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A Study of the Brushy Creek Feature, Saint Helena Parish, Louisiana

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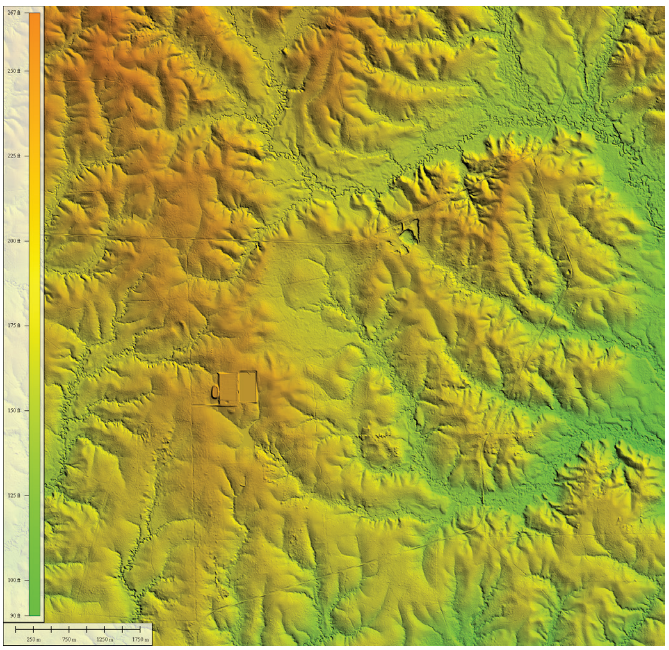

Abstract

This study was unable to determine the origin of the Brushy Creek feature. New thin sections were made and new and old thin sections were examined using the optical and scanning electron microscope (SEM). Powdered samples from the center of Brushy Creek were examined using X-ray diffraction (XRD). In sample 16SHPA, a half dozen new grains with probable planar deformation features (PDF) were found with orientations of {1012} and {1011}. Preliminary SEM studies of zircons showed no evidence for PDFs or reidite. Only one grain from the center of Brushy Creek structure showed possible rectangular fracture. XRD analysis found no evidence for high-pressure forms of quartz, coesite and stishovite. Suggestions for further study are included.

Introduction

North-south oriented ridges and ravines dominate the landscape in this part of Louisiana. The Brushy Creek is a “noticeable circular hole” in the ridge/ravine topography (Heinrich, 2003). The feature is about 2 kilometers in diameter and has a relief of 15 meters and Brushy Creek breeches the southeast rim of this feature. Exposed in the rim is the poorly lithified and highly fractured Pliocene Citronelle Formation. Near the Brushy Creek feature, the Citronelle formation consists of cross-bedded, massive, poorly sorted fine to coarse sand 9-12 meters thick underlain by 6 meters of laminated clay and silt. The Kentwood Brick and Tile Company has drilled the center of the feature and have found that the laminated clay and silt is absent. A meteorite impact is a plausible explanation of the Brushy Creek feature.

A meteorite large enough to produce a crater 2 kilometers in diameter would produce a crater 200 to 300 m deep with a rim height of 30 to 70 meters above its surroundings (Holsapple, 2003). Assuming a meteorite impact origin for the Brushy Creek feature and the present day topography, there must have been considerable erosion. The humid climate of Louisiana would have resulted in a crater rapidly filling with water and drilling would reveal the presence of lake sediments at depth. The rim of the crater would deflect regional drainage. Erosion of the rim may have removed from the rim the ejecta blanket, secondary craters and the overturned flap, which would have repeated the section of sand underlain by laminated clay-silt horizons of the Citronelle Formation. On the microscopic scale, an unusual characteristic of the Brushy Creek feature is the presence of highly fractured quartz grains. The intensity of fracturing is greater in the center of the feature. The fractures have an irregular shape (Figure 1a), whereas meteorite impact produces numerous sets of subparallel fractures (Figure 1b)

