SECONDARY MINERALIZATION ALONG THE IMPACTITE – LAKE DEPOSIT TRANSITION IN THE NÖRDLINGEN 1973 DRILL CORE, RIES IMPACT STRUCTURE, GERMANY. 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: The sequence of events recorded by the continuing sedimentation in the central and annular depressions of complex impact structures is valuable for preserving the history of lake formation and the evolution of such structures' host environment. At the Ries impact structure, southern Germany, studies of the post-impact lacustrine deposits have had a similar focus [e.g. 1, 2, 3]. Hydrothermal modification of the Ries' lacustrine deposits is also preserved by the sedimentary record [4, 5], providing an opportunity to study the Ries hydrothermal system and possibly its interaction with the overlying lake environment.

Lake environments with input from underlying hydrothermal systems could provide suitable habitats for life [6, 7]. This is especially relevant in Martian environments that would otherwise be less habitable. Jezero Crater, the landing site of the Mars 2020 sample return mission, hosts rover-accessible deltaic deposits and possible lacustrine carbonates [8, 9]. It remains unknown whether these deposits were modified by impact-generated hydrothermal activity. Studying secondary mineralization preserved in post-impact sedimentary deposits on Earth will better inform exploration of Jezero crater.

The crater-fill impact melt-bearing breccias ("suevite") and the post-impact lacustrine rocks sampled by Nördlingen 1973 drill core from the Ries impact structure have been studied extensively. Here, we revisit the transition from suevite to the post-impact lacustrine rock sampled by the Nördlingen 1973 drill core, provide a detailed log of the transition and study the main secondary phases previously reported by Füchtbauer et al. [4] and Jankowski et al. [5].

Background: The Ries impact structure is hosted in sedimentary Mesozoic rocks unconformably overlying a crystalline Hercynian basement. Ries is a ~24 km diameter complex crater with a ~16 km diameter inner ring enclosing a central basin (Fig. 1) [10]. Impact melt-bearing breccias deposited within the inner ring (crater-fill suevites) are overlain by ~336 m of siliciclastic lacustrine rocks (basin-center deposits). Impact melt-bearing breccias are also discontinuously deposited beyond the inner ring (surficial suevite) but are rarely in contact with overlying lacustrine deposits [11]. In general, suevite at the Ries consistently bears varying degrees of hydrothermal alteration, which suggests that it supplied the main source of heat for an impact-generated hydrothermal system [12]. Füchtbauer et al. [4] and Jankowski [5] documented glass- derived montmorillonite and analcime in the basal lacustrine deposits spanning 314–256 m in the Nördlingen 1973 drill core [4, 5] but did not focus on the secondary mineralization.

Objectives and Methods: This study contributes a detailed log of the transition from the crater-fill suevite to the post-impact lacustrine sediments sampled by the Nördlingen 1973 drill core at the Ries impact structure and highlights trends in secondary mineralization along this transition. Mineralogy was determined using optical microscopy, powder X-ray diffraction (pXRD), and back-scattered electron (BSE) imagery collected via electron microprobe analysis (EMPA). Micro X-ray fluorescence imaging (μXRF) was utilized to constrain the elemental distribution at the macroscale and contextualize microscale features.

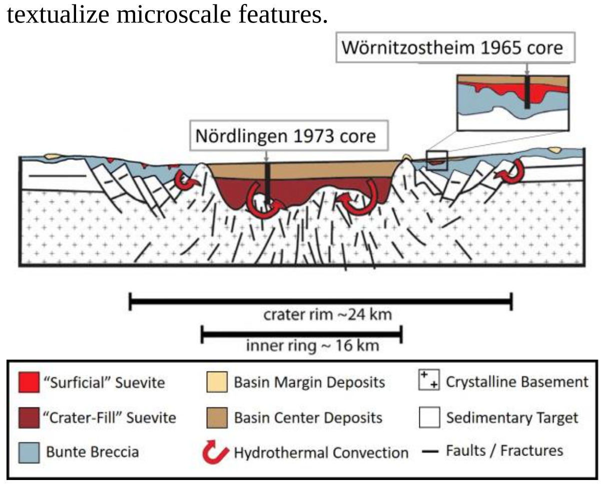

Figure 1: Cross section of the Ries impact structure showing the target rocks, proximal impactites, post-impact lacustrine deposits and major boreholes [13].

