

Supplementary Materials

Comparative study of three mixing methods in fusion technique for determining major and minor elements using wavelength dispersive X-ray fluorescence spectroscopy

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Table S1. Details of the certified reference materials (CRMs).

Source	CRMs used for the calibration	CRMs used for the validation	
IGGE ^a	GBW07101 ultramafic rock	GBW07112 gabbro	
		GBW07113 rhyolite	
	GBW07102 ultramafic rock	GBW07114 dolomite	
		GBW07120 limestone	
	GBW07103 granite	GBW07121 granite-gneiss	
	GBW07104 andesite	GBW07122 hornblendite	
	GBW07105 basalt	GBW07123 diabase	
	GBW07106 sandstone	GBW07124 kimberlite	
	GBW07107 shale	GBW07125 pegmatite	
	GBW07108 carbonate	GBW07212 phosphorite	
	GBW07109 syenite	GBW07312 stream sediment	
GBW07110 trachyte			
GBW07111 diorite	GBW07406 soil		
GSJ ^b	JG-1 granite	JR-1 rhyolite	JG-2 Granite
	JG-3 granodiorite	JP-1 peridotite	JG-1a Granodiorite
	JA-1 andesite	JF-1 feldspar	JA-3 Andesite
	JA-2 andesite		JB-2a Basalt
	JB-1b basalt		JB-3a Basalt
	JB-2 basalt		JH-1 Hornblendite
	JB-3 basalt		JGb-2 Gabbro
	JGb-1 gabbro		JR-2 Rhyolite
USGS ^c	AGV-2 andesite	STM-2 syenite	GSP-2 Granodiorite
	BIR-1a basalt	DNC-1a diabase	BCR-2 Basalt
	QLO-1a quartz latite	DTS-2B dunite	BHVO-2 Basalt
	SBC-1 shale	SDC-1 mica schist	W-2 Diabase
	COQ-1 carbonatite		RGM-2 Rhyolite
ANRT ^d	GA granite	DT-N gabbro	
	Mica-Fe biotite	FK-N feldspar	
	Mica-Mg phlogopite		
CRPG ^e	DR-N diorite		GH Granite
	GS-N granite		
	UB-N serpentinite		
IWG-GIT ^f	MA-N granite		AC-E Granite
	BE-N basalt		PM-S Microgabbro
	AL-I albite		WS-E Dolerite
CGL ^g			AN-G Anorthosite
			MGL-OShBO Granite

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^eCentre de Recherches Pétrographiques et Géochimiques. ^fInternational Working Group

“Analytical Standards of Minerals, Ores, and Rocks” - Groupe International de Travail “Etalons analytiques des minéraux, minéraux et roches”.

^gThe Central Geological Laboratory of Mongolia.

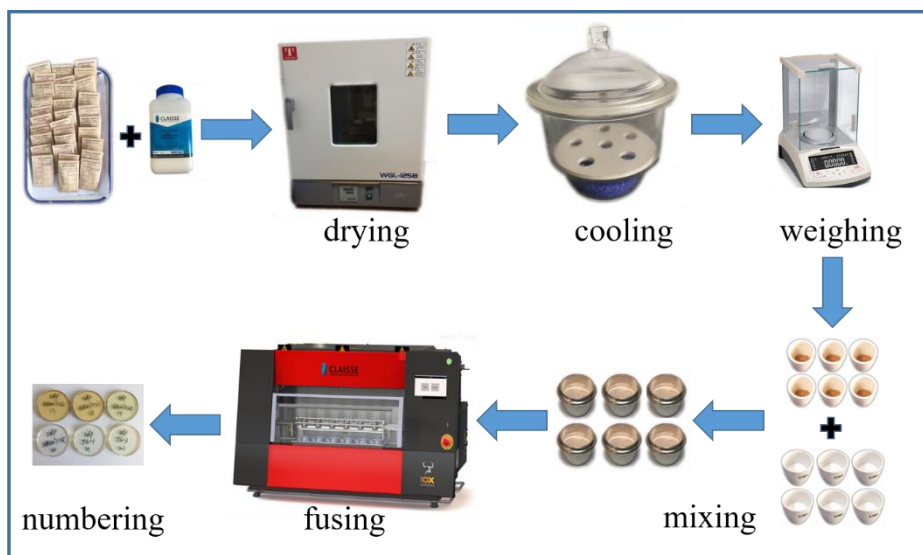


Figure S1. Fused glass disc preparation procedure

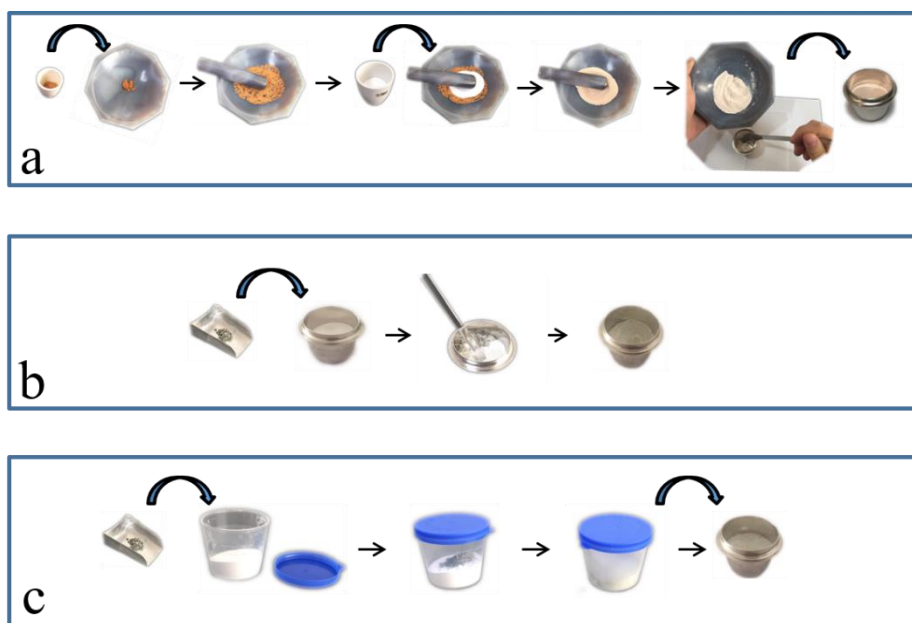


Figure S2. Procedures for mixing the samples and flux by (a) grinding, (b) stirring, and (c) shaking.

Table S2. Results of the major and minor element determination by X-ray fluorescence (XRF) analysis of the samples prepared by the three preparation procedures.

JG-2 (granite)									
Major	This work				Minor	This work			
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$		$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$
SiO ₂	76.98 ± 0.06	76.66 ± 0.09	77.02 ± 0.08	76.83 ± 0.57	Cr	5.0 ± 8.4	6.1 ± 2.4	7.0 ± 8.6	6.37 ± 2.09
TiO ₂	0.051 ± 0.002	0.047 ± 0.001	0.048 ± 0	0.044 ± 0.009	Cu	9.2 ± 12.1	16.9 ± 3.2	14.2 ± 2.7	0.49 ± 0.12
Al ₂ O ₃	12.44 ± 0.05	12.40 ± 0.03	12.40 ± 0.01	12.47 ± 0.32	Ba	70.0 ± 35.4	76.8 ± 26.2	55.2 ± 8.1	81.0 ± 23.5
TFe ₂ O ₃	0.98 ± 0.02	0.97 ± 0.01	0.99 ± 0.03	0.97 ± 0.06	Ni	5.0 ± 12.9	-0.3 ± 1.9	-2.1 ± 1.8	4.35 ± 3.07
MnO	0.020 ± 0	0.019 ± 0	0.018 ± 0	0.016 ± 0.003	Sr	-27.1 ± 0.1	-24.4 ± 1.7	-13.1 ± 1.9	17.9 ± 3.5
MgO	0.053 ± 0.006	0.050 ± 0	0.050 ± 0	0.037 ± 0.012	V	1.0 ± 3.7	5.7 ± 4.2	-4.3 ± 5.3	3.78 ± 1.58
CaO	0.69 ± 0.01	0.70 ± 0	0.70 ± 0	0.70 ± 0.05	Zr	104.0 ± 2.6	105.5 ± 1.6	90.9 ± 2.0	97.6 ± 10.8
Na ₂ O	3.57 ± 0.14	3.51 ± 0.01	3.55 ± 0.01	3.54 ± 0.11	Zn	7.6 ± 15.0	-0.7 ± 1.3	0.8 ± 1.9	13.6 ± 2.4
K ₂ O	4.69 ± 0.01	4.68 ± 0.01	4.72 ± 0.01	4.71 ± 0.09					
P ₂ O ₅	0.012 ± 0.001	0.008 ± 0	0.011 ± 0.001	0.002 ± 0					
LOI	0.41 ± 0.03	0.41 ± 0.03	0.41 ± 0.03	NRV					
Total	99.90	99.45	99.91	NC					

