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# **Chemical Composition Analysis and Product Consistency Tests Supporting Refinement of the Nepheline Model for the High Aluminum Hanford Glass Composition Region**

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March 2016

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## EXECUTIVE SUMMARY

In this report, Savannah River National Laboratory provides chemical analyses and Product Consistency Test (PCT) results for a series of simulated high level waste (HLW) glasses fabricated by Pacific Northwest National Laboratory (PNNL) as part of an ongoing nepheline crystallization study. The results of these analyses will be used to improve the ability to predict crystallization of nepheline as a function of composition and heat treatment for glasses formulated at high alumina concentrations.

The measured chemical composition data are reported and compared with the targeted values for each component for each glass. A detailed review showed no indications of errors in the preparation or measurement of the study glasses. All of the measured sums of oxides for the study glasses fell within the interval of 98 to 101 wt %, indicating recovery of all components. Comparisons of the targeted and measured chemical compositions showed that the measured values for the glasses met the targeted concentrations within 10% for those components present at more than 5 wt %.

Several of the study glasses exhibited unusual appearances during preparation for, or after performance of, the Product Consistency Tests (PCTs). In some cases this may be linked to low chemical durability. Future studies should include thorough analysis of the glasses after the PCTs to provide further information regarding glass behavior in durability testing.

A detailed review showed no issues with performance of the PCTs. The quenched versions of all of the study glasses have normalized boron concentration ( $NC_B$ ) values that are lower than the Environmental Assessment (EA) benchmark  $NC_B$  value of 16.695 g/L. Many of the study glasses have higher normalized concentration values after the canister centerline cooled (CCC) heat treatment. This is likely indicative of crystallization or phase separation. Sixteen of the study glasses have  $NC_B$  values that are below that of the EA benchmark for the quenched versions, but greater than that of the EA benchmark glass after the CCC heat treatment. These results can be combined with additional characterization, including X-ray diffraction, to determine the cause of the higher release rates.

Duplicate PCT testing was completed for a small subset of the study glasses to test reproducibility. Although limited in scope, the results of the duplicate tests indicate reasonable reproducibility for the PCT responses of the study glasses over a broad range of normalized concentration values.

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## LIST OF ABBREVIATIONS

AD	Acid Dissolution
AR	As Received
ARM	Approved Reference Material
BDL	Below Detection Limit
CCC	Canister Centerline Cooled
DOE	U.S. Department of Energy
EA	Environmental Assessment benchmark glass
HLW	High Level Waste
ICP-OES	Inductively Coupled Plasma – Optical Emission Spectroscopy
JHCM	Joule-Heated Ceramic Melter
LAW	Low Activity Waste
LRM	Low-level Reference Material
$NC_i$	Normalized Concentration of element “ <i>i</i> ”
ORP	U.S. Department of Energy – Office of River Protection
PCT	Product Consistency Test
PF	Peroxide Fusion
PNNL	Pacific Northwest National Laboratory
RSD	Relative Standard Deviation
SRNL	Savannah River National Laboratory
TTQAP	Task Technical and Quality Assurance Plan
wt %	Weight Percent
WTP	Hanford Waste Treatment and Immobilization Plant

## 1.0 Introduction

The U.S. Department of Energy (DOE) Office of River Protection (ORP) is building the Waste Treatment and Immobilization Plant (WTP) at the Hanford Site in Washington to remediate 55 million gallons of radioactive waste that is temporarily stored in 177 underground tanks. The low-activity waste (LAW) fraction will be partitioned from the high-level waste (HLW). Both the LAW and HLW will then be vitrified in borosilicate glass with Joule-heated ceramic melters (JHCM).

Efforts are being made to increase the loading of Hanford tank wastes in glass while maintaining the ability to meet processing, regulatory compliance, and product quality requirements. DOE-ORP has requested that SRNL support the advancement of glass formulations and process control strategies in key technical areas, as defined in the Task Technical and Quality Assurance Plan (TTQAP).<sup>1</sup> One of these areas is the development of advanced, predictive models for the crystallization of nepheline in glasses formulated at high alumina concentrations.

The performance of HLW glass is generally quantified by its resistance to chemical degradation, or durability. The durability of a HLW glass is dependent upon its composition and its crystalline content. If crystalline phases form within a glass during cooling, the composition of the residual glass network is altered, potentially affecting the durability of the glass. Crystallization of nepheline ( $\text{NaAlSi}_3\text{O}_8$ ) has been shown to adversely impact the durability of HLW glasses since it removes glass forming species (in this case, Al and Si) from the glass network.<sup>2</sup> The propensity for nepheline crystallization in a HLW glass increases with increasing concentrations of  $\text{Al}_2\text{O}_3$  and  $\text{Na}_2\text{O}$  in the glass.<sup>3</sup> Nepheline crystallization is therefore of concern for processing of HLW at WTP since a significant fraction of Hanford tank wastes is rich in  $\text{Al}_2\text{O}_3$  and  $\text{Na}_2\text{O}$ . The ability to correctly predict the formation of nepheline as a function of glass composition will allow WTP to maximize the loading of  $\text{Al}_2\text{O}_3$  and  $\text{Na}_2\text{O}$  in glass while maintaining acceptable durability.

In this report, SRNL provides chemical analyses and Product Consistency Test (PCT) results for a series of simulated HLW glasses fabricated by Pacific Northwest National Laboratory (PNNL) as part of an ongoing nepheline crystallization study.<sup>4,5</sup> The results of these analyses will be used to improve the ability to predict crystallization of nepheline as a function of composition and heat treatment for glasses formulated at high alumina concentrations.

## 2.0 Experimental Procedure

### 2.1 Glasses Selected for Study

PNNL fabricated 31 glasses for the analyses described in this report. The identifiers for these glasses are given in Table 2-1. Rapidly cooled (quenched) and Canister Centerline Cooled (CCC) versions of each glass were provided. The quenched glasses were used for chemical analyses. Both the quenched and the CCC glasses were used for the PCTs.

**Table 2-1. Identifiers for PNNL Nepheline Glasses Characterized in this Study**

Glass Identifier	Glass Identifier
BL3	NP-MC-AIBNa-1
Neph-NN-1-12	NP-MC-AIBNa-2
NP2 - High Al	NP-MC-AIBSi-1
NP2 - High B	NP-MC-AiLi-1
NP2 - High Li	NP-MC-AiLi-2
NP2 - High Na	NP-MC-AiLiNa-1
NP2 - High Si	NP-MC-AiLiSi-1
NP2 - Low Al	NP-MC-AINa-1
NP2 - Low B	NP-MC-AiSi-1
NP2 - Low Li	NP-MC-AiSi-2
NP2 - Low Na	NP-MC-BLiSi-1
NP2 - Low Si	NP-MC-BLiSi-2
NP2 - Very High Al	NP-MC-BNa-1
NP2 - Very High Si	NP-MC-BNaSi-1
NP2 - Very Low Si	NP-MC-BSi-1
NP-MC-AIB-1	

In the sections that follow, the methods used for measuring chemical composition and PCT performance are described and statistical reviews of the resulting data are provided. Detailed data from these analyses are included as appendices.

## 2.2 Compositional Analysis

Chemical analysis was performed under the auspices of an analytical plan<sup>6</sup> on a representative sample from the quenched version of each of the study glasses to allow for comparisons with the targeted compositions and normalization of the PCT data. Two preparation techniques, sodium peroxide fusion (PF) and acid dissolution (AD), were used to prepare the glass samples, in duplicate, for analysis. The PF method was selected for measurement of the major components of the glasses since SRNL experience has shown it to be an effective method for complete dissolution of simulated HLW glass samples.<sup>7-9</sup> Measurement of the minor components using samples prepared with this method is difficult due to the high concentration of salts in the resulting solutions. A 10x dilution is required before analysis of the PF prepared solutions to avoid issues with extinguishing the plasma in the Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES) instrument. This dilution results in higher detection limits. The AD method was used for those components that could not be measured via the PF preparation due to interferences or low (minor) concentrations. The PF method is described in an SRNL procedure,<sup>10</sup> and the AD method is described in an earlier report.<sup>11</sup>

The preparation methods used for each of the reported glass components are summarized in Table 2-2. Note that additional preparation methods for some of the glass components were requested in the analytical plan<sup>6</sup> due to the potential for crystalline phases to be present in the study glasses and uncertainty regarding the dissolution of those phases. In these cases, the analytical data from each method were reviewed in order to select the most appropriate method, and the selected methods are listed in Table 2-2.

Fluorine concentrations were not measured since this would have required the use of an additional preparation method. Targeted fluorine concentrations were also low (approximately



0.3 wt %), such that they were likely to be near or below analytical detection limits. After discussion with PNNL, it was determined that the effort needed to measure fluorine was not worthwhile.

Each of the prepared samples was analyzed, twice for each element of interest, by ICP-OES. A glass standard was also intermittently measured to assess the performance of the ICP-OES instrument over the course of these analyses. Specifically, several samples of the low-level reference material (LRM)<sup>12</sup> were included as part of the analytical plan.

**Table 2-2. Preparation Methods Used in Reporting the Concentrations of Each of the Components of the Study Glasses.**

Component	Preparation Method
Al	PF
B	PF
Bi	AD
Ca	AD
Cr	PF
F	Not analyzed
Fe	PF
Li	PF
Mn	PF
Na	AD
Ni	AD
P	AD
Ru	AD
S	AD
Si	PF
Zr	AD

### 2.3 Product Consistency Test

The PCT Method-A<sup>13</sup> was performed in triplicate on each of the quenched and CCC versions of the study glasses to assess chemical durability. Also included in the experimental test matrix was the Approved Reference Material (ARM) glass<sup>14</sup> and blanks from the vessel cleaning batch. Samples were ground, washed, and prepared according to the standard procedure.<sup>13</sup> Fifteen milliliters of Type-I ASTM water were added to 1.5 g of glass in stainless steel vessels. The vessels were closed, sealed, and placed in an oven at  $90 \pm 2$  °C where the samples were maintained at temperature for 7 days. The vessels were then removed from the oven and cooled to ambient temperature. Once cooled, a small aliquot was used to determine the ambient temperature pH of the leachate. The remaining solutions were sampled (filtered and acidified), then labeled and analyzed by ICP-OES under the auspices of a series of analytical plans.<sup>15-17</sup> Samples of a multi-element, standard solution<sup>a</sup> were also included in the analytical plans as a check on the accuracy of the ICP-OES instrument used for these measurements. Normalized concentrations were calculated based on the targeted (provided by PNNL) and measured compositions using the average of the common logarithms of the leachate concentrations.

<sup>a</sup> ICP multi-element custom solution, product number SM-744-013, High Purity Standards, Charleston, SC

### *2.3.1 PCT Reproducibility Testing*

During the course of the PCTs for this study, it was noted that normalized concentration values for some of the glasses were unusually high. It was postulated that these responses may be the result of inhomogeneous glasses. The PCT was therefore repeated in entirety for three of the study glasses in order to test the reproducibility of the normalized concentration results. The glasses selected for the reproducibility study were the CCC versions of:

- NP-MC-AIBNa-1
- NP-MC-AiLi-2
- NP-MC-AiNa-1

These glasses spanned a range of normalized concentration values in the first PCT group. Normalized concentrations were measured and calculated again for each of these glasses in the second group of PCTs. The results are discussed with the rest of the PCT outcomes later in this report.

### 2.4 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2. Laboratory data for this study were recorded in the SRNL Electronic Laboratory Notebook system, experiment C3489-00079-09.

## **3.0 Results and Discussion**

### 3.1 Review and Evaluation of Chemical Composition Measurements

Table A-1 in Appendix A provides the elemental concentration measurements in wt % from the study glasses that were prepared by the AD method. Table A-2 in Appendix A provides the elemental concentration measurements in wt % from these glasses as prepared by the PF method. Elemental measurements for samples of the LRM standard glass are also provided in the tables of Appendix A. These unprocessed data are provided as appendices to this report so that the values are readily available should they be of interest for future reviews.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements of the LRM standard glass are investigated, the measurements for each glass are reviewed, the average chemical composition for each glass is determined, and comparisons are made between the measurements and the targeted compositions for the glasses. JMP Pro Version 11.2.1 (SAS Institute, Inc.)<sup>18</sup> was used to support these analyses.

#### *3.1.1 Treatment of Detection Limits*

The elemental concentrations in Table A-1 and Table A-2 were converted to oxide concentrations by multiplying the values for each element by the gravimetric factor for the corresponding oxide. During the process of converting to oxide concentrations, an elemental concentration that was reported to be below the detection limit of the analytical process used was set to the detection limit as the oxide concentration was determined for the purposes of statistical review and calculating a sum of oxides for each glass. Those oxides with measured concentrations that were below the associated detection limit will be denoted with a less than symbol (<) as the measured compositions are reported.

### 3.1.2 Measurements in Analytical Sequence

Exhibit A-1 in Appendix A provides plots of the wt % measurements generated for prepared samples by oxide and analytical block. The plots are in analytical sequence within each calibration block with different symbols and colors being used to represent each of the study and standard glasses. These plots include all of the measurement data from Table A-1 and Table A-2, with each plotted point identified by its Lab ID. Plotting the data in this format provides an opportunity to identify gross trends in performance of the analytical instrument within and among calibration blocks. A review of these plots identified a slight, upward shift in the measurements of the second sub-block within the first block of  $\text{Cr}_2\text{O}_3$  measurements. There is also a slight, upward shift in the measurements of the second sub-block within the first block of MnO measurements. These shifts may be the result of minor differences in instrument calibrations. One of the four measurements of the  $\text{Li}_2\text{O}$  concentration in glass NP-MC-BLiSi-2 (Lab ID W12) is lower than the other three. There do not appear to be any other gross patterns or trends in the analytical process over the course of these measurements.

### 3.1.3 Composition Measurements by Glass Identifier

Exhibit A-2 in Appendix A provides plots of the oxide concentration measurements by the PNNL Glass ID (including the LRM reference glass) by Lab ID grouped by targeted concentration. Different symbols and colors are used to represent the different glasses. These plots show the individual measurements across the duplicates of each preparation method and the two instrument calibrations for each glass. Plotting the data in this format provides an opportunity to review the values for each individual glass as a function of the duplicate preparations and duplicate measurements. A review of the plots presented in these exhibits reveals the repeatability of the four individual values for each oxide for each glass and leads to the following observations:

- The measured  $\text{Bi}_2\text{O}_3$  concentrations of the study glasses are generally low by about 10%, although the targeted concentrations of this oxide are less than 1 wt %.
- The measured CaO concentrations of the study glasses are generally lower than the targeted values, although the targeted concentrations of this oxide are less than 1 wt %.
- One of the measured values for  $\text{Li}_2\text{O}$  in glass NP-MC-BLiSi-2 is low relative to the other three.
- The measured  $\text{Na}_2\text{O}$  values appeared to be biased somewhat high.
- Measurements of  $\text{RuO}_2$  were all below detection limits for the study glasses.
- Measurements of  $\text{SO}_3$  in the LRM glass are below the consensus average value of 0.3 wt % reported in the reference document,<sup>12</sup> but are close to the batch target of 0.2 wt % for this glass. Measurements of  $\text{SO}_3$  for the study glasses vary somewhat from the targeted values, depending on the individual glass composition.
- Measurements of  $\text{ZrO}_2$  in glass NP2-High Na are consistently above the targeted value by about a factor of two. This component may have been inadvertently double batched in this glass.

None of the observations noted above from Exhibit A-2 indicated an error in preparation or measurement that had to be addressed in treatment of the data. Therefore, the entire set of measurement data was used in determining representative, measured compositions for all of the oxides for the study glasses.

### 3.1.4 Results for the LRM Standard

Exhibit A-3 in Appendix A provides a review of the LRM results against acceptability limits utilized by SRNL. The review is in the form of plots of the measurements arranged by preparation method and element, framed by upper and lower acceptability limits for the

concentration of the element in question. The results show that all of the measurements for the elements present in the LRM standard glass were within the acceptability limits utilized by SRNL in conducting instrument and procedure assessments during the execution of these measurements. Note that as observed in the previous section, sodium measurements were elevated but were within acceptability limits.

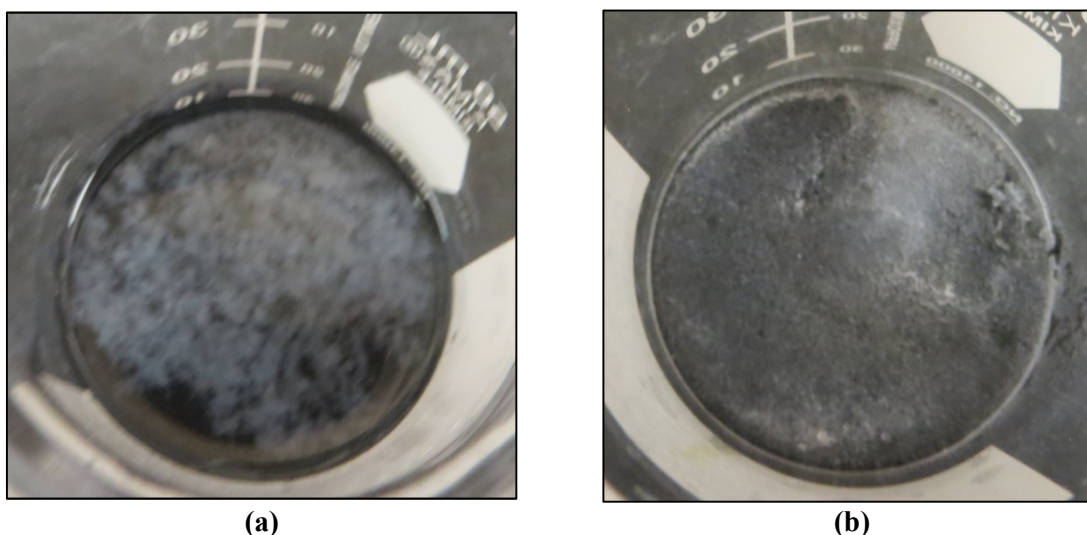
### 3.1.5 Measured versus Targeted Compositions

From the discussion of Section 3.1.3, all of the measurements for each oxide for each glass (i.e., all of the measurements in Appendix A, Table A-1 and Table A-2), were averaged to determine a representative chemical composition for each glass. A sum of oxides was also computed for each glass based upon the measured values. Exhibit A-4 in Appendix A provides a graphical representation of the results for each glass for each oxide to allow PNNL to draw comparisons between the measured and targeted values.

Table A-3 in Appendix A provides a summary of the average compositions as well as the targeted compositions and some associated differences and relative differences. All of the measured sums of oxides for the study glasses fall within the interval of 98 to 101 wt %, indicating recovery of all components. Entries in Table A-3 show the relative differences between the measured values and the targeted values for the oxides with targeted values above 5 wt %. The relative differences are typically shaded if they are 10% or more.<sup>a</sup> The measurements of the glasses in this study all exceeded these criteria, thus there are no shaded values found in Table A-3.

### 3.2 Review and Evaluation of PCT Measurements

Unusual appearances were noted for some of the study glasses during performance of the PCTs. The CCC versions of glasses NP-MC-ALLiNa-1 and NP-MC-BNaSi-1 expressed a whitish material during the washing steps after grinding the glass for the PCT. Washing consisted of several ASTM Type I water washes, followed by several absolute ethanol washes per procedure. Photos of this material are shown in Figure 3-1. The material persisted until the final alcohol wash.



**Figure 3-1. Photos of whitish material expressed from the CCC versions of glasses NP-MC-ALLiNa-1 (a) and NP-MC-BNaSi-1 (b) during washing for the PCT.**

<sup>a</sup> These criteria were selected arbitrarily for the purpose of highlighting differences from targeted concentrations that may be of practical concern.

Samples of the glasses shown in Figure 3-1 were collected and prepared for chemical composition analysis to identify changes to the glass composition that may have occurred during washing for the PCT. A sample of each glass was prepared once using the PF and AD methods described in Section 2.2. Each of the prepared samples was analyzed, twice for each element of interest, by ICP-OES. The average of the two values for each element was calculated, and the results are given in Table 3-1. Included in the table are the measured composition data for the quenched versions of these glasses, as described in Section 3.1 and reported in Table A-3 of Appendix A. The differences between the measured values for the quenched glasses and the measured values for the CCC versions of the glasses after washing for the PCT are also reported in the table. A review of these data shows that some changes occurred, either as a function of the CCC heat treatment, washing of the glass for the PCT, or both. Of most significance is the ~10% reduction in  $B_2O_3$  concentration for these glasses after the CCC heat treatment and preparation for the PCT. The concentrations of  $Li_2O$  and  $MnO$  are also reduced in these glasses after the CCC heat treatment and preparation for the PCT. The reduction in the concentrations of  $B_2O_3$ ,  $P_2O_5$ , and  $SO_3$  may be due in part to volatilization during the CCC heat treatment.

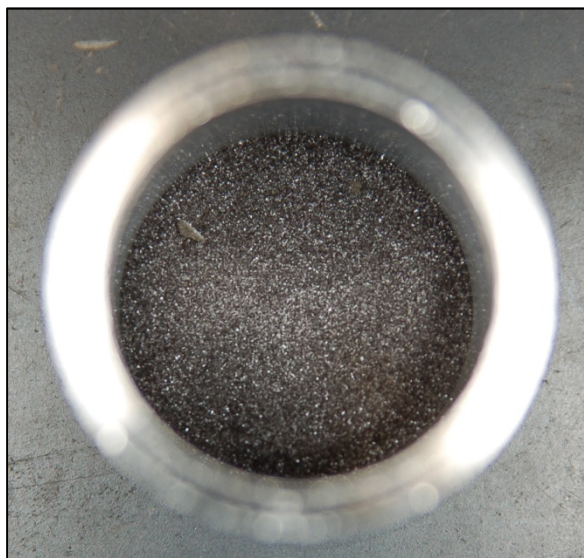
**Table 3-1. Measured Compositions of Two of the Study Glasses Before and After the CCC Heat Treatment and PCT Preparation**

Oxide	NP-MC-BNaSi-1 (Quenched)	NP-MC-BNaSi-1 (CCC, After Washing for PCT)	Difference	NP-MC-ALiNa-1 (Quenched)	NP-MC-ALiNa-1 (CCC, After Washing for PCT)	Difference
Al <sub>2</sub> O <sub>3</sub>	30.66	30.38	-0.90%	30.94	29.55	-4.49%
B <sub>2</sub> O <sub>3</sub>	14.21	12.80	-9.89%	15.15	13.71	-9.53%
Bi <sub>2</sub> O <sub>3</sub>	0.65	0.59	-10.27%	0.52	0.47	-8.89%
CaO	0.66	0.70	5.63%	0.53	0.58	9.83%
Cr <sub>2</sub> O <sub>3</sub>	1.17	1.14	-2.60%	0.88	0.95	7.61%
Fe <sub>2</sub> O <sub>3</sub>	2.72	2.44	-10.36%	2.18	3.08	40.85%
Li <sub>2</sub> O	5.31	5.00	-5.83%	5.70	4.70	-17.62%
MnO	1.07	0.68	-36.15%	0.82	0.55	-32.86%
Na <sub>2</sub> O	16.48	16.70	1.35%	15.70	16.44	4.68%
P <sub>2</sub> O <sub>5</sub>	0.71	0.66	-6.15%	0.58	0.52	-10.74%
SO <sub>3</sub>	0.27	0.23	-13.32%	0.24	0.20	-16.31%
SiO <sub>2</sub>	26.37	27.07	2.67%	26.47	26.39	-0.32%
ZrO <sub>2</sub>	0.26	0.27	5.24%	0.21	0.20	-3.91%

The technicians performing the PCTs noted that the leachates for glass NP2-Low-Si-CCC were difficult to pass through the syringe filter.

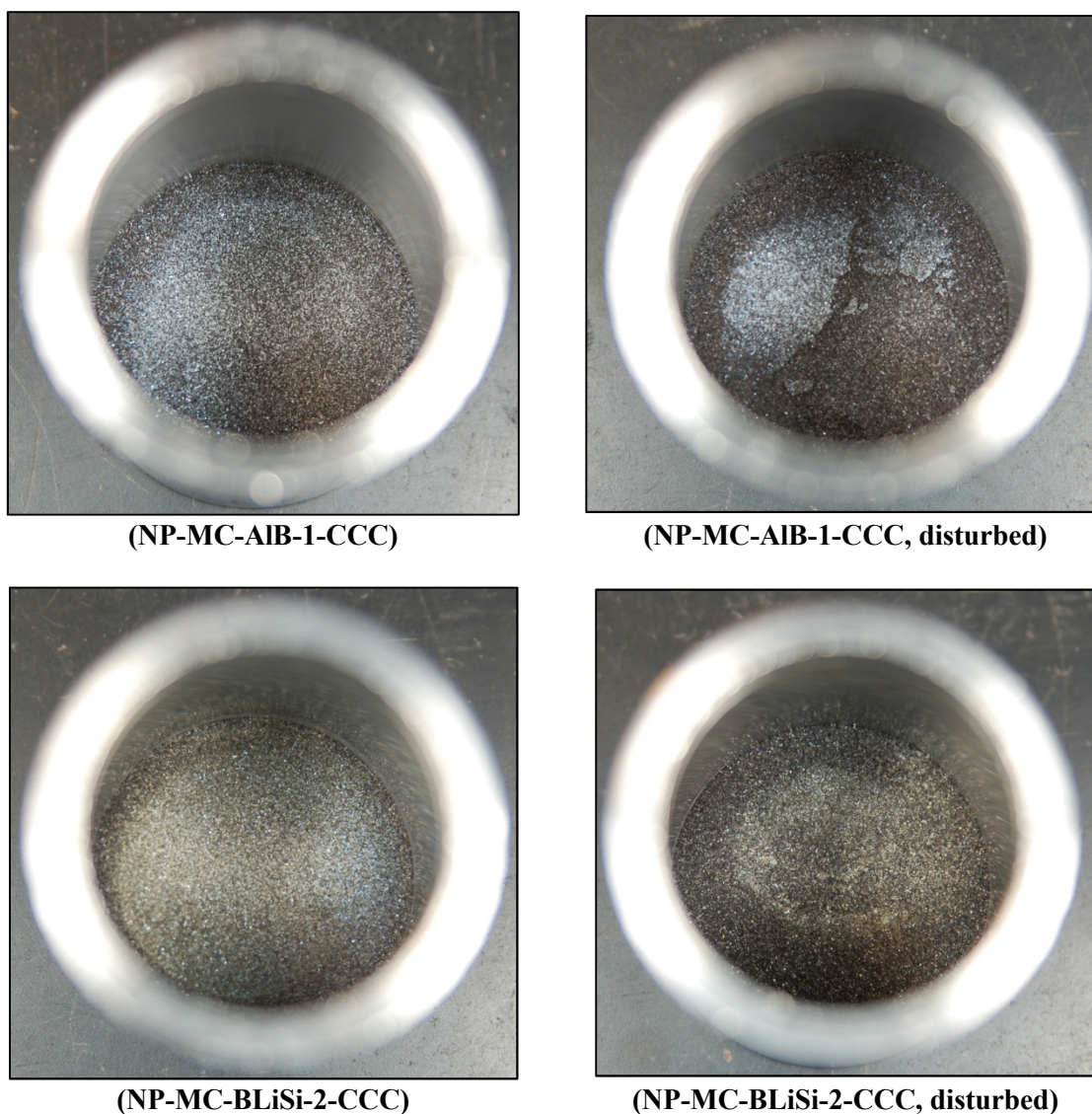
Although the scope of this study did not include any detailed observation or analysis of the leached glasses per Section 24.4.17 of the PCT (which includes water washing and drying of the leached powders at 90 °C), some observations of the leached glasses are discussed below. Most of the study glasses appeared uniform in color before and after the PCT. For example, a photo of ground NP2-Very-High-Si-CCC glass inside a PCT vessel after the test is shown in Figure 3-2. The photo in Figure 3-2 is generated after several steps following the PCT-A. These include removal of the sealed PCT vessels from the oven, cooling to ambient temperature, weighing and opening of the vessels, and removal of the leachate from the vessel. These steps leave the leached glass powder and some residual or interstitial leachate behind in the vessel. These ‘damp’ leached powders are then typically dried in an oven to render dried, leached glass powders that can be discarded. This process can produce visible solids on the leached glass powders.

Some of the study glasses had unusual appearances after the PCT was completed and the leached glasses containing various amounts of residual/interstitial amounts of leachate were dried in the vessels. The CCC versions of glasses NP-MC-AIB-1 and NP-MC-BLiSi-2 both had layers of whitish material on top of the ground glass. The layer could be broken to observe its thickness by gently tapping the PCT vessel, as shown in Figure 3-3.



**Figure 3-2. Example of typical, uniform glass appearance after PCT.**





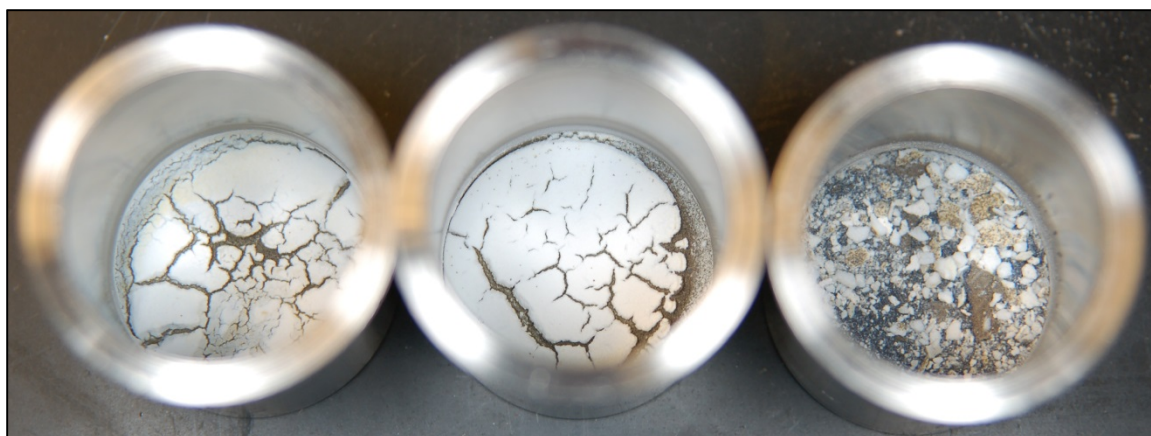
**Figure 3-3. Photos of the CCC versions of glasses NP-MC-AIB-1 and NP-MC-BLiSi-2 after the PCT, showing whitish layer that could be broken by tapping the vessel.**

The CCC version of glass NP-MC-AIBNa-1 left a dark coating on the inner surface of each of the triplicate PCT vessels, as shown in Figure 3-4. The CCC versions of glasses NP-MC-AiLi-2 and NP-MC-AiNa-1 had relatively thick, whitish coatings on top of the ground glass after the PCT as shown in Figure 3-5. Each of the three replicate PCT vessels is shown in these photos, with the third vessel having been gently tapped to disturb the layer such that its thickness is visible. These observations will be discussed further in this report as normalized PCT data are presented and reviewed.





**Figure 3-4. Photos of a PCT vessel for the CCC version of glass NP-MC-AIBNa-1 (left), showing dark coating left on the vessel after the test. A clean vessel is shown for comparison (right).**



(NP-MC-AlLi-2-CCC)



(NP-MC-AlNa-1-CCC)

**Figure 3-5. Photos of the CCC versions of glasses NP-MC-AlLi-2 and NP-MC-AlNa-1 after the PCT showing thick, whitish layer on top of the ground glass.**

Table B-1 in Appendix B provides the elemental leachate concentration measurements for the solution samples generated by the PCTs for the study glasses and standards. The values for these measurements are given in the table as-received (“ar”) from the laboratory analyses and after adjustments for the dilution factors. The measurements for the study glasses, blanks, and the ARM glass were multiplied by 1.6667 to determine the values in mg/L.

Based on the masses of the PCT vessels before and after the 7-day procedures, there were no samples that had water-loss issues. The ratio of leachant volume to the mass of ground glass was confirmed to be correct for each vessel. The measured concentrations of B, Li, Na, and Si in the leachates from the ARM glasses were compared to the control charts to demonstrate proper performance of the PCTs.<sup>14</sup> Two of the triplicate B values from the Group 1, Set 1 PCTs, three of the triplicate B values from the Group 1, Set 2 PCTs, and one of the triplicate B values from the Group 3, Set 1 PCTs fell outside the limits of the control chart. All of the measured Li, Na, and Si concentrations in the ARM glass leachates fell within the limits of the control charts. The expectation is that an error in the performance of a PCT would result in a consistent divergence of the concentrations of the analytes of the ARM glass away from the limits of the control charts. Since there were no consistent issues with the ARM values for any of the five sets of PCTs, the

tests were considered to have been performed properly and no bias correction was performed.<sup>a</sup> The measured, ambient temperature pH values for each of the PCT leachates are provided in Table B-2 through Table B-6 of Appendix B for reference.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements for each glass are reviewed, the measurements of the multi-element solution standard are investigated, the normalized PCT results for each glass are determined, and comparisons are made between the PCT results for the two heat treatments of each glass. JMP Pro Version 11.2.1 (SAS Institute, Inc.)<sup>18</sup> was used to support these analyses.

### *3.2.1 Treatment of Detection Limits*

Some of the “ar” measurements (Table B-1 in Appendix B) were below the detection limit of 1 mg/L (prior to correction for dilution). These measurements (indicated by a “<” symbol in Table B-1) were replaced by their detection limits in subsequent analyses for the purposes of statistical review and calculating normalized leachate values. Those elements with measured concentrations that were below the associated detection limit will be denoted with a less than symbol (<) as the normalized leachate values are reported.

### *3.2.2 Results for the Samples of the Multi-Element Solution Standard*

Table B-7 through Table B-9 of Appendix B provide a review of the measurements of the solution standard samples that were included in the analytical blocks for the PCT analyses. For each analytical block, the mean, standard deviation, and percent relative standard deviation (%RSD) are determined for each element present in the standard. Following the guidance in ASTM C 1285 (PCT), there were two primary evaluations conducted for these summary statistics: the mean value for each analytical block was found to be less than 10% from the reference value (i.e., a percent relative bias less than 10%) for the element in question, and the %RSD was less than 10% for the element in question. The results in Table B-7 through Table B-9 of Appendix B satisfy these criteria, and thus, the results for the standard suggest no significant issues with the analytical outcomes for the measurements of the PCT solutions.

### *3.2.3 Measurements in Analytical Sequence*

Exhibit B-1 in Appendix B provides plots of the common logarithms of the leachate concentrations (mg/L) in analytical sequence by analytical block by analytical set. Each of the analytical sets corresponds to an oven run that was used to conduct the PCT measurements needed to support the analyses of the nepheline study glasses. Plotting the data in this format provides an opportunity to identify gross trends in performance of the analytical instrument within and among calibration blocks. A review of these plots identified an outlying silicon measurement for one of the replicates (lab identifier M29) of glass NP2-Low-Si-Q in PCT Group 3, Set 1. This measurement was about an order of magnitude lower than those for the other two replicates, and therefore it was excluded from the normalized concentration calculations. No other issues were observed in these plots.

### *3.2.4 Measurements by Glass Identifier*

Exhibit B-2 in Appendix B provides plots of the leachate concentrations for both the quenched and CCC version of each of the study glasses and for the standards for each analytical set. These plots are in common logarithms of the mg/L values and allow for the assessment of the repeatability of the measurements and any differences between the quenched and CCC version of a given glass. For some of the glasses, minor scatter among the triplicate values of some analytes

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<sup>a</sup> Data are provided in Appendix B to support bias correction per ASTM C 1285, Section 25.2 if desired.

is observed. The outlier in the silicon measurements for one of the replicates of glass NP2-Low-Si-Q is again visible in these plots. In addition, there are differences in the PCT responses between the quenched and CCC versions of some of the study glasses. A closer look at the quenched and CCC outcomes is provided in the following sections.

### 3.2.5 Normalization of the PCT Results

The PCT leachate data were used to determine normalized concentrations for each element of interest using both the targeted and measured compositions of the glasses following the expression given in ASTM C1285:

$$NC_i = \frac{c_i(\text{sample})}{f_i}$$

where  $NC_i$  is the normalized concentration in units of  $\text{g}_{\text{waste form}}/\text{L}_{\text{leachant}}$ ,  $c_i$  is the concentration of element “ $i$ ” in the leachate in units of  $\text{g}_i/\text{L}$ , and  $f_i$  is the mass fraction of element “ $i$ ” in the unleached glass in units of  $\text{g}_i/\text{g}_{\text{glass}}$ .<sup>a</sup>

An equation was developed to allow for calculation of the  $NC_i$  values using the units of measurement provided with the analytical results for this study, and to accommodate the triplicate leachate measurements for each of the study glasses. Note that the symbols in this second equation were kept consistent with those used in ASTM C1285, but the units of measurement differ. The common logarithm of the normalized concentration for each element “ $i$ ” ( $NC_i$ ) for each of the study glasses was determined using the equation:

$$\log_{10}(NC_i) = \overline{\log_{10} c_i} - [1 + \log_{10} f_i]$$

where  $NC_i$  remains in units of  $\text{g}_{\text{waste form}}/\text{L}_{\text{leachant}}$ ,  $\overline{\log_{10} c_i}$  is the average of the common logarithms of the measured concentrations of element “ $i$ ” in the triplicate leachates in units of  $\text{mg}/\text{L}$ , and  $\log_{10} f_i$  is either the common logarithm of the targeted concentration of element “ $i$ ” in the glass in units of wt %, or the common logarithm of the average measured concentration of element “ $i$ ” in the glass in units of wt % (from Table A-3 of Appendix A). The calculated  $NC_i$  values are discussed further in the following sections.

### 3.2.6 PCT Reproducibility Testing

The PCT was repeated in its entirety for three of the study glasses in order to test reproducibility over a range of normalized concentration values. The results of the duplicate testing are shown in Table 3-2. The results for the ARM-1 glass are included for comparison, since samples of this reference glass were included in each of the five PCT groups and sets that composed this study. Each of the  $NC_i$  (g/L) values shown in Table 3-2 is the average of a triplicate data set.

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<sup>a</sup> Note that the waste forms in this study were assumed to be of similar density. The PCT-A reference volume of leachant to sample mass ratio was used, and the 100 to 200 mesh reference particle size was used. Thus, no adjustment for the density of the glasses was made in normalizing the PCT results. Data provided in the appendices of this report allow for the calculation of normalized elemental mass loss ( $NL_i$ ) if glass densities are measured at a later date.

**Table 3-2. Results of PCT Reproducibility Testing**

Group/Set	Glass ID	Heat Treatment	Comp. View	$NC_B$ (g/L)	$NC_{Li}$ (g/L)	$NC_{Na}$ (g/L)	$NC_{Si}$ (g/L)
1/1	ARM-1	ref	ref	0.443	0.559	0.461	0.259
1/2	ARM-1	ref	ref	0.965	0.612	0.527	0.306
2/1	ARM-1	ref	ref	0.476	0.573	0.493	0.257
3/1	ARM-1	ref	ref	0.582	0.603	0.525	0.277
3/2	ARM-1	ref	ref	0.523	0.597	0.507	0.277
1/2	NP-MC-AIBNa-1	CCC	measured	1.384	1.158	0.623	0.627
2/1	NP-MC-AIBNa-1	CCC	measured	1.026	1.054	0.597	0.539
1/2	NP-MC-AiLi-2	CCC	measured	21.207	12.955	6.547	0.199
2/1	NP-MC-AiLi-2	CCC	measured	21.514	13.113	6.624	0.194
1/2	NP-MC-AiNa-1	CCC	measured	95.382	75.916	18.092	0.120
2/1	NP-MC-AiNa-1	CCC	measured	95.576	78.893	18.714	0.117

A review of the data in Table 3-2 shows that the PCT responses for the three study glasses were consistent between the duplicate tests. The variation in the normalized concentration values is consistent with the variation seen in the responses for the ARM-1 glass. Although limited in scope, these results indicate reasonable reproducibility for the PCT responses of the study glasses over a broad range of normalized concentration values.

### 3.2.7 Effects of Heat Treatments

Exhibit B-3 in Appendix B provides plots of the normalized PCT responses for the two heat treatments for each of the study glasses as well as the responses for ARM-1. The results are grouped by compositional view. Note that an indicator is provided as part of these plots to show results involving below detection limit (bdl) values; however, all of the PCT results for the study glasses were above detection limits.

The plots of Exhibit B-3 provide a graphical comparison between the PCT responses for the two heat treatments of each study glass. Table 3-3 provides a listing of the normalized PCT responses in g/L. Values for the duplicate PCTs of the CCC versions of glasses NP-MC-AIBNa-1, NP-MC-AiLi-2, and NP-MC-AiNa-1 are included in the exhibit and table.

A review of the PCT data resulted in several observations:

- The use of either the targeted or measured compositions in calculating the normalized concentration values has little if any practical effect.
- The quenched versions of all of the study glasses have  $NC_B$  values that are lower than the EA benchmark  $NC_B$  value of 16.695 g/L.<sup>19</sup>
- Many of the study glasses have higher normalized concentration values after the CCC heat treatment. Note however that this is often not the case for Si;  $NC_{Si}$  values tend to decrease after the CCC heat treatment.
- Five of the study glasses have normalized concentration values that are relatively unaffected by heat treatment and that are lower than the EA benchmark value for  $NC_B$ . These glasses are NP2-High-B, NP2-Very-High-Si, NP-MC-AIB-1, NP-MC-AIBNa-1, and NP-MC-BSi-1.
- Ten of the study glasses have more significant increases in normalized concentration values after the CCC heat treatment, although their  $NC_B$  values after the CCC heat treatment remained below that of the EA benchmark glass. These glasses are NP2-Low-



- Al, NP2-Low-Li, NP2-Low-Na, NP2-Low-Si, NP-MC-AIBNa-2, NP-MC-AIBSi-1, NP-MC-AiLi-1, NP-MC-AiLiSi-1, NP-MC-AiSi-2, and NP-MC-BLiSi-2.
- The remaining 16 glasses in the study have  $NC_B$  values that are below that of the EA benchmark for the quenched versions, but after the CCC heat treatment, the  $NC_B$  values for these glasses are greater than that of the EA benchmark glass. In some cases the  $NC_B$  values are quite high, e.g., 95.58 g/L for the CCC version of glass NP-MC-AiNa-1. A value of this magnitude represents leaching of almost all of the boron from the glass (an  $NC_i$  value of 100 g/L is equivalent to complete leaching).

The PCT results appear to be somewhat related to the observations that were noted earlier in Section 3.2, although they are not uniform or consistent. It is important to note that the observations of the dried glass powders are likely confounded by the presence of compounds remaining after evaporation of the leachate. The presence of a whitish material after washing the CCC versions of glasses NP-MC-AiLiNa-1 and NP-MC-BNaSi-1 for the PCT (see Figure 3-1), may be linked to the poor durability and high  $NC_B$  values for these glasses (75.57 and 73.26 g/L, respectively, based on the measured compositions). Note also that the reduction in  $B_2O_3$  concentration measured in these glasses after preparation for the PCT (see Section 3.2) means that the actual  $NC_B$  values for these glasses are greater than reported since the measured compositions of the quenched glasses were used for normalizing the PCT data. The leachates that were difficult to filter, from the CCC version of glass NP2-Low-Si, led to an  $NC_B$  value of 9.85 g/L, which is relatively low as compared to the other glasses in this study.

The glasses that exhibited a thin white layer after the PCT (including removal of the leachate and drying of the damp, leached glass powders), which were the CCC versions of glasses NP-MC-AIB-1 and NP-MC-BLiSi-2 (Figure 3-3), had relatively low  $NC_B$  values of 4.01 and 6.63 g/L, respectively. Glass NP-MC-AIBNa-1, which left a dark coating on the inside of the PCT vessels (Figure 3-4), had a low  $NC_B$  value of 1.03 g/L. Neither of these behaviors appears to have contributed to unusually poor durability.

The glasses that exhibited a thick white layer after the PCT (including removal of the leachate and drying of the damp, leached glass powders), which were the CCC versions of glasses NP-MC-AiLi-2 and NP-MC-AiNa-1 (Figure 3-5), had relatively high  $NC_B$  values of 21.21 and 95.38 g/L, respectively. It appears that the thick white layer was indicative of poor leaching behavior. Future studies of the glasses after the PCT, if of interest, should include preparation of the leached glass per the ASTM procedure.

As noted earlier, the  $NC_{Si}$  values for the study glasses were generally low, and in most cases were reduced for the CCC versions of the glasses where the other  $NC_i$  values generally increased. Exhibit B-4 and Exhibit B-5 in Appendix B provide correlation factors and graphical representations of congruency among the  $NC_i$  values (normalized using the measured compositions) for the quenched and CCC glasses, respectively. In both cases, the  $NC_B$ ,  $NC_{Li}$ , and  $NC_{Na}$  values are well correlated, but the  $NC_{Si}$  values are inversely related to the others. This is unusual in that several earlier studies of nepheline crystallization in simulated HLW glasses showed generally good correlation of  $NC_{Si}$  values with those of other elements of interest.<sup>20-24</sup> In addition, note that Section 26.1 of the ASTM PCT procedure<sup>13</sup> states that the elements best representing the extent of dissolution of the glass waste form are the most important.<sup>a</sup> Thus,

<sup>a</sup> “The most important elements to be analyzed in the leachate are those that best represent the extent of dissolution of the glass waste form. For example, elements that are not sequestered in alteration phases that participate in surface alteration reactions, and are also not solubility limited, are good indicators of glass waste form durability.”<sup>13</sup>

boron is likely a better element to correlate the extent of glass dissolution in this study compared to either Na or Si, which could be sequestered in alteration phases such as zeolites or sodium aluminosilicates.

It is recommended that a more complete review of the influence of composition and heat treatment on the PCT responses of the glasses described in this report be performed in order to draw further conclusions. In particular, the cause of the inverse correlation in silicon dissolution should be investigated. Treatment of the leached glasses per the PCT procedure and additional characterization, such as examination by optical or scanning electron microscopy, and X-ray diffraction analysis to identify possible crystalline phases, would be beneficial for further interpretation of the PCT results.

**Table 3-3. Normalized PCT Results**

Group/Set	Glass ID	Heat Treatment	Comp. View	$NC_B$ (g/L)	$NC_{Li}$ (g/L)	$NC_{Na}$ (g/L)	$NC_{Si}$ (g/L)
3/1	ARM-1	ref	ref	0.582	0.603	0.525	0.277
3/2	ARM-1	ref	ref	0.523	0.597	0.507	0.277
2/1	ARM-1	ref	ref	0.476	0.573	0.493	0.257
1/1	ARM-1	ref	ref	0.443	0.559	0.461	0.259
1/2	ARM-1	ref	ref	0.965	0.612	0.527	0.306
1/1	BL3	CCC	measured	23.703	13.936	7.324	0.158
1/1	BL3	CCC	targeted	22.974	13.396	7.735	0.159
3/1	BL3	quenched	measured	1.888	1.848	1.095	0.502
3/1	BL3	quenched	targeted	1.830	1.777	1.156	0.505
1/1	Neph-NN-1-12	CCC	measured	83.722	66.472	15.095	0.087
1/1	Neph-NN-1-12	CCC	targeted	83.965	64.550	16.176	0.087
3/1	Neph-NN-1-12	quenched	measured	2.532	2.196	1.617	0.495
3/1	Neph-NN-1-12	quenched	targeted	2.539	2.133	1.732	0.498
1/1	NP2-High-Al	CCC	measured	17.576	9.055	6.628	0.157
1/1	NP2-High-Al	CCC	targeted	17.574	8.689	7.051	0.159
3/1	NP2-High-Al	quenched	measured	1.984	2.034	1.151	0.428
3/1	NP2-High-Al	quenched	targeted	1.984	1.952	1.224	0.434
1/1	NP2-High-B	CCC	measured	4.288	3.651	2.296	0.387
1/1	NP2-High-B	CCC	targeted	4.147	3.651	2.403	0.391
3/1	NP2-High-B	quenched	measured	3.632	3.385	2.174	0.365
3/1	NP2-High-B	quenched	targeted	3.512	3.385	2.276	0.369
1/1	NP2-High-Li	CCC	measured	70.430	52.412	13.162	0.086
1/1	NP2-High-Li	CCC	targeted	71.251	50.354	14.099	0.087
3/1	NP2-High-Li	quenched	measured	1.961	1.901	1.186	0.507
3/1	NP2-High-Li	quenched	targeted	1.984	1.826	1.270	0.514
1/1	NP2-High-Na	CCC	measured	79.474	67.680	18.124	0.078
1/1	NP2-High-Na	CCC	targeted	79.265	64.633	19.230	0.079
3/1	NP2-High-Na	quenched	measured	2.418	2.113	1.567	0.431
3/1	NP2-High-Na	quenched	targeted	2.411	2.018	1.662	0.434
1/1	NP2-High-Si	CCC	measured	39.818	26.822	8.390	0.161
1/1	NP2-High-Si	CCC	targeted	39.147	26.010	8.897	0.163



**Table 3-3. Normalized PCT Results (continued)**

<b>Group/Set</b>	<b>Glass ID</b>	<b>Heat Treatment</b>	<b>Comp. View</b>	<b><math>NC_B</math> (g/L)</b>	<b><math>NC_{Li}</math> (g/L)</b>	<b><math>NC_{Na}</math> (g/L)</b>	<b><math>NC_{Si}</math> (g/L)</b>
3/1	NP2-High-Si	quenched	measured	0.944	1.122	0.564	0.510
3/1	NP2-High-Si	quenched	targeted	0.928	1.088	0.598	0.518
1/1	NP2-Low-Al	CCC	measured	7.875	5.876	2.423	0.225
1/1	NP2-Low-Al	CCC	targeted	7.776	5.597	2.485	0.226
3/1	NP2-Low-Al	quenched	measured	2.236	2.082	1.302	0.481
3/1	NP2-Low-Al	quenched	targeted	2.208	1.984	1.335	0.483
1/1	NP2-Low-B	CCC	measured	82.945	59.198	11.658	0.070
1/1	NP2-Low-B	CCC	targeted	81.649	58.199	12.379	0.072
3/1	NP2-Low-B	quenched	measured	1.457	1.472	0.905	0.529
3/1	NP2-Low-B	quenched	targeted	1.434	1.447	0.961	0.539
1/1	NP2-Low-Li	CCC	measured	3.535	2.537	1.518	0.274
1/1	NP2-Low-Li	CCC	targeted	3.509	2.410	1.605	0.278
3/1	NP2-Low-Li	quenched	measured	1.634	1.759	0.953	0.495
3/1	NP2-Low-Li	quenched	targeted	1.622	1.671	1.007	0.502
1/1	NP2-Low-Na	CCC	measured	4.506	3.168	1.802	0.333
1/1	NP2-Low-Na	CCC	targeted	4.384	2.949	1.932	0.335
3/1	NP2-Low-Na	quenched	measured	1.270	1.536	0.649	0.553
3/1	NP2-Low-Na	quenched	targeted	1.235	1.429	0.696	0.556
1/1	NP2-Low-Si	CCC	measured	9.853	6.043	4.770	0.020
1/1	NP2-Low-Si	CCC	targeted	9.855	5.928	4.834	0.020
3/1	NP2-Low-Si	quenched	measured	3.081	2.866	2.100	0.332
3/1	NP2-Low-Si	quenched	targeted	3.081	2.811	2.128	0.337
1/1	NP2-Very-High-Al	CCC	measured	42.040	25.872	12.498	0.160
1/1	NP2-Very-High-Al	CCC	targeted	41.979	24.597	13.349	0.162
3/1	NP2-Very-High-Al	quenched	measured	2.304	2.225	1.305	0.395
3/1	NP2-Very-High-Al	quenched	targeted	2.300	2.115	1.394	0.401
2/1	NP2-Very-High-Si	CCC	measured	0.705	0.859	0.350	0.441
2/1	NP2-Very-High-Si	CCC	targeted	0.712	0.823	0.365	0.447
3/1	NP2-Very-High-Si	quenched	measured	0.588	0.920	0.316	0.467
3/1	NP2-Very-High-Si	quenched	targeted	0.593	0.882	0.328	0.473

**Table 3-3. Normalized PCT Results (continued)**

<b>Group/Set</b>	<b>Glass ID</b>	<b>Heat Treatment</b>	<b>Comp. View</b>	<b><math>NC_B</math> (g/L)</b>	<b><math>NC_{Li}</math> (g/L)</b>	<b><math>NC_{Na}</math> (g/L)</b>	<b><math>NC_{Si}</math> (g/L)</b>
1/1	NP2-Very-Low-Si	CCC	measured	54.125	40.086	26.033	0.037
1/1	NP2-Very-Low-Si	CCC	targeted	53.596	39.828	27.400	0.038
3/1	NP2-Very-Low-Si	quenched	measured	15.534	9.000	12.038	0.098
3/1	NP2-Very-Low-Si	quenched	targeted	15.382	8.942	12.671	0.100
2/1	NP-MC-AIB-1	CCC	measured	4.007	3.524	2.220	0.331
2/1	NP-MC-AIB-1	CCC	targeted	3.966	3.385	2.298	0.337
3/1	NP-MC-AIB-1	quenched	measured	4.180	3.863	2.363	0.373
3/1	NP-MC-AIB-1	quenched	targeted	4.137	3.711	2.446	0.379
1/2	NP-MC-AIBNa-1	CCC	measured	1.384	1.158	0.623	0.627
2/1	NP-MC-AIBNa-1	CCC	measured	1.026	1.054	0.597	0.539
1/2	NP-MC-AIBNa-1	CCC	targeted	1.344	1.149	0.662	0.631
2/1	NP-MC-AIBNa-1	CCC	targeted	0.996	1.046	0.635	0.543
3/2	NP-MC-AIBNa-1	quenched	measured	0.903	1.072	0.537	0.542
3/2	NP-MC-AIBNa-1	quenched	targeted	0.877	1.064	0.571	0.546
1/2	NP-MC-AIBNa-2	CCC	measured	12.012	7.933	6.232	0.034
1/2	NP-MC-AIBNa-2	CCC	targeted	12.092	7.508	6.682	0.034
3/2	NP-MC-AIBNa-2	quenched	measured	3.456	3.276	2.237	0.310
3/2	NP-MC-AIBNa-2	quenched	targeted	3.479	3.101	2.399	0.313
1/2	NP-MC-AIBSi-1	CCC	measured	3.634	3.162	2.209	0.025
1/2	NP-MC-AIBSi-1	CCC	targeted	3.634	3.122	2.340	0.026
3/2	NP-MC-AIBSi-1	quenched	measured	2.675	2.682	1.626	0.369
3/2	NP-MC-AIBSi-1	quenched	targeted	2.675	2.648	1.723	0.381
1/2	NP-MC-AiLi-1	CCC	measured	2.781	2.156	1.214	0.443
1/2	NP-MC-AiLi-1	CCC	targeted	2.701	2.063	1.226	0.439
3/2	NP-MC-AiLi-1	quenched	measured	1.950	1.847	1.131	0.442
3/2	NP-MC-AiLi-1	quenched	targeted	1.895	1.767	1.142	0.438
1/2	NP-MC-AiLi-2	CCC	measured	21.207	12.955	6.547	0.199
2/1	NP-MC-AiLi-2	CCC	measured	21.514	13.113	6.624	0.194
1/2	NP-MC-AiLi-2	CCC	targeted	20.848	12.377	6.943	0.200
2/1	NP-MC-AiLi-2	CCC	targeted	21.149	12.528	7.025	0.195

**Table 3-3. Normalized PCT Results (continued)**

Group/Set	Glass ID	Heat Treatment	Comp. View	$NC_B$ (g/L)	$NC_{Li}$ (g/L)	$NC_{Na}$ (g/L)	$NC_{Si}$ (g/L)
3/2	NP-MC-AlLi-2	quenched	measured	1.609	1.762	0.951	0.403
3/2	NP-MC-AlLi-2	quenched	targeted	1.582	1.683	1.009	0.406
1/2	NP-MC-AlLiNa-1	CCC	measured	75.566	55.417	23.508	0.034
1/2	NP-MC-AlLiNa-1	CCC	targeted	75.117	53.718	24.384	0.035
3/2	NP-MC-AlLiNa-1	quenched	measured	2.913	2.543	2.050	0.419
3/2	NP-MC-AlLiNa-1	quenched	targeted	2.896	2.465	2.127	0.427
1/2	NP-MC-AlLiSi-1	CCC	measured	14.101	9.621	6.459	0.183
1/2	NP-MC-AlLiSi-1	CCC	targeted	14.128	9.270	6.863	0.185
3/2	NP-MC-AlLiSi-1	quenched	measured	4.324	3.910	2.792	0.270
3/2	NP-MC-AlLiSi-1	quenched	targeted	4.333	3.767	2.967	0.273
1/2	NP-MC-AlNa-1	CCC	measured	95.382	75.916	18.092	0.120
2/1	NP-MC-AlNa-1	CCC	measured	95.576	78.893	18.714	0.117
1/2	NP-MC-AlNa-1	CCC	targeted	91.957	74.120	18.684	0.120
2/1	NP-MC-AlNa-1	CCC	targeted	92.144	77.027	19.326	0.117
3/2	NP-MC-AlNa-1	quenched	measured	2.782	2.291	1.753	0.426
3/2	NP-MC-AlNa-1	quenched	targeted	2.682	2.237	1.811	0.426
1/2	NP-MC-AlSi-1	CCC	measured	81.046	65.848	21.249	0.113
1/2	NP-MC-AlSi-1	CCC	targeted	80.339	63.856	22.808	0.115
3/2	NP-MC-AlSi-1	quenched	measured	4.264	3.807	2.726	0.368
3/2	NP-MC-AlSi-1	quenched	targeted	4.227	3.692	2.926	0.375
1/2	NP-MC-AlSi-2	CCC	measured	12.908	5.562	4.496	0.024
1/2	NP-MC-AlSi-2	CCC	targeted	12.728	5.290	4.793	0.024
3/2	NP-MC-AlSi-2	quenched	measured	0.827	1.317	0.410	0.489
3/2	NP-MC-AlSi-2	quenched	targeted	0.816	1.253	0.437	0.494
1/2	NP-MC-BLiSi-1	CCC	measured	86.483	55.250	9.651	0.111
1/2	NP-MC-BLiSi-1	CCC	targeted	86.474	53.080	10.328	0.113
3/2	NP-MC-BLiSi-1	quenched	measured	0.994	1.129	0.637	0.544
3/2	NP-MC-BLiSi-1	quenched	targeted	0.994	1.084	0.682	0.554
2/1	NP-MC-BLiSi-2	CCC	measured	6.634	5.998	3.654	0.310
2/1	NP-MC-BLiSi-2	CCC	targeted	6.602	5.439	3.729	0.315

**Table 3-3. Normalized PCT Results (continued)**

<b>Group/Set</b>	<b>Glass ID</b>	<b>Heat Treatment</b>	<b>Comp. View</b>	<b><math>NC_B</math> (g/L)</b>	<b><math>NC_{Li}</math> (g/L)</b>	<b><math>NC_{Na}</math> (g/L)</b>	<b><math>NC_{Si}</math> (g/L)</b>
3/2	NP-MC-BLiSi-2	quenched	measured	5.106	4.826	3.140	0.321
3/2	NP-MC-BLiSi-2	quenched	targeted	5.082	4.377	3.204	0.327
1/2	NP-MC-BNa-1	CCC	measured	81.479	65.450	14.125	0.055
1/2	NP-MC-BNa-1	CCC	targeted	80.720	63.211	14.926	0.056
3/2	NP-MC-BNa-1	quenched	measured	2.462	1.977	1.413	0.403
3/2	NP-MC-BNa-1	quenched	targeted	2.439	1.909	1.493	0.411
1/2	NP-MC-BNaSi-1	CCC	measured	73.258	53.334	22.720	0.034
1/2	NP-MC-BNaSi-1	CCC	targeted	74.346	52.177	24.155	0.034
3/2	NP-MC-BNaSi-1	quenched	measured	2.829	2.478	2.049	0.386
3/2	NP-MC-BNaSi-1	quenched	targeted	2.871	2.424	2.179	0.392
2/1	NP-MC-BSi-1	CCC	measured	2.170	1.974	1.087	0.403
2/1	NP-MC-BSi-1	CCC	targeted	2.156	1.906	1.169	0.410
3/2	NP-MC-BSi-1	quenched	measured	2.542	2.424	1.228	0.401
3/2	NP-MC-BSi-1	quenched	targeted	2.525	2.341	1.321	0.408

## 4.0 Summary

In this report, SRNL provides chemical analyses and PCT results for a series of simulated HLW glasses fabricated by PNNL as part of an ongoing nepheline crystallization study.<sup>4,5</sup> The results of these analyses will be used to improve the ability to predict crystallization of nepheline as a function of composition and heat treatment for glasses formulated at high alumina concentrations.

The measured chemical composition data are reported and compared with the targeted values for each component for each glass. Fluorine concentrations were not measured since this species would have required the use of an additional preparation method and its measured values were likely to be near or below analytical detection limits. A detailed review showed no indications of errors in the preparation or measurement of the study glasses. All of the measured sums of oxides for the study glasses fell within the interval of 98 to 101 wt %, indicating recovery of all components. Comparisons of the targeted and measured chemical compositions showed that the measured values for the glasses met the targeted concentrations within 10% for those components present at more than 5 wt %. Sodium measurements were elevated but were within acceptability limits. Measurements of  $\text{ZrO}_2$  in glass NP2-High Na were consistently above the targeted value by about a factor of two. This component may have been inadvertently double batched in this glass.

Several of the study glasses exhibited unusual appearances during preparation for, or after performance of, the PCTs. In some cases this may be linked to low chemical durability. Future studies should include thorough analysis of the glasses after the PCTs to provide further information regarding glass behavior in durability testing.

A detailed review showed no issues with performance of the PCTs. The PCT results were normalized to both the targeted and measured compositions of the study glasses. Several observations were made regarding the PCT results. The quenched versions of all of the study glasses have  $NC_B$  values that are lower than the EA benchmark  $NC_B$  value of 16.695 g/L.<sup>19</sup> Many of the study glasses have higher normalized concentration values after the CCC heat treatment. This is likely indicative of crystallization or phase separation. Sixteen of the study glasses have  $NC_B$  values that are below that of the EA benchmark for the quenched versions, but greater than that of the EA benchmark glass after the CCC heat treatment. In some cases the  $NC_B$  values are quite high, e.g., 95.58 g/L for the CCC version of glass NP-MC-AlNa-1. These results can be combined with additional characterization, including X-ray diffraction, to determine the cause of the higher release rates.

Duplicate PCT testing was completed for a small subset of the study glasses to test reproducibility. Although limited in scope, the results of the duplicate tests indicate reasonable reproducibility for the PCT responses of the study glasses over a broad range of normalized concentration values.

## 5.0 References

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## **Appendix A   Tables and Exhibits Supporting the Chemical Composition Measurements**



**Table A-1. AD Measurements of the Nepheline Study Glasses**

Glass ID	Block	Sub-Blk	Sequence	Lab ID	Bi (wt%)	Ca (wt%)	Na (wt%)	Ni (wt%)	P (wt%)	Ru (wt%)	S (wt%)	Zr (wt%)
LRM	1	1	1	LRMAD111	<0.100	0.341	15.7	0.135	0.231	<0.100	0.089	0.728
BL3	1	1	2	W15AD11	0.545	0.436	9.72	<0.100	0.296	<0.100	0.105	0.189
NP-MC-AiLi-2	1	1	3	W07AD11	0.515	0.418	9.49	<0.100	0.285	<0.100	0.081	0.178
NP2-Low-B	1	1	4	W27AD11	0.554	0.449	10.2	<0.100	0.305	<0.100	0.087	0.192
NP2-Very-High-Al	1	1	5	W20AD11	0.495	0.401	9.18	<0.100	0.270	<0.100	0.085	0.173
NP2-Low-B	1	1	6	W27AD21	0.562	0.452	10.1	<0.100	0.311	<0.100	0.093	0.195
BL3	1	1	7	W15AD21	0.537	0.432	9.54	<0.100	0.290	<0.100	0.103	0.186
NP-MC-BNa-1	1	1	8	W03AD21	0.531	0.434	12.1	<0.100	0.290	<0.100	0.105	0.187
NP2-High-Li	1	1	9	W30AD21	0.527	0.435	9.64	<0.100	0.290	<0.100	0.110	0.188
LRM	1	1	10	LRMAD112	<0.100	0.341	16.1	0.134	0.221	<0.100	0.094	0.715
NP-MC-AiSi-1	1	1	11	W17AD11	0.623	0.478	11.4	<0.100	0.339	<0.100	0.124	0.228
NP2-High-Li	1	1	12	W30AD11	0.534	0.431	9.77	<0.100	0.290	<0.100	0.108	0.189
NP-MC-AiSi-1	1	1	13	W17AD21	0.614	0.483	11.4	<0.100	0.338	<0.100	0.126	0.226
NP-MC-AIBNa-1	1	1	14	W13AD21	0.599	0.479	8.56	<0.100	0.330	<0.100	0.107	0.209
NP-MC-AiLi-2	1	1	15	W07AD21	0.520	0.419	9.60	<0.100	0.285	<0.100	0.084	0.182
NP-MC-BNa-1	1	1	16	W03AD11	0.537	0.424	12.0	<0.100	0.291	<0.100	0.102	0.188
NP-MC-AIBNa-1	1	1	17	W13AD11	0.607	0.481	8.43	<0.100	0.331	<0.100	0.102	0.214
NP2-Very-High-Al	1	1	18	W20AD21	0.490	0.404	8.94	<0.100	0.266	<0.100	0.081	0.172
LRM	1	1	19	LRMAD113	<0.100	0.343	16.2	0.136	0.220	<0.100	0.093	0.717
LRM	1	2	1	LRMAD121	<0.100	0.339	16.0	0.135	0.228	<0.100	0.092	0.731
NP2-High-Li	1	2	2	W30AD22	0.531	0.432	10.0	<0.100	0.288	<0.100	0.105	0.188
NP2-High-Li	1	2	3	W30AD12	0.524	0.429	9.91	<0.100	0.287	<0.100	0.108	0.187
NP-MC-BNa-1	1	2	4	W03AD22	0.529	0.434	12.2	<0.100	0.287	<0.100	0.109	0.186
NP2-Very-High-Al	1	2	5	W20AD22	0.490	0.399	9.11	<0.100	0.264	<0.100	0.088	0.171
NP2-Very-High-Al	1	2	6	W20AD12	0.498	0.407	9.06	<0.100	0.267	<0.100	0.089	0.174
NP-MC-BNa-1	1	2	7	W03AD12	0.536	0.431	12.3	<0.100	0.288	<0.100	0.100	0.186
NP-MC-AiLi-2	1	2	8	W07AD12	0.518	0.419	9.39	<0.100	0.282	<0.100	0.080	0.179
NP-MC-AiSi-1	1	2	9	W17AD12	0.615	0.483	11.6	<0.100	0.335	<0.100	0.123	0.227
LRM	1	2	10	LRMAD122	<0.100	0.337	16.0	0.135	0.230	<0.100	0.087	0.731
NP2-Low-B	1	2	11	W27AD12	0.552	0.446	10.3	<0.100	0.300	<0.100	0.096	0.193
NP-MC-AiLi-2	1	2	12	W07AD22	0.520	0.422	9.66	<0.100	0.280	<0.100	0.085	0.181
BL3	1	2	13	W15AD22	0.539	0.428	9.81	<0.100	0.289	<0.100	0.100	0.187
NP-MC-AIBNa-1	1	2	14	W13AD12	0.603	0.482	8.55	<0.100	0.328	<0.100	0.110	0.211
NP2-Low-B	1	2	15	W27AD22	0.555	0.453	10.3	<0.100	0.304	<0.100	0.090	0.193
NP-MC-AIBNa-1	1	2	16	W13AD22	0.603	0.481	8.52	<0.100	0.331	<0.100	0.106	0.211
NP-MC-AiSi-1	1	2	17	W17AD22	0.613	0.489	11.4	<0.100	0.333	<0.100	0.124	0.227
BL3	1	2	18	W15AD12	0.542	0.431	10.1	<0.100	0.288	<0.100	0.102	0.190
LRM	1	2	19	LRMAD123	<0.100	0.341	16.3	0.136	0.229	<0.100	0.092	0.729
LRM	2	1	1	LRMAD211	<0.100	0.339	16.0	0.136	0.225	<0.100	0.084	0.710
NP-MC-AiSi-2	2	1	2	W24AD21	0.452	0.372	8.21	<0.100	0.242	<0.100	0.063	0.146
NP2-Low-Li	2	1	3	W21AD11	0.551	0.437	9.63	<0.100	0.292	<0.100	0.089	0.178

Table A-1. AD Measurements of the Nepheline Study Glasses (continued)

Glass ID	Block	Sub-Blk	Sequence	Lab ID	Bi (wt%)	Ca (wt%)	Na (wt%)	Ni (wt%)	P (wt%)	Ru (wt%)	S (wt%)	Zr (wt%)
NP2-Very-High-Si	2	1	4	W25AD11	0.483	0.394	8.47	<0.100	0.257	<0.100	0.078	0.156
NP-MC-BNaSi-1	2	1	5	W11AD11	0.592	0.470	12.0	<0.100	0.313	<0.100	0.104	0.193
NP-MC-AIBNa-2	2	1	6	W22AD11	0.486	0.392	10.8	<0.100	0.258	<0.100	0.082	0.157
Neph-NN-1-12	2	1	7	W26AD11	0.578	0.300	11.7	0.148	0.385	<0.100	0.104	<0.100
NP2-Very-High-Si	2	1	8	W25AD21	0.478	0.393	8.54	<0.100	0.253	<0.100	0.075	0.153
Neph-NN-1-12	2	1	9	W26AD21	0.586	0.307	12.1	0.152	0.387	<0.100	0.102	<0.100
LRM	2	1	10	LRMAD212	<0.100	0.340	16.2	0.136	0.221	<0.100	0.085	0.700
NP-MC-AIBNa-2	2	1	11	W22AD21	0.483	0.393	10.7	<0.100	0.257	<0.100	0.084	0.156
NP2-Low-Li	2	1	12	W21AD21	0.549	0.455	9.90	<0.100	0.290	<0.100	0.092	0.178
NP-MC-AiLiNa-1	2	1	13	W14AD21	0.468	0.378	11.5	<0.100	0.253	<0.100	0.095	0.152
NP-MC-AiLiNa-1	2	1	14	W14AD11	0.472	0.380	11.5	<0.100	0.254	<0.100	0.095	0.153
NP2-High-Na	2	1	15	W18AD21	0.524	0.422	12.1	<0.100	0.277	<0.100	0.107	0.344
NP-MC-BNaSi-1	2	1	16	W11AD21	0.587	0.473	12.2	<0.100	0.307	<0.100	0.106	0.191
NP2-High-Na	2	1	17	W18AD11	0.516	0.416	12.1	<0.100	0.271	<0.100	0.103	0.336
NP-MC-AISi-2	2	1	18	W24AD11	0.453	0.399	8.19	<0.100	0.243	<0.100	0.068	0.146
LRM	2	1	19	LRMAD213	<0.100	0.339	15.8	0.135	0.223	<0.100	0.090	0.690
LRM	2	2	1	LRMAD221	<0.100	0.353	15.9	0.143	0.208	<0.100	0.085	0.700
NP2-Very-High-Si	2	2	2	W25AD22	0.470	0.392	8.69	<0.100	0.249	<0.100	0.082	0.152
NP-MC-AiLiNa-1	2	2	3	W14AD22	0.463	0.380	11.8	<0.100	0.249	<0.100	0.092	0.153
NP-MC-AISi-2	2	2	4	W24AD12	0.451	0.396	8.47	<0.100	0.240	<0.100	0.065	0.148
NP2-High-Na	2	2	5	W18AD22	0.516	0.420	12.3	<0.100	0.274	<0.100	0.105	0.348
NP-MC-AiLiNa-1	2	2	6	W14AD12	0.468	0.381	11.8	<0.100	0.253	<0.100	0.095	0.154
NP2-Very-High-Si	2	2	7	W25AD12	0.476	0.399	8.74	<0.100	0.254	<0.100	0.078	0.157
NP2-Low-Li	2	2	8	W21AD12	0.541	0.442	10.0	<0.100	0.288	<0.100	0.095	0.178
Neph-NN-1-12	2	2	9	W26AD12	0.565	0.303	11.9	0.149	0.377	<0.100	0.099	<0.100
LRM	2	2	10	LRMAD222	<0.100	0.374	16.0	0.152	0.203	<0.100	0.084	0.700
NP-MC-AISi-2	2	2	11	W24AD22	0.447	0.373	8.44	<0.100	0.240	<0.100	0.064	0.148
NP-MC-AIBNa-2	2	2	12	W22AD12	0.474	0.395	11.3	<0.100	0.253	<0.100	0.088	0.157
NP2-High-Na	2	2	13	W18AD12	0.509	0.416	12.3	<0.100	0.270	<0.100	0.101	0.341
NP-MC-BNaSi-1	2	2	14	W11AD12	0.587	0.470	12.5	<0.100	0.307	<0.100	0.109	0.194
NP-MC-BNaSi-1	2	2	15	W11AD22	0.582	0.473	12.2	<0.100	0.307	<0.100	0.110	0.194
Neph-NN-1-12	2	2	16	W26AD22	0.568	0.307	12.0	0.150	0.380	<0.100	0.101	<0.100
NP2-Low-Li	2	2	17	W21AD22	0.542	0.453	10.1	<0.100	0.290	<0.100	0.091	0.178
NP-MC-AIBNa-2	2	2	18	W22AD22	0.476	0.391	11.2	<0.100	0.254	<0.100	0.087	0.155
LRM	2	2	19	LRMAD223	<0.100	0.370	16.0	0.151	0.209	<0.100	0.089	0.690
LRM	3	1	1	LRMAD311	<0.100	0.295	15.8	0.137	0.215	<0.100	0.086	0.690
NP-MC-BSi-1	3	1	2	W06AD11	0.478	0.327	8.85	<0.100	0.260	<0.100	0.078	0.156
NP2-Low-Na	3	1	3	W01AD21	0.566	0.382	7.61	<0.100	0.302	<0.100	0.071	0.186
NP-MC-AIBSi-1	3	1	4	W08AD21	0.442	0.296	8.05	<0.100	0.242	<0.100	0.067	0.148
NP-MC-AiLiSi-1	3	1	5	W19AD21	0.664	0.439	11.8	<0.100	0.353	<0.100	0.120	0.216
NP-MC-BSi-1	3	1	6	W06AD21	0.487	0.328	8.64	<0.100	0.263	<0.100	0.079	0.157
NP2-High-Si	3	1	7	W23AD11	0.527	0.362	9.29	<0.100	0.276	<0.100	0.076	0.168

Table A-1. AD Measurements of the Nepheline Study Glasses (continued)

Glass ID	Block	Sub-Blk	Sequence	Lab ID	Bi (wt%)	Ca (wt%)	Na (wt%)	Ni (wt%)	P (wt%)	Ru (wt%)	S (wt%)	Zr (wt%)
NP-MC-AIBSi-1	3	1	8	W08AD11	0.442	0.316	7.84	<0.100	0.241	<0.100	0.065	0.146
NP2-High-Al	3	1	9	W10AD21	0.521	0.364	9.35	<0.100	0.281	<0.100	0.088	0.172
LRM	3	1	10	LRMAD312	<0.100	0.314	15.8	0.137	0.213	<0.100	0.088	0.710
NP2-High-Al	3	1	11	W10AD11	0.522	0.368	9.35	<0.100	0.283	<0.100	0.087	0.173
NP-MC-AiLiSi-1	3	1	12	W19AD11	0.652	0.464	11.7	<0.100	0.349	<0.100	0.123	0.214
NP2-High-Si	3	1	13	W23AD21	0.524	0.376	9.18	<0.100	0.279	<0.100	0.076	0.171
NP2-Very-Low-Si	3	1	14	W31AD21	0.590	0.411	10.5	<0.100	0.316	<0.100	0.109	0.192
NP2-Very-Low-Si	3	1	15	W31AD11	0.602	0.434	10.6	<0.100	0.321	<0.100	0.112	0.196
NP-MC-BLiSi-1	3	1	16	W05AD21	0.524	0.371	9.48	<0.100	0.280	<0.100	0.084	0.170
NP2-Low-Na	3	1	17	W01AD11	0.566	0.395	7.48	<0.100	0.301	<0.100	0.069	0.185
NP-MC-BLiSi-1	3	1	18	W05AD11	0.521	0.371	9.66	<0.100	0.280	<0.100	0.083	0.171
LRM	3	1	19	LRMAD313	<0.100	0.317	16.1	0.140	0.216	<0.100	0.082	0.720
LRM	3	2	1	LRMAD321	<0.100	0.310	16.3	0.136	0.223	<0.100	0.091	0.720
NP-MC-AiLiSi-1	3	2	2	W19AD22	0.645	0.452	11.9	<0.100	0.346	<0.100	0.124	0.215
NP2-Very-Low-Si	3	2	3	W31AD12	0.585	0.421	11.4	<0.100	0.314	<0.100	0.110	0.194
NP-MC-BLiSi-1	3	2	4	W05AD12	0.517	0.363	9.71	<0.100	0.277	<0.100	0.087	0.169
NP-MC-BSi-1	3	2	5	W06AD22	0.470	0.340	9.26	<0.100	0.255	<0.100	0.082	0.155
NP2-High-Al	3	2	6	W10AD12	0.506	0.367	9.65	<0.100	0.272	<0.100	0.082	0.168
NP-MC-BSi-1	3	2	7	W06AD12	0.472	0.335	8.94	<0.100	0.253	<0.100	0.076	0.154
NP-MC-AiLiSi-1	3	2	8	W19AD12	0.632	0.445	11.8	<0.100	0.336	<0.100	0.121	0.208
NP2-Low-Na	3	2	9	W01AD12	0.549	0.391	7.50	<0.100	0.294	<0.100	0.075	0.182
LRM	3	2	10	LRMAD322	<0.100	0.308	16.0	0.135	0.199	<0.100	0.084	0.680
NP-MC-AIBSi-1	3	2	11	W08AD22	0.433	0.305	8.15	<0.100	0.235	<0.100	0.071	0.146
NP2-Very-Low-Si	3	2	12	W31AD22	0.572	0.406	10.6	<0.100	0.309	<0.100	0.107	0.189
NP2-High-Si	3	2	13	W23AD12	0.506	0.362	9.31	<0.100	0.266	<0.100	0.076	0.165
NP-MC-BLiSi-1	3	2	14	W05AD22	0.508	0.362	9.67	<0.100	0.274	<0.100	0.088	0.167
NP2-High-Al	3	2	15	W10AD22	0.502	0.363	9.47	<0.100	0.272	<0.100	0.088	0.167
NP2-High-Si	3	2	16	W23AD22	0.503	0.366	9.51	<0.100	0.266	<0.100	0.074	0.165
NP2-Low-Na	3	2	17	W01AD22	0.545	0.391	7.64	<0.100	0.289	<0.100	0.071	0.182
NP-MC-AIBSi-1	3	2	18	W08AD12	0.430	0.313	8.25	<0.100	0.231	<0.100	0.066	0.145
LRM	3	2	19	LRMAD323	<0.100	0.306	16.1	0.134	0.199	<0.100	0.087	0.680
LRM	4	1	1	LRMAD411	<0.100	0.305	15.1	0.136	0.206	<0.100	0.084	0.711
NP-MC-AlNa-1	4	1	2	W28AD11	0.543	0.378	11.9	<0.100	0.292	<0.100	0.096	0.184
NP2-Low-Si	4	1	3	W16AD21	0.567	0.392	9.52	<0.100	0.302	<0.100	0.089	0.194
NP2-High-B	4	1	4	W29AD21	0.504	0.363	9.15	<0.100	0.274	<0.100	0.073	0.178
NP2-High-B	4	1	5	W29AD11	0.504	0.362	9.05	<0.100	0.274	<0.100	0.077	0.179
NP-MC-AlNa-1	4	1	6	W28AD21	0.535	0.380	11.7	<0.100	0.285	<0.100	0.100	0.183
NP-MC-BLiSi-2	4	1	7	W12AD11	0.503	0.351	8.96	<0.100	0.268	<0.100	0.095	0.177
NP-MC-AIB-1	4	1	8	W02AD11	0.524	0.367	9.29	<0.100	0.282	<0.100	0.097	0.180
NP2-Low-Al	4	1	9	W04AD21	0.558	0.416	9.77	<0.100	0.298	<0.100	0.097	0.197
LRM	4	1	10	LRMAD412	<0.100	0.306	15.1	0.134	0.203	<0.100	0.083	0.710
NP2-Low-Si	4	1	11	W16AD11	0.567	0.392	9.70	<0.100	0.300	<0.100	0.084	0.196

**Table A-1. AD Measurements of the Nepheline Study Glasses (continued)**

Glass ID	Block	Sub-Blk	Sequence	Lab ID	Bi (wt%)	Ca (wt%)	Na (wt%)	Ni (wt%)	P (wt%)	Ru (wt%)	S (wt%)	Zr (wt%)
NP-MC-BLiSi-2	4	1	12	W12AD21	0.508	0.378	8.89	<0.100	0.270	<0.100	0.094	0.179
NP2-Low-Al	4	1	13	W04AD11	0.555	0.401	9.95	<0.100	0.296	<0.100	0.102	0.195
NP-MC-AiLi-1	4	1	14	W09AD11	0.572	0.396	9.33	<0.100	0.307	<0.100	0.099	0.204
NP-MC-AiB-1	4	1	15	W02AD21	0.516	0.362	9.03	<0.100	0.279	<0.100	0.092	0.179
NP-MC-AiLi-1	4	1	16	W09AD21	0.568	0.405	10.2	<0.100	0.304	<0.100	0.100	0.204
LRM	4	1	17	LRMAD413	<0.100	0.304	15.5	0.133	0.203	<0.100	0.085	0.721
LRM	4	2	1	LRMAD421	<0.100	0.319	15.7	0.143	0.215	<0.100	0.088	0.719
NP2-High-B	4	2	2	W29AD12	0.514	0.355	9.19	<0.100	0.280	<0.100	0.073	0.181
NP-MC-BLiSi-2	4	2	3	W12AD12	0.515	0.355	9.17	<0.100	0.277	<0.100	0.099	0.180
NP2-High-B	4	2	4	W29AD22	0.511	0.363	9.20	<0.100	0.279	<0.100	0.074	0.179
NP2-Low-Al	4	2	5	W04AD12	0.563	0.409	9.80	<0.100	0.308	<0.100	0.098	0.197
NP-MC-AiLi-1	4	2	6	W09AD12	0.574	0.406	9.89	<0.100	0.314	<0.100	0.100	0.205
NP-MC-BLiSi-2	4	2	7	W12AD22	0.512	0.378	8.92	<0.100	0.275	<0.100	0.098	0.181
NP-MC-AlNa-1	4	2	8	W28AD12	0.545	0.372	11.8	<0.100	0.292	<0.100	0.103	0.186
NP-MC-AiLi-1	4	2	9	W09AD22	0.574	0.407	10.3	<0.100	0.312	<0.100	0.095	0.206
LRM	4	2	10	LRMAD422	<0.100	0.322	15.3	0.151	0.220	<0.100	0.087	0.722
NP2-Low-Al	4	2	11	W04AD22	0.563	0.422	10.1	<0.100	0.305	<0.100	0.104	0.200
NP-MC-AiB-1	4	2	12	W02AD12	0.527	0.374	9.42	<0.100	0.285	<0.100	0.100	0.181
NP-MC-AiB-1	4	2	13	W02AD22	0.528	0.366	9.39	<0.100	0.285	<0.100	0.095	0.181
NP2-Low-Si	4	2	14	W16AD12	0.567	0.393	10.2	<0.100	0.305	<0.100	0.089	0.195
NP-MC-AlNa-1	4	2	15	W28AD22	0.540	0.384	12.1	<0.100	0.288	<0.100	0.099	0.184
NP2-Low-Si	4	2	16	W16AD22	0.561	0.389	9.95	<0.100	0.301	<0.100	0.086	0.193
LRM	4	2	17	LRMAD423	<0.100	0.327	15.4	0.151	0.220	<0.100	0.088	0.712

**Table A-2. PF Measurements of the Nepheline Study Glasses**

ID	Block	Sub-Blk	Sequence	Lab ID	Al (wt%)	B (wt%)	Cr (wt%)	Fe (wt%)	Li (wt%)	Mn (wt%)	Si (wt%)
LRM	1	1	1	LRMPF111	5.02	2.50	<0.100	0.980	<0.100	<0.100	25.2
NP-MC-AiLiNa-1	1	1	2	W14PF11	16.3	4.77	0.582	1.52	2.67	0.613	12.5
NP2-Low-Na	1	1	3	W01PF11	15.5	5.45	0.673	1.81	2.33	0.733	14.4
NP-MC-AiSi-2	1	1	4	W24PF21	16.3	4.36	0.549	1.43	1.85	0.561	15.4
NP-MC-BLiSi-1	1	1	5	W05PF21	14.5	4.26	0.658	1.71	2.72	0.690	15.7
NP2-High-Al	1	1	6	W10PF21	16.6	5.07	0.640	1.67	2.15	0.670	13.3
NP2-High-Na	1	1	7	W18PF11	14.5	5.16	0.634	1.64	2.13	0.666	13.4
NP2-Very-High-Al	1	1	8	W20PF11	18.2	4.97	0.591	1.53	1.98	0.612	12.8
NP2-Low-Li	1	1	9	W21PF21	15.2	5.49	0.667	1.72	1.73	0.691	14.1
LRM	1	1	10	LRMPF112	5.02	2.45	<0.100	0.956	<0.100	<0.100	25.2
NP2-High-Al	1	1	11	W10PF11	16.8	5.29	0.618	1.63	2.09	0.646	13.6
NP-MC-AiSi-2	1	1	12	W24PF11	16.7	4.60	0.540	1.41	1.81	0.554	15.9
NP-MC-BLiSi-1	1	1	13	W05PF11	14.4	4.36	0.624	1.62	2.60	0.653	15.6
NP-MC-AiLiNa-1	1	1	14	W14PF21	16.4	4.70	0.560	1.46	2.56	0.586	12.3
NP2-Low-Na	1	1	15	W01PF21	14.9	5.19	0.648	1.75	2.24	0.706	13.9
NP2-Very-High-Al	1	1	16	W20PF21	18.0	4.86	0.597	1.56	2.01	0.617	12.7
NP2-High-Na	1	1	17	W18PF21	14.1	5.12	0.634	1.63	2.13	0.665	13.1
NP2-Low-Li	1	1	18	W21PF11	14.9	5.35	0.662	1.71	1.73	0.687	14.0
LRM	1	1	19	LRMPF113	5.10	2.51	<0.100	0.947	<0.100	<0.100	25.7
LRM	1	2	1	LRMPF121	5.12	2.55	<0.100	1.00	<0.100	<0.100	25.8
NP2-Low-Li	1	2	2	W21PF22	14.9	5.36	0.722	1.79	1.80	0.755	14.0
NP2-High-Na	1	2	3	W18PF22	14.3	5.14	0.688	1.69	2.18	0.724	13.4
NP2-High-Al	1	2	4	W10PF12	16.4	5.11	0.670	1.67	2.12	0.699	13.3
NP2-Very-High-Al	1	2	5	W20PF22	18.0	4.81	0.662	1.65	2.07	0.689	12.7
NP-MC-AiSi-2	1	2	6	W24PF22	16.1	4.27	0.600	1.48	1.88	0.616	15.2
NP2-Low-Na	1	2	7	W01PF12	15.7	5.47	0.717	1.83	2.33	0.774	14.6
NP-MC-AiLiNa-1	1	2	8	W14PF12	16.4	4.76	0.633	1.56	2.68	0.663	12.4
NP-MC-AiSi-2	1	2	9	W24PF12	16.7	4.52	0.607	1.49	1.90	0.623	15.8
LRM	1	2	10	LRMPF122	5.05	2.42	0.102	1.02	<0.100	<0.100	25.4
NP2-Very-High-Al	1	2	11	W20PF12	18.1	4.91	0.645	1.60	2.03	0.673	12.8
NP2-Low-Na	1	2	12	W01PF22	15.2	5.39	0.652	1.61	2.04	0.678	14.2
NP-MC-BLiSi-1	1	2	13	W05PF12	14.5	4.38	0.691	1.71	2.70	0.722	15.7
NP2-High-Al	1	2	14	W10PF22	16.3	5.00	0.689	1.71	2.18	0.720	13.1
NP2-Low-Li	1	2	15	W21PF12	15.1	5.23	0.729	1.79	1.80	0.756	14.1
NP-MC-AiLiNa-1	1	2	16	W14PF22	16.4	4.59	0.634	1.57	2.68	0.663	12.3
NP2-High-Na	1	2	17	W18PF12	14.6	5.16	0.672	1.66	2.13	0.703	13.5
NP-MC-BLiSi-1	1	2	18	W05PF22	14.6	4.39	0.688	1.71	2.69	0.720	15.8
LRM	1	2	19	LRMPF123	5.03	2.38	0.102	1.02	<0.100	<0.100	25.2
LRM	2	1	1	LRMPF211	5.09	2.53	0.114	1.03	<0.100	<0.100	25.6
NP2-High-B	2	1	2	W29PF21	13.9	6.63	0.650	1.69	2.17	0.727	13.1
NP-MC-AiBNa-1	2	1	3	W13PF11	13.6	4.57	0.837	2.05	2.64	0.886	15.3

**Table A-2. PF Measurements of the Nepheline Study Glasses (continued)**

ID	Block	Sub-Blk	Sequence	Lab ID	Al (wt%)	B (wt%)	Cr (wt%)	Fe (wt%)	Li (wt%)	Mn (wt%)	Si (wt%)
NP-MC-AiLi-1	2	1	4	W09PF21	12.9	5.36	0.781	1.88	1.80	0.810	14.2
NP-MC-AiBNa-1	2	1	5	W13PF21	14.0	4.69	0.840	2.05	2.63	0.886	15.6
NP2-High-B	2	1	6	W29PF11	14.0	6.62	0.681	1.75	2.24	0.756	13.0
NP2-Low-Si	2	1	7	W16PF21	15.6	5.63	0.772	1.88	2.40	0.816	12.3
NP-MC-AiLiSi-1	2	1	8	W19PF11	13.2	6.42	0.862	2.07	1.75	0.908	12.2
NP2-Low-Si	2	1	9	W16PF11	15.6	5.62	0.758	1.85	2.36	0.802	12.3
LRM	2	1	10	LRMPF212	5.00	2.41	0.117	1.04	<0.100	<0.100	25.2
NP-MC-AiLi-1	2	1	11	W09PF11	13.0	5.50	0.770	1.87	1.79	0.810	14.4
NP2-High-Si	2	1	12	W23PF21	14.0	4.80	0.677	1.67	2.13	0.721	15.5
NP2-High-Li	2	1	13	W30PF11	14.9	5.27	0.709	1.71	2.69	0.740	13.8
NP-MC-BSi-1	2	1	14	W06PF11	13.2	6.18	0.649	1.60	2.02	0.682	14.9
NP-MC-AiLiSi-1	2	1	15	W19PF21	13.5	6.53	0.895	2.14	1.82	0.946	12.4
NP-MC-BSi-1	2	1	16	W06PF21	13.4	6.35	0.655	1.61	2.05	0.688	15.2
NP2-High-Li	2	1	17	W30PF21	15.0	5.46	0.711	1.71	2.69	0.740	13.9
NP2-High-Si	2	1	18	W23PF11	14.3	5.09	0.696	1.68	2.15	0.723	15.8
LRM	2	1	19	LRMPF213	4.89	2.30	0.114	1.02	<0.100	<0.100	24.6
LRM	2	2	1	LRMPF221	4.94	2.41	0.144	1.05	<0.100	<0.100	24.8
NP-MC-AiLi-1	2	2	2	W09PF12	13.1	5.61	0.786	1.86	1.77	0.821	14.6
NP-MC-BSi-1	2	2	3	W06PF22	13.3	6.35	0.668	1.59	2.00	0.695	15.2
NP2-Low-Si	2	2	4	W16PF12	15.7	5.58	0.792	1.87	2.40	0.830	12.4
NP2-High-B	2	2	5	W29PF22	14.1	6.62	0.700	1.74	2.22	0.769	13.2
NP-MC-AiBNa-1	2	2	6	W13PF22	14.0	4.67	0.828	1.97	2.53	0.863	15.6
NP2-High-Li	2	2	7	W30PF22	14.7	5.30	0.745	1.74	2.71	0.767	13.7
NP-MC-AiLiSi-1	2	2	8	W19PF22	13.2	6.33	0.899	2.11	1.79	0.943	12.2
NP-MC-BSi-1	2	2	9	W06PF12	13.2	6.30	0.650	1.55	1.95	0.675	15.1
LRM	2	2	10	LRMPF222	4.97	2.40	0.144	1.03	<0.100	<0.100	25.0
NP2-High-Si	2	2	11	W23PF12	14.2	4.96	0.718	1.68	2.13	0.742	15.7
NP-MC-AiBNa-1	2	2	12	W13PF12	14.1	4.64	0.844	2.01	2.56	0.883	15.6
NP2-High-B	2	2	13	W29PF12	14.1	6.56	0.671	1.67	2.12	0.734	13.0
NP-MC-AiLi-1	2	2	14	W09PF22	13.3	5.53	0.784	1.85	1.75	0.808	14.5
NP2-Low-Si	2	2	15	W16PF22	15.7	5.56	0.793	1.88	2.39	0.831	12.4
NP2-High-Si	2	2	16	W23PF22	14.2	5.07	0.703	1.68	2.13	0.741	15.7
NP2-High-Li	2	2	17	W30PF12	14.8	5.36	0.718	1.68	2.62	0.742	13.7
NP-MC-AiLiSi-1	2	2	18	W19PF12	13.2	6.36	0.906	2.12	1.80	0.948	12.2
LRM	2	2	19	LRMPF223	5.17	2.50	0.147	1.05	<0.100	<0.100	25.9
LRM	3	1	1	LRMPF311	5.11	2.48	<0.100	0.982	<0.100	<0.100	25.5
NP-MC-AiNa-1	3	1	2	W28PF21	13.4	5.39	0.666	1.71	2.23	0.704	14.0
NP-MC-AiB-1	3	1	3	W02PF11	13.3	6.92	0.628	1.61	2.07	0.650	13.4
NP-MC-AiNa-1	3	1	4	W28PF11	13.4	5.29	0.678	1.73	2.24	0.711	13.9
NP-MC-AiBSi-1	3	1	5	W08PF21	16.6	6.81	0.560	1.44	1.86	0.576	12.5
NP2-Low-B	3	1	6	W27PF11	15.3	4.20	0.716	1.84	2.35	0.756	14.3
NP-MC-BNa-1	3	1	7	W03PF21	14.8	4.28	0.681	1.74	2.22	0.713	13.9

**Table A-2. PF Measurements of the Nepheline Study Glasses (continued)**

ID	Block	Sub-Blk	Sequence	Lab ID	Al (wt%)	B (wt%)	Cr (wt%)	Fe (wt%)	Li (wt%)	Mn (wt%)	Si (wt%)
NP-MC-AIB-1	3	1	8	W02PF21	13.2	6.71	0.654	1.75	2.13	0.679	13.5
NP-MC-AISi-1	3	1	9	W17PF11	13.0	6.02	0.769	1.96	2.48	0.799	12.2
LRM	3	1	10	LRMPF312	5.01	2.34	<0.100	0.946	<0.100	<0.100	25.1
BL3	3	1	11	W15PF11	14.8	5.29	0.700	1.81	2.28	0.733	13.9
NP-MC-AISi-1	3	1	12	W17PF21	13.3	6.18	0.794	2.04	2.57	0.831	12.4
NP2-Very-Low-Si	3	1	13	W31PF11	16.1	5.78	0.747	1.89	2.44	0.776	10.3
BL3	3	1	14	W15PF21	14.5	5.10	0.656	1.69	2.15	0.683	13.5
NP-MC-BNa-1	3	1	15	W03PF11	14.8	4.18	0.671	1.73	2.18	0.700	13.9
NP2-Very-Low-Si	3	1	16	W31PF21	16.5	5.78	0.775	1.97	2.51	0.802	10.6
NP-MC-AIBSi-1	3	1	17	W08PF11	16.6	6.75	0.596	1.53	1.96	0.616	12.5
NP2-Low-B	3	1	18	W27PF21	15.6	4.39	0.712	1.83	2.34	0.752	14.7
LRM	3	1	19	LRMPF313	5.03	2.34	<0.100	1.01	<0.100	<0.100	25.2
LRM	3	2	1	LRMPF321	4.96	2.24	<0.100	0.970	<0.100	<0.100	25.0
NP-MC-AINa-1	3	2	2	W28PF12	13.0	4.92	0.676	1.76	2.29	0.708	13.5
NP-MC-AIB-1	3	2	3	W02PF12	13.0	6.43	0.647	1.70	2.17	0.670	13.1
BL3	3	2	4	W15PF22	14.8	5.22	0.678	1.78	2.26	0.708	13.9
NP2-Low-B	3	2	5	W27PF22	15.6	4.33	0.698	1.84	2.37	0.741	14.7
NP-MC-BNa-1	3	2	6	W03PF12	15.2	4.37	0.681	1.79	2.28	0.713	14.2
NP-MC-AIB-1	3	2	7	W02PF22	13.6	6.99	0.677	1.85	2.25	0.706	14.0
NP-MC-AIBSi-1	3	2	8	W08PF22	16.8	6.95	0.542	1.42	1.83	0.554	12.7
NP-MC-AISi-1	3	2	9	W17PF12	13.3	6.18	0.795	2.07	2.62	0.833	12.5
LRM	3	2	10	LRMPF322	5.00	2.30	<0.100	0.993	<0.100	<0.100	25.1
NP-MC-AINa-1	3	2	11	W28PF22	13.0	5.00	0.684	1.78	2.31	0.720	13.5
BL3	3	2	12	W15PF12	14.9	5.10	0.671	1.76	2.24	0.699	13.9
NP2-Low-B	3	2	13	W27PF12	15.4	4.20	0.718	1.89	2.42	0.764	14.4
NP2-Very-Low-Si	3	2	14	W31PF22	16.6	5.86	0.803	2.08	2.67	0.837	10.5
NP-MC-BNa-1	3	2	15	W03PF22	15.1	4.40	0.688	1.79	2.31	0.718	14.1
NP-MC-AIBSi-1	3	2	16	W08PF12	16.6	6.82	0.553	1.46	1.89	0.568	12.5
NP2-Very-Low-Si	3	2	17	W31PF12	16.6	5.94	0.777	1.99	2.57	0.807	10.5
NP-MC-AIBSi-1	3	2	18	W17PF22	13.4	5.99	0.817	2.12	2.69	0.857	12.5
LRM	3	2	19	LRMPF323	4.99	2.14	<0.100	0.999	<0.100	<0.100	24.8
LRM	4	1	1	LRMPF411	5.02	2.29	<0.100	1.00	<0.100	<0.100	24.8
NP2-Very-High-Si	4	1	2	W25PF11	13.2	4.74	0.626	1.56	2.01	0.646	17.3
NP2-Low-Al	4	1	3	W04PF21	13.3	5.64	0.765	1.85	2.37	0.780	14.5
Neph-NN-1-12	4	1	4	W26PF21	14.2	5.43	0.278	1.65	2.57	0.681	13.8
NP-MC-AIBNa-2	4	1	5	W22PF21	15.5	6.10	0.620	1.49	1.95	0.644	12.2
NP-MC-BLiSi-2	4	1	6	W12PF11	14.3	6.98	0.692	1.68	2.74	0.711	12.5
Neph-NN-1-12	4	1	7	W26PF11	13.8	5.30	0.286	1.65	2.58	0.687	13.5
NP-MC-AiLi-2	4	1	8	W07PF21	16.3	5.10	0.681	1.66	1.75	0.708	13.3
NP-MC-AiLi-2	4	1	9	W07PF11	16.3	4.95	0.694	1.70	1.79	0.723	13.3
LRM	4	1	10	LRMPF412	5.00	2.28	<0.100	0.990	<0.100	<0.100	24.8
NP2-Very-High-Si	4	1	11	W25PF21	13.6	4.96	0.632	1.55	1.99	0.652	17.9

**Table A-2. PF Measurements of the Nepheline Study Glasses (continued)**

ID	Block	Sub-Blk	Sequence	Lab ID	Al (wt%)	B (wt%)	Cr (wt%)	Fe (wt%)	Li (wt%)	Mn (wt%)	Si (wt%)
NP-MC-BNaSi-1	4	1	12	W11PF11	16.4	4.52	0.799	1.91	2.46	0.826	12.4
NP-MC-AIBNa-2	4	1	13	W22PF11	15.8	6.18	0.641	1.51	1.99	0.660	12.4
NP-MC-BLiSi-2	4	1	14	W12PF21	14.1	6.84	0.646	1.53	2.01	0.669	12.3
NP-MC-BNaSi-1	4	1	15	W11PF21	16.0	4.34	0.794	1.88	2.44	0.814	12.2
NP2-Low-Al	4	1	16	W04PF11	13.1	5.38	0.748	1.79	2.30	0.764	14.2
LRM	4	1	17	LRMPF413	5.03	2.27	<0.100	1.01	<0.100	<0.100	25.0
LRM	4	2	1	LRMPF421	5.08	2.40	<0.100	1.02	<0.100	<0.100	25.2
NP-MC-BLiSi-2	4	2	2	W12PF22	14.0	6.64	0.667	1.64	2.67	0.692	12.2
NP2-Very-High-Si	4	2	3	W25PF22	13.2	4.73	0.632	1.53	1.97	0.645	17.4
Neph-NN-1-12	4	2	4	W26PF12	14.0	5.23	0.279	1.63	2.55	0.681	13.6
NP-MC-BNaSi-1	4	2	5	W11PF22	16.2	4.40	0.807	1.92	2.49	0.830	12.3
NP-MC-AiLi-2	4	2	6	W07PF12	16.5	5.16	0.685	1.68	1.78	0.719	13.5
NP-MC-AIBNa-2	4	2	7	W22PF22	15.6	5.99	0.628	1.49	1.98	0.651	12.3
NP-MC-AiLi-2	4	2	8	W07PF22	16.5	5.16	0.690	1.67	1.78	0.719	13.5
NP-MC-BLiSi-2	4	2	9	W12PF12	14.2	6.74	0.675	1.63	2.69	0.695	12.4
LRM	4	2	10	LRMPF422	5.00	2.28	<0.100	1.03	<0.100	<0.100	24.8
NP2-Low-Al	4	2	11	W04PF22	13.3	5.47	0.752	1.78	2.29	0.764	14.4
NP2-Very-High-Si	4	2	12	W25PF12	13.3	4.81	0.629	1.52	1.97	0.644	17.5
NP-MC-BNaSi-1	4	2	13	W11PF12	16.3	4.39	0.805	1.91	2.48	0.831	12.4
Neph-NN-1-12	4	2	14	W26PF22	14.0	5.22	0.277	1.59	2.53	0.672	13.7
NP-MC-AIBNa-2	4	2	15	W22PF12	15.5	5.89	0.596	1.41	1.87	0.617	12.2
NP2-Low-Al	4	2	16	W04PF12	13.2	5.49	0.736	1.75	2.26	0.748	14.4
LRM	4	2	17	LRMPF423	5.08	2.38	<0.100	0.969	<0.100	<0.100	25.3



**Table A-3. Comparison of Targeted and Measured Glass Compositions**

Glass ID	Oxide	BDL (<)	Measured (wt%)	Targeted (wt%)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
BL3	Al <sub>2</sub> O <sub>3</sub>		27.87	28.50	-0.63	-2.2%
BL3	B <sub>2</sub> O <sub>3</sub>		16.67	17.20	-0.53	-3.1%
BL3	Bi <sub>2</sub> O <sub>3</sub>		0.60	0.65	-0.05	
BL3	CaO		0.60	0.65	-0.05	
BL3	Cr <sub>2</sub> O <sub>3</sub>		0.99	1.10	-0.11	
BL3	Fe <sub>2</sub> O <sub>3</sub>		2.52	2.50	0.02	
BL3	Li <sub>2</sub> O		4.81	5.00	-0.19	-3.9%
BL3	MnO		0.91	1.00	-0.09	
BL3	Na <sub>2</sub> O		13.20	12.50	0.70	5.6%
BL3	NiO	<	0.13	0.00	0.13	
BL3	P <sub>2</sub> O <sub>5</sub>		0.67	0.70	-0.03	
BL3	RuO <sub>2</sub>	<	0.13	0.05	0.08	
BL3	SiO <sub>2</sub>		29.52	29.35	0.17	0.6%
BL3	SO <sub>3</sub>		0.26	0.25	0.01	
BL3	ZrO <sub>2</sub>		0.25	0.25	0.00	
BL3	Sum		99.13	99.70	-0.57	-0.6%
LRM	Al <sub>2</sub> O <sub>3</sub>		9.50	9.51	-0.01	-0.1%
LRM	B <sub>2</sub> O <sub>3</sub>		7.66	7.85	-0.19	-2.4%
LRM	Bi <sub>2</sub> O <sub>3</sub>	<	0.11	0.00	0.11	
LRM	CaO		0.46	0.54	-0.08	
LRM	Cr <sub>2</sub> O <sub>3</sub>	<	0.16	0.19	-0.03	
LRM	Fe <sub>2</sub> O <sub>3</sub>		1.43	1.38	0.05	
LRM	Li <sub>2</sub> O	<	0.22	0.11	0.11	
LRM	MnO	<	0.13	0.08	0.05	
LRM	Na <sub>2</sub> O		21.37	20.03	1.34	6.7%
LRM	NiO		0.18	0.19	-0.01	
LRM	P <sub>2</sub> O <sub>5</sub>		0.49	0.54	-0.05	
LRM	RuO <sub>2</sub>	<	0.13	0.00	0.13	
LRM	SiO <sub>2</sub>		53.86	54.20	-0.34	-0.6%
LRM	SO <sub>3</sub>		0.22	0.30	-0.08	
LRM	ZrO <sub>2</sub>		0.96	0.93	0.03	
LRM	Sum		96.87	95.85	1.02	1.1%
Neph-NN-1-12	Al <sub>2</sub> O <sub>3</sub>		26.45	26.92	-0.47	-1.7%
Neph-NN-1-12	B <sub>2</sub> O <sub>3</sub>		17.05	17.00	0.05	0.3%
Neph-NN-1-12	Bi <sub>2</sub> O <sub>3</sub>		0.64	0.71	-0.07	
Neph-NN-1-12	CaO		0.43	0.47	-0.04	
Neph-NN-1-12	Cr <sub>2</sub> O <sub>3</sub>		0.41	0.47	-0.06	
Neph-NN-1-12	Fe <sub>2</sub> O <sub>3</sub>		2.33	2.36	-0.03	
Neph-NN-1-12	Li <sub>2</sub> O		5.51	5.67	-0.16	-2.9%
Neph-NN-1-12	MnO		0.88	0.94	-0.06	
Neph-NN-1-12	Na <sub>2</sub> O		16.07	15.00	1.07	7.2%
Neph-NN-1-12	NiO		0.19	0.24	-0.05	
Neph-NN-1-12	P <sub>2</sub> O <sub>5</sub>		0.88	0.94	-0.06	
Neph-NN-1-12	RuO <sub>2</sub>	<	0.13	0.05	0.08	
Neph-NN-1-12	SiO <sub>2</sub>		29.20	28.99	0.21	0.7%
Neph-NN-1-12	SO <sub>3</sub>		0.25	0.24	0.01	
Neph-NN-1-12	ZrO <sub>2</sub>	<	0.14	0.00	0.14	
Neph-NN-1-12	Sum		100.56	100.00	0.56	0.6%
NP2 - High Al	Al <sub>2</sub> O <sub>3</sub>		31.22	31.50	-0.28	-0.9%
NP2 - High Al	B <sub>2</sub> O <sub>3</sub>		16.48	16.48	0.00	-0.01%
NP2 - High Al	Bi <sub>2</sub> O <sub>3</sub>		0.57	0.62	-0.05	
NP2 - High Al	CaO		0.51	0.62	-0.11	
NP2 - High Al	Cr <sub>2</sub> O <sub>3</sub>		0.96	1.05	-0.09	
NP2 - High Al	Fe <sub>2</sub> O <sub>3</sub>		2.39	2.40	-0.01	
NP2 - High Al	Li <sub>2</sub> O		4.60	4.79	-0.19	
NP2 - High Al	MnO		0.88	0.96	-0.08	
NP2 - High Al	Na <sub>2</sub> O		12.75	11.98	0.77	6.4%

