RE-EVALUATING THE ROCHECHOUART IMPACTITES: PETROGRAPHIC CLASSIFICATION, HYDROTHERMAL ALTERATION AND EVIDENCE FOR CARBONATE BEARING TARGET ROCKS. H. M. Sapers (hsapers@uwo.ca), G. R. Osinski, N. Banerjee, Centre for Planetary Science and Exploration & Dept. of Earth Sciences, University of Western Ontario, London, ON, N6A 5B7, Canada.

Introduction: The Rochechouart impact structure is a deeply eroded, late Triassic impact site located in south-central France [1,2]. Rochechouart impactites comprise five main lithological units from the base of the structure upwards, originally described as follows: unit 1) shocked autochthonous basement rock; unit 2) finely crystalline melt rock; unit 3) red 'welded' breccia/suevite; unit 4) lithic breccia; and unit 5) suevitic breccia [2]. Standardized nomenclature is important when studying impact structures, both for ease of correlating investigations and experimental studies as well as enabling a universal understanding of the subject matter. When correctly and consistently applied, unambiguous and informative nomenclature yields descriptive and often genetic information. The petrographic evaluation of the Rochechouart impactites (units 2–5) presented here allows for a systematic classification based on the most recent recommendations of the IUGS [3] and a recent review of the effects of target lithology on impact melting [4]. In addition, mineralogical and textural evidence for post-impact hydrothermal alteration was observed. A carbonate clast hosted within the lithic impact breccia suggests the existence of carbonate in the pre-impact target rocks.

Geologic Setting: The late Triassic (214 $\pm$ 8 Ma) Rochechouart impact structure [5] was formed by an ordinary chondritic impactor [6] in the crystalline Hercynian granites and gneisses of the French Massif Central [7]. The structure has been deeply eroded such that no topographic expression of the crater remains [2]. Originally interpreted as volcanic [8], the identification of shock metamorphic textures such as shatter cones and planar deformation features (PDFs) in quartz led to the recognition of an impact origin [1]. Rochechouart consists of scattered outcrops of impact breccias and melt rocks. The estimated crater diameter is ~23 km based mineralogical and structural constraints [9,10]. A crater of this diameter is expected to have a complex morphology with a central uplift [11]. Based on the distribution of shatter cones in the shocked basement, a 4 km diameter central uplift region has been proposed [2].

Methodology: Twelve representative thin sections of the Rochechouart impactite suites were chosen for petrographic study in transmitted light. Hand samples were also examined.

Results: All impactites examined, with the exception of the melt rock, contained petrographic indicators of shock including: PDFs in quartz, decorated PDFs in quartz, planar fractures, mosaicism of quartz, toasted quartz, isotropization of quartz and feldspar, kink banding in mica, and diaplectic glass. Shock metamorphic features were concentrated in quartzofeldspathic lithic clasts.

Evidence of hydrothermal alteration is pervasive in quartzofeldspathic-rich regions of all units. Fine-grained alteration assemblages are comprised of very fine-grained sericite, fine-grained andalusite and regions of carbonate mineralization. Feldspathic minerals are often completely replaced by these argillic assemblages. Extensive hydrothermal alteration and fine grain size made definitive mineral identification difficult. Descriptions of units 2 to 5 follow.

Unit 2: **Colour**: tan. **Matrix**: recrystallized quartzofeldspathic; regions of alteration. **Clasts:** rare, rounded. **Vesicles:** Numerous; partially infilled with fine-grained quartz. **Other**: prominent alteration is Fe-oxidation.

Unit 3: **Colour**: red. **Matrix**: recrystallized interlocking igneous texture. Mineral grains are fine-grained and have feathery margins. Pervasive alteration and oxidation give the matrix a "mesh-like" appearance. **Clasts**: Heavily altered quartzofeldspathic. Textures suggestive of assimilation often observed between the clasts and matrix; otherwise angular. Glass clasts highly altered (cloudy and/or devitrified) or fresh (translucent); varying in colour: brown – red, green, black and transparent. Immiscible textures often observed between the glass clasts and the matrix. **Vesicles**: highly vesicular regions; all fill minerals are extremely fine-grained. **Other:** regions of chloritization and secondary carbonate mineralization

Unit 4: **Colour**: grey-green. **Matrix**: quartzofeldspathic fine-grained to cryptocrystalline. **Clasts**: numerous angular lithic and mineral fragmental clasts. One carbonate clast observed. **Vesicles**: lined with botryoidal chalcedony.