JG-1a (granodiorite)									
Major	This work				Minor	This work			
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$		$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$
SiO ₂	72.40 ± 0.13	72.34 ± 0.02	72.45 ± 0.10	72.30 ± 0.51	Cr	14.2 ± 2.4	14.1 ± 5.3	15.8 ± 4.6	17.6 ± 4.4
TiO ₂	0.240 ± 0.006	0.243 ± 0.002	0.244 ± 0.001	0.25 ± 0.03	Cu	3.8 ± 3.0	14.5 ± 3.2	12.8 ± 1.2	1.67 ± 0.59
Al ₂ O ₃	14.15 ± 0.05	14.08 ± 0.03	14.13 ± 0.02	14.30 ± 0.41	Ba	478.5 ± 15.8	469.8 ± 18.9	486.3 ± 19.1	470 ± 38
TFe ₂ O ₃	1.96 ± 0.01	1.95 ± 0.01	1.94 ± 0.01	2.00 ± 0.10	Ni	-0.9 ± 0.8	1.5 ± 1.4	8.8 ± 3.1	6.91 ± 1.90
MnO	0.060 ± 0	0.059 ± 0	0.058 ± 0	0.057 ± 0.007	Sr	183.0 ± 0.7	187.8 ± 0.5	195.4 ± 0.7	187 ± 12
MgO	0.69 ± 0.01	0.70 ± 0	0.70 ± 0.01	0.69 ± 0.07	V	21.7 ± 1.0	22.4 ± 5.7	26.2 ± 1.1	22.7 ± 3.8
CaO	2.15 ± 0.02	2.16 ± 0.01	2.16 ± 0.01	2.13 ± 0.08	Zr	115.6 ± 2.9	117.0 ± 1.8	117.7 ± 9.4	118 ± 13
Na ₂ O	3.37 ± 0.04	3.37 ± 0.01	3.41 ± 0	3.39 ± 0.13	Zn	29.1 ± 3.8	35.4 ± 1.2	33.5 ± 2.8	36.5 ± 2.2
K ₂ O	3.96 ± 0.01	3.97 ± 0	3.98 ± 0.01	3.96 ± 0.16					
P ₂ O ₅	0.083 ± 0.001	0.083 ± 0.001	0.084 ± 0.001	0.083 ± 0.009					
LOI	0.68 ± 0.05	0.68 ± 0.05	0.68 ± 0.05	NRV					

Total	99.75	99.63	99.83	NC						
JA-3 (andesite)										
Major	This work				Literature	Minor	This work			Literature
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$			$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	
SiO ₂	61.87 ± 0.26	62.04 ± 0.10	62.10 ± 0.05	62.27 ± 0.34	Cr	64.9 ± 8.0	65.1 ± 4.7	64.9 ± 1.2	66.2 ± 10.0	
TiO ₂	0.650 ± 0.013	0.668 ± 0.004	0.675 ± 0.001	0.70 ± 0.06	Cu	43.5 ± 11.7	44.7 ± 1.2	45.0 ± 0.2	43.4 ± 3.9	
Al ₂ O ₃	15.62 ± 0.08	15.65 ± 0.06	15.69 ± 0.02	15.56 ± 0.20	Ba	323.7 ± 21.8	306.9 ± 13.0	327.1 ± 20.8	323 ± 28	
TFe ₂ O ₃	6.50 ± 0.02	6.49 ± 0.01	6.49 ± 0.01	6.60 ± 0.18	Ni	42.0 ± 25.0	24.9 ± 1.4	27.7 ± 2.5	32.2 ± 6.6	
MnO	0.103 ± 0.006	0.103 ± 0	0.103 ± 0.001	0.104 ± 0.010	Sr	280.7 ± 4.5	294.0 ± 3.6	297.3 ± 2.5	287 ± 18	
MgO	3.66 ± 0.02	3.67 ± 0.01	3.69 ± 0.01	3.72 ± 0.09	V	158.3 ± 3.6	160.2 ± 4.2	168.2 ± 3.1	169 ± 16	
CaO	6.33 ± 0.01	6.34 ± 0.01	6.34 ± 0.02	6.24 ± 0.16	Zr	108.4 ± 0.8	106.8 ± 2.7	105.3 ± 0.8	118 ± 9.6	
Na ₂ O	3.16 ± 0.05	3.18 ± 0.01	3.19 ± 0.01	3.19 ± 0.10	Zn	69.2 ± 8.1	67.3 ± 2.4	70.6 ± 3.4	67.7 ± 5.2	
K ₂ O	1.37 ± 0.01	1.37 ± 0	1.38 ± 0	1.41 ± 0.06						
P ₂ O ₅	0.112 ± 0.001	0.116 ± 0.001	0.114 ± 0.001	0.116 ± 0.019						
LOI	0.18 ± 0.06	0.18 ± 0.06	0.18 ± 0.06	NRV						
Total	99.54	99.79	99.95	NC						
JB-2a (basalt)										
Major	This work				Literature	Minor	This work			Literature
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$			$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	
SiO ₂	53.28 ± 0.13	53.16 ± 0.02	53.30 ± 0.06	53.22	Cr	24.9 ± 3.5	30.0 ± 5.1	29.5 ± 5.7	28	
TiO ₂	1.106 ± 0.023	1.139 ± 0.006	1.149 ± 0.003	1.18	Cu	201.3 ± 2.2	207.7 ± 2.6	205.6 ± 3.3	269	
Al ₂ O ₃	14.67 ± 0.05	14.66 ± 0.02	14.72 ± 0.02	14.67	Ba	226.6 ± 24.4	217.4 ± 19.0	219.9 ± 16.1	219	
TFe ₂ O ₃	14.13 ± 0.03	14.08 ± 0.01	14.10 ± 0.03	14.18	Ni	11.2 ± 5.5	8.9 ± 3.5	14.1 ± 0.6	14.5	
MnO	0.217 ± 0.006	0.212 ± 0.001	0.211 ± 0.001	0.214	Sr	140.0 ± 2.9	150.0 ± 1.0	147.2 ± 1.8	179	
MgO	4.56 ± 0.01	4.54 ± 0.01	4.57 ± 0.02	4.58	V	558.3 ± 4.9	564.6 ± 6.0	579.9 ± 7.7	574	
CaO	9.75 ± 0.03	9.72 ± 0.02	9.75 ± 0.02	9.79	Zr	58.5 ± 0.7	54.2 ± 1.3	52.1 ± 0.7	61.8	
Na ₂ O	2.03 ± 0.02	2.03 ± 0.01	2.05 ± 0.01	2.03	Zn	96.8 ± 3.1	100.8 ± 1.4	105.6 ± 4.1	107	
K ₂ O	0.41 ± 0	0.41 ± 0	0.41 ± 0	0.41						
P ₂ O ₅	0.096 ± 0.001	0.097 ± 0.001	0.098 ± 0.001	0.095						
LOI	-0.56 ± 0.08	-0.56 ± 0.08	-0.56 ± 0.08	NAV						