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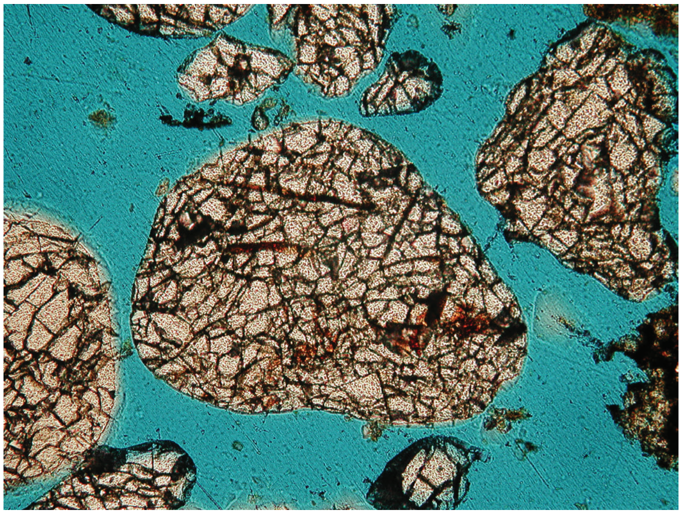


Figure 1a: Intensely fractured, medium quartz grains from 16SHPQ lying in the Brushy Creek feature. From Heinrich (2003)

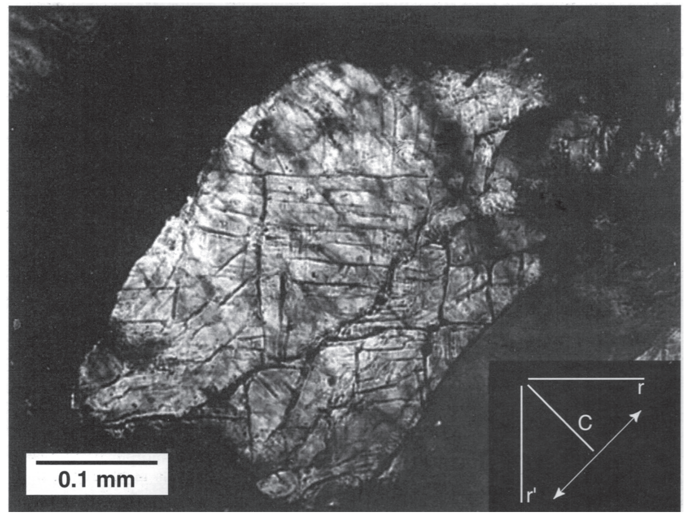


Figure 1b: Quartz cleavage in moderately shocked Coconino sandstone from Barringer Meteorite Crater Arizona. Note the three sets of cleavage parallel to the directions in the schematic in the lower right-hand corner of the schematic (picture from French, 1998).