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

Glass ID	Oxide	BDL ( $<$ )	Measured (wt%)	Targeted (wt%)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
NP2 - High Al	NiO	$<$	0.13	0.00	0.13	
NP2 - High Al	P <sub>2</sub> O <sub>5</sub>		0.63	0.67	-0.04	
NP2 - High Al	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP2 - High Al	SiO <sub>2</sub>		28.51	28.12	0.39	1.4%
NP2 - High Al	SO <sub>3</sub>		0.22	0.24	-0.02	
NP2 - High Al	ZrO <sub>2</sub>		0.23	0.24	-0.01	
NP2 - High Al	Sum		100.20	99.72	0.48	0.5%
NP2 - High B	Al <sub>2</sub> O <sub>3</sub>		26.50	26.85	-0.35	-1.3%
NP2 - High B	B <sub>2</sub> O <sub>3</sub>		21.28	22.00	-0.72	-3.3%
NP2 - High B	Bi <sub>2</sub> O <sub>3</sub>		0.57	0.61	-0.04	
NP2 - High B	CaO		0.50	0.61	-0.11	
NP2 - High B	Cr <sub>2</sub> O <sub>3</sub>		0.99	1.04	-0.05	
NP2 - High B	Fe <sub>2</sub> O <sub>3</sub>		2.45	2.36	0.09	
NP2 - High B	Li <sub>2</sub> O		4.71	4.71	0.00	
NP2 - High B	MnO		0.96	0.94	0.02	
NP2 - High B	Na <sub>2</sub> O		12.33	11.78	0.55	4.7%
NP2 - High B	NiO	$<$	0.13	0.00	0.13	
NP2 - High B	P <sub>2</sub> O <sub>5</sub>		0.63	0.66	-0.03	
NP2 - High B	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP2 - High B	SiO <sub>2</sub>		27.97	27.65	0.32	1.2%
NP2 - High B	SO <sub>3</sub>		0.19	0.24	-0.05	
NP2 - High B	ZrO <sub>2</sub>		0.24	0.24	0.00	
NP2 - High B	Sum		99.58	99.74	-0.16	-0.2%
NP2 - High Li	Al <sub>2</sub> O <sub>3</sub>		28.06	28.20	-0.14	-0.5%
NP2 - High Li	B <sub>2</sub> O <sub>3</sub>		17.22	17.02	0.20	1.2%
NP2 - High Li	Bi <sub>2</sub> O <sub>3</sub>		0.59	0.64	-0.05	
NP2 - High Li	CaO		0.60	0.64	-0.04	
NP2 - High Li	Cr <sub>2</sub> O <sub>3</sub>		1.05	1.09	-0.04	
NP2 - High Li	Fe <sub>2</sub> O <sub>3</sub>		2.44	2.47	-0.03	
NP2 - High Li	Li <sub>2</sub> O		5.76	6.00	-0.24	-3.9%
NP2 - High Li	MnO		0.96	0.99	-0.03	
NP2 - High Li	Na <sub>2</sub> O		13.25	12.37	0.88	7.1%
NP2 - High Li	NiO	$<$	0.13	0.00	0.13	
NP2 - High Li	P <sub>2</sub> O <sub>5</sub>		0.66	0.69	-0.03	
NP2 - High Li	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP2 - High Li	SiO <sub>2</sub>		29.47	29.04	0.43	1.5%
NP2 - High Li	SO <sub>3</sub>		0.27	0.25	0.02	
NP2 - High Li	ZrO <sub>2</sub>		0.25	0.25	0.00	
NP2 - High Li	Sum		100.86	99.70	1.16	1.2%
NP2 - High Na	Al <sub>2</sub> O <sub>3</sub>		27.16	27.52	-0.36	-1.3%
NP2 - High Na	B <sub>2</sub> O <sub>3</sub>		16.57	16.61	-0.04	-0.3%
NP2 - High Na	Bi <sub>2</sub> O <sub>3</sub>		0.58	0.63	-0.05	
NP2 - High Na	CaO		0.59	0.63	-0.04	
NP2 - High Na	Cr <sub>2</sub> O <sub>3</sub>		0.96	1.06	-0.10	
NP2 - High Na	Fe <sub>2</sub> O <sub>3</sub>		2.37	2.41	-0.04	
NP2 - High Na	Li <sub>2</sub> O		4.61	4.83	-0.22	
NP2 - High Na	MnO		0.89	0.97	-0.08	
NP2 - High Na	Na <sub>2</sub> O		16.45	15.50	0.95	6.1%
NP2 - High Na	NiO	$<$	0.13	0.00	0.13	
NP2 - High Na	P <sub>2</sub> O <sub>5</sub>		0.63	0.68	-0.05	
NP2 - High Na	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP2 - High Na	SiO <sub>2</sub>		28.56	28.34	0.22	0.8%
NP2 - High Na	SO <sub>3</sub>		0.26	0.24	0.02	
NP2 - High Na	ZrO <sub>2</sub>		0.46	0.24	0.22	
NP2 - High Na	Sum		100.33	99.71	0.62	0.6%
NP2 - High Si	Al <sub>2</sub> O <sub>3</sub>		26.78	27.03	-0.25	-0.9%
NP2 - High Si	B <sub>2</sub> O <sub>3</sub>		16.04	16.31	-0.27	-1.7%
NP2 - High Si	Bi <sub>2</sub> O <sub>3</sub>		0.57	0.62	-0.05	

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

Glass ID	Oxide	BDL (<)	Measured (wt%)	Targeted (wt%)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
NP2 - High Si	CaO		0.51	0.62	-0.11	
NP2 - High Si	Cr <sub>2</sub> O <sub>3</sub>		1.02	1.04	-0.02	
NP2 - High Si	Fe <sub>2</sub> O <sub>3</sub>		2.40	2.37	0.03	
NP2 - High Si	Li <sub>2</sub> O		4.60	4.74	-0.14	
NP2 - High Si	MnO		0.94	0.95	-0.01	
NP2 - High Si	Na <sub>2</sub> O		12.57	11.85	0.72	6.0%
NP2 - High Si	NiO	<	0.13	0.00	0.13	
NP2 - High Si	P <sub>2</sub> O <sub>5</sub>		0.62	0.66	-0.04	
NP2 - High Si	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP2 - High Si	SiO <sub>2</sub>		33.53	33.00	0.53	1.6%
NP2 - High Si	SO <sub>3</sub>		0.19	0.24	-0.05	
NP2 - High Si	ZrO <sub>2</sub>		0.23	0.24	-0.01	
NP2 - High Si	Sum		100.26	99.72	0.54	0.5%
NP2 - Low Al	Al <sub>2</sub> O <sub>3</sub>		24.99	25.50	-0.51	-2.0%
NP2 - Low Al	B <sub>2</sub> O <sub>3</sub>		17.69	17.92	-0.23	-1.3%
NP2 - Low Al	Bi <sub>2</sub> O <sub>3</sub>		0.62	0.68	-0.06	
NP2 - Low Al	CaO		0.58	0.68	-0.10	
NP2 - Low Al	Cr <sub>2</sub> O <sub>3</sub>		1.10	1.15	-0.05	
NP2 - Low Al	Fe <sub>2</sub> O <sub>3</sub>		2.56	2.60	-0.04	
NP2 - Low Al	Li <sub>2</sub> O		4.96	5.21	-0.25	-4.8%
NP2 - Low Al	MnO		0.99	1.04	-0.05	
NP2 - Low Al	Na <sub>2</sub> O		13.35	13.02	0.33	2.5%
NP2 - Low Al	NiO	<	0.13	0.00	0.13	
NP2 - Low Al	P <sub>2</sub> O <sub>5</sub>		0.69	0.73	-0.04	
NP2 - Low Al	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP2 - Low Al	SiO <sub>2</sub>		30.75	30.58	0.17	0.6%
NP2 - Low Al	SO <sub>3</sub>		0.25	0.26	-0.01	
NP2 - Low Al	ZrO <sub>2</sub>		0.27	0.26	0.01	
NP2 - Low Al	Sum		99.06	99.68	-0.62	-0.6%
NP2 - Low B	Al <sub>2</sub> O <sub>3</sub>		29.24	29.60	-0.36	-1.2%
NP2 - Low B	B <sub>2</sub> O <sub>3</sub>		13.78	14.00	-0.22	-1.6%
NP2 - Low B	Bi <sub>2</sub> O <sub>3</sub>		0.62	0.68	-0.06	
NP2 - Low B	CaO		0.63	0.68	-0.05	
NP2 - Low B	Cr <sub>2</sub> O <sub>3</sub>		1.04	1.14	-0.10	
NP2 - Low B	Fe <sub>2</sub> O <sub>3</sub>		2.64	2.60	0.04	
NP2 - Low B	Li <sub>2</sub> O		5.10	5.19	-0.09	-1.7%
NP2 - Low B	MnO		0.97	1.04	-0.07	
NP2 - Low B	Na <sub>2</sub> O		13.78	12.98	0.80	6.2%
NP2 - Low B	NiO	<	0.13	0.00	0.13	
NP2 - Low B	P <sub>2</sub> O <sub>5</sub>		0.70	0.73	-0.03	
NP2 - Low B	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP2 - Low B	SiO <sub>2</sub>		31.07	30.48	0.59	1.9%
NP2 - Low B	SO <sub>3</sub>		0.23	0.26	-0.03	
NP2 - Low B	ZrO <sub>2</sub>		0.26	0.26	0.00	
NP2 - Low B	Sum		100.33	99.69	0.64	0.6%
NP2 - Low Li	Al <sub>2</sub> O <sub>3</sub>		28.39	28.80	-0.41	-1.4%
NP2 - Low Li	B <sub>2</sub> O <sub>3</sub>		17.25	17.38	-0.13	-0.7%
NP2 - Low Li	Bi <sub>2</sub> O <sub>3</sub>		0.61	0.66	-0.05	
NP2 - Low Li	CaO		0.63	0.66	-0.03	
NP2 - Low Li	Cr <sub>2</sub> O <sub>3</sub>		1.02	1.11	-0.09	
NP2 - Low Li	Fe <sub>2</sub> O <sub>3</sub>		2.51	2.53	-0.02	
NP2 - Low Li	Li <sub>2</sub> O		3.80	4.00	-0.20	
NP2 - Low Li	MnO		0.93	1.01	-0.08	
NP2 - Low Li	Na <sub>2</sub> O		13.36	12.63	0.73	5.7%
NP2 - Low Li	NiO	<	0.13	0.00	0.13	
NP2 - Low Li	P <sub>2</sub> O <sub>5</sub>		0.66	0.71	-0.05	
NP2 - Low Li	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP2 - Low Li	SiO <sub>2</sub>		30.06	29.66	0.40	1.3%

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

Glass ID	Oxide	BDL (<)	Measured (wt%)	Targeted (wt%)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
NP2 - Low Li	SO <sub>3</sub>		0.23	0.25	-0.02	
NP2 - Low Li	ZrO <sub>2</sub>		0.24	0.25	-0.01	
NP2 - Low Li	Sum		99.93	99.70	0.23	0.2%
NP2 - Low Na	Al <sub>2</sub> O <sub>3</sub>		28.96	29.48	-0.52	-1.8%
NP2 - Low Na	B <sub>2</sub> O <sub>3</sub>		17.31	17.79	-0.48	-2.7%
NP2 - Low Na	Bi <sub>2</sub> O <sub>3</sub>		0.62	0.67	-0.05	
NP2 - Low Na	CaO		0.55	0.67	-0.12	
NP2 - Low Na	Cr <sub>2</sub> O <sub>3</sub>		0.98	1.14	-0.16	
NP2 - Low Na	Fe <sub>2</sub> O <sub>3</sub>		2.50	2.59	-0.09	
NP2 - Low Na	Li <sub>2</sub> O		4.81	5.17	-0.36	-6.9%
NP2 - Low Na	MnO		0.93	1.03	-0.10	
NP2 - Low Na	Na <sub>2</sub> O		10.19	9.50	0.69	7.2%
NP2 - Low Na	NiO	<	0.13	0.00	0.13	
NP2 - Low Na	P <sub>2</sub> O <sub>5</sub>		0.68	0.72	-0.04	
NP2 - Low Na	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP2 - Low Na	SiO <sub>2</sub>		30.54	30.36	0.18	0.6%
NP2 - Low Na	SO <sub>3</sub>		0.18	0.26	-0.08	
NP2 - Low Na	ZrO <sub>2</sub>		0.25	0.26	-0.01	
NP2 - Low Na	Sum		98.75	99.69	-0.94	-0.9%
NP2 - Low Si	Al <sub>2</sub> O <sub>3</sub>		29.57	29.85	-0.28	-0.9%
NP2 - Low Si	B <sub>2</sub> O <sub>3</sub>		18.02	18.02	0.00	0.02%
NP2 - Low Si	Bi <sub>2</sub> O <sub>3</sub>		0.63	0.68	-0.05	
NP2 - Low Si	CaO		0.55	0.68	-0.13	
NP2 - Low Si	Cr <sub>2</sub> O <sub>3</sub>		1.14	1.15	-0.01	
NP2 - Low Si	Fe <sub>2</sub> O <sub>3</sub>		2.67	2.62	0.05	
NP2 - Low Si	Li <sub>2</sub> O		5.14	5.24	-0.10	-1.9%
NP2 - Low Si	MnO		1.06	1.05	0.01	
NP2 - Low Si	Na <sub>2</sub> O		13.27	13.09	0.18	1.4%
NP2 - Low Si	NiO	<	0.13	0.00	0.13	
NP2 - Low Si	P <sub>2</sub> O <sub>5</sub>		0.69	0.73	-0.04	
NP2 - Low Si	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP2 - Low Si	SiO <sub>2</sub>		26.42	26.00	0.42	1.6%
NP2 - Low Si	SO <sub>3</sub>		0.22	0.26	-0.04	
NP2 - Low Si	ZrO <sub>2</sub>		0.26	0.26	0.00	
NP2 - Low Si	Sum		99.90	99.68	0.22	0.2%
NP2 - Very High Al	Al <sub>2</sub> O <sub>3</sub>		34.15	34.50	-0.35	-1.0%
NP2 - Very High Al	B <sub>2</sub> O <sub>3</sub>		15.74	15.76	-0.02	-0.1%
NP2 - Very High Al	Bi <sub>2</sub> O <sub>3</sub>		0.55	0.60	-0.05	
NP2 - Very High Al	CaO		0.56	0.60	-0.04	
NP2 - Very High Al	Cr <sub>2</sub> O <sub>3</sub>		0.91	1.01	-0.10	
NP2 - Very High Al	Fe <sub>2</sub> O <sub>3</sub>		2.27	2.29	-0.02	
NP2 - Very High Al	Li <sub>2</sub> O		4.35	4.58	-0.23	
NP2 - Very High Al	MnO		0.84	0.92	-0.08	
NP2 - Very High Al	Na <sub>2</sub> O		12.23	11.45	0.78	6.8%
NP2 - Very High Al	NiO	<	0.13	0.00	0.13	
NP2 - Very High Al	P <sub>2</sub> O <sub>5</sub>		0.61	0.64	-0.03	
NP2 - Very High Al	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP2 - Very High Al	SiO <sub>2</sub>		27.28	26.89	0.39	1.4%
NP2 - Very High Al	SO <sub>3</sub>		0.21	0.23	-0.02	
NP2 - Very High Al	ZrO <sub>2</sub>		0.23	0.23	0.00	
NP2 - Very High Al	Sum		100.19	99.75	0.44	0.4%
NP2 - Very High Si	Al <sub>2</sub> O <sub>3</sub>		25.18	25.41	-0.23	-0.9%
NP2 - Very High Si	B <sub>2</sub> O <sub>3</sub>		15.49	15.34	0.15	1.0%
NP2 - Very High Si	Bi <sub>2</sub> O <sub>3</sub>		0.53	0.58	-0.05	
NP2 - Very High Si	CaO		0.55	0.58	-0.03	
NP2 - Very High Si	Cr <sub>2</sub> O <sub>3</sub>		0.92	0.98	-0.06	
NP2 - Very High Si	Fe <sub>2</sub> O <sub>3</sub>		2.20	2.23	-0.03	
NP2 - Very High Si	Li <sub>2</sub> O		4.27	4.46	-0.19	

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

Glass ID	Oxide	BDL ( $<$ )	Measured (wt%)	Targeted (wt%)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
NP2 - Very High Si	MnO		0.84	0.89	-0.05	
NP2 - Very High Si	Na <sub>2</sub> O		11.61	11.15	0.46	4.1%
NP2 - Very High Si	NiO	$<$	0.13	0.00	0.13	
NP2 - Very High Si	P <sub>2</sub> O <sub>5</sub>		0.58	0.62	-0.04	
NP2 - Very High Si	RuO <sub>2</sub>	$<$	0.13	0.04	0.09	
NP2 - Very High Si	SiO <sub>2</sub>		37.49	37.00	0.49	1.3%
NP2 - Very High Si	SO <sub>3</sub>		0.20	0.22	-0.02	
NP2 - Very High Si	ZrO <sub>2</sub>		0.21	0.22	-0.01	
NP2 - Very High Si	Sum		100.32	99.72	0.60	0.6%
NP2 - Very Low Si	Al <sub>2</sub> O <sub>3</sub>		31.08	31.46	-0.38	-1.2%
NP2 - Very Low Si	B <sub>2</sub> O <sub>3</sub>		18.80	18.99	-0.19	-1.0%
NP2 - Very Low Si	Bi <sub>2</sub> O <sub>3</sub>		0.65	0.72	-0.07	
NP2 - Very Low Si	CaO		0.58	0.72	-0.14	
NP2 - Very Low Si	Cr <sub>2</sub> O <sub>3</sub>		1.13	1.21	-0.08	
NP2 - Very Low Si	Fe <sub>2</sub> O <sub>3</sub>		2.83	2.76	0.07	
NP2 - Very Low Si	Li <sub>2</sub> O		5.48	5.52	-0.04	-0.6%
NP2 - Very Low Si	MnO		1.04	1.10	-0.06	
NP2 - Very Low Si	Na <sub>2</sub> O		14.52	13.80	0.72	5.3%
NP2 - Very Low Si	NiO	$<$	0.13	0.00	0.13	
NP2 - Very Low Si	P <sub>2</sub> O <sub>5</sub>		0.72	0.77	-0.05	
NP2 - Very Low Si	RuO <sub>2</sub>	$<$	0.13	0.06	0.07	
NP2 - Very Low Si	SiO <sub>2</sub>		22.41	22.00	0.41	1.9%
NP2 - Very Low Si	SO <sub>3</sub>		0.27	0.28	-0.01	
NP2 - Very Low Si	ZrO <sub>2</sub>		0.26	0.28	-0.02	
NP2 - Very Low Si	Sum		100.07	99.67	0.40	0.4%
NP-MC-AIB-1	Al <sub>2</sub> O <sub>3</sub>		25.08	25.50	-0.42	-1.6%
NP-MC-AIB-1	B <sub>2</sub> O <sub>3</sub>		21.77	22.00	-0.23	-1.0%
NP-MC-AIB-1	Bi <sub>2</sub> O <sub>3</sub>		0.58	0.63	-0.05	
NP-MC-AIB-1	CaO		0.51	0.63	-0.12	
NP-MC-AIB-1	Cr <sub>2</sub> O <sub>3</sub>		0.95	1.06	-0.11	
NP-MC-AIB-1	Fe <sub>2</sub> O <sub>3</sub>		2.47	2.42	0.05	
NP-MC-AIB-1	Li <sub>2</sub> O		4.64	4.83	-0.19	
NP-MC-AIB-1	MnO		0.87	0.97	-0.10	
NP-MC-AIB-1	Na <sub>2</sub> O		12.51	12.09	0.42	3.5%
NP-MC-AIB-1	NiO	$<$	0.13	0.00	0.13	
NP-MC-AIB-1	P <sub>2</sub> O <sub>5</sub>		0.65	0.68	-0.03	
NP-MC-AIB-1	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP-MC-AIB-1	SiO <sub>2</sub>		28.88	28.38	0.50	1.8%
NP-MC-AIB-1	SO <sub>3</sub>		0.24	0.24	0.00	
NP-MC-AIB-1	ZrO <sub>2</sub>		0.24	0.24	0.00	
NP-MC-AIB-1	Sum		99.67	99.72	-0.05	-0.05%
NP-MC-AIBNa-1	Al <sub>2</sub> O <sub>3</sub>		26.31	26.80	-0.49	-1.8%
NP-MC-AIBNa-1	B <sub>2</sub> O <sub>3</sub>		14.95	15.39	-0.44	-2.9%
NP-MC-AIBNa-1	Bi <sub>2</sub> O <sub>3</sub>		0.67	0.73	-0.06	
NP-MC-AIBNa-1	CaO		0.67	0.73	-0.06	
NP-MC-AIBNa-1	Cr <sub>2</sub> O <sub>3</sub>		1.22	1.24	-0.02	
NP-MC-AIBNa-1	Fe <sub>2</sub> O <sub>3</sub>		2.89	2.81	0.08	
NP-MC-AIBNa-1	Li <sub>2</sub> O		5.58	5.62	-0.04	-0.8%
NP-MC-AIBNa-1	MnO		1.14	1.12	0.02	
NP-MC-AIBNa-1	Na <sub>2</sub> O		11.48	10.80	0.68	6.3%
NP-MC-AIBNa-1	NiO	$<$	0.13	0.00	0.13	
NP-MC-AIBNa-1	P <sub>2</sub> O <sub>5</sub>		0.76	0.79	-0.03	
NP-MC-AIBNa-1	RuO <sub>2</sub>	$<$	0.13	0.06	0.07	
NP-MC-AIBNa-1	SiO <sub>2</sub>		33.21	33.00	0.21	0.6%
NP-MC-AIBNa-1	SO <sub>3</sub>		0.27	0.28	-0.01	
NP-MC-AIBNa-1	ZrO <sub>2</sub>		0.29	0.28	0.01	
NP-MC-AIBNa-1	Sum		99.68	99.65	0.03	0.03%
NP-MC-AIBNa-2	Al <sub>2</sub> O <sub>3</sub>		29.48	29.83	-0.35	-1.2%

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

Glass ID	Oxide	BDL (<)	Measured (wt%)	Targeted (wt%)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
NP-MC-AIBNa-2	B <sub>2</sub> O <sub>3</sub>		19.45	19.32	0.13	0.7%
NP-MC-AIBNa-2	Bi <sub>2</sub> O <sub>3</sub>		0.53	0.58	-0.05	
NP-MC-AIBNa-2	CaO		0.55	0.58	-0.03	
NP-MC-AIBNa-2	Cr <sub>2</sub> O <sub>3</sub>		0.91	0.97	-0.06	
NP-MC-AIBNa-2	Fe <sub>2</sub> O <sub>3</sub>		2.11	2.21	-0.10	
NP-MC-AIBNa-2	Li <sub>2</sub> O		4.19	4.43	-0.24	
NP-MC-AIBNa-2	MnO		0.83	0.89	-0.06	
NP-MC-AIBNa-2	Na <sub>2</sub> O		14.83	13.83	1.00	7.2%
NP-MC-AIBNa-2	NiO	<	0.13	0.00	0.13	
NP-MC-AIBNa-2	P <sub>2</sub> O <sub>5</sub>		0.59	0.62	-0.03	
NP-MC-AIBNa-2	RuO <sub>2</sub>	<	0.13	0.04	0.09	
NP-MC-AIBNa-2	SiO <sub>2</sub>		26.26	26.00	0.26	1.0%
NP-MC-AIBNa-2	SO <sub>3</sub>		0.21	0.22	-0.01	
NP-MC-AIBNa-2	ZrO <sub>2</sub>		0.21	0.22	-0.01	
NP-MC-AIBNa-2	Sum		100.40	99.74	0.66	0.7%
NP-MC-AIBSi-1	Al <sub>2</sub> O <sub>3</sub>		31.46	31.50	-0.04	-0.1%
NP-MC-AIBSi-1	B <sub>2</sub> O <sub>3</sub>		22.00	22.00	0.00	0.00%
NP-MC-AIBSi-1	Bi <sub>2</sub> O <sub>3</sub>		0.49	0.53	-0.04	
NP-MC-AIBSi-1	CaO		0.43	0.53	-0.10	
NP-MC-AIBSi-1	Cr <sub>2</sub> O <sub>3</sub>		0.82	0.90	-0.08	
NP-MC-AIBSi-1	Fe <sub>2</sub> O <sub>3</sub>		2.09	2.05	0.04	
NP-MC-AIBSi-1	Li <sub>2</sub> O		4.06	4.11	-0.05	
NP-MC-AIBSi-1	MnO		0.75	0.82	-0.07	
NP-MC-AIBSi-1	Na <sub>2</sub> O		10.88	10.27	0.61	6.0%
NP-MC-AIBSi-1	NiO	<	0.13	0.00	0.13	
NP-MC-AIBSi-1	P <sub>2</sub> O <sub>5</sub>		0.54	0.58	-0.04	
NP-MC-AIBSi-1	RuO <sub>2</sub>	<	0.13	0.04	0.09	
NP-MC-AIBSi-1	SiO <sub>2</sub>		26.85	26.00	0.85	3.3%
NP-MC-AIBSi-1	SO <sub>3</sub>		0.17	0.21	-0.04	
NP-MC-AIBSi-1	ZrO <sub>2</sub>		0.20	0.21	-0.01	
NP-MC-AIBSi-1	Sum		100.99	99.75	1.24	1.2%
NP-MC-AiLi-1	Al <sub>2</sub> O <sub>3</sub>		24.71	25.50	-0.79	-3.1%
NP-MC-AiLi-1	B <sub>2</sub> O <sub>3</sub>		17.71	18.23	-0.52	-2.9%
NP-MC-AiLi-1	Bi <sub>2</sub> O <sub>3</sub>		0.64	0.69	-0.05	
NP-MC-AiLi-1	CaO		0.56	0.69	-0.13	
NP-MC-AiLi-1	Cr <sub>2</sub> O <sub>3</sub>		1.14	1.17	-0.03	
NP-MC-AiLi-1	Fe <sub>2</sub> O <sub>3</sub>		2.67	2.65	0.02	
NP-MC-AiLi-1	Li <sub>2</sub> O		3.83	4.00	-0.17	
NP-MC-AiLi-1	MnO		1.05	1.06	-0.01	
NP-MC-AiLi-1	Na <sub>2</sub> O		13.39	13.25	0.14	1.0%
NP-MC-AiLi-1	NiO	<	0.13	0.00	0.13	
NP-MC-AiLi-1	P <sub>2</sub> O <sub>5</sub>		0.71	0.74	-0.03	
NP-MC-AiLi-1	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP-MC-AiLi-1	SiO <sub>2</sub>		30.86	31.12	-0.26	-0.8%
NP-MC-AiLi-1	SO <sub>3</sub>		0.25	0.27	-0.02	
NP-MC-AiLi-1	ZrO <sub>2</sub>		0.28	0.27	0.01	
NP-MC-AiLi-1	Sum		98.03	99.69	-1.66	-1.7%
NP-MC-AiLi-2	Al <sub>2</sub> O <sub>3</sub>		30.99	31.50	-0.51	-1.6%
NP-MC-AiLi-2	B <sub>2</sub> O <sub>3</sub>		16.40	16.68	-0.28	-1.7%
NP-MC-AiLi-2	Bi <sub>2</sub> O <sub>3</sub>		0.58	0.63	-0.05	
NP-MC-AiLi-2	CaO		0.59	0.63	-0.04	
NP-MC-AiLi-2	Cr <sub>2</sub> O <sub>3</sub>		1.00	1.07	-0.07	
NP-MC-AiLi-2	Fe <sub>2</sub> O <sub>3</sub>		2.40	2.42	-0.02	
NP-MC-AiLi-2	Li <sub>2</sub> O		3.82	4.00	-0.18	
NP-MC-AiLi-2	MnO		0.93	0.97	-0.04	
NP-MC-AiLi-2	Na <sub>2</sub> O		12.85	12.12	0.73	6.0%
NP-MC-AiLi-2	NiO	<	0.13	0.00	0.13	
NP-MC-AiLi-2	P <sub>2</sub> O <sub>5</sub>		0.65	0.68	-0.03	

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

Glass ID	Oxide	BDL (<)	Measured (wt%)	Targeted (wt%)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
NP-MC-AiLi-2	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP-MC-AiLi-2	SiO <sub>2</sub>		28.67	28.47	0.20	0.7%
NP-MC-AiLi-2	SO <sub>3</sub>		0.21	0.24	-0.03	
NP-MC-AiLi-2	ZrO <sub>2</sub>		0.24	0.24	0.00	
NP-MC-AiLi-2	Sum		99.58	99.70	-0.12	-0.1%
NP-MC-AiLiNa-1	Al <sub>2</sub> O <sub>3</sub>		30.94	31.14	-0.20	-0.6%
NP-MC-AiLiNa-1	B <sub>2</sub> O <sub>3</sub>		15.15	15.24	-0.09	-0.6%
NP-MC-AiLiNa-1	Bi <sub>2</sub> O <sub>3</sub>		0.52	0.58	-0.06	
NP-MC-AiLiNa-1	CaO		0.53	0.58	-0.05	
NP-MC-AiLiNa-1	Cr <sub>2</sub> O <sub>3</sub>		0.88	0.97	-0.09	
NP-MC-AiLiNa-1	Fe <sub>2</sub> O <sub>3</sub>		2.18	2.21	-0.03	
NP-MC-AiLiNa-1	Li <sub>2</sub> O		5.70	5.88	-0.18	-3.1%
NP-MC-AiLiNa-1	MnO		0.82	0.89	-0.07	
NP-MC-AiLiNa-1	Na <sub>2</sub> O		15.70	15.14	0.56	3.7%
NP-MC-AiLiNa-1	NiO	<	0.13	0.00	0.13	
NP-MC-AiLiNa-1	P <sub>2</sub> O <sub>5</sub>		0.58	0.62	-0.04	
NP-MC-AiLiNa-1	RuO <sub>2</sub>	<	0.13	0.04	0.09	
NP-MC-AiLiNa-1	SiO <sub>2</sub>		26.47	26.00	0.47	1.8%
NP-MC-AiLiNa-1	SO <sub>3</sub>		0.24	0.22	0.02	
NP-MC-AiLiNa-1	ZrO <sub>2</sub>		0.21	0.22	-0.01	
NP-MC-AiLiNa-1	Sum		100.18	99.73	0.45	0.5%
NP-MC-AiLiSi-1	Al <sub>2</sub> O <sub>3</sub>		25.08	25.50	-0.42	-1.6%
NP-MC-AiLiSi-1	B <sub>2</sub> O <sub>3</sub>		20.64	20.60	0.04	0.2%
NP-MC-AiLiSi-1	Bi <sub>2</sub> O <sub>3</sub>		0.72	0.78	-0.06	
NP-MC-AiLiSi-1	CaO		0.63	0.78	-0.15	
NP-MC-AiLiSi-1	Cr <sub>2</sub> O <sub>3</sub>		1.30	1.32	-0.02	
NP-MC-AiLiSi-1	Fe <sub>2</sub> O <sub>3</sub>		3.02	2.99	0.03	
NP-MC-AiLiSi-1	Li <sub>2</sub> O		3.85	4.00	-0.15	
NP-MC-AiLiSi-1	MnO		1.21	1.20	0.01	
NP-MC-AiLiSi-1	Na <sub>2</sub> O		15.91	14.97	0.94	6.3%
NP-MC-AiLiSi-1	NiO	<	0.13	0.00	0.13	
NP-MC-AiLiSi-1	P <sub>2</sub> O <sub>5</sub>		0.79	0.84	-0.05	
NP-MC-AiLiSi-1	RuO <sub>2</sub>	<	0.13	0.06	0.07	
NP-MC-AiLiSi-1	SiO <sub>2</sub>		26.21	26.00	0.21	0.8%
NP-MC-AiLiSi-1	SO <sub>3</sub>		0.30	0.30	0.00	
NP-MC-AiLiSi-1	ZrO <sub>2</sub>		0.29	0.30	-0.01	
NP-MC-AiLiSi-1	Sum		100.21	99.64	0.57	0.6%
NP-MC-AiNa-1	Al <sub>2</sub> O <sub>3</sub>		24.94	25.50	-0.56	-2.2%
NP-MC-AiNa-1	B <sub>2</sub> O <sub>3</sub>		16.58	17.20	-0.62	-3.6%
NP-MC-AiNa-1	Bi <sub>2</sub> O <sub>3</sub>		0.60	0.65	-0.05	
NP-MC-AiNa-1	CaO		0.53	0.65	-0.12	
NP-MC-AiNa-1	Cr <sub>2</sub> O <sub>3</sub>		0.99	1.10	-0.11	
NP-MC-AiNa-1	Fe <sub>2</sub> O <sub>3</sub>		2.49	2.50	-0.01	
NP-MC-AiNa-1	Li <sub>2</sub> O		4.88	5.00	-0.12	-2.4%
NP-MC-AiNa-1	MnO		0.92	1.00	-0.08	
NP-MC-AiNa-1	Na <sub>2</sub> O		16.01	15.50	0.51	3.3%
NP-MC-AiNa-1	NiO	<	0.13	0.00	0.13	
NP-MC-AiNa-1	P <sub>2</sub> O <sub>5</sub>		0.66	0.70	-0.04	
NP-MC-AiNa-1	RuO <sub>2</sub>	<	0.13	0.05	0.08	
NP-MC-AiNa-1	SiO <sub>2</sub>		29.36	29.35	0.01	0.04%
NP-MC-AiNa-1	SO <sub>3</sub>		0.25	0.25	0.00	
NP-MC-AiNa-1	ZrO <sub>2</sub>		0.25	0.25	0.00	
NP-MC-AiNa-1	Sum		98.73	99.70	-0.97	-1.0%
NP-MC-AiSi-1	Al <sub>2</sub> O <sub>3</sub>		25.04	25.50	-0.46	-1.8%
NP-MC-AiSi-1	B <sub>2</sub> O <sub>3</sub>		19.62	19.79	-0.17	-0.9%
NP-MC-AiSi-1	Bi <sub>2</sub> O <sub>3</sub>		0.69	0.75	-0.06	
NP-MC-AiSi-1	CaO		0.68	0.75	-0.07	
NP-MC-AiSi-1	Cr <sub>2</sub> O <sub>3</sub>		1.16	1.27	-0.11	

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

Glass ID	Oxide	BDL ( $<$ )	Measured (wt%)	Targeted (wt%)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
NP-MC-ALiSi-1	Fe <sub>2</sub> O <sub>3</sub>		2.93	2.88	0.05	
NP-MC-ALiSi-1	Li <sub>2</sub> O		5.58	5.75	-0.17	-3.0%
NP-MC-ALiSi-1	MnO		1.07	1.15	-0.08	
NP-MC-ALiSi-1	Na <sub>2</sub> O		15.43	14.38	1.05	7.3%
NP-MC-ALiSi-1	NiO	$<$	0.13	0.00	0.13	
NP-MC-ALiSi-1	P <sub>2</sub> O <sub>5</sub>		0.77	0.81	-0.04	
NP-MC-ALiSi-1	RuO <sub>2</sub>	$<$	0.13	0.06	0.07	
NP-MC-ALiSi-1	SiO <sub>2</sub>		26.53	26.00	0.53	2.0%
NP-MC-ALiSi-1	SO <sub>3</sub>		0.31	0.29	0.02	
NP-MC-ALiSi-1	ZrO <sub>2</sub>		0.31	0.29	0.02	
NP-MC-ALiSi-1	Sum		100.36	99.67	0.69	0.7%
NP-MC-ALiSi-2	Al <sub>2</sub> O <sub>3</sub>		31.08	31.50	-0.42	-1.3%
NP-MC-ALiSi-2	B <sub>2</sub> O <sub>3</sub>		14.29	14.49	-0.20	-1.4%
NP-MC-ALiSi-2	Bi <sub>2</sub> O <sub>3</sub>		0.50	0.55	-0.05	
NP-MC-ALiSi-2	CaO		0.54	0.55	-0.01	
NP-MC-ALiSi-2	Cr <sub>2</sub> O <sub>3</sub>		0.84	0.93	-0.09	
NP-MC-ALiSi-2	Fe <sub>2</sub> O <sub>3</sub>		2.08	2.11	-0.03	
NP-MC-ALiSi-2	Li <sub>2</sub> O		4.00	4.21	-0.21	
NP-MC-ALiSi-2	MnO		0.76	0.84	-0.08	
NP-MC-ALiSi-2	Na <sub>2</sub> O		11.23	10.53	0.70	6.6%
NP-MC-ALiSi-2	NiO	$<$	0.13	0.00	0.13	
NP-MC-ALiSi-2	P <sub>2</sub> O <sub>5</sub>		0.55	0.59	-0.04	
NP-MC-ALiSi-2	RuO <sub>2</sub>	$<$	0.13	0.04	0.09	
NP-MC-ALiSi-2	SiO <sub>2</sub>		33.32	33.00	0.32	1.0%
NP-MC-ALiSi-2	SO <sub>3</sub>		0.16	0.21	-0.05	
NP-MC-ALiSi-2	ZrO <sub>2</sub>		0.20	0.21	-0.01	
NP-MC-ALiSi-2	Sum		99.81	99.76	0.05	0.05%
NP-MC-BLiSi-1	Al <sub>2</sub> O <sub>3</sub>		27.40	27.65	-0.25	-0.9%
NP-MC-BLiSi-1	B <sub>2</sub> O <sub>3</sub>		14.00	14.00	0.00	-0.01%
NP-MC-BLiSi-1	Bi <sub>2</sub> O <sub>3</sub>		0.58	0.63	-0.05	
NP-MC-BLiSi-1	CaO		0.51	0.63	-0.12	
NP-MC-BLiSi-1	Cr <sub>2</sub> O <sub>3</sub>		0.97	1.07	-0.10	
NP-MC-BLiSi-1	Fe <sub>2</sub> O <sub>3</sub>		2.41	2.43	-0.02	
NP-MC-BLiSi-1	Li <sub>2</sub> O		5.76	6.00	-0.24	-3.9%
NP-MC-BLiSi-1	MnO		0.90	0.97	-0.07	
NP-MC-BLiSi-1	Na <sub>2</sub> O		12.98	12.13	0.85	7.0%
NP-MC-BLiSi-1	NiO	$<$	0.13	0.00	0.13	
NP-MC-BLiSi-1	P <sub>2</sub> O <sub>5</sub>		0.64	0.68	-0.04	
NP-MC-BLiSi-1	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP-MC-BLiSi-1	SiO <sub>2</sub>		33.59	33.00	0.59	1.8%
NP-MC-BLiSi-1	SO <sub>3</sub>		0.21	0.24	-0.03	
NP-MC-BLiSi-1	ZrO <sub>2</sub>		0.23	0.24	-0.01	
NP-MC-BLiSi-1	Sum		100.44	99.72	0.72	0.7%
NP-MC-BLiSi-2	Al <sub>2</sub> O <sub>3</sub>		26.74	27.06	-0.32	-1.2%
NP-MC-BLiSi-2	B <sub>2</sub> O <sub>3</sub>		21.90	22.00	-0.10	-0.5%
NP-MC-BLiSi-2	Bi <sub>2</sub> O <sub>3</sub>		0.57	0.62	-0.05	
NP-MC-BLiSi-2	CaO		0.51	0.62	-0.11	
NP-MC-BLiSi-2	Cr <sub>2</sub> O <sub>3</sub>		0.98	1.04	-0.06	
NP-MC-BLiSi-2	Fe <sub>2</sub> O <sub>3</sub>		2.32	2.37	-0.05	
NP-MC-BLiSi-2	Li <sub>2</sub> O		5.44	6.00	-0.56	-9.3%
NP-MC-BLiSi-2	MnO		0.89	0.95	-0.06	
NP-MC-BLiSi-2	Na <sub>2</sub> O		12.11	11.87	0.24	2.0%
NP-MC-BLiSi-2	NiO	$<$	0.13	0.00	0.13	
NP-MC-BLiSi-2	P <sub>2</sub> O <sub>5</sub>		0.62	0.66	-0.04	
NP-MC-BLiSi-2	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP-MC-BLiSi-2	SiO <sub>2</sub>		26.42	26.00	0.42	1.6%
NP-MC-BLiSi-2	SO <sub>3</sub>		0.24	0.24	0.00	
NP-MC-BLiSi-2	ZrO <sub>2</sub>		0.24	0.24	0.00	



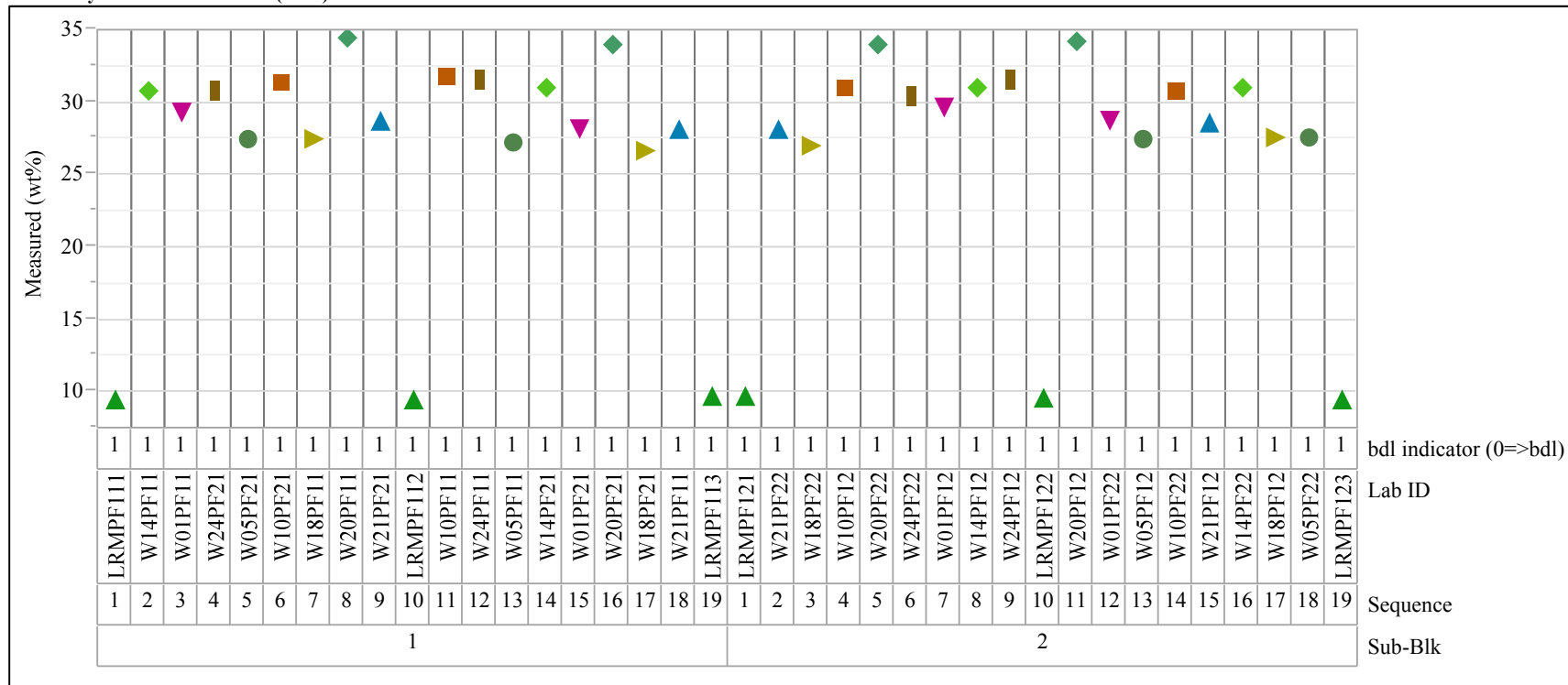
**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

Glass ID	Oxide	BDL ( $<$ )	Measured (wt%)	Targeted (wt%)	Difference of Measured versus Targeted	% Difference of Measured versus Targeted
NP-MC-BLiSi-2	Sum		99.24	99.72	-0.48	-0.5%
NP-MC-BNa-1	Al <sub>2</sub> O <sub>3</sub>		28.30	28.58	-0.28	-1.0%
NP-MC-BNa-1	B <sub>2</sub> O <sub>3</sub>		13.87	14.00	-0.13	-0.9%
NP-MC-BNa-1	Bi <sub>2</sub> O <sub>3</sub>		0.59	0.65	-0.06	
NP-MC-BNa-1	CaO		0.60	0.65	-0.05	
NP-MC-BNa-1	Cr <sub>2</sub> O <sub>3</sub>		0.99	1.10	-0.11	
NP-MC-BNa-1	Fe <sub>2</sub> O <sub>3</sub>		2.52	2.51	0.01	
NP-MC-BNa-1	Li <sub>2</sub> O		4.84	5.01	-0.17	-3.4%
NP-MC-BNa-1	MnO		0.92	1.00	-0.08	
NP-MC-BNa-1	Na <sub>2</sub> O		16.38	15.50	0.88	5.7%
NP-MC-BNa-1	NiO	$<$	0.13	0.00	0.13	
NP-MC-BNa-1	P <sub>2</sub> O <sub>5</sub>		0.66	0.70	-0.04	
NP-MC-BNa-1	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP-MC-BNa-1	SiO <sub>2</sub>		30.00	29.43	0.57	1.9%
NP-MC-BNa-1	SO <sub>3</sub>		0.26	0.25	0.01	
NP-MC-BNa-1	ZrO <sub>2</sub>		0.25	0.25	0.00	
NP-MC-BNa-1	Sum		100.45	99.68	0.77	0.8%
NP-MC-BNaSi-1	Al <sub>2</sub> O <sub>3</sub>		30.66	30.97	-0.31	-1.0%
NP-MC-BNaSi-1	B <sub>2</sub> O <sub>3</sub>		14.21	14.00	0.21	1.5%
NP-MC-BNaSi-1	Bi <sub>2</sub> O <sub>3</sub>		0.65	0.71	-0.06	
NP-MC-BNaSi-1	CaO		0.66	0.71	-0.05	
NP-MC-BNaSi-1	Cr <sub>2</sub> O <sub>3</sub>		1.17	1.20	-0.03	
NP-MC-BNaSi-1	Fe <sub>2</sub> O <sub>3</sub>		2.72	2.72	0.00	
NP-MC-BNaSi-1	Li <sub>2</sub> O		5.31	5.43	-0.12	-2.2%
NP-MC-BNaSi-1	MnO		1.07	1.09	-0.02	
NP-MC-BNaSi-1	Na <sub>2</sub> O		16.48	15.50	0.98	6.3%
NP-MC-BNaSi-1	NiO	$<$	0.13	0.00	0.13	
NP-MC-BNaSi-1	P <sub>2</sub> O <sub>5</sub>		0.71	0.76	-0.05	
NP-MC-BNaSi-1	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP-MC-BNaSi-1	SiO <sub>2</sub>		26.37	26.00	0.37	1.4%
NP-MC-BNaSi-1	SO <sub>3</sub>		0.27	0.27	0.00	
NP-MC-BNaSi-1	ZrO <sub>2</sub>		0.26	0.27	-0.01	
NP-MC-BNaSi-1	Sum		100.79	99.68	1.11	1.1%
NP-MC-BSi-1	Al <sub>2</sub> O <sub>3</sub>		25.08	25.50	-0.42	-1.6%
NP-MC-BSi-1	B <sub>2</sub> O <sub>3</sub>		20.27	20.40	-0.13	-0.6%
NP-MC-BSi-1	Bi <sub>2</sub> O <sub>3</sub>		0.53	0.58	-0.05	
NP-MC-BSi-1	CaO		0.47	0.58	-0.11	
NP-MC-BSi-1	Cr <sub>2</sub> O <sub>3</sub>		0.96	0.98	-0.02	
NP-MC-BSi-1	Fe <sub>2</sub> O <sub>3</sub>		2.27	2.24	0.03	
NP-MC-BSi-1	Li <sub>2</sub> O		4.32	4.47	-0.15	
NP-MC-BSi-1	MnO		0.88	0.89	-0.01	
NP-MC-BSi-1	Na <sub>2</sub> O		12.03	11.18	0.85	7.6%
NP-MC-BSi-1	NiO	$<$	0.13	0.00	0.13	
NP-MC-BSi-1	P <sub>2</sub> O <sub>5</sub>		0.59	0.63	-0.04	
NP-MC-BSi-1	RuO <sub>2</sub>	$<$	0.13	0.05	0.08	
NP-MC-BSi-1	SiO <sub>2</sub>		32.30	31.78	0.52	1.6%
NP-MC-BSi-1	SO <sub>3</sub>		0.20	0.22	-0.02	
NP-MC-BSi-1	ZrO <sub>2</sub>		0.21	0.22	-0.01	
NP-MC-BSi-1	Sum		100.37	99.72	0.65	0.6%

## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence

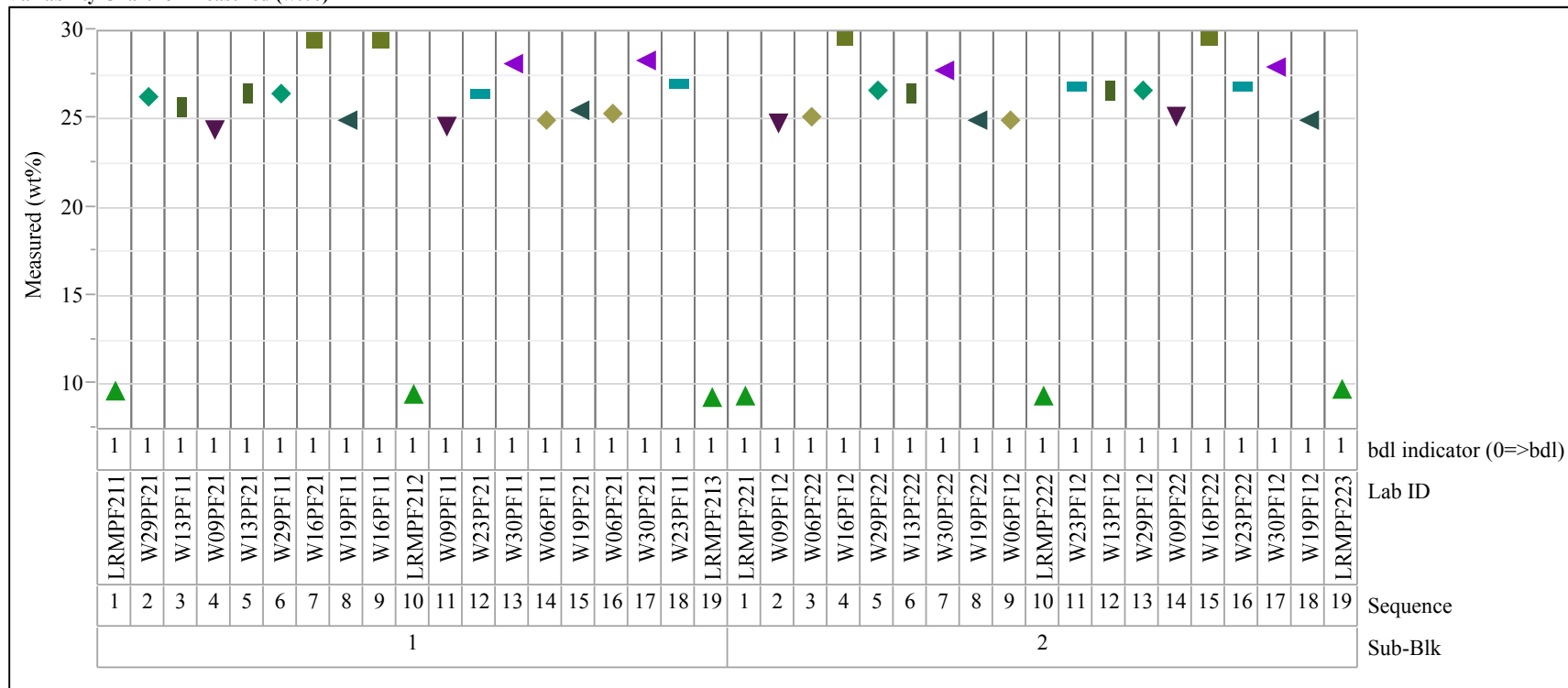
Oxide=Al<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=1

Variability Chart for Measured (wt%)



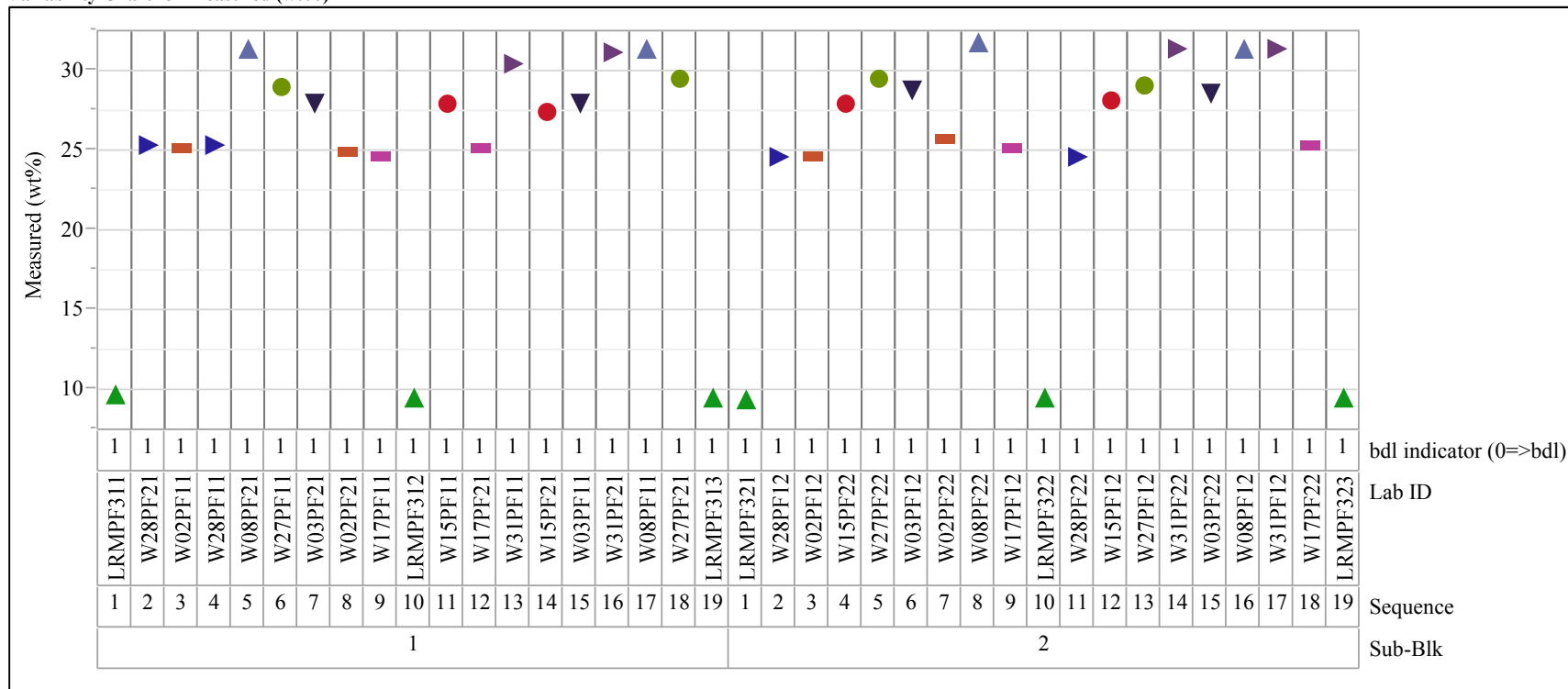
**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Al<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=2

Variability Chart for Measured (wt%)



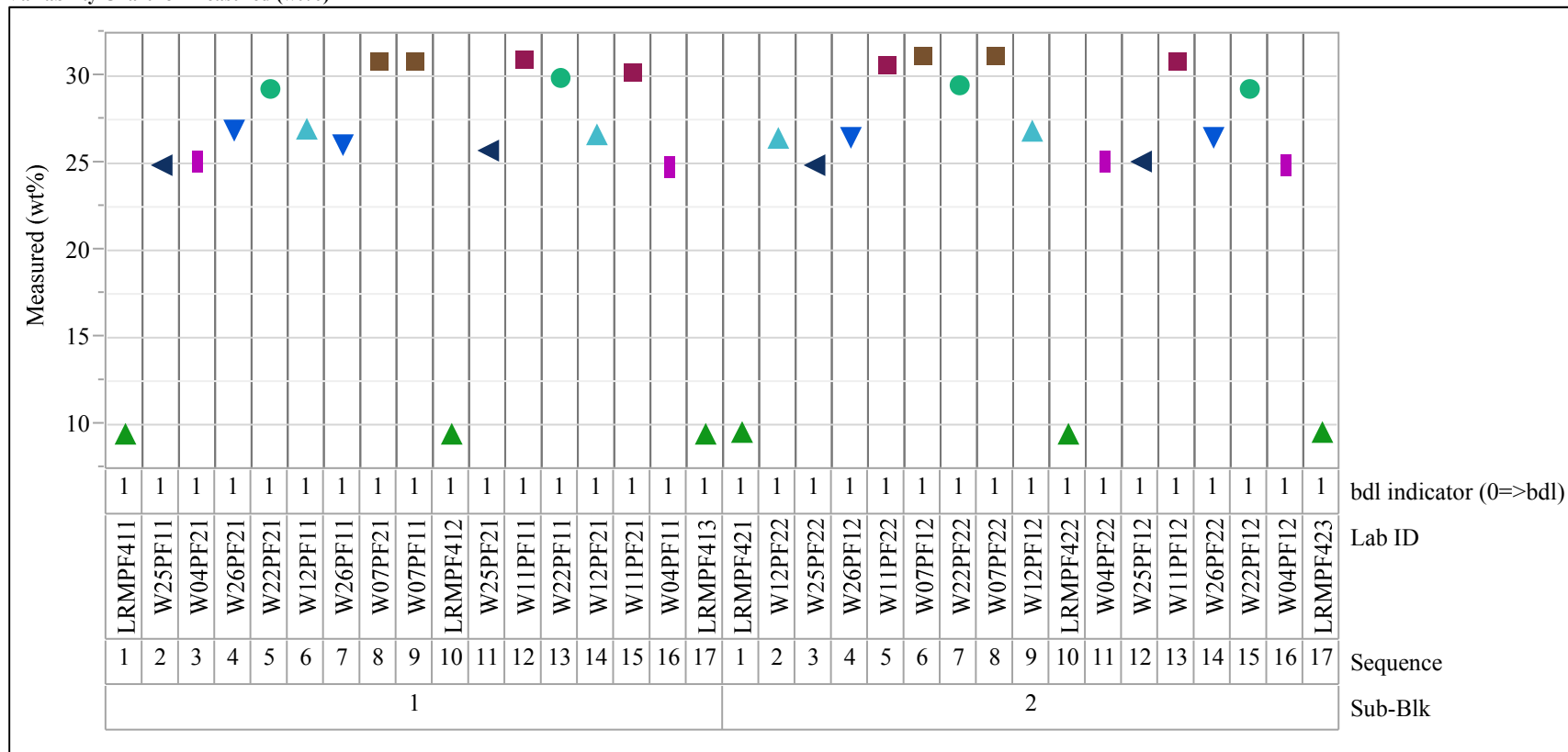
**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Al<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=3

Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Al<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=4

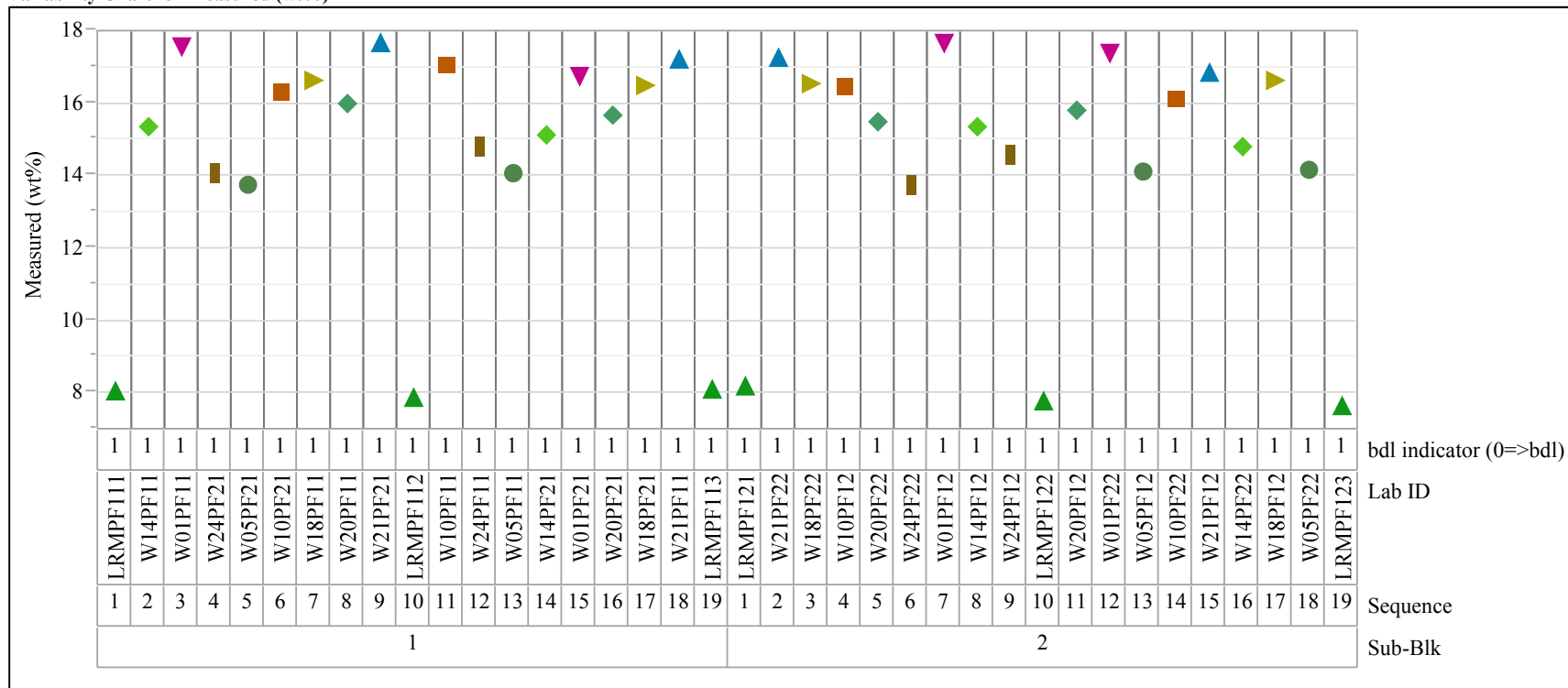
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=B2O3 (wt%), Prep Method=PF, Block=1

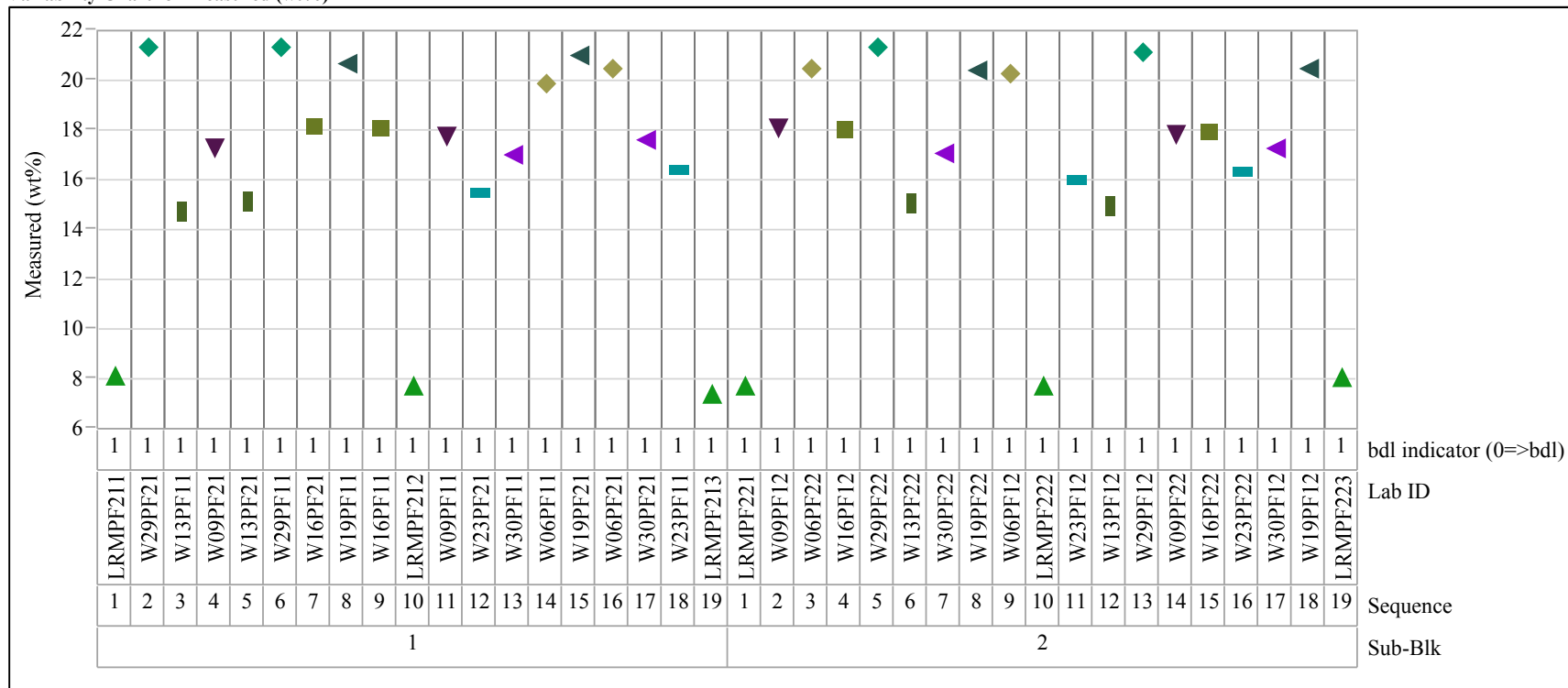
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=B2O3 (wt%), Prep Method=PF, Block=2

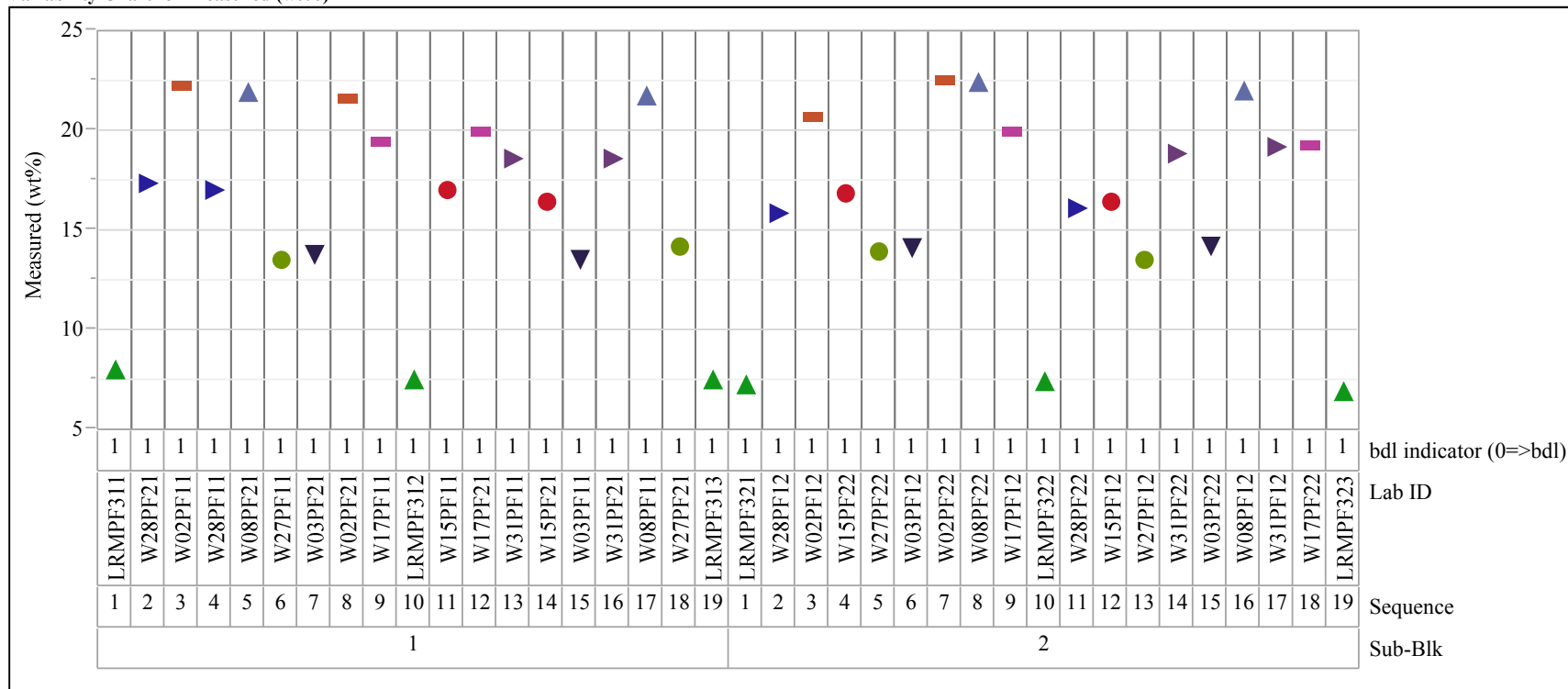
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=B2O3 (wt%), Prep Method=PF, Block=3

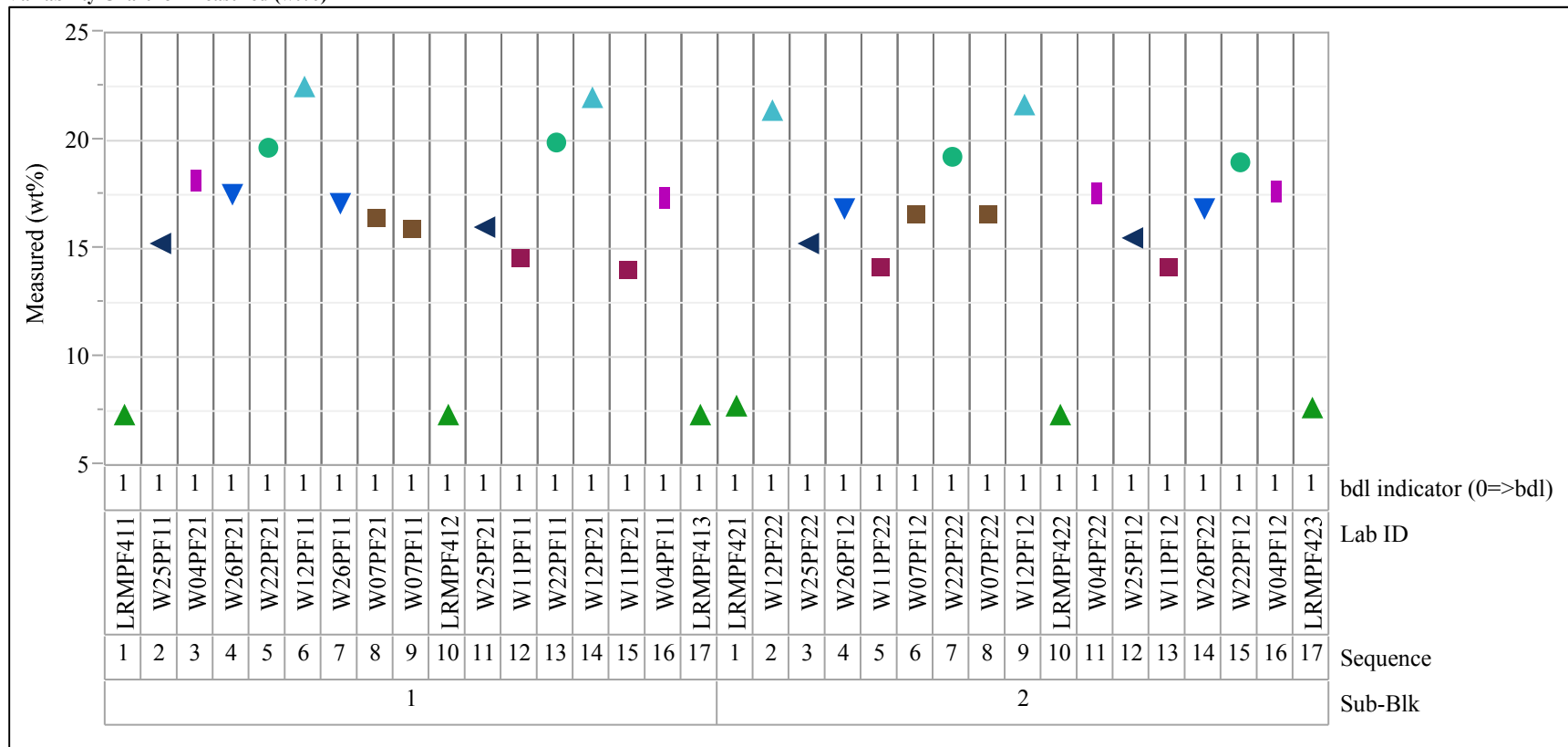
Variability Chart for Measured (wt%)





**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

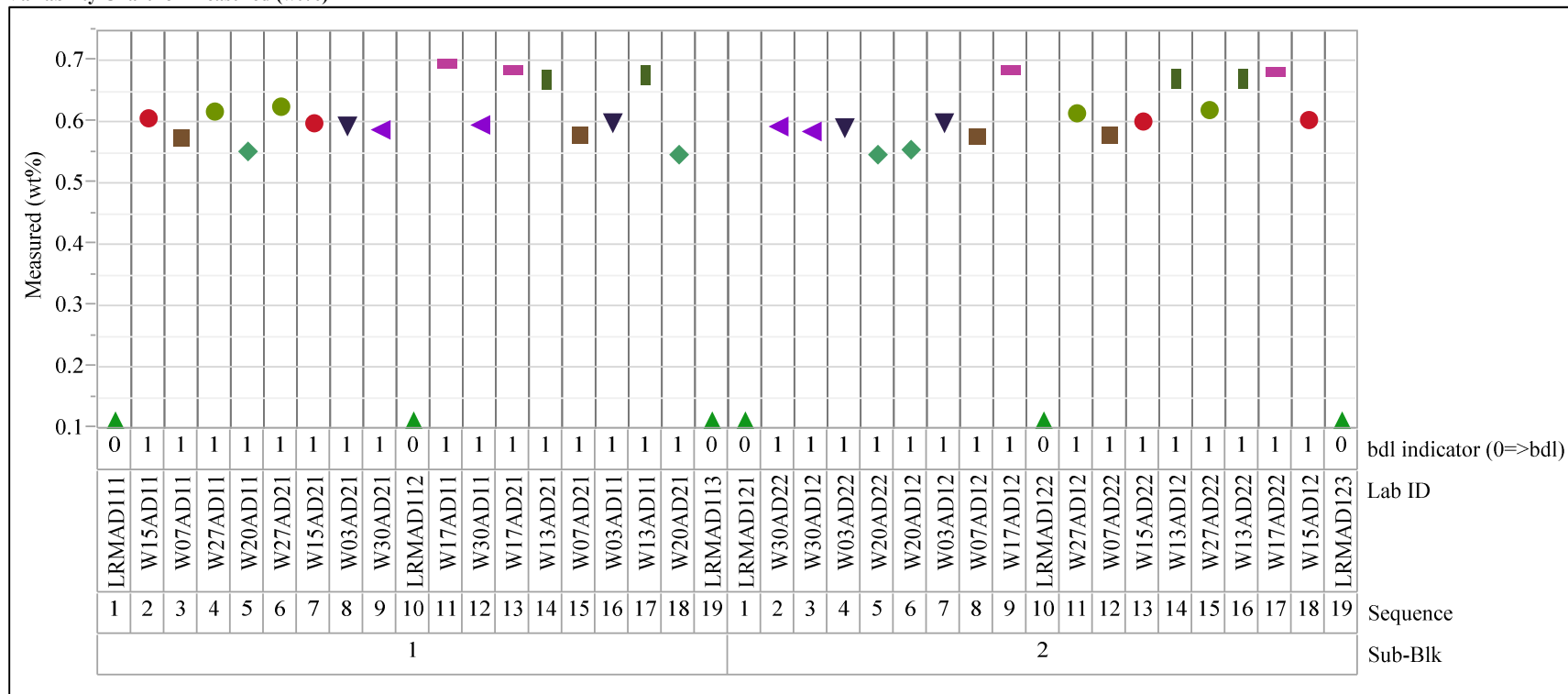
Oxide=B2O3 (wt%), Prep Method=PF, Block=4  
 Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

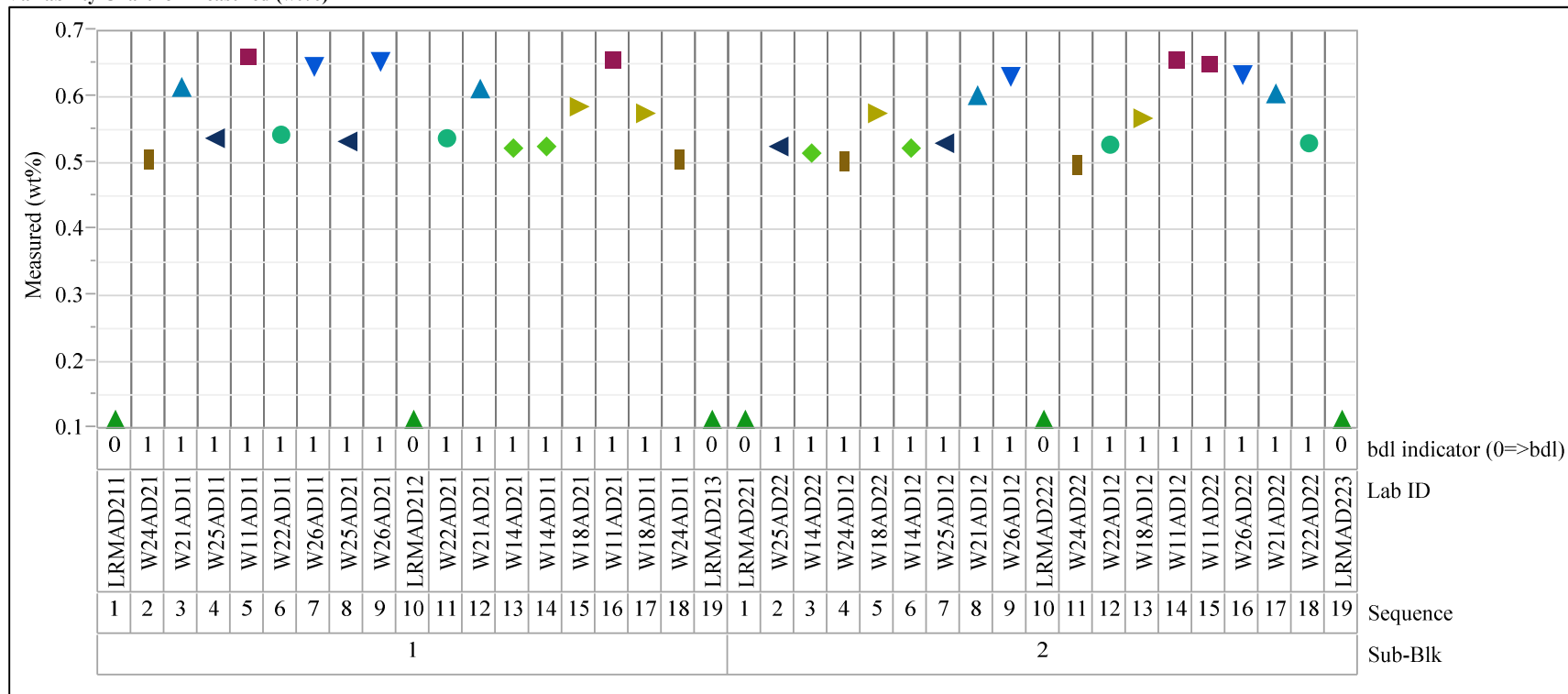
Oxide=Bi<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=AD, Block=1

Variability Chart for Measured (wt%)



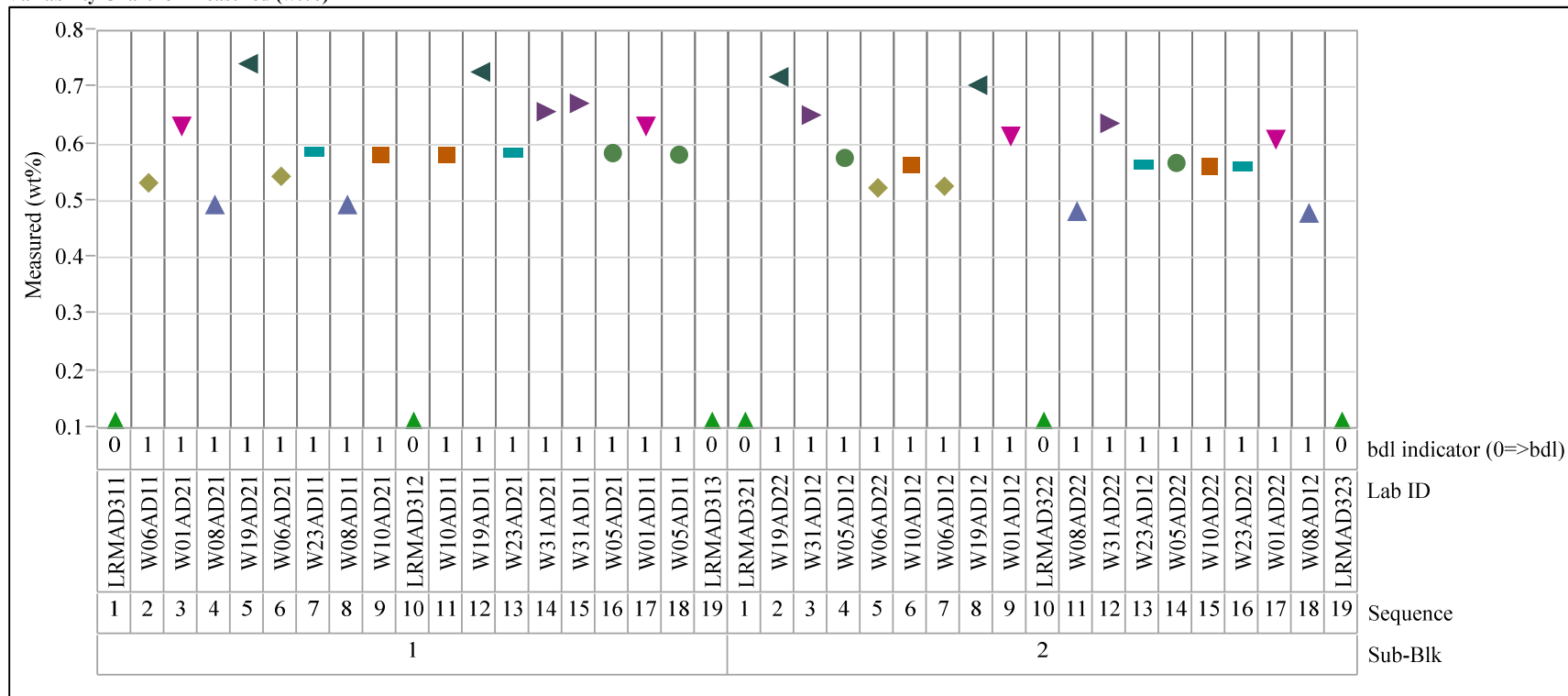
**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Bi<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=AD, Block=2

Variability Chart for Measured (wt%)



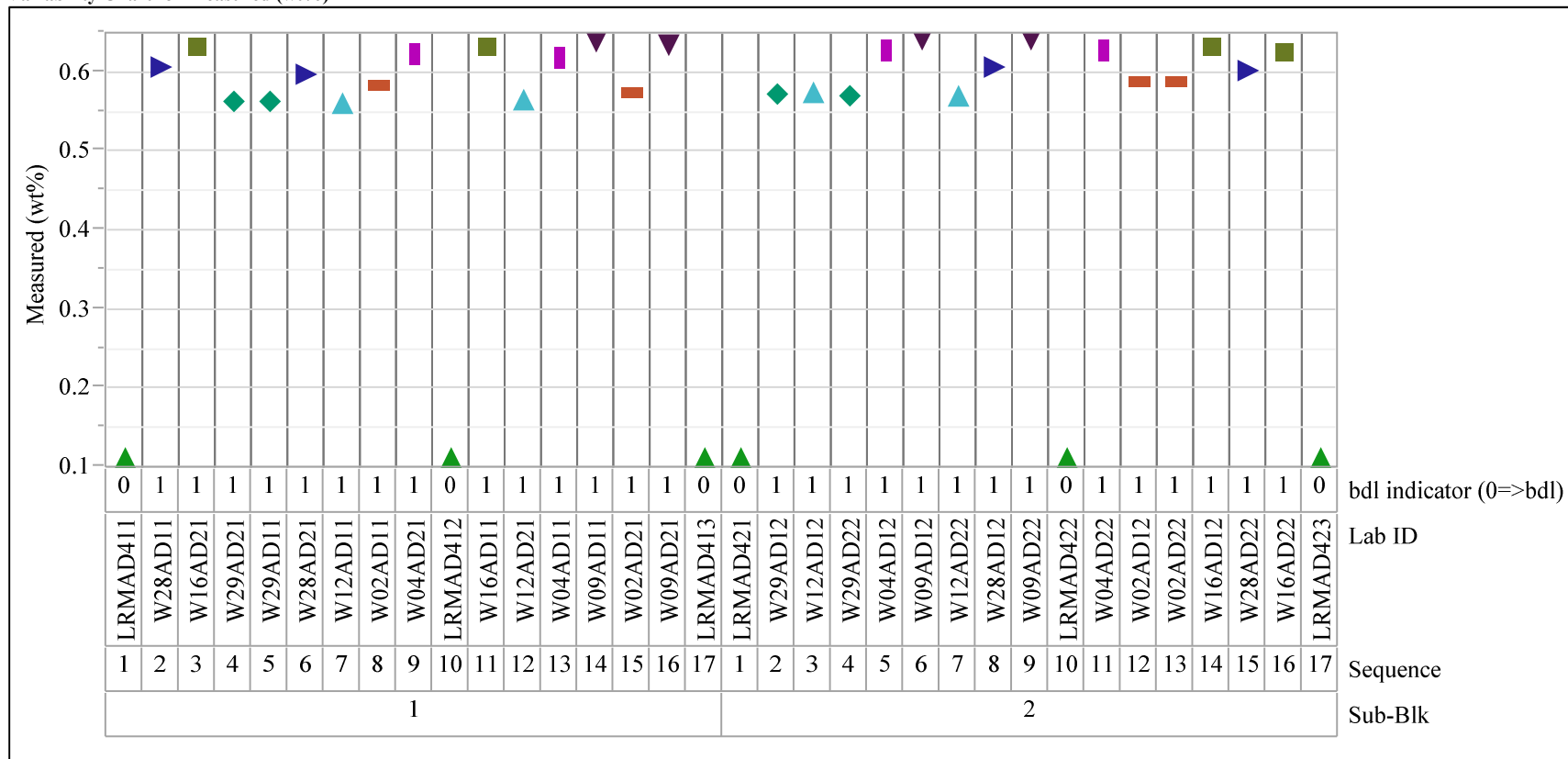
**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Bi<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=AD, Block=3

Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Bi<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=AD, Block=4

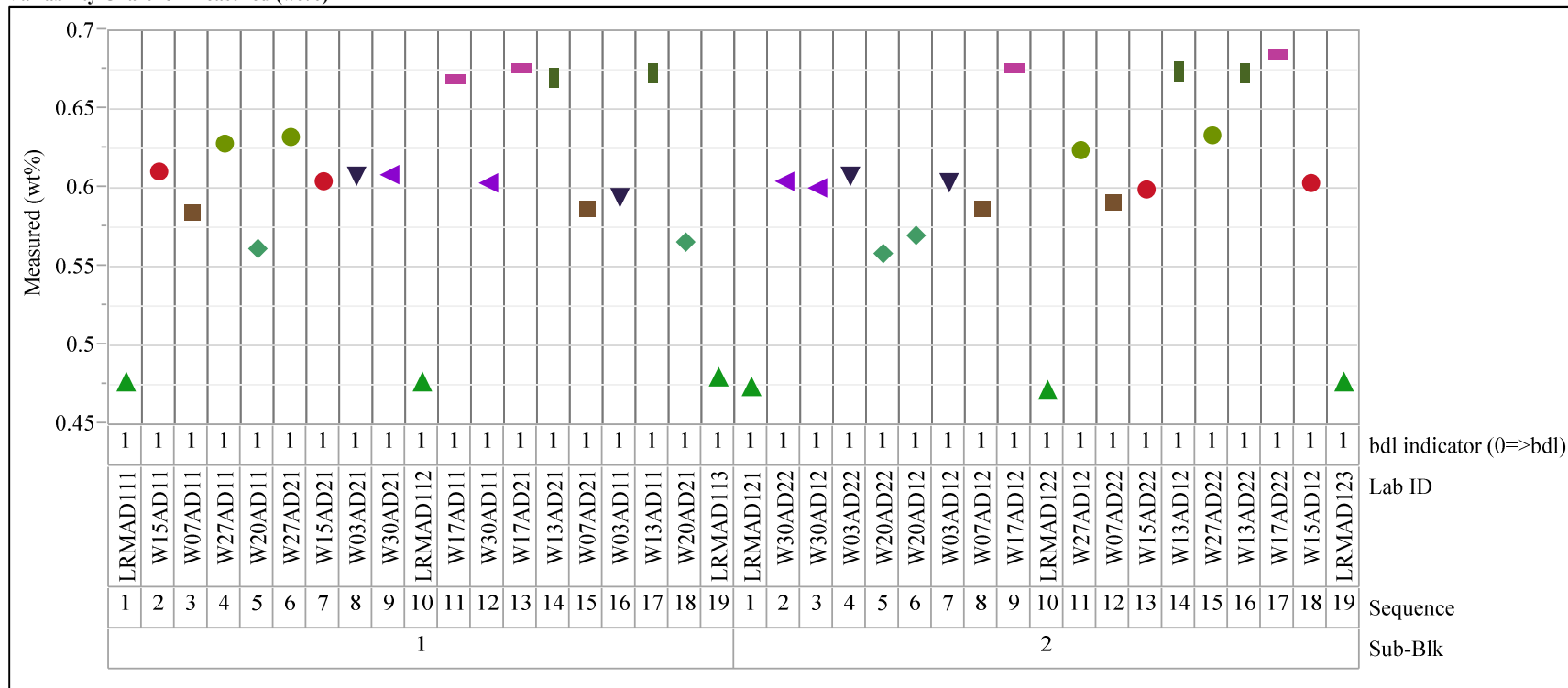
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=CaO (wt%), Prep Method=AD, Block=1

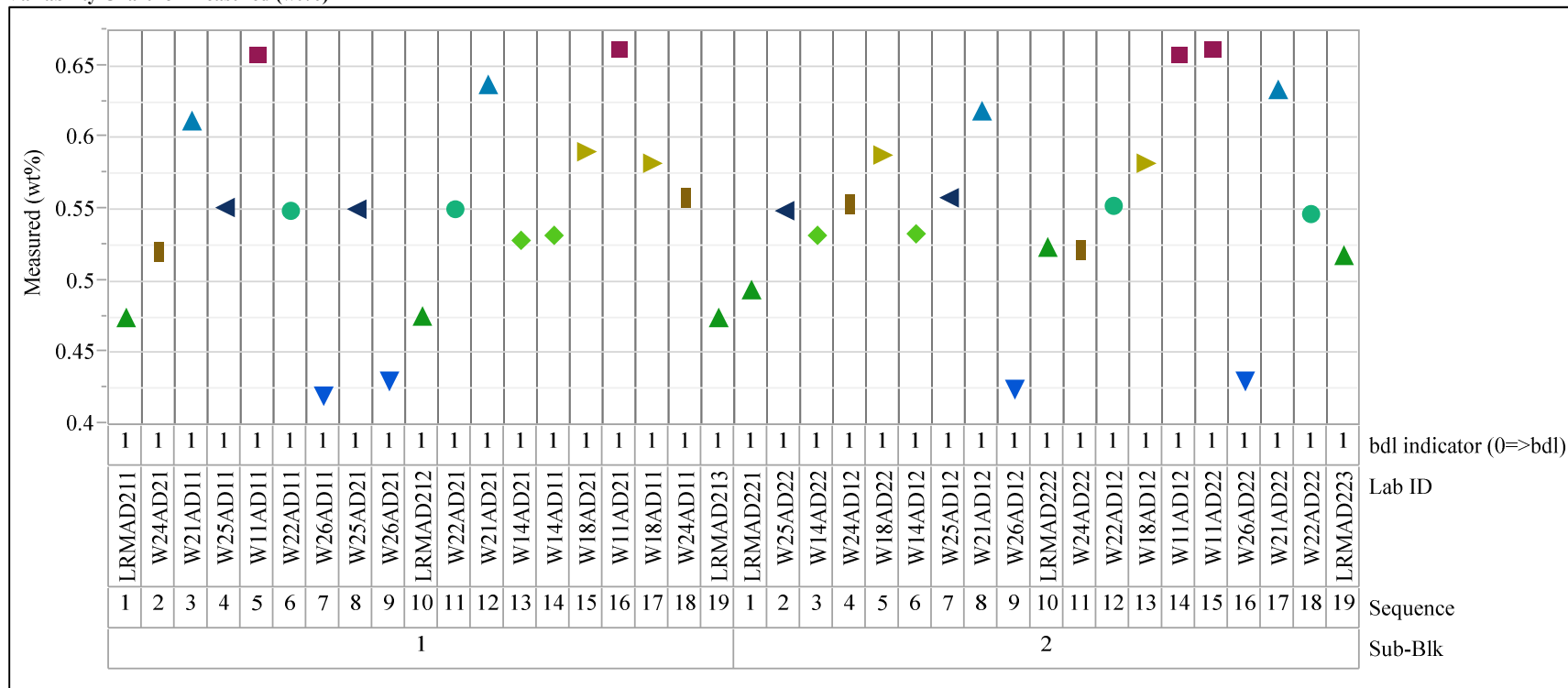
Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=CaO (wt%), Prep Method=AD, Block=2

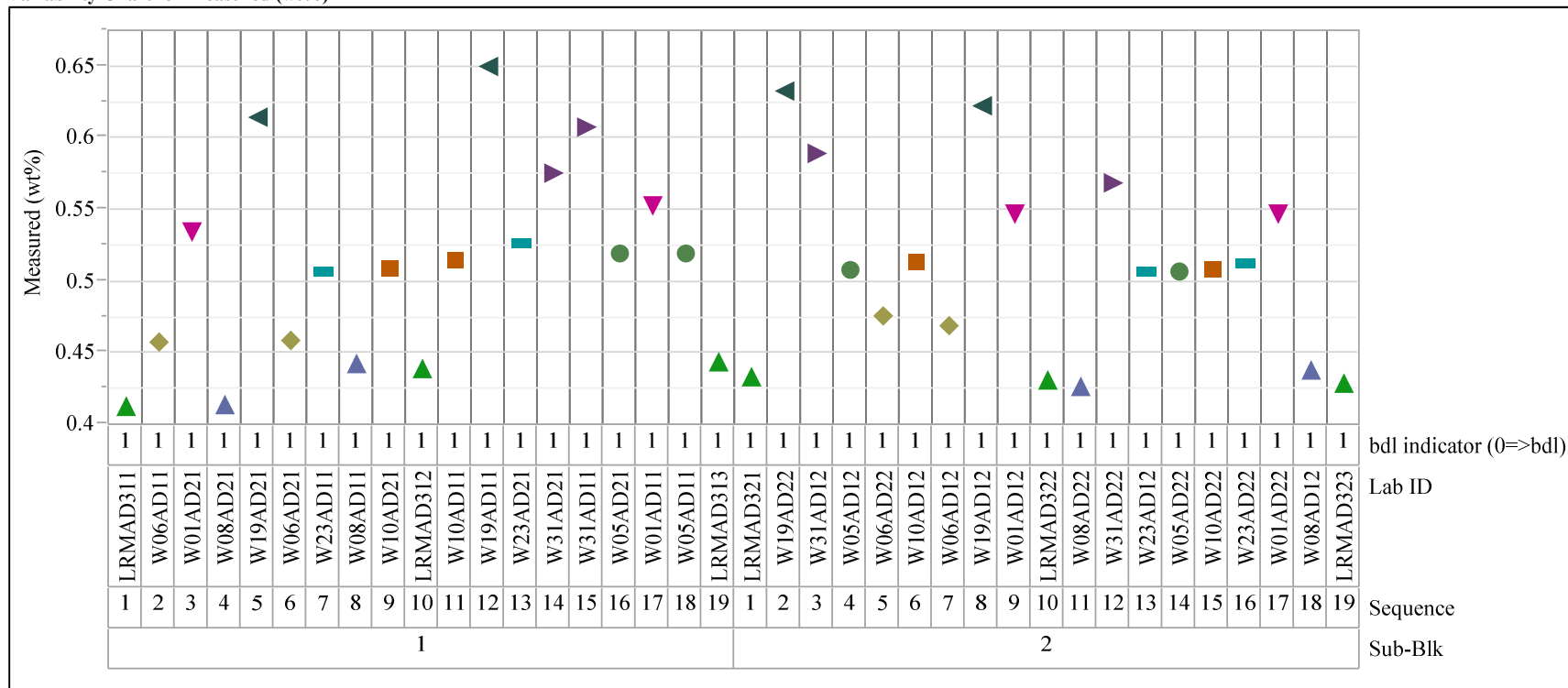
Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=CaO (wt%), Prep Method=AD, Block=3

Variability Chart for Measured (wt%)

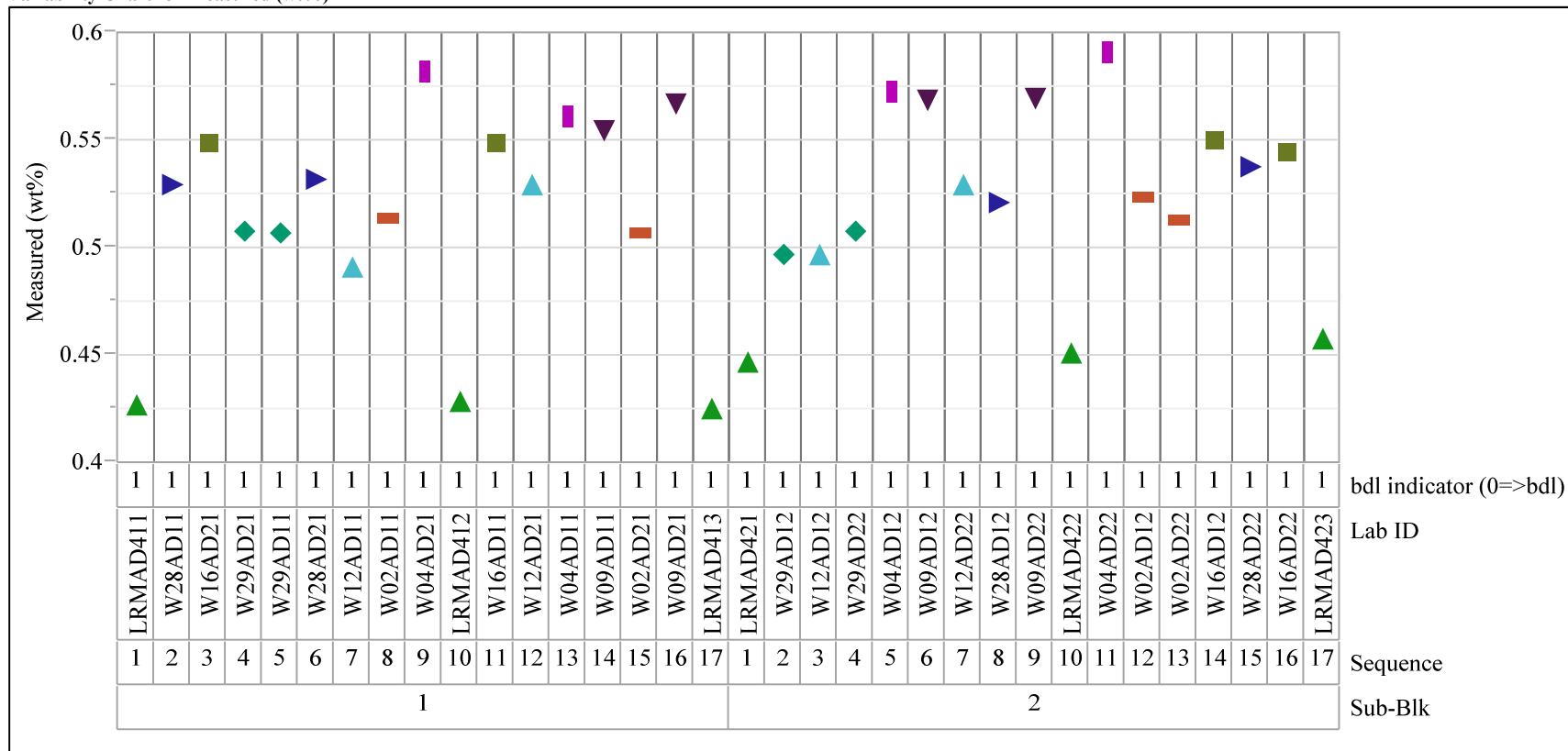




**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=CaO (wt%), Prep Method=AD, Block=4

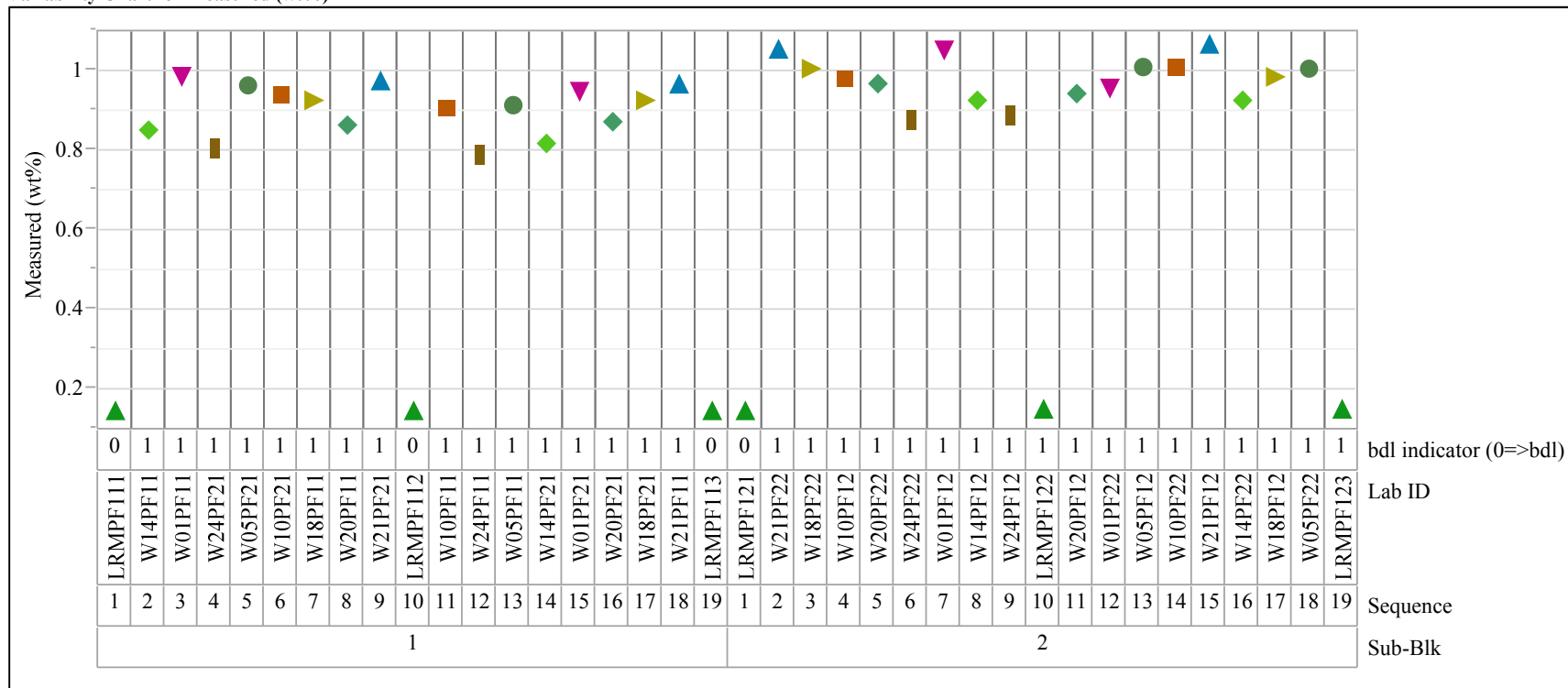
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=Cr2O3 (wt%), Prep Method=PF, Block=1

