X-RAY COMPUTED TOMOGRAPHY OF BUBBLE-CORED TEKTITES. A. Krauss[1], [1]Dr. Eng., Consultant Engineer (andreas.krauss@krauss-engineering.de); A. Whymark[2], [2]Consultant Wellsite Geologist (aubrey@tektites.co.uk); G. Kloess[3], [3]Prof. Dr. habil., Crystallographer, Leipzig University, (kloess@uni-leipzig.de).

Introduction: X-ray computed tomography, (X-ray CT), is a non-destructive method for inspecting materials, composites, sintered materials and ceramics, but can also be used to analyze geological or biological samples. Tektites have previously been investigated with X-ray CT [1] [2], but only pores and very small cavities in tektites were examined. Research has been carried out on the gas content of bubbles, but very little research has been performed on bubble shape, size, abundance and distribution in tektites [3] [4] [5] [6]. Origin of the bubbles has been discussed in [4] [7] [8].

Investigation: Ten bubble-cored tektites from Guangdong Province, China (properties in Table 1) were scanned. Samples 01-09 were scanned at Fraunhofer Institute for Electronic Nano Systems in Chemnitz, Germany, on the Phoenix Nanofocus Computed Tomography System. Due to the larger size of sample 10, it was analyzed in the Fraunhofer Institute for Industrial Mathematics ITWM, Dresden, Germany, on Fraunhofer IKTS-MD Computed Tomography System.

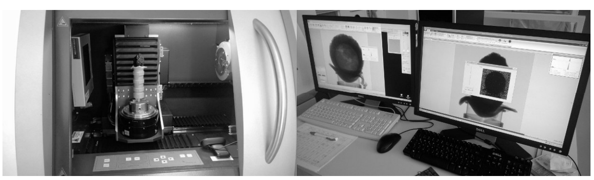

Fig. 1: Analysis (left) and reconstruction (right).

Smpl. #	Weight g	Length mm	Width mm	Height mm	Volume cm^3	Bubble Vol. %
01	89.4	59.8	53.3	39.2	56.8	35.8
02	67.5	109.8	33.7	25.8	35.2	21.7
03	83.0	54.2	44.7	40.9	45.7	25.9
04	78.3	54.9	51.5	23.1	35.2	9.2
05	53.5	51.0	50.3	16.8	23.8	8.2
06	93.3	60.1	48.5	44.8	55.0	30.8
07	114.2	74.1	59.2	34.0	67.0	30.4
08	107.7	55.6	53.0	46.6	68.0	35.4
09	104.2	57.3	54.6	46.7	59.3	28.3
10	256.2	75.1	72.8	49.5	141.2	25.9

Table 1: Properties of the tektite samples.

Samples 01-09 were scanned with identical parameters. Sample 10, utilized different equipment and parameters (bracketed). Resolution: 50-60 (76.5) µm; Number of images: 1000 (753); Image width: 1148 (1023) pixels; Image height: 1152 (1023) pixels; Voltage: 110-120 (210) kV; Current: 70 (200) µA.

Software VGStudion Max was used for processing and reconstruction of X-ray CT data. In this software scan data has been read, filtered (removed noise and artifacts) and cut (removed mounting / plasticine which had similar absorption densities and could not be distinguished from the tektite material). Then the surface of the tektite was determined: Focus of the parameterisation was on the correct determination of the inner surface. Software Autodesk 3ds MAX was used for further processing of polygonal meshes. In this software materials were assigned, compositions were built and images were rendered.

Results: Figures 2 to 11 show three views of each sample. The outer glass layer of samples has been removed in viewing direction, so the interior bubble surface is visible.

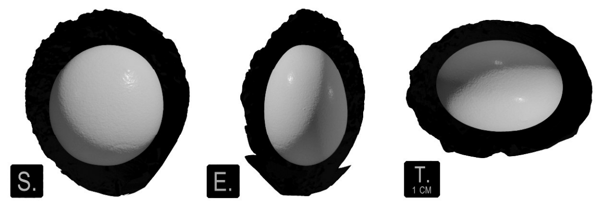

Fig. 2: Sample 01 (Cat. # TC00166_0446,9_059,8).