Total	99.69	99.48	99.81	NC						
JB-3a (basalt)										
Major	This work				Literature	Minor	This work			Literature
	X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	X _{lit} ± SD _{lit}			X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	
SiO ₂	50.90 ± 0.06	50.88 ± 0.04	50.96 ± 0.17	50.87		Cr	52.8 ± 2.2	56.8 ± 4.4	54.8 ± 5.1	57
TiO ₂	1.346 ± 0.025	1.383 ± 0.002	1.401 ± 0.005	1.44		Cu	138.6 ± 4.4	151.6 ± 2.1	150.8 ± 1.2	195
Al ₂ O ₃	17.27 ± 0.07	17.29 ± 0.02	17.29 ± 0.02	17.16		Ba	243.1 ± 10.5	243.1 ± 15.7	244.2 ± 12.0	244
TFe ₂ O ₃	11.73 ± 0.01	11.66 ± 0.02	11.69 ± 0.01	11.83		Ni	29.3 ± 2.1	34.0 ± 4.0	34.1 ± 2.9	39
MnO	0.180 ± 0	0.174 ± 0	0.174 ± 0	0.179		Sr	389.1 ± 7.0	398.0 ± 4.6	405.8 ± 3.1	404
MgO	5.10 ± 0.03	5.10 ± 0.01	5.13 ± 0.01	5.17		V	364.0 ± 6.0	383.7 ± 2.8	385.6 ± 3.9	375
CaO	9.64 ± 0.02	9.63 ± 0.01	9.65 ± 0.03	9.75		Zr	95.7 ± 0.2	90.7 ± 0.2	95.4 ± 0.3	100
Na ₂ O	2.71 ± 0.02	2.74 ± 0.01	2.75 ± 0.01	2.74		Zn	98.4 ± 8.0	104.3 ± 2.1	105.7 ± 1.7	104
K ₂ O	0.75 ± 0	0.75 ± 0	0.75 ± 0	0.78						
P ₂ O ₅	0.282 ± 0.002	0.290 ± 0.002	0.283 ± 0.001	0.291						
LOI	-0.38 ± 0	-0.38 ± 0	-0.38 ± 0	NAV						
Total	99.53	99.52	99.70	NC						
JH-1 (hornblende)										
Major	This work				Literature	Minor	This work			Literature
	X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	X _{lit} ± SD _{lit}			X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	
SiO ₂	47.91 ± 0.12	47.81 ± 0.06	47.91 ± 0.08	48.18 ± 0.695		Cr	596.8 ± 16.2	593.9 ± 7.9	599.5 ± 2.0	616 ± 54.4
TiO ₂	0.648 ± 0.013	0.658 ± 0.005	0.662 ± 0.003	0.665 ± 0.017		Cu	3.7 ± 10.1	10.6 ± 3.8	8.8 ± 1.1	8.61 ± 1.33
Al ₂ O ₃	5.68 ± 0.05	5.67 ± 0.01	5.68 ± 0.01	5.657 ± 0.248		Ba	130.9 ± 15.3	108.6 ± 13.7	132.4 ± 7.7	106 ± 14.2
TFe ₂ O ₃	10.17 ± 0.05	10.09 ± 0.01	10.12 ± 0.01	10.27 ± 0.164		Ni	64.4 ± 43.4	51.3 ± 2.4	52.5 ± 1.5	58.2 ± 8.19
MnO	0.180 ± 0	0.177 ± 0	0.177 ± 0	0.190 ± 0.0084		Sr	122.0 ± 3.9	130.4 ± 0.5	124.6 ± 1.2	153 ± 5.48
MgO	16.50 ± 0.08	16.49 ± 0.01	16.59 ± 0.03	16.73 ± 0.593		V	220.3 ± 4.4	224.7 ± 4.5	236.8 ± 5.9	228 ± 7.86
CaO	14.63 ± 0.03	14.54 ± 0.01	14.57 ± 0.04	15.02 ± 0.20		Zr	52.9 ± 1.5	50.6 ± 1.2	41.8 ± 0.4	48.3 ± 5.30
Na ₂ O	0.70 ± 0.02	0.69 ± 0	0.70 ± 0.01	0.707 ± 0.027		Zn	57.8 ± 16.5	51.0 ± 3.4	57.0 ± 1.8	61.8 ± 6.0
K ₂ O	0.52 ± 0	0.53 ± 0	0.53 ± 0	0.526 ± 0.021						
P ₂ O ₅	0.100 ± 0.001	0.100 ± 0.001	0.100 ± 0	0.0991 ± 0.0102						
LOI	2.13 ± 0.10	2.13 ± 0.10	2.13 ± 0.10	1.780 ± 0.324						

Total	99.17	98.90	99.16	99.82					
JGb-2 (gabbro)									
Major	This work				Minor	Literature			
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$		$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$
SiO ₂	46.28 ± 0.13	46.11 ± 0.13	46.19 ± 0.07	46.47 ± 0.365	Cr	117.8 ± 6.2	119.7 ± 3.4	116.1 ± 2.4	125 ± 4.91
TiO ₂	0.546 ± 0.011	0.552 ± 0.003	0.559 ± 0.001	0.561 ± 0.016	Cu	2.5 ± 1.5	14.4 ± 2.3	14.2 ± 0.8	11.4 ± 1.79
Al ₂ O ₃	23.51 ± 0.09	23.45 ± 0.03	23.49 ± 0.02	23.48 ± 0.272	Ba	27.5 ± 7.9	37.4 ± 11.7	11.5 ± 18.4	36.5 ± 7.75
TFe ₂ O ₃	6.68 ± 0.02	6.62 ± 0.01	6.64 ± 0.01	6.691 ± 0.137	Ni	28.7 ± 43.2	11.2 ± 1.4	8.6 ± 3.5	13.6 ± 1.90
MnO	0.130 ± 0	0.123 ± 0.001	0.123 ± 0	0.126 ± 0.010	Sr	450.7 ± 1.4	458.9 ± 2.3	462.7 ± 1.1	438 ± 12.3
MgO	6.05 ± 0.03	6.06 ± 0.03	6.11 ± 0.02	6.183 ± 0.119	V	165.6 ± 6.9	169.6 ± 1.3	175.4 ± 5.4	174 ± 5.28
CaO	13.73 ± 0.04	13.66 ± 0.03	13.7 ± 0.02	14.10 ± 0.113	Zr	12.8 ± 1.5	11.2 ± 0.9	35.9 ± 0.6	11.6 ± 4.93
Na ₂ O	0.94 ± 0.04	0.92 ± 0	0.95 ± 0.01	0.921 ± 0.027	Zn	34.6 ± 0.6	40.7 ± 2.9	42.0 ± 1.8	48.5 ± 5.47
K ₂ O	0.060 ± 0	0.056 ± 0	0.062 ± 0	0.059 ± 0.0073					
P ₂ O ₅	0.015 ± 0.001	0.012 ± 0	0.016 ± 0.001	0.017 ± 0.0080					
LOI	1.36 ± 0.03	1.36 ± 0.03	1.36 ± 0.03	1.357 ± 0.154					
Total	99.31	98.94	99.20	99.97					
JR-2 (rhyolite)									
Major	This work				Minor	Literature			
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$		$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$
SiO ₂	75.28 ± 0.15	75.32 ± 0.18	75.56 ± 0.11	75.69 ± 0.37	Cr	2.5 ± 3.2	6.9 ± 3.4	2.7 ± 3.5	3.10 ± 1.18
TiO ₂	0.066 ± 0.003	0.063 ± 0.003	0.063 ± 0.001	0.07 ± 0.01	Cu	5.5 ± 2.0	17.2 ± 1.2	15.2 ± 1.5	1.36 ± 0.47
Al ₂ O ₃	12.54 ± 0.01	12.52 ± 0.04	12.61 ± 0.01	12.72 ± 0.28	Ba	12.8 ± 11.6	39.2 ± 17.7	19.7 ± 18.3	39.5 ± 17.2
TFe ₂ O ₃	0.77 ± 0.01	0.69 ± 0.01	0.71 ± 0	0.77 ± 0.06	Ni	-3.5 ± 2.8	-0.3 ± 4.6	-0.5 ± 1.5	1.99 ± 1.59
MnO	0.11 ± 0	0.107 ± 0	0.107 ± 0.001	0.112 ± 0.007	Sr	-37.8 ± 0.7	-35.7 ± 1.0	-24.0 ± 2.2	8.11 ± 2.31
MgO	0.06 ± 0.01	0.05 ± 0	0.05 ± 0.01	0.04 ± 0.01	V	3.3 ± 5.5	2.3 ± 6.1	6.4 ± 6.9	3.00 ± 1.76
CaO	0.52 ± 0.01	0.53 ± 0.01	0.52 ± 0.01	0.50 ± 0.06	Zr	92.8 ± 0.9	93.0 ± 0.5	80.4 ± 0.5	96.3 ± 6.4
Na ₂ O	3.94 ± 0.02	3.98 ± 0.01	4 ± 0.01	3.99 ± 0.18	Zn	14.4 ± 4.6	20.9 ± 1.7	22.0 ± 1.8	27.8 ± 2.7
K ₂ O	4.44 ± 0.01	4.45 ± 0.01	4.46 ± 0	4.45 ± 0.12					
P ₂ O ₅	0.012 ± 0	0.008 ± 0.001	0.012 ± 0.001	0.012 ± 0.005					
LOI	1.95 ± 0.03	1.95 ± 0.03	1.95 ± 0.03	NRV					

