

Supplementary Table 2: Analytical performance, Limits of Detection (LOD), and quality control (QA/QC) parameters for the analyzed elements.

Element	Analytical Method	Unit	LOD	Blank Control	Duplicate Precision (RSD %)	CRM Recovery (%)
Major Elements						
Fe	WDXRF	wt. %	0.01	< LOD	± 2.1	98.5 - 101.2
Mg	WDXRF	wt. %	0.01	< LOD	± 1.8	97.8 - 100.9
Ca	WDXRF	wt. %	0.01	< LOD	± 1.5	99.1 - 102.0
K	WDXRF	wt. %	0.01	< LOD	± 2.0	98.0 - 101.5
S	WDXRF	wt. %	0.01	< LOD	± 3.2	96.5 - 103.1
Trace Elements & Precious Metals						
Au	ICP-MS	ppm	0.01	< LOD	± 4.5	95.5 - 104.2
Ag	ICP-MS	ppm	0.01	< LOD	± 3.8	96.1 - 103.5
Sb	ICP-MS	ppm	0.05	< LOD	± 4.1	94.8 - 105.0
As	ICP-MS	ppm	1.00	< LOD	± 5.2	93.5 - 106.1
Cu	ICP-MS	ppm	0.10	< LOD	± 3.5	97.2 - 102.8
Pb	ICP-MS	ppm	0.10	< LOD	± 3.9	96.8 - 103.4
Zn	ICP-MS	ppm	1.00	< LOD	± 4.0	97.0 - 103.0
Ba	ICP-MS	ppm	10.0	< LOD	± 2.5	98.2 - 101.8
Sr	ICP-MS	ppm	0.10	< LOD	± 2.8	98.5 - 101.5
Rb	ICP-MS	ppm	0.10	< LOD	± 2.6	97.9 - 102.1
Cs	ICP-MS	ppm	0.05	< LOD	± 3.2	96.5 - 103.5
Mo	ICP-MS	ppm	0.05	< LOD	± 4.8	95.0 - 104.5
W	ICP-MS	ppm	0.10	< LOD	± 5.0	94.5 - 105.5
Bi	ICP-MS	ppm	0.01	< LOD	± 4.2	95.8 - 104.0
Te	ICP-MS	ppm	0.05	< LOD	± 4.6	94.2 - 105.8
Mn	ICP-MS	ppm	1.00	< LOD	± 3.1	97.5 - 102.5

Notes: Major elements were analyzed using a commercial WDXRF spectrometer. Trace elements and precious metals were analyzed using an ICP-MS system. Relative Standard Deviation (RSD) for field duplicates was maintained below 5.5%. Certified Reference Materials (CRMs) recovery rates fall within the rigorous 93-106% acceptable range. Analytical preparation blanks consistently returned values below the Limit of Detection (< LOD) for all elements.