

INVESTIGATIONS OF IMPACTITES AND CRYSTALLINE TARGET ROCKS IN THE ICDP-USGS EYREVILLE-B CORE, CHESAPEAKE BAY IMPACT STRUCTURE. J. W. Horton Jr.¹, M. J. Kunk¹, H. E. Belkin¹, J. N. Aleinikoff², J. C. Jackson¹, and I-M. Chou¹, ¹U. S. Geological Survey, 926A National Center, Reston, VA 20192 USA, whorton@usgs.gov, ²U. S. Geological Survey, MS 963, DFC, Denver, CO 80225 USA.

Introduction: The ICDP-USGS Eyreville core-holes in the Chesapeake Bay impact structure (CBIS) were drilled during 2005-2006 on the Delmarva Peninsula, 7 km northeast of the town of Cape Charles, Virginia, USA [1]. The drilling penetrated the moat of the central crater that surrounds the central uplift as delineated by seismic and gravity surveys [2,3]. This study focuses on impactites and crystalline target rocks in the deepest core, Eyreville-B, from 1,766.2 to 1,095.7 m depth (shaded in Table 1). The geologic sequences include, in ascending order: 215 m of basement-derived schist, pegmatite, and coarse granite with veins and dikes of impact breccia; 154 m of suevites and lithic impact breccias; 26 m of quartz sand with lithic boulders and blocks; and a 275 m allochthonous granite body. These are overlain by 652 m of sedimentary breccias and sediment megablocks, and 444 m of post-impact sediments.

Table 1. Composite geologic section for Eyreville cores A, B, and C [4,5]; shaded units discussed herein.

<i>Depth in meters</i>	<i>Geologic sequence</i>
0 - 443.9	Post-impact sediments
443.9 - 618.2	Diamicton with clasts in muddy glauconite-quartz sand matrix (ocean-resurge sediments)
618.2 - 866.7	Nonmarine sediment blocks injected by quartz-glauconite sand
866.7 - 1,095.7	Nonmarine sediment blocks (sediment-avalanche deposits)
1,095.7 - 1,371.1	Granite (allochthonous)
1,371.1 - 1,397.2	Gravelly sand & lithic blocks (basal avalanche deposit?)
1,397.2 - 1,474.1	Suevites and clast-rich impact melt rocks
1,474.1 - 1,551.2	Polymict impact breccias and cataclastic gneiss blocks
1,551.2- 1,766.2	Schist and granite/pegmatite with impact breccia veins and dikes

Schist, pegmatite, and granite with impact breccia dikes (1,766–1,551 m depth): The deepest sequence consists of basement-derived mica schists, and granite pegmatite that grades into coarse granite. The schists commonly contain graphite and knots of fibrolitic sillimanite. A zone (1,655-1,641 m) of variably mylonitic muscovite-rich schist, gneiss, and amphibolite

contains disseminated calcite, minor epidote, and rare tourmalinite [4]. Ductile structures are inherited from the pre-impact basement. Brittle cataclastic deformation is much more pervasive than that observed outside the structure, and drilling did not reach undisturbed rock. The rocks locally are cut by dikes of breccia, including suevite, which decrease in size and abundance with depth [4,6]. Shock-metamorphic features are rare except in association with breccia dikes. ⁴⁰Ar/³⁹Ar plateau ages of two muscovites from the pegmatite indicate cooling through the ~350°C isotherm at ~244 Ma [6] without disturbance by the ~35.5 Ma impact.

Suevites and lithic impact breccias (1,551–1,397 m depth): The suevites and lithic impact breccias include a lower section of polymict impact breccias and blocks (up to 17 m) of cataclastic gneiss, and an upper section (above 1,474 m) of suevites and clast-rich impact melt rocks. Lithic clasts in the sequence include variably cataclastic greenschist-facies rocks, metaplutonic rocks, and sub-greenschist-facies sedimentary rocks previously unknown in the target.

Impact-melt clasts in the suevite include anhydrous to hydrous glasses that are commonly flow laminated, partly devitrified, and variably altered. Meniscus-like textures between glasses of different composition indicate immiscible silicate melts at quench. Coexisting sulfide melts now appear as small Fe+S ± Ni spheres. Tiny crystals of the oxide minerals chrome spinel, baddeleyite, and corundum in silicate glass indicate high-temperature crystallization under conditions of silica undersaturation. X-ray diffraction (XRD) indicates that melt glass is partly altered to well-crystallized Fe-rich smectite.

