NÖRDLINGER RIES AND STEINHEIM BASIN – ANOTHER DIVORCED IMPACT CRATER COUPLE?

E. Buchner[1], M. Schmieder[1], and V. J. Sach[2], [1]HNU - Neu-Ulm University of Applied Sciences, Wileystraße 1, D-89231 Neu-Ulm, Germany, E-mail: elmar.buchner@hnu; martin.schmieder@hnu.de, [2]Fokus Natur, Am Heselsberg 29, D-88416 Ochsenhausen, Germany, E-Mail: vsach@gmx.de.

Introduction: The ~24 km-diameter Nördlinger Ries and the ~4 km–diameter Steinheim Basin [1] in Southern Germany count among the best-preserved asteroid impact structures on Earth. The complex Ries crater is characterized by a partially preserved blanket of proximal impact ejecta [2,3]. A coarse-grained distal Ries ejecta layer forms a marker bed in sediments of the North Alpine Foreland Basin (NAFB) [3]. The components of this layer were ballistically transported over distances up to 180 km [2,3]. The Steinheim Basin, ~40 km SW of the center of the Ries crater, is a complex impact crater with a prominent central uplift set in a sequence of Mesozoic sediments and is well known for its shatter cones of outstanding shape and quality [1]. Unlike at the Ries, Steinheim ejecta are scarce to virtually absent in the surroundings of the crater. Hence, distal impact ejecta occurences in southern Germany and northern Switzerland that include shattered limestone clasts and fossils and/or shocked quartz grains [3] are generally attributed to the Ries impact. While isotopic techniques failed to yield a meaningful age for Steinheim, the crater is generally thought to have formed simultaneously with the Ries crater at ca. 14.81 Ma [2] by the impact of a binary asteroid. However, crater lake deposits of different age in both structures cast some doubt on the double impact theory.

A new aspect of understanding the Ries-Steinheim scenario is the sedimentologic study of the seismic damage the two impact events caused in their wider surroundings. Large asteroid impacts are known to trigger intense earthquakes. According to energy equations and numerical modeling [5], the Ries impact likely caused a magnitude M_W ~8.5 earthquake, while the much smaller Steinheim impact event may have caused an earthquake of M_W ~6.5 to 7. Impact-earthquakes can produce seismites in extensive volumes of near-surface sediment [3,6]. Systematic sedimentologic, structural, and stratigraphic evidence for palaeo-earthquakes in the surroundings of the two Ries and Steinheim impact structures in the form of impact-produced seismites is currently emerging [3,4,7].

Results: We discovered ~5 to 15 m-thick sedimentary successions characterized by distinct soft-sediment deformation structures at various outcrop sites in the western part of the NAFB, mainly in ravines in the Hochgeländ plateau (Biberach a. d. Riß) and near Ravensburg [3]. Soft-sediment deformation structures include meter-sized slumps, convolute bedding, ball-and-pillow and flame structures, and clastic dikes [3]. Such soft-sediment deformation features in continental deposits are typical of seismites caused by large earthquakes. The horizon of distal Ries ejecta that often caps the seismite unit provides compelling evidence that the Ries impact was the source for this seismic event [3,4]. Large clastic dikes crosscutting the Ries seismite horizon described in an earlier study [3] strongly support a second major seismic event that postdates the Ries impact. We recently discovered two independent seismite horizons in outcrops at distances 50–100 km from the Ries crater and 50–70 km from the Steinheim Basin. Both the lower and upper seismite horizons feature the full inventory of seismically produced dewatering structures. The two seismite units are separated by ~5 to 12 m of undisturbed mid-Miocene Upper Freshwater Molasse deposits.

Discussion and Conclusions: The up to 15 m-thick (lower) Ries seismite unit overlain by distal ejecta forms a unique continental seismite-ejecta couplet in the western part of the NAFB [3]. The upper seismite horizon resembles the Ries seismite in many ways, but is only ~2 to 5 m thick. Bio-lithostratigraphic analysis and correlation indicate the upper seismite has an age of ~14.3 to 14.0 Ma, that is, ~0.5 to 0.8 Myr younger than the Ries impact [2,3]. No distal impact ejecta have thus far been found on top of the upper seismite horizon. Hence, endogenic potential trigger mechanisms and source regions should be considered to explain the formation of this horizon, such as tectono-seismic (e.g., Alpine tectonics; Rhine Graben and Hohenzollern-Graben) and volcano-seismic (e.g., Hegau and Urach-Kirchheim volcanic fields) activity. Although tectono- or volcano-seismic activity may have played an important role in the NAFB, exposures of the upper seismite horizon situated only 50 km south of both impact craters are arguably too far away to be convincingly explained by any of those endogenic seismic sources in the mid-Miocene [3]. Instead, the upper seismite horizon may be an effect of the Steinheim impact event. Support for a Steinheim-related origin of the upper seismite horizon comes from fossils found associated with this layer. The lower seismite, corresponding to mammal zone (MN) MN5/6, and the upper seismite, corresponding to MN6 to 6/7, are biostratigraphically separated by (almost) an entire biozone. Furthermore, both seismite horizons can be biostratigraphically correlated with the basal crater lake sediments in the Ries (MN5/6) and Steinheim (MN6 to MN6/7) impact craters [1,2]. The bio-litho-stratigraphic constraints lead us to conclude that (1) the Ries and Steinheim craters were produced by two separate impact events only ~40 km and ~0.5 to 0.8 Myr apart; and (2) both impacts likely triggered major earthquakes.

References: [1] Heizmann, E.P.J. and Reiff, W. (2002) *Der Steinheimer Meteorkrater*. Pfeil, Munich. [2] Schmieder, M. et al. (2018) *GCA* 220:146–157. [3] Buchner. E. et al. (2020). *Sci. Rep.* 10:22143. [4] Sach, V.J. et al. (2020) *Sed. Geol.*, 398:105571. [5] Collins, G. et al. (2005) *MAPS* 40:817–840. [6] Tohver, E. et al. (2018) *GSA Bull.*, 130:1099–1120. [7] Buchner, E. et al. (2021) *Nat. Comm.* 12, 6731.