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**ELECTRON MICROPROBE ANALYSES OF MINERALS
IN CORE SAMPLES FROM DRY VALLEY DRILLING
PROJECT (DVDP) HOLES 1 AND 2, ROSS ISLAND,
ANTARCTICA.**

Philip R. Kyle

**N. Z. ANTARCTIC RESEARCH PROGRAMME
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Philip R. Kyle
Antarctic Research Centre
Department of Geology
Victoria University of Wellington
Private Bag
WELLINGTON, NEW ZEALAND

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INTRODUCTION

This paper presents quantitative electron microprobe analyses of minerals in core samples from the Dry Valley Drilling Project (DVDP) holes 1 and 2. Preliminary petrographic descriptions of some of the samples and detailed core logs are given elsewhere (Treves and Kyle, 1973).

In the tables contained herein the analysed samples are listed in order of increasing depth within each hole. The sample number refers firstly to the hole and this is followed by the depth in metres. Analyses for all ferromagnesium minerals are listed in order of increasing FeO. Felspars and apatites are listed by increasing Na₂O and CaO respectively. Where there is more than one analysis per grain the core is always listed first. To designate the position of analysis the following symbols are used:

- C - core
- R - rim
- I - intermediate between core and rim

Scans were made to determine the homogeneity of grains and where only one analysis is presented this usually indicates no zoning or only weak zoning. In such grains the analysis was made near the centre.

The following lower case symbols were used where applicable to denote the type of crystal analysed:

- a - alteration product
- g - groundmass; used only when the sample was porphyritic
- i - inclusion within another mineral
- x - xenocryst
- (010) - sector when crystal showed sector zoning.

Analytical Method

Analyses were made using a Japanese Electron Optics Laboratory electron probe X-ray microanalyser Model JXA-5A at the Department of Geology, University of Otago. Instrumental settings were: 15kV accelerating potential, 2.0 to 3.0 X10⁻⁸ amps specimen current on periclase and a 1-2 μm beam size. Corrections for absorption, fluorescence and atomic number were applied using the method of Bence and Albee (1968) and the alpha correction factors, for a 40° takeoff angle, listed in Kushiro and Nakamura (1970). Corrections for dead-time, background and drift were made. Each complete analysis and also the partial analyses of pyroxenes and olivines represents a minimum of 5 individual 10 second counts per element. For the feldspars it was usual only to accumulate a single 10 second count. Corrections for the partial analyses were made assuming the mineral was stoichiometric and consisted purely of the end members CaSiO₃, MgSiO₃, FeSiO₃ for the pyroxenes, Fe₂SiO₄, Mg₂SiO₃ for the olivines and KAlSi₃O₈, NaAlSi₃O₈, CaAl₂Si₂O₈ for the feldspars. Data was reduced at the Computer Centre, University of Canterbury.

Standard materials were as follows: natural albite from Amelia (Na), adularia from Gotthard (K), hematite from Sennin Mine (Fe), maganosite from Nodatamagawa Mine (Mn); synthetic corundum (Al), wollastonite (Ca, Si), NiO(Ni), Cr₂O₃ (Cr), periclase (Mg), rutile (Ti).

In all analyses total iron was determined as FeO, in the pyroxenes however Fe₂O₃ was calculated by allotting equivalent amounts of Fe₂O₃ to Na₂O.

Recalculation of magnetite and ilmenite analyses were made using the methods of Carmichael (1967). For the spinels total Fe has been assigned to Fe²⁺ and Fe³⁺ on the assumption of a formula R²⁺R₂³⁺O₄ with dissolved Fe₂TiO₄.

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TABLE 1

Electron Microprobe Analyses of Olivines in DVDP 1 and 2 Core Samples

Sample Grain	1-121.88		6C	6R	4	2C	2R	8	7-g	3-g
	1C	1R								
SiO ₂	39.5	39.4	39.2		38.8	38.0	37.1	38.4	38.2	36.8
Al ₂ O ₃	0.05	0.06	0.03		0.07	0.06	0.05	0.04	0.06	0.03
TiO ₂	0.03	0.03	0.02		0.05	0.03	0.06		0.02	0.05
FeO	13.2	14.3	14.3	20.1	15.1	16.3	22.2	18.8	20.3	23.2
MnO	0.17	0.19	0.19		0.19	0.20	0.44	0.31	0.25	0.49
MgO	46.1	44.8	44.6	39.7	44.3	42.7	37.8	40.6	40.2	37.7
CaO	0.26	0.30	0.29	0.33	0.28	0.34	0.38	0.20	0.19	0.36
NiO	0.21	0.15	0.15		0.08	0.15	0.11	0.13	0.09	0.06
Cr ₂ O ₃	0.03	-	-		-	-	-	-	-	-
Sum	99.55	99.23	98.78		98.87	97.78	98.14	98.48	99.31	98.69

Number of Ions on the Basis of 4(0)

Si	0.991	0.997	0.996		0.989	0.986	0.989	0.999	0.992	0.980
Al	0.001	0.002	0.001		0.002	0.002	0.001	0.001	0.002	0.001
Ti	-	-	-		0.001	-	0.001	-	-	0.001
Fe	0.277	0.302	0.304		0.322	0.355	0.495	0.410	0.442	0.517
Mn	0.004	0.004	0.004		0.004	0.004	0.010	0.007	0.006	0.011
Mg	1.723	1.686	1.687		1.682	1.652	1.501	1.575	1.558	1.497
Ca	0.007	0.008	0.008		0.008	0.010	0.011	0.006	0.005	0.010
Ni	0.004	0.003	0.003		0.002	0.003	0.002	0.003	0.002	0.001
Cr	0.004	-	-		-	-	-	-	-	-
Z	0.991	0.997	0.996		0.989	0.986	0.989	0.999	0.992	0.980
X	2.020	2.005	2.007		2.021	2.026	2.021	2.002	2.015	2.038
Sum	3.001	3.002	3.003		3.010	3.012	3.010	3.001	3.007	3.018
Fo	86.2	84.8	84.7	77.9	83.9	82.3	75.2	79.4	77.9	74.3
Fa	13.8	15.2	15.3	22.1	16.1	17.7	24.8	20.6	22.1	25.7

Sample Grain	1-131.36		1-187.64		1I	1R	3	5C	5R	6
	1	1C	1I	1I						
SiO ₂	37.8	39.5			39.6	39.7	40.1	39.9	39.8	
Al ₂ O ₃	0.06	0.11			0.05	0.04	0.06	0.06	0.04	
TiO ₂	0.04	0.03			0.04	0.03	0.03	-	-	
FeO	22.2	16.3	16.7	15.4	16.2	13.2	13.6	13.7	13.8	14.0
MnO	1.05	0.25			0.23	0.20	0.20	0.17	0.21	
MgO	38.0	44.3	43.9	45.3	44.4	46.3	46.4	46.2	45.9	46.1
CaO	0.43	0.31	0.30	0.32	0.30	0.36	0.34	0.36	0.41	0.38
NiO	nd	0.09			0.11	0.17	0.21	0.21	0.22	
Cr ₂ O ₃	nd	-			-	0.03	0.03	0.03	-	
Sum	99.58	100.79			100.93	100.03	100.97	100.63	100.38	

Number of Ions on the Basis of 4(0)

Si	0.993	0.991			0.992	0.990	0.992	0.991	0.992	
Al	0.002	0.003			0.002	0.001	0.002	0.002	0.001	
Ti	0.001	-			0.001	-	-	-	-	
Fe	0.489	0.342			0.339	0.276	0.281	0.284	0.288	
Mn	0.023	0.005			0.005	0.004	0.004	0.004	0.004	
Mg	1.486	1.655			1.658	1.723	1.712	1.712	1.705	
Ca	0.012	0.008			0.008	0.010	0.009	0.010	0.011	
Ni	-	0.002			0.002	0.003	0.004	0.004	0.004	
Cr	-	-			-	0.001	0.001	0.001	-	
Z	0.993	0.991			0.992	0.990	0.992	0.991	0.992	
X	2.013	2.015			2.015	2.018	2.013	2.019	2.013	
Sum	3.006	3.006			3.007	3.008	3.005	3.008	3.005	
Fo	75.2	82.9	82.4	84.0	83.0	86.2	85.9	85.8	85.6	85.4
Fa	24.8	17.1	17.6	16.0	17.0	13.8	14.1	14.2	14.4	14.6

TABLE 1 Continued

Sample Grain	1-187.64 cont.			2-39.28					2-62.41
	4C-g	4R-g	2	2-x	4-x	1C-x	1R-x	3-x	1-x
SiO ₂	40.1			38.8	38.6	39.1		38.5	35.1
Al ₂ O ₃	0.05			-	-	-		-	0.03
TiO ₂	0.05			-	0.03	-		0.05	-
FeO	14.3	16.4	15.0	16.4	17.15	17.2	22.5	17.9	34.1
MnO	0.22			0.24	0.27	0.24	0.56	0.24	1.45
MgO	45.4	43.6	45.1	43.2	43.0	42.8	38.4	42.1	28.7
CaO	0.47	0.54	0.38	0.29	0.30	0.30		0.27	0.26
NiO	0.20			n.d.	n.d.	n.d.		n.d.	-
Cr ₂ O ₃	-			n.d.	n.d.	n.d.		n.d.	-
Sum	100.79			98.93	99.35	99.64		99.06	99.64

Number of Ions on the Basis of 4 (0)

Si	0.998			0.993	0.989	0.997		0.990	0.982
Al	0.001			-	-	-		-	0.001
Ti	0.001			-	0.001	-		0.001	-
Fe	0.298			0.351	0.367	0.367		0.386	0.797
Mn	0.005			0.005	0.006	0.005		0.005	0.034
Mg	1.682			1.650	1.640	1.625		1.618	1.195
Ca	0.013			0.008	0.008	0.008		0.007	0.008
Ni	0.004			-	-	-		-	-
Cr	-			-	-	-		-	-
Z	0.998			0.993	0.989	0.997		0.990	0.982
X	2.004			2.014	2.022	2.005		2.017	2.035
Sum	3.002			3.007	3.011	3.002		3.007	3.017
Fo	85.0	82.6	84.3	82.5	81.7	81.6	75.3	80.8	60.0
Fa	15.0	17.4	15.7	17.5	18.3	18.3	24.7	19.2	40.0

