INTERDISCIPLINARY INVESTIGATIONS INTO THE CHICXULUB CRATER IMPACT INDUCED HYDROTHERMAL SYSTEM. S.P.S. Gulick[1,2,3], N. McCall[1,2,3,4], C. Ross[1,2,3], D. Stockli[2], C. Rasmussen[1,3], G.L. Christeson[1,5], M. Hesse[2,3], S.M. Tikoo-Schantz[6] and T. Vanorio[6]. [1]Institute for Geophysics, Jackson School of Geoscience, University of Texas at Austin, 10100 Burnet Rd Bldg ROC, Austin, TX 78758 USA; sean@ig.utexas.edu, [2]Department of Geological Sciences, Jackson School of Geosciences, University of Texas at Austin, Austin, TX 78712 USA, [3]Center for Planetary Systems Habitability, University of Texas at Austin, Austin, TX 78712 USA, , [4]NASA Goddard Spaceflight Center, Greenbelt MD, 20771 USA, [5]National Science Foundation, Alexandria, VA 22314 USA, [6]Department of Geophysics, School of Earth, Energy, and Environmental Sciences, Stanford University, Stanford, CA 94305 USA

Résumé: Nous présentons ici un résumé des observations portant sur la durée de vie du système hydrothermal induit par l'impact de Chicxulub initié il y a 66 millions d'années (limite Crétacé-Paléogène). Les résultats géo- et thermo-chronométriques donnent certains âges inférieurs à 66 Ma pour le zircon et l'apatite U-Th/He et les feldspaths authigènes. Les données sismiques permettent de cartographier les impactites du pointement circulaire à la dépression centrale où des structures diapiriques semblent s'être développées au sein de la suévite stratifiée et avoir perturbé les couches dans l'Éocène. Les perméabilités de ces suévites sont étonnamment faibles (microdarcies) malgré une porosité allant jusqu'à 30 %, ce qui peut avoir réduit l'échange entre l'eau de mer sus-jacente plus froide et les impactites qui ont hébergé le système hydrothermal, en particulier lorsqu'elles ont été recouvertes ultérieurement par des calcaires à faible porosité. De telles inversions de densité combinées à une activité hydrothermale continue peuvent avoir généré des instabilités créant les structures diapiriques observées des millions d'années après l'impact. Les conclusions préliminaires sont qu'un système hydrothermal actif de longue durée (> 11 Ma) était présent à Chicxulub qui a pu permettre le développement d'un écosystème thermophile.

Introduction: Extraterrestrial impacts can generate hydrothermal systems due to the delivery of extreme kinetic energy to the target rock and the mobilization of fluids in the newly formed impact structure [1]. Fluid flow within such hydrothermal systems may be enhanced by shock processes greatly increasing the porosity, and thus potentially the permeability, of the target rock [e.g., 2]. However, impactite stratigraphy and deformation during the crater modification stage may partition, channelize, or impede such flow affecting timescales of cooling.

Impact hydrothermal systems can host an ecosystem conducive to thermophilic life as demonstrated at both the Chesapeake Bay impact structure, USA, and the 200 km diameter, 66 million year old Chicxulub impact structure, México. In both craters, modern cell counts show a greater number of active cells within impact materials versus the overlying geology [3,4]. At Chicxulub, DNA was isolated from the samples within the suevite and thermophilic bacteria were cultured demonstrating a living thermophilic ecosystem, if significantly reduced from what likely existed 66 Ma [4].

Interdisciplinary Observations: Our NASA funded collaborative team at the University of Texas at Austin and Stanford University has been investigating the Chicxulub impactites and uplifted granitoids of the peak ring for thermal history, permeability, structure and stratigraphy, and paleomagnetic properties. Additional work is ongoing on the petrology of hydrothermally altered materials by colleagues at Lunar and Planetary Institute and University of Arizona.

Here we discuss preliminary observations of the thermal history of the peak ring as it pertains to potential duration of the hydrothermal system, permeability of impact materials, structure and stratigraphy of the impact crater, and future work planned to model and better image the hydrothermally altered impact basin.

International Ocean Discovery Program-International Continental Scientific Drilling Program Site M0077 drilled into the peak ring of Chicxulub providing samples from the granitoid peak ring and overlying melt rock, unsorted suevite, and sorted suevite. These samples have been investigated for their thermochronology and physical properties [5,6] including permeability.

