REVISTING THE ORIGIN OF THE RIES GRADED SUEVITE: IMPLICATIONS FOR PLUME FALLBACK PRESERVATION. M. J. O. Svensson[1], G. R. Osinski[1], F. J. Longstaffe[1], [1]Institute for Earth and Space Exploration / Dept. Earth Sciences, The University of Western Ontario, 1151 Richmond Street N. London, Ontario, Canada, N6A 5B7 (msvenss@uwo.ca)

Introduction: Graded deposits of impact generated subaerial fallback (material that has settled out of an ejecta plume and back into the crater) are the subject of some debate as they can be difficult to conclusively identify [e.g., 1–5]. While many impact craters boast a long lived and continuous post-impact sedimentary record, few studies have reported on graded material subaerially deposited from the ejecta plume [e.g. 6]. In this study, we apply the classification criteria for such subaerial fallback deposits at Bosumtwi crater to similar deposits at the Ries crater and speculate what processes may control their preservation. While the term “fallback” has been used to describe melt-bearing breccias often called “suevite” at many impact craters, the merits of such terminology has been the subject of some discussion [e.g., 2, 3, 7], so for the purposes of this study subaerial fallback shall specifically refer to graded deposits.

Background: The ~24 km diameter, ~ 14.8 Ma [8] Ries crater in southern Germany is a complex impact structure with an inner and outer ring. The inner ring of the impact structure hosts the majority of the post-impact sedimentary deposits from the crater’s lacustrine system, and hosts melt-bearing breccias that comprised a significant source of heat for the impact generated hydrothermal system [9]. At the transition from lacustrine deposits to impact melt-bearing breccias is a graded sequence dubbed the “graded suevite” [2, 10]. This graded unit, sampled by the Nördlingen 1973 drill core (FBN73), transitions from medium gravel at its base to silt at its top (Fig 1a), and is interbedded with pervasively altered breccias. While this is interpreted as a single depositional event [10], there are contradicting interpretations regarding the nature of this event. Original interpretations of Jankowski (1977) suggest that the most probable explanation is that this graded sequence was formed from the fallback of ejected impact material; however, the author does acknowledge the possibility of deposition from a turbidity current and states that such an interpretation would require further study. Artimeiva et al. (2013) studied the same graded sequence and used a comparison of subaerial and subaqueous particle settling models to determine the amount of water or air necessary to grade such a mixture of sediment [5]. The results showed that subaerial deposits were well-mixed, whereas the subaqueous deposits were well-graded, thus suggesting subaqueous deposition of the graded unit.

If the graded unit at the Ries was deposited subaerially it is reasonable to expect that such subaerial fallback should contain accretionary lapilli, or glass spherules similar volcanic deposits [11]. Such particles have been documented at the Ries impact structure by Graup (1981) and more recently by Meyer & van Gasselt (2012); however, these spherules were found in a basal unit of the lacustrine deposits (FBN73: 296–314 m) overlying the graded unit (FBN73: 314 – 331 m). To date, no such particles have been reported in the graded unit itself.

The ~10.5 km diameter, ~1.0 Ma [12, 13] Bosumtwi crater in southern Ghana is a complex impact structure with an exposed outer rim and a small central uplift submerged beneath Lake Bosumtwi. Bosumtwi hosts graded fallback deposits similar to the Ries’ graded unit, which provides a standard by which Ries’ graded unit can be studied. Roughly spherical aggregates of clastic material comprise Bosumtwi’s accretionary lapilli, and glass clasts occur in spherical, teardrop, dumbbell and irregular shapes [6]. These lapilli were most abundant at the top of the graded fallback deposit and showed a notable population decrease with depth.

Objectives / Methods: This study revisits the graded unit from 314–331 m in FBN73, contributing a focused report on the nature of any accretionary lapilli and glass clasts, and draws a comparison to the fallback deposits of Bosumtwi crater. The mineral character and textures of the graded unit was determined using optical microscopy, and back-scattered electron (BSE) imagery collected via electron microprobe analysis (EMPA). Micro X-ray fluorescence imaging (μXRF) was used to qualitatively estimate the elemental composition of the most friable material and to contextualize microscale features.

Results / Discussion: The 17 m graded unit at the Ries was logged in detail, with 15 representative thin sections made to document the 13 lithological changes observed along this transect. Glass occurred in the basal gravelstone of the graded sequence (324 m) in mm scale, sub-rounded, irregular, and dumbbell shapes (Fig. 1b–1d) with sub-rounded glasses being the most common. These glasses were internally fractured with argillic alteration along the fractures. Additionally, these glasses were felsic with inclusions of fine clastic material. Coarser, cm scale glasses were also documented towards the base of the Ries’ graded unit at 323 and 322 m. These Fe / S rich glasses are bordered by smectitic alteration halos and are associated with the deposition of bladed calcite along fractures that link multiple occurrences of these cm scale clasts together [14]. Spherules of glass or accretionary lapilli were absent throughout the graded unit.