Sample Grain	2-99.34				2-103.15				
	1	3	4-i	2	1	5-i	4	2	3
SiO ₂	40.0	40.0	39.5	39.3	39.9	39.0	38.2	38.3	38.5
Al ₂ O ₃	0.09	0.07	0.08	0.09	0.08	0.06	0.07	0.05	0.07
TiO ₂	-	-	0.03	0.05	0.03	0.03	-	0.03	-
FeO	11.9	13.2	14.9	16.5	12.6	17.5	17.6	20.3	20.6
MnO	0.16	0.17	0.20	0.23	0.20	0.24	0.39	0.28	0.32
MgO	47.9	47.0	45.1	44.2	46.35	42.3	41.9	39.8	39.5
CaO	0.25	0.18	0.39	0.35	0.29	0.31	0.32	0.24	0.22
NiO	0.21	0.28	0.15	0.10	0.24	0.09	0.16	0.06	0.04
Cr ₂ O ₃	0.05	0.06	0.03	-	-	-	-	-	-
Sum	100.56	100.96	100.38	100.82	99.69	99.53	98.64	99.06	99.25

Number of Ions on the Basis of 4 (0)

Si	0.986	0.988	0.989	0.988	0.995	0.997	0.989	0.998	1.001
Al	0.003	0.002	0.002	0.003	0.002	0.002	0.002	0.001	0.002
Ti	-	-	-	0.001	0.001	0.001	-	0.001	-
Fe	0.246	0.273	0.313	0.346	0.264	0.374	0.381	0.442	0.448
Mn	0.003	0.004	0.004	0.005	0.004	0.005	0.008	0.006	0.007
Mg	1.761	1.731	1.684	1.656	1.724	1.611	1.617	1.544	1.533
Ca	0.007	0.005	0.010	0.009	0.008	0.009	0.009	0.007	0.006
Ni	0.004	0.006	0.003	0.002	0.005	0.002	0.003	0.001	0.001
Cr	0.001	0.001	0.001	-	-	-	-	-	-
Z	0.986	0.988	0.989	0.988	0.995	0.997	0.989	0.998	1.001
X	2.025	2.022	2.017	2.022	2.008	2.004	2.020	2.002	1.997
Sum	3.011	3.010	3.006	3.010	3.003	3.001	3.009	3.000	2.998
Fo	87.3	86.4	84.3	82.7	86.7	81.2	80.9	77.7	77.4
Fa	12.3	13.6	15.7	17.3	13.3	18.8	19.1	22.3	22.6

TABLE 2

Electron Microprobe Analyses of Pyroxene in DVDP 1 and 2 Core Samples

Sample Grain	1-57.94		1-85.35				1-88.55		
	1	2	1C	1I	1R	2R	5-g	1R-g	4-g
SiO ₂		48.3	46.0	45.1	46.0	48.9	48.7	48.6	48.4
Al ₂ O ₃		4.14	6.79	7.17	7.20	3.59	3.24	4.27	3.44
TiO ₂		1.65	2.15	1.89	2.37	1.54	1.76	1.64	1.69
FeO	8.29	9.12	15.5	16.0	13.5	8.65	8.66	8.85	10.3
MnO		0.41	0.59	0.58	0.48	0.44	0.40	0.42	0.42
MgO	12.3	12.4	6.22	5.99	7.58	12.2	12.5	12.1	12.1
CaO	25.2	22.8	21.0	20.8	21.2	22.5	22.7	22.3	22.7
Na ₂ O		0.79	1.17	1.22	1.13	0.74	0.69	0.81	0.70
Cr ₂ O ₃		n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sum		99.61	99.42	98.75	99.46	98.56	98.65	98.99	99.75
Fe ₂ O ₃		2.04	3.01	3.14	2.91	1.91	1.78	2.09	1.80
FeO		7.28	12.8	13.2	10.9	6.93	7.06	6.97	8.68
Total		99.81	99.73	99.09	99.77	98.75	98.83	99.20	99.93

Number of Ions on the Basis of 6(O)

Si	1.825	1.784	1.766	1.767	1.859	1.853	1.840	1.837
Al	0.175	0.216	0.234	0.233	0.141	0.145	0.160	0.154
Ti	-	-	-	-	-	0.002	-	0.009
Al	0.009	0.094	0.097	0.092	0.019	-	0.031	-
Ti	0.047	0.063	0.056	0.068	0.044	0.048	0.047	0.039
Fe ³⁺	0.058	0.088	0.093	0.084	0.055	0.051	0.060	0.051
Fe ²⁺	0.230	0.415	0.432	0.350	0.220	0.225	0.221	0.276
Mn	0.013	0.019	0.019	0.016	0.014	0.013	0.014	0.014
Mg	0.698	0.360	0.350	0.434	0.692	0.709	0.683	0.684
Ca	0.923	0.872	0.873	0.872	0.917	0.926	0.905	0.923
Na	0.058	0.088	0.093	0.084	0.055	0.051	0.060	0.052
Cr	-	-	-	-	-	-	-	-
Z	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
XY	2.036	1.999	2.013	2.002	2.016	2.024	2.018	2.038
Ca	51.7	48.0	49.7	49.4	49.7	48.3	48.1	47.4
Mg	35.0	36.3	20.5	19.8	24.7	36.5	36.9	35.1
*Fe _T +Mn	13.3	15.7	29.8	30.8	25.6	15.2	15.0	17.5
Na	5.8	10.0	10.4	9.5	5.6	5.1	6.1	5.0
Mg ₂₊	69.9	40.8	39.1	49.1	70.5	71.1	69.9	66.8
Fe ₂₊ +Mn	24.3	49.2	50.5	41.4	23.9	23.8	24.0	28.2

$$*Fe_T = Fe^{2+} + Fe^{3+}$$

TABLE 2 continued

Sample 1-121.88									
Grain	6C	6I	6I	6I	6R	5C	5I	5R	2
SiO ₂	45.2				45.7				45.7
Al ₂ O ₃	10.2				7.45				8.78
TiO ₂	4.28				4.05				2.71
FeO	6.00	6.64	5.64	6.54	6.69	5.75	5.52	7.15	6.94
MnO	0.05				0.08				0.09
MgO	12.2	12.1	12.5	11.1	12.4	12.6	12.8	10.8	12.2
CaO	22.2	22.7	22.6	22.7	22.6	21.9	22.1	22.9	21.0
Na ₂ O	0.57				0.44				0.94
Cr ₂ O ₃	0.40				-				0.24
Sum	101.10				99.41				98.60
Fe ₂ O ₃	1.47				1.13				2.42
FeO	4.68				5.67				4.76
Total	101.25				99.52				98.84

Number of Ions on the Basis of 6(0)

Si	1.659				1.715				1.717
Al	0.341				0.285				0.283
Al	0.100				0.095				0.106
Ti ³⁺	0.118				0.114				0.077
Fe ²⁺	0.041				0.032				0.068
Fe	0.144				0.178				0.150
Mn	0.002				0.002				0.003
Mg	0.668				0.694				0.683
Ca	0.873				0.909				0.846
Na	0.041				0.032				0.068
Cr	0.012				-				0.007
Z	2.000				2.000				2.000
XY	1.997				2.006				2.008
Ca	50.6	50.8	50.8	52.4	50.1	49.9	49.9	49.9	48.3
Mg ⁺	38.7	37.6	39.3	35.8	38.2	39.9	40.3	40.3	39.1
Fe ^T +Mn	10.7	11.6	9.9	11.8	11.7	10.2	9.8	9.8	12.6
Na	4.8				3.5				7.6
Mg ²⁺	78.2				76.6				75.6
Fe ²⁺ +Mn	17.0				19.9				16.8

TABLE 2 continued

Sample Grain	1-121.88 cont.					1-131.36			
	4C	4I	4R	3C	3R	1	2	4	3
SiO ₂	46.0	44.3	42.0	43.5	45.6	47.6	47.5	49.9	47.6
Al ₂ O ₃	7.30	9.47	10.4	8.53	8.98	4.85	5.43	3.07	4.66
TiO ₂	2.28	3.90	5.02	1.99	4.32	2.38	2.38	1.31	2.06
FeO	10.7	6.37	7.42	17.6	6.35	7.68	7.79	8.14	8.80
MnO	0.34	0.06	0.07	0.54	0.11	0.38	0.33	0.45	0.39
MgO	9.20	12.0	10.8	4.90	12.8	13.4	13.2	13.6	12.3
CaO	21.6	22.5	22.5	20.4	22.6	21.1	20.6	22.4	21.8
Na ₂ O	1.44	0.55	0.52	1.64	0.46	0.81	0.85	0.56	0.79
Cr ₂ O ₃	0.05	0.34	0.03	-	0.20	n.d.	n.d.	n.d.	n.d.
Sum	98.91	99.49	98.76	99.10	101.42	98.20	98.08	99.43	98.40
Fe ₂ O ₃	3.71	1.42	1.34	4.23	1.19	2.09	2.19	1.44	2.04
FeO	7.36	5.09	6.21	13.8	5.28	5.80	5.82	6.84	6.96
Total	99.28	99.63	98.89	99.53	101.54	98.41	98.30	99.57	98.60

Number of Ions on the Basis of 6(O)

Si	1.755	1.661	1.600	1.710	1.674	1.805	1.800	1.874	1.814
Al	0.245	0.339	0.400	0.290	0.326	0.195	0.200	0.126	0.186
Al	0.083	0.079	0.067	0.105	0.063	0.022	0.042	0.010	0.023
Ti	0.065	0.110	0.144	0.059	0.119	0.068	0.068	0.037	0.059
Fe ³⁺	0.106	0.040	0.038	0.125	0.033	0.060	0.062	0.041	0.058
Fe ²⁺	0.235	0.160	0.198	0.454	0.162	0.184	0.184	0.215	0.222
Mn	0.011	0.002	0.002	0.018	0.003	0.012	0.011	0.014	0.013
Mg	0.523	0.671	0.614	0.287	0.701	0.757	0.746	0.762	0.699
Ca	0.883	0.904	0.919	0.859	0.889	0.857	0.836	0.902	0.890
Na	0.106	0.040	0.038	0.125	0.033	0.060	0.062	0.041	0.058
Cr	0.002	0.010	0.001	-	0.006	-	-	-	-
Z	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
XY	2.015	2.015	2.022	2.033	2.009	2.019	2.011	2.021	2.022
Ca	50.2	50.9	51.9	49.3	49.7	45.8	45.5	46.6	47.3
Mg	29.8	37.8	34.6	16.5	39.2	40.5	40.5	39.4	37.1
Fe _T +Mn	20.0	11.3	13.5	34.2	11.1	13.7	14.0	14.0	15.6
Na	12.2	4.6	4.5	14.1	3.6	5.9	6.2	4.0	5.9
Mg	57.8	76.9	72.0	32.5	78.0	74.8	74.3	73.8	70.5
Fe ²⁺ +Mn	28.0	18.5	23.5	53.4	18.4	19.3	19.5	22.2	23.6

