

Table A1. Geochemical data for Towada Volcano

Sample No.	Ak-4	Bm-4	Cc-6	Og-2	Do-3	En-5	Fn-3	Fn-4	Gs-3	H-1	J-1	K'-1	K-1	Gs-1
Unit	A	B	C	D'	D	E	F	F	G	H	J	K'	K	Gs
Occurrence	Pfl	Pfa	Pfa	Lv	Pfa	Pfa	Pfa	Pfa	Pfa	Pfa	Pfa	Pfa	Pfa	Lv
Locality	Kazuno Mayogatai	Kazuno Mayogatai	Towada Utarube	Towada Ogurayama	Kazuno Mayogatai	Towada Utarube	Towada Utarube	Towada Utarube	Towada Utarube	Towada Utarube	Kazuno Tshirotai	Kazuno Tshirotai	Sannohe Kaimori	Towada Yasumiya
<i>Major elements (wt.%)</i>														
SiO ₂	68.41	72.34	66.76	67.96	68.72	63.95	59.02	61.51	65.94	50.97	54.71	53.25	54.86	55.80
TiO ₂	0.75	0.43	0.77	0.65	0.61	0.83	0.98	0.98	0.84	0.88	1.03	0.83	0.87	0.88
Al ₂ O ₃	14.87	13.85	15.61	15.15	15.41	16.09	16.65	16.18	15.45	18.07	16.64	17.55	17.84	17.50
Fe ₂ O ₃ *	4.47	2.46	5.02	4.06	3.68	6.40	8.63	8.02	5.50	10.73	10.69	9.96	9.27	9.19
MnO	0.14	0.11	0.13	0.12	0.11	0.13	0.14	0.14	0.12	0.16	0.17	0.16	0.15	0.15
MgO	1.36	0.64	1.46	1.11	0.96	2.03	2.72	2.19	1.53	5.43	4.02	4.90	3.80	3.58
CaO	4.21	2.66	4.85	4.31	4.29	5.60	7.59	6.80	5.12	10.61	8.66	9.55	9.10	9.20
Na ₂ O	4.14	4.29	3.95	4.15	4.24	3.44	3.02	3.31	3.88	2.06	2.65	2.33	2.63	2.89
K ₂ O	1.08	1.24	0.94	0.94	1.04	0.87	0.59	0.67	0.94	0.24	0.42	0.34	0.43	0.41
P ₂ O ₅	0.20	0.07	0.17	0.16	0.13	0.16	0.15	0.17	0.18	0.09	0.12	0.12	0.11	0.12
Total	99.62	98.09	99.66	98.59	99.18	99.50	99.49	99.97	99.51	99.23	99.11	98.99	99.05	99.72
LOI**	1.47	1.56	1.46	0.07	1.59	2.13	0.45	0.26	1.40	0.23	0.34	0.61	0.56	-0.18
<i>Trace elements (ppm)</i>														
Zr	127.8	136.3	108.9	117.1	122.6	112.5	74.5	84.3	111.6	32.9	63.5	50.1	61.2	61.3
Th	3.4	3.6	2.8	3.0	3.1	2.8	1.8	2.0	2.7	0.6	1.1	0.9	1.1	1.1
La														
Ce														
Pr														
Nd														
Sm														
Eu														
Gd														
Tb														
Dy														
Ho														
Er														
Tm														
Yb														
Lu														
<i>Isotope ratio</i>														
⁸⁷ Sr/ ⁸⁶ Sr	0.704369	0.704374		0.704297										

*Total Fe as Fe₂O₃. **loss on ignition.

Abbreviations: V. volcano; Pfl, pyroclastic flow deposits; Pfa, pyroclastic fall deposits; Lv, lava; R. river.

Major and trace-elements were measured by XRF and ICP mass spectrometry, respectively.

Sr isotope ratios were measured by TIMS.