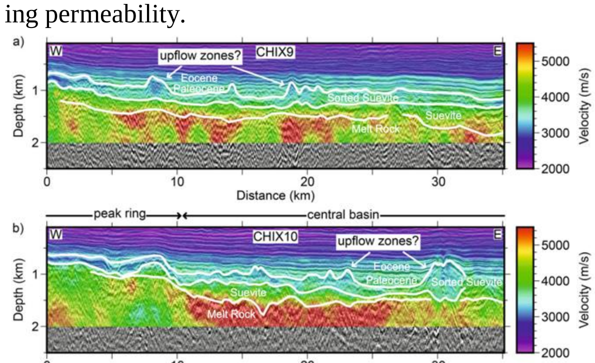

Figure 1. Full waveform inversion (FWI) velocity model overlain on depth converted seismic image for seismic lines CHIX9 (a) and CHIX10 (b). Eocene Paleocene labels are consistent with mapping of the

drilled section at Site IODP Site M0077 as are the impactite sequences- sorted suevite, suevite, and melt rock. Potential diapiric or upflow zones are labeled. Modified from [7].

Full waveform seismic velocity analysis [7] shows a clear relationship between these drilled units and the velocity structure of the infilled crater materials with highest velocity melt rock adjacent to lower velocity granitoid peak ring. The sorted suevite that drapes all units of impactites forms a distinctly lower velocity layer but also exhibits upflow zones or diapiric structures (Figure 1). Mapping the stratigraphy from Site M0077 to the central basin where these zones are present shows the Paleocene section and some of the Eocene section are disturbed or pinch out against these zones.

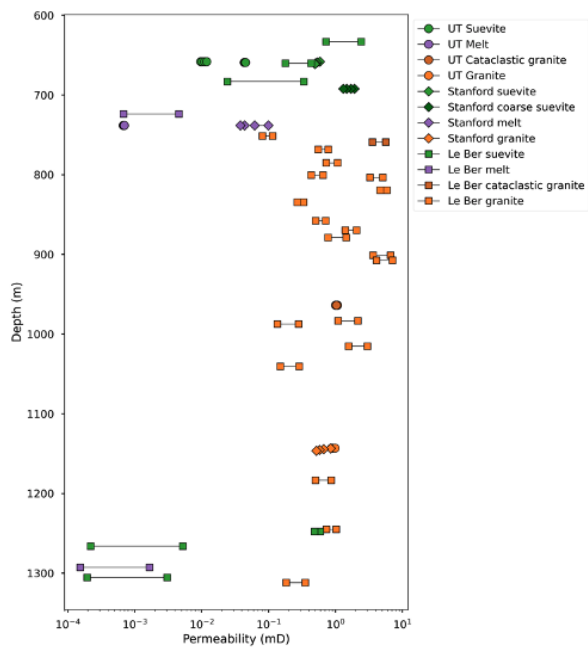

Figure 2. Permeability measurements from UT Austin, Stanford and Montpelier Universities (Le Ber [8]) shown according to depth.

Core plugs from sorted suevite, suevite, melt rock, cataclastically deformed granite and macroscopically intact granite were measured for permeability. All samples were micro-CT scanned before and after permeability testing; permeability was measured both by using a steady-state liquid permeameter at UT Austin and by using a helium gas pulse decay method at Stanford. Granitoid samples with porosities >10% exhibited millidarcy permeabilities whereas the sorted suevite exhibited microdarcy permeabilities despite having porosities up to 30% [6,8] with melt rock exhibiting the lowest values (Figure 2). Ongoing work will examine the effects of different fluids and drying procedures in the permeability measurements, and use these values and impact stratigraphy in a COMSOL hydrologic model to examine the post-impact hydrothermal system dynamics.

Geo- and thermos-chronology of the peak ring granitoids at IODP Site M0077 have yielded a number of surprising insights including a dominantly Carboniferous age (zircon U-Pb) of the peak ring granitoids implying emplacement as a subduction related volcanic arc [5], Jurassic dolerite dikes emplaced during the opening of the Gulf of Mexico (apatite U-Pb) [9,10], the Cretaceous-Paleogene impact age preserved in shocked and metamict zircons (U-Pb and (U-Th)/He) [11] and Paleocene to early Eocene ages from U-Th/He. These results suggest that the granitoids were above the closure temperature, >180-200 °C, for several million years post-impact. Similarly Ar/Ar ages on authigenic feldspars produced Paleogene ages (up to 7 Myr post-impact) [12].

Preliminary Conclusions: Multiple lines of evidence suggest an impact-generated hydrothermal system was present at the Chicxulub crater for >11 million years post-impact. The low permeability of the sorted suevite may have reduced exchange with overlying, cooler seawater especially when later buried by low-porosity limestones. Such density inversions combined with continued hydrothermal activity may have generated instabilities creating the seismically observed diapiric structures that appear to have occurred into the Eocene. This long-lived active hydrothermal system at Chicxulub could have supported the thermophilic ecosystem evidenced by the finding of extant thermophilic bacteric in the IODP Site M0077 cores [4].

References:

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