A GRAVITY ANOMALY IN THE RIES IMPACT CRATER EJECTA BLANKET: SECONDARY OR PRIMARY CRATERING? K. Ernstson, Faculty of Philosophy, University of Würzburg, D-97074 Würzburg, Germany (kernstson@ernstson.de)

Introduction: Secondary cratering has been discussed in planetary impact research for a long time and is understood as a striking phenomenon of large impacts. Secondary craters occur when excavated material is ejected from the formation of primary craters and, when landing outside (sometimes inside) the primary craters, produce their own craters. On other planets and their moons the phenomenon can be well studied as part of landscape formation. In the Ries crater, the so-called "ballistic erosion" and "secondary cratering" have been discussed early and have been described in detail in connection with drilling in the ejecta blanket [1], where the "secondary wasting", which is widely used today as an expression of the abrasion of local material and an intensive mixing on ejecta emplacement could well be observed. Here, I report on a gravity survey that sheds some light on an unexpected feature of the Ries crater ejecta blanket (Fig. 2, 3).

. **Fig. 1**. Location map.

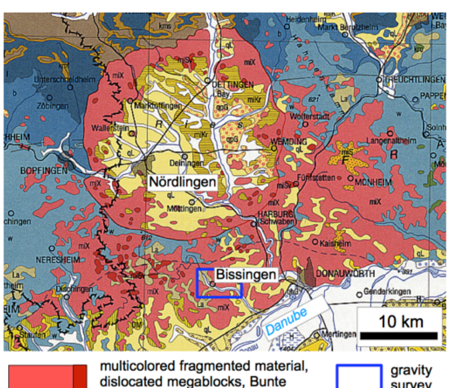

Fig. 2. Geological general map of the Ries impact crater and field for the gravity survey in the ejecta blanket. Modified from Geological Map of Bavaria, 1:500,000.

The gravity survey: Extensive gravity measurements in the Ries impact structure have been performed as early as in the sixties [2], and later only a few student courses for some local improvement of the existing gravity data followed.

Fig. 3. Typical aspect of the Ries crater ejecta (Bunte Breccia on top of autochthonous Jurassic limestones). Gundelsheim quarry.

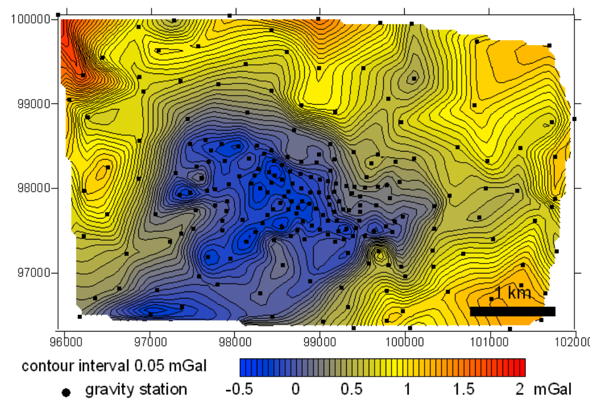

Fig. 4. The Bissingen gravity Bouguer anomaly.

The discovery of the exceptional, kilometer-sized gravity anomaly within the ejecta blanket was a matter of fortuity related with a gravity campaign for hydrogeological purposes. The survey comprised well over 200 gravity stations the distribution of which is shown in Fig. 4. Data processing with the usual reductions led to the Bouguer gravity map in Fig. 4 of a basically distinct negative anomaly. Because of the numerous short-wavelength gravity anomalies due to dislocated megablocks within the Bunte Breccia ejecta, a stronger low-pass filtering was used for simple modeling (Fig. 5), and a gravity profile was taken from this map for a very simple 2.5D model calculation the result of which is also shown in Fig. 5. For lack of more specific density data a straightforward modeling has produced a two-layer density distribution that assumes a mass deficit responsible for the gravity anomaly. Because of this simple assumption the shape of the negative mass follows more or less the shape of the gravity curve. This reveals a steplike slope of the central depression with a depth of about 200 m. This value depends of course on the density difference, but -0.25 g/cm^3 corresponds well with earlier measured seismic velocities for ejecta and autochthonous Jura limestones [3].