Sample No.	Gs-2	Gs-3	Gs-4	Gs-5	Lh-1	Lh-2	Lh-3	Lh-4	Lh-5	Lh-6	HP5-1	HP2-1	HP1-1	M-1
Unit	Gs	Gs	Gs	Gs	L	L	L	L	L	L	L	L	L	M
Occurrence	Lv	Lv	Lv	Lv	Pfl	Pfl	Pfl	Pfl	Pfl	Pfl	Pfa	Pfa	Pfa	Pfl
Locality	Towada Yasumiya	Towada Yasumiya	Towada Utarube	Towada Yasumiya	Kazuno Koshimawari	Kazuno Tshirotai	Kazuno Tshirotai	Kuroishi Okawara	Towada Sobe R.	Shingo Hosono	Towada Nakayashiki	Towada Nakayashiki	Towada Nakayashiki	Towada Sobe R.
<i>Major elements (wt.%)</i>														
SiO ₂	54.09	56.52	56.80	52.09	69.68	70.36	71.64	71.74	70.27	70.83	70.62	66.24	67.68	73.15
TiO ₂	0.82	1.05	0.88	0.85	0.59	0.54	0.50	0.50	0.56	0.53	0.52	0.68	0.68	0.47
Al ₂ O ₃	17.53	16.24	17.27	17.58	15.25	15.11	15.07	14.74	15.29	15.22	15.14	15.56	15.65	14.43
Fe ₂ O ₃ *	9.73	9.85	8.95	10.28	3.70	3.34	3.06	3.04	3.51	3.31	3.16	5.07	4.52	2.68
MnO	0.16	0.16	0.15	0.16	0.12	0.11	0.11	0.11	0.12	0.11	0.11	0.14	0.13	0.12
MgO	4.46	3.19	3.79	5.52	1.06	0.93	0.80	0.83	0.98	0.92	0.85	2.02	1.48	0.66
CaO	9.80	7.96	8.49	10.57	4.24	3.95	3.73	3.70	4.05	4.02	3.98	5.25	4.86	2.81
Na ₂ O	2.49	3.15	2.95	2.26	4.33	4.36	4.31	4.27	4.40	4.41	4.41	3.97	4.02	4.74
K ₂ O	0.38	0.51	0.46	0.26	1.02	1.09	1.11	1.10	1.04	1.07	1.03	0.86	0.94	1.21
P ₂ O ₅	0.11	0.14	0.13	0.10	0.13	0.12	0.10	0.10	0.13	0.11	0.11	0.17	0.18	0.08
Total	99.58	98.76	99.85	99.67	100.12	99.91	100.42	100.13	100.33	100.51	99.93	99.95	100.12	100.36
LOI**	-0.24	-0.18	0.27	-0.26	2.47	2.39	2.91	2.99	2.50	2.39	2.96	1.78	2.71	3.64
<i>Trace elements (ppm)</i>														
Zr	53.3	77.4	68.5	40.9	117.5	123.6	124.8	125.0	119.3	120.0	120.5	101.3	107.1	145.9
Th	1.0	1.4	1.3	0.7	2.8	3.0	3.0	3.0	2.9	2.9	2.9	2.4	2.6	3.6
La							11.5	11.4		11.1			10.5	
Ce							27.8	27.6		26.8			25.4	
Pr							3.5	3.5		3.4			3.3	
Nd							16.6	16.5		16.1			15.7	
Sm							4.5	4.4		4.3			4.2	
Eu							1.3	1.2		1.3			1.3	
Gd							5.1	5.2		5.0			4.8	
Tb							0.9	0.9		0.87			0.85	
Dy							5.7	5.8		5.6			5.5	
Ho							1.3	1.2		1.2			1.2	
Er							3.7	3.7		3.6			3.5	
Tm							0.56	0.57		0.55			0.53	
Yb							3.8	3.8		3.7			3.5	
Lu							0.61	0.61		0.59			0.56	
<i>Isotopic ratio</i>														
⁸⁷ Sr/ ⁸⁶ Sr					0.704216			0.704210	0.704218			0.704220		0.704284

