

American Mineralogist: August 2017 Deposit AM-17-86112
 PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

SAH 99555	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>Weight percent oxides</i>																
SiO ₂	35.15	34.97	35.02	34.83	34.62	34.68	34.64	34.61	34.30	34.02	33.19	31.78	30.81	31.20	30.20	30.37
Al ₂ O ₃	0.11	0.11	0.09	0.09	0.10	0.08	0.09	0.11	0.10	0.15	0.10	0.16	0.17	0.76	0.06	0.04
TiO ₂	0.04	0.06	0.05	0.06	0.05	0.03	0.05	0.05	0.05	0.05	0.07	0.09	0.13	0.14	0.08	0.06
Cr ₂ O ₃	BDL	BDL	BDL	BDL	0.11	BDL	BDL	BDL	BDL	0.08	BDL	BDL	BDL	BDL	BDL	BDL
MgO	29.88	29.92	30.11	30.01	29.92	29.72	29.47	28.89	28.07	26.74	22.27	15.03	10.58	8.07	5.82	4.37
FeO	33.97	33.93	33.96	33.91	33.95	34.32	35.08	35.29	36.28	38.13	43.00	49.18	51.06	51.25	55.62	54.16
MnO	0.36	0.36	0.34	0.34	0.39	0.39	0.38	0.36	0.40	0.42	0.49	0.60	0.72	0.74	0.82	0.77
CaO	1.01	1.05	1.04	1.03	1.06	1.04	1.04	1.05	1.05	1.20	1.49	3.63	5.99	7.60	7.40	10.25
P ₂ O ₅	0.16	0.15	0.11	0.18	0.16	0.12	0.17	0.14	0.12	0.02	0.02	0.05	0.03	0.09	0.04	0.06
Na ₂ O	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
NiO	0.00	0.00	0.00	0.02	0.00	0.04	0.01	0.01	0.02	0.02	0.00	0.04	0.05	0.00	0.03	0.00
K ₂ O	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.03	0.03	0.02	0.03	0.01	0.01	0.03	0.01
V ₂ O ₃	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.02
Total	100.72	100.60	100.80	100.55	100.41	100.48	101.01	100.58	100.46	100.83	100.71	100.63	99.57	99.86	100.10	100.14
<i>Cation formula based on 4 oxygens</i>																
Si	0.968	0.965	0.964	0.962	0.958	0.961	0.958	0.962	0.960	0.959	0.962	0.962	0.965	0.976	0.970	0.976
Al	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.003	0.005	0.003	0.006	0.006	0.028	0.002	0.001
Ti	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.002	0.001
Cr	BDL	BDL	BDL	BDL	0.002	BDL	BDL	BDL	BDL	0.002	BDL	BDL	BDL	BDL	BDL	BDL
Mg	1.227	1.230	1.236	1.235	1.235	1.228	1.215	1.198	1.172	1.123	0.963	0.678	0.494	0.376	0.278	0.209
Fe	0.782	0.783	0.782	0.783	0.786	0.795	0.811	0.821	0.850	0.899	1.043	1.245	1.337	1.341	1.494	1.455
Mn	0.008	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.009	0.010	0.012	0.015	0.019	0.020	0.022	0.021
Ca	0.030	0.031	0.031	0.031	0.032	0.031	0.031	0.031	0.031	0.036	0.046	0.118	0.201	0.255	0.255	0.353
P	0.004	0.004	0.003	0.004	0.004	0.003	0.004	0.003	0.003	0.000	0.000	0.001	0.001	0.002	0.001	0.002
Na	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
Ni	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.000
K	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000
V	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.024	3.027	3.029	3.030	3.032	3.032	3.033	3.030	3.032	3.037	3.034	3.031	3.028	3.003	3.026	3.020
XFe	0.38	0.38	0.38	0.38	0.38	0.39	0.39	0.40	0.41	0.44	0.51	0.61	0.66	0.68	0.74	0.72

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
 limit = 102 ppm

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Appendix 1. Angrite olivine.

SAH 99555	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
<i>Weight percent oxides</i>																
SiO ₂	30.46	30.83	30.17	30.14	30.24	29.97	30.00	29.67	29.13	29.39	29.27	29.39	29.22	29.34	29.30	29.20
Al ₂ O ₃	0.01	0.01	0.00	0.02	0.00	0.05	0.01	0.01	0.02	0.02	0.03	0.04	0.02	0.03	0.01	0.03
TiO ₂	0.08	0.08	0.08	0.06	0.08	0.08	0.09	0.13	0.11	0.11	0.10	0.15	0.12	0.18	0.15	0.17
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	2.61	2.36	2.12	1.93	1.66	1.58	1.67	1.50	1.36	1.16	1.01	0.81	0.69	0.58	0.41	0.44
FeO	44.61	45.16	45.34	45.68	46.78	48.89	53.78	57.44	58.02	58.54	58.94	58.70	58.78	58.29	57.51	58.11
MnO	0.68	0.67	0.64	0.69	0.69	0.72	0.75	0.83	0.82	0.77	0.84	0.77	0.82	0.80	0.76	0.80
CaO	20.60	20.60	20.96	20.64	20.05	18.06	14.32	10.22	9.50	9.33	9.32	9.39	9.99	10.37	10.61	10.64
P ₂ O ₅	0.05	0.09	0.06	0.03	0.05	0.09	0.05	0.07	0.06	0.05	0.03	0.07	0.06	0.10	0.06	0.05
Na ₂ O	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
NiO	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
K ₂ O	0.02	0.03	0.02	0.02	0.01	0.02	0.03	0.03	0.02	0.02	0.04	0.03	0.02	0.01	0.02	0.00
V ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.00	0.04	0.01
Total	99.12	99.85	99.42	99.20	99.61	99.45	100.70	99.91	99.08	99.43	99.62	99.35	99.71	99.68	98.88	99.44
<i>Cation formula based on 4 oxygens</i>																
Si	0.975	0.979	0.968	0.970	0.972	0.970	0.970	0.975	0.970	0.976	0.973	0.978	0.971	0.973	0.979	0.972
Al	0.000	0.000	0.000	0.001	0.000	0.002	0.000	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.001
Ti	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.003	0.004	0.004	0.004
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	0.124	0.112	0.101	0.093	0.080	0.076	0.081	0.074	0.067	0.057	0.050	0.040	0.034	0.029	0.020	0.022
Fe	1.194	1.199	1.216	1.230	1.258	1.324	1.454	1.579	1.616	1.625	1.638	1.633	1.634	1.617	1.606	1.618
Mn	0.019	0.018	0.017	0.019	0.019	0.020	0.020	0.023	0.023	0.022	0.024	0.022	0.023	0.022	0.021	0.023
Ca	0.706	0.701	0.720	0.712	0.691	0.626	0.496	0.360	0.339	0.332	0.332	0.334	0.356	0.368	0.380	0.379
P	0.001	0.003	0.002	0.001	0.001	0.002	0.001	0.002	0.002	0.001	0.001	0.002	0.002	0.003	0.002	0.001
Na	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Ni	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.000
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.000
Total	3.022	3.016	3.029	3.027	3.024	3.023	3.026	3.019	3.024	3.020	3.023	3.015	3.024	3.018	3.015	3.021
XFe	0.59	0.60	0.60	0.60	0.62	0.65	0.72	0.78	0.80	0.81	0.81	0.81	0.81	0.80	0.80	0.80

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

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Appendix 1. Angrite olivine.