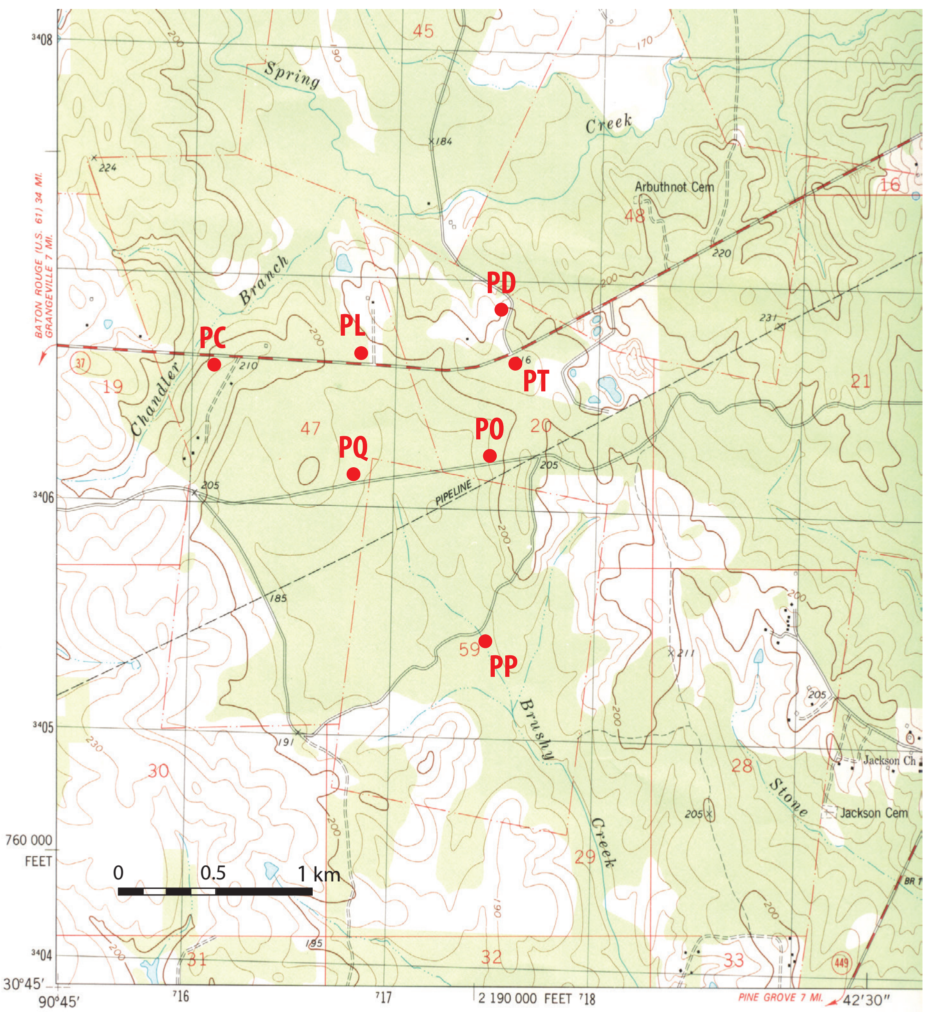


Figure 2: Sample location map from the 7.5' Greensburg quadrangle. On the map, the last two letters of the sample identification number indicate the sample location.

Methodology:

Figure 2 shows sample locations. Samples 16SHPC, 16SHPD and 16SHPT are from the rim of the feature and samples 16SHPO, 16SHPP and 16SHPQ come from the center of the feature. Brushy Creek breeches the circular feature and sample 16SHPA comes from stream bed sediments just below the breech. The interior samples, 16SHPO, 16SHPP and 16SHPQ are material derived from the interior of the presumed crater and hence should record the highest pressures.

In poorly lithified and porous sediments such as the Citronelle, there will be an inhomogeneous distribution of pressure and temperature, which would favor the formation of high-pressure polymorphs of SiO_2, coesite and stishovite, over PDFs (Grieve et al. 1996). For powdered XRD patterns, the most prominent peak of coesite is 28'92°20", the most prominent peak of coesite is 30'25°20" and the most prominent peak of quartz is 26'66°20". Thus, XRD is one way to identify high-pressure polymorphs of SiO_2. The high-pressure phases were hypothesized to form along the irregular fracture boundaries.

Recently, there has been a great interest in using shocked zircons to study meteorite impact processes (e.g., Cavoise et al., 2016). Usually zircon grains are obtained by 1) disaggregating rock, 2) magnetic separation using the Frantz Isodynamic Separator, 3) density separation using heavy liquids, 4) shape-density separation using

Wilfley Table and 5) finally the zircons are handpicked using a binocular microscope. At West Virginia State University, we lack the facilities for zircon separation, so our objective was to do a preliminary study of zircons in thin sections using the scanning electron microscope (SEM). Because of the high atomic number of Zr, back-scatter-electron (BSE) SEM images of zircons are very bright. Thus, scanning thin sections in BSE mode at low magnification is an easy way to spot grains that might be zircons. Acquiring an EDS spectrum allows one to identify zircons. Thin sections from the rim, 16SHPC, center, 16SHPQ, and the stream exiting the feature, 16SPHA, were examined. Once a zircon was identified, secondary, backscattered and cathodoluminescence images were taken of the zircon.

The most widely used method of identifying terrestrial impacts are PDFs in quartz. Typically, this is done by taking U-stage measurements on 50 grains, which all have multiple sets of PDFs from a particular sample. There may be up to a 5° error in measuring the angle between the c-axis and the presumed PDF using a u-stage, so the PDF cannot be identified with certainty. On the other hand, if there are two orientations of PDFs, then the angle between them and their angle with the c-axis usually allows one to index the PDF(s).

