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A great deal of attention has been given recently to natural glasses, especially tektites, impact glasses, and the glass phases of lunar rocks. However, fulgurites, natural glasses formed as a result of fusion of rock by lightning, have not been the subject of modern study.

Fulgurites may be conveniently divided into two types, those formed by fusion of loose sand, or sand fulgurites, and those formed by fusion of solid rock, usually referred to as rock fulgurites.

[1] Presented orally at the International Mineralogical Association Seventh General Meeting, Tokyo and Kyoto, Japan, August 1970.

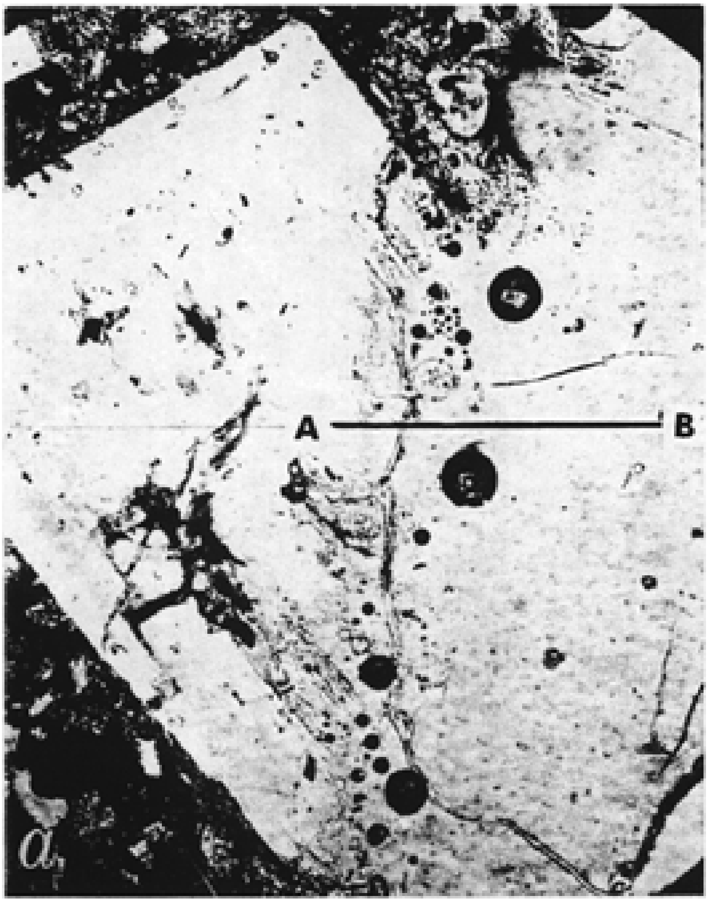

Figure 1a: Partially melted plagioclase phenocryst. Andesite, Little Ararat, Turkey

Sand fulgurites are normally of simple composition, from about 90 to 99 percent SiO_2 depending on the purity of the sand. They are quite common and have been described in detail by numerous investigators beginning in the year 1711.

Rock fulgurites on the other hand appear to be relatively uncommon, or at least have been observed less frequently than sand fulgurites. Also, they are petrologically more interesting since they may result from fusion of any rock type. They have

