THE NATURE OF THE GROUNDMASS OF SURFICIAL SUEVITES FROM THE RIES IMPACT STRUCTURE, GERMANY. G. R. Osinski[1], R. A. F. Grieve[2], and J. G. Spray[1], [1]Planetary and Space Science Centre, Dept. of Geology, University of New Brunswick, 2 Bailey Drive, Fredericton, NB E3B 5A3, Canada, [2]Earth Science Sector, Natural Resources Canada, Ottawa, ON K1A 0E8, Canada. (osinski@lycos.com).

Introduction: Hypervelocity impact events generate pressures and temperatures that can vaporize, melt, shock metamorphose, and/or deform a substantial volume of the target sequence. The transport and mixing of impact-metamorphosed rocks and minerals during the excavation and formation of impact craters produces a wide variety of distinctive impactites [1].

Here, we present the results of a detailed field, optical, and analytical SEM study of surficial suevites from the Ries impact structure. Suevite has been generally defined as a polymict impact breccia with a *clastic* matrix containing *fragments* of impact glass and shocked mineral and lithic clasts [1]. Our study focussed specifically on the little studied and poorly understood matrix of the surficial suevites. The results of our study reveal that the matrix is not clastic as previously thought, but contains a variety of impact melt phases.

Ries impact structure: The target rocks at the ~24 km diameter, ~14.5 Ma old Ries impact structure consist of a flat-lying sequence of predominantly Mesozoic sedimentary rocks (~470-820 m thick) that unconformably overlie Hercynian crystalline basement. The basement comprises a series of steeply inclined gneisses, amphibolites and ultrabasic rocks that are cut by a later series of granitic intrusions [2]. The Ries structure possesses a sequence of impactites, including a thick series of crater-fill rocks ('crater suevite'), various types of proximal ejecta deposits (preserved up to ~37 km radius from the crater centre), and a tektite ('moldavite') strewn field extending out to distances of 260-400 km to the east of the Ries [2]. The current study focuses on the surficial suevites.

Samples and analytical techniques: Polished thin sections were investigated using a JEOL 6400 digital scanning electron microscope (SEM) equipped with a Link Analytical eXL energy dispersive spectrometer (EDS) and Si(Li) LZ-4 Pentafet detector. Beam operating conditions were 15 kV and 2.5 nA at a working distance of 37 mm, with count times of 60-100s. The clast content and modal composition of the suevite matrix were measured on representative digital BSE images using an image analysis program (Scion Image).

Petrography of the matrix: The groundmass of surficial suevites at the Ries has previously been defined optically, as all material with a grain size <1 mm [3]. Optically unresolvable phases were termed "matrix". The analytical SEM, with its greater resolution, however, reveals that the grain size fraction <1 mm comprises a number of discrete components (with ranges of vol% in parentheses): (1) silicate mineral and lithic fragments (8.9-50.1%); (2) carbonate mineral and lithic fragments (0-12.0%); (3) angular impact glass particles (0-18.3%); (4) unshocked crystalline calcite (0-42.6%); (5) fine-grained mesostasis (1.6-70.6%) (it should be noted that our classification of mesostasis encompasses that phase which has be termed montmorillonite by earlier workers); (6) impact glass commingled with calcite and mesostasis (0-16.6%) (7) Fe-Mg-bearing plagioclase and rare garnet (0-7.5%) and pyroxene crystallites (<0.5%); (9) francolite or carbonate-hydroxy-fluoro-apatite (0-5.3%); (10) Ba-phillipsite, a Ca-K-Ba zeolite (0-34.2%).

Origin of matrix phases: Here, we redefine the "groundmass" as the fine-grained *interstitial* material that encloses fragments of shocked/unshocked target material. The matrix of the Ries surficial suevites, as defined here, comprises calcite, mesostasis, impact melt glass, crystallites (plagioclase, garnet, pyroxene), francolite, and Ba-phillipsite. The phillipsite is clearly a secondary replacement mineral and will not be considered further.

Calcite. The results of this study are consistent with the hypothesis of Graup [4] that calcite within the groundmass of surficial suevites is also an impact-generated melt phase. Evidence for this includes: (1) unequivocal evidence for liquid immiscibility between calcite, silicate-rich glass, *and* mesostasis; (2) the groundmass-supported nature of calcite-rich samples; (3) the difference in composition between carbonate clasts and groundmass calcite, including high amounts of Si (up to 0.7 wt%) in the latter; (4) the presence of isolated spheroids of pyrrhotite within calcite.