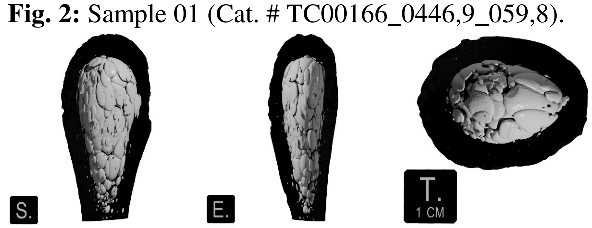

Fig. 3: Sample 02 (Cat. # TC00167_0337,3_109,8).

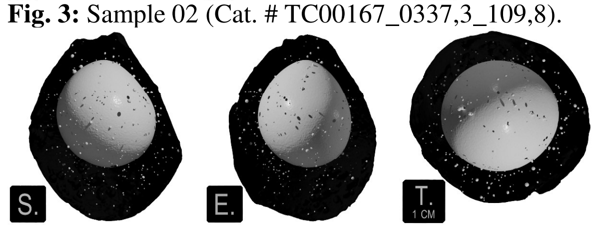

Fig. 4: Sample 03 (Cat. # TC00168_0415,2_054,2).

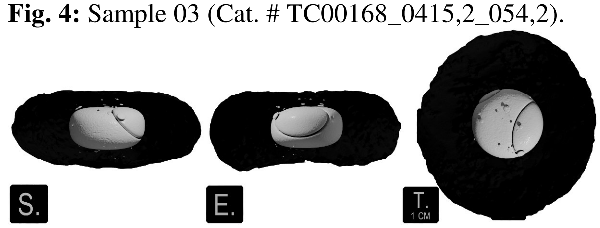

Fig. 5: Sample 04 (Cat. # TC00169_0391,3_054,9).

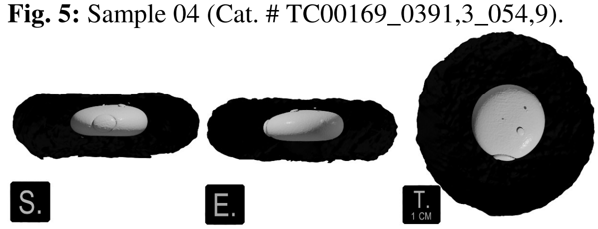

Fig. 6: Sample 05 (Cat. # TC00170_0267,3_051,0).

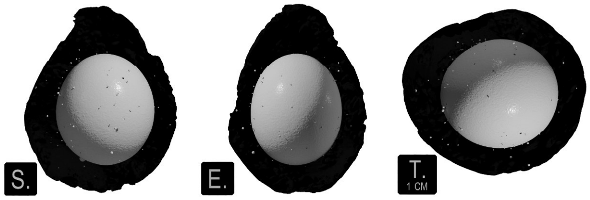

Fig. 7: Sample 06 (Cat. # TC00171_0466,7_060,1).

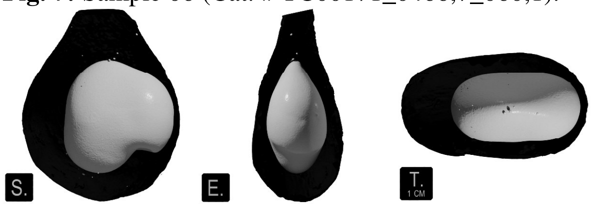

Fig. 8: Sample 07 (Cat. # TC00172_0571,0_074,1).

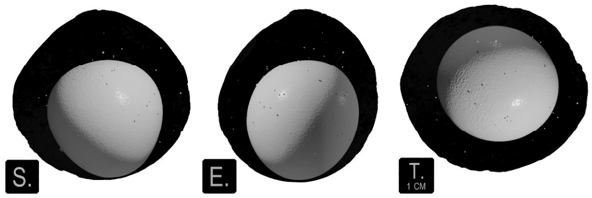

Fig. 9: Sample 08 (Cat. # TC00173_0538,7_055,6).

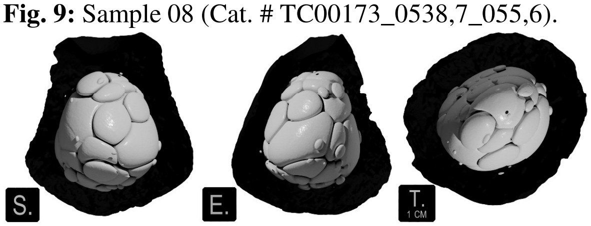

Fig. 10: Sample 09 (Cat. # TC00174_0521,2_057,3).