SAH 99555	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
<i>Weight percent oxides</i>																
SiO ₂	29.23	29.48	29.24	29.17	29.19	29.12	28.74	29.07	28.70	34.03	34.39	34.19	34.24	34.66	34.89	34.63
Al ₂ O ₃	0.05	0.00	0.02	0.01	0.01	0.04	0.02	0.04	0.05	0.10	0.07	0.11	0.16	0.20	0.14	0.15
TiO ₂	0.13	0.16	0.16	0.18	0.16	0.16	0.17	0.18	0.20	0.05	0.03	0.04	0.06	0.05	0.05	0.06
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	0.34	0.33	0.23	0.17	0.15	0.11	0.05	0.10	0.08	29.69	29.93	30.13	30.37	30.66	30.95	31.09
FeO	58.91	59.39	58.66	58.92	59.45	58.61	57.29	57.35	58.77	33.77	33.66	33.60	33.10	32.81	32.57	32.07
MnO	0.78	0.71	0.73	0.69	0.76	0.70	0.71	0.71	0.74	0.31	0.35	0.37	0.36	0.37	0.34	0.34
CaO	9.97	9.83	10.06	9.99	9.83	10.56	11.54	11.22	9.98	1.01	0.98	0.96	0.95	0.93	0.94	0.97
P ₂ O ₅	0.06	0.10	0.10	0.13	0.09	0.09	0.22	0.26	0.27	0.17	0.13	0.11	0.08	0.03	0.00	0.06
Na ₂ O	0.02	0.00	0.00	0.00	0.04	0.00	0.00	0.05	0.03	0.00	0.00	0.00	0.01	0.01	0.00	0.00
NiO	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.03	0.00	0.03	0.00
K ₂ O	0.03	0.03	0.02	0.03	0.03	0.02	0.02	0.00	0.01	0.02	0.03	0.04	0.04	0.02	0.04	0.03
V ₂ O ₃	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.01	0.02	0.00	0.02
Total	99.54	100.05	99.23	99.28	99.71	99.42	98.75	98.98	98.86	99.24	99.60	99.58	99.43	99.81	99.99	99.48
<i>Cation formula based on 4 oxygens</i>																
Si	0.974	0.977	0.976	0.975	0.973	0.972	0.964	0.971	0.964	0.954	0.959	0.954	0.955	0.960	0.963	0.960
Al	0.002	0.000	0.001	0.000	0.000	0.001	0.001	0.001	0.002	0.003	0.002	0.004	0.005	0.007	0.005	0.005
Ti	0.003	0.004	0.004	0.005	0.004	0.004	0.004	0.005	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	0.017	0.016	0.011	0.008	0.007	0.005	0.003	0.005	0.004	1.241	1.245	1.254	1.263	1.266	1.274	1.284
Fe	1.641	1.645	1.638	1.646	1.657	1.636	1.608	1.601	1.652	0.792	0.785	0.785	0.772	0.760	0.752	0.743
Mn	0.022	0.020	0.021	0.020	0.021	0.020	0.020	0.020	0.021	0.007	0.008	0.009	0.008	0.009	0.008	0.008
Ca	0.356	0.349	0.360	0.357	0.351	0.378	0.415	0.401	0.359	0.030	0.029	0.029	0.028	0.028	0.028	0.029
P	0.002	0.003	0.003	0.004	0.002	0.002	0.006	0.007	0.008	0.004	0.003	0.003	0.002	0.001	0.000	0.002
Na	0.001	0.000	0.000	0.000	0.003	0.000	0.000	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.001	0.000
K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.020	3.016	3.015	3.016	3.021	3.020	3.022	3.015	3.019	3.037	3.034	3.039	3.039	3.034	3.034	3.034
XFe	0.81	0.82	0.82	0.82	0.82	0.81	0.79	0.80	0.82	0.38	0.38	0.38	0.37	0.37	0.37	0.36

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

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Appendix 1. Angrite olivine.

SAH 99555	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
<i>Weight percent oxides</i>																
SiO ₂	34.91	34.94	34.70	34.50	34.36	34.51	34.14	34.31	33.82	32.83	31.10	31.08	30.01	29.97	30.17	29.92
Al ₂ O ₃	0.17	0.11	0.08	0.10	0.08	0.09	0.09	0.03	0.05	0.19	0.01	0.92	0.09	0.05	0.02	0.02
TiO ₂	0.03	0.03	0.03	0.04	0.03	0.02	0.01	0.02	0.05	0.06	0.07	0.19	0.09	0.07	0.08	0.09
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	31.06	30.86	30.59	30.20	29.72	29.55	29.08	28.00	24.87	20.84	11.05	6.82	6.01	2.79	2.04	1.59
FeO	32.33	32.75	32.92	33.66	34.04	34.42	35.00	36.23	39.78	43.43	52.15	51.56	56.38	45.61	45.89	49.24
MnO	0.36	0.34	0.38	0.36	0.31	0.38	0.37	0.36	0.43	0.47	0.71	0.73	0.80	0.68	0.71	0.71
CaO	0.92	0.94	0.95	0.98	0.99	0.98	0.98	1.03	1.31	1.92	4.54	8.18	6.02	19.46	20.67	17.81
P ₂ O ₅	0.03	0.05	0.09	0.04	0.10	0.02	0.04	0.02	0.03	0.02	0.02	0.14	0.02	0.07	0.04	0.07
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00
NiO	0.00	0.06	0.00	0.00	0.03	0.01	0.05	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00
K ₂ O	0.00	0.03	0.02	0.03	0.02	0.02	0.02	0.03	0.04	0.03	0.00	0.05	0.05	0.02	0.04	0.02
V ₂ O ₃	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02
Total	99.89	100.16	99.82	99.94	99.71	100.00	99.85	100.08	100.43	99.83	99.68	99.68	99.48	98.72	99.67	99.50
<i>Cation formula based on 4 oxygens</i>																
Si	0.963	0.964	0.962	0.959	0.959	0.962	0.957	0.965	0.966	0.965	0.972	0.978	0.971	0.967	0.967	0.969
Al	0.006	0.004	0.003	0.003	0.003	0.003	0.003	0.001	0.002	0.007	0.000	0.034	0.003	0.002	0.001	0.001
Ti	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.001	0.002	0.004	0.002	0.002	0.002	0.002
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	1.278	1.269	1.264	1.251	1.237	1.228	1.216	1.173	1.059	0.914	0.515	0.320	0.290	0.134	0.098	0.077
Fe	0.746	0.755	0.763	0.782	0.795	0.803	0.821	0.852	0.950	1.068	1.364	1.357	1.525	1.230	1.230	1.334
Mn	0.008	0.008	0.009	0.008	0.007	0.009	0.009	0.009	0.010	0.012	0.019	0.019	0.022	0.019	0.019	0.019
Ca	0.027	0.028	0.028	0.029	0.029	0.029	0.029	0.031	0.040	0.061	0.152	0.276	0.209	0.673	0.710	0.618
P	0.001	0.001	0.002	0.001	0.002	0.000	0.001	0.000	0.001	0.000	0.001	0.004	0.000	0.002	0.001	0.002
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
Ni	0.000	0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
K	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.002	0.002	0.001	0.002	0.001
V	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.031	3.032	3.033	3.037	3.035	3.036	3.039	3.034	3.031	3.030	3.026	2.996	3.025	3.028	3.030	3.025
XFe	0.36	0.37	0.37	0.38	0.39	0.39	0.40	0.41	0.46	0.52	0.67	0.69	0.75	0.60	0.60	0.66

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

SAH 99555	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
<i>Weight percent oxides</i>																
SiO ₂	29.72	29.07	29.26	28.91	29.07	28.92	28.98	29.38	29.55	29.38	29.18	29.15	29.40	28.88	28.97	28.81
Al ₂ O ₃	0.02	0.01	0.05	0.04	0.02	0.04	0.02	0.02	0.02	0.05	0.03	0.03	0.03	0.05	0.05	0.02
TiO ₂	0.11	0.09	0.16	0.17	0.17	0.14	0.19	0.14	0.19	0.15	0.17	0.16	0.18	0.20	0.20	0.20
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	0.84	0.64	0.33	0.41	0.39	0.45	0.35	0.19	0.20	0.22	0.24	0.26	0.31	0.31	0.35	0.32
FeO	48.14	57.27	57.90	58.42	57.00	58.05	57.59	56.95	56.31	57.44	54.67	56.00	58.28	59.21	59.18	58.15
MnO	0.70	0.73	0.72	0.75	0.69	0.68	0.72	0.71	0.67	0.68	0.70	0.75	0.67	0.73	0.77	0.72
CaO	19.44	11.22	11.11	10.52	11.41	10.48	10.73	12.19	12.41	11.40	14.02	12.54	10.62	9.55	9.72	10.51
P ₂ O ₅	0.10	0.05	0.22	0.17	0.19	0.11	0.18	0.10	0.17	0.13	0.15	0.15	0.13	0.18	0.23	0.20
Na ₂ O	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.03	0.00	0.00
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
K ₂ O	0.02	0.02	0.03	0.02	0.04	0.03	0.01	0.02	0.02	0.01	0.01	0.02	0.04	0.02	0.00	0.03
V ₂ O ₃	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.01	0.00
Total	99.16	99.13	99.76	99.43	98.99	98.95	98.77	99.72	99.54	99.53	99.15	99.05	99.67	99.19	99.49	98.98
<i>Cation formula based on 4 oxygens</i>																
Si	0.967	0.970	0.969	0.964	0.970	0.968	0.970	0.973	0.977	0.975	0.967	0.970	0.975	0.967	0.966	0.965
Al	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.002	0.001
Ti	0.003	0.002	0.004	0.004	0.004	0.004	0.005	0.004	0.005	0.004	0.004	0.004	0.005	0.005	0.005	0.005
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	0.041	0.032	0.016	0.020	0.020	0.023	0.018	0.009	0.010	0.011	0.012	0.013	0.015	0.016	0.017	0.016
Fe	1.310	1.597	1.604	1.630	1.590	1.626	1.613	1.577	1.556	1.593	1.515	1.558	1.617	1.658	1.651	1.629
Mn	0.019	0.021	0.020	0.021	0.019	0.019	0.021	0.020	0.019	0.019	0.020	0.021	0.019	0.021	0.022	0.021
Ca	0.678	0.401	0.394	0.376	0.408	0.376	0.385	0.432	0.439	0.405	0.498	0.447	0.377	0.343	0.347	0.377
P	0.003	0.001	0.006	0.005	0.005	0.003	0.005	0.003	0.005	0.004	0.004	0.004	0.004	0.005	0.006	0.006
Na	0.000	0.002	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.002	0.000	0.000
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.002	0.001	0.000	0.001
V	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.025	3.027	3.017	3.023	3.018	3.024	3.017	3.020	3.012	3.017	3.022	3.020	3.015	3.020	3.018	3.021
XFe	0.65	0.79	0.80	0.80	0.79	0.80	0.80	0.78	0.78	0.79	0.75	0.77	0.80	0.82	0.82	0.81

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

Appendix 1. Angrite olivine.