TABLE 2 continued

Sample Grain	1-187.64					2-39.28			
	2	1C	1R	3	4	5-x	4C-x	4R-x	3C
SiO ₂	43.2	42.9	42.3			51.2	51.0	51.0	49.55
Al ₂ O ₃	8.56	10.2	9.93			3.93	4.37	3.75	4.31
TiO ₂	4.52	5.17	5.48			0.82	1.04	0.92	2.24
FeO	6.85	6.96	7.58	6.04	7.32	6.20	6.58	6.66	7.18
MnO	0.10	0.09	0.10			0.16	0.16	0.14	0.24
MgO	11.4	11.4	10.6	14.2	11.5	14.1	14.1	14.0	13.4
CaO	22.6	22.6	22.2	22.5	22.4	22.2	21.45	22.4	22.4
Na ₂ O	0.48	0.45	0.59			1.01	1.21	0.89	0.56
Cr ₂ O ₃	0.31	0.24	0.04			n.d.	n.d.	n.d.	n.d.
Sum	98.02	100.01	98.82			99.62	99.91	99.76	99.88
Fe ₂ O ₃	1.24	1.16	1.52			2.60	3.12	2.29	1.44
FeO	5.73	5.92	6.21			3.86	3.77	4.60	5.88
Total	98.14	100.13	98.97			99.88	100.22	99.99	100.02

Number of Ions on the Basis of 6(O)

Si	1.655	1.610	1.610			1.888	1.874	1.885	1.842
Al	0.345	0.390	0.390			0.112	0.126	0.115	0.158
Al	0.041	0.061	0.056			0.059	0.063	0.048	0.031
Ti ₃₊	0.130	0.146	0.157			0.023	0.029	0.026	0.063
Fe ₂₊	0.036	0.033	0.044			0.072	0.086	0.064	0.040
Fe	0.184	0.186	0.198			0.119	0.116	0.142	0.183
Mn	0.003	0.003	0.003			0.005	0.005	0.004	0.008
Mg	0.651	0.638	0.602			0.775	0.772	0.772	0.743
Ca	0.928	0.909	0.906			0.877	0.844	0.887	0.892
Na	0.036	0.033	0.044			0.072	0.086	0.064	0.040
Cr	0.009	0.007	0.001			-	-	-	-
Z	2.000	2.000	2.000			2.000	2.000	2.000	2.000
XY	2.017	2.015	2.009			2.003	2.001	2.007	2.000
Ca	51.5	51.4	51.7	47.9	50.8	47.5	46.3	47.5	47.8
Mg	36.1	36.1	34.3	42.1	36.2	41.9	42.3	41.3	39.8
Fe _T +Mn	12.4	12.5	14.0	10.0	13.0	10.6	11.4	11.2	12.4
Na	4.1	3.8	5.1			7.4	8.8	6.5	4.1
Mg	74.5	74.2	71.1			79.8	78.9	78.6	76.3
Fe ₂₊ +Mn	21.4	22.0	23.8			12.8	12.3	14.9	19.6

TABLE 2 continued

Sample Grain	2-39.28 cont.		2-54.72					
	3I	3R	11-a	10-a	4	2	3	1
SiO ₂	48.3	43.8	46.6	49.9	49.3	49.1	46.2	44.8
Al ₂ O ₃	4.45	8.01	6.73	3.83	3.76	4.17	6.90	7.57
TiO ₂	2.06	4.32	3.26	1.86	1.69	1.94	2.99	3.96
FeO	7.17	8.28	7.31	7.51	8.09	9.03	9.07	9.70
MnO	0.25	0.22	0.30	0.39	0.37	0.37	0.31	0.27
MgO	13.2	10.9	12.7	13.3	13.0	12.0	11.0	10.3
CaO	22.8	22.3	21.3	21.6	22.6	22.4	22.3	22.3
Na ₂ O	0.64	0.80	0.99	0.70	0.70	0.66	0.89	0.86
Cr ₂ O ₃	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Sum	98.97	98.63	99.19	99.09	99.51	99.67	99.66	99.76
Fe ₂ O ₃	1.65	2.06	2.55	1.80	1.80	1.70	2.29	2.22
FeO	5.69	6.43	5.02	5.89	6.47	7.50	7.01	7.70
Total	99.04	98.84	99.45	99.27	99.69	99.84	99.89	99.98
Number of Ions on the Basis of 6(O)								
Si	1.821	1.673	1.747	1.868	1.851	1.847	1.744	1.699
Al	0.179	0.327	0.253	0.132	0.149	0.153	0.256	0.301
Al	0.019	0.034	0.044	0.037	0.017	0.032	0.051	0.037
Ti ³⁺	0.058	0.124	0.092	0.052	0.048	0.055	0.085	0.113
Fe ³⁺	0.047	0.059	0.072	0.051	0.051	0.048	0.065	0.063
Fe ²⁺	0.179	0.205	0.157	0.184	0.203	0.236	0.221	0.244
Mn	0.008	0.007	0.010	0.012	0.019	0.012	0.010	0.009
Mg	0.742	0.621	0.710	0.742	0.728	0.673	0.619	0.582
Ca	0.921	0.913	0.856	0.866	0.909	0.903	0.902	0.906
Na	0.047	0.059	0.072	0.051	0.051	0.048	0.065	0.063
Z	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
XY	2.021	2.022	2.013	1.996	2.018	2.006	2.018	2.019
Ca	48.5	50.6	47.4	46.7	47.8	48.2	49.6	50.2
Mg	39.1	34.4	39.3	40.0	38.2	26.0	34.1	32.3
Fe _T +Mn	12.4	15.0	13.2	13.3	14.0	15.8	16.3	17.3
Na	4.8	6.6	7.6	5.1	5.1	5.0	7.1	7.0
Mg	76.0	69.6	74.8	75.0	73.3	69.4	67.6	64.8
Fe ²⁺ +Mn	19.2	23.8	17.6	19.9	21.6	25.6	25.3	28.2

TABLE 2 continued

Sample Grain	2-62.41								
	2C	2R	13C	13R	23-x	16C	16R	20-x	4C-x
SiO ₂	45.5	45.0	44.3	44.2	50.4	44.4	43.4	50.2	50.8
Al ₂ O ₃	8.50	8.90	9.47	9.48	4.66	9.50	9.95	4.99	4.64
TiO ₂	3.11	3.20	3.66	3.57	0.88	3.50	3.49	1.07	0.95
FeO	7.26	7.80	7.26	7.67	7.40	7.61	8.65	7.61	7.62
MnO	0.14	0.19	0.11	0.09	0.24	0.14	0.16	0.30	0.31
MgO	12.4	11.6	11.8	11.5	13.5	11.4	10.65	13.2	13.3
CaO	21.8	21.7	22.0	22.05	21.9	22.1	21.85	21.6	21.8
Na ₂ O	0.83	0.70	0.76	0.85	0.88	0.87	0.97	1.08	1.04
Cr ₂ O ₃	-	-	-	-	-	-	-	0.04	0.03
Sum	99.54	99.09	99.36	99.41	99.86	99.52	99.12	100.09	100.49
Fe ₂ O ₃	2.14	1.80	1.96	2.19	2.27	2.24	2.50	2.78	2.68
FeO	5.33	6.18	5.50	5.70	5.36	5.59	6.40	5.11	5.21
Total	99.75	99.27	99.56	99.63	100.09	99.74	99.37	100.37	100.76
Number of Ions on the Basis of 6(0)									
Si	1.703	1.697	1.665	1.663	1.866	1.668	1.646	1.854	1.869
Al	0.297	0.303	0.335	0.337	0.134	0.332	0.354	0.146	0.131
Al	0.078	0.093	0.085	0.083	0.069	0.089	0.091	0.071	0.070
Ti ₃₊	0.088	0.091	0.103	0.101	0.024	0.099	0.100	0.030	0.026
Fe	0.060	0.051	0.055	0.062	0.063	0.063	0.071	0.077	0.074
Fe ²⁺	0.167	0.195	0.173	0.179	0.166	0.176	0.203	0.158	0.160
Mn	0.004	0.006	0.004	0.003	0.008	0.004	0.005	0.009	0.010
Mg	0.692	0.652	0.661	0.645	0.745	0.638	0.602	0.727	0.729
Ca	0.874	0.877	0.886	0.889	0.869	0.890	0.888	0.855	0.859
Na	0.060	0.051	0.055	0.062	0.063	0.063	0.071	0.077	0.074
Cr	-	-	-	-	-	-	-	0.001	0.001
Z	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
XY	2.022	2.015	2.022	2.025	2.008	2.023	2.032	2.007	2.002
Ca	48.6	49.2	49.8	50.0	46.9	50.2	50.2	46.8	46.9
Mg	38.5	36.6	37.2	36.3	40.3	36.1	34.0	39.8	39.8
Fe _T +Mn	12.9	14.2	13.0	13.7	12.8	13.7	15.8	13.4	13.3
Na	6.5	5.7	6.2	7.0	6.4	7.2	8.1	8.0	7.6
Mg	74.9	72.1	74.0	72.5	75.9	72.4	68.3	74.8	74.9
Fe ²⁺ +Mn	18.6	22.2	19.8	20.5	17.7	20.4	23.6	17.2	17.5

TABLE 2 continued

Sample Grain	2-62.41 21-x	cont. 15C	15R	14C	14R	22-x	10C	10R
SiO ₂	50.4	43.8	44.5	41.7	41.7	50.1	45.6	46.4
Al ₂ O ₃	4.49	10.0	9.58	11.6	12.5	3.47	7.07	5.06
TiO ₂	0.92	3.54	3.41	3.85	4.12	0.71	1.91	2.64
FeO	7.69	8.14	7.78	8.89	8.63	11.7	15.1	7.99
MnO	0.29	0.14	0.12	0.16	0.15	0.56	0.62	0.26
MgO	13.2	10.75	11.6	9.57	9.53	10.4	6.75	13.0
CaO	22.1	22.05	22.15	21.7	21.8	21.4	20.9	22.8
Na ₂ O	0.97	0.90	0.88	0.95	0.90	1.20	1.43	0.57
Cr ₂ O ₃	0.03	-	-	-	-	0.03	-	-
Sum	100.09	99.32	100.02	98.42	99.33	99.57	99.38	98.72
Fe ₂ O ₃	2.50	2.32	2.27	2.45	2.32	3.09	3.68	1.47
FeO	5.44	6.05	5.74	6.69	6.54	8.92	11.8	6.67
Total	100.34	99.55	100.25	98.67	99.56	99.88	99.76	98.87

Number of Ions on the Basis of 6(O)