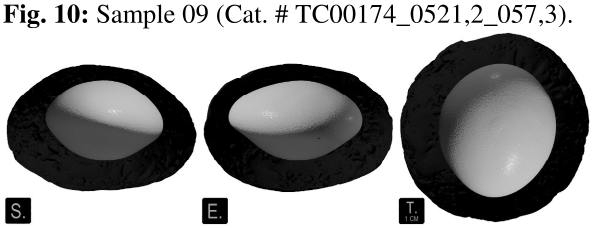

Fig. 11: Sample 10 (Cat. # TC00175_1280,8_075,1).

Samples 01, 03, 06, 07, 08 and 10 have one prominent large bubble. The shape of the bubble mimics the tektite morphology and is variably near spherical to ellipsoidal, becoming discoidal in disc-shaped tektites. When off-central, the bubbles appear to be closer to the posterior surface. Together with this single large bubble, isolated 'micro-bubbles' are occasionally noted in samples 06, 07 and 08 and very commonly observed in sample 03.

Samples 04 and 05 exhibit bubble coalescence with a main bubble and a smaller attached 'parasitic' bubble. Sample 07 may be gradationally related.

Samples 02 and 09 show foams formed by the coalescence of similarly moderately sized bubbles. Sample 02 and 09 are teardrop morphologies.

Figure 12 (left) shows slices through samples 02 & 09. Thin surfaces of the bubbles could not be fully reconstructed due to image noise and artifacts. However, fine structures of bubbles can be seen clearly in X-ray images of samples 02, 04, 05 and 09. Figure 12 (right) compares black line of reconstructed surface and fine structure of X-ray image. All bubbles are completely closed, separated by very thin bubble skins.

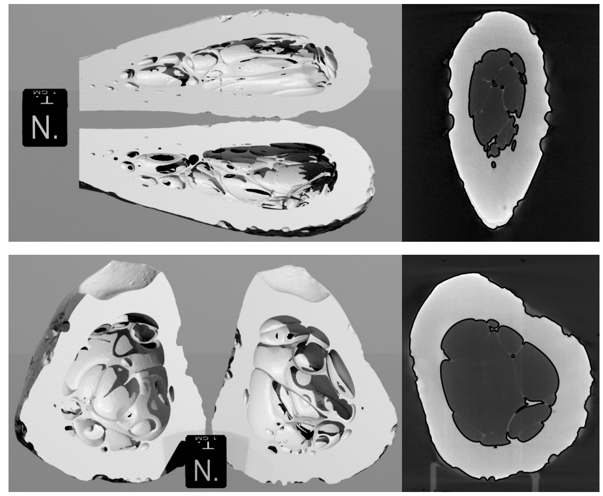

Fig. 12: Sections through (left) and X-ray images (right) of Sample 02 (top) and Sample 09 (bottom).

Fig. 13: Photographic image of a bubble-cored tektite fragment (Cat. # TC00176_0033,1_038,3).

Discussion: Bubble shape [3], size and number are influenced by the melt history of the tektite. Large singular bubbles probably formed from a hotter, more fluid, melt or melt that remained hot longer. Large bubbles have been flattened, presumably by aerodynamic deformation causing subtle internal flow of a cooling and increasingly viscous melt. Bubbles are found towards the posterior, as the tektite will orient heavy side down. Foam occurred in teardrop morphologies in this study: Both teardrop shape and foam require higher viscosity melts to form.

References: [1] Pratesi, G. et al. (2014) *Materials, 7,* 3319-3336. [2] Rantzsch, U.; Franz, A.; Kloess (2013), *Eur. J. Mineral., 25,* 705-710. [3] Barnes V. E. (1964) *Geochim. Cosmochim. Acta, 28*, 1267-1271. [4] Barnes V. E. and Russell R. V. (1966) *Geochim. Cosmochim. Acta, 30*, 143-152. [5] McColl D. H. (2008) *Met. Mag., 14 (2),* 40-42. [6] Lehrman, N. (2013) *Meteorite Times Magazine, May.* [7] Jessberger E. and Gentner W. (1971) Eos, Trans. Amer. Geophys. Union, *52 (4),* 366. [8] Melosh H. J. and Artemieva N. (2004) *LPS XXXV,* Abstract #1723.