SAH 99555	81	82
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<i>Weight percent oxides</i>		
SiO ₂	28.84	29.63
Al ₂ O ₃	0.03	0.04
TiO ₂	0.18	0.16
Cr ₂ O ₃	BDL	BDL
MgO	0.28	0.20
FeO	58.71	53.37
MnO	0.70	0.64
CaO	10.17	14.93
P ₂ O ₅	0.14	0.15
Na ₂ O	0.01	0.00
NiO	0.00	0.00
K ₂ O	0.02	0.02
V ₂ O ₃	0.00	0.00
Total	99.08	99.14
 <i>Cation formula based on 4 oxygens</i>		
Si	0.967	0.976
Al	0.001	0.002
Ti	0.005	0.004
Cr	BDL	BDL
Mg	0.014	0.010
Fe	1.646	1.471
Mn	0.020	0.018
Ca	0.365	0.527
P	0.004	0.004
Na	0.000	0.000
Ni	0.000	0.000
K	0.001	0.001
V	0.000	0.000
Total	3.023	3.013
XFe	0.81	0.73

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
 limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

SAH 99555 - High Precision	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>Weight percent oxides</i>																
SiO ₂	36.09	32.57	32.20	32.00	31.08	30.89	30.85	30.66	34.90	34.82	31.52	30.94	31.54	31.13	30.95	36.92
Al ₂ O ₃	0.12	0.02	0.03	0.02	0.03	0.03	0.03	0.04	0.05	0.06	0.04	0.02	0.02	0.18	0.01	0.11
TiO ₂	0.04	0.07	0.06	0.08	0.11	0.14	0.16	0.10	0.06	0.05	0.09	0.14	0.11	0.10	0.12	0.01
Cr ₂ O ₃	0.04	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.04	0.05	BDL	BDL	BDL	BDL	BDL	0.03
MgO	26.60	8.15	2.30	1.69	1.30	0.58	0.14	0.03	21.17	21.28	3.85	0.54	0.37	0.87	0.97	30.86
FeO	36.94	53.62	44.72	47.02	58.38	59.35	60.19	58.43	42.89	42.87	55.76	51.92	48.16	47.31	58.53	32.52
MnO	0.40	0.77	0.68	0.69	0.82	0.78	0.71	0.71	0.48	0.50	0.83	0.67	0.60	0.63	0.77	0.34
CaO	1.14	5.94	21.43	19.65	9.76	9.59	9.49	10.41	2.12	1.95	8.69	16.22	20.22	19.20	9.72	0.92
P ₂ O ₅	0.08	0.03	0.08	0.06	0.04	0.05	0.08	0.14	0.07	0.10	0.06	0.14	0.10	0.09	0.07	0.09
Na ₂ O	0.01	0.00	0.03	0.02	0.03	0.01	0.03	0.02	0.00	0.00	0.01	0.00	0.00	0.06	0.00	0.02
NiO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K ₂ O	0.02	0.02	0.03	0.03	0.03	0.04	0.03	0.04	0.03	0.02	0.04	0.03	0.03	0.06	0.03	0.03
V ₂ O ₃	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total	101.49	101.19	101.55	101.26	101.60	101.47	101.70	100.57	101.83	101.70	100.87	100.62	101.13	99.61	101.17	101.85
<i>Cation formula based on 4 oxygens</i>																
Si	0.997	1.007	0.998	1.002	0.999	0.999	0.999	1.001	0.995	0.993	1.002	0.993	0.997	0.996	1.001	0.993
Al	0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.007	0.001	0.003
Ti	0.001	0.002	0.001	0.002	0.003	0.003	0.004	0.003	0.001	0.001	0.002	0.003	0.003	0.002	0.003	0.000
Cr	0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.001	0.001	BDL	BDL	BDL	BDL	BDL	0.001
Mg	1.095	0.376	0.106	0.079	0.062	0.028	0.007	0.001	0.900	0.905	0.182	0.026	0.017	0.041	0.047	1.237
Fe	0.853	1.387	1.159	1.231	1.569	1.606	1.630	1.595	1.022	1.023	1.483	1.394	1.274	1.267	1.582	0.731
Mn	0.009	0.020	0.018	0.018	0.022	0.021	0.019	0.019	0.012	0.012	0.022	0.018	0.016	0.017	0.021	0.008
Ca	0.034	0.197	0.711	0.659	0.336	0.333	0.329	0.364	0.065	0.060	0.296	0.558	0.685	0.659	0.337	0.027
P	0.002	0.001	0.002	0.001	0.001	0.001	0.002	0.004	0.002	0.002	0.002	0.004	0.003	0.002	0.002	0.002
Na	0.000	0.000	0.002	0.001	0.002	0.001	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.001
Ni	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	2.997	2.990	2.999	2.995	2.997	2.995	2.994	2.991	3.000	3.001	2.994	2.998	2.996	2.998	2.994	3.003
XFe	0.43	0.71	0.59	0.63	0.80	0.82	0.83	0.81	0.51	0.51	0.76	0.70	0.64	0.64	0.80	0.37

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

Appendix 1. Angrite olivine.

SAH 99555 - High Precision 17 18

Weight percent oxides

SiO ₂	36.83	36.69
Al ₂ O ₃	0.10	0.11
TiO ₂	0.02	0.03
Cr ₂ O ₃	0.04	0.04
MgO	31.20	30.57
FeO	32.24	33.16
MnO	0.33	0.35
CaO	0.91	0.91
P ₂ O ₅	0.09	0.08
Na ₂ O	0.01	0.01
NiO	N/A	N/A
K ₂ O	0.03	0.03
V ₂ O ₃	0.01	0.00
Total	101.80	101.98

Cation formula based on 4 oxygens

Si	0.990	0.989
Al	0.003	0.004
Ti	0.000	0.001
Cr	0.001	0.001
Mg	1.250	1.228
Fe	0.725	0.747
Mn	0.008	0.008
Ca	0.026	0.026
P	0.002	0.002
Na	0.000	0.000
Ni	N/A	N/A
K	0.001	0.001
V	0.000	0.000
Total	3.005	3.007

XFe 0.36 0.37

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
 limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
 PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

LEW 86010	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>Weight percent oxides</i>																
SiO ₂	33.08	33.19	32.84	31.95	33.59	33.71	33.81	33.72	33.48	33.37	33.28	33.05	32.94	33.05	32.89	33.11
Al ₂ O ₃	0.03	0.01	0.00	0.02	0.02	0.00	0.00	0.01	0.03	0.01	0.02	0.01	0.02	0.03	0.04	0.05
TiO ₂	0.08	0.05	0.03	0.05	0.01	0.02	0.00	0.06	0.08	0.06	0.07	0.07	0.08	0.07	0.06	0.07
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	14.43	14.46	14.63	8.24	5.43	5.36	5.26	14.17	13.77	13.95	14.00	5.34	5.34	5.42	5.53	5.43
FeO	51.59	51.71	51.97	39.26	32.46	32.39	32.09	51.31	51.45	51.39	51.50	33.08	33.16	33.24	32.73	33.03
MnO	0.62	0.62	0.63	0.47	0.37	0.40	0.36	0.59	0.68	0.66	0.64	0.43	0.42	0.48	0.50	0.45
CaO	1.63	1.57	1.71	19.87	29.99	29.97	30.27	2.07	2.41	2.41	2.45	28.54	28.59	28.73	28.81	28.78
P ₂ O ₅	0.02	0.01	0.02	0.00	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.15	0.16	0.13	0.15	0.18
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.02
NiO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K ₂ O	0.02	0.01	0.02	0.02	0.03	0.04	0.03	0.03	0.02	0.01	0.02	0.00	0.02	0.03	0.02	0.01
V ₂ O ₃	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.01
Total	101.50	101.63	101.86	99.88	101.94	101.93	101.87	101.98	101.92	101.90	101.97	100.68	100.76	101.18	100.72	101.14
<i>Cation formula based on 4 oxygens</i>																
Si	0.992	0.994	0.985	0.977	0.995	0.998	1.001	1.004	1.000	0.998	0.995	0.993	0.990	0.989	0.988	0.990
Al	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.002
Ti	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.002	0.001	0.002	0.002	0.002	0.002	0.001	0.001
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	0.646	0.646	0.654	0.375	0.240	0.237	0.232	0.629	0.614	0.622	0.624	0.239	0.239	0.242	0.248	0.242
Fe	1.294	1.296	1.303	1.004	0.804	0.802	0.794	1.278	1.286	1.285	1.288	0.831	0.833	0.832	0.822	0.826
Mn	0.016	0.016	0.016	0.012	0.009	0.010	0.009	0.015	0.017	0.017	0.016	0.011	0.011	0.012	0.013	0.011
Ca	0.052	0.050	0.055	0.651	0.952	0.951	0.960	0.066	0.077	0.077	0.078	0.919	0.920	0.921	0.927	0.922
P	0.001	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.003	0.004	0.005
Na	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.001
Ni	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.000
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.005	3.004	3.014	3.022	3.004	3.002	3.000	2.995	2.997	3.002	3.004	3.000	3.002	3.004	3.005	3.001
XFe	0.65	0.65	0.65	0.49	0.40	0.40	0.40	0.65	0.65	0.65	0.65	0.42	0.42	0.42	0.41	0.42

