β-cristobalite in Libyan Desert Glass

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The high-temperature silica polymorph, ß-cristobalite, is rarely, if ever, preserved in natural samples due to polymorphic transformation to α-cristobalite at low temperature [1]. Formation mechanisms for ß-cristobalite are difficult to discern because silica melt and glass have similar properties at high temperature; rates of heating/cooling, bulk composition, and trace elements all influence whether cristobalite crystallizes as a liquidus phase from melt, or by devitrification of glass. Here we report microstructural (EBSD) and elemental (LAICPMS, EMPA, ToF-SIMS) data for α-cristobalite inferred to have originated as ß-cristobalite in Libyan Desert Glass (LDG). LDG is a nearly pure silica natural glass of likely impact origin found in western Egypt [2,3]. Cristobalite grains in LDG preserve evidence of a multi-stage growth history, including ~250 µm-wide coarse cores surrounded by ~50 µm-wide fine-grained rims. Layering in surrounding glass, corresponding primarily to Al distribution, extends uninterrupted across boundaries of cristobalite rims, but is disrupted in cores. Al in cores records oscillatory growth zoning, whereas Al in rims defines grain boundaries. Cores thus nucleated within layered melt at conditions that allowed significant remobilisation of Al into crystallographically–controlled growth zones, whereas rims grew later, when Al was less mobile, presumably in the solid-state. Orientation analysis by EBSD demonstrates the presence of twins resulting from transformation of ß to α cristobalite. Phase heritage analysis of {112} twin relations confirms that cores were formerly large single crystals of ß-cristobalite, whereas the fine-grained rims originated by dendritic growth. The microstructural and elemental data, including growth zoning and analysis of twin relations, combined with published experimental work, provide compelling evidence for high-temperature (>1350 °C) crystallization of ß-cristobalite cores in LDG glass. Dendritic rim growth likely occurred during devitrification, after significant undercooling.

References: [1] Dollase, W.A. (1965) Zeitschrift. Krist., v. 121, 369-377 [2] Cavosie, A.J. and Koeberl, C. (2019) Geology, v. 47, 609-612 [3] Koeberl, C. and Ferriere, L. (2019) Meteor. Planet. Sci. Lett., v. 54, no. 10.

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