APPLICATION OF A TWO-PYROXENE THERMOMETER: CORRELATION OF APPARENT
TEMPERATURE WITH $\text{Al}_2\text{O}_3$ IN AUGITE. D. J. Andersen and D. H. Lindsley, Dept.
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In order to apply the 2-pyroxene thermometer of (1,2), it is necessary
to project natural pyroxenes to the Ca-Mg-Fe quadrilateral so as to estimate
equilibrium temperatures. Using available data, (1,3) proposed a projection
scheme that gives reasonable and consistent temperatures for many
augite-orthopyroxene pairs and for aluminous Ca-Mg synthetic pyroxenes.
However, the Fe-bearing pairs used to develop the projection scheme were
relatively low in $\text{Al}_2\text{O}_3$. It has since come to our attention (4) that estimated
temperatures for high-aluminum augites may be unreasonably high and in
some cases there is a correlation between $\text{Al}_2\text{O}_3$ content of augites and their
apparent temperatures. Because of this, (2) advised against using the pro-
jection for pyroxenes containing more than 10% non-quadrilateral components.
Fortunately, many lunar highlands pyroxenes are quite low in such components
and both the projection and thermometer should be applicable to them.

To determine whether apparent temperatures are correlated with $\text{Al}_2\text{O}_3$
content of augites, we examined several suites of two-pyroxene assemblages;
each suite was thought to represent a uniform temperature. The most striking
correlation is shown by augites from granulate xenoliths from North
Queensland, Australia (5) (Fig.1). The apparent augite temperatures are also
consistently higher than those for the coexisting orthopyroxenes. For the
orthopyroxenes there is no apparent correlation between temperature and
$\text{Al}_2\text{O}_3$ content. There are several potential problems with the results in Fig.
1: (a) Many of the augites are zoned and hence the compositions reported
may not all have been saturated with Opx. (b) Because the samples are
xenoliths from several different basalts, some temperature differences may be
real, reflecting different degrees of re-heating. (c) All the augites
represented by Fig. 1 contain more than 10% non-quadrilateral components and
thus fall outside the recommended range for use of the projection; they are
presented only for illustration.

However, similar correlations between apparent temperature and $\text{Al}_2\text{O}_3$
content of augite also appear for several suites that avoid such problems.
Hornblende granulites from Quairading (6) and Agto (7) are plotted in Fig. 2,
along with data for lunar highlands sample 67075 and one low-temperature
point from (5). The range of apparent temperatures for the Agto augites,
earlier ascribed to uncertainties in $\text{Fe}_2\text{O}_3$ content (1), clearly correlates
with $\text{Al}_2\text{O}_3$. Note, however, that the tie=lines for the two lowest temperature
samples from Agto cross the other tie-lines (Fig. 18 in (7)) and thus may
reflect either analytical problems or real differences in temperature.

When uncertainties in the individual apparent temperatures in Fig. 2 are
considered, the trend for each suite is marginally significant. But because
all three suites show a positive correlation between apparent temperature and
the $\text{Al}_2\text{O}_3$ content of augites, we consider it to be real. There are two
possible explanations for the correlation: (1) The projection scheme of (1)
overcorrects for the effects of $\text{Al}_2\text{O}_3$ in augites; according to this
explanation not all the Al in augite should be ascribed to Ca-Tschermak's
component. (2) The apparent temperature differences are real and reflect
the action of Al on blocking temperatures. This interpretation suggests for
example that Al in augite might inhibit the exchange of Ca between the M2
sites of augite and orthopyroxene upon cooling. Unfortunately, we have insuf-
ficient information to choose between these explanations at the present time;
experiments now in progress on aluminous pyroxenes may provide an answer.
In conclusion, application of the two-pyroxene thermometer with the present projection must be used with caution for augites having high Al$_2$O$_3$ contents. Even the upper limit of 10% "others" components may be unrealistically high.

REFERENCES


Figure 1. Apparent temperature vs wt% Al$_2$O$_3$ for augites from granulite xenoliths [5]. The regression line (which also is based on point KK in Fig. 2) is drawn for reference purposes only.

Figure 2. Apparent temperature vs wt% Al$_2$O$_3$ for augites from hornblende granulites [6,7] and cataclastic anorthosite 67075 [8]. Solid circles and line D are from Quairading [6]; triangles and line GS from Agto [7]; squares and line 67075 from [8]; and open circle KK from [5]. The regression lines are for reference only.