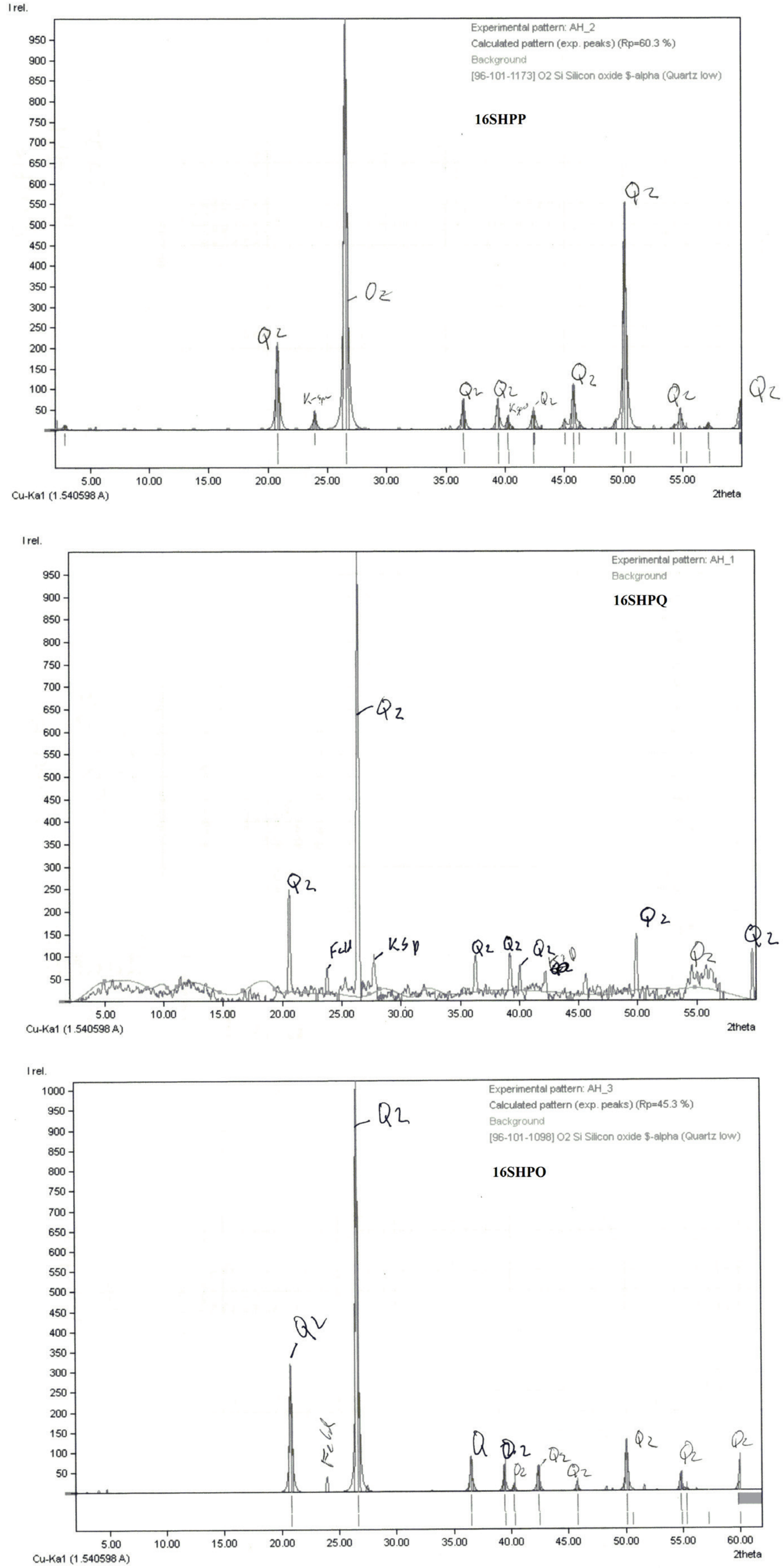