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
 limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

LEW 86010	17	18	19	20	21	22	23	24	25	26	27	28	29	30
<i>Weight percent oxides</i>														
SiO ₂	33.13	32.90	33.04	33.08	32.96	32.89	32.56	32.45	33.03	32.74	33.00	32.91	33.10	33.02
Al ₂ O ₃	0.04	0.05	0.03	0.03	0.04	0.04	0.03	0.02	0.01	0.04	0.03	0.02	0.02	0.06
TiO ₂	0.04	0.05	0.08	0.07	0.07	0.03	0.05	0.08	0.07	0.07	0.07	0.07	0.07	0.06
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	5.32	5.28	5.23	5.34	5.30	14.89	11.21	5.38	4.97	5.15	5.24	5.22	5.31	5.29
FeO	32.70	32.74	32.62	32.43	32.46	51.86	46.71	33.20	32.49	32.52	32.70	32.62	32.74	32.84
MnO	0.43	0.39	0.42	0.42	0.39	0.56	0.51	0.42	0.39	0.44	0.42	0.45	0.44	0.42
CaO	29.09	29.05	29.46	29.46	29.61	1.27	9.46	28.08	29.64	29.43	29.56	29.24	29.17	29.21
P ₂ O ₅	0.19	0.15	0.13	0.12	0.15	0.15	0.16	0.16	0.18	0.17	0.20	0.16	0.16	0.16
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
NiO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K ₂ O	0.02	0.01	0.02	0.01	0.02	0.02	0.01	0.03	0.04	0.03	0.07	0.03	0.06	0.04
V ₂ O ₃	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Total	100.96	100.64	101.06	100.96	101.01	101.73	100.69	99.86	100.82	100.60	101.30	100.74	101.06	101.12
<i>Cation formula based on 4 oxygens</i>														
Si	0.992	0.989	0.989	0.991	0.987	0.984	0.987	0.986	0.991	0.986	0.986	0.989	0.991	0.988
Al	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.002
Ti	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.001
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	0.237	0.236	0.233	0.238	0.237	0.664	0.507	0.243	0.223	0.231	0.233	0.234	0.237	0.236
Fe	0.819	0.823	0.817	0.812	0.813	1.298	1.184	0.843	0.816	0.819	0.817	0.820	0.820	0.822
Mn	0.011	0.010	0.011	0.011	0.010	0.014	0.013	0.011	0.010	0.011	0.011	0.011	0.011	0.011
Ca	0.933	0.936	0.945	0.945	0.950	0.041	0.307	0.914	0.953	0.950	0.947	0.941	0.935	0.937
P	0.005	0.004	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004	0.004
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Ni	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.002	0.001
V	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Total	3.000	3.003	3.003	3.003	3.005	3.009	3.005	3.006	3.001	3.006	3.005	3.003	3.002	3.004
XFe	0.41	0.41	0.41	0.41	0.41	0.65	0.59	0.42	0.41	0.41	0.41	0.41	0.41	0.41

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

LEW 86010 - High Precision	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>Weight percent oxides</i>																
SiO ₂	33.37	33.41	33.34	33.03	33.10	33.20	32.94	32.91	33.00	32.15	32.00	31.88	31.64	31.66	32.05	32.27
Al ₂ O ₃	0.02	0.02	0.02	0.02	0.13	0.04	0.03	0.01	0.03	0.05	0.02	0.01	0.05	0.06	0.05	0.02
TiO ₂	0.05	0.06	0.05	0.05	0.06	0.04	0.08	0.06	0.07	0.05	0.04	0.05	0.06	0.08	0.11	0.05
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	13.53	13.12	13.02	14.16	14.05	14.16	5.08	5.17	5.15	4.94	4.96	4.96	13.92	13.76	13.34	11.68
FeO	51.59	51.32	51.29	50.75	50.98	50.93	33.50	33.54	33.36	34.34	34.35	34.19	52.81	52.86	52.23	47.47
MnO	0.63	0.64	0.66	0.62	0.63	0.64	0.43	0.43	0.44	0.43	0.45	0.44	0.61	0.60	0.62	0.57
CaO	2.58	3.33	3.50	2.09	2.27	2.19	28.84	28.70	28.82	28.33	28.29	28.57	1.19	1.28	2.28	8.52
P ₂ O ₅	0.00	0.01	0.01	0.00	0.00	0.00	0.14	0.14	0.16	0.06	0.06	0.05	0.15	0.12	0.04	0.02
Na ₂ O	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NiO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K ₂ O	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.03
V ₂ O ₃	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Total	101.83	101.94	101.90	100.75	101.26	101.24	101.07	101.00	101.05	100.39	100.19	100.21	100.45	100.44	100.75	100.61
<i>Cation formula based on 4 oxygens</i>																
Si	1.000	1.000	1.000	0.997	0.995	0.997	0.989	0.989	0.990	0.978	0.977	0.974	0.970	0.971	0.979	0.982
Al	0.001	0.001	0.001	0.001	0.005	0.001	0.001	0.000	0.001	0.002	0.001	0.001	0.002	0.002	0.002	0.001
Ti	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.003	0.001
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	0.604	0.586	0.582	0.637	0.629	0.634	0.227	0.232	0.230	0.224	0.226	0.226	0.636	0.629	0.607	0.530
Fe	1.293	1.285	1.286	1.281	1.281	1.280	0.841	0.843	0.837	0.874	0.877	0.873	1.354	1.356	1.334	1.208
Mn	0.016	0.016	0.017	0.016	0.016	0.016	0.011	0.011	0.011	0.011	0.012	0.011	0.016	0.016	0.016	0.015
Ca	0.083	0.107	0.112	0.068	0.073	0.071	0.928	0.924	0.926	0.924	0.925	0.935	0.039	0.042	0.075	0.278
P	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.004	0.001	0.002	0.001	0.004	0.003	0.001	0.000
Na	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.000	2.998	2.999	3.002	3.002	3.001	3.004	3.005	3.002	3.018	3.020	3.023	3.023	3.022	3.017	3.016
XFe	0.65	0.65	0.65	0.65	0.65	0.64	0.42	0.42	0.42	0.43	0.43	0.43	0.67	0.67	0.66	0.60

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

Appendix 1. Angrite olivine.

LEW 86010 - High Precision	17	18
<i>Weight percent oxides</i>		
SiO ₂	32.09	32.50
Al ₂ O ₃	0.02	0.01
TiO ₂	0.05	0.03
Cr ₂ O ₃	BDL	BDL
MgO	5.29	5.21
FeO	33.20	32.62
MnO	0.44	0.39
CaO	29.05	29.71
P ₂ O ₅	0.12	0.00
Na ₂ O	0.00	0.00
NiO	N/A	N/A
K ₂ O	0.03	0.02
V ₂ O ₃	0.02	0.00
Total	100.30	100.48
<i>Cation formula based on 4 oxygens</i>		
Si	0.974	0.983
Al	0.001	0.000
Ti	0.001	0.001
Cr	BDL	BDL
Mg	0.239	0.235
Fe	0.843	0.825
Mn	0.011	0.010
Ca	0.945	0.963
P	0.003	0.000
Na	0.000	0.000
Ni	N/A	N/A
K	0.001	0.001
V	0.000	0.000
Total	3.020	3.017
XFe	0.42	0.41

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
 limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

