encountered during normal operation, transportation and storage. Temperatures of 600 and 700°C produced the most crystalline and the least durable glasses at longer annealing times. These annealing times were extreme (most were over 48 hours), so in an accident, this scenario would not be expected, although the required information is available should it become necessary.

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ATTACHMENT I
XRD RESULTS FOR EACH OF THE SEVEN GLASS COMPOSITIONS

Attachment I - Quantitative and Qualitative XRD Results

			BATCH 1		Phases present
Temp-Time	Sample 1	Sample 2	Volume % Average	Standard Dev.	
400-0.75	0.0	0.0	0.0	0.0	
400-12	0.0	0.0	0.0	0.0	
400-192	0.0	0.0	0.0	0.0	
500-0.75	0.0	0.0	0.0	0.0	
500-3	0.6	0.0	0.3	0.4	Trevorite
500-12	0.0	0.0	0.0	0.0	
500-48	0.0	0.0	0.0	0.0	
500-192	0.0	0.0	0.0	0.0	
500-768	0.0	0.0	0.0	0.0	
600-0.75	0.0	0.0	0.0	0.0	
600-3	0.0	0.0	0.0	0.0	
600-12	3.7	3.8	3.8	0.1	Acmite
600-48	31.6	31.2	31.4	0.3	Acmite, Li ₂ SiO ₃
600-192	40.4	40.8	40.6	0.3	Acmite, neph, Li ₂ SiO ₃
600-768	46.5	47.5	47.0	0.7	Acmite, neph, Li ₂ SiO ₃
650-0.75	0.4	0.4	0.4	0.0	Trevorite
650-3	0.9	0.9	0.9	0.0	Trevorite
700-0.75	0.6	0.7	0.7	0.1	Trevorite
700-3	2.2	2.3	2.3	0.1	Trevorite, acmite
700-12	13.8	15.2	14.5	1.0	Acmite
700-48	29.5	28.4	29.0	0.8	Acmite, Li ₂ SiO ₃
700-192	31.0	34.1	32.6	2.2	Acmite, neph, Li ₂ SiO ₃
700-768	37.9	35.6	36.8	1.6	Acmite, neph, Li ₂ SiO ₃
800-0.75	1.6	1.7	1.7	0.1	Trevorite
800-3	2.5	2.3	2.4	0.1	Trevorite, acmite
800-12	2.4	2.3	2.4	0.1	Trevorite, acmite
800-48	9.5	10.6	10.1	0.8	Trevorite, acmite
800-192	15.4	16.8	16.1	1.0	Trevorite, acmite
800-768	18.7	17.8	18.3	0.6	Trev, acmite, Li ₂ SiO ₃
900-0.75	0.8	0.8	0.8	0.0	Trevorite
900-3	1.3	1.2	1.3	0.1	Trevorite
900-12	1.7	1.5	1.6	0.1	Trevorite
900-48	1.7	1.9	1.8	0.1	Trevorite
900-192	2.1	2.0	2.1	0.1	Trevorite
900-768	2.0	2.0	2.0	0.0	Trevorite
1000-0.75	0.0	0.0	0.0	0.0	
1000-3	0.0	0.0	0.0	0.0	
1000-12	0.6	0.0	0.3	0.4	Trevorite
1000-48	0.5	0.6	0.6	0.1	Trevorite
1000-192	0.6	0.6	0.6	0.0	Trevorite
1000-768	0.7	0.8	0.8	0.1	Trevorite
1100-0.75	0.0	0.0	0.0	0.0	
1100-3	0.0	0.0	0.0	0.0	
1100-12	0.0	0.0	0.0	0.0	
1100-48	0.0	0.0	0.0	0.0	
1100-192	0.0	0.0	0.0	0.0	
1100-768	0.5	0.6	0.6	0.1	Trevorite

Attachment I - Quantitative and Qualitative XRD Results.

Temp-Time	Sample 1	Sample 2	BATCH 2		Phases Present
			Volume %	Standard Dev.	
400-0.75	0.0	0.0	0.0	0.0	
400-12	0.0	0.0	0.0	0.0	
400-192	0.0	0.0	0.0	0.0	
500-0.75	0.0	0.0	0.0	0.0	
500-3	0.0	0.0	0.0	0.0	
500-12	0.0	0.0	0.0	0.0	
500-48	0.0	0.0	0.0	0.0	
500-192	0.0	0.0	0.0	0.0	
500-768	0.0	0.0	0.0	0.0	
600-0.75	0.0	0.0	0.0	0.0	
600-3	1.2	1.2	1.2	0.0	Acmite
600-12	15.6	14.9	15.3	0.5	Acmite
600-48	38.1	39.1	38.6	0.7	Acmite, Li ₂ SiO ₃
600-192	43.9	45.0	44.5	0.8	Acmite, neph, Li ₂ SiO ₃
600-768	48.0	44.9	46.5	2.2	Acmite, neph, Li ₂ SiO ₃
650-0.75	0.6	0.6	0.6	0.0	Trevorite
650-3	2.2	2.3	2.3	0.1	Trevorite, acmite
700-0.75	0.7	0.7	0.7	0.0	Trevorite
700-3	7.9	9.0	8.5	0.8	Trevorite, acmite
700-12	22.8	20.8	21.8	1.4	Acmite, Li ₂ SiO ₃
700-48	31.1	32.5	31.8	1.0	Acmite, neph, Li ₂ SiO ₃
700-192	37.2	36.6	36.9	0.4	Acmite, neph, Li ₂ SiO ₃
700-768	31.6	33.3	32.5	1.2	Acmite, neph, Li ₂ SiO ₃
800-0.75	0.8	0.8	0.8	0.0	Trevorite
800-3	2.5	2.3	2.4	0.1	Trevorite, acmite
800-12	2.7	2.7	2.7	0.0	Trevorite, acmite
800-48	4.5	4.6	4.6	0.1	Trevorite, acmite
800-192	15.0	13.1	14.1	1.3	Trevorite, acmite
800-768	17.1	16.7	16.9	0.3	Trevorite, acmite, Li ₂ O ₃
900-0.75	0.6	0.5	0.6	0.1	Trevorite
900-3	1.1	1.1	1.1	0.0	Trevorite
900-12	1.3	1.4	1.4	0.1	Trevorite
900-48	1.4	1.5	1.5	0.1	Trevorite
900-192	1.7	1.7	1.7	0.0	Trevorite
900-768	1.7	1.6	1.7	0.1	Trevorite
1000-0.75	0.0	0.0	0.0	0.0	
1000-3	0.0	0.0	0.0	0.0	
1000-12	0.0	0.0	0.0	0.0	
1000-48	0.6	0.5	0.6	0.1	Trevorite
1000-192	0.6	0.7	0.7	0.1	Trevorite
1000-768	0.9	0.9	0.9	0.0	Trevorite
1100-0.75	0	0.0	0.0	0.0	
1100-3	0	0.0	0.0	0.0	
1100-12	0	0.0	0.0	0.0	
1100-48	0	0.0	0.0	0.0	
1100-192	0	0.0	0.0	0.0	
1100-768	0.4	0.4	0.4	0.0	Trevorite

4.

Attachment I - Quantitative and Qualitative XRD Results.

			BATCH 3		
			Volume %		
Temp-Time	Sample 1	Sample 2	Average	Standard Dev.	Phases Present
400-0.75	0.0	0.0	0.0	0.0	
400-12	0.0	0.0	0.0	0.0	
400-192	0.0	0.0	0.0	0.0	
500-0.75	0.0	0.0	0.0	0.0	
500-3	0.0	0.0	0.0	0.0	
500-12	0.0	0.0	0.0	0.0	
500-48	0.0	0.0	0.0	0.0	
500-192	0.0	0.0	0.0	0.0	
500-768	0.8	0.8	0.8	0.0	Trevorite, nepheline
600-0.75	0.0	0.0	0.0	0.0	
600-3	1.7	1.6	1.7	0.1	Acmite
600-12	13.5	13.3	13.4	0.1	Acmite
600-48	33.2	33.8	33.5	0.4	Acmite, Li2SiO3
600-192	38.1	39.4	38.8	0.9	Acmite, neph, Li2SiO3
600-768	45.2	44.5	44.9	0.5	Acmite, neph, Li2SiO3
650-0.75	0.7	0.7	0.7	0.0	Trevorite
650-3	3.0	3.0	3.0	0.0	Acmite
700-0.75	0.6	0.6	0.6	0.0	Trevorite
700-3	8.6	8.8	8.7	0.1	Trevorite, acmite
700-12	23.9	23.4	23.7	0.4	Acmite, Li2SiO3
700-48	31.6	32.0	31.8	0.3	Acmite, Li2SiO3
700-192	29.7	28.8	29.3	0.6	Acmite, neph, Li2SiO3
700-768	37.6	38.6	38.1	0.7	Acmite, neph, Li2SiO3
800-0.75	0.7	0.7	0.7	0.0	Trevorite
800-3	2.2	2.0	2.1	0.1	Trevorite, acmite
800-12	2.4	2.4	2.4	0.0	Trevorite, acmite
800-48	3.5	3.5	3.5	0.0	Trevorite, acmite
800-192	10.8	11.2	11.0	0.3	Trevorite, acmite
800-768	16.5	15.6	16.1	0.6	Trevorite, acmite, Li2SiO3
900-0.75	0.6	0.6	0.6	0.0	Trevorite
900-3	0.8	0.8	0.8	0.0	Trevorite
900-12	1.2	1.2	1.2	0.0	Trevorite
900-48	1.5	1.5	1.5	0.0	Trevorite
900-192	1.8	1.8	1.8	0.0	Trevorite
900-768	1.6	1.5	1.6	0.1	Trevorite
1000-0.75	0.0	0.0	0.0	0.0	
1000-3	0.0	0.0	0.0	0.0	
1000-12	0.0	0.0	0.0	0.0	
1000-48	0.6	0.6	0.6	0.0	Trevorite
1000-192	0.5	0.7	0.6	0.1	Trevorite
1000-768	0.8	0.7	0.8	0.1	Trevorite
1100-0.75	0.0	0.0	0.0	0.0	
1100-3	0.0	0.0	0.0	0.0	
1100-12	0.0	0.0	0.0	0.0	
1100-48	0.0	0.0	0.0	0.0	
1100-192	0.5	0.0	0.3	0.4	Trevorite
1100-768	0.7	0.7	0.7	0.0	Trevorite

4.

Attachment I - Quantitative and Qualitative XRD Results

BATCH 4					
Volume %					
Temp-Time	Sample 1	Sample 2	Average	Standard Dev.	Phases Present
400-0.75	0.0	0.0	0.0	0.0	
400-12	0.0	0.0	0.0	0.0	
400-192	0.5	0.6	0.6	0.1	Trevorite
500-0.75	0.0	0.0	0.0	0.0	
500-3	0.0	0.0	0.0	0.0	
500-12	0.6	0.0	0.3	0.4	Trevorite
500-48	0.0	0.6	0.3	0.4	Trevorite
500-192	0.6	0.6	0.6	0.0	Trevorite
500-768	0.6	0.6	0.6	0.0	Trevorite
600-0.75	0.7	0.8	0.8	0.1	Trevorite
600-3	0.6	0.6	0.6	0.0	Trevorite
600-12	5.9	5.7	5.8	0.1	Acmite
600-48	37.0	35.7	36.4	0.9	Acmite, Li ₂ SiO ₃
600-192	44.2	42.4	43.3	1.3	Acmite, neph, Li ₂ SiO ₃
600-768	47.9	47.3	47.6	0.4	Acmite, neph, Li ₂ SiO ₃
650-0.75	0.8	0.8	0.8	0.0	Trevorite
650-3	2.6	2.6	2.6	0.0	Trevorite
700-0.75	1.1	1.1	1.1	0.0	Trevorite
700-3	0.9	0.9	0.9	0.0	Trevorite, acmite
700-12	2.5	2.8	2.7	0.2	Acmite
700-48	26.1	25.4	25.8	0.5	Acmite, Li ₂ SiO ₃
700-192	29.3	28.8	29.1	0.4	Acmite, Li ₂ SiO ₃
700-490	36.1	34.6	35.4	1.1	Acmite, Li ₂ SiO ₃
700-768	33.6	34.3	34.0	0.5	Acmite, neph, Li ₂ SiO ₃
800-0.75	2.4	2.3	2.4	0.1	Trevorite
800-2	12.4	13.4	12.9	0.7	Trevorite, acmite
800-3	3.1	3.0	3.1	0.1	Trevorite, acmite
800-12	3.0	3.2	3.1	0.1	Trevorite, acmite
800-48	3.4	3.2	3.3	0.1	Trevorite, acmite
800-192	8.4	7.7	8.1	0.5	Trevorite, acmite
800-363	17.2	15.7	16.5	1.1	Trevorite, acmite, Li ₂ SiO ₃
800-768	10.6	10.8	10.7	0.1	Trevorite, acmite, Li ₂ SiO ₃
900-0.75	1.6	1.6	1.6	0.0	Trevorite
900-3	1.6	1.6	1.6	0.0	Trevorite
900-12	2.0	1.9	2.0	0.1	Trevorite
900-48	2.2	2.2	2.2	0.0	Trevorite
900-192	2.4	2.5	2.5	0.1	Trevorite
900-511	2.7	2.7	2.7	0.0	Trevorite
900-768	2.0	2.0	2.0	0.0	Trevorite
1000-0.75	0.0	0.0	0.0	0.0	
1000-3	0.0	0.0	0.0	0.0	
1000-12	0.0	0.0	0.0	0.0	
1000-48	0.7	0.6	0.7	0.1	Trevorite
1000-192	0.7	0.7	0.7	0.0	Trevorite
1000-768	1.5	1.4	1.5	0.1	Trevorite
1100-0.75	0.0	0.0	0.0	0.0	
1100-3	0.0	0.0	0.0	0.0	
1100-12	0.0	0.0	0.0	0.0	
1100-48	0.0	0.0	0.0	0.0	
1100-192	0.5	0.6	0.6	0.1	Trevorite
1100-768	0.5	0.6	0.6	0.1	Trevorite

