Shock-Induced Transformations in the System NaAlSiO₄ – SiO₂:
a new Interpretation

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Abstract. New internally consistent interpretations of the phases represented by the high pressure phase shock wave data for an albite-rich rock, jadeite, and nepheline in the system NaAlSiO₄ – SiO₂, are obtained using the results of static high pressure investigations, and the recent discovery of the hollandite phase in a shocked meteorite. We conclude that nepheline transforms directly to the calcium ferrite structure, whereas albite transforms possibly to the hollandite structure. Shock Hugoniot data for the other plagioclase and alkali feldspars indicate that these transform to hollandite structures. The pressure-volume data at high pressure could alternatively represent the compression of an amorphous phase. Moreover, the shock Hugoniot data are expected to reflect the properties of the melt above shock stresses of 60–80 GPa. The third order Birch-Murnaghan equation of state parameters are: Kₐ = 275 ± 38 GPa and Kₐ = 1.6 ± 1.5 for the calcium ferrite type NaAlSiO₄, Kₐ = 186 ± 33 GPa and Kₐ = 2.6 ± 1.7 for the albite-rich hollandite, Kₐ = 226 ± 45 GPa and Kₐ = 2.3 ± 2.0 for the orthoclase-rich hollandite, and Kₐ = 190 to 210 GPa and Kₐ = 2.2 for the anorthite-rich hollandite.

Introduction

Recently Simakov and Trunin (1980) reported Hugoniot data for nepheline (NaAlSiO₄) of almost pure NaAlSiO₄ composition. By taking the Hugoniots of albite (NaAlSiO₄), jadeite (NaAlSiO₄), and nepheline and applying the mixed-monomer model for Hugoniot in the system NaAlSiO₄ – SiO₂, the behaviors of the high-pressure phases are investigated in detail. In the mixed-monomer model of Hugoniot, the Hugoniot specific volume of a mixture at a given pressure is obtained by the addition of the partial volume of each constituent at the same pressure. This procedure thus neglects the (small) differences in the Hugoniot temperature and possible differences in partial molar volume for each constituent between the different shocked assemblages. This assumption does not affect greatly the even greater temperature differences in systems containing H₂O (Ahrens 1989; Duffy et al. 1991). There are many examples where the mixed oxide assemblage approximates the high pressure phase very well (Telegin et al. 1980). Energetic considerations suggest that the shock-induced high pressure phases of the feldspar may melt at Hugoniot states above 60–80 GPa (Williams and Jeannot 1989). Moreover, recent static high pressure experiments on anorthite indicate the amorphization occurs at pressures of 22 to 28 GPa and thus the high pressure phase could be amorphous.

The high-pressure phase relations in the system NaAlSiO₄ – SiO₂ including albite and jadeite, have been investigated in considerable detail (Liu 1977; Liu 1978). By applying pressures up to about 25 GPa in the diamond-anvil cell with YAG laser heating, albite, jadeite and nepheline compositions transform to assemblages of CaFe₂O₄-type NaAlSiO₄ and stishovite. In the case of albite, the hollandite-type NaAlSiO₄ appears in a small, limited pressure range as an intermediate high-pressure phase. In both the hollandite and calcium ferrite-type structures (Liu 1977; Ringwood et al. 1967), the Al and Si atoms are octahedrally coordinated to oxygen and the Na atoms are in eight-fold coordinated sites. The calcium ferrite structure displays the most closely packed known structure of octahedra of oxygen (Redd and Ringwood 1968).

Although a simple calculation of the zero-pressure density indicates that the mixture of α-NaAlO₂ (Redd and Ringwood 1968) and stishovite is slightly denser by about 1% than the CaFe₂O₄-type NaAlSiO₄, the diamond-anvil experiments (Liu 1978) did not indicate any evidence for the dissociation. Therefore, we will not consider the assemblage of α-NaAlO₂ plus stishovite since the 1% difference in density is only marginally distinguishable in the shock wave data.

