

DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

**Chemical Analyses of Rocks and Sediments from
Central Chile**

by

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Open-file Report 89-78

This report is preliminary and has not been reviewed for conformity with U. S. Geological Survey editorial standards (and stratigraphic nomenclature). Any use of trade names is for descriptive purposes only and does not imply endorsement by the U. S. G. S.

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INTRODUCTION

This report contains chemical analyses of Quaternary volcanic rocks from the volcanic front of the southern volcanic zone (SVZ) of the active Andean arc in Central Chile (latitudes 33° to 36° S). Also given are a few data for Mesozoic and Paleozoic basement rocks and present-day river-mouth sediments from the same latitudes. The Mesozoic basement suite is from the Río Yeso adjacent to Volcan Marmolejo; location of other samples are tabulated or discussed in Hildreth and Moorbath (1988). All samples were very fresh, the volcanic rocks being mostly glassy lavas, scoriae, or pumice. Most were collected by Hildreth, Fierstein, and Drake during a series of expeditions to this high, remote, and uninhabited part of the Andes between 1980 and 1985. A few were sampled by Drake in the course of earlier regional studies (Drake 1976), and the two lavas from Nevado de Longavi were collected by M. Gardeweg (1981). A larger suite has been analyzed and forms the basis of ongoing work and future reports; the chemical data presented here complement the isotopic data given in Hildreth and Moorbath (1988), which should be consulted for their interpretation.

ANALYTICAL METHODS

The samples listed in Table 1 have been analyzed for major and trace elements, for $^{87}\text{Sr}/^{86}\text{Sr}$, and a subset of them for Pb- and Nd-isotope ratios (Hildreth and Moorbath 1988). All were ground in a WC shatterbox, and separate splits of chunks of the same hand-samples were ground in an alumina shatterbox for instrumental neutron-activation analysis (INAA). Fierstein prepared all powders using identical procedures; all chemical analyses were made in USGS laboratories by well-established methods and are presented as raw, non-normalized data.

Major elements were determined by x-ray fluorescence (XRF) in Lakewood, Colorado, by Bartel, Stewart, and Taggart. Rb, Sr, Y, Zr, and Ba were determined by energy-dispersive x-ray fluorescence in Menlo Park by Bruggman. Rare-earth elements, Co, Cr, Cs, Hf, Sb, Ta, Th, U, Zn, Sc, Na, and Fe were determined by INAA in Reston by Schwarz.

Precision of the three methods is measured by repeated analysis of internal USGS standards, as tabulated and discussed by Bacon and Druitt (1988).

REFERENCES

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KEY TO ABBREVIATIONS IN TABLE 1

CT	Cerro Tupungato
TT	Volcan Tupungatito
CA	Cerro Alto-Nevado Piuquenes
CM	Cerro Marmolejo-Espiritu Santo-San Jose
VP	Volcan Palomo
VT	Volcan Tinguiririca-Fray Carlos
SL	Sordo Lucas
PPA	Volcan Peteroa-Planchon-Azufre
AQD	Cerro Azul-Quizapu-Descabezado Grande
NL	Nevado de Longavi
CF	Paleozoic-Triassic basement samples: Cordillera Frontal terrane north of Tupungato
RY	Mesozoic basement samples: Río Yeso west of Marmolejo
RMS	River-mouth sediments; see Figure 1 of Hildreth and Moorbath (1988).
LOI	Loss-on-ignition at 900° C

TABLE 1
Chemical Analyses

Sample No. Center	AB-1 CF	AB-2 CF	AB-4 CF	AB-5 CF	AB-6 CF	AB-7 CF	AB-8 CF	MB-1 RY	MB-4 RY	MB-5 RY	MB-6 RY	AP-3 SL
pct												
SiO ₂	73.1	58.9	72.6	76.2	76.6	69.6	64.2	61.2	59.3	55.9	42.5	59.9
TiO ₂	0.91	0.98	0.25	0.09	0.08	0.85	1.03	0.49	0.53	0.99	0.46	0.64
Al ₂ O ₃	11.2	17.9	12.3	12.2	11.7	12.6	15	10.5	17.3	16.6	11.8	17.6
Fe ₂ O ₃	5.17	8.43	2.86	1.35	1.09	5.39	6.8	5.17	7.53	8.15	4.36	6.26
MnO	0.04	0.06	0.07	-	-	0.04	0.05	0.29	0.1	0.13	0.17	0.12
MgO	1.67	2.85	0.17	0.11	-	2.51	3.21	1.3	2.26	2.6	2.46	2.75
CaO	0.58	0.49	0.89	0.3	0.11	1.25	0.93	5.54	1.52	4.8	17.7	5.6
Na ₂ O	2.27	1.49	3.32	2.48	2.86	1.77	2.73	1.4	7.58	4.08	2.72	4
K ₂ O	1.81	4.14	5.32	5.03	5.39	1.88	1.98	1.81	0.76	1.61	1.83	2.21
P ₂ O ₅	0.15	0.17	-	-	-	0.14	0.19	0.1	0.36	0.24	0.23	0.24
LOI	2.69	4.44	1.65	1.4	1.2	3.77	3.45	10.3	2	4.19	15.9	0.48
Fe%	-	-	-	-	-	-	-	-	-	-	-	4.6
Na%	-	-	-	-	-	-	-	-	-	-	-	2.8