Total	99.69	99.66	100.05	NC						
GSP-2 (granodiorite)										
Major	This work				Literature	Minor	This work			Literature
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$			$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	
SiO ₂	66.41 ± 0.10	66.40 ± 0.18	66.82 ± 0.12	66.60 ± 0.8	Cr	11.4 ± 2.3	20.5 ± 3.7	15.4 ± 4.1	20 ± 6	
TiO ₂	0.640 ± 0.013	0.661 ± 0.002	0.665 ± 0.002	0.66 ± 0.02	Cu	43.3 ± 6.5	49.7 ± 0.6	52.1 ± 5.5	43 ± 4	
Al ₂ O ₃	14.76 ± 0.04	14.76 ± 0.05	14.9 ± 0.04	14.90 ± 0.2	Ba	1331.3 ± 12.2	1331.0 ± 26.2	1324.7 ± 23.0	1340 ± 44	
TFe ₂ O ₃	4.87 ± 0.02	4.87 ± 0.01	4.88 ± 0.01	4.90 ± 0.16	Ni	10.8 ± 1.7	13.0 ± 1.6	15.0 ± 2.1	17 ± 2	
MnO	0.040 ± 0	0.041 ± 0	0.042 ± 0	0.041 ± 0.003	Sr	236.8 ± 2.2	247.5 ± 2.8	251.7 ± 4.5	240 ± 10	
MgO	0.95 ± 0.01	0.96 ± 0.01	0.97 ± 0.01	0.96 ± 0.03	V	45.8 ± 4.4	47.2 ± 3.4	43.2 ± 6.0	52 ± 4	
CaO	2.08 ± 0.02	2.10 ± 0.01	2.10 ± 0.01	2.10 ± 0.06	Zr	529.1 ± 7.4	538.1 ± 9.7	493.7 ± 8.9	550 ± 30	
Na ₂ O	2.77 ± 0.01	2.79 ± 0	2.81 ± 0.01	2.78 ± 0.09	Zn	124.1 ± 4.1	135.7 ± 0.5	137.6 ± 1.4	120 ± 10	
K ₂ O	5.36 ± 0.01	5.38 ± 0.02	5.40 ± 0	5.38 ± 0.14						
P ₂ O ₅	0.281 ± 0.003	0.289 ± 0.002	0.285 ± 0.001	0.29 ± 0.02						
LOI	1.12 ± 0.52	1.12 ± 0.52	1.12 ± 0.52	NRV						
Total	99.27	99.36	99.99	NC						
BCR-2 (basalt)										
Major	This work				Literature	Minor	This work			Literature
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$			$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	
SiO ₂	54.16 ± 0.02	54.19 ± 0.12	54.17 ± 0.09	54.10 ± 0.8	Cr	14.7 ± 0.7	17.8 ± 7.9	18.0 ± 1.2	18 ± 2	
TiO ₂	2.338 ± 0.005	2.310 ± 0.005	2.293 ± 0.006	2.26 ± 0.05	Cu	5.2 ± 1.0	16.4 ± 1.2	13.8 ± 2.3	19 ± 2	
Al ₂ O ₃	13.37 ± 0.03	13.4 ± 0.03	13.39 ± 0.02	13.50 ± 0.2	Ba	661.6 ± 22.8	679.7 ± 22.5	679.1 ± 20.3	683 ± 28	
TFe ₂ O ₃	13.82 ± 0.02	13.78 ± 0.03	13.76 ± 0.02	13.80 ± 0.2	Ni	12.1 ± 2.5	11.2 ± 0.7	12.7 ± 1.1	12.57	
MnO	0.200 ± 0	0.194 ± 0	0.193 ± 0	0.196 ± 0.008	Sr	310.2 ± 5.6	319.1 ± 4.1	320.2 ± 1.4	346 ± 14	
MgO	3.55 ± 0.02	3.54 ± 0.01	3.56 ± 0.01	3.59 ± 0.05	V	419.6 ± 2.6	404.3 ± 5.8	409.5 ± 5.4	416 ± 14	
CaO	7.14 ± 0	7.13 ± 0.02	7.12 ± 0.01	7.12 ± 0.11	Zr	171.0 ± 2.6	165.1 ± 0.3	155.3 ± 0.9	188 ± 16	
Na ₂ O	3.16 ± 0.04	3.17 ± 0.02	3.17 ± 0.01	3.16 ± 0.11	Zn	121.9 ± 6.3	134.7 ± 3.0	134.2 ± 2.7	127 ± 9	
K ₂ O	1.75 ± 0	1.75 ± 0	1.75 ± 0	1.79 ± 0.05						
P ₂ O ₅	0.348 ± 0.001	0.359 ± 0.001	0.348 ± 0.002	0.35 ± 0.02						
LOI	-0.06 ± 0.03	-0.06 ± 0.03	-0.06 ± 0.03	NRV						