On the basis of these high-pressure investigations in the system NaAlSiO₄ – SiO₂, Liu (1978) assumed the Hugoniots of albite and jadeite studied by McGreeen...
et al. (1967) transformed into the assemblages CaFe₂O₄-
insider assemblages Na₂SiO₃ plus stishovite as possible high-pressure phases. However, no data was not available at that time. Our new interpretation is internal-
High-Pressure Transformations

Table 1 lists the zero-pressure densities of the phases in the system Na₂SiO₃–SiO₂ and some silicate hollan-
lites. Since the CaAl₂Si₂O₆ hollans have not been identified in static experiments, the density of this phase was estimated by assuming the same volume change for the dissociation of hollandsite (HoI) into assemblages of calcium ferrite (CF) and stishovite (St) as follows:

Na₂SiO₃(HoI) = Na₂SiO₃(CF) + 2 SiO₂(St) (1)
CaAl₂Si₂O₆(HoI) = CaAl₂O₄(CF) + 2 SiO₂(St) (2)

The calculated density of the CaAl₂Si₂O₆ hollandsite is 3.74 g/cm³ which is between Na₂SiO₃(3.69 g/cm³) and KAl₂O₃(3.84 g/cm³) hollandsites. The density of the calcium ferrite-type CaAl₂O₄ was taken from Reid and Ringwood (1969). If we use the volume change from olivine to the calculated density of about 30%, the CaAl₂Si₂O₆ hollandsite has the zero-

Table 1: Molar volume and densities of phases in the system NaAl-

<table>
<thead>
<tr>
<th>Composition</th>
<th>Molar volume (cm³/mol)</th>
<th>Density (g/cm³)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz (Qtz)</td>
<td>SiO₂</td>
<td>22.688</td>
<td>2.649</td>
</tr>
<tr>
<td>Corundum (Cor)</td>
<td>dO₂</td>
<td>20.641</td>
<td>2.911</td>
</tr>
<tr>
<td>Stishovite (St)</td>
<td>SiO₂</td>
<td>14.914</td>
<td>4.288</td>
</tr>
<tr>
<td>β-NaAl₂O₄</td>
<td>Na₂Al₄O₇</td>
<td>29.92</td>
<td>2.74</td>
</tr>
<tr>
<td>e-NaAl₂O₄</td>
<td>Na₂Al₄O₇</td>
<td>22.71</td>
<td>3.61</td>
</tr>
<tr>
<td>Nepheline (Np)</td>
<td>Na₂Al₂O₄</td>
<td>54.169</td>
<td>2.623</td>
</tr>
<tr>
<td>Calcium ferrite (CF)</td>
<td>Na₂SiO₃</td>
<td>36.87</td>
<td>3.853</td>
</tr>
<tr>
<td>Jadeite (Jd)</td>
<td>Na₂Al₂O₄</td>
<td>49.690</td>
<td>3.347</td>
</tr>
<tr>
<td>Albite (Ab)</td>
<td>Na₂SiO₃</td>
<td>106.430</td>
<td>2.611</td>
</tr>
<tr>
<td>Holandite (HoI)</td>
<td>Na₂Al₂O₄</td>
<td>71.9</td>
<td>5.69</td>
</tr>
<tr>
<td>Holandite (HoII)</td>
<td>KAl₂O₃</td>
<td>72.5</td>
<td>3.84</td>
</tr>
<tr>
<td>Holandite (HoII)</td>
<td>CaAl₂O₄</td>
<td>74.4</td>
<td>3.74</td>
</tr>
</tbody>
</table>

* Robie et al. (1978)
* Reid and Ringwood (1968)
* Liu (1977)
* Liu (1978)
* Ringwood et al. (1967)
* Estimated in the Present Study, see Text

**Nepheline**

According to the experimental results of Liu (1978), nepheline disproportionate into jadeite plus α-NaAl₂O₄ at a pressure of 12 GPa (at ~900°C), and then transforms into the more closely packed calcium ferrite-type Na₂SiO₃ above 18 GPa (at ~1000°C).

The Hugoniot for nepheline studied by Simakov and Tranqu (1998) is displayed in Fig. 1, and indicates a phase transition which commences at about 20 GPa and completes at about 40 GPa. The pressure region for this phase transition is quite similar to the shock-induced quartz-stishovite transition (Wackete 1952).

It is interesting to note that the high-pressure phase of nepheline has an almost identical Hugoniot to the high-pressure phase of albite. The high-pressure phase of nepheline is not interpreted to be the assemblage of jadeite plus α-NaAl₂O₄ found in the static data, because the zero-pressure density of the jadeite plus α-NaAl₂O₄ assemblage is less dense than that of the CaFe₂O₄-type Na₂SiO₃. Therefore, the high-pressure phase of NaAl-

**Jadeite**

Jadeite is a stable high-pressure phase up to about 23 GPa (at ~1000°C) above which it decomposes to the Fe₂O₄-type Na₂SiO₃ plus stishovite (Liu 1978).

