Stable isotope studies of the Rochechouart impact structure: sources of secondary carbonates and sulphides within allochthonous and parautochthonous impactites. S. L. Simpson[1], A. J. Boyce[1], P. Lambert[2], M. R. Lee[1], P. Lindgren[1]. University of Glasgow, University Ave, Glasgow, G12 8QQ, UK. [2]Sciences et Applications, 218 Boulevard Albert 1er, 33800 Bordeaux, France. S.Simpson.1@Research.gla.ac.uk.

Introduction: Hypervelocity impacts are among the most ubiquitous processes to affect solid bodies within our solar system [1, 2]. Although they are notoriously devastating, citing responsibility for mass extinction events and global climate perturbations, impacts can also create temporary environments which are favorable for life to thrive, if there is enough water present in the target, and sufficient energy is released as heat [1, 2]. One-third of impact structures on Earth contain fossil impact-initiated hydrothermal systems, and they are therefore being explored as potential “cradles of life” on other solid planets and satellites in our solar system [1].

We are presenting a case for the evaluation of the Mesozoic Rochechouart impact structure in France as a once-habitable environment. Initial $\delta^{13}C$, $\delta^{18}O$ and $\delta^{34}S$ isotope data collected in 2014 from hydrothermal carbonates and sulphides within monomict lithic impact breccia, collected from a site located 7.5km from the center of the structure at Champagnac quarry, supports our hypothesis of a warm, wet environment; we also found evidence for metabolically reduced sulphate [3]. Similar mineral assemblages can be found throughout the structure, including allochthonous breccias and low to unshocked target material. In order to explore our hypothesis further, a larger sample set was collected from various lithologies within the Champagnac site containing sulphide and carbonate mineralization for $\delta^{13}C$, $\delta^{18}O$ and $\delta^{34}S$ isotope analysis in January 2015. These results will allow us to determine the relationships between the many hydrothermal mineral assemblages within this area of the structure, and ask whether the isotopic compositions recorded in secondary sulphides and carbonates of the impactites are inherited from the target, or possibly represent colonization by thermophilic microbes during the post-impact hydrothermal period.

The Rochechouart impact structure: The 23km diameter Rochechouart impact structure has been dated to 201±2Ma [4, 5], placing it on the Triassic-Jurassic boundary. The crater is located in west-central France, on the western margin of the Central-Massif and north-eastern edge of the Aquitaine basin, with a mixed crystalline target composition of primarily granitic metamorphic and intrusive igneous rocks of the Variscan orogeny [4]. It is highly eroded; none of the original morphology is preserved, yet enough material remains to provide a full suite of impactites representing varying degrees of shock and mixing [4, 6]. Pervasive hydrothermal alteration has been observed at Rochechouart by previous authors [1, 4, 5, 6], and presents itself throughout all impact lithologies most notably as K-metasomatism, as well as argillic alteration and late stage carbonates [1, 4, 5, 7].

Initial data: During a previous study, secondary carbonates and sulphides were extracted from a small sample set of autochthonous and parautochthonous (monomict lithic impact breccia, fig. 1 and 2) impactites from the study site of Champagnac for $\delta^{13}C$, $\delta^{18}O$ and $\delta^{34}S$ analysis [3, 7]. Pyrite $\delta^{34}S$ values range from -10‰ to -26‰ (VCDT) indicating reduction of sulphate, possibly by thermophilic microbes during the post-impact hydrothermal period. Carbonate values reflect a mixture of organic and inorganic reservoirs, and a warm (50 to 70°C) environment of crystallization.

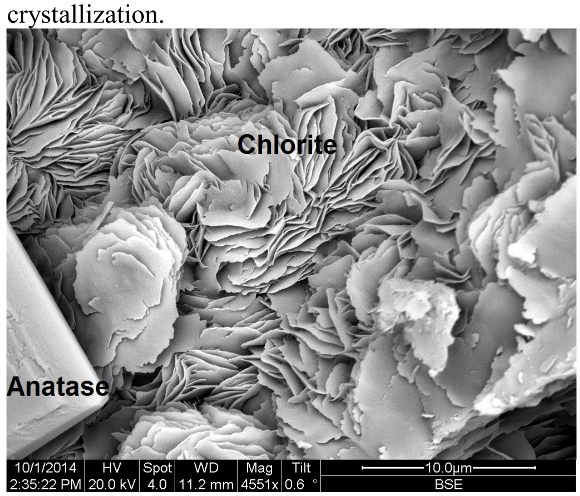

Figure 1: SEM image of a clast of monomict lithic impact breccia, showing secondary chlorite (platy mineral) and accessory anatase (TiO_2, left).

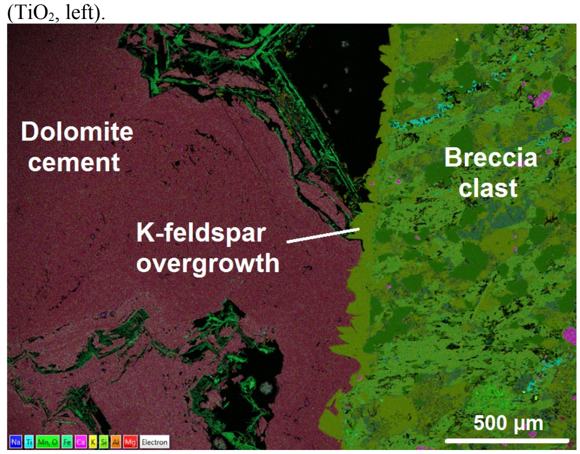

Figure 2: Chemical map (EDX) of monomict lithic breccia clast (right, green) showing secondary silicate overgrowth, K-feldspar, and dolomite cement (left, purple).