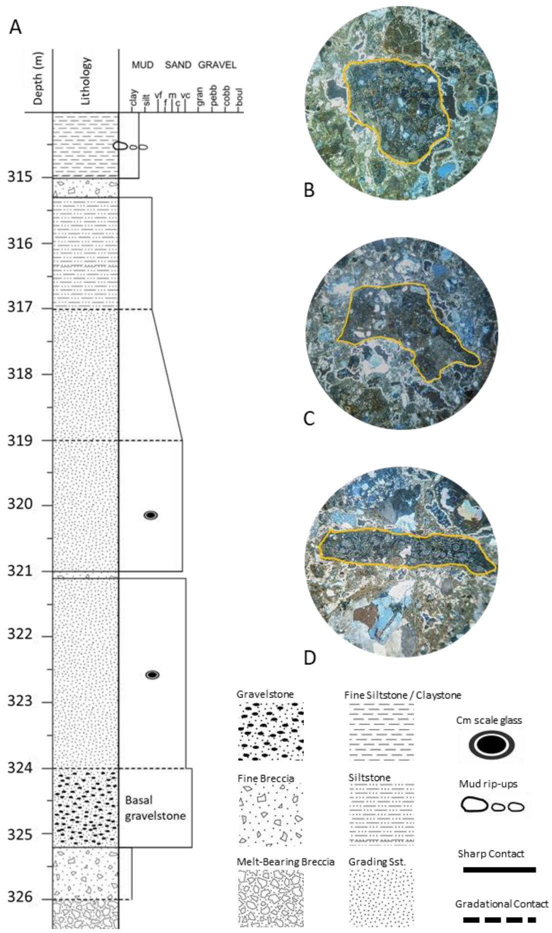

Figure 1. A stratigraphic column illustrating the general lithological trends in the Ries graded unit (A). Cross polarized images of glass clasts found in the basal gravelstone: sud-rounded (B), irregular (C), dumbbell (D).

An important distinction between the glass lapilli-like features in the Ries' graded unit and those in Bosumtwi's fallback deposits is that there is an inverse population distribution. The glass clasts at the Ries are more common at the base of the graded unit, whereas they occur in abundance at the top of the unit at Bosumtwi [6]. The top of Ries' graded unit lacked any accretionary lapilli or glass clasts.

The absence of accretionary lapilli throughout the graded unit and the inverted distribution of glass clasts is in contrast to the findings from Bosumtwi crater. Additionally, the concentration of the coarser glass clasts towards the base of the sequence and the prevalence of sub-rounded glass clasts suggests they were subject to erosional transport. As such, deposition from a turbidity current as suggested by Artimeiva et al. (2013) seems the more likely scenario in this case. This depositional setting would also explain the grading observed throughout the unit.

There remains some debate regarding whether there are any "true" ejecta plume fallback deposits are at the Ries impact structure [e.g., 1–5]. An important consideration for this discussion would be the climate and hydrological conditions under which the impact event occurred. The age of the Ries suggests it occurred during the Mid-Miocene Climatic Optimum, and reports on its lacustrine history suggest an early and rapid influx of water [15, 16]. The rapid infilling of water combined with ongoing hydrothermal activity and subaerial fallout are likely processes that impeded the preservation of subaerial fallback from the ejecta plume. In contrast, the age of the Bosumtwi impact crater suggests it occurred during arid episodes that marked the terminal Pliocene, and that precipitation and evaporation had a greater influence on its early lacustrine processes [17]. A slower influx of water into Bosumtwi's basin could have resulted in better preserved ejecta plume fallback deposits; however, this would require additional research to fully explore.

Conclusions: The results of this study suggest that the graded unit present in FBN73 is more likely to have formed from subaqueous deposition than subaerial. This would indicate that they in fact represent early lacustrine processes at the Ries. It is possible that the complex interaction of multiple post-impact modification processes at the Ries impeded the preservation of ejecta plume fallback, but this requires further study.

References: [1] Graup G. (1981) *Earth and Planetary Science Letters*, **55**: 407-418. [2] Stöffler D. (1977) *Geologica Bavrica*, **75**: 443–458. [3] Osinski G. R. et al. (2004) *Meteoritics and Planetary Science*, **39**: 1655–1683. [4] Meyer C. & Gesselt S. v. (2012) *Ph.D. Dissertation*. [5] Artimeiva N. A. et al. (2013) *Meteoritics and Planetary Science*, **48**: 590 – 627. [6] Koeberl C. et al. (2007) *Meteoritics and Planetary Science*, **42**: 709–729. [7] Engelhardt W. v. et al. (1995) *Meteoritics and Planetary Science*, **30**: 279–293. [8] Schmieder et al. (2018) *Geochimica et Cosmochimica Acta*, **220**: 146–157. [9] Osinski G. R. (2005) *Geofluids*, **5**: 202–220. [10] Jankowski B. (1977) *Geologica Bavarica*, **75**: 21–36. [11] Brown R. J. et al. (2010) *Geological Society of America Bulletin*. [12] Schnetzler C. C. et al. (1966) *Science*, **151**: 817–819. [13] Koeberl C. et al. (1998) *Geochemica et Cosmochimica Acta*, **62**: 2179–2196. [14] Svensson M. J. O. et al. (2019) *LPSC LI*, Abstract #3072. [15] Pohl et al. (1977) *Impact and Explosion Cratering*. Pergamon, New York: 343-458. [16] Stöffler D. et al. (2013) *Meteoritics and Planetary Science*, **48**: 515–589. [17] Shanahan T. M. et al. (2006) *Palaeo*, **242**: 287–302.

Acknowledgements: The authors acknowledge the funding from the Natural Sciences and Engineering Research Council of Canada Discovery Grants Program and the Canada Research Chairs Program, and the sampling assistance of the ZERIN team.