THE ORIGIN OF "TOASTED" QUARTZ IN IMPACTITES REVISITED. L. Ferrière[1], C. Koeberl[1], W. U. Reimold[2], L. Hecht[2], and K. Bartosova[1], [1]Department of Lithospheric Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria (ludovic.ferriere@univie.ac.at, christian.koeberl@univie.ac.at), [2]Museum for Natural History, Leibniz-Institute at Humboldt University Berlin, Invalidenstrasse 43, D-10115 Berlin, Germany (uwe.reimold@museum.hu-berlin.de).

Introduction: Quartz is one of the most abundant minerals in terrestrial crustal rocks. Viewed in plane-polarized light with a petrographic microscope, quartz is clear (i.e., transparent). In cross-polarized light, quartz typically displays gray to white interference colors. Quartz (and other minerals) is deformed and transformed when subjected to strong shock waves, as a consequence of impact events. Shock-induced deformations and transformations in quartz include changes in refractive index, and formation of planar fractures (PFs), planar deformation features (PDFs), high-pressure polymorphs, diaplectic glass, and lechatelierite [e.g., 1]. Another feature, so-called "toasted" quartz [2] (quartz grains of orange-brown to grayish-reddish brown appearance, Fig. 1), which has been so far only reported in rocks affected by shock metamorphism [3, 4], is possibly related to post-shock temperatures, but the exact formation mechanism for "toasted" quartz is still unresolved.

To assess this enigmatic phenomenon, hundreds of thin sections of samples from several impact structures were studied by optical microscopy. In addition, investigations of thin sections of Bosumtwi and Chesapeake Bay impactites by electron microscopy and electron microprobe (EMP) analysis were carried out.**Previous work:** Toasted quartz has been considered a post-shock feature, probably the result of "hydrothermal or other post-shock modification" [3], or resulting from "the exsolution of water from glass, primarily along PDFs, during heat-driven recrystallization" [4]. It was also noted by [4] that "no compositional origin for the browning is evident", and they concluded that the brownish appearance of quartz was caused by a high proportion of very small fluid inclusions mainly located along decorated PDFs.

Results and Discussion: In addition to the 15 impact structures from which toasted quartz was previously described by [3, 4], we can add 11 further impact structures (Aorounga, Boltysh, Bosumtwi, Chesapeake Bay, Ilynets, Paasselkä, Puchezk-Katunki, Santa Fe, Shoemaker, Ternovka, and Upheaval Dome) to this list. Toasted quartz grains were observed in various lithologies, mainly in clasts of impact melt rocks and suevite.

At Bosumtwi, toasting occurs in up to 41 rel% of the quartz grains in impact breccia samples from the deep crater moat [5], and ~20 rel%, on average, of the shocked quartz grains from the basement meta-graywacke in drill core LB-08A are toasted [6]. Quartz grains are partially (i.e., only locally) or totally toasted. Even though commonly, as also noted by [5], toasted appearance does indeed occur in close association with PDFs, frequently toasted quartz grains are barren of PDFs.

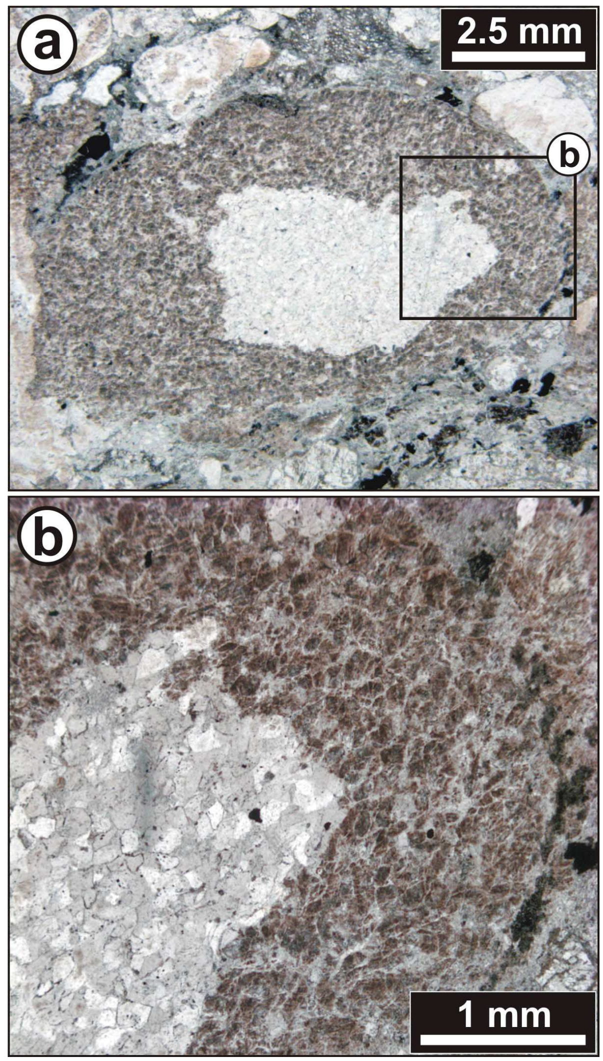

Fig. 1: Microphotographs in plane-polarized light of a partially toasted sandstone clast in a conglomerate sample from the Chesapeake Bay crater (CB6-125; depth: 1522.72 m). Note that only the quartz grains from the rim of the sandstone clast are toasted.

