# "SUEVITES" OF THE WEST CLEARWATER LAKE IMPACT STRUCTURE, CANADA: A DEMONSTRATION OF THE NEED FOR A REVISED CLASSIFICATION SCHEME FOR IMPACTITES.

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**Introduction:** The term "impactite" refers to all rocks produced or affected by a hypervelocity impact event [1]. They can be subdivided into 3 main types [2]: *autochthonous* (i.e., formed in place), *parautochthonous* (i.e., moved but appear to be in place) and *allochthonous* (i.e., formed elsewhere and clearly moved to their current location). They may then be classified as *proximal* or *distal* depending on their location within and around a crater. It is allochthonous impactites that are perhaps the most well-known and interesting from the perspective of crater formation as this group includes impact breccias and impact melt rocks. In the current IUGS classification of impactites, proximal allochthonous impactites can be classified as either *polymict breccia* or *melt rock*. Melt rocks are then further classified based on clast content, which is initiative. Polymict breccias are sub-classified as either *lithic impact breccias* (without melt particles) or "*suevite*" (with melt particles)

While lithic impact breccias and impact melt rocks are relatively well understood, the term "suevite" remains the topic of considerable debate and is an ambiguous term that hampers our understanding of impact cratering processes. As reviewed most recently by. Grieve and Therriault [2] the definition of the term "suevite" has evolved over time since its original application to impactites at the Ries impact structure, Germany [3], to the point where it has been applied to impactites of such vastly different properties that it currently provides little information as to the type of impactite present. For example, in the literature, one can find reference to "suevites" that have melt clast contents from <1% to >90% and with a matrix or groundmass that ranges from purely clastic, to igneous in nature. This led Grieve and Therriault [2] to recommend that "until there is a better understanding, it may be best that the term "suevite" be reserved for the original occurrences at the Ries. Other occurrences should be termed "suevitic breccias" or, even better, be referred to more generically as melt-bearing breccias."

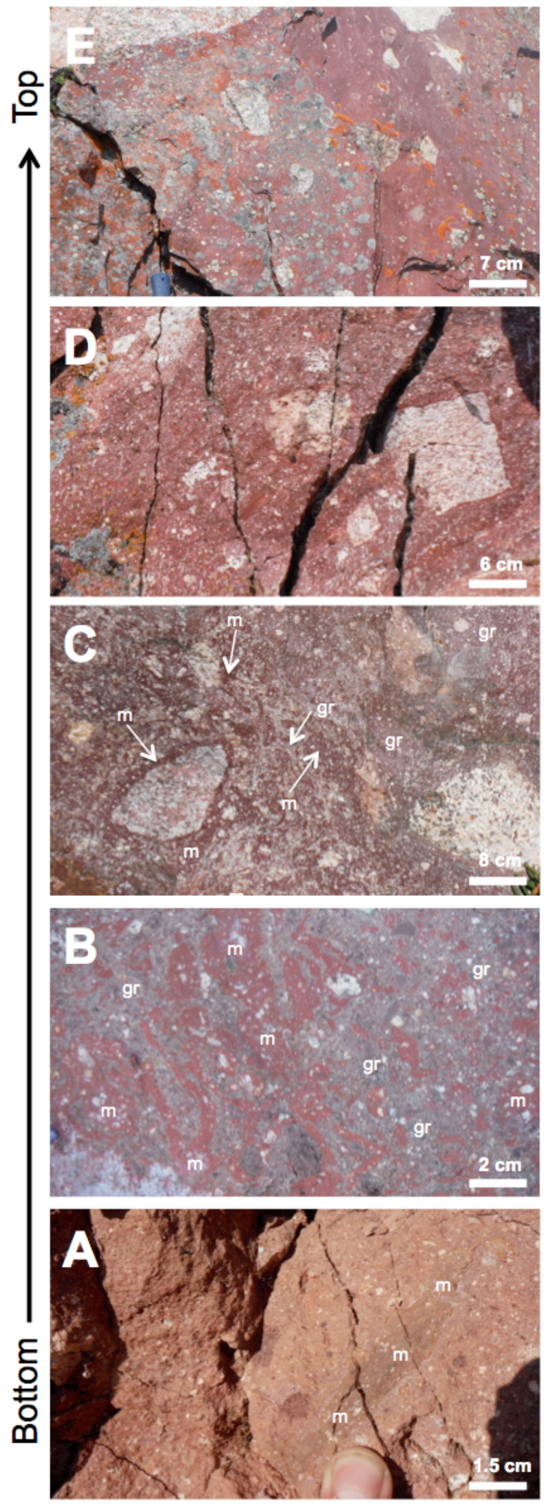


**Fig. 1.** Stratigraphy of impact melt-bearing breccias or "suevites" (A–D) underlying clast-rich impact melt rock (E) and overlying lithic impact breccia (not shown) at the West Clearwater Lake impact structure. m = melt particles; gr = groundmass. Note that in C and D it is difficult to impossible in the field to determine what is the groundmass and what is a "clast".