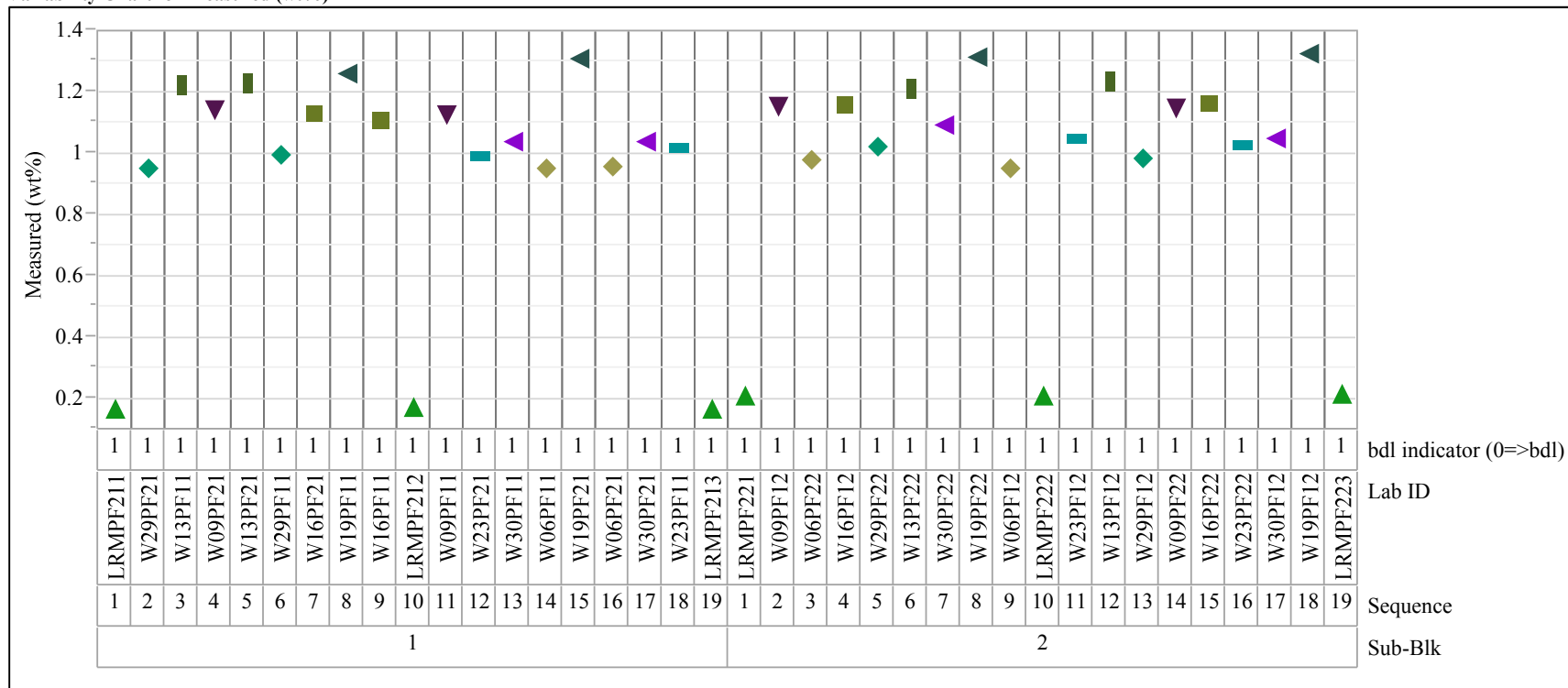
Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=Cr2O3 (wt%), Prep Method=PF, Block=2

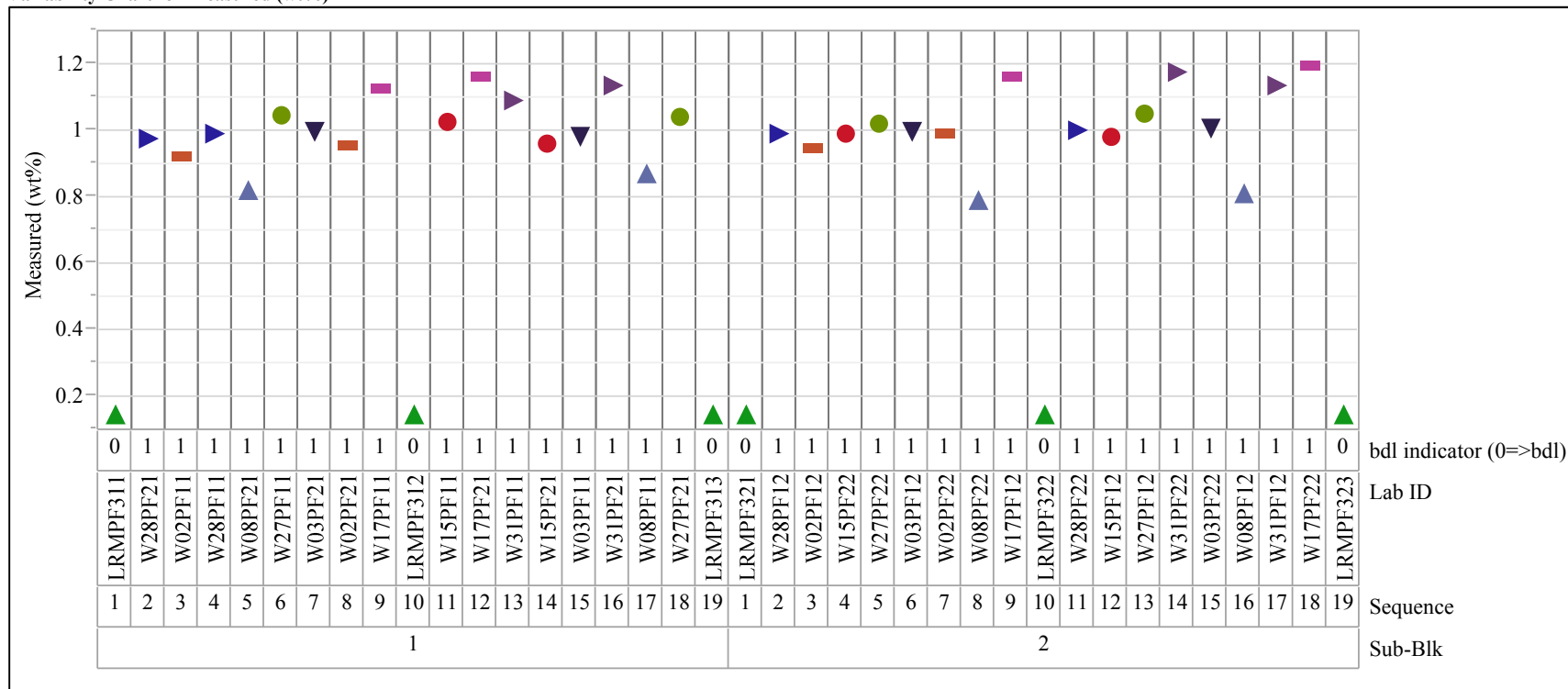
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=Cr2O3 (wt%), Prep Method=PF, Block=3

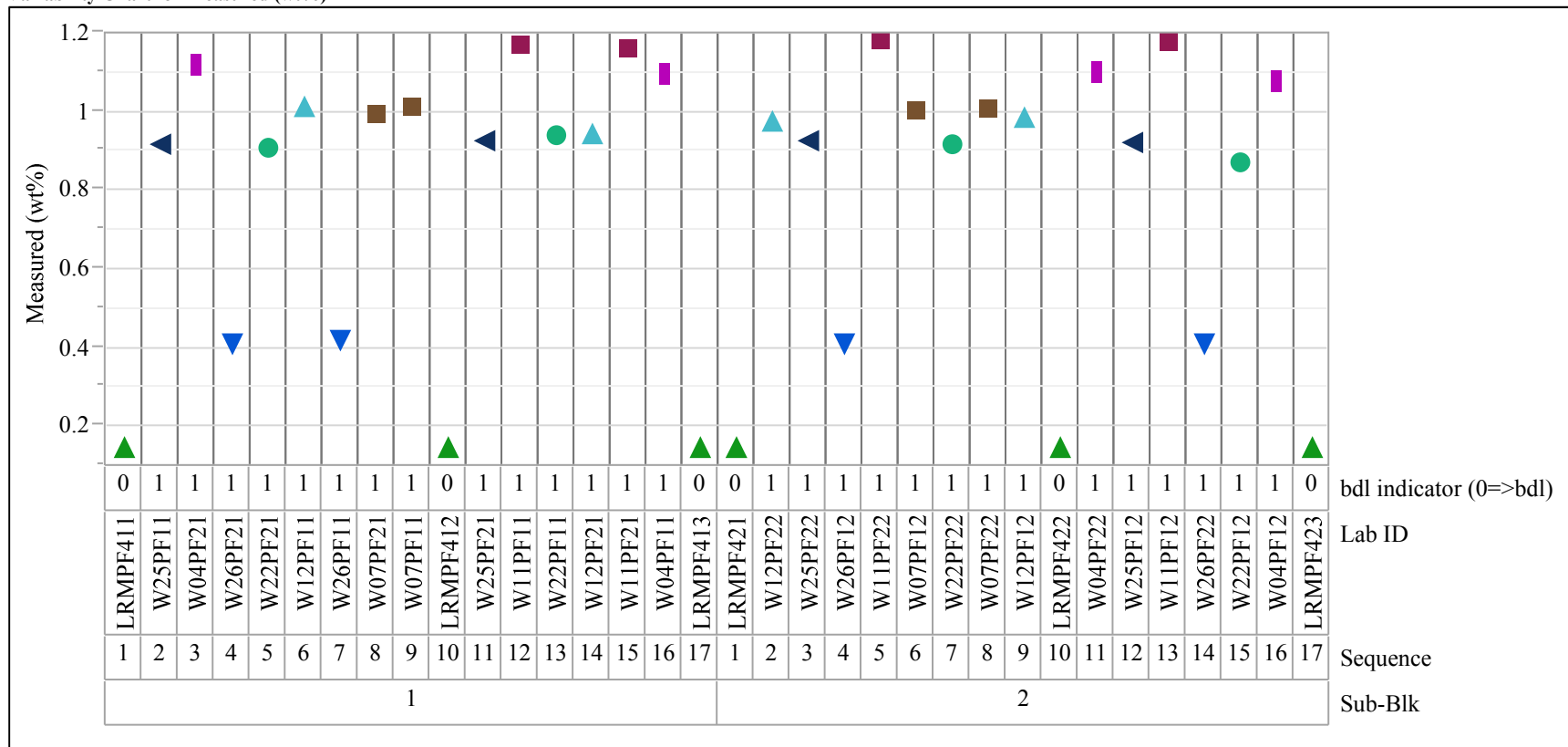
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=Cr2O3 (wt%), Prep Method=PF, Block=4

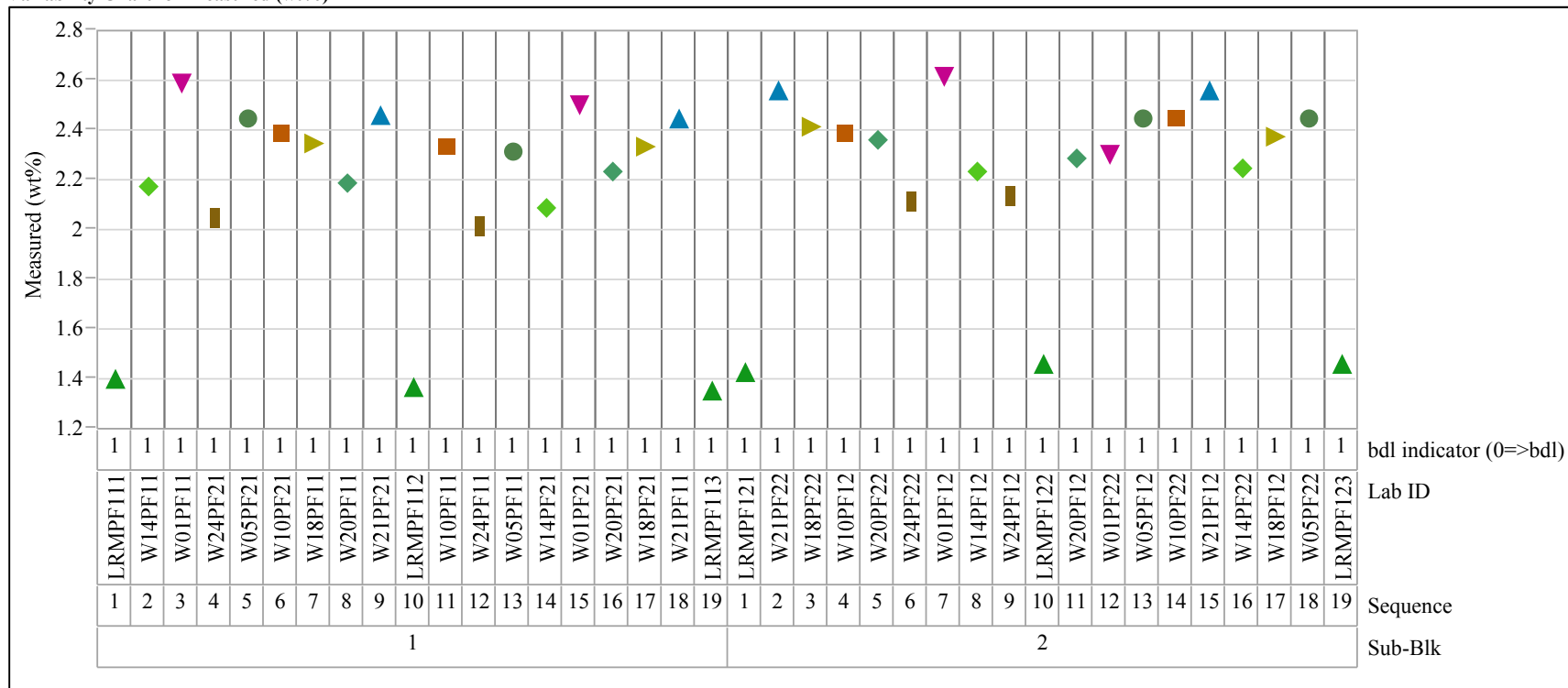
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=Fe<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=1

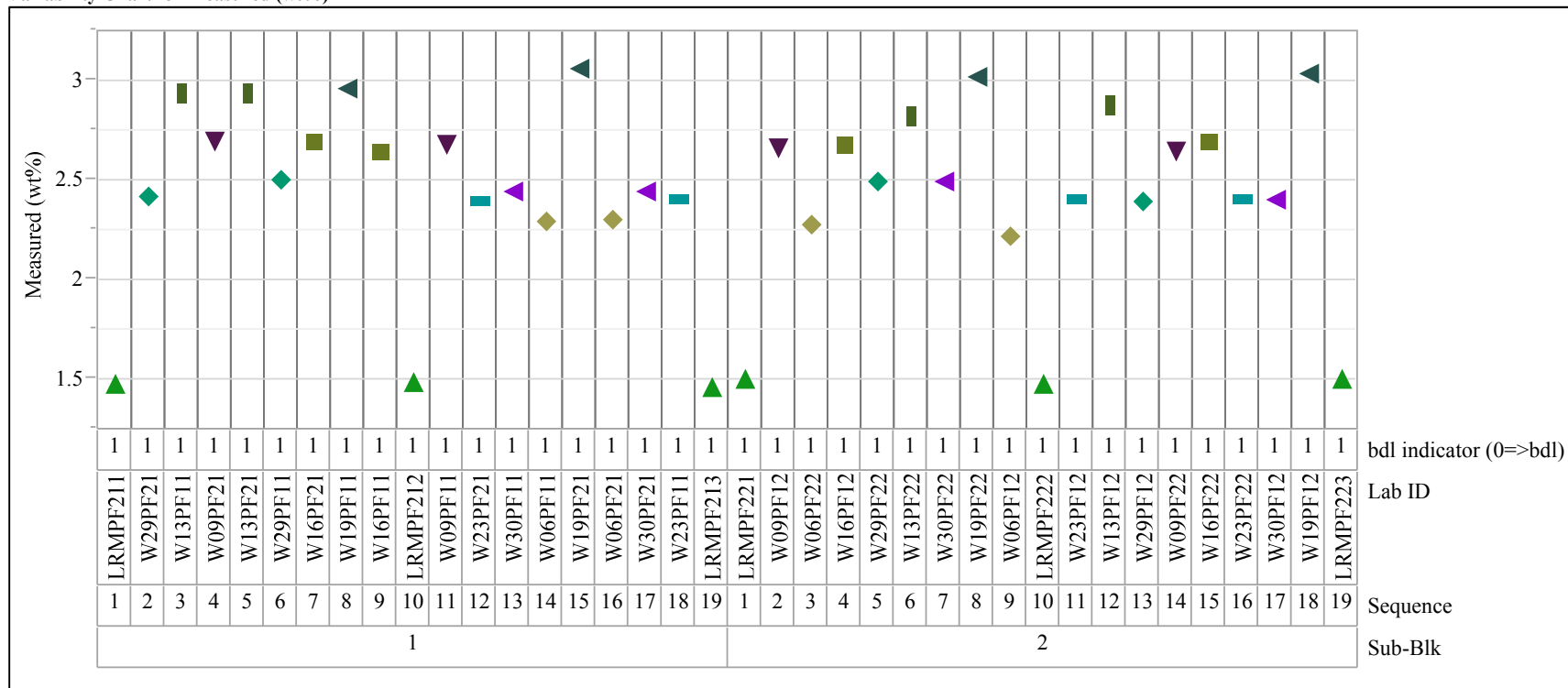
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

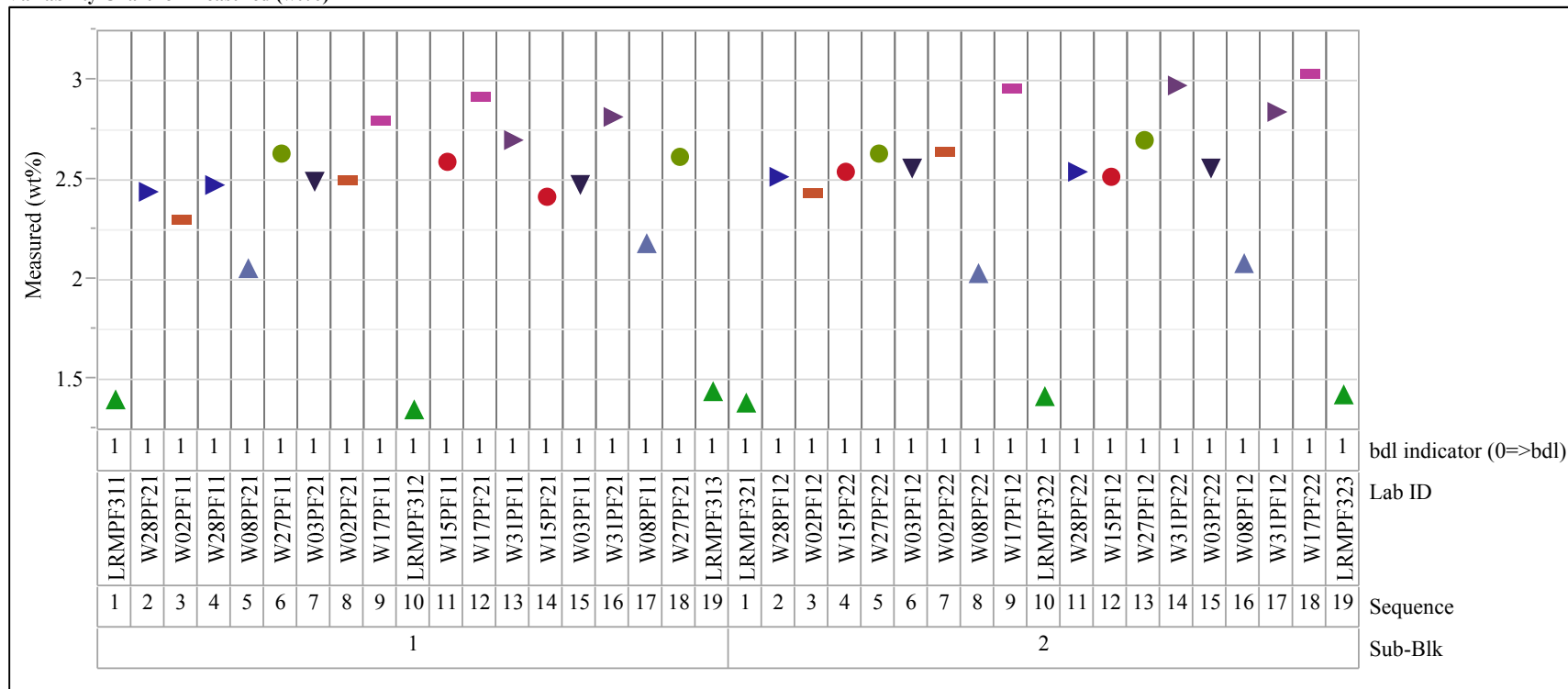
Oxide=Fe<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=2

Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Fe<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=3

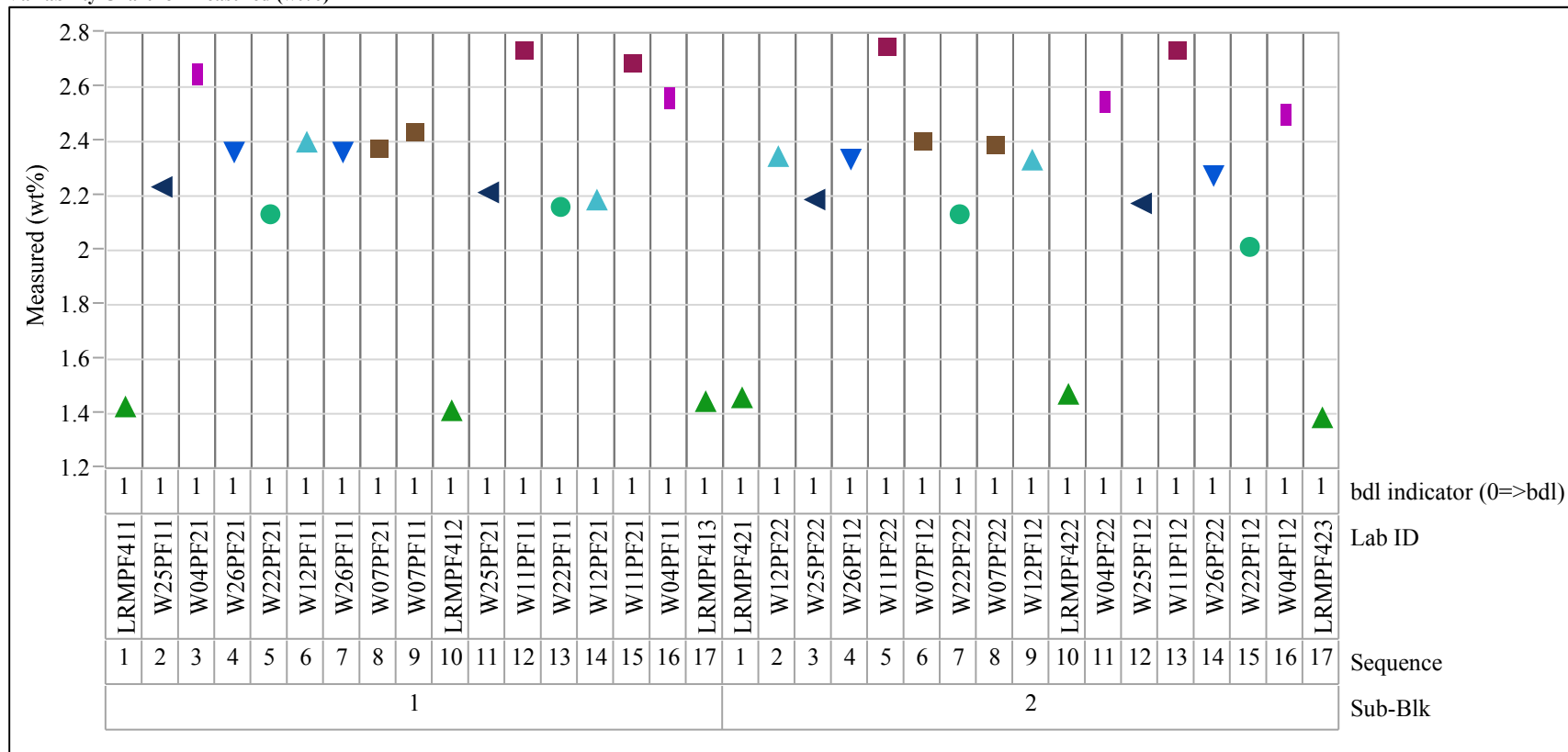
Variability Chart for Measured (wt%)





**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Fe<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=4

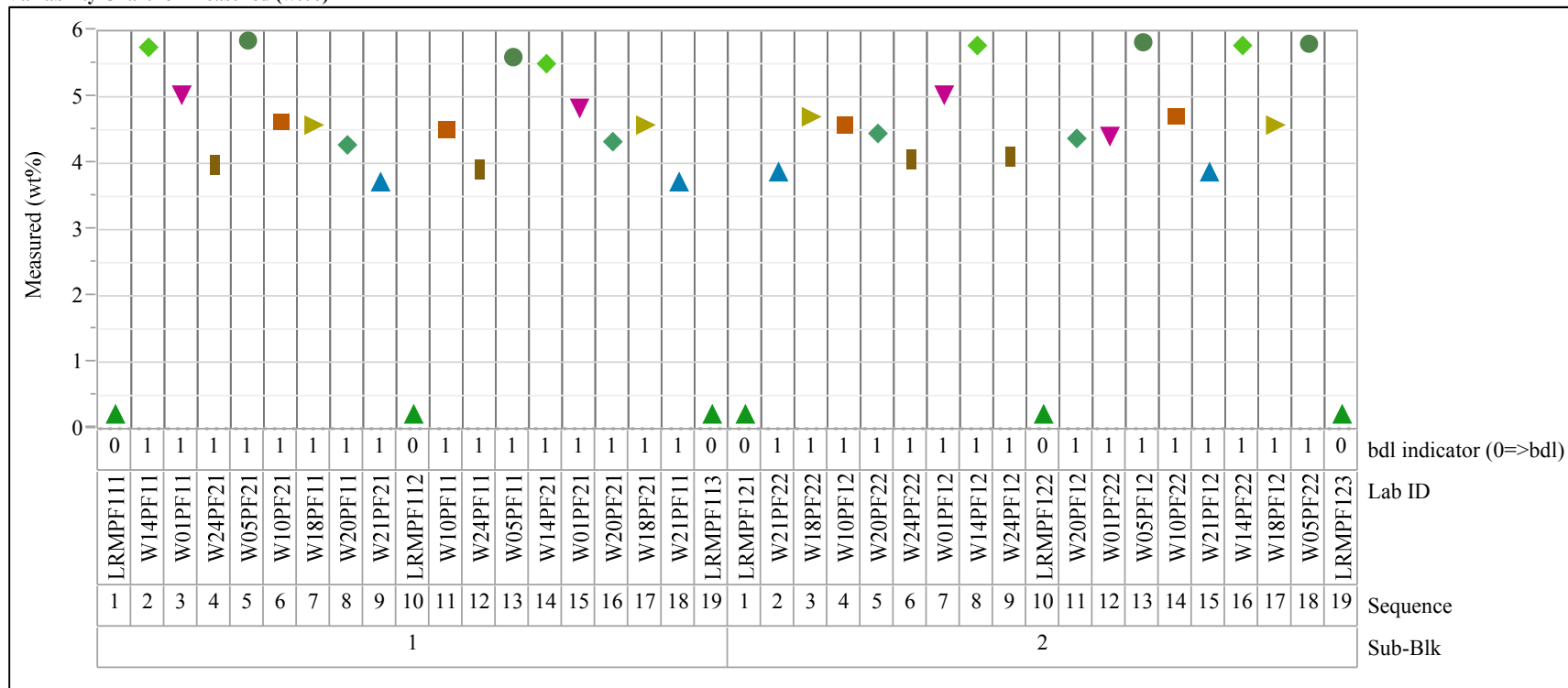
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=Li<sub>2</sub>O (wt%), Prep Method=PF, Block=1

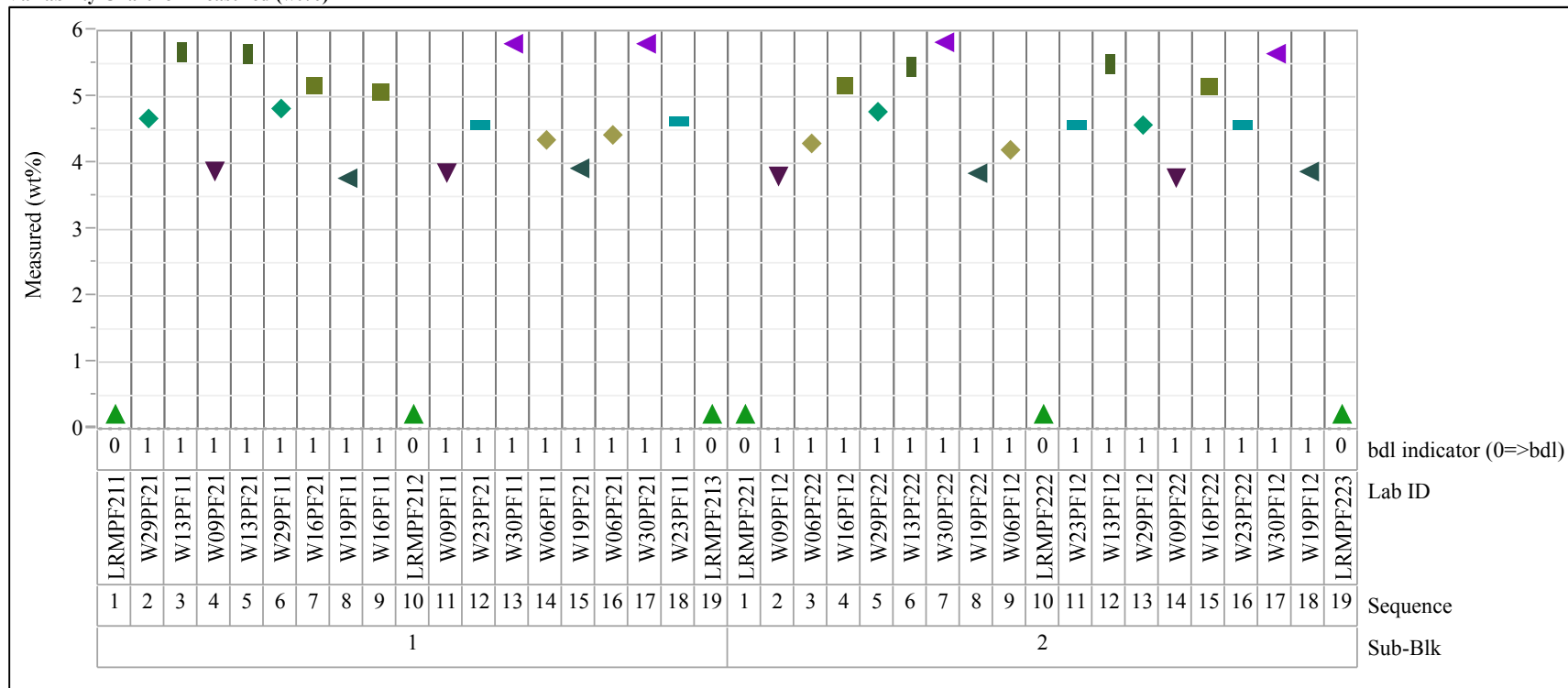
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=Li<sub>2</sub>O (wt%), Prep Method=PF, Block=2

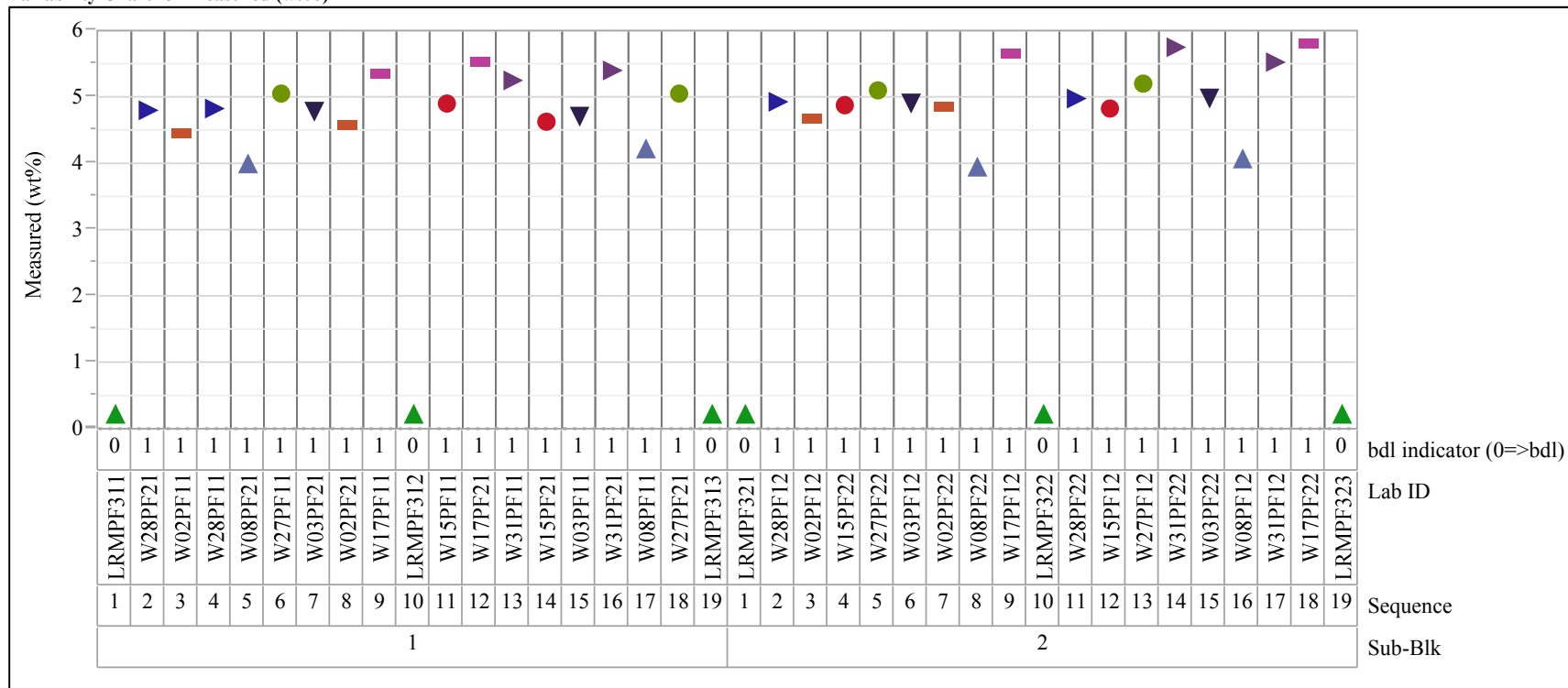
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=Li<sub>2</sub>O (wt%), Prep Method=PF, Block=3

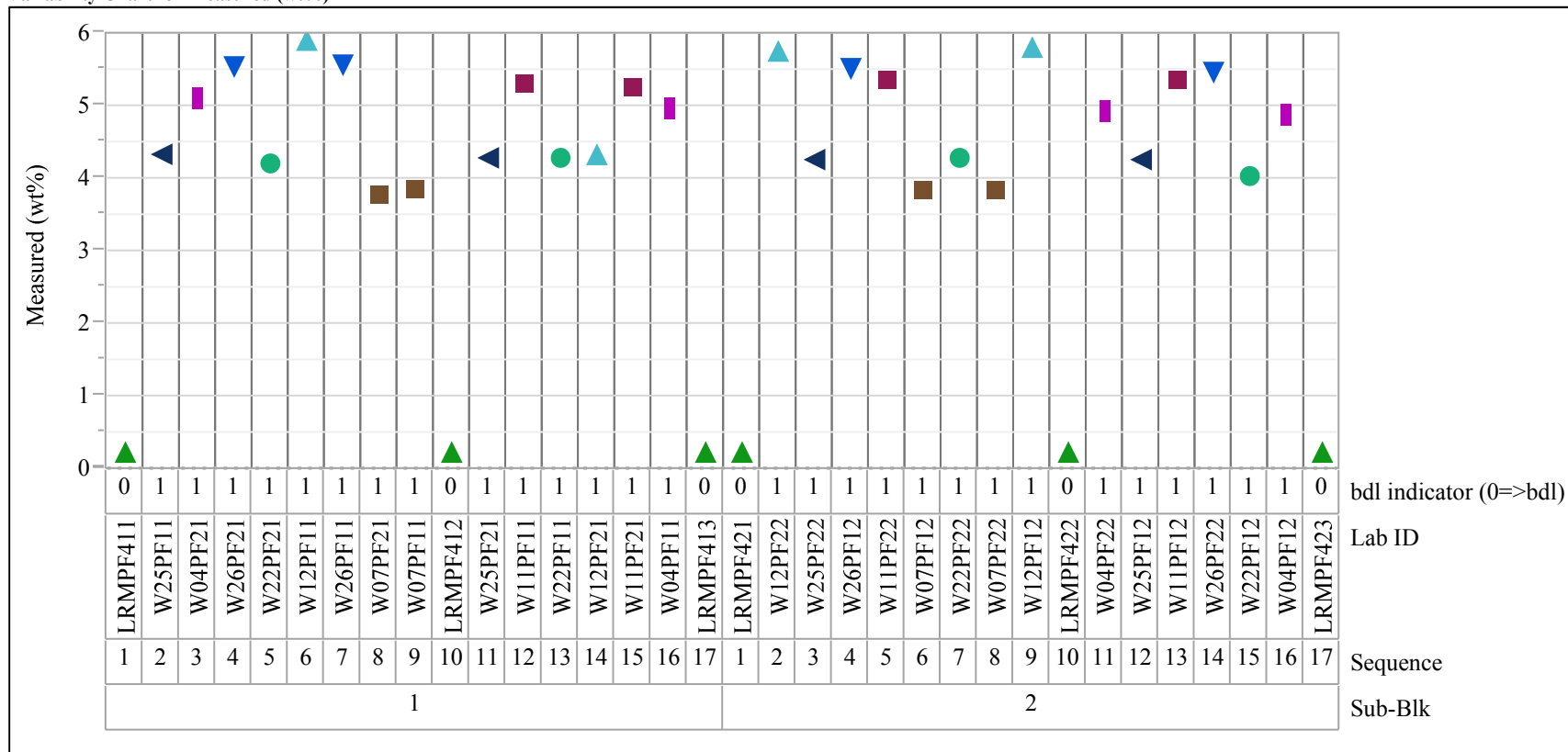
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=Li<sub>2</sub>O (wt%), Prep Method=PF, Block=4

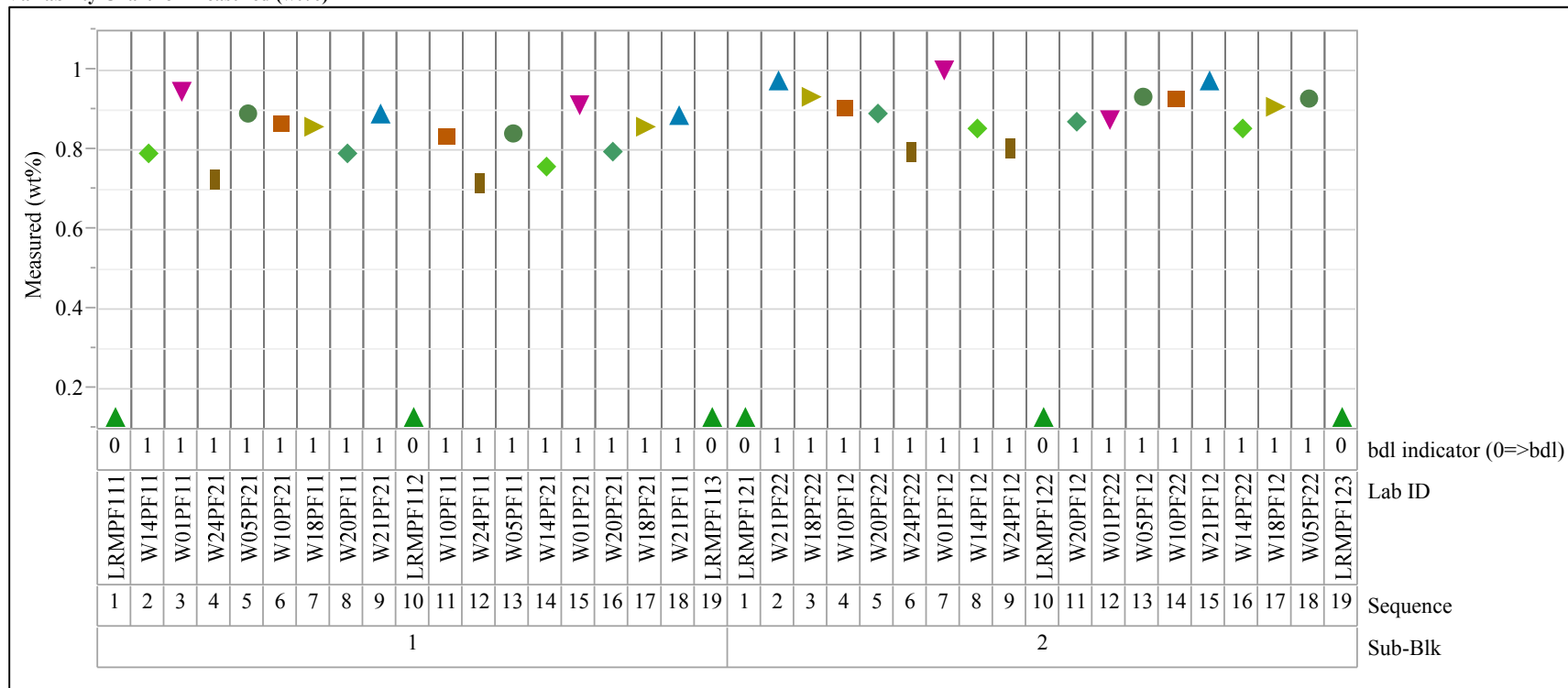
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=MnO (wt%), Prep Method=PF, Block=1

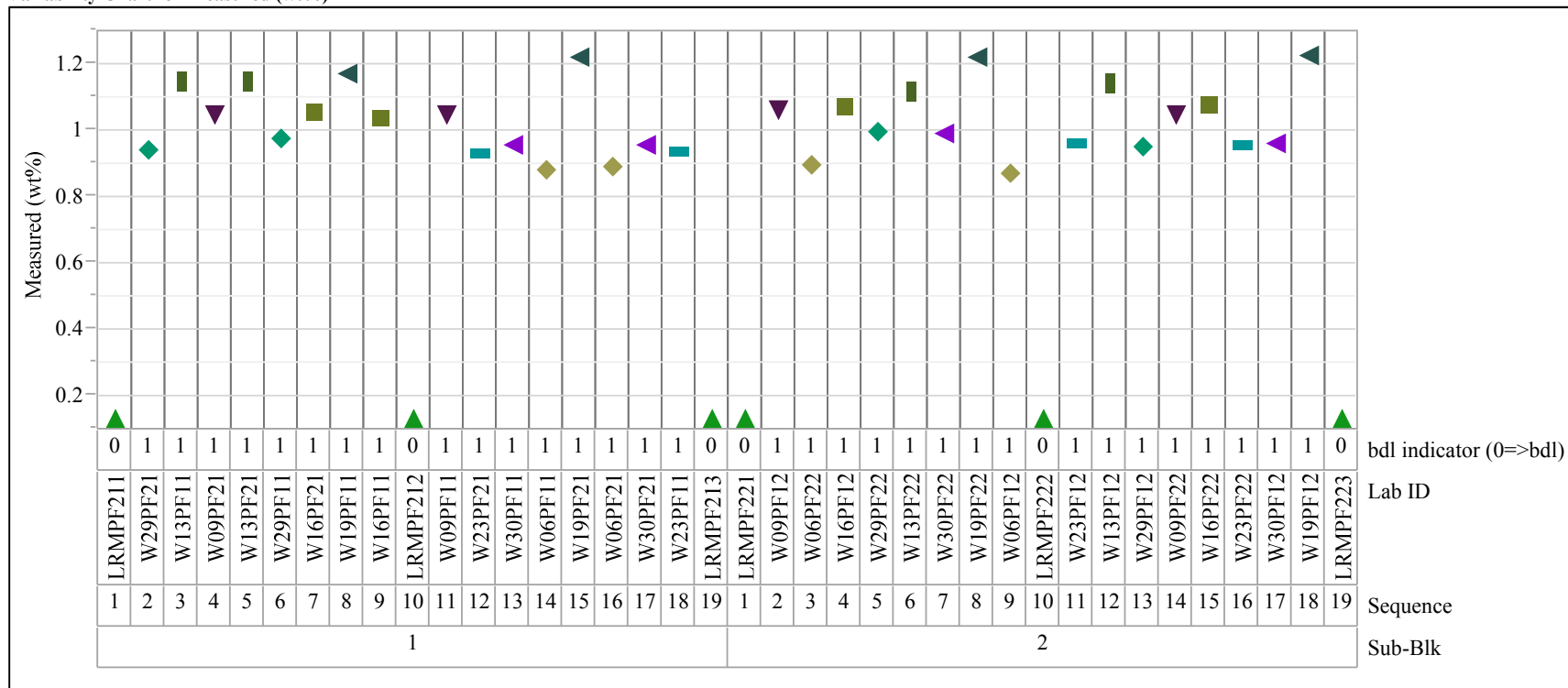
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=MnO (wt%), Prep Method=PF, Block=2

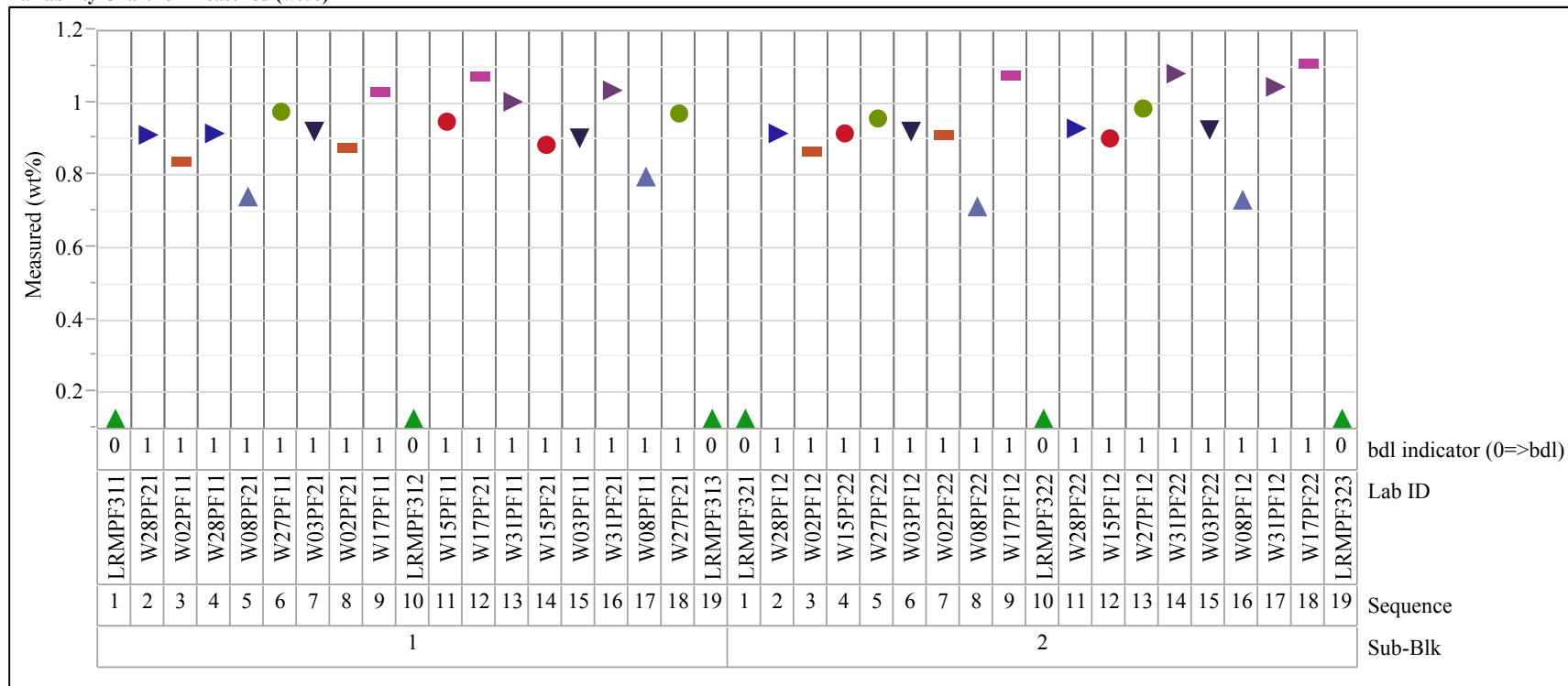
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=MnO (wt%), Prep Method=PF, Block=3

Variability Chart for Measured (wt%)

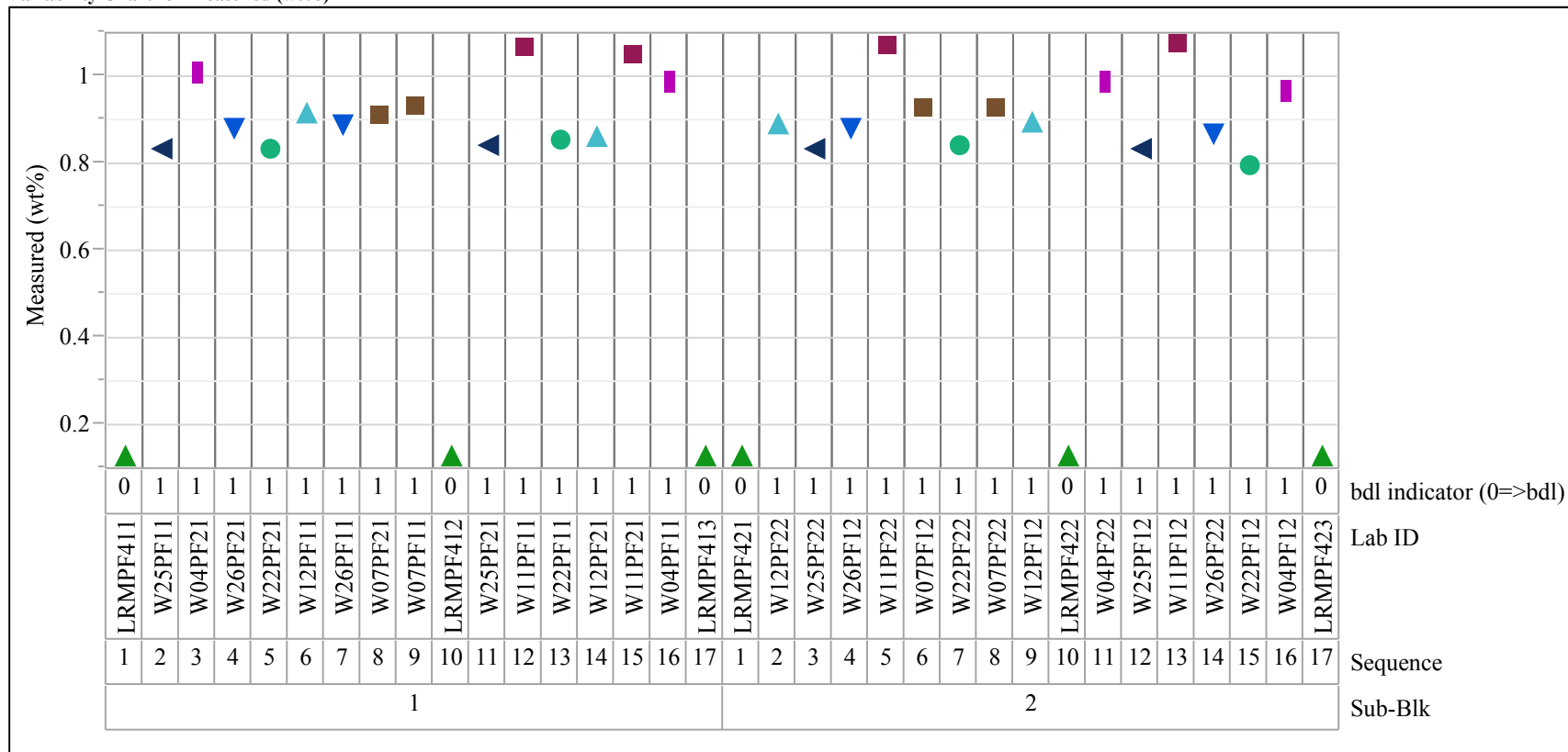




**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=MnO (wt%), Prep Method=PF, Block=4

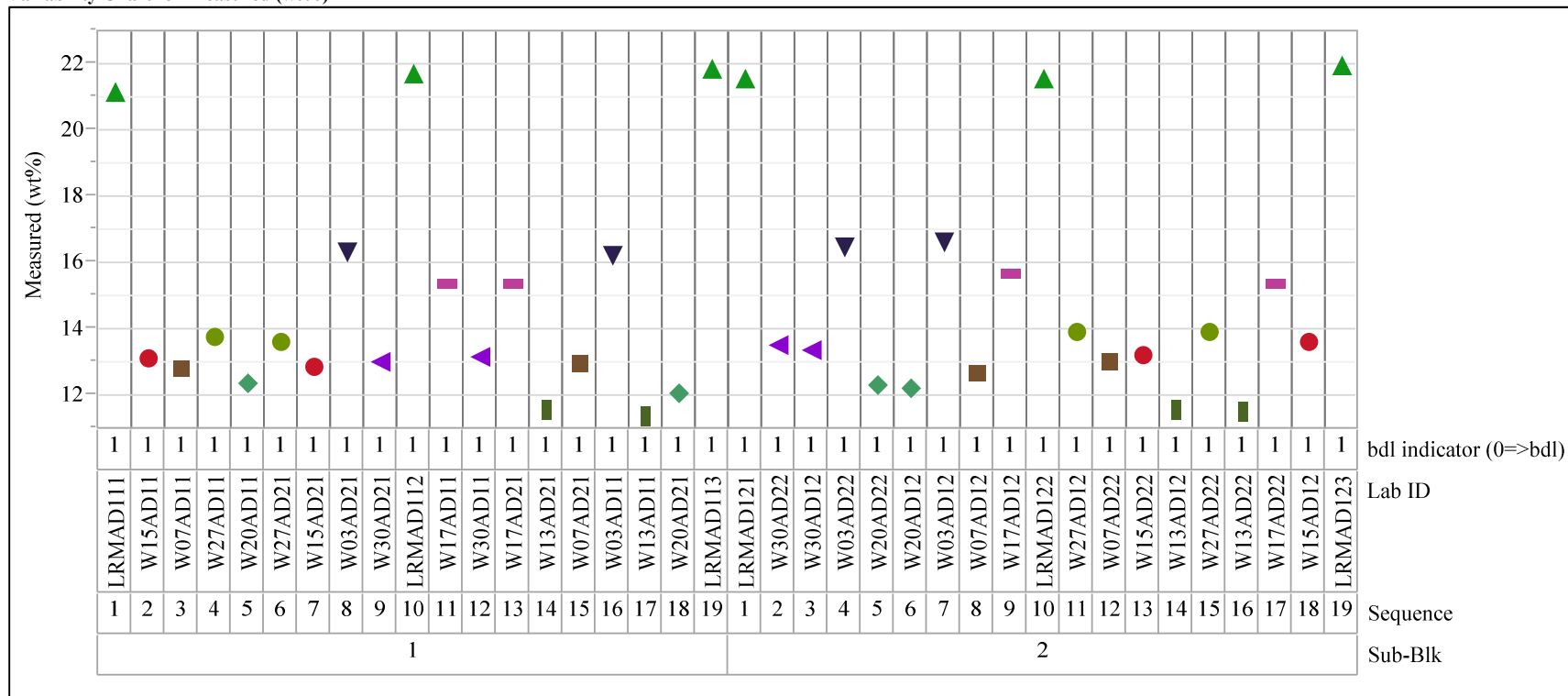
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

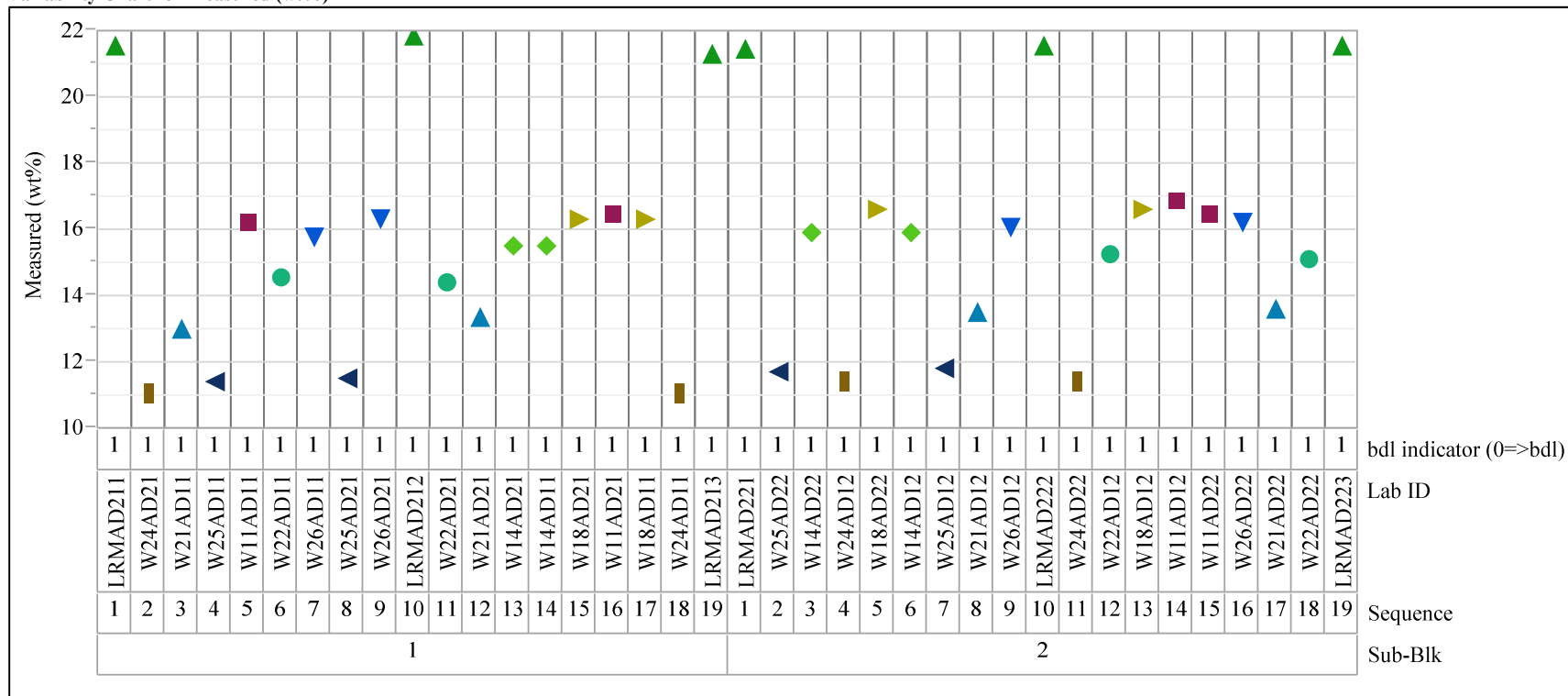
Oxide=Na<sub>2</sub>O (wt%), Prep Method=AD, Block=1

Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Na<sub>2</sub>O (wt%), Prep Method=AD, Block=2

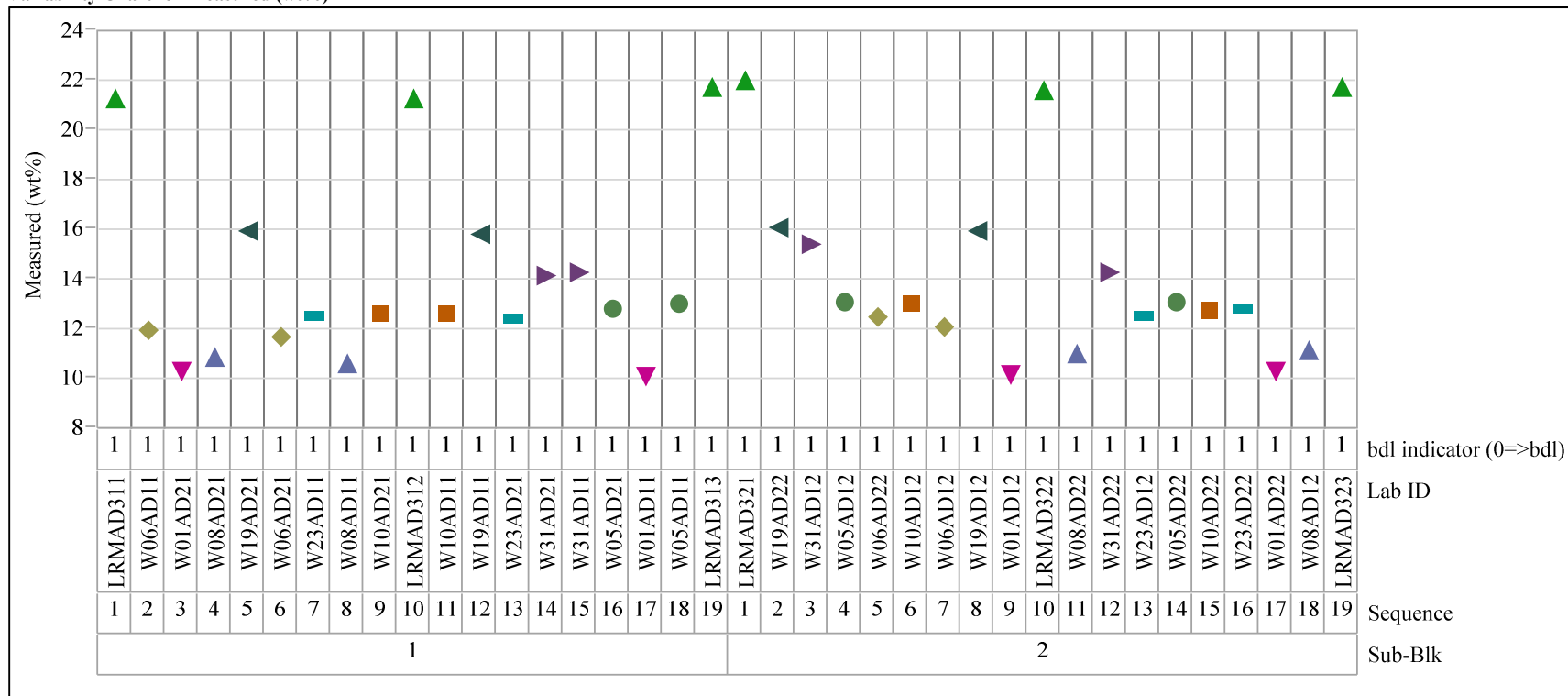
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

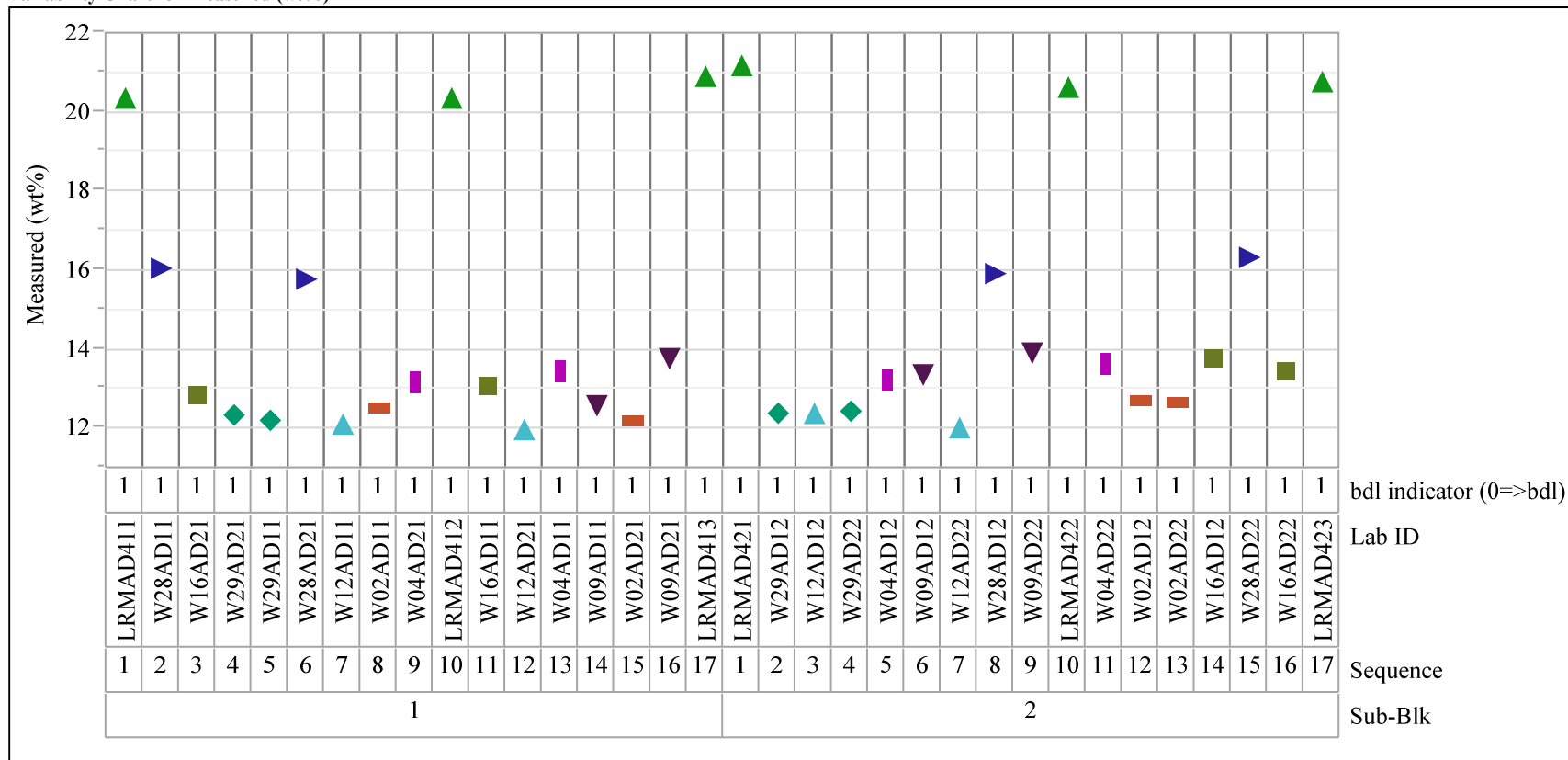
Oxide=Na<sub>2</sub>O (wt%), Prep Method=AD, Block=3

Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=Na<sub>2</sub>O (wt%), Prep Method=AD, Block=4

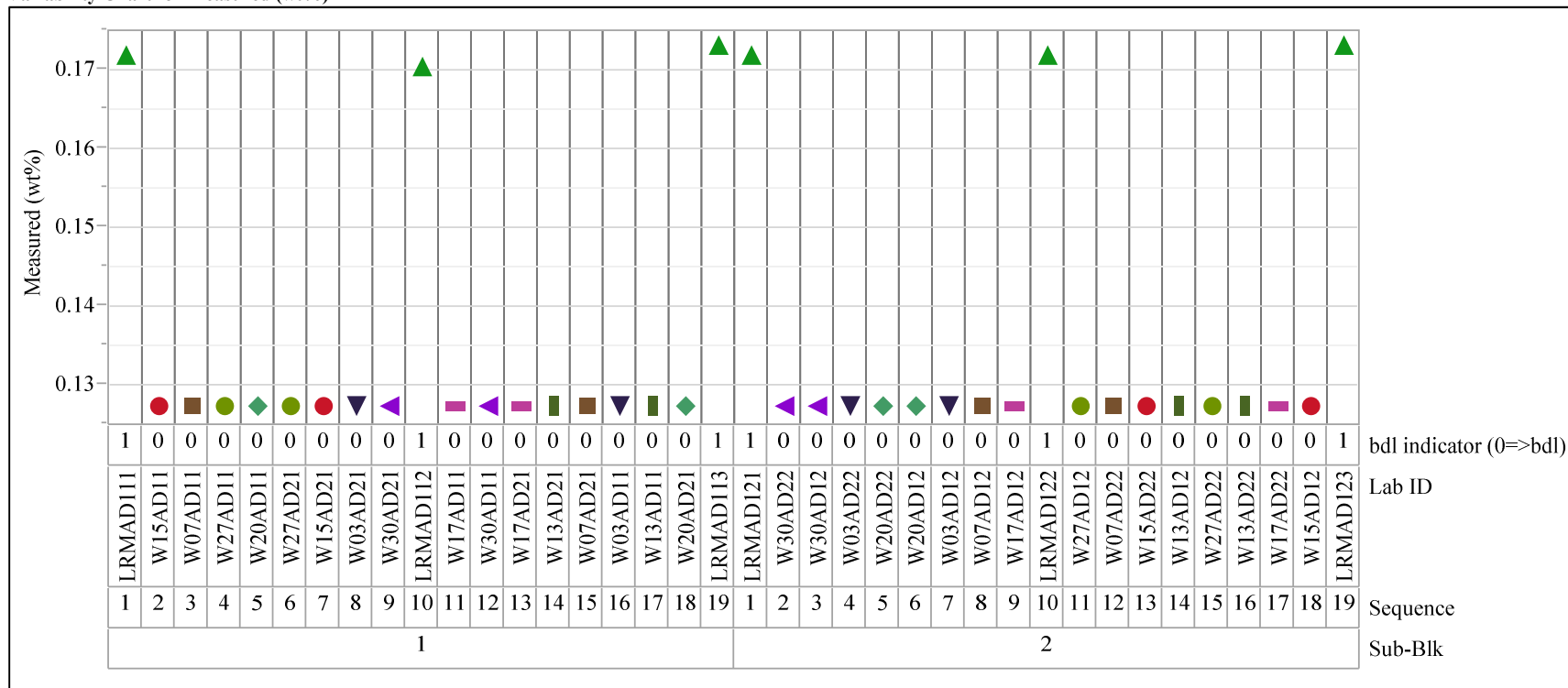
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=NiO (wt%), Prep Method=AD, Block=1

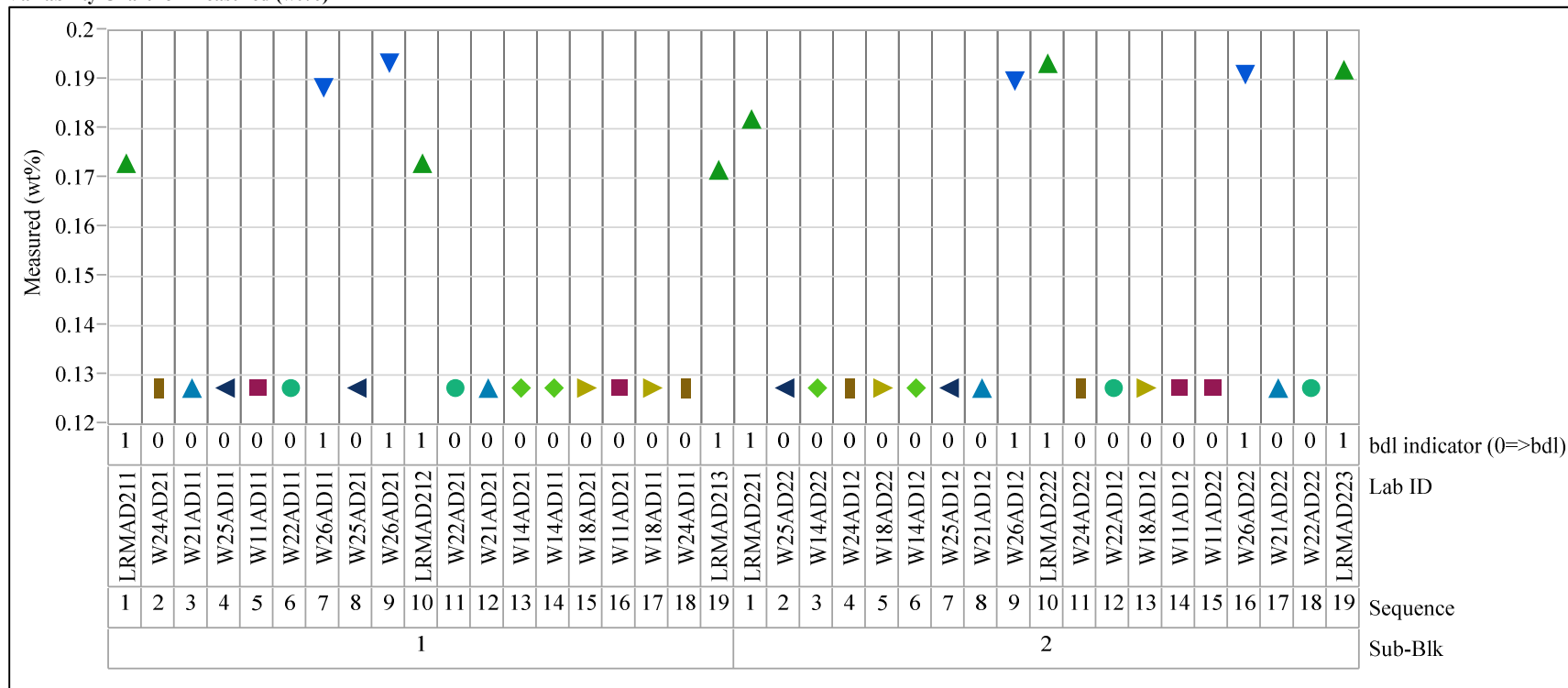
Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=NiO (wt%), Prep Method=AD, Block=2

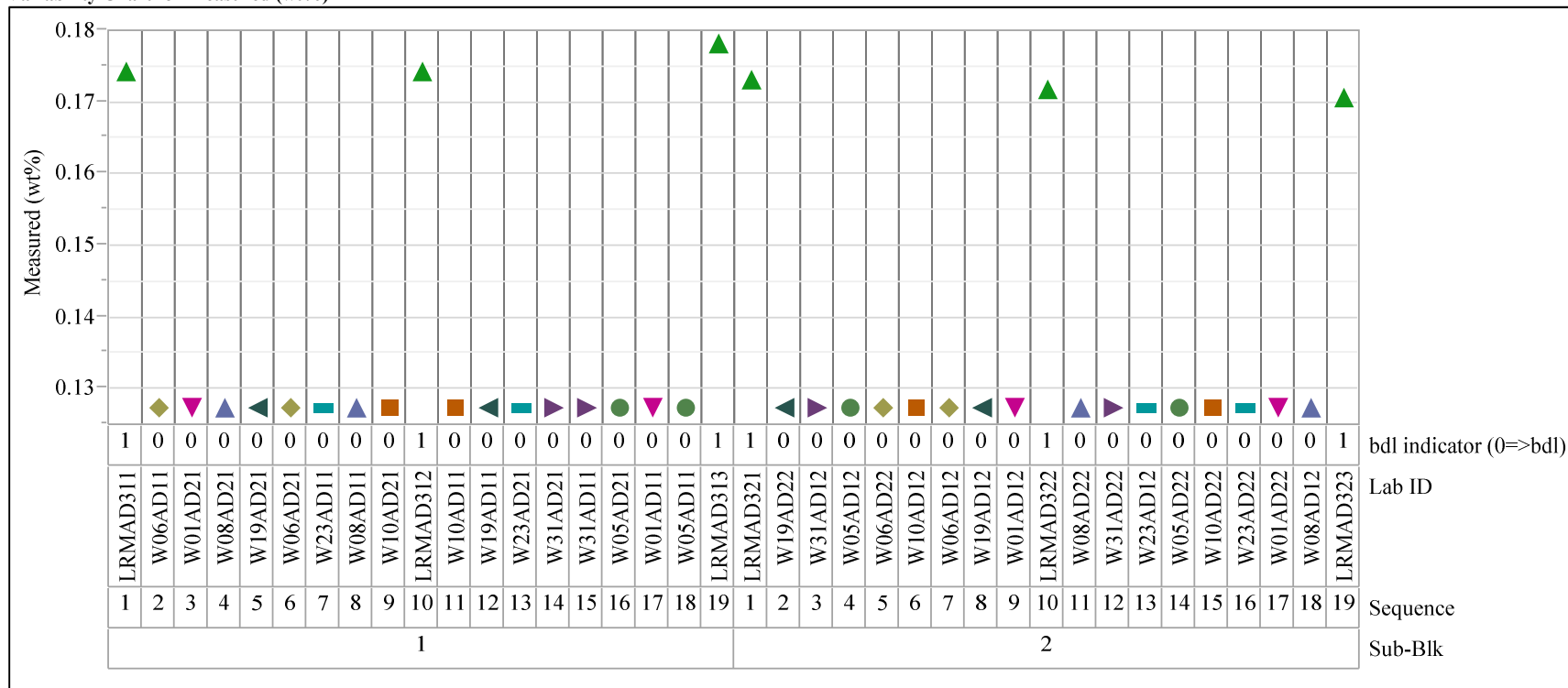
Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=NiO (wt%), Prep Method=AD, Block=3

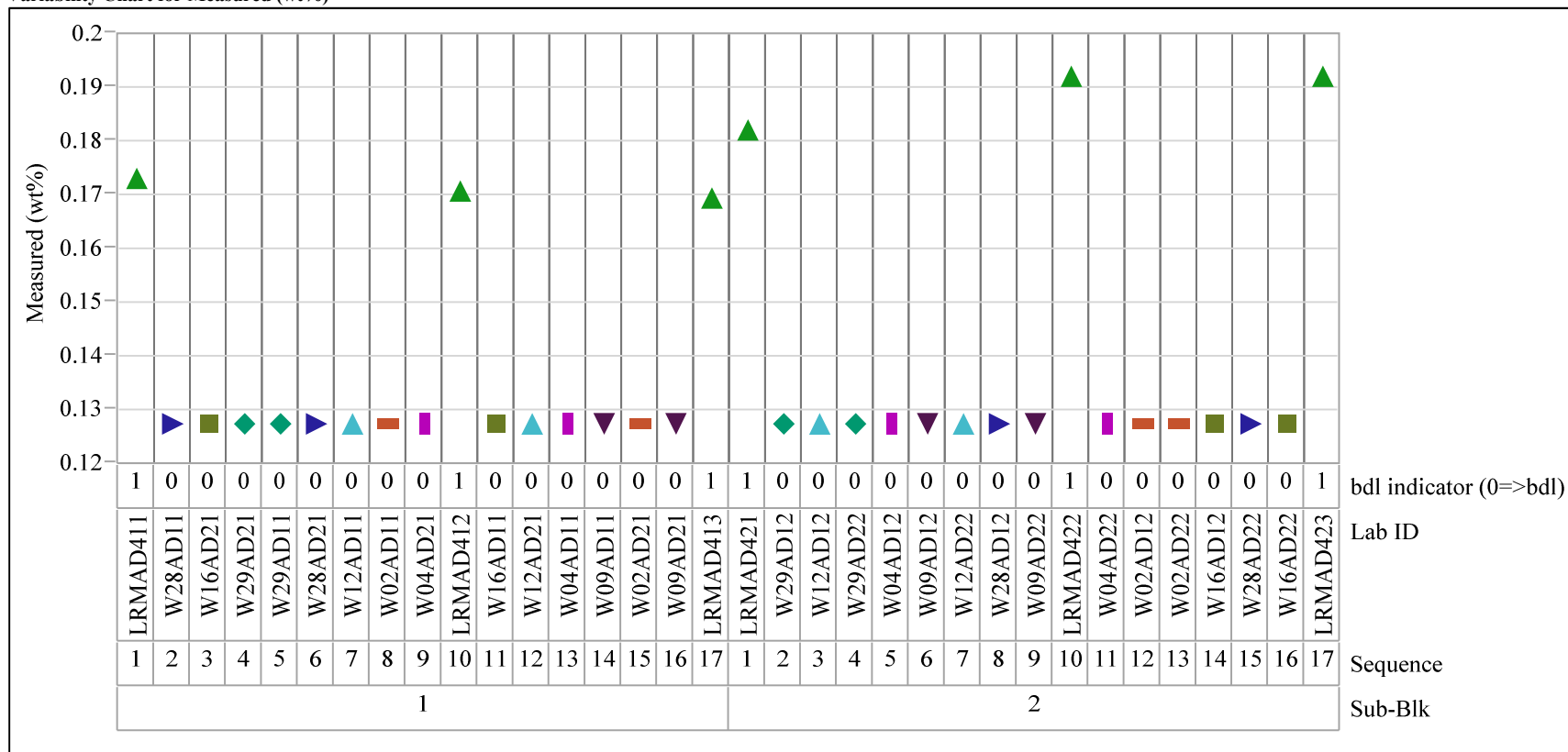
Variability Chart for Measured (wt%)





## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

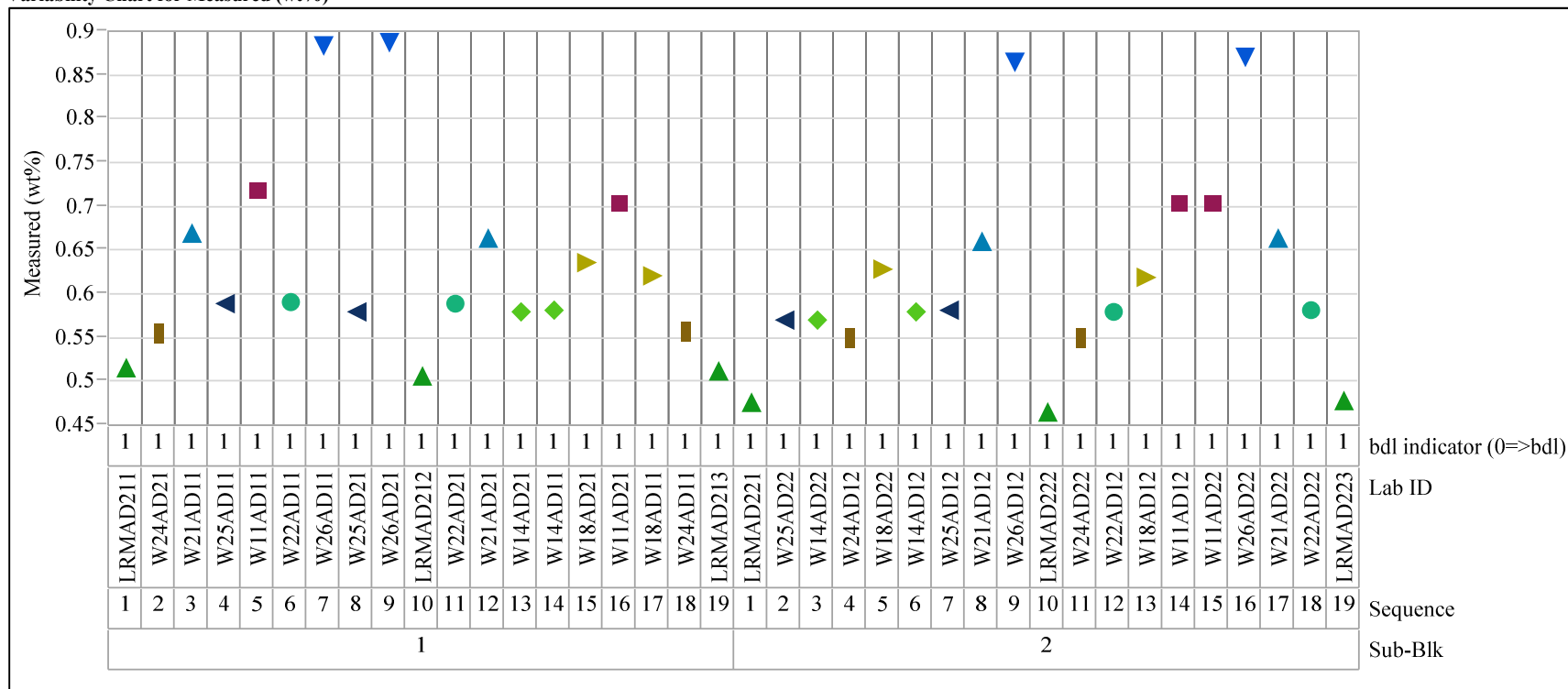
Oxide=NiO (wt%), Prep Method=AD, Block=4  
 Variability Chart for Measured (wt%)



**Oxide=P2O5 (wt%), Prep Method=AD, Block=1**  
**Variability Chart for Measured (wt%)**



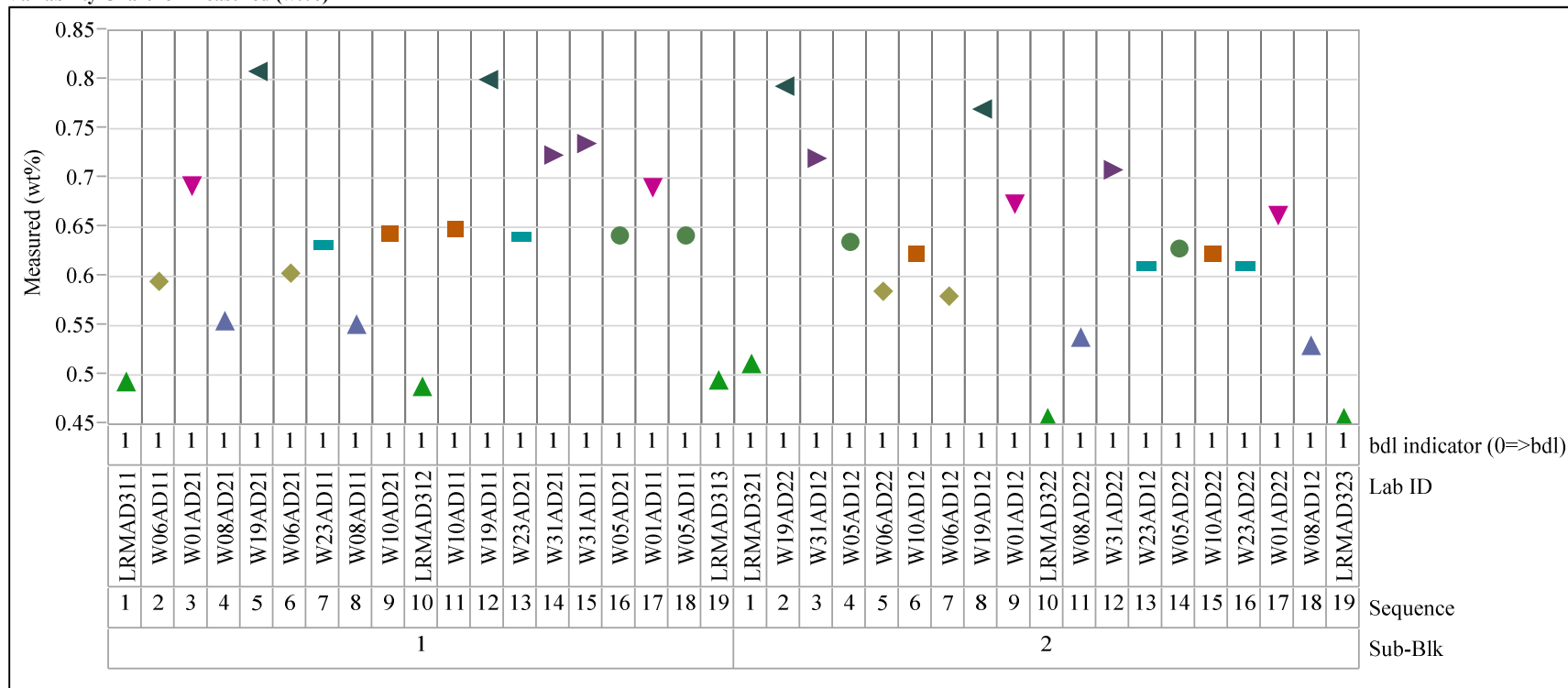
**Oxide=P2O5 (wt%), Prep Method=AD, Block=2**  
**Variability Chart for Measured (wt%)**



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=P2O5 (wt%), Prep Method=AD, Block=3

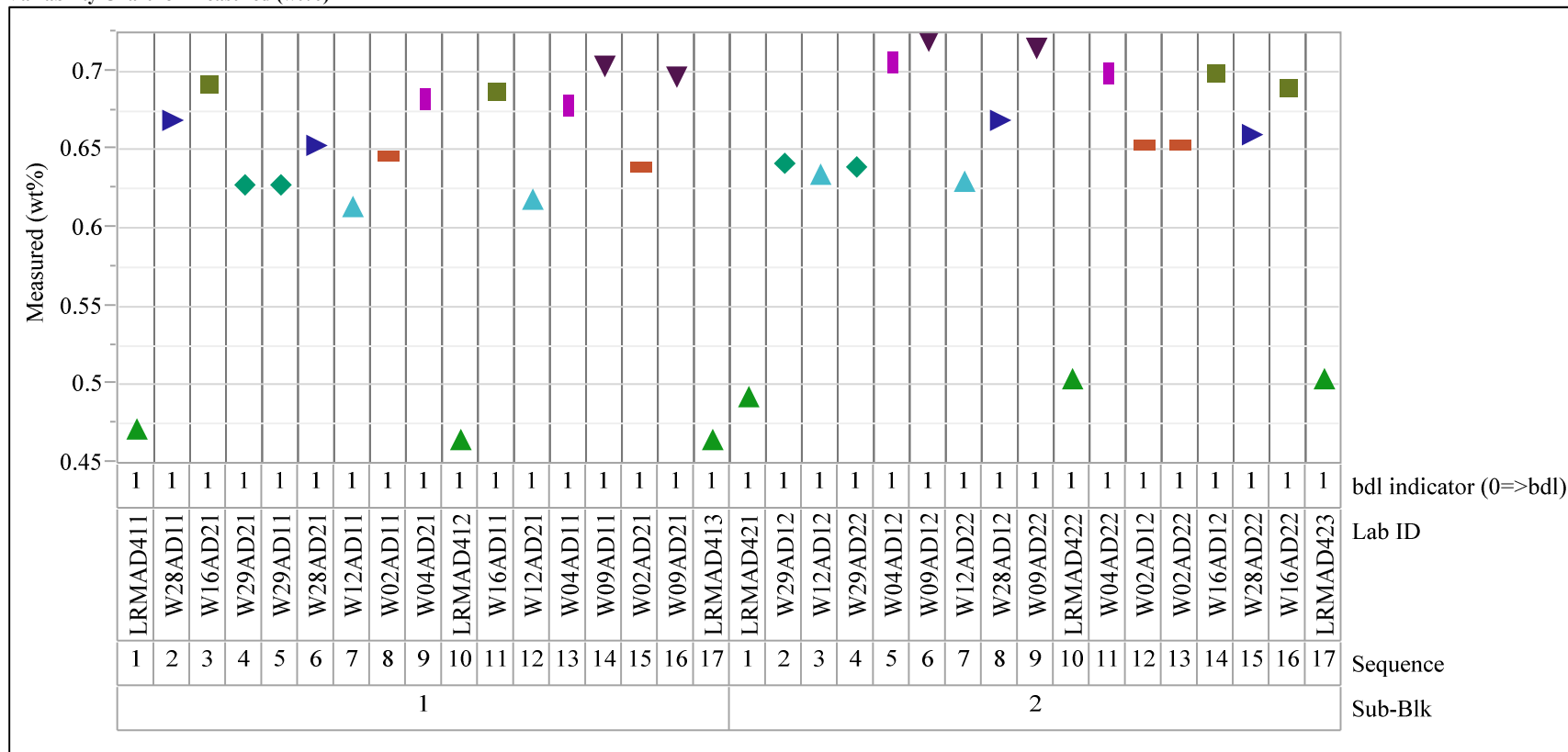
Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=P2O5 (wt%), Prep Method=AD, Block=4

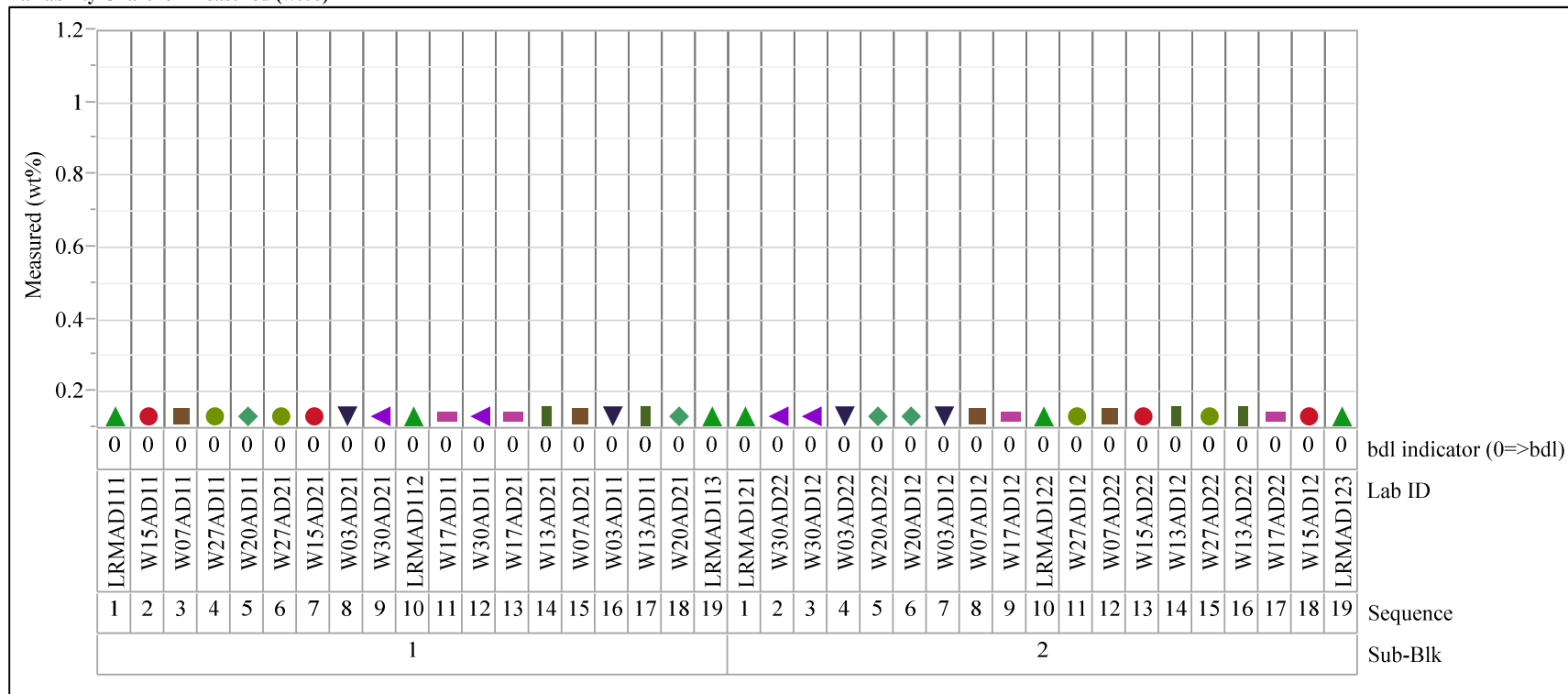
Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=RuO2 (wt%), Prep Method=AD, Block=1

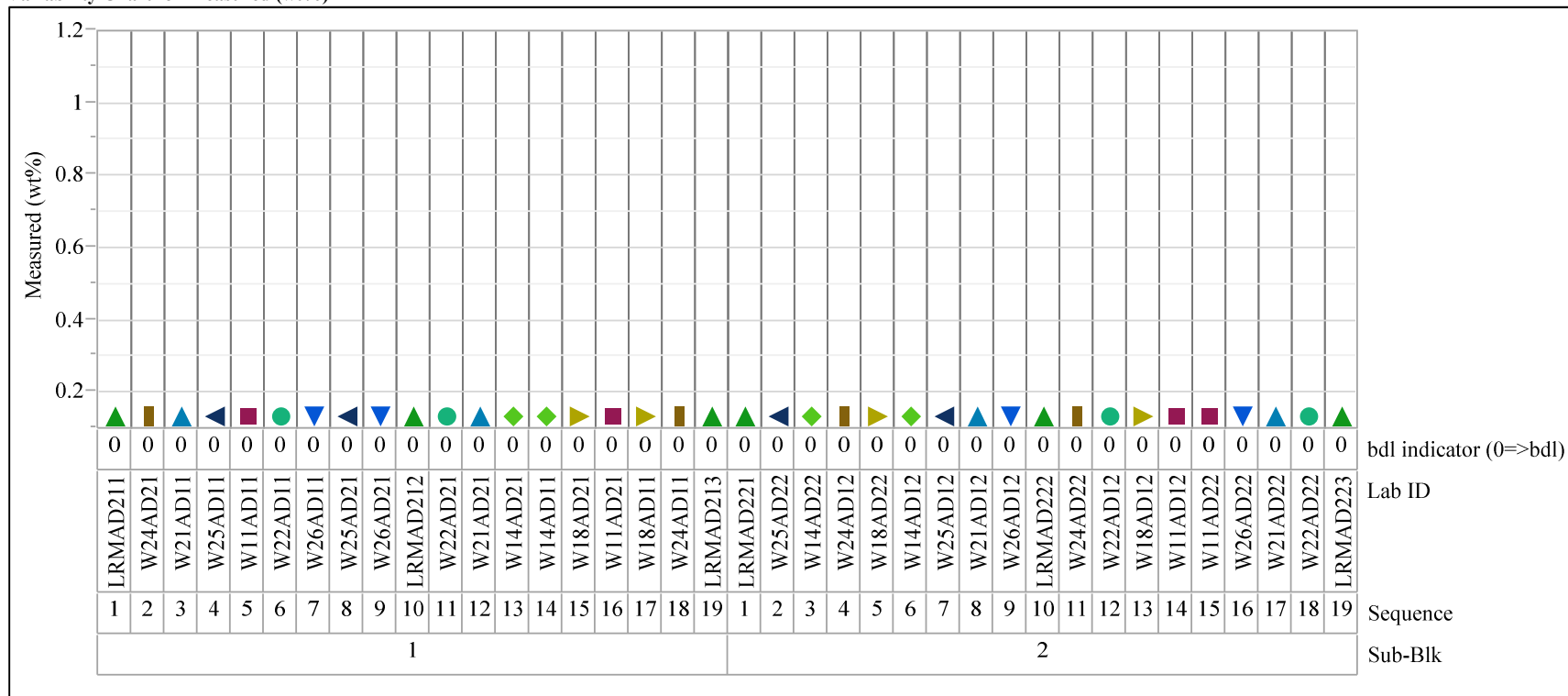
Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=RuO2 (wt%), Prep Method=AD, Block=2

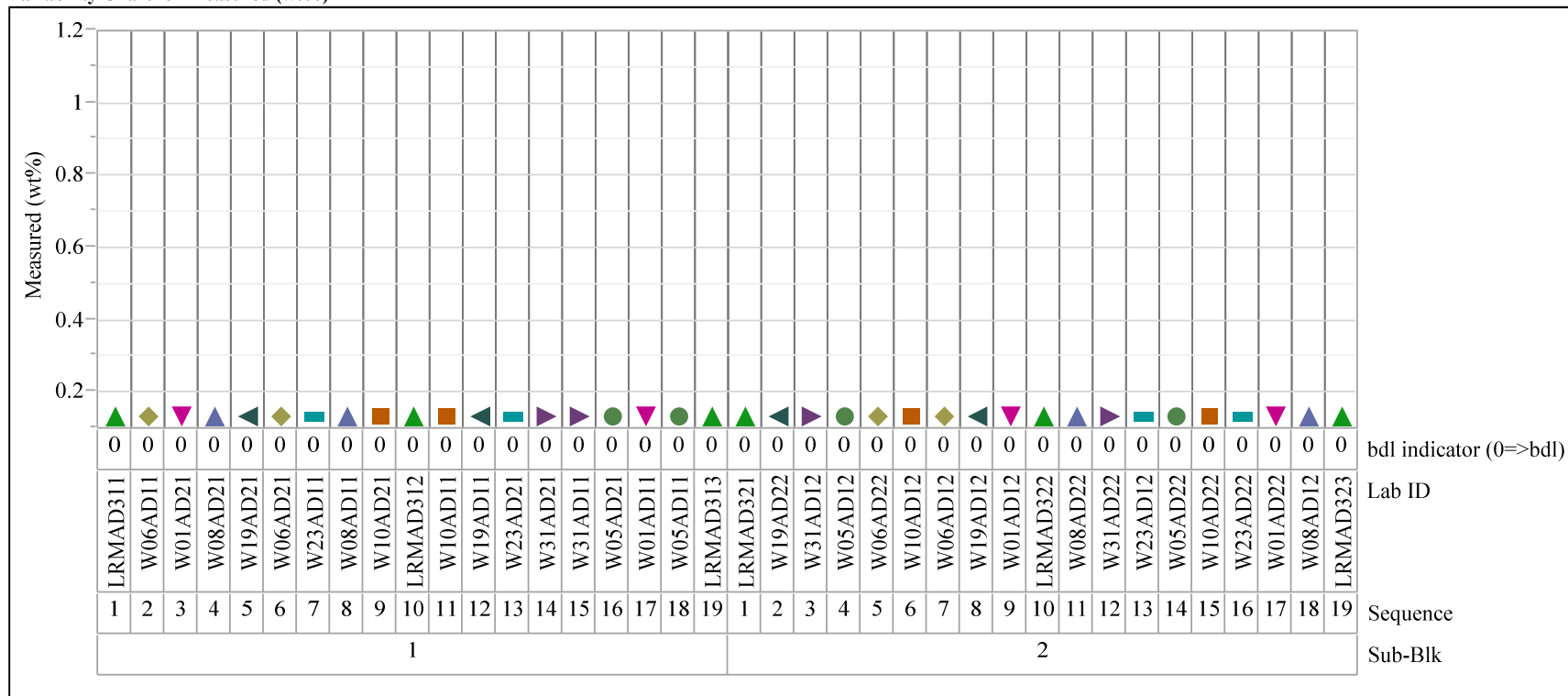
Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=RuO2 (wt%), Prep Method=AD, Block=3

Variability Chart for Measured (wt%)

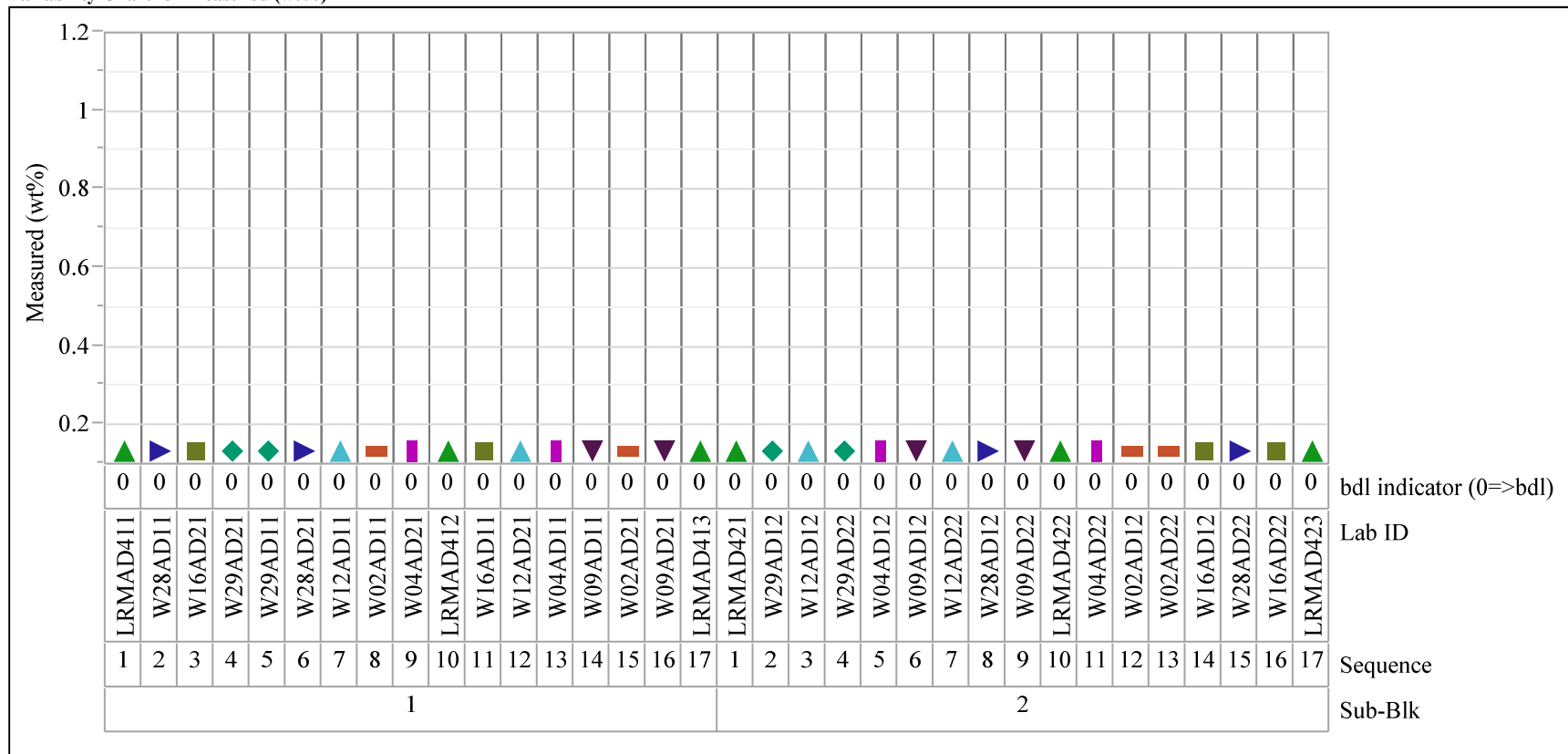




**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

Oxide=RuO2 (wt%), Prep Method=AD, Block=4

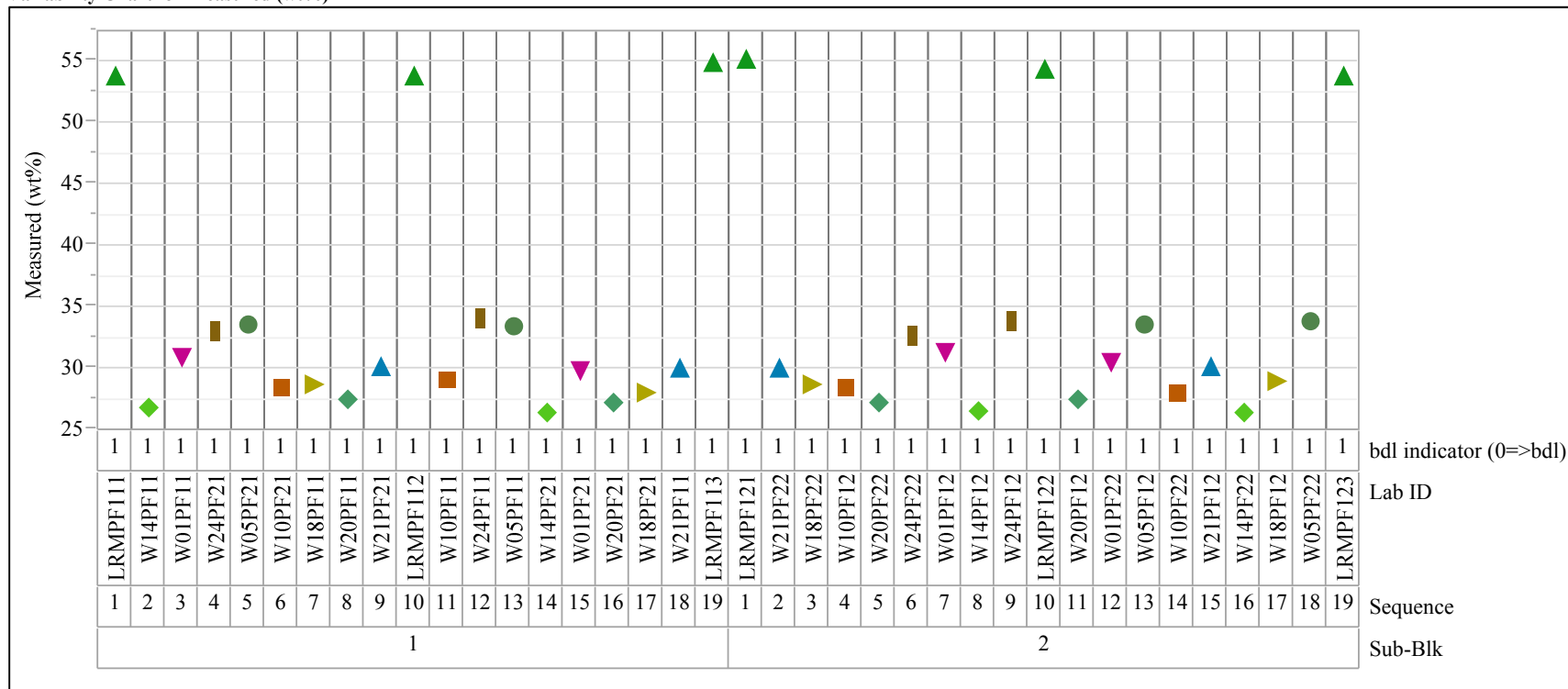
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=SiO<sub>2</sub> (wt%), Prep Method=PF, Block=1