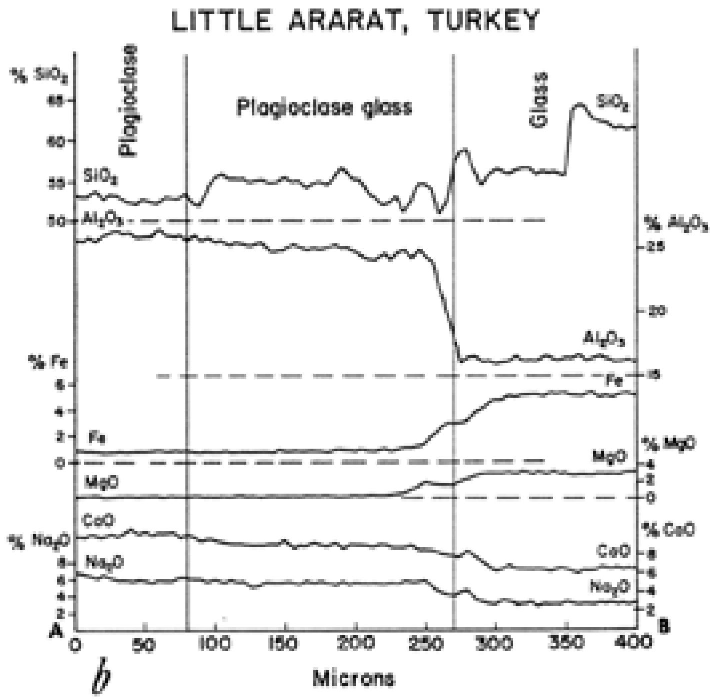

Figure 1b: Composition of glass along AB, Figure la

been described as formed from rocks ranging as widely as andesite, granite, hornfels, glaucophane schist, and serpentinite.

Investigation of rock fulgurite glass composition by microprobe has revealed that these glasses are extremely heterogeneous. As examples, we have looked at the composition of glasses formed by fusion of andesite from Little Ararat, Turkey; quartz diorite porphyry from Crested Butte, Colorado; and hornfels from Castle Peak, Colorado.

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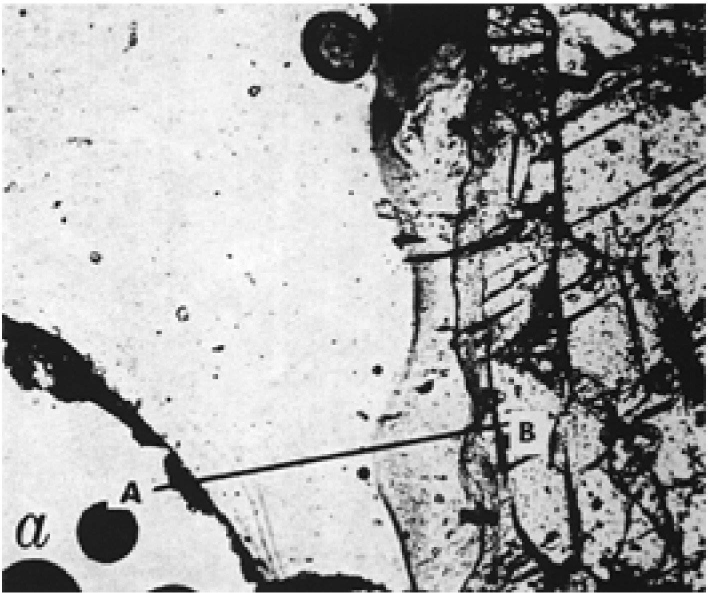


Figure 2a: Partially melted diopside phenocryst. Andesite, Little Ararat, Turkey

Little Ararat

Little Ararat, in eastern Turkey, elevation 12,877 feet, has the most extensive development of fulgurites reported anywhere in the world. The fulgurites are in hypersthene diopside andesite.

Detailed chemical analyses were made of areas in two thin sections of specimen USNM 52094. Figure 1a shows a partially melted plagioclase phenocryst. A microprobe step scan, at five micron intervals, was made along the line shown, and the results of the analysis as given in Figure 1b The plagioclase-glass interface shows clearly in the photograph but is not so clearly discernible from the chemistry. For some distance beyond the interface the glass has plagioclase composition. It then changes abruptly to a composition representing melted groundmass.

