EVIDENCE FOR MELTING AND DECOMPOSITION OF SEDIMENTARY TARGET ROCKS FROM THE STEEN RIVER IMPACT STRUCTURE: MINERALOGY AND MICROTEXTURES

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Introduction: Sedimentary units are present in the target rocks of ~70% of terrestrial impact structures [1]. Despite their widespread occurrence, the products of impact-induced melting and decomposition of these rock types remains poorly understood, and is an active area of research. Important physical properties distinct between crystalline and sedimentary lithologies, which may affect impact products, include porosity, grain size and the presence of volatiles. In this study, we present evidence in support of melting and decomposition of sedimentary rocks at the Steen River Impact Structure (SRIS). Target rocks comprised a ~1.6 km thick sequence of predominantly Devonian carbonates, shale and evaporates overlying crystalline basement rocks [2]. The response of sedimentary rocks to the crater-forming hypervelocity impact event involved melting close to the point of impact and decomposition in response to elevated residual temperatures during postshock cooling.

Crater Overview, Samples and Methods: The SRIS is a 25 km diameter complex crater in NW Alberta, which is, at present, buried beneath ~200 m of post-impact Cretaceous shale and sandstone. The fortuitous location of the structure within the oil and gas producing Western Canada Sedimentary Basin has led to exploration of this remote site through geophysical and drilling studies, though the former remains proprietary. As a result of an drilling campaign in 2000, >1 km total length of continuous but shallow diamond drill core was collected from three locations penetrating the crater fill deposits of the SRIS. From these core over 300 m of melt-bearing polymict breccia was intersected. Detailed sampling of one core (ST003) situated ~4 km from the crater center, was conducted. The length of the core (381 m) may be divided into 11 m of crystalline basement rocks from the central uplift, overlain by 164 m of impact melt-bearing polymict breccia. The upper 206 m of shale was not sampled in this study. A census of 72 thin sections produced from sampled core was conducted using optical microscopy; of these, several from the uppermost breccia (210 m depth) and deeper units (290 m and 304 m) were carbon coated for detailed analysis using a ZEISS Sigma FESEM and a JEOL 8900 EMP at the University of Alberta, and a SENTERRA Raman spectrometer at MacEwan University. These instruments were used to characterize the microtextures of the breccia clasts and matrix, as well as to determine their mineralogy, and quantify major and minor elemental abundances.

Results: ST003 intersected a 164 m thick continuous sequence of melt-bearing polymict breccia. This breccia is subdivided into several intervals based on clast content, matrix mineralogy and impact melt composition.

Breccia interval between 242–370 m. In deeper portions of the core, the breccia exhibits mm- to cm-size dark, generally contorted and flow textured clasts of quenched impact melt embedded in a distinctly green-colored matrix. The mineralogy of this matrix has been described by [3]. Within the breccia matrix, clusters of newly formed minerals are heterogeneously distributed – some appear bright green under transmitted light while others are largely opaque. The mineralogy of green crystal clusters is distinct from the surrounding matrix, comprising equant euhedral or skeletal grossular and andradite garnet poikilitically enclosing micrometer-size anhydrite, clinopyroxene and / or albite. Opaque minerals are nearly pure end-member magnesioferrite, $MgFe^{3+}_2O_4$, associated with calcite, anhydrite and clinopyroxene. Clasts from target rocks are predominantly derived from crystalline basement rocks.

Breccia interval between 242–206 m. In upper units of the core (<242 m) there is a decrease in the abundance of granitic clasts, with a concomitant increase in clasts clearly derived from the target sedimentary successions. Clasts of impact melt are distinctly lighter in color compared with those encountered >242 m, yield low wt% oxide elemental totals and are extremely beam-sensitive. Within the lighter impact melt clasts, internal ocellar textures of carbonate globules (calcite) with lechatelierite, or stringers of lechatelierite and calcite have been documented. An immiscible intergrowth of calcite and quenched silicate melt (now altered to clay minerals) is also observed.

Discussion: Garnet and spinel crystal clusters are interpreted as clasts of carbonates and / or sulphates from target rocks entrained within the breccia and subsequently decomposed in response to high postshock temperature. This is based on their unique mineralogy and heterogeneous distribution within the breccia, as well as the occurrence of identical mineral assemblages in skarns and other high temperature contact metamorphic deposits. Based on the phase diagram for $CaCO_3$ [4], this would occur at low pressure (<0.003 GPa) and temperatures >923 °C. Microtextures documented from upper units of the core are indicative of liquid immiscibility, and are evidence of impact melting of target rock carbonates. The Steen River impact structure can be added to the growing list of terrestrial craters where evidence for impact melting and decomposition of sedimentary rocks is recognized.

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