RIES CENTRAL BASIN AS RESOLVED BY HIGH RESOLUTION SEISMIC PROFILES N. McCall[1], S.P.S. Gulick[1], K. Sarv[2], A. Jõeleht[2], J. Wilk[3], G. Pösges[4], [1]University of Texas at Austin, Jackson School of Geosciences, Institute for Geophysics, 10100 Burnet Rd Bldg ROC, Austin, Texas 78758, USA (nmccall@utexas.edu),[2]University of Tartu, Department of Geology, Tartu, Estonia, [3]University of Freiburg, Institute of Earth and Environmental Sciences, Freiburg, Germany, [4]Geopark Ries, Harburg, Germany.

Introduction: In August 2017, we collected 4 seismic profiles at Ries Crater, Germany, imaging one half of the crater profile from outside the southern crater rim to the crater center (Figure 1). The seismic source was an Earth tamper capable of visualizing reflections 1.5 km deep. The tamper generated about 300-500 compressions over a 45 second listening period. Our acquisition configuration had 72 channels with 5 geophones each and channel spacing at 10 m. Maximum offset from source to receiver was 710 m. We present 2 seismic profiles of the inner crater to better our understanding of the subsurface structure of Ries and the emplacement of the suevite in the crater basin. The last seismic survey at the crater was in 1968 and this is the first high resolution seismic data acquired

The 15 Ma, 26 km wide Ries Crater in Southern Germany is a well preserved mid-sized impact crater (Figure 1). Its diameter is near the 25-30km threshold to form a peak ring [1, 2] however current interpretations identify a crystalline ring formed by an upturned crater rim [3] but not a true peak ring formed by material outwardly collapsing from a central uplift [4]. Proposed suevite deposition processes include fallback from an impact plume [5], melt flow [6] and impactoclastic density current [7] and melt-coolant interaction [8].

Interpretations: Within the inner basin, we identify 3 seismic facies on our profiles (Figure 2). Seismic facies A is defined by thin, low amplitude nearly horizontal reflectors. When not horizontal, they drape over relief from below. Seismic facies B expresses higher amplitude reflectors than facies A. The reflectors are also less continuous, and they show changes in topography, with pronounced peaks at the proposed crystalline ring and subdued peaks towards the crater center (Figure 2). In between the crystalline ring and crater center the reflectors in facies B are subparallel, and some reflectors terminate (layers pinch out) in both directions of the profile. Seismic facies C resolves few reflectors, the reflectors that are visible are discontinuous with multiple dipping orientations and a hummocky relief. Reflectors are generally not resolvable by 0.5s two-way-travel time (twtt) and the profile shows no reflectors present past 0.75s twtt (Figure 2).

We use the Nördlingen 1973 core descriptions and sonic log as well as the low-resolution 1968 seismic data aid our interpretation of the subsurface. The generalized lithology units recovered in the 1973 core are as follows: post-impact pelitic lake sediments (0-256m), reworked suevite (256m-314.5m), graded suevite (314.5-331.5m), high temperature, melt rich suevite (331.5-525m), low temperature, melt poor suevite and crystalline basement (525-605m), and crystalline basement with dike breccias (605-1206m) [9,10].

The Nördlingen 1973 borehole is 1.95km from the NW end of seismic line 1701 and 2.5 km from the northern end of seismic line 1702 (Figure 1). Although our new seismic lines do not intersect the well, the lower resolution 1968 seismic profile crosses the borehole and shows prominent reflectors that correspond to our seismic facies B, indicating that the deposition near the crater center in our seismic profiles and the 1973 borehole are similar. The sonic log provides travel times for the lithological units in the borehole which can be used as check on our seismic velocities and interpretation.

Based on the continuous and near horizontal expression of the reflectors and slow seismic velocities we interpret seismic facies A to be the pelitic post-impact lake sediments and possibly reworked lithologies from the suevite unit and graded suevite.

We interpret Seismic facies B (Figure 2) to image the high temperature suevite. Using the sonic log the high temperature suevite should begin near a depth of 331m or 0.35s twtt for comparison with seismic profiles. Our seismic profiles display high amplitude reflectors beginning between 0.3 - 0.35s which are also present at 0.35s present on the 1968 seismic profile. There are multiple reflectors in the suevite with morphology suggesting the suevite flowed multiple directions in the inner crater, possibly from a pyroclastic like-flow (Figure 2).