Si	1.866	1.654	1.664	1.597	1.580	1.897	1.766	1.767
Al	0.134	0.346	0.336	0.403	0.420	0.103	0.234	0.227
Ti	-	-	-	-	-	-	-	0.006
Al	0.062	0.099	0.056	0.121	0.138	0.052	0.089	-
Ti	0.026	0.100	0.096	0.111	0.117	0.020	0.056	0.070
Fe ³⁺	0.070	0.066	0.064	0.071	0.066	0.088	0.107	0.042
Fe ²⁺	0.168	0.191	0.180	0.214	0.207	0.282	0.382	0.212
Mn	0.009	0.004	0.004	0.005	0.005	0.018	0.020	0.008
Mg	0.728	0.605	0.647	0.546	0.538	0.587	0.390	0.738
Ca	0.877	0.892	0.888	0.891	0.885	0.868	0.867	0.930
Na	0.070	0.066	0.064	0.071	0.066	0.088	0.107	0.042
Cr	0.001	-	-	-	-	0.001	-	-
Z	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
XY	2.010	2.023	2.028	2.030	2.023	2.005	2.018	2.044
Ca	47.3	50.7	49.8	51.6	52.0	47.1	49.1	48.2
Mg	39.3	34.4	36.3	31.6	31.6	31.8	22.1	38.2
Fe _T +Mn	13.4	14.9	13.9	16.8	16.4	21.1	28.8	13.6
Na	7.1	7.6	7.1	8.4	8.1	9.0	11.9	4.2
Mg ₂₊	74.7	69.8	72.4	65.3	65.9	60.2	43.3	73.7
Fe ²⁺ +Mn	18.2	22.6	20.5	26.3	26.0	30.8	44.8	22.1

TABLE 2 continued

Sample Grain	2-70.41						2-99.34	
	3	4	5	2	1C	1R	1	3C
SiO ₂	43.7	43.4	44.8	44.7	47.2	44.6	44.3	45.1
Al ₂ O ₃	10.1	9.99	6.98	9.16	5.75	7.76	10.1	9.27
TiO ₂	3.73	3.67	3.67	3.00	1.90	3.85	4.11	3.29
FeO	7.96	7.97	8.11	9.20	14.5	8.23	6.45	8.34
MnO	0.14	0.13	0.20	0.22	0.70	0.18	0.07	0.14
MgO	10.8	10.9	11.5	10.35	7.32	11.5	12.1	10.7
CaO	22.0	22.1	22.5	21.4	20.5	22.4	22.1	22.3
Na ₂ O	0.89	0.90	0.67	1.13	1.86	0.73	0.56	1.04
Cr ₂ O ₃	-	-	-	-	-	-	0.03	-
Sum	99.32	99.06	98.43	99.16	99.73	99.25	99.82	100.18
Fe ₂ O ₃	2.29	2.32	1.73	2.91	4.79	1.88	1.44	2.68
FeO	5.90	5.88	6.55	6.58	10.2	6.54	5.15	5.93
Total	99.55	99.29	98.60	99.45	100.22	99.44	99.96	100.45

Number of Ions on the Basis of 6(O)

Si	1.649	1.644	1.712	1.692	1.808	1.690	1.652	1.686
Al	0.351	0.356	0.288	0.308	0.192	0.310	0.348	0.314
Al	0.098	0.090	0.026	0.101	0.068	0.037	0.096	0.094
Ti	0.106	0.104	0.106	0.085	0.055	0.110	0.115	0.092
Fe ³⁺	0.065	0.066	0.050	0.083	0.138	0.054	0.040	0.075
Fe ²⁺	0.186	0.186	0.209	0.208	0.327	0.207	0.161	0.185
Mn	0.004	0.004	0.006	0.007	0.023	0.006	0.002	0.004
Mg	0.607	0.615	0.655	0.584	0.418	0.650	0.673	0.596
Ca	0.889	0.897	0.922	0.868	0.841	0.910	0.883	0.893
Na	0.065	0.066	0.050	0.083	0.138	0.054	0.041	0.075
Cr	-	-	-	-	-	-	0.001	-
Z	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
XY	2.021	2.029	2.025	2.019	2.008	2.027	2.011	2.017
Ca	50.7	50.7	50.0	49.6	48.2	49.8	50.2	50.9
Mg	34.7	34.8	35.6	33.4	23.9	35.6	38.2	34.0
Fe _T +Mn	14.6	14.5	14.4	17.0	27.9	14.6	11.6	15.1
Na	7.5	7.6	5.4	9.4	15.2	5.9	4.6	8.8
Mg	70.4	70.6	71.2	66.2	46.2	70.9	76.8	69.2
Fe ²⁺ +Mn	22.1	21.8	23.4	24.4	38.6	23.2	18.6	22.0

TABLE 2 continued

Sample Grain	2-99.34 cont.			2-103.15				
	3R	4C	4R	16	3C	3I	3R	4(010)
SiO ₂	45.7	46.8	44.7	46.3	48.4		46.9	46.1
Al ₂ O ₃	8.93	8.18	8.29	8.26	6.72		8.02	7.30
TiO ₂	3.38	2.72	3.69	3.23	1.98		2.35	4.05
FeO	6.88	9.07	6.49	5.43	5.71	6.17	6.81	6.34
MnO	0.12	0.16	0.08	0.08	0.13		0.12	0.11
MgO	12.5	10.8	13.1	12.4	13.9	13.8	12.6	12.5
CaO	22.3	22.0	23.0	22.7	21.75	21.8	21.4	22.8
Na ₂ O	0.60	1.17	0.38	0.61	0.75		0.95	0.53
Cr ₂ O ₃	0.03	-	0.24	0.66	0.64		0.59	-
Sum	100.44	100.90	99.97	99.67	99.98		99.74	99.73
Fe ₂ O ₃	1.55	3.01	0.98	1.57	1.93		2.45	1.37
FeO	5.48	6.36	5.61	4.02	3.97		4.61	5.11
Total	100.59	101.20	100.07	99.83	100.17		99.99	99.87

Number of Ions on the Basis of 6(0)

Si	1.694	1.735	1.673	1.721	1.784		1.742	1.721
Al	0.306	0.265	0.327	0.279	0.216		0.258	0.279
Al	0.084	0.093	0.039	0.081	0.076		0.093	0.042
Ti	0.094	0.076	0.104	0.090	0.055		0.066	0.114
Fe ³⁺	0.043	0.084	0.028	0.044	0.054		0.068	0.038
Fe ²⁺	0.170	0.197	0.176	0.125	0.122		0.143	0.160
Mn	0.004	0.005	0.002	0.002	0.004		0.004	0.004
Mg	0.691	0.597	0.731	0.687	0.764		0.698	0.696
Ca	0.886	0.874	0.922	0.904	0.859		0.852	0.912
Na	0.043	0.084	0.028	0.044	0.054		0.068	0.038
Cr	0.001	-	0.007	0.019	0.019		0.017	-
Z	2.000	2.000	2.000	2.000	2.000		2.000	2.000
XY	2.016	2.010	2.037	1.998	2.006		2.008	2.004
Ca	49.4	49.7	49.6	51.3	47.6	47.5	48.3	50.4
Mg	38.5	34.0	39.3	39.0	42.4	42.0	39.5	38.5
Fe _T +Mn	12.1	16.3	11.1	9.7	10.0	10.5	12.2	11.1
Na	4.8	9.5	2.9	5.1	5.7		7.5	4.3
Mg	76.1	67.6	78.1	80.0	80.9		76.4	77.5
Fe ²⁺ +Mn	19.1	22.9	19.0	14.9	13.4		16.1	18.2

TABLE 2 continued

Sample Grain	2-103.15 cont.		4(100)	5C	5R	6C	6I	6R
	4(10)	4(100)						
SiO ₂	45.3	42.3	40.1	44.1	44.1	47.0	46.2	46.7
Al ₂ O ₃	7.63	10.15	11.75	10.5	10.4	5.66	6.14	7.22
TiO ₂	3.76	4.84	6.60	4.21	3.88	1.08	3.22	2.60
FeO	6.82	7.09	7.19	6.40	6.23	15.6	6.62	6.39
MnO	0.13	0.09	0.10	0.08	0.08	0.70	0.12	0.09
MgO	12.5	11.0	10.3	11.9	11.8	6.54	12.3	13.0
CaO	22.7	22.9	22.8	21.6	22.4	20.8	23.1	22.6
Na ₂ O	0.53	0.54	0.55	0.81	0.66	1.94	0.65	0.54
Cr ₂ O ₃	-	-	0.05	-	0.11	-	0.26	0.38
Sum	99.37	98.91	99.44	99.60	99.66	99.32	98.61	99.52
Fe ₂ O ₃	1.37	1.39	1.42	2.09	1.70	5.00	1.67	1.39
FeO	5.59	5.84	5.91	4.52	4.70	11.10	5.12	5.14
Total	99.51	99.05	99.58	99.81	99.83	99.82	98.78	99.66

Number of Ions on the Basis of 6(O)

Si	1.704	1.608	1.524	1.644	1.646	1.819	1.750	1.745
Al	0.296	0.392	0.476	0.356	0.354	0.181	0.250	0.255
Al	0.042	0.063	0.050	0.105	0.104	0.077	0.024	0.063
Ti	0.106	0.138	0.189	0.118	0.109	0.031	0.092	0.073
Fe ³⁺	0.039	0.040	0.041	0.059	0.048	0.146	0.048	0.039
Fe ²⁺	0.176	0.186	0.188	0.141	0.147	0.359	0.162	0.161
Mn	0.004	0.003	0.003	0.002	0.002	0.023	0.004	0.003
Mg	0.701	0.624	0.584	0.661	0.657	0.377	0.695	0.724
Ca	0.915	0.933	0.928	0.863	0.896	0.862	0.938	0.905
Na	0.039	0.040	0.040	0.058	0.048	0.146	0.048	0.039
Cr	-	-	0.002	-	0.003	-	0.008	0.011
Z	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
XY	2.021	2.026	2.024	2.007	2.014	2.021	2.017	2.018
Ca	49.9	52.3	53.2	50.0	51.2	48.8	50.8	49.4
Mg	38.2	34.9	33.5	38.3	37.5	21.3	37.6	39.5
Fe _T +Mn	11.9	12.8	13.3	11.7	11.3	29.9	11.6	11.1
Na	4.2	4.7	5.0	6.8	5.6	16.1	5.3	4.2
Mg	76.2	73.2	71.6	76.6	76.9	41.7	76.5	78.1
Fe ²⁺ +Mn	19.6	22.1	23.4	16.6	17.5	42.2	18.2	17.7