Major Elements

Trace Elements

	364	700	142	66	135	275	530	210	400	347	230	491
Ba	-	-	-	-	-	-	-	-	-	-	-	15.5
Co	-	-	-	-	-	-	-	-	-	-	-	20
Cr	-	-	-	-	-	-	-	-	-	-	-	3
Cs	-	-	-	-	-	-	-	-	-	-	-	3.67
Hf	-	-	-	-	-	-	-	-	-	-	-	61
Rb	59	155	174	190	211	96	68	70	11	43	59	14
Sb	-	-	-	-	-	-	-	-	-	-	-	0.37
Sc	-	-	-	-	-	-	-	-	-	-	-	14
Sr	65	65	38	47	44	61	96	203	515	445	343	429
Ta	-	-	-	-	-	-	-	-	-	-	-	0.45
Th	-	-	-	-	-	-	-	-	-	-	-	11
U	-	-	-	-	-	-	-	-	-	-	-	2.8
Y	34	36	58	50	57	29	35	23	20	19	21	17
Y _n	-	-	-	-	-	-	-	-	-	-	-	73
Zr	336	203	487	200	144	225	264	114	147	133	118	155
La	-	-	-	-	-	-	-	-	-	-	-	23
Ce	-	-	-	-	-	-	-	-	-	-	-	42
Nd	-	-	-	-	-	-	-	-	-	-	-	19
Sm	-	-	-	-	-	-	-	-	-	-	-	4.11
Eu	-	-	-	-	-	-	-	-	-	-	-	0.99
Gd	-	-	-	-	-	-	-	-	-	-	-	3.2
Tb	-	-	-	-	-	-	-	-	-	-	-	0.51
Yb	-	-	-	-	-	-	-	-	-	-	-	1.6
Lu	-	-	-	-	-	-	-	-	-	-	-	0.27

Sample Center	No.	AP-4 SL	AP-5 SL	CM-1 CM	CM-2 CM	CM-3 CM	CM-5 CM	CM-7 CM	CM-7A CM	CM-11 CM	CM-11A CM	CM-12 CM	CM-16 CM
Major Elements													
pct													
SiO ₂		62.1	59	59.8	61.3	57.7	64.8	64.5	56.6	65.2	59.7	61.5	65.8
TiO ₂		1.03	0.7	0.88	0.77	0.94	0.47	0.61	1.04	0.63	0.96	0.72	0.62
Al ₂ O ₃		16.2	17.9	17	16	17.4	16.4	17.5	19.2	16.4	17.4	16.7	16.4
Fe ₂ O ₃		6.04	6.81	5.78	5.03	6.38	3.69	3.75	7.13	4.38	6.3	5.7	4.27
MnO		0.15	0.12	0.07	0.06	0.08	0.07	0.07	0.16	0.06	0.08	0.09	0.06
MgO		1.64	2.72	3.57	2.71	3.84	1.53	1.52	2.8	1.92	3.32	3.03	1.82
CaO		3.99	6.08	5.66	4.39	6.23	3.58	4	6.46	4.17	5.77	5.4	4.13
Na ₂ O		4.65	3.99	4.24	3.84	4.05	3.93	4.49	4.02	3.99	3.91	3.9	4.09
K ₂ O		2.83	1.87	2.03	3.4	1.81	2.73	2.7	0.96	2.64	2.07	2.43	2.66
P ₂ O ₅		0.39	0.23	0.25	0.23	0.25	0.2	0.23	0.28	0.19	0.26	0.2	0.18
LOI		0.34	0.49	0.44	1.93	0.88	1.73	0.21	1.37	0.09	0.04	0.35	-
Fe%		4.31	4.8	4.17	3.63	4.6	2.75	2.63	4.54	3	4.56	4.01	-
Na%		3.5	2.9	3.2	2.9	3.11	3.05	3.48	2.78	3.11	2.99	2.99	-

Trace Elements

Sample Center	No.	AP-4 SL	AP-5 SL	CM-1 CM	CM-2 CM	CM-3 CM	CM-5 CM	CM-7 CM	CM-7A CM	CM-11 CM	CM-11A CM	CM-12 CM	CM-16 CM
Trace Elements													
ppm													
Ba		548	435	606	554	488	592	583	424	451	388	443	458
Co		6.04	16.2	18	14.5	20.1	8.16	7.39	14.1	9.95	18.8	15.6	-
Cr		-	15	137	84.3	109	6.3	6	16	23	87.3	41.6	-
Cs		6.74	1.5	1.64	7.82	1.5	3.28	2.91	1.6	3.1	1.7	2.2	-
Hf		7.02	3.47	4.38	8.17	4.1	5.62	5.34	3.71	4.7	4.5	4.33	-
Rb		98	57	55	166	51	109	94	12	102	67	82	106
Sb		0.98	0.49	0.18	0.9	-	0.3	0.48	0.4	0.29	-	0.38	-
Sc		18	16	10.1	10.6	12.2	5.99	6.46	12.1	6.62	10.5	12.3	-
Sr		313	429	647	425	596	469	460	627	368	488	413	383
Ta		0.672	0.37	0.526	1.3	0.51	0.95	1.04	0.568	1.4	1	0.945	-
Th		12.4	7.04	5.38	20.2	4.7	10	9.91	5.03	11.6	8.06	9.74	-
U		3.3	1.9	1.4	5.51	1.2	2.29	3.2	1.8	4	2.5	2.8	-
Y		40	19	15	29	17	25	21	19	24	19	22	22
Zn		96.2	77	75.9	69.8	76.4	63.1	61	110	62	87	70	-
Zr		262	145	194	321	184	220	224	171	186	184	168	183
La		32.9	21	24.2	36.6	22.5	35.1	28.8	19.6	27.3	25.9	25.2	-
Ce		64.2	39	45.4	73.2	44	65.4	55	39.5	53	51	48.9	-
Ni		38	22	23	32	22	28	24	21	24	24	25	-
Sm		8.48	4.23	4.6	6.46	4.66	5.17	4.71	4.43	4.87	5.38	4.6	-
Eu		1.66	1.1	1.13	1.1	1.1	0.931	0.97	1	0.97	1.2	0.961	-
Gd		8.3	3.4	3.8	6.5	-	4.7	-	-	-	-	-	-
Tb		1.22	0.58	0.32	0.66	0.48	0.66	0.6	0.55	0.6	0.63	0.6	-
Yb		3.86	1.7	0.9	2.1	1.2	2.15	1.8	1.6	1.8	1.4	2	-
Lu		0.63	0.28	0.13	0.33	0.17	0.318	0.29	0.23	0.26	0.21	0.31	-