Attachment I - Quantitative and Qualitative XRD Results

			HM		
			Volume %		
Temp-Time	Sample 1	Sample 2	Average	Standard Dev.	Phases Present
400-0.75	0.0	0.0	0.0	0.0	
400-12	0.0	0.0	0.0	0.0	
400-192	0.6	0.5	0.6	0.1	Trevorite, (RuO2)
500-0.75	0.0	0.0	0.0	0.0	
500-3	0.0	0.0	0.0	0.0	
500-12	0.0	0.0	0.0	0.0	
500-48	0.0	0.0	0.0	0.0	
500-192	0.0	0.0	0.0	0.0	
500-768	0.0	0.0	0.0	0.0	
600-0.75	0.0	0.0	0.0	0.0	
600-3	0.0	0.0	0.0	0.0	
600-12	2.8	2.5	2.7	0.2	Acmite
600-48	23.4	24.1	23.8	0.5	Acmite, Li2SiO3
600-192	24.8	25.1	25.0	0.2	Acmite, Li2SiO3
600-768	45.2	40.6	42.9	3.3	Acmite, neph, Li2SiO3
650-0.75	0.0	0.0	0.0	0.0	
650-3	0.4	0.5	0.5	0.1	Trevorite
700-0.75	0.0	0.0	0.0	0.0	
700-3	0.8	0.7	0.8	0.1	Acmite
700-12	19.5	19.1	19.3	0.3	Acmite
700-48	24.9	24.9	24.9	0.0	Acmite, neph, Li2SiO3
700-192	27.8	27.9	27.9	0.1	Acmite, neph, Li2SiO3
700-768	25.9	26.5	26.2	0.4	Acmite, neph, Li2SiO3
800-0.75	0.0	0.0	0.0	0.0	
800-3	0.6	0.6	0.6	0.0	Trevorite
800-12	0.9	1.0	1.0	0.1	Trevorite
800-48	1.2	1.2	1.2	0.0	Trevorite
800-192	1.8	1.8	1.8	0.0	Trevorite, Acmite
800-768	12.2	12.3	12.3	0.1	Trevorite, acmite, Li2SiO3
900-0.75	0.0	0.0	0.0	0.0	
900-3	0.0	0.0	0.0	0.0	
900-12	0.5	0.6	0.6	0.1	Trevorite
900-48	0.7	0.7	0.7	0.0	Trevorite
900-192	0.8	0.8	0.8	0.0	Trevorite
900-768	0.9	0.9	0.9	0.0	Trevorite
1000-0.75	0.0	0.0	0.0	0.0	
1000-3	0.0	0.0	0.0	0.0	
1000-12	0.0	0.0	0.0	0.0	
1000-48	0.0	0.0	0.0	0.0	
1000-192	0.0	0.0	0.0	0.0	
1000-768	0.7	0.7	0.7	0.0	Trevorite
1100-0.75	0.0	0.0	0.0	0.0	
1100-3	0.0	0.0	0.0	0.0	
1100-12	0.0	0.0	0.0	0.0	
1100-48	0.0	0.0	0.0	0.0	
1100-192	0.6	0.0	0.3	0.4	Trevorite, RuO2
1100-768	0.0	0.0	0.0	0.0	

Attachment I - Quantitative and Qualitative XRD Results.

Temp-Time	Sample 1	Sample 2	Purex	Standard Dev.	Phases Present
			Volume % Average		
400-0.75	0.0	0.0	0.0	0.0	
400-12	0.0	0.0	0.0	0.0	
400-192	0.0	0.0	0.0	0.0	
500-0.75	0.0	0.0	0.0	0.0	
500-3	0.0	0.0	0.0	0.0	
500-12	0.0	0.0	0.0	0.0	
500-48	0.0	0.0	0.0	0.0	
500-192	0.0	0.0	0.0	0.0	
500-768	1.0	1.1	1.1	0.1	Nepheline
600-0.75	0.3	0.3	0.3	0.0	Nepheline
600-3	0.6	0.5	0.6	0.1	Nepheline
600-12	1.4	1.4	1.4	0.0	Nepheline
600-48	1.8	1.5	1.7	0.2	Nepheline
600-192	1.6	1.6	1.6	0.0	Acmite, nepheline
600-768	6.1	6.3	6.2	0.1	Acmite, nepheline
650-0.75	0.6	0.4	0.5	0.1	Nepheline
650-3	1.5	1.4	1.5	0.1	Nepheline
700-0.75	0.0	0.0	0.0	0.0	
700-3	0.0	0.0	0.0	0.0	
700-12	2.0	1.5	1.8	0.4	Nepheline
700-48	4.3	3.9	4.1	0.3	Acmite, neph
700-192	16.6	14.2	15.4	1.7	Acmite, nepheline
700-768	23.1	22.8	23.0	0.2	Acmite, nepheline
800-0.75	0.9	1.2	1.1	0.2	Trevorite, nepheline
800-3	1.0	1.0	1.0	0.0	Trevorite, nepheline
800-12	1.3	1.3	1.3	0.0	Trevorite, nepheline
800-48	2.3	2.3	2.3	0.0	Trevorite, nepheline
800-192	3.7	3.8	3.8	0.1	Trevorite, nepheline
800-768	5.7	5.6	5.7	0.1	Trevorite, acmite, neph
900-0.75	1.2	1.1	1.2	0.1	Trevorite, nepheline
900-3	1.3	1.6	1.5	0.2	Trevorite, nepheline
900-12	1.7	1.5	1.6	0.1	Trevorite, nepheline
900-48	1.6	1.4	1.5	0.1	Trevorite, nepheline
900-126	1.8	2.0	1.9	0.1	Trevorite, nepheline
900-192	2.4	2.2	2.3	0.1	Trevorite, nepheline
900-768	1.8	1.9	1.9	0.1	Trevorite, nepheline
1000-0.75	0.0	0.0	0.0	0.0	
1000-3	0.7	0.6	0.7	0.1	Trevorite
1000-12	0.8	0.7	0.8	0.1	Trevorite
1000-48	1.0	1.1	1.1	0.1	Trevorite, Mg-Al-O
1000-192	1.4	1.3	1.4	0.1	Trevorite, Mg-Al-O
1000-768	3.5	3.5	3.5	0.0	Trevorite, nepheline
1100-0.75	0.0	0.0	0.0	0.0	
1100-3	0.0	0.0	0.0	0.0	
1100-12	0.7	0.6	0.7	0.1	Trevorite, Mg-Al-O
1100-48	1.0	0.8	0.9	0.1	Trevorite, Mg-Al-O
1100-192	1.5	1.6	1.6	0.1	Trevorite, Mg-Al-O
1100-768	0.9	0.8	0.9	0.1	Trevorite

Attachment I - Quantitative and Qualitative XRD Results

			BLEND		
			Volume %		
Temp-Time	Sample 1	Sample 2	Average	Standard Dev.	Phases Present
400-0.75	0.0	0.0	0.0	0.0	
400-12	0.0	0.0	0.0	0.0	
400-192	0.0	0.0	0.0	0.0	
500-0.75	0.0	0.0	0.0	0.0	
500-3	0.0	0.0	0.0	0.0	
500-12	0.0	0.0	0.0	0.0	
500-48	0.0	0.0	0.0	0.0	
500-192	0.0	0.0	0.0	0.0	
500-768	0.8	0.8	0.8	0.0	acmite
600-0.75	0.0	0.0	0.0	0.0	
600-3	0.7	0.6	0.7	0.1	Acmite
600-12	4.8	5.0	4.9	0.1	Acmite
600-48	29.6	32.1	30.9	1.8	Acmite, Li ₂ SiO ₃
600-192	36.1	35.2	35.7	0.6	Acmite, neph, Li ₂ SiO ₃
600-768	41.6	43.7	42.7	1.5	Acmite, neph, Li ₂ SiO ₃
650-0.75	0.5	0.5	0.5	0.0	Trevorite
650-3	0.6	0.6	0.6	0.0	Trevorite
650-4	2.7	2.4	2.6	0.2	Acmite
700-0.75	0.0	0.0	0.0	0.0	
700-3	3.1	2.7	2.9	0.3	Acmite
700-12	20.2	19.2	19.7	0.7	Acmite, Li ₂ SiO ₃
700-48	27.1	28.3	27.7	0.8	Acmite, Li ₂ SiO ₃
700-192	34.9	34.9	34.9	0.0	Acmite, neph, Li ₂ SiO ₃
700-768	35.1	34.3	34.7	0.6	Acmite, neph, Li ₂ SiO ₃
800-0.75	0.6	0.7	0.7	0.1	Trevorite
800-3	2.0	1.9	2.0	0.1	Trevorite, acmite
800-12	2.0	2.1	2.1	0.1	Trevorite, acmite
800-48	6.9	7.7	7.3	0.6	Trevorite, acmite
800-192	13.7	12.0	12.9	1.2	Trevorite, acmite
800-768	9.9	9.6	9.8	0.2	Trevorite, acmite, Li ₂ SiO ₃
900-0.75	0.0	0.0	0.0	0.0	
900-3	0.7	0.7	0.7	0.0	Trevorite
900-12	0.9	1.0	1.0	0.1	Trevorite
900-48	1.2	1.2	1.2	0.0	Trevorite
900-192	1.5	1.5	1.5	0.0	Trevorite
900-768	1.4	1.5	1.5	0.1	Trevorite
1000-0.75	0.0	0.0	0.0	0.0	
1000-3	0.0	0.0	0.0	0.0	
1000-12	0.0	0.0	0.0	0.0	
1000-48	0.0	0.6	0.3	0.4	Trevorite
1000-192	0.7	0.7	0.7	0.0	Trevorite
1000-768	0.7	0.7	0.7	0.0	Trevorite
1100-0.75	0.0	0.0	0.0	0.0	
1100-3	0.0	0.0	0.0	0.0	
1100-12	0.0	0.0	0.0	0.0	
1100-48	0.0	0.0	0.0	0.0	
1100-192	0.0	0.0	0.0	0.0	
1100-768	0.6	0.6	0.6	0.0	Trevorite

ATTACHMENT II
PCT RESULTS (IN PPM) FOR EACH OF THE SEVEN GLASS COMPOSITIONS

	BATCH 1												
Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	Al	Fe	Mn	Mg	Ca	Ni	pH
400-0.75	15.60	89.42	41.41	44.42	11.97	14.02	6.05	3.05	0.26	0.30	0.10	0.05	9.49
400-12	17.02	93.02	44.84	45.92	11.92	14.97	6.78	3.82	0.34	0.37	0.17	0.05	9.50
400-192	13.35	80.86	37.73	32.44	10.78	12.51	6.66	2.93	0.25	0.32	0.11	0.04	9.44
500-0.75	15.05	85.72	42.11	41.39	11.46	13.98	5.49	2.62	0.26	0.33	0.10	0.01	9.69
500-3	14.46	87.07	42.88	41.39	10.63	13.64	7.40	3.26	0.30	0.34	0.12	0.06	9.89
500-12	13.15	75.82	38.84	40.07	10.40	12.53	8.18	3.59	0.33	0.32	0.13	0.07	9.60
500-48	14.65	86.47	40.48	42.08	11.24	13.54	5.69	2.98	0.28	0.34	0.07	0.10	9.50
500-192	13.88	83.85	38.68	40.84	10.25	13.09	7.66	3.72	0.36	0.36	0.15	0.08	9.72
500-768	13.74	80.86	39.45	38.08	17.40	12.87	9.98	4.23	0.42	0.31	0.00	0.12	9.17
600-0.75	15.51	92.23	43.22	43.07	11.93	13.95	5.30	2.92	0.25	0.31	0.06	0.00	9.56
600-3	15.40	88.76	42.70	44.34	11.92	14.20	5.57	2.93	0.25	0.33	0.08	0.03	9.54
600-12	15.51	91.47	42.86	41.66	12.39	14.37	6.32	3.62	0.37	0.41	0.12	0.06	9.54
600-48	152.56	345.99	231.00	252.76	69.05	145.76	6.44	2.30	3.70	1.69	0.01	0.12	11.14
600-192	147.56	327.83	210.84	224.49	67.84	144.21	0.15	0.00	0.04	0.05	0.20	0.08	11.16
600-768	182.68	316.77	231.34	195.26	71.04	157.68	2.14	0.01	0.12	0.06	0.35	0.08	11.22
650-0.75	15.24	91.36	42.94	39.53	12.02	13.98	6.44	3.27	0.31	0.35	0.17	0.07	9.33
650-3	14.58	87.31	41.41	45.32	13.73	13.53	6.25	3.40	0.33	0.38	0.10	0.05	9.26
700-0.75	15.33	85.85	41.62	36.57	11.33	13.59	5.98	3.13	0.30	0.40	0.11	0.03	9.80
700-3	15.00	85.91	39.93	39.28	11.38	13.83	6.46	3.64	0.44	0.47	0.09	0.00	9.67
700-12	42.75	109.89	79.10	80.70	21.99	30.68	9.45	6.29	1.87	0.86	0.10	0.12	10.13
700-48	165.40	289.52	225.80	247.55	66.92	137.94	7.00	2.02	2.30	1.05	0.24	0.12	11.21
700-192	185.67	279.11	252.57	267.50	65.25	130.00	19.82	7.86	12.18	5.58	0.09	1.11	11.24
700-768	172.88	254.06	250.36	252.52	76.30	134.19	20.43	7.12	11.63	5.68	0.27	0.69	11.41
800-0.75	14.54	88.39	40.69	40.29	11.31	13.75	6.04	3.05	0.30	0.37	0.10	0.01	9.57
800-3	15.04	92.31	41.38	41.39	11.24	14.25	6.07	2.91	0.28	0.38	0.12	0.01	9.77
800-12	14.57	90.91	40.74	40.69	11.52	14.04	6.12	3.17	0.33	0.45	0.13	0.00	9.61
800-48	16.87	89.68	38.83	44.50	11.32	14.80	7.76	3.88	0.57	0.54	0.08	0.01	9.88
800-192	25.03	87.48	54.20	50.48	13.34	19.81	9.63	5.13	1.27	0.67	0.11	0.09	9.65
800-768	29.62	85.50	58.61	51.56	15.60	21.48	11.81	6.15	1.92	0.91	0.16	0.17	10.01
900-0.75	15.38	91.65	41.41	43.68	11.95	14.35	6.20	3.29	0.30	0.35	0.12	0.05	9.54
900-3	12.58	70.46	32.39	41.02	9.99	11.52	5.49	2.19	0.18	0.25	0.11	0.00	9.61
900-12	13.63	83.17	36.61	39.59	11.02	13.45	6.99	3.01	0.29	0.42	0.13	0.00	9.56
900-48	14.94	84.00	36.88	40.44	11.07	13.49	7.13	3.57	0.37	0.47	0.10	0.02	9.67
900-192	14.29	85.80	41.31	37.96	10.24	13.56	6.36	3.49	0.37	0.47	0.12	0.01	9.45
900-768	11.50	78.55	35.18	34.79	10.35	11.32	8.54	3.39	0.36	0.50	0.14	0.00	9.17
1000-0.75	13.86	82.68	39.83	41.65	10.71	13.09	6.23	2.86	0.26	0.34	0.10	0.02	9.73
1000-3	12.57	74.15	33.40	36.58	10.41	11.81	7.62	2.87	0.26	0.34	0.09	0.07	9.56
1000-12	12.58	75.86	35.25	37.95	10.10	11.85	7.57	2.71	0.26	0.32	0.08	0.06	9.50
1000-48	13.22	78.72	38.16	38.55	10.56	13.03	8.13	3.34	0.31	0.38	0.12	0.00	9.81
1000-192	10.69	69.92	31.87	30.06	8.95	10.93	10.72	2.69	0.24	0.35	0.13	0.03	9.51
1000-768	8.80	62.64	25.95	25.61	8.55	9.47	17.22	3.02	0.29	0.38	0.19	0.02	9.07
1100-0.75	12.89	78.07	38.62	38.25	9.81	12.54	8.80	3.21	0.31	0.36	0.12	0.06	9.60
1100-3	11.51	68.55	35.32	35.72	8.82	11.55	11.69	3.35	0.33	0.38	0.15	0.06	9.74
1100-12	12.70	76.66	37.66	35.28	9.88	12.56	9.22	3.09	0.28	0.35	0.09	0.05	9.59
1100-48	10.93	69.19	31.56	8.98	8.93	11.07	11.26	2.61	0.22	0.30	0.09	0.02	9.57
1100-192	8.43	59.01	23.79	1.09	7.09	9.15	15.26	2.13	0.18	0.29	0.10	0.00	9.63
1100-768	6.84	53.56	17.40	19.36	9.93	8.37	21.36	2.04	0.21	0.28	0.00	0.01	9.04
Non-annealed	15.57	89.06	44.21	42.36	11.66	15.00	7.35	3.52	0.31	0.35	0.10	0.07	9.67