TABLE 3

Electron Microscope Analyses of Amphiboles in DVDP 1 and 2 Core Samples

Sample 1-57.64

Grain	3C	3R	4I	4R	5g	1C	1R	2C	2R
SiO ₂	38.5	38.7	39.7	39.0	38.8	38.8	38.9	38.1	38.9
Al ₂ O ₃	13.6	13.1	12.8	13.2	13.6	13.3	12.8	13.3	13.0
TiO ₂	6.19	5.40	6.02	5.22	6.34	5.90	5.35	4.91	5.15
FeO	10.5	11.9	10.8	12.2	11.2	11.4	11.5	15.4	11.9
MnO	0.14	0.22	0.16	0.22	0.17	0.19	0.22	0.34	0.22
MgO	13.0	12.3	13.0	12.15	12.35	12.2	12.5	9.93	12.2
CaO	11.9	11.6	11.6	11.6	11.7	11.7	11.8	11.5	11.7
Na ₂ O	2.71	2.80	2.72	2.94	2.78	2.79	2.86	2.68	2.79
K ₂ O	1.38	1.43	1.26	1.39	1.38	1.37	1.34	1.42	1.38
Cr ₂ O ₃	-	-	-	-	-	-	-	-	0.04
Sum	97.92	97.45	98.06	97.92	98.32	97.65	97.27	97.58	97.28

Number of Ions on the Basis of 23(O)

Si	5.724	5.812	5.875	5.834	5.745	5.789	5.842	5.811	5.847
Al	2.276	2.188	2.125	2.166	2.255	2.211	2.158	2.189	2.153
Al	0.104	0.134	0.108	0.152	0.116	0.135	0.108	0.203	0.150
Ti	0.691	0.610	0.670	0.586	0.706	0.662	0.604	0.563	0.582
Fe	1.303	1.491	1.332	1.526	1.390	1.426	1.441	1.958	1.496
Mn	0.018	0.028	0.020	0.028	0.021	0.024	0.029	0.044	0.028
Mg	2.868	2.745	2.874	2.708	2.726	2.722	2.801	2.256	2.734
Ca	1.888	1.864	1.826	1.863	1.853	1.873	1.895	1.872	1.884
Na	0.782	0.816	0.780	0.851	0.799	0.809	0.833	0.791	0.813
K	0.261	0.274	0.239	0.264	0.260	0.261	0.257	0.276	0.265
Cr	-	-	-	-	-	-	-	-	-
Z	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Y	4.984	5.008	5.004	5.000	4.959	4.969	4.983	5.024	4.990
X	2.931	2.954	2.845	2.978	2.912	2.943	2.985	2.939	2.962
Sum	15.915	15.962	15.849	15.978	15.871	15.912	15.968	15.963	15.952
$\frac{100 \text{ Fe}}{\text{Fe}+\text{Mg}}$	31.2	35.2	31.7	36.0	33.8	34.3	34.0	46.5	35.3

Sample 1-85.35

Grain	4C	4I	6	2	1I	1R	1-88.55 1C	1I	1R
SiO ₂	40.3	39.3	38.0	35.8	36.7	36.6	37.8	37.8	38.3
Al ₂ O ₃	10.1	10.8	13.2	12.9	12.2	12.6	13.9	13.4	12.9
TiO ₂	3.45	3.58	4.82	5.57	5.09	5.27	6.23	5.75	5.26
FeO	9.16	9.26	10.2	11.7	11.7	11.9	10.4	11.8	12.1
MnO	0.21	0.19	0.12	0.18	0.19	0.18	0.16	0.17	0.23
MgO	9.88	9.85	13.0	12.2	12.3	12.4	12.7	11.9	12.0
CaO	21.9	21.9	11.9	11.8	11.6	11.7	11.9	11.8	11.7
Na ₂ O	0.98	0.97	2.96	2.87	2.90	3.08	2.63	2.67	2.78
K ₂ O	-	-	1.16	1.31	1.23	1.23	1.27	1.28	1.36
Sum	95.98	95.85	95.36	94.33	93.91	94.96	96.99	96.57	96.63

Number of Ions on the Basis of 23(O)

Si	6.153	6.021	5.790	5.594	5.744	5.683	5.666	5.732	5.810
Al	1.812	1.950	2.210	2.381	2.249	2.297	2.334	2.268	2.190
Al	-	-	0.164	-	-	-	0.115	0.124	0.116
Ti	0.396	0.413	0.552	0.655	0.600	0.615	0.703	0.656	0.601
Fe	1.171	1.188	1.301	1.524	1.534	1.539	1.307	1.494	1.532
Mn	0.027	0.025	0.015	0.024	0.026	0.024	0.021	0.022	0.029
Mg	2.252	2.251	2.950	2.843	2.874	2.873	2.849	2.682	2.712
Ca	3.589	3.597	1.938	1.975	1.943	1.939	1.909	1.923	1.905
Na	0.289	0.290	0.875	0.869	0.880	0.926	0.764	0.784	0.817
K	-	-	0.226	0.261	0.246	0.244	0.243	0.248	0.263
Z	7.965	7.971	8.000	7.975	7.993	7.980	8.000	8.000	8.000
Y	3.846	3.877	4.982	5.046	4.991	5.051	4.995	4.978	4.990
X	3.878	3.887	3.039	3.105	3.069	3.109	2.916	2.955	2.985
Sum	15.689	15.735	16.021	16.126	16.096	16.140	15.911	15.933	15.975
$\frac{100 \text{ Fe}}{\text{Fe}+\text{Mg}}$	34.2	34.5	30.6	43.6	44.1	44.2	31.4	35.8	36.1

TABLE 3 Continued

Sample 1-88.55 cont.		3	8C	8R	9	6C	6I	6R	2I	2I	7
SiO ₂	37.8	38.0	37.9	36.8	38.1	38.2	38.3	38.4	38.6	37.9	
Al ₂ O ₃	13.8	13.8	13.5	14.9	14.0	14.3	13.2	13.5	13.0	13.5	
TiO ₂	6.50	5.98	5.95	7.05	6.23	6.24	5.48	5.46	5.23	5.66	
FeO	10.8	10.9	11.0	11.4	11.4	11.5	12.8	12.2	13.4	13.0	
MnO	0.17	0.15	0.15	0.15	0.13	0.11	0.19	0.17	0.23	0.24	
MgO	12.4	12.4	12.6	11.5	11.6	11.6	11.4	11.9	11.1	11.4	
CaO	11.5	11.6	11.8	11.6	11.9	11.8	11.4	11.6	11.5	11.2	
Na ₂ O	2.64	2.59	2.67	2.43	2.41	2.43	2.70	2.79	2.75	2.88	
K ₂ O	1.38	1.35	1.36	1.41	1.30	1.33	1.30	1.23	1.29	1.44	
Sum	96.99	96.77	96.93	97.24	97.07	97.51	96.77	97.25	97.10	97.22	

Number of Ions on the Basis of 23(0)

Si	5.674	5.717	5.701	5.535	5.724	5.701	5.808	5.783	5.855	5.733
Al	2.326	2.283	2.299	2.465	2.276	2.299	2.192	2.217	2.145	2.267
Al	0.121	0.158	0.099	0.166	0.206	0.225	0.168	0.176	0.174	0.147
Ti	0.734	0.677	0.674	0.797	0.703	0.701	0.625	0.618	0.596	0.645
Fe	1.361	1.376	1.383	1.434	1.431	1.438	1.621	1.539	1.694	1.645
Mn	0.021	0.019	0.019	0.019	0.017	0.015	0.025	0.022	0.030	0.030
Mg	2.771	2.780	2.827	2.573	2.587	2.591	2.577	2.659	2.499	2.574
Ca	1.845	1.867	1.903	1.873	1.914	1.887	1.850	1.863	1.869	1.814
Na	0.767	0.757	0.779	0.707	0.702	0.705	0.795	0.815	0.808	0.845
K	0.265	0.260	0.261	0.271	0.249	0.254	0.250	0.236	0.249	0.278
Z	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Y	5.008	5.010	5.002	4.989	4.944	4.970	5.016	5.014	4.993	5.041
X	2.877	2.884	2.943	2.851	2.865	2.846	2.895	2.914	2.926	2.937
Sum	15.885	15.894	15.945	15.840	15.809	15.816	15.911	15.928	15.919	15.978

100 Fe

Fe + Mg	32.9	33.1	32.9	35.8	35.6	35.7	38.6	36.7	40.4	39.0
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Sample 1-88.55 cont.		1-131.36							2-39.28	
Grain	10C	10R	1C	1I	1I	1R	1R	2	2	1
SiO ₂	37.6	37.5	38.5	39.3	39.1	38.8	38.8	38.8	39.6	39.1
Al ₂ O ₃	14.1	14.1	12.8	12.6	12.8	12.9	12.8	13.4	12.7	12.7
TiO ₂	5.88	5.81	5.31	5.40	5.29	5.33	5.29	5.56	5.81	5.61
FeO	13.0	13.7	11.2	11.3	12.6	12.7	12.8	11.4	9.79	10.2
MnO	0.22	0.26	0.21	0.20	0.22	0.24	0.24	0.20	0.13	0.16
MgO	11.1	10.6	12.9	12.5	11.8	11.6	11.8	12.4	13.6	13.5
CaO	11.4	11.4	11.6	11.5	11.4	11.6	11.6	11.6	11.6	11.4
Na ₂ O	2.72	2.69	2.94	2.82	2.84	2.86	2.83	2.86	2.90	2.78
K ₂ O	1.23	1.35	1.07	1.07	1.01	1.01	1.01	1.05	1.29	1.38
Sum	97.25	97.41	96.53	96.69	97.06	97.04	97.17	97.27	97.42	96.83

Number of Ions on the Basis of 23(0)

Si	5.685	5.684	5.819	5.909	5.892	5.863	5.851	5.808	5.874	5.853
Al	2.315	2.316	2.181	2.091	2.108	2.137	2.149	2.192	2.126	2.147
Al	0.197	0.200	0.091	0.140	0.162	0.151	0.130	0.172	0.097	0.098
Ti	0.668	0.662	0.603	0.611	0.600	0.605	0.600	0.626	0.648	0.631
Fe	1.640	1.731	1.410	1.424	1.593	1.602	1.614	1.422	1.213	1.273
Mn	0.028	0.033	0.027	0.025	0.028	0.030	0.031	0.025	0.016	0.021
Mg	2.492	2.400	2.894	2.794	2.643	2.610	2.657	2.774	3.007	3.003
Ca	1.850	1.844	1.884	1.858	1.835	1.876	1.867	1.852	1.847	1.833
Na	0.796	0.790	0.861	0.822	0.829	0.836	0.826	0.828	0.832	0.806
K	0.238	0.262	0.206	0.206	0.195	0.195	0.195	0.200	0.244	0.263
Z	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Y	5.025	5.026	5.025	4.994	5.026	4.998	5.032	5.019	4.981	5.026
X	2.884	2.896	2.951	2.886	2.859	2.907	2.888	2.880	2.923	2.902
Sum	15.909	15.922	15.976	15.880	15.885	15.905	15.920	15.899	15.904	15.928