Sample Center	No.	CM-16A	CM-18	CM-19	CM-19A	CM-22	CM-27	MG-9	MG-181	PP-1	PP-2	PP-6	PP-7
		CM	CM	CM	CM	CM	CM	NL	NL	PPA	PPA	PPA	PPA
pct													
SiO ₂		56.4	65.9	60.5	54.9	58.3	59.4	56.2	56.8	51.7	52.7	57.2	59.6
TiO ₂		1.19	0.5	0.8	0.96	0.97	0.82	0.87	0.85	1.1	1.03	0.96	0.85
Al ₂ O ₃		18.3	15.7	17.3	17.8	17.2	17.8	17.6	17.6	17.5	17.6	17.4	16.9
Fe ₂ O ₃		7.82	3.8	6.13	8.09	6.92	6.2	7.25	7.09	9.66	9.27	7.52	6.61
MnO		0.1	0.08	0.1	0.13	0.1	0.09	0.12	0.12	0.15	0.15	0.13	0.11
MgO		3.71	1.54	2.84	4.55	3.76	2.88	4.76	4.59	6.33	6.07	3.68	3.23
CaO		7.1	3.48	5.68	7.69	6.21	5.94	7.11	7.31	8.96	8.63	6.86	6.03
Na ₂ O		3.4	4.14	3.95	3.28	4.23	4.04	3.68	3.86	3.56	3.55	3.81	3.88
K ₂ O		1.47	3.02	2.37	1.84	2.08	2.13	1.03	1.05	1.03	1.04	1.99	2.42
P ₂ O ₅		0.26	0.16	0.2	0.21	0.25	0.23	0.22	0.23	0.28	0.26	0.22	0.19
LOI		0.14	0.75	-	-	-	0.04	0.69	0.01	-	-	0.1	0.16
Fe%		-	2.8	4.6	5.63	4.92	4.47	5.21	5.11	-	6.8	5.34	4.6
Na%		-	3.28	3.02	2.5	3.19	3.11	2.97	3.09	-	2.6	2.8	2.9

Major Elements

Trace Elements

ppm	Ba	Co	Cr	Cs	Hf	Rb	Sb	Sc	Sr	Ta	Th	U	Y	Zn	Zr	La	Ce	Ni	Sm	Eu	Gd	Tb	Yb	Lu	
282	513	8.1	10	4.3	4.78	109	0.53	6.1	339	1.2	14	4.3	23	54	177	31.1	59	26	4.45	0.81	-	-	-	-	
430	17.5	19	1.9	4.66	82	-	-	14.2	426	2.8	9.8	2.8	24	81	179	25.1	50.1	21	5.13	1.05	-	-	-	-	
344	23	63	1.2	3.79	61	-	-	22.1	473	1.6	5.53	1.6	24	88	154	19.3	38	19	4.64	1.1	-	-	-	-	
488	20.5	55.5	1.3	4.67	65	-	-	12.8	528	2.1	8.16	2.1	20	75	198	25.8	50	26	5.34	1.2	-	-	-	-	
466	15.7	18	1.6	4.68	66	-	-	13.8	481	0.68	8.23	2.1	23	74	196	25.7	50	24	5.07	1.1	-	-	-	-	
305	23.4	110	0.99	2.6	28	-	-	16.5	584	0.26	2.7	0.81	15	77	121	12.9	25	15	3.4	0.94	-	-	-	-	
307	23.6	103	0.68	2.7	28	-	-	16.3	565	0.23	2.73	0.74	15	77.1	119	12.5	25	14	3.3	0.948	-	-	-	-	
302	-	-	-	-	17	-	-	0.25	556	0.24	2.3	0.68	22	84	126	18.5	30	21	4.35	1.1	-	-	-	-	
295	33.5	139	1	2.8	26	-	-	24	545	0.24	2.3	0.68	20	84	128	18.5	30	21	4.35	1.1	-	-	-	-	
417	19.3	47.2	2.7	4.03	67	-	-	21.9	456	0.45	7.21	1.7	23	82	170	18.5	38	20	4.59	1.1	-	-	-	-	
434	16	32	3.7	4.74	85	-	-	18.3	402	0.53	9.6	2.2	24	74	190	21	42	21	4.88	1	-	-	-	-	

Sample No. Center	PP-8 PPA	PP-10 PPA	PP-13 PPA	Q-2 AQD	Q-5 AQD	Q-9 AQD	Q-17 AQD	Q-19 AQD	Q-22 AQD	Q-27 AQD	Q-28 AQD	Q-29A AQD
pct												
SiO ₂	68.7	52.3	52.4	69.6	67.5	59.7	52.8	74.2	68.7	53.2	53.9	70.1
TiO ₂	0.45	0.91	0.96	0.43	0.56	0.8	1.04	0.11	0.53	0.8	0.93	0.34
Al ₂ O ₃	15.3	17.9	17.6	15.4	15.8	17.4	18.7	12.9	16.2	17.8	17.7	15
Fe ₂ O ₃	2.68	9.44	9.44	2.6	3.27	6.28	8.7	0.91	3.24	8.15	8.06	2.47
MnO	0.05	0.15	0.15	0.07	0.08	0.11	0.13	0.03	0.08	0.13	0.13	0.06
MgO	0.77	6.27	6.67	0.68	0.95	3.29	5.37	0.18	0.95	5.54	5.34	0.82
CaO	2.28	8.73	8.97	1.81	2.4	5.9	9.16	0.54	2.45	9.57	8.59	2.16
N ₂ O	4.24	3.4	3.32	4.9	5	4.19	3.4	3.75	4.96	3.23	3.65	3.99
K ₂ O	4.29	0.86	0.95	3.71	3.34	2.07	0.98	5.13	3.36	0.96	1.21	4.06
P ₂ O ₅	0.11	0.2	0.23	0.1	0.1	0.19	0.23	-	0.16	0.17	0.24	0.1
LOI	0.79	-	-	1.15	0.98	-	-	0.39	0.21	-	-	0.24
Fe%	1.88	-	6.64	2.04	2.29	4.52	6.2	0.79	2.44	5.96	5.86	-
Na%	3.3	-	2.47	3.64	3.9	3.28	2.6	2.93	4.03	2.54	2.83	-