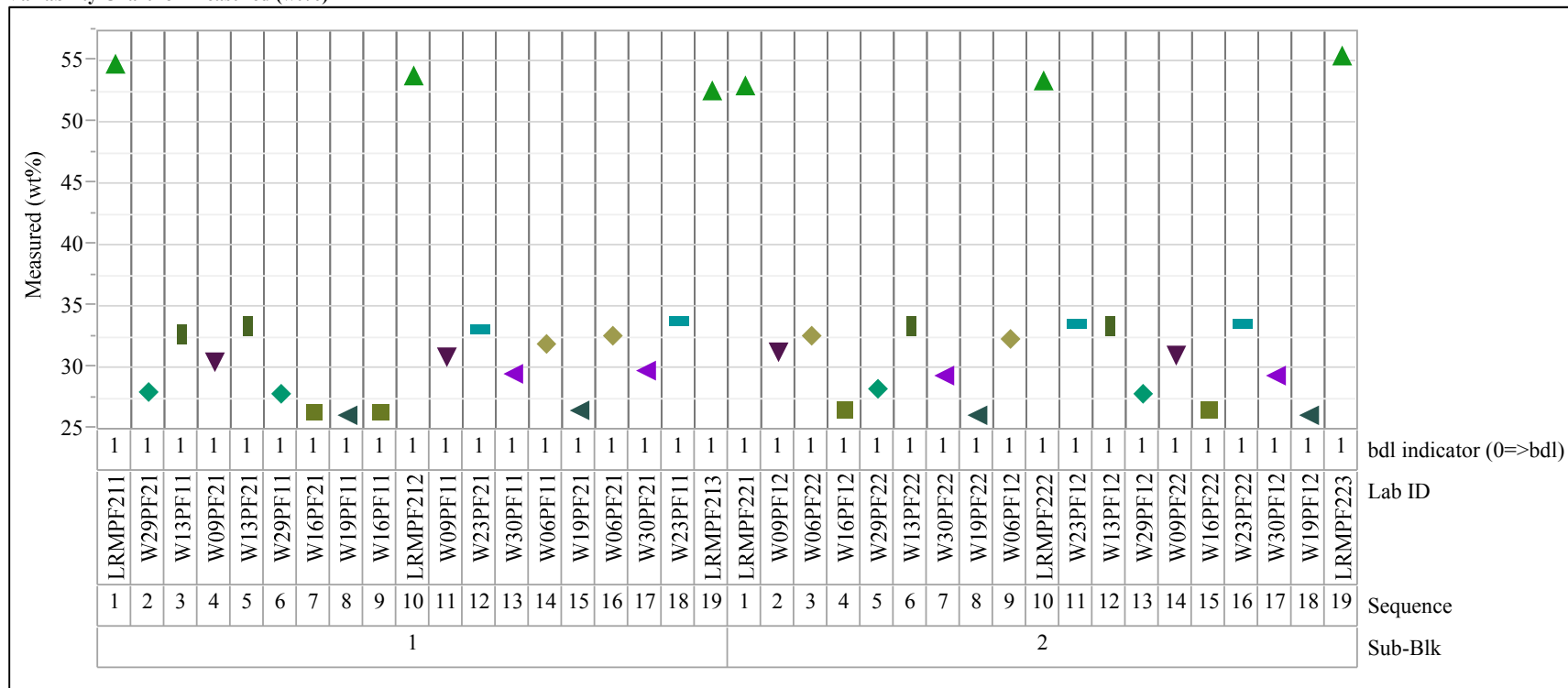
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=SiO<sub>2</sub> (wt%), Prep Method=PF, Block=2

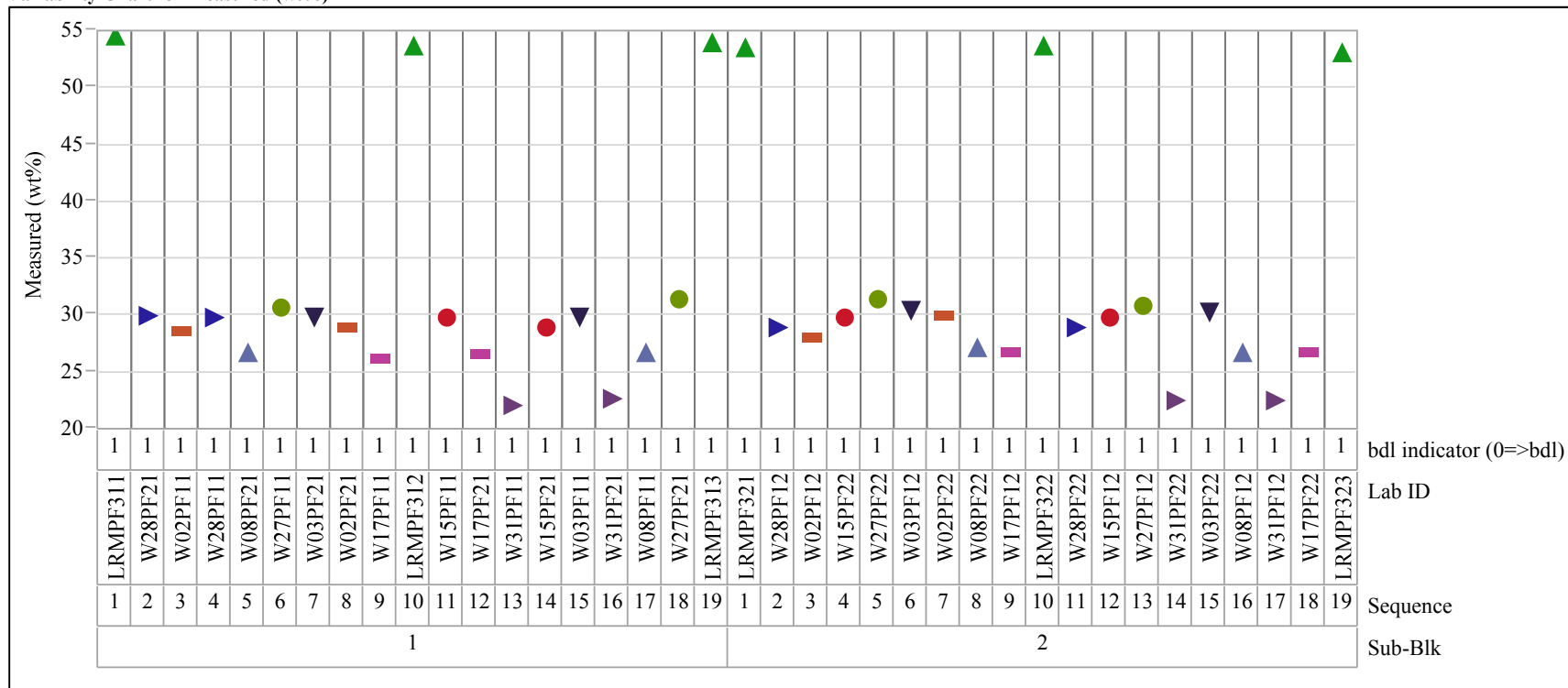
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

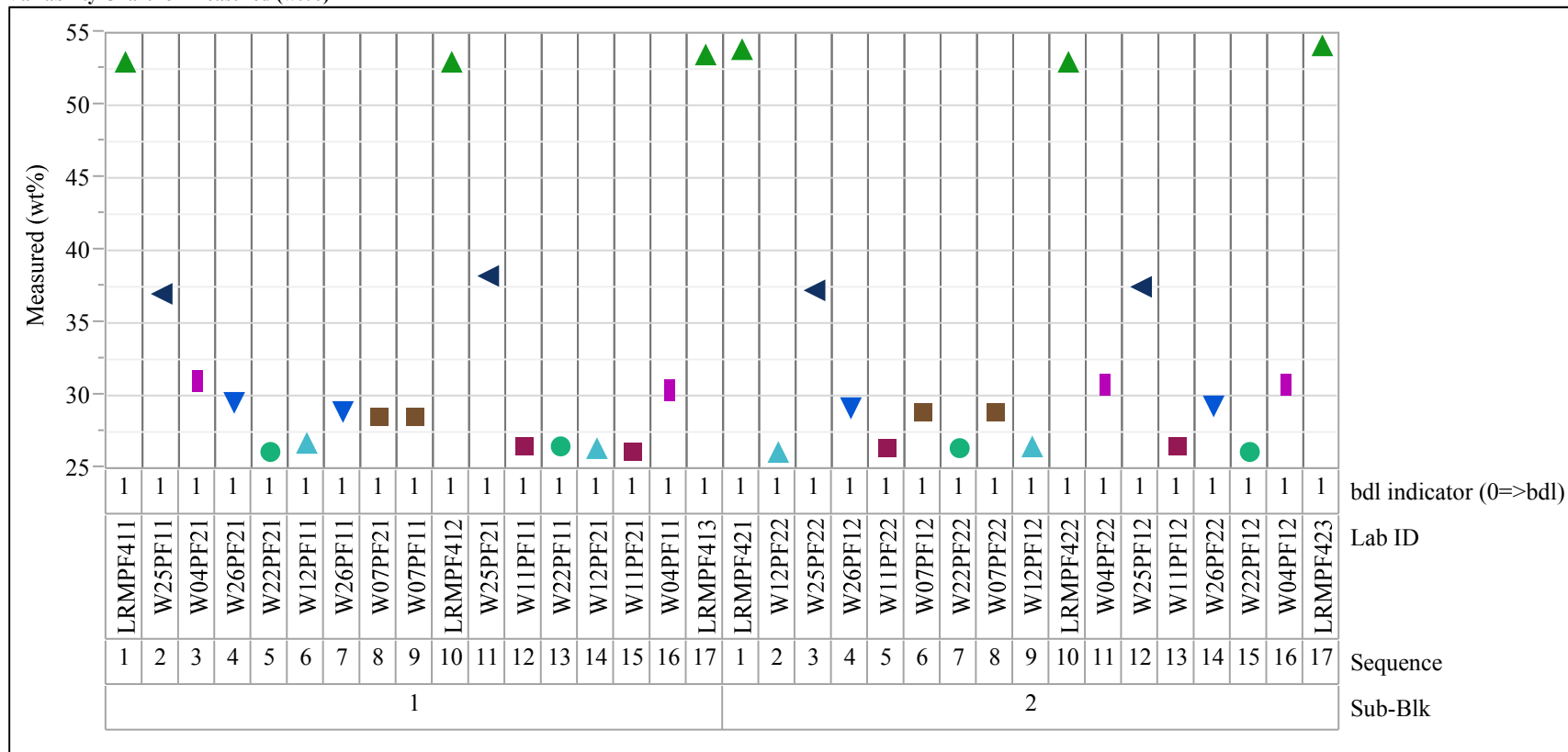
Oxide=SiO<sub>2</sub> (wt%), Prep Method=PF, Block=3

Variability Chart for Measured (wt%)



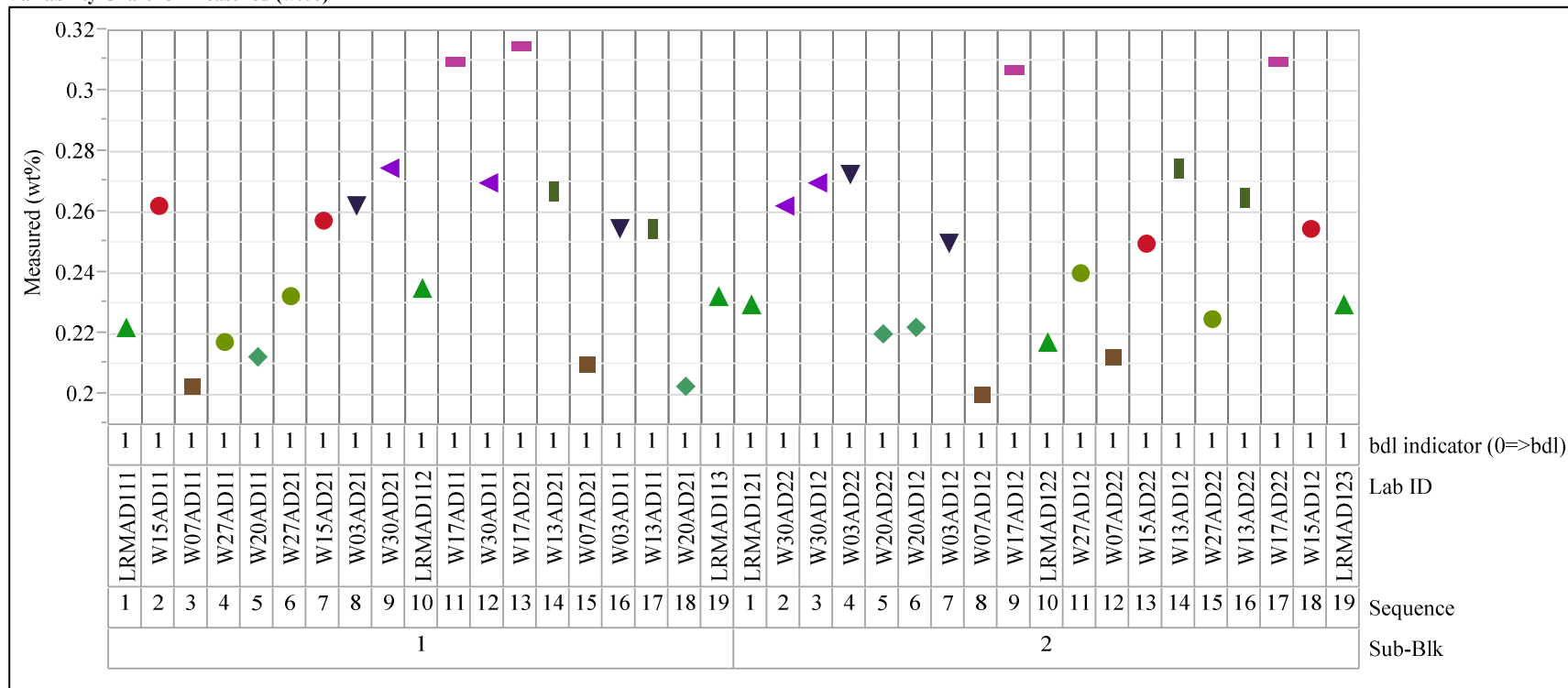
**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=SiO<sub>2</sub> (wt%), Prep Method=PF, Block=4

Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=SO<sub>3</sub> (wt%), Prep Method=AD, Block=1

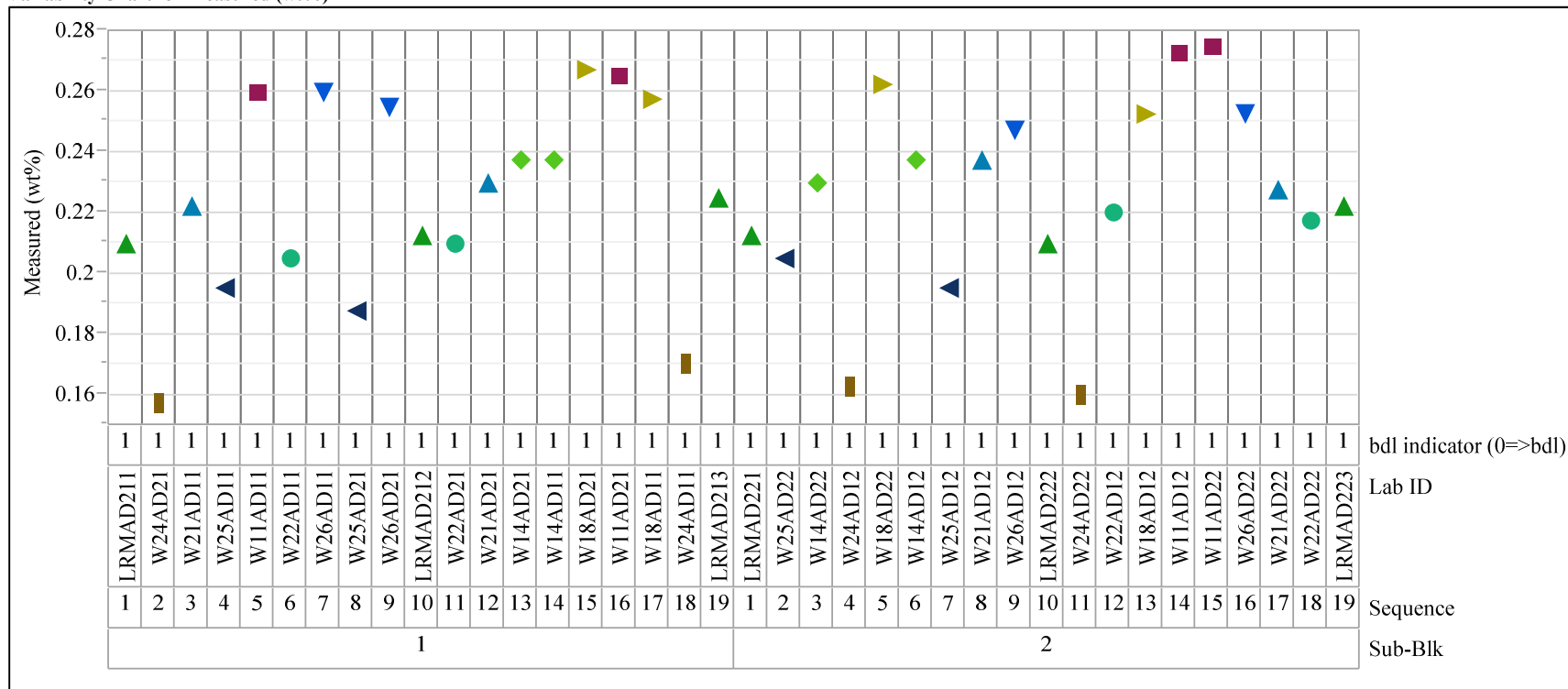
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

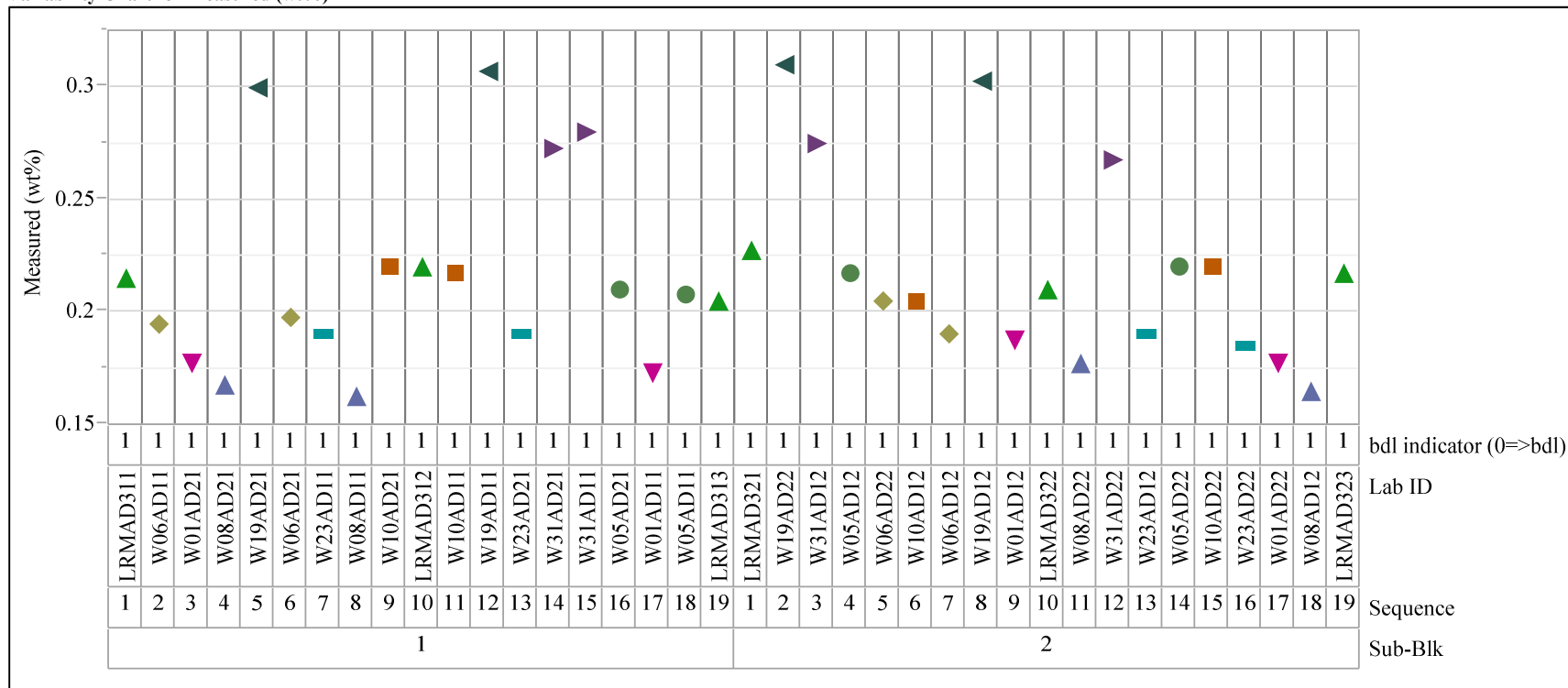
Oxide=SO<sub>3</sub> (wt%), Prep Method=AD, Block=2

Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=SO<sub>3</sub> (wt%), Prep Method=AD, Block=3

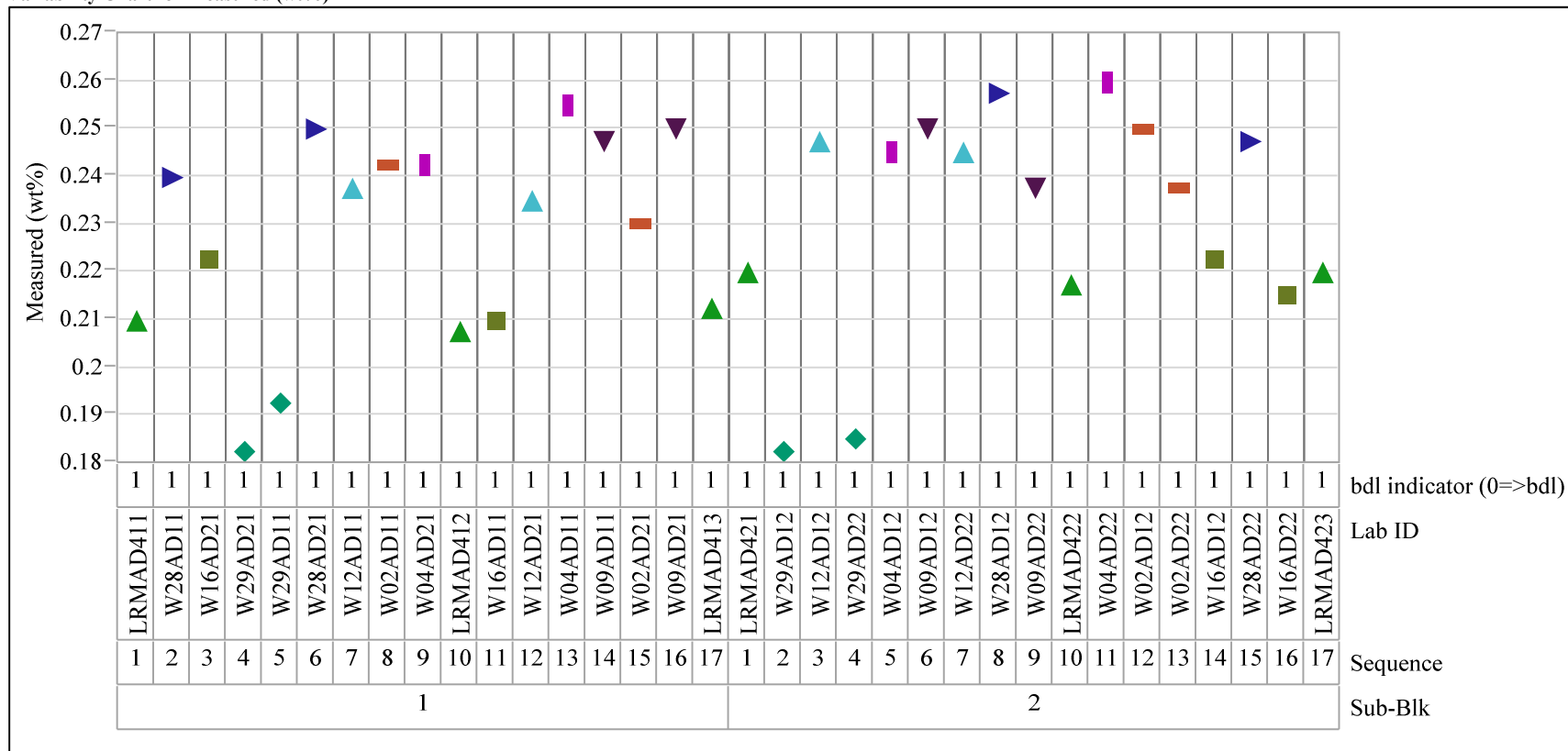
Variability Chart for Measured (wt%)





**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=SO<sub>3</sub> (wt%), Prep Method=AD, Block=4

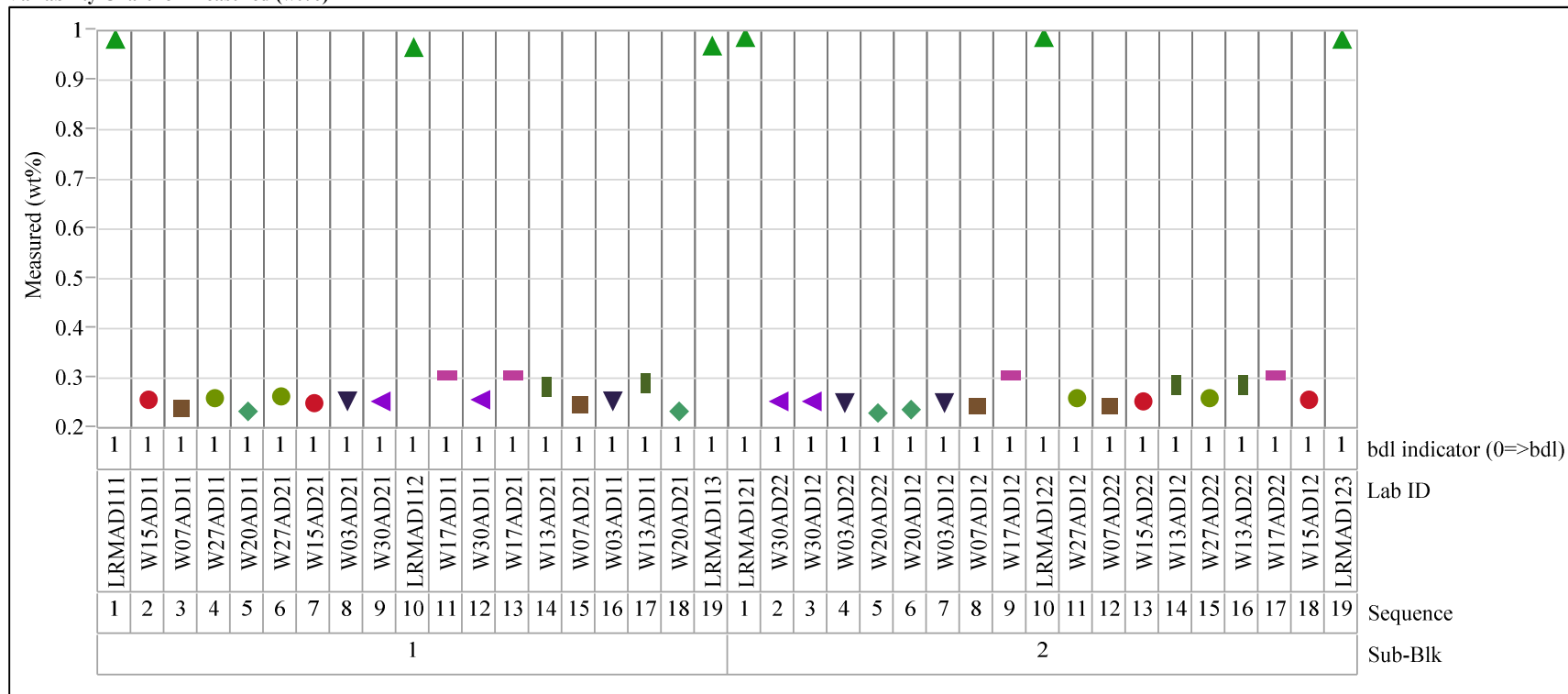
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

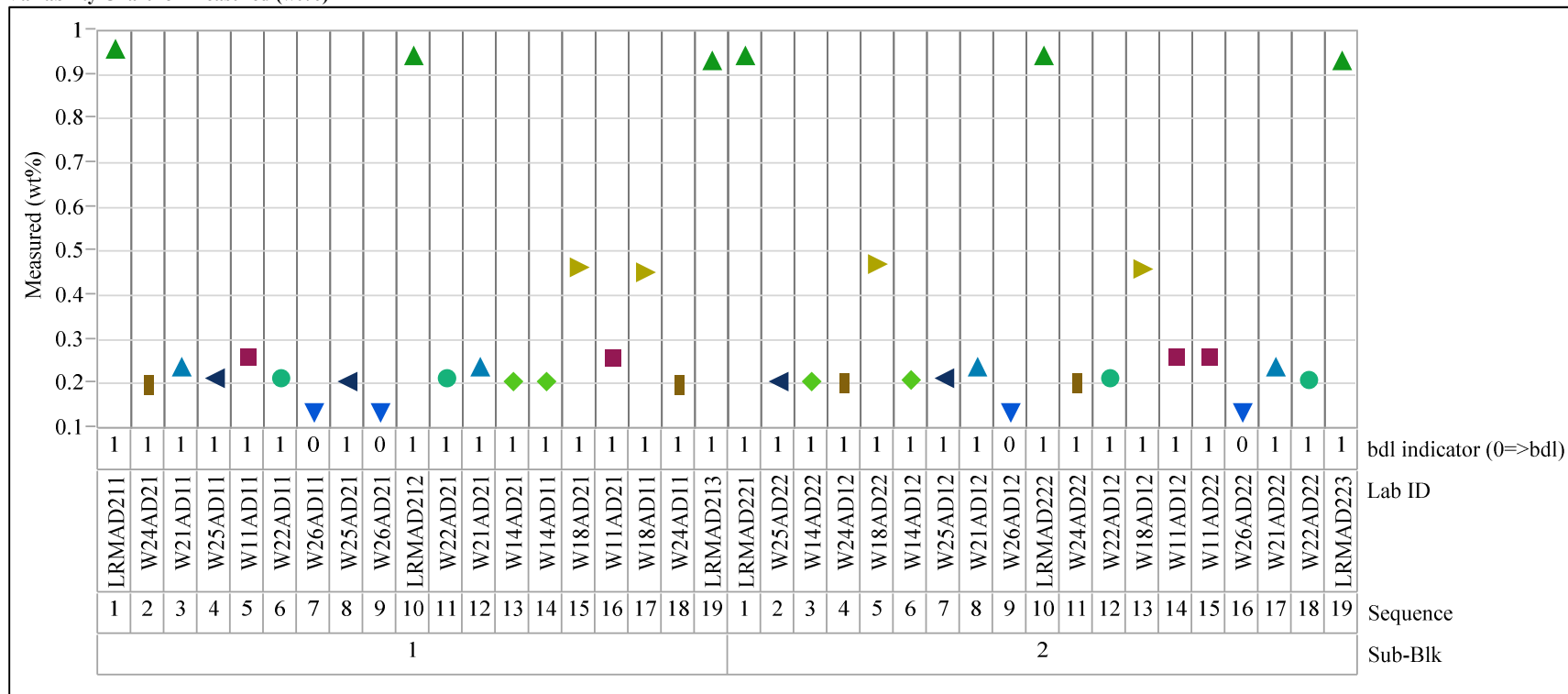
Oxide=ZrO<sub>2</sub> (wt%), Prep Method=AD, Block=1

Variability Chart for Measured (wt%)



**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**Oxide=ZrO<sub>2</sub> (wt%), Prep Method=AD, Block=2

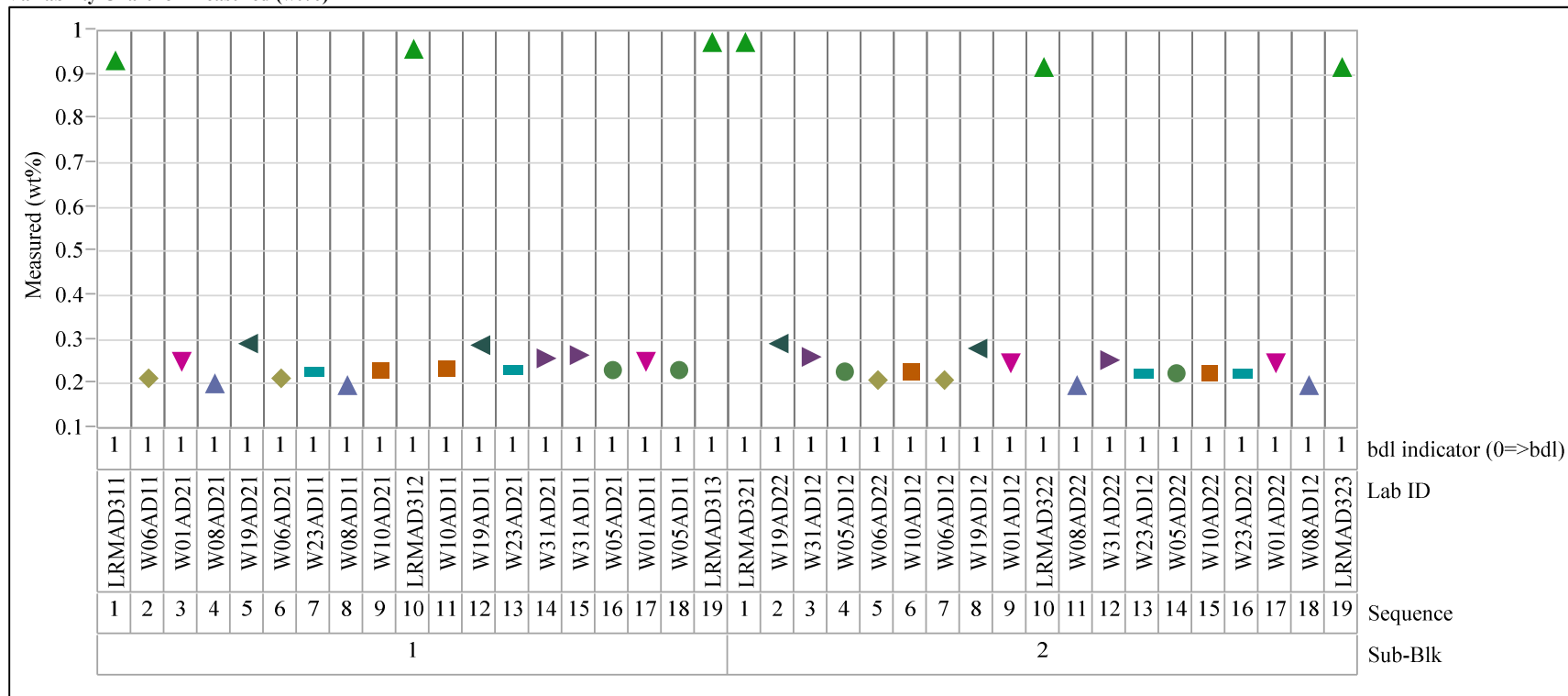
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=ZrO<sub>2</sub> (wt%), Prep Method=AD, Block=3

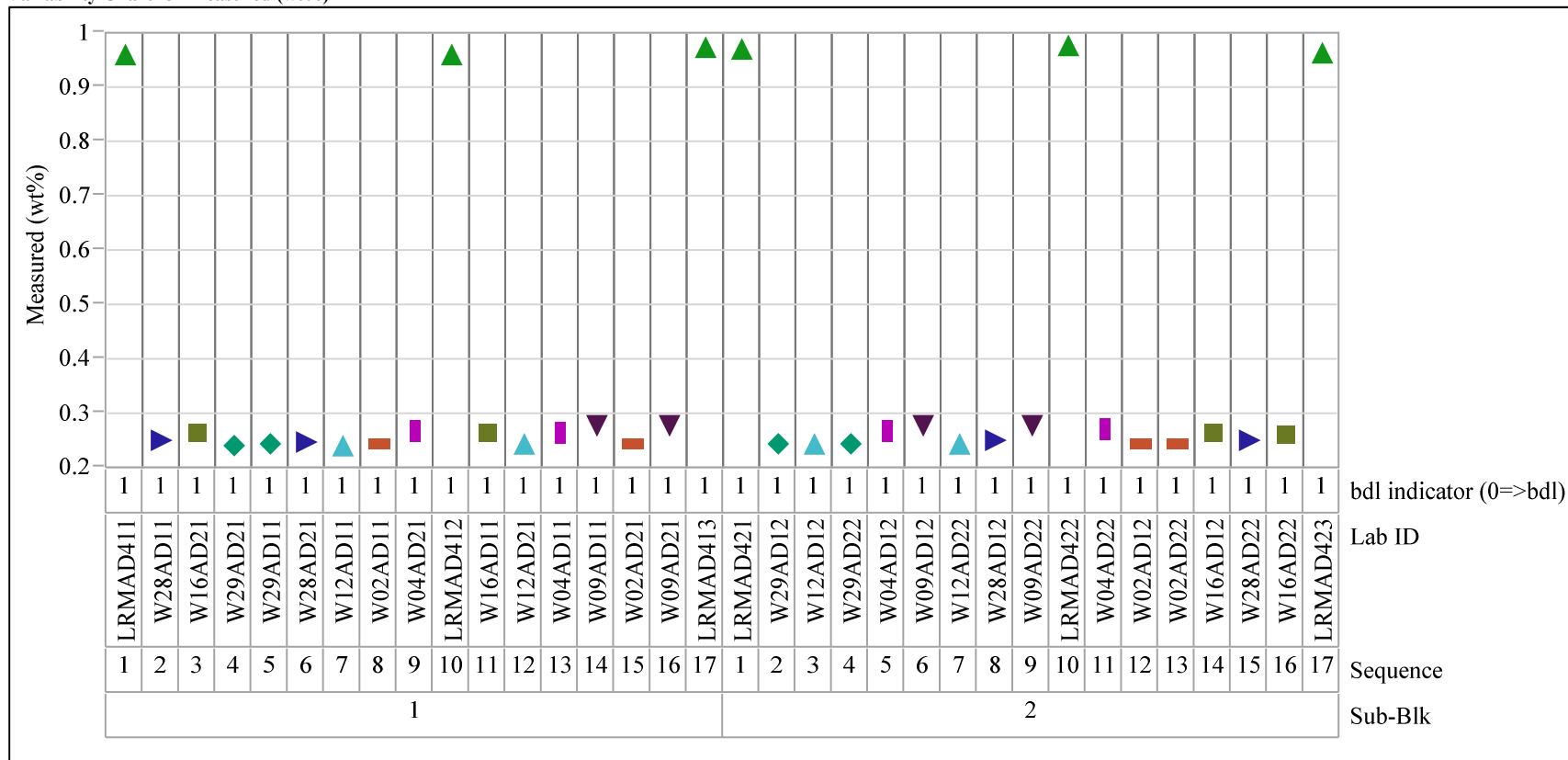
Variability Chart for Measured (wt%)



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

Oxide=ZrO<sub>2</sub> (wt%), Prep Method=AD, Block=4

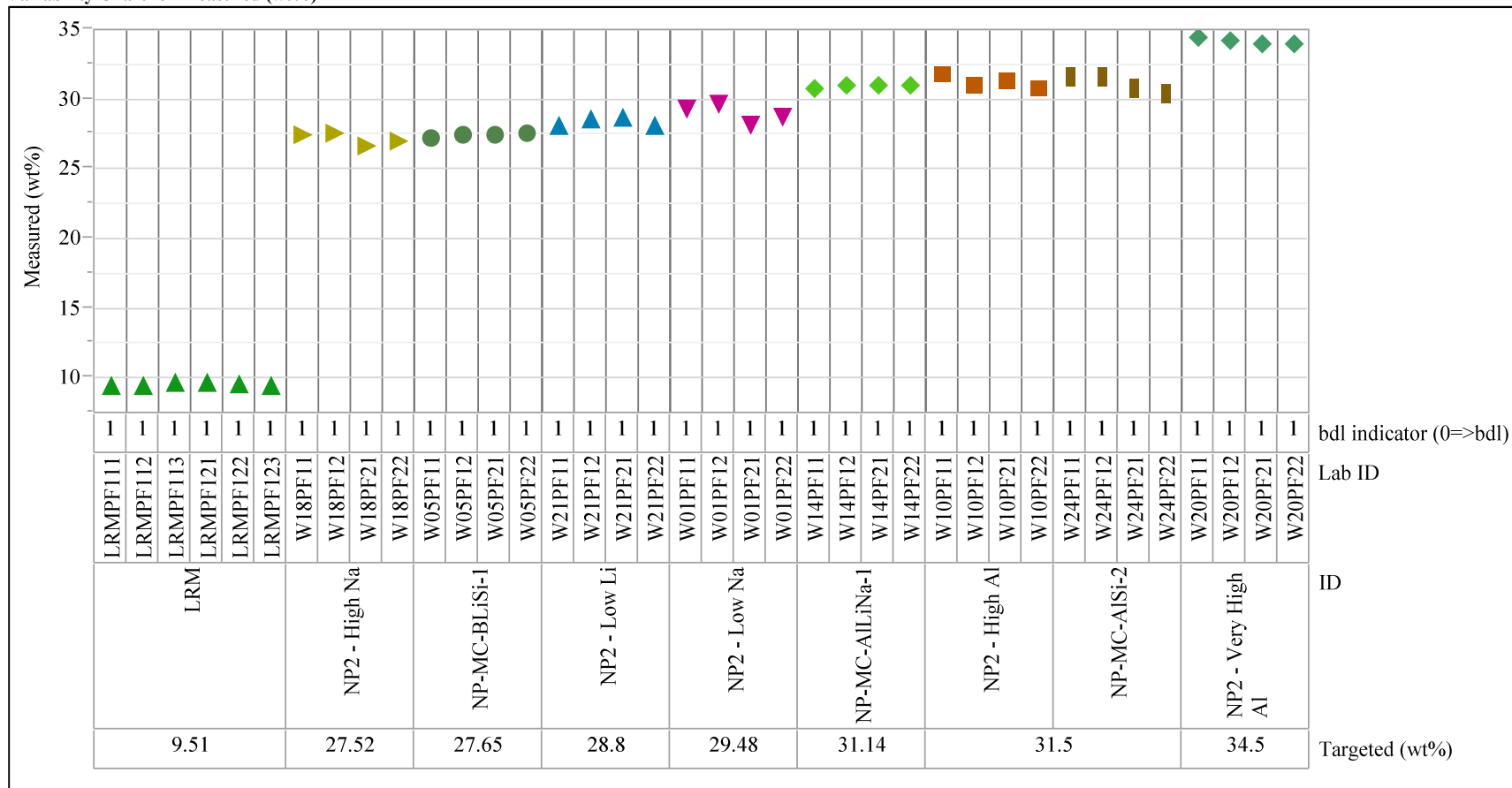
Variability Chart for Measured (wt%)



## Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations

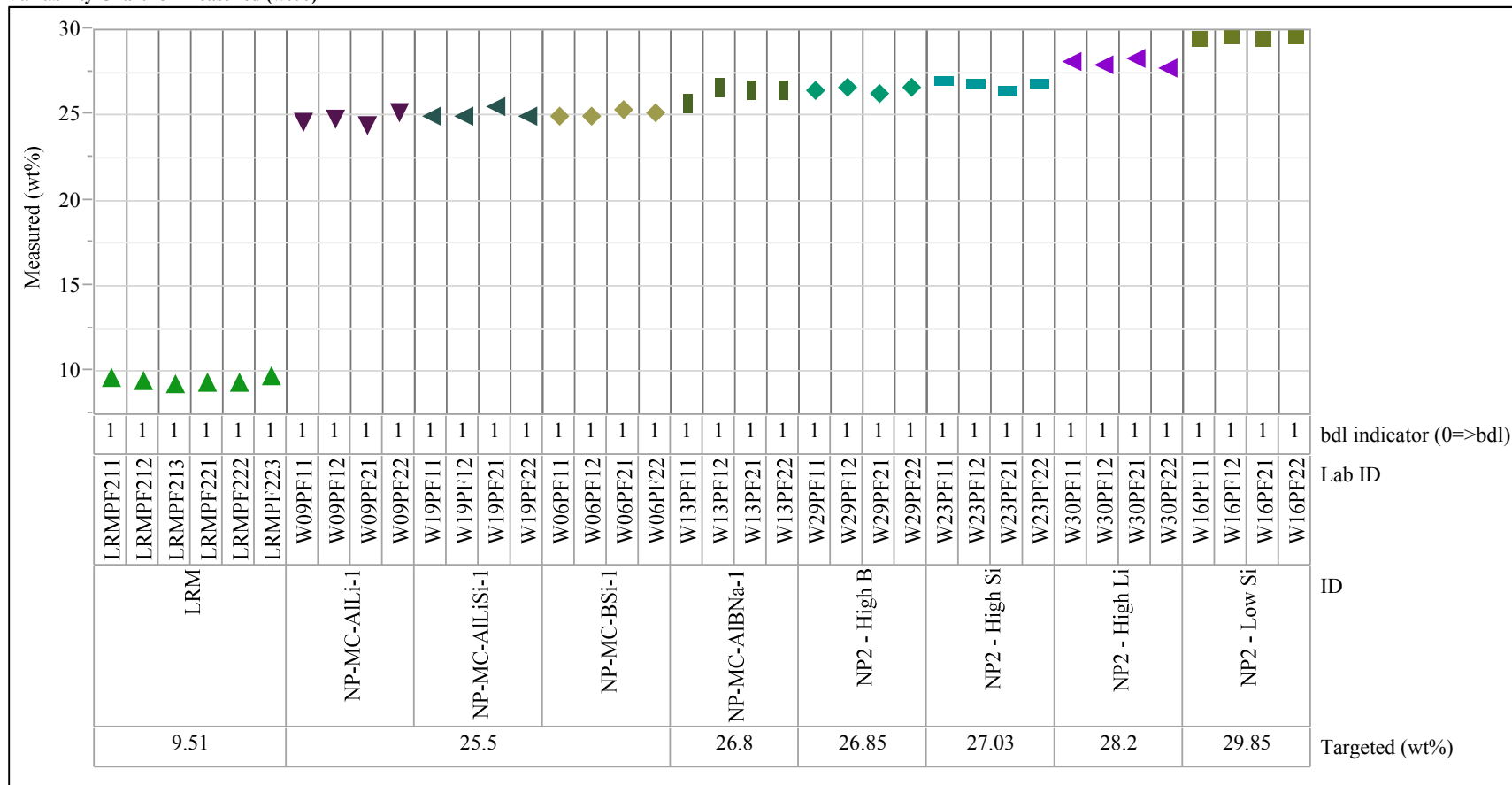
Oxide=Al<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=1

Variability Chart for Measured (wt%)



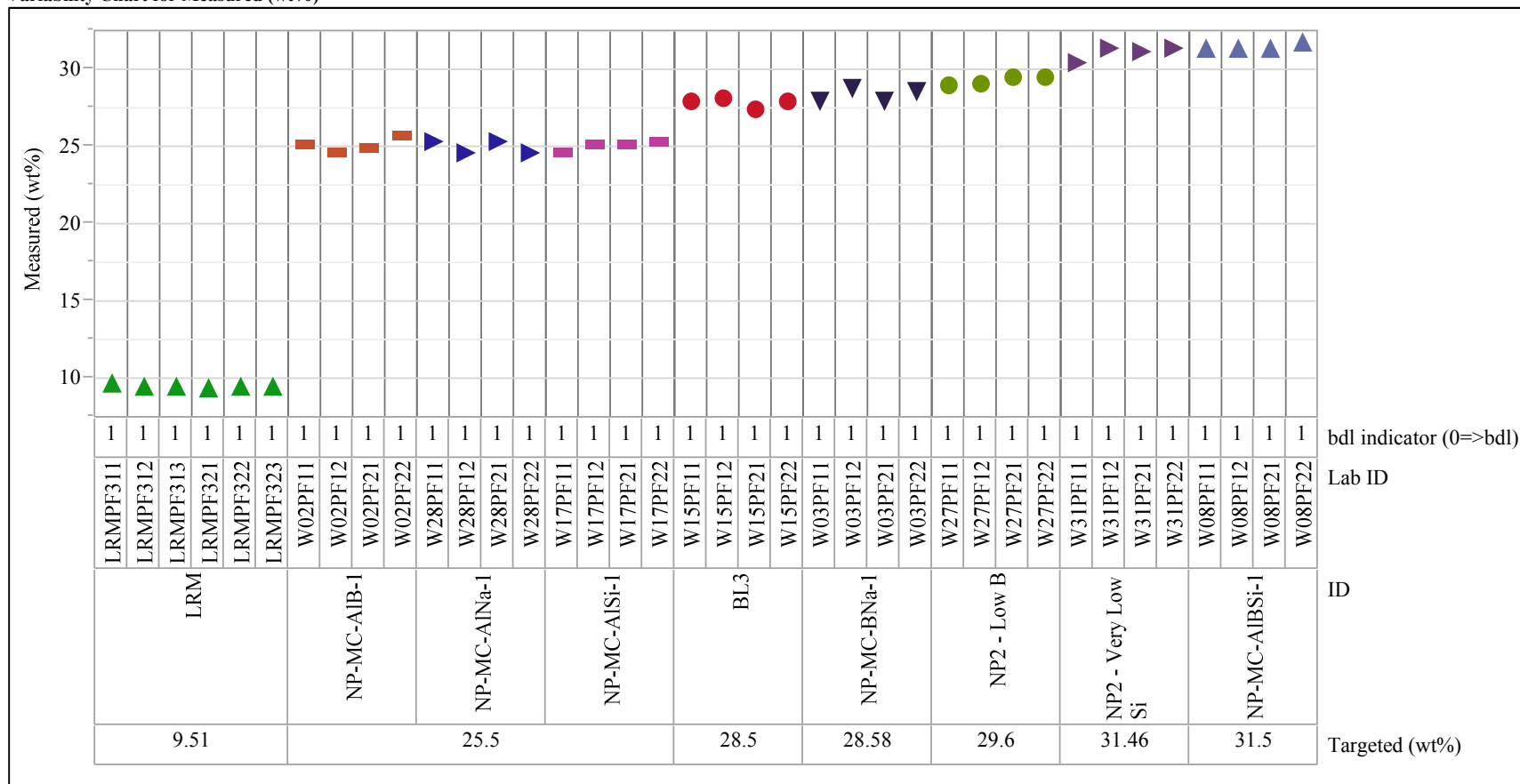
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Al<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=2

Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Al<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=3

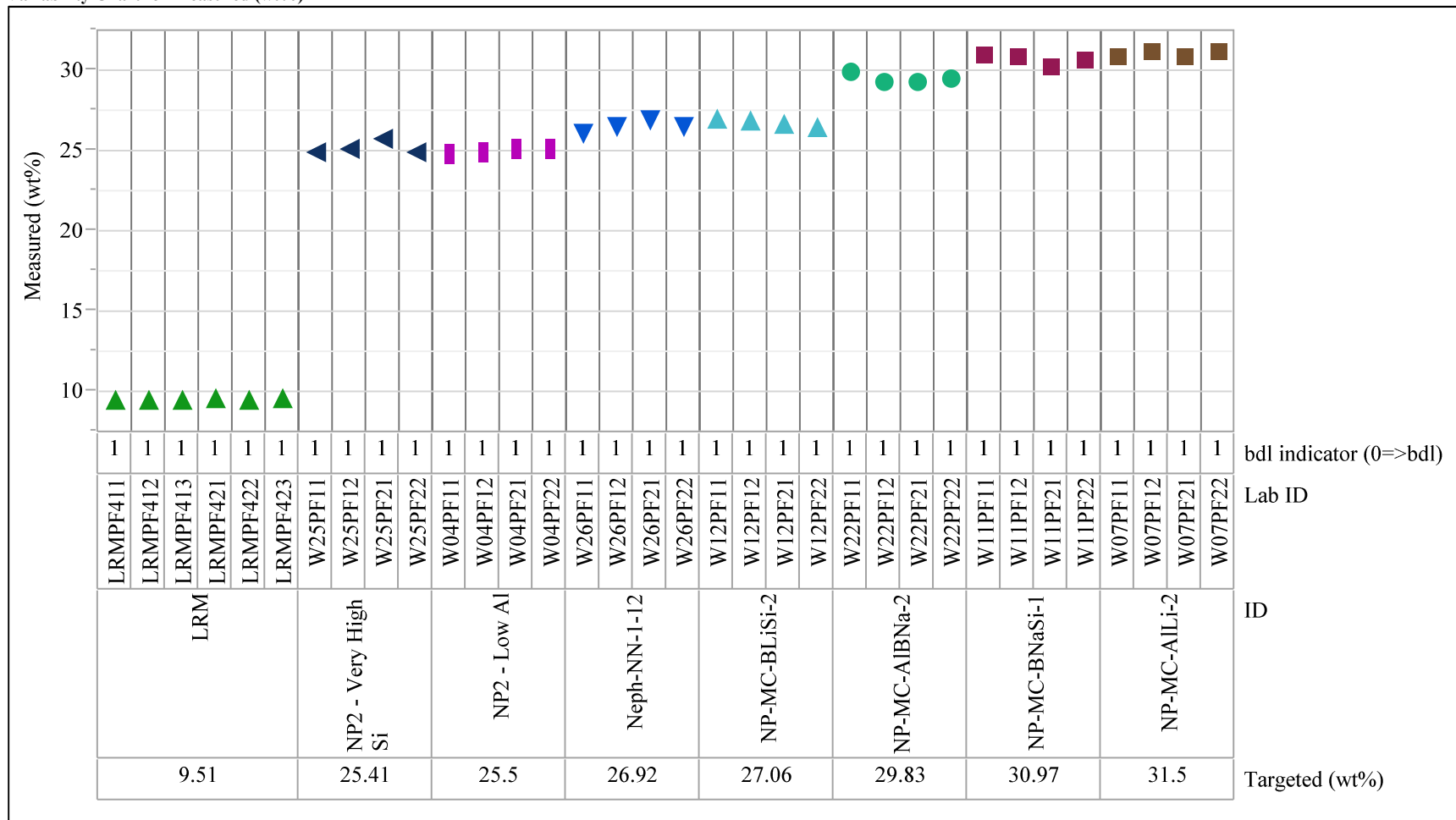
Variability Chart for Measured (wt%)





**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Al<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=4

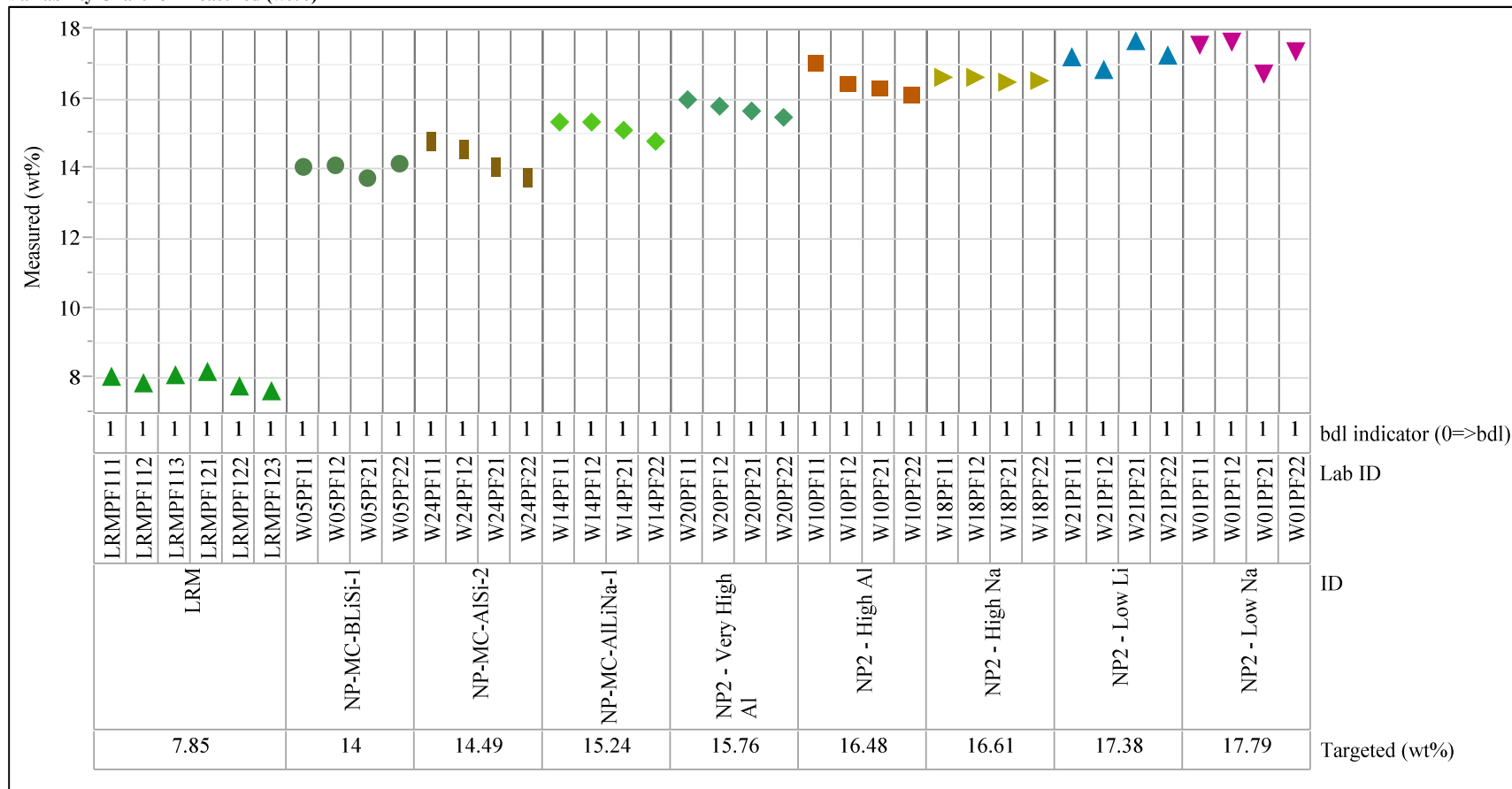
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=B2O3 (wt%), Prep Method=PF, Block=1

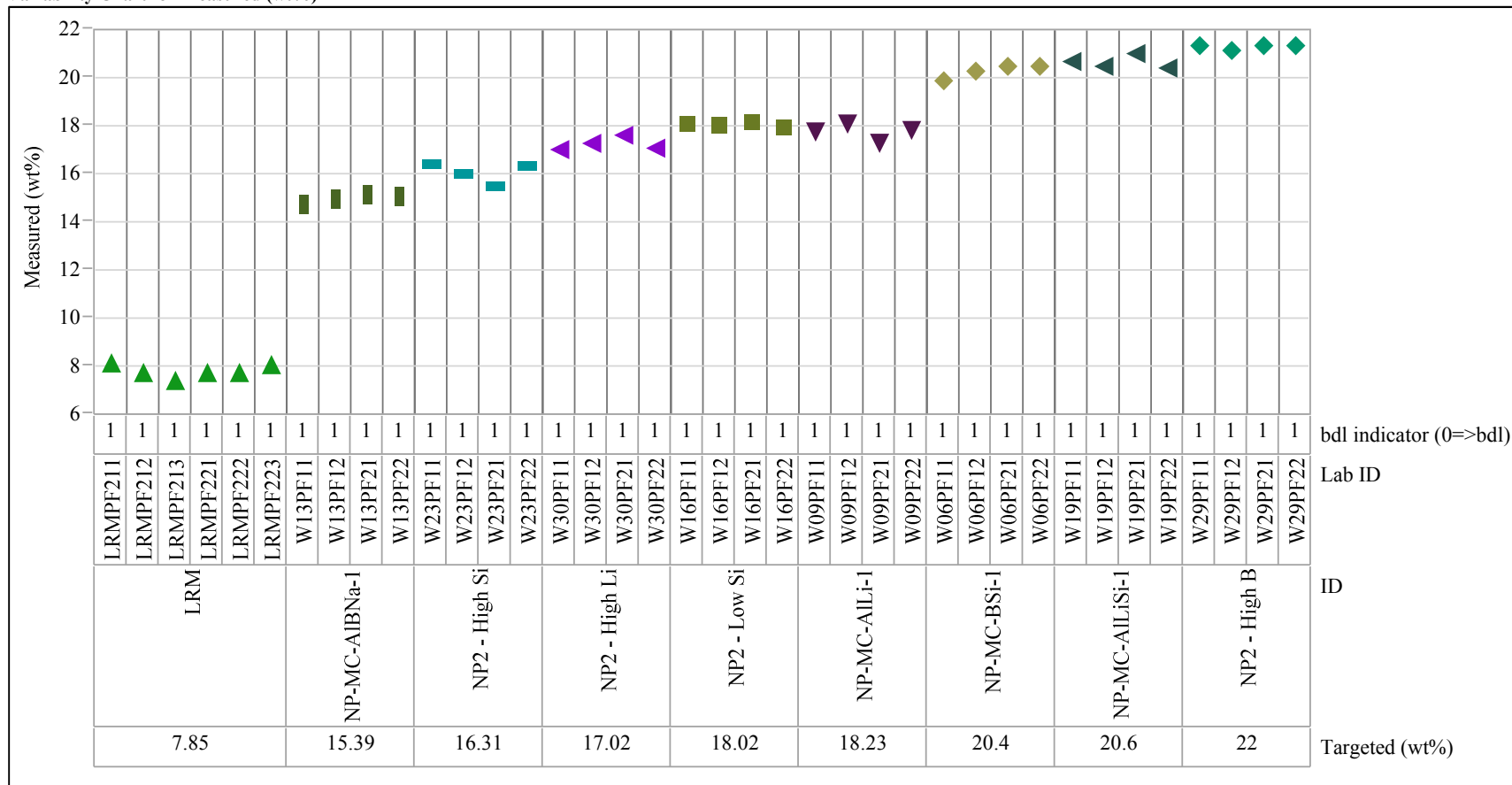
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=B2O3 (wt%), Prep Method=PF, Block=2

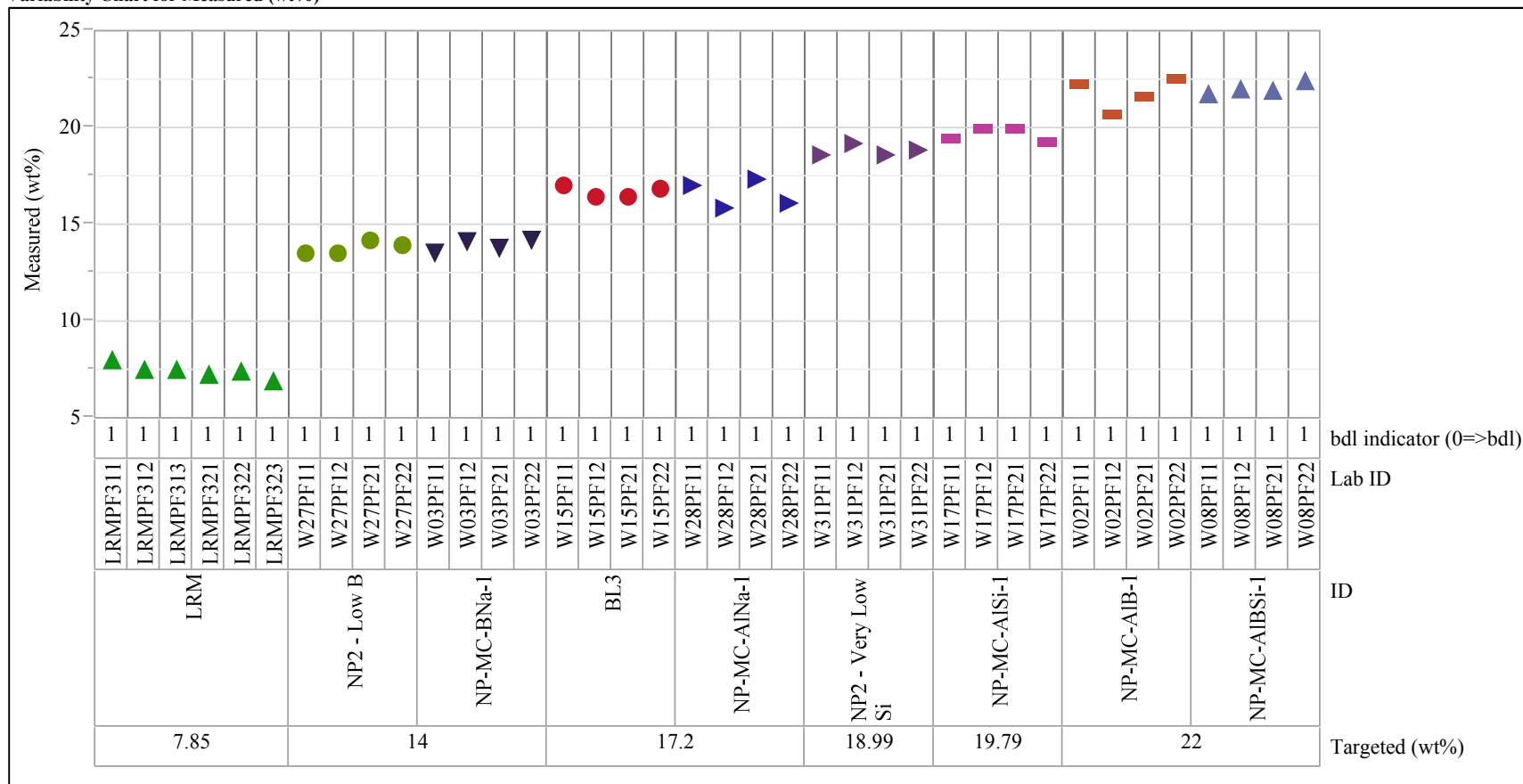
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

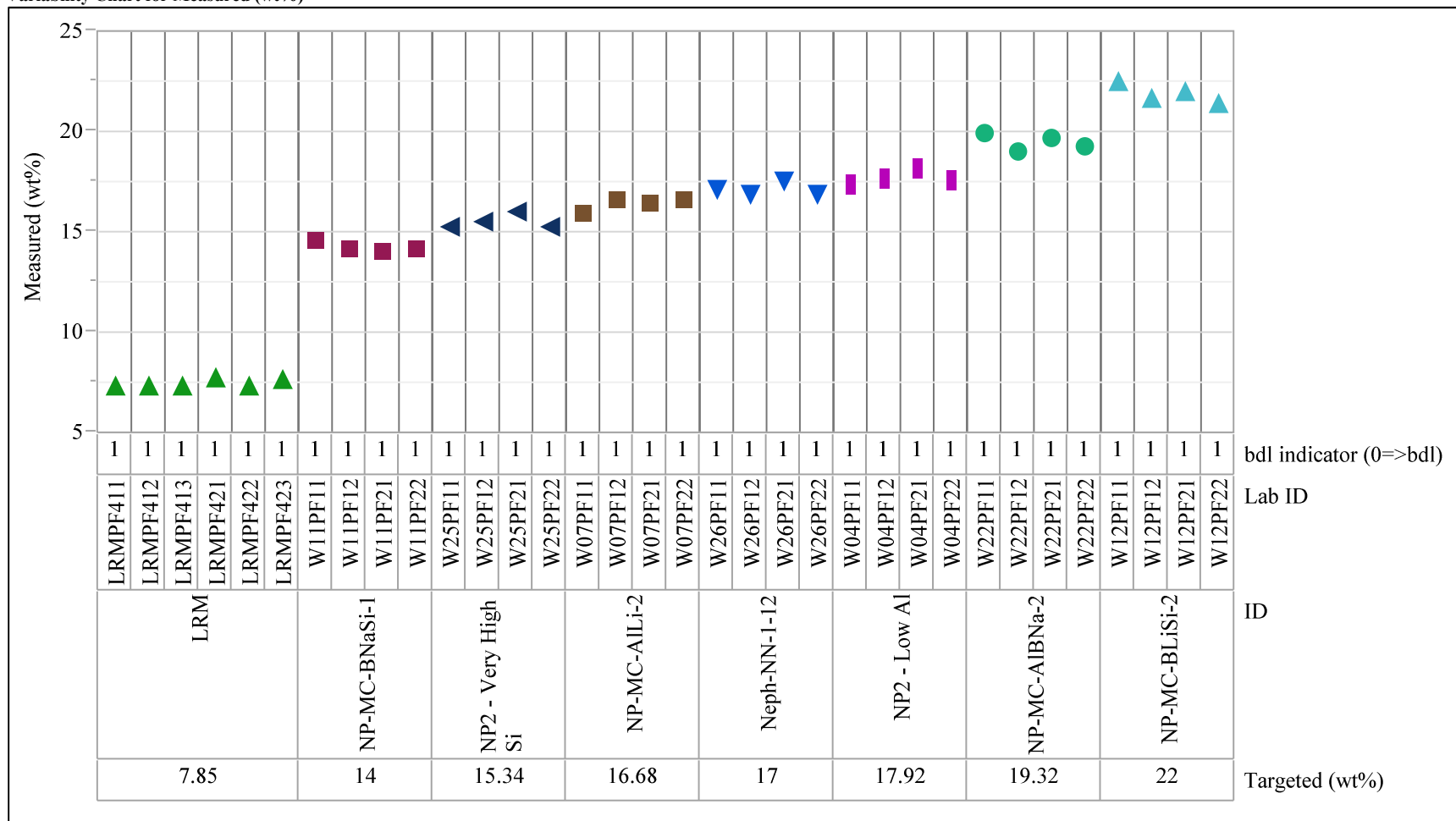
Oxide=B2O3 (wt%), Prep Method=PF, Block=3

Variability Chart for Measured (wt%)



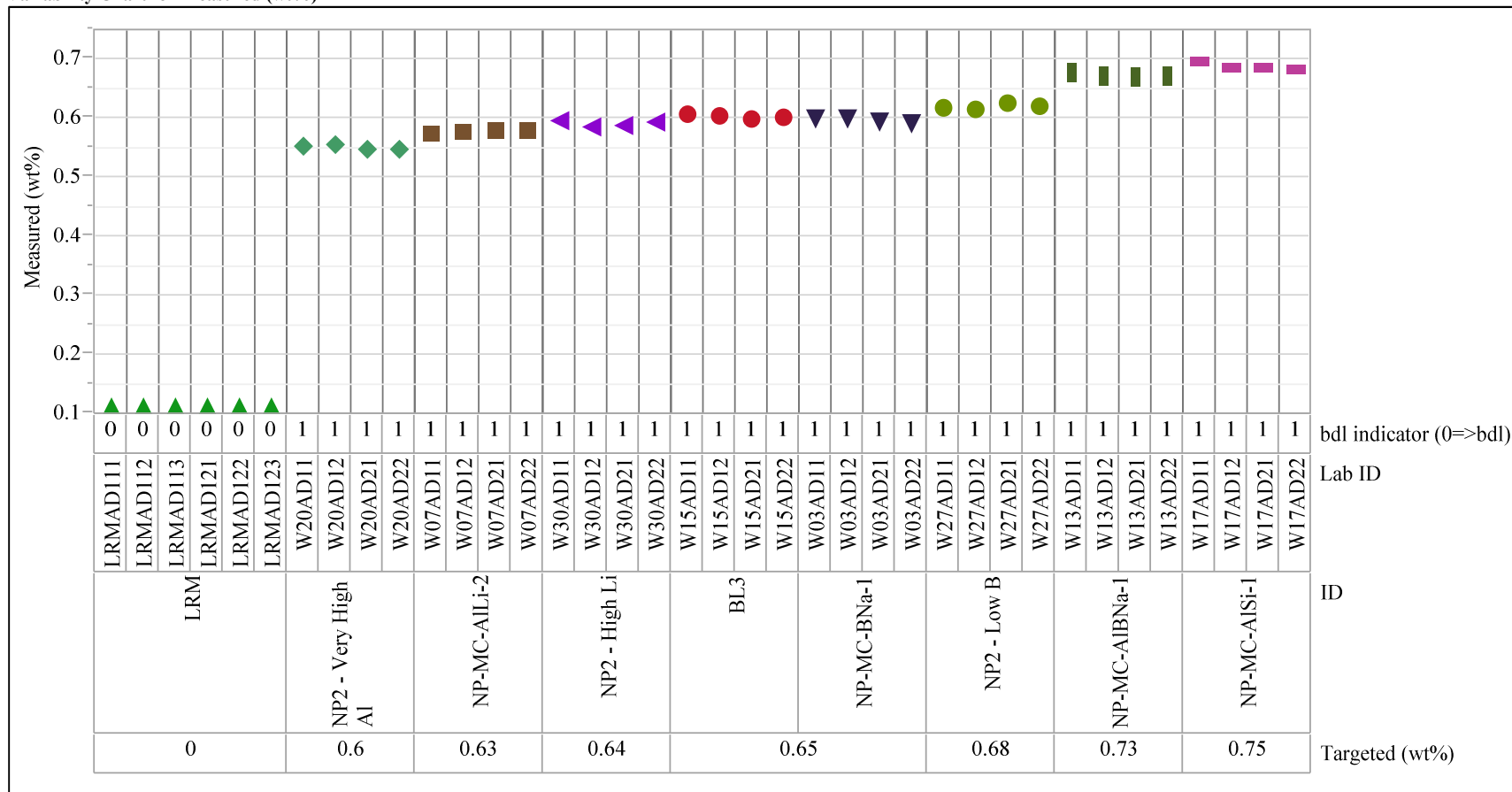
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=B<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=4  
 Variability Chart for Measured (wt%)



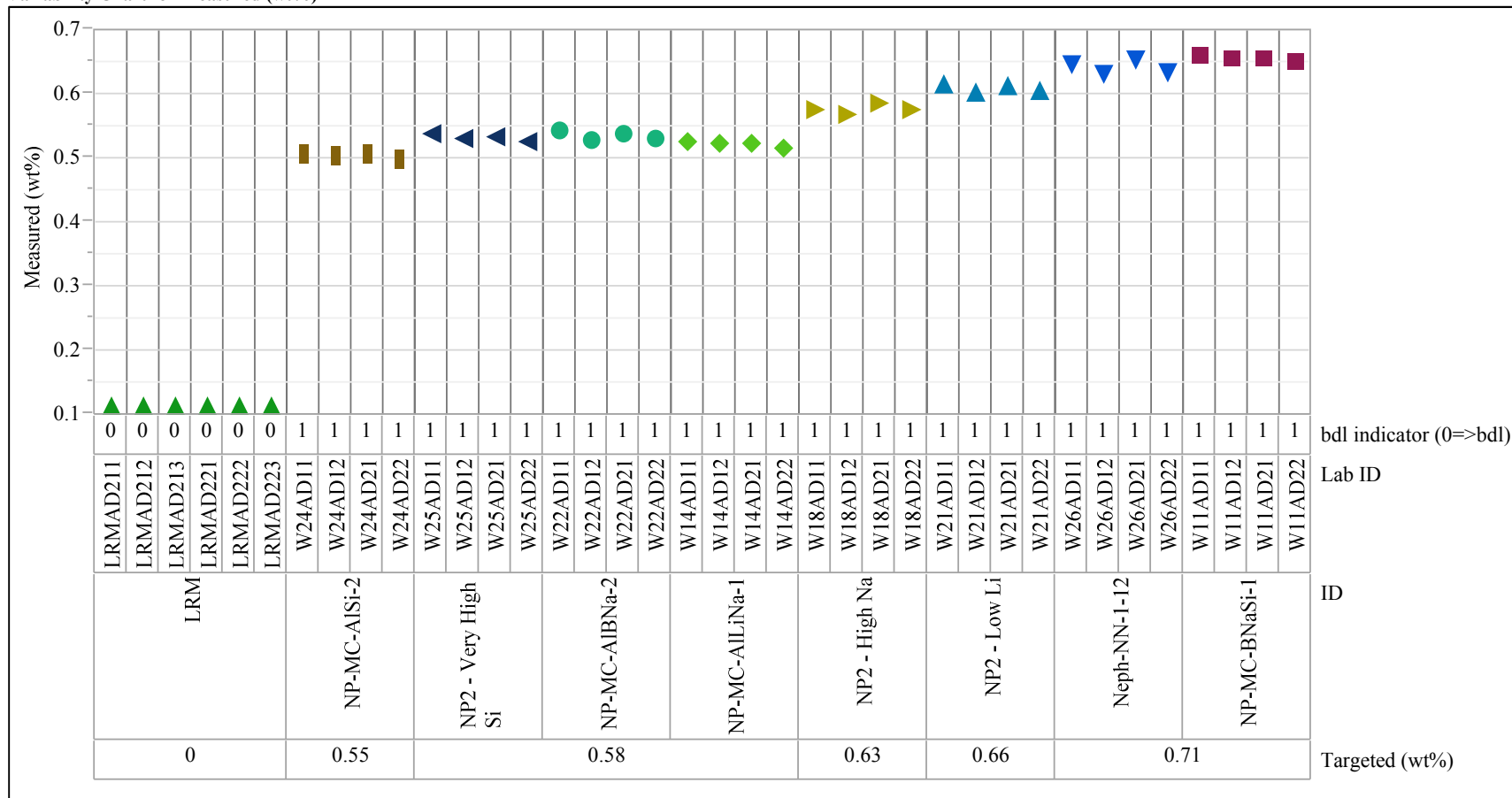
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Bi<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=AD, Block=1

Variability Chart for Measured (wt%)



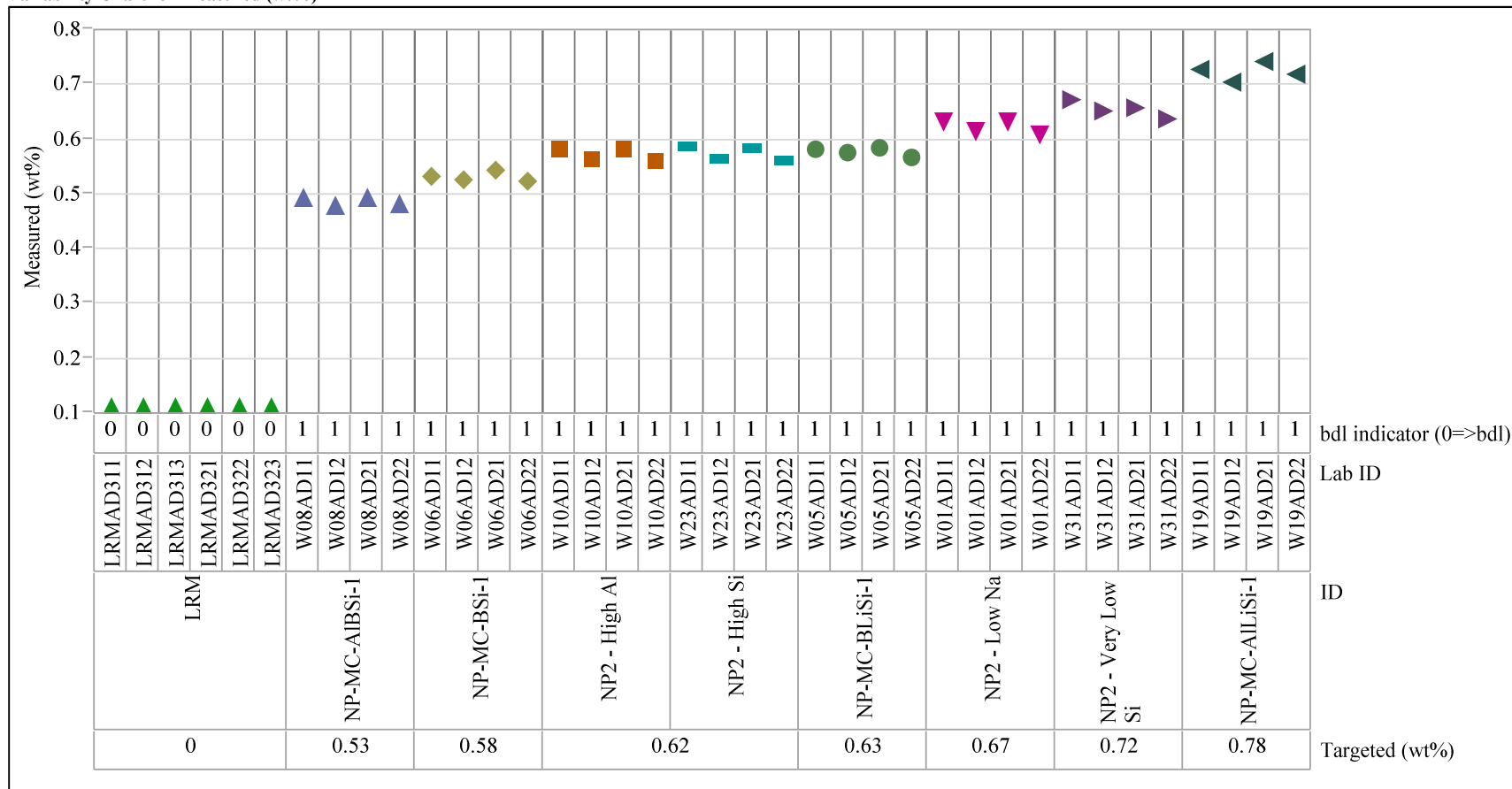
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Bi<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=AD, Block=2

Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Bi<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=AD, Block=3

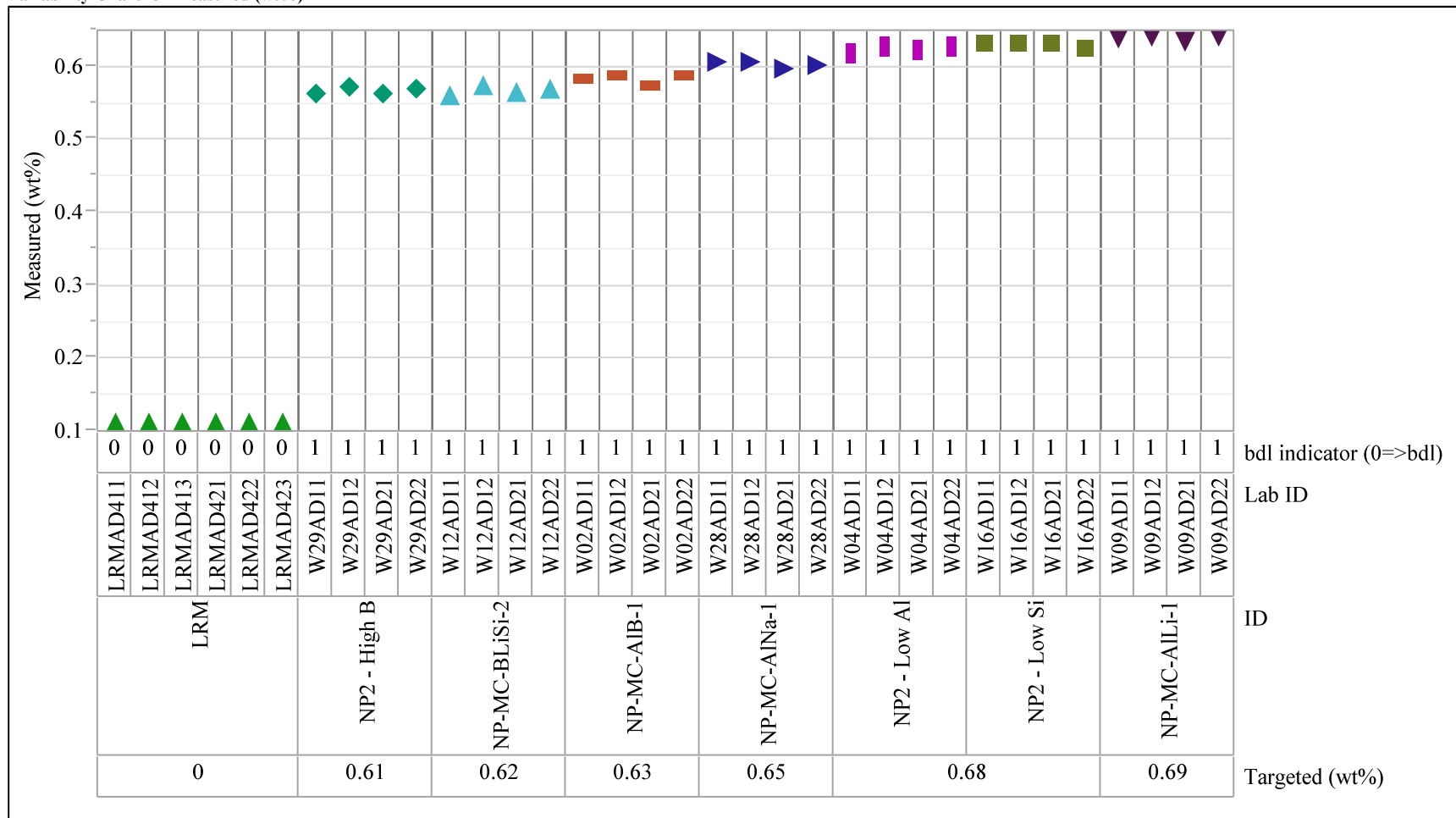
Variability Chart for Measured (wt%)





**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Bi<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=AD, Block=4

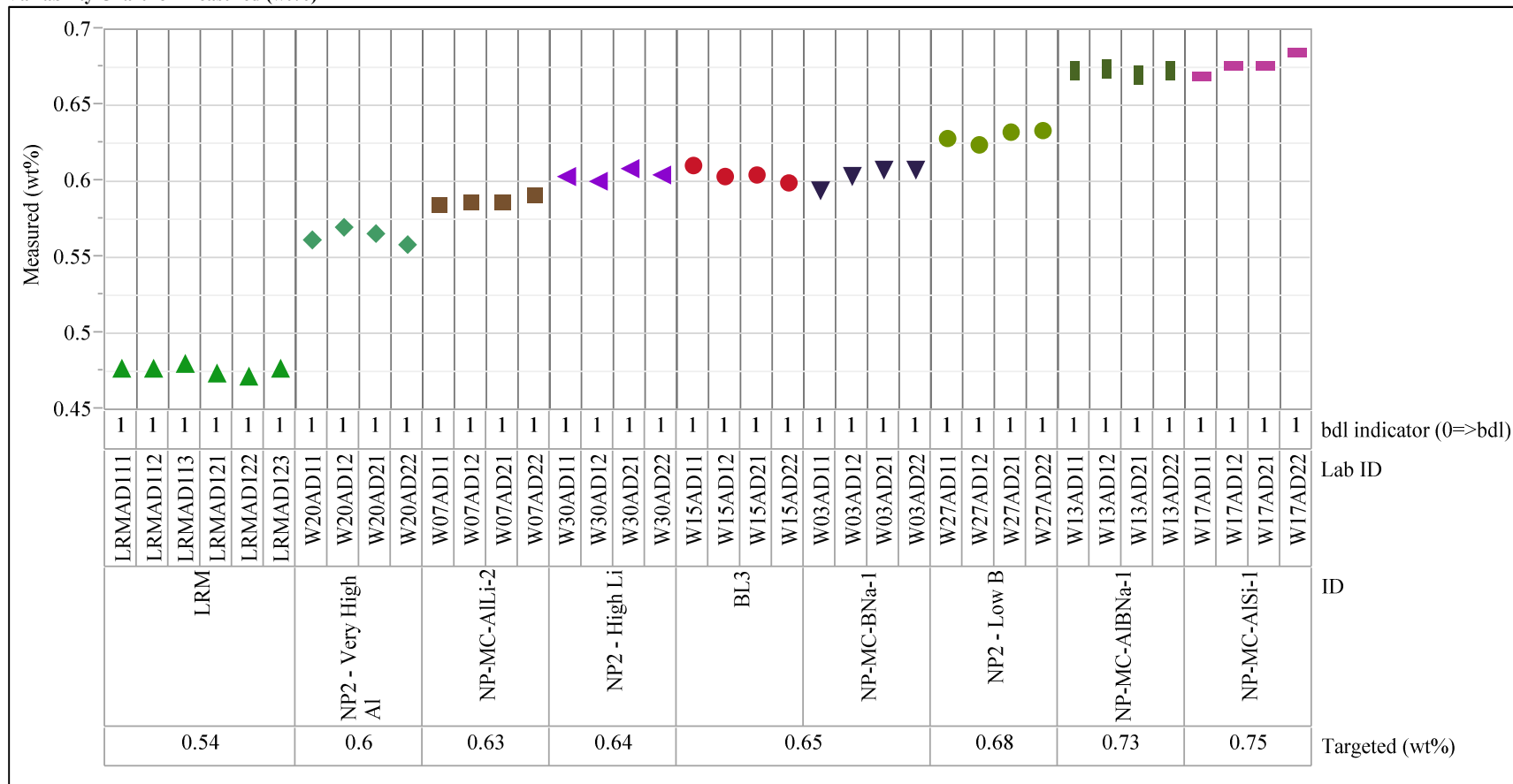
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=CaO (wt%), Prep Method=AD, Block=1

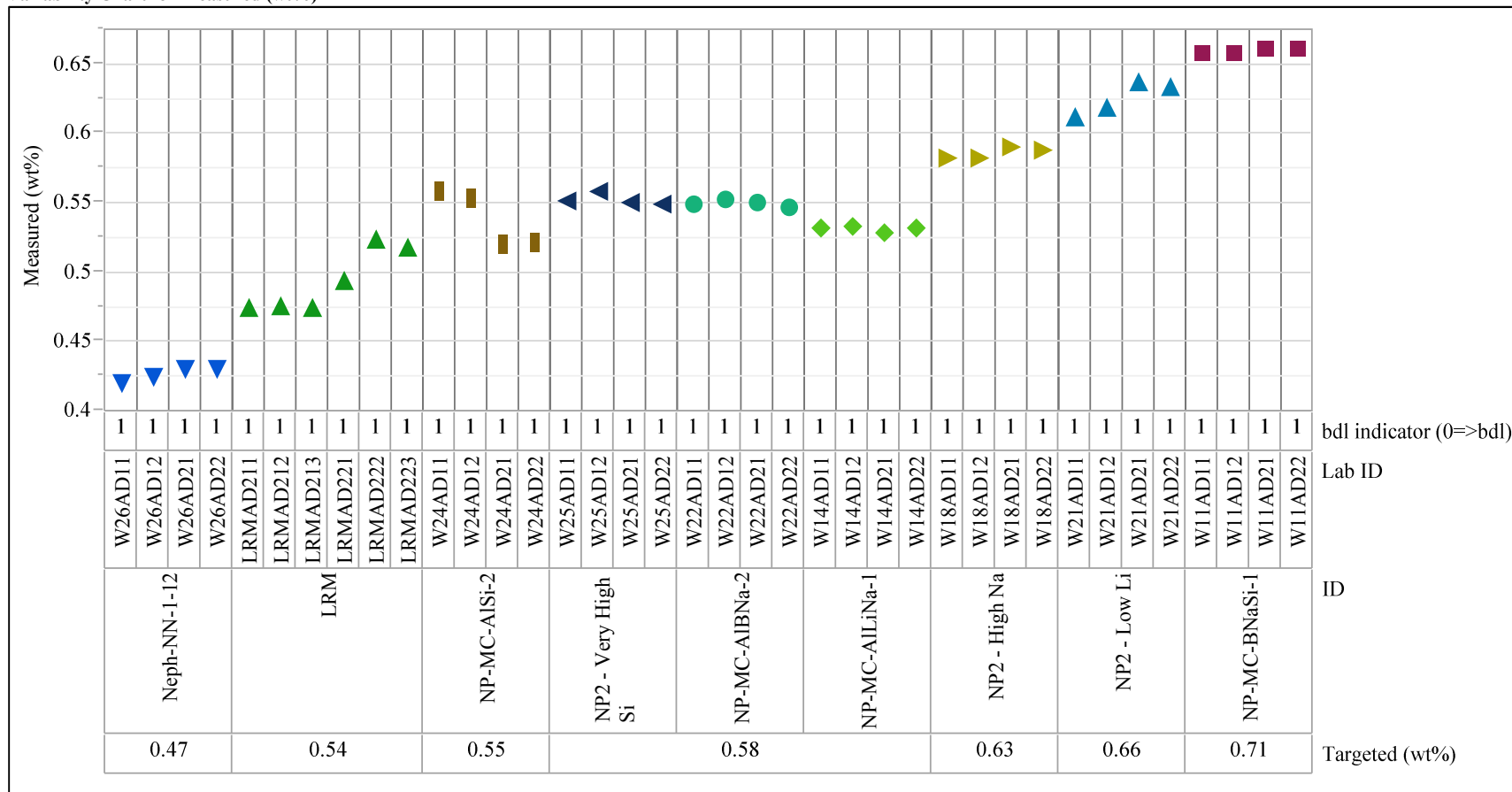
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=CaO (wt%), Prep Method=AD, Block=2

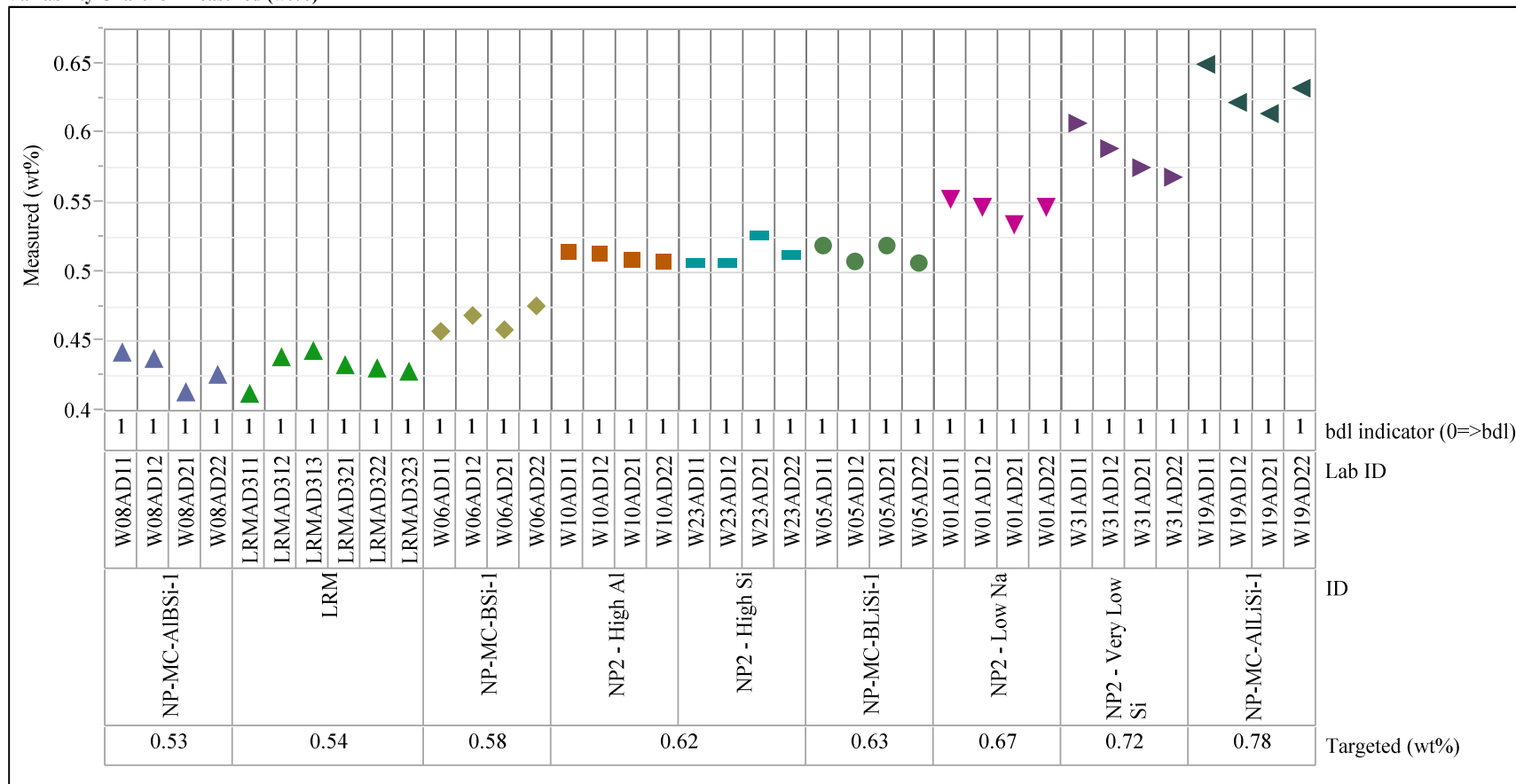
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=CaO (wt%), Prep Method=AD, Block=3

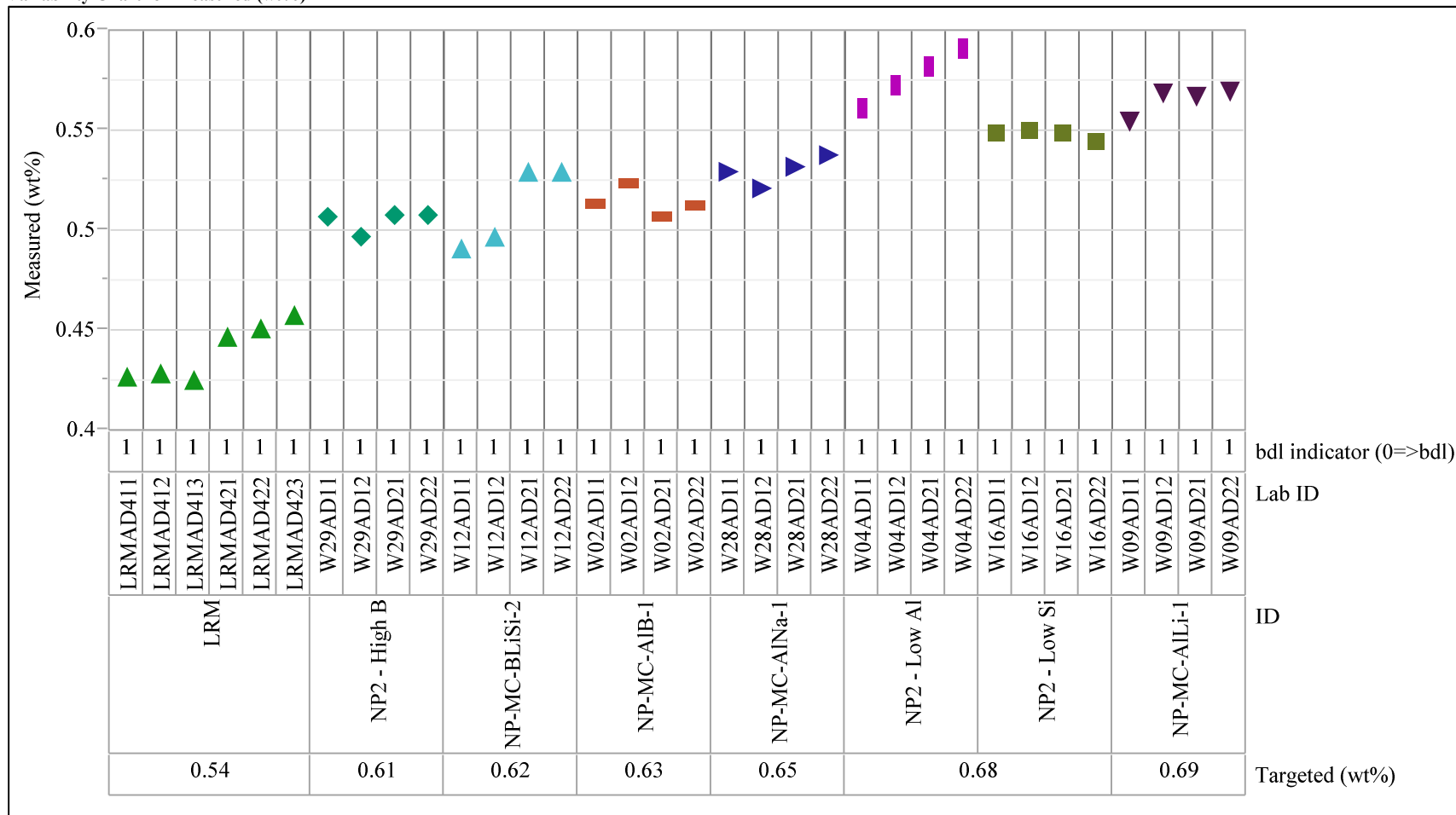
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

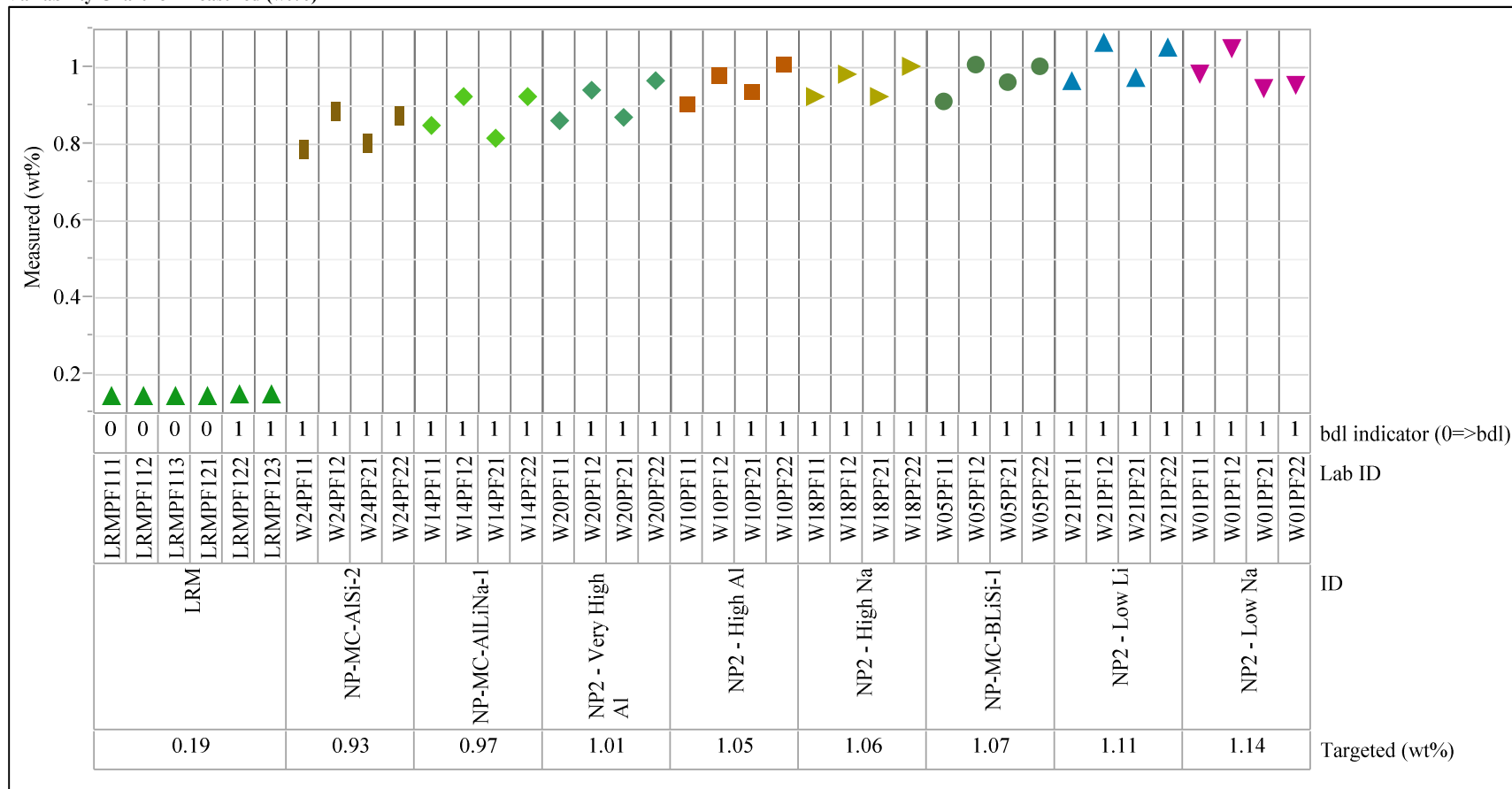
Oxide=CaO (wt%), Prep Method=AD, Block=4

Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Cr<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=1

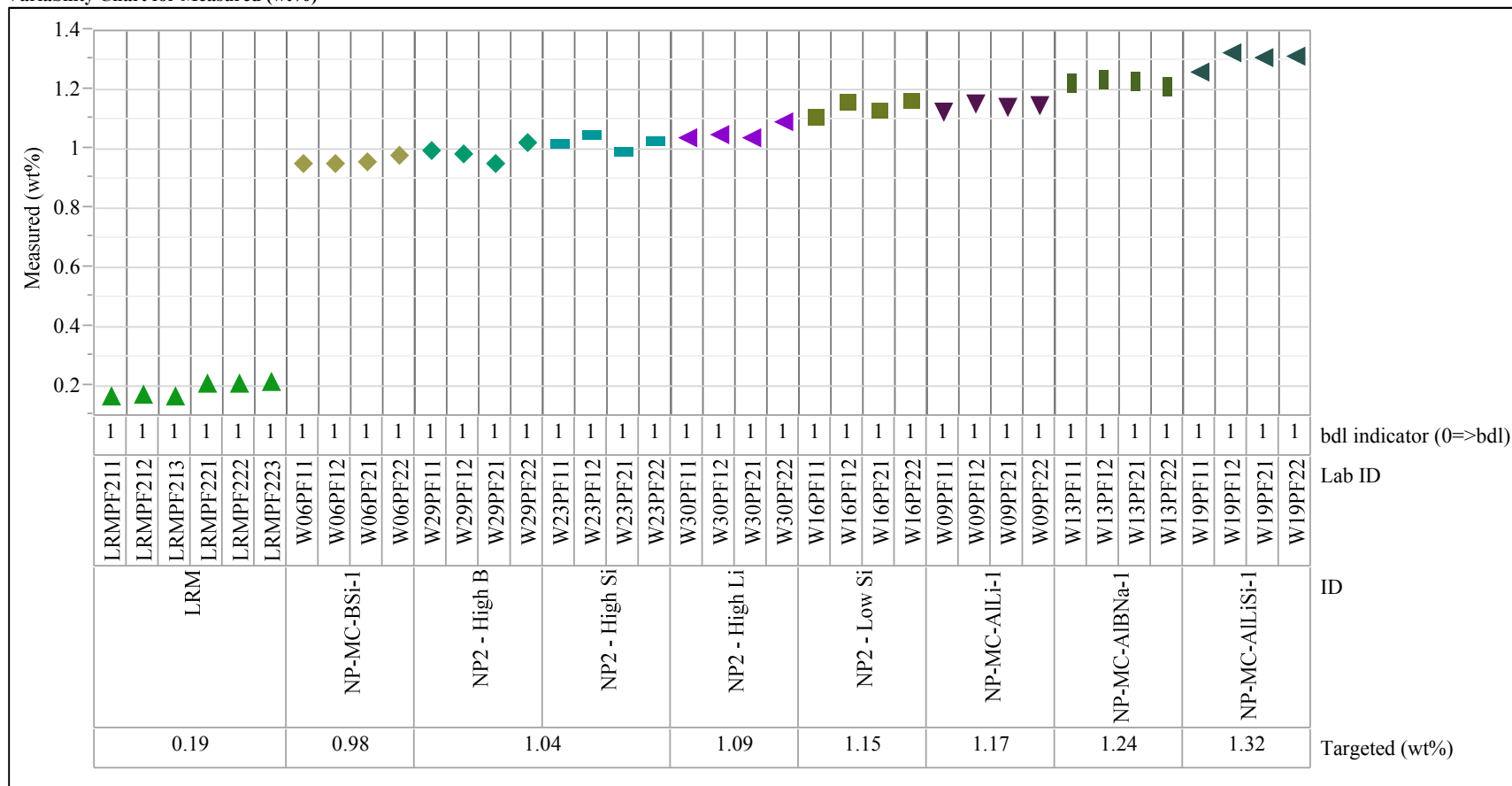
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

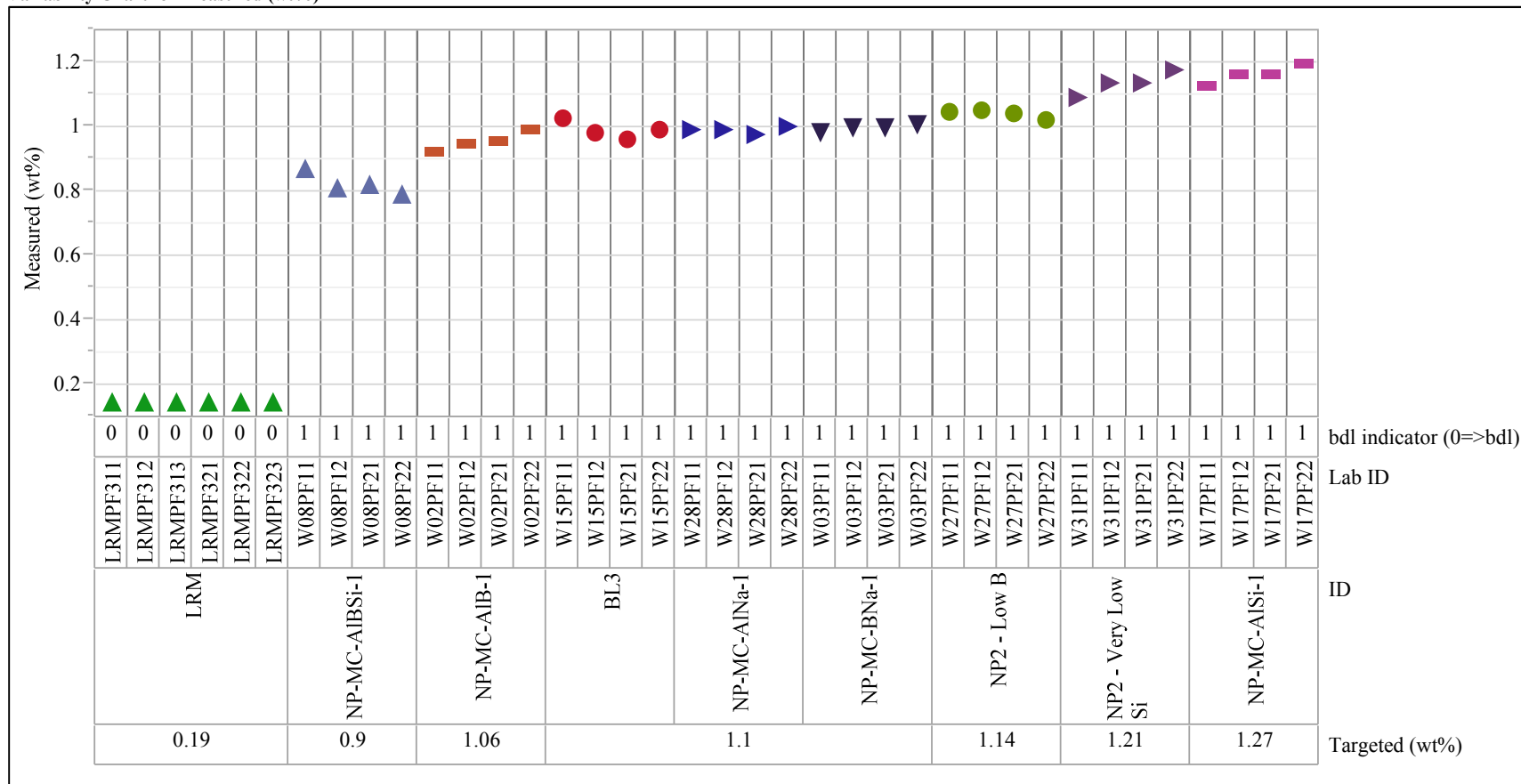
Oxide=Cr2O3 (wt%), Prep Method=PF, Block=2

Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Cr<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=3

Variability Chart for Measured (wt%)

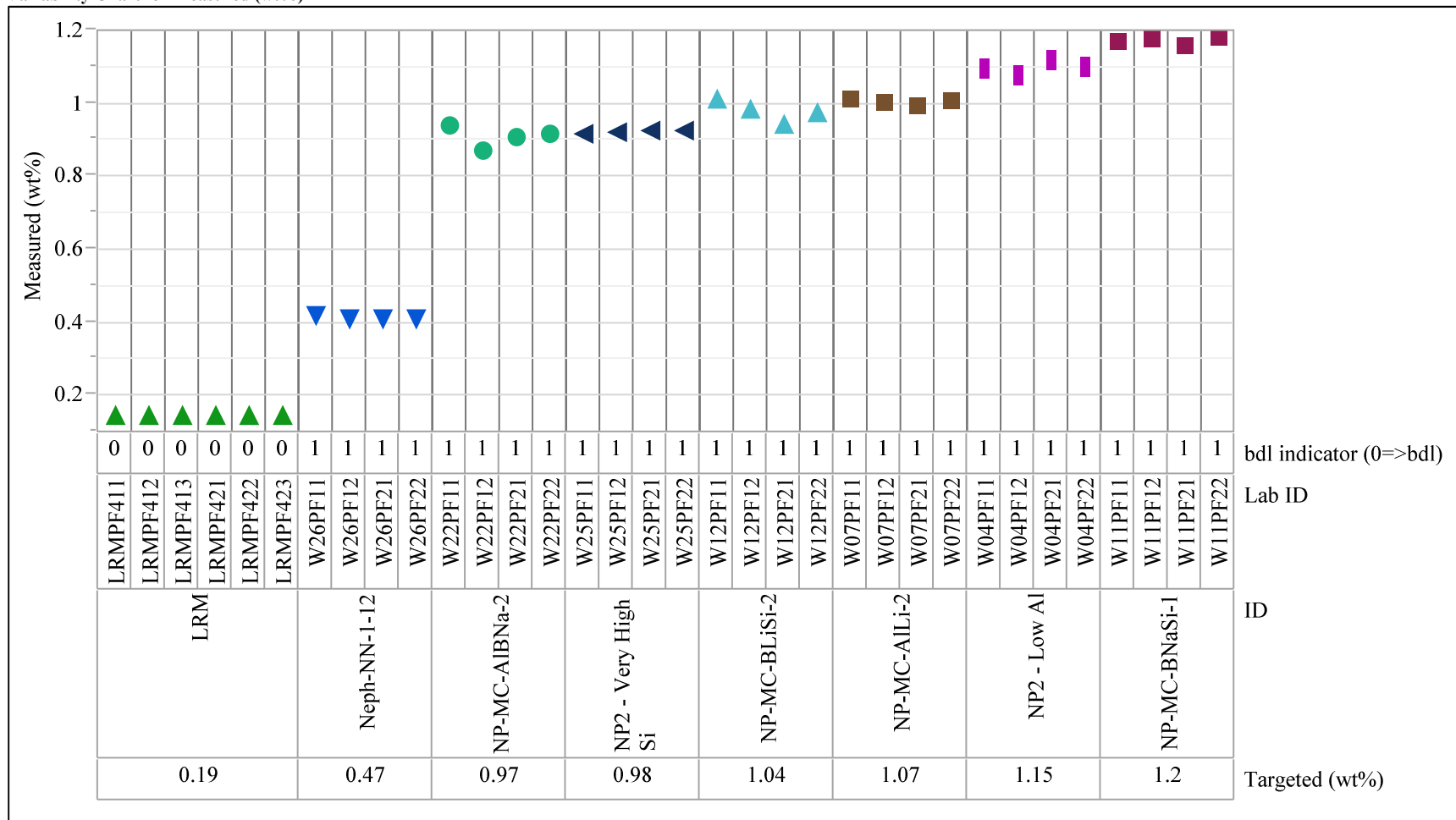




**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

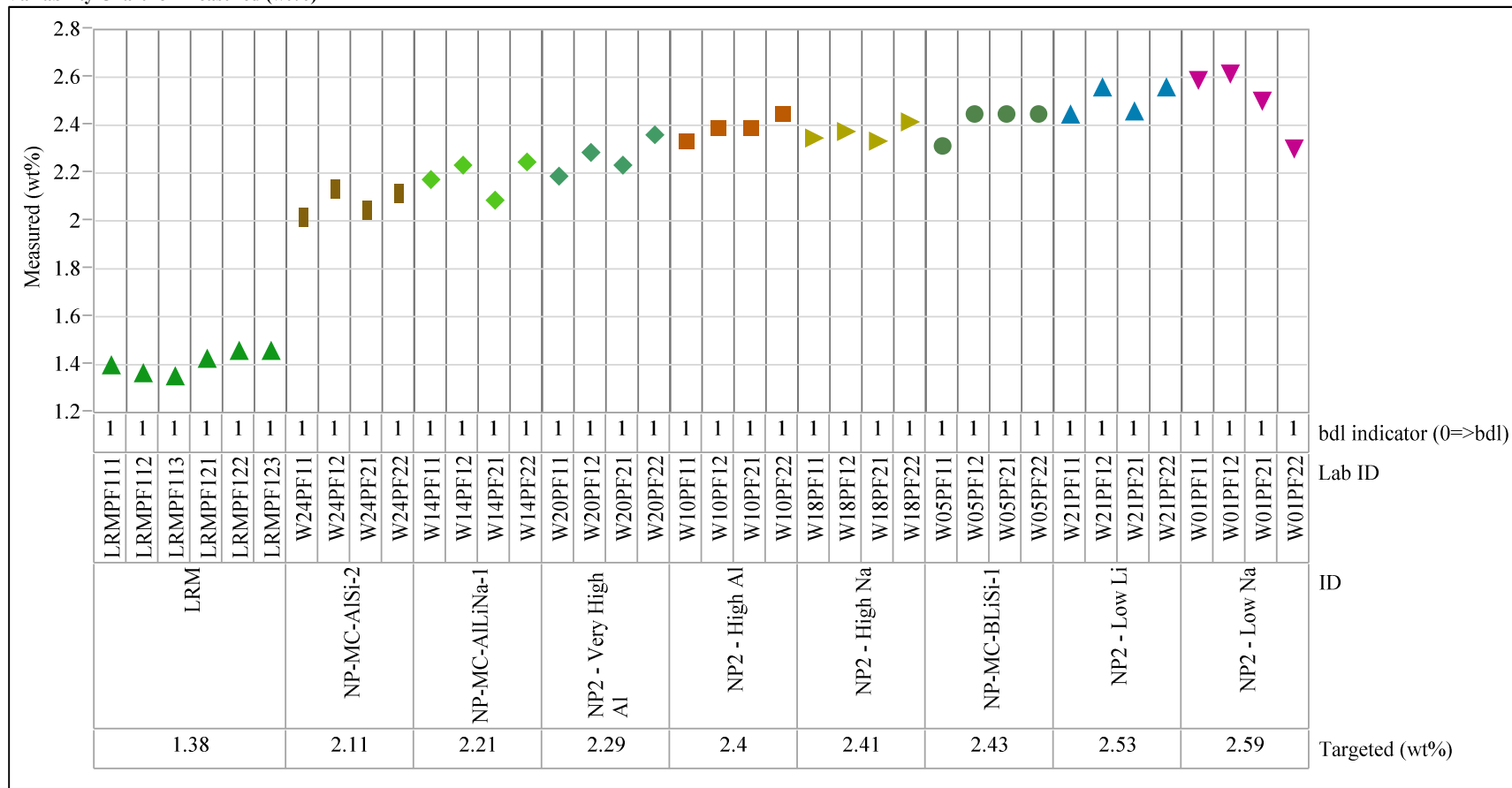
Oxide=Cr2O3 (wt%), Prep Method=PF, Block=4

Variability Chart for Measured (wt%)



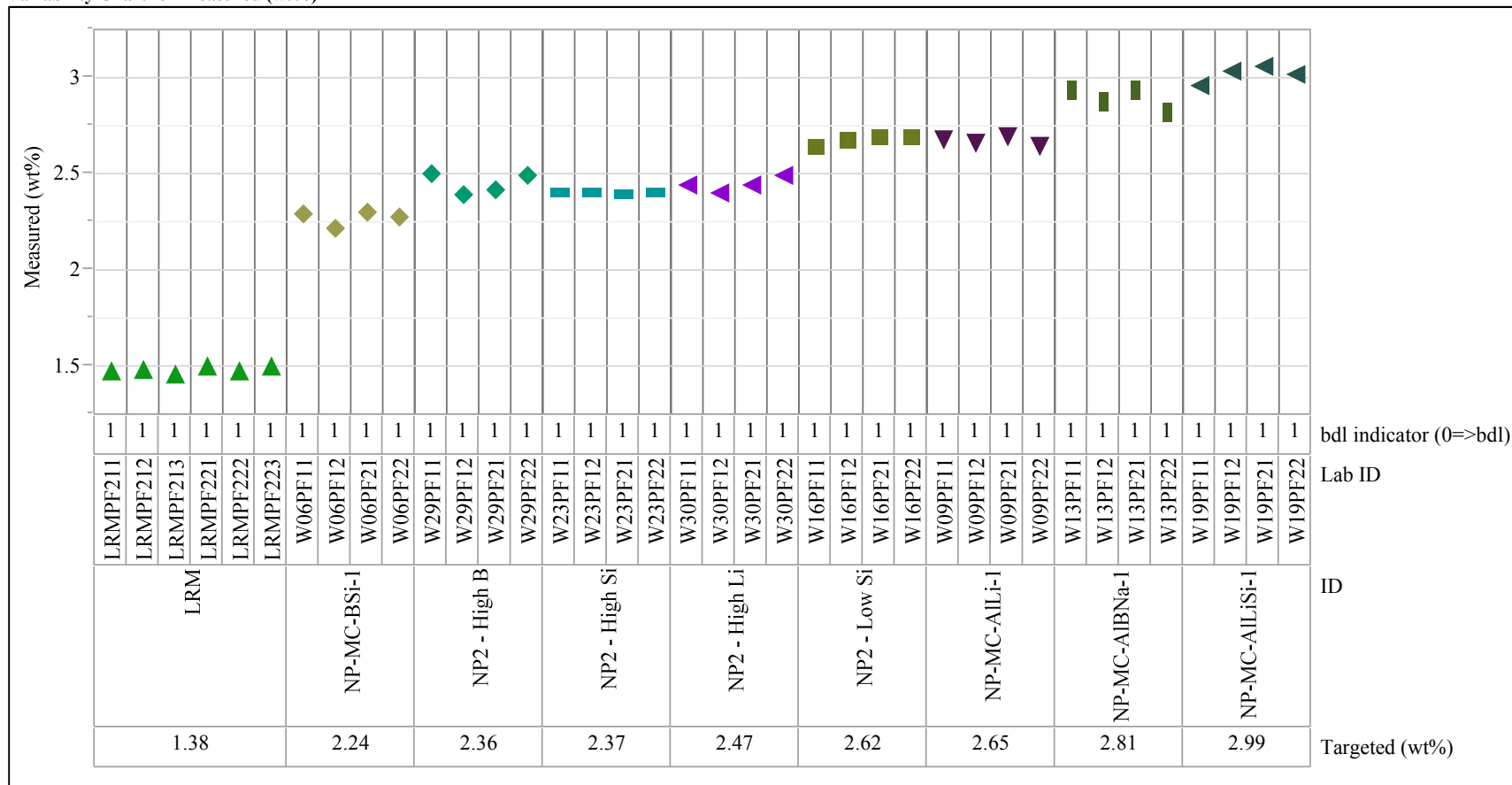
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Fe<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=1

Variability Chart for Measured (wt%)



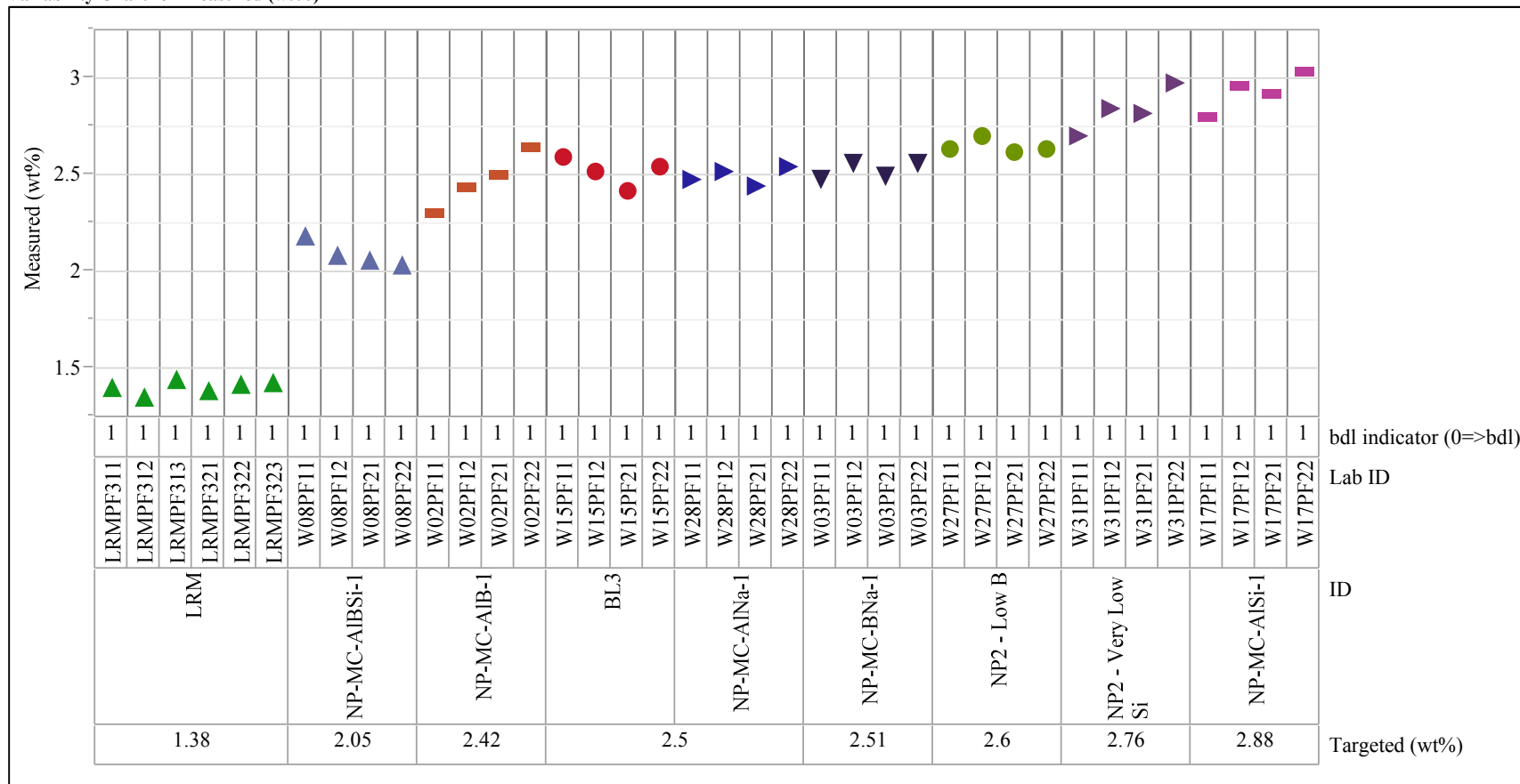
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Fe<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=2

Variability Chart for Measured (wt%)



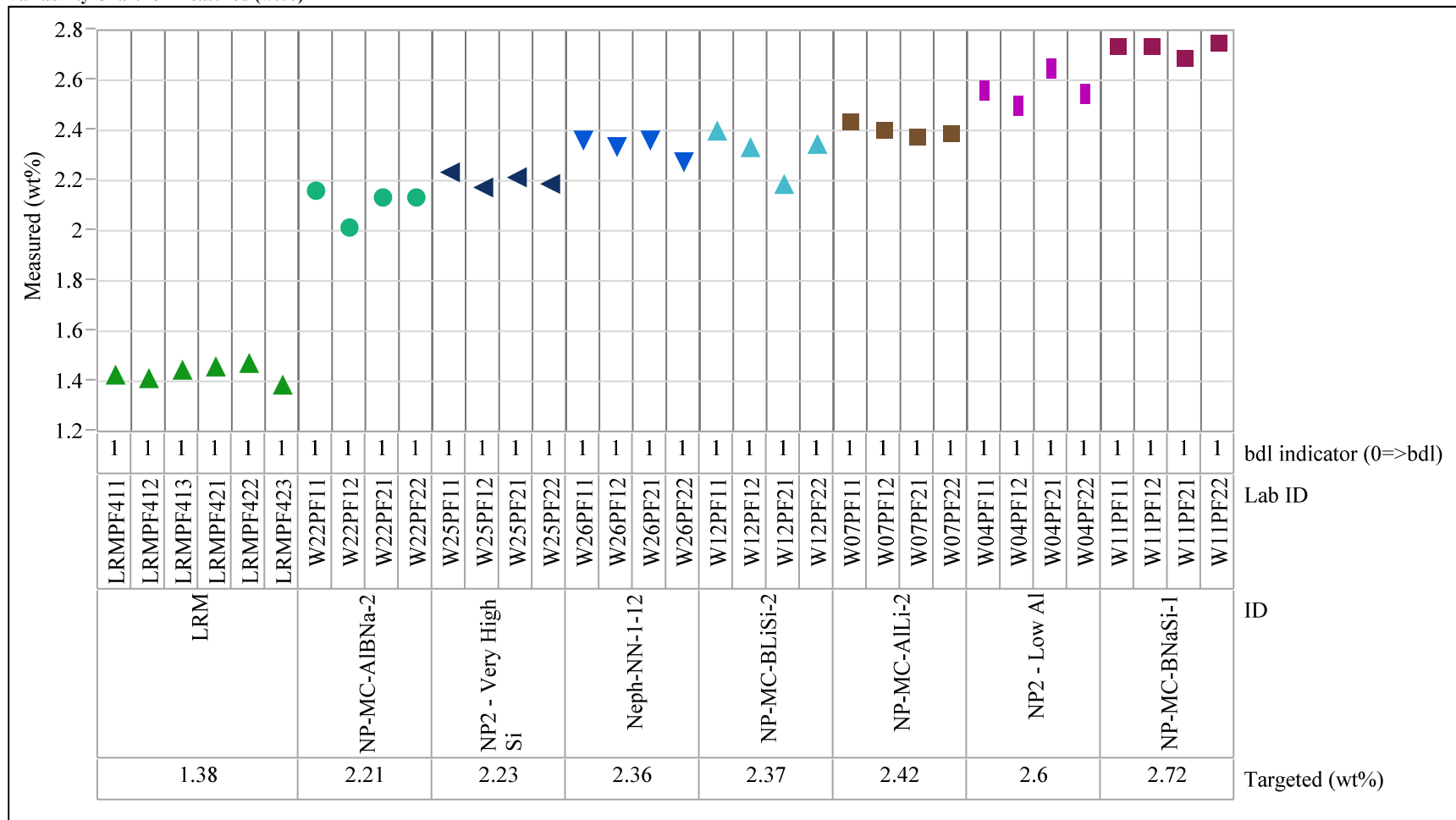
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Fe<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=3

Variability Chart for Measured (wt%)



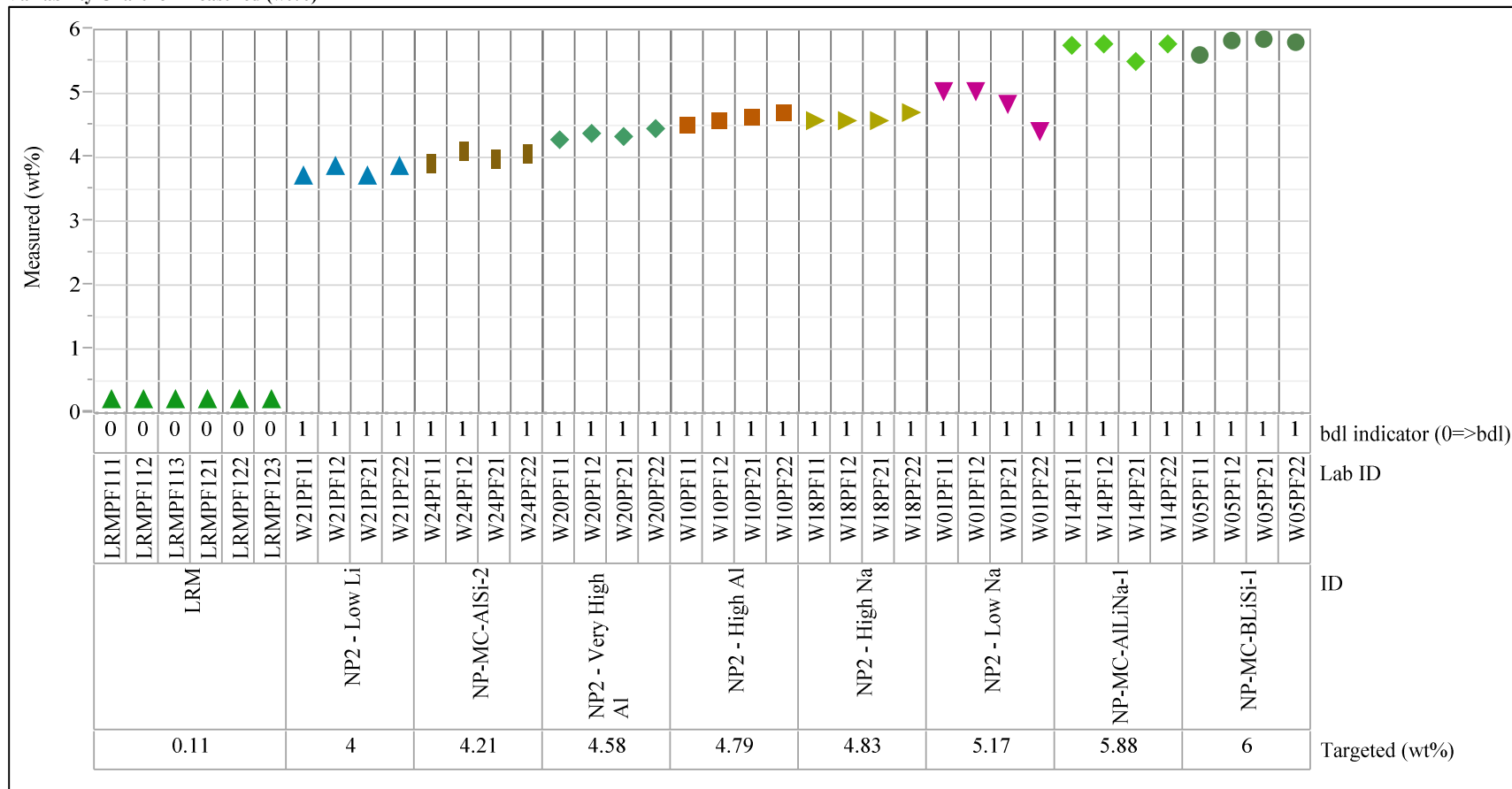
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Fe<sub>2</sub>O<sub>3</sub> (wt%), Prep Method=PF, Block=4

Variability Chart for Measured (wt%)



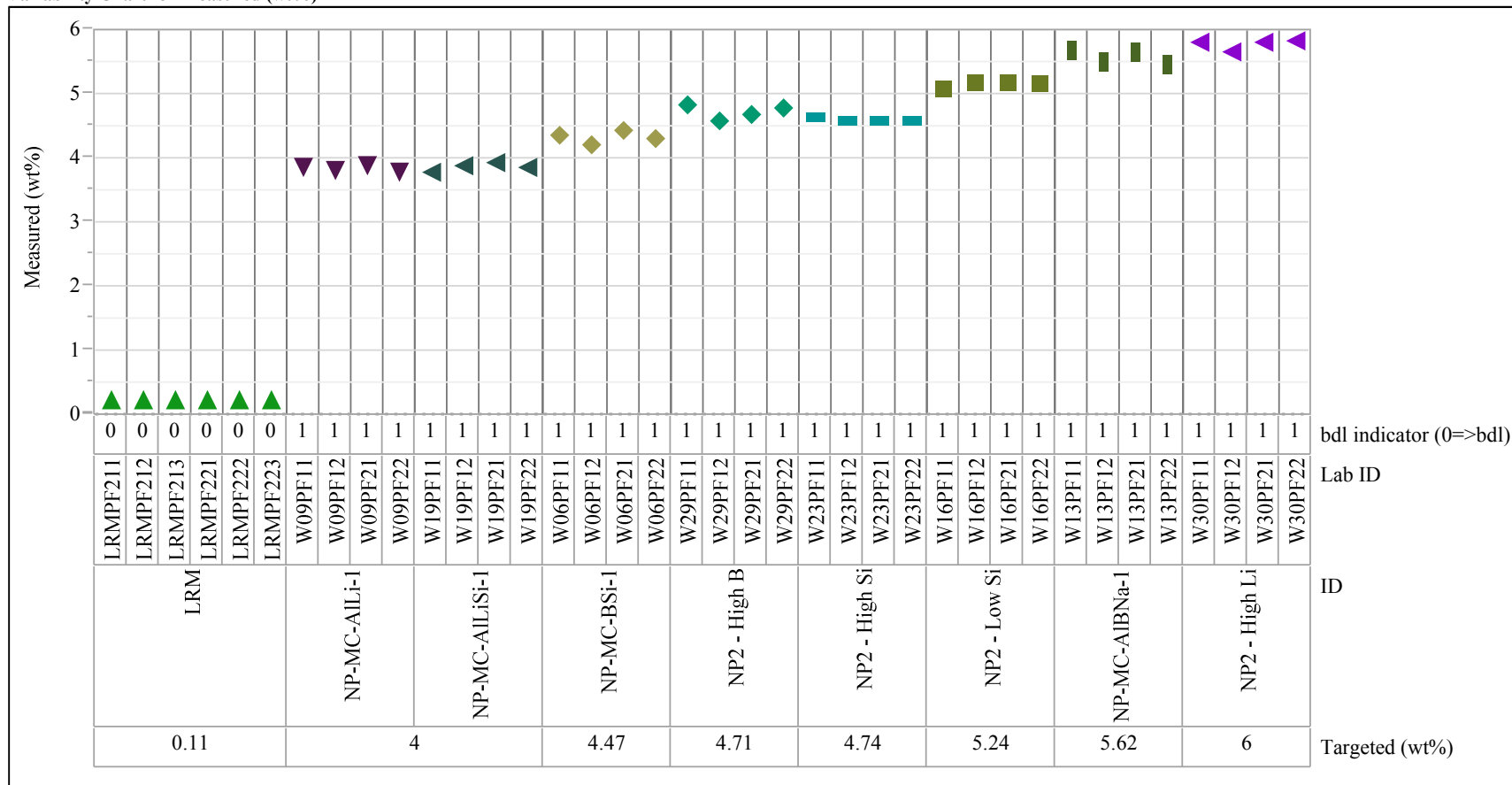
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Li<sub>2</sub>O (wt%), Prep Method=PF, Block=1

Variability Chart for Measured (wt%)



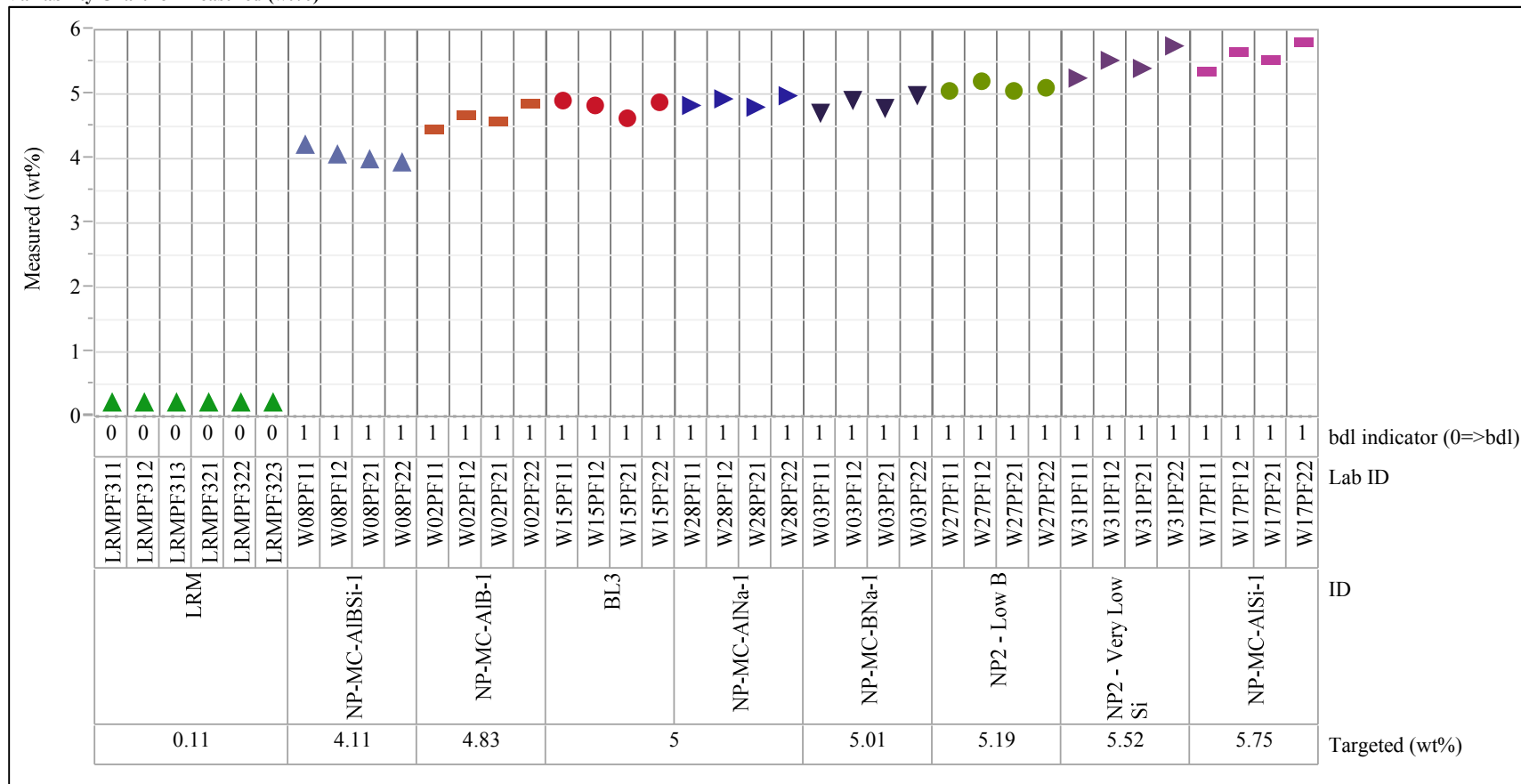
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Li<sub>2</sub>O (wt%), Prep Method=PF, Block=2

Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Li<sub>2</sub>O (wt%), Prep Method=PF, Block=3

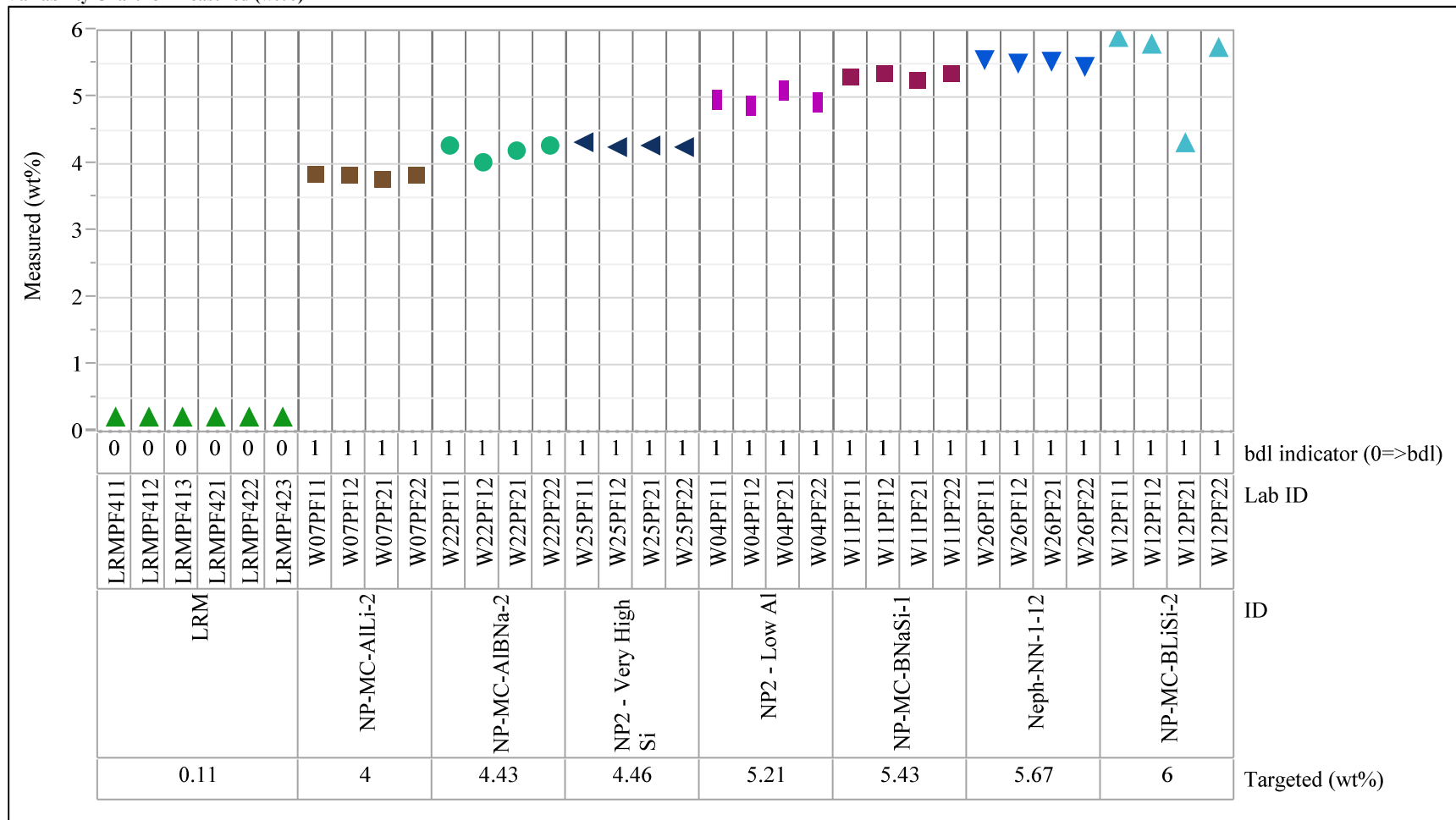
Variability Chart for Measured (wt%)





**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Li<sub>2</sub>O (wt%), Prep Method=PF, Block=4

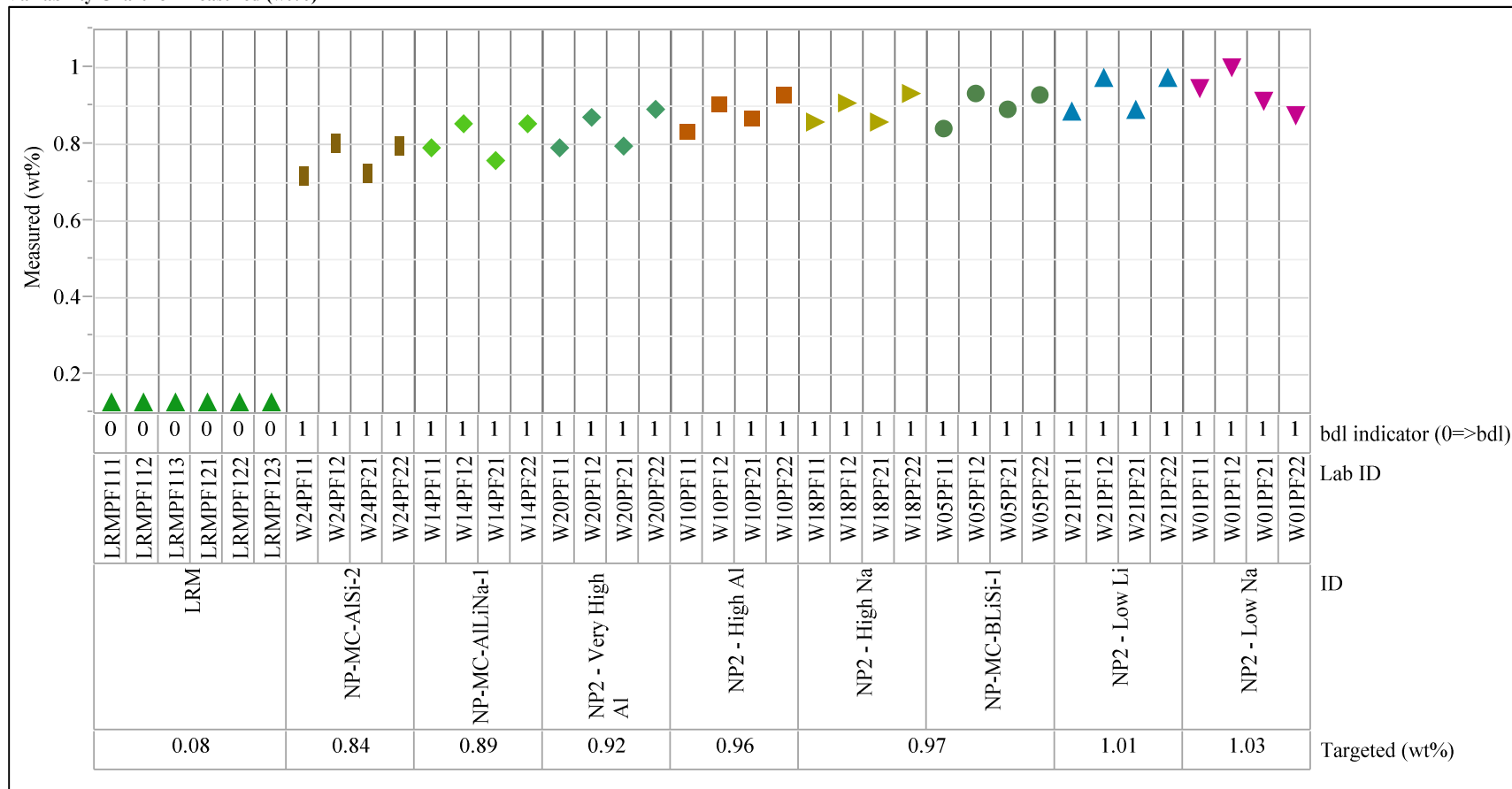
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=MnO (wt%), Prep Method=PF, Block=1

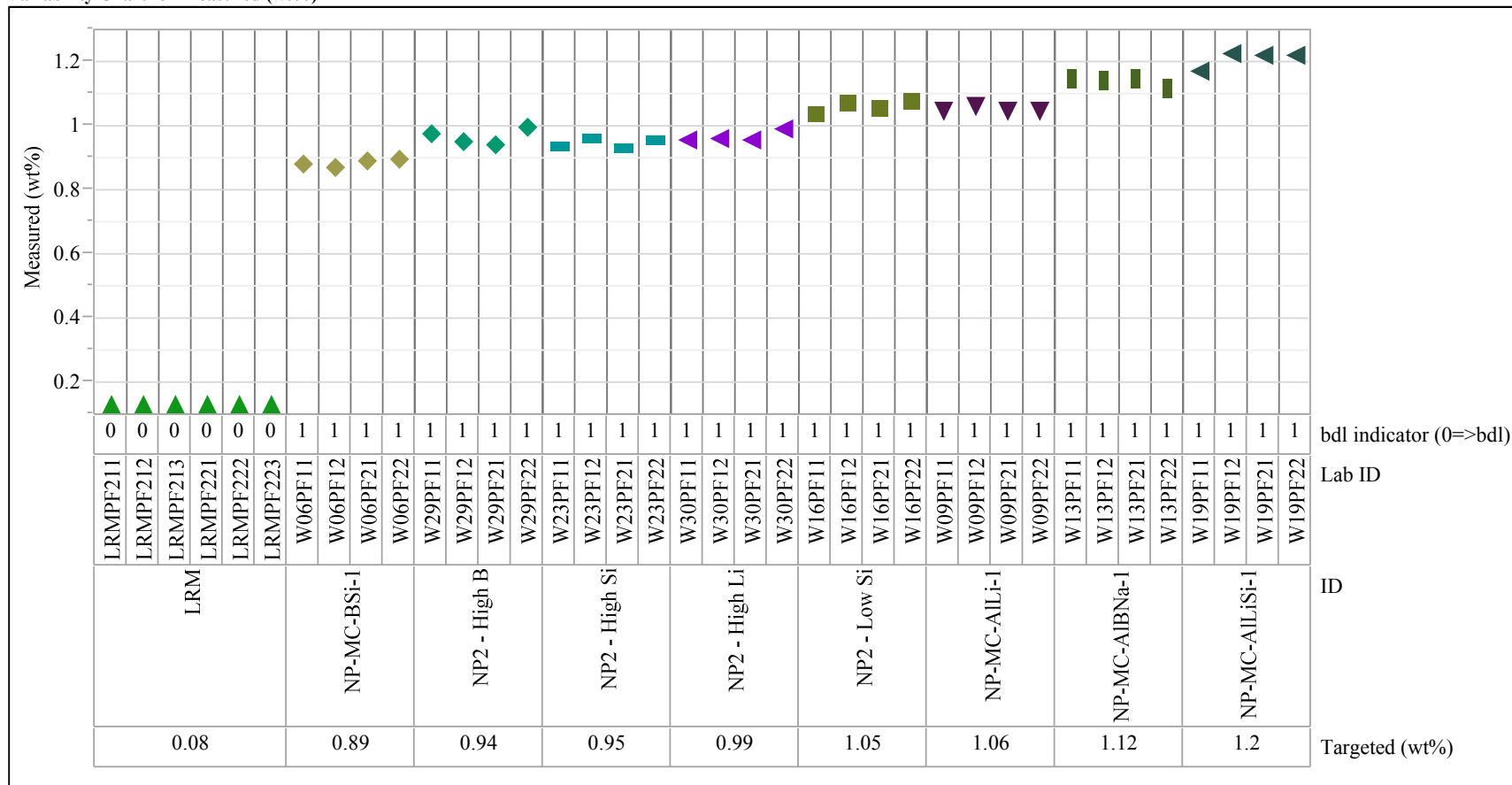
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=MnO (wt%), Prep Method=PF, Block=2

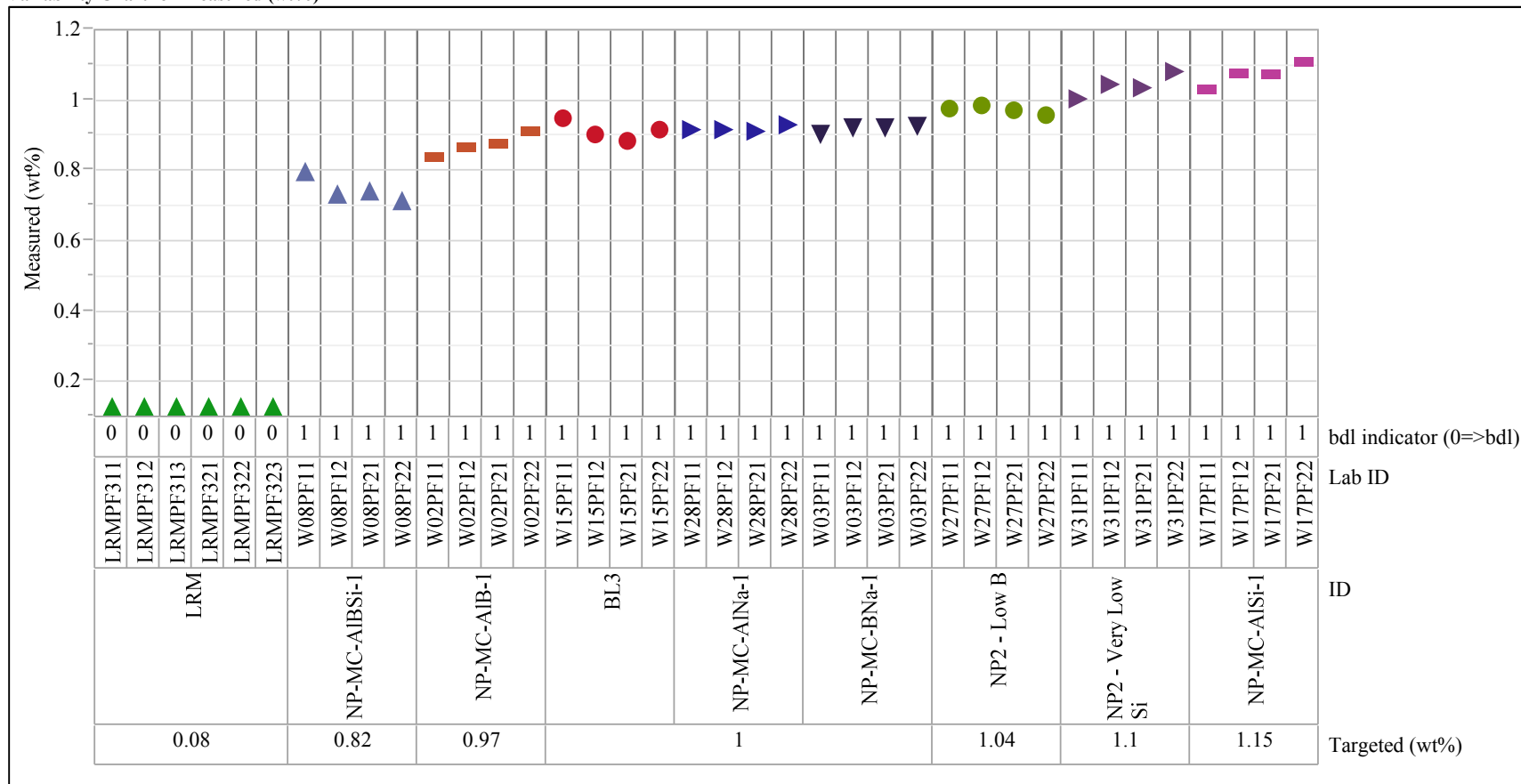
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=MnO (wt%), Prep Method=PF, Block=3

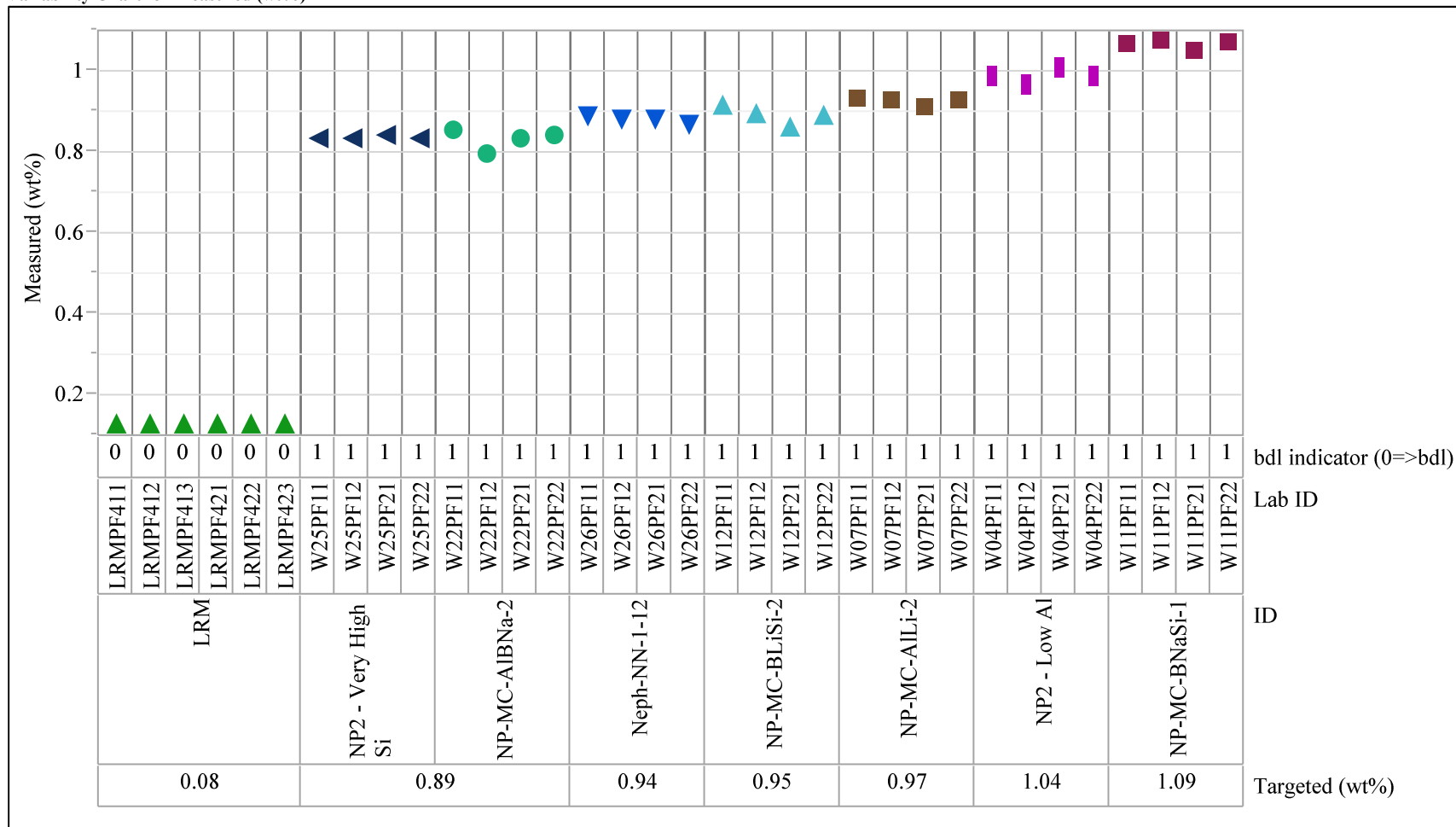
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

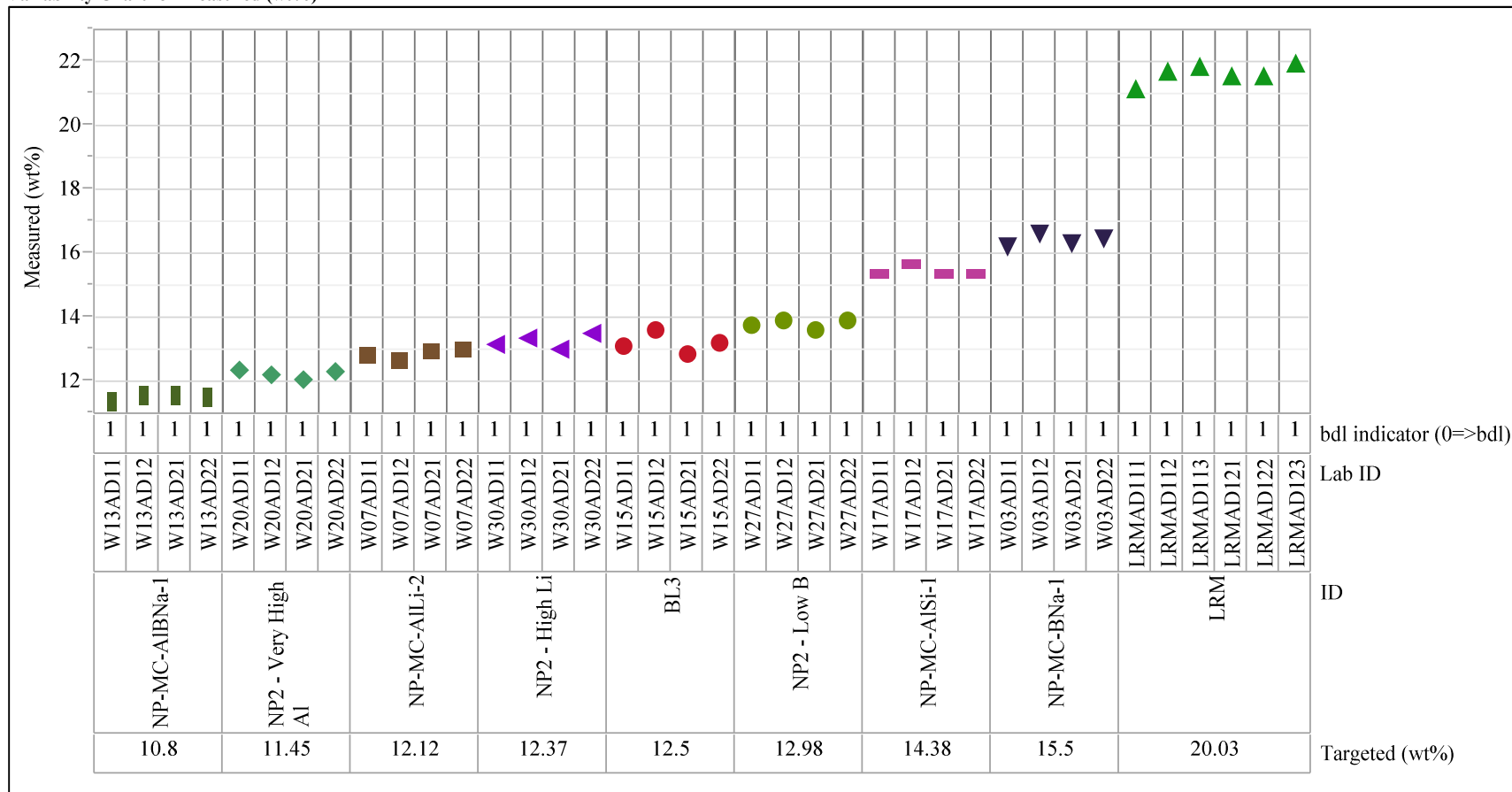
Oxide=MnO (wt%), Prep Method=PF, Block=4

Variability Chart for Measured (wt%)



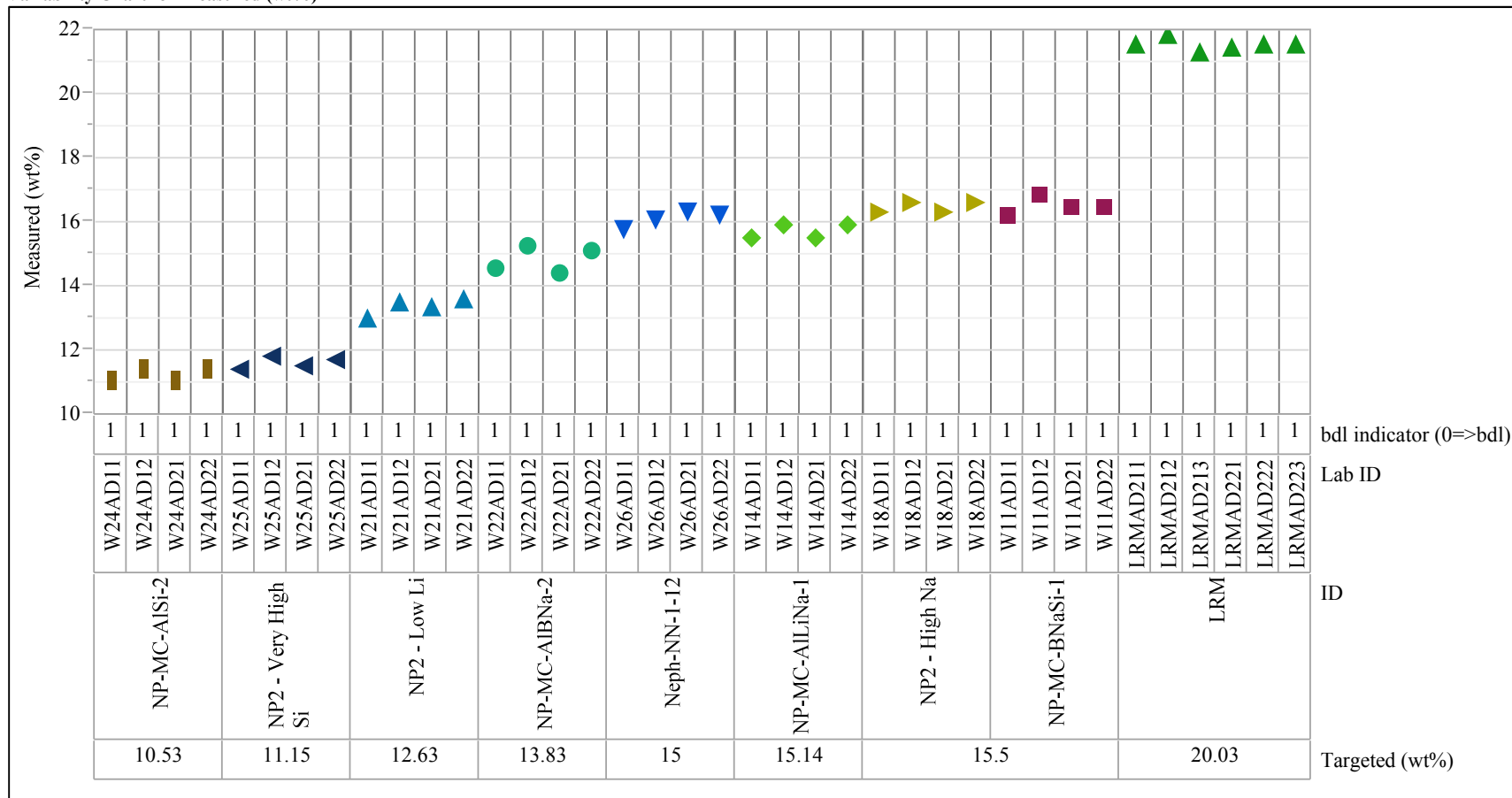
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Na<sub>2</sub>O (wt%), Prep Method=AD, Block=1

Variability Chart for Measured (wt%)



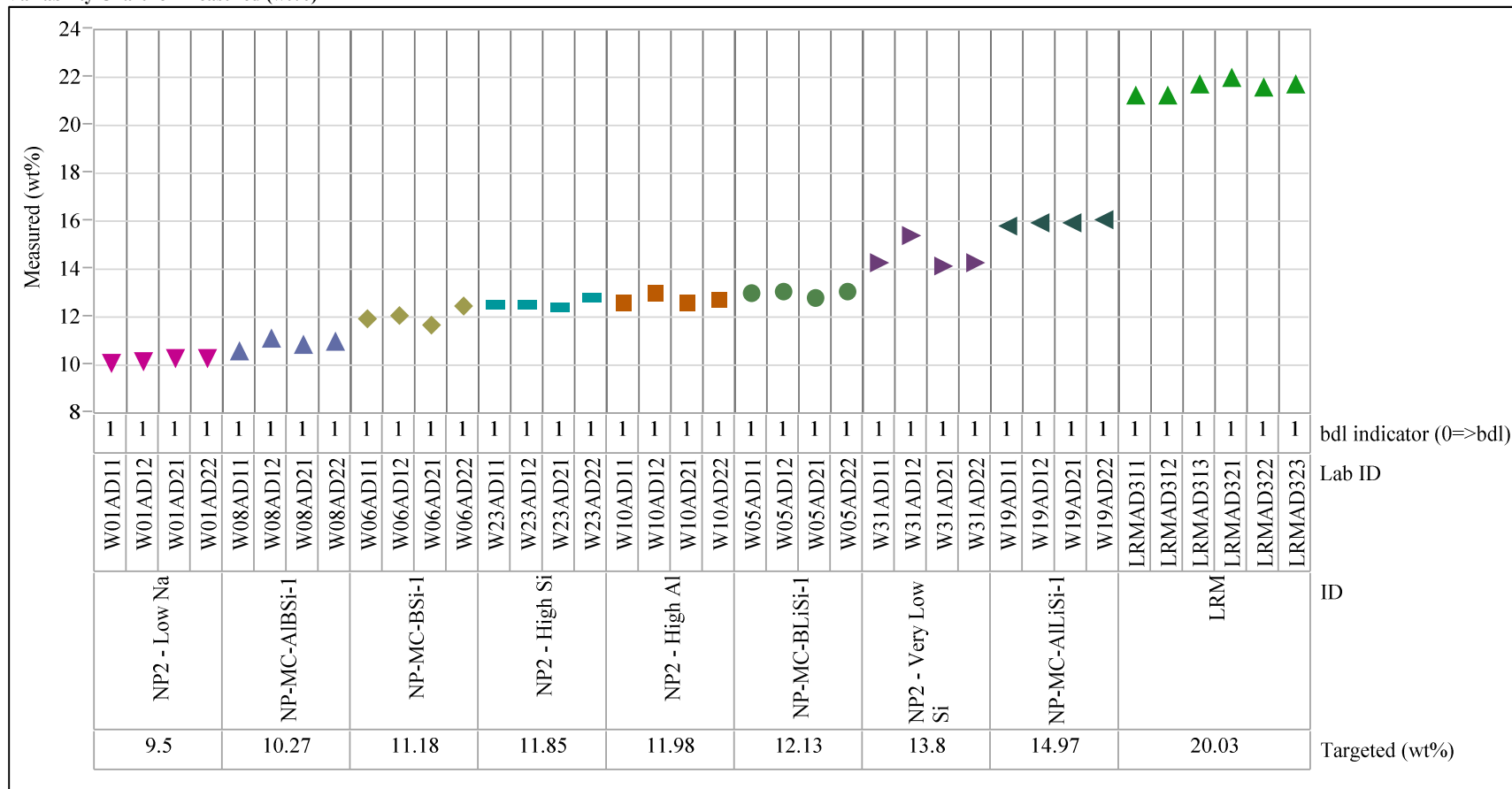
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Na<sub>2</sub>O (wt%), Prep Method=AD, Block=2

Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Na<sub>2</sub>O (wt%), Prep Method=AD, Block=3

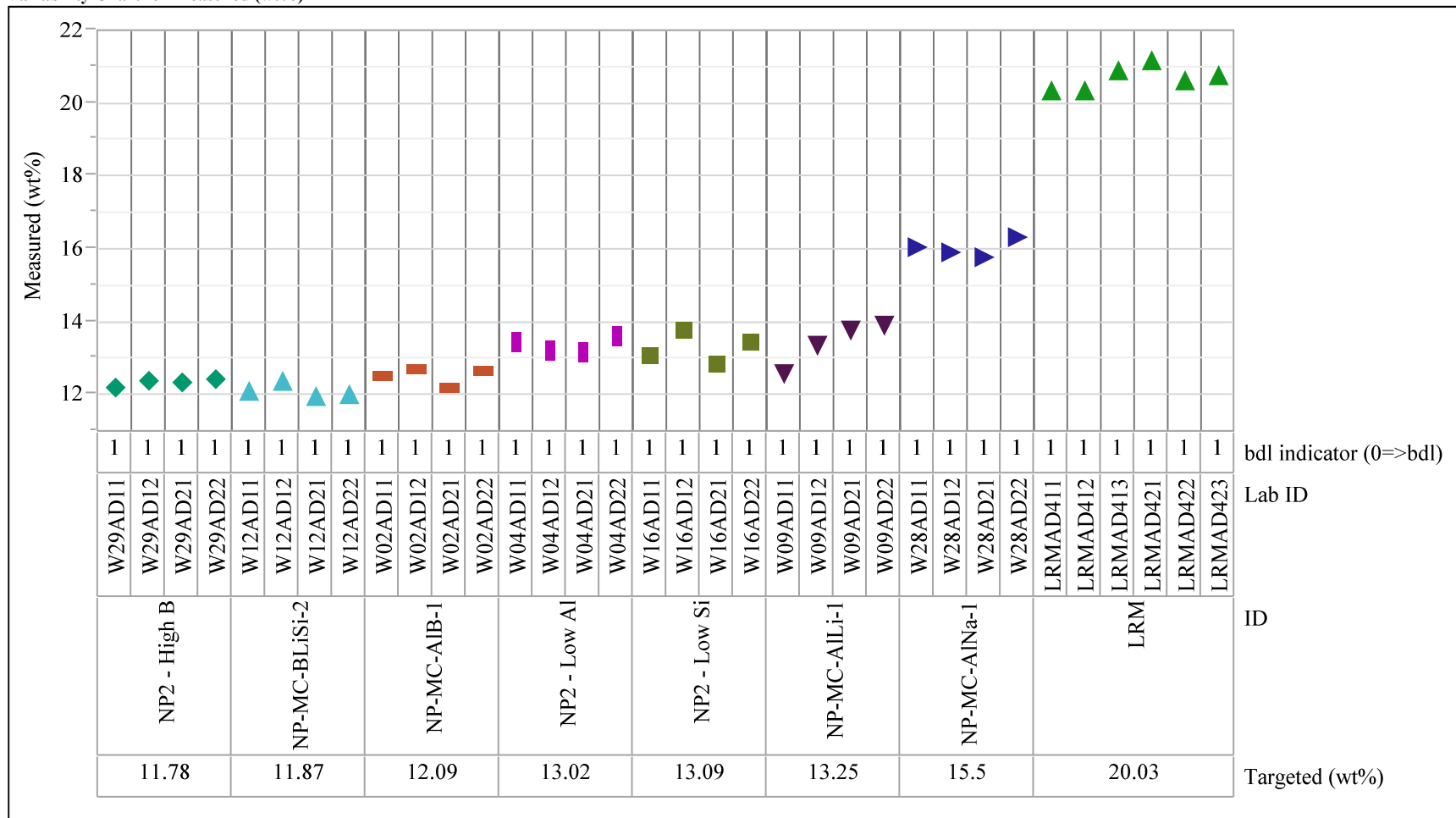
Variability Chart for Measured (wt%)





**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=Na<sub>2</sub>O (wt%), Prep Method=AD, Block=4

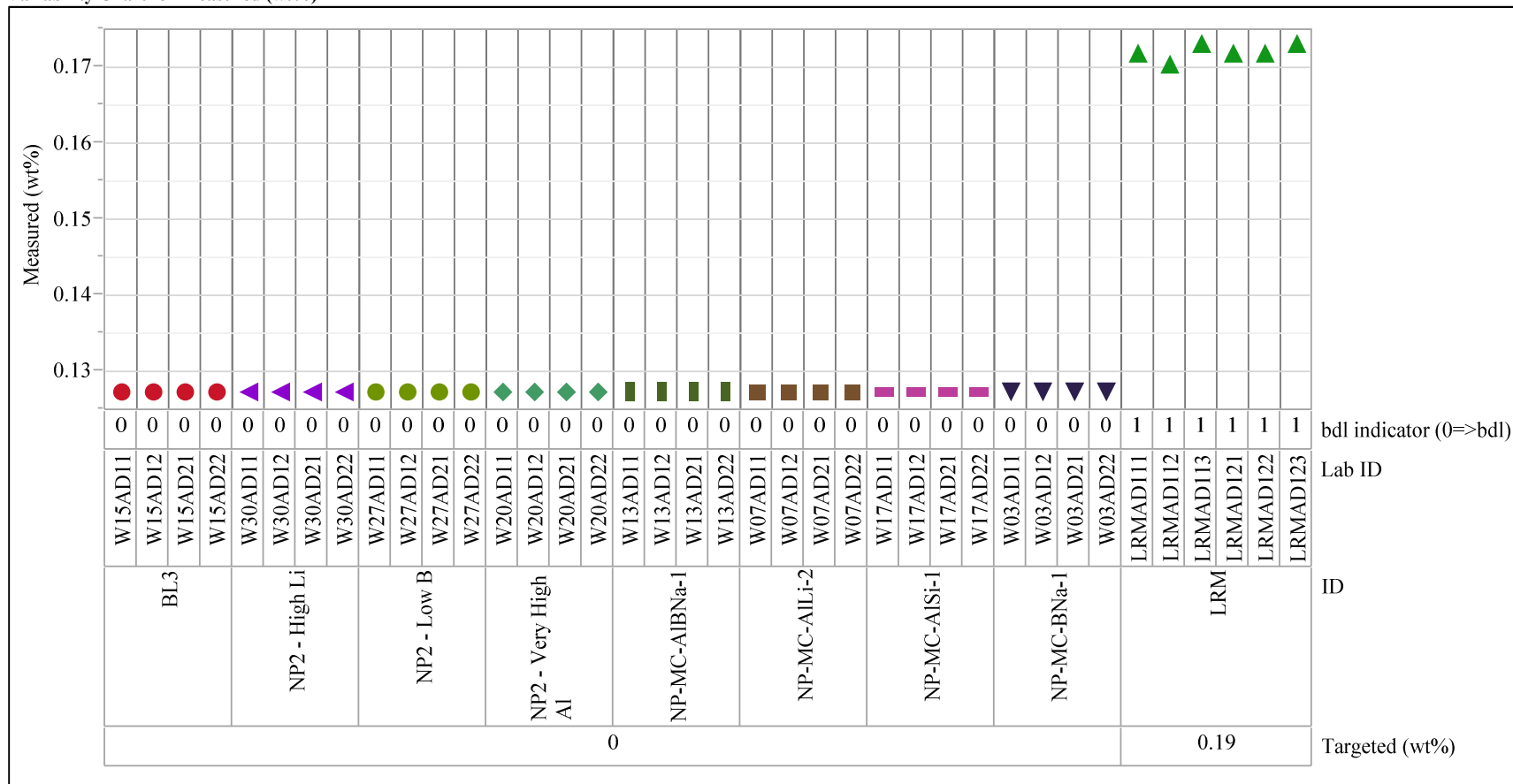
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=NiO (wt%), Prep Method=AD, Block=1

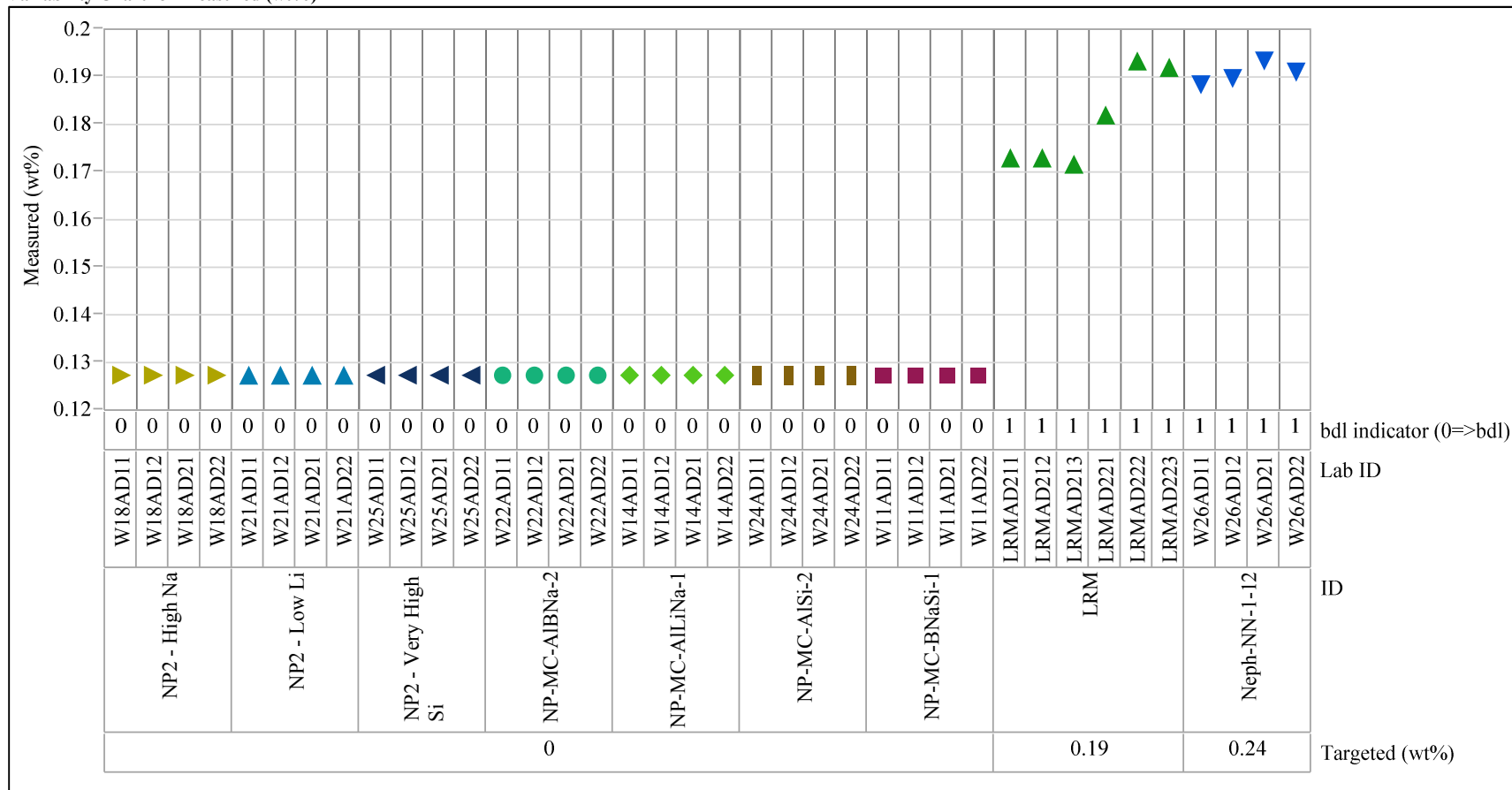
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=NiO (wt%), Prep Method=AD, Block=2

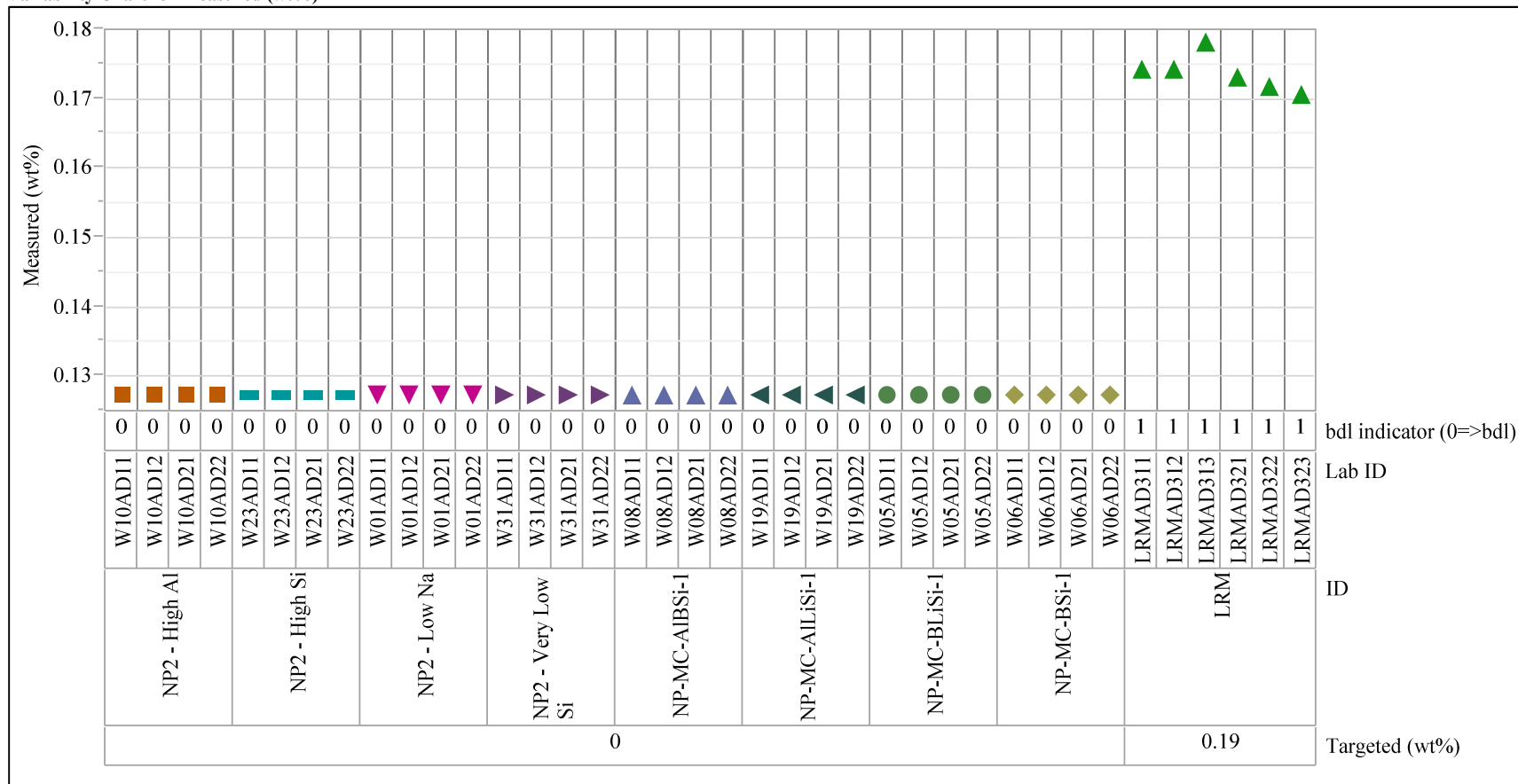
Variability Chart for Measured (wt%)



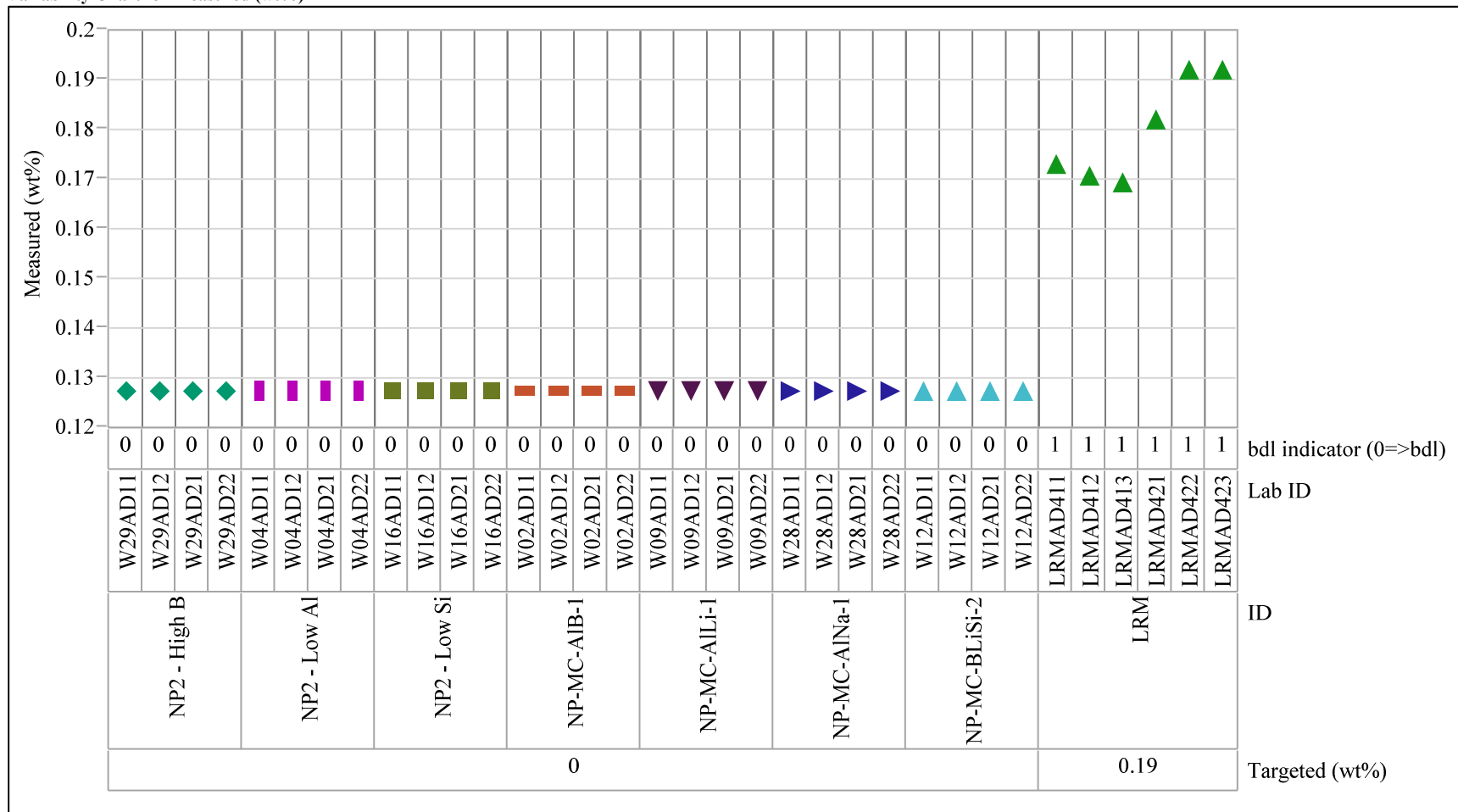
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=NiO (wt%), Prep Method=AD, Block=3

Variability Chart for Measured (wt%)



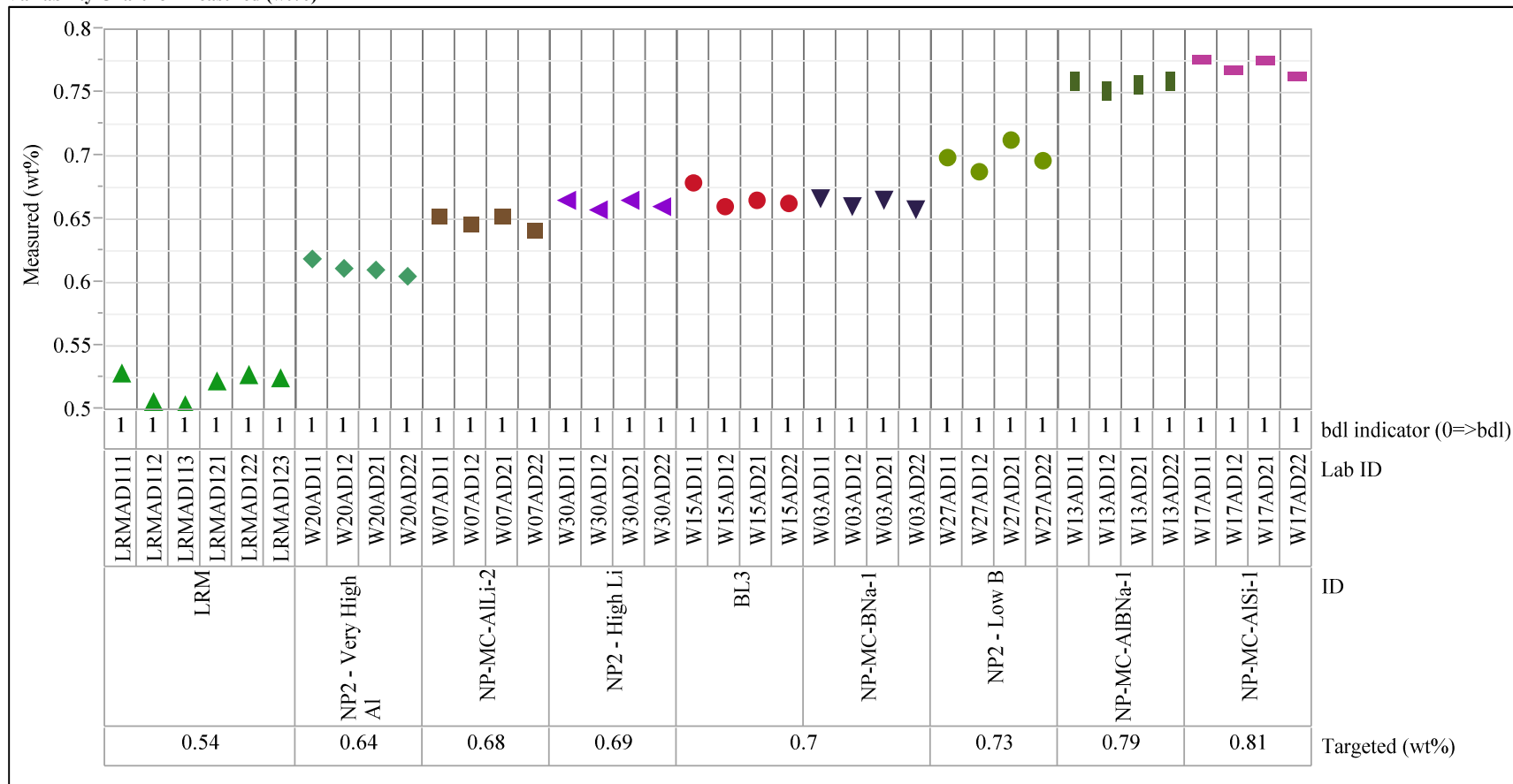
**Oxide=NiO (wt%), Prep Method=AD, Block=4**  
**Variability Chart for Measured (wt%)**



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=P2O5 (wt%), Prep Method=AD, Block=1

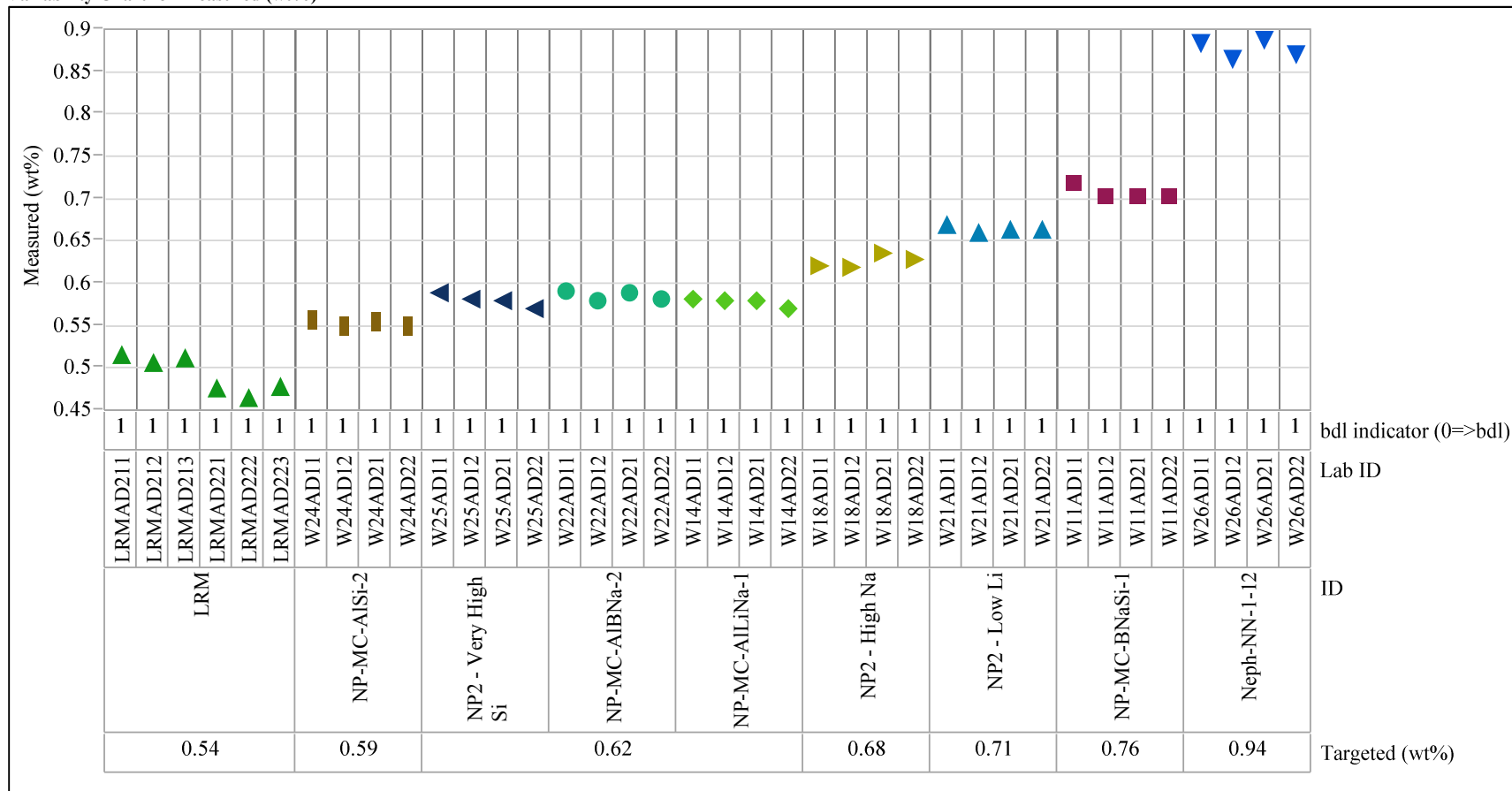
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=P2O5 (wt%), Prep Method=AD, Block=2

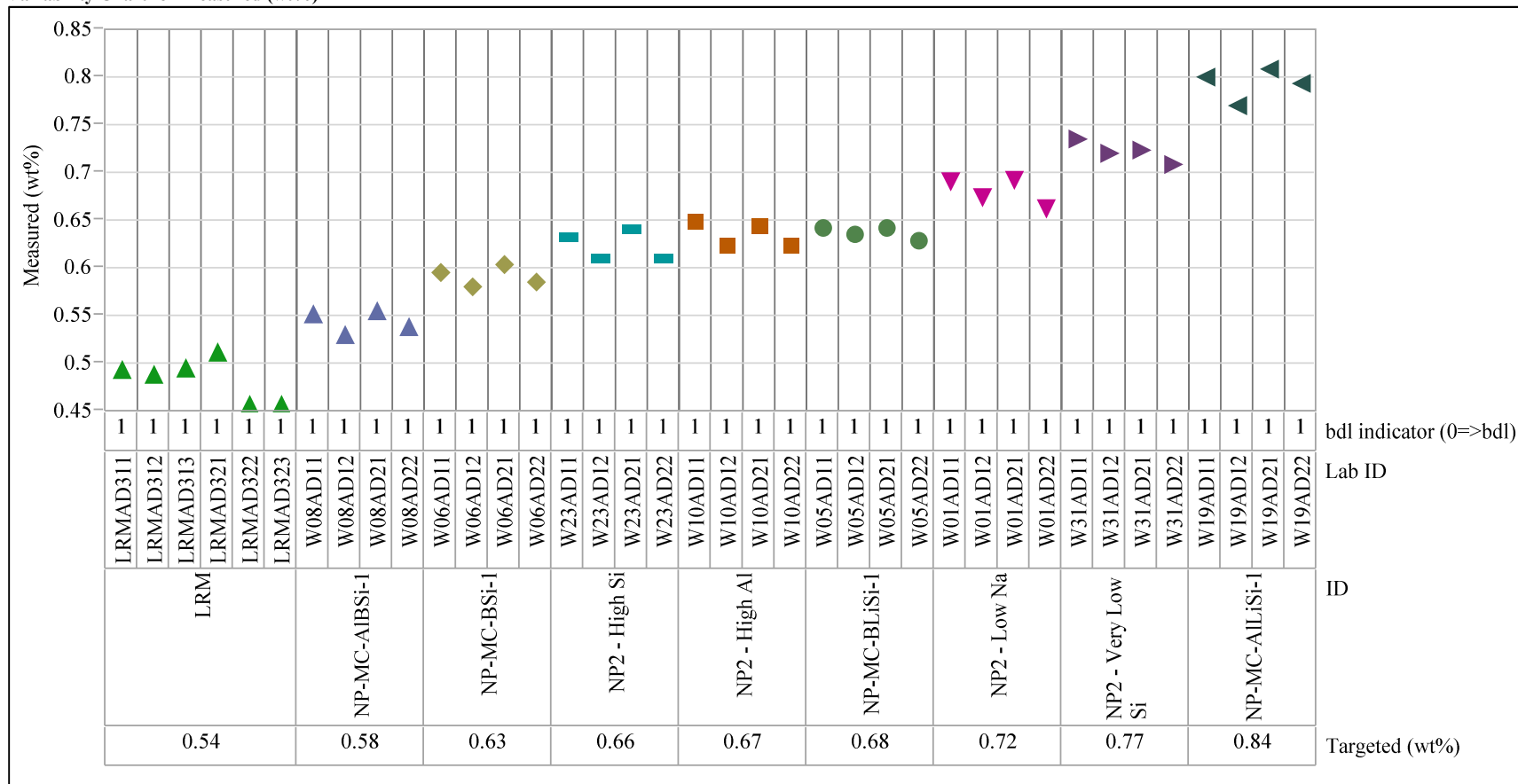
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=P2O5 (wt%), Prep Method=AD, Block=3

Variability Chart for Measured (wt%)

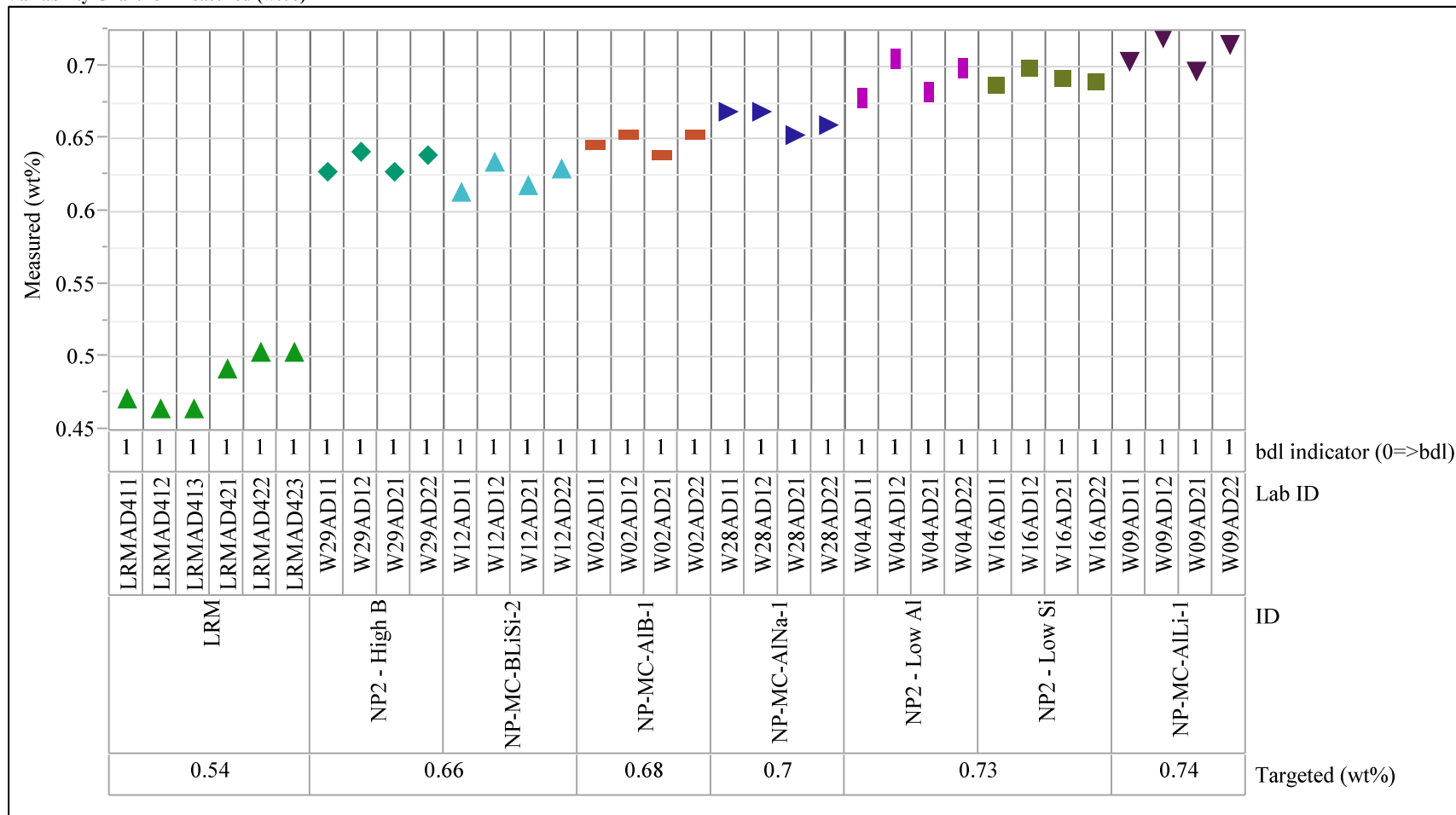




**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=P2O5 (wt%), Prep Method=AD, Block=4

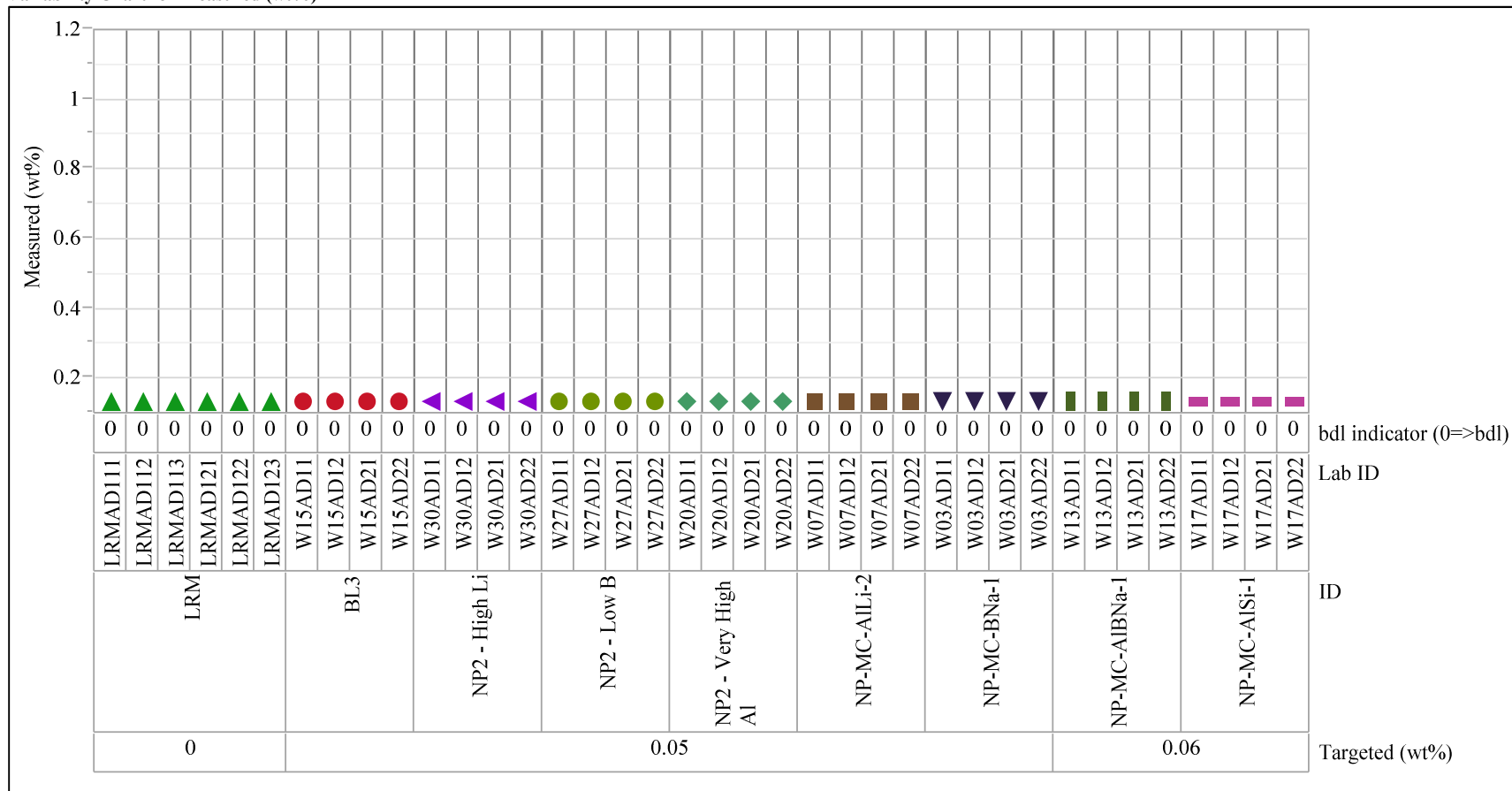
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=RuO2 (wt%), Prep Method=AD, Block=1