LEW 87051	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>Weight percent oxides</i>																
SiO ₂	37.39	37.66	38.02	38.45	38.55	38.61	39.05	39.02	38.99	38.88	38.86	38.77	39.08	38.47	38.61	38.49
Al ₂ O ₃	0.06	0.08	0.07	0.07	0.10	0.09	0.09	0.07	0.08	0.06	0.09	0.08	0.09	0.08	0.08	0.09
TiO ₂	0.04	0.03	0.02	0.02	0.03	0.00	0.02	0.03	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01
Cr ₂ O ₃	0.15	0.11	0.10	0.08	0.12	BDL	0.13	0.10	0.12	0.09	0.09	0.12	0.10	0.11	BDL	0.11
MgO	35.68	37.70	38.81	41.07	42.07	42.27	43.24	44.04	42.67	43.06	43.79	43.42	42.97	41.84	41.74	41.03
FeO	26.74	23.50	22.68	20.04	18.89	17.74	17.19	16.77	18.03	17.06	16.80	16.99	17.34	17.78	18.36	18.94
MnO	0.29	0.26	0.24	0.20	0.21	0.20	0.18	0.16	0.18	0.19	0.20	0.16	0.19	0.20	0.17	0.21
CaO	0.72	0.65	0.67	0.65	0.58	0.59	0.50	0.54	0.53	0.56	0.53	0.55	0.54	0.56	0.60	0.60
P ₂ O ₅	0.05	0.03	0.02	0.01	0.00	0.00	0.03	0.02	0.01	0.00	0.01	0.00	0.02	0.02	0.01	0.00
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
NiO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K ₂ O	0.02	0.01	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.01	0.02	0.02	0.02	0.03	0.03
V ₂ O ₃	0.02	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.02	0.02	0.00	0.00	0.03	0.01	0.02
Total	101.17	100.02	100.67	100.61	100.57	99.58	100.48	100.78	100.65	99.95	100.39	100.12	100.36	99.11	99.70	99.54
<i>Cation formula based on 4 oxygens</i>																
Si	0.985	0.988	0.987	0.986	0.984	0.989	0.988	0.983	0.989	0.989	0.983	0.985	0.991	0.991	0.991	0.992
Al	0.002	0.003	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.002	0.003	0.002	0.003	0.002	0.002	0.003
Ti	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cr	0.003	0.002	0.002	0.002	0.002	BDL	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	BDL	0.002
Mg	1.401	1.474	1.501	1.569	1.600	1.615	1.631	1.654	1.613	1.633	1.652	1.644	1.624	1.607	1.597	1.577
Fe	0.589	0.516	0.492	0.430	0.403	0.380	0.364	0.353	0.382	0.363	0.355	0.361	0.368	0.383	0.394	0.408
Mn	0.006	0.006	0.005	0.004	0.004	0.004	0.004	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005
Ca	0.020	0.018	0.019	0.018	0.016	0.016	0.014	0.014	0.014	0.015	0.014	0.015	0.015	0.015	0.016	0.017
P	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Total	3.010	3.008	3.010	3.012	3.013	3.009	3.008	3.014	3.009	3.009	3.014	3.013	3.007	3.006	3.007	3.005
XFe	0.29	0.26	0.24	0.21	0.20	0.19	0.18	0.17	0.19	0.18	0.18	0.18	0.18	0.19	0.20	0.20

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

LEW 87051	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
<i>Weight percent oxides</i>																
SiO ₂	38.34	38.64	38.20	38.11	37.57	37.09	37.35	30.80	35.16	36.00	36.98	37.47	37.31	36.80	36.34	29.88
Al ₂ O ₃	0.08	0.18	0.10	0.12	0.06	0.07	0.12	0.30	0.06	0.06	0.08	0.06	0.05	0.09	0.09	0.08
TiO ₂	0.00	0.00	0.04	0.00	0.01	0.02	0.01	0.25	0.02	0.02	0.02	0.00	0.00	0.03	0.01	0.10
Cr ₂ O ₃	0.10	0.09	BDL	0.10	0.12	0.15	0.13	BDL	0.15	0.11	0.09	0.17	0.09	0.11	0.14	BDL
MgO	40.93	40.23	39.75	38.84	37.21	35.09	29.81	1.27	34.06	36.84	39.96	46.54	41.63	40.67	39.47	7.52
FeO	19.44	20.05	20.88	21.80	23.64	26.63	32.08	55.56	28.14	24.26	20.59	13.50	18.63	19.54	21.17	55.19
MnO	0.18	0.22	0.21	0.22	0.25	0.30	0.36	0.78	0.30	0.25	0.20	0.16	0.20	0.20	0.22	0.73
CaO	0.58	0.63	0.68	0.67	0.67	0.76	0.91	11.17	0.76	0.68	0.61	0.26	0.60	0.61	0.63	4.82
P ₂ O ₅	0.01	0.02	0.00	0.01	0.01	0.01	0.02	0.13	0.04	0.02	0.01	0.00	0.03	0.00	0.01	0.05
Na ₂ O	0.01	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NiO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K ₂ O	0.02	0.04	0.02	0.02	0.03	0.01	0.03	0.02	0.04	0.00	0.02	0.02	0.02	0.02	0.02	0.03
V ₂ O ₃	0.00	0.02	0.00	0.03	0.00	0.00	0.03	0.02	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00
Total	99.69	100.12	99.94	99.91	99.59	100.14	100.85	100.31	98.73	98.24	98.57	98.19	98.55	98.06	98.10	98.40
<i>Cation formula based on 4 oxygens</i>																
Si	0.989	0.994	0.990	0.992	0.991	0.988	1.011	0.995	0.962	0.970	0.974	0.959	0.973	0.970	0.966	0.969
Al	0.002	0.006	0.003	0.004	0.002	0.002	0.004	0.011	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003
Ti	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002
Cr	0.002	0.002	BDL	0.002	0.003	0.003	0.003	BDL	0.003	0.002	0.002	0.003	0.002	0.002	0.003	BDL
Mg	1.574	1.544	1.536	1.507	1.463	1.393	1.203	0.061	1.390	1.480	1.569	1.775	1.619	1.599	1.564	0.363
Fe	0.420	0.432	0.453	0.475	0.522	0.593	0.726	1.501	0.644	0.547	0.454	0.289	0.406	0.431	0.471	1.497
Mn	0.004	0.005	0.005	0.005	0.006	0.007	0.008	0.021	0.007	0.006	0.005	0.003	0.004	0.004	0.005	0.020
Ca	0.016	0.017	0.019	0.019	0.019	0.022	0.026	0.387	0.022	0.020	0.017	0.007	0.017	0.017	0.018	0.168
P	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.004	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.001
Na	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
V	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.009	3.002	3.007	3.005	3.007	3.009	2.985	2.988	3.034	3.027	3.024	3.039	3.025	3.027	3.031	3.025
XFe	0.21	0.22	0.23	0.24	0.26	0.30	0.37	0.77	0.31	0.27	0.22	0.14	0.20	0.21	0.23	0.74

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
 PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

LEW 87051	33	34	35	36	37	38	39	40	41	42	43	44	45
<i>Weight percent oxides</i>													
SiO ₂	35.90	36.89	36.93	37.28	37.68	38.09	38.08	38.29	37.84	37.61	36.83	36.53	30.44
Al ₂ O ₃	0.03	0.07	0.05	0.09	0.07	0.06	0.05	0.11	0.09	0.07	0.10	0.07	2.32
TiO ₂	0.03	0.03	0.00	0.01	0.02	0.00	0.04	0.00	0.00	0.01	0.01	0.02	0.10
Cr ₂ O ₃	0.11	0.11	0.11	0.11	0.10	0.16	0.15	0.14	0.12	0.12	0.11	0.10	BDL
MgO	34.00	40.75	42.15	43.32	44.13	45.53	46.85	46.72	46.42	45.21	42.94	40.51	3.43
FeO	27.89	20.26	18.23	16.87	15.59	13.99	12.55	12.45	12.96	14.45	17.36	20.32	55.45
MnO	0.33	0.24	0.22	0.19	0.17	0.15	0.15	0.17	0.13	0.15	0.19	0.24	0.82
CaO	0.72	0.63	0.61	0.56	0.53	0.38	0.31	0.36	0.41	0.43	0.56	0.64	7.65
P ₂ O ₅	0.00	0.02	0.03	0.02	0.01	0.00	0.05	0.00	0.00	0.03	0.06	0.00	0.03
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.03	0.02	0.02
NiO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K ₂ O	0.02	0.01	0.02	0.02	0.03	0.02	0.03	0.03	0.04	0.00	0.02	0.02	0.02
V ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.00	0.00	0.01	0.00
Total	99.04	99.01	98.34	98.47	98.32	98.39	98.25	98.26	98.07	98.07	98.21	98.49	100.30
<i>Cation formula based on 4 oxygens</i>													
Si	0.976	0.966	0.965	0.966	0.971	0.973	0.968	0.972	0.966	0.967	0.960	0.963	0.969
Al	0.001	0.002	0.001	0.003	0.002	0.002	0.002	0.003	0.003	0.002	0.003	0.002	0.087
Ti	0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.002
Cr	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.002	0.002	BDL
Mg	1.378	1.591	1.642	1.673	1.695	1.734	1.775	1.768	1.767	1.732	1.669	1.593	0.163
Fe	0.634	0.444	0.398	0.366	0.336	0.299	0.267	0.264	0.277	0.311	0.379	0.448	1.476
Mn	0.008	0.005	0.005	0.004	0.004	0.003	0.003	0.004	0.003	0.003	0.004	0.005	0.022
Ca	0.021	0.018	0.017	0.016	0.015	0.010	0.008	0.010	0.011	0.012	0.016	0.018	0.261
P	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.001
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.001
Ni	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Total	3.022	3.030	3.033	3.031	3.026	3.025	3.028	3.025	3.032	3.030	3.036	3.035	2.984
XFe	0.31	0.22	0.19	0.18	0.16	0.15	0.13	0.13	0.13	0.15	0.18	0.22	0.78