Major Elements

Trace Elements

	622	265	258	-	622	445	273	147	643	254	316	585
Ba	622	265	258	-	622	445	273	147	643	254	316	585
Co	3.65	-	33.6	3.1	19.3	17.4	29	0.55	4.3	27.4	25.3	-
Cr	1.9	-	156	2.2	1.2	36	69	-	-	100	89.8	-
Cs	7.2	-	0.91	6.27	5.2	2.95	1	2.5	4.18	1.3	1.1	-
Hf	7.91	-	2.62	7.53	6.6	4.58	2.4	5.3	6.68	2	2.68	-
Rb	167	19	22	-	108	62	24	221	103	26	33	135
Sb	0.88	-	0.25	0.79	0.73	0.37	0.33	0.59	0.68	-	-	-
Sc	6.13	-	26.1	6.84	7.5	16.2	24	2.6	7.81	28.8	23.9	-
Sr	202	500	478	-	262	434	599	85	285	653	680	261
Ta	0.893	-	0.2	0.688	1.72	0.426	0.24	0.91	0.607	0.16	0.27	-
Th	19.9	-	1.8	14.5	12.1	7.25	2.6	36	12.1	2.71	3.64	-
U	4.65	-	0.4	3.3	3.1	1.66	0.63	8.9	2.91	0.71	0.82	-
Y	30	19	20	-	28	23	18	24	27	18	19	19
Zn	42	-	90.6	57	63	77.9	88	84	53.4	82.1	85.9	-
Zr	285	105	115	-	260	182	121	109	256	94	131	181
La	30.9	-	12	25	25	19.1	12.8	34	26.2	10.4	15.6	-
Ce	62.3	-	24	53.5	50	37.3	27	69	49.9	20.8	31	-
Ni	27	-	17	24	25	21	17	26	26	16	18	-
Sm	5.55	-	3.88	5.1	4.6	4.27	3.8	5.07	5.02	3.09	4.04	-
Eu	0.8	-	0.97	0.863	1.02	1.03	1.1	0.33	1.03	0.816	1.04	-
Gd	5.7	-	3.7	4.7	5.2	3.7	4.3	4.3	5.4	2.9	3.3	-
Tb	0.65	-	0.52	0.669	0.69	0.567	0.45	0.53	0.636	0.34	0.43	-
Yb	2.7	-	1.8	2.67	2.5	2.01	1.6	2.4	2.41	1.37	1.7	-
Lu	0.409	-	0.272	0.409	0.39	0.306	0.23	0.36	0.382	0.24	0.254	-

Sample Center	Q-29B AOD	Q-30 AOD	Q-32 AOD	Q-36 AOD	Q-42 AOD	Q-44 AOD	Q-45 AOD	Q-47 AOD	Q-47A AOD	Q-53 AOD	Q-55 AOD	Q-58 AOD
pct												
SiO ₂	53.8	53.6	51.1	68.6	52.2	53.3	53.2	64.1	52.3	61.5	69	57
TiO ₂	0.82	0.92	0.72	0.51	1.01	0.98	0.94	0.81	1.17	0.81	0.51	1.2
Al ₂ O ₃	17.3	17.8	17.2	15.2	17.7	19.4	17.8	16.1	18	16.5	15.1	16.6
Fe ₂ O ₃	8.43	8.29	8.79	3.06	9.12	8.53	8.49	4.92	8.69	5.9	3.06	8.94
MnO	0.14	0.13	0.14	0.07	0.14	0.14	0.12	0.11	0.13	0.1	0.07	0.14
MgO	5.83	5.48	8	0.85	6.92	3.77	5.55	1.69	5.04	2.89	0.75	3.2
CaO	8.72	8.48	10.7	1.73	8.35	8.37	8.36	3.58	9.09	4.84	1.69	6.67
Na ₂ O	3.3	3.61	2.68	5.13	3.49	4.07	3.61	5.03	3.65	4.63	5.14	4.43
K ₂ O	1.04	1.16	0.65	3.79	0.98	1.05	1.16	2.92	1.07	2.43	3.79	1.48
P ₂ O ₅	0.2	0.23	0.14	0.1	0.23	0.26	0.24	0.24	0.31	0.19	0.1	0.27
LOI	-	-	-	0.08	-	-	0.17	0.56	0.16	0.06	0.23	-
Fe%	-	-	6.2	2.18	6.6	6.14	-	3.43	6.2	4.2	-	-
Na%	-	-	2	3.88	2.84	3.23	-	3.88	2.84	3.32	-	-