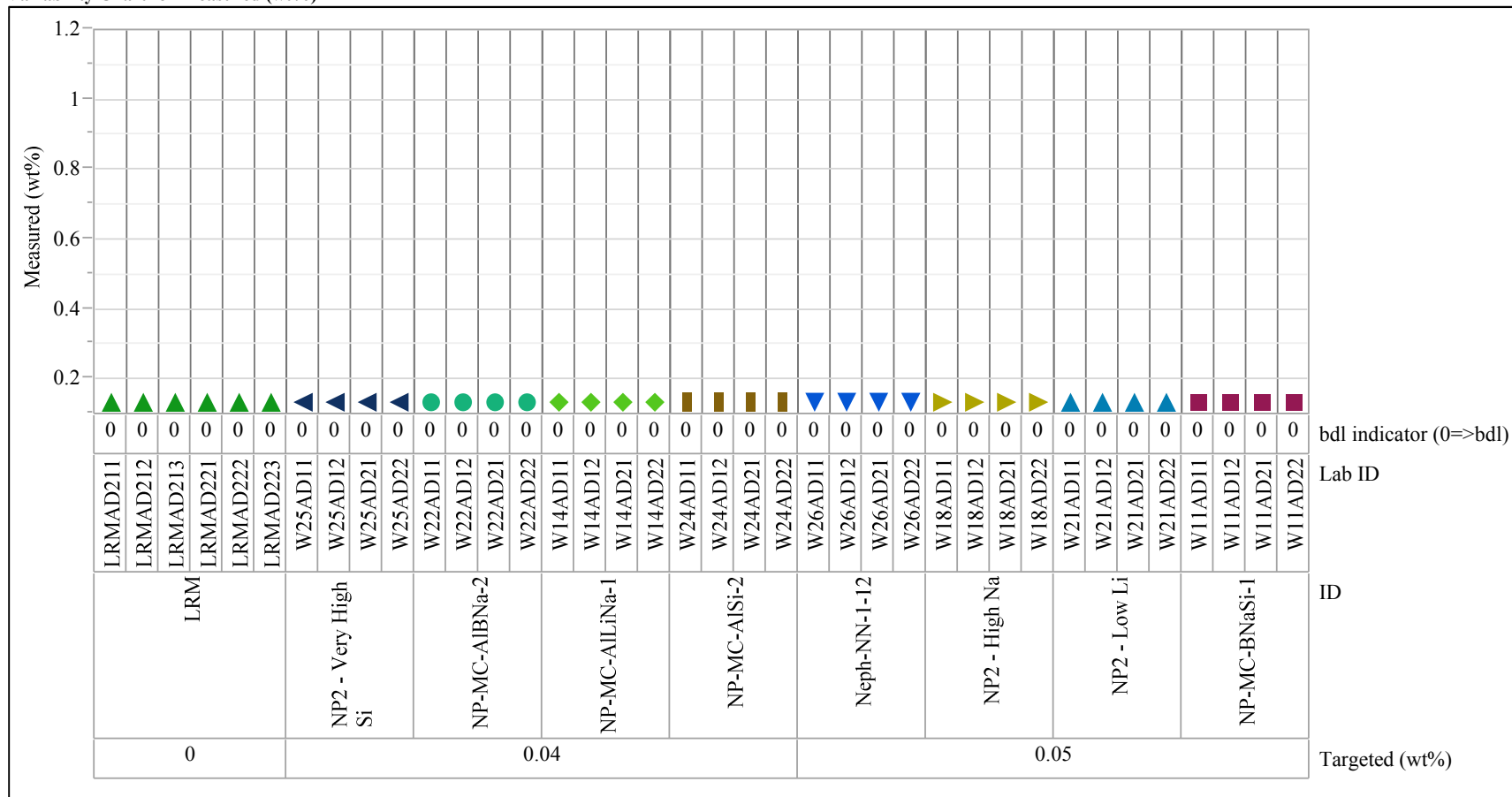
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

Oxide=RuO2 (wt%), Prep Method=AD, Block=2

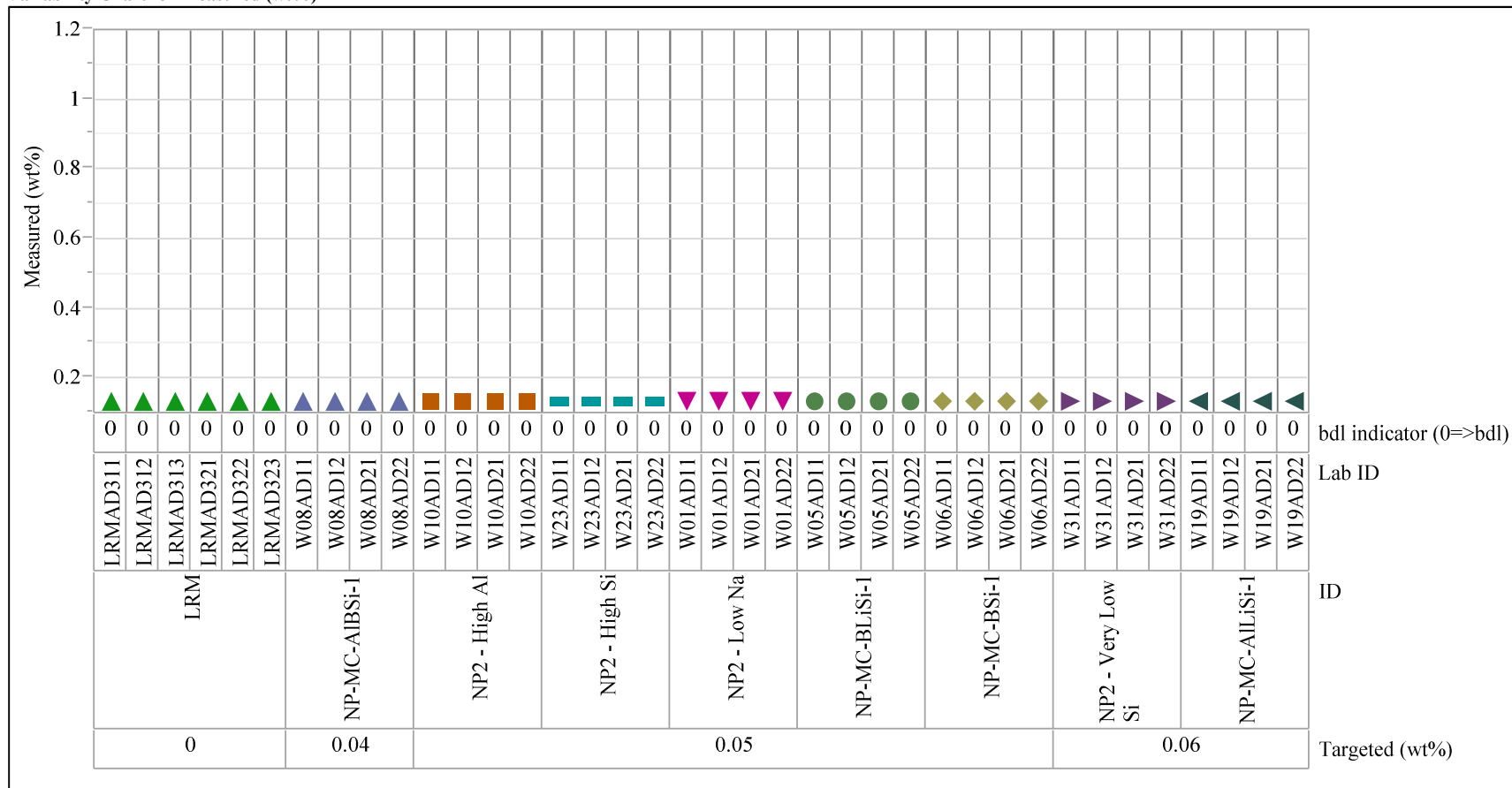
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

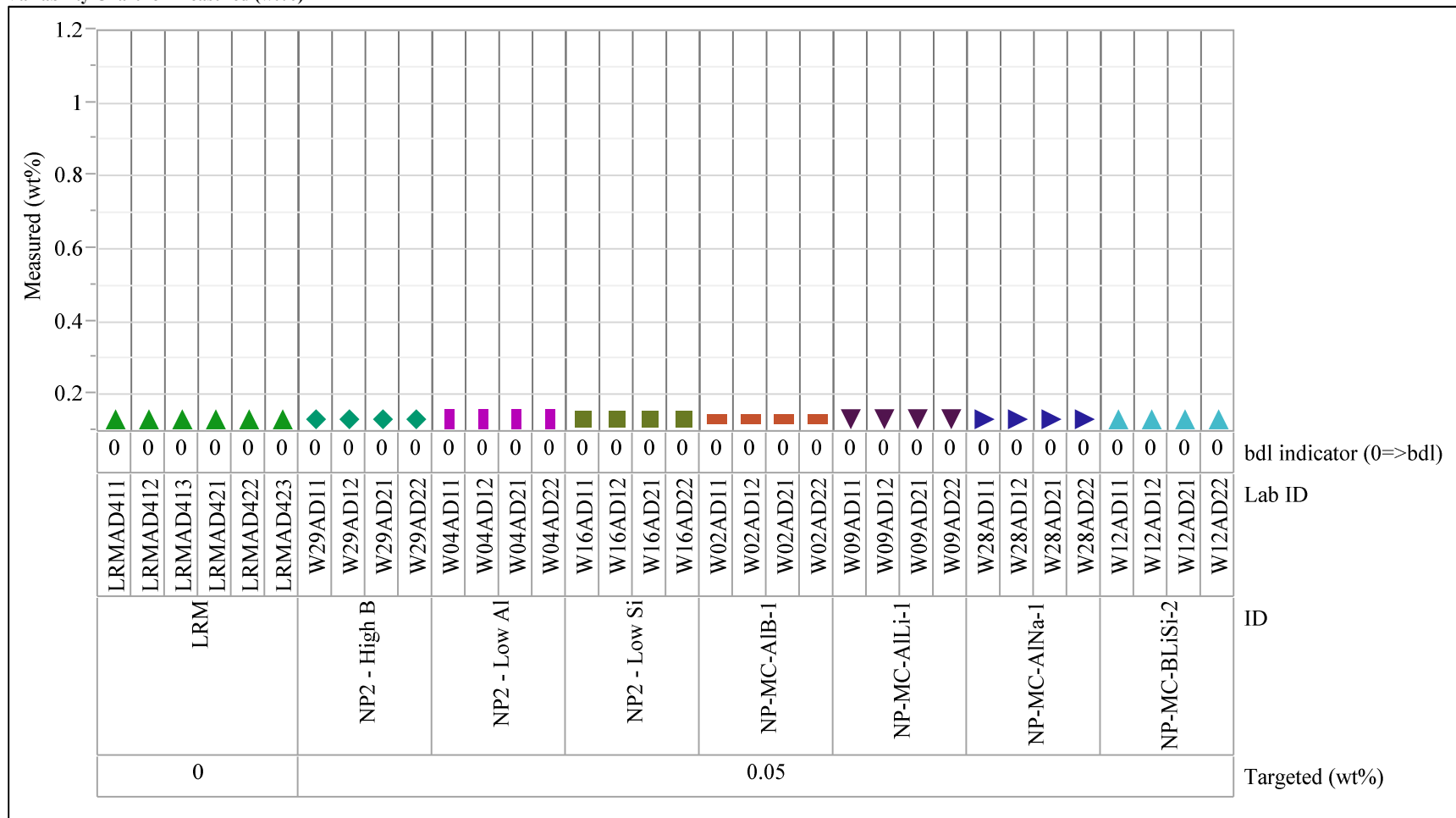
Oxide=RuO2 (wt%), Prep Method=AD, Block=3

Variability Chart for Measured (wt%)



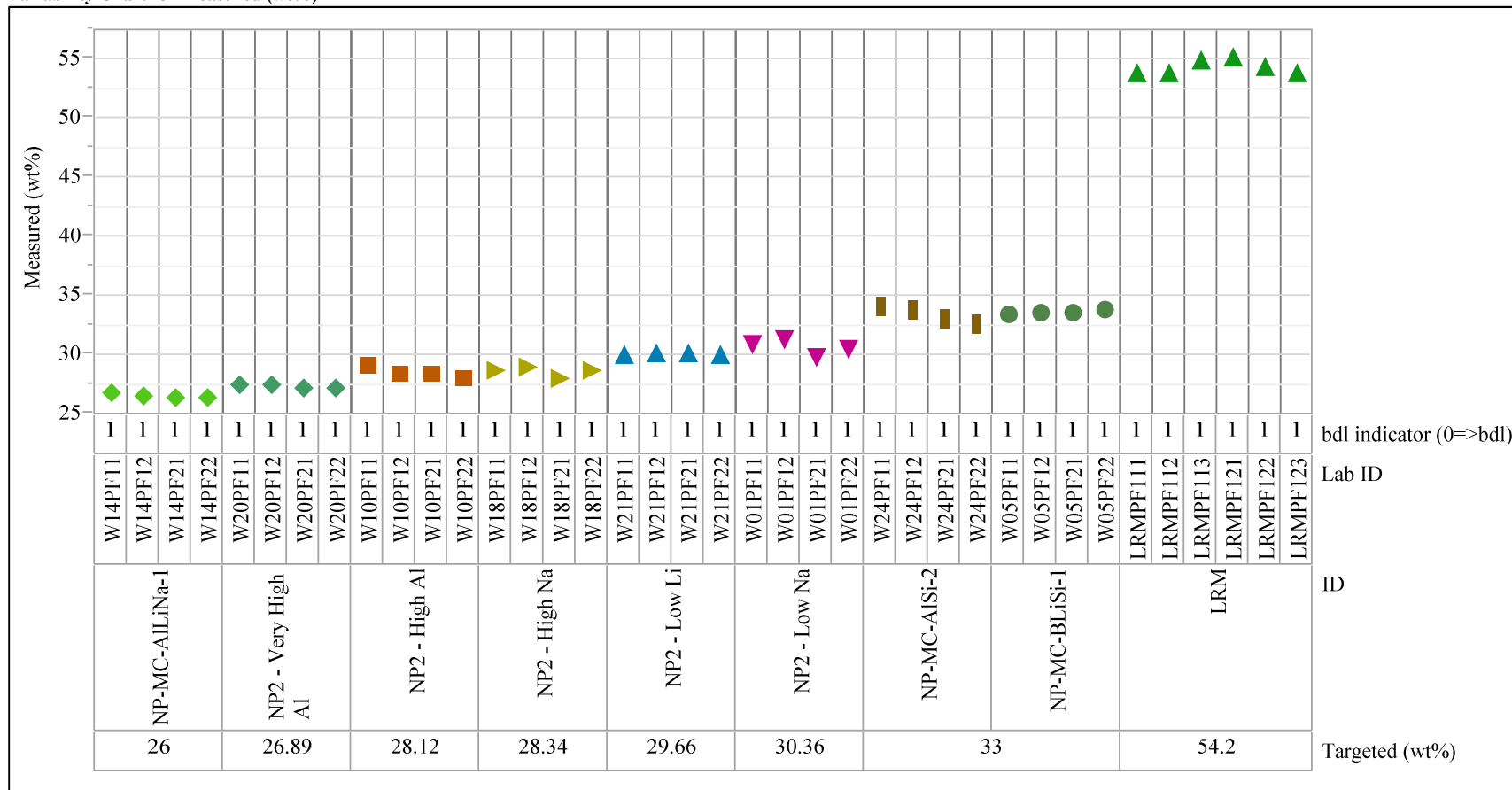
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=RuO<sub>2</sub> (wt%), Prep Method=AD, Block=4

Variability Chart for Measured (wt%)



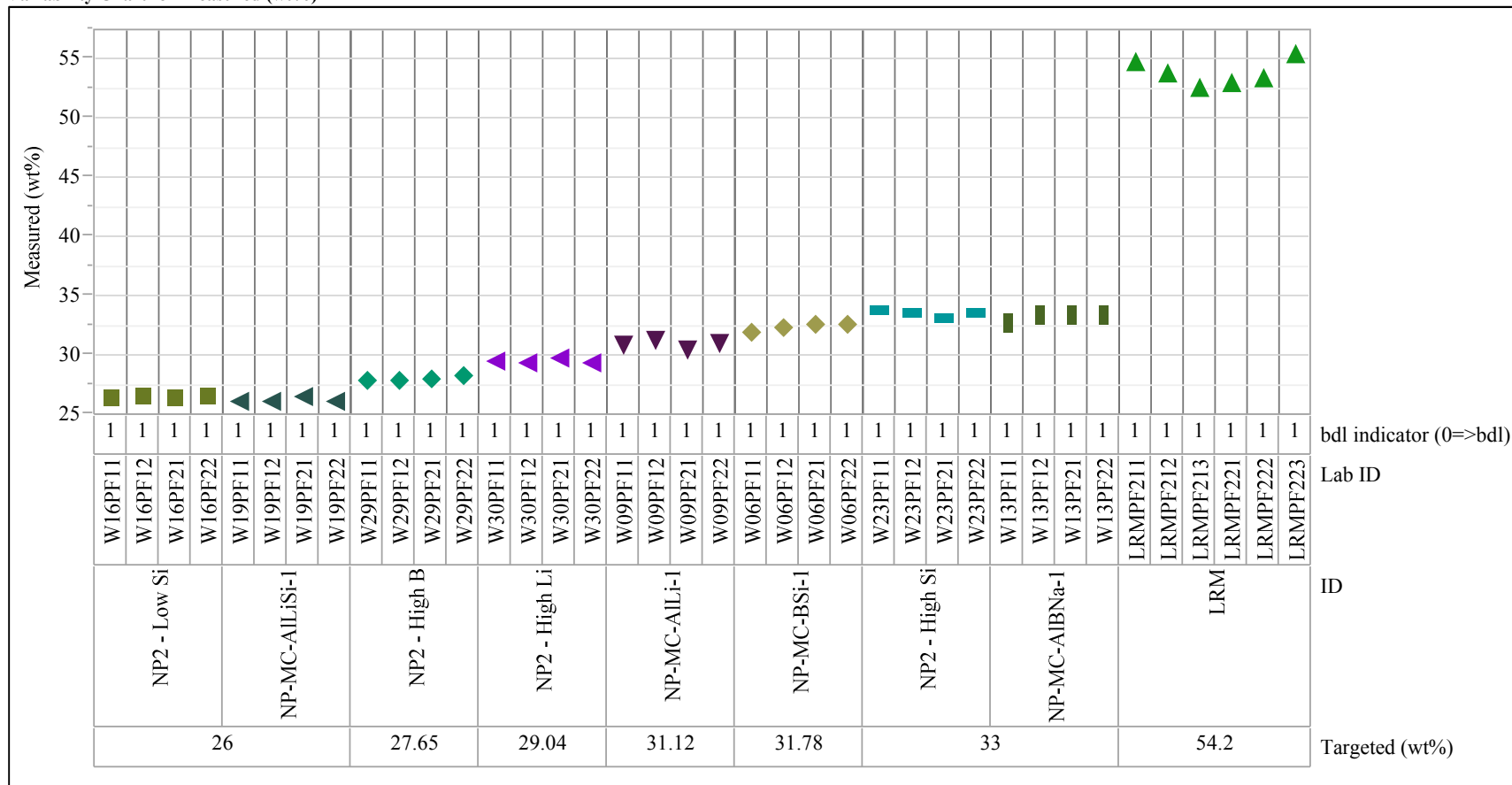
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=SiO<sub>2</sub> (wt%), Prep Method=PF, Block=1

Variability Chart for Measured (wt%)



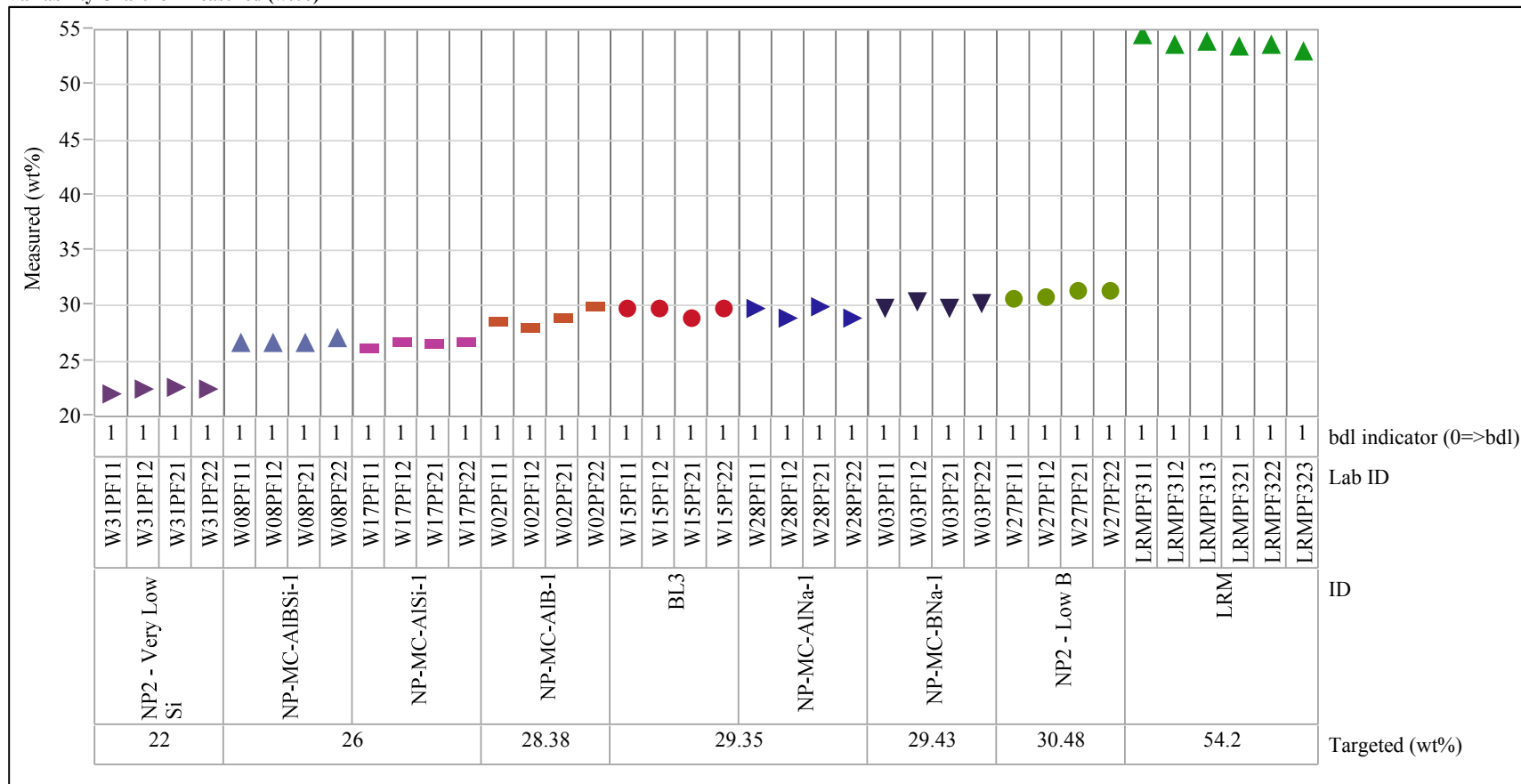
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=SiO<sub>2</sub> (wt%), Prep Method=PF, Block=2

Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=SiO<sub>2</sub> (wt%), Prep Method=PF, Block=3

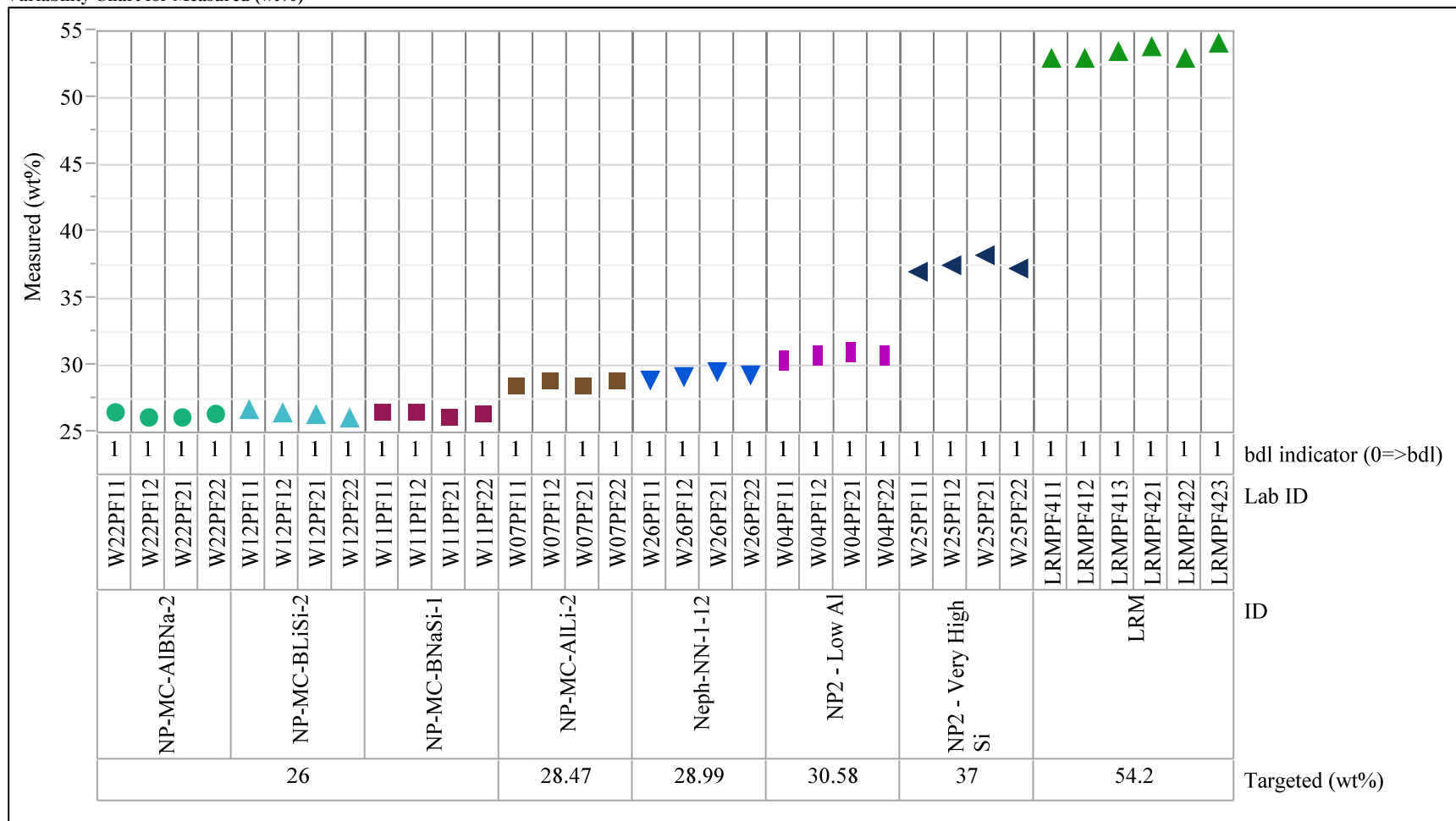
Variability Chart for Measured (wt%)





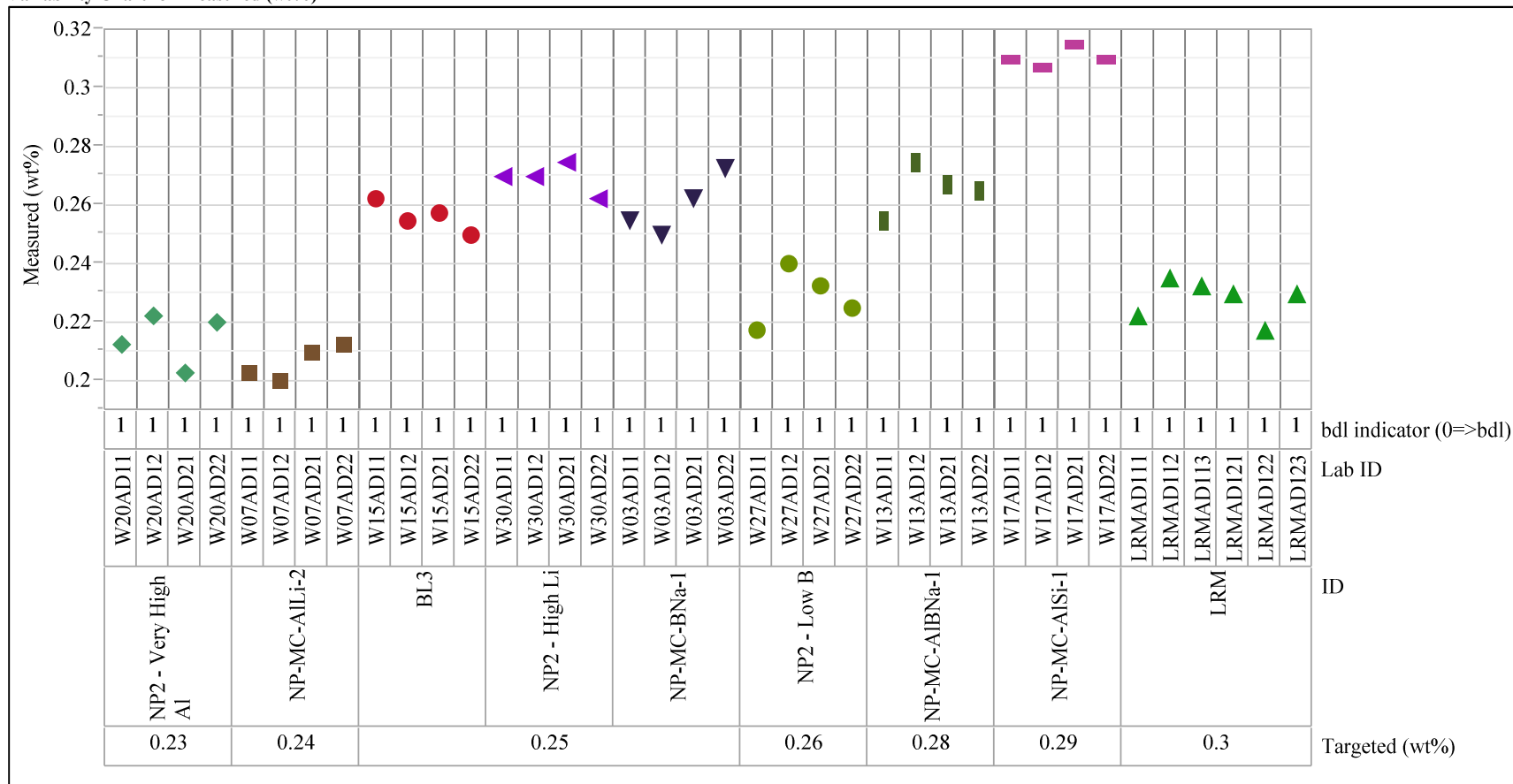
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=SiO<sub>2</sub> (wt%), Prep Method=PF, Block=4

Variability Chart for Measured (wt%)



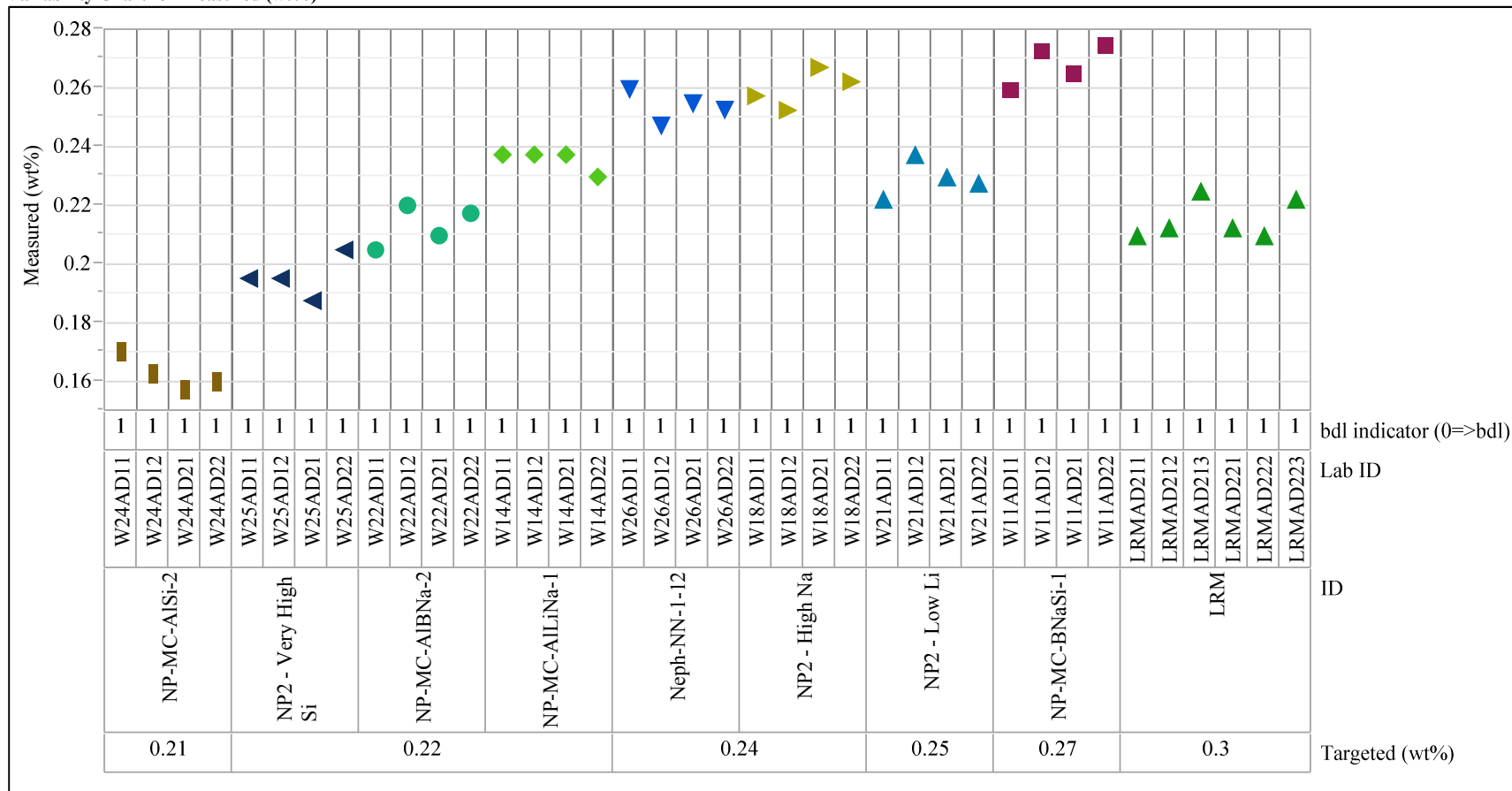
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=SO<sub>3</sub> (wt%), Prep Method=AD, Block=1

Variability Chart for Measured (wt%)



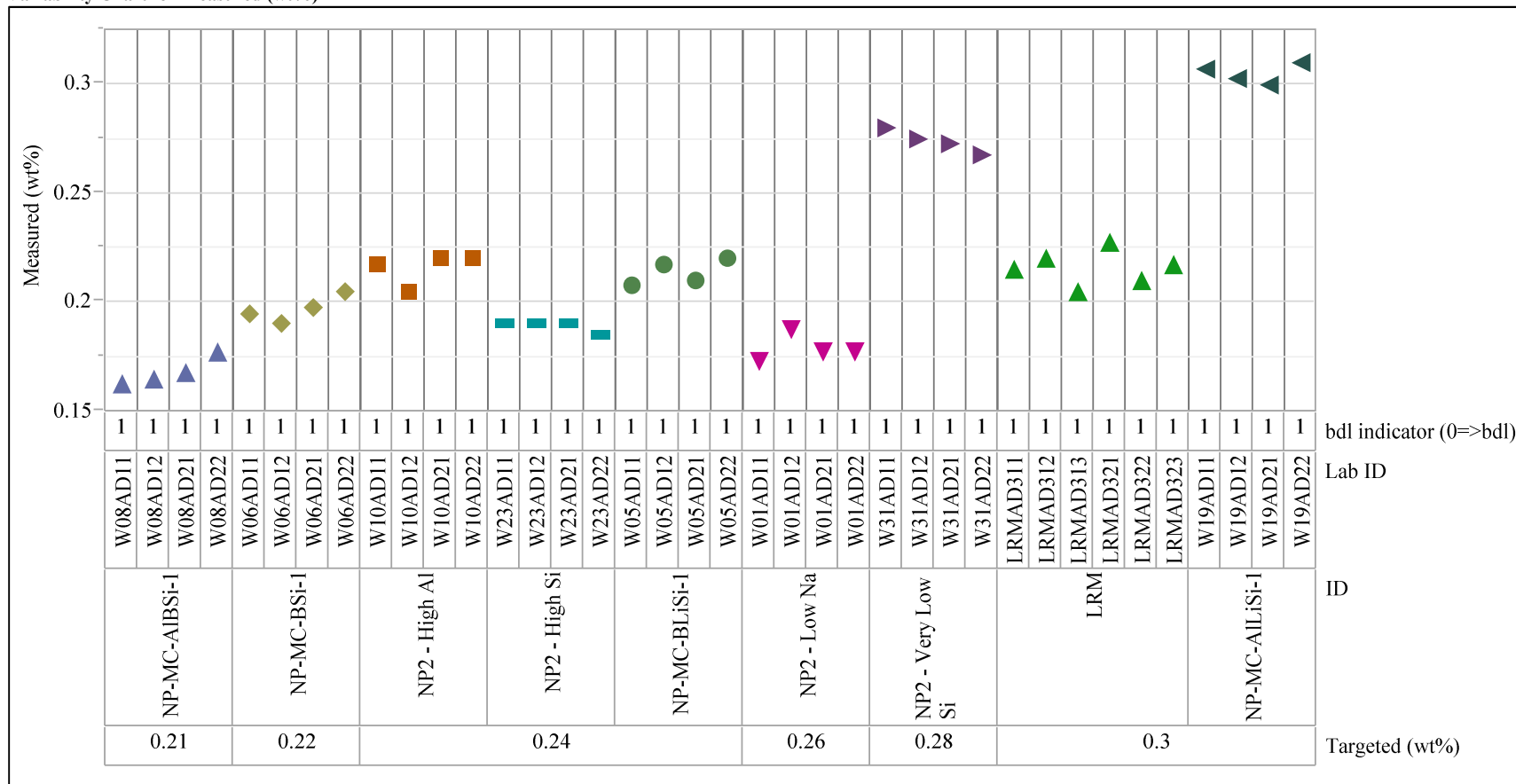
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=SO<sub>3</sub> (wt%), Prep Method=AD, Block=2

Variability Chart for Measured (wt%)



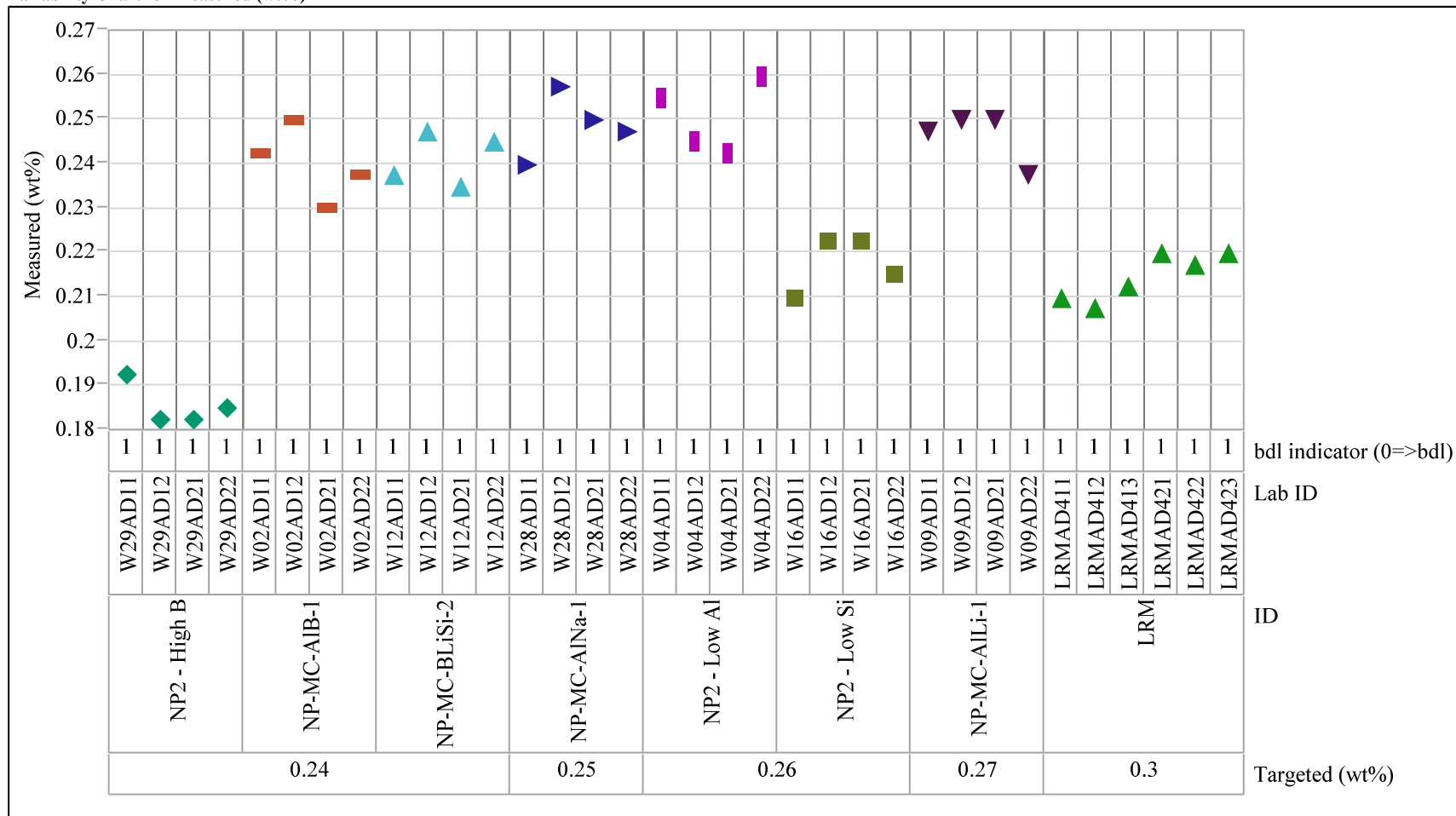
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=SO<sub>3</sub> (wt%), Prep Method=AD, Block=3

Variability Chart for Measured (wt%)



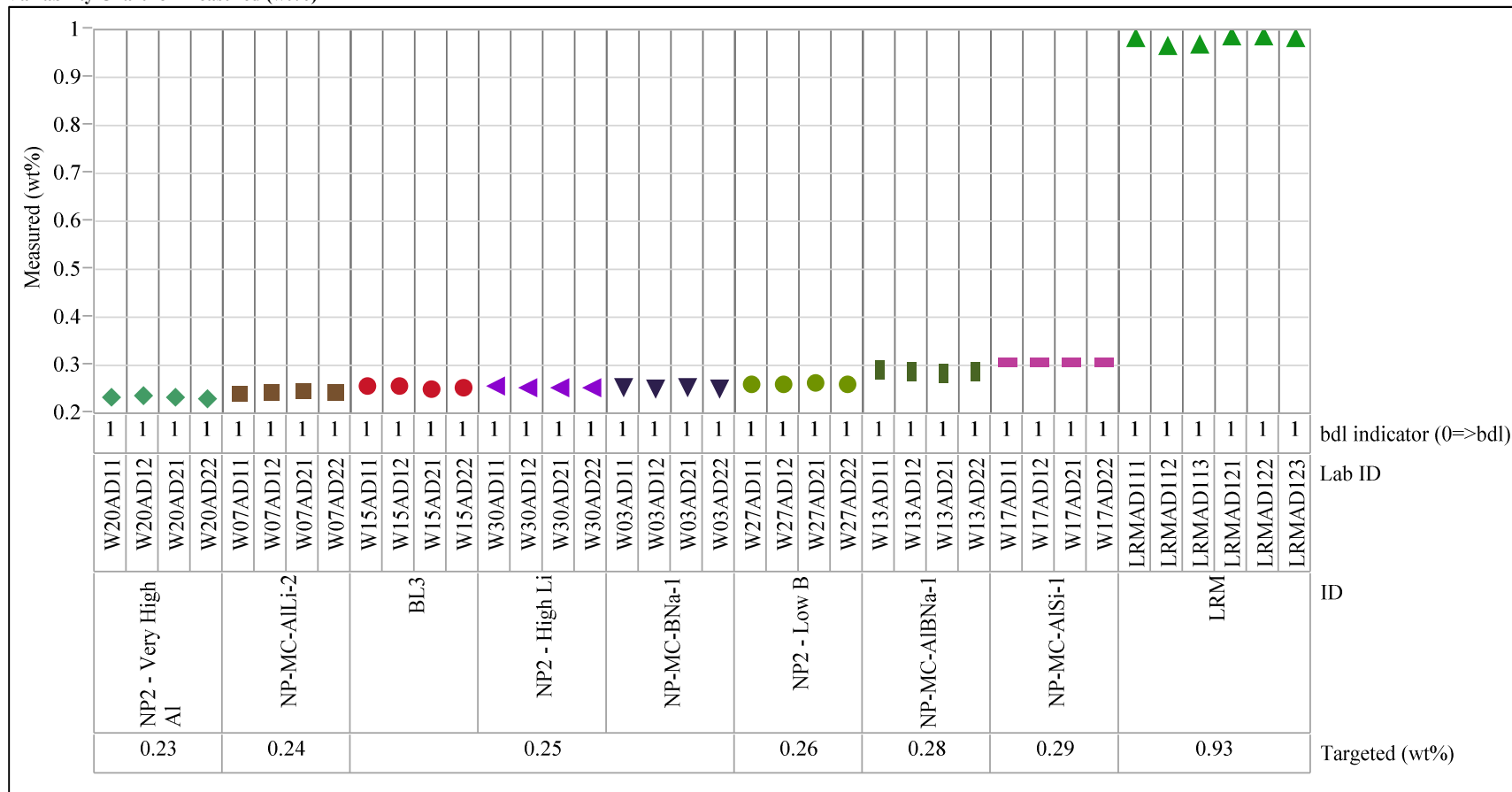
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=SO<sub>3</sub> (wt%), Prep Method=AD, Block=4

Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=ZrO<sub>2</sub> (wt%), Prep Method=AD, Block=1

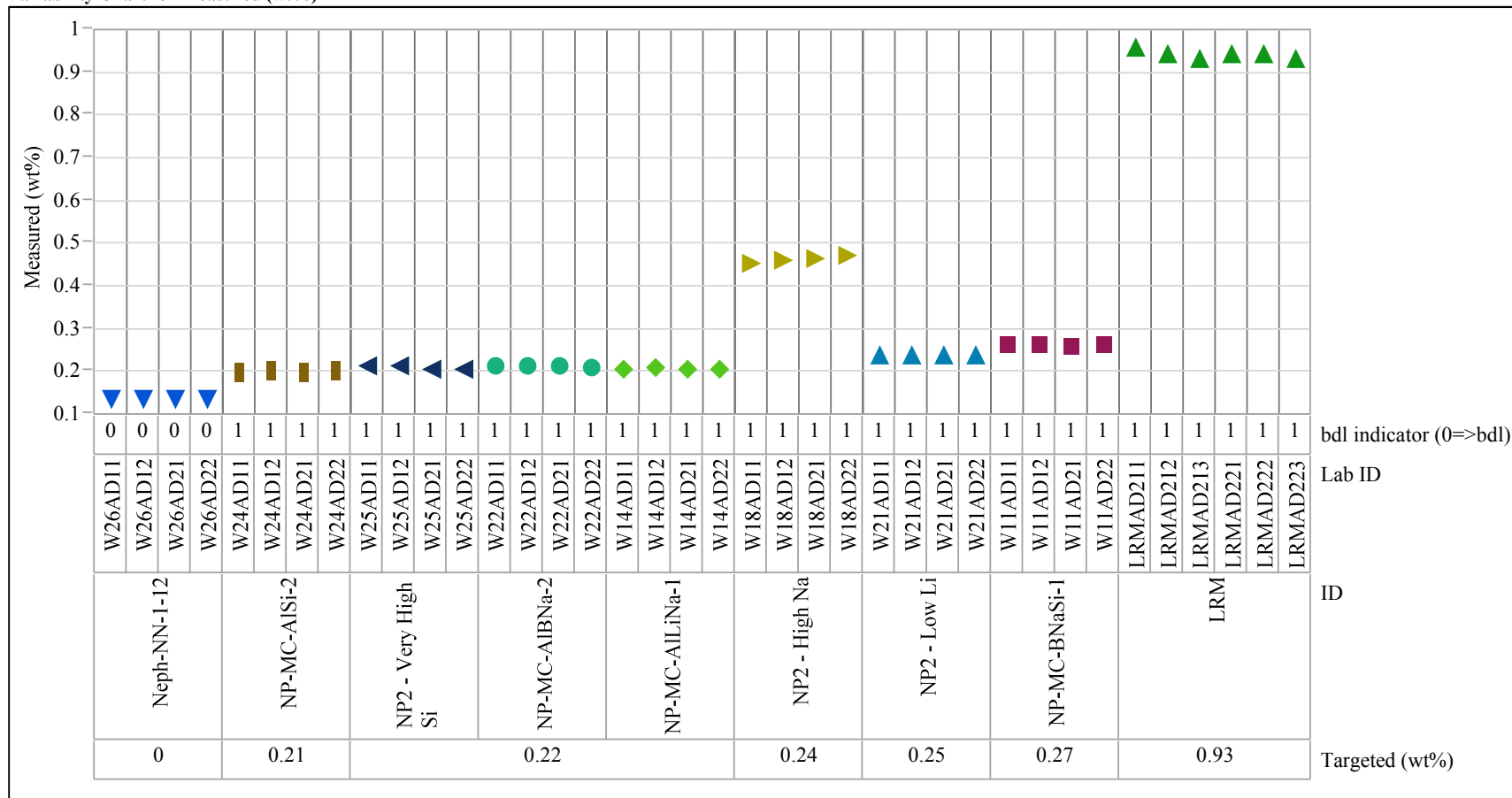
Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

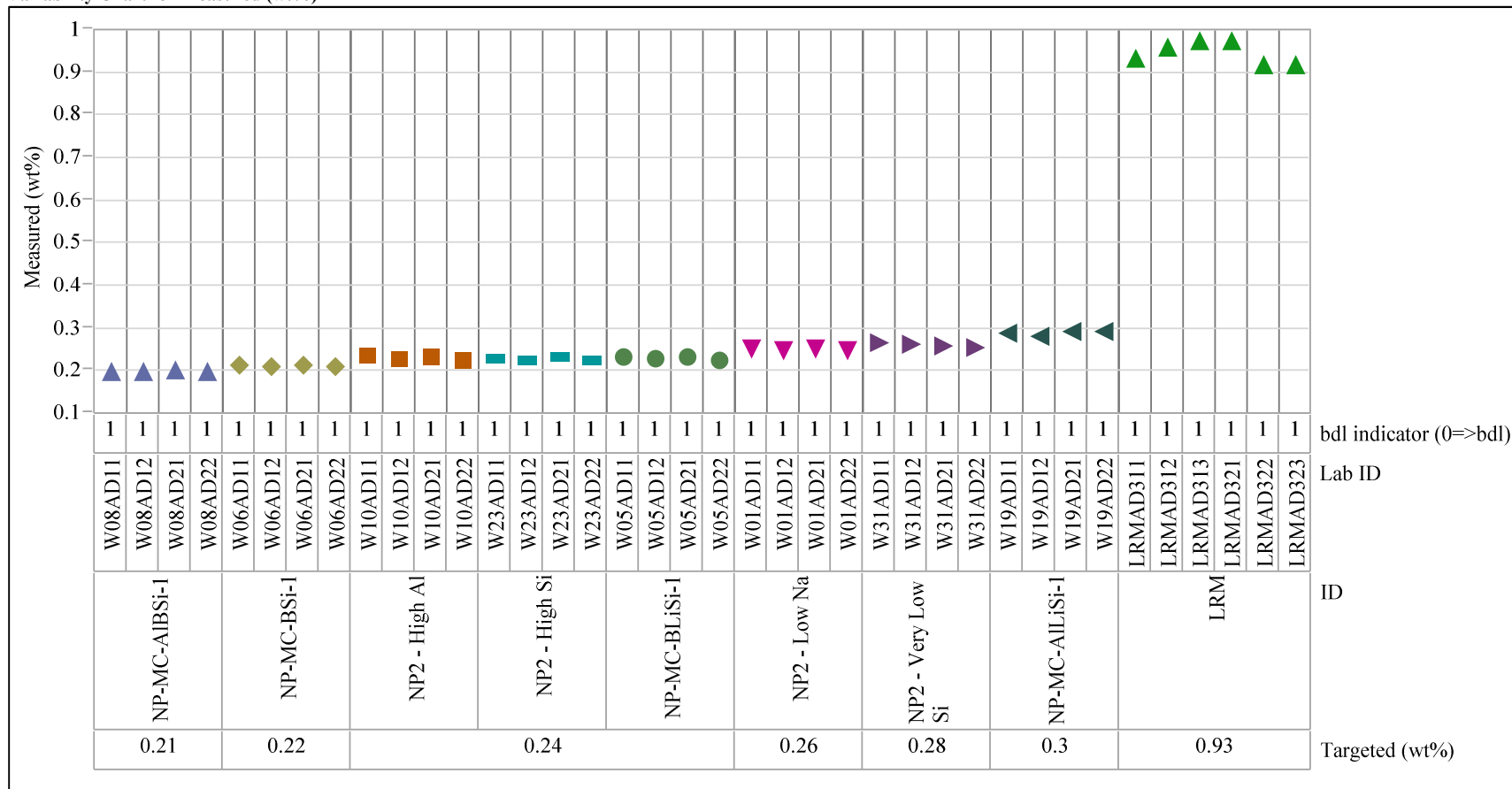
Oxide=ZrO2 (wt%), Prep Method=AD, Block=2

Variability Chart for Measured (wt%)



**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=ZrO<sub>2</sub> (wt%), Prep Method=AD, Block=3

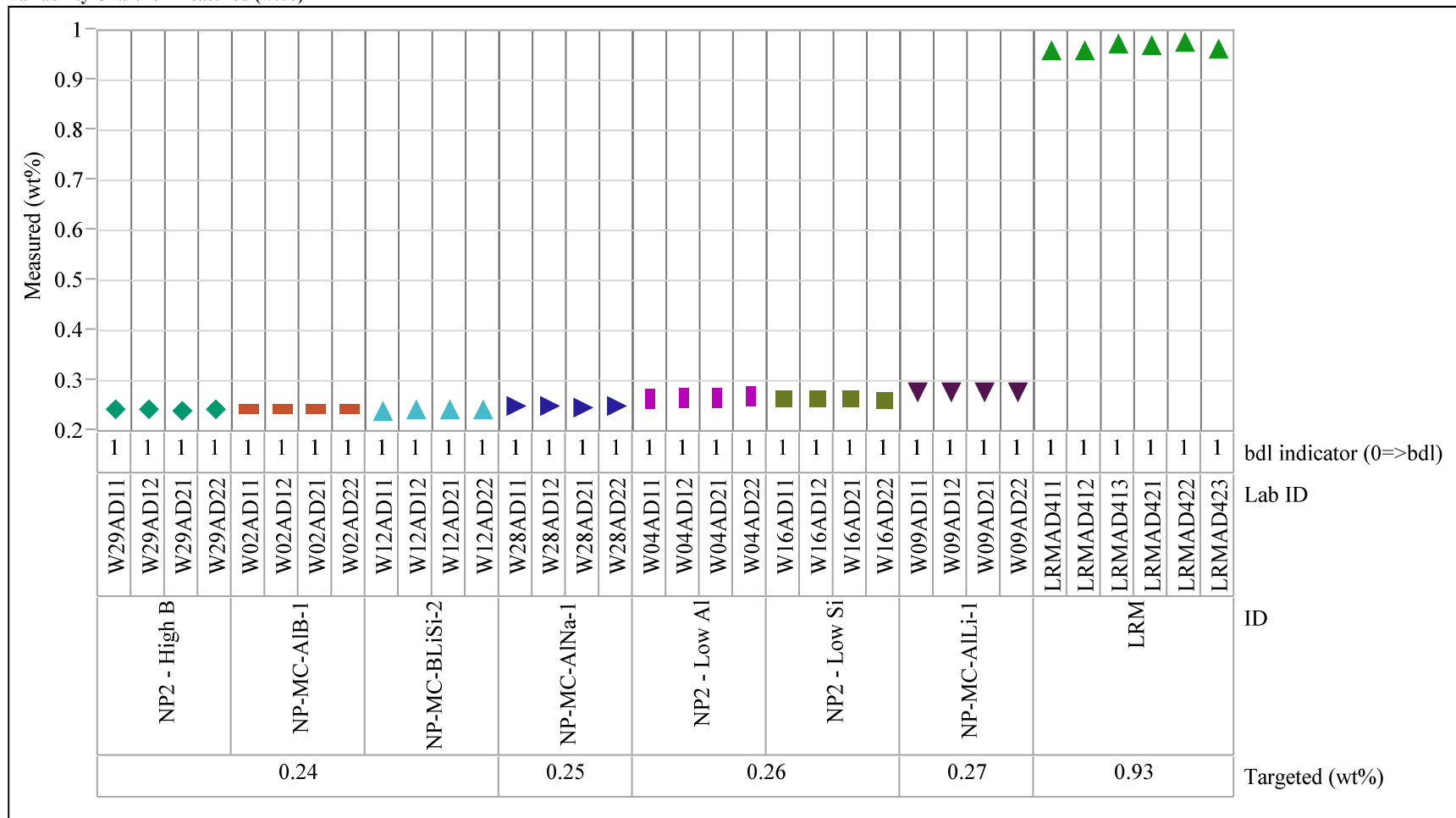
Variability Chart for Measured (wt%)





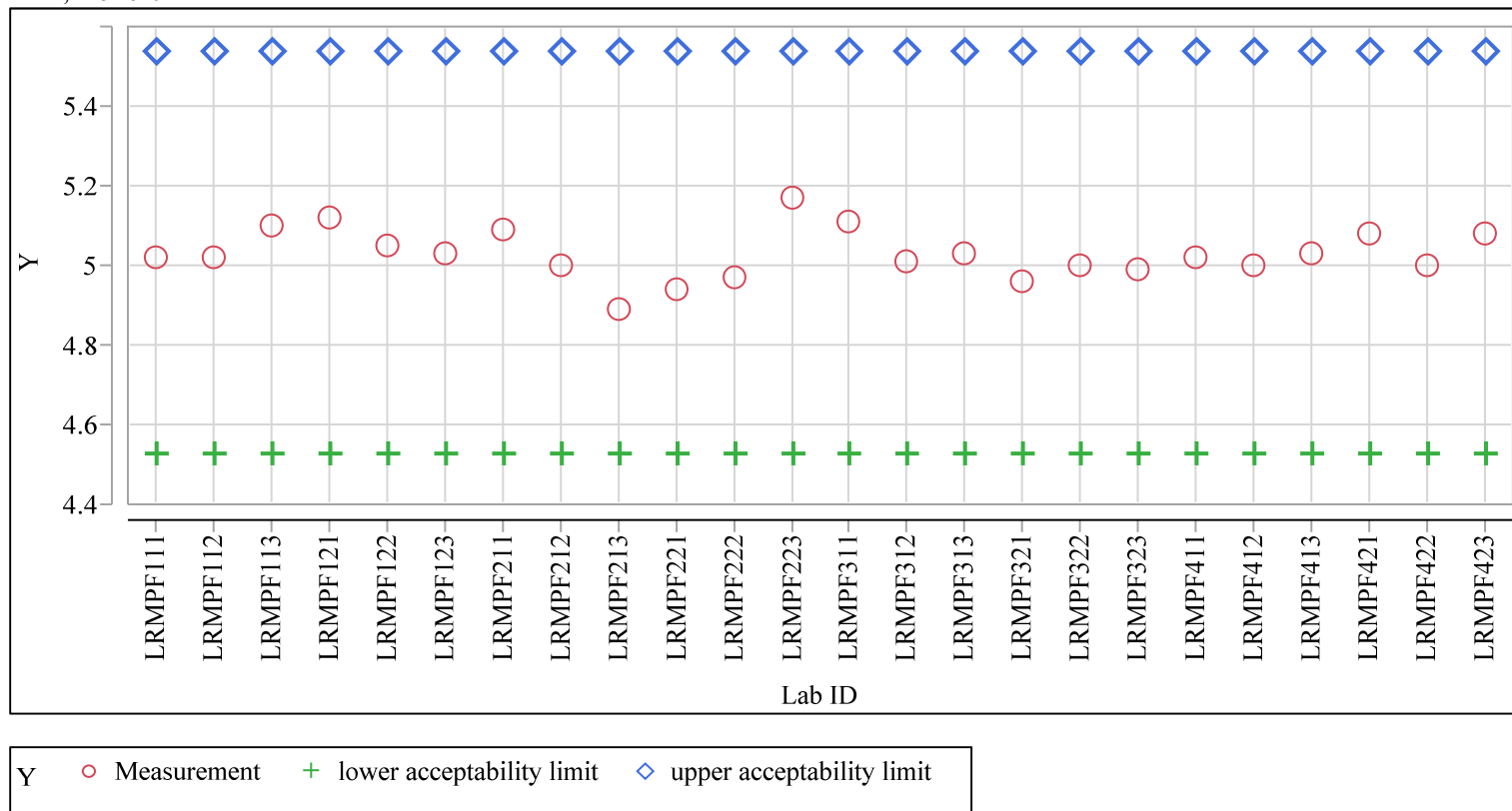
**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**Oxide=ZrO<sub>2</sub> (wt%), Prep Method=AD, Block=4

Variability Chart for Measured (wt%)



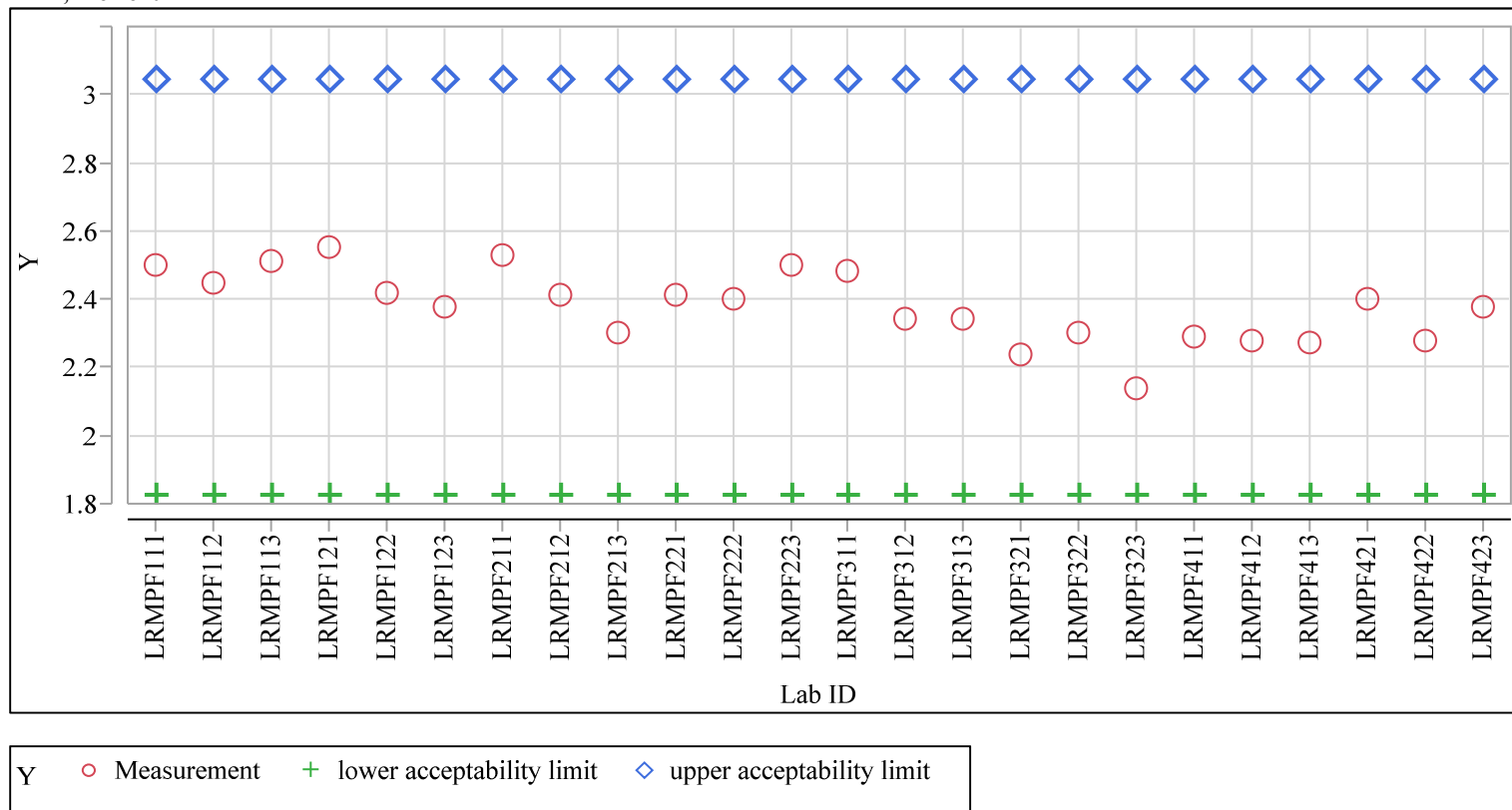
**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass**

LRM, Element=Al



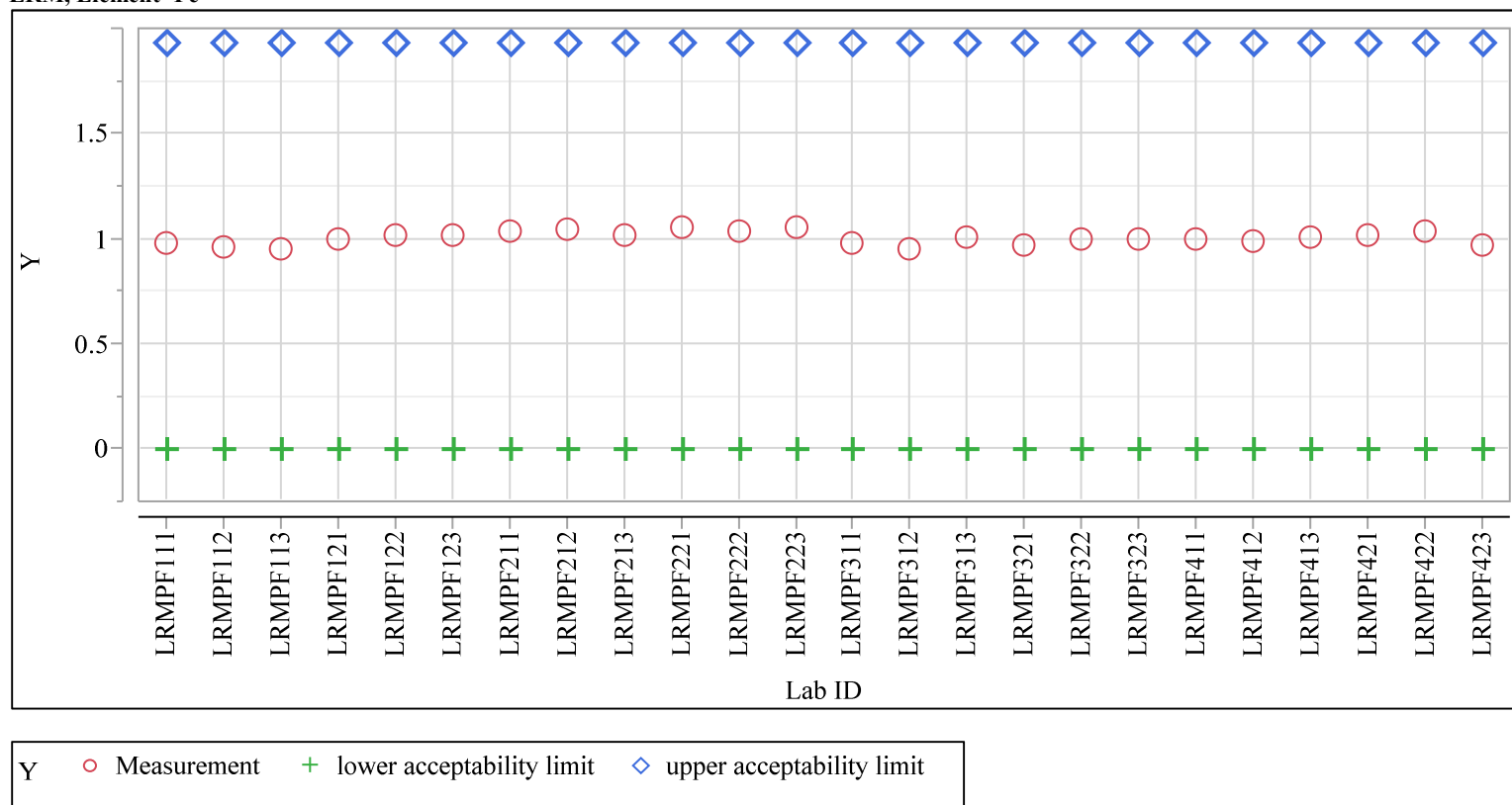
**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

LRM, Element=B



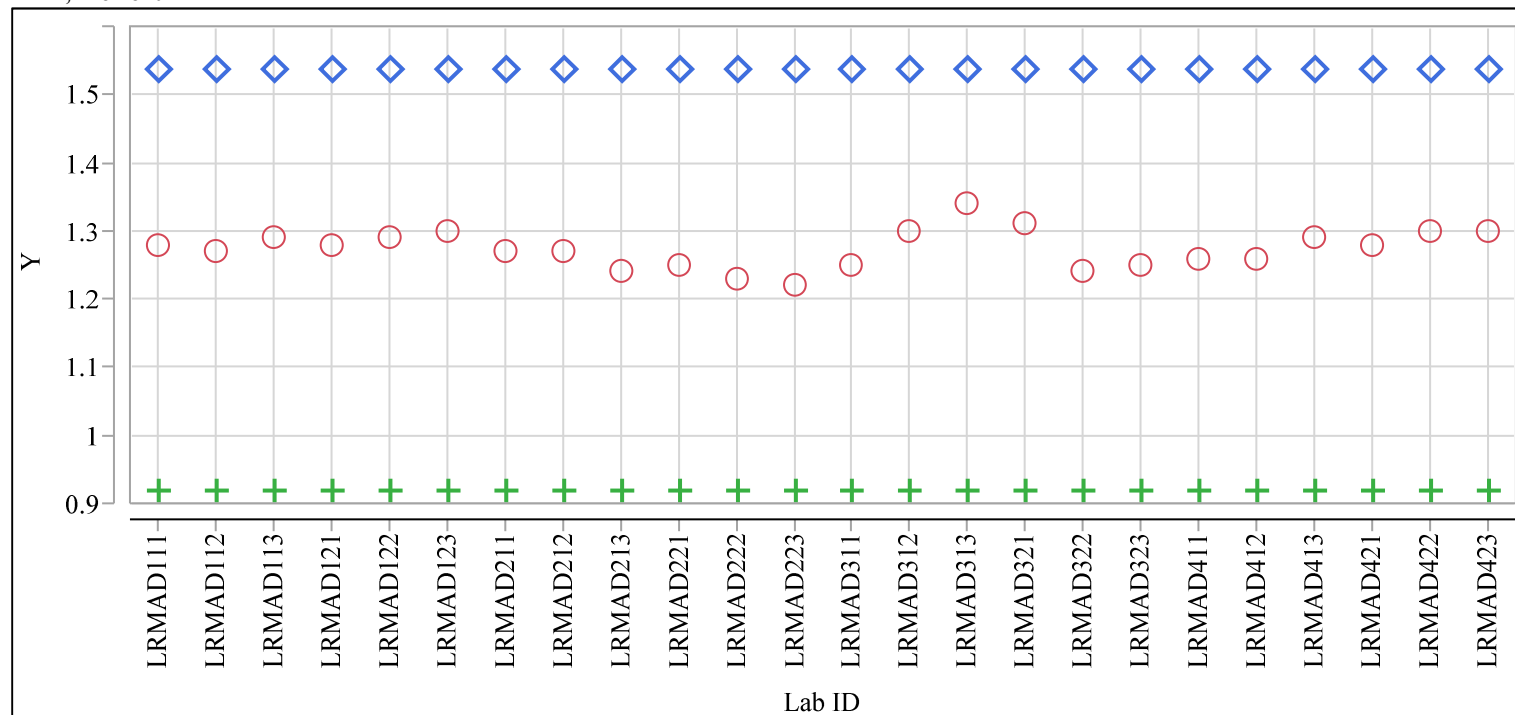
**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

LRM, Element=Fe



**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

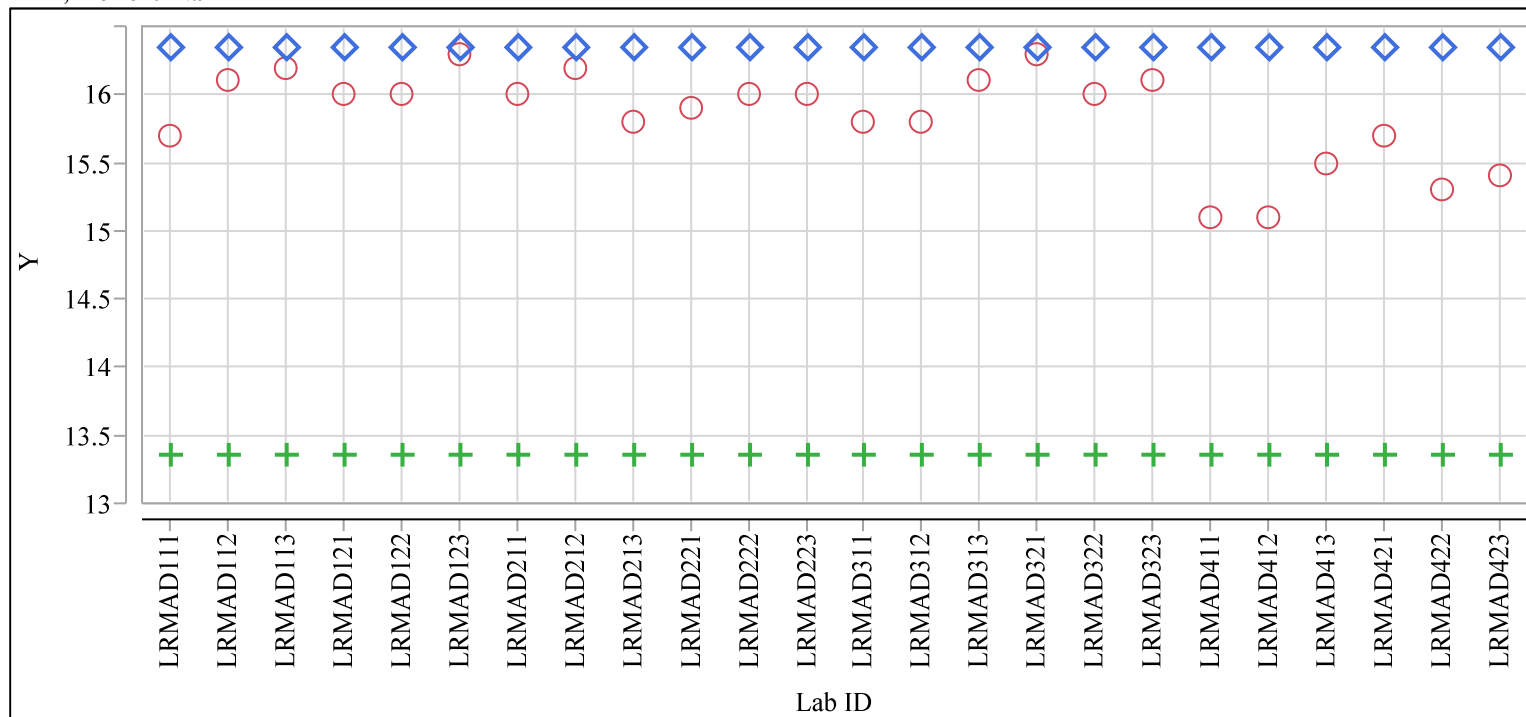
LRM, Element=K



Y    ○ Measurement    + lower acceptability limit    ◇ upper acceptability limit

**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

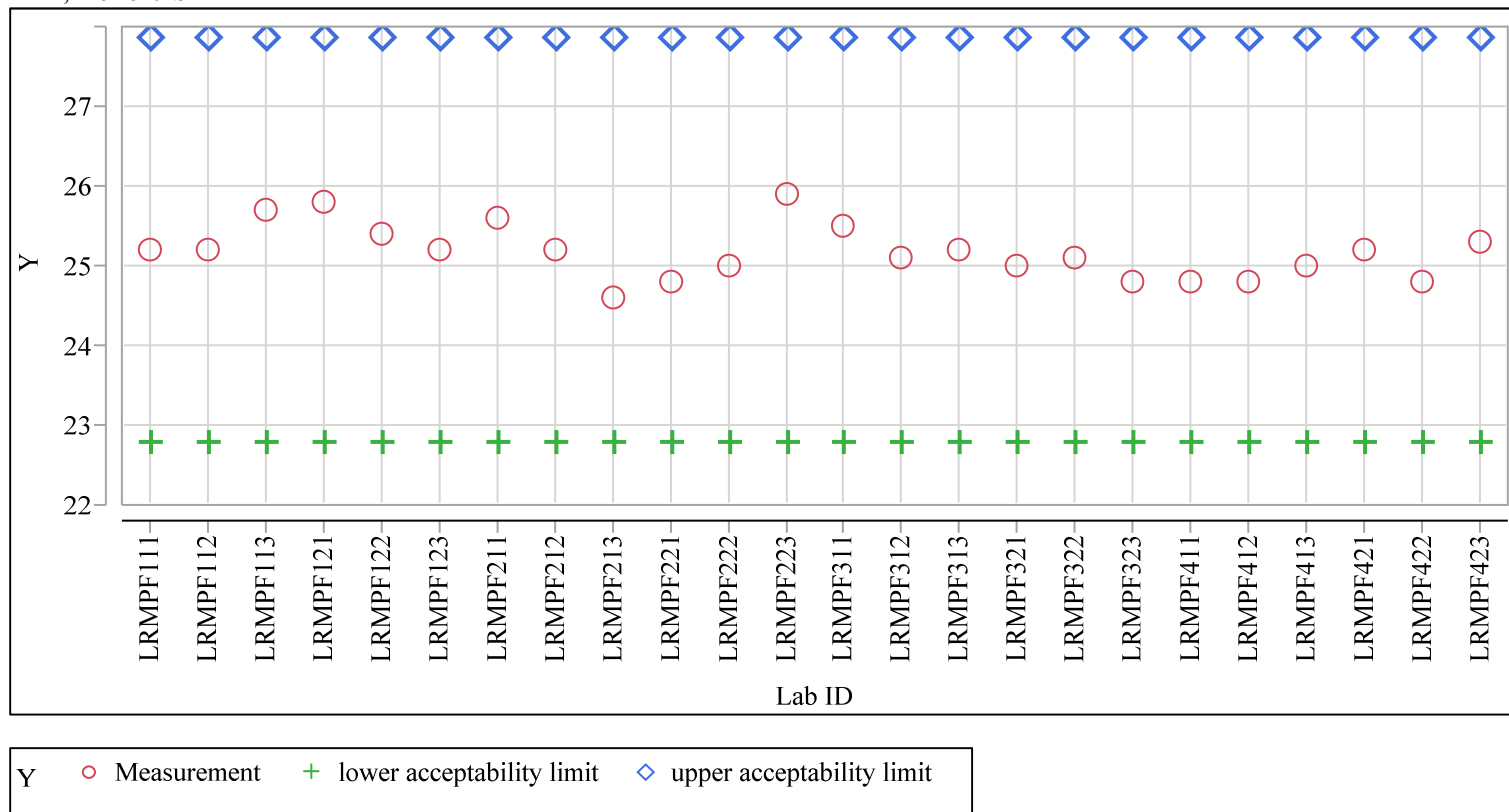
LRM, Element=Na



Y    ○ Measurement    + lower acceptability limit    ◇ upper acceptability limit

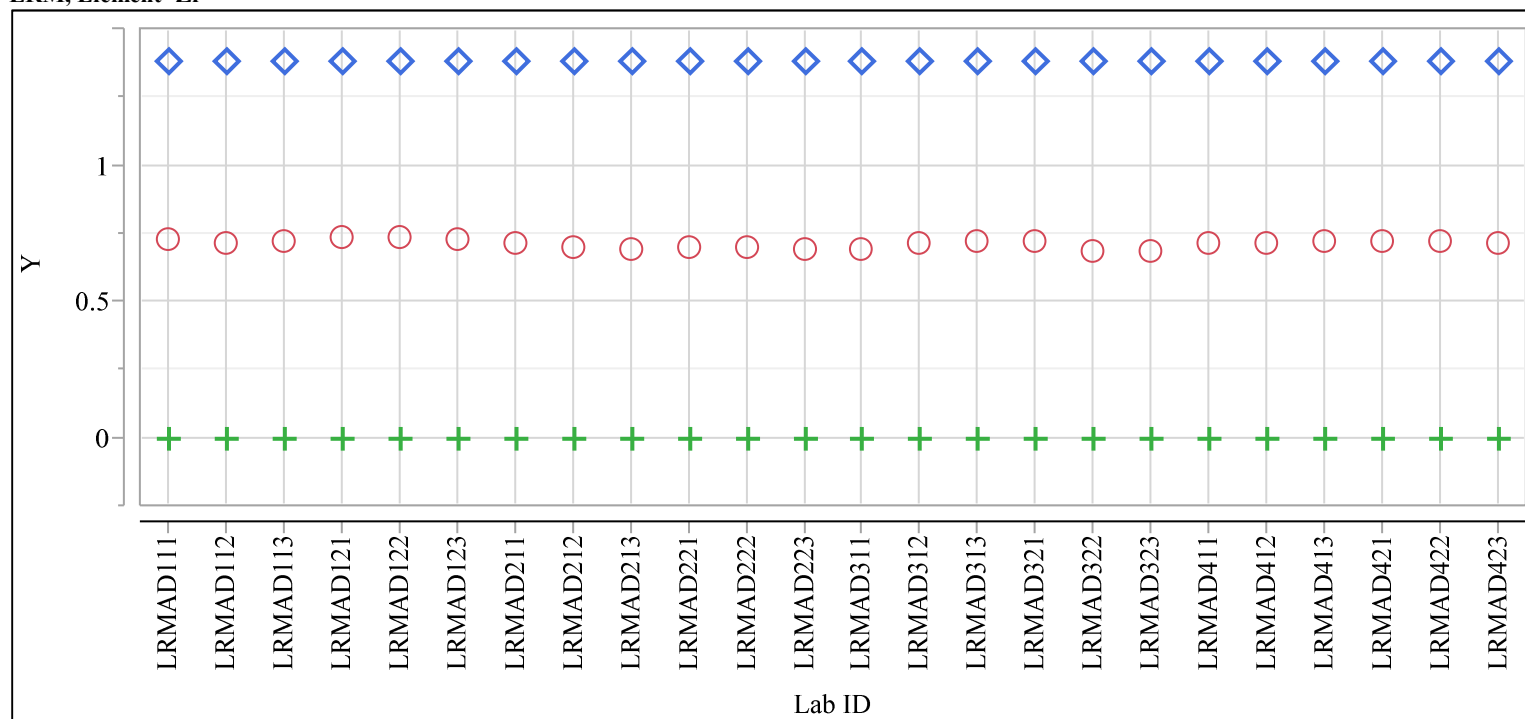
**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

LRM, Element=Si



**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

LRM, Element=Zr



Y    ○ Measurement    + lower acceptability limit    ◇ upper acceptability limit



Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide

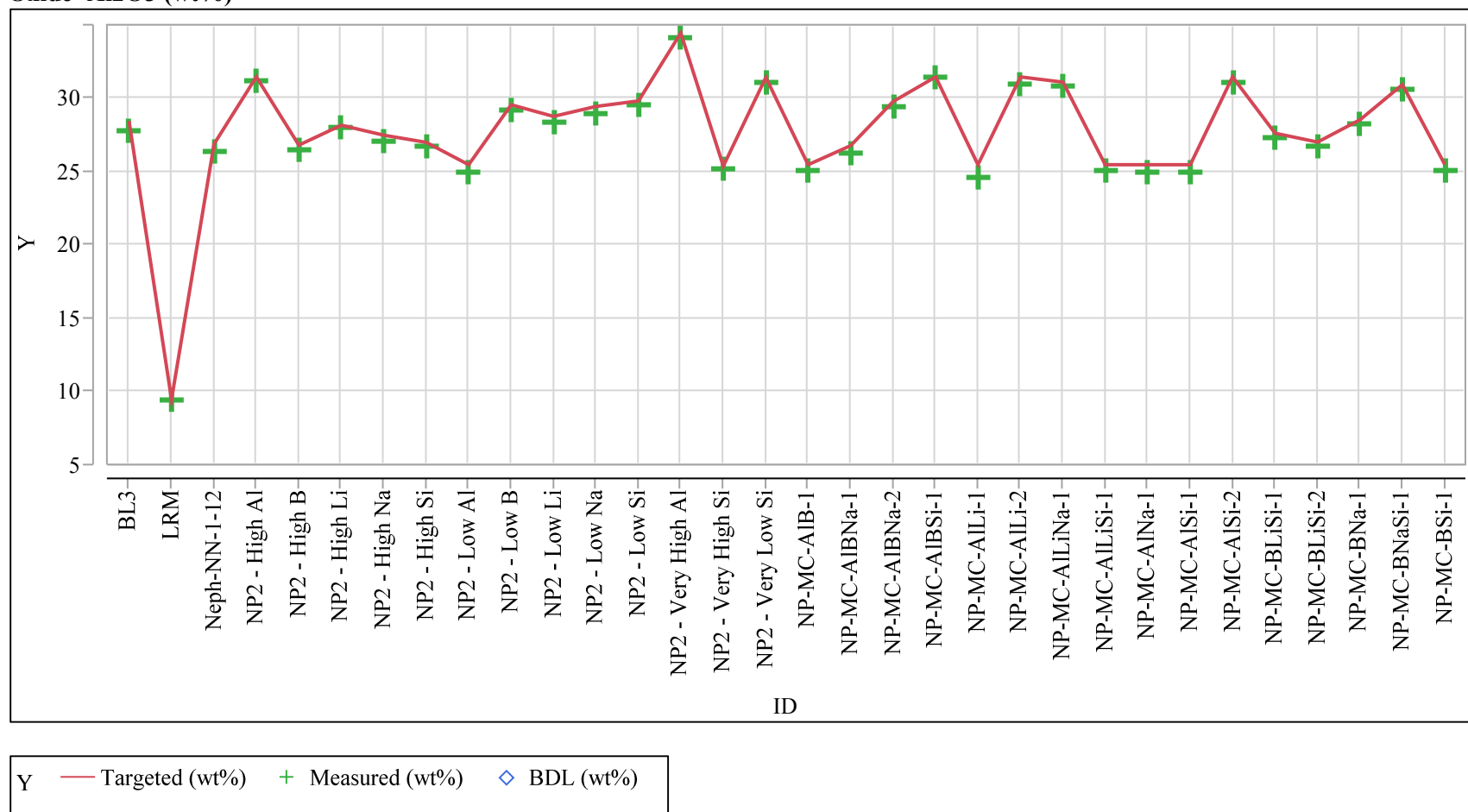
Oxide=Al<sub>2</sub>O<sub>3</sub> (wt%)

Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

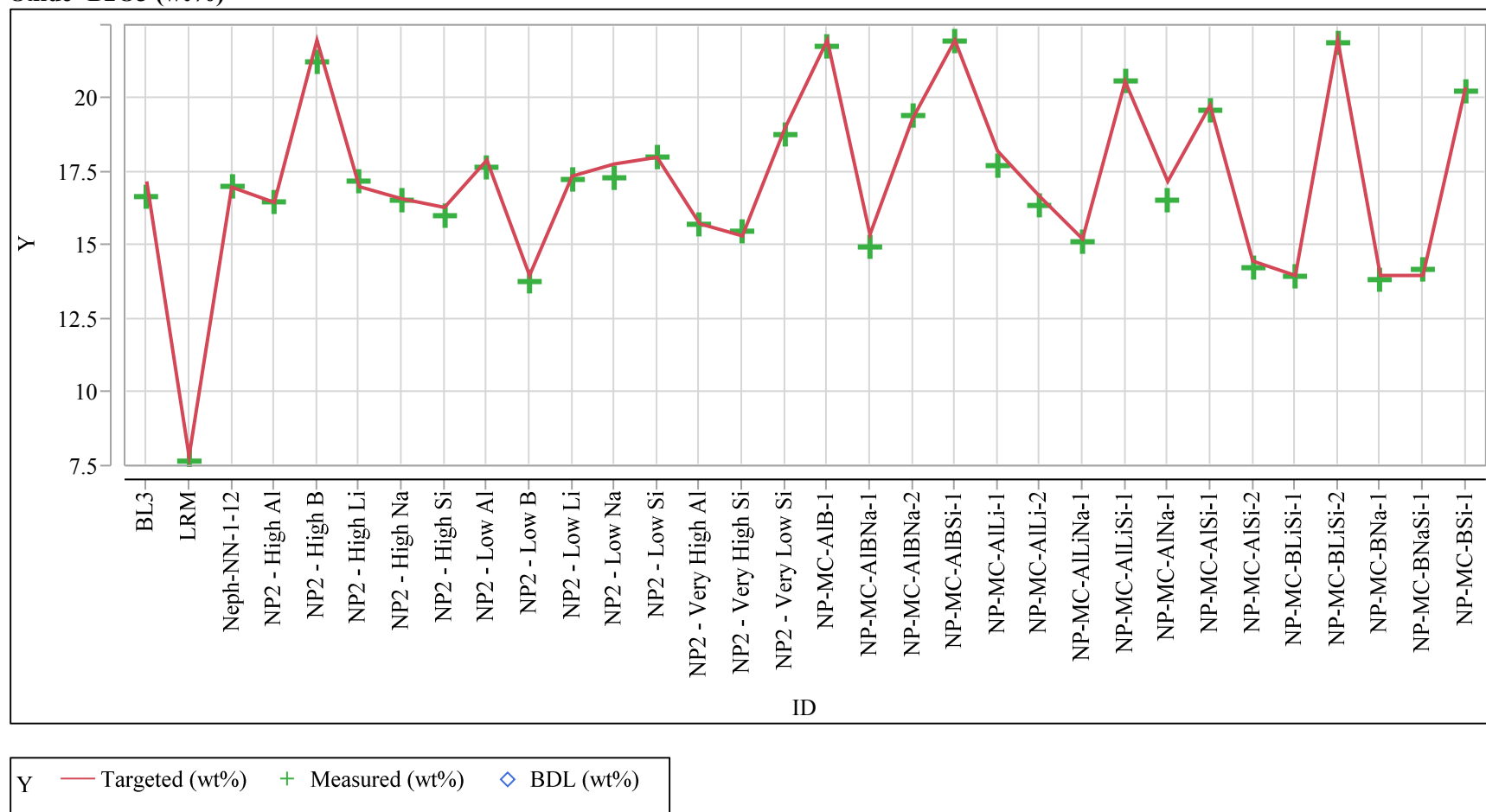
Oxide=B<sub>2</sub>O<sub>3</sub> (wt%)

Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

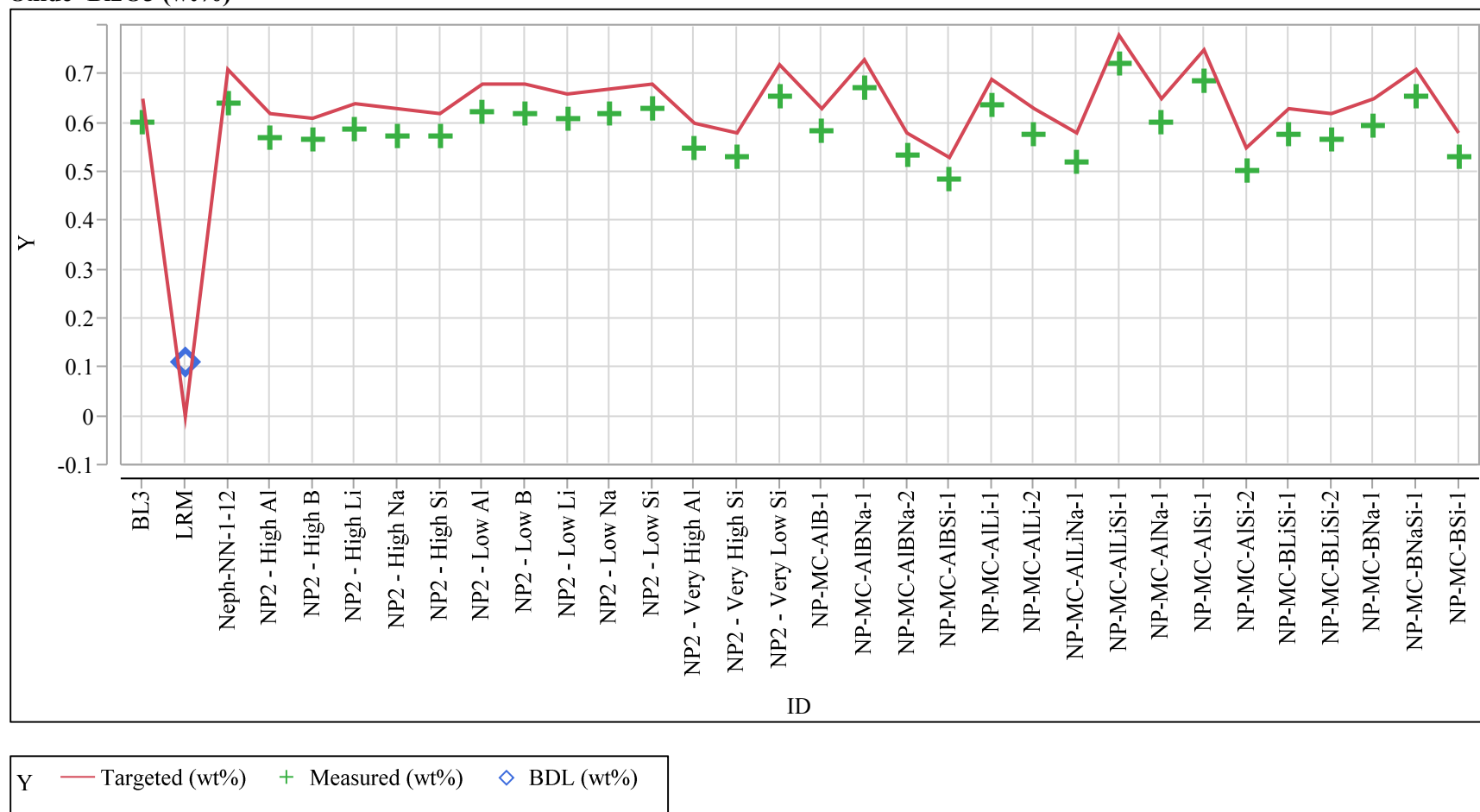
Oxide=Bi<sub>2</sub>O<sub>3</sub> (wt%)

Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Oxide=CaO (wt%)

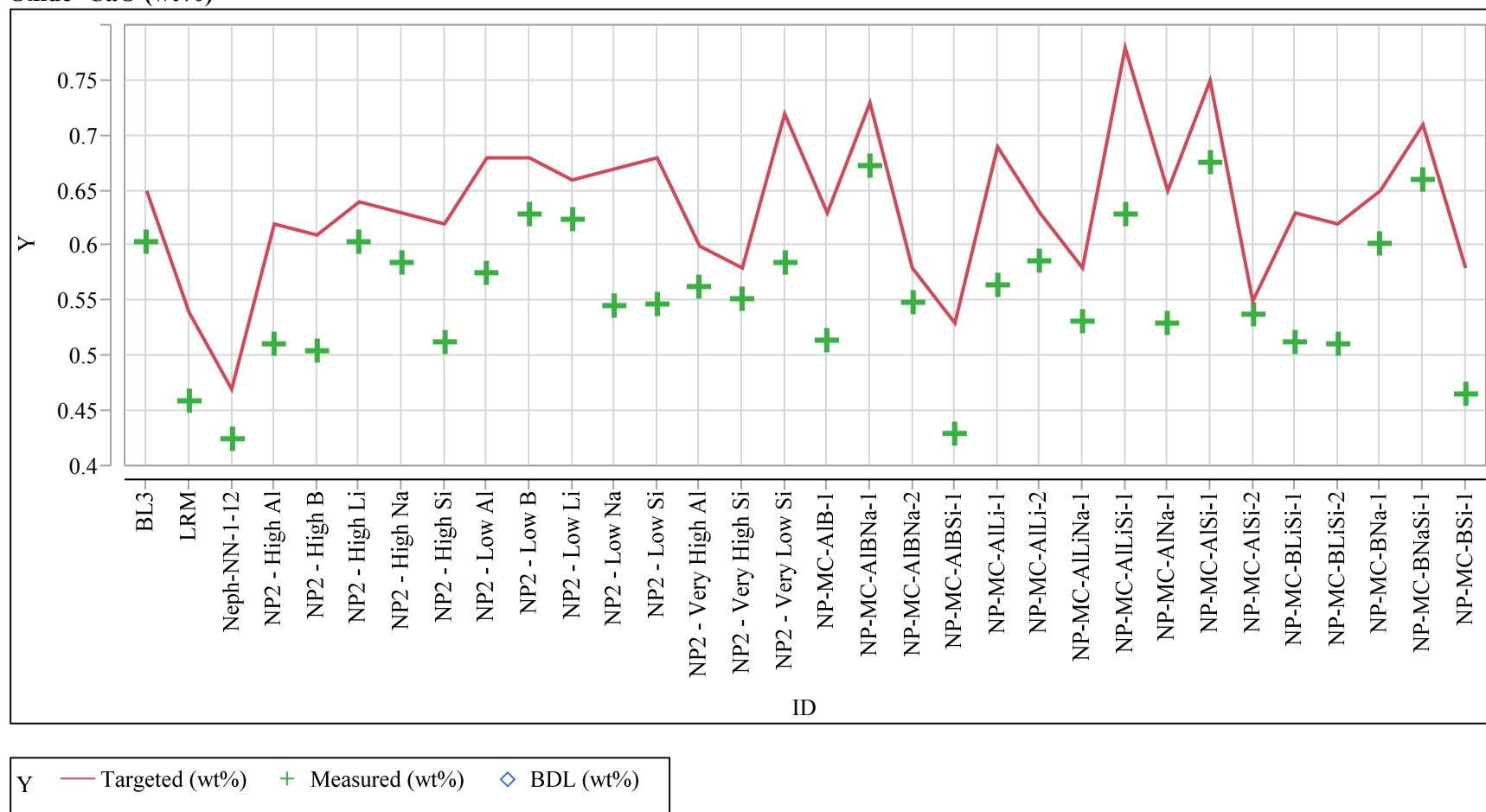


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

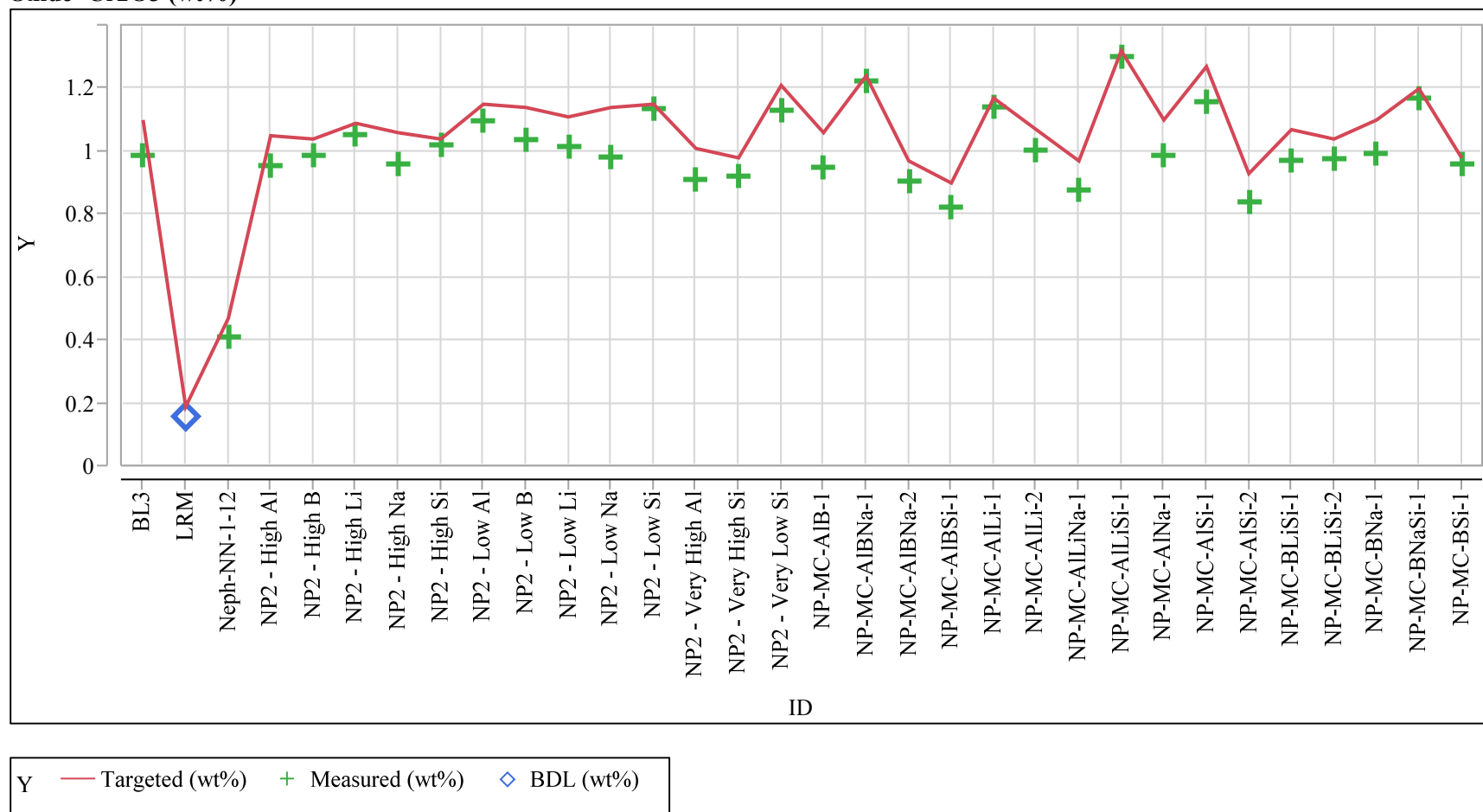
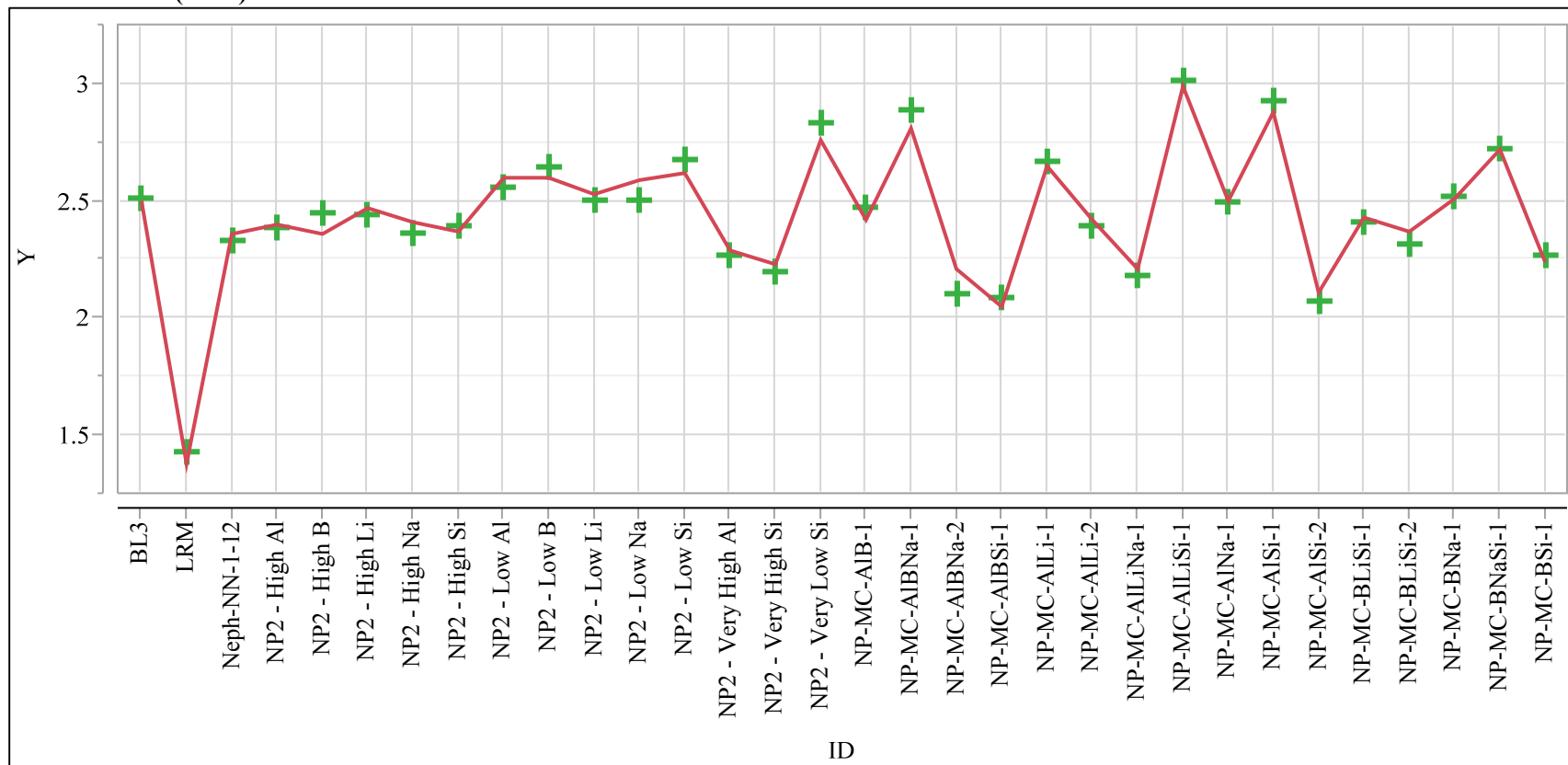
Oxide=Cr<sub>2</sub>O<sub>3</sub> (wt%)

Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Oxide=Fe<sub>2</sub>O<sub>3</sub> (wt%)

Y — Targeted (wt%) + Measured (wt%) ◇ BDL (wt%)

Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

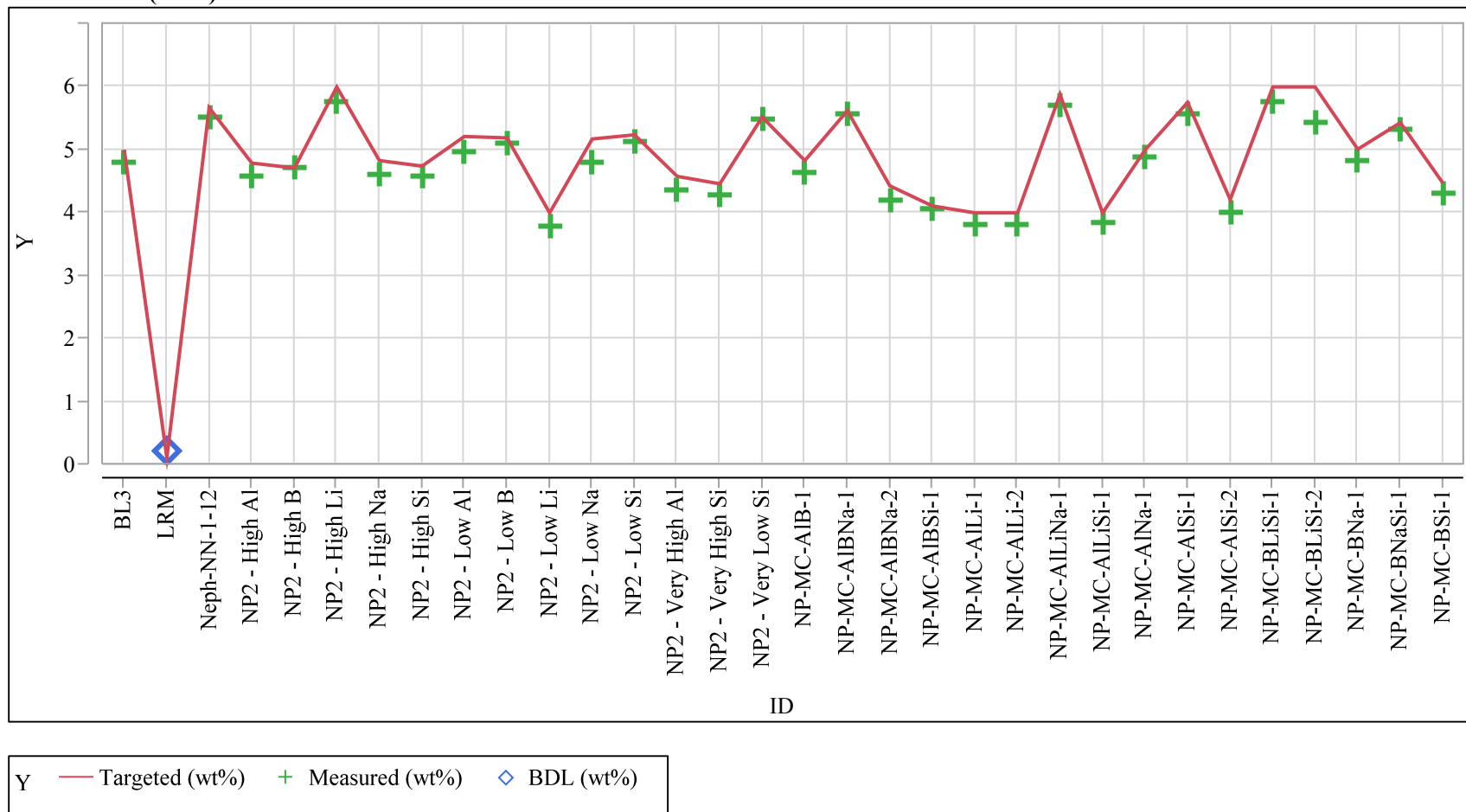
Oxide=Li<sub>2</sub>O (wt%)

Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Oxide=MnO (wt%)

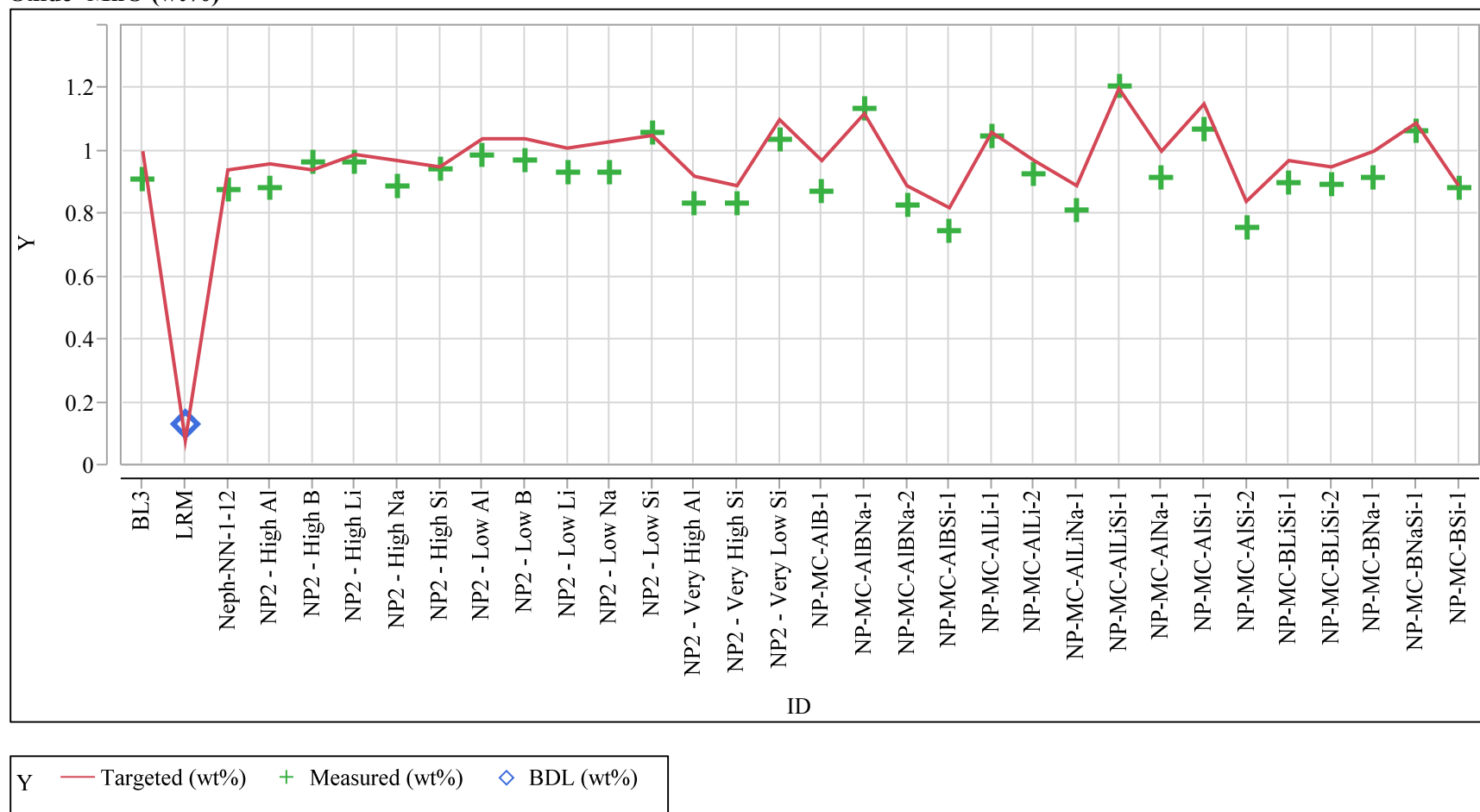




Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

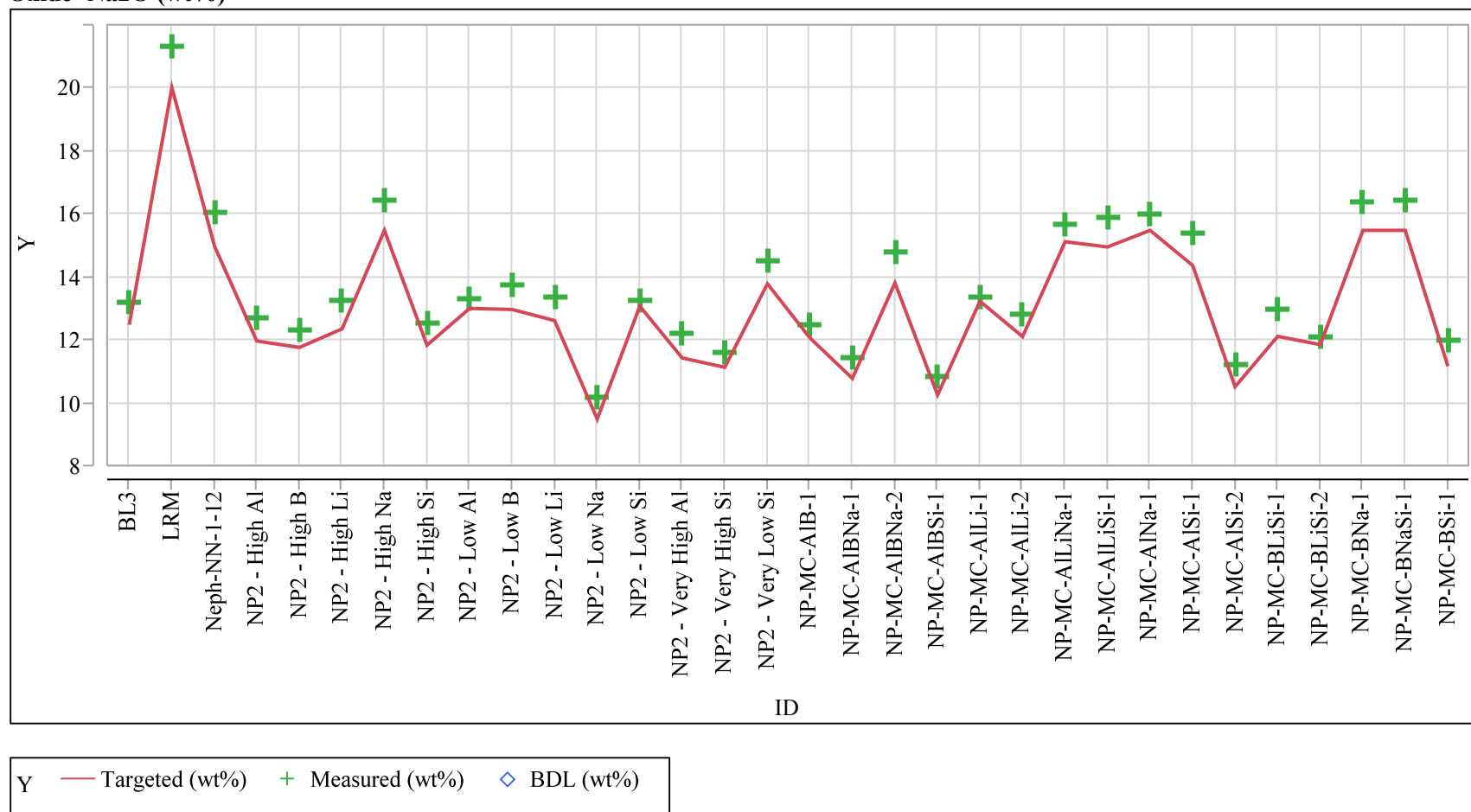
Oxide=Na<sub>2</sub>O (wt%)

Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Oxide=NiO (wt%)

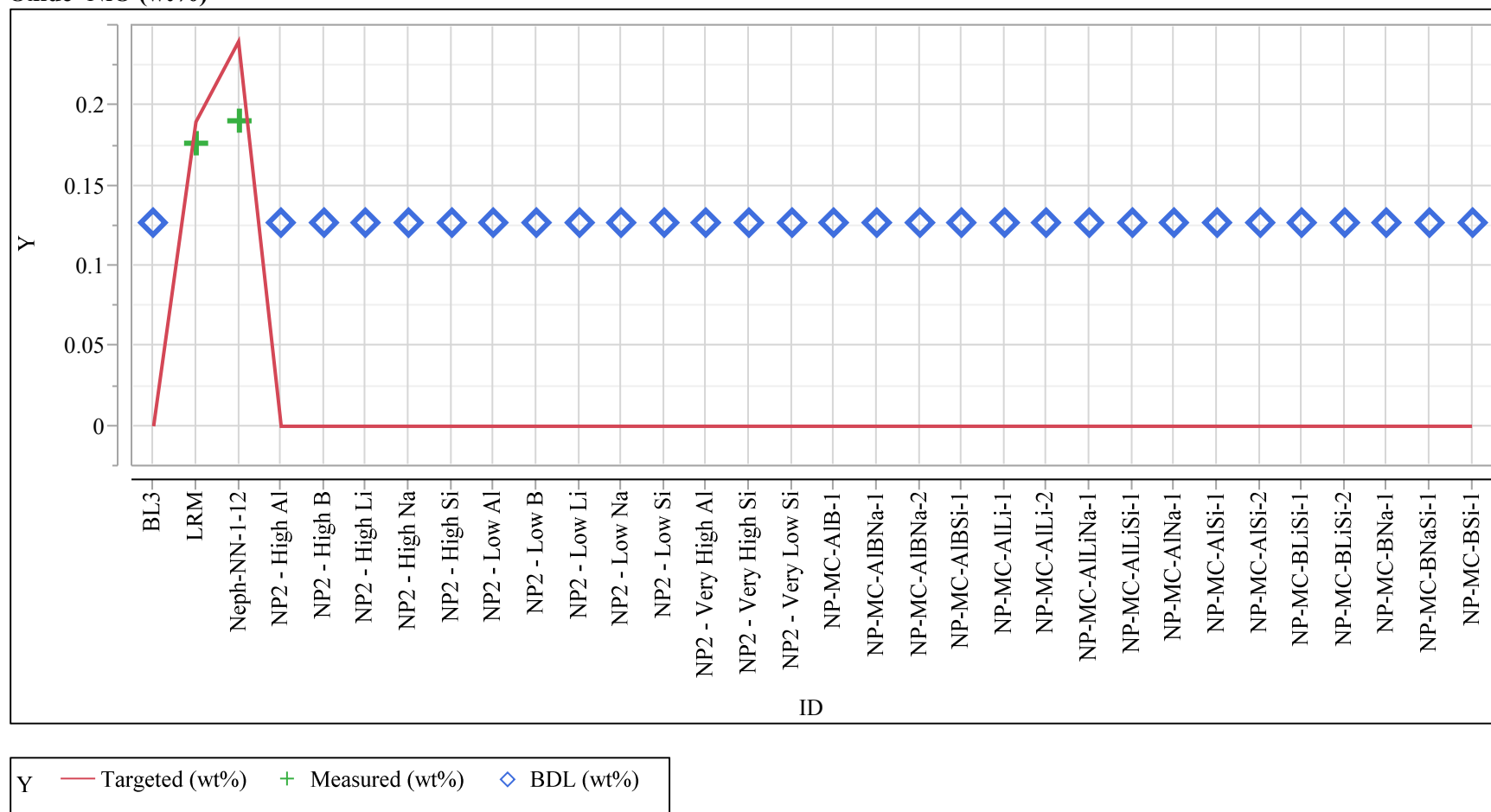
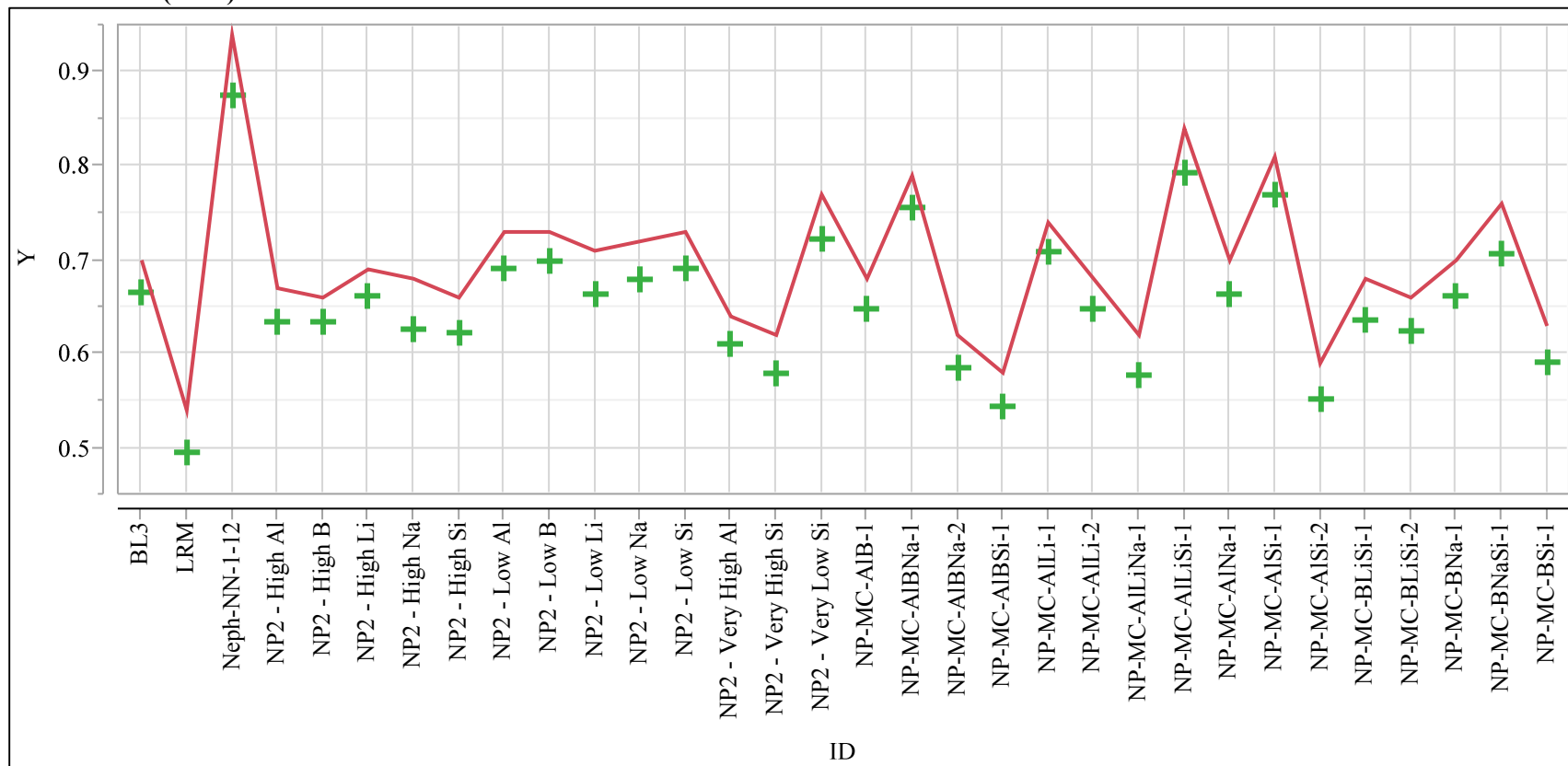


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Oxide=P2O5 (wt%)



Y — Targeted (wt%) + Measured (wt%) ◇ BDL (wt%)

Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Oxide=RuO2 (wt%)

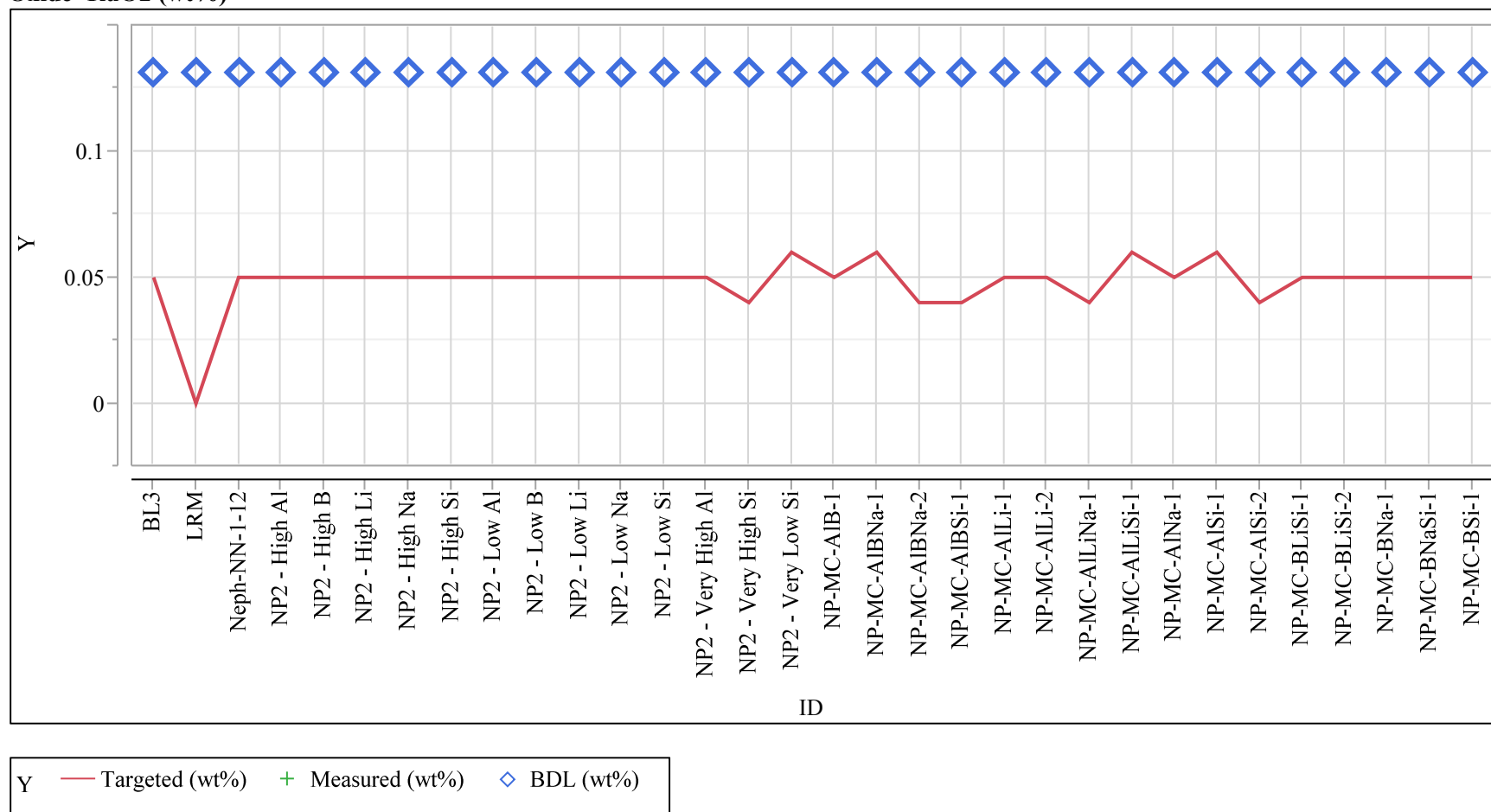


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Oxide=SiO2 (wt%)

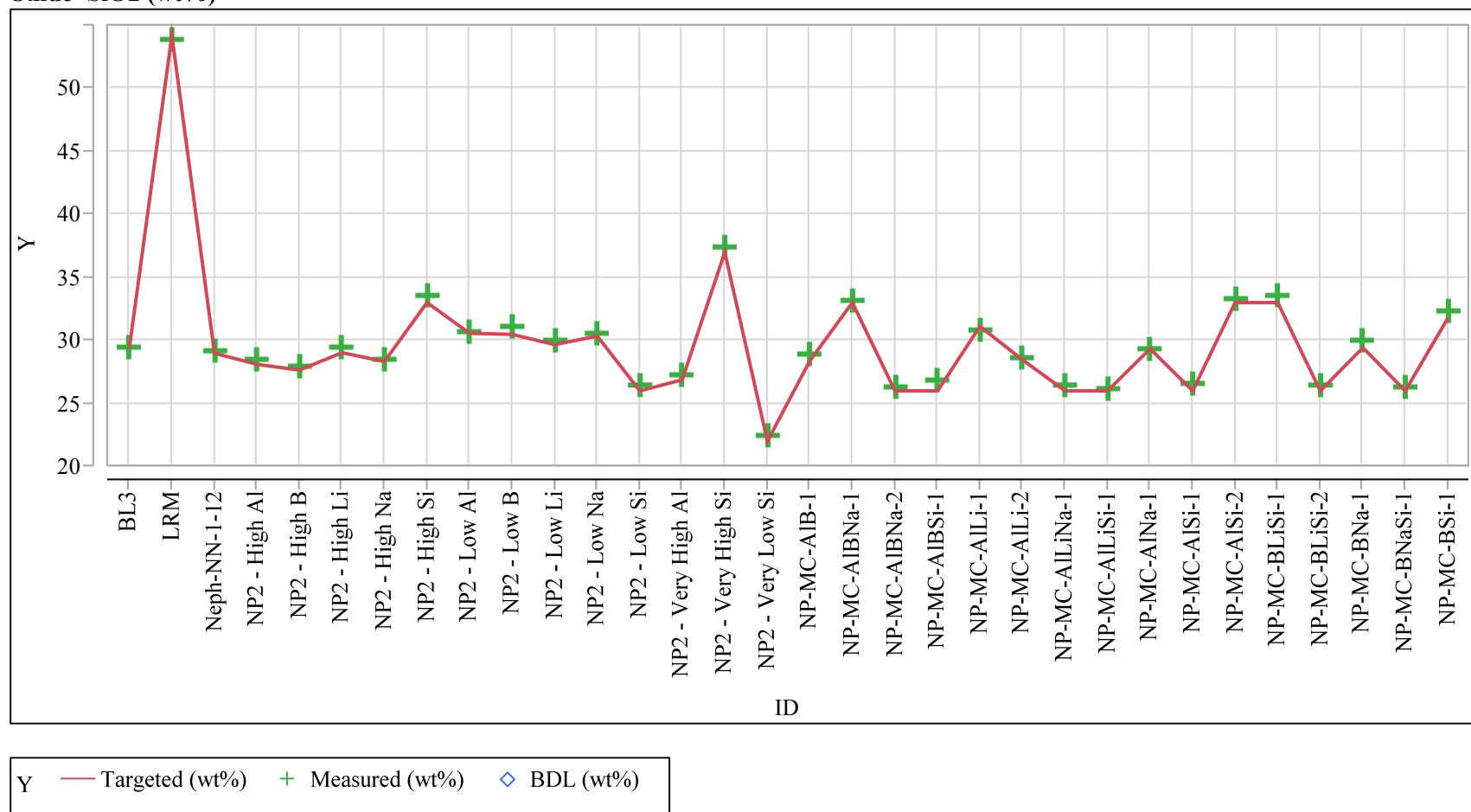


Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

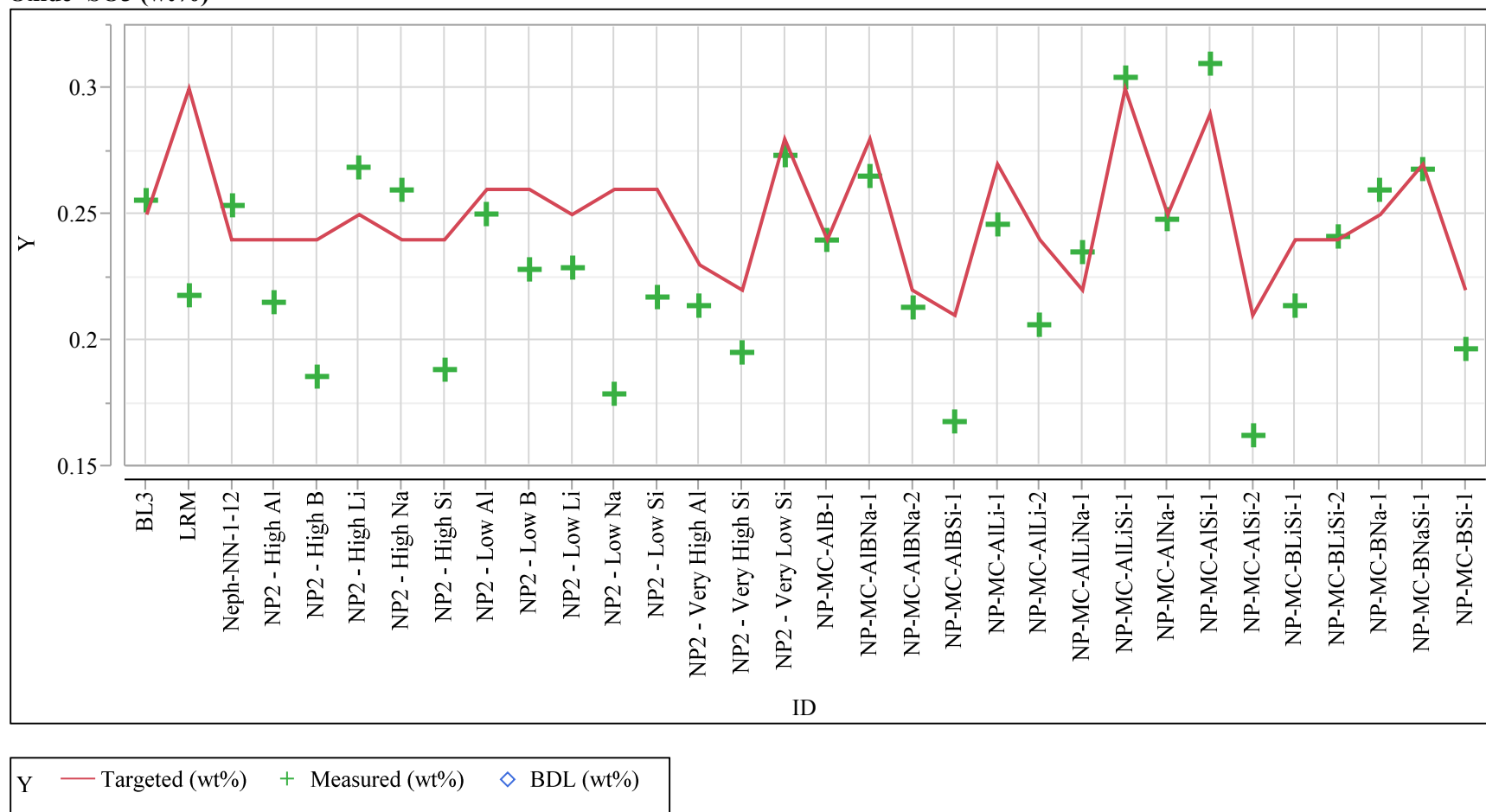
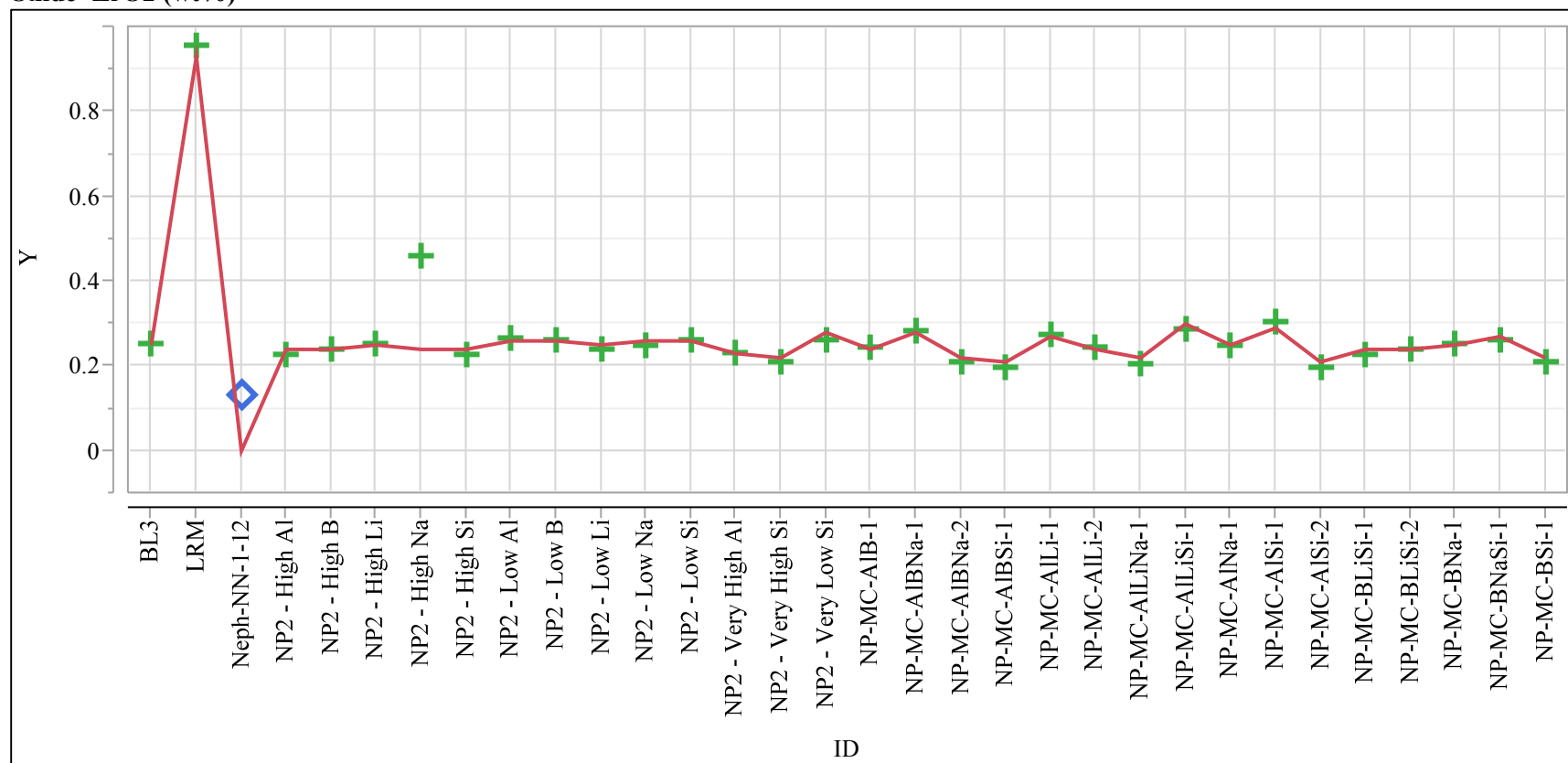
Oxide=SO<sub>3</sub> (wt%)

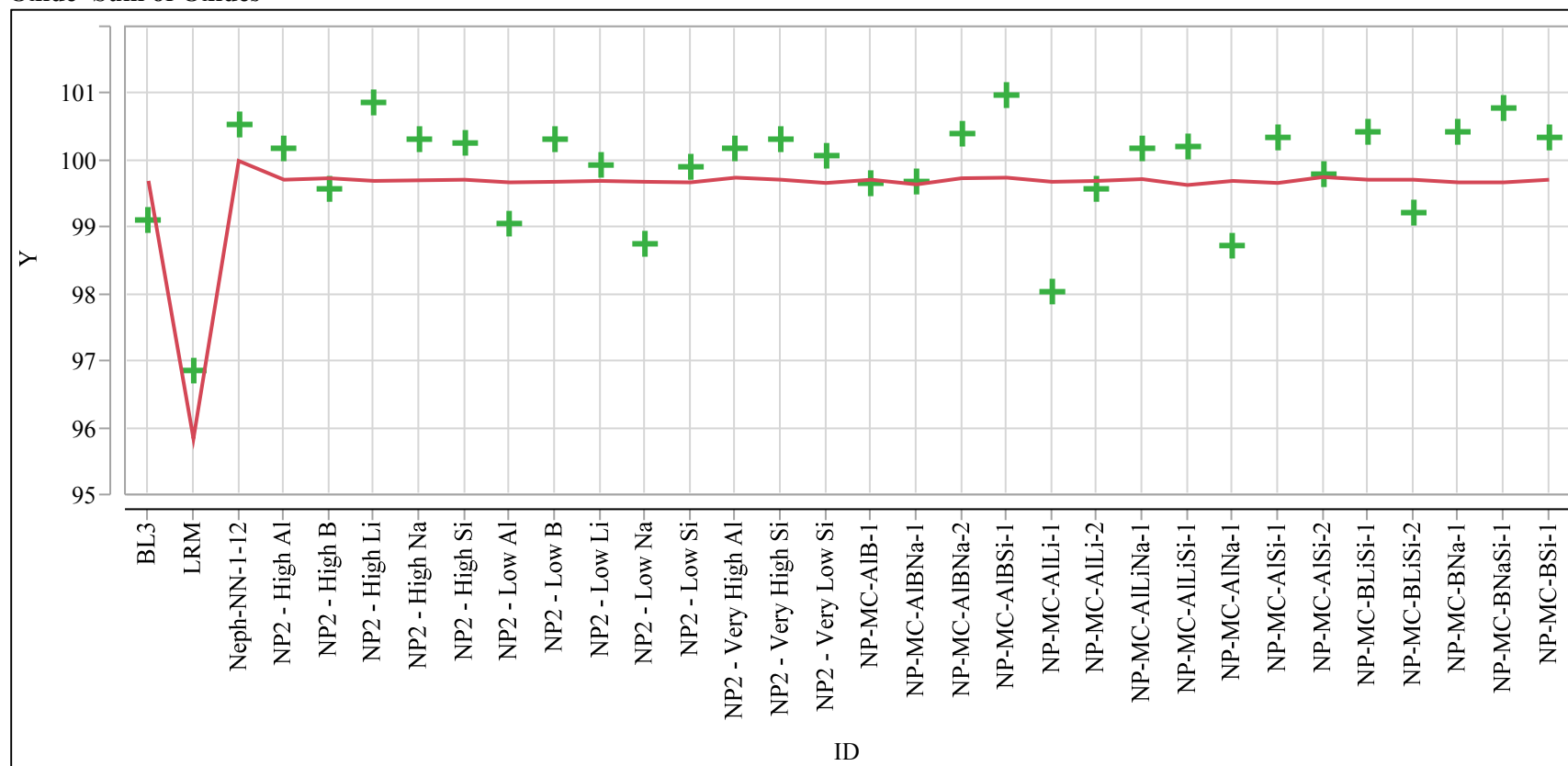
Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Oxide=ZrO<sub>2</sub> (wt%)

Y — Targeted (wt%) + Measured (wt%) ◇ BDL (wt%)

Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)

Oxide=Sum of Oxides



Y — Targeted (wt%) + Measured (wt%) ◇ BDL (wt%)



## **Appendix B   Tables and Exhibits Supporting the PCT Results**

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received)**

Group/Set	Glass ID (w HT)	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (mg/L)	Li (mg/L)	Na (mg/L)	Si (mg/L)
1/1	soln std	1	1	std-J1-1	19.1	9.73	79.7	49.3	19.100	9.730	79.700	49.300
1/1	NP2-High-B-CCC	1	2	J26	171	49.1	126	30.6	285.006	81.835	210.004	51.001
1/1	NP2-Low-Si-CCC	1	3	J27	321	86.3	279	1.63	535.011	143.836	465.009	2.717
1/1	NP2-Low-Na-CCC	1	4	J44	144	44.0	87.0	30.2	240.005	73.335	145.003	50.334
1/1	ARM-1	1	5	J46	9.44	8.10	20.4	34.5	15.734	13.500	34.001	57.501
1/1	blank	1	6	J09	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667
1/1	NP2-Very-High-Al-CCC	1	7	J04	1280	321	729	12.5	2133.376	535.011	1215.024	20.834
1/1	NP2-High-Si-CCC	1	8	J30	1190	334	497	15.2	1983.373	556.678	828.350	25.334
1/1	NP2-High-Li-CCC	1	9	J47	2270	843	784	7.09	3783.409	1405.028	1306.693	11.817
1/1	soln std	1	10	std-J1-2	19.3	9.83	80.1	48.9	19.300	9.830	80.100	48.900
1/1	NP2-Low-Al-CCC	1	11	J03	255	81.3	143	19.0	425.009	135.503	238.338	31.667
1/1	NP2-Low-Li-CCC	1	12	J07	113	27.2	92.3	23.5	188.337	45.334	153.836	39.167
1/1	NP2-Very-Low-Si-CCC	1	13	J19	1890	588	1670	2.56	3150.063	980.020	2783.389	4.267
1/1	BL3-CCC	1	14	J18	739	186	430	13.1	1231.691	310.006	716.681	21.834
1/1	NP2-High-Na-CCC	1	15	J32	2470	846	1330	6.29	4116.749	1410.028	2216.711	10.484
1/1	NP2-High-Al-CCC	1	16	J20	537	115	374	12.9	895.018	191.671	623.346	21.500
1/1	Neph-NN-1-12-CCC	1	17	J06	2660	1020	1080	7.29	4433.422	1700.034	1800.036	12.150
1/1	NP2-Low-B-CCC	1	18	J01	2140	869	731	6.29	3566.738	1448.362	1218.358	10.484
1/1	soln std	1	19	std-J1-3	19.9	9.77	79.5	49.0	19.900	9.770	79.500	49.000
1/1	soln std	2	1	std-J2-1	19.5	9.86	80.5	48.9	19.500	9.860	80.500	48.900
1/1	NP2-High-Na-CCC	2	2	J24	2440	919	1330	6.20	4066.748	1531.697	2216.711	10.334
1/1	BL3-CCC	2	3	J13	742	188	433	12.9	1236.691	313.340	721.681	21.500
1/1	NP2-Very-Low-Si-CCC	2	4	J38	1930	663	1730	2.11	3216.731	1105.022	2883.391	3.517
1/1	NP2-Low-Si-CCC	2	5	J45	338	86.3	284	1.37	563.345	143.836	473.343	2.283
1/1	NP2-Low-B-CCC	2	6	J37	2130	858	697	6.12	3550.071	1430.029	1161.690	10.200
1/1	NP2-Very-High-Al-CCC	2	7	J42	1230	313	637	12.0	2050.041	521.677	1061.688	20.000
1/1	NP2-High-Si-CCC	2	8	J11	1160	345	452	14.8	1933.372	575.012	753.348	24.667
1/1	ARM-1	2	9	J21	14.0	7.80	19.5	33.5	23.334	13.000	32.501	55.834
1/1	soln std	2	10	std-J2-2	21.7	9.64	77.5	48.2	21.700	9.640	77.500	48.200
1/1	Neph-NN-1-12-CCC	2	11	J14	2620	1020	1080	6.94	4366.754	1700.034	1800.036	11.567
1/1	NP2-Low-Na-CCC	2	12	J41	148	41.2	77.5	28.1	246.672	68.668	129.169	46.834
1/1	NP2-Low-Al-CCC	2	13	J02	261	81.6	146	19.4	435.009	136.003	243.338	32.334
1/1	NP2-High-Li-CCC	2	14	J40	2210	834	765	6.83	3683.407	1390.028	1275.026	11.384
1/1	NP2-Low-Li-CCC	2	15	J35	117	26.6	87.8	22.6	195.004	44.334	146.336	37.667
1/1	NP2-High-B-CCC	2	16	J36	168	47.8	128	30.4	280.006	79.668	213.338	50.668
1/1	NP2-High-Al-CCC	2	17	J29	539	116	373	12.4	898.351	193.337	621.679	20.667
1/1	soln std	2	18	std-J2-3	21.4	9.71	77.9	49.1	21.400	9.710	77.900	49.100
1/1	soln std	3	1	std-J3-1	18.8	9.79	80.8	49.6	18.800	9.790	80.800	49.600
1/1	BL3-CCC	3	2	J08	728	186	428	13.2	1213.358	310.006	713.348	22.000
1/1	NP2-Very-Low-Si-CCC	3	3	J12	1870	590	1650	2.30	3116.729	983.353	2750.055	3.833
1/1	NP2-Low-Li-CCC	3	4	J16	111	26.8	90.6	23.2	185.004	44.668	151.003	38.667
1/1	ARM-1	3	5	J17	6.15	7.86	19.6	33.3	10.250	13.100	32.667	55.501

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

Group/Set	Glass ID (w HT)	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (mg/L)	Li (mg/L)	Na (mg/L)	Si (mg/L)
1/1	NP2-Low-Al-CCC	3	6	J22	263	80.9	143	19.7	438.342	134.836	238.338	32.834
1/1	NP2-High-Li-CCC	3	7	J34	2300	849	780	7.45	3833.410	1415.028	1300.026	12.417
1/1	NP2-Low-Na-CCC	3	8	J05	144	42.3	80.9	27.3	240.005	70.501	134.836	45.501
1/1	NP2-High-Si-CCC	3	9	J39	1220	352	460	15.4	2033.374	586.678	766.682	25.667
1/1	soln std	3	10	std-J3-2	18.5	9.64	78.1	48.5	18.500	9.640	78.100	48.500
1/1	Neph-NN-1-12-CCC	3	11	J25	2700	1020	1080	7.08	4500.090	1700.034	1800.036	11.800
1/1	blank	3	12	J33	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667
1/1	NP2-High-Na-CCC	3	13	J43	2450	847	1320	6.24	4083.415	1411.695	2200.044	10.400
1/1	NP2-High-B-CCC	3	14	J28	171	46.9	124	30.0	285.006	78.168	206.671	50.001
1/1	NP2-High-Al-CCC	3	15	J10	543	117	381	12.4	905.018	195.004	635.013	20.667
1/1	NP2-Low-Si-CCC	3	16	J23	334	87.1	282	1.45	556.678	145.170	470.009	2.417
1/1	NP2-Low-B-CCC	3	17	J15	2120	800	718	5.98	3533.404	1333.360	1196.691	9.967
1/1	NP2-Very-High-Al-CCC	3	18	J31	1190	308	678	12.2	1983.373	513.344	1130.023	20.334
1/1	soln std	3	19	std-J3-3	18.5	9.72	78.6	48.8	18.500	9.720	78.600	48.800
1/2	soln std	1	1	std-K1-1	20.9	9.84	82.6	51.1	20.900	9.840	82.600	51.100
1/2	NP-MC-BLiSi-1-CCC	1	2	K01	2200	902	570	10.6	3666.740	1503.363	950.019	17.667
1/2	NP-MC-BNaSi-1-CCC	1	3	K10	1930	799	1690	2.54	3216.731	1331.693	2816.723	4.233
1/2	blank	1	4	K31	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667
1/2	NP-MC-ALi-1-CCC	1	5	K04	80.0	23.2	73.0	38.5	133.336	38.667	121.669	64.168
1/2	NP-MC-AIBNa-2-CCC	1	6	K29	435	93.3	417	2.45	725.015	155.503	695.014	4.083
1/2	NP-MC-ALiSi-1-CCC	1	7	K13	3000	1040	1490	8.24	5000.100	1733.368	2483.383	13.734
1/2	NP-MC-AIBSi-1-CCC	1	8	K40	147	36.2	110	1.94	245.005	60.335	183.337	3.233
1/2	NP-MC-AINa-1-CCC	1	9	K23	3120	1080	1360	10.2	5200.104	1800.036	2266.712	17.000
1/2	soln std	1	10	std-K1-2	20.6	9.80	81.2	51.1	20.600	9.800	81.200	51.100
1/2	NP-MC-BNa-1-CCC	1	11	K39	2110	897	1060	4.63	3516.737	1495.030	1766.702	7.717
1/2	NP-MC-ALiSi-1-CCC	1	12	K35	540	103	462	13.5	900.018	171.670	770.015	22.500
1/2	NP-MC-ALi-2-CCC	1	13	K18	664	140	384	16.0	1106.689	233.338	640.013	26.667
1/2	NP-MC-AIBNa-1-CCC	1	14	K11	35.7	18.2	32.2	57.9	59.501	30.334	53.668	96.502
1/2	NP-MC-ALiNa-1-CCC	1	15	K08	2110	888	1670	2.66	3516.737	1480.030	2783.389	4.433
1/2	NP-MC-ALiSi-2-CCC	1	16	K28	343	62.1	224	2.20	571.678	103.502	373.341	3.667
1/2	ARM-1	1	17	K17	17.6	8.84	23.3	40.3	29.334	14.734	38.834	67.168
1/2	soln std	1	18	std-K-1-3	20.7	9.81	82.3	50.9	20.700	9.810	82.300	50.900
1/2	soln std	2	1	std-K2-1	20.6	9.57	82.7	51.5	20.600	9.570	82.700	51.500
1/2	NP-MC-BNa-1-CCC	2	2	K22	2030	866	1000	4.40	3383.401	1443.362	1666.700	7.333
1/2	NP-MC-AIBNa-2-CCC	2	3	K33	439	91.9	405	2.29	731.681	153.170	675.014	3.817
1/2	NP-MC-ALiSi-1-CCC	2	4	K36	540	103	452	13.2	900.018	171.670	753.348	22.000
1/2	NP-MC-ALiSi-1-CCC	2	5	K27	2870	1010	1430	8.31	4783.429	1683.367	2383.381	13.850
1/2	NP-MC-AINa-1-CCC	2	6	K26	2810	1010	1240	9.52	4683.427	1683.367	2066.708	15.867
1/2	NP-MC-ALi-2-CCC	2	7	K02	618	134	363	16.7	1030.021	223.338	605.012	27.834
1/2	NP-MC-ALiSi-2-CCC	2	8	K16	344	61.7	222	1.96	573.345	102.835	370.007	3.267
1/2	NP-MC-AIBNa-1-CCC	2	9	K12	40.8	17.6	31.5	57.9	68.001	29.334	52.501	96.502
1/2	soln std	2	10	std-K2-2	19.4	9.49	81.3	50.9	19.400	9.490	81.300	50.900

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

Group/Set	Glass ID (w HT)	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (mg/L)	Li (mg/L)	Na (mg/L)	Si (mg/L)
1/2	NP-MC-BNaSi-1-CCC	2	11	K24	1890	774	1630	2.27	3150.063	1290.026	2716.721	3.783
1/2	NP-MC-BLiSi-1-CCC	2	12	K41	2230	870	549	10.4	3716.741	1450.029	915.018	17.334
1/2	NP-MC-AiLi-1-CCC	2	13	K43	102	23.4	74.5	38.8	170.003	39.001	124.169	64.668
1/2	ARM-1	2	14	K34	22.5	8.47	22.6	40.1	37.501	14.117	37.667	66.835
1/2	NP-MC-AiLiNa-1-CCC	2	15	K14	2120	866	1610	2.35	3533.404	1443.362	2683.387	3.917
1/2	NP-MC-AIBSi-1-CCC	2	16	K37	153	35.7	105	1.66	255.005	59.501	175.004	2.767
1/2	soln std	2	17	std-K2-3	19.7	9.46	82.4	50.8	19.700	9.460	82.400	50.800
1/2	soln std	3	1	std-k3-1	21.8	10.2	84.7	53.1	21.800	10.200	84.700	53.100
1/2	NP-MC-AiLi-2-CCC	3	2	K03	663	140	377	15.3	1105.022	233.338	628.346	25.501
1/2	NP-MC-AIBNa-1-CCC	3	3	K06	39.3	18.2	31.8	59.5	65.501	30.334	53.001	99.169
1/2	NP-MC-AiSi-1-CCC	3	4	K09	3020	1020	1460	8.59	5033.434	1700.034	2433.382	14.317
1/2	NP-MC-BNa-1-CCC	3	5	K25	2180	885	1030	4.88	3633.406	1475.030	1716.701	8.133
1/2	NP-MC-AIBNa-2-CCC	3	6	K21	432	92.9	412	2.68	720.014	154.836	686.680	4.467
1/2	NP-MC-AiLi-1-CCC	3	7	K30	94.7	22.4	69.5	37.7	157.836	37.334	115.836	62.835
1/2	NP-MC-AiLiSi-1-CCC	3	8	K32	547	104	458	13.7	911.685	173.337	763.349	22.834
1/2	blank	3	9	K42	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667
1/2	soln std	3	10	std-K3-2	21.7	9.89	79.8	51.0	21.700	9.890	79.800	51.000
1/2	NP-MC-AiSi-2-CCC	3	11	K05	344	62.4	228	2.54	573.345	104.002	380.008	4.233
1/2	ARM-1	3	12	K07	21.2	8.67	22.2	39.3	35.334	14.450	37.001	65.501
1/2	NP-MC-BLiSi-1-CCC	3	13	K44	2340	891	554	10.3	3900.078	1485.030	923.352	17.167
1/2	NP-MC-AiLiNa-1-CCC	3	14	K15	2170	887	1650	2.64	3616.739	1478.363	2750.055	4.400
1/2	NP-MC-AiNa-1-CCC	3	15	K20	2920	1010	1270	9.94	4866.764	1683.367	2116.709	16.567
1/2	NP-MC-AIBSi-1-CCC	3	16	K38	147	35.4	106	2.10	245.005	59.001	176.670	3.500
1/2	NP-MC-BNaSi-1-CCC	3	17	K19	2000	796	1680	2.66	3333.400	1326.693	2800.056	4.433
1/2	soln std	3	18	std-K3-3	20.2	10.0	82.7	51.3	20.200	10.000	82.700	51.300
2/1	soln std	1	1	std-1-1	19.4	10.2	84.8	50.9	19.400	10.200	84.800	50.900
2/1	NP-MC-AIB-1-CCC	1	2	Y04	156	45.3	125	27.3	260.005	75.502	208.338	45.501
2/1	blank	1	3	Y14	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667
2/1	NP2-Very-High-Si-CCC	1	4	Y18	15.0	10.3	18.3	46.5	25.001	17.167	30.501	77.502
2/1	NP-MC-BSi-1-CCC	1	5	Y03	76.9	22.6	55.1	34.3	128.169	37.667	91.835	57.168
2/1	NP-MC-AiLi-2-CCC	1	6	Y20	656	137	382	16.1	1093.355	228.338	636.679	26.834
2/1	soln std	1	7	std-1-2	21.7	10.0	82.1	48.3	21.700	10.000	82.100	48.300
2/1	NP-MC-AIBNa-1-CCC	1	8	Y12	27.9	16.9	31.4	51.6	46.501	28.167	52.334	86.002
2/1	ARM-1	1	9	Y19	9.39	8.21	21.4	33.7	15.650	13.684	35.667	56.168
2/1	NP-MC-AiNa-1-CCC	1	10	Y05	2920	1070	1330	9.95	4866.764	1783.369	2216.711	16.584
2/1	NP-MC-BLiSi-2-CCC	1	11	Y10	266	87.0	196	23.3	443.342	145.003	326.673	38.834
2/1	soln std	1	12	std-1-3	20.6	10.6	85.7	48.7	20.600	10.600	85.700	48.700
2/1	soln std	2	1	std-2-1	19.0	9.79	80.9	47.0	19.000	9.790	80.900	47.000
2/1	NP-MC-AIB-1-CCC	2	2	Y01	169	46.6	124	27.2	281.672	77.668	206.671	45.334
2/1	NP-MC-BSi-1-CCC	2	3	Y07	81.3	23.9	58.8	36.2	135.503	39.834	98.002	60.335
2/1	ARM-1	2	4	Y24	10.4	8.19	21.5	33.3	17.334	13.650	35.834	55.501
2/1	NP-MC-AIBNa-1-CCC	2	5	Y02	25.5	15.4	28.8	47.1	42.501	25.667	48.001	78.502

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

Group/Set	Glass ID (w HT)	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (mg/L)	Li (mg/L)	Na (mg/L)	Si (mg/L)
2/1	NP-MC-AiLi-2-CCC	2	6	Y23	658	140	373	15.0	1096.689	233.338	621.679	25.001
2/1	soln std	2	7	std-2-2	19.0	9.79	80.0	47.2	19.000	9.790	80.000	47.200
2/1	NP-MC-AiNa-1-CCC	2	8	Y08	2960	1070	1330	8.65	4933.432	1783.369	2216.711	14.417
2/1	NP2-Very-High-Si-CCC	2	9	Y21	27.8	10.2	18.1	46.0	46.334	17.000	30.167	76.668
2/1	NP-MC-BLiSi-2-CCC	2	10	Y06	274	93.2	197	22.6	456.676	155.336	328.340	37.667
2/1	soln std	2	11	std-2-3	18.4	9.80	80.8	46.6	18.400	9.800	80.800	46.600
2/1	soln std	3	1	std-3-1	19.4	10.0	82.1	49.1	19.400	10.000	82.100	49.100
2/1	NP-MC-AiNa-1-CCC	3	2	Y11	2980	1080	1340	10.3	4966.766	1800.036	2233.378	17.167
2/1	NP-MC-BLiSi-2-CCC	3	2	Y13	272	92.8	198	23.1	453.342	154.670	330.007	38.501
2/1	NP-MC-AiBNa-1-CCC	3	3	Y16	32.8	16.9	31.4	52.2	54.668	28.167	52.334	87.002
2/1	NP-MC-AiLi-2-CCC	3	4	Y25	658	142	382	15.6	1096.689	236.671	636.679	26.001
2/1	NP2-Very-High-Si-CCC	3	6	Y26	20.2	10.2	17.9	46.7	33.667	17.000	29.834	77.835
2/1	soln std	3	7	std-3-2	21.6	9.79	80.3	47.9	21.600	9.790	80.300	47.900
2/1	blank	3	8	Y09	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667
2/1	ARM-1	3	9	Y22	10.3	7.95	20.8	33.5	17.167	13.250	34.667	55.834
2/1	NP-MC-BSi-1-CCC	3	10	Y15	88.0	24.8	60.8	39.2	146.670	41.334	101.335	65.335
2/1	NP-MC-AiB-1-CCC	3	11	Y17	163	44.8	122	26.0	271.672	74.668	203.337	43.334
2/1	soln std	3	12	std-3-3	19.9	9.86	81.5	48.1	19.900	9.860	81.500	48.100
3/1	soln std	1	1	std-M1-1	20.8	10.2	84.1	51.5	20.800	10.200	84.100	51.500
3/1	ARM-1	1	2	M25	11.2	8.75	22.9	37.1	18.667	14.584	38.167	61.835
3/1	NP2-Very-High-Si-Q	1	3	M03	16.4	11.4	16.4	51.0	27.334	19.000	27.334	85.002
3/1	NP2-High-Na-Q	1	4	M39	73.9	27.9	115	35.8	123.169	46.501	191.671	59.668
3/1	BL3-Q	1	5	M12	58.5	25.7	65.3	42.4	97.502	42.834	108.836	70.668
3/1	NP2-Very-Low-Si-Q	1	6	M10	549	145	792	6.45	915.018	241.672	1320.026	10.750
3/1	NP2-Low-B-Q	1	7	M51	37.1	21.3	55.4	46.4	61.835	35.501	92.335	77.335
3/1	Neph-NN-1-12-Q	1	8	M24	78.9	34.1	115	41.0	131.503	56.834	191.671	68.335
3/1	NP2-High-Al-Q	1	9	M19	62.2	27.1	67.1	34.3	103.669	45.168	111.836	57.168
3/1	NP2-Low-Li-Q	1	10	M42	53.4	19.3	57.7	43.4	89.002	32.167	96.169	72.335
3/1	soln std	1	11	std-M1-2	20.9	10.2	83.7	52.1	20.900	10.200	83.700	52.100
3/1	NP-MC-AiB-1-Q	1	12	M30	168	50.5	131	30.3	280.006	84.168	218.338	50.501
3/1	NP2-Low-Al-Q	1	13	M37	74.2	28.7	76.0	41.7	123.669	47.834	126.669	69.501
3/1	NP2-High-B-Q	1	14	M17	147	45.2	120	28.6	245.005	75.335	200.004	47.668
3/1	NP2-High-Li-Q	1	15	M45	62.3	30.6	68.9	41.9	103.835	51.001	114.836	69.835
3/1	blank	1	16	M14	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667
3/1	NP2-Low-Na-Q	1	17	M43	39.1	20.5	28.8	47.0	65.168	34.167	48.001	78.335
3/1	NP2-Very-High-Al-Q	1	18	M32	67.1	27.2	71.2	30.0	111.836	45.334	118.669	50.001
3/1	NP2-Low-Si-Q	1	19	M28	106	41.0	123	25.2	176.670	68.335	205.004	42.001
3/1	NP2-High-Si-Q	1	20	M53	28.6	14.5	31.6	48.7	47.668	24.167	52.668	81.168
3/1	soln std	1	21	std-M1-3	21.1	10.3	84.1	52.8	21.100	10.300	84.100	52.800
3/1	soln std	2	1	std-M2-1	20.9	10.2	83.9	52.0	20.900	10.200	83.900	52.000
3/1	NP2-High-Al-Q	2	2	M47	60.3	25.5	63.5	35.0	100.502	42.501	105.835	58.335
3/1	NP2-Very-High-Al-Q	2	3	M40	66.3	26.5	69.9	29.9	110.502	44.168	116.502	49.834

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

Group/Set	Glass ID (w HT)	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (mg/L)	Li (mg/L)	Na (mg/L)	Si (mg/L)
3/1	NP2-High-Li-Q	2	4	M16	62.3	30.5	69.9	42.4	103.835	50.834	116.502	70.668
3/1	Neph-NN-1-12-Q	2	5	M01	81.3	33.8	117	40.8	135.503	56.334	195.004	68.001
3/1	NP2-High-B-Q	2	6	M52	144	44.0	119	29.1	240.005	73.335	198.337	48.501
3/1	NP2-Low-Si-Q	2	7	M48	101	41.1	125	24.0	168.337	68.501	208.338	40.001
3/1	NP2-High-Na-Q	2	8	M44	74.6	27.0	115	34.3	124.336	45.001	191.671	57.168
3/1	NP2-Very-High-Si-Q	2	9	M15	17.2	10.8	16.1	48.4	28.667	18.000	26.834	80.668
3/1	NP2-Low-Na-Q	2	10	M35	43.7	21.2	30.2	47.8	72.835	35.334	50.334	79.668
3/1	soln std	2	11	std-M2-2	20.3	10.2	82.9	51.1	20.300	10.200	82.900	51.100
3/1	NP2-Low-Li-Q	2	12	M33	51.9	18.4	56.0	41.3	86.502	30.667	93.335	68.835
3/1	NP2-High-Si-Q	2	13	M07	27.9	14.4	31.8	48.1	46.501	24.000	53.001	80.168
3/1	ARM-1	2	14	M11	11.9	8.54	22.5	36.0	19.834	14.234	37.501	60.001
3/1	NP2-Low-Al-Q	2	15	M26	72.4	28.8	78.0	42.0	120.669	48.001	130.003	70.001
3/1	NP2-Low-B-Q	2	16	M06	36.4	20.6	55.1	45.5	60.668	34.334	91.835	75.835
3/1	BL3-Q	2	17	M23	59.7	24.8	64.8	41.4	99.502	41.334	108.002	69.001
3/1	NP2-Very-Low-Si-Q	2	18	M36	547	136	769	6.18	911.685	226.671	1281.692	10.300
3/1	NP-MC-AIB-1-Q	2	19	M41	165	48.2	127	29.3	275.006	80.335	211.671	48.834
3/1	soln std	2	20	std-M2-3	20.4	10.2	83.1	51.5	20.400	10.200	83.100	51.500
3/1	soln std	3	1	std-M3-1	19.8	9.92	81.7	50.3	19.800	9.920	81.700	50.300
3/1	NP2-Low-B-Q	3	2	M31	38.8	20.9	56.0	46.3	64.668	34.834	93.335	77.168
3/1	Neph-NN-1-12-Q	3	3	M49	81.1	33.2	115	39.8	135.169	55.334	191.671	66.335
3/1	NP2-High-Si-Q	3	4	M22	28.1	14.2	31.2	47.0	46.834	23.667	52.001	78.335
3/1	NP2-High-B-Q	3	5	M04	141	44.1	119	28.1	235.005	73.501	198.337	46.834
3/1	NP2-Low-Si-Q	3	6	M29	103	35.8	123	3.35	171.670	59.668	205.004	5.583
3/1	NP2-Low-Al-Q	3	7	M05	74.6	28.9	78.1	40.7	124.336	48.168	130.169	67.835
3/1	NP2-High-Al-Q	3	8	M20	60.3	25.6	65.3	33.4	100.502	42.668	108.836	55.668
3/1	NP-MC-AIB-1-Q	3	9	M13	176	51.2	137	31.0	293.339	85.335	228.338	51.668
3/1	NP2-Low-Li-Q	3	10	M38	52.3	18.2	56.2	40.6	87.168	30.334	93.669	67.668
3/1	soln std	3	11	std-M3-2	19.7	10.0	82.9	50.4	19.700	10.000	82.900	50.400
3/1	NP2-Very-Low-Si-Q	3	12	M46	537	132	774	5.82	895.018	220.004	1290.026	9.700
3/1	ARM-1	3	13	M34	13.8	8.33	22.4	35.4	23.000	13.884	37.334	59.001
3/1	NP2-Very-High-Al-Q	3	14	M27	69.3	27.3	72.1	30.8	115.502	45.501	120.169	51.334
3/1	BL3-Q	3	15	M50	57.8	23.8	62.9	40.8	96.335	39.667	104.835	68.001
3/1	NP2-High-Na-Q	3	16	M02	75.4	26.6	114	33.5	125.669	44.334	190.004	55.834
3/1	NP2-Low-Na-Q	3	17	M08	40.2	20.1	29.3	47.2	67.001	33.501	48.834	78.668
3/1	NP2-Very-High-Si-Q	3	18	M18	17.3	10.7	16.4	48.0	28.834	17.834	27.334	80.002
3/1	NP2-High-Li-Q	3	19	M21	64.2	30.5	71.0	41.4	107.002	50.834	118.336	69.001
3/1	blank	3	20	M09	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667
3/1	soln std	3	21	std-M3-3	19.8	10.1	83.6	50.5	19.800	10.100	83.600	50.500
3/2	soln std	1	1	std-P1-1	20.6	10.3	82.6	51.6	20.600	10.300	82.600	51.600
3/2	NP-MC-AISi-2-Q	1	2	P37	21.8	14.7	20.4	47.4	36.334	24.500	34.001	79.002
3/2	NP-MC-BSi-1-Q	1	3	P10	95.6	29.3	65.9	39.6	159.337	48.834	109.836	66.001
3/2	NP-MC-AiLi-1-Q	1	4	P42	63.3	19.6	67.0	38.6	105.502	32.667	111.669	64.335

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

Group/Set	Glass ID (w HT)	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (mg/L)	Li (mg/L)	Na (mg/L)	Si (mg/L)
3/2	NP-MC-AINa-1-Q	1	5	P05	85.5	31.5	131	36.0	142.503	52.501	218.338	60.001
3/2	NP-MC-AIBSi-1-Q	1	6	P48	108	30.1	77.3	29.5	180.004	50.168	128.836	49.168
3/2	NP-MC-AiLi-2-Q	1	7	P07	45.8	18.1	52.2	33.3	76.335	30.167	87.002	55.501
3/2	NP-MC-AiSi-1-Q	1	8	P31	149	56.5	183	28.2	248.338	94.169	305.006	47.001
3/2	NP-MC-AiLiSi-1-Q	1	9	P15	163	40.6	197	21.7	271.672	67.668	328.340	36.167
3/2	NP-MC-BNa-1-Q	1	10	P33	60.7	25.7	104	34.2	101.169	42.834	173.337	57.001
3/2	soln std	1	11	std-P1-2	20.0	9.84	77.3	48.7	20.000	9.840	77.300	48.700
3/2	NP-MC-AIBNa-1-Q	1	12	P49	24.9	16.5	27.0	52.2	41.501	27.501	45.001	87.002
3/2	NP-MC-BNaSi-1-Q	1	13	P36	71.4	35.4	150	28.8	119.002	59.001	250.005	48.001
3/2	NP-MC-BLiSi-1-Q	1	14	P44	25.6	18.2	37.2	53.4	42.668	30.334	62.001	89.002
3/2	NP-MC-AiLiNa-1-Q	1	15	P19	82.6	40.3	146	32.0	137.669	67.168	243.338	53.334
3/2	blank	1	16	P32	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667
3/2	NP-MC-BLiSi-2-Q	1	17	P28	211	71.1	174	24.7	351.674	118.502	290.006	41.167
3/2	ARM-1	1	18	P16	11.4	8.64	21.9	37.2	19.000	14.400	36.501	62.001
3/2	NP-MC-AIBNa-2-Q	1	19	P04	120	36.9	149	22.6	200.004	61.501	248.338	37.667
3/2	soln std	1	20	std-P1-3	20.0	9.79	76.6	48.4	20.000	9.790	76.600	48.400
3/2	soln std	2	1	std-P2-1	21.3	10.3	84.8	50.9	21.300	10.300	84.800	50.900
3/2	NP-MC-AiLi-2-Q	2	2	P27	51.3	19.2	55.4	34.5	85.502	32.001	92.335	57.501
3/2	NP-MC-BNa-1-Q	2	3	P03	66.5	27.6	104	36.8	110.836	46.001	173.337	61.335
3/2	NP-MC-AINa-1-Q	2	4	P12	87.8	31.3	123	36.1	146.336	52.168	205.004	60.168
3/2	NP-MC-BNaSi-1-Q	2	5	P46	76.0	37.2	148	29.5	126.669	62.001	246.672	49.168
3/2	NP-MC-AiLiSi-1-Q	2	6	P40	167	42.8	198	20.9	278.339	71.335	330.007	34.834
3/2	NP-MC-AiSi-2-Q	2	7	P25	22.6	14.8	20.5	46.3	37.667	24.667	34.167	77.168
3/2	NP-MC-AiLiNa-1-Q	2	8	P45	83.1	40.8	144	30.9	138.503	68.001	240.005	51.501
3/2	NP-MC-AiSi-1-Q	2	9	P34	164	62.0	195	29.4	273.339	103.335	325.007	49.001
3/2	ARM-1	2	10	P30	11.7	8.61	22.4	37.3	19.500	14.350	37.334	62.168
3/2	soln std	2	11	std-P2-2	20.9	10.1	81.8	49.8	20.900	10.100	81.800	49.800
3/2	NP-MC-BLiSi-2-Q	2	12	P26	208	74.1	166	24.3	346.674	123.502	276.672	40.501
3/2	NP-MC-AIBNa-2-Q	2	13	P43	131	39.5	149	22.9	218.338	65.835	248.338	38.167
3/2	NP-MC-BSi-1-Q	2	14	P21	95.3	28.8	64.7	35.4	158.837	48.001	107.835	59.001
3/2	NP-MC-BLiSi-1-Q	2	15	P06	25.7	18.0	36.4	51.1	42.834	30.001	60.668	85.168
3/2	NP-MC-AIBSi-1-Q	2	16	P41	110	30.3	78.6	28.4	183.337	50.501	131.003	47.334
3/2	NP-MC-AIBNa-1-Q	2	17	P24	26.5	17.1	28.0	52.0	44.168	28.501	46.668	86.668
3/2	NP-MC-AiLi-1-Q	2	18	P35	65.6	19.8	67.6	37.4	109.336	33.001	112.669	62.335
3/2	soln std	2	19	std-P2-3	21.2	10.0	81.4	48.9	21.200	10.000	81.400	48.900
3/2	soln std	3	1	std-P3-1	19.8	9.81	79.2	48.3	19.800	9.810	79.200	48.300
3/2	NP-MC-AiLi-1-Q	3	2	P39	64.2	19.7	67.5	38.8	107.002	32.834	112.502	64.668
3/2	NP-MC-AIBNa-2-Q	3	3	P38	125	38.5	145	23.0	208.338	64.168	241.672	38.334
3/2	NP-MC-AiLiNa-1-Q	3	4	P22	81.0	40.1	140	30.5	135.003	66.835	233.338	50.834
3/2	ARM-1	3	5	P01	10.0	8.10	21.2	34.0	16.667	13.500	35.334	56.668
3/2	NP-MC-AINa-1-Q	3	6	P29	84.6	30.7	121	33.2	141.003	51.168	201.671	55.334
3/2	blank	3	7	P14	<1.00	<1.00	<1.00	<1.00	<1.667	<1.667	<1.667	<1.667

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

Group/Set	Glass ID (w HT)	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (mg/L)	Li (mg/L)	Na (mg/L)	Si (mg/L)
3/2	NP-MC-AIBNa-1-Q	3	8	P09	24.1	16.4	27.3	47.5	40.167	27.334	45.501	79.168
3/2	NP-MC-AISi-2-Q	3	9	P18	21.7	14.6	20.6	43.6	36.167	24.334	34.334	72.668
3/2	NP-MC-BLiSi-2-Q	3	10	P08	206	74.4	168	22.5	343.340	124.002	280.006	37.501
3/2	soln std	3	11	std-P3-2	19.8	9.75	79.6	45.1	19.800	9.750	79.600	45.100
3/2	NP-MC-BNaSi-1-Q	3	12	P11	77.4	37.5	153	27.4	129.003	62.501	255.005	45.668
3/2	NP-MC-BSi-1-Q	3	13	P50	97.1	29.4	66.6	34.3	161.837	49.001	111.002	57.168
3/2	NP-MC-AiLi-2-Q	3	14	P20	50.6	19.0	55.7	29.7	84.335	31.667	92.835	49.501
3/2	NP-MC-AIBSi-1-Q	3	15	P02	111	30.6	80.4	25.5	185.004	51.001	134.003	42.501
3/2	NP-MC-BNa-1-Q	3	16	P23	63.8	26.7	101	31.0	106.335	44.501	168.337	51.668
3/2	NP-MC-BLiSi-1-Q	3	17	P47	26.5	18.2	36.9	49.4	44.168	30.334	61.501	82.335
3/2	NP-MC-AiSi-1-Q	3	18	P17	155	59.1	184	24.7	258.339	98.502	306.673	41.167
3/2	NP-MC-AiLiSi-1-Q	3	19	P13	169	42.6	198	17.3	281.672	71.001	330.007	28.834
3/2	soln std	3	20	std-P3-3	20.9	10.0	81.6	45.0	20.900	10.000	81.600	45.000



**Table B-2. Group 1, Set 1 PCT Leachate pH Values for the Nepheline Glasses**

Identifier	pH	Identifier	pH
BLANK-1	6.98	NP2-High-Si-CCC-1	9.29
BLANK-2	6.91	NP2-High-Si-CCC-2	9.30
ARM-1-1	10.16	NP2-High-Si-CCC-3	9.30
ARM-1-2	10.15	NP2-Low-Al-CCC-1	9.31
ARM-1-3	10.14	NP2-Low-Al-CCC-2	9.29
BL3-CCC-1	9.31	NP2-Low-Al-CCC-3	9.31
BL3-CCC-2	9.31	NP2-Low-B-CCC-1	9.67
BL3-CCC-3	9.32	NP2-Low-B-CCC-2	9.70
Neph-NN-1-12-CCC-1	9.93	NP2-Low-B-CCC-3	9.70
Neph-NN-1-12-CCC-2	9.81	NP2-Low-Li-CCC-1	9.22
Neph-NN-1-12-CCC-3	9.94	NP2-Low-Li-CCC-2	9.17
NP2-High-Al-CCC-1	9.30	NP2-Low-Li-CCC-3	9.15
NP2-High-Al-CCC-2	9.28	NP2-Low-Na-CCC-1	9.21
NP2-High-Al-CCC-3	9.28	NP2-Low-Na-CCC-2	9.19
Np2-High-B-CCC-1	9.28	NP2-Low-Na-CCC-3	9.18
Np2-High-B-CCC-2	9.27	NP2-Low-Si-CCC-1	9.49
Np2-High-B-CCC-3	9.25	NP2-Low-Si-CCC-2	9.50
NP2-High-Li-CCC-1	9.70	NP2-Low-Si-CCC-3	9.49
NP2-High-Li-CCC-2	9.71	NP2-Very-High-Al-CCC-1	9.37
NP2-High-Li-CCC-3	9.72	NP2-Very-High-Al-CCC-2	9.39
NP2-High-Na-CCC-1	9.87	NP2-Very-High-Al-CCC-3	9.39
NP2-High-Na-CCC-2	9.88	NP2-Very-Low-Si-CCC-1	10.18
NP2-High-Na-CCC-3	9.88	NP2-Very-Low-Si-CCC-2	10.20
		NP2-Very-Low-Si-CCC-3	10.20

**Table B-3. Group 1, Set 2 PCT Leachate pH Values for the Nepheline Glasses**

Identifier	pH	Identifier	pH
BLANK-1	8.57	NP-MC-AiLiSi-1-CCC-1	9.49
BLANK-2	8.15	NP-MC-AiLiSi-1-CCC-2	9.47
ARM-1-1	10.24	NP-MC-AiLiSi-1-CCC-3	9.46
ARM-1-2	10.26	NP-MC-AiNa-1-CCC-1	9.93
ARM-1-3	10.25	NP-MC-AiNa-1-CCC-2	9.93
NP-MC-AIBNa-1-CCC-1	9.34	NP-MC-AiNa-1-CCC-3	9.93
NP-MC-AIBNa-1-CCC-2	9.28	NP-MC-AiSi-1-CCC-1	9.98
NP-MC-AIBNa-1-CCC-3	9.28	NP-MC-AiSi-1-CCC-2	9.96
NP-MC-AIBNa-2-CCC-1	9.50	NP-MC-AiSi-1-CCC-3	9.97
NP-MC-AIBNa-2-CCC-2	9.51	NP-MC-AiSi-2-CCC-1	9.24
NP-MC-AIBNa-2-CCC-3	9.50	NP-MC-AiSi-2-CCC-2	9.23
NP-MC-AIBSi-1-CCC-1	9.32	NP-MC-AiSi-2-CCC-3	9.17
NP-MC-AIBSi-1-CCC-2	9.30	NP-MC-BLiSi-1-CCC-1	9.71
NP-MC-AIBSi-1-CCC-3	9.34	NP-MC-BLiSi-1-CCC-2	9.76
NP-MC-AiLi-1-CCC-1	9.25	NP-MC-BLiSi-1-CCC-3	9.76
NP-MC-AiLi-1-CCC-2	9.26	NP-MC-BNa-1-CCC-1	10.16
NP-MC-AiLi-1-CCC-3	9.24	NP-MC-BNa-1-CCC-2	10.17
NP-MC-AiLi-2-CCC-1	9.27	NP-MC-BNa-1-CCC-3	10.19
NP-MC-AiLi-2-CCC-2	9.29	NP-MC-BNaSi-1-CCC-1	11.07
NP-MC-AiLi-2-CCC-3	9.29	NP-MC-BNaSi-1-CCC-2	11.06
NP-MC-AiLiNa-1-CCC-1	10.93	NP-MC-BNaSi-1-CCC-3	11.09
NP-MC-AiLiNa-1-CCC-2	10.95		
NP-MC-AiLiNa-1-CCC-3	10.96		

**Table B-4. Group 2 PCT Leachate pH Values for the Nepheline Glasses**

Identifier	pH
blank-1	6.76
blank-2	6.07
ARM-1-1	10.14
ARM-1-2	10.31
ARM-1-3	10.29
NP2-Very-High-Si-CCC-1	9.28
NP2-Very-High-Si-CCC-2	9.21
NP2-Very-High-Si-CCC-3	9.22
NP-MC-AIB-1-CCC-1	9.55
NP-MC-AIB-1-CCC-2	9.54
NP-MC-AIB-1-CCC-3	9.54
NP-MC-BLiSi-2-CCC-1	9.72
NP-MC-BLiSi-2-CCC-2	9.73
NP-MC-BLiSi-2-CCC-3	9.73
NP-MC-Bsi-1-CCC-1	9.42
NP-MC-Bsi-1-CCC-2	9.42
NP-MC-Bsi-1-CCC-3	9.40
NP-MC-AIBNa-1-CCC-1	9.39
NP-MC-AIBNa-1-CCC-2	9.44
NP-MC-AIBNa-1-CCC-3	9.41
NP-MC-AiLi-2-CCC-1	9.41
NP-MC-AiLi-2-CCC-2	9.44
NP-MC-AiLi-2-CCC-3	9.45
NP-MC-AiNa-1-CCC-1	10.05
NP-MC-AiNa-1-CCC-2	10.08
NP-MC-AiNa-1-CCC-3	10.07

**Table B-5. Group 3, Set 1 PCT Leachate pH Values for the Nepheline Glasses**

Identifier	pH	Identifier	pH
BLANK-1	6.65	NP2-Low-Al-Q-1	9.70
BLANK-2	6.24	NP2-Low-Al-Q-2	9.70
ARM-1-1	10.33	NP2-Low-Al-Q-3	9.67
ARM-1-2	10.21	NP2-Low-B-Q-1	9.55
ARM-1-3	10.21	NP2-Low-B-Q-2	9.52
BL3-Q-1	9.48	NP2-Low-B-Q-3	9.49
BL3-Q-2	9.46	NP2-Low-Li-Q-1	9.40
BL3-Q-3	9.46	NP2-Low-Li-Q-2	9.43
Neph-NN-1-12-Q-1	10.41	NP2-Low-Li-Q-3	9.45
Neph-NN-1-12-Q-2	10.47	NP2-Low-Na-Q-1	9.40
Neph-NN-1-12-Q-3	10.45	NP2-Low-Na-Q-2	9.40
NP2-High-Al-Q-1	9.60	NP2-Low-Na-Q-3	9.41
NP2-High-Al-Q-2	9.55	NP2-Low-Si-Q-1	9.77
NP2-High-Al-Q-3	9.54	NP2-Low-Si-Q-2	9.78
NP2-High-B-Q-1	9.41	NP2-Low-Si-Q-3	9.78
NP2-High-B-Q-2	9.40	NP2-Very-High-Al-Q-1	9.60
NP2-High-B-Q-3	9.42	NP2-Very-High-Al-Q-2	9.55
NP2-High-Li-Q-1	9.71	NP2-Very-High-Al-Q-3	9.55
NP2-High-Li-Q-2	9.71	NP2-Very-High-Si-Q-1	9.06
NP2-High-Li-Q-3	9.70	NP2-Very-High-Si-Q-2	9.00
NP2-High-Na-Q-1	10.05	NP2-Very-High-Si-Q-3	9.02
NP2-High-Na-Q-2	10.05	NP2-Very-Low-Si-Q-1	10.76
NP2-High-Na-Q-3	10.04	NP2-Very-Low-Si-Q-2	10.78
NP2-High-Si-Q-1	9.30	NP2-Very-Low-Si-Q-3	10.79
NP2-High-Si-Q-2	9.22	NP-MC-AlB-1-Q-1	9.48
NP2-High-Si-Q-3	9.17	NP-MC-AlB-1-Q-2	9.47
		NP-MC-AlB-1-Q-3	9.49

**Table B-6. Group 3, Set 2 PCT Leachate pH Values for the Nepheline Glasses**

Identifier	pH	Identifier	pH
BLANK-1	6.71	NP-MC-AlNa-1-Q-1	10.16
BLANK-2	6.08	NP-MC-AlNa-1-Q-2	10.14
ARM-1-1	10.02	NP-MC-AlNa-1-Q-3	10.11
ARM-1-2	10.02	NP-MC-AlSi-1-Q-1	10.06
ARM-1-3	10.00	NP-MC-AlSi-1-Q-2	10.07
NP-MC-AlBNa-1-Q-1	9.22	NP-MC-AlSi-1-Q-3	10.09
NP-MC-AlBNa-1-Q-2	9.27	NP-MC-AlSi-2-Q-1	9.25
NP-MC-AlBNa-1-Q-3	9.26	NP-MC-AlSi-2-Q-2	9.23
NP-MC-AlBNa-2-Q-1	9.51	NP-MC-AlSi-2-Q-3	9.22
NP-MC-AlBNa-2-Q-2	9.49	NP-MC-BLiSi-1-Q-1	9.65
NP-MC-AlBNa-2-Q-3	9.51	NP-MC-BLiSi-1-Q-2	9.67
NP-MC-AIBSi-1-Q-1	9.20	NP-MC-BLiSi-1-Q-3	9.64
NP-MC-AIBSi-1-Q-2	9.22	NP-MC-BLiSi-2-Q-1	9.52
NP-MC-AIBSi-1-Q-3	9.21	NP-MC-BLiSi-2-Q-2	9.54
NP-MC-AiLi-1-Q-1	9.30	NP-MC-BLiSi-2-Q-3	9.54
NP-MC-AiLi-1-Q-2	9.32	NP-MC-BNa-1-Q-1	9.84
NP-MC-AiLi-1-Q-3	9.33	NP-MC-BNa-1-Q-2	9.84
NP-MC-AiLi-2-Q-1	9.35	NP-MC-BNa-1-Q-3	9.85
NP-MC-AiLi-2-Q-2	9.34	NP-MC-BNaSi-1-Q-1	9.96
NP-MC-AiLi-2-Q-3	9.32	NP-MC-BNaSi-1-Q-2	9.97
NP-MC-AiLiNa-1-Q-1	9.90	NP-MC-BNaSi-1-Q-3	9.95
NP-MC-AiLiNa-1-Q-2	9.93	NP-MC-BSi-1-Q-1	9.25
NP-MC-AiLiNa-1-Q-3	9.94	NP-MC-BSi-1-Q-2	9.26
NP-MC-AiLiSi-1-Q-1	9.55	NP-MC-BSi-1-Q-3	9.24
NP-MC-AiLiSi-1-Q-2	9.55		
NP-MC-AiLiSi-1-Q-3	9.55		

**Table B-7. Results from Samples of the Multi-Element Solution Standard for the Group 1 PCTs**

Set	1			2			Reference values (mg/L)
Block	1	2	3	1	2	3	
Mean (B (ppm))	19.43	20.87	18.60	20.73	19.90	21.23	20
Mean (Li (ppm))	9.78	9.74	9.72	9.82	9.51	10.03	10
Mean (Na (ppm))	79.77	78.63	79.17	82.03	82.13	82.40	81
Mean (Si (ppm))	49.07	48.73	48.97	51.03	51.07	51.80	50
% relative bias, B	-2.8%	4.3%	-7.0%	3.7%	-0.5%	6.2%	<10% per ASTM C 1285
% relative bias, Li	-2.2%	-2.6%	-2.8%	-1.8%	-4.9%	0.3%	
% relative bias, Na	-1.5%	-2.9%	-2.3%	1.3%	1.4%	1.7%	
% relative bias, Si	-1.9%	-2.5%	-2.1%	2.1%	2.1%	3.6%	
Std Dev (B (ppm))	0.416	1.193	0.173	0.153	0.624	0.896	
Std Dev (Li (ppm))	0.050	0.112	0.075	0.021	0.057	0.157	
Std Dev (Na (ppm))	0.306	1.629	1.436	0.737	0.737	2.464	
Std Dev (Si (ppm))	0.208	0.473	0.569	0.115	0.379	1.136	
%RSD (B (ppm))	2.1%	5.7%	0.9%	0.7%	3.1%	4.2%	<10% per ASTM C 1285
%RSD (Li (ppm))	0.5%	1.2%	0.8%	0.2%	0.6%	1.6%	
%RSD (Na (ppm))	0.4%	2.1%	1.8%	0.9%	0.9%	3.0%	
%RSD (Si (ppm))	0.4%	1.0%	1.2%	0.2%	0.7%	2.2%	

**Table B-8. Results from Samples of the Multi-Element Solution Standard for the Group 2 PCTs**

<b>Block</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>Reference values (mg/L)</b>
<b>Mean (B (mg/L))</b>	20.57	18.80	20.30	20
<b>Mean (Li (mg/L))</b>	10.27	9.79	9.88	10
<b>Mean (Na (mg/L))</b>	84.20	80.57	81.30	81
<b>Mean (Si (mg/L))</b>	49.30	46.93	48.37	50
<b>% relavtive bias, B</b>	2.8%	-6.0%	1.5%	<10% per ASTM C 1285
<b>% relavtive bias, Li</b>	2.7%	-2.1%	-1.2%	
<b>% relavtive bias, Na</b>	4.0%	-0.5%	0.4%	
<b>% relavtive bias, Si</b>	-1.4%	-6.1%	-3.3%	
<b>Std Dev (B (mg/L))</b>	1.150	0.346	1.153	
<b>Std Dev (Li (mg/L))</b>	0.306	0.006	0.107	
<b>Std Dev (Na (mg/L))</b>	1.873	0.493	0.917	
<b>Std Dev (Si (mg/L))</b>	1.400	0.306	0.643	
<b>%RSD (B (mg/L))</b>	5.6%	1.8%	5.7%	<10% per ASTM C 1285
<b>%RSD (Li (mg/L))</b>	3.0%	0.1%	1.1%	
<b>%RSD (Na (mg/L))</b>	2.2%	0.6%	1.1%	
<b>%RSD (Si (mg/L))</b>	2.8%	0.7%	1.3%	

**Table B-9. Results from Samples of the Multi-Element Solution Standard for the Group 3 PCTs**

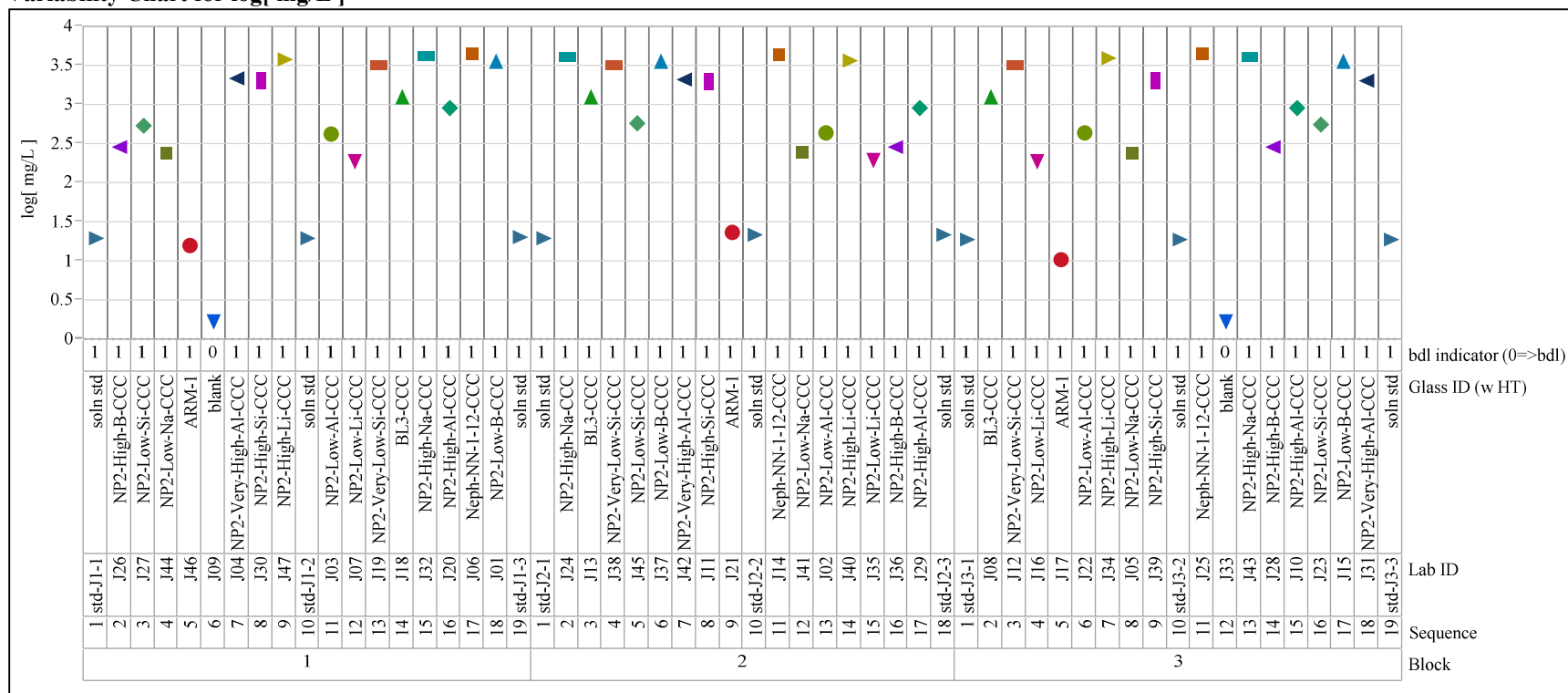
Set	1			2			Reference values (mg/L)
Block	1	2	3	1	2	3	
Mean (B (mg/L))	20.93	20.53	19.77	20.20	21.13	20.17	20
Mean (Li (mg/L))	10.23	10.20	10.01	9.98	10.13	9.85	10
Mean (Na (mg/L))	83.97	83.30	82.73	78.83	82.67	80.13	81
Mean (Si (mg/L))	52.13	51.53	50.40	49.57	49.87	46.13	50
% relative bias, B	4.7%	2.7%	-1.2%	1.0%	5.7%	0.8%	<10% per ASTM C 1285
% relative bias, Li	2.3%	2.0%	0.1%	-0.2%	1.3%	-1.5%	
% relative bias, Na	3.7%	2.8%	2.1%	-2.7%	2.1%	-1.1%	
% relative bias, Si	4.3%	3.1%	0.8%	-0.9%	-0.3%	-7.7%	
Std Dev (B (mg/L))	0.153	0.321	0.058	0.346	0.208	0.635	
Std Dev (Li (mg/L))	0.058	0.000	0.090	0.281	0.153	0.131	
Std Dev (Na (mg/L))	0.231	0.529	0.961	3.281	1.858	1.286	
Std Dev (Si (mg/L))	0.651	0.451	0.100	1.767	1.002	1.877	
%RSD (B (mg/L))	0.7%	1.6%	0.3%	1.7%	1.0%	3.1%	<10% per ASTM C 1285
%RSD (Li (mg/L))	0.6%	0.0%	0.9%	2.8%	1.5%	1.3%	
%RSD (Na (mg/L))	0.3%	0.6%	1.2%	4.2%	2.2%	1.6%	
%RSD (Si (mg/L))	1.2%	0.9%	0.2%	3.6%	2.0%	4.1%	



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set

Group/Set=1/1, Analyte=log[B mg/L]

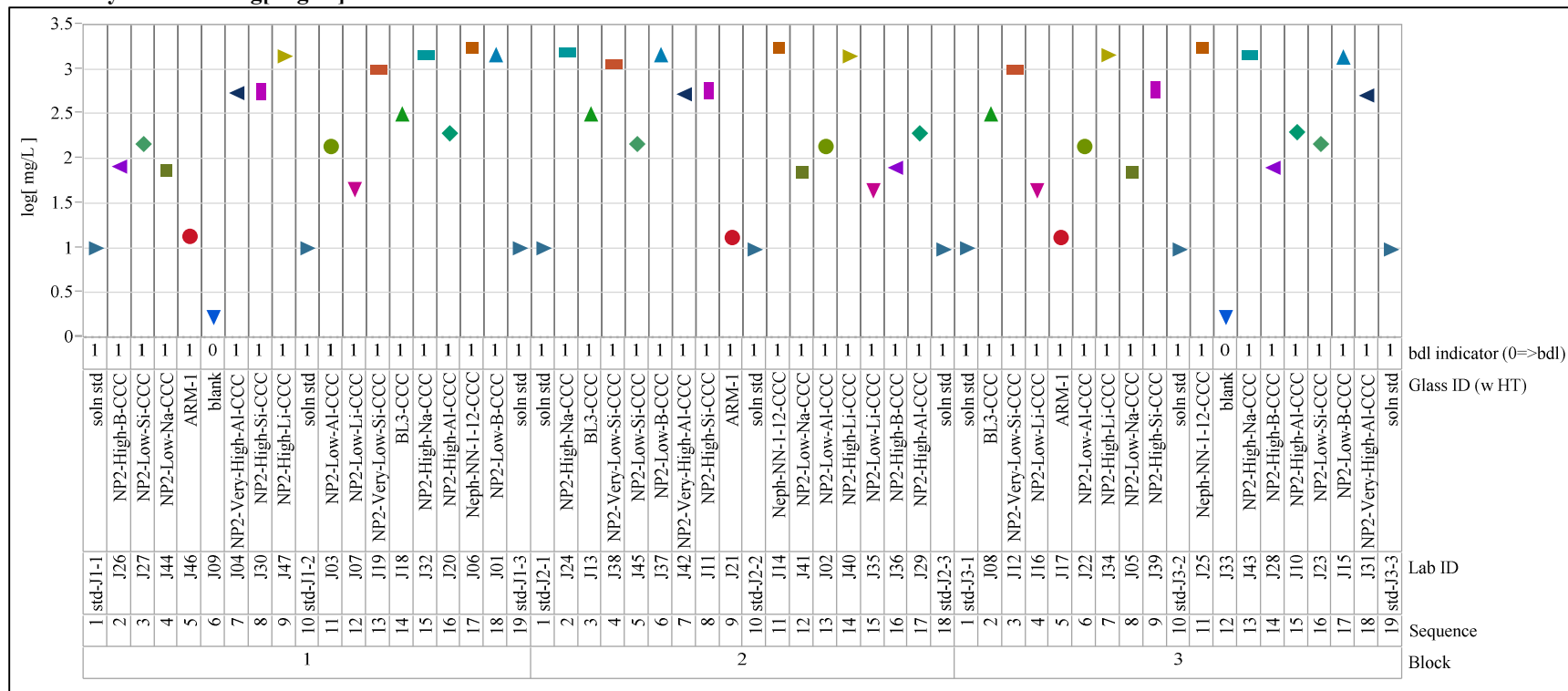
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=1/1, Analyte=log[Li mg/L]

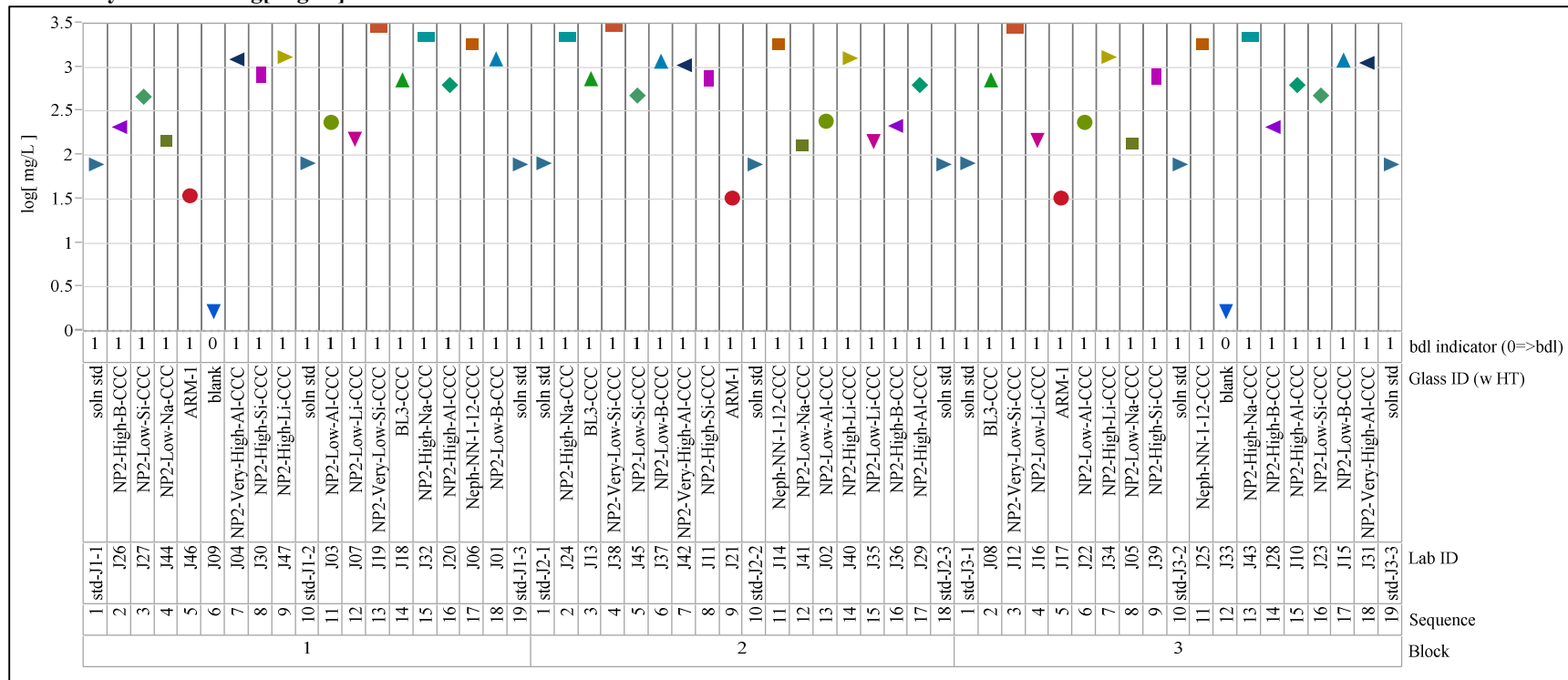
Variability Chart for log mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=1/1, Analyte=log[Na mg/L]

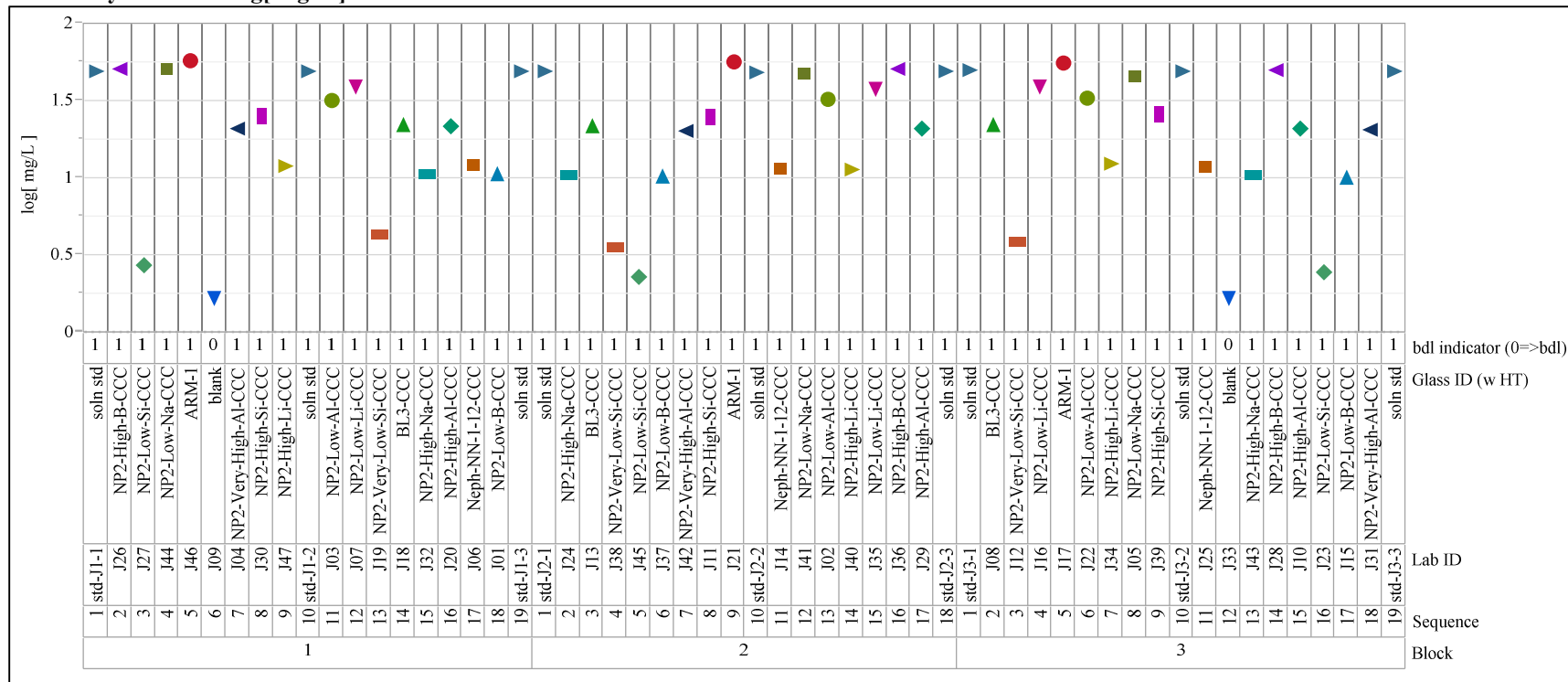
Variability Chart for log mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=1/1, Analyte=log[Si mg/L]

