

Revision 1

Si-rich Mg-sursassite $\text{Mg}_4\text{Al}_5\text{Si}_7\text{O}_{23}(\text{OH})_5$ with octahedrally-coordinated Si: a new ultra-high-pressure hydrous phase

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ABSTRACT

The crystal structure of a new high-pressure hydrous phase, Si-rich Mg-sursassite, of ideal composition $\text{Mg}_4\text{Al}_5\text{Si}_7\text{O}_{23}(\text{OH})_5$, that was produced by sub-solidus reaction at 24 GPa and 1400 °C in an experiment using a model sedimentary bulk composition, has been determined by single-crystal X-ray diffraction. The phase was found to be topologically identical to Mg-sursassite, $\text{Mg}_5\text{Al}_5\text{Si}_6\text{O}_{21}(\text{OH})_7$, and has space group $P2_1/m$ and lattice parameters $a = 8.4222(7)$, $b = 5.5812(3)$, $c = 9.4055(9)$ Å, $\beta = 106.793(8)^\circ$, $V = 423.26(6)$ Å³ and $Z = 1$. The empirical formula determined by electron microprobe analysis of the same crystal as was used in the X-ray experiment is $[\text{Mg}_{3.93(3)}\text{Fe}_{0.03(1)}]_{\Sigma 3.96}[\text{Al}_{4.98(3)}\text{Cr}_{0.04(1)}]_{\Sigma 5.02}\text{Si}_{7.02(4)}\text{O}_{23}(\text{OH})_5$, with hydroxyl content implied by the crystal structure analysis. The most significant aspect of the structure of Si-rich Mg-sursassite is the presence of octahedrally-coordinated Si. Its structural formula is $^{M1,VI}\text{Mg}_2$ $^{M2,VI}\text{Mg}^{2+}_2$ $^{M3,VI}(\text{Al}_{0.5}\text{Si}_{0.5})_2$ $^{M4,VI}\text{Al}_2$ $^{M5,VI}\text{Al}_2$ $^{T1,IV}\text{Si}_2$ $^{T2,IV}\text{Si}_2$ $^{T3,IV}\text{Si}_2$ $\text{O}_{23}(\text{OH})_5$. Si-rich Mg-sursassite joins the group of hydrous ultra-high-pressure phases with octahedrally-coordinated Si that have been discovered by experiment, and that may play a significant role in the distribution and hosting of water in the deep mantle at subduction zones. The reactions defining the stability

32 of Si-rich Mg-sursassite are unknown, but are likely to be fundamentally different from those of
33 Mg-sursassite, and involve other ultra-high-pressure dense structures such as Phase D, rather
34 than Phase A.

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36 **Keywords:** Mg-sursassite; hydrous dense magnesium silicate; synthesis; microprobe analysis;
37 X-ray diffraction; crystal structure.

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INTRODUCTION

40 Sursassite, ideally $Mn_4Al_6Si_6O_{22}(OH)_6$, occurs in Mn ore deposits (Nagashima et al. 2009),
41 and is characteristically a low-pressure mineral. It is a sorosilicate with Si_2O_7 and SiO_4 groups
42 that is related structurally to pumpellyite and ardennite. However, a fully Mg-substituted
43 analogue of composition $Mg_5Al_5Si_6O_{21}(OH)_7$ was first reported by Schreyer (1988) in
44 experiments in the MgO-Al₂O₃-SiO₂-H₂O (MASH) system up to 5 GPa, 900 °C; he referred to
45 this phase as “MgMgAl-pumpellyite”. Fockenburg (1998) determined the maximum stability of
46 this phase to 10 GPa and found that it had a thermal limit of 800 °C defined by the reactions Mg-
47 sursassite = pyrope + topaz-OH + coesite/stishovite + H₂O. Using a model ultrabasic bulk
48 composition, Bromiley and Pawley (2002) determined the phase relations of Mg-sursassite to 10
49 GPa, and showed that Mg-sursassite replaces chlorite as a major host of H₂O above 6 GPa *via*
50 the reaction chlorite + enstatite = Mg-sursassite + forsterite + H₂O. The high-temperature limit of
51 Mg-sursassite at 7–10 GPa (700–750 °C) for ultrabasic bulk compositions is defined by the
52 reaction Mg-sursassite + phase A + enstatite = pyrope + H₂O. The general structural formula of
53 sursassite-group minerals is $M^{1,VII}M^{2+}_2 M^{2,VI}M^{2+}_2 M^{3,VI}(M^{2+}, Al, Si)_2 M^{4,VI}Al_2 M^{5,VI}Al_2 T^{1,IV}Si_2 T^{2,IV}Si_2$
54 $T^{3,IV}Si_2 O_{21-23}(OH)_{5-7}$. T^2Si and T^3Si form a sorosilicate Si_2O_7 unit. Occupancies of H sites vary
55 from 0.5 to 1. Compositional variation in sursassite-type phases involves (a) homovalent
56 substitution at $M(1,2)$ sites, e.g. Mg, Mn²⁺, Fe²⁺; (b) heterovalent substitution at the $M3$ site, e.g.
57 Mg for Al; (c) charge balancing by $O^{2-} \rightarrow OH^-$. Two distinct stoichiometries have been reported:
58 $M^{2+}_4Al_6Si_6O_{22}(OH)_6$ and $M^{2+}_5Al_5Si_6O_{21}(OH)_7$, being related by the substitution $Al + O^{2-} \leftrightarrow M^{2+}$