Total	99.79	99.75	99.68	NC						
BHVO-2 (basalt)										
Major	This work				Literature	Minor	This work			Literature
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$			$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	
SiO ₂	49.70 ± 0.15	49.75 ± 0.07	49.91 ± 0.11	49.90 ± 0.6	Cr	266.6 ± 5.6	275.2 ± 2.4	277.9 ± 2.7	280 ± 19	
TiO ₂	2.827 ± 0.005	2.785 ± 0.004	2.780 ± 0.007	2.73 ± 0.04	Cu	91.1 ± 3.2	100.9 ± 2.7	98.5 ± 4.1	127 ± 7	
Al ₂ O ₃	13.46 ± 0.02	13.46 ± 0.03	13.52 ± 0.01	13.50 ± 0.2	Ba	132.0 ± 23.2	103.6 ± 1.8	101.9 ± 11.6	130 ± 13	
TFe ₂ O ₃	12.37 ± 0.03	12.34 ± 0.01	12.37 ± 0.02	12.30 ± 0.2	Ni	110.6 ± 1.4	113.8 ± 2.3	114.2 ± 3.2	119 ± 7	
MnO	0.170 ± 0	0.166 ± 0.001	0.165 ± 0	0.167 ± 0.005	Sr	359.4 ± 5.0	373.9 ± 5.6	377.0 ± 2.4	389 ± 23	
MgO	7.13 ± 0.01	7.15 ± 0.02	7.15 ± 0	7.23 ± 0.12	V	337.2 ± 2.3	307.2 ± 5.2	303.9 ± 4.5	317 ± 11	
CaO	11.35 ± 0.03	11.35 ± 0.03	11.37 ± 0.03	11.40 ± 0.2	Zr	158.6 ± 0.6	153.6 ± 1.0	133.3 ± 0.6	172 ± 11	
Na ₂ O	2.22 ± 0.02	2.22 ± 0.01	2.23 ± 0.01	2.22 ± 0.08	Zn	86.5 ± 2.2	97.0 ± 1.5	99.8 ± 1.6	103 ± 6	
K ₂ O	0.51 ± 0	0.50 ± 0	0.51 ± 0	0.52 ± 0.01						
P ₂ O ₅	0.262 ± 0.001	0.270 ± 0.002	0.262 ± 0.002	0.27 ± 0.02						
LOI	-0.55 ± 0.03	-0.55 ± 0.03	-0.55 ± 0.03	NRV						
Total	99.45	99.42	99.72	NC						
W-2a (diabase)										
Major	This work				Literature	Minor	This work			Literature
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$			$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	
SiO ₂	52.30 ± 0.05	52.28 ± 0.06	52.33 ± 0.08	52.44 ± 0.64	Cr	87.8 ± 10.2	89.1 ± 2.9	92.8 ± 2.4	93 ± 6	
TiO ₂	1.026 ± 0.018	1.049 ± 0.001	1.056 ± 0.002	1.06 ± 0.03	Cu	78.0 ± 4.4	87.5 ± 2.1	88.1 ± 0.9	103 ± 12	
Al ₂ O ₃	15.21 ± 0.02	15.2 ± 0.01	15.32 ± 0.04	15.35 ± 0.23	Ba	182.8 ± 14.8	174.9 ± 12.6	170.8 ± 8.6	182 ± 23	
TFe ₂ O ₃	10.79 ± 0.04	10.74 ± 0.03	10.73 ± 0.01	10.74 ± 0.23	Ni	64.5 ± 7.4	67.1 ± 3.1	66.6 ± 3.2	70 ± 8	
MnO	0.170 ± 0	0.164 ± 0.001	0.163 ± 0.001	0.163 ± 0.009	Sr	163.9 ± 1.4	172.2 ± 2.9	170.3 ± 2.9	194 ± 17	
MgO	6.28 ± 0.01	6.27 ± 0.01	6.29 ± 0.01	6.37 ± 0.18	V	251.7 ± 6.3	258.2 ± 2.6	264.9 ± 1.6	262 ± 14	
CaO	10.81 ± 0.02	10.78 ± 0.01	10.78 ± 0.02	10.87 ± 0.29	Zr	95.3 ± 1.7	91.1 ± 0.6	77.8 ± 0.3	94 ± 9	
Na ₂ O	2.22 ± 0.01	2.22 ± 0	2.23 ± 0.01	2.14 ± 0.12	Zn	65.1 ± 7.5	72.7 ± 3.3	72.6 ± 1.6	77 ± 5	
K ₂ O	0.620 ± 0	0.613 ± 0	0.618 ± 0	0.627 ± 0.025						
P ₂ O ₅	0.123 ± 0.001	0.127 ± 0.001	0.124 ± 0.001	0.131 ± 0.016						
LOI	-0.01 ± 0.08	-0.01 ± 0.08	-0.01 ± 0.08	NRV						

Total	99.52	99.43	99.62	NC						
RGM-2 (rhyolite)										
Major	This work				Literature	Minor	This work			Literature
	X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	X _{lit} ± SD _{lit}			X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	
SiO ₂	73.32 ± 0.17	73.17 ± 0.04	73.40 ± 0.03	73.40 ± 0.41		Cr	10.8 ± 16.8	5.2 ± 5.2	5.7 ± 2.4	4
TiO ₂	0.266 ± 0.005	0.272 ± 0.003	0.273 ± 0.001	0.25 ± 0.023		Cu	10.5 ± 2.4	26.1 ± 2.1	25.9 ± 3.3	9.8 ± 0.8
Al ₂ O ₃	13.64 ± 0.06	13.61 ± 0.02	13.67 ± 0.02	14.00 ± 0.3		Ba	837.0 ± 4.3	853.2 ± 20.8	801.9 ± 24.8	842 ± 35
TFe ₂ O ₃	1.84 ± 0.01	1.84 ± 0.01	1.84 ± 0.01	1.86 ± 0.04		Ni	15.5 ± 37.8	1.2 ± 2.2	1.4 ± 2.8	4
MnO	0.030 ± 0	0.035 ± 0.001	0.035 ± 0.001	0.035 ± 0.001		Sr	87.6 ± 0.6	91.6 ± 0.8	99.3 ± 0.5	108 ± 5
MgO	0.29 ± 0.01	0.28 ± 0.01	0.29 ± 0.01	0.28 ± 0.02		V	13.1 ± 4.0	17.7 ± 11.0	15.9 ± 3.5	NRV
CaO	1.22 ± 0.01	1.23 ± 0.01	1.23 ± 0.01	1.23 ± 0.03		Zr	217.0 ± 1.7	215.8 ± 0.8	200.0 ± 0.8	222 ± 17
Na ₂ O	4.10 ± 0.03	4.11 ± 0.01	4.13 ± 0	4.14 ± 0.12		Zn	19.5 ± 2.5	30.0 ± 3.8	29.0 ± 2.8	33 ± 2
K ₂ O	4.31 ± 0.01	4.30 ± 0	4.32 ± 0.01	4.35 ± 0.16						
P ₂ O ₅	0.049 ± 0.001	0.049 ± 0.001	0.050 ± 0	0.05 ± 0.014						
LOI	0.69 ± 0.04	0.69 ± 0.04	0.69 ± 0.04	NRV						
Total	99.74	99.59	99.92	NC						
AC-E (granite)										
Major	This work				Literature	Minor	This work			Literature
	X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	X _{lit} ± SD _{lit}			X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	
SiO ₂	70.63 ± 0.07	70.61 ± 0.14	70.49 ± 0.14	70.35 ± 0.42		Cr	-4.9 ± 0.7	2.8 ± 1.8	5.7 ± 6.4	3.4 ± 4.1
TiO ₂	0.108 ± 0.002	0.105 ± 0.002	0.106 ± 0	0.11 ± 0.11		Cu	8.8 ± 7.2	15.7 ± 2.4	14.1 ± 2.9	4 ± 3.2
Al ₂ O ₃	14.69 ± 0.05	14.65 ± 0.01	14.68 ± 0.04	14.70 ± 0.29		Ba	71.5 ± 15.4	50.1 ± 18.9	55.8 ± 7.7	55 ± 20
TFe ₂ O ₃	2.49 ± 0.01	2.46 ± 0.01	2.48 ± 0.03	2.53 ± 0.13		Ni	-1.9 ± 6.2	-4.0 ± 3.2	-2.6 ± 3.5	1.5 ± 4.4
MnO	0.060 ± 0	0.058 ± 0.001	0.057 ± 0.001	0.058 ± 0.010		Sr	-43.6 ± 0.3	-42.3 ± 1.4	-33.6 ± 1.4	3 ± 3
MgO	0.03 ± 0.01	0.03 ± 0	0.03 ± 0	0.03 ± 0.04		V	2.7 ± 5.0	-2.5 ± 2.6	-3.3 ± 7.7	3 ± 2.4
CaO	0.35 ± 0.01	0.36 ± 0.01	0.35 ± 0	0.34 ± 0.09		Zr	789.5 ± 8.6	792.8 ± 4.5	728.1 ± 7.8	780 ± 81
Na ₂ O	6.50 ± 0.08	6.58 ± 0.02	6.59 ± 0.02	6.54 ± 0.23		Zn	296.9 ± 10.1	313.4 ± 2.5	311.2 ± 1.6	224 ± 26
K ₂ O	4.44 ± 0.01	4.46 ± 0.01	4.46 ± 0.01	4.49 ± 0.13						
P ₂ O ₅	0.015 ± 0.001	0.013 ± 0.001	0.016 ± 0	0.014 ± 0.020						
LOI	0.27 ± 0.09	0.27 ± 0.09	0.27 ± 0.09	0.37 ± 0.12						