Sample No.	M-2	M-3	M-4	No-1	No-2	No-3	No-4	No-5	No-6	No-7	No-8	KR3-1	KR3-2	KR3-3
Unit	M	M	M	N	N	N	N	N	N	N	N	N	N	N
Occurrence	Pfl	Pfl	Pfl	Pfl	Pfl	Pfl	Pfl	Pfl	Pfl	Pfl	Pfl	Pfa	Pfa	Pfa
Locality	Towada Sobe R.	Towada Aobuna	Towada Oirase	Kuroishi Okawara	Kuroishi Okawara	Towada Sennosawa	Towada Sennosawa	Towada Nakayashiki	Towada Nakayashiki	Towada Aobuna	Towada Aobuna	Towada Aobuna	Towada Aobuna	Towada Aobuna
<i>Major elements (wt.%)</i>														
SiO ₂	72.15	73.99	72.61	73.27	72.32	73.60	72.84	73.00	72.76	71.94	70.40	71.77	71.64	71.67
TiO ₂	0.48	0.46	0.47	0.49	0.55	0.49	0.52	0.52	0.52	0.56	0.59	0.57	0.60	0.61
Al ₂ O ₃	14.93	14.33	14.91	14.07	14.21	13.89	14.08	13.98	14.21	14.24	14.80	14.65	14.79	14.57
Fe ₂ O ₃ *	2.78	2.62	2.69	3.00	3.28	3.07	3.23	3.19	3.16	3.37	3.70	3.81	3.74	3.84
MnO	0.12	0.12	0.12	0.11	0.13	0.11	0.11	0.12	0.11	0.12	0.13	0.13	0.12	0.13
MgO	0.66	0.65	0.62	0.73	0.85	0.74	0.77	0.77	0.77	0.81	0.93	0.88	0.92	0.99
CaO	2.73	2.79	2.82	3.11	3.27	2.98	3.17	3.02	3.19	3.21	3.59	3.41	3.55	3.49
Na ₂ O	4.65	4.68	4.73	4.53	4.50	4.43	4.44	4.47	4.61	4.48	4.52	4.30	4.47	4.49
K ₂ O	1.19	1.19	1.21	1.19	1.11	1.19	1.13	1.13	1.13	1.09	1.02	1.07	1.02	1.03
P ₂ O ₅	0.08	0.09	0.08	0.09	0.11	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.12	0.12
Total	99.76	100.92	100.26	100.60	100.33	100.60	100.39	100.28	100.55	99.93	99.80	100.70	100.97	100.94
LOI**	3.89	3.47	3.86	2.85	2.99	3.29	3.23	3.49	3.16	3.73	3.47	4.53	3.78	3.74
<i>Trace elements (ppm)</i>														
Zr	149.1	142.3	143.0	143.4	135.6	143.2	139.5	147.1	138.2	142.7	132.3	135.4	133.1	132.8
Th	3.8	3.5	3.6	3.1	2.9	3.1	3.0	3.0	2.9	2.9	2.7	2.9	2.7	2.8
La														
Ce														
Pr														
Nd														
Sm														
Eu														
Gd														
Tb														
Dy														
Ho														
Er														
Tm														
Yb														
Lu														
<i>Isotopic ratio</i>														
⁸⁷ Sr/ ⁸⁶ Sr	0.704301			0.704175		0.704189		0.704190				0.704194		0.704178