59 + OH⁻. In this paper we add a new stoichiometry, $M^{2+}_4Al_5Si_7O_{23}(OH)_5$, which we refer to as Si-
60 rich Mg-sursassite.

61 In sursassite *sensu stricto* the *M3* site is fully occupied by Al and there are five non-
62 equivalent H sites bonded to three non-equivalent oxygen atoms; four of the H sites are half-
63 occupied (Nagashima et al. 2009). The *M3* site in Mg-sursassite has an average composition
64 $Mg_{0.5}Al_{0.5}$ and there are four non-equivalent H sites, one of which is half-occupied. The
65 structural formula of end-member Mg-sursassite is $M^{1,VII}Mg_2 M^{2,VI}Mg^{2+}_2 M^{3,VI}(Mg_{0.5}Al_{0.5})_2 M^{4,VI}Al_2$
66 $M^{5,VI}Al_2 T^{1,IV}Si_2 T^{2,IV}Si_2 T^{3,IV}Si_2 O_{22}(OH)_7$. As described below, the new phase Si-rich Mg-sursassite
67 has the structural formula $M^{1,VII}Mg_2 M^{2,VI}Mg^{2+}_2 M^{3,VI}(Al_{0.5}Si_{0.5})_2 M^{4,VI}Al_2 M^{5,VI}Al_2 T^{1,IV}Si_2 T^{2,IV}Si_2$
68 $T^{3,IV}Si_2 O_{23}(OH)_5$. The possible significance of this new type of sursassite is considered.

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EXPERIMENTAL METHODS

71 A high-pressure experiment was performed at 24 GPa and 1400°C using a 2000-ton
72 Kawai-type multi-anvil apparatus at the Geodynamics Research Center, Ehime University,
73 Matsuyama, Japan. A sintered mixture of 83%MgO + 17% CoO was used as the pressure
74 medium. This mixture was formed into an octahedron of 8 mm edges and was compressed by
75 eight cubic tungsten carbide anvils with 3 mm truncation edges. Pyrophyllite gaskets were placed
76 between the anvils to support the anvil flanks. A cylindrical LaCrO₃ heater, 3.2/2.0 mm in
77 outer/inner diameter and 4 mm long was used. The samples were loaded into rhenium capsules
78 isolated from heater by a MgO insulator.

79 The starting material, chosen to model “global subducted sediment” (GLOSS) of Plank and
80 Langmuir (1998), was a mixture of high-purity reagents (in wt%): 58.66 SiO₂, 0.62 TiO₂, 11.93
81 Al₂O₃, 5.96 CaO, 5.22 FeO, 2.49 MgO, 0.32 MnO, 2.44 Na₂O, 2.04 K₂O, 3.02 CO₂ and 7.30
82 H₂O. Temperature was controlled by a W₉₇Re₃-W₇₅Re₂₅ thermocouple (0.1 mm diameter).
83 Pressure was calibrated at room temperature using the semiconductor-to-metal transitions of Bi,
84 ZnS and GaAs (Irifune et al. 2004). The sample was initially pressurized to 24 GPa in 1 hour and
85 then heated to 1400 °C at a rate of 50°C/min. The effect of temperature on pressure was further

86 corrected using the α - β and β - γ transitions in Mg_2SiO_4 (Katsura and Ito 1989). The experiment
87 lasted 4 hours and was quenched by turning off power to the heater. The capsule was recovered,
88 mounted in epoxy, sectioned, and polished.