We interpret seismic faces C to be the low temperature suevite and the basement. Instead of a sharp contact between the suevite and the basement, the Nördlingen borehole shows sequences of suevite followed by large blocks brecciated basement from 505m to 605m, at 605 m the core is mostly brecciated basement with some suevite dikes [9]. This may be why the reflectors below facies B are discontinuous and only resolvable close to the facies B-C transition (Figure 2). Facies C forms 3 structural highs on line 1702, centered at CDPs ~0, 2500 and 8000, This corresponds to 2 peaks near the projected location of the crystalline ring and a more subdued peak towards the center of the of the crater; this inwardmost topography that may represent a collapsed central uplift.

Conclusion: We present the first seismic profiles from Ries crater in many decades. These high-resolution data image post impact sediments, suevite and basement showing the subsurface morphology. Geometry of the reflectors in the suevite within the crater is suggestive of deposition as lateral flows, which points to a ground hugging density currents (impactoclastic flows) rather than deposition from fallout. Topographic highs expressed in the basement are interpreted as expressions of the crystalline ring, which is not a peak ring, and a collapsed central uplift. This morphology places Ries Crater near the upper limit of a central peak crater where dynamic collapse occurred but was limited in duration and extent.

Acknowledgments: This research supported by the Barringer Family Fund for Meteorite Impact Research and the Jackson School of Geosciences Off Campus Research Award funded by the Ronald K. DeFord Field Scholarship Fund. Data acquisition supported by the University of Tartu.

References:

[1] Alexopoulos, J. S. and McKinnon, W. B. Geol. Soc. Am. Spec. Pap. 293, 29–50 (1994). [2] Melosh, H. J. Impact Cratering: A Geologic Process (Oxford Univ. Press, New York, 1989). [3] Wünnemann, K., Morgan, J. V., & Jödicke, H. (2005). Large meteorite impacts III (384) Geol. Soc. of Am.[4] Morgan, J. V., et al., (2016). Science, 354(6314), 878-882. [5] Stöffler, D., et al., (2013). Met. & Pl. Sci.e, 48(4), 515-589.
[6] Osinski, G. R. (2004). Earth and Pl. Sci. Letters, 226(3-4), 529-543. [7] Branney, M. J., & Brown, R. J. (2011). The Journal of Geol., 119(3), 275-292. [8] Artemieva, N. A., et al., Met. & Pl. Sci., 48(4), 590-627.
[9] Pohl, J., Bader, K., Berthold, A., Blohm, E., Bram, K., Ernston, K., … Wiesner, H. (1977). The research Drillhoe Nördlingen 1973 in the Ries crater - a summary of geophysical investigations. Geologica Bavarica , (75), 323–328. [10] Stöffler, D. (1977). Research drilling Nördlingen 1973: Polymict breccias, crater basement, and cratering model of the Ries impact structure. Geologica Bavarica, 75, 443-458.

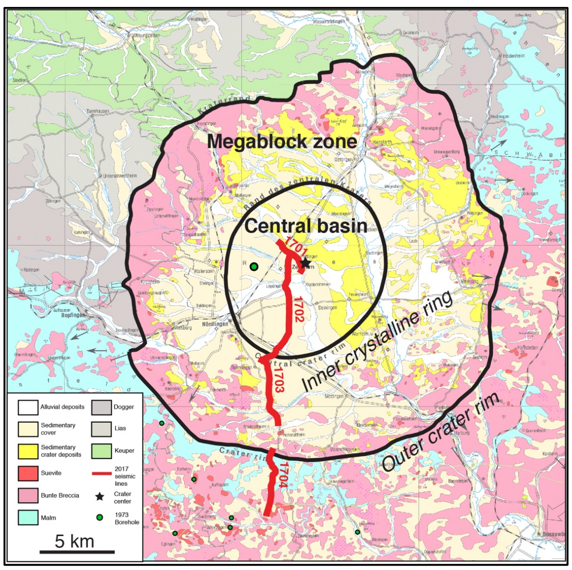

Figure 1 (left): Geologic map of Ries crater with 2017 seismic profiles plotted in red. Map by Schmidt-Kaler 1999 Bayerisches Geologisches

Figure 2 (below): Seismic line 1702 with seismic facies. Location shown on Figure 1.