THE 4[TH] GEOLOGICAL CONFERENCE OF THE GEOLOGICAL SOCIETY OF TRINIDAD AND TOBAGO

June 17-22, 2007, Hilton Trinidad & Conference Centre, Port-of-Spain, Trinidad and Tobago

"Caribbean Exploration – Planning for the Future"

ABSTRACT

LATE EOCENE IMPACT EJECTA: THE NORTH AMERICAN TEKTITE STREWN FIELD AND ITS SOURCEE, THE CHESAPEAKE BAY IMPACT STRUCTURE: UPDATE ON THE ICDP-US GS DEEP DRILLING PROJECTS

Christian Koeberl[1], W. Uwe Reimold[2], Gregory S. Gohn[3], Kenneth G. Miller[4]. *[1]Center of Earth Sciences, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria (christian.koeberl@univie.ac.at); [2]Museum of Natural History, Humboldt-University, Invalidenstrasse 43, D-10115 Berlin, Germany (uwe.reimold@museum.hu-berlin.de); [3]U.S. Geological Survey, Reston, VA 20192, USA (ggohn@usgs.gov); [4]Rutgers University, Department of Geological Sciences, Piscataway, NJ 08854, USA (kgm@rci.rutgers.edu).*

Late Eocene Impacts and the North American Tektite Strewn Field. Upper Eocene marine sediments around the world contain evidence for at least two closely spaced impactoclastic layers – i.e., layers containing impact debris, such as tektites and microtektites and shocked minerals and rock fragments (for references see e.g., Montanari and Koeberl [1]). Initially, it was thought that there is only one layer known from the eastern U.S. coast, the Caribbean, and the Gulf of Mexico, which is correlated with the North American tektite strewn field. This layer contains microtektites (i.e., glassy, not recrystallized spherules), shocked minerals, and high-pressure phases (e.g., coesite), but no marked siderophile element anomaly. The presence of crystalline spherules composed mostly of clinopyroxene (cpx) was detected in the same deep sea sediments and initially it was considered that these spherules also belong to the North American tektite strewn field. The cpx spherules were found not only in the Caribbean and the Gulf of Mexico but also in the Pacific Ocean.

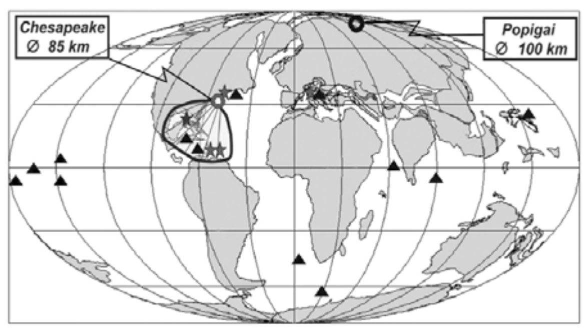

Fig. 1. The two large late Eocene impact craters (Chesapeake Bay and Popigai) and location of coeval impact ejecta deposits. The North American tektite strewn field is also outlined (from [2]).

Impact-produced, crystallite-bearing spherules are called "microkrystites". More detailed work showed that the microtektite layer and the microkrystite (cpx) layer (both in middle to lower magnetic chron C15) are in fact separated from each other by about 25 cm, with the cpx layer being the lower (i.e., older) one. The separation between the two layers amounts to about 10 to 20 k.y. Microtektites and tektite fragments at DSDP Site 612 show chemical and isotopic similarities with other North American tektites (e.g., [1, 2]). The microkrystite layer has now been found at numerous other locations, indicating that it has a more or less global distribution, and it seems to be associated at several locations with enhanced Ir abundances. Impact ejecta interpreted to be part of the cpx layer also have been found in rocks from the marine Umbria-Marche succession in Italy at the Global Stratotype Section and Point for the Eocene-Oligocene boundary at Massignano near Ancona. At this location two impactoclastic layers – the other possibly related to Chesapeake Bay – are present.

As mentioned above, the source of the North American tektite strewn field has now been linked, with a certain degree of confidence, to the Chesapeake Bay impact structure [3]. An impact event that created a crater of this size would be capable of globally distributing its distal ejecta (e.g., [1]). There is a second large crater with an age indistinguishable from that of the Chesapeake Bay structure and the two ejecta layers, namely the 100-km-diameter Popigai impact structure in Siberia, which has been dated at 35.7±0.8 Ma. The Popigai structure is exposed in Archean crystalline rocks of the Anabar Shield, with overlying Proterozoic to Mesozoic sedimentary sequences (e.g., [1, 3]), and is the largest Cenozoic crater on Earth. It is now commonly assumed that the global upper Eocene microkrystite layer originated from the Popigai impact event, but this link has yet to be confirmed, probably by using isotope geochemical methods, because radiometric age determinations do not allow to resolve an age difference of 10 or 20 k.y. It is also interesting to note that much enhanced levels of ^{3}He were found to coincide with the two upper Eocene impactoclastic layers. This isotope is a proxy for the influx of extraterrestrial dust and is interpreted as indicating that, during the late Eocene, there was a time of enhanced comet activity in the inner solar system, probably resulting in a higher impact rate than usual. There are numerous questions associated with the link between the Chesapeake Bay crater and the North American tektites.

