TESTING A MODEL OF IMPACT-GENERATED HYDROTHERMAL SYSTEMS WITH IODP-ICDP EXPEDITION 364 TO THE CHICXULUB IMPACT CRATER.

D. A. Kring[1,2], M. Schmieder[1,2], U. Riller[3], S. L. Simpson[4], G. R. Osinski[4], C. Cockell[5], J. L. Coolen[6], and the Expedition 364 Science Party, [1]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058 (kring@lpi.usra.edu), [2]NASA Solar System Exploration Research Virtual Institute, [3]Institut für Geologie, Universität Hamburg, Hamburg 20146 Germany, [4]Centre for Planetary Science and Exploration, Universty of Western Ontario, London ON Canada, [5]School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD UK, [6]Dept. Chemistry, Curtin University, Bentley WA 6102 Australia.

Introduction: As we continue to explore the environmental and biological implications of impact cratering, a growing amount of attention is directed at subsurface domains. Impact heating and a cratering process that liberally generates a porous permeable structure is an ideal host for a hydrothermal system. Alteration in the Chicxulub crater was previously detected within core samples from the Yucatán-6 [1] and Yaxcopoil-1 (Yax-1) [2-6] boreholes located between the peak ring and crater rim. A thermal model of that system [7] suggested it generated high temperatures within the peak ring and was active for 1.5 to 2.3 Myr. To further evaluate the Chicxulub system, a new borehole was drilled at offshore site M0077A by the International Ocean Discovery Program (IODP) and International Continental Scientific Drilling Program (ICDP) [8]. The project recovered impactites from a depth of 617 to 1335 mbsf, consisting of 130 m of impact melt rock and suevite overlying granitoids with impact-generated horizons of melt rock and suevite that were emplaced [9] during upward and outward displacement of the peak ring [8].

Hydrothermal Alteration: Calcium-Na and K-metasomatism is evident along the entire core. In impact melt rock at a depth of 717 mbsf, a matrix of <10 μm-long laths of feldspar and rare Ca-pyroxene is overprinted with alkali feldspar alteration fronts and cross-cut by fractures with margins enriched in Ca-plagioclase. Relict quartz from the target entrained in the melt has been partially to wholly dissolved, implying a hot Si-undersaturated fluid, and the resulting void space filled with secondary calcite. A K-feldspar and albite vein cuts through the peak ring granite at 887 mbsf. Deeper within the peak ring (1256 mbsf), the granite is honeycombed with quartz dissolution cavities that may be a consequence of that metasomatism at temperatures of 300 to 400 ºC. Related dissolution of quartz along planar fractures and silica glass along planar deformation features enhanced system porosity. Secondary muscovite cross-cuts shock-metamorphic kinking of feldspar and is probably of post-impact hydrothermal origin at temperature in excess of 350 ºC. As the system cooled, Mg-Fe and Na-K sheet silicates precipitated. Melt fragments in the suevite are, for example, altered to saponite and montomorillonite-like smectite-group minerals with significant chemcal zoning and variable nH2O. Ti-rich biotite is being replaced by chlorite and epidote is present. The granite is cross-cut by seveal types of veins consisting of quartz; muscovite; a mafic aluminosilicate; calcite with sphene and galena; and Ti-oxide with zircon and calcite. Lower temperature fillings of vugs and open cavities followed, producing surfaces covered with analcime, dachiardite, and other secondary minerals.

Conclusions: The initial high temperatures implied by the alteration sequence are consistent with peak ring hydrothermal temperatures in the evolutionary model of [7]. Those high temperatures imply the system was long lived as calculated in the model of [7]. The initially high temperatures would have sterilized local regions within the peak ring sequence. As the system cooled, it could have supported hyperthermophilic and thermophilic microorganisms. We are still assessing potential energy sources, but sulfide framboids in several open fractures and veins with relatively low-temperature mineral assemblages of dachiardite and analcime suggest sulfate reduction was a possible energy source. If the model of [7] is correct, as suggested by our observations thus far, then conditions for hyperthermophilic and thermophilic life may have existed in this part of the peak ring for 10^4 to 10^5 years.

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