Unit 5: **Colour**: green. **Matrix**: highly altered and cryptocrystalline, to fine-grained and clastic; quartzofeldspathic composition. **Clasts**: similar to lithic breccia. **Glass**: high abundance and diversity of glass clasts, often highly altered. **Vesicles**: in the matrix and within larger glass clasts infilled with fine-grained alteration assemblages. **Other**: regions of secondary carbonate both in the matrix and within the lithic clasts.

Discussion and Conclusions:

Classification of Rochechouart impactites: Recommendations proposed by the IUGS subcommission on the systematics of metamorphic rocks by [3], involve a classification scheme for impactites based on texture, degree of shock metamorphism and lithological components. Inconsistency and misuse throughout the literature has lead to ambiguity surrounding many impactite suites. Of particular interest and common misuse is the term "suevite". A suevite, *sensu stricto,* is an impact breccia with a fine-grained lithic matrix hosting both lithic and glass clasts [12]. This term is often misused to refer to impactites containing glass both as clasts and as matrix/groundmass. For example, the Rochechouart unit 3 has been mapped as a "red welded suevite" [e. g. 5]. In an attempt to resolve these issues, a recent sub-classification of melt-bearing impactites has been proposed based on textural characteristics of the groundmass/matrix, with respect to melt phases, and clast content [4].

In accord with these most recent impactite classification schemes, the following nomenclature is proposed for the Rochechouart impactites. Unit 2: clast-poor to clast-free aphanitic vesicular impact melt rock. Unit 3: particulate clast-rich melt rock. Unit 3, previously known as a red welded breccia or suevite has a crystalline, rather than clastic, matrix. Immiscible textures between the matrix and glass clasts indicate that both the clasts and matrix were molten, as such, this unit is classified as melt rock. Unit 4: polymict lithic impact breccia. Unit 5: fragmental melt-bearing breccia or suevite. The distinct compositions of the Rochechouart melt rocks and the diversity of glass clasts suggest heterogeneous melt compositions and warrants further geochemical investigation.

Post-impact hydrothermal system: The pervasive argillic alteration assemblages together with fine-grained quartz and carbonate mineralization are consistent with the development of a post-impact hydrothermal system as suggested by [13]. Any hypervelocity impact into a water-rich target on a solid planetary body may generate hydrothermal systems [e g. 14]. This has implications for the identification of terrestrial and extraterrestrial impact structures and as endolithic micro-habitats for extremophillic microorganisms [15].

Target lithology: The presence of a carbonate clast within the lithic impact breccia suggests the presence of carbonate- bearing sediments in the target rocks. The Aquitaine basin adjacent to the impact site is comprised of Triassic-Cretaceous limestones [8]. Previously, the lack of sedimentary clasts hosted with the impact breccias suggested impact into a shallow sea or water free area [e.g., 2,8]. However, the identification of a carbonate clast in the polymict lithic breccia challenges this interpretation and may require the existence of a thin carbonate veneer over the crystalline target rocks at the time of impact.

The general absence of carbonate within the Rochechouart impactites may be explained by the differing responses of sedimentary and crystalline targets to shock metamorphism. Carbonate-rich sedimentary targets melt at lower shock pressures and temperatures than silicate crystalline targets [16]. Impact into the mixed sedimentary-crystalline target may have resulted in the formation of a volatile rich melt and a siliceous H_2O-CO_2 rich supercritical fluid. Following pressure release, the residual high temperature of the silicate melt may have enabled carbonate decomposition and the exsolution of the H_2O-CO_2 phase. In carbonate targets, the lower temperature of the melt precludes decomposition and the carbonate phase is rapidly quenched and preserved as carbonate melt globules infiltrating silicate melt [16]. Decomposition of carbonate as a post-impact contact metamorphic process in silica-rich melts has been previously described [e g. 17]. The formation of a siliceous, volatile-rich supercritical fluid may be an important phenomenon during hypervelocity impacts [16].