Chesapeake Bay impact structure: The late Eocene Chesapeake Bay impact structure is among the largest and best preserved of the known impact craters on Earth [3]. It has a diameter of 85 km (Fig. 2) with what has been called an “inverted sombrero”-.shape cross section. The crystalline basement beneath the impact structure, and beneath the Mid-Atlantic Coastal Plain in general, is one of the most poorly understood geologic provinces in the United States. Granite is the only basement rock type encountered by the five boreholes that reached pre-Cretaceous rocks below the impact structure [3]). Clasts of basement rock found as reworked ejecta within the impact structure consist primarily of cataclastic granites and porphyritic felsites.

Atlantic Coastal Plain sediments overlie this basement and constitute a seaward-thickening wedge of dominantly unconsolidated to poorly consolidated siliciclastic sands, silts, and clays of marine and nonmarine origin. This succession was deposited between the Early Cretaceous and the Holocene Chesapeake Bay is distinctive among impact craters on Earth because it is a relatively young and well-preserved structure, which is the source of the North American tektites – one of only 4 known tektite strewn fields on Earth. The Chesapeake Bay structure is unique among subaerial and submarine impact craters on Earth because: (1) it is a relatively young structure and, in comparison to other known impact structures of such size, very well-preserved; (2) its location on a passive continental margin has prevented tectonic or orogenic disruption or distortion that is typical of many large terrestrial craters; (3) its original location on a relatively deep continental shelf allowed marine deposition to resume immediately following the impact, which buried it rapidly and completely, thereby preventing subsequent erosion; (4) the upper part of the breccia section inside the crater was derived from resurge currents and impact-generated tsunami waves; (5) the breccia body contains a large volume of impact-generated brine; (6) the crater underlies a densely populated urban corridor, whose two million citizens are still affected by crater-related phenomena, such as freshwater availability. Previous studies have raised many questions that can only be answered by a deep drilling project. The ICDP drilling project also included a deep biosphere research opportunity.

Drilling: The International Continental Scientific Drilling Program (ICDP) and the U.S. Geological Survey (USGS) completed two deep coreholes to a composite depth of almost 1.8 km into the Chesapeake Bay impact structure during September-December 2005. Post-impact sediments were cored from land surface to a depth of 140 m in a third corehole during April and May 2006. Field operations began in July 2005 with site preparations at Eyreville Farm in Northampton County, Virginia; subsequently, three coreholes were drilled at the Eyreville site. Eyreville hole A was cored between depths of 125 m and 941 m from September through early October 2005. Problems with lost mud circulation and swelling clays in Eyreville A led to a lengthy period of reaming and ultimately to deviation of the bit from Eyreville A to a new hole, Eyreville B, at a depth of 738 m. Eyreville B was cored from that depth to a final depth of 1,766 m from October through early December 2005. Post-impact sediments were cored from land surface to a depth of 140 m in the Eyreville C hole during April and May 2006.

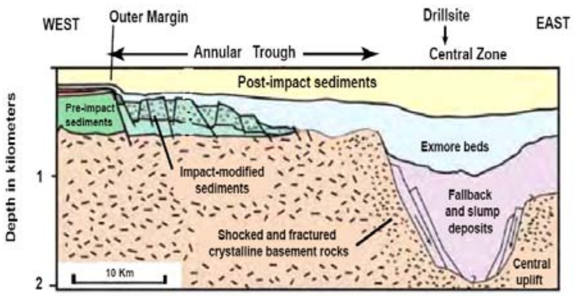

Fig. 2. Schematic cross section through half of the Chesapeake Bay impact structure, showing the deep central part of the crater (including the central uplift), and the location of the ICDP-USGS deep corehole (from [4]).

Drilling Results: A first report on the drilling was given at LPSC in 2006 [5]. The cored impactite section (Fig. 3) consists of five major lithologic units. The lowest unit consists of about 216 m of fractured mica schist and pegmatite with minor gneiss and several impact breccia veins. These rocks could represent the autochthonous crater floor or they could be parautochthonous basement blocks. Above these rocks follow about 157 m of suevitic and lithic impact breccias that are considered fallback and (or) ground-surge deposits.