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CHEMICAL AND STRUCTURAL CHARACTERIZATION

91 The chemical composition of Mg-sursassite was first analyzed qualitatively with energy-
92 dispersive X-ray spectroscopy (EDS) using a CamScan electron microscope MV2300. No
93 elements with $Z > 9$ other than Al, Mg, Si and minor Cr and Fe were detected. A small fragment
94 of the of crystal analyzed by EDS ($15 \times 18 \times 24 \mu\text{m}^3$) was extracted from the polished block for
95 crystal structure determination by single-crystal X-ray diffraction (see below). After the X-ray
96 experiment, this crystal fragment was analyzed by quantitative wavelength-dispersive X-ray
97 (WDS) using a JEOL-JXA 8200 microprobe operated at 15 kV, 10 nA, and 1 μm beam size, with
98 counting times of 20 s on-peak and 10 s for each background position. $K\alpha$ lines for all analyzed
99 elements were referenced to synthetic mineral standards [olivine (Mg, Fe, Si), albite (Al), and
100 knorringite (Cr)].

101 The crystal fragment was mounted on a 5 μm diameter carbon fiber, itself attached to a
102 glass rod. Single-crystal X-ray diffraction intensity data were collected with a Bruker D8
103 Venture Photon 100 CMOS equipped with graphite-monochromatized $\text{MoK}\alpha$ radiation. The
104 detector-to-crystal distance was 50 mm. Data were collected using ω and ϕ scan modes, with a
105 0.5° frame-width and an exposure time of 50 s per frame. The data were corrected for Lorentz
106 and polarization factors and absorption using the software package *APEX3* (Bruker AXS Inc.
107 2016).

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RESULTS AND DISCUSSION

110 Phases in the run product were identified using EMPA and single-crystal XRD. The
111 product assemblage consisted of (vol%) Si-rich Mg-sursassite (1%) + phase D (20%) +

112 hollandite (13%) + Al-phase D (13%) + Ca-perovskite (15%) + stishovite (38%) (Fig. 1). The
113 compositions of run products are shown in Table 1.

114 As for the studied Si-rich sursassite, three very similar analyses were obtained by WDS
115 microprobe analysis. The average has in wt% oxides (ranges in parentheses): MgO = 17.87
116 (17.69–17.93), Al₂O₃ = 28.66 (28.32–29.01), FeO = 0.29 (0.19–0.40), Cr₂O₃ = 0.37 (0.29–0.49),
117 SiO₂ = 47.64 (47.40–48.11), total = 94.83 (94.22–95.05). The H₂O content, calculated from the
118 crystal structure analysis (see below), is 5.09 wt%, which gives an analysis total of 99.92 wt%.
119 The empirical formula (16 cations p.f.u.), assuming all Fe is divalent, all Cr is trivalent, and a
120 H₂O content calculated from the ideal formula Mg₄Al₅Si₇O₂₃(OH)₅, is
121 [Mg_{3.93(3)}Fe_{0.03(1)}]_{Σ3.96}[Al_{4.98(3)}Cr_{0.04(1)}]_{Σ5.02}Si_{7.02(4)}O₂₃(OH)₅. The minor Cr content (not present in
122 the starting material) is likely due to a contamination from the LaCrO₃ heater.

123 The diffraction data indicate that the structure is monoclinic. Systematic absences are
124 consistent with space groups *P*2₁ and *P*2₁/*m*. Unit-cell parameters obtained from least-squares
125 refinement of 198 reflections with *I*/*σ*(*I*) > 10 are *a* = 8.4222(7), *b* = 5.5812(3), *c* = 9.4055(9) Å,
126 β = 106.793(8)°, *V* = 423.26(6) Å³. The unit-cell parameters and *P*2₁/*m* symmetry indicated a
127 close correspondence with those of synthetic Mg-sursassite reported by Gottschalk et al. (2000),
128 for which *a* = 8.5424(8), *b* = 5.5717(3), *c* = 9.6484(6) Å, β = 108.298(4)°, *V* = 447.0(1) Å³.
129 Consequently, the atom coordinates of the structure of Mg-sursassite reported by Gottschalk et
130 al. (2000) were used as the starting model for structure refinement by full-matrix least-squares
131 methods using SHELXL-97 (Sheldrick 2008).

