Lunar plagioclase posed an enigma because optical properties indicate slow cooling while structural properties suggest rapid quenching when compared directly to terrestrial plagioclase. If, however, the An-content is inferred from the Al/Si ratio rather than from the Ca/Na ratio, lunar plagioclase corresponds more closely to normal volcanic plagioclase. The differences between $An = 4(Al/(Al + Si)) - 1$ and $An = Ca/(Ca + Na + K)$ is caused by substitutions which appear so far to be unique to lunar feldspars.

We have devoted some time to analysis of the large amount of published chemical data on lunar plagioclase. It speaks for the high quality of these data that they fall into such a surprisingly regular pattern related to the measured amounts of Fe + Mg and Si + Al. A vector representation of chemical composition makes it possible to single out several substitutions which account for the chemical peculiarities of lunar plagioclase (Figure 1). 1) The deficiency in Al + Si (up to 0.06 per formula unit) is compensated for by Fe, Mg, and small amounts of Na or Ca occupying tetrahedral sites. The Ca/Na ratio is increased accordingly to balance the electric charge. This substitution accounts for most of the differences. 2) The vacancy-coupled substitution $Ca + \square \rightarrow 2Na [1]$ is another cause for the increased Ca/Na ratio. 3) The amount of alkali evaporation from plagioclase, if it occurred, is probably small. These unusual substitutions are an expression of special conditions on the moon during the crystallization of plagioclase. It may be primarily because of the high crystallization temperatures and low viscosities of lunar lavas relative to terrestrial lavas that lunar plagioclase is able to crystallize with such significant departures from ideality, while terrestrial plagioclase is not. In this regard, it is interesting to note that plagioclase analyses from Apollo 14 rocks (most of them from igneous rock 14310) fall closer to the curves representing ideal plagioclase than do the analyses of plagioclase from Apollo 11 and 12 rocks.

The reason for the correlation between the degree of departure from ideality and the Na content is not immediately obvious. Explanation is probably to be sought in the atomic proportions of cations in the silicate melt from which the feldspar crystallized. It appears that melts containing greater amounts of Na were deficient in Al with respect to Ca. Though many lunar rocks are slightly oversaturated with SiO$_2$ (showing up as normative cristobalite), substitution of Si for the deficient Al would have reduced the amount of Ca needed for large-cation sites. Instead, substitution of ions of lower charge occurred, allowing excess Ca to compensate the resulting charge.


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LUNAR PLAGIOCLASE


in the framework.

Crystallization at high temperatures, rapid cooling, and peculiar magma composition seem to be important factors for the nonideality, but experimental work and detailed study of terrestrial volcanic plagioclase are necessary to interpret the chemical composition quantitatively.

The method developed here for displaying chemical data on feldspars can certainly find wider application in discussions of mineral composition and site occupancy. It is particularly well suited to minerals which belong to a solid solution series involving coupled substitutions. It also lends itself quite well to determining analytical errors if assumptions are made about the ideality of the cation distribution. Analytical errors behave like vacancy substitutions in the structure and therefore also appear as vectors. In Figure g-i we show vectors for the analytical errors superimposed on points representing terrestrial plagioclase. Though terrestrial feldspars contain up to about 0.06 per formula unit of minor cations, the scatter of the data is much larger than one would expect from substitution vectors for these ions. In particular, points falling below and to the left of the ideal points in Figures h and i would require either an absolute excess of cations in large-cation sites or an absolute deficiency of tetrahedral cations. Therefore, unless these specimens are truly non-ideal, the scatter is due to an analytical error of about 2%. The regularity of the pattern for lunar plagioclase suggests a somewhat smaller analytical error, possibly because most of these analyses were performed with an electron microprobe.
Figure 1. Variations of $\text{Al} + \text{Si}$, $\text{Al} - \text{Ca}$, and $\text{Si} - (\text{Na} + \text{K})$ in lunar and terrestrial plagioclase formulae based on Ca, Na, K, Al, and Si only. (a-c) Lunar plagioclase substitution vectors radiating from the point representing ideal plagioclase to a length corresponding to $\Delta = 0.05$. Symbols represent the amount of Fe + Mg in the formulae. (d-f) Same as a-c except symbols represent the quantity $\text{Al} + \text{Si} + \text{Fe} + \text{Mg}$ in the formulae. (g-i) Terrestrial plagioclase. Substitution vectors are shown to a length corresponding to $\Delta = 0.05$.

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