Above these breccias, a thin interval of quartz sand (22 m) contains lithic clasts of varied size (cm to decimeters); it occurs below a 275-m-thick megablock of granitic rock, which appears unshocked and thus must have been transported tens of kilometers during the cratering process. The uppermost and thickest impactite unit consists of about 652 m of deformed sediment megablocks and overlying sedimentary breccia (Exmore beds – Fig. 2). The sedimentary breccia at the top of the impactite section contains clasts of target sediments and crystalline-rock ejecta and is interpreted to represent late-stage collapse of the marine water column and its catastrophic flow into the crater.

The post-impact sedimentary section consists of 444 m of upper Eocene to Pliocene marine sediments and Pleistocene paralic sediments. Preliminary studies indicate thick upper Eocene and middle Miocene to Pliocene successions and relatively thin lower Miocene and Oligocene sections.

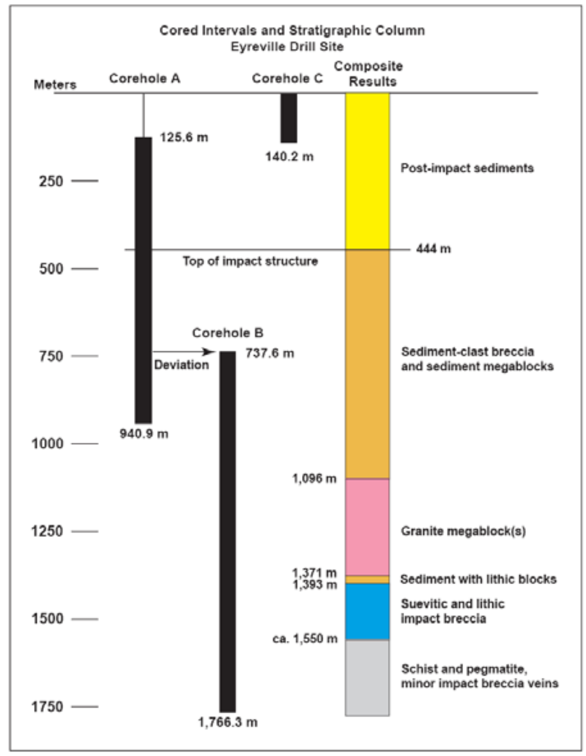

Fig. 3. Cored intervals and composite geological-lithostratigraphic cross-section of the Eyreville corehole (after [6]).

Sample Distribution and Recent Research: The research phase of the project began on March 19-22, 2006, with an international sampling party at the USGS National Center in Reston, USA. At that time, the cores from the Eyreville A and B coreholes were displayed for examination by the project science-team members. About thirty project scientists from eight countries attended the sampling party. Approximately 2,200 core samples identified at the sampling party in March 2006 (and several individual follow-on viewings) were cut and distributed to project scientists during March-July 2006. Including the samples taken at the drill site, a total of approximately 3,800 cores samples have been distributed for study.

The USGS acquired two 1.5-km-long, high-resolution seismic lines across the Eyreville drill-site in September 2006 using seisgun and small explosion sources. These surveys should produce reflection images to the depth reached by the corehole. In October 2006, Project scientists from USGS used a GeoTek scanner to record physical properties of representative core samples selected from all but the uppermost part of the core. The measured properties included: density, P-wave velocity, magnetic susceptibility, porosity, and electrical resistivity.

The success of this drilling project was a result of extensive pre-drilling planning for onsite core curation, persistence in reaching stated drilling goals, and the financial and operational contingencies to address the inevitable problems encountered during deep drilling. The detailed geochemical and petrographic studies on the Chesapeake Bay impactites will establish to evaluate the exact source rocks of the North American tektites.

Acknowledgements: Funding for the Chesapeake Bay impact crater deep corehole was provided by the ICDP, the USGS, and the NASA Science Mission Directorate. DOSECC, Inc., managed the drilling operations. Major Drilling America, Inc., did the core drilling. We thank the Buyrn family for permission to use Eyreville Farm as a drilling site and for their interest in the project. CK acknowledges funding from the Austrian Science Foundation FWF (grant P-P18862-N10).

References: [1] Montanari A. and Koeberl C., 2000. *Impact Stratigraphy*, Springer, Heidelberg. [2] Deutsch A. and Koeberl C. 2006, *Meteoritics Planet. Sci.* **41**, 689-703. [3] Poag, C.W., Koeberl, C., and Reimold, W.U., 2004. *Chesapeake Bay Crater: Geology and Geophysics of a Late Eocene Submarine Impact Structure.* Springer, 522 pp. [4] Gohn et al. 2006. *Scientific Drilling* No. 3, p. 34-37. [5] Gohn et al. 2006. Lunar Planet. Sci. 37, abs. No. 1713. [6] Gohn et al. 2006. *EOS, Trans. Am. Geophys. Un.* **87**, 349, 355.