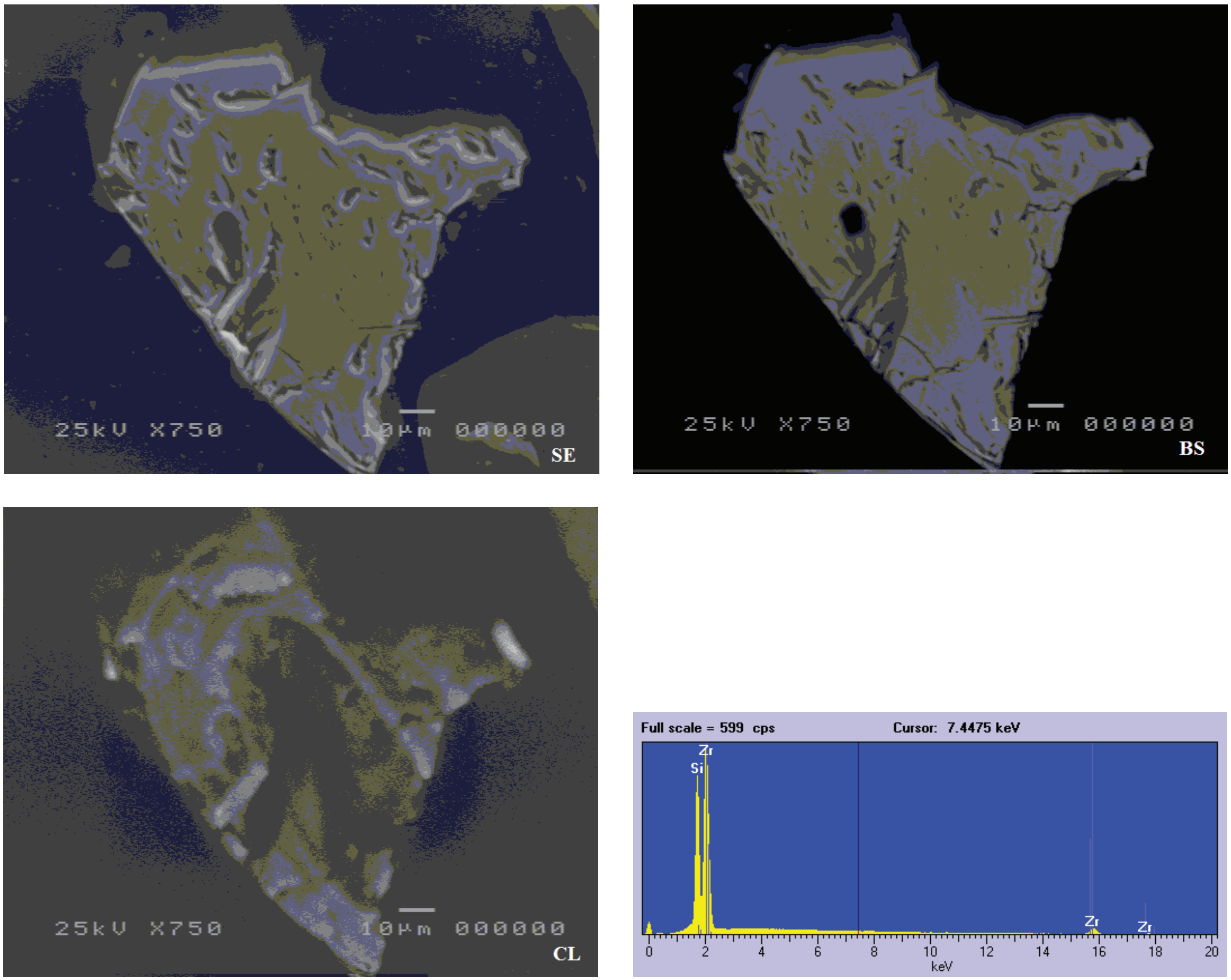