Total	99.57	99.59	99.53	99.53					
GH (granite)									
Major	This work				Minor	This work			Literature
	X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	X _{lit} ± SD _{lit}		X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	
SiO ₂	75.73 ± 0.14	75.69 ± 0.08	75.68 ± 0.05	75.80 ± 0.61	Cr	0.8 ± 3.3	3.9 ± 2.8	-0.8 ± 5.2	3 ± 7.4
TiO ₂	0.080 ± 0	0.077 ± 0.001	0.077 ± 0.003	0.08 ± 0.04	Cu	6.9 ± 3.7	15.7 ± 1.6	17.1 ± 2.3	3 ± 7.2
Al ₂ O ₃	12.48 ± 0.06	12.50 ± 0.03	12.51 ± 0.01	12.50 ± 0.35	Ba	11.3 ± 9.4	27.4 ± 8.0	22.7 ± 15.8	20 ± 32.9
TFe ₂ O ₃	1.32 ± 0.01	1.3 ± 0	1.31 ± 0	1.34 ± 0.23	Ni	-1.0 ± 1.8	-2.5 ± 2.7	1.1 ± 1.4	3 ± 4.8
MnO	0.050 ± 0	0.046 ± 0.001	0.046 ± 0.001	0.05 ± 0.01	Sr	-37.8 ± 0.6	-34.3 ± 2.3	-22.4 ± 2.1	10
MgO	0.04 ± 0.01	0.03 ± 0.01	0.04 ± 0	0.03 ± 0.1	V	0.2 ± 7.1	-0.5 ± 3.4	3.3 ± 8.5	5 ± 7.8
CaO	0.72 ± 0.01	0.73 ± 0	0.73 ± 0	0.69 ± 0.13	Zr	151.7 ± 0.7	151.4 ± 0.6	127.0 ± 2.3	150 ± 65.7
Na ₂ O	3.78 ± 0.05	3.80 ± 0	3.82 ± 0.01	3.85 ± 0.22	Zn	52.3 ± 3.5	59.4 ± 3.4	60.4 ± 4.3	55 ± 17.4
K ₂ O	4.72 ± 0	4.74 ± 0.01	4.73 ± 0.01	4.76 ± 0.15					
P ₂ O ₅	0.010 ± 0.002	0.007 ± 0.001	0.011 ± 0.001	0.01 ± 0.01					
LOI	0.77 ± 0.05	0.77 ± 0.05	0.77 ± 0.05	0.70					
Total	99.71	99.69	99.72	99.81					
PM-S (microgabbro)									
Major	This work				Minor	This work			Literature
	X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	X _{lit} ± SD _{lit}		X _{GR} ± SD _{GR}	X _{ST} ± SD _{ST}	X _{SH} ± SD _{SH}	
SiO ₂	47.00 ± 0.05	46.90 ± 0.02	46.78 ± 0.22	47.00 ± 0.65	Cr	292.8 ± 4.4	292.9 ± 4.1	299.7 ± 3.7	314 ± 26.9
TiO ₂	1.065 ± 0.025	1.094 ± 0.003	1.096 ± 0.005	1.10 ± 0.05	Cu	43.3 ± 3.5	49.9 ± 4.8	51.0 ± 1.9	59 ± 7.33
Al ₂ O ₃	17.06 ± 0.03	17.06 ± 0.02	16.97 ± 0.07	17.15 ± 0.48	Ba	151.8 ± 0.6	155.8 ± 16.6	147.9 ± 6.2	148 ± 14.95
TFe ₂ O ₃	10.02 ± 0.01	10.00 ± 0.01	9.95 ± 0.05	10.1 ± 0.28	Ni	110.1 ± 5.7	116.5 ± 2.0	112.9 ± 1.6	115 ± 11.83
MnO	0.160 ± 0	0.154 ± 0.001	0.152 ± 0.001	0.16 ± 0.01	Sr	252.5 ± 0.7	261.3 ± 1.7	257.3 ± 2.1	280 ± 23.15
MgO	9.22 ± 0.03	9.27 ± 0.01	9.27 ± 0.05	9.34 ± 0.39	V	176.4 ± 4.5	181.5 ± 3.8	183.1 ± 1.1	192 ± 22.49
CaO	12.22 ± 0.02	12.17 ± 0.01	12.12 ± 0.06	12.48 ± 0.26	Zr	43.1 ± 0.5	40.0 ± 2.0	46.1 ± 0.7	39 ± 7.2
Na ₂ O	2.03 ± 0.02	2.03 ± 0	2.03 ± 0.02	2.08 ± 0.11	Zn	47.0 ± 7.6	49.4 ± 2.2	51.1 ± 2.0	60 ± 6.74
K ₂ O	0.14 ± 0	0.13 ± 0	0.14 ± 0	0.14 ± 0.02					
P ₂ O ₅	0.032 ± 0.001	0.029 ± 0.001	0.032 ± 0.001	0.03 ± 0.05					
LOI	0.38 ± 0.12	0.38 ± 0.12	0.38 ± 0.12	0.3					

Total	99.33	99.22	98.91	99.88						
WS-E (dolerite)										
Major	This work				Literature	Minor	This work			Literature
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$			$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	
SiO ₂	51.13 ± 0.03	50.93 ± 0.01	51.15 ± 0.22	50.70 ± 0.58	Cr	82.6 ± 3.4	95.6 ± 4.0	96.3 ± 1.7	99 ± 9.9	
TiO ₂	2.506 ± 0.003	2.474 ± 0.006	2.453 ± 0.011	2.40 ± 0.08	Cu	41.8 ± 4.3	50.8 ± 2.3	51.8 ± 2.9	65 ± 10.84	
Al ₂ O ₃	13.73 ± 0.04	13.64 ± 0.01	13.69 ± 0.07	13.78 ± 0.28	Ba	324.1 ± 27.4	316.3 ± 10.0	333.9 ± 11.2	338 ± 27.52	
TFe ₂ O ₃	13.23 ± 0.02	13.2 ± 0.02	13.2 ± 0.07	13.15 ± 0.37	Ni	50.4 ± 1.5	50.2 ± 3.4	57.2 ± 8.3	55 ± 7.51	
MnO	0.170 ± 0	0.168 ± 0.001	0.167 ± 0.001	0.17 ± 0.01	Sr	384.6 ± 1.6	395.4 ± 1.5	396.4 ± 3.8	410 ± 25.62	
MgO	5.51 ± 0.02	5.48 ± 0.02	5.50 ± 0.03	5.55 ± 0.21	V	345.7 ± 4.7	326.3 ± 7.5	327.6 ± 6.4	340 ± 31.83	
CaO	9.00 ± 0	8.96 ± 0.01	8.96 ± 0.04	8.95 ± 0.25	Zr	189.3 ± 1.2	184.8 ± 1.1	166.8 ± 0.5	195 ± 10.92	
Na ₂ O	2.48 ± 0.04	2.45 ± 0.01	2.47 ± 0.01	2.47 ± 0.14	Zn	101.8 ± 1.1	113.5 ± 1.7	114.1 ± 2.0	117 ± 0.22	
K ₂ O	0.99 ± 0	0.97 ± 0	0.98 ± 0	1.00 ± 0.06						
P ₂ O ₅	0.296 ± 0.002	0.303 ± 0.002	0.298 ± 0.003	0.30 ± 0.04						
LOI	0.88 ± 0.05	0.88 ± 0.05	0.88 ± 0.05	0.85						
Total	99.92	99.46	99.75	99.32						
AN-G (anorthosite)										
Major	This work				Literature	Minor	This work			Literature
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$			$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	
SiO ₂	46.11 ± 0.07	46.04 ± 0.08	46.68 ± 0.11	46.30 ± 0.69	Cr	45.3 ± 5.7	40.0 ± 1.1	48.9 ± 5.1	50 ± 10.4	
TiO ₂	0.219 ± 0.004	0.217 ± 0.003	0.219 ± 0.002	0.22 ± 0.04	Cu	11.8 ± 2.4	23.9 ± 2.4	23.8 ± 2.7	19 ± 4.58	
Al ₂ O ₃	29.89 ± 0.05	29.88 ± 0.05	29.68 ± 0.10	29.80 ± 0.94	Ba	15.4 ± 9.0	17.2 ± 7.8	32.5 ± 19.3	34 ± 11	
TFe ₂ O ₃	3.23 ± 0.01	3.22 ± 0	3.22 ± 0.01	3.36 ± 0.20	Ni	17.0 ± 1.2	25.6 ± 1.4	27.2 ± 1.4	35 ± 9.75	
MnO	0.040 ± 0	0.044 ± 0.001	0.043 ± 0	0.04 ± 0.01	Sr	45.6 ± 0.3	49.2 ± 1.2	49.2 ± 2.2	76 ± 14.84	
MgO	1.68 ± 0.01	1.77 ± 0.01	1.77 ± 0.01	1.80 ± 0.18	V	65.0 ± 2.6	70.6 ± 5.7	65.3 ± 4.7	70 ± 13.64	
CaO	15.55 ± 0.02	15.51 ± 0.02	15.40 ± 0.03	15.90 ± 0.50	Zr	23.2 ± 0.9	20.2 ± 1.3	19.2 ± 0.4	11 ± 7.68	
Na ₂ O	1.65 ± 0.03	1.64 ± 0	1.65 ± 0.01	1.63 ± 0.17	Zn	6.3 ± 5.8	5.9 ± 1.7	6.1 ± 2.5	20 ± 11.58	
K ₂ O	0.14 ± 0	0.13 ± 0	0.14 ± 0	0.13 ± 0.04						
P ₂ O ₅	0.016 ± 0	0.014 ± 0.001	0.018 ± 0	0.01 ± 0.06						
LOI	0.63 ± 0.02	0.63 ± 0.02	0.63 ± 0.02	0.65 ± 0.66						