100 Fe

Fe + Mg	39.7	41.9	32.8	33.8	37.6	38.0	37.8	33.9	28.7	29.8
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TABLE 3 continued

Sample 2-62.41										
Grain	6	8	10C	10R	7	11-g	5	23	2	1
SiO ₂	38.7	38.6	38.2	38.8	37.8	39.0	38.1	38.6	40.2	40.2
Al ₂ O ₃	13.0	14.3	13.6	13.2	13.2	12.4	13.9	12.9	13.2	13.2
TiO ₂	6.39	6.65	6.64	6.37	6.83	5.86	6.32	5.96	3.85	4.00
FeO	9.24	9.33	10.0	9.51	10.4	10.6	10.8	11.1	12.9	13.6
MnO	0.12	0.11	0.12	0.14	0.13	0.19	0.14	0.19	0.28	0.36
MgO	13.65	13.2	12.9	13.3	13.0	12.95	12.2	12.7	11.7	11.1
CaO	12.2	12.1	12.3	12.0	11.9	11.9	12.1	12.0	11.6	11.5
Na ₂ O	2.46	2.31	2.17	2.57	2.61	2.74	2.37	2.70	3.22	3.16
K ₂ O	1.38	1.52	1.66	1.38	1.24	1.24	1.46	1.27	0.97	0.98
Cr ₂ O ₃	0.17	-	-	0.13	-	-	-	-	0.08	0.09
Sum	97.31	98.12	97.59	97.40	97.11	96.88	97.39	97.42	98.00	98.19

Number of Ions on the Basis of 23(0)

Si	5.734	5.662	5.685	5.765	5.653	5.845	5.679	5.780	5.996	5.994
Al	2.266	2.338	2.315	2.235	2.322	2.155	2.231	2.220	2.004	2.006
Al	0.011	0.142	0.075	0.071	-	0.045	0.116	0.048	0.312	0.316
Ti	0.712	0.734	0.744	0.712	0.768	0.661	0.708	0.671	0.432	0.449
Fe	1.144	1.146	1.249	1.181	1.298	1.334	1.350	1.394	1.612	1.704
Mn	0.015	0.013	0.015	0.018	0.017	0.024	0.018	0.024	0.036	0.046
Mg	3.014	2.893	2.855	2.949	2.886	2.896	2.715	2.838	2.595	2.480
Ca	1.937	1.896	1.965	1.916	1.903	1.919	1.937	1.927	1.856	1.835
Na	0.707	0.658	0.626	0.740	0.756	0.795	0.684	0.784	0.930	0.915
K	0.261	0.284	0.316	0.261	0.237	0.237	0.278	0.242	0.184	0.187
Cr	0.020	-	-	0.015	-	-	-	-	0.009	0.011
Z	8.000	8.000	8.000	8.000	7.975	8.000	8.000	8.000	8.000	8.000
Y	4.916	4.928	4.938	4.946	4.946	4.960	4.907	4.975	4.996	5.006
X	2.905	2.838	2.907	2.917	2.896	2.951	2.899	2.953	2.970	2.937
Sum	15.821	15.766	15.845	15.863	15.840	15.911	15.806	15.928	15.966	15.943
100 Fe										
Fe + Mg	27.5	28.4	30.4	28.6	31.0	31.5	33.2	32.9	38.3	40.7

Sample 2-62.41			2-70.41						
Grain	9C	9R	21	1	10-i	4	3	2C	2R
SiO ₂	38.6	39.0	38.3	38.3	38.2	38.2	38.5	38.4	38.7
Al ₂ O ₃	14.1	13.5	11.7	14.0	14.3	14.3	13.8	13.2	13.5
TiO ₂	6.20	5.78	4.98	6.52	6.49	6.36	6.24	6.05	6.41
FeO	14.1	11.1	17.8	10.7	10.8	11.8	11.9	15.0	12.9
MnO	0.29	0.21	0.57	0.14	0.13	0.17	0.16	0.38	0.26
MgO	10.3	12.6	8.53	12.1	12.1	11.5	11.4	9.38	10.8
CaO	11.7	11.8	11.2	12.3	12.2	12.0	12.1	11.5	11.5
Na ₂ O	2.68	2.72	2.93	2.35	2.32	2.52	2.63	2.71	2.81
K ₂ O	1.09	1.28	1.47	1.54	1.57	1.38	1.45	1.17	0.99
Sum	99.06	97.99	97.48	97.95	98.11	98.23	98.18	97.79	97.87

Number of Ions on the Basis of 23(0)

Si	5.724	5.796	5.968	5.694	5.676	5.679	5.741	5.819	5.789
Al	2.276	2.204	2.032	2.306	2.324	2.321	2.259	2.181	2.211
Al	0.188	0.153	0.088	0.146	0.172	0.191	0.161	0.176	0.172
Ti	0.691	0.646	0.575	0.729	0.724	0.711	0.701	0.690	0.720
Fe	1.745	1.384	2.289	1.331	1.342	1.464	1.486	1.897	1.610
Mn	0.036	0.027	0.075	0.018	0.017	0.022	0.021	0.049	0.033
Mg	2.272	2.783	1.953	2.680	2.675	2.553	2.529	2.120	2.417
Ca	1.856	1.874	1.837	1.961	1.939	1.918	1.933	1.869	1.847
Na	0.771	0.782	0.873	0.676	0.668	0.728	0.761	0.797	0.815
K	0.207	0.243	0.288	0.292	0.297	0.261	0.276	0.226	0.189
Z	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Y	4.932	4.993	4.980	4.904	4.930	4.941	4.898	4.932	4.952
X	2.834	2.899	2.998	2.929	2.904	2.907	2.970	2.892	2.851
Sum	15.766	15.892	15.978	15.833	15.834	15.848	15.868	15.824	15.803
100 Fe									
Fe + Mg	43.4	33.2	54.0	33.2	33.4	36.4	37.0	47.2	40.0

TABLE 4

Electron Microprobe Analyses of Rhönite from DVDP 1 and 2 Core Samples

Sample Grain	1-121.88			2-99.34			2-103.15			
	2	3	1	1	4	2	2	3	1	1
SiO ₂	23.6	23.8	23.4	23.7	23.6	23.8	23.2	23.7	23.4	23.6
Al ₂ O ₃	16.6	17.0	17.1	16.8	16.7	17.1	17.4	17.4	17.2	17.45
TiO ₂	11.4	11.6	12.1	11.9	11.9	12.2	12.0	11.7	11.8	11.7
FeO	20.8	21.3	21.5	21.0	21.0	21.4	20.9	20.9	21.5	21.9
MnO	0.15	0.19	0.12	0.16	0.16	0.18	0.18	0.17	0.20	0.20
MgO	13.4	12.7	13.1	13.05	13.1	12.4	12.7	12.45	12.3	12.2
CaO	11.8	11.8	12.0	12.05	12.3	12.4	12.2	12.3	12.3	12.1
Na ₂ O	1.00	0.96	0.90	0.97	0.92	0.88	0.89	0.91	0.89	0.96
Cr ₂ O ₃	0.05	-	-	0.06	0.13	0.05	0.15	0.19	0.17	0.08
NiO	0.07	0.10	0.04	0.04	0.06	-	0.03	0.06	0.07	0.06
Sum	98.87	99.45	100.26	99.73	99.87	100.41	99.65	99.78	99.83	100.25
Number of Ions on the Basis of 40(O)										
Si	6.514	6.536	6.385	6.489	6.460	6.480	6.360	6.481	6.422	6.450
Al	5.400	5.464	5.499	5.421	5.388	5.487	5.622	5.519	5.564	5.550
Al	-	0.038	-	-	-	-	-	0.089	-	0.071
Ti	2.366	2.396	2.483	2.450	2.450	2.498	2.474	2.406	2.436	2.406
Fe	4.801	4.892	4.906	4.808	4.808	4.873	4.792	4.780	4.935	5.006
Mn	0.035	0.044	0.028	0.037	0.037	0.042	0.042	0.039	0.047	0.046
Mg	5.514	5.199	5.329	5.326	5.346	5.033	5.190	5.075	5.033	4.971
Ca	3.490	3.472	3.508	3.535	3.608	3.617	3.583	3.604	3.617	3.543
Na	0.535	0.511	0.476	0.515	0.488	0.465	0.473	0.483	0.474	0.509
Cr	0.011	-	-	0.013	0.028	0.011	0.033	0.041	0.037	0.017
Ni	0.016	0.022	0.009	0.009	0.013	-	0.007	0.013	0.016	0.013
Z	11.914	12.000	11.884	11.910	11.848	11.967	11.982	12.000	11.986	12.000
Y	12.743	12.591	12.755	12.643	12.682	12.457	12.538	12.443	12.504	12.529
X	4.025	3.983	3.984	4.050	4.096	4.082	4.056	4.087	4.091	4.052
Sum	28.682	28.574	28.623	28.603	28.626	28.506	28.576	28.530	28.581	28.581

TABLE 5

Electron Microprobe Analyses of Spinel in DVDP 1 and 2 Core Samples

Sample Grain	1-57.94			1-88.55	1-121.88				
	1C	1R	2	2	3C	3R	6-i	7-i	2
SiO ₂	0.12	0.12	0.14	0.04	0.11	-	0.11	0.08	-
TiO ₂	0.66	14.9	19.1	17.5	2.21	15.6	6.01	8.03	22.2
Al ₂ O ₃	15.1	3.14	2.40	1.79	28.1	11.2	28.3	22.9	5.13
Cr ₂ O ₃	45.6	5.64	n.d.	n.d.	29.3	11.2	9.14	8.35	5.39
FeO	30.5	68.3	71.0	73.8	30.0	52.9	42.3	47.6	59.4
MnO	1.01	1.36	1.47	1.49	0.51	0.65	0.29	0.32	0.74
MgO	5.69	2.33	2.09	1.22	9.21	6.11	11.6	9.64	5.02
CaO	-	-	0.17	0.06	-	0.05	-	-	-
NiO	n.d.	n.d.	n.d.	n.d.	0.10	0.04	0.21	0.22	0.06
Sum	98.68	95.79	96.37	95.90	99.54	97.75	97.96	97.14	97.94
Fe ₂ O ₃	5.96	31.0	29.7	33.2	6.83	17.3	20.8	22.6	17.1
FeO	25.2	40.4	44.2	44.0	23.9	37.4	23.5	27.2	44.0
Total	99.34	98.89	99.27	99.30	100.27	99.55	99.96	99.34	99.64

Number of Ions on the Basis of 32(O)