Figure 2a shows a partially melted diopside phenocryst. Two interfaces are clearly discernible, one between diopside and di-

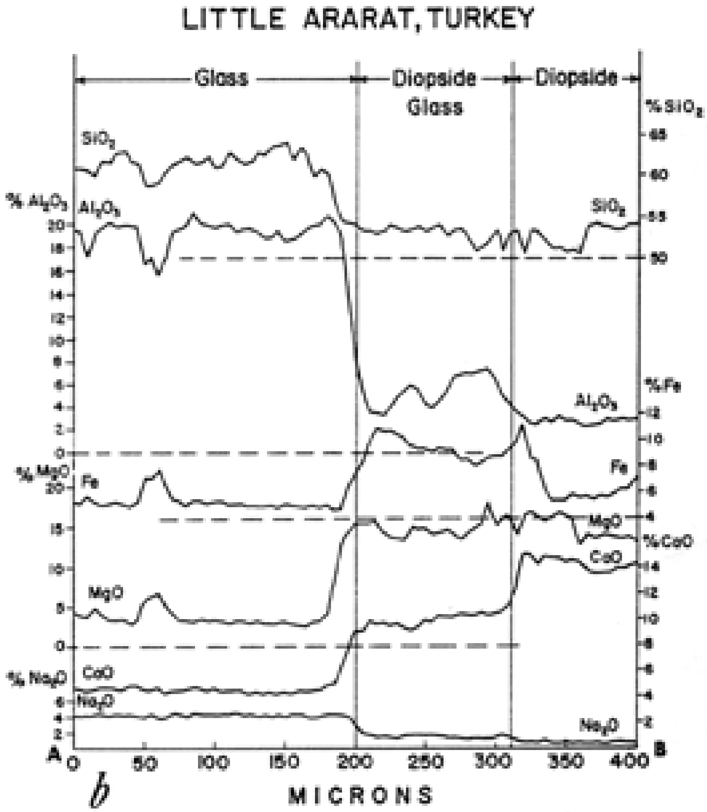


Figure 2b: Composition of glass along AB, Figure 2a

opside glass, and the other between diopside glass and glass derived by melting of groundmass. The same boundaries are reflected in the chemistry, as shown in Figure 2b.

Crested Butte, Colorado

Crested Butte, elevation 12,172 feet, is a Tertiary quartz diorite porphyry laccolith lying about 3 miles northeast of the town of Crested Butte in west central Colorado. The specimens used in this study (USNM 52981) were collected by Whitman Cross in 1885.

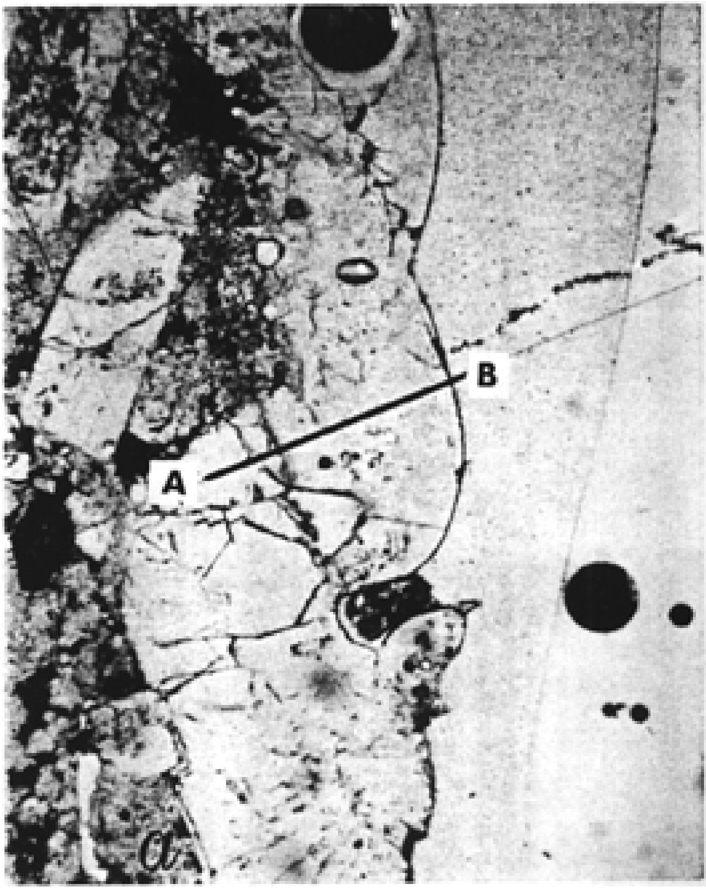


Figure 3b: Composition of glass along AB, Figure 3a

The extreme heterogeneity of rock fulgurite glass, resulting from essentially no mixing while in the molten state, is especially well exemplified by this material. In thin section, shown in Figure 3a, the plagioclase-glass interface is clearly seen, and heterogeneity of the glass is indicated by swirl marks, not visible in the photograph.

