

COOLING HISTORY OF APOLLO 17 ORANGE AND BLACK GLASSES: IMPLICATIONS FOR THEIR FORMATION; J.Arndt and W.v.Engelhardt, Mineralogisch-Petrographisches Institut, Universität Tübingen, Federal Republic of Germany

Since the discovery of orange and black glasses by the Apollo 17 astronauts several hypotheses about their origin have been discussed. Main and trace element chemistry and surface enrichment of volatile elements favour the hypothesis of the formation of the glass beads by explosive fire-fountaining of a magma from the deep lunar interior.

To elucidate the process of formation we have tried to determine the cooling history of the droplets by an investigation of orange and black glass beads in soil 74220 and by cooling and crystallization experiments with a synthetic melt of orange glass composition.

The size frequency distributions of glassy (orange) and vitrophyric (black) beads in the 125-250 μm sieve fraction of soil 74220 were determined by measuring the diameters of cross sections in thin section 74220,239. 39% of the glassy and 63% of the vitrophyric beads have elliptical cross sections. For elliptical beads the mean between longest and shortest axes was taken as the average diameter. The average diameter (0.160 mm) of the vitrophyric beads is not much, but significantly larger than that (0.144 mm) of the glassy ones (Fig. 1).

Some of the glassy and vitrophyric spherules contain crystals and fragments of olivine formed before droplet formation. Crystallized phases in the now vitrophyric droplets are olivine and ilmenite. Olivine crystallized first and forms thin skeletal platelets, probably parallel (100) which are elongated either in the $c=[001]$ or $b=[010]$ direction. The plates consist either of one set of lamellae oriented at 90° to the elongation, or of a feather-like array of two lamellae systems emerging from a central quill at angles of about 45° . The olivine crystals appear as long needles if seen in directions parallel to (100). In most spherules the olivine crystals are oriented exactly parallel to each other and started to grow from the surface. In elliptical beads the olivine crystals are in most cases oriented parallel, sometimes perpendicular, and rarely in two sets at 45° to the long axis. This indicates that the shaping of melt droplets by rotational forces was finished when crystallization began. Ilmenite forming small dendritic spikes mantles the olivine crystals.

In the cooling experiments liquid droplets of a synthetic orange glass composition (Table 1) were allowed to cool under "free-flight" radiation cooling conditions in an induction heated vacuum furnace (1). The experiments showed that the critical diameter for crystallization of droplets under "free-flight" conditions is about 2 mm, corresponding to a critical cooling rate of about $100^\circ\text{C}\cdot\text{sec}^{-1}$ in the temperature interval $1100-1000^\circ\text{C}$. The crystallization is indicated by an exothermic heat effect in the thermocouple emf records at $1000-950^\circ\text{C}$. Theoretical cooling rates may be calculated with a modified Stefan-Boltzmann equation (1). Assuming a total emissivity of 0.8, a density of $3.4\text{ g}\cdot\text{cm}^{-3}$, a temperature of 200 K for the interplanetary space (2) and using the specific heat capacity of $0.34\text{ cal}\cdot\text{g}^{-1}\cdot\text{K}^{-1}$ for liquid orange glass (3), an average "free-flight" cooling rate of $86^\circ\text{C}\cdot\text{sec}^{-1}$ at 1050°C is obtained for liquid orange glass droplets 2 mm in diameter. For droplets 0.15 mm in diameter, the average size of lunar beads in the 125-250 μm fraction of 74220, the calculated "free-flight" cooling rate is $1148^\circ\text{C}\cdot\text{sec}^{-1}$ at 1050°C .

We conclude that orange and black beads in 74220 cooled, similarly to the Apollo 15 green glasses (4), at rates lower than those they would expe-

rience at "free-flight" conditions. The retardation in cooling may be due to a hot vapour environment or be caused by the radiation shielding effect in a dense cloud of radiating droplets.

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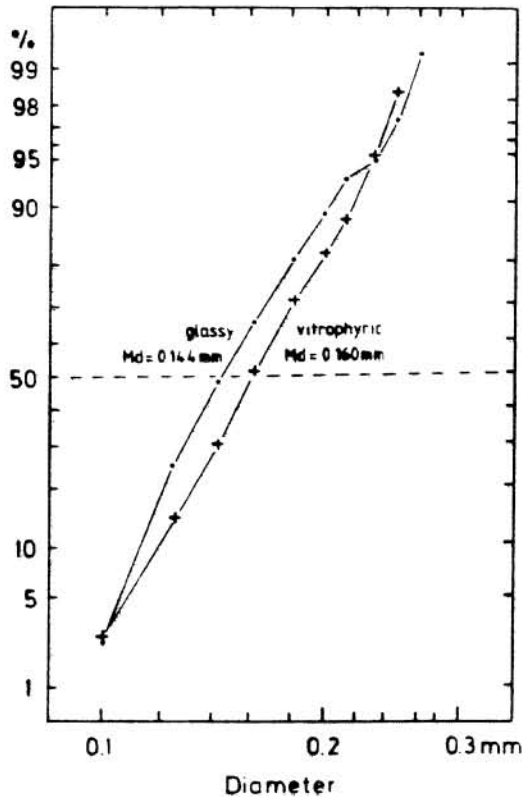


Fig.1 Size frequency distributions of glassy and vitrophyric cross sections in the 125-250 μ m sieve fraction of 74220. Log-probability scale.

Table 1. Chemical composition of Apollo 17 orange glasses

wt%	<u>Synth.</u>	<u>Lunar</u> (Av. (5,6,7))
SiO ₂	39.17	38.94
TiO ₂	9.05	9.04
Al ₂ O ₃	5.84	5.94
Cr ₂ O ₃	-	0.61
FeO	23.32	22.51
MnO	0.06	0.29
MgO	14.64	15.10
CaO	6.82	6.99
Na ₂ O	0.07	0.53
K ₂ O	0.04	0.07
Total	99.01	100.02