	BATCH 2												
Temp-Time	B	Si	Na	Na (AA)	K (AA)	U	Al	Fe	Mn	Mg	Ca	Ni	pH
400-0.75	13.22	82.26	35.83	37.96	9.96	12.33	5.88	2.27	0.19	0.28	0.08	0.05	9.40
400-12	13.27	79.19	36.52	37.83	9.43	12.30	9.48	2.66	0.23	0.31	0.06	0.07	9.49
400-192	12.29	78.08	35.78	31.56	9.70	11.68	8.84	2.63	0.23	0.32	0.11	0.07	9.39
500-0.75	12.89	79.96	36.94	36.30	9.94	12.33	5.24	2.19	0.18	0.29	0.07	0.04	9.54
500-3	14.04	88.43	39.95	36.84	9.64	13.39	5.90	2.50	0.22	0.31	0.10	0.07	9.75
500-12	13.28	83.01	37.85	39.11	10.10	12.62	4.94	2.28	0.19	0.28	0.07	0.04	9.49
500-48	12.93	80.77	35.92	35.89	9.54	12.26	6.08	2.49	0.25	0.33	0.07	0.11	9.50
500-192	12.90	79.75	36.04	37.37	8.92	12.39	8.19	2.63	0.25	0.30	0.12	0.07	9.64
500-768	13.74	76.07	36.28	33.28	14.76	12.16	7.80	2.37	0.22	0.23	0.00	0.07	9.06
600-0.75	13.67	86.02	38.89	39.46	10.43	12.78	5.50	2.25	0.18	0.29	0.05	0.01	9.53
600-3	14.47	91.13	41.87	40.81	10.86	13.61	4.52	2.37	0.19	0.31	0.08	0.00	9.56
600-12	28.57	99.12	59.85	57.04	15.18	22.53	7.99	4.34	0.96	0.77	0.06	0.11	9.83
600-48	193.22	537.15	314.94	337.18	99.61	194.10	1.05	0.00	0.00	0.00	0.00	0.00	11.27
600-192	187.95	456.74	246.92	261.78	74.22	171.93	0.15	0.00	0.01	0.02	0.20	0.08	11.13
600-768	173.88	388.03	255.89	254.21	72.73	159.49	0.15	0.01	0.02	0.03	0.19	0.08	11.28
650-0.75	15.26	79.35	38.29	35.92	9.92	13.04	8.00	2.75	0.26	0.35	0.13	0.08	9.33
650-3	14.15	86.89	39.48	42.87	13.37	13.35	5.72	2.80	0.29	0.44	0.09	0.01	9.29
700-0.75	14.11	85.27	37.76	37.43	10.14	13.06	5.04	2.45	0.22	0.35	0.07	0.03	9.85
700-3	17.70	88.51	44.22	44.69	11.18	15.81	6.94	3.46	0.55	0.54	0.06	0.00	9.66
700-12	114.80	251.21	184.28	182.52	44.87	75.91	4.32	5.84	3.14	1.62	0.03	0.38	10.57
700-48	199.15	490.46	286.59	314.74	83.37	184.79	0.57	0.00	0.00	0.02	0.32	0.08	11.33
700-192	186.07	474.88	255.23	288.28	71.06	164.33	1.92	0.00	0.02	0.00	0.00	0.00	11.25
700-768	173.18	432.76	273.10	270.57	89.54	171.59	1.41	0.04	0.10	0.09	0.28	0.08	11.44
800-0.75	13.59	87.30	37.12	38.25	10.51	12.97	5.01	2.25	0.20	0.32	0.10	0.02	9.13
800-3	14.04	89.00	38.28	39.07	10.28	13.39	5.72	2.32	0.22	0.34	0.11	0.03	9.63
800-12	13.45	88.61	40.64	38.76	10.73	13.21	5.42	2.49	0.24	0.41	0.10	0.02	9.53
800-48	14.14	89.72	35.52	41.76	10.41	13.55	6.10	29.10	0.34	0.52	0.05	0.01	9.73
800-192	19.56	83.28	45.26	45.98	10.90	16.44	8.61	5.33	1.21	0.83	0.12	0.26	9.48
800-768	25.36	85.40	55.96	56.00	14.61	19.67	8.31	4.65	1.13	0.76	0.12	0.24	9.78
900-0.75	14.12	85.78	37.57	40.37	10.88	13.49	5.76	2.60	0.24	0.34	0.09	0.06	9.50
900-3	15.22	92.56	42.36	44.64	11.64	14.47	5.85	3.16	0.29	0.37	0.14	0.00	9.65
900-12	13.81	88.36	39.10	40.27	11.01	13.72	5.97	2.44	0.21	0.33	0.11	0.01	9.54
900-48	15.79	81.78	39.27	41.47	10.15	13.82	7.56	4.11	0.47	0.50	0.13	0.11	9.56
900-192	13.45	86.10	39.21	35.18	9.18	13.00	6.11	3.16	0.33	0.46	0.11	0.06	9.38
900-768	10.62	74.07	32.73	32.34	9.53	10.78	9.83	2.92	0.30	0.48	0.14	0.04	9.14
1000-0.75	13.14	87.14	39.37	38.91	10.32	12.68	5.40	2.46	0.21	0.32	0.11	0.03	9.56
1000-3	13.01	80.80	34.60	37.60	10.20	12.42	6.25	2.40	0.22	0.32	0.08	0.08	9.52
1000-12	11.46	72.92	30.75	34.64	10.01	11.23	7.78	2.43	0.22	0.30	0.09	0.09	9.52
1000-48	11.06	70.65	33.41	31.87	8.39	11.28	10.84	2.47	0.23	0.31	0.11	0.07	9.60
1000-192	9.70	87.88	28.39	5.97	8.24	10.14	9.87	2.11	0.18	0.30	0.11	0.03	9.47
1000-768	8.89	65.62	26.21	25.77	7.96	10.10	15.65	2.77	0.26	0.41	0.17	0.04	9.07
1100-0.75	12.27	78.48	37.56	35.81	9.45	12.13	8.83	2.51	0.23	0.32	0.10	0.07	9.51
1100-3	12.85	79.74	37.20	38.81	10.21	12.74	6.04	2.35	0.21	0.31	0.08	0.00	9.75
1100-12	11.93	78.18	33.83	35.10	9.39	11.84	5.44	2.07	0.17	0.29	0.06	0.00	9.63
1100-48	10.18	71.56	29.80	30.47	7.94	10.43	8.32	1.96	0.16	0.28	0.10	0.02	9.51
1100-192	8.25	61.08	22.93	-0.12	6.85	9.27	14.06	2.15	0.19	0.29	0.12	0.04	9.48
1100-768	6.32	54.14	15.70	18.85	9.66	8.10	19.13	1.93	0.19	0.28	0.00	0.03	8.91
Non-annealed	13.17	80.10	38.51	37.46	10.48	12.79	8.40	2.61	0.24	0.30	0.08	0.08	9.55

	BATCH 3												
Temp-Time	B	Si	Na	Na (AA)	K (AA)	U	Al	Fe	Mn	Mg	Ca	N	pH
400-0.75	18.18	103.87	46.81	49.52	12.96	16.06	3.45	2.72	0.26	0.30	0.06	0.09	9.46
400-12	18.69	99.84	47.19	47.98	12.54	15.59	4.95	2.90	0.27	0.32	0.04	0.09	9.56
400-192	13.68	82.98	38.07	33.99	10.51	12.62	6.37	2.71	0.26	0.33	0.08	0.09	9.41
500-0.75	14.76	82.16	40.62	41.01	10.74	13.47	5.12	2.71	0.28	0.35	0.07	0.08	9.56
500-3	19.21	111.08	51.41	50.73	13.15	17.10	3.82	3.18	0.32	0.35	0.09	0.12	9.82
500-12	15.08	83.73	41.47	42.03	10.89	13.59	5.46	3.10	0.31	0.34	0.07	0.12	9.57
500-48	16.70	97.59	43.85	44.91	12.50	14.80	3.52	2.63	0.27	0.33	0.05	0.13	9.51
500-192	17.00	99.33	44.02	45.21	11.37	15.11	4.09	2.90	0.29	0.34	0.09	0.09	9.64
500-768-2	17.07	91.46	44.32	44.64	12.03	14.93	6.06	3.81	0.37	0.34	1.24	0.16	9.69
600-0.75	17.14	101.11	46.45	47.32	12.49	15.05	3.47	2.53	0.24	0.31	0.02	0.04	9.55
600-3	18.99	112.51	49.21	49.29	13.84	16.65	3.35	3.02	0.31	0.36	0.07	0.09	9.47
600-12	92.49	292.15	170.90	169.43	49.45	67.92	2.04	7.29	2.48	1.66	0.06	0.31	10.19
600-48	397.01	1053.53	640.12	645.85	227.78	309.63	0.08	0.01	0.01	0.00	0.27	0.07	11.34
600-192	346.35	928.31	542.19	576.76	223.79	281.15	0.15	0.00	0.01	0.00	0.18	0.08	11.21
600-768	340.20	649.07	535.02	461.21	219.21	289.85	0.15	0.01	0.01	0.00	0.17	0.08	11.47
650-0.75	18.38	103.48	47.73	41.86	13.82	15.94	4.32	3.42	0.36	0.42	0.10	0.12	9.36
650-3	18.35	101.36	47.27	50.46	14.97	16.01	3.97	3.43	0.38	0.43	0.08	0.12	9.34
700-0.75	18.65	108.69	48.04	43.16	13.11	16.51	2.85	2.68	0.26	0.34	0.06	0.04	9.63
700-3	40.44	151.54	82.74	83.99	22.71	30.43	3.03	5.36	1.12	0.78	0.07	0.10	10.02
700-12	341.00	714.24	587.23	588.05	160.85	213.53	0.03	0.03	0.00	0.01	0.25	0.08	11.08
700-48	419.61	970.80	625.33	697.97	247.78	296.18	0.14	0.00	0.00	0.01	0.32	0.08	11.44
700-192	394.57	924.44	652.89	688.73	220.80	277.78	0.15	0.00	0.01	0.00	0.20	0.08	11.49
700-768	368.16	883.39	589.86	473.51	198.43	276.02	1.13	0.10	0.02	0.02	0.31	0.11	11.24
800-0.75	17.58	106.52	45.73	46.16	13.41	15.78	3.07	2.71	0.26	0.34	0.08	0.03	9.26
800-3	17.07	100.79	44.31	44.57	12.33	15.44	3.56	2.84	0.31	0.40	0.09	0.06	9.61
800-12	19.19	115.14	54.18	51.92	14.20	17.47	3.50	3.16	0.37	0.33	0.08	0.05	9.61
800-48	18.29	108.05	46.98	52.61	13.48	17.11	3.94	3.29	0.40	0.49	0.09	0.03	9.46
800-192	32.94	133.84	72.09	68.90	18.55	25.47	3.28	4.43	0.79	0.63	0.06	0.13	9.65
800-768	64.51	205.46	126.80	140.98	34.83	45.83	2.44	6.91	1.82	1.17	0.11	0.39	9.98
900-0.75	17.49	97.42	44.83	47.77	12.17	15.77	5.17	3.08	0.32	0.36	0.11	0.10	9.60
900-3	18.72	111.35	49.44	51.91	13.42	16.98	2.90	2.91	0.29	0.35	0.11	0.03	9.64
900-12	17.47	104.48	46.67	47.66	13.20	16.24	3.61	2.62	0.28	0.38	0.07	0.03	9.55
900-48	21.12	112.88	52.63	56.09	14.76	18.07	4.03	4.33	0.52	0.52	0.08	0.14	9.60
900-192	17.83	103.62	48.54	42.55	12.15	16.03	3.76	3.47	0.39	0.47	0.10	0.08	9.47
900-768	12.30	81.33	35.99	35.40	10.55	11.86	7.16	3.23	0.36	0.48	0.13	0.06	9.17
1000-0.75	18.08	106.25	48.57	25.88	13.77	16.03	2.91	2.63	0.27	0.32	0.09	0.07	9.79
1000-3	18.11	104.28	44.10	49.51	13.28	15.65	3.18	2.84	0.28	0.34	0.05	0.13	9.52
1000-12	13.93	84.59	36.59	34.25	10.80	12.92	6.59	2.66	0.25	0.32	0.09	0.09	9.60
1000-48	12.17	75.27	35.16	35.80	9.25	11.80	8.60	2.63	0.26	0.32	0.11	0.08	9.64
1000-192	10.86	74.05	30.86	26.66	8.98	10.81	7.92	2.47	0.23	0.33	0.10	0.06	9.45
1000-768	8.77	66.80	25.05	24.63	8.41	9.73	14.57	3.03	0.31	0.38	0.17	0.06	9.03
1100-0.75	17.63	102.69	48.38	49.36	12.61	15.87	3.66	2.86	0.30	0.36	0.08	0.09	9.70
1100-3	15.49	89.78	42.22	18.07	11.04	14.12	5.31	2.78	0.29	0.35	0.08	0.09	9.73
1100-12	15.38	96.15	43.50	43.49	11.61	14.16	4.22	2.85	0.28	0.36	0.06	0.08	9.52
1100-48	11.12	74.70	31.81	33.26	8.74	11.10	7.76	2.16	0.18	0.27	0.09	0.02	9.63
1100-192	8.77	64.49	24.16	2.22	7.59	9.55	14.02	2.50	0.23	0.30	0.12	0.06	9.41
1100-768	6.55	54.12	15.26	17.84	9.86	8.24	19.24	2.40	0.25	0.31	0.00	0.05	8.84
Non-annealed	17.57	98.97	47.69	45.85	12.82	15.64	4.42	2.81	0.27	0.31	0.05	0.11	9.56