Sample No.	KR3-4	T25-1	P-1	P-2	P-3	Qo-1	Qo-2	Qo-3	Q-1	Q-2	Q-3	SP-1	SP-2	ZP-1
Unit	N	T-25	P	P	P	Q	Q	Q	Q	Q	Q	SP	SP	ZP
Occurrence	Pfa	Pfa	Pfa	Pfa	Pfa	Pfl	Pfl	Pfl	Pfa	Pfa	Pfa	Pfa	Pfa	Pfa
Locality	Towada Aobuna	Towada Aobuna	Towada Oirase	Towada Oirase	Towada Oirase	Towada Katabuchi R.	Towada Sobe R.	Towada Sobe R.	Towada Katabuchi R.	Towada Katabuchi R.	Towada Katabuchi R.	Towada Hirayama	Towada Hirayama	Towada Nenokuchi
<i>Major elements (wt.%)</i>														
SiO ₂	71.66	67.23	68.13	67.64	67.99	62.13	61.87	61.81	67.56	67.54	67.47	57.94	59.38	58.17
TiO ₂	0.58	0.78	0.82	0.84	0.83	0.99	1.00	0.99	0.80	0.80	0.80	1.09	1.05	0.89
Al ₂ O ₃	14.51	15.70	15.16	15.46	15.49	15.98	15.89	15.69	15.39	15.44	15.61	16.60	16.79	17.07
Fe ₂ O ₃ *	3.66	5.11	4.80	5.00	4.98	7.74	7.83	7.73	5.44	5.38	5.33	9.45	8.33	8.78
MnO	0.12	0.15	0.15	0.16	0.16	0.18	0.18	0.18	0.17	0.16	0.16	0.19	0.18	0.18
MgO	0.93	1.48	1.27	1.38	1.37	2.49	2.51	2.52	1.40	1.42	1.38	3.18	2.36	3.55
CaO	3.52	4.85	4.30	4.43	4.46	6.40	6.41	6.39	4.56	4.51	4.53	7.76	7.43	7.97
Na ₂ O	4.56	4.09	4.18	4.15	4.15	3.72	3.77	3.70	4.00	3.89	3.99	3.37	3.63	3.22
K ₂ O	1.05	0.89	0.98	0.94	0.95	0.63	0.59	0.59	0.76	0.77	0.80	0.40	0.43	0.47
P ₂ O ₅	0.11	0.19	0.19	0.19	0.20	0.18	0.18	0.17	0.18	0.18	0.18	0.18	0.19	0.13
Total	100.70	100.45	99.98	100.18	100.58	100.43	100.23	99.76	100.26	100.09	100.23	100.15	99.76	100.41
LOI**	3.65	3.43	2.73	3.07	3.20	0.90	0.79	0.34	3.54	3.72	3.62	0.54	0.07	1.37
<i>Trace elements (ppm)</i>														
Zr	131.6	107.7	120.1	119.1	117.2	85.7	86.7	86.6	117.1	116.7	116.7	70.0	77.0	64.7
Th	2.8	2.4	2.7	2.7	2.6	1.4	1.4	1.4	1.9	1.9	1.8	1.0	1.1	1.1
La									10.4					
Ce									25.4					
Pr									3.6					
Nd									18.2					
Sm									5.2					
Eu									1.5					
Gd									6.3					
Tb									1.08					
Dy									7.0					
Ho									1.5					
Er									4.4					
Tm									0.65					
Yb									4.3					
Lu									0.67					
<i>Isotopic ratio</i>														
⁸⁷ Sr/ ⁸⁶ Sr		0.704291	0.704273			0.704143		0.704140	0.704148		0.704122	0.704138		0.704003