In this contribution, we present the results of a combined field and analytical study of allochthonous impactites from the crater-fill of the West Clearwater Lake impact structure (WCIS), Canada.

**Overview of the West Clearwater Lake impact structure:** The ~ 36 km diameter West and ~26 km East Clearwater Lake impact structures are two of the most distinctive and recognizable impact structures on Earth (56°10 N, 74°20 W) [4]. Long thought to represent a rare example of a double impact, recent age dating has called this into question with ages of ~286 Ma and ~460–470 Ma being proposed for the West and East structures, respectively [5]. Target lithologies comprise predominantly granitic gneiss, granodiorite, and quartz monzodiorite with later diabase dykes.

The WCIS is relatively well preserved with large ring of islands in the ~30 km diameter lake. Much of the work done on West Clearwater stems from field investigations carried out in 1977 driven by the Apollo program, with a focus on the impact melt rocks and other impactites [6, 7], which are well exposed on the ring of islands. In August and September 2014 we carried out an expedition to the WCIS, under the auspices of the FINESSE (Field Investigations to Enable Solar System Science and Exploration).

**Impactites of the West Clearwater Lake impact structure:** Over the course of the 5-week field campaign we were able to visit and map all of the major islands within West Clearwater Lake. Excellent cliff exposures around the coasts of many of the islands allow a general stratigraphy of impactites to be defined (from the bottom upwards): Fractured basement => lithic impact breccia => impact melt-bearing breccia or "suevite" => clast-rich impact melt rock => clast-poor impact melt rock.

*"Suevite".* One of the most distinctive impactites at WCIS is a breccia containing variable proportions of red, oxidized impact melt particles set in a fine-grained matrix (Figs. 1A–D). This impactite can form cliffs >40 m high in places and is missing in others so that clast-rich impact melt rocks (Fig. 1E) immediately overly fractured basement.

Where exposed, these impact melt-bearing breccias overlie melt-free lithic impact breccias. No obvious contacts were discernable in the field and instead, the first occurrence of impact melt-bearing breccia was defined with the first unequivocal identification of (now altered) glass particles (Fig. 1A) in an impactite that otherwise is the same as the underlying lithic impact breccias. Moving upwards stratigraphically there is a general increase in melt content (see sequence from Fig. 1A to 1D).

Whereas in the lower levels of the impact melt-bearing breccias, it is possible to easily differentiate glass particles (Figs. 1A,B), with increasing proximity to the upper contact with the clast-rich impact melt rock is approached, the proportion of "melt particles" and "groundmass" approach equality and it is difficult to impossible in the field to determine what is the groundmass and what is a "clast". Indeed, the upper contact with the clast-rich impact melt rocks can best be described as gradual over distances ranging from several 10s of cm to several 10s of m.

With respect to the term "clast", most of the glass component of the impact melt-bearing breccias cannot be described as such: they do not have angular obviously broken shapes and instead intermingle with the surrounding clastic "groundmass" component. And as noted above, in some instances one could easily call the melt the groundmass or the clastic component the groundmass (Figs. 1C,D).

**Summary and implications:** There is a complete continuum from melt-free lithic impact breccias to clast-poor impact melt rocks at WCIS. Contacts are gradual in most instances and in many outcrops, both the melt and clastic component can be considered the groundmass and vice versa. It is, therefore, not possible to classify these rocks according to the current IUGS classification scheme. When taken together with studies of other terrestrial impact structures in the past decade, we propose that a revised classification scheme for allochthonous impactites be developed that more clearly captures the *properties* of impactites such that nomenclature informs studies of the *processes* of impact cratering rather than being an impediment. We welcome ideas and input from the community.

Of further note is that "melt-rimmed" lithic clasts and "aerodynamically-shaped glass bombs" are common in the impact melt-bearing breccias at WCIS beneath the coherent impact melt sheet. Elsewhere, these textures would be interpreted to mean an airborne mode of transport (e.g., [3]). However, these impactites at West Clearwater can never have been airborne as they lie *beneath* the impact melt sheet. Thus, such textures should not be automatically used to invoke an airborne mode of origin, nor do these textures mean that the deposits in question are ejecta deposits.

**References:** [1] Stöffler, D. and Grieve, R.A.F. (2007) *in* D. Fettes and J. Desmons, eds. Cambridge University Press. 82–92. [2] Grieve, R.A.F. and Therriault, A.M. (2012) in *Impact Cratering: Processes and Products*. G.R. Osinski and E. Pierazzo, eds. Wiley-Blackwell. 90–105. [3] Stöffler, D. (1977) *Geol. Bav.*, *75*, 443–458. [4] Grieve, R.A.F. (2006) *Impact Structures in Canada*. Geol. Assoc. Canada. [5] Schmieder, M. et al. (2015) *Geochim. Cos. Acta*, *148*, 304–324. [6] Simonds, C.H. et al. (1978) *Proc. LPSC*, *9*, 2633–2658. [7] Phinney, W.C. et al. (1978) *Proc. LPSC*, *9*, 2659–2693. [8] Bostock, H.H. (1969) *The Clearwater Complex, New Quebec. GSC Bulletin 178*.