THE SUEVITE CONUNDRUM: A GENERAL PERSPECTIVE. R. A. F. Grieve[1] (rgrieve@nrcan.gc.ca), G. R. Osinski[1,2] and A. Chanou[1], [1]Dept. Earth Sciences / Centre for Planetary Science and Exploration, University of Western Ontario, London, Ontario, Canada, N6A 5B7, [2]Dept. Physics and Astronomy, University of Western Ontario.

Background: The impact breccia lithology termed suevite is defined currently from its type occurrence at the Ries impact structure. Named after the Latin name for the province of Suevia (Schwaben) of southern Germany, it is a polymict breccia with a particulate matrix, containing lithic and mineral clasts in all stages of shock metamorphism, including vitric impact melt particles [1]. The use of "particulate" to describe the matrix replaces the earlier use of "clastic" [2] and was in response to the discovery that some suevite samples from the Ries have melt material in the matrix, at the scale of SEM observations [3]. This change exemplifies the inherent nature of the definition of specific lithologies in that they are arbitrary and evolve, with changing technology and understanding of their genesis. Since the original discovery of suevite at the Ries and the conclusion that it was produced by impact processes, the occurrence of so-called "suevite" has been described from a large number of impact structures (e.g., [4]) and from a variety of geologic and spatial contexts within impact structures.

The original proposed impact genesis for the main variants of the Ries suevite was as ejecta (fallback and fallout) [5]. This remained the working hypothesis for over three decades, until it was proposed that the Ries (fallout or surficial) suevite has characteristics more in keeping with a flow, with a matrix consisting of particles of various impact melts [3]. Most recently, this working hypothesis has been challenged and replaced by one in which the genesis of the majority of the Ries suevites (so-called crater (fallback) and outer (fallout or surficial)) was the result of the explosive reaction ("fuel-coolant interaction" (FCI)) between a temporary impact melt pool with water and volatile-rich sedimentary target rocks [6].

By analogy, it has been suggested that the FCI mechanism for the origin of Ries suevite may be extended to suevite occurrences at other mid-size to large terrestrial impact structures [7]. This mechanism is acknowledged [6,7] to be equivalent to the working hypothesis for the genesis the 1.4–1.6 km thick complex series of breccias known as the Onaping Formation at the Sudbury impact structure. The working hypothesis for the genesis of the Onaping is the repeated melt-fuel-coolant-interaction (MFCI) between inundating seawater and the massive coherent impact melt pool (now represented by the Sudbury Igneous Complex (SIC)) [8]. Many of the observations in [8], however, are not equivalent to what is observed in the Ries (surficial) suevite and it is argued that, in fact, the breccias of the Onaping Formation are not suevites [8]. Thus, we have the current conundrum as to what constitutes suevite breccias and how do they form, both at the Ries type-site and at other impact structures.

The occurrence of "suevite": While suevite *sensu stricto* is defined by its occurrence at the Ries, some workers, particularly in Europe and the former Soviet Union, use the term to describe essentially any breccia with melt clasts (e.g., [9]), or provide so little descriptive detail (e.g., [4,10]), that it is not known if the lithology being discussed actually conforms to the definition of suevite. With these caveats, the literature cites the occurrence of "suevite" at simple and complex structures in crystalline, sedimentary and mixed targets [9-12]. "Suevite" appears to be the dominant allochthonous crater-fill impactite at several structures in mixed targets [12]. The absence of identified impact melt glasses in the crater-fill allochthonous breccias at some structures in sedimentary targets, e.g., [10], may be more apparent than real and reflect the level and scale of examination This is based on the more recent discoveries of melt material derived from sediments at several structures (e.g., [9,13]). In addition to crater-fill, "suevite" occurs in dikes in the parautochtonous rocks of the crater floor; below, above and within coherent impact melt sheets; and as "ejecta" [14].

