PETROGRAPHY, GEOCHEMISTRY, AND RADIOMETRIC DATING OF IMPACT MELTS FROM THE CHESAPEAKE BAY IMPACT STRUCTURE, USA.

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Introduction: A first continuous sequence of impact melt bearing lithologies became available from the 80-95 km diameter Chesapeake Bay impact structure with the recent USGS-ICDP Eyreville-B drilling. Located in the annular moat within the collapsed transient cavity, ~9 km from the presumed center of the impact structure, the drilling reached a final depth of 1776.2 m [1]. Impact melt-bearing rocks give insight into the formation of deposits of highly shocked components from an oceanic impact. Geochemical and petrographic analyses are aimed at resolving the formation of impact melt rocks and suevites, taking into account the role of abundant volatiles in the target. Moreover, direct dating of impact melt rocks from the Chesapeake Bay impact structure became possible. At present, the age of the impact event is only indirectly constrained by biostratigraphy of post-impact deposits and distal ejecta (tektites and microcrystites) that have been related to the crater [2,3].

Samples and Methods: Whole rock geochemistry by XRF were carried out on fused glass beads (5 samples, 1402 – 1407 m depth and one sample at 1450.7 m depth), and petrographic analyses by optical microscopy and SEM (19 samples, 459-1470 m depth). Element concentration mappings were made from selected thin sections with an ultra-fine beam to detect zonation patterns in liquidus phase phenocrysts. Quantitative chemical analyses with 20 µm beam diameter were produced on 18 thin sections (459-1470 m depth) to determine the compositions of impact melts and with a focused beam on four thin sections of impact melt rocks to determine the compositions of liquidus phase phenocrysts. Radiometric dating will be done using the ^{40}Ar-^{39}Ar methods by step heating and total fusion on one sample of hypocrystalline impact melt rock from 1450.73 m depth and one sample of holocrystalline impact melt rock from 1404.91 m depth. The dating of the impact melt rocks will be complemented by argon isotope analysis of a bediasite and a georgiaite tektite from the North American Tektite Strewn Field [2,3]. At present, the radiometric dating study is underway and results are expected to be ready for presentation at LPSC.

Results: *Impact melt particles:*

(1) Altered melt particles in suevite deposits between 1397.18 m – ~1470 m. Detailed petrography of these deposits is given in [4]. Shard-shaped melt particles are variably altered to phyllosilicates. They have SiO_2 concentrations of ~63 wt.%. Fluidal-textured melt particles occur variably colored but closely associated as translucent types that are mainly composed of SiO_2 (>80 wt.%) and as brown types that typically have SiO_2 contents of ~64 wt.%. Further compositional differences, e.g. in Al_2O_3, are present, whereas average TiO_2 contents are generally similar below 1 wt.%.

(2) Within the resurge deposits (“Exmore Beds”, depth interval 444-1397 m) impact melt particles occur as late fallback from the ejecta plume and reworked particles from suevites that were deposited during an earlier stage of deposition, mostly as vesicle-rich, shard-shaped, altered particles up to ~5 mm in size. These melt particles are altered to montmorillonite.

Clast-rich, unbrecciated, fluidal- textured impact melt rocks:

(A) The “Lower Impact Melt Rock” at 1450.20 – 1451.51 m is a hypocrystalline impact melt rock (Fig. 1). Most shock metamorphic features of incorporated tectosilicate clasts are annealed, e.g. to decorated planar deformation features in quartz and ballen-textured quartz that indicates high temperature (~1100°C) recrystallization of diaplectic quartz glass. Also, some granular-textured zircon clasts with relic ZrO_2 float in the melt and confirm its origin as an impact melt [5]. Some dark veins of melt that is rich in iron-titanium oxides and spinel occur as well, suggesting assimilation of debris under differing oxygen fugacity conditions or different quench rates in the impact melt [6]. Alteration features occasionally present include zeolites that fill voids, spherulitic devitrification to phyllosilicates, and apparent chloritization of glassy melt. Separate, circular aggregates, <100 µm in diameter that are composed of pyrrhotine, and pentlandite, +/- nickeline, and bornite may represent remanants of immiscible sulfide melt. Phenocrysts include zoned, acicular and sometimes skeletal, up to ~100 µm long orthopyroxene (enstatite-rich cores, ferrosilite-rich rims) with up to ~14 wt.% Al_2O_3. Hercynitic spinel showing zonation towards an ulvöspinel-like composition occurs as up to 3 x 2 µm euhedral crystals. Frequently, globular, several 100 µm diameter domains of spiny laths of phyllosilicates are graphically intergrown with iron-titanium oxides (Fig. 1). Some euhedral laths of cordierite are present in more strongly devitrified glass that has a normative composition akin to ternary feldspar . The pristine glass has a rhyolitic composition with a volatile content of about 5 wt.% (water and halogenides?) and SiO_2 content of ~72 wt.%. The glass retained small average concentrations of MgO (0.16 wt.%) and FeO (1.76 wt.%; as total iron), possibly due to the crystallization of liquidus phase phenocrysts. Average concentrations of 3.14 wt.% K_2O in the glass confirms the potential for ^{40}Ar-^{39}Ar dating.