	BATCH 4												
Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	Al	Fe	Mn	Mg	Ca	Ni	pH
400-0.75	19.71	98.08	49.17	52.00	15.29	15.70	3.73	2.26	0.38	0.28	0.05	0.06	9.52
400-12	20.59	101.75	50.87	51.67	15.42	16.02	4.64	2.60	0.41	0.28	0.05	0.08	9.63
400-192	20.26	98.52	52.46	45.64	15.49	16.08	4.04	2.59	0.43	0.31	0.07	0.08	9.61
500-0.75	20.74	99.73	54.13	53.91	15.98	16.65	3.09	2.35	0.40	0.29	0.04	0.05	9.66
500-3	21.68	107.47	55.24	46.25	15.57	17.30	3.41	2.34	0.41	0.29	0.04	0.09	9.90
500-12	18.93	89.77	49.94	50.64	14.18	15.34	3.95	2.47	0.44	0.31	0.03	0.07	9.66
500-48	20.38	100.18	52.17	52.02	14.75	16.32	3.86	2.63	0.49	0.33	0.05	0.13	9.66
500-192	20.57	103.53	51.19	57.64	15.08	16.29	3.63	2.54	0.45	0.31	0.05	0.08	9.72
500-768	22.14	94.48	52.41	52.76	23.36	16.56	5.04	2.99	0.55	0.28	0.00	0.11	9.53
600-0.75	20.91	104.89	54.20	54.07	15.96	16.64	2.88	2.32	0.42	0.32	0.00	0.02	9.63
600-3	21.90	108.29	57.61	55.12	16.33	17.51	2.13	2.32	0.39	0.31	0.04	0.00	9.81
600-12	23.89	106.48	56.50	64.60	19.03	18.54	3.23	3.27	0.72	0.44	0.03	0.11	9.71
600-48	420.71	923.02	684.74	680.29	280.07	306.80	0.00	0.00	0.00	0.00	0.00	0.00	11.39
600-192	369.60	792.99	535.56	544.03	250.96	281.89	0.15	0.00	0.01	0.00	0.21	0.08	11.37
600-768	386.86	775.41	552.22	456.14	204.46	290.83	0.15	0.01	0.01	0.00	0.11	0.08	11.63
650-0.75	21.39	107.86	55.94	45.84	18.38	17.13	3.67	2.96	0.54	0.39	0.07	0.10	9.48
650-3	25.92	108.41	61.57	63.40	18.91	19.50	4.02	3.05	0.66	0.46	0.06	0.01	9.56
700-0.75	22.09	101.12	54.91	48.51	15.66	17.23	3.58	2.80	0.55	0.40	0.05	0.04	9.72
700-3	22.84	106.61	56.88	57.21	17.71	18.04	3.60	3.07	0.70	0.51	0.01	0.00	9.64
700-12	39.65	142.20	64.34	78.79	29.18	28.39	3.20	4.12	1.30	0.64	0.05	0.00	9.98
700-48	471.85	737.54	648.27	741.92	279.85	267.36	0.14	0.00	0.00	0.01	0.28	0.08	11.53
700-192	514.36	848.85	797.48	847.24	305.91	300.59	0.15	0.00	0.01	0.00	0.26	0.08	11.58
700-768	430.43	765.80	646.73	594.59	243.54	282.70	1.41	0.08	0.01	0.02	0.33	0.12	11.45
800-0.75	21.26	104.55	52.41	53.81	15.56	17.02	3.47	2.55	0.51	0.42	0.04	0.00	9.43
800-3	21.72	108.13	54.63	55.61	16.13	17.70	3.26	2.53	0.52	0.44	0.06	0.01	9.80
800-12	22.33	110.31	55.24	53.76	15.69	18.25	3.33	2.88	0.61	0.51	0.07	0.01	9.73
800-48	22.29	105.37	52.37	58.44	15.97	17.86	3.33	2.82	0.61	0.51	0.06	0.01	9.56
800-192	35.91	132.59	79.42	71.51	22.31	26.10	2.81	3.33	0.91	0.52	0.06	0.04	9.79
800-768	49.70	164.59	103.95	84.89	28.94	34.72	2.55	4.14	1.45	0.67	0.07	0.10	9.94
900-0.75	21.21	106.68	53.15	55.48	16.15	17.32	3.37	2.71	0.50	0.37	0.04	0.04	9.66
900-3	22.50	111.97	57.96	57.36	19.67	18.57	3.47	2.68	0.50	0.39	0.05	0.01	9.67
900-12	20.88	104.05	53.03	53.60	15.81	17.22	3.53	2.47	0.47	0.40	0.05	0.01	9.67
900-48	21.87	102.32	52.42	55.51	15.81	16.93	3.86	2.69	0.52	0.40	0.00	0.05	9.64
900-192	20.31	100.02	53.94	50.01	15.31	16.71	5.27	3.26	0.65	0.48*	0.10	0.04	9.51
900-768	13.97	77.38	39.43	39.91	13.61	12.23	7.17	2.93	0.60	0.48	0.10	0.06	9.44
1000-0.75	20.08	102.90	52.94	49.99	15.26	16.31	3.03	2.30	0.40	0.32	0.03	0.06	9.65
1000-3	19.09	95.47	47.82	50.44	15.69	15.15	3.94	2.28	0.38	0.29	0.06	0.10	9.68
1000-12	19.23	96.39	47.98	49.26	15.43	15.19	3.76	2.21	0.37	0.29	0.05	0.09	9.66
1000-48	12.99	69.59	36.86	38.26	10.64	11.37	9.55	2.08	0.36	0.28	0.06	0.03	9.74
1000-192	10.82	62.73	31.62	31.73	9.25	9.92	14.47	2.14	0.36	0.29	0.10	0.03	9.61
1000-768	9.64	60.70	28.29	28.16	9.41	9.41	17.21	2.00	0.33	0.31	0.10	0.03	9.11
1100-0.75	22.61	103.47	58.33	34.27	86.76	17.06	3.29	2.28	0.42	0.30	0.03	0.05	9.88
1100-3	19.42	99.08	52.29	48.03	14.58	15.94	3.65	2.17	0.39	0.29	0.01	0.06	9.68
1100-12	15.98	84.59	42.60	42.52	13.26	13.67	4.13	1.91	0.30	0.27	0.03	0.00	9.81
1100-48	11.62	71.38	33.89	32.84	10.08	10.65	8.71	1.92	0.29	0.27	0.07	0.03	9.48
1100-192	9.23	60.36	26.48	26.20	8.57	9.30	15.95	1.77	0.27	0.26	0.09	0.04	9.52
1100-768	7.37	56.31	18.83	18.80	7.43	8.22	20.80	1.64	0.28	0.29	0.06	0.02	8.87
Non-annealed	20.98	98.86	54.82	52.31	14.68	16.69	4.29	2.55	0.46	0.30	0.02	0.11	9.69

							BLEND						
Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	Al	Fe	Mn	Mg	Ca	Ni	pH
400-0.75	17.42	95.49	44.24	49.28	12.26	15.06	4.73	2.43	0.28	0.32	0.07	0.07	9.81
400-12	18.28	83.96	47.06	47.79	11.40	14.04	9.08	2.51	0.01	0.30	0.03	0.12	9.75
400-192	14.17	83.73	38.90	37.75	11.28	12.80	7.57	2.55	0.29	0.32	0.07	0.08	9.27
500-0.75	16.09	87.97	44.17	44.40	12.10	14.40	5.31	2.45	0.27	0.29	0.06	0.05	9.83
500-3	16.72	93.99	44.37	43.45	12.22	14.81	5.28	2.51	0.30	0.33	0.09	0.11	9.83
500-12	15.31	88.44	43.10	37.76	11.07	13.87	5.61	2.43	0.28	0.31	0.08	0.07	9.71
500-48	15.14	85.18	40.02	41.39	11.90	13.35	5.03	2.21	0.28	0.30	0.05	0.11	9.60
500-192	15.61	86.85	40.21	43.33	10.90	13.61	6.38	2.97	0.37	0.36	0.12	0.11	9.77
500-768	23.36	78.11	45.85	42.51	18.16	15.61	7.48	2.37	0.28	0.61	0.00	0.07	9.40
600-0.75	17.07	98.43	43.28	47.02	13.75	15.06	4.50	2.54	0.29	0.34	0.09	0.07	9.53
600-3	15.00	88.08	42.48	45.46	13.18	13.42	2.90	2.06	0.21	0.29	0.08	0.00	9.54
600-12	42.71	104.03	86.20	45.66	13.29	20.70	4.86	2.75	0.41	0.38	0.06	0.10	9.61
600-48	336.82	833.94	520.27	489.16	160.44	281.27	0.08	0.01	0.01	0.02	0.23	0.07	11.35
600-192	225.05	582.08	315.71	335.06	115.15	208.81	1.47	0.14	0.01	0.00	0.20	0.15	11.24
600-768	245.07	571.99	360.82	303.09	123.96	229.79	0.15	0.01	0.01	0.00	0.22	0.08	11.49
650-0.75	18.61	71.08	39.21	37.50	12.26	13.66	9.84	2.81	0.36	0.35	0.12	0.11	9.52
650-3-2	17.76	96.46	47.72	48.46	16.33	15.61	4.60	2.71	0.32	0.34	0.07	0.07	9.58
700-0.75	17.28	98.83	45.03	41.29	13.40	15.19	3.98	2.42	0.27	0.32	0.07	0.04	9.56
700-3	17.32	91.29	44.40	44.22	12.57	15.02	5.49	2.96	0.43	0.46	0.04	0.00	9.61
700-12	185.28	360.34	282.08	310.61	79.17	115.66	1.93	3.21	2.52	1.20	0.03	0.23	10.88
700-48	291.47	580.33	406.15	500.85	162.51	202.33	0.14	0.00	0.00	0.10	0.30	0.08	11.47
700-192	283.05	553.23	379.83	395.23	118.21	216.22	0.83	0.04	0.01	0.00	0.25	0.09	11.28
700-768	270.88	579.73	397.98	425.28	140.57	226.51	0.50	0.03	0.01	0.02	0.29	0.08	11.43
800-0.75	16.01	93.03	42.10	42.36	12.30	14.39	4.41	2.30	0.26	0.33	0.08	0.05	9.78
800-3	16.40	95.64	41.75	43.40	12.66	14.73	4.52	2.50	0.31	0.39	0.08	0.02	9.59
800-12	16.07	92.17	43.46	44.19	12.53	14.65	4.90	2.66	0.35	0.64	0.15	0.01	9.71
800-48-2	20.59	95.75	48.17	50.05	13.35	16.92	6.45	3.29	0.58	0.56	0.06	0.01	9.49
800-192	30.22	100.27	62.97	57.44	17.26	22.71	6.17	3.59	1.00	0.55	0.07	0.11	9.83
800-768	21.49	93.22	51.61	54.88	15.73	17.25	6.03	3.12	0.63	0.51	0.09	0.06	9.63
900-0.75	15.68	89.33	42.05	44.29	11.77	14.28	5.77	2.41	0.27	0.30	0.12	0.00	9.67
900-3	15.86	93.17	44.17	43.75	12.88	14.67	4.88	2.35	0.25	0.32	0.08	0.02	9.53
900-12	15.89	89.98	38.15	43.35	12.32	14.21	6.05	2.70	0.32	0.36	0.08	0.06	9.49
900-48	17.54	92.54	43.24	47.25	13.01	14.71	5.19	2.59	0.31	0.35	0.06	0.06	9.56
900-192	15.46	90.82	42.72	39.24	12.39	13.98	5.20	2.79	0.35	0.44	0.09	0.04	9.49
900-768	13.15	80.13	38.08	38.04	12.18	12.38	7.34	3.17	0.43	0.49	0.13	0.06	9.25
1000-0.75	15.70	93.06	44.27	42.67	12.54	14.15	4.85	2.45	0.28	0.33	0.09	0.05	9.56
1000-3	14.33	83.36	38.01	38.53	11.80	12.69	5.51	2.15	0.24	0.30	0.07	0.12	9.62
1000-12	13.21	75.45	35.65	37.17	11.19	11.83	7.65	2.29	0.26	0.32	0.09	0.09	9.65
1000-48	13.79	84.47	40.51	39.12	11.65	12.79	6.95	2.49	0.28	0.32	0.08	0.04	9.56
1000-192	6.71	61.59	15.23	15.29	3.89	9.82	17.25	1.41	0.22	0.28	0.08	0.04	9.17
1000-768	8.26	57.26	23.38	24.35	10.11	8.52	15.24	2.24	0.28	0.36	0.14	0.04	9.00
1100-0.75	15.22	90.21	41.96	38.96	11.36	13.70	5.11	2.47	0.30	0.34	0.06	0.08	9.55
1100-3	13.28	79.29	38.64	38.66	10.72	12.36	7.30	2.46	0.28	0.33	0.07	0.05	9.58
1100-12	14.09	83.36	39.88	40.55	11.40	12.96	5.83	2.17	0.25	0.31	0.06	0.04	9.68
1100-48	11.89	72.72	33.08	9.52	10.09	11.36	9.67	2.21	0.22	0.27	0.11	0.03	9.62
1100-192	7.97	56.07	21.21	21.40	7.00	8.68	14.71	1.89	0.21	0.29	0.11	0.00	9.50
1100-768	7.21	57.80	17.79	17.84	7.20	8.82	22.42	2.56	0.35	0.40	0.15	0.05	8.75
Non-annealed	15.15	83.35	42.24	40.92	11.46	13.73	7.39	2.62	0.30	0.33	0.07	0.06	9.60