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
 limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

NWA 10463	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>Weight percent oxides</i>																
SiO ₂	34.36	35.94	36.54	36.93	36.69	36.82	35.69	34.88	34.46	32.59	32.49	32.60	34.59	36.05	35.78	35.95
Al ₂ O ₃	0.00	0.03	0.04	0.07	0.12	0.09	0.05	0.02	0.02	0.29	0.00	0.00	0.06	0.04	0.07	0.03
TiO ₂	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.05	0.04	0.04	0.00	0.00	0.00	0.00
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	18.93	24.93	27.34	29.14	28.25	28.07	23.08	19.85	17.38	11.20	12.52	13.17	24.19	27.29	28.00	27.61
FeO	45.14	38.61	36.06	33.99	34.67	35.13	40.23	43.71	46.72	53.16	52.01	50.40	39.66	36.90	35.55	35.67
MnO	0.53	0.40	0.37	0.36	0.35	0.37	0.45	0.53	0.58	0.67	0.67	0.65	0.40	0.38	0.34	0.34
CaO	2.16	1.30	1.02	0.85	1.07	1.10	1.81	2.30	2.48	2.36	3.48	4.01	1.00	0.89	0.90	0.96
P ₂ O ₅	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	101.40	101.21	101.67	101.50	101.39	101.58	101.30	101.30	101.80	100.32	101.36	100.88	100.05	101.54	100.64	100.56
<i>Cation formula based on 4 oxygens</i>																
Si	1.000	1.004	1.005	1.004	1.004	1.005	1.006	1.005	1.005	1.003	0.988	0.989	0.989	0.995	0.991	0.997
Al	0.000	0.001	0.001	0.002	0.004	0.003	0.002	0.001	0.001	0.010	0.000	0.000	0.002	0.001	0.002	0.001
Ti	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	0.821	1.039	1.121	1.182	1.152	1.142	0.970	0.852	0.756	0.513	0.568	0.595	1.031	1.122	1.156	1.141
Fe	1.099	0.902	0.829	0.773	0.793	0.802	0.949	1.053	1.140	1.368	1.323	1.278	0.948	0.852	0.824	0.827
Mn	0.013	0.009	0.009	0.008	0.008	0.009	0.011	0.013	0.014	0.017	0.017	0.017	0.010	0.009	0.008	0.008
Ca	0.067	0.039	0.030	0.025	0.031	0.032	0.055	0.071	0.078	0.078	0.113	0.130	0.031	0.026	0.027	0.029
P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.000	2.995	2.995	2.994	2.993	2.993	2.993	2.995	2.994	2.991	3.011	3.010	3.010	3.005	3.008	3.003
XFe	0.55	0.46	0.42	0.39	0.40	0.41	0.48	0.53	0.58	0.70	0.66	0.64	0.47	0.43	0.41	0.41

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
 PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

NWA 10463	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
<i>Weight percent oxides</i>																
SiO ₂	35.48	35.30	35.56	35.39	35.62	35.52	35.54	35.86	35.74	36.46	36.38	36.15	36.14	35.79	35.61	35.15
Al ₂ O ₃	0.09	0.12	0.05	0.04	0.03	0.04	0.11	0.04	0.18	0.09	0.08	0.05	0.11	0.11	0.09	0.03
TiO ₂	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.03	0.03	0.04	0.02	0.00
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	26.63	26.86	26.90	26.37	26.58	26.34	26.52	27.33	27.23	28.71	29.20	28.20	27.62	27.06	27.17	26.12
FeO	36.87	36.62	36.50	36.86	36.50	36.51	36.56	36.00	36.14	34.61	33.77	35.11	35.68	36.05	36.40	37.20
MnO	0.39	0.41	0.37	0.39	0.41	0.39	0.38	0.39	0.37	0.35	0.31	0.35	0.37	0.39	0.37	0.37
CaO	1.10	1.09	1.20	1.36	1.47	1.67	1.55	1.20	1.13	1.03	0.99	1.20	1.25	1.22	1.24	1.23
P ₂ O ₅	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V ₂ O ₃	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.77	100.50	100.58	100.42	100.79	100.74	100.88	100.82	100.82	101.33	100.81	101.09	101.19	100.73	101.15	100.09
<i>Cation formula based on 4 oxygens</i>																
Si	0.991	0.987	0.992	0.992	0.994	0.993	0.991	0.994	0.991	0.997	0.997	0.994	0.996	0.995	0.989	0.990
Al	0.003	0.004	0.002	0.001	0.001	0.001	0.004	0.001	0.006	0.003	0.002	0.002	0.004	0.004	0.003	0.001
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.001	0.001	0.001	0.000	0.000
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	1.109	1.120	1.118	1.101	1.105	1.098	1.103	1.130	1.126	1.171	1.193	1.156	1.135	1.121	1.125	1.096
Fe	0.862	0.857	0.851	0.864	0.852	0.854	0.853	0.835	0.838	0.792	0.774	0.808	0.822	0.838	0.846	0.876
Mn	0.009	0.010	0.009	0.009	0.010	0.009	0.009	0.009	0.009	0.008	0.007	0.008	0.009	0.009	0.009	0.009
Ca	0.033	0.033	0.036	0.041	0.044	0.050	0.046	0.036	0.033	0.030	0.029	0.035	0.037	0.036	0.037	0.037
P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.007	3.010	3.008	3.008	3.006	3.006	3.006	3.005	3.005	3.001	3.002	3.004	3.002	3.003	3.009	3.010
XFe	0.43	0.43	0.42	0.43	0.43	0.43	0.43	0.42	0.42	0.40	0.39	0.40	0.41	0.42	0.42	0.44

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
 PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

NWA 10463	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
<i>Weight percent oxides</i>																
SiO ₂	35.28	35.08	35.34	33.88	33.14	32.05	31.46	31.12	31.56	31.48	31.93	31.30	31.51	32.43	32.37	32.38
Al ₂ O ₃	0.02	0.06	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	0.00	0.00	0.00	0.04	0.04	0.07	0.07	0.07	0.04	0.02	0.06	0.05	0.04	0.00	0.04	0.04
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	25.92	25.54	21.58	19.62	14.66	8.19	7.14	5.58	7.03	5.94	7.08	6.40	6.32	3.18	3.20	3.24
FeO	38.02	38.51	42.41	44.83	49.80	57.45	59.16	59.84	59.32	60.35	58.62	59.50	59.32	38.88	39.04	38.28
MnO	0.41	0.40	0.46	0.49	0.56	0.69	0.70	0.69	0.73	0.73	0.72	0.68	0.69	0.50	0.57	0.53
CaO	1.15	1.14	1.57	1.81	2.78	3.30	2.85	3.93	2.87	3.16	3.58	3.42	4.00	26.17	25.87	26.54
P ₂ O ₅	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K ₂ O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	100.95	100.74	101.62	100.71	100.98	101.94	101.37	101.23	101.55	101.68	101.99	101.47	101.88	101.25	101.08	101.14
<i>Cation formula based on 4 oxygens</i>																
Si	0.989	0.987	1.006	0.989	0.995	0.997	0.993	0.992	0.994	0.997	0.998	0.992	0.993	0.993	0.993	0.992
Al	0.001	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ti	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	1.084	1.072	0.916	0.854	0.656	0.380	0.336	0.265	0.330	0.280	0.330	0.302	0.297	0.145	0.146	0.148
Fe	0.892	0.907	1.010	1.095	1.250	1.495	1.561	1.595	1.563	1.598	1.532	1.577	1.563	0.996	1.001	0.981
Mn	0.010	0.010	0.011	0.012	0.014	0.018	0.019	0.019	0.020	0.019	0.019	0.018	0.018	0.013	0.015	0.014
Ca	0.035	0.034	0.048	0.057	0.089	0.110	0.096	0.134	0.097	0.107	0.120	0.116	0.135	0.859	0.850	0.871
P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	3.010	3.012	2.993	3.009	3.005	3.001	3.006	3.006	3.005	3.003	3.001	3.007	3.007	3.007	3.006	3.007
XFe	0.44	0.45	0.51	0.55	0.63	0.75	0.78	0.80	0.79	0.80	0.77	0.79	0.78	0.50	0.50	0.49

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
 limit = 102 ppm

Appendix 1. Angrite olivine.

