AGES AND GEOCHEMISTRY OF THE BASEMENT GRANITES OF THE CHICXULUB IMPACT CRATER: IMPLICATIONS FOR PEAK RING FORMATION.

L. Xiao[*1,2], J.W. Zhao[1], H.S. Liu[1], Z.Y. Xiao[1], J. Morgan[3], S. Gulick[4], D. Kring[5], P. Claeys[6], U. Riller[7], and the Expedition 364 Scientists. [1]Planetary Science Institute, China University of Geosciences, Wuhan, 430074, P. R. China, [2]Space Science Institute, Macau University of Science and Technology, Avenida Wai Long, Taipa, Macau, China (longxiao@cug.edu.cn). [3] Department of Earth Science and Engineering, Imperial College London, SW7 2AZ, UK. [4]Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin, TX 78758-4445,USA. [5]Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston, TX 77058, USA, [6] Analytical, Environmental and Geo-Chemistry, Vrije Universiteit Brussel, Pleinlaan 2, Brussels 1050, Belgium. [7]Institut für Geologie, Universität Hamburg, Bundesstrasse 55, Hamburg, 20146, Germany.

Introduction: The IODP-ICDP Expedition 364 has succefully drilled the peak ring of the Chicxulub impact crater and recovered 829m of core [1]. The expedition found that the the peak ring of this crater was formed of basement granite, supporting the dynamic collapse model [2-3]. However, the peak-ring basement granite does not resemble basement clasts in breccias inside and outside the crater.

If the granite is a new geological unit, it provides an opportunity to study the target basement, better understand the formation mechanism of the crater, reveal the petrogenesis of the granite, and shed light on the tectonic development of the Yucatán Peninsula of Mexico.

In this study, we conducted zircon U-Pb geochronological and whole rock geochemical studies of the peak-ring granites, and discuss their implications for impact processes and pre-impact tectonic setting.

Sample and methods: All granite cores were described in Bremen University by the Expedition 364 scientists. In addition to visual core descriptions and chemical analyses in Bremen, this study made petrographic observations of all requested samples. Zircon was separated from five core pieces and dated using LA-ICP-MS. Ten cores from about every 40 meter interval were selected for geochemical analysis, including major elements (XRF) at the China University of Geosciences (CUG-Wuhan).

Results: *Petrography:* The granite commonly shows coarse grain size textural and compositional variation over a few 10's of centimeters. The granitic rocks are intruded by three or more types of sub-volcanic dikes or dike swarms including felsite/phonotephrite, dacite/trachyite and diabase/dolerite. Major rock-forming minerals of the granitoid are alkali feldspar (~25-40%), plagioclase (~25-35%), quartz (~25-35%) and biotite (~1-5%). Accessory minerals observed in thin section include zircon, apatite, sphene, and opaques. Shock metamorphism is extensive throughout the core; planar deformation features developed in quartz and plagioclase at mineral scale.

Age: Five samples taken from depths of 829mbsf (Sample No. IBCR0364EXXG501), 927mbsf (IBCR0364EX67601), 979mbsf (IBCR0364EX4I601), 1076mbsf (IBCR0364EXD2701) and 1200 mbsf (IBCR0364EXNS701) were dated. Their $^{206}Pb/^{238}U$ ages with concorde degree higher than 90% are 304+10Ma (MSWD=2.8, n=10), 321+7.7Ma (MSWD=0.68 N=5), 313+14Ma (MSWD=1.7, n=13), 325.9+7.5Ma (MSWD = 0.69, n=5) and 340.8+9.9 Ma (MSWD=1.8, n=15) (Fig.1).

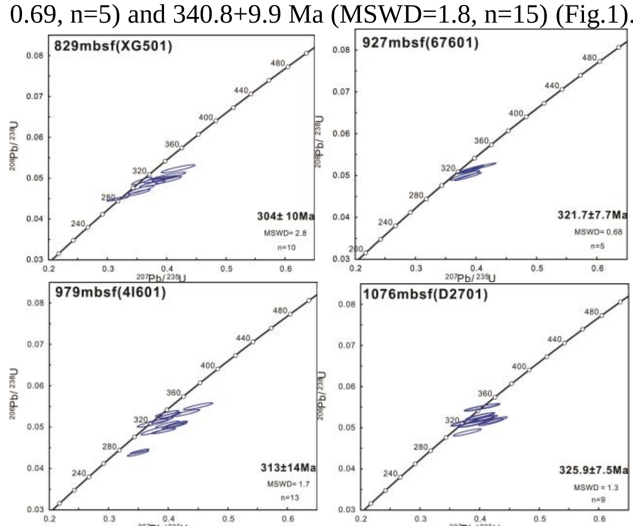

Figure 1. The concordia diagram of $^{206}Pb/^{238}U$ vs. $^{207}Pb/^{235}U$ of zircons from depths of 829mbsf, 927mbsf, 979mbsf and 1076mbsf of the IODP-ICDP Expedition 364 drill cores.

