INVESTIGATING THE FORMATION CONDITIONS OF HIGH-TEMPERATURE BRECCIAS AT THE STEEN RIVER IMPACT STRUCTURE (ALBERTA, CANADA): AN INTEGRATED EXPERIMENTAL AND COMPUTATIONAL APPROACH.

H. A. M. Jurak[1], E. L. Walton[2], and C. S. J. Shaw[2], [1]Department of Earth Sciences, University of New Brunswick, 2 Bailey Drive, Fredericton, New Brunswick, E3B 5A3, Canada (hjurak@unb.ca), [2]Department of Physical Sciences, MacEwan University, 10700 104 Avenue, Edmonton, Alberta, T5J 4S2, Canada

Introduction: The Steen River impact structure (SRIS) is a complex crater located in NW Alberta, Canada (59º31'N, 117º38'W) [1–3]. The impact event occurred ~141 Ma in mixed target rocks, comprising an ~1.3 km-thick sequence of Devonian shales, carbonates, and evaporites, overlying Proterozoic granites and gneisses [1–4]. In 2017, an ~128 m-thick unit of impact melt–bearing breccia was identified in drill core intersecting crater-fill deposits on the side of the central uplift [5]. The matrix of the breccia is defined by a suite of high-temperature minerals, hypothesized by [5] to have grown in the solid state from an initially clastic matrix, in response to high post-shock temperatures. Here, we test the hypothesis that SRIS breccias were deposited at very high temperatures (>800 ºC), resulting in decomposition of $CaCO_3$-bearing rocks to form Ca-rich minerals (pyroxene). The goal is to constrain the temperature at which the thermally-metamorphosed breccias were deposited and the proportion of $CaCO_3$-bearing target rocks originally present in the matrix.

Experimental Methods: Shocked SRIS granites and non-SRIS limestones were milled to fine powders (<100 μm). Mixtures of 25:75, 50:50, and 75:25 granite-limestone were loaded into a Thermo Fisher Scientific Lindberg / Blue M tube furnace (University of New Brunswick) and sintered at constant pressure ($P = 0.1$ MPa), temperatures ($T = 800, 900,$ and 1000 ºC), and oxygen fugacity ($fO_2 = QFM + 2$) for the duration of 6 months. The texture, mineralogy, and mineral abundances of the run products were characterized using a ZEISS Sigma 300 VP field emission scanning electron microscope (University of Alberta) and a Bruker SENTERRA micro-Raman spectrometer (MacEwan University).

Computational Methods: Theriak-Domino software [6,7] was used to construct P-T diagrams of granite-limestone experiments. Bulk rock compositions were "mixed" to reflect the proportion of granite to limestone in 25:75, 50:50, and 75:25 granite-limestone runs. Domino calculations [8] were made in the Na_2O-K_2O-MgO-CaO-MnO-FeO-Fe_2O_3-Al_2O_3-SiO_2-TiO_2-H_2O-CO_2 system using the internally-consistent thermodynamic database of [9], where pressures and temperatures ranged from 0.1–1000 MPa and 700–1100 ºC, respectively.

Results and Discussion: *Experimental.* Ca-rich minerals (olivine, pyroxene, pyroxenoid) occur as fine-grained vermicular textures mantling shocked quartz and feldspar grains (800, 900, and 1000 ºC); as patchy, poorly-formed grains within run products retaining clastic textures (900 and 1000 ºC); and as laths within run products that melted (900 and 1000 ºC). Since the breccia matrix was sintered, but not melted, we suggest SRIS breccias were deposited at ≤800 ºC. This constraint is supported by [4], who limit the temperature of post-deposition sintering to 450 ºC < T < 800 ºC based on U-Pb dating of accessory phases within SRIS breccias. Ca-pyroxenoid (wollastonite) lining quartz and feldspar grains was observed in 800 ºC runs containing <50% granite but >25% limestone (25:75 and 50:50 granite-limestone). While these experiments lack the occurrence of Ca-pyroxene, we suggest the size of the starting materials was too coarse to facilitate the growth of this mineral at 800 ºC.

Computational. Ca-silicates and -aluminosilicates are observed at $P = $ ~0.1 MPa and $T = $ ~800 ºC in <50% granite but >25% limestone models (25:75 and 50:50 granite-limestone). Assemblages include merwinite (25:75 and 50:50 granite-limestone), melilite (åkermanite-gehlenite series; 25:75 and 50:50 granite-limestone), and olivine (monticellite; 50:50 granite-limestone). Since natural and experimental Ca-bearing minerals are not in agreement with those modeled by Theriak-Domino, we suggest natural and experimental assemblages are not at equilibrium. We speculate that heterogeneity in the distribution of granite and limestone clasts is responsible for the growth of relatively Si-saturated, rather than Si-undersaturated Ca-bearing matrix minerals.

Future Work: These findings will inform a series of experiments that investigate the run products of very fine-grained (<1 μm) starting materials, sintered to 450 ºC < T < 800 ºC. We hypothesize, that by decreasing the size of granite-limestone starting materials, while maintaining their heterogeneous distribution, Ca-pyroxene will form at <800 ºC temperatures.

References: [1] Carrigy M. A. and Short N. M. (1968) in *Shock Metamorphism of Natural Materials*, Mono Book Corp., 367–378. [2] Winzer S. R. (1972) *24th International Geological Congress*, 148–156. [3] Walton E. L. et al. (2016) *Geochimica et Cosmochimica Acta* 180:256–270. [4] McGregor M. et al. (2020) *Geochimica et Cosmochimica Acta* 274:136–156. [5] Walton E. L. et al. (2017) *Geology* 45:291–294. [6] de Capitani C. and Brown T. H. (1987) *Geochimica et Cosmochimica Acta* 51:2639–2652. [7] de Capitani C. (1994) *Jahrestagung der Deutschen Mineralogischen Gesellschaft,* 6, 48. [8] de Capitani C. and Petrakakis K. (2010) *American Mineralogist* 95:1006–1016. [9] Berman R. G. (1988) *Journal of Petrology* 29:445–522.