							PUREX						
Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	Al	Fe	Mn	Mg	Ca	Ni	pH
400-0.75	42.47	85.19	105.92	113.20	16.04	18.04	24.81	2.61	0.53	0.39	0.09	0.23	10.15
400-12	29.76	61.47	82.37	159.81	12.86	12.85	39.72	2.92	0.19	0.32	0.15	0.23	9.92
400-192	23.49	51.51	71.52	61.66	11.89	10.60	45.08	3.00	0.43	0.28	0.12	0.20	9.70
500-0.75	22.49	47.80	69.23	69.17	11.03	10.06	39.50	2.84	0.43	0.30	0.11	0.16	9.79
500-3	30.20	80.62	84.02	74.57	12.48	13.06	37.65	3.20	0.54	0.32	0.11	0.26	10.30
500-12	38.30	79.46	104.27	92.90	14.83	15.97	26.11	4.06	0.66	0.40	0.11	0.24	10.34
500-48	35.90	58.53	85.28	84.44	11.94	13.15	24.99	3.24	0.49	0.27	0.11	0.16	9.91
500-192	42.40	73.68	98.28	102.39	13.05	15.67	20.55	3.51	0.57	0.34	0.15	0.22	10.10
500-768	60.37	44.60	89.82	92.14	17.25	12.90	27.03	2.65	0.29	0.12	0.00	0.13	9.31
600-0.75	29.43	55.55	80.96	76.88	12.62	12.26	38.51	2.52	0.39	0.30	0.10	0.13	9.80
600-3	59.85	70.76	110.89	107.16	15.88	19.49	17.63	1.55	0.24	0.21	0.05	0.04	9.83
600-12	88.03	122.40	162.05	163.11	25.34	29.54	3.08	1.84	0.30	0.25	0.05	0.08	9.93
600-48	111.29	146.16	196.72	198.15	34.19	35.08	1.93	3.45	0.52	0.47	0.06	0.17	10.24
600-192	102.60	156.56	189.94	212.72	30.36	33.67	2.63	4.63	0.70	0.53	0.06	0.25	10.09
600-768	180.70	72.20	249.15	251.39	34.45	55.27	4.31	0.17	0.11	0.21	0.30	0.08	10.14
650-0.75	51.04	65.43	104.17	89.09	16.10	17.90	25.20	2.76	0.48	0.40	0.12	0.20	9.89
650-3	78.32	59.48	120.63	123.37	18.07	22.14	17.33	1.89	0.30	0.35	0.07	0.11	9.54
700-0.75	56.98	102.37	128.90	126.66	21.99	22.51	14.97	2.72	0.58	0.46	0.06	0.22	10.11
700-3	90.23	137.73	175.14	178.45	28.28	31.38	2.74	3.90	0.66	0.57	0.08	0.25	10.02
700-12	106.35	86.47	162.31	159.82	24.29	30.28	8.91	1.98	0.44	0.48	0.05	0.12	9.81
700-48-2	134.75	115.27	217.71	191.91	35.76	40.58	5.93	1.87	0.57	0.56	0.07	0.15	10.22
700-192	374.98	325.33	639.99	609.60	111.70	133.44	0.55	1.05	0.48	0.38	0.17	0.08	10.95
700-768	623.26	429.06	1009.41	888.78	261.24	230.09	1.66	0.03	0.00	0.02	0.23	0.08	11.51
800-0.75	101.53	177.39	211.47	212.96	35.25	37.55	2.90	5.86	0.93	0.69	0.12	0.41	10.46
800-3	90.57	175.64	194.78	209.46	34.01	34.49	2.71	7.79	1.23	0.92	0.13	0.53	10.34
800-12	81.38	171.23	183.25	191.52	31.65	31.84	2.48	6.74	0.98	0.70	0.12	0.38	10.36
800-48-2	53.00	55.96	92.78	101.97	12.97	15.91	21.80	3.12	0.55	0.45	0.10	0.18	9.88
800-192	46.21	44.26	89.70	76.38	12.70	13.85	31.70	4.91	0.88	0.51	0.17	0.12	9.57
800-768	67.30	65.62	135.05	151.92	24.24	21.52	21.77	5.37	1.16	0.65	0.16	0.05	9.94
900-0.75	61.90	57.79	106.16	109.89	14.70	19.68	30.25	3.16	0.52	0.43	0.14	0.12	9.85
900-3	54.21	43.32	89.04	95.36	13.09	16.18	33.36	3.40	0.50	0.43	0.15	0.16	9.50
900-12	45.28	34.36	77.43	14.36	11.68	13.23	44.02	3.51	0.50	0.29	0.17	0.14	9.22
900-48	48.53	75.67	98.33	107.57	16.17	17.12	16.06	6.34	1.12	0.67	0.18	0.45	9.95
900-192	33.91	53.17	78.10	71.22	12.21	12.01	26.33	6.93	1.13	0.65	0.24	0.24	9.71
900-768	31.72	40.13	67.98	66.89	11.91	10.22	38.64	4.73	0.71	0.41	0.22	0.11	9.31
1000-0.75	29.22	49.41	82.25	76.54	13.25	11.86	52.03	2.41	0.41	0.29	0.09	0.12	9.78
1000-3	28.49	46.37	69.36	69.63	11.90	10.73	42.26	2.82	0.45	0.34	0.16	0.17	9.64
1000-12	26.89	38.36	61.83	65.15	11.30	9.92	47.04	2.28	0.40	0.24	0.11	0.11	9.43
1000-48	41.19	46.04	92.38	91.30	15.59	14.05	97.42	1.83	0.39	0.17	0.20	0.00	9.09
1000-192	52.29	48.64	108.02	93.99	16.91	16.41	124.17	1.08	0.19	0.06	0.12	0.03	8.82
1000-768	61.44	47.45	111.58	12.06	17.75	17.79	130.50	1.05	0.17	0.04	0.12	0.01	9.15
1100-0.75	25.06	54.17	77.48	74.44	12.35	11.17	41.04	2.68	0.43	0.33	0.08	0.13	9.89
1100-3	26.33	67.64	82.44	76.95	12.20	12.55	37.87	2.83	0.49	0.36	0.08	0.16	10.00
1100-12	20.59	44.97	64.45	64.43	11.02	9.51	55.30	2.15	0.36	0.29	0.12	0.02	9.63
1100-48	23.86	60.59	72.87	68.09	12.20	10.71	81.68	2.41	0.54	0.32	0.25	0.09	9.60
1100-192	13.41	40.24	43.66	39.52	7.79	7.23	51.89	1.30	0.33	0.22	0.18	0.02	9.89
1100-768	9.81	61.85	31.10	28.85	6.88	6.21	27.99	2.74	0.32	0.39	0.15	0.05	8.68
Non-annealed	28.33	53.39	84.56	76.12	12.49	12.50	52.84	3.07	0.50	0.33	0.10	0.18	9.84

Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	HM	Al	Fe	Mn	Mg	Ca	Ni	pH
400-0.75	8.95	72.94	25.07	27.11	4.93	10.82	8.41	1.43	0.21	0.29	0.11	0.00	0.00	9.25
400-12	9.83	76.28	27.06	27.26	4.98	11.47	9.62	1.53	0.22	0.30	0.09	0.00	0.00	9.63
400-192	8.29	68.94	24.45	21.83	5.29	9.75	9.71	1.28	0.18	0.25	0.08	0.01	0.01	9.19
500-0.75	8.90	70.33	26.05	26.75	4.89	11.05	9.22	1.33	0.19	0.24	0.10	0.00	0.00	9.48
500-3	9.38	73.09	26.81	25.79	4.16	11.69	11.11	1.44	0.22	0.26	0.13	0.03	0.03	9.66
500-12	11.65	71.02	28.21	27.22	3.91	12.22	13.55	1.66	0.26	0.28	0.12	0.02	0.02	9.47
500-48	8.53	66.74	24.16	24.73	4.53	10.28	10.29	1.39	0.22	0.26	0.08	0.06	0.06	9.43
500-192	8.50	69.92	23.69	26.76	4.30	10.34	9.92	1.67	0.27	0.34	0.16	0.03	0.03	9.50
500-768	8.77	70.12	25.85	27.58	8.09	10.67	11.04	1.68	0.28	0.25	0.00	0.03	0.03	9.24
600-0.75	8.70	70.96	25.04	24.95	4.77	10.58	9.25	1.40	0.20	0.30	0.07	0.00	0.00	9.36
600-3	9.28	76.36	27.70	26.98	5.13	11.31	7.51	1.29	0.18	0.27	0.11	0.00	0.00	9.36
600-12	10.99	79.58	27.46	27.34	5.48	12.32	9.22	1.58	0.25	0.29	0.09	0.01	0.01	9.39
600-48	16.90	76.77	36.10	37.77	6.46	16.37	12.17	1.55	1.16	0.60	0.04	0.00	0.00	9.80
600-192	28.67	219.70	57.76	61.88	10.11	70.49	16.70	3.26	3.06	1.50	0.09	0.07	0.07	10.54
600-768	94.29	311.76	120.01	121.69	14.03	128.11	10.55	2.23	8.33	4.07	0.34	0.08	0.08	11.14
650-0.75	14.16	66.92	25.98	25.10	4.43	12.38	13.01	1.82	0.31	0.33	0.15	0.04	0.04	9.25
650-3	12.23	72.19	27.29	29.39	8.19	12.29	9.92	1.66	0.26	0.33	0.13	0.03	0.03	9.22
700-0.75	9.57	77.08	26.54	24.48	5.05	11.60	7.89	1.55	0.23	0.33	0.12	0.00	0.00	9.41
700-3	9.49	76.86	26.79	27.21	5.18	11.45	8.19	1.37	0.19	0.27	0.07	0.00	0.00	9.40
700-12	15.28	81.95	34.39	33.67	5.88	15.04	13.03	2.64	1.23	0.63	0.05	0.01	0.01	9.55
700-48	37.36	63.28	43.02	48.71	6.11	21.58	23.16	0.92	0.77	0.43	0.00	0.01	0.01	9.83
700-192	36.13	235.55	68.20	69.07	9.87	83.09	24.86	3.60	4.22	1.91	0.10	0.24	0.24	10.96
700-768	32.13	217.35	62.83	67.49	9.29	83.01	27.88	4.06	3.85	1.63	0.18	0.24	0.24	10.65
800-0.75	9.43	73.71	24.41	25.57	4.82	10.97	8.30	1.30	0.19	0.26	0.11	0.03	0.03	9.01
800-3	9.60	75.32	24.87	25.52	4.98	11.38	8.84	1.37	0.20	0.28	0.10	0.01	0.01	9.24
800-12-2	11.66	69.50	25.37	25.51	4.72	11.67	10.88	1.57	0.26	0.31	0.00	0.01	0.01	9.22
800-48-2	9.43	77.94	26.53	26.37	4.97	11.63	9.29	1.41	0.21	0.30	0.11	0.01	0.01	9.11
800-192	8.79	73.19	25.58	23.09	4.11	10.98	8.47	1.58	0.26	0.40	0.10	0.01	0.01	9.13
800-768	9.79	74.48	26.20	29.19	6.16	10.94	10.61	3.18	1.06	0.65	0.18	0.10	0.10	9.28
900-0.75	9.07	77.11	25.95	27.96	5.37	11.50	8.98	1.63	0.25	0.34	0.16	0.00	0.00	9.35
900-3	8.82	74.83	25.50	26.19	5.47	11.32	8.00	1.30	0.18	0.28	0.10	0.00	0.00	9.30
900-12	8.97	75.41	25.89	27.47	5.43	11.45	8.35	1.26	0.16	0.25	0.10	0.00	0.00	9.31
900-48	9.39	74.80	25.50	28.92	5.30	11.33	8.55	1.49	0.22	0.29	0.10	0.02	0.02	9.31
900-192	8.55	71.93	25.77	23.88	4.92	10.79	8.91	1.57	0.24	0.35	0.13	0.00	0.00	9.10
900-768	6.95	62.22	20.99	22.96	5.22	9.11	11.29	1.71	0.29	0.36	0.14	0.05	0.05	9.00
1000-0.75	8.66	70.50	26.19	24.38	4.77	11.17	12.33	1.51	0.23	0.28	0.11	0.02	0.02	9.43
1000-3	7.88	67.11	23.57	21.32	4.53	10.03	10.75	1.38	0.21	0.27	0.13	0.00	0.00	9.40
1000-12	8.22	68.44	23.41	24.88	4.76	10.13	8.25	1.23	0.19	0.26	0.09	0.04	0.04	9.31
1000-48	8.05	65.28	23.27	24.41	6.01	10.50	12.29	1.84	0.31	0.37	0.15	0.00	0.00	9.52
1000-192	7.61	64.93	21.63	1.80	4.80	10.04	12.10	1.42	0.23	0.29	0.12	0.01	0.01	9.43
1000-768	6.42	59.01	15.81	15.78	4.86	9.38	17.98	1.47	0.25	0.33	0.16	0.02	0.02	8.89
1100-0.75	8.64	70.99	26.24	24.14	4.77	11.08	10.65	1.46	0.23	0.23	0.09	0.01	0.01	9.45
1100-3	8.71	74.20	26.40	25.81	5.15	10.87	8.76	1.43	0.22	0.30	0.08	0.00	0.00	9.31
1100-12	8.14	69.20	23.98	24.53	4.53	10.33	9.06	1.28	0.19	0.27	0.09	0.00	0.00	9.52
1100-48	7.38	65.09	20.59	18.09	4.27	9.78	12.58	1.54	0.24	0.30	0.14	0.03	0.03	9.29
1100-192	9.50	59.49	28.24	24.84	8.65	9.53	16.39	2.42	0.30	0.33	0.15	0.07	0.07	9.46
1100-768	5.58	55.56	8.24	8.06	3.77	9.87	21.65	1.34	0.25	0.34	0.14	0.01	0.01	8.69
Non-annealed	9.07	72.61	27.00	25.31	5.24	11.35	10.38	1.42	0.21	0.26	0.08	0.02	0.02	9.35