A step scan was made along the line shown and the results are shown in Figure 3b. There has been so little mixing that areas of glass representing the original phase can be recognized.

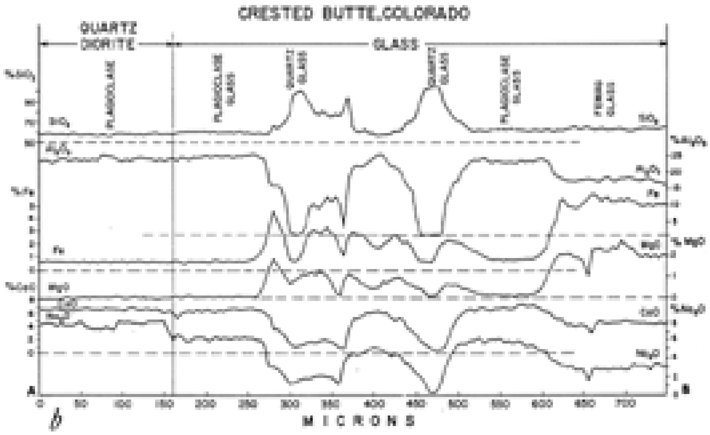


Figure 3a: Fusion crust on quartz diorite, Crested Butte, Colorado

Moving from left to right the composition is first that of plagioclase, then plagioclase glass. It then changes to quartz glass (as shown by SiO_2, nearly 100 percent, all other elements near zero), back to plagioclase glass, then quartz glass, plagioclase glass once again, and finally a glass high in Fe and Mg, probably representing fused biotite. The areas cannot be detected optically, but their dimensions correspond closely to the ground mass grain size of the rock.

Castle Peak, Colorado

Castle Peak, elevation 14,265 feet, is in west central Colorado and is the highest point in the Elk Mountains. The specimens studied (USNM 52980) were collected by Whitman Cross in 1887. The rock is an albite-quartz hornfels, with minor epidote, andradite, hornblende, calcite, and pyrite.

A photomicrograph of the glass analyzed, a bleb attached to the wall of a tube, is shown in Figure 4a. Because of the fine grain size, the glass appears optically homogeneous, and isochemical melting of individual grains cannot be seen. The results of a step scan analysis along the line shown are given in Figure 4b. This analysis reflects the fine grain size of the rock,