Si	0.032	0.036	0.041	0.012	0.027	-	0.027	0.020	-
Ti	0.133	3.311	4.245	3.936	0.409	3.206	1.104	1.537	4.723
Al	4.780	1.094	0.836	0.631	8.158	3.607	8.149	6.871	1.710
Cr	9.683	1.318	-	-	5.706	2.420	1.766	1.681	1.206
Fe ³⁺	1.205	6.893	6.605	7.473	1.266	3.558	3.824	4.330	3.641
Fe ²⁺	5.660	9.984	10.924	11.007	4.924	8.548	4.802	5.791	10.410
Mn	0.230	0.340	0.368	0.378	0.106	0.150	0.060	0.069	0.177
Mg	2.278	1.026	0.921	0.544	3.382	2.489	4.225	3.658	2.117
Ca	-	-	0.054	0.019	-	0.015	-	-	-
Ni	-	-	-	-	0.020	0.009	0.041	0.045	0.014
Usp%*	-	43.6	52.2	48.2	-	-	-	-	66.2

Recalculated Spinel End Members

Usp	2.1	41.8	53.5	50.2	5.4	40.0	14.1	19.4	59.0
Ch	28.5	8.2	-	-	35.7	15.2	11.0	10.5	7.5
Sp	-	4.6	5.2	4.0	6.9	16.2	42.3	35.8	10.7
Hc	29.9	2.2	-	-	44.1	6.4	8.6	7.2	-
Mf	-	-	7.0	3.1	-	-	-	-	8.5
Mt	7.5	43.1	34.3	42.7	7.9	22.1	23.9	27.1	14.3
Pc	32.0	-	-	-	-	-	-	-	-

Usp	-Ulvospinel	2FeO. TiO ₂	Mf-Magnesioferrite	MgO. Fe ₂ O ₃
Ch	-Chromite	MgO. Cr ₂ O ₃	Mt-Magnetite	FeO. Fe ₂ O ₃
Sp	-Spinel	MgO. Al ₂ O ₃	Pc-Picrochromite	FeO. Cr ₂ O ₃
Hc	-Hercynite	FeO. Al ₂ O ₃		

* Calculated by method of Carmichael (1967)

TABLE 5 continued

Sample Grain	1-121-88 cont.			1-131.36	1-187.64				
	4	1C	1R	1	6-i	5-i	2	4	3C
SiO ₂	0.05	0.06	0.05	0.12	0.07	0.09	0.10	0.09	0.17
TiO ₂	23.3	18.4	18.5	20.0	3.34	3.24	3.54	3.25	3.51
Al ₂ O ₃	4.49	4.96	6.27	2.34	22.95	23.0	25.8	23.45	23.5
Cr ₂ O ₃	4.97	-	-	n.d.	31.8	31.15	27.8	31.2	31.2
FeO	59.7	69.5	67.9	69.9	28.3	28.7	28.8	29.2	29.3
MnO	0.71	0.57	0.60	1.42	0.29	0.30	0.28	0.26	0.34
MgO	5.11	3.96	3.14	2.39	13.3	13.3	13.9	13.0	13.1
CaO	-	-	-	0.12	-	-	-	-	0.03
NiO	0.06	-	-	n.d.	0.18	0.18	0.20	0.15	0.17
Sum	98.39	97.45	96.46	96.29	100.23	99.96	100.42	100.60	101.32
Fe ₂ O ₃	16.3	30.0	27.0	28.0	11.1	11.8	11.9	11.4	11.2
FeO	45.0	42.5	43.6	44.7	18.3	18.1	18.1	18.9	19.2
Total	99.99	100.45	99.16	99.09	101.33	101.16	101.62	101.70	102.42

Number of Ions on the Basis of 32(O)

Si	0.014	0.017	0.014	0.035	0.017	0.022	0.024	0.022	0.041
Ti	4.950	3.941	4.006	4.442	0.611	0.594	0.637	0.593	0.636
Al	1.495	1.665	2.128	0.815	6.582	6.604	7.273	6.704	6.671
Cr	1.110	-	-	-	6.118	6.001	5.257	5.984	5.942
Fe ³⁺	3.465	6.430	5.850	6.224	2.033	2.164	2.142	2.081	2.030
Fe ²⁺	10.631	10.123	10.499	11.042	3.724	3.688	3.620	3.834	3.868
Mn	0.170	0.138	0.146	0.355	0.060	0.062	0.057	0.053	0.069
Mg	2.152	1.681	1.348	1.052	4.825	4.831	4.956	4.701	4.704
Ca	-	-	-	0.038	-	-	-	-	0.008
Ni	0.014	-	-	-	0.035	0.035	0.038	0.029	0.033
Usp%	68.7	48.7	52.7	54.7	-	-	-	-	-

Recalculated Spinel End-Members

Usp	62.1	49.4	50.3	56.0	7.9	7.7	8.3	7.7	8.4
Ch	6.9	-	-	-	38.2	37.5	32.9	37.4	37.2
Sp	9.3	10.4	13.3	5.1	22.3	23.4	29.4	21.7	22.1
Hc	-	-	-	-	18.8	17.9	16.0	20.2	19.6
Mf	10.8	10.7	3.5	8.6	-	-	-	-	-
Mt	10.9	29.5	32.9	30.3	12.8	13.5	13.4	13.0	12.7

TABLE 5 continued

Sample Grain	1-187.64 cont.			2-39.28	2-54.72			11-g	6-a	12-g
	3R	1	1	1	1	1	1			
SiO ₂	0.09	0.13	0.11	0.10	0.10	0.09	0.12	0.24	0.14	
TiO ₂	25.0	13.35	13.7	16.9	26.5	26.9	21.9	21.5	21.9	
Al ₂ O ₃	5.52	16.65	16.5	8.02	2.37	2.28	2.80	2.05	2.48	
Cr ₂ O ₃	2.08	3.62	3.63	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	
FeO	59.7	52.9	52.9	66.2	64.0	64.1	68.6	68.8	69.2	
MnO	0.63	0.27	0.31	0.90	1.47	1.47	1.43	1.29	1.50	
MgO	4.07	10.5	10.4	4.82	3.67	3.54	2.03	1.36	1.57	
CaO	0.10	-	-	-	-	0.07	0.07	0.30	0.08	
NiO	0.06	0.23	0.17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	
Sum	97.25	97.65	97.72	96.94	98.11	98.45	96.95	95.54	98.87	
Fe ₂ O ₃	13.2	25.4	25.0	29.2	16.6	16.1	23.8	23.9	23.7	
FeO	47.9	30.05	30.4	39.9	49.0	49.6	47.2	47.3	47.8	
Total	98.65	100.20	100.22	99.84	99.71	100.05	99.35	97.94	99.17	

Number of Ions on the Basis of 32(0)

Si	0.026	0.034	0.028	0.028	0.029	0.026	0.035	0.072	0.042
Ti	5.385	2.592	2.662	3.565	5.762	5.836	4.845	4.862	4.878
Al	1.863	5.067	5.025	2.652	0.808	0.775	0.971	0.726	0.866
Cr	0.471	0.739	0.742	-	-	-	-	-	-
Fe ³⁺	2.845	4.935	4.861	6.164	3.612	3.495	5.269	5.408	5.283
Fe ²⁺	11.474	6.489	6.569	9.361	11.848	11.967	11.612	11.895	11.842
Mn	0.153	0.059	0.068	0.214	0.360	0.359	0.356	0.329	0.376
Mg	1.738	4.042	4.006	2.016	1.582	1.522	0.890	0.610	0.693
Ca	0.031	-	-	-	-	0.022	0.022	0.097	0.025
Ni	0.014	0.048	0.035	-	-	-	-	-	-
Usp%	75.8	18.5	20.5	44.6	72.8	73.8	61.7	62.1	62.3

Recalculated Spinel End-members

Usp	67.7	32.8	33.5	44.9	72.4	73.3	61.0	61.7	61.5
Ch	2.9	4.6	4.6	-	-	-	-	-	-
Sp	11.6	31.7	31.5	16.6	5.0	4.8	6.1	4.5	5.4
Hc	-	-	-	-	-	-	-	-	-
Mf	7.7	14.7	14.5	8.6	14.7	14.5	5.3	4.3	3.5
Mt	10.1	16.2	15.9	29.9	7.8	7.4	27.6	29.5	29.5

TABLE 5 continued

Sample Grain	2-62.41					2-70.41		
	15C	15R	10	7	5	4	5	1
SiO ₂	0.07	0.12	0.14	0.11	0.10	0.13	0.12	0.12
TiO ₂	2.07	15.8	18.0	17.5	17.8	18.45	16.5	16.6
Al ₂ O ₃	49.15	11.7	10.7	10.1	7.58	7.17	7.71	7.22
Cr ₂ O ₃	-	-	0.13	0.07	0.04	0.08	-	-
FeO	33.9	61.9	60.4	61.3	63.3	65.3	66.1	66.4
MnO	0.26	0.45	0.35	0.32	0.54	0.71	0.66	0.62
MgO	13.4	6.95	8.26	8.34	6.43	5.66	6.00	5.80
CaO	-	0.03	-	-	-	-	0.03	0.03
NiO	-	-	-	0.04	-	n.d.	n.d.	n.d.
Sum	98.85	96.95	97.98	97.78	95.79	97.50	97.12	96.79
Fe ₂ O ₃	14.4	28.0	26.1	27.8	27.9	27.8	31.1	31.25
FeO	20.7	36.7	37.0	36.25	38.2	40.3	38.1	38.3
Total	100.05	99.75	100.68	100.53	98.59	100.30	100.22	99.94

Number of Ions on the Basis of 32(O)

Si	0.016	0.033	0.038	0.030	0.028	0.036	0.033	0.034
Ti	0.346	3.229	3.627	3.542	3.761	3.864	3.447	3.489
Al	12.881	3.747	3.379	3.203	2.510	2.353	2.524	2.379
Cr	-	-	0.028	0.015	0.009	0.018	-	-
Fe ³⁺	2.410	5.726	5.262	5.630	5.898	5.826	6.502	6.574
Fe ²⁺	3.850	8.340	8.296	8.158	8.975	9.386	8.852	8.953
Mn	0.049	0.104	0.079	0.073	0.128	0.168	0.155	0.147
Mg	4.442	2.816	3.299	3.346	2.693	2.350	2.485	2.417
Ca	-	0.009	-	-	-	-	0.009	0.009
Ni	-	-	-	0.009	-	-	-	-
Usp%	-	38.7	42.9	39.8	44.6	47.6	41.2	40.5