Total	99.15	99.09	99.44	99.84						
MGL-OShBO (granite)										
Major	This work				Literature	Minor	This work			Literature
	$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	$X_{lit} \pm SD_{lit}$			$X_{GR} \pm SD_{GR}$	$X_{ST} \pm SD_{ST}$	$X_{SH} \pm SD_{SH}$	
SiO ₂	71.98 ± 0.24	71.59 ± 0.12	71.82 ± 0.08	71.72 ± 0.572	Cr	179.1 ± 2.3	190.6 ± 6.8	188.1 ± 6.0	164 ± 38.1	
TiO ₂	0.014 ± 0.001	0.010 ± 0.001	0.010 ± 0.001	NRV	Cu	<i>13.5 ± 2.2</i>	<i>21.9 ± 3.7</i>	<i>21.9 ± 1.0</i>	7.1 ± 1.17	
Al ₂ O ₃	15.96 ± 0.07	15.97 ± 0.04	16.02 ± 0.03	16.12 ± 0.362	Ba	<i>6.6 ± 27.7</i>	<i>23.1 ± 10.9</i>	<i>1.2 ± 16.9</i>	12.3 ± 0.79	
TFe ₂ O ₃	0.51 ± 0	0.39 ± 0.01	0.41 ± 0.01	0.500 ± 0.032	Ni	10.4 ± 4.1	13.2 ± 1.7	14.4 ± 1.2	10.7 ± 2.91	
MnO	0.160 ± 0	0.155 ± 0	0.155 ± 0.001	0.149 ± 0.014	Sr	<i>-32.3 ± 1.0</i>	<i>-32.0 ± 0.8</i>	<i>-17.1 ± 3.1</i>	12.3 ± 2.02	
MgO	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0	NRV	V	<i>2.7 ± 3.0</i>	<i>2.5 ± 1.6</i>	<i>3.1 ± 4.3</i>	NRV	
CaO	0.39 ± 0.01	0.39 ± 0	0.39 ± 0	0.388 ± 0.019	Zr	31.8 ± 1.1	32.2 ± 0.8	23.2 ± 0.5	40.1 ± 3.41	
Na ₂ O	5.43 ± 0.05	5.44 ± 0.01	5.46 ± 0.03	5.34 ± 0.189	Zn	110.0 ± 2.9	120.3 ± 3.8	125.1 ± 1.7	92.4 ± 7.59	
K ₂ O	3.56 ± 0	3.55 ± 0.01	3.57 ± 0.01	3.58 ± 0.105						
P ₂ O ₅	0.024 ± 0.001	0.024 ± 0	0.025 ± 0.001	0.029 ± 0.002						
LOI	1.09 ± 0.04	1.09 ± 0.04	1.09 ± 0.04	1.10 ± 0.066						
Total	99.13	98.63	98.98	NC						

The symbols used in the table are explained as follows: X_{GR} is the mean measured value ($n = 3$) and SD_{GR} is the corresponding standard deviation value for the grinding (GR) method; X_{ST} is the mean measured value ($n = 3$) and SD_{ST} is the corresponding standard deviation value for the stirring rod (ST) method; X_{SH} is the mean measured value ($n = 3$) and SD_{SH} is the corresponding standard deviation value for the shaker cup (SH) method; X_{lit} is the recommended value and SD_{lit} is the corresponding recommended standard deviation value by literature; NRV = no recommended value; NC = no calculation. The ST and SH methods adopt the LOI values of the GR method. Some erroneous data are marked in italics and red.

Table S3. Source of recommend values of 19 CRMs.

Certificated reference materials	Source of recommend values
JG-2, JG-1a, JA-3, JR-2	Shigeru et al. [1] Noboru IMAI et al. [2]
JB-2a	Certified Geochemical Reference Material GSJ CRM JB-2a Basalt (Oshima volcano) Geochemical Reference Material Technical Information
JB-3a	Certified Geochemical Reference Material GSJ CRM JB-3a Basalt (Fuji volcano) Geochemical Reference Material Technical Information
JH-1, JGb-2	Imai et al. [3]
GSP-2	Wilson S.A. [4]
BCR-2	Wilson S.A. [5]
BHVO-2	Wilson S.A. [6]
W-2a	Gladney et al. [7]
RGM-2	United States Geological Survey Certificate of Analysis
AC-E, GH, PM-S, WS-E, AN-G	K. Govindaraju [8]
MGL-OShBO	Jean et al. [9]

Table S4. The values of J_{Si} by grinding method.

Samples	J_{Si} (GR)																	
	Major oxides									Minor elements								
	SiO ₂	TiO ₂	Al ₂ O ₃	TFe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Cr	Cu	Ba	Ni	Sr	V	Zr	Zn
JG-2	0.07	0.58	0.01	0.03	1.78	1.42	0.04	0.03	0.05	NC	NC	NC	0.07	NC	NC	NC	0.33	NC
JG-1a	0.04	0.11	0.13	0.16	0.18	0.00	0.06	0.02	0.00	0.00	0.46	NC	0.04	NC	0.11	0.06	0.03	2.84
JA-3	0.87	0.66	0.08	0.30	0.01	0.42	0.32	0.07	0.43	0.04	0.01	0.00	0.00	0.14	0.12	0.43	0.99	0.02
JB-2a	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
JB-3a	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
JH-1	0.15	0.63	0.01	0.34	1.42	0.15	3.72	0.04	0.08	0.01	0.11	NC	1.42	0.02	21.24	0.73	0.70	0.05
JGb-2	0.24	0.60	0.01	0.01	0.16	1.17	9.53	0.16	0.02	0.06	0.83	14.52	NC	0.12	1.05	0.93	0.05	6.38
JR-2	1.05	0.15	0.41	0.00	0.08	2.00	0.11	0.08	0.01	0.00	NC	NC	NC	NC	NC	NC	0.29	6.31
GSP-2	0.06	0.70	0.47	0.03	0.11	0.10	0.10	0.01	0.02	0.20	1.79	0.00	0.04	5.58	0.10	1.09	0.46	0.14
BCR-2	0.01	2.41	0.41	0.01	0.25	0.55	0.03	0.00	0.64	0.01	2.43	38.09	0.35	NC	5.64	0.06	1.10	0.22
BHVO-2	0.10	5.79	0.04	0.12	0.36	0.69	0.06	0.00	1.00	0.16	0.46	21.76	0.01	1.38	1.58	3.23	1.48	6.67
W-2a	1.67	2.73	2.22	0.04	0.56	2.34	0.39	0.27	0.25	0.02	0.19	3.83	0.00	0.25	3.11	0.45	0.02	1.74
RGM-2	0.03	0.46	1.38	0.24	25.00	0.20	0.10	0.10	0.06	0.01	NC	NC	0.02	NC	16.41	NC	0.09	17.78
AC-E	0.43	0.00	0.00	0.09	0.04	0.00	0.01	0.03	0.15	0.00	NC	NC	0.43	NC	NC	NC	0.01	6.83
GH	0.01	0.00	0.00	0.01	0.00	0.01	0.05	0.10	0.07	0.00	NC	NC	NC	NC	NC	NC	0.00	0.02
PM-S	0.00	0.39	0.04	0.08	0.00	0.09	0.99	0.20	0.00	0.00	0.60	3.74	0.06	0.14	1.41	0.46	0.32	1.64
WS-E	0.55	1.75	0.03	0.05	0.00	0.04	0.04	0.00	0.03	0.01	2.45	3.96	0.13	0.36	0.98	0.03	0.27	183.60
AN-G	0.08	0.00	0.01	0.42	0.00	0.44	0.49	0.01	0.06	0.01	0.16	1.94	NC	3.36	4.19	0.13	2.49	1.12
MGL-OshBO	0.18	NC	0.19	0.10	0.62	NC	0.01	0.21	0.04	7.78	0.16	NC	NC	0.00	NC	NC	5.37	4.69

NC=no calculation.