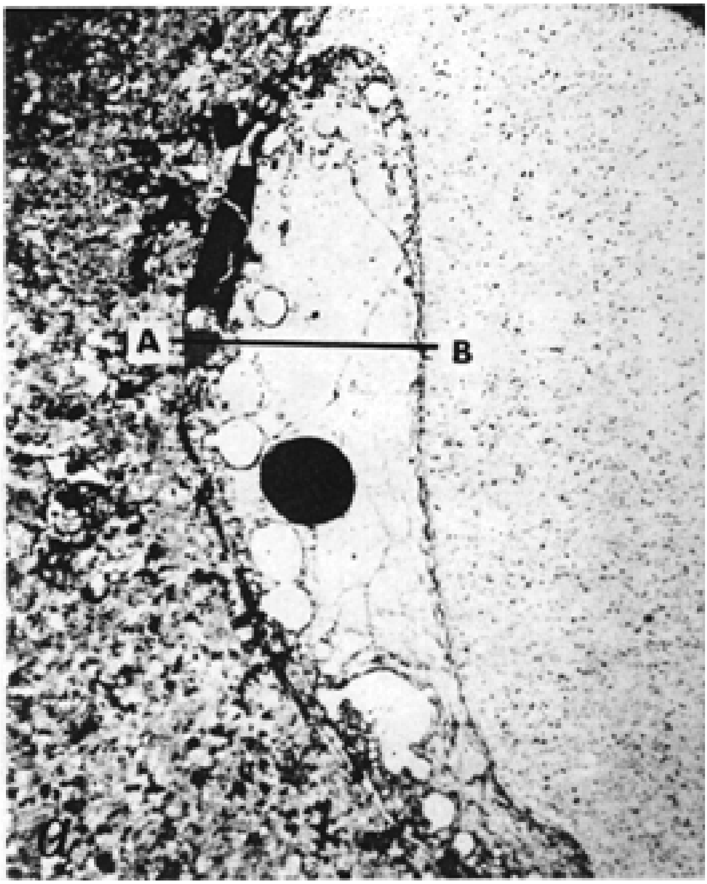
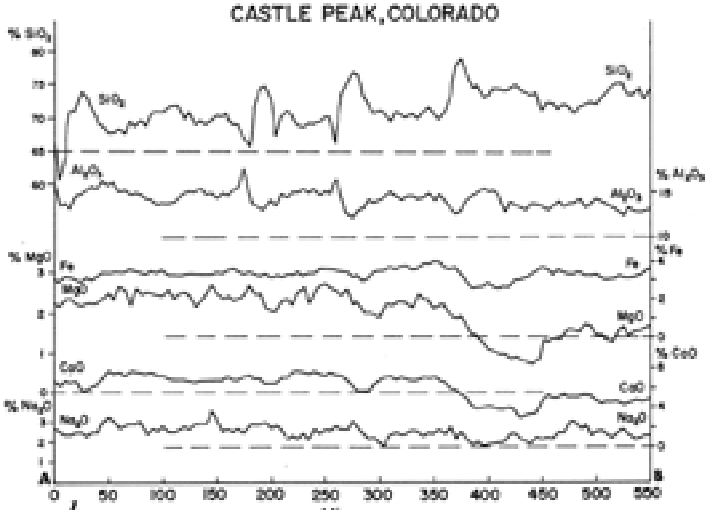


Figure 4a: Fusion crust on hornfels, Castle Peak, Colorado

but shows that even on this scale there has been relatively little homogenization.

Discussion

A remarkable feature of some of the rock fulgurites studied is the physical effect of the lightning strike. For example, the hornfels from Castle Peak has a nearly straight, glass-lined tube, 4 mm in diameter, and extending entirely through 9 cm of



b

Figure 4b: Composition of glass along AB, Figure 4a

rock. The "entrance" of the tube is spalled and glass spattered, and the "exit" has a raised glass lip.

Specimens from other localities, such as Little Ararat, show both broad surfaces covered by a thin fusion crust, as well as irregular, sometimes branching, glass-lined tubes.

The rock fulgurite glasses examined contain no crystallites. This feature, combined with the observed isochemical melting of individual mineral grains and the extreme heterogeneity of the glasses, indicates rapid melting and cooling. These features are predictable since the duration of a lightning strike is of the order of one millisecond.

Measurements of lightning made by many investigators have shown that:

1. The potential difference between cloud base and ground is of the order of 100,000,000 volts.

2. Peak current may be as high as 10,000 amperes, and during most of the duration of the strike is of the order of 1,000 amperes.

3. Air particles within a radius of 2 cm of the channel are ionized at a temperature of about 30,000°K.

The tubes, such as the one described in hornfels, if formed by lightning, must also have been formed in a time interval of the order of millisecond. This is a phenomenon difficult for us to comprehend even knowing the vast amount of energy released by a lightning stroke. Other explanations for the formation of these remarkable tubes must be considered, particularly for the unusually straight tube in the sample from Castle Peak, although as yet none more plausible has occurred to us.

The extremely high temperatures conceivably reached by fulgurites might lead to volatilization of metallic oxides, particularly silica and those of the alkalies. All the sand and rock fulgurites we examined contain gas cavities, but these appear to have formed mainly by boiling off of surface and combined water; we have detected no loss of metallic oxides.

THE EVENT

Petrified Lightning from Central Florida

A Project by Allan McCollum

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