Sample No.	ZP-2	ZP-3	Ao-1	Ao-2	Ao-3	Ao-4	Ao-5	Ao-6	Ao-7	Ao-8	Ao-9	Ao-10	Ao-11	Ao-12
Unit	ZP	ZP	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.
Occurrence	Pfa	Pfa	Lv	Lv	Lv	Pfa	Pfa	Pfa	Pfa	Pfl	Pfl	Pfl	Pfl	Pfl
Locality	Towada Nenokuchi	Towada Sosupe R.	Towada Oirase	Towada Aobuna	Towada Aobuna	Towada Nenokuchi	Towada Nenokuchi	Towada Aobuna	Towada Aobuna	Towada Aobuna	Towada Aobuna	Towada Aobuna	Towada Aobuna	Towada Aobuna
<i>Major elements (wt.%)</i>														
SiO ₂	59.21	55.56	56.19	60.91	57.16	59.92	57.60	61.31	68.89	69.89	68.01	68.83	69.45	69.01
TiO ₂	0.93	0.99	1.01	1.10	0.96	0.95	0.91	0.90	0.69	0.67	0.73	0.71	0.68	0.73
Al ₂ O ₃	16.77	17.53	18.19	15.59	18.01	17.41	16.85	16.79	15.44	14.90	15.35	15.08	15.30	15.23
Fe ₂ O ₃ *	8.88	9.94	9.50	9.28	9.02	7.98	9.10	7.47	4.21	4.10	4.61	4.33	3.97	4.42
MnO	0.18	0.18	0.17	0.19	0.17	0.16	0.17	0.19	0.13	0.13	0.14	0.14	0.13	0.13
MgO	3.38	3.44	2.55	1.99	2.39	2.13	3.87	2.28	1.13	1.08	1.21	1.26	1.10	1.19
CaO	7.47	7.96	9.00	6.50	8.51	7.25	8.04	6.53	4.25	4.12	4.50	4.44	4.29	4.32
Na ₂ O	3.27	2.74	3.17	3.86	3.32	3.64	3.21	3.52	4.27	4.51	4.55	4.49	4.61	4.52
K ₂ O	0.49	0.36	0.40	0.58	0.45	0.51	0.44	0.54	0.86	0.88	0.81	0.82	0.84	0.84
P ₂ O ₅	0.14	0.13	0.14	0.18	0.14	0.17	0.12	0.18	0.16	0.16	0.17	0.18	0.16	0.17
Total	100.73	98.81	100.31	100.18	100.12	100.11	100.32	99.71	100.03	100.44	100.06	100.28	100.53	100.57
LOI**	1.72	2.19	-0.06	-0.19	-0.13	1.24	0.79	1.69	4.14	3.27	1.96	2.46	2.56	3.25
<i>Trace elements (ppm)</i>														
Zr	67.8	62.9	60.9	92.7	70.8	85.1	68.3	77.4	111.2		111.1	108.2	112.8	111.6
Th	1.1	1.0	0.8	1.4	0.9	1.2	0.9	1.3	2.1		2.1	2.1	2.1	2.1
La														
Ce														
Pr														
Nd														
Sm														
Eu														
Gd														
Tb														
Dy														
Ho														
Er														
Tm														
Yb														
Lu														
<i>Isotopic ratio</i>														
⁸⁷ Sr/ ⁸⁶ Sr				0.704026	0.703981					0.704142	0.704126	0.704140		0.704125

Sample No.	Ao-13	Ao-14	Ao-15	Ao-16	Ao-17	Ao-18
Unit	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.	Aobuna V.
Occurrence	Pfl	Pfl	Pfl	Pfl	Pfl	Pfl
Locality	Towada Nenokuchi	Towada Oirase	Towada Yourousawa	Towada Aobuna	Towada Aobuna	Towada Aobuna
<i>Major elements (wt.%)</i>						
SiO ₂	68.70	68.50	67.82	62.59	65.16	63.55
TiO ₂	0.72	0.71	0.75	0.83	0.83	0.84
Al ₂ O ₃	15.43	15.60	15.30	16.34	15.56	16.34
Fe ₂ O ₃ *	4.51	4.59	4.79	7.11	6.26	6.81
MnO	0.14	0.14	0.14	0.16	0.16	0.16
MgO	1.21	1.23	1.38	2.29	1.91	2.11
CaO	4.33	4.42	4.51	6.46	5.41	6.29
Na ₂ O	4.53	4.73	4.39	3.74	4.09	3.94
K ₂ O	0.84	0.83	0.80	0.64	0.76	0.66
P ₂ O ₅	0.16	0.17	0.17	0.15	0.17	0.16
Total	100.56	100.91	100.03	100.32	100.30	100.87
LOI**	2.61	2.07	2.66	1.78	2.24	1.90
<i>Trace elements (ppm)</i>						
Zr	114.7	111.0	114.1	84.3	98.1	86.0
Th	2.1	2.1	2.2	1.5	1.8	1.6
La						
Ce						
Pr						
Nd						
Sm						
Eu						
Gd						
Tb						
Dy						
Ho						
Er						
Tm						
Yb						
Lu						
<i>Isotopic ratio</i>						
⁸⁷ Sr/ ⁸⁶ Sr				0.704109	0.704127	