Results/ Discussion: The Nördlingen 1973 core was drilled within the bounds of Ries' inner ring (Fig. 1) where it sampled siliciclastic basin center deposits underlying crater-fill suevite and the fractured crystalline basement. For this study, 142.6 m of core was logged from a depth of 334.6-192.0 m, capturing the transition from crater-fill suevite to post-impact sedimentary rocks. There were 82 changes in lithology documented along the 142.6 m transect. A set of 38 samples were taken and those along the transition showing signs of secondary mineralization were targeted for focused study.

There are 3 main styles of secondary mineralization throughout the logged section of drill core, which vary with rock type and depth. The styles include (1) alteration halos associated with glass clasts, (2) bladed calcite in fractures and vugs, and (3) varying degrees of lithic and glass clast replacement with argillic material.

Alteration halos associated with glass clasts occurs throughout most rock types sampled over the 142.6 m transect. Generally, the frequency and size of the alteration halos increases with depth. The most prominent occurrences exist in sandstones from 320-323 m depth (Figs. 2a, b); a section previously described as part of a "graded suevite" unit [14]. The *p*XRD and *μ*XRF analyses show that the argillic material comprising the halos consists mainly of Fe-Mg smectite.

Fillings of fractures and vugs with bladed calcite occur at depths greater than 320 m. From 320-323 m, fracture-fillings of bladed calcite are associated with glass fragments (Fig. 2b). At depths greater than 323 m bladed calcite occurs mainly as vug fillings in brecciated material and crater-fill suevite (Fig. 2c).

BSE imagery, *p*XRD and optical microscopy shows that pre-impact K-feldspar mineral clasts, glass fragments, and potassic granitic lithic clasts are commonly altered to argillic material in breccias and conglomerates throughout the drill core with varying degrees of intensity. Below 287.3 m, this style of secondary mineralization generally is more pervasive. Glass fragments are consistently replaced predominantly by smectite, whereas K-feldspar grains and potassic granitic fragments are altered to illitic clays.

The majority of secondary mineralization in the transect studied here is concentrated in a 36.7 m subsection spanning 287.3-324.0 m. This subsection comprises a fining-upward sequence of sandstones that host the first and second mineralization styles interbedded with breccias that host the third mineralization style.

Conclusions: The bladed calcite present in sandstones throughout this subsection indicates that boiling occurred during secondary mineralization [14]. The association of glass fragments with both bladed calcite and argillic alteration halos suggests that the origin and timing for both styles of mineralization were similar in the sandstones. The sharp contacts between the breccias and sandstones suggest differing depositional origins. The fact that the third mineralization style exclusively occurs in breccias, and the fact that the alteration to the breccias is consistently more pervasive than the sandstones, indicates that the timing and origin of the third style of mineralization could differ from the first and second. The material comprising the breccias may have been altered, at least in part, prior to deposition and, therefore, predate the first and second styles. Intermittent slumping of previously altered material from the crater-rim [15] could allow for pervasively altered breccias to become interbedded within a fining upward sandstone sequence, which was concomitantly affected by alteration that diminishes in intensity with decreasing depth. However, the exact timing of the mineralization in the breccias with respect to the sandstones remains unclear. Upcoming *p*XRD and $\delta^{18}O$ measurements of <2 μm clay separates will provide more insight into the hydrothermal alteration history.

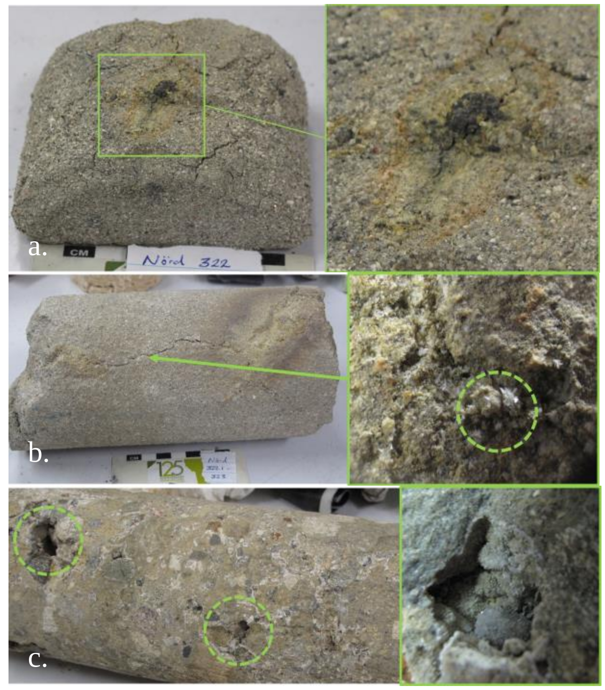

Figure 2: Hand specimens showing mineralization styles: (a) alteration halos associated with glass clasts; (b, c) bladed calcite in fractures and vugs.

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