Major Elements

Trace Elements

Ba	250	325	182	684	288	306	310	597	336	483	679	365
Co	-	-	37.2	3.32	33.8	24	-	7.6	26.7	15	-	-
Cr	-	-	278	5.6	280	10	-	12	68	38	-	-
Cs	-	-	0.63	5.98	-	0.41	-	4.2	0.72	3.3	-	-
Hf	-	-	1.48	8.08	2.3	2.4	-	6.2	2.9	5.26	-	-
Rb	24	31	15	116	21	23	27	87	28	70	115	38
Sb	-	-	-	0.72	-	-	-	0.55	-	0.42	-	-
Sc	-	-	29	8.55	21.8	20	-	12.7	24	15	-	-
Sr	639	683	622	165	642	766	602	326	673	377	155	513
Ta	-	-	-	0.737	0.2	0.19	-	0.64	0.36	0.48	-	-
Th	-	-	2.51	14.3	2.3	2.16	-	11	2.98	8.1	-	-
U	-	-	0.5	3.28	0.73	0.64	-	2.7	0.72	2.3	-	-
Y	17	19	16	32	17	21	17	27	19	24	33	24
Zn	-	-	75	61.9	94	82	-	81	88	79	-	-
Zr	103	116	81	303	106	122	113	247	131	212	307	136
La	-	-	9.17	28.9	14.1	14.3	-	26.8	18.1	19.9	-	-
Ce	-	-	18	57.5	26.5	28	-	54	36	42	-	-
Ni	-	-	9.5	26	17	17	-	26	21	22	-	-
Sm	-	-	2.63	6.18	3.85	3.97	-	6.27	4.47	5.03	-	-
Eu	-	-	0.695	1.07	1.1	1.1	-	1.3	1.2	1.1	-	-
Gd	-	-	2.9	5.9	2.6	3.3	-	5.7	3.8	4.1	-	-
Tb	-	-	0.34	0.44	0.47	0.52	-	0.8	0.5	0.67	-	-
Yb	-	-	1.2	3.18	1.7	1.9	-	2.7	1.4	2.2	-	-
Lu	-	-	0.19	0.478	0.23	0.27	-	0.41	0.21	0.35	-	-

Sample Center	No.	Q-60 AOD	Q-62 AOD	Q-63 AOD	Q-64 AOD	Q-66 AOD	D2-1-24F AOD	D2-1-25A AOD	D2-1-25B AOD	C85-2 AOD	SED-1 RMS	SED-3 RMS	SED-5 RMS
Major Elements													
pct													
SiO ₂	55	64.7	61.9	60.6	-	-	-	-	58.5	52.8	58.8	58.3	59.5
TiO ₂	1.09	0.83	0.92	1.05	-	-	-	-	0.98	0.96	0.89	0.96	1.06
Al ₂ O ₃	17.8	16.1	16.6	16.5	-	-	-	-	16.9	19.3	16.2	15.1	16.1
Fe ₂ O ₃	8.62	4.77	6.12	6.76	-	-	-	-	6.21	8.54	6.86	7.35	7.52
MnO	0.13	0.11	0.12	0.14	-	-	-	-	0.11	0.14	0.13	0.12	0.11
MgO	3.51	1.34	1.93	2.11	-	-	-	-	3.36	4.32	1.87	2.16	1.94
CaO	7.2	3.28	4.48	4.7	-	-	-	-	5.91	8.08	4.62	6	4.19
Na ₂ O	4.39	5.37	5.08	4.94	-	-	-	-	4.29	3.74	3.62	3.73	3.58
K ₂ O	1.36	2.77	2.31	1.92	-	-	-	-	2.69	1.15	1.84	1.88	1.81
P ₂ O ₅	0.24	0.25	0.25	0.32	-	-	-	-	0.28	0.24	0.23	0.24	0.18
LOI	0.64	0.14	0.24	1.14	-	-	-	-	0.55	0.8	5.03	4.12	3.39
Fe%	6.2	3.51	4.29	-	-	-	-	-	4.42	-	-	-	-
Na%	3.48	4	3.88	-	-	-	-	-	3.2	-	-	-	-

Trace Elements

ppm	Ba	Co	Cr	Cs	Hf	Rb	Sb	Sc	Sr	Ta	Th	U	Y	Zn	Zr	La	Ce	Ni	Sm	Eu	Gd	Tb	Yb	Lu	
338	400	582	512	476	343	723	425	304	429	489	414														
22.5	-	6.6	10.5	-	81	-	17.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	33.3	-	54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.6	-	4.04	3.2	-	0.56	-	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.91	-	5.77	4.8	-	2.64	-	6.64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	49	81	61	45	34	138	135	28	57	54	59														
0.21	-	0.48	0.46	-	0.24	-	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21.3	-	12.7	15.2	-	15.7	-	16.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
525	474	320	383	457	811	103	454	849	396	432	432														
0.29	-	0.553	0.43	-	0.53	-	0.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.66	-	9.6	7.57	-	3.15	-	16.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	2.3	2	-	0.56	-	4.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	19	28	24	25	19	34	28	21	24	21	23														
92	-	79	80	-	103	-	91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
125	147	220	190	169	124	342	233	101	155	192	206														
14	-	23.9	21	-	14	-	24.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	-	49.9	41.3	-	28.9	-	53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	22	22	-	16	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.01	-	5.72	5.22	-	3.72	-	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1	-	1.34	1.2	-	0.955	-	1.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.2	-	5.2	5.1	-	3.3	-	6.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.52	-	0.81	0.69	-	0.44	-	0.73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.6	-	2.5	2.5	-	1.5	-	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.26	-	0.44	0.39	-	0.213	-	0.323	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample No. Center	SED-7 RMS	SED-9 RMS	SED-10 RMS	T-5 CT	T-12 CT	T-15 CT	T-17 CT	T-20 CT	T-41 CT	T-49 CT	T-53 CT	T-55 CT
pct												
SiO ₂	60	74.4	58.9	63.3	59.9	57.1	61.4	62.2	61.1	62.2	62.2	62.2
TiO ₂	0.9	0.8	1.19	0.56	0.79	0.91	0.63	0.59	0.68	0.72	0.65	0.64
Al ₂ O ₃	16.6	11	15.3	16.6	17.6	17.3	16.8	16.8	17	17.3	16.6	16.7
Fe ₂ O ₃	6.81	3.79	8.72	4	5.28	6.24	4.51	4.17	4.91	4.82	4.26	4.61
MnO	0.13	0.11	0.15	0.07	0.07	0.09	0.07	0.07	0.07	0.07	0.06	0.07
MgO	2.19	0.84	2.85	2.16	2.55	4.01	2.8	2.35	2.7	2.63	2.46	2.73
CaO	4.27	1.42	4.56	4.22	5.83	6.4	4.81	4.43	5.02	4.89	4.48	4.71
Na ₂ O	3.97	1.65	3.3	4.66	4.4	4.09	4.71	4.75	4.43	4.48	4.48	4.43
K ₂ O	2.05	2.36	1.59	2.34	2.07	1.81	2.22	2.39	2.39	2.37	2.58	2.48
P ₂ O ₅	0.19	0.05	0.19	0.25	0.3	0.27	0.24	0.24	0.25	0.25	0.23	0.22
LOI	3.02	3.05	3.31	1.13	0.64	1.11	1.04	1.54	0.75	0.44	1.35	0.56
Fe%	-	-	-	2.97	4.1	4.6	-	3.11	3.45	3.45	3.2	3.02
Na%	-	-	-	3.73	3.3	3	-	3.5	3.2	3.4	3.6	3.3