The origin of "suevite": It is virtually impossible to believe that all the different geo- and litho-spatial occurrences of so-called "suevite" in impact structures have the same genesis, beyond being impactites. "Suevite" occurring beneath coherent impact sheets is most likely created by the admixture of impact melt into clastic breccia lining the cavity during transient cavity formation and subsequent modification. This is exemplified by a documented increase in the melt clast content from zero to 100% melt in "suevite", as the base of the coherent melt rocks is approached at the Mistastin structure [15]. "Suevite" occurring as dikes in the crater floor are most likely an extension of this formational process but intruded into dilatant fractures. In the case of Mistastin, this intrusion occurred when the melt bodies are still malleable, as indicated by their elongated shape and preferred orientation with respect to the flow direction. "Suevite" occurring above coherent impact melt sheets is best explained by the fallback of melt and clastic materials from a plume over the impact site. As such, it serves to cap the impact melt sheet. Although initially thermally digested by the super-heated melt, the incorporation of relatively cold clastic material from the plume and its thermal equilibration with the melt and the latent heat of melting of such fall-back debris also serves to rapidly reduce the temperature of the uppermost melt [16] and produce fine-grained, clast-rich roof rocks to the melt sheet [14,17]. Although seldom preserved in the terrestrial environment, such "suevite" deposits capping coherent melt sheets are relatively thin compared to the thickness of the melt sheet [8]. There is no intellectually satisfying explanation for the occurrence of "suevite" bodies or lenses with coherent impact melt sheets beyond the suggestion that they may be the result of the sinking of a portion of the "suevite" deposit capping the melt sheet or the rip-up of a portion of the "suevite" deposit at the base of the melt sheet [15].

The melt-bearing breccias at simple craters (e.g., Brent) have also been cited as "suevites" [10,11]. In detail, however, they differ at Brent from suevite *sensu stricto* in that the (now altered) melt glass clasts have few (< 5 %) included mineral and lithic debris and it appears unshocked, although the particulate (clastic) matrix of the breccias show abundant evidence of shock. These breccias are concentrated towards the top and center of the breccia lens and are generally explained to be the result of the collapse of the transient cavity wall and the admixing of melt lining the cavity and lithic wall material [14].

Brent illustrates that, while lithologies described as "suevite" in the literature are melt-bearing breccias, they do not necessarily have the petrographic character of suevite from the Ries (RS). This can lead to considerable misunderstanding as to the genesis of the lithologies in question. The most glaring example of this is the designation of the Onaping Formation (OF) at Sudbury as "suevite", its comparison to suevite *sensu stricto* (RS) and that call for an equivalent genesis [6,7].

The OF has distinct lithological units, gradational internal contacts, "breccia in breccia" textures and clast size and frequency diminishes with stratigraphic height. This is not the case for the RS. Within individual members of the OF there are identifiable variants, e.g., "Equant Shard" and "Fluidal" variants of the Sandcherry Member. Shock effects are relatively rare in the OF, with 90% of the lithic clasts in the OF appearing unshocked. At the microscopic level, the examination of several hundred thin sections of the OF has detected only two cases of shocked quartz clasts to-date. In contrast, 90% of the lithic clasts in the outer RS display evidence of shock [18].

The devitrified melt clasts in the OF tend to have similar shapes and are relatively well sorted and do not contain lithic or mineral clasts. In contrast, the glass clasts in the RS have "a wide range of sizes, shapes, and textures" and they contain abundant mineral and lithic clasts, many of which show evidence of shock.

The significant lithological, stratigraphic and petrographic differences between the OF and RS are clear in comparing the descriptions of the two lithologies (cf., [6, 8]). The Sudbury impact occurred in a shallow marine setting and physical interaction between sea-water and the uppermost portions of its voluminous impact melt sheet (now the SIC) is a potential outcome. If (M)FCI is a viable working hypothesis for the genesis of the OF, these differences argue against the viability of (M)FCI as a working hypothesis for the genesis of the RS.

Concluding Remarks: The variety of geo- and litho-spatial occurrences of "suevite" argues for multiple generation mechanisms and results in potential confusion both within and, more importantly, outside the impact community. While it has been argued that it is incorrect to use (initially local) terms such as "karnite" or "tagamite" to describe all coherent impact melt rocks, in general [9], the same argument may be applied to the general use of "suevite" to describe all melt-bearing breccias at impact structures.

In the end, what constitutes suevite is for the impact community, in general, to decide. The clear differences between the OF and RS, however, also argues against the (M)FCI genesis of RS and again places the genesis of the original "suevite" (RS) as potentially a still open question to be answered.

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