Shocked quartz is common in the suevite and lithic blocks within it. Two sets of planar deformation features (PDFs) are common, and three are visible in some grains. Ballen quartz [6], is observed locally in melt clasts and melt-rich domains. Raman spectra of selected grains from the melt-rich suevite show that some consist of coesite + quartz. Coesite from the CBIS was first reported in samples from this core [6], and studies are in progress to understand its distribution with depth and lithology.

Examination of suevites and clast-rich impact melt rocks by optical and electron-beam scanning microscopy, cathodoluminescence, electron microprobe analysis, and Raman micro-spectroscopy confirms the

presence of zircon (ZrSiO_4); its shocked equivalent, reidite; and baddeleyite (ZrO_2). Zircon textures include: (1) seemingly un-shocked, euhedral to sub-hedral crystals; (2) fractured to highly fractured but unaltered crystals; (3) altered crystals with decomposition zones; severely altered crystals with decomposition zones containing baddeleyite; (4) and severely altered crystals partially transformed to reidite and also with decomposition zones containing baddeleyite.

Sand and lithic blocks (1,397–1,371 m depth):

The sequence of suevites and lithic impact breccias is overlain by the gravelly quartz sand that contains a block of amphibolite, a cataclasite boulder, a probable rip-up clast of suevite, and smaller lithic clasts. The lowest gravelly quartz sand contains altered melt clasts [4]; it is also slightly darker and more lithified, suggesting a hydrothermal overprint within meters of the underlying suevite. Individual detrital microcline grains from the sand have $^{40}\text{Ar}/^{39}\text{Ar}$ laser fusion ages of ~328–218 Ma. Age spectra from three size fractions of the microcline have climbing spectra with ages ranging from 267–252 Ma and show no clear indication of the time of impact, so maximum temperatures in the sand during and after the ~35.5 Ma impact must have been $< \sim 150^\circ\text{C}$.

Granite (1,371–1,096 m depth): The 275 m granite body overlies the sand and must be allochthonous. It is free of intervening material that would require more than one slab but is locally faulted and fractured. The rocks are not shocked, and cataclastic fabrics are lacking except locally. The main rock types are gneissic biotite granite, medium- to coarse-grained biotite granite, fine-grained biotite granite, and a red altered granite near the base [4]. The gneissic biotite granite has a SHRIMP U-Pb zircon age of 615 ± 7 Ma [6], which is similar to Neoproterozoic granites from drill cores in the western part of the CBIS. The massive, medium- to coarse-grained biotite granite has a SHRIMP U-Pb zircon age of 254 ± 3 Ma (Permian)[6] and must be from a late Alleghanian pluton. The granite is overlain by gravelly sand derived from the Lower Cretaceous Potomac Formation.

Discussion: The Eyreville drilling recovered a remarkable variety of basement-derived Proterozoic and Paleozoic rocks, including multiply-deformed, upper-amphibolite-facies schist (and pegmatite) in the deep, basement-derived sequence, greenschist-facies metamorphic rocks and sub-greenschist-facies sedimentary rocks as clasts in the sequence of suevites and lithic impact breccias, an amphibolite block in sand above the suevites, and Neoproterozoic to Permian granites. This structural partitioning of basement-derived rocks is attributed mostly to the late, modification stage of crater formation. In addition to the impact effects,

these rocks provide important information about the deeply buried and rarely sampled eastern part of the Appalachian orogen beneath the Atlantic Coastal Plain.

Clast lithologies suggest that the suevites and lithic impact breccias formed mostly from basement-derived material that never left the crater. The vertical distributions suggest a lithic block-rich ground surge near the base with more melt-rich deposition from the collapsing ejecta plume in the upper part. Modeling [7] allows only about 7 minutes for deposition of the 154 m sequence of suevites and lithic impact breccias before it was covered by crater-fill sediments at the corehole location 9 km from the center.

The granite slab above the sand and suevite must be allochthonous, and its source is constrained by a general lack of shock metamorphism. A likely source is part of the transient crater rim that collapsed and slid into the moat, with underlying sand providing a low friction substrate. This is consistent with modeling [7] that shows the radius of the central crater expanding 6 km by inward collapse.

Syn- and post-impact heating below the suevite was $< \sim 350^\circ\text{C}$ based on the undisturbed $^{40}\text{Ar}/^{39}\text{Ar}$ plateau age spectra of muscovites. Temperatures in sand above the suevite were $< \sim 150^\circ\text{C}$, based on undisturbed $^{40}\text{Ar}/^{39}\text{Ar}$ laser-fusion ages of detrital microcline. Ongoing studies will further constrain the thermal histories.

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