Shock experiments on natural jadeite studied by McQueen et al. (1967) up to 120 GPa, also indicate no phase change up to about 70 GPa. There is a discontinuity in the Hugoniot density-pressure relation for jadeite.

![Fig. 1: Hugoniots density-pressure relations for albite-rich rock (Cr). jadeite (solid curve 1A and 0C), nepheline (+x) and quartz (broken curve and solid curve 1B for stishovite). Data from McQueen et al. (1967), Simakov and Tranqu (1980), Wackete (1982) and Tranqu et al. (1978). Dotted curves are calculated for the assemblages jadeite + stishovite (Jd + St) and calcium ferrite Na₂SiO₃ + 2 stish-

For abbreviations and zero-pressure densities, see Table 1
as shown in Fig. 1. The density of the high pressure form above 100 GPa is greater than that of either stilbo-
vide or a mixture of stilbovide plus calcium ferrite. McQueen et al. (1967) point out the need for data for
jadeite above 100 GPa.
Liu (1978) suggested that the high-pressure phase of
jadeite might be a mixture of CaFeO2-type NaAlSiO4
plus stilbovide. Since Hugoniot data for nepheline was
unknown at that time, we can now conclude instead,
that jadeite transforms to yet a denser assemblage than
stilbovide plus calcium ferrite structure. It might be a
perovskite phase.

Albite
Albite converts into an assemblage of jadeite plus silica
phase (quartz, coesite, or tridymite depending on pres-
sure) and then forms the NaAlSi2O6 hollandite in a
small, restricted, pressure range of 20 to 23 GPa (Liu
1978). With increasing pressure further, the hollandite
decomposes into CaFeO2-type NaAlSiO4 plus stilbo-
vide.

The Hugoniot data for an albite-rich rock (McQueen et
al. 1967) are also shown in Fig. 1. The rock consists of
98 vol% plagioclase (Ab₃₄An₆₆) and 2 vol% actino-
line. In Fig. 2, the Hugoniot density-pressure relations
are summarized for plagioclase and alkali feldspars. The
amorhousite (McQueen et al. 1967) contains 10 vol% al-
bite pyroxene as well. This impurity might accompany

\[ Ab - An - Or \]

\[ Ab₃₄An₆₆ (100\% \text{ Ab}) \]
\[ An₁₀₄ \text{ (100\% An)} \]
\[ Mn \]
\[ Si \]
\[ Ab₃₄An₆₆ \text{ (20\% Ab)} \]
\[ Oi₃₄Re₄ \]
\[ Ab₃₄An₆₆ \text{ (Amphibole)} \]

Fig. 2. Hugoniot density-pressure relations for plagioclase and al-
kalil feldspars. Data from McQueen et al. (1967) (1), Simakov
et al. (1974) (2), McQueen et al. (1969) (a, x), Alvern and Liu
(1973) (c), and Leblanc and Alvern (1986) (a, x). Upper and lower
broken curves are best-square fittings for high-pressure regimes
for NaAlSiO₄ and KAlSiO₄-rich feldspars (a, x, c, o) and
CaAl₂Si₃O₈-rich plagioclase (o, x), respectively. Abbreviations:
Ab = albite, An = anortite, Mi = microcline, Or = orthoclase, Act = actino-
line, Ang = Angite, and HES = Hugoniot elastic limit.

A slight shift of the plagioclase Hugoniot to the denser
side. However, the three Hugoniot data on actino-
line-rich plagioclase (Ab₃₂An₃₈) indicate that the an-
ortosite Hugoniot data by McQueen et al. (1967) are
in coincidence with the Ab₃₂An₃₈ plagioclase (Anor-
site and Alvern 1989). Therefore the actinolite-rich plagi-
oclase Hugoniot can be represented by these Hugoniot
data.

The Hugoniot density-pressure relations for the albite
and orthooclase-rich feldspars are indistinguishable in
Fig. 2. It seems that the presence of 2% actinolite in
the albite-rich rock is also negligible.

This albite-rich rock Hugoniot lies close to the Dis-
line Hugoniot (Fig. 1). If the albite transformed
to CaFeO₂-type NaAlSiO₄, plus stilbovide it’s Hugon-
iot would be denser than that of nepheline above the
transition pressure.