Major Elements

Trace Elements

	434	468	394	768	565	568	718	730	668	650	815	771
Ba	-	-	-	10.4	14.8	21.2	-	11.3	13	12.9	12	11.2
Co	-	-	-	31.3	31	77	-	34.4	26.5	53.8	45	32.3
Cr	-	-	-	1.92	3.4	1.2	-	1.68	2.13	1.4	2.44	2.34
Cs	-	-	-	4.45	3.91	4	-	4.23	4.45	4.41	4.22	4.25
Hf	-	-	-	57	54	40	59	60	67	61	72	72
Rb	61	78	46	0.23	-	0.23	-	0.27	0.27	0.28	0.29	0.32
Sb	-	-	-	7.19	11	14	-	8.05	9.35	8.9	8.52	7.99
Sc	-	-	-	733	872	719	788	793	723	692	702	673
Sr	390	127	363	0.689	0.54	0.39	-	0.559	0.606	0.555	0.566	0.58
Ta	-	-	-	5.61	4.9	3.56	-	6.01	6.54	6.02	6.01	6.5
Th	-	-	-	1.3	1.3	0.75	-	1.6	1.7	1.6	1.9	1.9
U	-	-	-	60.5	74	77	19	13	18	18	16	15
Y	22	20	25	15	18	17	19	65	67.1	65.6	58.7	61.5
Zn	-	-	-	185	167	184	197	191	188	197	184	182
Zr	163	237	191	27.8	23	21	-	27.1	26.4	23.2	25.1	25.3
La	-	-	-	50.9	47.6	43	-	49.4	48.7	44.9	46.3	46
Ce	-	-	-	23	22	19	-	21	21	22	22	20
Ni	-	-	-	4.16	4.47	4.52	-	4	4.36	4.12	4.04	3.84
Sm	-	-	-	1.1	1.18	1.3	-	1.05	1.11	1.09	1.11	0.99
Eu	-	-	-	3.3	4	3.2	-	3.1	3.3	3.3	3.3	3.3
Gd	-	-	-	0.37	0.5	0.51	-	0.39	0.43	0.23	0.36	0.19
Tb	-	-	-	1.1	1.1	1.1	-	0.96	1.17	1.15	0.97	1
Yb	-	-	-	0.15	0.2	0.18	-	0.166	0.18	0.179	0.15	0.16
Lu	-	-	-	-	-	-	-	-	-	-	-	-

Sample No. Center	T-57 CT	T-65 CT	T-6 TT	T-27 TT	T-29 TT	T-31 TT	T-32 TT	T-33 TT	T-38i TT	T-48 TT	T-84 CA	T-85 CA
Major Elements												
pct												
SiO ₂	59.7	62.2	62	76.2	58	77.2	56.1	56.9	73.9	62.6	58	56
TiO ₂	0.69	0.63	0.71	0.1	0.86	0.12	0.97	0.93	0.09	0.54	0.8	1
Al ₂ O ₃	16.7	16.9	16.2	12.8	17.3	13.4	17.7	17.6	13.2	16.2	17.8	17.2
Fe ₂ O ₃	4.86	4.4	5.01	1.07	6.68	0.51	7.59	7.03	0.16	3.42	6.18	7.13
MnO	0.07	0.07	0.07	0.03	0.1	0.02	0.11	0.1	0.04	0.05	0.1	0.11
MgO	2.81	2.48	2.76	0.21	3.7	0.41	4.53	3.83	0.1	1.87	3.11	3.77
CaO	4.85	4.55	4.67	0.48	5.98	0.42	6.94	6.32	0.97	3.63	6.4	7.03
Na ₂ O	4.4	4.62	3.96	4.66	4.05	1.54	4.02	4	4.23	4.01	4.23	3.91
K ₂ O	2.39	2.33	3.27	3.71	2.4	4.93	1.94	2.17	4.08	3.89	2	1.91
P ₂ O ₅	0.26	0.24	0.21	-	0.26	-	0.28	0.28	0.05	0.15	0.26	0.32
LOI	2.58	0.87	0.73	0.68	0.06	0.74	-	0.47	0.69	2.84	0.78	1.3
Fe%	3.41	3.17	3.64	0.718	4.92	0.387	5.47	-	0.13	2.53	4.4	5.16
Na%	3.3	3.7	2.9	3	3	1.1	2.9	-	3	3	3.32	3.11