As an example, 24 single zircon grains from granite at a depth of 1200mbsf were dated and their concordia diagram of $^{206}Pb/^{238}U$ vs. $^{207}Pb/^{235}U$ is shown in Fig. 2.

The abundance and normalized patterns of rare earth elements (REE) of zircon are an indicator of their origin (Fig. 2). Total REE abundances vary from 4761 to 1325 ppm, in which light REE are 12 –to 249 ppm, and heavy REE are 463 to 1075 ppm, with LREE/HREE of 0.06 (average), showing remarkable enrichment of HREE and strong light-heavy REE fractionation. These samples also display strong Ce positive anomalies ($\delta Ce\__{average}$ = 31.95) and very weak negative Eu anomalies ($\delta Eu\__{average}$ = 0.62). This indicates they were formed under the conditions of high pressure magma chamber with little plagioclase crystallization/fractionation, and high oxygen fugacity. There is also a correlation between the LREE abundances and concordia ages. The less concordial age zircons have high LREE contents, and these zircon show more fractures (e.g., PFs). This phenomena was caused by common Pb loss and LREE enrichment that had been resulted from post impact fluid alteration along the fractures.

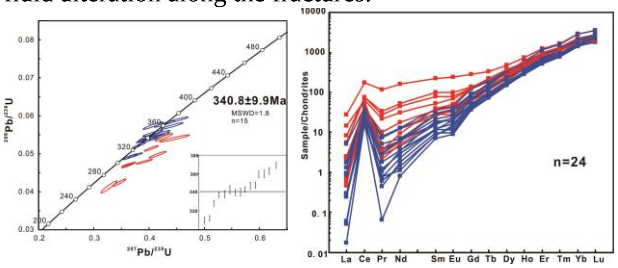

Figure 2. The concodial diagram of $^{206}Pb/^{238}U$ vs. $^{207}Pb/^{235}U$ of zircons (left) and Chondrite-nomalized REE patterns of all dated zircons (right), from peak-ring basement granite from the Chicxulub crater, at depth of 1200 mbsf (IBCR0364EXNS701).

Geochemistry: A total of 147 analyses at Bremen by the Science Party and 10 analyses at CUG-Wuhan yielded major element oxide contents for SiO_2 of 64wt% - 79wt% with average 71.5wt%, Al_2O_3 of 10-17wt% with average of 13wt%, Na_2O of 3.5wt% - 7wt% with average of 5wt%, and K_2O of 2wt% - 8wt% with average of 4.2wt%. In the TAS diagram, most samples plot within the granite field, while some are in the quartz monzonite and syenite field. These samples have very low Rb/Sr (<0.4) and Rb/Ba ratios (<0.2). A/CNK values are mostly lower than 0.8. All of these indicate that the granites have I-type affinities.

Disscusion and conclusion: Our zircon dating results suggest that the peak-ring granites were formed mostly around ~300-340 Ma ago. However, many zircons had been heavely shocked and fractured, and altered by later fluids, resulting in common Pb loss and low concorde degree in the $^{206}Pb/^{238}U$ vs. $^{207}Pb/^{235}U$ concordia diagram. The ages listed above are a few of the ones with high concorde degrees. The large age variation of the five samples may indicate that this was not a single granitic intrusion, but it was a intrusive complex composed of multiple episodes (lasting over 20 Ma long) during the Carboniferous era.

Granites with these ages were seldom seen previously in dated basement clasts [4, 5] and outcrops in the Yucatán Penisula [6]. Plutonic outcrops from the Maya orogen formed in the Late Silurian (>400 Ma [7]). Samples from Deep Sea Drilling Project (Leg 77) in the southeastern Gulf of Mexico suggest the basement amphibolite and gneiss are older than 500 Ma and that they were intruded by ~160-190 Ma diabase dikes [8]. The only comparable zircon found in distal ejecta are from Saskatchewan and Colorado [4, 9], where three zircon grains yielded ages of 360±26Ma, 320±31Ma [4], and ~330Ma [9]. One zircon grain within an impact breccia with the age of 345Ma was found in northern Maya block [10].

The geochemical characteristics of these early Carboniferous granites show a volcanic arc or syn-collisional tectonic setting in Rb vs. Y+Nb and Nb vs. Y in tectonic discrimination diagrams (Pearce et al., 1984). While, the Maya Block is dominated by a pan-African assembly age of about 500 Ma, it was intruded by several younger plutons, the time span of alssembly and collision might have lasted longer than previously thought. Those young plutons may have been small in dimensions relative to the size of the Chicxulub excavation cavity or the granite in our core may have been at the margin of that excavation cavity. In either case, it might not be an abundant component in excavated clasts that were deposited in breccias.

If the peak-ring formation model (e.g., dynamic collapse model) is correct, this fact could be a result of the original lithological sequence. The excavation depth is about 10-12 km, and there was a 2-3km thick layer of Cretaceous carbonates at surface [11-12]. We infer that the basement granite was originally located just below or adjacent to the excavation cavity and only a little of this compressed rock was excavated and ejected. Then, post-compression lifting and collapsing resulted in the emplacement of the granite and formed the peak ring.

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