OPTICAL PROPERTIES OF GLASS FROM ALAMOGORDO, NEW MEXICO*

CLARENCE S. ROSS, *U. S. Geological Survey, Washington, D. C.*

ABSTRACT

The explosion of the atomic bomb at Alamogordo, New Mexico, fused the immediate surface of the arkosic sands of the area. This produced two distinct types of glass, one derived from the feldspar clay fraction of the sands, and the other direct fusion of the quartz to silica glass. The properties and relations of these materials are described in detail.

Specimens of glass resulting from the explosion of the experimental atomic bomb at Alamogordo, New Mexico, have, by various means, come into the hands of numerous institutions and collectors. Notwithstanding this availability, no studies of the material have been published, although a mere description of its physical character would have no bearing on atomic problems. Samples of the glass were collected by C. A. Anderson of the Geological Survey with the permission of Major General Leslie R. Groves, Commanding General for the Manhattan District. The results of a brief study of this glass, made in the laboratories of the U. S. Geological Survey, will no doubt be of interest to mineralogists and petrologists.

The glass, in general, formed a layer 1 to 2 centimeters thick, with the upper surface marked by a very thin sprinkling of dust which fell upon it while it was still molten. At the bottom is a thicker film of partly fused material, which grades into the soil from which it was derived. The color of the glass is a pale bottle green, and the material is extremely vesicular, with the size of the bubbles ranging to nearly the full thickness of the specimen. Figure 1 shows photomicrographs of typical specimens of the Alamogordo glass.

The material from which the Alamogordo glass was derived was an arkosic sand composed of angular quartz grains, abundant feldspar including both microcline and smaller amounts of plagioclase, together with small amounts of calcite, hornblende, and augite in a matrix of sandy clay. These materials fused into two distinct types of glass. The feldspars, clay material, and accessory minerals were the most fusible and molten glass derived from them must have been fairly mobile, for it shows marked flow lines best illustrated in Fig. 1, *A* and *B*.

The glass is colorless in thin section, and so the strong relief, shown by the dark flow lines in the left-hand part of Fig. 1, *A*, is due only to the differences in indices of refraction. The relief is accentuated by the in-

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clined illumination used in photographing the glass.† The marked differences in the indices of refraction are confirmed by direct measurement.