Employing the Hugoniot data for CaFeO₂-type NaAl-
SiO₄ and jadeite as well as stilbovide and a mixing model
for the Hugoniot corresponding to albite composition,
calculated Hugoniot for possible phase mixtures of al-
bite can be obtained and compared with the observed
data. In Fig. 1, we show calculated Hugoniot for the
two alternate albite high-pressure assemblages: (I) ja-
dite + stilbovide and (II) CaFeO₂-type NaAlSiO₄ + 2
stilbovide. Assemblage (I) has the zero-pressure density
of 3.5 g/cm³ and is less dense than the measured Pla-
gonolite. Assemblage (II) has the zero-pressure density
of 4.04 g/cm³ and is denser than the Hugoniot data in
the pressure range between 40 and 80 GPa. The calculat-
ed Hugoniot for the assemblage (II) approaches the al-
bite Hugoniot at pressures of 80 to 90 GPa (Fig. 1).

The hollandite-type NaAlSiO₄ has an intermediate zero-
pressure density of 3.69 g/cm³ (Liu 1970), and is the
most likely high pressure structure which corresponds
to the shock-induced phase of albite from 40 to 80 GPa.
Taking into account the zero-pressure density differ-
ence between the NaAlSiO₄ and CaAl₂Si₃O₈ holland-
ites, the density difference between NaAlSiO₄ and
Na₉K₆Ca₉Al₂Si₃O₈ could be negligible (Ta-
ble 1).

For KAl₂Si₃O₈-rich feldspars, shock compression data
have suggested a phase change to the hollandite struc-
ture above 70 GPa (Alvern and Liu 1973). The similar
behavior of the high-pressure phases in shocked plagi-
oclase and alkali feldspars is seen in Fig. 2. It should be
mentioned that the pressures of initiation and comple-
tion of the phase transitions are almost identical to that
of the quartz-stilbovide transformation (Wackere 1962)
via shock compression. The hollandite structure appar-
ently is taken up over a wide compositional variation
in the system NaAlSiO₄—KAl₂Si₃O₈—CaAl₂Si₃O₈ unci
shock compression that static compression. This
observation may provide insight into the shock-induced
phase transformation mechanism in natural silicates.

In this context, Stooper and Alvern (1987) and Tan
and Alvern (1990) proposed a mechanism of pressure-
induced phase transformation through local amorphiza-
tion within shock-induced shear bands. The rate of the
phase transformation may be affected by kinetics, and
dependent on time scales.
Isotropic and monoclinic (amorphous phase) were detected by the association products in shocked silicate glass from the Ries Crater, Germany (Jenni et al. 1989). The formation of jadeite in a natural occurrence as a result of a long-duration shock wave is expected to be similar to what occurs under static compression. Moreover, recently the high-pressure equilibrium phase of NaAlSiO\(_4\) has been identified in a naturally shocked meteors in (Müller 1990). According to his investigations, the shock-induced veins (\(>100 \mu m\) wide) in Yamato 790729 contain crystal aggregates of high-pressure phases, spinel phase from olivine (for example, garnet from orthopyroxene (majorite), and hollandaite-type phase from albite. The dimensions of the hollandaite-type crystals are less than 50 \(\mu m\). The aggregates (several tens micrometers in size) display the electron diffractions giving the tetragonal symmetry (\(a=0.935 \text{ nm}, c=0.227 \text{ nm}\) and have the composition \(Na_x,\text{Al}_2,\text{Si}_3\text{O}_8\)). This suggests, for the first time, that shock-induced albitization in the hollandaite structure occurs. Recent diamond-anvil cell experiments also confirm the presence of the high-pressure phase very similar to the hollandaite structure with composition \(Ca_{0.8}Mg_{0.2}Al_{2}Si_3O_8\) (Mishin et al. 1990).

**Equation of State**

In the previous sections, the high-pressure forms of shocked the silicate and albite-rich plagioclase are found to be the CaFeO\(_4\)-type and the hollandaite-type, respectively. In this section we employ the Hugoniots data to obtain the isentropic equation of state parameters.

Because pertinent thermodynamic parameters (e.g. transformation energy and Grüneisen parameters) are poorly constrained, it should be understood that the resulting equation of state parameters for high pressure phases can only be approximately inferred. The Fuller et al. strain\(f\) is expressed as:

\[
\frac{f}{f_{0}} = 1 + \frac{1}{2} \left[ \frac{\rho_{0}}{\rho_{0}} \right] \left[ \frac{\rho_{0}}{\rho_{0}} \right] - 1
\]

(3)