In partially toasted sandstone clasts in conglomerate from Chesapeake Bay only the marginal part of the clasts is toasted (Fig. 1). In contrast, for quartz veinlets, generally, only quartz in the inner part of the veinlet is toasted. For single quartz grains in matrix of either suevite or impact melt rock samples, marginal, partial, or complete toasting of grains is observed.

Electron microscope investigations have revealed that abundant vesicles or cavities, with sizes typically from <1 µm to ~5 µm, occur at the surface of toasted quartz grains (Fig. 2). Also, strongly toasted regions often have a higher volume proportion of vesicles than slightly toasted regions.

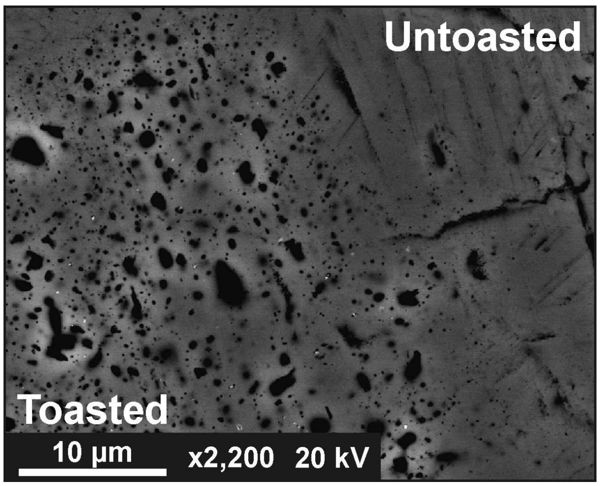

Fig. 2: Backscattered electron image showing the typical vesicular (or sponge-like) texture of toasted quartz (sample CB6-125; depth: 1522.72 m).

Preliminary X-ray mapping and EMP spot analysis in sample CB6-125 show that the Al content is significantly lower in toasted than in untoasted quartz. On average, the Al content is ~5 times lower in toasted than in untoasted quartz, i.e. ~200 vs. ~1150 ppm, respectively. Less drastic differences were noted also for Na, Ca, and Fe contents. Strong positive linear correlations are observed between the contents in Al, Ca, and Na in untoasted quartz, whereas only weak correlation is observed for the contents of these elements in toasted quartz. This indicates that the contents of these elements, which co-vary in untoasted quartz, have been heterogeneously removed from the quartz structure during the process responsible for the formation of toasted quartz.

Quartz is normally composed of 100% SiO_2, but small amounts of, e.g., Al, Ti, Fe, Mn, Mg, Ba, Na, Ca, K, and Li can occur mainly as the result of cation substitution but also being hosted by fluid or mineral inclusions (e.g., [7]). Thus, based on our microprobe results, it seems that some of the trace elements originally present in quartz, mostly Al, were removed from the quartz lattice and/or from inclusions in the quartz during “toasting”, also causing vesiculation. Toasted quartz may, thus, represent the beginning of quartz breakdown due to heating. Textures very similar to that shown in Fig. 2 are typical for the products of sintering (i.e., material heated just below its melting point [8]).

The orange-brown to grayish-reddish brown appearance of toasted quartz is probably caused by an increase in light scattering due to the presence of numerous vesicles in toasted quartz, as noted by [4]. It is unlikely that the minor differences between the chemical compositions of toasted and untoasted quartz can be the cause of the brownish hue of toasted quartz.

Conclusions: Our study confirms the finding of [4] that toasted quartz contains a high proportion of small vesicles and that these vesicles probably enhance scattering of transmitted light. However, the vesicles observed in toasted quartz, with highly variable sizes, are not related to recrystallization of PDF glass, as suggested by [4]. As shown in Fig. 1, in some clasts, only the quartz grains in the marginal part of the clast are toasted, whereas most quartz grains of the entire clast are shocked. Thus, it would be difficult to explain that only the PDFs occurring in the marginal part of the clast were recrystallized and not the others.

Microprobe investigations show that some trace elements (and inclusions), originally present in quartz, were removed from the quartz structure. Therefore, toasted quartz is formed by vesiculation after pressure release, at high post-shock temperatures, and, thus, represents the beginning of quartz breakdown due to heating.

Acknowledgments: Drilling at Bosumtwi was supported by ICDP, the U.S. NSF, the Austrian FWF, the Canadian NSERc, and the Austrian Academy of Sciences. Drilling at Chesapeake Bay was funded by ICDP, USGS, and NASA. This work is supported by the Austrian Science Foundation (FWF), grant P18862-N10, the Austrian Academy of Sciences, and a SYNTHESYS grant. Dieter Stöffler is gratefully acknowledged for allowing investigation of some thin sections from his collection.

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