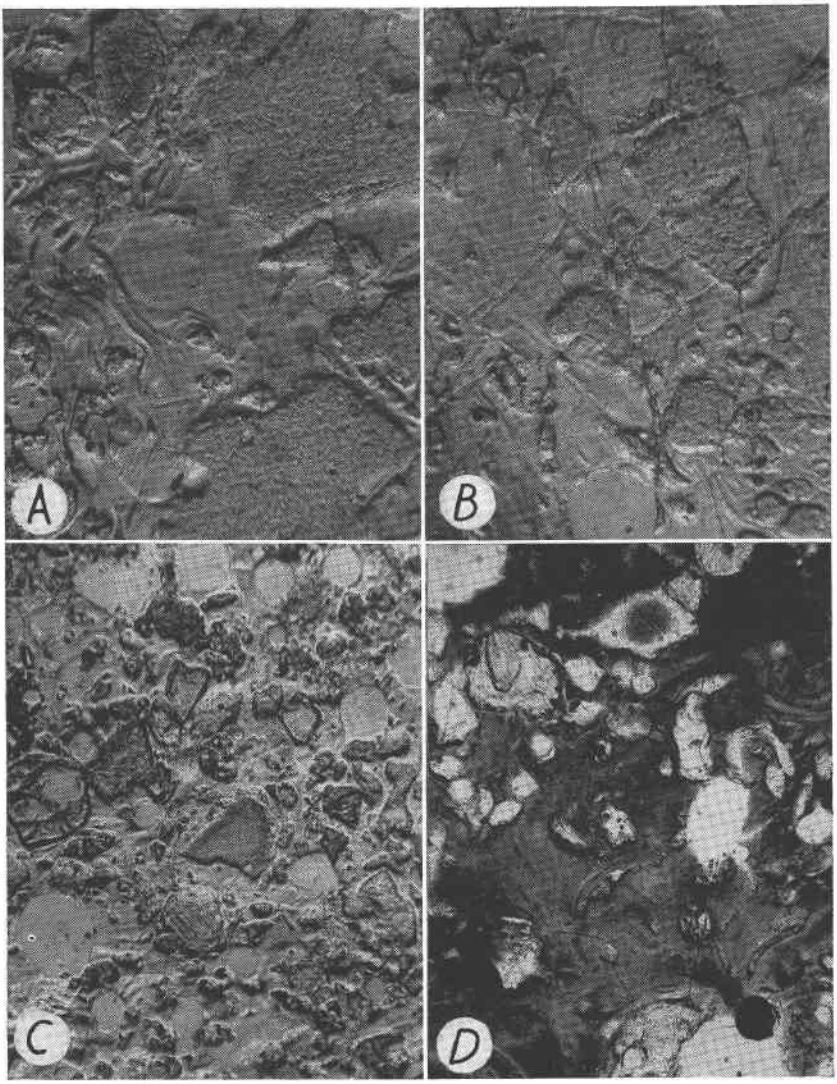

Fig. 1. Photomicrographs of glass from Alamogordo, New Mexico.

Most of the material ranges from $n=1.51$ to 1.53, but a little ranges as high as $n=1.54$, and a few areas, no doubt partly derived from ferro-

† Ross, Clarence S., Photomicrography by inclined illumination, *Am. Mineral.*, this issue, pp. 363-365.

magnesian minerals, reach 1.55. Gas bubbles show in a number of places in Fig. 1, *B*, and a large one occurs at the bottom. The amount of flowage indicates that this glass was fairly fluid, for all movement must have occurred during the very short period during which so thin a layer could have remained molten.

Other areas in Fig. 1, *A* and *B*, present a very rough surface, and the low index of refraction, together with the inclined illumination, causes them to appear as depressions. The index of refraction is close to 1.46, indicating that this material is almost pure silica glass. The boundary between the glass derived from feldspar and clay, and that derived from quartz is very sharp, showing that there was little diffusion of one into the other during the brief time they remained molten. There is also evidence that the areas of silica glass underwent little or no distortion of shape due to movement. In other words, the silica glass must have been exceedingly viscous compared with the other glass. However, the silica glass commonly contains small gas bubbles as shown in the large area of silica glass in Fig. 1, *B*.

Silica glass forms normally by the fusion of cristobalite at 1713° C. However, when the temperature rises so rapidly that there is insufficient time for inversion to cristobalite, quartz can fuse directly to silica glass. The fusion point of quartz is not known accurately, but is thought to be slightly below 1470° C. The temperature of the explosion at Alamogordo, although unknown, must have been much higher than 1470° C. and reached so suddenly that the quartz present in the sand fused directly to silica glass.

The partly fused material is represented in Fig. 1, *C*. The low-index lighter-colored material in the groundmass is a porous glass, but scattered through it are residual masses of unfused, or only partly fused grains, which stand in relief. These are mostly quartz, but a striated grain just below the center of the photomicrograph is plagioclase. One small area was characterized by glass which is oxblood red in hand specimen. In thin section this material is highly mottled, as shown by the photomicrograph, Fig. 1, *D*. Varying shades of red are nearly black in photographic reproduction. Others, mottled gray in thin section, show as gray in the photomicrograph. The colorless areas are pigment-free silica glass. Spectrographic tests show that the material contains essential amounts of copper. By reflected light both the red and the gray areas give a metallic copper color. Thus it is evident that both the red and the gray colors are due to dispersed copper, the differences in color representing the degree of dispersion of the copper. The copper was probably derived from copper wire as copper minerals are not evident in the original arkosic sand.