132 Scattering curves for neutral atoms were taken from the *International Tables for*
133 *Crystallography* (Wilson 1992). In refining site-scattering at sites, vacancies were allowed on all
134 *M* sites. Initially, site-scattering values were obtained by allowing unconstrained occupancies of
135 sites using Mg (*M*1, *M*2), Al (*M*4, *M*5) and Si (*M*3, *T*1, *T*2, *T*3). Refined occupancy levels
136 indicated that *M*1 and *M*2 are filled by Mg, whereas *M*4 and *M*5 are filled by Al. However, the
137 refined occupancy of *M*3 using a neutral scattering factor for Si is 0.967(2) and corresponds to
138 13.47(2) electrons. Hence, the most reasonable interpretation of the site-scattering at *M*3 is that

139 this site has an occupancy of $\text{Al}_{0.5}\text{Si}_{0.5}$. The high Si occupancy of this site is consistent with the
140 small volume of the $M3$ octahedron (7.53 \AA^3), which is much smaller than 9.40 \AA^3 for ${}^{M3}\text{AlO}_6$ in
141 sursassite (Nagashima et al. 2009) and 10.30 \AA^3 for ${}^{M3}(\text{Mg}_{0.5}\text{Al}_{0.5})\text{O}_6$ in Mg-sursassite
142 (Gottschalk et al. 2000). The SiO_6 octahedron in stishovite has a volume of 6.61 \AA^3 (Hill et al.
143 1983). Thus, there is compelling evidence from chemistry and structure that the crystal of this
144 study has stoichiometric amounts of excess Si relative to Mg-sursassite and that this excess Si is
145 octahedrally-coordinated Si.

146 On the basis of refined site-scattering values, the occupancies of sites were fixed at $M(1,2)$
147 = Mg, $M3 = (\text{Al}_{0.5}\text{Si}_{0.5})$, $M(4,5) = \text{Al}$, $T(1,2,3) = \text{Si}$ for subsequent anisotropic refinement. With
148 full anisotropic refinement to convergence gave agreement indices of $R_1 = 0.040$, $wR_2 = 0.074$,
149 $\text{GoF} = 0.935$. Unsurprisingly for such a small crystal, no hydrogen atoms were located in
150 difference-Fourier maps.

151 A list of observed and calculated structure factors and the CIF are deposited¹. Details
152 relating to the data collection and structure refinement are given in Table 2. Table 3 gives bond-
153 valence sums (BVS), computed on the basis of bond-valence parameters of Brese and O’Keeffe
154 (1991), for cations and oxygen atoms. The key features of the structure of Si-rich Mg-sursassite
155 is summarized in Figure 2.

156 The interpretation of oxygen donors and acceptors in sursassite-group structures requires
157 some care, as there are half-occupied and fully-occupied H sites, and mixed occupancies of
158 cation sites. In the case of sursassite *sensu stricto*, these issues have been addressed in detail by
159 Nagashima et al. (2009), and we have used their analysis to aid interpretation of the bond-
160 valences of some of the more problematic oxygen atoms in Si-rich Mg-sursassite, namely O(5),
161 O(7) and O(10).

¹ For a copy of the list of observed and calculated structure factors and CIF, document item AMxxxxx, contact the Business Office of the Mineralogical Society of America (see inside front cover of recent issue) for price information. Deposit items may also be available on the American Mineralogist web site at <http://www.minsocam.org>.

162 In Si-rich Mg-sursassite, atoms O(6) (BVS = 1.21 v.u.) and O(11) (BVS = 1.16 v.u.) are
163 obvious oxygen donors for OH groups and are very likely to be associated with fully-occupied H
164 atom sites. The BVS values for O(7) and O(10) are very similar to those of sursassite. As pointed
165 out by Nagashima et al. (2009), O(10) is anomalous in that it is two-coordinate, being bonded
166 only to ^{T1}Si and ^{M2}Mn (^{M2}Mg in Mg-sursassite and Si-rich Mg-sursassite). There is no evidence
167 for protonation of this oxygen atom, as occurs in the related mineral macfallite (Nagashima et al.
168 2008), e.g. location of nearby H or lengthening of the Si1-O(10) bond. There is, however, the
169 likelihood of O(10) receiving a strong hydrogen-bond from O(6)H, thereby raising its BVS value
170 to ~ 1.7 v.u. (Nagashima et al. 2009): $d[\text{O}(6)\dots\text{O}(10)] = 2.80 \text{ \AA}$.