NWA 10463	49	50
<i>Weight percent oxides</i>		
SiO ₂	32.81	32.48
Al ₂ O ₃	0.00	0.00
TiO ₂	0.04	0.00
Cr ₂ O ₃	BDL	BDL
MgO	2.56	3.04
FeO	38.89	38.85
MnO	0.49	0.51
CaO	26.62	26.30
P ₂ O ₅	N/A	N/A
Na ₂ O	N/A	N/A
NiO	0.00	0.00
K ₂ O	N/A	N/A
V ₂ O ₃	N/A	N/A
Total	101.41	101.17
<i>Cation formula based on 4 oxygens</i>		
Si	1.002	0.995
Al	0.000	0.000
Ti	0.001	0.000
Cr	BDL	BDL
Mg	0.117	0.139
Fe	0.993	0.995
Mn	0.013	0.013
Ca	0.871	0.863
P	N/A	N/A
Na	N/A	N/A
Ni	0.000	0.000
K	N/A	N/A
V	N/A	N/A
Total	2.997	3.005
XFe	0.50	0.50

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
 limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
 PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

NWA 10463 - High Precision

Weight percent oxides

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SiO ₂	35.19	35.14	35.34	34.85	34.65	33.79	34.60	34.81	34.22	34.64	34.13	34.40	34.43	34.47	34.66	35.60
Al ₂ O ₃	0.01	0.04	0.01	0.01	0.03	0.02	0.01	0.01	0.04	0.07	0.03	0.06	0.02	0.05	0.03	0.03
TiO ₂	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.05	0.01	0.00	0.00	0.01	0.00	0.01	0.01
Cr ₂ O ₃	BDL	0.02	0.10	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.02	0.02	BDL	0.03	0.05
MgO	20.53	22.40	22.82	21.82	19.59	15.81	20.26	19.87	16.86	19.30	20.81	20.71	19.84	20.19	21.02	23.76
FeO	42.54	40.89	40.38	41.14	42.50	47.51	43.16	43.80	45.83	43.97	42.25	41.44	43.00	42.96	41.99	38.51
MnO	0.50	0.46	0.47	0.46	0.48	0.54	0.51	0.49	0.56	0.54	0.48	0.47	0.51	0.50	0.48	0.44
CaO	2.22	1.87	1.77	1.93	2.13	2.77	1.97	2.10	3.26	2.35	2.14	2.10	2.32	2.10	2.21	2.06
P ₂ O ₅	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na ₂ O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NiO	0.02	0.00	0.04	0.00	0.00	0.00	0.00	0.03	0.02	0.03	0.01	0.00	0.03	0.03	0.00	0.06
K ₂ O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V ₂ O ₃	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	101.02	100.82	100.92	100.22	99.38	100.44	100.52	101.11	100.85	100.92	99.87	99.20	100.18	100.31	100.41	100.53

Cation formula based on 4 oxygens

Si	1.010	1.001	1.003	1.002	1.013	1.006	1.002	1.005	1.006	1.004	0.994	1.004	1.002	1.001	1.000	1.006
Al	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.001
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cr	BDL	0.000	0.002	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.000	0.001	0.001	BDL	0.001	0.001
Mg	0.878	0.952	0.965	0.935	0.854	0.702	0.875	0.855	0.739	0.834	0.903	0.901	0.861	0.874	0.904	1.001
Fe	1.021	0.974	0.959	0.989	1.039	1.183	1.046	1.057	1.127	1.066	1.029	1.011	1.047	1.043	1.013	0.910
Mn	0.012	0.011	0.011	0.011	0.012	0.014	0.012	0.012	0.014	0.013	0.012	0.012	0.013	0.012	0.012	0.011
Ca	0.068	0.057	0.054	0.059	0.067	0.088	0.061	0.065	0.103	0.073	0.067	0.066	0.073	0.065	0.068	0.062
P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ni	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.001
K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	2.990	2.998	2.996	2.998	2.986	2.994	2.997	2.995	2.992	2.994	3.006	2.995	2.997	2.998	2.999	2.993

XFe	0.52	0.49	0.48	0.50	0.53	0.60	0.53	0.53	0.57	0.54	0.51	0.51	0.53	0.53	0.51	0.46
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BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
 PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

NWA 10463 - High Precision	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
<i>Weight percent oxides</i>																
SiO ₂	35.37	35.83	35.43	35.59	35.92	35.55	31.45	32.59	31.68	36.90	36.52	36.27	36.29	34.73	36.30	37.15
Al ₂ O ₃	0.01	0.02	0.06	0.01	0.05	0.02	0.01	0.01	0.00	0.00	0.08	0.07	0.08	0.20	0.04	0.04
TiO ₂	0.02	0.00	0.01	0.01	0.00	0.02	0.52	0.14	0.29	0.00	0.04	0.03	0.03	0.02	0.00	0.00
Cr ₂ O ₃	0.04	0.03	0.03	0.03	0.03	0.05	BDL	BDL	BDL	BDL	0.04	0.03	0.02	0.02	BDL	0.01
MgO	23.40	23.82	22.91	24.22	24.13	24.28	6.31	3.51	6.24	29.21	27.37	26.43	26.15	24.05	26.54	29.75
FeO	38.63	38.32	39.22	37.63	37.89	37.58	58.01	42.45	58.25	34.07	36.13	36.98	37.33	39.81	36.47	33.75
MnO	0.48	0.42	0.48	0.42	0.44	0.43	0.64	0.48	0.68	0.35	0.39	0.41	0.39	0.40	0.41	0.33
CaO	2.18	2.04	2.23	2.07	1.89	1.97	3.67	21.70	3.69	0.87	1.37	1.48	1.47	1.04	1.49	0.85
P ₂ O ₅	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na ₂ O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NiO	0.08	0.03	0.00	0.00	0.04	0.02	0.02	0.01	0.03	0.04	0.00	0.04	0.02	0.00	0.00	0.00
K ₂ O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V ₂ O ₃	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	100.21	100.50	100.37	99.98	100.39	99.92	100.63	100.89	100.85	101.45	101.93	101.74	101.78	100.27	101.26	101.88
<i>Cation formula based on 4 oxygens</i>																
Si	1.005	1.010	1.007	1.007	1.011	1.006	0.998	1.004	1.003	1.003	1.000	1.000	1.002	0.989	1.004	1.003
Al	0.000	0.001	0.002	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.003	0.002	0.003	0.007	0.001	0.001
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.003	0.007	0.000	0.001	0.001	0.001	0.000	0.000	0.000
Cr	0.001	0.001	0.001	0.001	0.001	0.001	BDL	BDL	BDL	BDL	0.001	0.001	0.000	0.001	BDL	0.000
Mg	0.991	1.001	0.970	1.021	1.013	1.025	0.298	0.161	0.294	1.184	1.117	1.087	1.076	1.021	1.094	1.197
Fe	0.918	0.904	0.932	0.890	0.892	0.889	1.539	1.094	1.542	0.775	0.827	0.853	0.862	0.948	0.843	0.762
Mn	0.012	0.010	0.012	0.010	0.011	0.010	0.017	0.013	0.018	0.008	0.009	0.010	0.009	0.010	0.010	0.008
Ca	0.066	0.062	0.068	0.063	0.057	0.060	0.125	0.716	0.125	0.025	0.040	0.044	0.044	0.032	0.044	0.025
P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Na	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ni	0.002	0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000
K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	2.994	2.989	2.992	2.993	2.988	2.993	2.990	2.992	2.990	2.997	2.998	2.998	2.996	3.007	2.996	2.996
XFe	0.46	0.46	0.47	0.45	0.45	0.45	0.78	0.55	0.79	0.39	0.42	0.43	0.43	0.47	0.43	0.38

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
 limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

