Quantitative EPMA Compositional Mapping of Lunar Mare Basalt Breccia
Northwest Africa NWA 12384

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Summary
Lunar basalt breccia meteorite NWA 12384 overview detailed in [1] and adjacent poster
Fully quantitative EPMA compositional stage mapping applied to clast 2 of NWA 12384
Multipass WDS X-ray intensity maps for 13 elements
Full q(µ) correction at each pixel yields element wt% data directly
EPMA calibration and MAN background correction yield improved accuracy
Quantitative map data and wt% Iff images used for analysis and clustering
Downstream processing using Matlab, Fiji Xlib cluster plugin
Mineral classification method produces phase image and quantitative phase chemistry
Method applied to basalt clast 2 of NWA 12384 end-cut EC-1
Provides discrete point analysis
Modal recalculations to obtain bulk chemistry of clast
Compared with bulk analysis of NWA 12384 and shock melt vein

EPMA Compositional Mapping Procedures

A. EPMA Stage Mapping
Mosaic BSE imaging and full-sample X-ray stage mapping of NWA 12384 end-cut EC-1
Al-Mg-Fe RGB map used to identify and delineate 25 clasts
Probe for EPMA and Probe Image:
13 element WDS calibration, mean atomic number background correction
Fixed electron beam, stage slew for map strip collection
Map conditions: 15kV 1000A, 1024x1024 pixel, 5 micron step, 30 msec dwell for each map pass
Raw X-ray maps: 32-bit intensity resolution, deadtime corrected.
B. Catching map correction: X-ray map intensities to concentration
Full q(µ) ZAF correction, complete analysis protocol same as used for point analysis.
C. Map data produced:
Element, analytical total, oxide, formula, MAN, detection limit
Golden Software Surfer & Surfer: generate contour quantitative maps.
D. Data processing:
Two methods used here
1. Filtered data phases identified via stoichiometric formula
   Filtered by cation sum (x 0.1 cation sum per 24 oxygen) and analytical total (99-101 wt%)
   These data plotted on ternary composition plots, represent subset of total map data
2. Cluster analysis of full map data set
   Matlab script converts EPMA map data to 32-bit tiff quant images, stoichiometric inspection
   Fiji Xlib: clustering and phase classification using quantitative element weight % data
   Cluster data used for classification map and modal recalculations of EPMA bulk composition
E. Advances over previous mapping procedures:
   Method is concentration-based with accurate MAN background correction
   Historical X-ray intensity map conversion of a to C via y = ax + b conversion from b to C
   Neither slope m (ZAF) nor intercept b (background) are constants. Derived C not accurate.

Quantitative EPMA Map QM1

NWA 12384 Quantitative Map QM1 and BSE detail image
Left: Al-Mg-Fe RGB end map phases (olivine blue-green, pigeonite – augite green,
Fe-rich pyroxene and ilmenite blue), plotted with mineral phases (olivine blue-green,
Pigeonite blue, augite green, Fe-rich pyroxene and ilmenite blue, plagioclase red).
Right: Detail BSE shows representative textural relations.

Quantitative Element Wt% Maps

NWA 12384 QM1 Element Wt% Contour Maps
Quantitative element wt% maps for labelled elements
Maps have adjusted color scale to highlight phase chemistry.
Each map is fully quantified with oxygen calculated by stoichiometry.
Not shown are maps for MAN background, analytical total, detection limit (typically ~ 0.1 wt%),
calcite, and cation stoichiometry on 24 oxygen basis.
Fiji Xlib plugin is used for cluster analysis with 32-bit tiff versions of wt% element maps as input.

Mineral Chemistry Using Filtered Data Set

Table 1
Cluster Compositions and Bulk Chemistry Recombination

NWA 12384 QM1 Cluster Analysis

Table 2
CIPW Normative Calculation

Conclusions
1. Fully quantitative EPMA compositional stage mapping is applied to analysis of NWA 12384.
2. Mineral chemistry is evaluated using filtered data and cluster means with excellent agreement.
3. Modal recalculations using cluster means is accurate and agrees with bulk wet chemistry.
4. Preliminary equilibrium crystalization modelling agrees with petrographic observations and results of EPMA compositional mapping.

References