Trace Elements

	T-57 CT	T-65 CT	T-6 TT	T-27 TT	T-29 TT	T-31 TT	T-32 TT	T-33 TT	T-38i TT	T-48 TT	T-84 CA	T-85 CA
Trace Elements												
ppm												
Ba	724	706	617	138	517	240	474	507	461	623	626	571
Co	13.5	11.9	14.9	0.46	21.2	0.844	24.8	-	0.2	12.1	19	19.6
Cr	43.2	35.3	36.5	-	38.3	-	61.5	-	-	22.1	23	44.2
Cs	1.89	1.76	5.69	2.48	3.59	7.58	2.4	-	5.83	7.77	0.99	1.2
Hf	4.32	4.19	5.96	5.3	5.3	6.06	4.6	-	4.09	7.86	3.9	4.52
Rb	63	64	122	119	86	247	62	62	134	163	50	42
Sb	0.32	0.27	0.89	0.5	0.57	0.46	0.44	-	0.63	1.3	-	0.25
Sc	8.2	8.19	10	2.97	14.3	2.83	17.4	-	2.1	6.7	14	17.3
Sr	732	741	549	37	589	40	634	630	194	457	739	747
Ta	0.531	0.527	1	1.4	0.729	1.56	0.59	-	1.4	1.25	0.42	0.44
Th	5.57	6.03	14.8	15.5	9.54	16.3	6.8	-	7.88	20.3	4.13	3.89
U	1.5	1.5	4.82	3.6	2.5	3.98	1.7	-	4.2	5.63	1	0.72
Y	16	16	23	41	24	53	24	24	21	24	19	22
Zn	71.8	65.8	67.9	8.9	82.5	17	81.1	24	39	55.8	72	85
Zr	202	194	241	132	220	156	200	216	120	306	181	206
La	24.8	26.9	31.8	48.8	27.2	48.8	23.6	-	7.7	34.1	22.7	25.5
Ce	46.4	47	62.9	110	52.4	102	46.6	-	16	66	43	49.1
Nd	23	21	27	45	24	41.3	23	-	7.3	29	22	26
Sm	4.15	4	5.59	9.26	5.16	9.11	5.05	-	2.63	5.24	4.4	5.29
Eu	1.13	1.05	1.06	0.29	1.15	0.327	1.18	-	0.31	0.931	1.1	1.3
Gd	3.1	H	4.1	8.2	4.8	9.3	4.2	-	2.9	5.4	-	-
Tb	0.37	0.33	0.59	1.34	0.6	0.99	0.5	-	0.61	0.57	0.48	0.62
Yb	0.93	0.997	1.8	4.8	1.69	5.21	1.6	-	3.2	1.8	1.6	1.7
Lu	0.14	0.159	0.27	0.75	0.261	0.78	0.261	-	0.47	0.278	0.21	0.26

Sample No. Center	T-88 CA	T-95 CA	T-99 CA	T-100 CA	T-109 CA	T-110 CA	VP-1 VP	VP-2 VP	VP-4 VP	VP-5 VP	VP-8 VP	VP-10 VP
Major Elements												
pct												
SiO ₂	60.6	61.2	58.3	57.8	56	62	56.1	60.1	65.7	66	62	53
TiO ₂	0.63	0.7	0.81	0.79	0.95	0.66	0.95	0.66	0.41	0.41	0.54	0.89
Al ₂ O ₃	17	17	17.8	18.1	18	15.8	18.6	17.8	16.9	17	16.8	19.8
Fe ₂ O ₃	5.08	5.2	6.31	6.12	7.16	4.97	7.67	6.47	3.64	3.59	5.23	8.11
MnO	0.09	0.08	0.1	0.09	0.11	0.07	0.13	0.11	0.12	0.12	0.1	0.13
MgO	2.53	2.97	3.32	3.17	3.92	3.35	3.1	2.62	1.06	1.08	1.9	4.14
CaO	5.08	5.14	6.15	6.06	6.71	4.61	7.1	5.6	3.19	3.19	4.5	9.76
Na ₂ O	4.46	4.36	4.34	4.59	3.91	3.96	4.37	4.4	5.14	5.15	4.2	3.01
K ₂ O	2.52	2.42	2.19	1.88	1.83	3	1.48	2.05	2.55	2.55	2.57	1.18
P ₂ O ₅	0.27	0.25	0.3	0.33	0.28	0.2	0.29	0.27	0.25	0.24	0.25	0.17
LOI	1.43	0.32	0.36	0.7	1.25	0.78	0.56	0.29	0.9	0.35	1.19	-
Fe%	3.51	-	-	4.47	5.09	3.54	5.4	4.44	-	2.55	3.66	5.84
Na%	3.35	-	-	3.63	3.11	3.12	3.24	3.29	-	4.07	3.29	2.32

Trace Elements

ppm	T-88 CA	T-95 CA	T-99 CA	T-100 CA	T-109 CA	T-110 CA	VP-1 VP	VP-2 VP	VP-4 VP	VP-5 VP	VP-8 VP	VP-10 VP
Ba	791	678	718	645	481	628	408	488	698	683	556	327
Co	11	-	-	18.2	22	15.7	19	15	-	3.6	10.9	23
Cr	20	-	-	25	54	114	11	8.2	-	-	4.4	47
Cs	1.6	-	-	1.5	1.2	4.25	1.7	3.1	-	2.7	4.37	1.1
Hf	4.9	-	-	4.51	4	4.91	3.2	3.44	-	4.9	3.88	2.69
Rb	61	68	46	46	50	95	37	68	71	70	89	34
Sb	0.21	-	-	0.31	-	0.83	-	0.37	-	0.36	0.56	-
Sc	9.3	-	-	10.8	15	10.8	17	11.2	-	3.41	8.35	25.6
Sr	712	771	727	856	705	554	614	575	484	491	508	512
Ta	0.51	-	-	0.47	0.5	0.874	0.34	0.56	-	0.61	0.706	0.3
Th	5.41	-	-	4.45	4.8	10.8	4.3	7.68	-	8.16	10.3	4.78
U	1.3	-	-	1	1.4	3.5	1.3	2.4	-	2.4	3.4	1.3
Y	19	18	18	16	21	19	21	20	20	21	22	18
Zn	64	-	-	82	78	60	82	71	-	64	63	79
Zr	184	184	247	209	175	208	132	148	203	208	163	118
La	29.4	-	-	25.1	22.2	27.4	18.3	21.4	-	28.8	25	16
Ce	55	-	-	48	43	51	36	42	-	54	48	31.5
Ni	25	-	-	24	22	21	24	21	-	23	22	20
Sm	4.72	-	-	4.29	4.89	4.52	4.74	4.5	-	4.68	4.5	3.87
Eu	1.2	-	-	1.2	1.2	0.961	1.2	0.99	-	1.07	0.97	1
Gd	-	-	-	-	-	-	-	-	-	-	-	-
Tb	0.49	-	-	0.49	0.57	0.47	0.61	0.6	-	0.5	0.58	0.57
Yb	1.4	-	-	1.1	1.4	1.2	1.9	1.8	-	1.8	1.8	1.9
Lu	0.21	-	-	0.16	0.21	0.21	0.28	0.29	-	0.29	0.3	0.28