171 The O(7) atom is bonded to two M3 and one Mg1 sites. There are two possibilities for
172 assigning its bond-valence deficiency: (a) O(7) receives a strong hydrogen-bond from O(6), or
173 (b) O(7) = 50% O/50% OH. How might we choose between these two options? The composition
174 of Si-rich Mg-sursassite is very well-defined by EMPA (see above). The cation composition
175 4Mg:5Al:7Si requires 51 negative charges to charge-balance. There are 28 oxygens p.f.u and so
176 five of these must be OH. O(6) and O(11) are fully-occupied OH groups. Hence, an additional
177 half-occupied OH group must be present that would have an oxygen atom BVS of ~1.5 v.u.:
178 atoms O(7) and O(10) are the only candidates. However, we have seen above that O(10) is very
179 unlikely to be an OH group, half- or fully-occupied. This leaves O(7) as the only other
180 possibility. This atom also correlates with a hydroxyl group in sursassite (M3 = Al) and Mg-
181 sursassite (M3 = Mg_{0.5}Al_{0.5}). Hence, it would seem reasonable to propose that it is a 50/50 O/OH
182 site in Si-rich Mg-sursassite; O(6) with which it likely forms a strong hydrogen bond has two
183 half-occupied H sites and so has full OH occupancy overall (as its BVS value of 1.21 v.u.
184 indicates). The corresponding configuration occurs in sursassite (Nagashima et al. 2009).

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IMPLICATIONS

187 The experiment reported in this paper was a synthesis, and as such it is not proof *sensu*
188 *stricto* of the thermodynamic stability under these *P-T* conditions of any of the product phases.

189 However, as noted above, Si-rich Mg-sursassite grew at 24 GPa during heating to 1400 °C and
190 persisted to the end of the experiment. This temperature is much higher than the 800 °C limit at
191 10 GPa of Mg-sursassite (Fockenburg 1998).

192 The presence of octahedrally-coordinated Si in Si-rich Mg-sursassite suggests that the
193 reactions defining its *P-T* stability in ultrabasic and basic bulk compositions are likely to be
194 fundamentally different from those of Mg-sursassite (which, in turn, has a much greater *P-T*
195 stability than sursassite), and involve ultra-high-pressure structures such as Phase D, rather than
196 Phase A. Future experiments at 10–25 GPa and 800–1400 °C on ultrabasic, basic and felsic
197 model bulk compositions, and on Si-rich Mg-sursassite itself, should provide insights into the
198 significance of this phase for the hydrous mineralogy of deep subduction.

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244

245

FIGURE CAPTIONS

246 Figure 1. SEM-BSE image of the experimental run synthesized at $P = 24$ GPa and $T = 1400$ °C.

247 Si-rich Mg-sursassite (Si-Sur) is associated with phase δ , hollandite (holl), stishovite
248 (Sti), phase D, and Ca-perovskite (CaPrv). CamScan electron microscope MV2300.

249 Figure 2. (a) View of the structure of Si-rich Mg-sursassite determined in this study projected

250 onto the (010) plane. Blue = isolated SiO_4 and Si_2O_7 sorosilicate groups, pink = $M4$

251 and $M5$ octahedra (Al), green = $M3$ octahedron (50%Al, 50%Si), orange spheres = $M1$

252 (Mg) and $M2$ (Mg). Rows of $M(2,3,4,5)$ octahedra and $^{\text{VII}}M1$ polyhedra extend into the

253 page parallel to [010]. (b) A fragment of a row of $M3$ octahedra in Si-rich Mg-

254 sursassite showing the coordination of O(5) and O(7) oxygen atoms. The two O(1)

255 atoms of the $M3\text{O}_6$ octahedron have been omitted for clarity. The proposed local

256 ordering of Al and Si in the $M3$ sites is indicated. All atoms are shown as displacement

257 ellipsoids at the 68% probability level.

