
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-de-
tion halos associated with glass clasts, (2) bladed calcite in fractures and vugs, and (3) varying degrees of lithic and glass clast replacement with argillitic material.

Alteration halos associated with glass clasts occur 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 µXRD and µXRF analyses show that the argillitic 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, µXRD and optical microscopy shows that pre-impact K-feldspar mineral clasts, glass fragments, and potassic granitic lithic clasts are commonly altered to argillitic 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 µXRD and δ18O 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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