

LIQUID IMMISCIBILITY AND GAS CONTENT IN DARK SCHLIEREN OF LIBYAN DESERT GLASS.

M. C. Böllitz¹ and F. Langenhorst¹, ¹Bayerisches Geoinstitut, Universität Bayreuth, D-95440 Bayreuth, Germany (Marie-Christin.Boelitz@uni-bayreuth.de, Falko.Langenhorst@uni-bayreuth.de)

Introduction: Libyan Desert Glass (LDG) is an enigmatic natural silica glass found in an 130 km (N-S) by 30 km (E-W) oval area in the Western part of the Egyptian Great Sand Sea. Fission-track studies revealed a consistent formation age for LDG of around 29 Ma [1-2]. Since the first scientific description of LDG [3] various theories have been proposed for its origin, ranging from a sol-gel formation to an impact origin. There are several clear lines of evidence that LDG formed at very high temperatures, such as the presence of baddeleyite, the breakdown product of zircon forming at temperatures $>1670^{\circ}\text{C}$ [4]. Further indications for a high-temperature event are the presence of lechatelierite (a high temperature melt of silica), cristobalite (a high-temperature polymorph of silica), schlieren with immiscibility features [5]. The detection of a possible meteoritic component [6] and the discovery of shocked quartz in bedrocks of the LDG area [7] have finally resulted in the wide acceptance of LDG as an impact product, although the source crater is still unknown. In this study we have focused on the chemical and textural characteristics of dark schlieren. Our investigation aims at obtaining further information on the cooling history and precursor material of LDG.

Samples and methods: For this study we have particularly selected transparent glass samples with brownish to black schlieren. All LDG samples selected are pervaded by numerous bubbles, which in some parts of specimens are aligned in form of streaks.

For chemical and textural analysis of glass specimens we have used polarizing microscopy, direct coupled evolved gas analysis spectrometry (DEGAS), inductively coupled plasma mass spectrometry (ICP-MS), electron microprobe, and scanning electron microscopy (SEM).

Results: Backscattered electron (BSE) images were taken on the SEM and microprobe in order to monitor chemical variations in LDG and to detect tiny inclusions. Schlieren-free, bulk LDG samples show only slight variations in chemistry, with two different greyscales in BSE images. Dark grey, lens-like areas consist of almost pure SiO_2 and thus represent lechatelierite, the melt product of quartz. Bright grey areas have on average a SiO_2 content of 98 – 99 wt.%; additional minor elements are Mg, Fe, Al, Ca, K, and Na.

Compared to the bulk glass, the brownish-black schlieren in LDG are distinctly enriched in Mg, Fe,

and Al; the concentrations of measured trace elements such as Ti, Ni, Cr, and La are equally enhanced. In some parts of schlieren the SiO_2 content decreases down to 86 wt %. Within the dark schlieren we observe furthermore distinctly larger chemical variations than in the bulk glass sample.

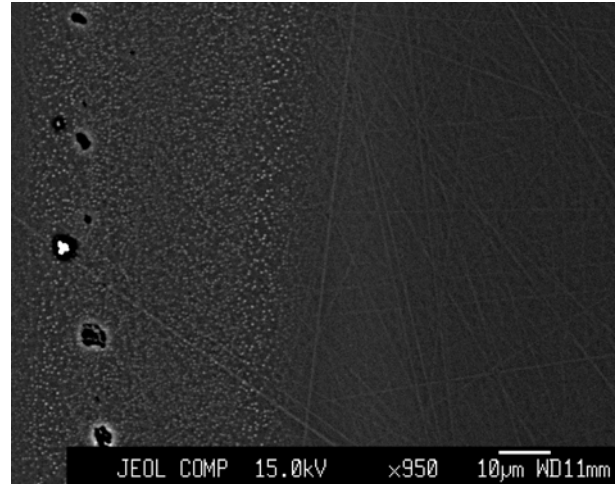


Fig. 1. BSE image of a dark schliere in LDG, consisting of numerous tiny glass spherules.

