
Electron-probe analyses have been performed on glasses of impact origin in Apollo 11 breccias (10059, 10060, 10061) and separates from Apollo 12 soil 12070. This study has found evidence for massive losses of K, Na, Si, and Fe during impact melting. Because of the wide-spread occurrence of this open-system behavior, cluster-analysis procedures have serious limitations in providing meaningful interpretations of impact glasses. For example, fractional vaporization would cause two glasses derived by fusion of identical regoliths to have dramatically different major-element compositions. In this study, we have been successful in "seeing through" the effects of fractional vaporization in order to obtain chemical information about the mare and highland components that were in the regolith before it was impact-melted to make glass.

APOLLO 11 GLASSES

Figure 1 shows the vapor pressures as a function of temperature for the major rock-forming oxide-components. The volatility decreases from K$_2$O to Na$_2$O to SiO$_2$ to metallic Fe to MnO to the refractory oxides MgO, Al$_2$O$_3$, and CaO. In order to "see through" the effects of fractional vaporization, one must select only those elements that are not volatile (i.e., Ca, Al, Mg, Ti). When ratios of these elements are plotted for the Apollo 11 impact-glasses, the data display a high degree of order (Fig. 2). The hyperbolic distribution of the data in Fig. 2 is caused by differing proportions of mare and highland components among these impact-glasses. The interpretation is that these differences were present in the parental regoliths of these glasses. The line drawn in Fig. 2 is NOT a regression through the data; it is a mixing line between a mare end-member (i.e., one Apollo 11 glass, as shown) and a highland end-member (i.e., soil 61241). The data fall along that mare/highland mixing line with high correlation. Representative analyses of these Apollo 11 glasses are provided in Table 1.

When these same glasses from Apollo 11 are plotted against a volatile component, such as SiO$_2$, the evidence for mare/highland mixing evaporates (Fig. 3). Two component (i.e., mare/highland) mixing in a closed system should be represented in Fig. 3 by the points lying along a line extending through Apollo 11 soil 10084 and highlands soil 61241. The fact that the data depart so dramatically from the simple mixing line is evidence that these glasses were not closed systems with respect to SiO$_2$ (Fig. 3) during impact-fusion. Comparable SiO$_2$-loss has been reported from Apollo 16 [1] and Apollo 17 [2] glasses known as HASP (high alumina, silica poor).

APOLLO 12 GLASSES

When the data from Apollo 12 impact-glasses are plotted against ratios of refractory elements (Fig. 4), a high degree of order is evident. However, the data are in chaos when a volatile oxide such as SiO$_2$ is considered (Fig. 5). This indicates the...
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importance of fractional vaporization during impact-melting to form these glasses. In Fig. 4, the glasses fall along the hyperbolic distribution that would be caused by binary mixing between mare and highland components. The line (Fig. 4) is NOT a regression through the data; it is a mixing line between a mare end-member (i.e., one Apollo 12 glass, as shown) and a highland end-member (i.e., Apollo 14 soil). The analyses fall along this line and must, therefore, be a record of different mare/highland mixtures in the parental regoliths from which these glasses were formed.

While this study has made considerable progress toward understanding and utilizing impact-glasses, there are still some problems. First, the combination of refractory ratios used in Figs. 2 and 4 is sensitive to different mare components (e.g., low-Ti vs. high-Ti), but is largely insensitive to highland components. Secondly, there is scatter when Mg is included within a ratio. The cause of that is NOT vaporization but probably a third component (e.g., Mg-rich volcanic glass) that existed in varying proportions in the regoliths parental to these impact-glasses.

REFERENCES

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Figure 2

APOLLO 11 YELLOW GLASSES

Figure 3

APOLLO 12 GLASSES

Figure 4

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Figure 5

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