ATTACHMENT III
NORMALIZED PCT RESULTS FOR EACH OF THE SEVEN GLASS COMPOSITIONS

							Batch 1					normalized	
Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	Al	Fe	Mn	Mg	Ca	N	pH
400-0.75	0.65	0.38	0.62	0.67	0.43	0.68	0.23	0.034	0.020	0.035	0.011	0.008	9.49
400-12	0.70	0.40	0.67	0.69	0.43	0.73	0.26	0.043	0.026	0.043	0.019	0.008	9.50
400-192	0.55	0.35	0.57	0.49	0.39	0.61	0.26	0.033	0.019	0.037	0.013	0.007	9.44
500-0.75	0.62	0.37	0.63	0.62	0.41	0.68	0.21	0.031	0.020	0.039	0.011	0.002	9.69
500-3	0.60	0.37	0.64	0.62	0.38	0.66	0.29	0.036	0.023	0.040	0.014	0.010	9.89
500-12	0.54	0.32	0.58	0.60	0.38	0.61	0.32	0.040	0.025	0.037	0.015	0.012	9.60
500-48	0.61	0.37	0.61	0.63	0.41	0.66	0.22	0.033	0.021	0.040	0.008	0.017	9.50
500-192	0.57	0.36	0.58	0.61	0.37	0.64	0.30	0.041	0.027	0.042	0.017	0.014	9.72
500-768	0.57	0.34	0.59	0.57	0.63	0.63	0.39	0.047	0.032	0.036	0.000	0.020	9.17
600-0.75	0.64	0.39	0.65	0.65	0.43	0.68	0.21	0.033	0.019	0.036	0.007	0.000	9.56
600-3	0.64	0.38	0.64	0.66	0.43	0.69	0.22	0.033	0.019	0.039	0.009	0.005	9.54
600-12	0.64	0.39	0.64	0.62	0.45	0.70	0.24	0.040	0.028	0.048	0.014	0.010	9.54
600-48	6.31	1.47	3.46	3.79	2.50	7.08	0.25	0.026	0.278	0.197	0.001	0.020	11.14
600-192	6.11	1.40	3.16	3.36	2.45	7.01	0.01	0.000	0.003	0.006	0.023	0.014	11.16
600-768	7.56	1.35	3.46	2.92	2.57	7.66	0.08	0.000	0.009	0.007	0.040	0.014	11.22
650-0.75	0.63	0.39	0.64	0.59	0.43	0.68	0.25	0.036	0.023	0.041	0.019	0.012	9.33
650-3	0.60	0.37	0.62	0.68	0.50	0.68	0.24	0.038	0.025	0.044	0.011	0.008	9.26
700-0.75	0.63	0.37	0.62	0.55	0.41	0.66	0.23	0.035	0.023	0.047	0.013	0.005	9.80
700-3	0.62	0.37	0.60	0.59	0.41	0.67	0.25	0.041	0.033	0.055	0.010	0.000	9.67
700-12	1.77	0.47	1.18	1.21	0.80	1.49	0.37	0.070	0.140	0.100	0.011	0.020	10.13
700-48	6.84	1.23	3.38	3.71	2.42	6.70	0.27	0.022	0.173	0.123	0.028	0.020	11.21
700-192	7.68	1.19	3.78	4.01	2.36	6.32	0.76	0.088	0.914	0.652	0.010	0.188	11.24
700-768	7.15	1.08	3.75	3.78	2.76	6.52	0.79	0.079	0.872	0.663	0.031	0.117	11.41
800-0.75	0.60	0.38	0.61	0.60	0.41	0.67	0.23	0.034	0.023	0.043	0.011	0.002	9.57
800-3	0.62	0.39	0.62	0.62	0.41	0.69	0.23	0.032	0.021	0.044	0.014	0.002	9.77
800-12	0.60	0.39	0.61	0.61	0.42	0.68	0.24	0.035	0.025	0.053	0.015	0.000	9.61
800-48	0.70	0.37	0.58	0.67	0.41	0.72	0.30	0.043	0.043	0.063	0.009	0.002	9.88
800-192	1.04	0.37	0.61	0.76	0.46	0.66	0.37	0.057	0.095	0.078	0.013	0.015	9.65
800-768	1.23	0.36	0.68	0.77	0.56	1.04	0.46	0.068	0.144	0.106	0.018	0.029	10.01
900-0.75	0.64	0.39	0.62	0.65	0.43	0.70	0.24	0.037	0.023	0.041	0.014	0.008	9.54
900-3	0.52	0.30	0.49	0.61	0.36	0.56	0.21	0.024	0.014	0.029	0.013	0.000	9.61
900-12	0.56	0.35	0.58	0.59	0.40	0.65	0.27	0.034	0.022	0.049	0.015	0.000	9.56
900-48	0.62	0.36	0.58	0.61	0.40	0.66	0.28	0.040	0.028	0.055	0.011	0.003	9.67
900-192	0.59	0.37	0.62	0.57	0.37	0.66	0.25	0.039	0.028	0.055	0.014	0.002	9.45
900-768	0.46	0.33	0.53	0.52	0.37	0.55	0.37	0.038	0.027	0.058	0.016	0.000	9.17
1000-0.75	0.57	0.35	0.60	0.62	0.39	0.64	0.24	0.032	0.020	0.040	0.011	0.003	9.73
1000-3	0.52	0.32	0.50	0.55	0.38	0.57	0.30	0.032	0.020	0.040	0.010	0.012	9.56
1000-12	0.52	0.32	0.53	0.57	0.37	0.58	0.29	0.030	0.020	0.037	0.009	0.010	9.50
1000-48	0.55	0.34	0.57	0.58	0.38	0.63	0.31	0.037	0.023	0.044	0.014	0.000	9.81
1000-192	0.44	0.30	0.48	0.45	0.32	0.53	0.42	0.030	0.018	0.041	0.015	0.005	9.51
1000-768	0.36	0.27	0.39	0.38	0.31	0.46	0.67	0.034	0.022	0.044	0.022	0.003	9.07
1100-0.75	0.53	0.33	0.58	0.54	0.35	0.61	0.34	0.036	0.023	0.042	0.014	0.010	9.60
1100-3	0.48	0.30	0.53	0.53	0.32	0.56	0.45	0.037	0.025	0.044	0.017	0.010	9.74
1100-12	0.53	0.33	0.58	0.53	0.35	0.61	0.36	0.034	0.021	0.041	0.010	0.008	9.59
1100-48	0.45	0.29	0.47	0.13	0.32	0.54	0.44	0.029	0.017	0.035	0.010	0.003	9.57
1100-192	0.35	0.25	0.36	0.02	0.26	0.44	0.59	0.024	0.014	0.034	0.011	0.000	9.63
1100-768	0.28	0.23	0.26	0.29	0.36	0.41	0.83	0.023	0.016	0.033	0.000	0.002	9.04
Non-annealed	0.64	0.36	0.66	0.63	0.42	0.73	0.28	0.039	0.023	0.041	0.011	0.012	9.67

							Batch 2					normalized	
Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	Al	Fe	Mn	Mg	Ca	N	pH
400-0.75	0.54	0.34	0.52	0.56	0.35	0.59	0.24	0.029	0.017	0.033	0.010	0.007	9.40
400-12	0.54	0.33	0.53	0.55	0.34	0.59	0.39	0.034	0.021	0.036	0.008	0.010	9.49
400-192	0.50	0.32	0.52	0.46	0.35	0.56	0.36	0.034	0.021	0.037	0.014	0.010	9.39
500-0.75	0.53	0.33	0.54	0.53	0.35	0.59	0.21	0.028	0.016	0.034	0.009	0.006	9.54
500-3	0.57	0.36	0.58	0.57	0.34	0.64	0.24	0.032	0.020	0.036	0.013	0.010	9.75
500-12	0.54	0.34	0.55	0.57	0.36	0.60	0.20	0.029	0.017	0.033	0.009	0.006	9.49
500-48	0.53	0.33	0.53	0.53	0.34	0.59	0.25	0.032	0.023	0.039	0.009	0.016	9.50
500-192	0.53	0.33	0.53	0.55	0.32	0.59	0.33	0.034	0.023	0.035	0.016	0.010	9.64
500-768	0.56	0.31	0.53	0.49	0.53	0.58	0.32	0.030	0.020	0.027	0.000	0.010	9.06
600-0.75	0.56	0.35	0.57	0.58	0.37	0.61	0.22	0.029	0.016	0.034	0.006	0.001	9.53
600-3	0.59	0.37	0.61	0.60	0.39	0.65	0.18	0.030	0.017	0.036	0.010	0.000	9.56
600-12	1.17	0.41	0.87	0.83	0.54	1.08	0.33	0.056	0.088	0.090	0.008	0.016	9.83
600-48	7.89	2.21	4.61	4.93	3.55	9.28	0.04	0.000	0.000	0.000	0.000	0.000	11.27
600-192	6.86	1.88	3.61	3.83	2.85	8.22	0.01	0.000	0.001	0.002	0.026	0.011	11.13
600-768	7.10	1.59	3.74	3.72	2.59	7.63	0.01	0.000	0.002	0.004	0.025	0.011	11.28
650-0.75	0.62	0.33	0.56	0.53	0.35	0.62	0.33	0.035	0.024	0.041	0.017	0.011	9.33
650-3	0.58	0.36	0.58	0.63	0.48	0.64	0.23	0.036	0.027	0.051	0.012	0.001	9.29
700-0.75	0.58	0.35	0.55	0.55	0.36	0.62	0.21	0.032	0.020	0.041	0.009	0.004	9.65
700-3	0.72	0.36	0.65	0.65	0.40	0.75	0.28	0.044	0.050	0.063	0.008	0.000	9.66
700-12	4.69	1.03	2.70	2.87	1.60	3.63	0.18	0.075	0.287	0.189	0.004	0.054	10.57
700-48	8.14	2.01	4.19	4.61	2.97	8.64	0.02	0.000	0.000	0.002	0.041	0.011	11.33
700-192	7.60	1.95	3.74	4.22	2.53	7.86	0.08	0.000	0.002	0.000	0.000	0.000	11.25
700-768	7.07	1.78	4.00	3.96	2.48	8.21	0.06	0.001	0.009	0.011	0.036	0.011	11.44
800-0.75	0.56	0.36	0.54	0.56	0.37	0.62	0.20	0.029	0.018	0.037	0.013	0.003	9.13
800-3	0.57	0.37	0.56	0.57	0.37	0.64	0.23	0.030	0.020	0.040	0.014	0.004	9.63
800-12	0.55	0.36	0.59	0.57	0.38	0.63	0.22	0.032	0.022	0.048	0.013	0.003	9.53
800-48	0.58	0.37	0.52	0.61	0.37	0.65	0.25	0.374	0.031	0.061	0.006	0.001	9.73
800-192	0.80	0.34	0.66	0.67	0.39	0.79	0.35	0.069	0.111	0.097	0.016	0.037	9.48
800-768	1.04	0.39	0.82	0.85	0.52	0.94	0.34	0.060	0.103	0.089	0.016	0.034	9.78
900-0.75	0.58	0.35	0.55	0.59	0.39	0.65	0.24	0.033	0.022	0.040	0.012	0.006	9.50
900-3	0.62	0.38	0.62	0.65	0.41	0.69	0.23	0.041	0.027	0.043	0.018	0.000	9.65
900-12	0.56	0.36	0.57	0.59	0.39	0.66	0.24	0.031	0.019	0.039	0.014	0.001	9.54
900-48	0.65	0.34	0.57	0.61	0.36	0.66	0.31	0.053	0.043	0.058	0.017	0.016	9.56
900-192	0.55	0.35	0.57	0.51	0.33	0.62	0.25	0.041	0.030	0.054	0.014	0.008	9.38
900-768	0.43	0.30	0.48	0.47	0.34	0.52	0.39	0.038	0.027	0.056	0.018	0.006	9.14
1000-0.75	0.54	0.36	0.58	0.57	0.37	0.61	0.22	0.032	0.019	0.037	0.014	0.004	9.56
1000-3	0.53	0.33	0.51	0.55	0.36	0.59	0.26	0.031	0.020	0.037	0.010	0.011	9.52
1000-12	0.47	0.30	0.45	0.51	0.36	0.54	0.32	0.031	0.020	0.035	0.012	0.013	9.52
1000-48	0.45	0.29	0.49	0.47	0.30	0.54	0.44	0.032	0.021	0.036	0.014	0.010	9.60
1000-192	0.40	0.28	0.42	0.09	0.29	0.49	0.40	0.027	0.016	0.035	0.014	0.004	9.47
1000-768	0.36	0.27	0.38	0.38	0.28	0.48	0.64	0.036	0.024	0.049	0.022	0.006	9.07
1100-0.75	0.50	0.32	0.55	0.52	0.34	0.58	0.35	0.032	0.021	0.037	0.013	0.010	9.51
1100-3	0.53	0.33	0.54	0.57	0.36	0.61	0.25	0.030	0.019	0.036	0.008	0.000	9.75
1100-12	0.49	0.32	0.50	0.51	0.33	0.57	0.22	0.027	0.016	0.034	0.008	0.000	9.63
1100-48	0.42	0.29	0.43	0.45	0.28	0.50	0.34	0.025	0.015	0.033	0.013	0.003	9.51
1100-192	0.34	0.25	0.34	0.00	0.24	0.44	0.57	0.028	0.017	0.034	0.016	0.006	9.48
1100-768	0.26	0.22	0.23	0.28	0.34	0.39	0.78	0.025	0.017	0.033	0.000	0.004	8.91
Non-annealed	0.54	0.33	0.56	0.55	0.37	0.61	0.34	0.034	0.022	0.035	0.010	0.011	9.55

							Batch 3					normalized	
Temp-Time	B	Si	Na	Na (AA)	K (AA)	U	Al	Fe	Mn	Mg	Ca	Ni	pH
400-0.75	0.78	0.42	0.70	0.74	0.48	0.77	0.19	0.033	0.022	0.035	0.008	0.011	9.48
400-12	0.78	0.41	0.71	0.72	0.44	0.74	0.27	0.035	0.023	0.037	0.006	0.011	9.56
400-192	0.58	0.34	0.57	0.51	0.37	0.60	0.35	0.033	0.022	0.039	0.011	0.011	9.41
500-0.75	0.82	0.33	0.61	0.61	0.38	0.64	0.28	0.033	0.024	0.041	0.010	0.010	9.56
500-3	0.80	0.45	0.77	0.76	0.47	0.82	0.21	0.039	0.027	0.041	0.013	0.015	9.82
500-12	0.63	0.34	0.62	0.63	0.39	0.65	0.30	0.038	0.026	0.040	0.010	0.015	9.57
500-48	0.70	0.40	0.66	0.67	0.44	0.71	0.19	0.032	0.023	0.039	0.007	0.016	9.51
500-192	0.71	0.40	0.66	0.68	0.40	0.72	0.22	0.035	0.025	0.040	0.013	0.011	9.64
500-768-2	0.71	0.37	0.66	0.67	0.43	0.71	0.33	0.047	0.031	0.040	0.175	0.019	9.69
600-0.75	0.72	0.41	0.69	0.71	0.44	0.72	0.19	0.031	0.020	0.036	0.003	0.005	9.55
600-3	0.80	0.46	0.74	0.74	0.49	0.79	0.18	0.037	0.026	0.042	0.010	0.011	9.47
600-12	3.87	1.19	2.56	2.53	1.75	3.24	0.11	0.089	0.210	0.194	0.008	0.038	10.19
600-48	16.62	4.29	9.58	9.66	8.07	14.78	0.00	0.000	0.001	0.000	0.038	0.008	11.34
600-192	14.50	3.78	8.11	8.53	7.93	13.42	0.01	0.000	0.001	0.000	0.025	0.010	11.21
600-768	14.24	2.84	8.00	8.90	7.77	13.83	0.01	0.000	0.001	0.000	0.024	0.010	11.47
650-0.75	0.77	0.42	0.71	0.63	0.49	0.76	0.24	0.042	0.030	0.049	0.014	0.015	9.36
650-3	0.77	0.41	0.71	0.75	0.53	0.76	0.22	0.042	0.032	0.050	0.008	0.015	9.34
700-0.75	0.78	0.44	0.72	0.65	0.46	0.79	0.16	0.033	0.022	0.040	0.008	0.005	9.63
700-3	1.69	0.82	1.24	1.28	0.80	1.45	0.17	0.065	0.095	0.091	0.010	0.012	10.02
700-12	14.28	2.91	8.49	8.50	5.70	10.19	0.00	0.000	0.000	0.001	0.035	0.007	11.08
700-48	17.57	3.95	9.35	10.44	8.78	14.14	0.01	0.000	0.000	0.001	0.045	0.010	11.44
700-192	16.52	3.78	9.78	10.30	7.82	13.28	0.01	0.000	0.001	0.000	0.028	0.010	11.49
700-768	15.41	3.59	8.82	7.08	7.07	13.17	0.06	0.001	0.002	0.002	0.044	0.013	11.24
800-0.75	0.74	0.43	0.68	0.69	0.48	0.75	0.17	0.033	0.022	0.040	0.011	0.004	9.26
800-3	0.71	0.41	0.68	0.67	0.44	0.74	0.20	0.035	0.026	0.047	0.013	0.007	9.61
800-12	0.80	0.47	0.81	0.78	0.50	0.83	0.19	0.039	0.031	0.039	0.011	0.006	9.61
800-48	0.81	0.44	0.70	0.79	0.48	0.82	0.22	0.040	0.034	0.057	0.013	0.004	9.46
800-192	1.38	0.54	1.08	1.00	0.66	1.22	0.19	0.054	0.067	0.074	0.008	0.016	9.65
800-768	2.70	0.84	1.90	2.11	1.23	2.19	0.13	0.084	0.154	0.137	0.016	0.047	9.98
900-0.75	0.73	0.40	0.67	0.71	0.43	0.75	0.28	0.038	0.027	0.042	0.016	0.012	9.60
900-3	0.78	0.45	0.74	0.78	0.48	0.81	0.16	0.036	0.025	0.041	0.016	0.004	9.64
900-12	0.73	0.42	0.70	0.71	0.47	0.78	0.20	0.034	0.024	0.044	0.010	0.004	9.55
900-48	0.88	0.46	0.79	0.84	0.52	0.86	0.22	0.053	0.044	0.061	0.011	0.017	9.60
900-192	0.75	0.42	0.73	0.64	0.43	0.77	0.21	0.042	0.033	0.055	0.014	0.010	9.47
900-768	0.61	0.33	0.54	0.53	0.37	0.57	0.39	0.039	0.030	0.058	0.018	0.007	9.17
1000-0.75	0.76	0.43	0.73	0.39	0.49	0.77	0.16	0.032	0.023	0.037	0.013	0.008	9.79
1000-3	0.76	0.42	0.68	0.74	0.47	0.75	0.17	0.035	0.024	0.040	0.007	0.016	9.52
1000-12	0.58	0.34	0.58	0.51	0.38	0.62	0.36	0.032	0.021	0.037	0.013	0.011	9.60
1000-48	0.51	0.31	0.53	0.54	0.33	0.56	0.47	0.032	0.022	0.037	0.016	0.010	9.64
1000-192	0.45	0.30	0.46	0.40	0.32	0.52	0.43	0.030	0.019	0.039	0.014	0.007	9.45
1000-768	0.37	0.27	0.37	0.37	0.30	0.48	0.80	0.037	0.026	0.044	0.024	0.007	9.03
1100-0.75	0.74	0.42	0.72	0.74	0.45	0.76	0.20	0.035	0.025	0.042	0.011	0.011	9.70
1100-3	0.65	0.37	0.63	0.27	0.39	0.67	0.29	0.034	0.025	0.041	0.011	0.011	9.73
1100-12	0.64	0.39	0.65	0.65	0.41	0.68	0.23	0.035	0.024	0.042	0.008	0.010	9.52
1100-48	0.47	0.30	0.48	0.50	0.31	0.53	0.43	0.026	0.015	0.032	0.013	0.002	9.63
1100-192	0.37	0.26	0.36	0.03	0.27	0.46	0.77	0.031	0.019	0.035	0.017	0.007	9.41
1100-768	0.27	0.22	0.23	0.27	0.35	0.39	1.06	0.029	0.021	0.036	0.000	0.006	8.84
Non-annealed	0.74	0.40	0.71	0.68	0.45	0.75	0.24	0.034	0.023	0.036	0.007	0.013	9.56