NWA 10463 - High Precision	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
<i>Weight percent oxides</i>																
SiO ₂	34.66	35.11	34.56	31.76	32.88	33.20	32.95	32.97	32.90	32.16	32.04	32.12	34.95	35.31	30.03	30.49
Al ₂ O ₃	0.05	0.03	0.05	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.05	0.06	0.05	0.48
TiO ₂	0.04	0.02	0.02	0.11	0.04	0.01	0.01	0.03	0.04	0.03	0.02	0.03	0.03	0.02	0.12	0.10
Cr ₂ O ₃	0.03	0.03	0.02	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.03	BDL	BDL
MgO	18.89	21.37	19.24	4.85	2.95	2.84	3.06	2.81	2.56	7.57	7.35	6.73	27.68	31.27	5.09	4.04
FeO	44.17	42.10	43.99	51.58	37.69	38.05	37.90	38.96	38.98	58.20	57.96	58.67	36.02	32.24	60.67	52.04
MnO	0.53	0.49	0.50	0.61	0.50	0.54	0.52	0.54	0.53	0.71	0.71	0.74	0.40	0.34	0.78	0.64
CaO	2.66	2.39	2.63	11.42	26.67	26.35	25.97	25.29	25.97	2.32	2.51	2.80	1.51	0.93	3.32	11.79
P ₂ O ₅	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.01	0.01	0.12	0.11
Na ₂ O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	0.00	0.00	0.00
NiO	0.00	0.02	0.02	0.00	0.03	0.00	0.02	0.00	0.00	0.00	0.06	0.00	N/A	N/A	N/A	N/A
K ₂ O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.02	0.02	0.02	0.03
V ₂ O ₃	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	0.00	0.00	0.00
Total	101.02	101.56	101.02	100.34	100.76	101.01	100.44	100.61	100.99	101.00	100.67	101.09	100.68	100.22	100.20	99.70
<i>Cation formula based on 4 oxygens</i>																
Si	1.005	1.000	1.002	1.002	1.006	1.012	1.010	1.012	1.008	1.009	1.010	1.011	0.975	0.970	0.976	0.976
Al	0.002	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002	0.002	0.002	0.018
Ti	0.001	0.000	0.000	0.003	0.001	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.000	0.003	0.002
Cr	0.001	0.001	0.000	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.001	BDL	BDL
Mg	0.817	0.908	0.831	0.228	0.135	0.129	0.140	0.129	0.117	0.354	0.345	0.316	1.151	1.280	0.246	0.193
Fe	1.072	1.003	1.067	1.361	0.964	0.970	0.972	1.000	0.999	1.528	1.528	1.545	0.840	0.740	1.648	1.393
Mn	0.013	0.012	0.012	0.016	0.013	0.014	0.014	0.014	0.014	0.019	0.019	0.020	0.010	0.008	0.021	0.017
Ca	0.083	0.073	0.082	0.386	0.874	0.861	0.853	0.832	0.852	0.078	0.085	0.095	0.045	0.027	0.116	0.404
P	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.003	0.003
Na	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.000	0.000
Ni	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.002	0.000	N/A	N/A	N/A	N/A
K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.001	0.001	0.001	0.001
V	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.000	0.000	0.000	0.000
Total	2.993	2.998	2.997	2.996	2.993	2.987	2.990	2.987	2.991	2.990	2.989	2.988	3.024	3.029	3.016	3.008
XFe	0.54	0.51	0.54	0.69	0.49	0.49	0.49	0.51	0.51	0.78	0.78	0.79	0.41	0.36	0.82	0.70

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
 PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

Angra dos Reis	1	2	3	4	5	6
<i>Weight percent oxides</i>						
SiO ₂	35.08	35.00	35.25	33.64	33.53	33.74
Al ₂ O ₃	0.05	0.03	0.04	0.03	0.01	0.01
TiO ₂	0.06	0.06	0.06	0.01	0.02	0.01
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL
MgO	24.34	24.12	24.19	8.79	8.88	8.90
FeO	39.01	39.24	39.12	25.51	25.82	25.82
MnO	0.52	0.51	0.54	0.35	0.38	0.39
CaO	1.48	1.44	1.49	30.63	30.65	30.85
P ₂ O ₅	0.02	0.01	0.03	0.04	0.04	0.04
Na ₂ O	0.04	0.01	0.00	0.01	0.00	0.05
NiO	N/A	N/A	N/A	N/A	N/A	N/A
K ₂ O	0.03	0.03	0.03	0.03	0.03	0.05
V ₂ O ₃	0.00	0.02	0.00	0.00	0.00	0.00
Total	100.62	100.45	100.76	99.04	99.34	99.85
<i>Cation formula based on 4 oxygens</i>						
Si	0.993	0.993	0.996	0.997	0.992	0.993
Al	0.002	0.001	0.001	0.001	0.000	0.000
Ti	0.001	0.001	0.001	0.000	0.000	0.000
Cr	BDL	BDL	BDL	BDL	BDL	BDL
Mg	1.027	1.020	1.019	0.388	0.392	0.390
Fe	0.923	0.931	0.924	0.632	0.639	0.636
Mn	0.013	0.012	0.013	0.009	0.009	0.010
Ca	0.045	0.044	0.045	0.972	0.972	0.973
P	0.000	0.000	0.001	0.001	0.001	0.001
Na	0.002	0.000	0.000	0.001	0.000	0.003
Ni	N/A	N/A	N/A	N/A	N/A	N/A
K	0.001	0.001	0.001	0.001	0.001	0.002
V	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.006	3.005	3.002	3.002	3.006	3.007
XFe	0.46	0.47	0.46	0.32	0.32	0.32

BDL = below detection limit.

3 σ Cr₂O₃ detection limit = 748 ppm

3 σ High Precision Cr₂O₃ detection
limit = 102 ppm

American Mineralogist: August 2017 Deposit AM-17-86112
PAPIKE ET AL.: MN-FE SYSTEMATICS IN MAJOR PLANETARY BODY RESERVOIRS

Appendix 1. Angrite olivine.

Angra dos Reis - High Precision	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>Weight percent oxides</i>																
SiO ₂	34.72	34.79	34.74	34.79	33.02	33.09	33.50	35.03	34.84	35.01	35.13	34.99	34.74	33.03	33.31	34.89
Al ₂ O ₃	0.02	0.01	0.02	0.02	0.02	0.00	0.02	0.03	0.04	0.03	0.02	0.03	0.04	0.23	0.01	0.01
TiO ₂	0.04	0.02	0.03	0.04	0.04	0.02	0.03	0.04	0.02	0.03	0.05	0.03	0.05	0.03	0.02	0.04
Cr ₂ O ₃	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MgO	25.16	25.10	25.40	25.57	8.85	8.98	8.92	25.34	25.31	25.12	25.30	25.20	25.37	8.78	8.62	21.33
FeO	38.72	38.57	38.70	38.33	26.06	26.12	26.20	38.79	38.77	39.16	39.12	38.88	38.76	26.21	26.31	35.40
MnO	0.56	0.55	0.55	0.54	0.37	0.38	0.37	0.54	0.54	0.57	0.56	0.56	0.54	0.34	0.37	0.48
CaO	1.35	1.45	1.37	1.21	31.24	31.21	31.22	1.21	1.31	1.33	1.22	1.21	1.13	31.28	31.21	7.96
P ₂ O ₅	0.04	0.07	0.03	0.04	0.07	0.05	0.07	0.01	0.04	0.02	0.02	0.03	0.04	0.11	0.03	0.03
Na ₂ O	0.00	0.01	0.01	0.01	0.01	0.00	0.03	0.00	0.02	0.01	0.00	0.01	0.00	0.01	0.00	0.00
NiO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K ₂ O	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.02	0.03	0.04	0.03	0.03	0.02	0.02	0.03
V ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Total	100.64	100.60	100.88	100.59	99.70	99.88	100.37	101.02	100.92	101.30	101.47	100.96	100.69	100.05	99.90	100.16
<i>Cation formula based on 4 oxygens</i>																
Si	0.982	0.984	0.980	0.982	0.978	0.978	0.984	0.986	0.982	0.984	0.985	0.986	0.981	0.975	0.984	0.995
Al	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.008	0.000	0.000
Ti	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	1.061	1.058	1.068	1.076	0.391	0.396	0.391	1.063	1.063	1.053	1.058	1.058	1.068	0.386	0.380	0.907
Fe	0.916	0.912	0.913	0.905	0.645	0.646	0.643	0.912	0.914	0.921	0.917	0.916	0.916	0.647	0.650	0.844
Mn	0.013	0.013	0.013	0.013	0.009	0.010	0.009	0.013	0.013	0.014	0.013	0.013	0.013	0.009	0.009	0.012
Ca	0.041	0.044	0.041	0.037	0.991	0.988	0.982	0.037	0.039	0.040	0.037	0.036	0.034	0.989	0.988	0.243
P	0.001	0.002	0.001	0.001	0.002	0.001	0.002	0.000	0.001	0.000	0.001	0.001	0.001	0.003	0.001	0.001
Na	0.000	0.000	0.000	0.001	0.001	0.000	0.002	0.000	0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.000
Ni	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
V	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.016	3.014	3.019	3.016	3.019	3.020	3.014	3.013	3.016	3.015	3.013	3.013	3.016	3.017	3.014	3.004
XFe	0.45	0.45	0.45	0.45	0.32	0.32	0.32	0.45	0.45	0.46	0.46	0.46	0.45	0.32	0.32	0.42

BDL = below detection limit.

3σ Cr₂O₃ detection limit = 748 ppm

3σ High Precision Cr₂O₃ detection
limit = 102 ppm