(Abouch and Keane 1983; Bhat 1978; Scalapino 1989) and \(\rho_{0}\) and \(\rho_{0}\) are densities at Hugoniot and ambient states, respectively. The normalized pressure \(f\) reduced from Hugoniot to isentropic conditions is:

\[
f = F_{0} + AF_{0} = K_{0}(1 - 2sF_{0}) + (1 - 2sF_{0})
\]

(4)

\[
F_{0} = \frac{3}{2} \left[ 1 + 3 \left( 2 - \frac{\rho}{\rho_{0}} \right) \right] \rho_{0}
\]

(5)

\[
F_{0} = \frac{3}{2} \left[ 1 + 3 \left( 2 - \frac{\rho}{\rho_{0}} \right) \right] \rho_{0}
\]

(6)

\[
F_{0} = \frac{3}{2} \left[ 1 + 3 \left( 2 - \frac{\rho}{\rho_{0}} \right) \right] \rho_{0}
\]

(7)

\[
\rho_{0} = 344 K_{0}/\rho_{0}
\]

(8)

where \(\rho_{0}\) and \(\rho_{0}\) are the standard energy of transition, the specific volume, the Grüneisen parameter and the Hugoniot pressure, respectively. We further assume that as a function of pressure:

\[
7 = 3sF_{0} F_{0}
\]

(9)

where \(\gamma_{0}\) and \(\gamma_{0}\) are constants. The parameters \(F_{0}\) and \(F_{0}\) are derived from the shock wave data, and the parameters \(K_{0}\) and \(K_{0}\) are derived from a least fit to Eq. (4). \(K_{0}\) is the zero-pressure isentropic bulk modulus and \(K_{0}\) is the first pressure derivative. Errors in \(F_{0}\) and \(F_{0}\)

**Table 2. Equation of State Parameters of High-Pressure Phases in the System NaAlSiO\(_4\) - SiO\(_2\)**

<table>
<thead>
<tr>
<th>High Pressure Phase</th>
<th>(\rho_{0}) (g/cm(^3))</th>
<th>Pressure range (GPa)</th>
<th>Number of data</th>
<th>(\gamma_{0})</th>
<th>(\gamma_{0})</th>
<th>(K_{0}) (GPa)</th>
<th>(K_{0}) (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albite(^{a})</td>
<td>4.29(^{b})</td>
<td>44 - 92</td>
<td>4</td>
<td>1.0</td>
<td>316(^{c})</td>
<td>3.4</td>
<td>0.93 (\pm) 0.05 (^{d})</td>
</tr>
<tr>
<td>Calcium ferro Al2SiO(_4)</td>
<td>3.85(^{c})</td>
<td>27 - 70</td>
<td>10</td>
<td>1.0 (\pm) 0.5 (^{d})</td>
<td>1.0 (\pm) 0.5 (^{d})</td>
<td>190 (\pm) 4</td>
<td>3.1 (\pm) 3</td>
</tr>
<tr>
<td>Jadeite(^{e})</td>
<td>3.34(^{a})</td>
<td>21 - 70</td>
<td>10</td>
<td>1.0 (\pm) 0.5 (^{d})</td>
<td>1.0 (\pm) 0.5 (^{d})</td>
<td>150 (\pm) 4</td>
<td>3.1 (\pm) 3</td>
</tr>
</tbody>
</table>

\(^{a}\) after [Tan and Atrens (1990) and Windhorst et al. (1982)]

\(^{b}\) after [Rohe et al. (1978)]

\(^{c}\)nominal pressure

\(^{d}\)estimated in the present study (see text)

\(^{e}\)7 points for for albite-rich rock (McQueen et al. 1985) and 3 points for olivine (Scalapino and Atrens 1990)
are estimated through (4) and (7) (Abrams and Jeanloz 1987). The transition energy $E_t$ terms are evaluated in the difference in the free energy of formation between the low-pressure and high-pressure phases. The free energy of formation for the high-pressure phases are estimated via the following equilibrium reactions:

$$\text{NaAlSiO}_4 (\text{H}) + \text{SiO}_2 (\text{S}) \rightarrow \text{NaAlSiO}_4 (160)$$

(10)

$$\text{NaAlSiO}_4 (\text{H}) + \text{Na}_2 \text{SiO}_3 (\text{CF}) \rightarrow 2 \text{SiO}_2 (\text{S})$$

(11)

$$2 \text{K}_2 \text{AlSiO}_4 (\text{Wad}) + \text{Al}_2 \text{SiO}_5 (\text{Ky}) + \text{SiO}_2 (\text{Coe})$$