Table S5. The values of $J_{s,i}$ by stirring rod method.

Samples	$J_{s,i}$ (ST)																	
	Major oxides										Minor elements							
	SiO ₂	TiO ₂	Al ₂ O ₃	TFe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Cr	Cu	Ba	Ni	Sr	V	Zr	Zn
JG-2	0.09	0.11	0.05	0.00	1.00	1.17	0.00	0.07	0.11	NC	NC	NC	0.01	NC	NC	NC	0.52	NC
JG-1a	0.01	0.05	0.29	0.25	0.08	0.02	0.14	0.02	0.00	0.00	0.26	NC	0.00	NC	0.00	0.00	0.01	0.19
JA-3	0.42	0.28	0.19	0.37	0.01	0.30	0.39	0.01	0.44	0.00	0.01	0.10	0.27	1.17	0.15	0.28	1.26	0.00
JB-2a	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
JB-3a	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
JH-1	0.28	0.16	0.00	1.20	2.40	0.16	5.75	0.40	0.04	0.01	0.16	NC	0.02	0.65	16.87	0.13	0.18	2.45
JGb-2	0.86	0.31	0.01	0.27	0.09	1.00	14.16	0.00	0.17	0.39	0.79	1.06	NC	1.03	2.79	0.65	0.01	1.59
JR-2	0.81	0.45	0.50	1.73	0.51	1.00	0.24	0.00	0.00	0.62	NC	NC	NC	NC	NC	NC	0.26	4.68
GSP-2	0.06	0.00	0.46	0.04	0.00	0.00	0.00	0.01	0.00	0.00	0.01	2.74	0.03	2.44	0.52	0.84	0.14	2.46
BCR-2	0.01	0.99	0.24	0.01	0.06	0.96	0.01	0.01	0.64	0.20	0.00	1.24	0.01	NC	3.40	0.60	2.05	0.66
BHVO-2	0.06	1.87	0.04	0.04	0.04	0.43	0.06	0.00	4.00	0.00	0.06	12.10	4.05	0.50	0.41	0.65	2.78	0.94
W-2a	1.82	1.20	2.43	0.18	0.53	2.89	1.03	0.29	1.17	0.01	0.34	1.62	0.07	0.11	1.60	0.07	0.10	0.52
RGM-2	0.31	0.90	1.68	0.24	0.00	0.00	0.00	0.06	0.10	0.01	NC	NC	0.08	NC	10.49	NC	0.13	0.49
AC-E	0.34	0.00	0.03	0.29	0.00	0.00	0.05	0.03	0.05	0.00	NC	NC	0.03	NC	NC	NC	0.02	11.71
GH	0.03	0.01	0.00	0.03	0.16	0.00	0.09	0.05	0.02	0.09	NC	NC	NC	NC	NC	NC	0.00	0.06
PM-S	0.02	0.01	0.04	0.13	0.36	0.03	1.42	0.21	0.25	0.00	0.60	1.08	0.12	0.02	0.65	0.21	0.02	2.24
WS-E	0.16	0.85	0.25	0.02	0.04	0.11	0.00	0.02	0.25	0.01	0.10	1.64	0.55	0.34	0.32	0.18	0.86	4.17
AN-G	0.14	0.01	0.01	0.49	0.16	0.03	0.61	0.00	0.00	0.00	0.91	0.90	NC	0.91	3.24	0.00	1.40	1.45
MGL-OShBO	0.05	NC	0.17	10.77	0.18		0.01	0.28	0.08	10.09	0.47	NC	NC	0.55	NC	NC	5.09	10.80

NC=no calculation.

Table S6. The values of J_{Si} by shaker cup method.

Samples	J_{Si} (SH)																	
	Major oxides										Minor elements							
	SiO ₂	TiO ₂	Al ₂ O ₃	TFe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Cr	Cu	Ba	Ni	Sr	V	Zr	Zn
JG-2	0.11	0.20	0.05	0.09	0.44	1.17	0.00	0.01	0.01	NC	NC	NC	1.08	NC	NC	NC	0.37	NC
JG-1a	0.08	0.04	0.17	0.36	0.02	0.02	0.14	0.02	0.02	0.01	0.08	NC	0.15	NC	0.49	0.78	0.00	0.71
JA-3	0.24	0.17	0.42	0.37	0.01	0.11	0.38	0.00	0.25	0.01	0.02	0.17	0.01	0.41	0.32	0.00	1.74	0.22
JB-2a	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
JB-3a	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
JH-1	0.15	0.03	0.01	0.83	2.40	0.06	4.87	0.06	0.04	0.01	0.09	NC	2.67	0.47	25.63	0.80	1.50	0.59
JGb-2	0.57	0.02	0.00	0.14	0.09	0.37	12.15	1.01	0.17	0.02	2.65	2.04	NC	1.58	4.00	0.03	23.94	1.27
JR-2	0.11	0.49	0.15	1.00	0.50	0.50	0.11	0.00	0.01	0.00	NC	NC	NC	NC	NC	NC	6.13	3.19
GSP-2	0.07	0.06	0.00	0.02	0.11	0.10	0.00	0.11	0.02	0.06	0.40	1.79	0.09	0.48	1.14	1.49	3.24	3.04
BCR-2	0.01	0.43	0.30	0.04	0.14	0.35	0.00	0.01	0.64	0.01	0.00	2.91	0.01	NC	3.36	0.19	4.16	0.59
BHVO-2	0.00	1.52	0.01	0.12	0.16	0.44	0.02	0.02	1.00	0.16	0.01	12.34	2.60	0.39	0.27	1.21	12.34	0.27
W-2a	1.35	0.15	0.62	0.23	0.94	1.85	0.99	0.61	0.44	0.02	0.00	1.53	0.21	0.16	1.89	0.04	3.24	0.70
RGM-2	0.00	1.00	1.20	0.24	0.00	0.20	0.00	0.01	0.04	0.00	NC	NC	0.87	NC	3.00	NC	1.67	1.35
AC-E	0.10	0.00	0.00	0.14	0.01	0.00	0.01	0.05	0.05	0.01	NC	NC	0.00	NC	NC	NC	0.41	11.21
GH	0.04	0.01	0.00	0.02	0.16	0.01	0.09	0.02	0.04	0.01	NC	NC	NC	NC	NC	NC	0.12	0.09
PM-S	0.10	0.01	0.14	0.28	0.63	0.03	1.82	0.20	0.00	0.00	0.28	1.12	0.00	0.03	0.95	0.16	0.96	1.60
WS-E	0.53	0.43	0.10	0.02	0.09	0.06	0.00	0.00	0.11	0.00	0.07	1.38	0.02	0.04	0.28	0.15	6.65	2.08
AN-G	0.79	0.00	0.02	0.49	0.09	0.03	1.00	0.01	0.06	0.02	0.01	0.82	NC	0.63	3.19	0.11	1.14	1.38
MGL-OshBO	0.03	NC	0.08	7.21	0.18	NC	0.01	0.39	0.01	3.91	0.39	NC	NC	1.38	NC	NC	24.05	17.67

NC=no calculation.

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