GEOPHYSICS AND DEEP COREHOLES REVEAL ANATOMY AND COMPLEX INFILLING OF THE CENTRAL CRATER, CHESAPEAKE BAY IMPACT STRUCTURE, U.S.A. D.S. Powars[1], R.D. Catchings[2], G.S. Gohn[1], J.W. Horton, Jr.[1], L.E. Edwards[1], D.L. Daniels[1], [1]U.S. Geological Survey, MS 926A, Reston, VA 20192, USA, dspowars@usgs.gov, [2] U.S. Geological Survey, 345 Middlefield Rd., MS 977, Menlo Park, CA 94857.

Introduction: The Chesapeake Bay impact structure (CBIS) is the largest known impact crater in the United States. It formed at 35.5 Ma when a ~3-km-diameter asteroid or comet crashed into the Atlantic Ocean ~160 km offshore from Virginia's late Eocene paleo-coastline (located west of the present Fall Line) [1]. The multi-layered wet-target consisted of an eastward dipping crystalline basement overlain by a wedge of eastward thickening (450- to 1220-m) unconsolidated sediments and an eastward deepening (90- to >300-m) ocean. The eastern part of the target had significantly deeper basement rocks, deeper and thicker sediment cover, and deeper water than the western part. This asymmetry significantly affected the complex infilling of the central crater.

The elevation of the suevite in the moat of the central crater appears to be at about the same depth as the top of the crystalline basement at its deepest part. The basement elevation would affect the possibility of spillover. Similarly, the elevations of the top of the impact-related sediment-clast breccias and the top of preimpact sediment layers on the eastern side are approximately the same and may be causally related.

The upper crater fill is interpreted as deposits formed by multi-directional, multiple resurge-wave reverberations (termed here oscillation resurge waves) and represent thoroughly remixed impact debris.

Recent USGS Focus On the Central Crater: Since 2004, the USGS has focused on mapping the structure, stratigraphy, and water quality of the central crater. A partially cored, 823-m-deep test hole was drilled at the town of Cape Charles over the central uplift, and the continuously cored ICDP-USGS 1.76-km-deep Eyreville corehole (EC) was drilled into the moat. A variety of geophysical data were gathered in the 85 to 90-km-diameter CBIS. A 30-km long, low-fold seismic reflection and refraction survey, and a parallel detailed gravity survey were acquired along a radial transect from the crater's center to nearly half-way across the annular trough. Several 1- to 2-km long high-resolution seismic profiles (5-m source and geophone spacing) were also acquired at various points along the transect, including two 1.4-km-long profiles that crisscross over the deep EC [2,3]. These images provide semi-3D, detailed views of the stratigraphy and structure of the upper 1.0 km of the central part of the moat [4,5].

Overview of the Central Crater: On the basis of our seismic, gravity, and corehole data, we interpret a 35- to 38-km-diameter, asymmetrical central crater with a 10-km-wide (short axis, SW-NE), flat-topped, crystalline central uplift. This central uplift corresponds to a gravity high (up to -22.5 mGal) and is overlain by (in ascending order): ~350 m of polymict, suevitic crystalline-clast breccia, ~300-m of sediment-clast breccia, and ~355-m of post-impact sediments (largely based on Cape Charles test hole) [6,7]. Seismic, gravity, and corehole data show that the ~13-km-wide elliptical moat surrounds the central uplift and contains ~215 m of basement-derive schist and granite pegmatite with impact breccia dikes and veins; ~150 m of suevite and lithic impact breccias; ~925 m of low-velocity and low-density, mixed sediment breccia and crystalline-rock megablocks, including a 275 m granitic megablock(s); ~650 m of sediment clast/block breccia; and ~444 m of postimpact sediments [8]. The low-fold seismic reflection images suggest the moat may extend to as deep as 3.5 km. A complex multi-layered sequence of high- and low-velocity materials in the lowest ~km of the moat likely consists of crystalline-rock breccias, as well as possible sedimentary breccias (some stratified), and/or metamorphic or cataclastic remnants of the transient cavity wall, or possibly a melt sheet [9]. The central uplift is highly fractured and has collapsed onto the top of the lowest (2.25-km-depth) low-velocity layer of the moat, suggesting that the central uplift was elevated prior to the time all or most of the collapse debris from the transient cavity wall reached the inner moat. Relatively steep gravity (19.5 mGal to 25.0 mGal), resistivity, and seismic-velocity gradients, and inward-dipping reflections, mark the collapsed central crater's margin and raised rim. The moat is ~13-km-wide, irregularly shaped, and locally includes several gravity highs that suggest local pockets of melt and basement-derived megablocks, uplifted fault blocks, or irregularities in the inner basin's margin due to differences in target rock properties.

The upper 652 m of sediment clast/block breccia penetrated by the EC have been subdivided into four lithostratigraphic units, here interpreted in descending order as: (1) a matrix-supported, sediment- and crystalline-clast oscillation-resurge breccia with boulders (83 m); (2) a 50:50 matrix:clast, sediment-and crystalline-clast oscillation-resurge breccia with boulders and blocks (91 m); (3) a boulder- and block-supported, sediment-clast resurge breccia 249 m); and (4) a block-supported, sediment avalanche deposit (229 m) [10,11].