Figure 3: X-ray Diffraction patterns of samples from center of the Brushy Creek Feature. The pattern at the top of the page is from sample 16SHPP; the middle pattern is from sample 16SHPQ and the bottom pattern is from sample 16SHPO.

Results:

XRD powder patterns are shown for 16SHPP, 16SHPQ and 16SHPO are shown in figure 3. Almost all peaks can be matched to the peaks of quartz and K-feldspar. The diffraction patterns between 28° and 31° are flat.

Zircons were relatively easy to find in 16SHPC-2CM and 16SHPA-F1 compared to 16SHPQ-1S. In slides 16SHPC-2 CM and 16SHPA-F1, zircons show little evidence of fracturing and cathodoluminescence shows evidence of zoning due to crystal growth (Figure 4a).



4a: SEM pictures of zircon 3 in slide 16SHPA-F1. The scale bar is 10 microns. The letters to the right side of image is the type of image. The first image is produced from secondary electrons (SE); going clockwise, the second image is produced by backscattered electrons (BS). The blue image is the energy dispersive spectra, the energies of x-rays emitted from the zircon; the third image is the cathodoluminescence picture (CL). The dark and light zoning in the CL image is compositional layering formed during crystal growth.

The zircon found 16SHPQ-1S shows irregular fracture and is not very luminescent (Figure 4b). None of the SEM images suggested the presence of PDFs or the high-pressure polymorph of zircon, reidite.