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Table 1. Microprobe data (wt. % of oxides) of the different phases in the run product together with the atomic ratios calculated on the basis of atoms (phase δ and phase D) or oxygen content ($Holl$ and $Ca-Prv$)

Phase	δ	D	$Holl$	$Ca-Prv$
SiO ₂	13.99	38.39	65.97	57.58
TiO ₂	0.86	0.21	-	0.16
Al ₂ O ₃	63.48	23.40	19.70	-
FeO	2.47	6.61	0.31	0.57
MnO	-	0.15	-	-
MgO	5.85	17.25	0.36	0.54
CaO	-	0.05	0.60	40.26
Na ₂ O	-	-	0.53	0.23
K ₂ O	0.09	-	12.80	-
H ₂ O*	14.77	13.88	-	-
Total	101.51	99.94	100.27	99.34
O	-	-	8	3
Si	0.139	1.181	2.984	1.079
Ti	0.006	0.005	-	0.002
Al	0.746	0.848	1.050	-
Fe	0.021	0.170	0.012	0.009
Mn	-	0.004	-	-
Mg	0.087	0.790	0.024	0.015
Ca	-	0.002	0.029	0.808
Na	-	-	0.046	0.008
K	0.001	-	0.738	-
Total	1.000	3.000	4.883	1.921

H₂O calculated from ideal formulae [Al-phase D:

Mg(Si_{1-x}Al_x)₂O₆H_{2+2x}, phase δ : (AlMgSi)OOH]

Table 2. Data and experimental details for the selected Si-rich Mg-sursassite crystal

Crystal data	
Formula	$\text{Mg}_4\text{Al}_5\text{Si}_7\text{O}_{23}(\text{OH})_5$
Crystal size (mm)	$0.015 \times 0.018 \times 0.024$
Form	block
Colour	white
Crystal system	monoclinic
Space group	$P2_1/m$ (#11)
a (Å)	8.4222(7)
b (Å)	5.5812(3)
c (Å)	9.4055(9)
β (°)	106.793(8)
V (Å ³)	423.26(6)
Z	1
Data collection	
Instrument	Bruker D8 Venture
Radiation type	$\text{MoK}\alpha$ ($\lambda = 0.71073$)
Temperature (K)	295(3)
Detector to sample distance (cm)	5
Number of frames	1102
Measuring time (s)	50
Maximum covered 2θ (°)	66.08
Absorption correction	multi-scan
Collected reflections	3488
Unique reflections	1734
Reflections with $F_o > 4\sigma(F_o)$	850
R_{int}	0.0228
R_{σ}	0.0834
Range of h, k, l	$-12 \leq h \leq 11, -8 \leq k \leq 8, 0 \leq l \leq 13$
Refinement	
Refinement	Full-matrix least squares on F^2
Final R_1 [$F_o > 4\sigma(F_o)$]	0.0343
Final R_1 (all data)	0.0401
Number refined parameters	124
GoF	0.935
$\Delta\rho_{\text{max}}$ (e Å ⁻³)	0.50
$\Delta\rho_{\text{min}}$ (e Å ⁻³)	-0.39

Table 3. Bond valence sums (v.u.) in the structure of Si-rich Mg-sursassite.

	<i>M1</i>	<i>M2</i>	<i>M3</i>	<i>M4</i>	<i>M5</i>	<i>T1</i>	<i>T2</i>	<i>T3</i>	ΣO
	(Mg)	(Mg)	(Al _{0.50} Si _{0.50})	(Al)	(Al)	(Si)	(Si)	(Si)	
O1	0.247 ^{×2}	0.267 ^{×2}	0.530 ^{×2↓}					0.912 ^{×2}	1.956
O2	0.375 ^{×2}				0.452 ^{×2↓}	1.079 ^{×2}			1.906
O3		0.420 ^{×2}		0.489 ^{×2↓}			1.067 ^{×2}		1.976
O4				0.544 ^{×2↓}		0.920			2.008
O5		0.124	0.660 ^{×2↓→}			0.937			2.381
O6					0.605 ^{×2↓→}				1.210
O7	0.244		0.714 ^{×2↓→}						1.672
O8	0.099				0.495 ^{×2↓→}		1.093		2.182
O9	0.177						0.932	0.950	2.059
O10		0.425						1.036	1.461
O11				0.581 ^{×2↓}					1.162
	1.764	1.923	3.808	3.228	3.104	4.015	4.159	3.810	