High-Resolution Seismic and Eyreville Core Correlation: Preliminary data processing and analysis indicate excellent correlation of the seismic images with the EC, including individual block and impact-debris patterns in the upper 300 to 400 m of the impactites that reveal a multidirectional emplacement. Reflection patterns are consistent with variations in conditions and processes within the central crater during impact and suggest deposition by resurge and oscillation-resurge wave interactions for these upper impactites.

Postimpact sediments. Strong, mostly continuous, subhorizontal reflections typical of marine strata represent the postimpact sediment units (upper Eocene to upper Miocene) identified in the EC from 444 to 60 m depth. Continuous reflections, including reflections that dip into a paleochannel, characterize the top 60 m of the core and correlate with Pliocene to late Pleistocene shallow-marine to marginal marine sands and basal gravels. On the 30-km-long, low-fold seismic profile, the postimpact strata dip toward, and thicken above, the center of the moat with relatively minor disruption. Reflection patterns reveal both differential compaction and faulting.

Synimpact breccias. In contrast to the postimpact reflectors, the upper ~80 to 90 m of synimpact deposits are represented by subhorizontal, overlapping-to-shingled reflections that dip and pinch out in various directions. These reflections correlate with EC where there are multiple fining-upward sequences in matrix-supported breccia. The upper sequence grades into to stratified sand and laminated clay-silt. This section is dominated by a muddy glauconite-quartz sand matrix containing mixed-age microfossils, Cretaceous sediment clasts, and locally abundant ejected crystalline clasts (some shocked, some melt fragments, most <1m) [12]. These shingled fining-upward sequences are interpreted as oscillation resurge waves.

Seismic signatures vary laterally in the underlying ~100 to 125 m-thick section of the moat, and the reflections are highly disrupted. This interval has discontinuous, chaotic reflections that bound relatively continuous lenses. These lenses truncate, overlap, and pinch out in multiple directions and correlate with the 618 to 527 m depth in the EC, where matrix-supported breccias have about a 50:50 mixture of matrix and boulder and blocks. The majority these clasts are oxidized clay-silt clasts. Crystalline clasts are locally common. A few fining-upward sequences are also present. This section is here interpreted as oscillation-resurge deposits that bulldozed and deposited large piles of blocky debris. This unit is underlain by ~250 m of relatively continuous reflections that pinch out in various directions and by chaotic, discontinuous reflections, some of which show imbrication. This interval correlates with clast-supported, sediment-clast breccias assigned to the lower resurge section in the EC (867 to 618 m depth), and it is dominated by Lower Cretaceous clasts of sand and oxidized clay-silts (1-30 m intersected diameter). The mixed-age resurge matrix is absent from a 142 m interval above the basal 13 m, but is sporadically present as layers and/or injections in the immediately overlying 106.5 m interval. Many of the clasts have relict bedding that is highly contorted at various scales. Clast margins are highly deformed; and within-clast shearing and brecciation are evident. Some preimpact stratigraphy appears to be preserved. This interval is interpreted as a chaotic combination of ocean-resurge deposits and reworking of the underlying Lower Cretaceous sediment debris-avalanche deposits (1,096 to 867 m depth). The seismic data show an overall decrease in the size of the blocks from the top of the suevite upward and that there is considerable lateral variability throughout the impactite section.

High-Resolution and Low-Fold Seismic Correlation: Correlation of the high-resolution seismic images with the 30-km-long low-fold seismic profile [8] shows that four strong reflections correlate with the upper 652 m of impactites. These reflections represent, in descending order: (1) the lower 65 m of the shingled, matrix-supported, sediment- and crystalline-clast oscillation-resurge unit; (2) the upper 60 m of the more chaotic boulder- and block-supported, sediment-clast resurge unit; (3) 55 m of liquefied sand in the lower half of this boulder- and block-supported, sediment-clast resurge unit; (4) and the lower 100 m of the clast-supported, sediment-clast breccia unit interpreted as sediment avalanche from collapse of the upper part of the transient crater-wall. Across the inner part of the moat the upper three strong reflectors dip away from the central uplift into the central part of the moat, suggesting either an anti-resurge or postdepositional compaction of these units away from the central uplift. The lowest reflector dips from the opposite direction inward from the central-crater rim to the central part of the moat and is consistent with a transient crater-wall avalanche interpretation.

Collectively, the seismic images suggest that the upper impactites in the central crater are highly variable laterally, with lithologically similar units at different depths deposited from multiple directions at multiple times.

References: [1] Horton J.W. Jr. et al. (2005) in Horton et al., *USGS Professional Paper 1688*, A1-A24. [2] Catchings, R.D. et al. (2007) *GSA Abstracts 39(6)*, 450. [3] Powars, D.S. et al. (2007) *GSA Abstracts 39(6),* 533. [4] Powars, D.S. et al. (2007) *EOS 88(52),* Fall Meet. Suppl., Abstract U21E-07. [5] Catchings R. D. et al., (2007) *EOS, 88(52)*, Fall Meet. Suppl., Abstract U21E-06. [6] Sanford et al. (2004) *EOS 85(39), 369.* [7] Gohn, G.S. et al. *USGS OFR* 2007-1094. [8] Gohn G.S. et al. *EOS 87(35), 349.* [9] Catchings et al., JGR, (in press). [10] Gohn, G.S. et al. (2007) *GSA Abstracts, 39(6), 532*. [11] Powars, D.S. et al. (2007) *GSA Abstracts, 39(6), 314*. [12] Morrow J.R. (2007) *GSA Abstracts 39(6), 451*.