							Batch 4					normalized	
Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	Al	Fe	Mn	Mg	Ca	Ni	pH
400-0.75	0.78	0.42	0.72	0.77	0.48	0.79	0.21	0.028	0.019	0.032	0.008	0.007	9.52
400-12	0.81	0.43	0.75	0.78	0.48	0.80	0.26	0.032	0.021	0.032	0.008	0.010	9.63
400-192	0.80	0.42	0.77	0.87	0.48	0.81	0.22	0.032	0.022	0.036	0.012	0.010	9.61
500-0.75	0.82	0.43	0.80	0.79	0.50	0.84	0.17	0.029	0.020	0.034	0.007	0.006	9.66
500-3	0.88	0.46	0.81	0.88	0.49	0.87	0.19	0.029	0.021	0.034	0.007	0.011	9.90
500-12	0.75	0.38	0.73	0.75	0.44	0.77	0.22	0.030	0.022	0.036	0.005	0.008	9.66
500-48	0.81	0.43	0.77	0.77	0.46	0.82	0.21	0.032	0.025	0.038	0.008	0.016	9.66
500-192	0.81	0.44	0.75	0.85	0.47	0.82	0.20	0.031	0.023	0.036	0.008	0.010	9.72
500-768	0.88	0.40	0.77	0.78	0.73	0.83	0.28	0.037	0.028	0.032	0.000	0.013	9.53
600-0.75	0.83	0.45	0.80	0.80	0.50	0.83	0.18	0.028	0.021	0.037	0.000	0.002	9.63
600-3	0.87	0.46	0.85	0.81	0.51	0.88	0.12	0.028	0.020	0.036	0.007	0.000	9.81
600-12	0.94	0.45	0.83	0.95	0.59	0.93	0.18	0.040	0.037	0.051	0.005	0.013	9.71
600-48	16.64	3.94	10.08	10.01	8.74	15.39	0.00	0.000	0.000	0.000	0.000	0.000	11.39
600-192	14.62	3.39	7.88	8.01	7.83	14.14	0.01	0.000	0.001	0.000	0.035	0.010	11.37
600-768	15.30	3.31	8.13	8.71	6.38	14.59	0.01	0.000	0.001	0.000	0.018	0.010	11.63
650-0.75	0.85	0.46	0.82	0.87	0.57	0.88	0.20	0.036	0.027	0.045	0.012	0.012	9.48
650-3	1.03	0.46	0.91	0.93	0.59	0.98	0.22	0.037	0.034	0.053	0.010	0.001	9.58
700-0.75	0.87	0.43	0.81	0.71	0.48	0.86	0.20	0.034	0.028	0.046	0.008	0.005	9.72
700-3	0.90	0.46	0.84	0.84	0.55	0.91	0.20	0.037	0.036	0.059	0.002	0.000	9.64
700-12	1.57	0.61	1.24	1.16	0.91	1.42	0.18	0.050	0.066	0.074	0.008	0.000	9.98
700-48	18.66	3.15	9.64	10.92	8.55	13.41	0.01	0.000	0.000	0.001	0.047	0.010	11.53
700-192	20.34	3.63	11.73	12.47	9.55	15.08	0.01	0.000	0.001	0.000	0.043	0.010	11.58
700-768	17.02	3.27	9.52	8.75	7.80	14.18	0.08	0.001	0.001	0.002	0.055	0.014	11.45
800-0.75	0.84	0.45	0.77	0.79	0.49	0.85	0.19	0.031	0.028	0.049	0.007	0.000	9.43
800-3	0.86	0.46	0.80	0.82	0.50	0.89	0.18	0.031	0.026	0.051	0.010	0.001	9.80
800-12	0.88	0.47	0.81	0.79	0.49	0.92	0.18	0.035	0.031	0.059	0.012	0.001	9.73
800-48	0.88	0.45	0.77	0.86	0.50	0.90	0.18	0.034	0.031	0.059	0.010	0.001	9.56
800-192	1.42	0.57	1.17	1.05	0.70	1.31	0.15	0.041	0.046	0.060	0.010	0.005	9.79
800-768	1.97	0.70	1.53	1.40	0.90	1.74	0.14	0.051	0.074	0.078	0.012	0.012	9.94
900-0.75	0.84	0.46	0.78	0.82	0.50	0.87	0.19	0.033	0.025	0.043	0.007	0.005	9.66
900-3	0.89	0.48	0.85	0.84	0.61	0.93	0.19	0.033	0.025	0.045	0.008	0.001	9.67
900-12	0.82	0.44	0.78	0.79	0.49	0.86	0.19	0.030	0.024	0.046	0.008	0.001	9.67
900-48	0.87	0.44	0.77	0.82	0.49	0.85	0.21	0.033	0.026	0.046	0.000	0.006	9.64
900-192	0.80	0.43	0.79	0.74	0.48	0.84	0.29	0.040	0.033	0.056	0.017	0.005	9.51
900-768	0.55	0.33	0.58	0.59	0.42	0.61	0.39	0.038	0.031	0.056	0.017	0.007	9.44
1000-0.75	0.79	0.44	0.78	0.74	0.48	0.82	0.17	0.028	0.020	0.037	0.005	0.007	9.65
1000-3	0.76	0.41	0.70	0.74	0.49	0.76	0.22	0.028	0.019	0.034	0.010	0.012	9.68
1000-12	0.76	0.41	0.71	0.72	0.48	0.76	0.21	0.027	0.019	0.034	0.008	0.011	9.66
1000-48	0.51	0.30	0.54	0.56	0.33	0.57	0.53	0.025	0.018	0.032	0.010	0.004	9.74
1000-192	0.43	0.27	0.47	0.47	0.29	0.50	0.80	0.026	0.018	0.034	0.017	0.004	9.61
1000-768	0.38	0.26	0.42	0.41	0.29	0.47	0.95	0.024	0.017	0.036	0.017	0.004	9.11
1100-0.75	0.89	0.44	0.86	0.50	2.71	0.86	0.18	0.028	0.021	0.035	0.005	0.006	9.88
1100-3	0.77	0.42	0.77	0.71	0.45	0.80	0.20	0.026	0.020	0.034	0.002	0.007	9.68
1100-12	0.83	0.36	0.63	0.63	0.41	0.89	0.23	0.023	0.015	0.031	0.005	0.000	9.81
1100-48	0.46	0.30	0.50	0.48	0.31	0.53	0.48	0.023	0.015	0.031	0.012	0.004	9.48
1100-192	0.37	0.26	0.39	0.39	0.27	0.47	0.88	0.022	0.014	0.030	0.015	0.005	9.52
1100-768	0.29	0.24	0.28	0.28	0.23	0.41	1.15	0.020	0.014	0.034	0.010	0.002	8.87
Non-annealed	0.83	0.42	0.81	0.77	0.46	0.84	0.24	0.031	0.023	0.035	0.003	0.013	9.69

							Blend					normalized	
Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	Al	Fe	Mn	Mg	Ca	Ni	pH
400-0.75	0.70	0.39	0.65	0.73	0.40	0.73	0.21	0.318	0.022	0.038	0.010	0.010	9.81
400-12	0.73	0.35	0.69	0.71	0.37	0.68	0.41	0.329	0.001	0.035	0.004	0.017	9.75
400-192	0.57	0.35	0.57	0.56	0.37	0.61	0.34	0.334	0.022	0.038	0.010	0.011	9.27
500-0.75	0.64	0.36	0.65	0.66	0.40	0.70	0.24	0.321	0.021	0.034	0.008	0.007	9.63
500-3	0.67	0.39	0.66	0.64	0.40	0.72	0.24	0.329	0.023	0.039	0.012	0.018	9.83
500-12	0.81	0.36	0.84	0.56	0.36	0.67	0.25	0.318	0.022	0.036	0.011	0.010	9.71
500-48	0.61	0.35	0.59	0.61	0.39	0.65	0.23	0.290	0.020	0.035	0.007	0.016	9.60
500-192	0.62	0.36	0.59	0.64	0.36	0.66	0.29	0.369	0.029	0.042	0.016	0.016	9.77
500-768	0.93	0.32	0.68	0.63	0.69	0.76	0.34	0.311	0.022	0.072	0.000	0.010	9.40
600-0.75	0.68	0.41	0.64	0.69	0.45	0.73	0.20	0.333	0.022	0.040	0.012	0.010	9.53
600-3	0.60	0.38	0.63	0.67	0.43	0.65	0.13	0.270	0.018	0.034	0.011	0.000	9.54
600-12	1.71	0.43	1.27	0.67	0.44	1.00	0.22	0.360	0.032	0.045	0.008	0.014	9.61
600-48	13.47	3.44	7.68	7.22	5.25	13.64	0.00	0.001	0.001	0.002	0.031	0.010	11.35
600-192	9.00	2.32	4.66	4.95	3.77	10.12	0.07	0.018	0.001	0.000	0.027	0.021	11.24
600-768	9.80	2.36	5.33	4.47	4.06	11.14	0.01	0.001	0.001	0.000	0.030	0.011	11.49
650-0.75	0.74	0.29	0.58	0.55	0.40	0.66	0.45	0.368	0.028	0.041	0.016	0.016	9.52
650-3-2	0.71	0.40	0.70	0.72	0.53	0.76	0.21	0.355	0.025	0.040	0.010	0.010	9.58
700-0.75	0.69	0.41	0.66	0.61	0.44	0.74	0.18	0.317	0.021	0.038	0.010	0.006	9.56
700-3	0.69	0.38	0.66	0.65	0.41	0.73	0.25	0.388	0.033	0.054	0.005	0.000	9.61
700-12	7.41	1.49	4.16	4.59	2.59	5.61	0.09	0.421	0.195	0.141	0.004	0.033	10.88
700-48	11.66	2.31	8.00	7.39	5.32	9.81	0.01	0.000	0.000	0.012	0.041	0.011	11.47
700-192	10.52	2.28	5.61	5.83	3.87	10.48	0.04	0.005	0.001	0.000	0.034	0.013	11.28
700-768	10.83	2.39	5.88	6.28	4.60	10.98	0.02	0.004	0.001	0.002	0.039	0.011	11.43
800-0.75	0.64	0.38	0.62	0.63	0.40	0.70	0.20	0.301	0.020	0.039	0.011	0.007	9.78
800-3	0.66	0.39	0.62	0.64	0.41	0.71	0.21	0.328	0.024	0.046	0.011	0.003	9.59
800-12	0.64	0.38	0.64	0.65	0.41	0.71	0.22	0.349	0.027	0.075	0.020	0.001	9.71
800-48-2	0.82	0.39	0.71	0.74	0.44	0.82	0.29	0.431	0.045	0.068	0.008	0.001	9.49
800-192	1.21	0.41	0.93	0.85	0.57	1.10	0.28	0.470	0.077	0.065	0.010	0.016	9.83
800-768	0.86	0.38	0.76	0.81	0.51	0.84	0.27	0.409	0.049	0.060	0.012	0.009	9.63
900-0.75	0.63	0.37	0.62	0.65	0.39	0.69	0.26	0.318	0.021	0.035	0.016	0.000	9.67
900-3	0.63	0.38	0.65	0.65	0.42	0.71	0.21	0.308	0.019	0.038	0.011	0.003	9.53
900-12	0.64	0.37	0.56	0.64	0.40	0.69	0.27	0.354	0.025	0.042	0.011	0.009	9.49
900-48	0.70	0.38	0.64	0.70	0.43	0.71	0.24	0.339	0.024	0.041	0.008	0.009	9.56
900-192	0.82	0.37	0.63	0.56	0.41	0.68	0.24	0.366	0.027	0.052	0.012	0.006	9.49
900-768	0.53	0.33	0.56	0.56	0.40	0.60	0.33	0.415	0.033	0.058	0.018	0.009	9.25
1000-0.75	0.63	0.38	0.65	0.63	0.41	0.69	0.22	0.321	0.022	0.039	0.012	0.007	9.56
1000-3	0.57	0.34	0.56	0.57	0.39	0.62	0.25	0.282	0.019	0.035	0.010	0.017	9.62
1000-12	0.53	0.31	0.53	0.55	0.37	0.57	0.35	0.300	0.020	0.038	0.012	0.013	9.65
1000-48	0.55	0.35	0.60	0.58	0.38	0.62	0.32	0.328	0.022	0.038	0.011	0.006	9.56
1000-192	0.27	0.25	0.22	0.23	0.13	0.46	0.78	0.185	0.017	0.033	0.011	0.006	9.17
1000-768	0.33	0.24	0.35	0.36	0.33	0.41	0.89	0.294	0.022	0.042	0.019	0.006	9.00
1100-0.75	0.61	0.37	0.62	0.58	0.37	0.66	0.23	0.324	0.023	0.040	0.008	0.011	9.55
1100-3	0.53	0.33	0.57	0.57	0.35	0.60	0.33	0.322	0.022	0.039	0.010	0.007	9.58
1100-12	0.56	0.34	0.59	0.60	0.37	0.63	0.26	0.284	0.019	0.036	0.008	0.006	9.68
1100-48	0.47	0.30	0.49	0.14	0.33	0.55	0.44	0.290	0.017	0.032	0.015	0.004	9.62
1100-192	0.32	0.23	0.31	0.32	0.23	0.42	0.67	0.246	0.016	0.034	0.015	0.000	9.50
1100-768	0.29	0.24	0.26	0.26	0.24	0.43	1.02	0.335	0.027	0.047	0.020	0.007	8.75
Non-annealed	0.61	0.34	0.62	0.60	0.38	0.67	0.34	0.343	0.023	0.039	0.010	0.009	9.60