The unit 2 melt rock is highly vesicular, consistent with exsolution of a vapour phase. In addition, unit 2 is enriched in K and depleted in Na relative to the target rocks. A CO_2 rich fluid phase acts to increase the solubility of alkalis which would result in K enrichment of the melt rock. Na is relatively volatile and would likely partition into the vapour phase [18]. Further, subsequent hydrothermal activity would likely remobilize residual carbonate providing a source for the pervasive secondary carbonate mineralization.

Melt sheet: Units 2 and 3 represent compositionally and chemically distinct melt rocks. This segregation may reflect compositional heterogeneities in the target rocks: Unit 2 formed following crystallization of a volatile rich melt reflecting the presence of a carbonate veneer while unit 3 represents melting of the underlying Hercyian granites and gneisses. It is also possible that the distinct melt units represent partial differentiation of the melt sheet along chemical and thermal gradients. Unit 3 is clast-rich often preserving evidence of partial clast assimilation, while Unit 2 is comparatively homogeneous and clast poor. More thorough clast assimilation in unit 2 may reflect higher temperatures. Consistent with this hypothesis, outcrops of unit 2 are clustered around the proposed point of impact, while outcrops of unit 3 are distributed around the estimated crater rim [1,2].

In summary, the Rochechouart impactites illustrate a fundamental problem with discrete classification schemes. In reality, there is likely a continuum between clast-rich impact melt rocks and glass-rich clastic breccias (suevites). Unit 3 may represent the transition between a melt rock and a melt-rich breccia. The observation of both fragmental clasts (lithic and glass) and partially assimilated clasts is consistent with this interpretation. Furthermore, the outcrop distribution of unit 3, stratigraphically and with respect to the crater center, is intermediate between unit 2 (melt) and unit 4 (allochthonous breccia) [1,2].

References: [1] Kraut, F. et al. (1969) *Meteoritics. 4*, 190-191. [2] Kraut, F. and French, B. M. (1971) *J. Geophys. Res. 76,* 5407-5413. [3] Stoffler, D, and Grieve, R. A. F. (2007) *IUGS SCMR Recommendations*. web version 01.02.2007. [4] Osinski, G. R. (2008) *Meteor. Planet. Sci. 43*, in press. [5] Kelley, S. P. and Spray, J. G. (1997) *Meteor. Planet. Sci.* 32, 629–636. [6] Koeberl, C. (2007) *Earth Planet. Sci. Lett. 256*, 534-546. [7] Turpin, L. et al. (1990) *Contrib. Mineral. Petrol. 104,* 163-172. [8] Manes, W. (1833) *Ducourtieux, Limoges,* 140pp. [9] Lambert, P. (1974) *B.R.G.M. 2,* 153-164. [10] Lambert, P. (1977) *Earth Planet. Sci. Lett. 35,* 258-268. [11] Melosh, H. J. (1989) *Oxf Monogr. Geol. Geophys. 11,* 245pp. [12] Pohl, J. et al. (1977) The Ries impact crater. *In*: Impact and Explosion Cratering. *Eds*: D.J. Roddy, R.O. Pepin, R.B. Merrill. pp 343-404. [13] Reimold, W. U. et al. (1987) *J. Geophys. Res. 92*, E737-E748. [14] Naumov, M.V. (2005) *Geofluids. 5,* 165-184. [15] Cockell, C. S. (2006) *Phil. Trans R. Soc. Lon. G. 361*, 1845-1856. [16] Osinski, G. R. (2007) *Meteor. Planet. Sci* 42, 1945-1960. [17] Osinski G. R. et al. (2008) *GSA Special Paper #437*. [18] Reimold, W. U. et al. (1984) *LPS XV*, 685-686.