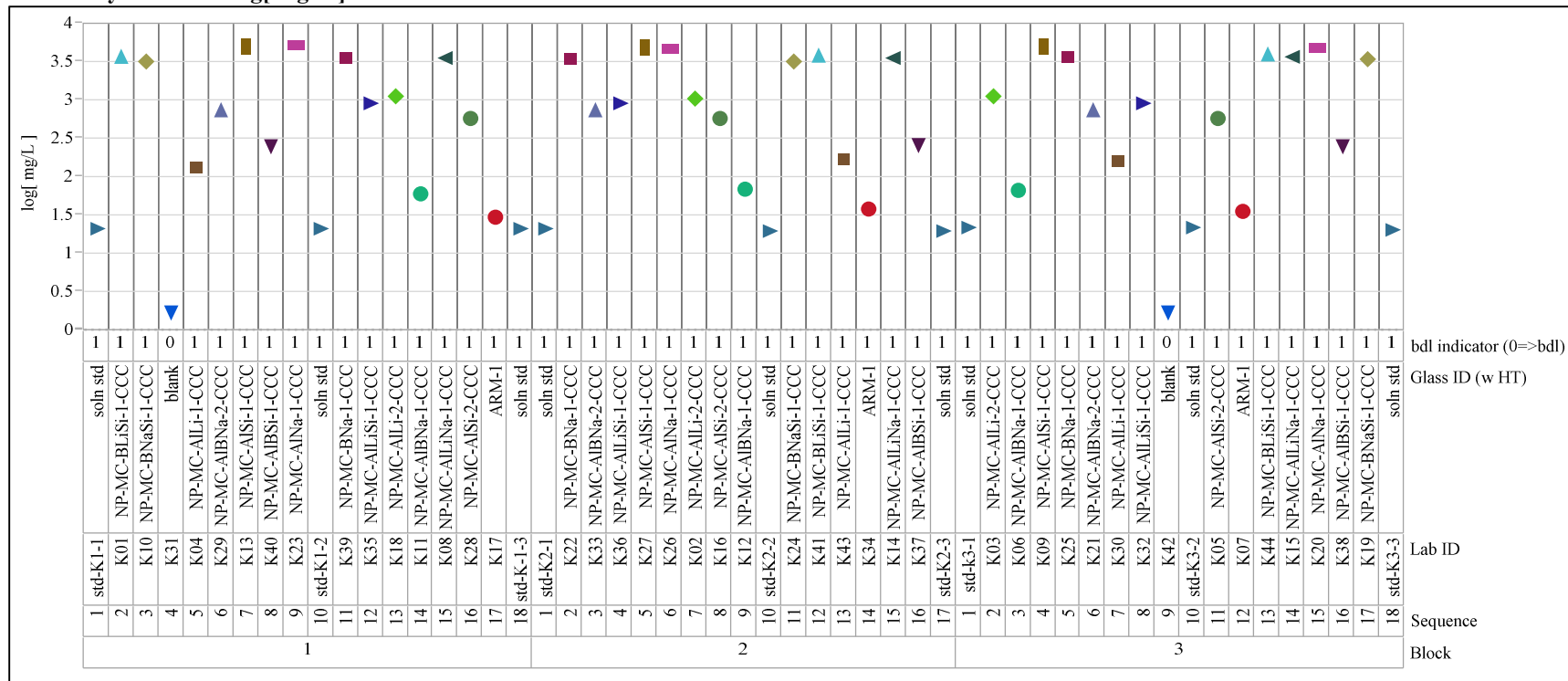
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=1/2, Analyte=log[B mg/L]

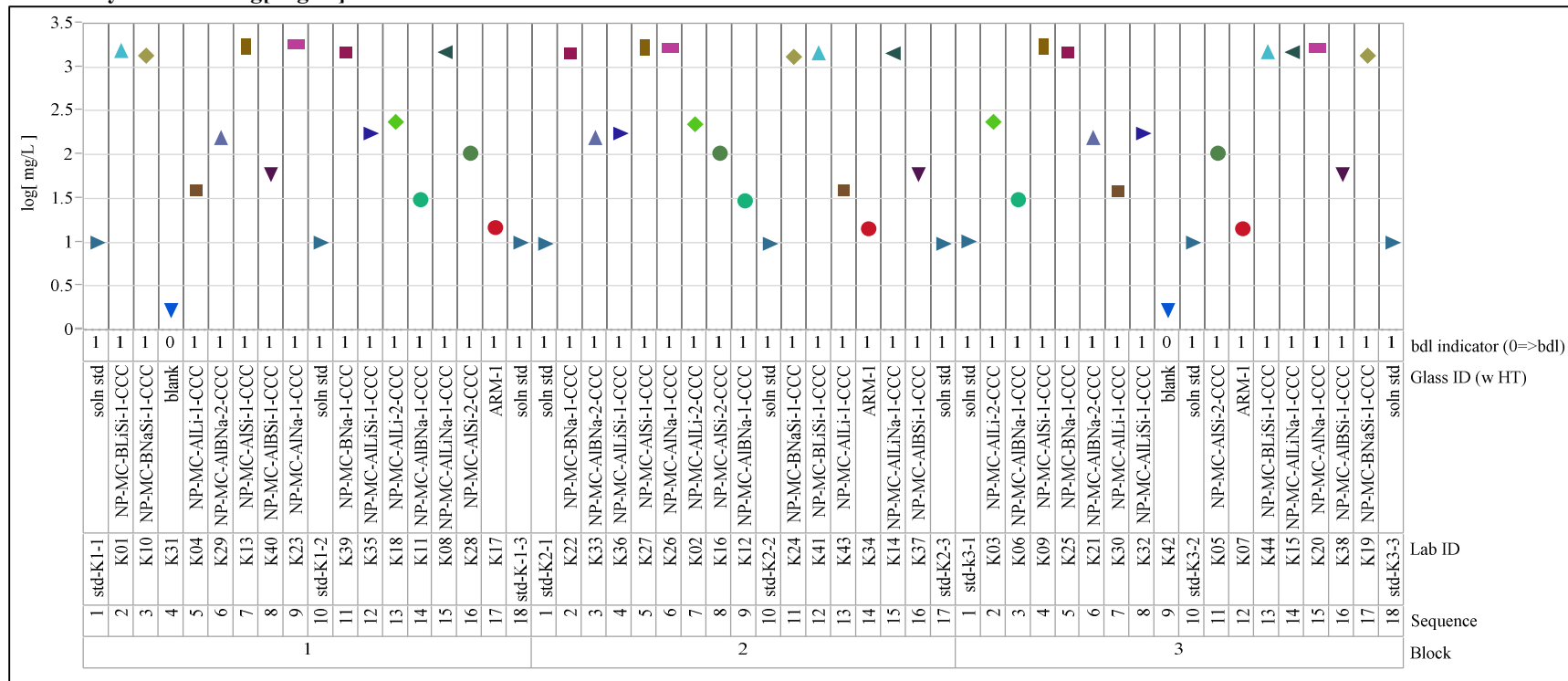
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=1/2, Analyte=log[Li mg/L]

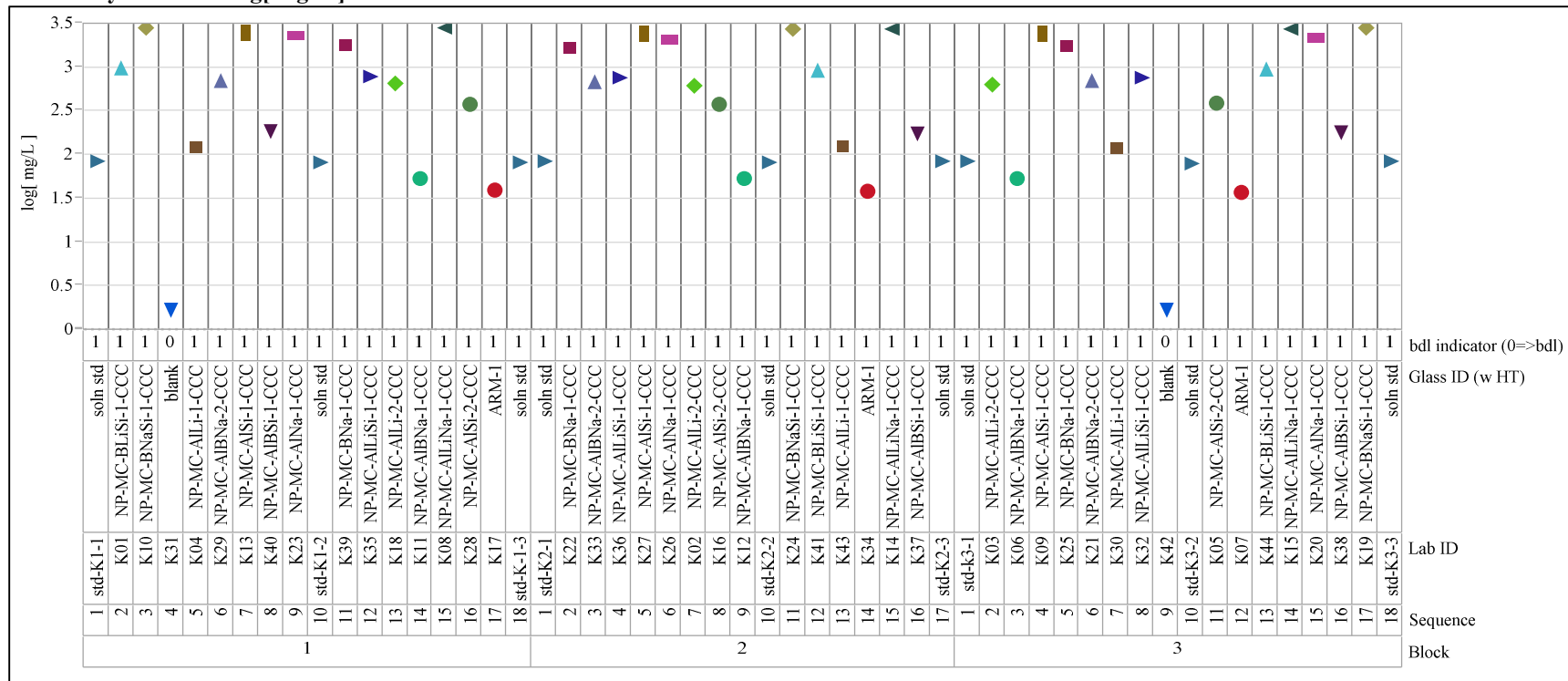
Variability Chart for log mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=1/2, Analyte=log[Na mg/L]

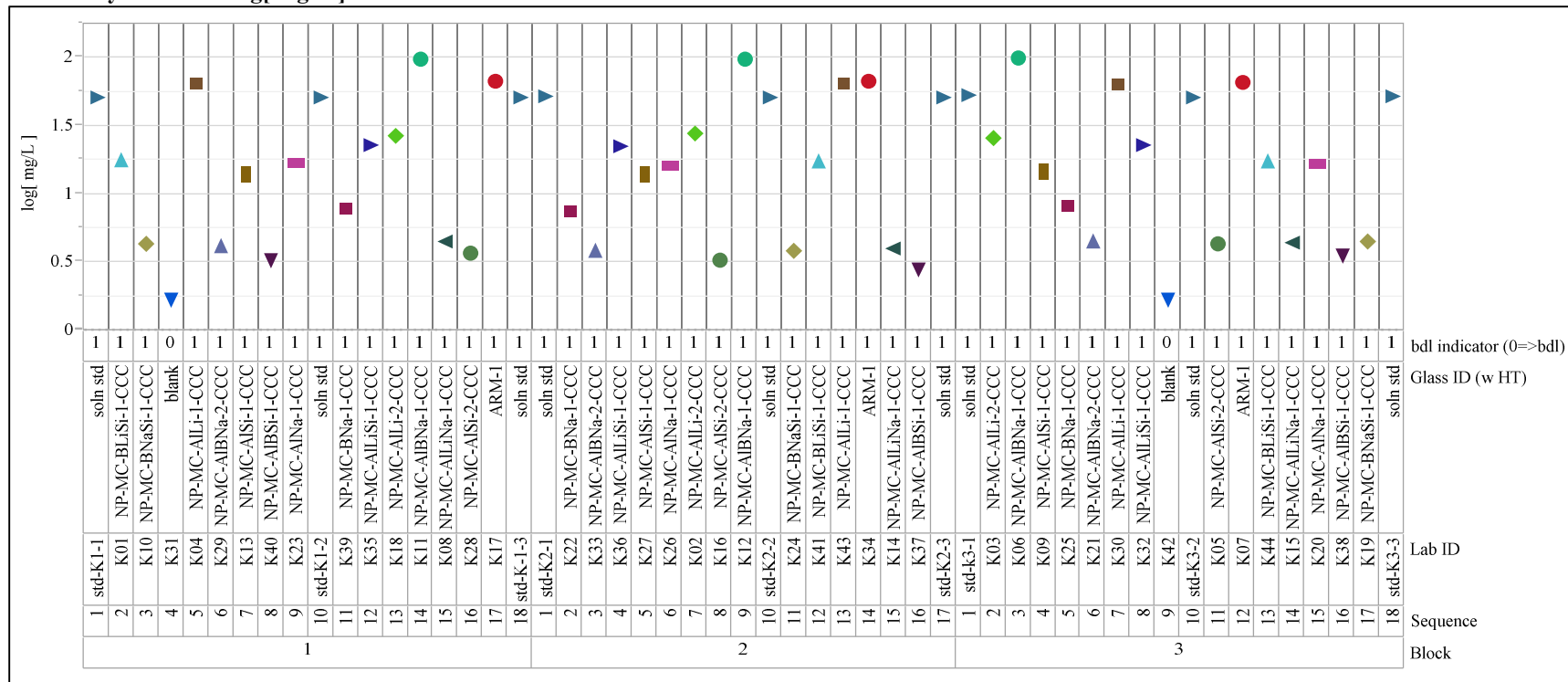
Variability Chart for log mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=1/2, Analyte=log[Si mg/L]

Variability Chart for log mg/L ]

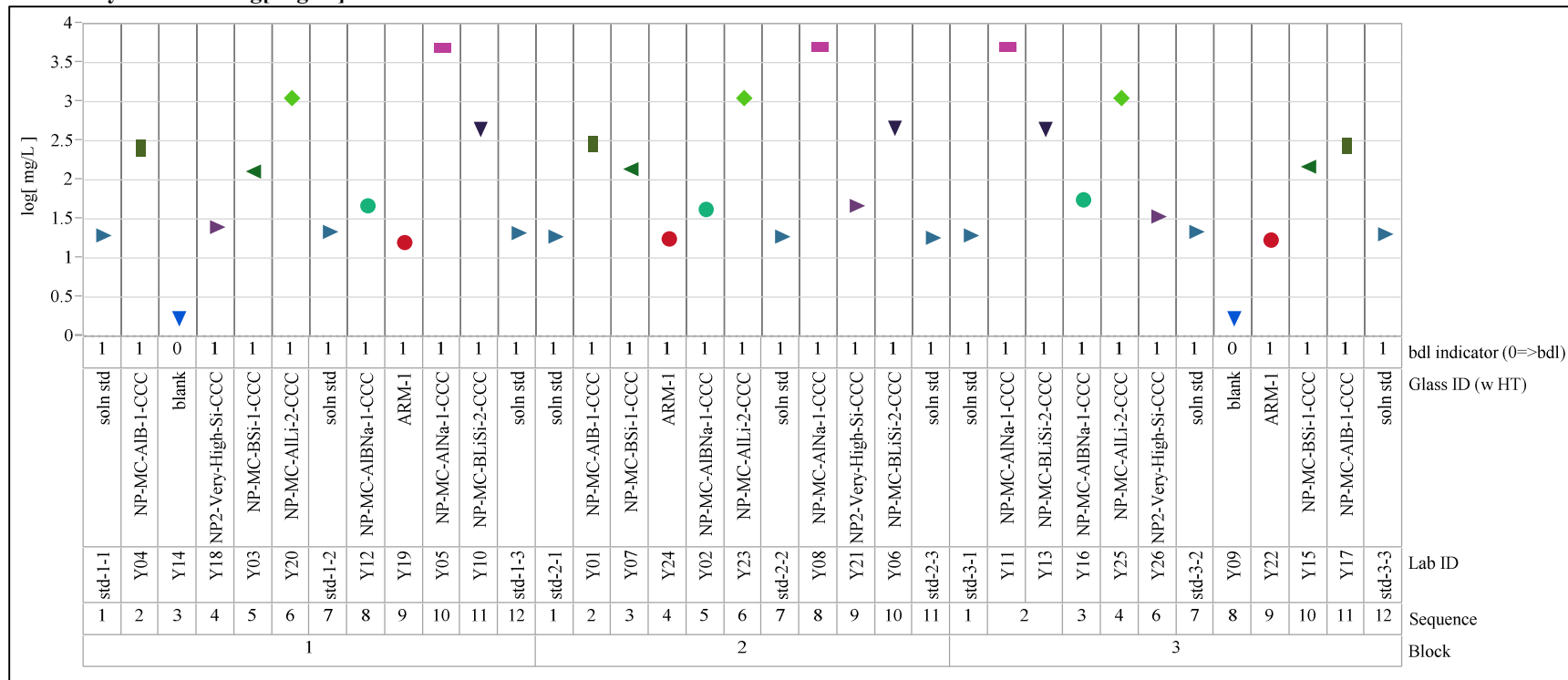




## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=2, Analyte=log[B mg/L]

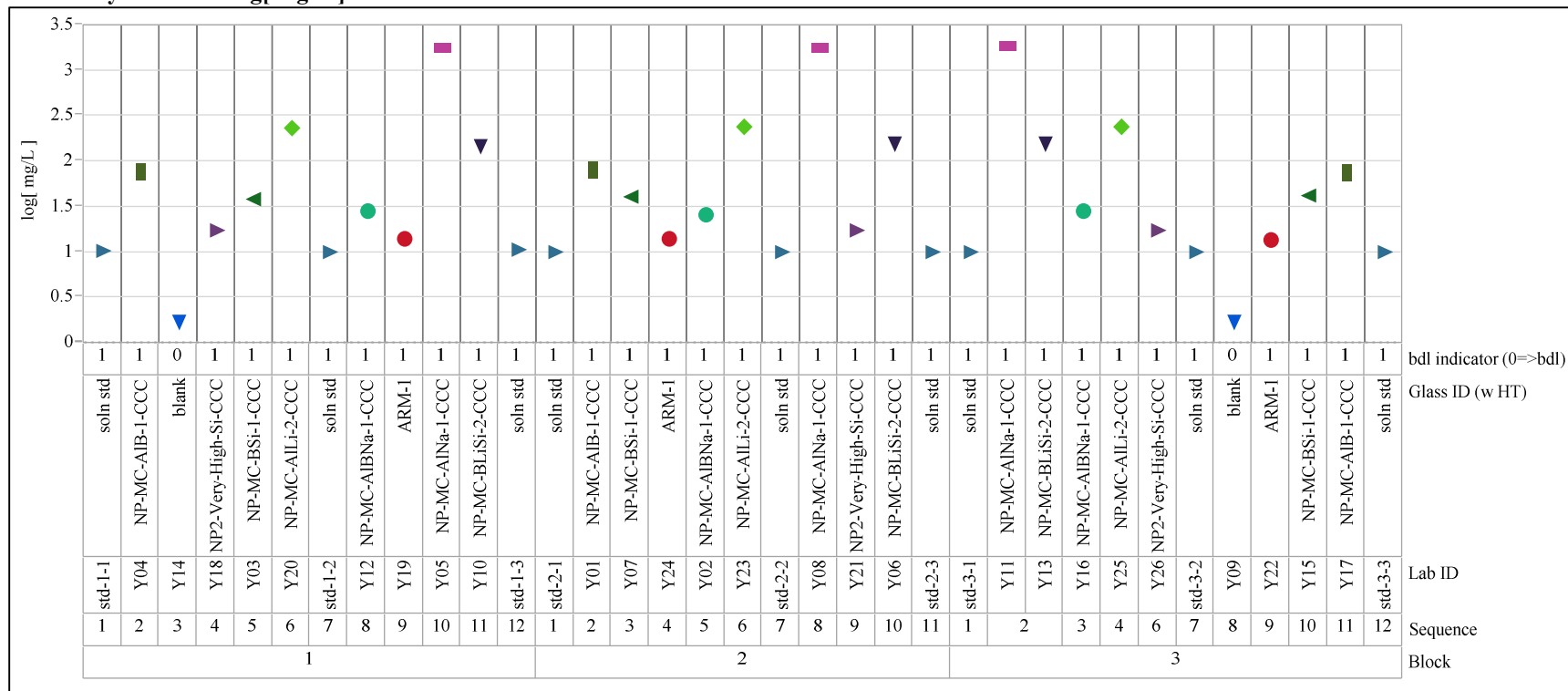
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=2, Analyte=log[Li mg/L]

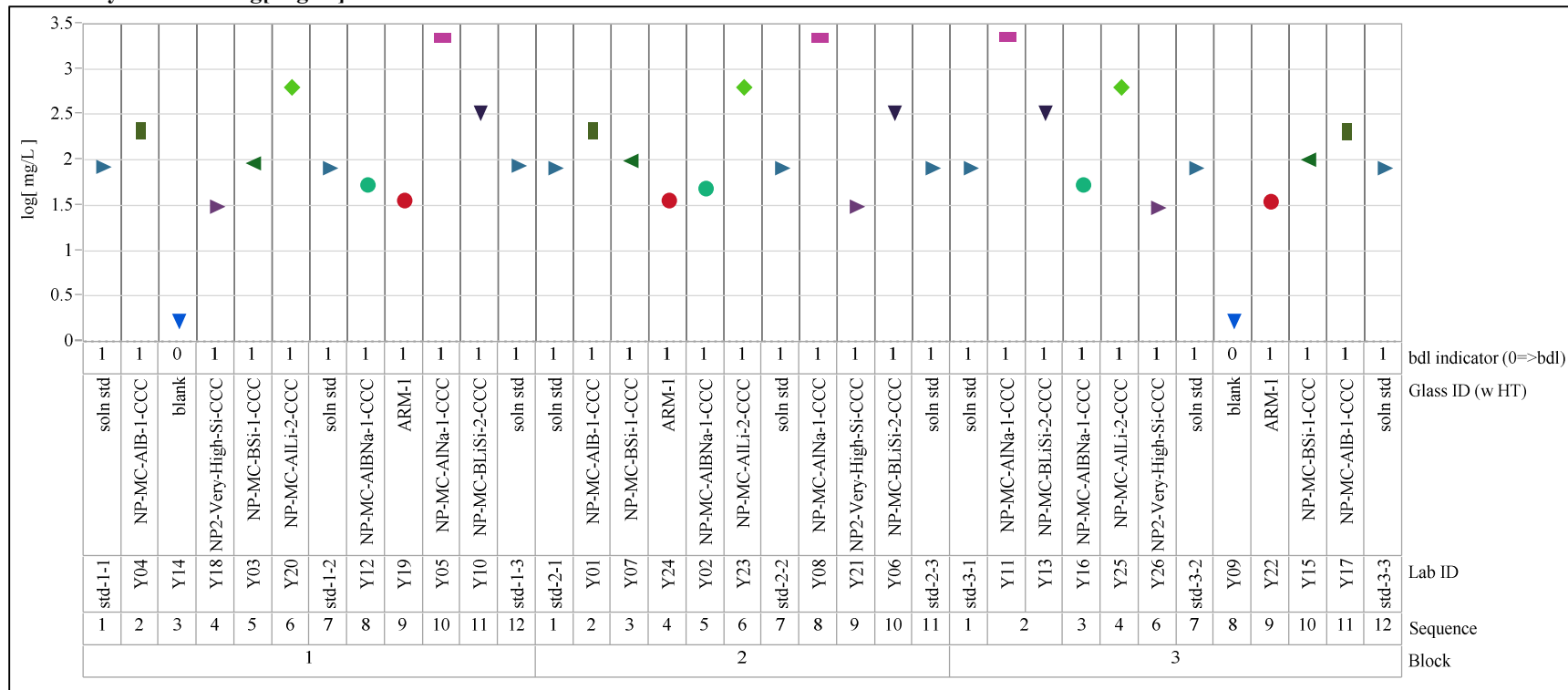
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=2, Analyte=log[Na mg/L]

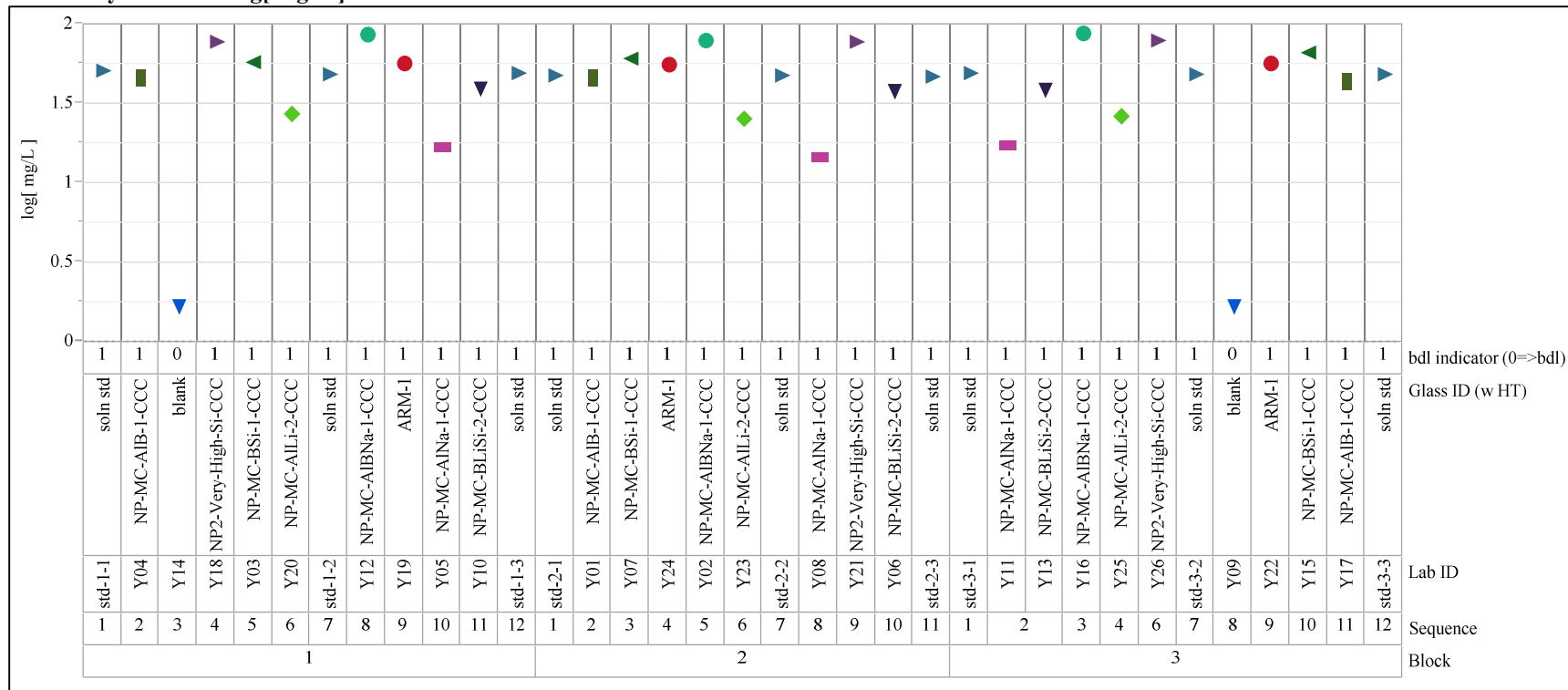
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=2, Analyte=log[Si mg/L]

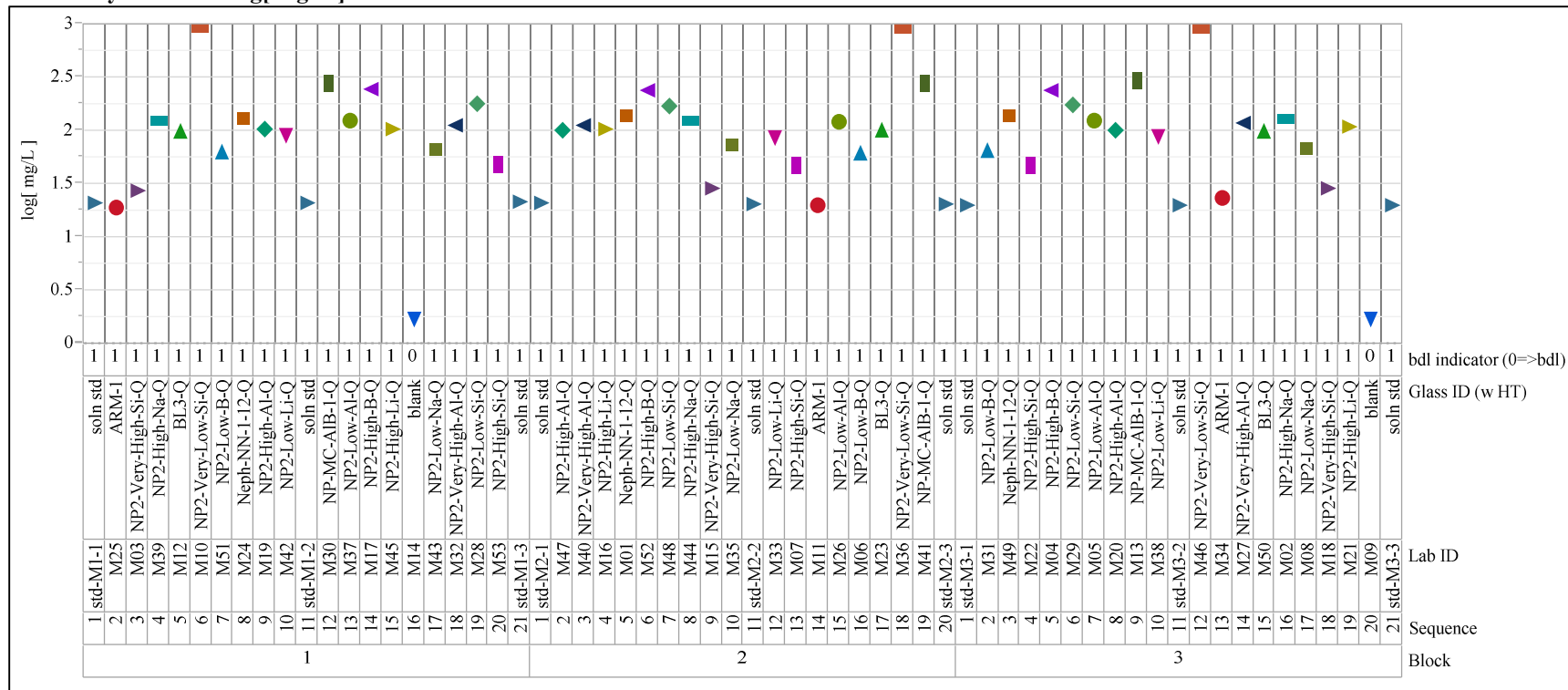
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=3/1, Analyte=log[B mg/L]

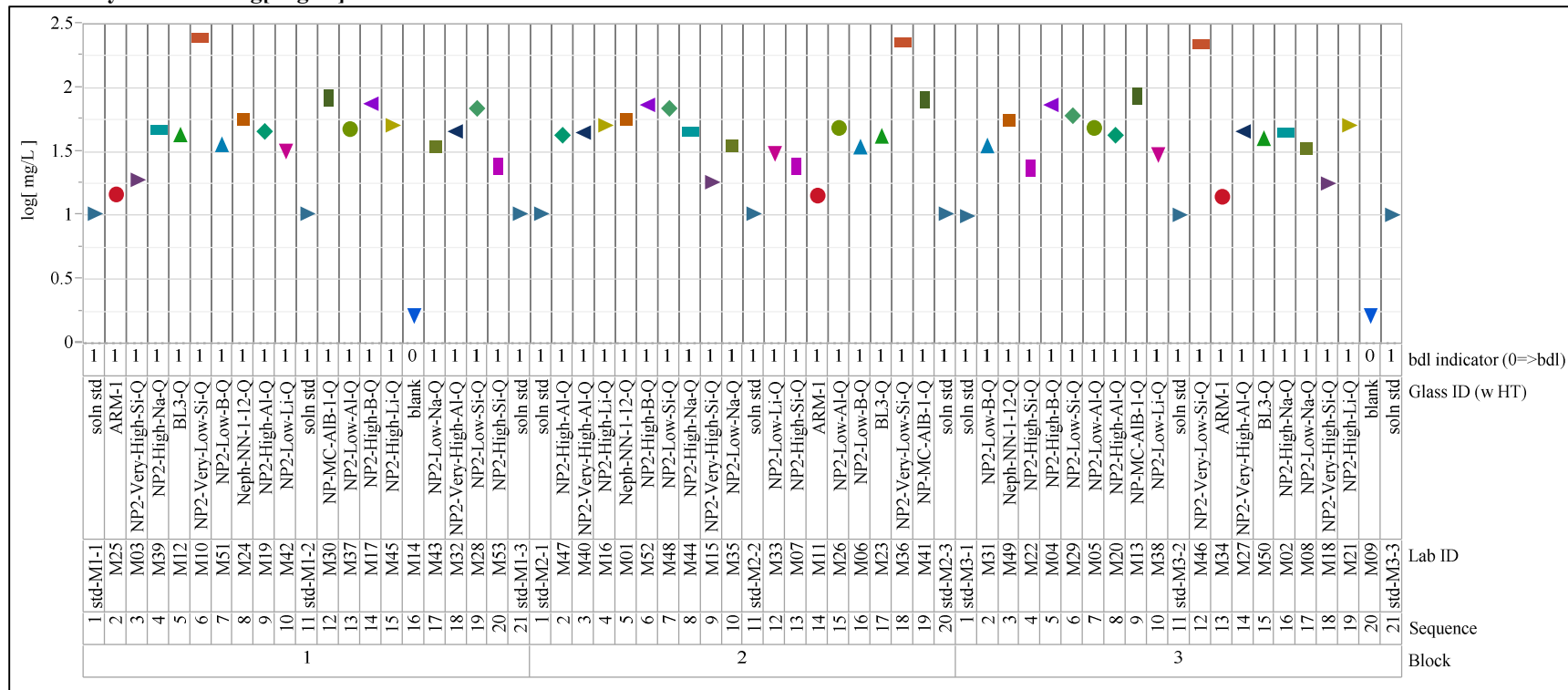
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=3/1, Analyte=log[Li mg/L]

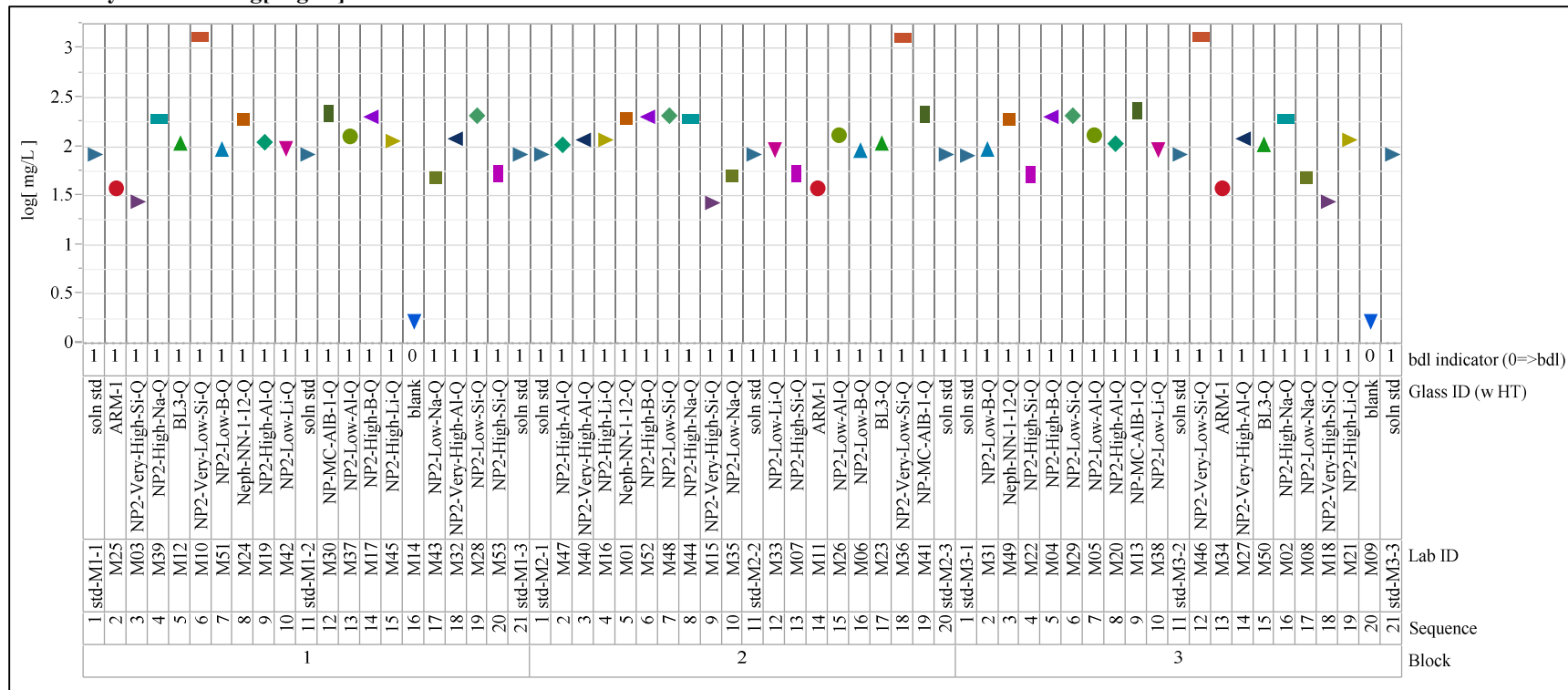
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=3/1, Analyte=log[Na mg/L]

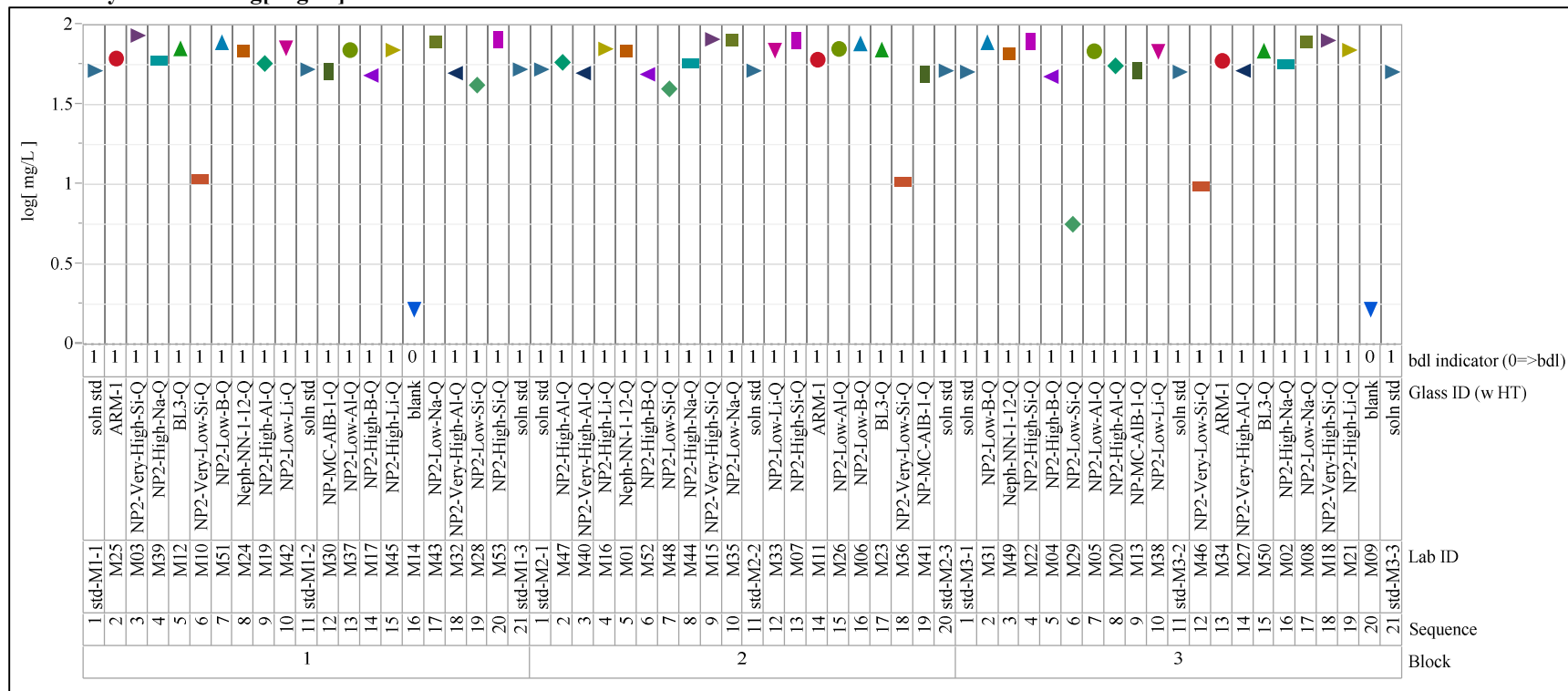
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=3/1, Analyte=log[Si mg/L]

Variability Chart for log mg/L ]

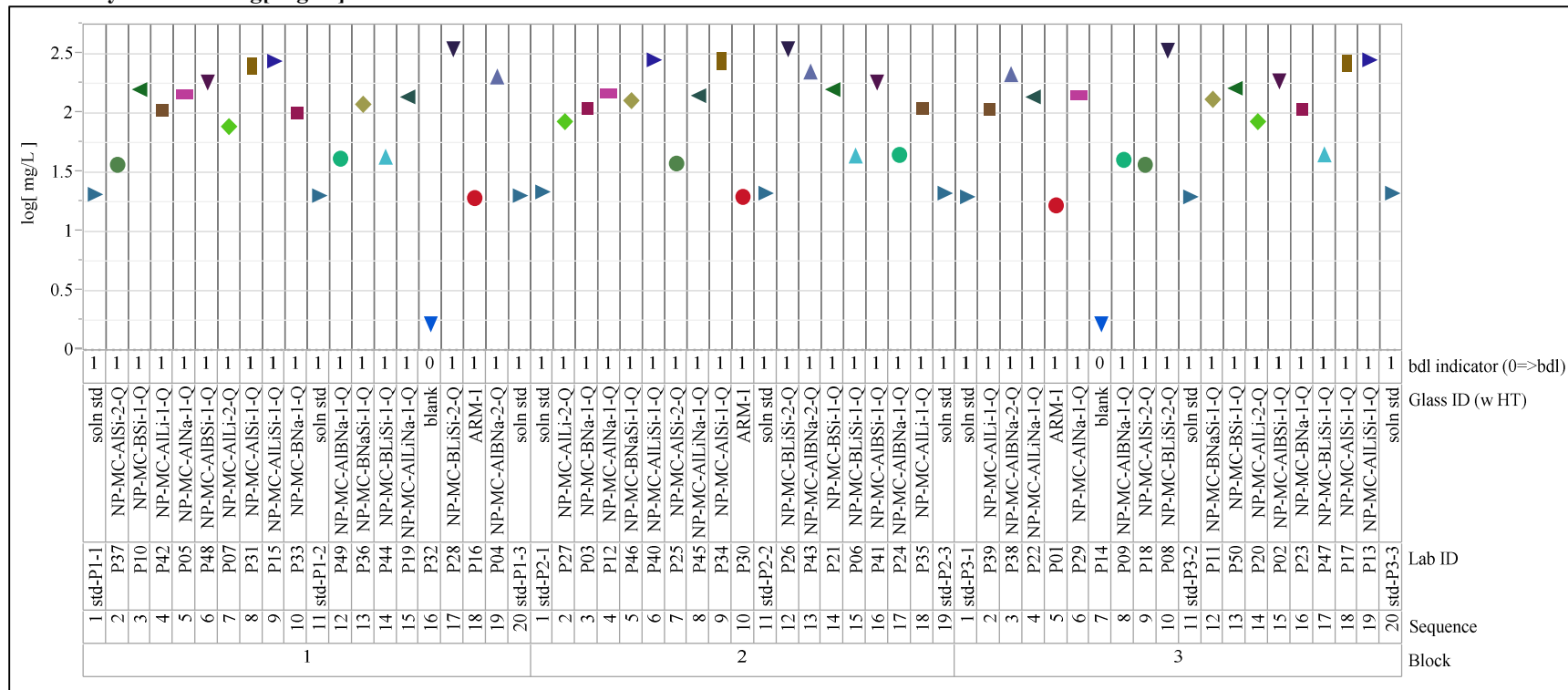




## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=3/2, Analyte=log[B mg/L]

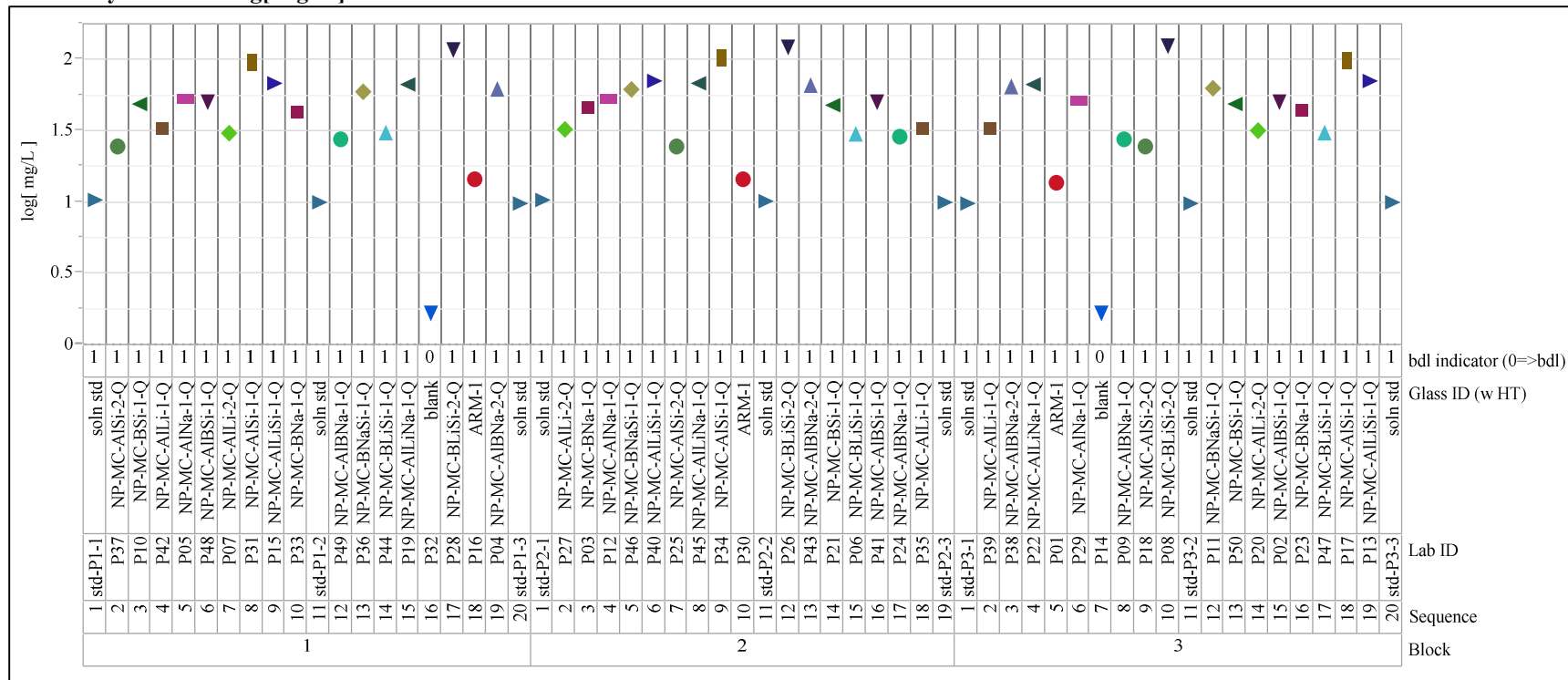
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=3/2, Analyte=log[Li mg/L]

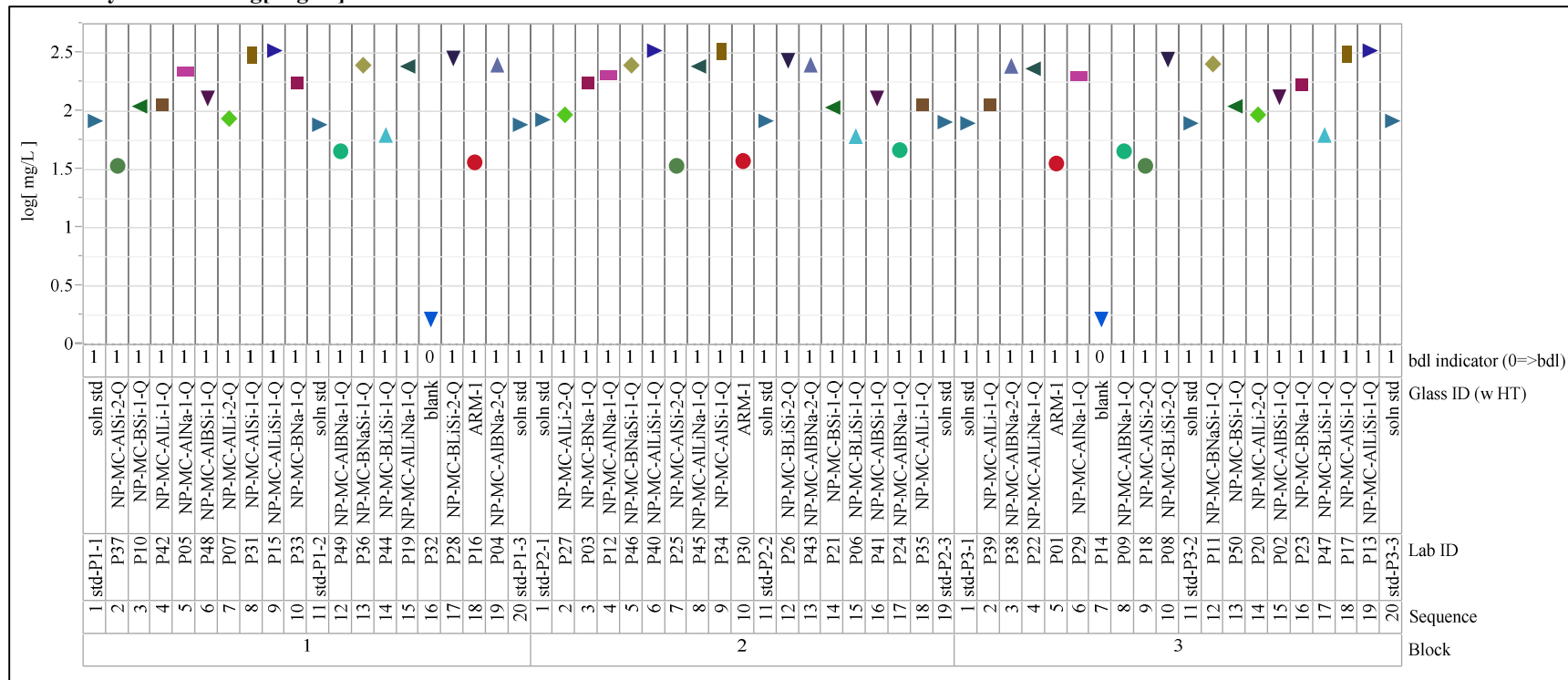
Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=3/2, Analyte=log[Na mg/L]

Variability Chart for log[ mg/L ]



## Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)

Group/Set=3/2, Analyte=log[Si mg/L]

Variability Chart for log[ mg/L ]

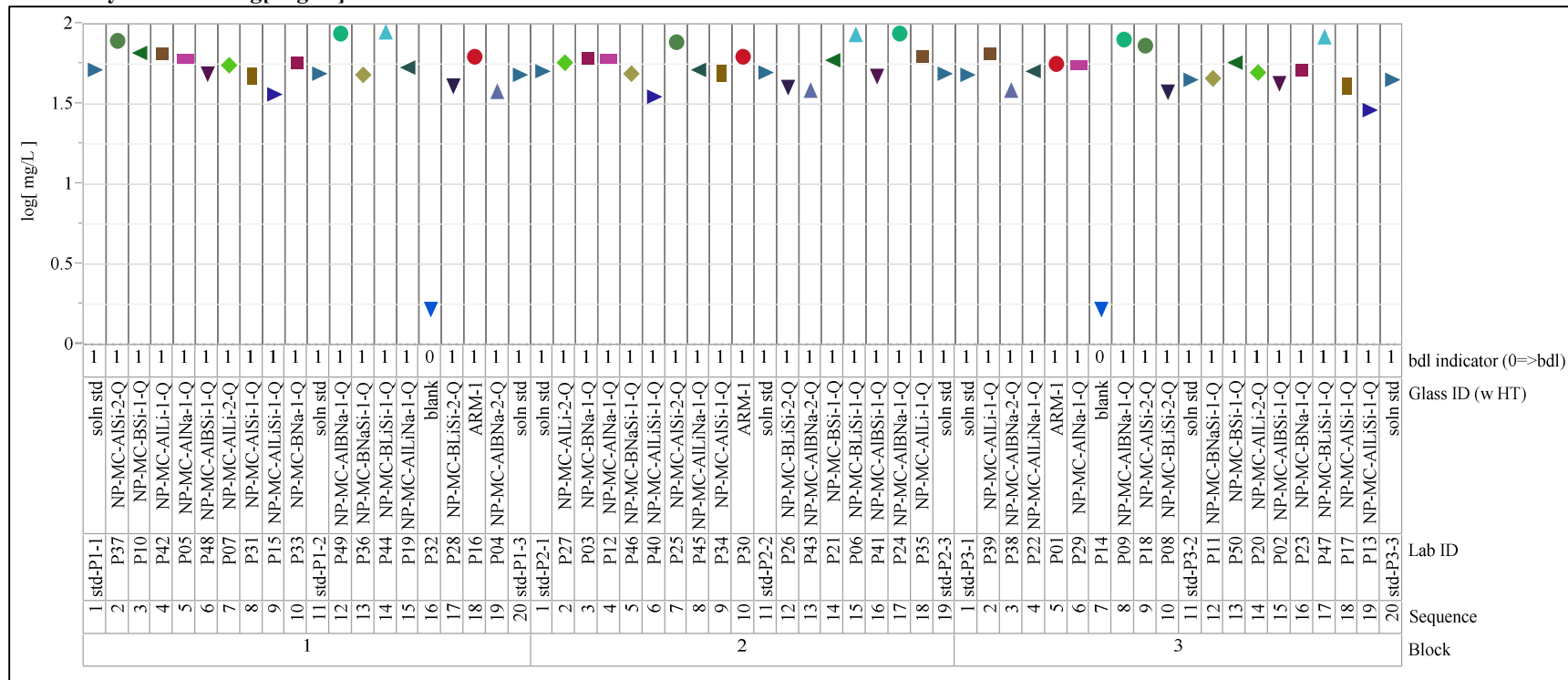
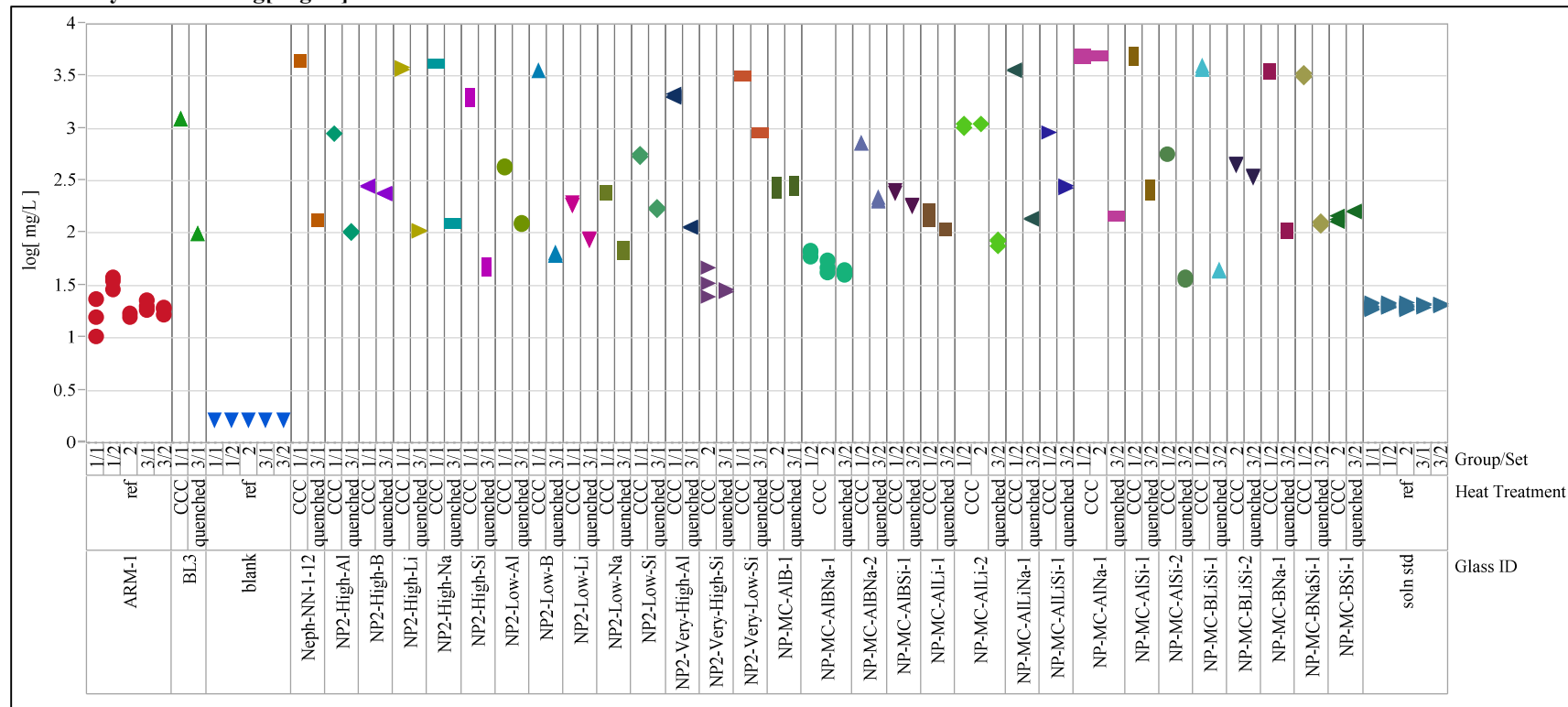


Exhibit B-2. PCT Measurements for Each Set of Nepheline Study Glasses

Analyte=log[B mg/L]

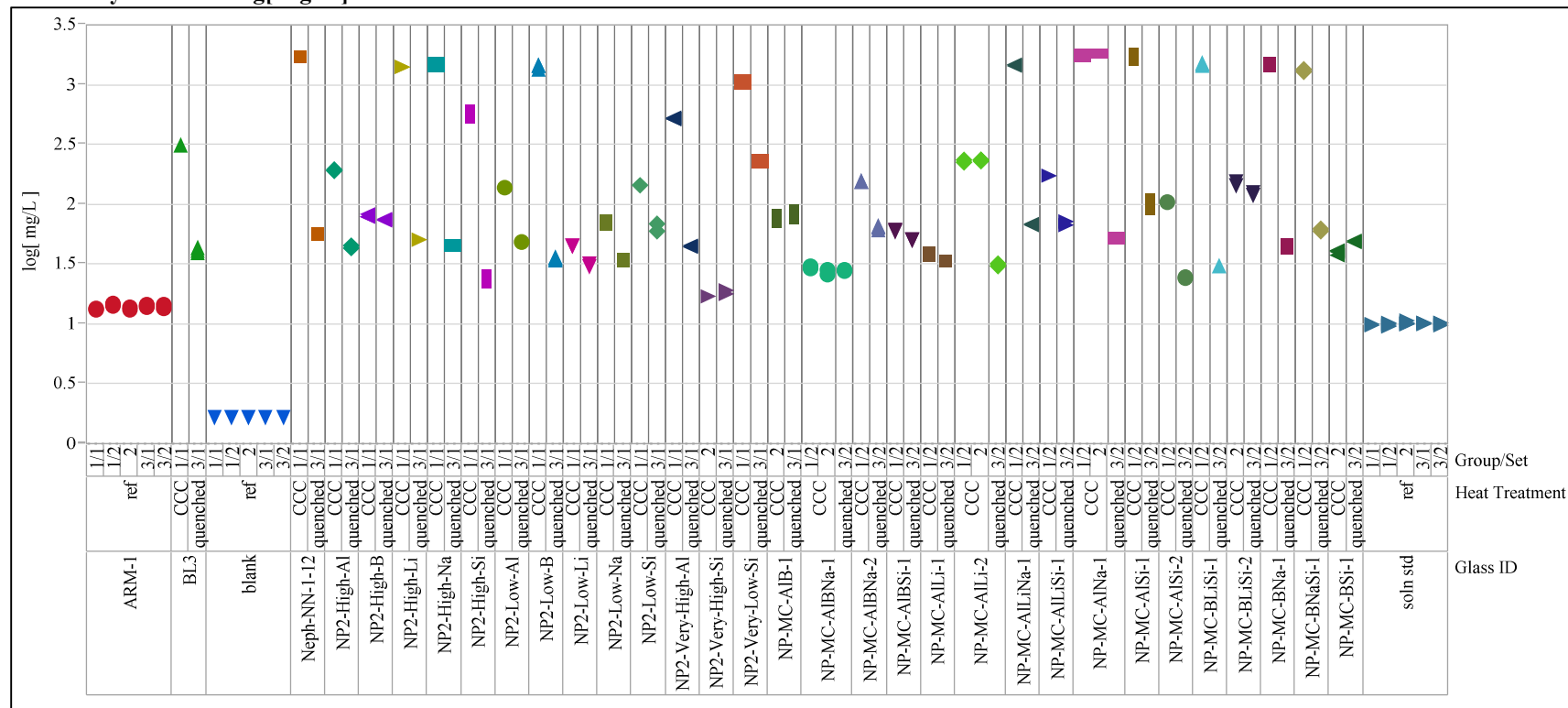
Variability Chart for log[ mg/L ]



## Exhibit B-2. PCT Measurements for Each Set of Nepheline Study Glasses (continued)

Analyte=log[Li mg/L]

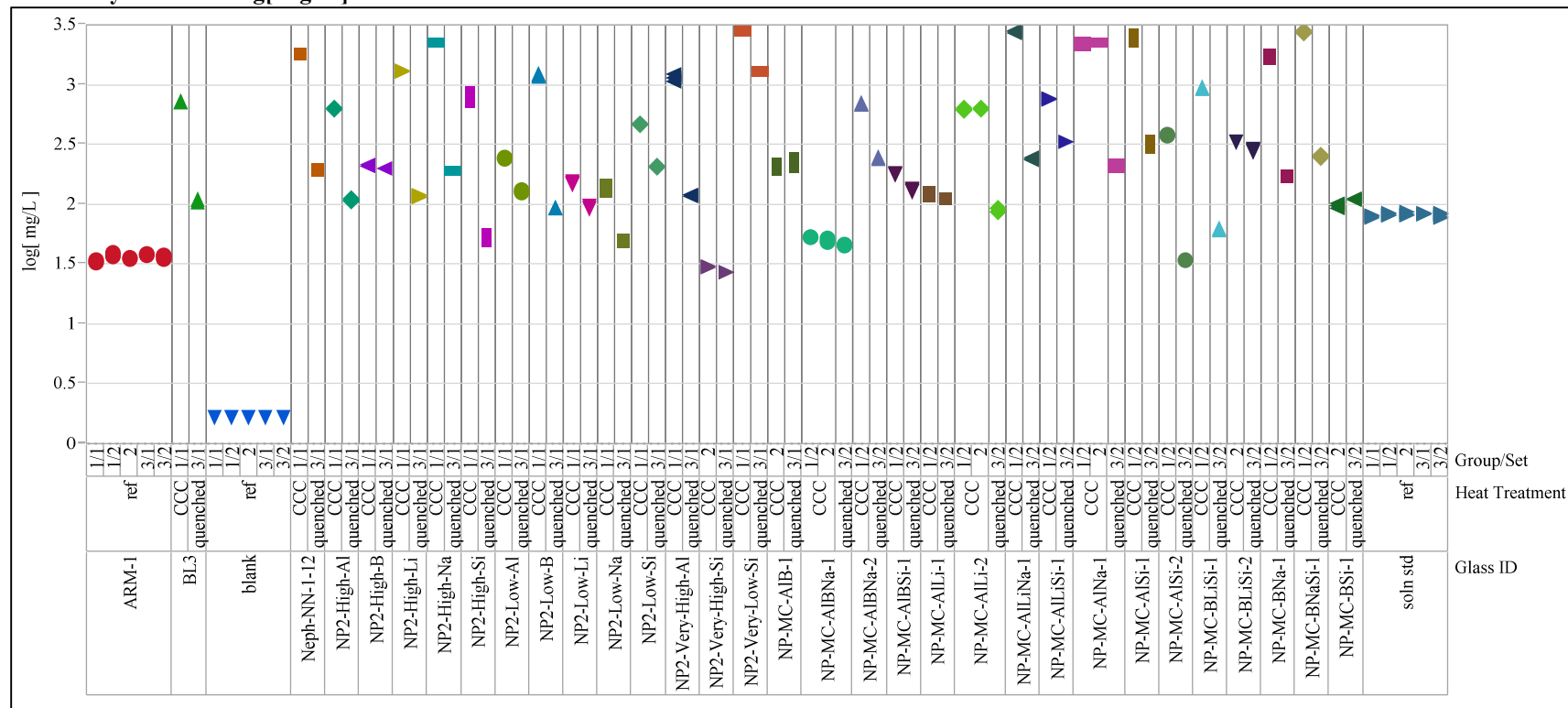
Variability Chart for log mg/L ]



## Exhibit B-2. PCT Measurements for Each Set of Nepheline Study Glasses (continued)

Analyte=log[Na mg/L]

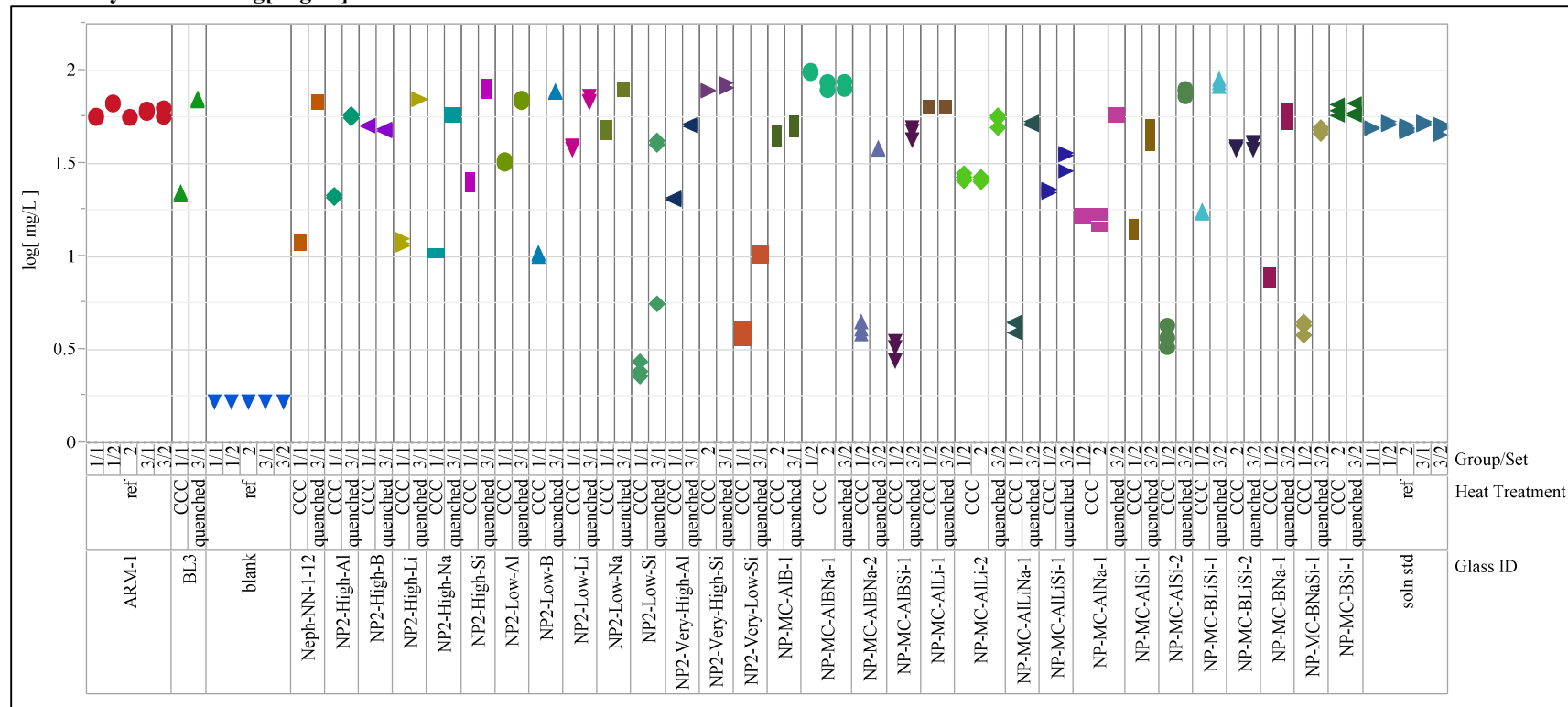
Variability Chart for log[ mg/L ]



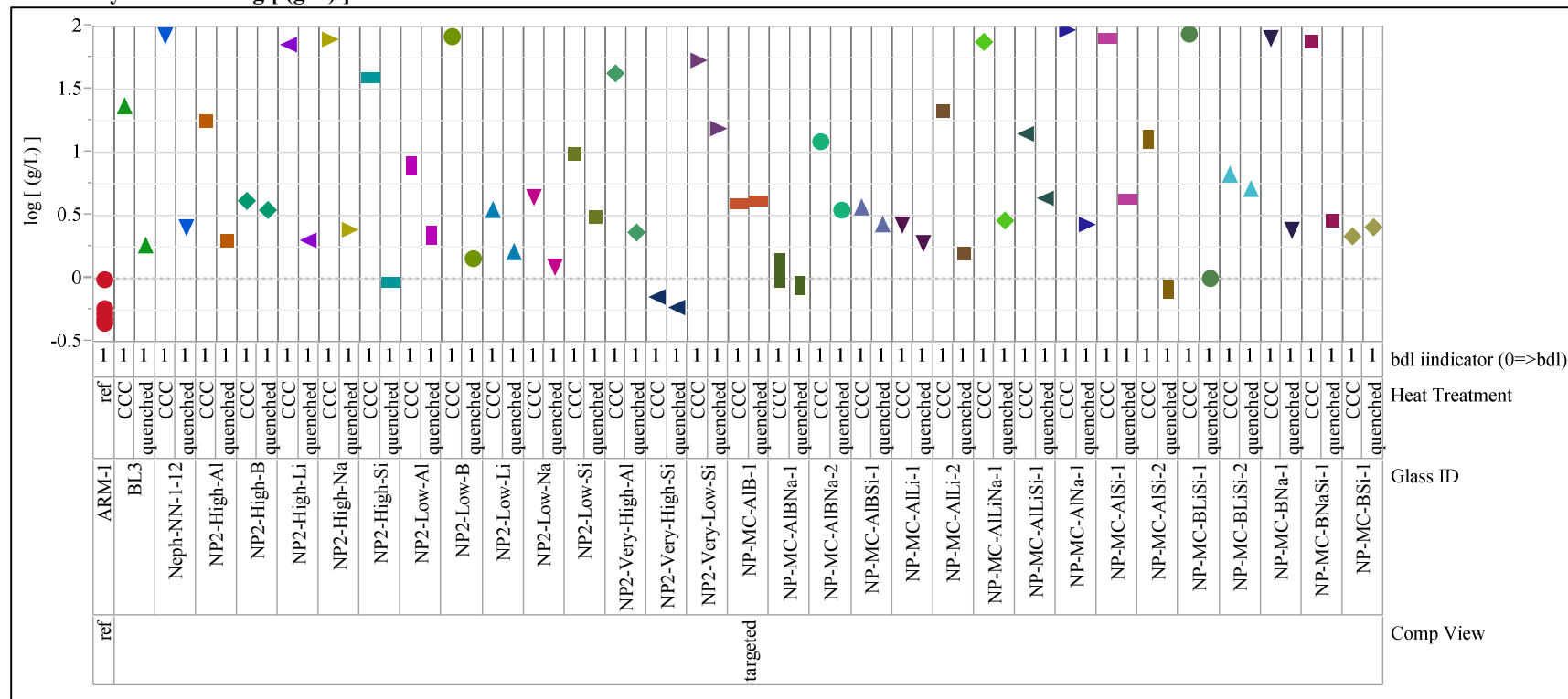
## Exhibit B-2. PCT Measurements for Each Set of Nepheline Study Glasses (continued)

Analyte=log[Si mg/L]

Variability Chart for log[ mg/L ]

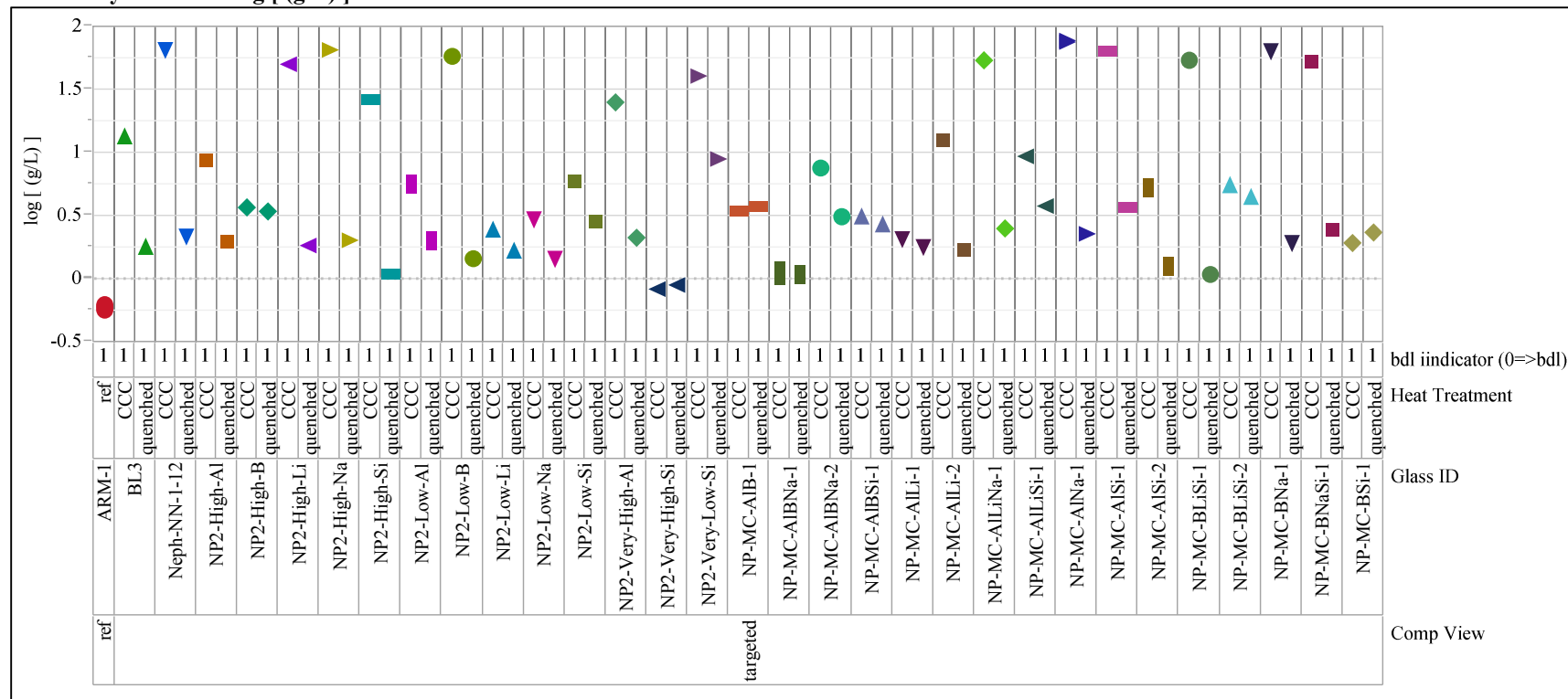




**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass**Analyte= $NC_B$ Variability Chart for  $\log [ \text{ (g/L) } ]$ 

**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**Analyte= $NC_{Li}$ 

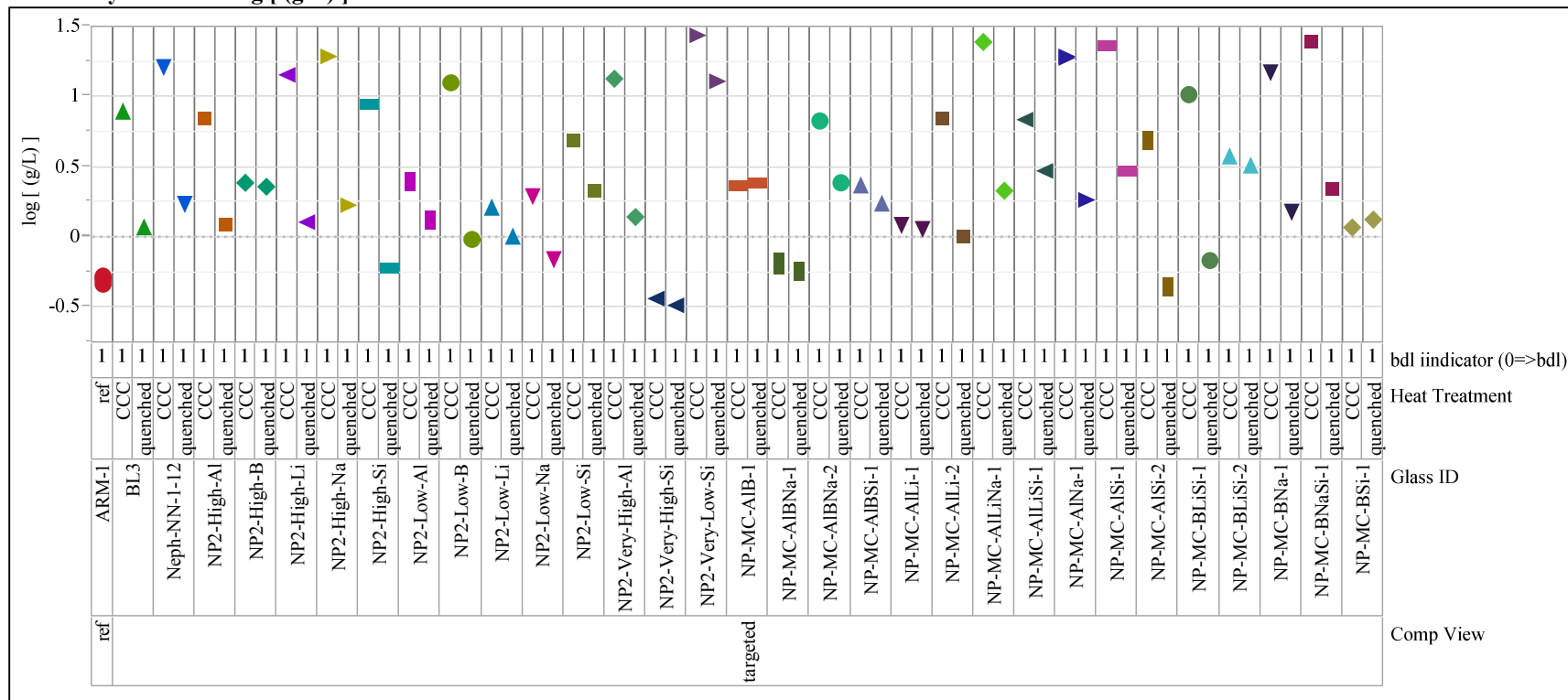
Variability Chart for log [ (g/L) ]



**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**

$$\text{Analyte} = NC_{Na}$$

### Variability Chart for $\log [(\text{g/L})]$



**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**

**Analyte=NC<sub>Si</sub>**

### Variability Chart for $\log [ (g/L) ]$

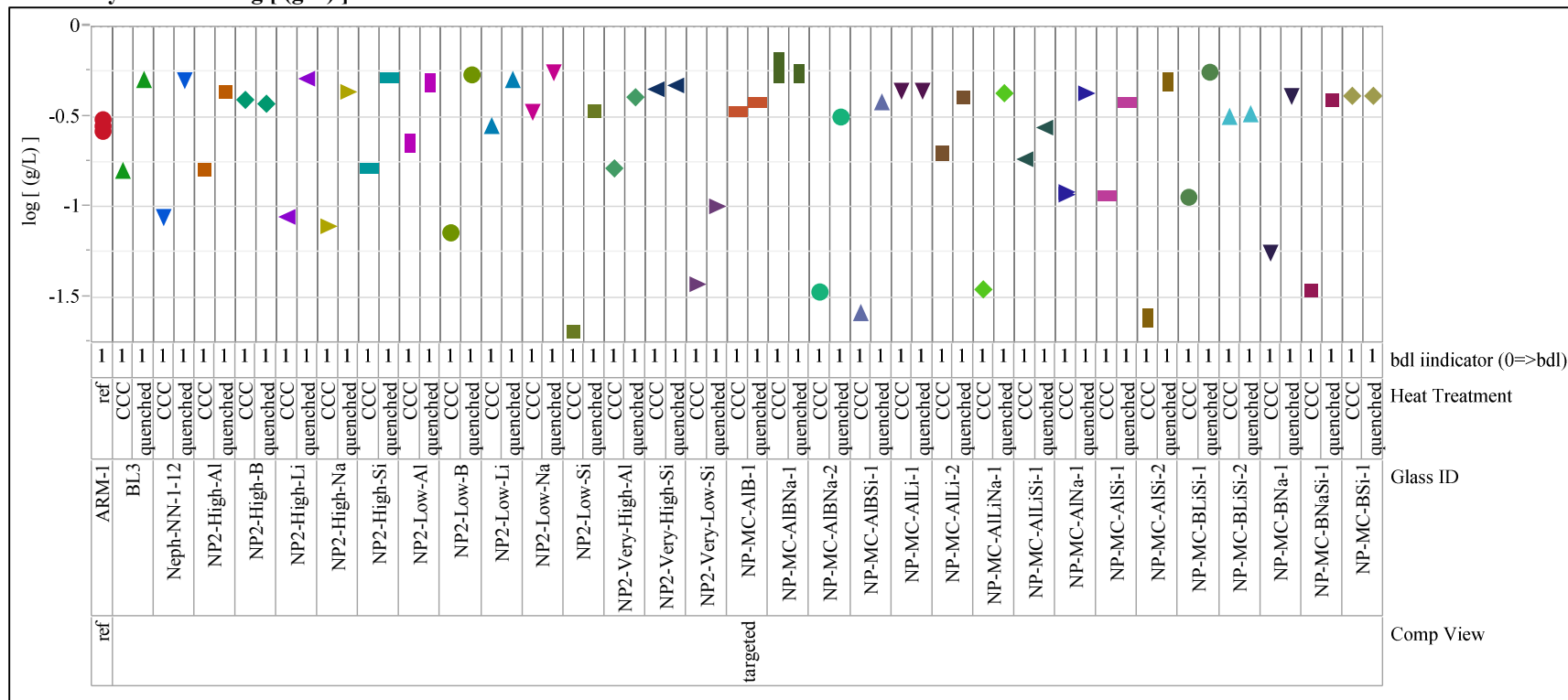


Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)

Analyte= $NC_B$

Variability Chart for  $\log [ (g/L) ]$

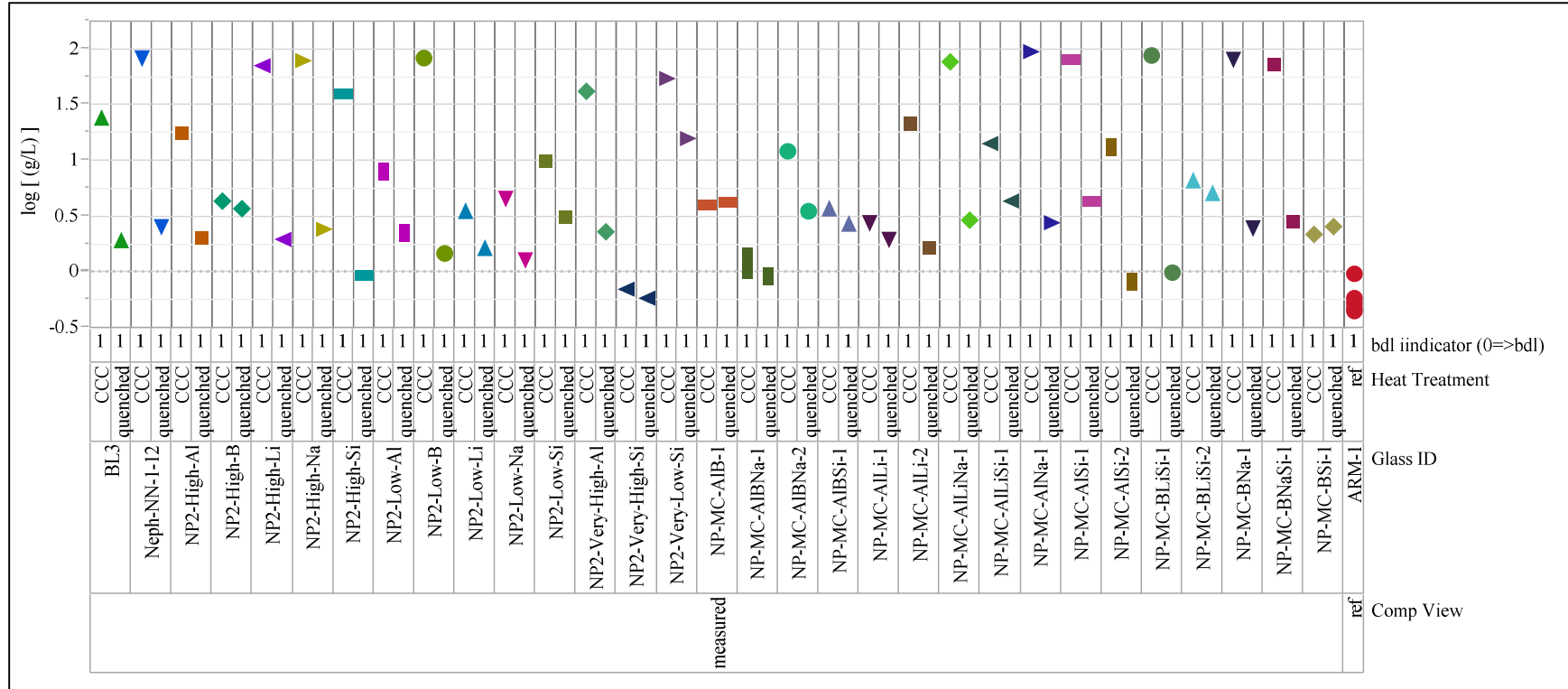
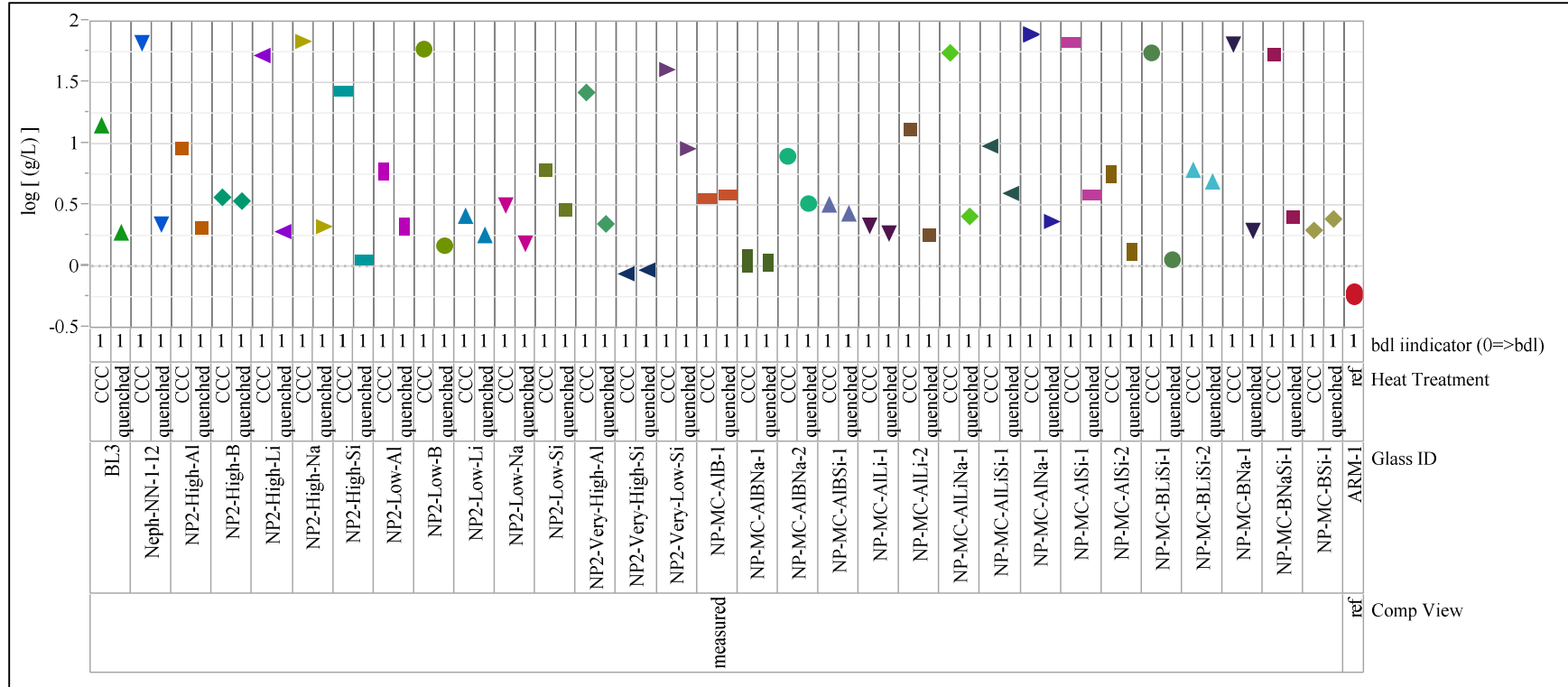


Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)

Analyte= $NC_{Li}$

Variability Chart for  $\log [ (g/L) ]$



**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**Analyte= $NC_{Na}$ 

Variability Chart for log [ (g/L) ]

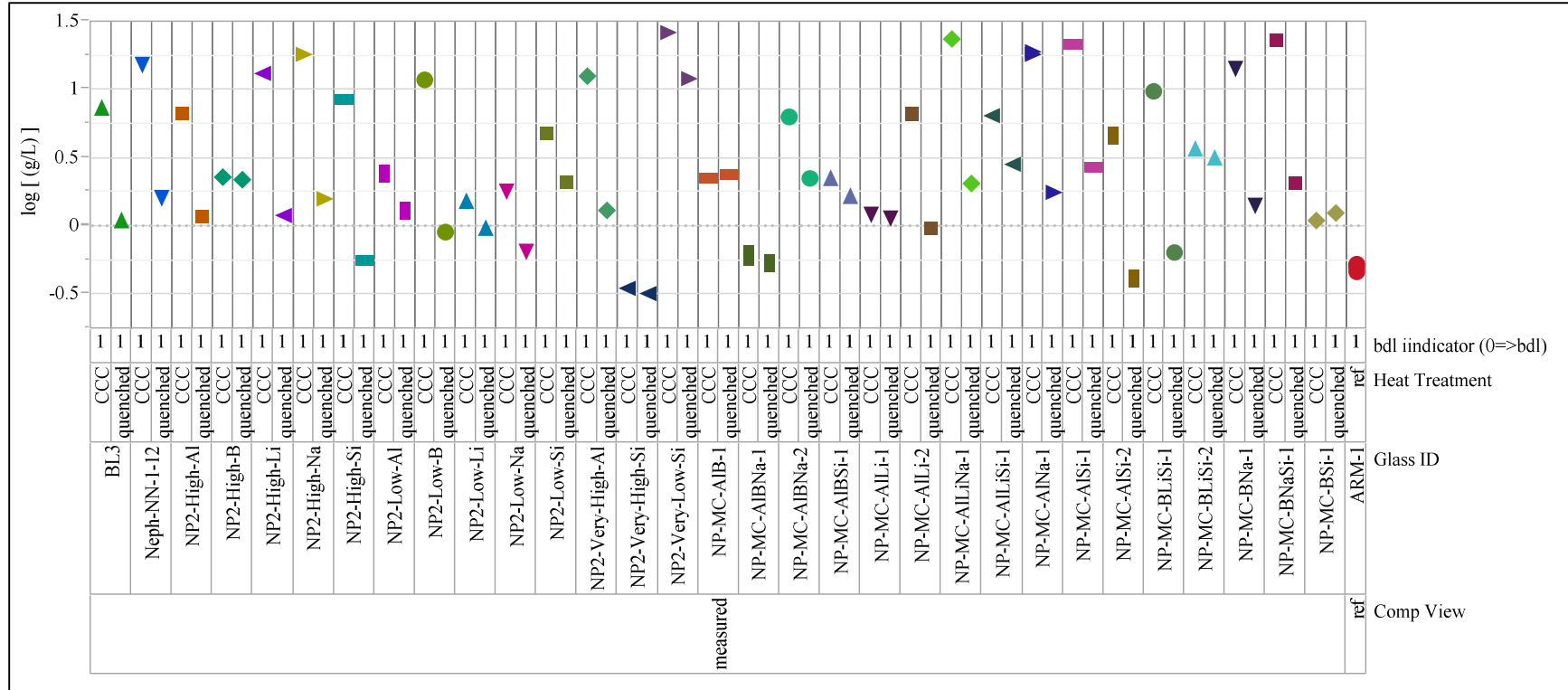
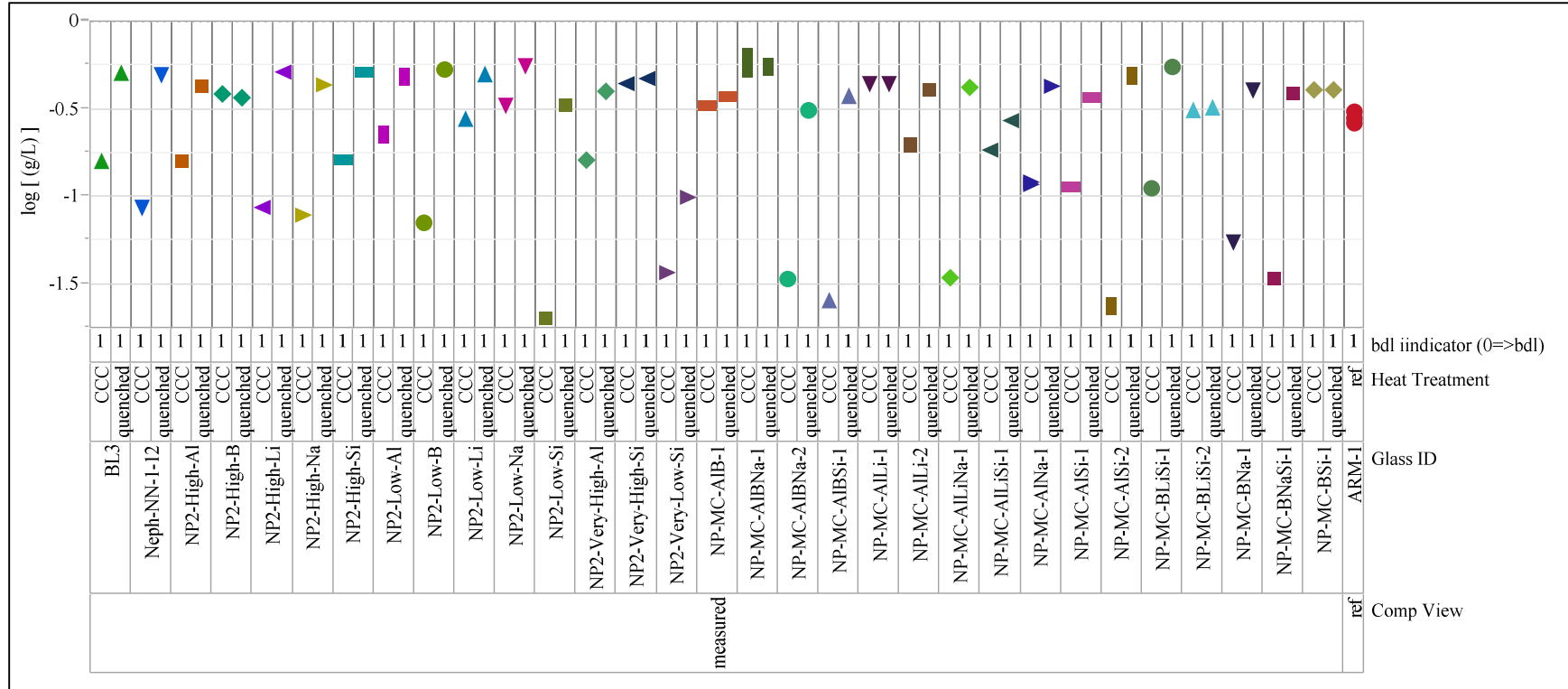


Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)

Analyte= $NC_{Si}$

Variability Chart for log [ (g/L) ]



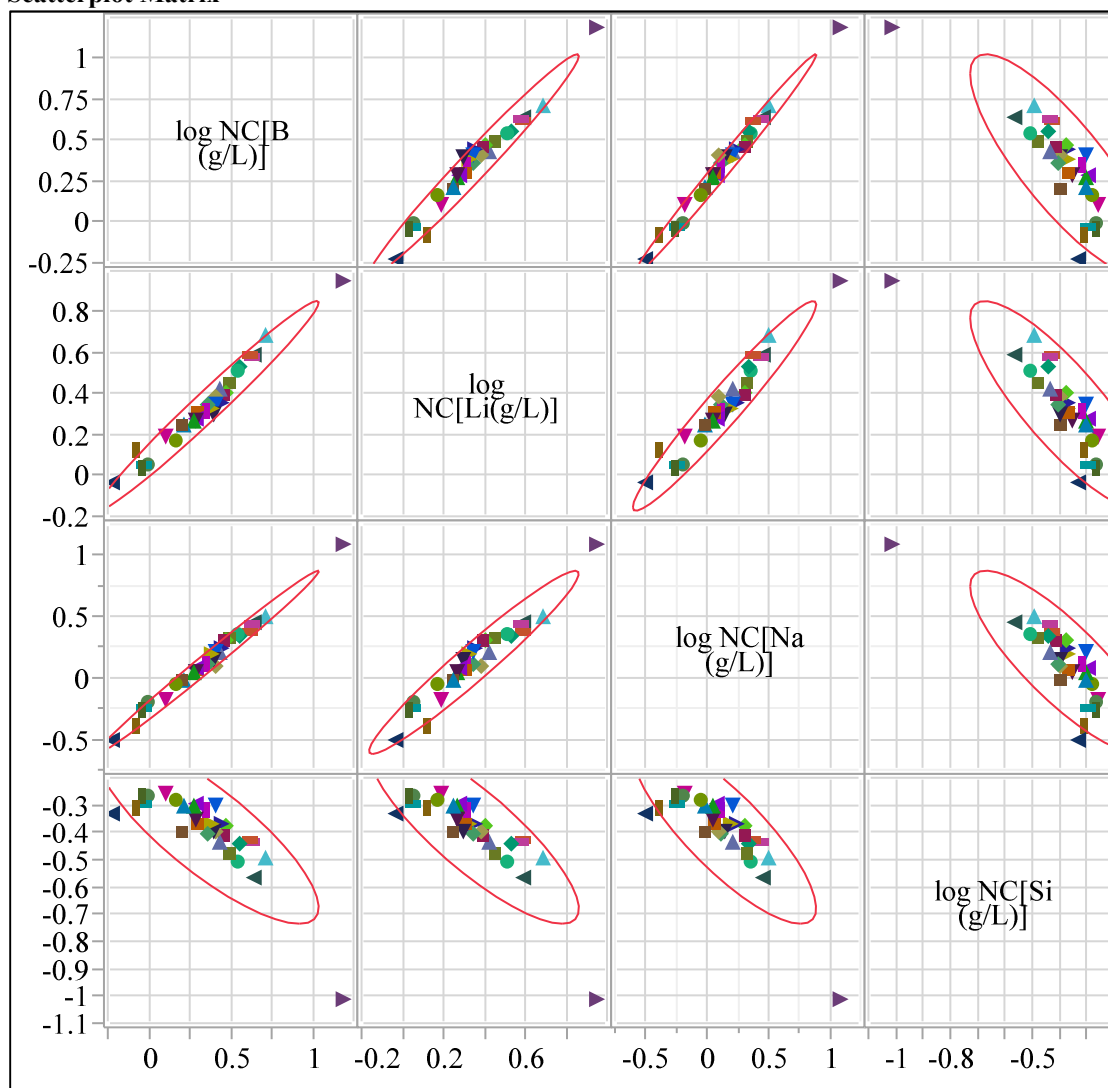


**Exhibit B-4. Congruent Leaching Analysis for the Quenched Versions of the Nepheline Glasses**

**Correlations**

	log NC[B (g/L)]	log NC[Li(g/L)]	log NC[Na (g/L)]	log NC[Si (g/L)]
log NC[B (g/L)]	1.0000	0.9829	0.9929	-0.8258
log NC[Li(g/L)]	0.9829	1.0000	0.9674	-0.8408
log NC[Na (g/L)]	0.9929	0.9674	1.0000	-0.8294
log NC[Si (g/L)]	-0.8258	-0.8408	-0.8294	1.0000

**Scatterplot Matrix**

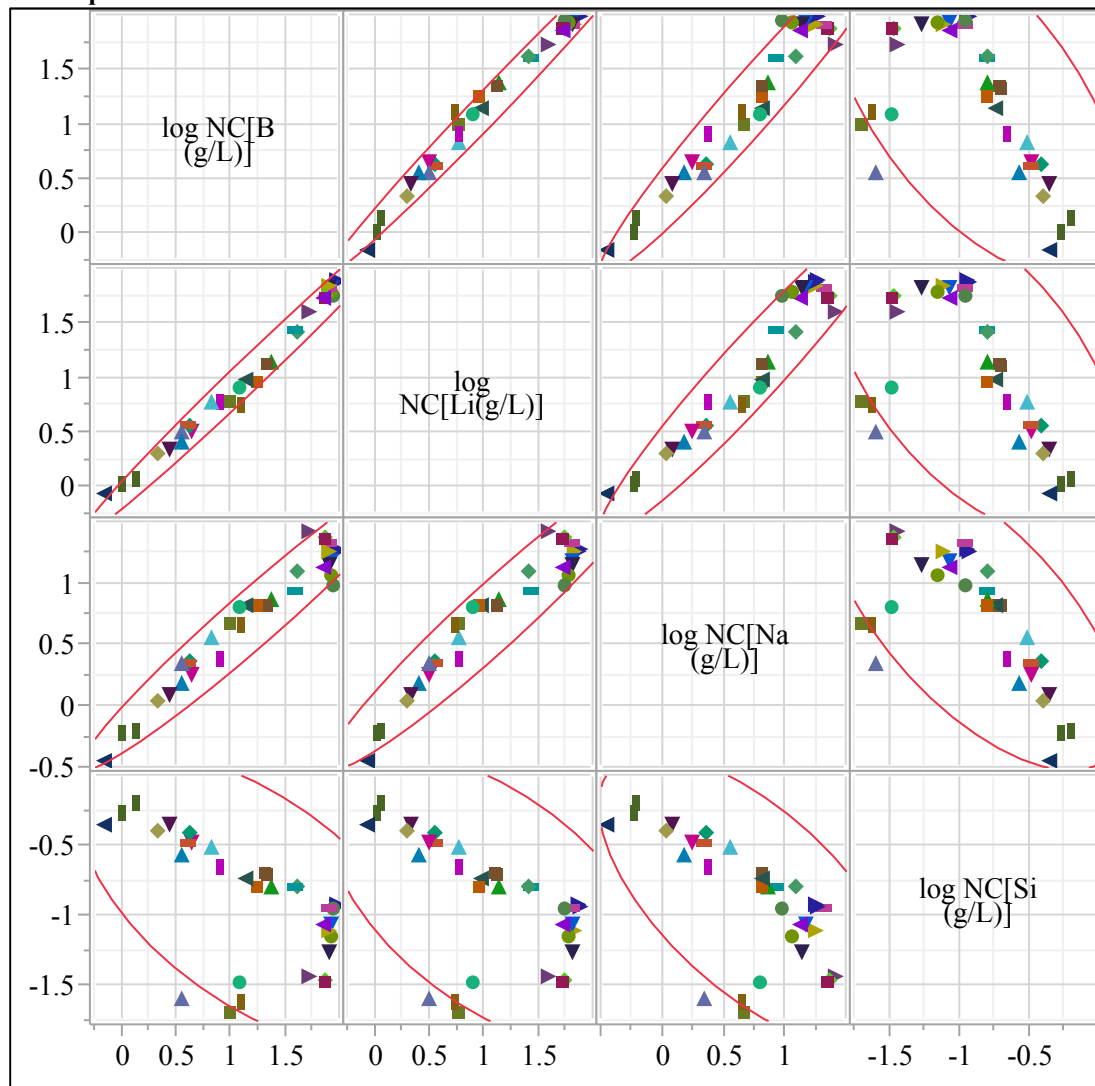


**Exhibit B-5. Congruent Leaching Analysis for the CCC Versions of the Nepheline Glasses**

**Correlations**

	log NC[B (g/L)]	log NC[Li(g/L)]	log NC[Na (g/L)]	log NC[Si (g/L)]
log NC[B (g/L)]	1.0000	0.9920	0.9730	-0.5822
log NC[Li(g/L)]	0.9920	1.0000	0.9616	-0.5502
log NC[Na (g/L)]	0.9730	0.9616	1.0000	-0.6484
log NC[Si (g/L)]	-0.5822	-0.5502	-0.6484	1.0000

**Scatterplot Matrix**



**Distribution:**

J. W. Amoroso, 999-W  
T. B. Brown, 773-A  
H. H. Burns, 773-41A  
A. S. Choi, 999-W  
Y. S. Chou, PNNL  
A. D. Cozzi, 999-W  
C. L. Crawford, 773-42A  
J. V. Crum, PNNL  
D. E. Dooley, 999-W  
A. P. Fellingner, 773-42A  
S. D. Fink, 773-A  
K. M. Fox, 999-W  
E. K. Hansen, 999-W  
C. C. Herman, 773-A  
E. N. Hoffman, 999-W  
J. E. Hyatt, 773-A  
C. M. Jantzen, 773-A  
F. C. Johnson, 999-W

D. S. Kim, PNNL  
J. O. Kroll, PNNL  
A. A. Kruger, DOE-ORP  
D. J. McCabe, 773-42A  
D. L. McClane, 999-W  
D. H. McGuire, 999-W  
D. H. Miller, 999-W  
D. K. Peeler, PNNL  
F. M. Pennebaker, 773-42A  
M. R. Poirier, 773-42A  
M. J. Schweiger, PNNL  
M. E. Stone, 999-W  
C. L. Trivelpiece, 999-W  
J. D. Vienna, PNNL  
A. L. Washington II, 773-42A  
W. R. Wilmarth, 773-A  
Records Administration (EDWS)