Further tests of the 'habitable Rochechouart hypothesis': Carbonate and sulphide mineralization is prevalent throughout the study site of Champagnac, and can be found within basement, autochthonous, parautochthonous and allochthonous lithologies [3, 6]. In order to determine the relationship and origin of these deposits in the context of our 'habitable Rochechouart' hypothesis, a larger sample set consisting of a variety of lithologies was collected for $\delta^{13}C$, $\delta^{18}O$ and $\delta^{34}S$ isotope analysis at the Scottish Universities Environmental Research Center (SUERC) [8]. The following rock types and mineral deposits are central to these tests:

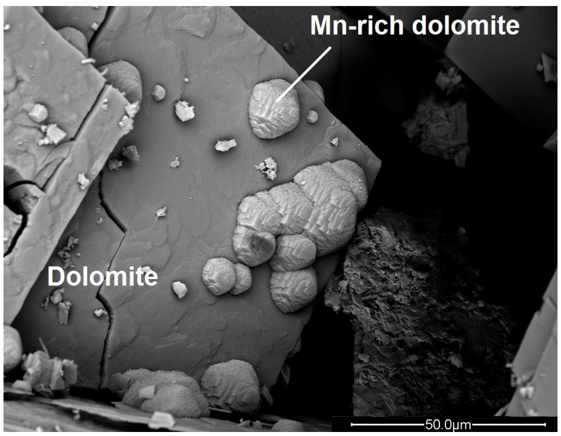

Figure 3: SEM image of secondary dolomite cement in monomict lithic impact breccia, used for initial $\delta^{13}C$, $\delta^{18}O$ isotope analysis and further testing.

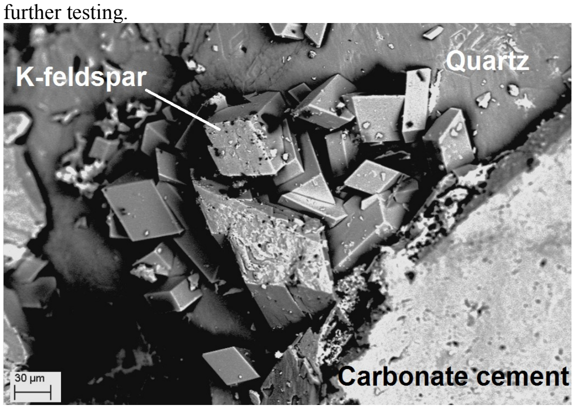

Figure 4: Highly altered polymict lithic breccia (matrix) from breccia dyke found below transient crater floor, showing carbonate cement (bottom right) and secondary k-feldspar (middle, rhombohedral crystals) on quartz.

Target and autochthonous material: Samples of minimally-altered basement amphibolite gneiss containing sulphides both within the fabric and cross-cut by secondary carbonate and sulphide veins (1), coarse crystalline calcite, pyrite and chalcopyrite coatings on fracture surfaces (2) and k-feldspar veins containing minor amounts of euhedral pyrite were collected for analysis (3). *Parautochthonous and allochthonous material:* A further amount of monomict lithic breccia was collected (1) as well as samples of a previously undiscovered polymict breccia dike containing carbonate mineralization, located beneath the transient crater floor. Clasts of the polymict breccia dike display high temperature reaction rims (100<°C), as well as a secondary carbonate cement suggestive of cooler (100>°C) temperature alteration, supporting a complex hydrothermal history, also in agreement with other authors [4, 6].

Jurassic-Triassic boundary limestones and the Aquitaine basin shoreline: As the target was in a marginal marine environment [4, 6], the question is raised as to what influences the sea may have had on the geochemistry of Rochechouart impactites. What is left preserved of the Jurassic-Triassic shoreline unconformably overlies crystalline basement approximately 17km WSW of the structure's center, only 5km outside the currently accepted diameter. The age of these limestones is poorly constrained, and mapped by the French Geological Survey as "Triassic-Jurassic limestones", spanning a 20 million year period, from 210 to 190Ma (Rhaetian to Hettangian) [9]. These limestones are contemporaneous with the age of the Rochechouart event. It is also worth mentioning that evidence presented by other authors supports a larger diameter (40 to 50km) for the Rochechouart structure than what is currently accepted (23km) [4, 6]. These limestones were collected from an outcrop at Montbron. Results from this research will shed light on how impacts interact with volatiles in their targets, and more specifically, test the hypothesis that impact structures are ideal environments to search for life on other terrestrial bodies in our solar system.

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References: [1] Osinski, G. R. et al. (2013) *Icarus 224, 347–363* [2] Naumov, M. (2005) *Geofluids 5, p165 to 184.* [3] Simpson, S. et al (2014) *Meteoritics and Planetary Science 49, Nr S1, A5 to A454*. [4] Lambert, P. (2010*) The Geological Society of America Special Paper 465*. [5] Schmeider, M. et al. (2010) *Meteoritics & Planetary Science 45, Nr 8, 1225–1242* [6] Sapers, H. et al (2014) *Meteoritics and Planetary Science 49, Nr 12, 2152 - 2168.* [7] Simpson, S. et al. (2014) *45th Lunar and Planetary Science Conference #1039.* [8] *Scottish Universities Environmental Research Center,* Rankine Ave, East Kilbride, G75 0QF, U. K. [9] *Bureau de Recherches Géologiques et Minières*, geologic maps 686, 687. [10] *Barringer Crater Company,* PO Box 697, Flagstaff, AZ. [11] *Réserve Naturelle de l'Astroblème de Rochechouart - Chassenon*, CCPM Mairie-Place-du-Chateau, Rochechouart, France.