Recalculated Spinel End-members

Usp	4.5	40.8	45.8	44.7	47.0	48.8	43.6	44.0
Ch	-	-	0.2	0.1	0.1	0.1	-	-
Sp	55.9	23.5	21.2	20.0	15.7	14.7	15.8	14.9
Hc	24.4	-	-	-	-	-	-	-
Mf	-	11.8	19.9	21.8	17.9	14.6	15.4	15.4
Mt	15.2	23.9	13.0	13.4	19.3	21.8	25.2	25.7

TABLE 5 continued

Sample Grain	2-70.41 cont.		2-99.34					
	3	7	3	12	10-i	2	11-i	1
SiO ₂	0.16	0.08	0.14	0.12	0.17	0.09	0.59	0.10
TiO ₂	20.2	16.8	1.62	1.42	3.36	18.3	14.5	24.0
Al ₂ O ₃	3.70	5.89	32.6	29.5	41.7	7.43	11.7	3.67
Cr ₂ O ₃	0.07	-	29.6	31.6	5.35	10.9	3.50	3.44
FeO	66.6	68.2	20.2	22.0	31.6	52.3	57.0	60.8
MnO	1.26	0.63	0.29	0.26	0.21	0.68	0.32	0.69
MgO	4.67	5.18	15.5	15.1	15.1	5.90	8.54	4.90
CaO	0.06	0.03	-	-	0.03	0.06	-	0.04
NiO	n.d.	n.d.	0.21	0.13	0.24	0.05	0.17	0.04
Sum	96.72	96.81	100.16	100.13	97.76	95.71	96.32	97.68
Fe ₂ O ₃	27.4	32.3	6.05	7.9	15.3	14.9	26.15	16.8
FeO	42.0	39.2	14.8	14.8	17.8	38.9	33.5	45.7
Total	99.52	100.11	100.81	100.83	99.26	97.21	98.97	99.38

Number of Ions on the Basis of 32(O)

Si	0.046	0.023	0.032	0.028	0.039	0.026	0.159	0.029
Ti	4.361	3.566	0.282	0.251	0.575	3.911	2.945	5.156
Al	1.252	1.959	8.898	8.173	11.191	2.489	3.724	1.236
Cr	0.016	-	5.420	5.873	0.963	2.449	0.747	0.777
Fe ³⁺	5.919	6.861	1.054	1.397	2.622	3.187	5.314	3.612
Fe ²⁺	10.083	9.253	2.866	2.909	3.390	9.246	7.566	10.919
Mn	0.306	0.151	0.057	0.052	0.040	0.164	0.073	0.167
Mg	1.999	2.180	5.351	5.291	5.126	2.500	3.438	2.087
Ca	0.018	0.009	-	-	0.007	0.018	-	0.012
Ni	-	-	0.039	0.025	0.044	0.011	0.037	0.009
Usp%	52.4	41.3	-	-	-	62.0	33.4	69.1

Recalculated Spinel End-members

Usp	55.1	44.8	3.9	3.5	7.7	49.2	38.8	64.8
Ch	0.1	-	33.9	36.7	6.0	15.3	4.7	4.8
Sp	7.8	12.2	33.6	29.7	58.7	15.5	23.3	7.7
Hc	-	-	22.0	21.3	11.1	-	-	-
Mf	17.3	15.1	-	-	-	0.8	15.5	13.8
Mt	19.6	27.8	6.6	8.8	16.4	19.1	17.7	8.8

TABLE 5 continued

Sample	2-103.15		
Grain	10-i	3	5-i
SiO ₂	0.11	0.12	0.12
TiO ₂	4.11	21.3	15.2
Al ₂ O ₃	32.3	4.25	10.7
Cr ₂ O ₃	10.6	5.14	0.83
FeO	38.1	58.7	63.0
MnO	0.28	0.68	0.34
MgO	12.6	5.85	6.25
CaO	0.06	0.06	0.04
NiO	0.19	0.10	0.08
Sum	98.35	96.20	96.56
Fe ₂ O ₃	19.0	19.2	29.0
FeO	21.0	41.4	36.9
Total	100.25	98.1	99.46

Number of Ions on the Basis of 32(O)

Si	0.026	0.034	0.033
Ti	0.736	4.592	3.145
Al	9.069	1.436	3.470
Cr	1.997	1.165	6.004
Fe ³⁺	3.406	4.142	0.181
Fe ²⁺	4.184	9.926	8.490
Mn	0.056	0.165	0.079
Mg	4.475	2.500	2.564
Ca	0.015	0.018	0.012
Ni	0.036	0.023	0.018

Usp% - 61.3 38.0

Recalculated Spinel End-members

Usp	9.6	57.8	39.7
Ch	12.5	7.3	1.1
Sp	44.0	9.0	21.7
Hc	12.6	-	-
Mf	-	15.5	9.6
Mt	21.3	10.4	27.9

TABLE 6

Electron Microprobe Analyses of Ilmenite in DVDP 1 and 2 Core Samples

Sample Grain	1-121.88		2-54.72		2-62.41		
	2	1	2	1	1	2	6
SiO ₂	-	0.06	0.04	-	-	-	-
Al ₂ O ₃	0.10	0.12	0.38	0.38	0.38	0.35	1.01
TiO ₂	51.8	53.1	50.3	50.4	50.8	50.5	47.3
FeO	38.2	38.5	42.6	42.9	40.1	40.5	44.1
MnO	0.80	0.71	1.34	1.34	0.84	1.12	0.45
MgO	7.01	7.07	4.96	4.95	7.19	6.63	6.47
CaO	0.17	0.12	-	-	-	0.06	-
Cr ₂ O ₃	0.23	0.24	n.d.	n.d.	0.04	0.03	-
NiO	0.03	-	n.d.	n.d.	0.03	-	-
Sum	98.34	99.92	99.62	99.97	99.38	99.19	99.33
Fe ₂ O ₃	5.71	4.60	8.41	8.69	8.94	9.01	15.0
FeO	33.1	34.3	35.1	35.1	32.1	32.4	30.6
Total	98.95	100.32	100.53	100.86	100.32	100.10	100.83
Mole%							
FeTiO ₃	67.0	68.6	71.1	71.0	64.1	65.1	61.1
RTiO ₃	27.4	26.9	20.7	20.6	27.3	26.2	24.0
R ₂ O ₃	5.6	4.5	8.2	8.4	8.6	8.7	14.9
Hm%*	7.7	6.2	10.3	10.6	11.8	11.8	19.6

Sample Grain	2-70.41			2-99.34	2-103.15
	2	3	1	1	1
SiO ₂	-	0.07	-	0.12	0.14
Al ₂ O ₃	1.04	0.74	0.90	0.19	0.10
TiO ₂	47.9	47.9	46.6	51.9	51.1
FeO	41.6	43.7	44.0	39.5	41.6
MnO	0.42	0.72	0.44	0.72	0.69
MgO	7.39	5.96	6.29	5.98	4.91
CaO	0.06	0.04	0.05	0.17	0.14
Cr ₂ O ₃	-	-	-	-	-
NiO	n.d.	n.d.	n.d.	-	-
Sum	98.41	99.13	98.28	98.58	98.68
Fe ₂ O ₃	13.5	13.35	15.4	4.79	5.70
FeO	29.4	31.7	30.2	35.2	36.5
Total	99.71	100.48	99.88	99.07	99.28
Mole%					
FeTiO ₃	58.9	63.8	61.1	71.7	74.8
RTiO ₃	27.4	23.0	23.7	23.6	19.8
R ₂ O ₃	13.5	13.2	15.2	4.7	5.4
Hm%*	18.6	17.1	19.9	6.1	6.7

* Calculated by method of Carmichael (1967)

TABLE 7

Electron Microprobe Analyses of Feldspars in DVDP 1 and 2 Core Samples

Sample Grain	1-57.94		1-131.36		2-54.72		2-103.15	
	1	2	1-a	3-a	1	2	1	3
SiO ₂	57.8	59.4	57.9	56.5	57.5	56.7	50.4	51.7
Al ₂ O ₃	26.0	24.6	25.3	26.7	26.9	26.9	30.9	29.9
TiO ₂	0.11	0.15	0.19	0.22	0.15	0.13	0.28	0.28
FeO	0.41	0.48	0.47	0.60	0.50	0.60	0.73	0.53
MgO	0.03	-	0.03	0.04	0.04	0.29	0.03	0.05
CaO	8.27	6.59	7.96	9.58	8.79	9.48	14.6	12.3
Na ₂ O	6.61	7.36	6.88	5.74	5.75	5.90	3.14	4.21
K ₂ O	0.64	0.68	0.76	0.51	0.71	0.54	0.18	0.24
Sum	99.87	99.26	99.49	99.89	100.34	100.54	100.26	99.21

Number of Ions on the Basis of 32(0)

Si	10.407	10.699	10.471	10.199	10.299	10.177	9.200	9.469
Al	5.510	5.230	5.394	5.680	5.676	5.690	6.650	6.464
Ti	0.015	0.021	0.026	0.030	0.020	0.017	0.039	0.039
Fe	0.061	0.072	0.071	0.091	0.074	0.091	0.111	0.081
Mg	0.008	-	0.007	0.011	0.009	0.078	0.009	0.013
Ca	1.594	1.273	1.542	1.853	1.686	1.821	2.853	2.416
Na	2.307	2.571	2.412	2.008	1.996	2.052	1.110	1.497
K	0.147	0.157	0.176	0.118	0.163	0.123	0.042	0.056
Z	15.917	15.929	15.865	15.879	15.975	15.867	15.850	15.933
X	4.132	4.094	4.234	4.111	3.948	4.182	4.164	4.102
Sum	20.049	20.023	20.099	19.990	19.923	20.049	20.014	20.035
An	39.4	31.8	37.3	46.6	43.9	45.6	71.2	60.9
Ab	57.0	64.3	58.4	50.5	51.9	51.3	27.7	37.7
Or	3.6	3.9	4.3	2.9	4.2	3.1	1.1	1.4

TABLE 8

Electron Microprobe Analyses of Apatite in DVDP 1 and 2 Core Samples

Sample Grain	2-54.72	2-62.41		2-70.41	
	1	1-i	2	2-i	1
SiO ₂	0.36	0.36	0.29	0.50	0.28
Al ₂ O ₃	-	0.04	-	0.03	0.03
TiO ₂	-	-	-	0.05	-
FeO	0.18	0.39	0.26	0.40	0.25
MnO	0.07	0.03	0.04	0.05	-
MgO	0.17	0.47	0.36	0.38	0.36
CaO	50.9	51.2	51.6	51.4	51.7
Na ₂ O	0.15	0.16	0.15	0.12	0.16
K ₂ O	-	-	-	-	-
P ₂ O ₅	43.3	43.3	43.6	42.5	43.7
Total	95.13	95.95	96.30	95.43	96.48