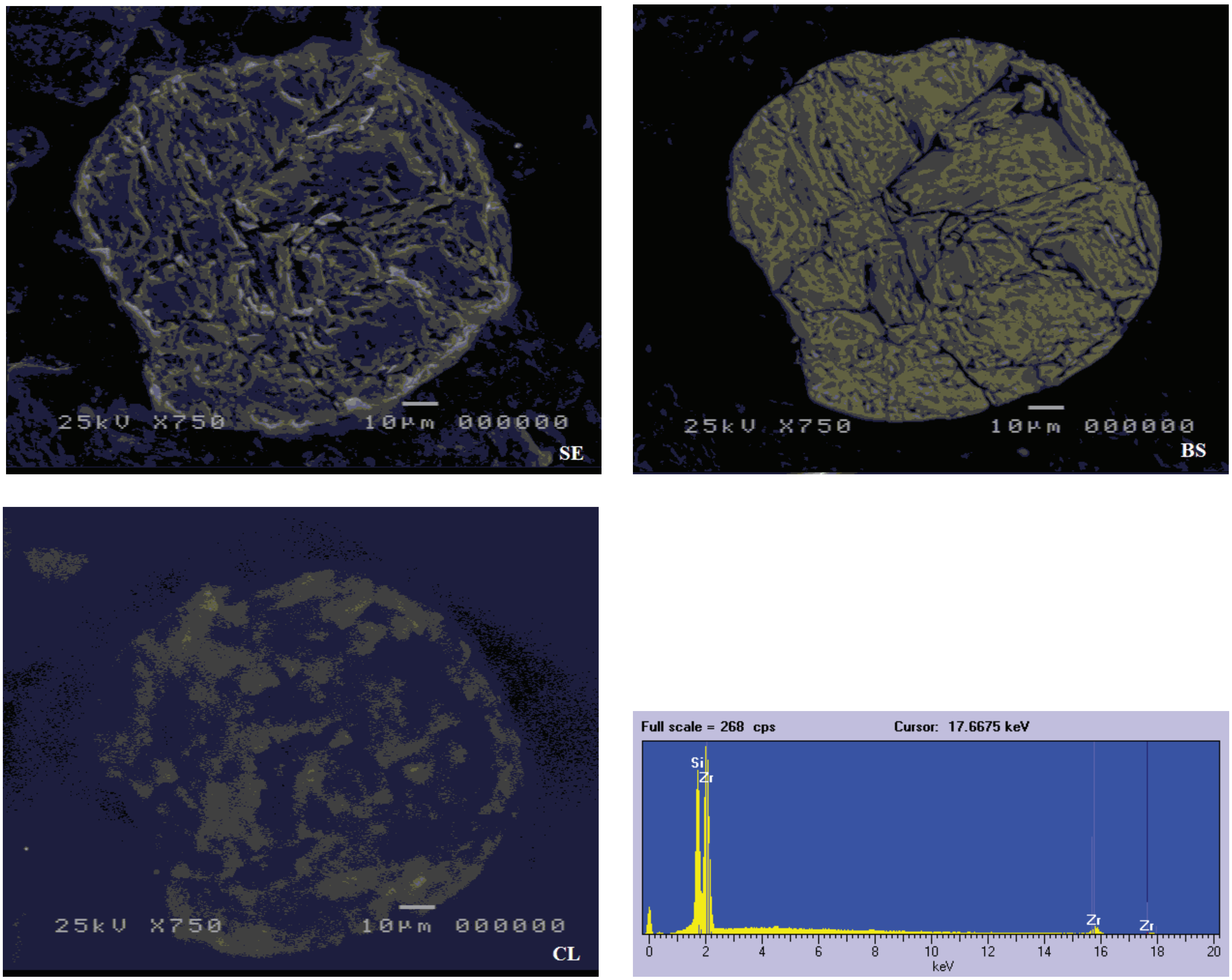


Figure 4b: SEM pictures of zircon 3 in slide 16SHPQ-1S. The scale bar is 10 microns. The letters to the right side of image is the type of image. The first image is produced from secondary electrons (SE); going clockwise, the second image is produced by backscattered electrons (BS). The blue image is the energy dispersive spectra, the energies of x-rays emitted from the zircon; the third image is the cathodoluminescence picture (CL). All images show that the zircon is highly fractured.

Table 1 gives the grains of quartz with likely PDFs based on morphology and orientation of the PDF with respect to the crystallographic c-axis for slide 16SHPA-F1. The grain with a photo identification of 119 has two measurable sets of PDFs with Miller Indices of $\{10\bar{1}2\}$. Three grains have c-axes to PDF angles consistent with $\{10\bar{1}2\}$ and one grain has angles consistent with a PDF of $\{10\bar{1}1\}$.

Table 1: Slide 16SHPA-F1

Photo Id Number	Angle between PDF and c-axis (o)	Miller Index of plane
113	52	$\{10\bar{1}1\}$
115	30	$\{10\bar{1}2\}$
118	35	{1012}
118	34	$\{10\bar{1}2\}$
121	36	$\{10\bar{1}2\}$

Discussion:

The absence of any peaks for 20' between 28° and 36° argues against the presence of significant amounts of coesite or stishovite. Coesite and stishovite may be present, but their concentrations are less than a few percent. Laser micro-Raman spectroscopy (e. g., Jackson et al., 2016) allows one to identify these high pressure polymorphs of quartz as small as 1 µm in diameter. Micro-Raman might be used in a future study.

The high density of irregular fracturing such as observed in sample 16SHPQ-1S is consistent with meteorite impact, but not proof (Gucsik et al., 2002). With additional thin sections, more probable PDFs would be found, but not in sufficient quantity to argue effectively for an impact origin of the Brushy Creek feature. The low number of shocked quartz grains raises the possibility that they are detrital and transported in from elsewhere. One observation that supports this hypothesis is that of the probable shocked grains found by Benoist in 16SHPC from the fractured Citronelle Formation along the rim of the structure. Except in the ejecta blanket, the rim is not where one expects to find shocked quartz. The indices of the grains $\{10\underline{1}2\}$, $\{10\underline{1}3\}$ and $\{10\underline{2}1\}$ are consistent with strong shock (Stöfller and Langenhorst, 1994). The orange-brown to greyish-red brown color of some of these grains is consistent with toasting (Ferrière and Osinski, 2013), another feature of strong shock. One would expect to find strong shock in the center of an impact crater.

Drilling and taking a core would allow one to test definitively the meteorite impact hypothesis, but would be expensive. Geophysical methods generally do not provide a unique interpretation of the data. An analysis of zircon grains from Brushy Creek stream sediments outside the Brushy Creek feature would provide the best test of the impact hypothesis.

This is a project which an LSU graduate student could do. Zircon is one of the most resistant minerals to both chemical and physical weathering and because zircons can be radiometrically dated, its provenance can sometimes be determined. Prado et al., (2011) were able to identify shocked zircon in a Pleistocene fluvial terrace deposits and link it with the Vredefort impact crater over 750 km away (They also found shocked quartz and monazite in the same sediments). The results in this open-file report suggest that shocked zircons are not abundant. Thus, about half dozen samples a few kilograms each would need to be taken from along Brushy Creek and the zircons separated using the procedure described earlier.