Sample Center	No.	VP	VT-1	VT-2	VT-3	VT-6	VT-7	VT-9	VT-10	VT-11	VT-12	VT-13	VT-20
Major Elements													
pct													
SiO ₂		74.5	58.4	57.9	57.4	58.8	60.7	59.9	60.4	56.6	64.9	60.8	61.9
TiO ₂		0.06	0.94	0.88	0.86	0.86	0.82	0.85	0.88	1.09	0.8	0.82	0.8
Al ₂ O ₃		13.2	17	16.9	16.7	16.9	16.8	16.8	16.8	17.6	14.7	16.7	16.2
Fe ₂ O ₃		0.78	7.08	7.06	7.01	6.56	5.99	6.46	6.35	7.8	3.09	6.07	5.35
MnO		0.07	0.11	0.12	0.11	0.1	0.09	0.1	0.1	0.12	0.06	0.09	0.08
MgO		0.11	3.61	3.96	3.8	3.08	2.71	3.16	2.95	3.66	1.55	2.96	2.25
CaO		0.61	6.5	6.62	6.52	5.77	5.33	5.65	5.52	7.02	2.99	5.29	4.49
Na ₂ O		4.41	3.84	3.72	3.53	3.79	4.06	3.91	4	3.97	3.13	4.05	4
K ₂ O		4.05	2.59	2.43	2.49	2.71	2.93	2.83	3.02	2.16	3.64	2.93	3.56
P ₂ O ₅		-	0.2	0.2	0.19	0.21	0.2	0.2	0.2	0.23	0.1	0.21	0.19
LOI		1.38	-	0.46	1.36	0.96	0.45	0.16	0.12	0.2	4.6	0.14	1.06
Fe%		0.65	4.87	4.76	4.93	4.1	4.48	4.66	4.64	5.75	3.95	4.51	3.65
Na%		3.38	2.89	2.71	2.67	2.92	3.12	3.02	3.03	3.1	2.91	3.07	3.11

Trace Elements

ppm	Ba	Co	Cr	Cs	Hf	Rb	Sb	Sc	Sr	Ta	Th	U	Y	Zn	Zr	La	Ce	Nd	Sm	Eu	Gd	Tb	Yb	Lu
688	401	19.1	42.5	6.29	5.51	115	0.87	18.6	509	0.57	8.6	3.4	19	22	70	14	28.6	12	3.16	3.38	4.5	0.64	1.9	0.266
0.37	19.1	42.5	6.29	5.51	115	0.87	18.6	509	0.57	8.6	3.4	19	22	70	14	28.6	12	3.16	3.38	4.5	0.64	1.9	0.266	
0.86	0.87	19.3	4.93	0.79	0.87	0.69	0.88	14.2	451	0.68	16.6	4.49	26	76	210	21.1	43	25	4.95	0.99	1.1	0.58	2.1	0.33
2.76	18.6	19.3	4.93	0.79	0.87	0.69	0.88	14.2	451	0.68	16.6	4.49	26	76	210	21.1	43	25	4.95	0.99	1.1	0.58	2.1	0.33
156	509	487	487	487	474	459	451	443	453	553	343	452	122	161	122	161	122	161	122	161	122	161	122	161
1.05	0.57	0.5	0.5	0.5	0.51	0.63	0.68	16.1	16.1	0.7	17.9	4.5	5.92	0.68	0.79	20.8	17	0.7	0.53	11.5	5.7	4.7	5.6	0.78
8.6	14.9	12.6	3.3	3.3	3.5	4.4	4.49	16.1	16.1	0.7	17.9	4.5	5.92	0.68	0.79	20.8	17	0.7	0.53	11.5	5.7	4.7	5.6	0.78
3.4	4.3	3.3	3.3	3.3	3.5	4.4	4.49	16.1	16.1	0.7	17.9	4.5	5.92	0.68	0.79	20.8	17	0.7	0.53	11.5	5.7	4.7	5.6	0.78
19	22	23	23	23	24	26	24	24	24	21	24	24	24	24	24	24	24	24	24	24	24	24	24	24
22	72.4	76	76	76	74	57	66	71	68.8	78	57	68	55	55	55	55	55	55	55	55	55	55	55	55
70	216	210	210	210	200	215	240	230	242	186	291	220	289	289	289	289	289	289	289	289	289	289	289	289
14	22.7	21.1	21.1	21.1	21.2	25.1	25.3	25.4	24.7	20.1	25.8	23.8	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6
28.6	46.6	43	43	43	43	48.8	52.8	53	51.9	43.1	54.6	50.4	57	57	57	57	57	57	57	57	57	57	57	57
12	24	24	24	24	25	25	25	26	22	21	25	22	27	27	27	27	27	27	27	27	27	27	27	27
3.16	5.17	4.95	4.95	4.95	5.02	5.39	5.48	5.37	5.48	5.08	5.53	5.21	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
0.436	1.01	0.99	0.99	0.99	1.1	0.99	1.08	1.1	1.05	1.2	0.96	1	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
3.8	4.5	0.58	0.58	0.58	0.7	0.65	0.58	0.61	0.6	0.63	0.57	0.53	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
0.496	0.64	2.1	2.1	2.1	2.1	1.9	2	1.9	2.1	1.7	2	1.8	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
1.9	2.1	2.1	2.1	2.1	2.1	1.9	2	1.9	2.1	1.7	2	1.8	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
0.266	0.31	0.33	0.33	0.33	0.35	0.31	0.29	0.28	0.31	0.26	0.31	0.28	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31