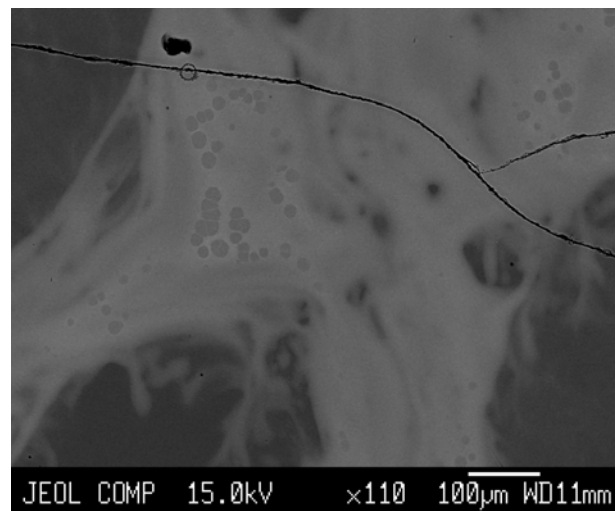


Fig. 2. BSE images of a dark schliere in LDG, showing a fluidal texture und dark exsolved glass spherules.

BSE images indicate that there are two types of dark schlieren. One type of dark schlieren consists exclusively of tiny, mostly 100 nm in size, glass spherules. This type of schlieren have been previously described in a transmission electron microscopy study [5], as well. In comparison to the glass matrix, the

spherules are enriched in Al, Fe, Mg, and Ni and depleted in Ca.

The other type of dark schlieren displays flow structures and large, up to 25 μm diameter glass spherules (Fig. 2). The overall texture of these schlieren indicates an immiscibility of two silicate liquids. To detect the miscibility gap, the chemical compositions of spherules and the surrounding groundmass in dark schlieren have been measured with the microprobe and are plotted in a ternary $\text{MgO-Al}_2\text{O}_3\text{-SiO}_2$ diagram (Fig. 3). The analytical data define a trend that deviates from the known stable miscibility gap along the MgO-SiO_2 join. Instead, the data points follow closely the $\text{Al}_2\text{O}_3\text{-SiO}_2$ tie line, along which a metastable miscibility gap has been described [8].

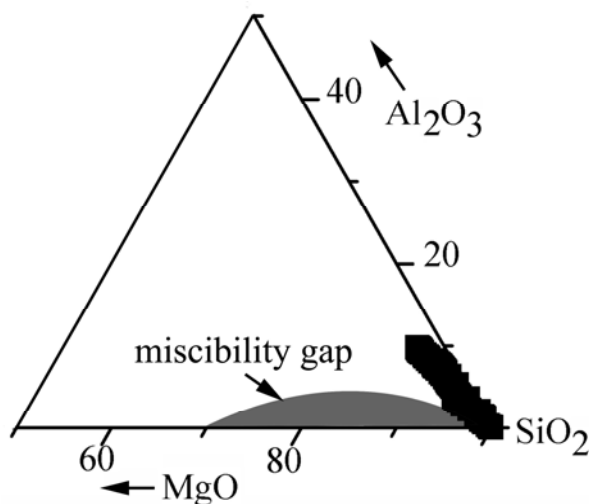


Fig. 3. Microprobe analyses of spherules and groundmass in dark schlieren of LDG. The ternary plot shows also the known stable miscibility gap along the MgO-SiO_2 join.

To analyse gases in LDG and to gain information on the precursor material of schlieren we have performed DEGAS analyses. This technique consists of a thermogravimeter in combination with a quadrupole mass spectrometer that simultaneously records 28 masses with mass numbers up to 200.

LDG samples with and without black schlieren were stepwisely heated up to 1450°C. In both samples, bursting bubbles released mostly H_2O and CO_2 . The black schlieren contain however one order of magnitude more H_2O and CO_2 than the bulk silica glass. Another difference between black schlieren and bulk glass concerns the temperatures of gas release. For example, CO_2 is released from black schlieren in two temperature intervals between 250° - 300°C and 450° - 550°C. In the bulk sample, CO_2 is however only liberated in the upper temperature interval between 420° - 650°C.

Discussion: The data presented here provide hints to the cooling history of LDG and the precursor material of dark schlieren. Microprobe data of glass spherules and surrounding matrix in dark schlieren indicate that the compositions of the two immiscible silicate liquids are close to the $\text{Al}_2\text{O}_3\text{-SiO}_2$ join. According to experimental studies [8], this binary system displays only metastable immiscibility for very rapid cooling of the melt, as it is expected for LDG.

DEGAS analyses reveal that dark schlieren are distinctly richer in volatiles, particularly in H_2O , than bulk LDG. It is thus likely that the precursor material might have contained hydrous phases.

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Acknowledgements: We are grateful for the financial support provided by the Deutsche Forschungsgemeinschaft (Leibniz program, LA 830/14-1).