Assuming the electron microprobe at LSU still has a cathodoluminescence spectrometer, one should be able to identify likely shocked grains for further study (Erickson et al., 2013). The probable shocked zircons could then be mounted and examined using an SEM with an electron-backscattered detector (EBSD) to confirm impact origin and look for possible datable material, granular zircons or zircon neoblasts (Cavosie et al., 2016; Kenny et al., 2017). Suitable grains could then be dated using an ion microprobe. Shocked zircons in distal ejecta sites in Spain and Italy from the Cretaceous-Paleocene boundary give peak ages of 66 and 550 Ma (Kamo et al., 2011). If the shocked zircons from Brushy Creek fall into these two age ranges, then the zircons are derived from Chicxulub. If ages are <2.0 Ma, then Brushy Creek is an impact crater.

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References:

Cavosie, A. J., Timms, N. E., Erickson, T. M., Hagerty, J. J., and Hörz, F., 2016, Transformation of granular zircon related: Twinning, reidite, and ZrO_2 in shocked zircon from Meteorite Crater (Arizona, USA). Geology, 44:703-706. doi: 10.1130/G380431

Erickson, T. E., Cavosie, A. J., Moser, D. E., Barker, I. R., and Radovon, H. A., 2013, Correlating planar microstructures in shocked zircon from the Vredefort Dome at multiple scales: Crystallographic modeling, external and internal imaging and EBSD structural analysis. American Mineralogist, 98:53-65. doi: 10.2138/am.2013.4165

Ferrière, L. and Osinski, G. R., 2013, Shock metamorphism. *In*: G. R. Osinski and E. Pierazzo (eds.), Impact Cratering: Processes and Products. Blackwell LTD, London, p. 106-124.

French, B. M., 1998, Traces of Catastrophe: A Handbook of Shock-Metamorphic Effects in Terrestrial Meteorite Impact Structures. LPI Contribution No. 954, Lunar and Planetary Institute, Houston, TX, 120 pp.

Greive, R. A. F., Langenhorst, F., and Stöffler, D., 1996, Shock metamorphism of quartz in nature and experiment: II significance in geoscience. Meteoritics and Planetary Science, 31:6-35.

Gucsik, A., Koeberl, C., Brandstäter, F., Reimold, W. U., and Libowitzky, E., 2002, Cathodoluminescence, electron microscopy and spectroscopy of experimentally shock-metamorphosed zircon. Earth and Planetary Science Letters, 202:495-509.

Heinrich, P V., 2003, Origin of a circular depression and associated fractured and shocked quartz, St. Helena Parish, LA. Gulf Coast Association of Geological Societies, 53:313-322.

Holsapple, K. A., 2003, Theory and equations for "Craters from Impacts and Explosions". https://www.lpi.usra.edu/lunar/tools/lunarcratercalc/theory.pdf

Jackson, J. C., Horton, J. W., Jr., Chou, I.-M., and Belkin, H. E. 2016, Coesite in suevites from the Chesapeake Bay impact structure. Meteoritics and Planetary Science, 1-20. doi: 10.1111/maps.12638

Kamo, S. L., Lana, C. and Morgan, J. V., 2011, U-Pb ages of shocked zircon grains linked to K-Pg boundary sites in Spain and Italy with the Chicxulub impact. Earth and Planetary Science Letters, 310:401-408. doi: 10.1016/epsl.2011.08.031

Kenny, G. G., Morales, L. F., Whitehouse, M. J., Petrus, J. A., and Kamber, B. S., 2017, The formation of large neoblasts in shocked zircon and their utility in dating impacts. Geology, 45:1003-1006. doi: 10.1130/G39328.1

Prado, D. C., Cavosie, A. J., Gibbon, R. J., Radovan, H. A., Moser,, D. E. and Wooden, J., 2011, Geochronology of detrital shocked zircons in a Pleistocene (CA. 1.6 Ma) fluvial deposit 500 km downriver from the Vredefort Dome South Africa. 42nd Lunar and Planetary Science Conference, Abst. #2247.

Stöffler, D., and Langenhorst, F., 1994, Shock metamorphism of quartz in nature and experiment: I basic observation and theory. Meteoritics, 29:155-181.

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