Francolite. Francolite (carbonate-hydroxy-fluoro-apatite) is only present in surficial suevites that also contain granitic fluoro-apatite-bearing clasts. Clasts of fluoro-apatite typically display euhedral to subhedral overgrowths of francolite, indicating that francolite crystallized from a melt.

Glass. Impact-generated glasses form a locally important component of the groundmass in the Ries surficial suevites. There is abundant textural evidence indicating that these glasses were not quenched until after deposition. This evidence includes: (1) the presence of glass in the interstices between globules of mesostasis and calcite; (2) the preservation of delicate flow textures; (3) amorphous shapes with a lack of angular fragments.

Mesostasis. As noted, the 'clay' component of the groundmass from earlier investigations has been termed as mesostasis. At the SEM scale, several important characteristics of the mesostasis appear to be incompatible with a secondary hydrothermal origin. For example:

(1) A previously unrecognized feature of Ries surficial suevites is the presence of plagioclase, garnet, and pyroxene crystallites in the mesostasis. Plagioclase is invariably skeletal and typically displays hollow 'swallow tail' terminations, indicating rapid crystallization from a melt in response to high degrees of undercooling and supersaturation, and low nucleation densities [e.g., 5].

(2) Impact-generated glasses in the groundmass of Ries surficial suevites are intimately associated with mesostasis. Larger glass bodies can be seen to be deformed and streaked out into schlieren in mesostasis and vice versa. The preservation of delicate flow textures between groundmass-forming phases indicates that these glasses were liquid at the time of deposition (i.e., they were emplaced as silicate-rich melts). The same must, therefore, be true of the interfingering mesostasis.

(3) There is abundant textural evidence for liquid immiscibility between mesostasis and calcite and/or silicate-rich glass. It includes: (1) curved menisci with sharp boundaries between silicate-rich glass, calcite, and montmorillonite; (2) isolated globules of mesostasis within silicate glass and/or calcite; (3) the 'budding-off' of mesostasis globules into glass and/or calcite; (4) coalesced, or partially coalesced, mesostasis globules within silicate glass and/or calcite; (5) intermingling, but not blending, of mesostasis with calcite and silicate-rich glass; (6) highly deformed and streaked out mesostasis 'globules' associated with silicate-rich impact glass.

(4) Some vesicles (up to 16.8 vol%) in the mesostasis of surficial suevites (Fig. 4) retain a (sub-) rounded shape, whilst others have been deformed (Figs. 7a-c, 8b-d). A basic interpretation of the origin of vesicles is that the host phase (i.e., mesostasis) must have initially been a volatile-rich melt.

(5) There is considerable variation in the composition of the mesostasis (Fig. 11). Chemical heterogeneity is not typical of hydrothermal smectite group clays but is consistent in an initial impact melt origin for this phase.

(6) Even in surficial suevites that comprise >50 vol% mesostasis, silicate-rich glass fragments are typically fresh. This was noted previously by Graup [4], which led him to conclude that the preservation of these fresh glasses "simply rules out large-scale [hydrothermal] replacement processes".

Summary: The proposal of Graup [4], that calcite within the groundmass of surficial suevites crystallized from an impact-generated carbonate melt, is confirmed in this study. Silicate-rich glasses in the groundmass must also have quenched from an impact melt with the transformation to glass occurring after deposition. Crystallites, vesicles, and impact-generated glass and/or calcite intermingled with mesostasis are not compatible with a hydrothermal replacement model for the mesostasis. This work indicates that the calcite, silicate-rich glass, and mesostasis in the groundmass of the Ries surficial suevites originated as a variety of impact-generated melts.

Redefinition and classification of Ries surficial suevites? According to the suggested nomenclature of Stöffler and Grieve [1], suevite is defined as "polymict impact breccia with a *clastic* matrix/groundmass containing lithic and mineral clasts in various stages of shock metamorphism including cogenetic impact melt *clasts* which are in a glassy of crystallized state". However, the results of this study reveal that the calcite, silicate-rich glass, and mesostasis in the groundmass of Ries surficial suevites represent a series of impact-generated melts and that the bulk of these phases remained molten after deposition. Given that the Ries is the original type occurrence of "suevite", some reinterpretation of this term may be in order. Implications for the emplacement of surficial suevite will be also be discussed.

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