(B) The "Upper Impact Melt Rock" at 1409.37–1401.84 m is a holocrystalline impact melt rock. Structurally and compositionally, it is similar to the Lower Impact Melt Rock. The aluminum-rich orthopyroxene phenocrysts frequently exhibit embayments and sometimes are partly dissolved, which may indicate slight resorption. The melt matrix is composed of garben-structured, zoned plagioclase phenocrysts with anorthite-rich cores and albite to anorthoclase-rich rims embedded in a SiO_2-rich mesostasis. Globular devitrification features are more coarsely crystallized to spiny, segmented laths of cordierite that are frequently pinitized. The cordierite laths are zoned with magnesium-rich cores and iron-rich rims. More rarely, titanium-rich biotite occurs as 10 µm size laths.

Whole rock geochemistry: The whole rock chemical compositions of the Lower and Upper Impact Melt Rocks are within the range of the Eyreville B suevite compositions (Tab. 1). The differences between the Upper and Lower Impact Melt rock in SiO_2 (decrease), and TiO_2 and Fe_2O_3 (increase) are similar to the trend of the suevites with depth. The Upper Impact Melt Rock shows a significantly higher K_2O content in comparison to the Lower Impact Melt Rock. The Na_2O content of both impact melt rocks is low in comparison to the ~30% higher value for the average suevites.

Tab. 1: Chemical composition of Upper (average of 4 samples) and Lower (1 sample) Impact Melt Rock (IMR) in comparison to the the Eyreville-B suevite (67 analysis).

wt.%	Upper IMR	Lower IMR	Suevite mean	std.dev	min	max
SiO_2	69.8	66.5	67.3	3.7	61.3	82.2
TiO_2	0.80	0.89	0.85	0.15	0.34	1.35
Al_2O_3	14.2	14.5	14.5	1.4	7.6	17.2
Fe_2O_3	5.11	5.72	5.33	1.07	1.98	7.78
MnO	0.06	0.08	0.08	0.03	0.02	0.20
MgO	0.99	1.99	1.69	0.48	0.44	2.76
CaO	1.76	1.45	1.53	0.48	0.68	3.12
Na_2O	1.29	1.47	1.68	0.85	0.66	5.13
K_2O	3.55	2.55	3.16	0.77	0.25	5.09
P_2O_5	0.12	0.13	0.13	0.04	0.04	0.34
SO_3	<0.1	<0.1	<0.1		<0.1	0.4
LOI	1.9	3.9	3.3	1.2	1.0	6.6

Petrogenetic implications:

In drill core Eyreville-B, different types of impact melts occur. In the suevites, melt particles were rapidly cooled below the glass transition temperature of 600 - 775 °C for rhyolitic melts [7] from initial temperatures above ~1800 °C that are indicated by the presence of decomposed zircon clasts [4,5]. Although these melt particles are pervasively altered, some indicate compositional differences that suggest retention of characteristics of precursor rocks, and thus, incomplete chemical homogenization. In contrast, the phenocryst-bearing impact melt rocks appear geochemically fairly homogeneous. Furthermore, these rocks indicate in-situ cooling in the absence of water because they do not exhibit hyaloclastic fragmentation. In contrast, fluidal textures may indicate welding of viscous, hydrous melts [7], due to lithostatic loading [4]. This may bear implications for the effect and the distribution of volatiles during an oceanic impact event.

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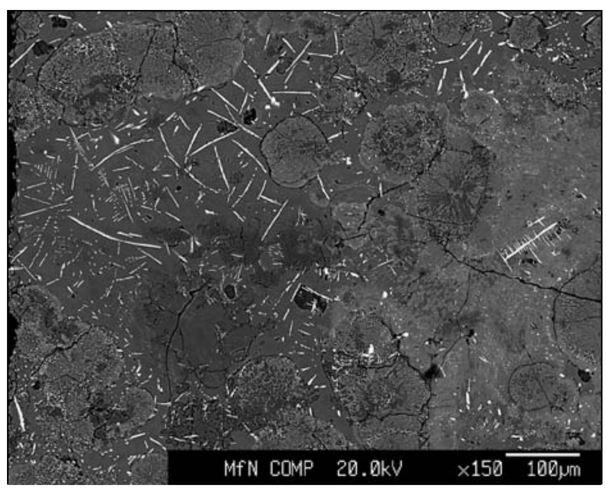

Fig. 1 Hypocrystalline impact melt rock at 1450.51 m depth, SEM-BSE image. Bright laths of orthopyroxene in pristine glass matrix, globular devitrification features and dark grey quartz clast with resorption embayments.