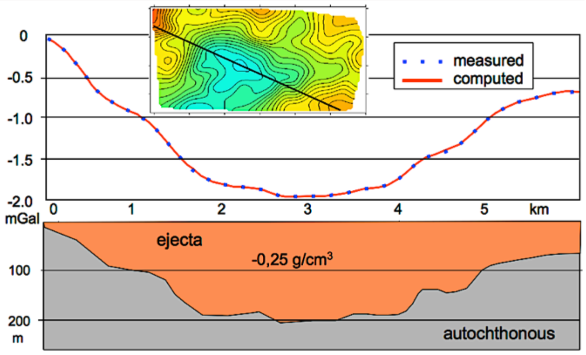

Fig. 5. Low-pass filtered Bissingen anomaly, gravity profile and 2.5D modeling.

Discussion: What does the low density filling of the roughly bowl-shaped structure consist of? A filling with Ries ejecta masses makes sense, if one uses previously published thicknesses of the Bunte Breccia masses for comparison. While at the Bissingen distance of 20 km from the crater center average thicknesses of 50 - 30 m (primary and secondary wasting ejecta) are given [4], >100 m have often been found [5], and in a pre-Ries erosion channel, seismic and geoelectric measurement resulted in up to 200 m mighty Bunte Breccia [3]. This is exactly the order of the thickness of the mass deficit in the Bissingen crateriform structure. However, a comparable pre-Ries erosion channel which abruptly has deepened on such a short distance from NW and which also has no real runoff should be eliminated. The explanation remains that the deepening and subsequent refilling occurred during the Ries event itself, and I refer to the "ballistic erosion" and "secondary cratering" from the *Introduction* and to [5]. Not to be completely excluded and not yet discussed for the Ries environment is a direct impact of a small companion projectile possibly separated from the main impact body, which at a diameter of perhaps 100 - 200 m has produced an independent Bissingen crater, which was filled up immediately afterwards by the ejecta masses originating from the main crater. This might explain the rounded shape better, and the nearly symmetrical gravity profile with the steplike slope may remind of a kind of an inner ring. A certain uncertainty is caused by the unsymmetrical extension of the negative gravity anomaly to the southwest, which could not be further measured within the scope of the project.

Both models, which are here discussed, have some appeal for the Ries crater research. There has never been much discussion about secondary cratering and ballistic erosion at the Ries impact. After the detection of a more or less bowl-shaped structure several kilometers in size, obviously filled with ejecta up to depths of about 200 m, the impact-mechanical question of the secondary cratering arises concerning both the secondary projectile ejection from the primary crater (starting location, angle and speed) and the associated landing mechanism, and in particular the role of the secondary projectile as a component of the total ejection mass with the consequence of secondary impact and filling. This is postponed here for the time being in favor of the discussion of the second model. The fact that the Ries projectile did not fall from the sky alone is due to the existence of the small Steinheim impact crater as generally accepted, and there have also been considerations of accompanying impacts much further east and west [6-9].

Conclusions: Gravimetry has long been an important tool in the investigation of impact structures in terms of structural investigations, mass estimations and energy considerations. The Ries crater is no exception. What is new, however, is that gravity measurements with large impact structures can look into the underground in more detail, from where, if at all, only point-by-point information from deep boreholes is available. Although this can make important contributions to the understanding of impact processes, as the NASA boreholes in the Vorries not far west of Bissingen have shown, these drillings have completely escaped that in the immediate vicinity a structural feature exists, which can make important contributions to the understanding of ejecta emplacement and deposits. Accordingly, a coupled impact with projectiles differing by one order of magnitude is conceivable at a distance of only 20 km. Details of the impact sequence for the possible small companion - influence by the large main impact, the individual phases of contact and compression, excavation and modification - must remain unanswered for the time being. Therefore, it might be interesting to significantly expand the existing area of gravity measurements.

References: [1] Hörz, F. et al. (1983) *Reviews of Geophysics*, 21, 1667-1725. [2] Kahle, H.-G. (1969) *Z. Geophys.,* 33, 317-345. [3] Bader, K. and Schmidt-Kaler, H. (1977) *Geologica Bavarica*, 75,401-410. [4] Zhu, M.H. and Wünnemann, K. (2013*) 44th LPSC*, Abstract #1921. [5] Hörz, F. (1982) *Geol. Soc. Amer., Spec. Pap*., 190, 39-55. [6] Rutte, E. (1971) *Geoforum*, 7, 84-92. [7] Rutte, E. (2003) Land der neuen Steine, 110 p., Regensburg (Univ.Verlag). [8] Ernstson, K. et al. (2019) *50th LPSC,* Abstract #1370. [9] Hofmann, F. (1978) Bull. Ver. schweiz. Petroleum-Geol. u. -Ing., 44, 17-27.