(12)

and

$$\text{K}_2 \text{SiO}_4 (\text{Wad}) + \text{Na}_2 \text{SiO}_3 (\text{Ky}) + \text{SiO}_2 (\text{SS}) \rightarrow \text{K}_2 \text{AlSiO}_4 (\text{Hfs})$$

(13)

The equilibrium pressure of the above reactions at 295°C are at 20, 23, 6.3 and 8.4 GPa, respectively (Lin and Bassett 1986). The transition energies thus obtained are listed in Table 2, and used for the calculations of equation of state parameters. Table 2 lists the zero-pressure densities, Hugoniot pressure ranges, and numbers of data for each pressure phase. With these parameters, we obtain the adiabatic bulk modulus $K_a$ and its first pressure derivative $K'_a$ (Table 2), for the CaAl$_2$Si$_2$O$_8$ hollandite, the equilibrium reaction is not known and $K_a$ is taken to be 69, 590, and 1000 for each of the state parameters are calculated for each value. The results are not much different (Table 2). The NaAlSiO$_4$-rich hollandite has slightly smaller adiabatic bulk modulus than the K$_2$AlSiO$_4$ hollandsite. The CaAl$_2$Si$_2$O$_8$-rich hollandite shows a similar $K_a$ to the NaAlSiO$_4$-rich hollandite.

Abrams and Lin (1975) gave a preferred value of $K_a = 280$ ± $20$ GPa for the hollandite $K_a$ of NaAl$_2$SiO$_4$. The sound velocity measurements of a feldespar (Owen1982) at high pressures by Grady et al. (1975) indicate that the high-pressure phase has a $K_a$ value of about 260 GPa. These data are consistent for our results for orthoclase-rich feldspars.

Jeanloz and Abrams (1980) inferred a non-equilibrium high-pressure phase of anorthite which was characterized by a calculated initial density of 3.4 g/cm$^3$ and $K_a$ essentially identical to the low-pressure anorthite itself. These analyses gave quite similar results to McQueen et al. (1967). In calculations of equation of state parameters for high-pressure phases, the estimation of the zero-pressure density is most critical and strongly affects the result. If we take 3.74 ± 0.10 g/cm$^3$ as a range of the zero-pressure density of the CaAl$_2$Si$_2$O$_8$-rich hollandite (Table 2), the $K_a$ and $K'_a$ range, between 196 and 214 GPa and between 2.0 and 2.3 for $\gamma_a = 1.0$ ± 0.5 and $K'_a = 0$ to 1000 GPa.

Bednauth et al. (1986) calculated the high-pressure equation of state of anorthite through a mitted oxide model in the candidate high-pressure assembly of CaO in the 02 phase, Al$_2$O$_3$ cristobalite and SiO$_2$ tridymite, $K_a = 227$ GPa and $K'_a = 5.1$ were given for the candidate with a zero pressure density of 4.68 g/cm$^3$. These values are in a reasonable agreement with our calculation although Bodough et al. (1986) and the present study differ in the high-pressure phases and the zero-pressure density assumed.

The zero-pressure adiabatic bulk modulus of calcium ferric type NaSiO$_4$ is similar to that of stishovite, and is greater than that of the hollandite-type NaAl$_2$SiO$_4$. The zero-pressure bulk modulus of jadeite estimated in this study agrees with the results derived by McQueen et al. (1967) within slightly high values of $\gamma_a$ (1.20 and 1.80) and with the elastic measurement by Brillouin spectroscopy (Kandel and Weidner 1988).

Conclusions

The phase transition previously indicated by shock wave data of albite-rich rock and nephelane can be explained by the high-pressure phases of hollandite and calcium ferric type. The Hugoniot data for the other plagioclase and albite feldspars also can be explained by the hollandite phase. These transitions to the hollandite structure are considered to be metastable. These new interpretation cast doubt on the previous analyses that the high-pressure forms of albite and albite display low bulk modulus. The silicate hollandite structure can occur over a wider chemical variation and over a wider pressure range under shock conditions than under static high pressures. The derived $K_a$ and $K'_a$ are 275 ± 38 GPa and 1.4 ± 0.5 for the calcium ferrite NaSiO$_4$, 150 ± 14 GPa and 2.1 ± 0.5 for CaMg$_2$, 186 ± 23 GPa and 2.6 ± 1.7 for the albrite-rich hollandite, and 196 to 210 GPa and about 2.2 for the anorthite-rich hollandite. The orthoclase-rich hollandite has a significantly higher initial bulk modulus than the others because of the greater initial density.

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