							Purex					normalized	
Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	Al	Fe	Mn	Mg	Ca	N	pH
400-0.75	1.32	0.39	1.13	1.21	0.57	1.21	1.57	0.028	0.041	0.046	0.012	0.025	10.15
400-12	0.93	0.28	0.88	1.71	0.45	0.86	2.51	0.032	0.015	0.038	0.019	0.025	9.92
400-192	0.73	0.24	0.76	0.66	0.42	0.71	2.85	0.032	0.033	0.033	0.015	0.021	9.70
500-0.75	0.70	0.22	0.74	0.74	0.39	0.67	2.50	0.031	0.033	0.035	0.014	0.017	9.79
500-3	0.94	0.28	0.90	0.80	0.44	0.87	2.38	0.035	0.041	0.038	0.014	0.028	10.30
500-12	1.19	0.37	1.11	0.99	0.52	1.07	1.65	0.044	0.050	0.047	0.014	0.026	10.34
500-48	1.12	0.27	0.91	0.90	0.42	0.88	1.58	0.035	0.037	0.032	0.014	0.017	9.91
500-192	1.32	0.34	1.05	1.09	0.46	1.05	1.30	0.038	0.044	0.040	0.019	0.024	10.10
500-768	1.57	0.21	0.96	0.98	0.61	0.86	1.71	0.029	0.022	0.014	0.000	0.014	9.31
600-0.75	0.92	0.26	0.86	0.82	0.45	0.82	2.43	0.027	0.030	0.035	0.013	0.014	9.80
600-3	1.86	0.33	1.18	1.14	0.56	1.30	1.11	0.017	0.018	0.025	0.006	0.004	9.83
600-12	2.74	0.56	1.73	1.74	0.90	1.97	0.19	0.020	0.023	0.029	0.006	0.009	9.93
600-48	3.47	0.67	2.10	2.12	1.21	2.34	0.12	0.037	0.040	0.055	0.008	0.018	10.24
600-192	3.20	0.72	2.03	2.27	1.07	2.25	0.17	0.050	0.054	0.062	0.008	0.027	10.09
600-768	5.63	0.33	2.66	2.66	1.22	3.69	0.27	0.002	0.008	0.025	0.039	0.009	10.14
650-0.75	1.59	0.30	1.11	0.95	0.57	1.20	1.59	0.030	0.037	0.047	0.015	0.021	9.89
650-3	2.44	0.27	1.29	1.32	0.64	1.48	1.10	0.020	0.023	0.041	0.009	0.012	9.54
700-0.75	1.78	0.47	1.38	1.35	0.78	1.50	0.95	0.029	0.044	0.054	0.008	0.024	10.11
700-3	2.81	0.63	1.87	1.91	1.00	2.10	0.17	0.042	0.050	0.067	0.008	0.027	10.02
700-12	3.31	0.40	1.73	1.71	0.86	2.02	0.56	0.021	0.034	0.056	0.006	0.013	9.81
700-48-2	4.20	0.53	2.33	2.05	1.26	2.71	0.37	0.020	0.044	0.066	0.009	0.016	10.22
700-192	11.69	1.50	6.84	6.51	3.95	6.92	0.03	0.011	0.037	0.045	0.022	0.009	10.95
700-768	19.43	1.97	10.78	9.28	9.23	15.38	0.10	0.000	0.000	0.002	0.030	0.009	11.51
800-0.75	3.16	0.82	2.26	2.27	1.25	2.51	0.18	0.063	0.071	0.081	0.015	0.044	10.46
800-3	2.82	0.81	2.08	2.24	1.20	2.31	0.17	0.084	0.094	0.108	0.017	0.057	10.34
800-12	2.54	0.79	1.96	2.05	1.12	2.13	0.16	0.073	0.075	0.082	0.015	0.041	10.36
800-48-2	1.65	0.26	0.99	1.09	0.46	1.06	1.36	0.034	0.042	0.053	0.013	0.019	9.88
800-192	1.44	0.20	0.96	0.84	0.45	0.93	2.00	0.053	0.067	0.060	0.022	0.013	9.57
800-768	2.10	0.30	1.44	1.62	0.86	1.44	1.38	0.058	0.089	0.076	0.021	0.005	9.94
900-0.75	1.93	0.27	1.16	1.17	0.52	1.32	1.91	0.034	0.040	0.051	0.018	0.013	9.85
900-3	1.69	0.20	0.95	1.02	0.46	1.08	2.11	0.037	0.038	0.051	0.019	0.017	9.50
900-12	1.41	0.16	0.83	0.15	0.41	0.88	2.78	0.038	0.038	0.034	0.022	0.015	9.22
900-48	1.51	0.35	1.05	1.15	0.57	1.14	1.01	0.068	0.088	0.079	0.023	0.048	9.95
900-192	1.06	0.24	0.83	0.76	0.43	0.80	1.66	0.075	0.086	0.078	0.031	0.026	9.71
900-768	0.99	0.16	0.73	0.71	0.42	0.68	2.44	0.051	0.054	0.048	0.028	0.012	9.31
1000-0.75	0.91	0.23	0.68	0.62	0.47	0.79	3.29	0.026	0.031	0.034	0.012	0.013	9.78
1000-3	0.89	0.21	0.74	0.74	0.42	0.72	2.67	0.030	0.034	0.040	0.021	0.018	9.64
1000-12	0.84	0.18	0.66	0.70	0.40	0.66	2.97	0.025	0.031	0.028	0.014	0.012	9.43
1000-48	1.28	0.21	0.99	0.98	0.55	0.94	6.16	0.020	0.030	0.020	0.026	0.000	9.09
1000-192	1.63	0.22	1.15	1.00	0.60	1.10	7.85	0.012	0.015	0.007	0.015	0.003	8.82
1000-768	1.91	0.22	1.19	0.13	0.63	1.19	6.25	0.011	0.013	0.005	0.015	0.001	9.15
1100-0.75	0.76	0.25	0.83	0.80	0.44	0.75	2.59	0.029	0.033	0.039	0.010	0.014	9.89
1100-3	0.88	0.27	0.88	0.82	0.43	0.84	2.39	0.031	0.037	0.042	0.010	0.017	10.00
1100-12	0.64	0.21	0.69	0.69	0.39	0.64	3.49	0.023	0.028	0.034	0.015	0.002	9.63
1100-48	0.74	0.23	0.78	0.73	0.43	0.72	5.16	0.026	0.041	0.038	0.032	0.010	9.60
1100-192	0.42	0.19	0.47	0.42	0.28	0.48	3.28	0.014	0.025	0.028	0.023	0.002	9.89
1100-768	0.31	0.24	0.33	0.31	0.24	0.42	1.77	0.030	0.024	0.046	0.019	0.005	8.68
Non-annealed	0.88	0.25	0.90	0.81	0.44	0.84	3.34	0.033	0.038	0.039	0.013	0.019	9.84

Temp-Time	B	Si	Na	Na (AA)	K (AA)	Li	HM	Al	Fe	Mn	Mg	Ca	N	pH
													normalized	
400-0.75	0.41	0.28	0.39	0.43	0.27	0.50	0.222	0.026	0.015	0.032	0.015	0.000	9.25	
400-12	0.45	0.29	0.43	0.43	0.27	0.53	0.254	0.028	0.016	0.033	0.013	0.000	9.63	
400-192	0.38	0.26	0.38	0.34	0.29	0.45	0.257	0.024	0.013	0.028	0.011	0.003	9.19	
500-0.75	0.41	0.27	0.41	0.42	0.27	0.51	0.244	0.024	0.014	0.027	0.014	0.000	9.48	
500-3	0.43	0.28	0.42	0.41	0.23	0.54	0.294	0.026	0.016	0.029	0.018	0.009	9.66	
500-12	0.53	0.27	0.44	0.43	0.21	0.57	0.358	0.031	0.019	0.031	0.017	0.006	9.47	
500-48	0.39	0.26	0.38	0.39	0.25	0.48	0.272	0.026	0.016	0.029	0.011	0.019	9.43	
500-192	0.39	0.27	0.37	0.42	0.23	0.48	0.262	0.031	0.020	0.038	0.022	0.009	9.50	
500-768	0.40	0.27	0.41	0.43	0.44	0.50	0.292	0.031	0.021	0.028	0.000	0.009	9.24	
600-0.75	0.40	0.27	0.39	0.39	0.26	0.49	0.244	0.026	0.015	0.033	0.010	0.000	9.36	
600-3	0.43	0.29	0.44	0.42	0.28	0.53	0.198	0.024	0.013	0.030	0.015	0.000	9.36	
600-12	0.50	0.31	0.43	0.43	0.30	0.57	0.244	0.029	0.018	0.032	0.013	0.003	9.39	
600-48	0.77	0.29	0.57	0.59	0.35	0.76	0.322	0.028	0.085	0.067	0.006	0.000	9.80	
600-192	1.31	0.84	0.91	0.97	0.55	3.28	0.441	0.060	0.225	0.167	0.013	0.022	10.54	
600-768	4.32	1.20	1.89	1.92	0.76	5.97	0.279	0.041	0.813	0.452	0.047	0.025	11.14	
650-0.75	0.65	0.26	0.41	0.40	0.24	0.58	0.344	0.033	0.023	0.037	0.021	0.013	9.25	
650-3	0.58	0.28	0.43	0.46	0.45	0.57	0.262	0.031	0.019	0.037	0.018	0.009	9.22	
700-0.75	0.44	0.30	0.42	0.39	0.28	0.54	0.208	0.028	0.017	0.037	0.017	0.000	9.41	
700-3	0.43	0.29	0.42	0.43	0.28	0.53	0.216	0.025	0.014	0.030	0.010	0.000	9.40	
700-12	0.70	0.31	0.54	0.53	0.32	0.70	0.344	0.049	0.090	0.070	0.007	0.003	9.55	
700-48	1.71	0.24	0.68	0.77	0.33	1.01	0.612	0.017	0.057	0.048	0.000	0.003	9.83	
700-192	1.65	0.90	1.07	1.09	0.54	3.87	0.657	0.066	0.310	0.212	0.014	0.075	10.96	
700-768	1.47	0.83	0.99	1.06	0.51	3.87	0.737	0.075	0.283	0.181	0.025	0.075	10.65	
800-0.75	0.43	0.28	0.38	0.40	0.27	0.51	0.219	0.024	0.014	0.029	0.015	0.009	9.01	
800-3	0.44	0.29	0.39	0.40	0.27	0.53	0.234	0.025	0.015	0.031	0.014	0.003	9.24	
800-12-2	0.53	0.27	0.40	0.40	0.26	0.54	0.290	0.029	0.019	0.035	0.000	0.003	9.22	
800-48-2	0.43	0.30	0.42	0.42	0.27	0.54	0.245	0.026	0.015	0.033	0.015	0.003	9.11	
800-192	0.40	0.28	0.40	0.36	0.22	0.51	0.224	0.029	0.019	0.044	0.014	0.003	9.13	
800-768	0.45	0.29	0.41	0.46	0.34	0.51	0.280	0.058	0.078	0.072	0.025	0.031	9.28	
900-0.75	0.42	0.30	0.41	0.44	0.29	0.54	0.237	0.030	0.018	0.038	0.022	0.000	9.35	
900-3	0.40	0.29	0.40	0.41	0.30	0.53	0.211	0.024	0.013	0.031	0.014	0.000	9.30	
900-12	0.41	0.29	0.41	0.43	0.30	0.53	0.221	0.023	0.012	0.028	0.014	0.000	9.31	
900-48	0.43	0.29	0.40	0.46	0.29	0.53	0.226	0.027	0.016	0.032	0.014	0.006	9.31	
900-192	0.39	0.28	0.41	0.38	0.27	0.50	0.235	0.029	0.018	0.039	0.018	0.000	9.10	
900-768	0.32	0.24	0.33	0.36	0.28	0.42	0.298	0.031	0.021	0.040	0.019	0.016	9.00	
1000-0.75	0.40	0.27	0.41	0.38	0.26	0.52	0.326	0.028	0.017	0.031	0.015	0.006	9.43	
1000-3	0.38	0.26	0.37	0.34	0.25	0.47	0.284	0.025	0.015	0.030	0.018	0.000	9.40	
1000-12	0.38	0.26	0.37	0.39	0.26	0.47	0.218	0.023	0.014	0.029	0.013	0.013	9.31	
1000-48	0.37	0.25	0.37	0.38	0.33	0.49	0.325	0.034	0.023	0.041	0.021	0.000	9.52	
1000-192	0.35	0.25	0.34	0.00	0.25	0.47	0.320	0.026	0.017	0.032	0.017	0.003	9.43	
1000-768	0.29	0.23	0.25	0.25	0.26	0.44	0.475	0.027	0.018	0.037	0.022	0.006	8.89	
1100-0.75	0.40	0.27	0.41	0.38	0.26	0.52	0.281	0.027	0.017	0.026	0.013	0.003	9.45	
1100-3	0.40	0.28	0.42	0.41	0.28	0.51	0.231	0.026	0.016	0.033	0.011	0.000	9.31	
1100-12	0.37	0.27	0.38	0.39	0.25	0.48	0.239	0.024	0.014	0.030	0.013	0.000	9.52	
1100-48	0.34	0.25	0.32	0.28	0.23	0.46	0.332	0.028	0.018	0.033	0.019	0.009	9.29	
1100-192	0.44	0.23	0.44	0.39	0.47	0.44	0.433	0.044	0.022	0.037	0.021	0.022	9.46	
1100-768	0.26	0.21	0.13	0.13	0.21	0.46	0.572	0.025	0.018	0.038	0.019	0.003	8.69	
Non-annealed	0.42	0.28	0.43	0.40	0.29	0.53	0.274	0.026	0.015	0.029	0.011	0.006	9.35	

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