**REVIEW OF LITERATURE DATA FROM THE RIES IMPACT CRATER: EVIDENCE OF A PALLASITIC PROJECTILE.** Gerhard Schmidt, orcid.org/0000-0001-5487-8917 (SchmdtGerhard@aol.com).

**Introduction:** As early as 1977, O'Keefe and Ahrens [1] reported that impact cratering models suggested that the largest meteoritic contribution should be expected in glasses, impact melts, and strongly shocked suevites. After El Goresy and Chao [2], Morgan et al. [3], and Pernicka et al. [4] assumed to have identified apparently meteoritic material in granites, gneiss, metal-bearing amphibolite as well as in the fallback sediments (graded unit) of the Ries crater, rocks of the research core Nördlingen 1973 (FBN73) were systematically examined by the author with a slightly modified version of the Ni sulfide fire-assay method regarding Os, Ir, Ru, Pt, Pd, Au, and Re at the Max Planck Institute of Nuclear Physics in Heidelberg. In this study published by Schmidt and Pernicka [5], no meteoritic contamination of Ir from the Ries impactor was detected in suevite, fallback sediments (graded unit), amphibolite, and granite. Palladium and Os concentrations of all 55 analyzed samples were always below the detection limit of about 2 to 10 ng/g and 0.2 to 2 ng/g, respectively. The detection limit of the elements depended on the amount of Ni in the residue containing the extracted and enriched platinum group elements, which were separated by filtration through a filter and irradiated in the Heidelberg TRIGA-HD II reactor at the Cancer Research Institute. Iridium in ultramafic rocks from the FBN73 core was found to be as high as 0.546 ng/g. The range of Ir in amphibolite was from 2 pg/g to 37 pg/g Ir. In granite Ir contents ranged from 5 to 43 pg/g. The Ir content in the suevite ranged from 7 pg/g to 31 pg/g. In sediments from the graded unit Ir contents ranged from 13 to 20 pg/g. The results demonstrated that there is no indication of unequivocal extraterrestrial contamination in the cored materials of the FBN73.

In a study by Reimold et al. [6] on suevite samples from the drill core of Enkingen, significantly increased Ir (0.37-0.88 ng/g), Ru (0.56-1.08 ng/g) and Rh (0.23-0.62 ng/g) contents were measured (Figs. 1-3) compared to previously analyzed suevites [5]. Reimold et al. [6] concluded that elevated concentrations and near-chondritic ratios of the most immobile PGE were consistent with an extraterrestrial contribution of 0.1 to 0.2% chondrite-equivalent. The authors noted further (page 1561); (1) “For the most Ir and Ru-enriched subsuite, Ru/Ir ratios are within 10% of the chondritic ratio (1.47)”, (2) “Ratios of Ir with other PGE are significantly higher than chondritic in all these samples”, (3) “All samples display a positive anomaly at Pt that is most likely to reflect a Pt background in the target rocks that is elevated relative to the other platinum group elements.” Finally, Reimold et al. concluded, “Finally, our PGE results, together with the Cr-Ir data for some Enkingen suevite samples suggest that the Ries projectile could well be of a chondritic nature. However, the apparent presence of a chondritic component is severely limited to 0.1 - 0.2%, at best.” Incidentally, the Cr contents of the Ir-enriched suevites vary from 37.1 to 56.7 µg/g and are lower than the recommended continental upper crust concentration of 92 ± 17 µg/g [7].

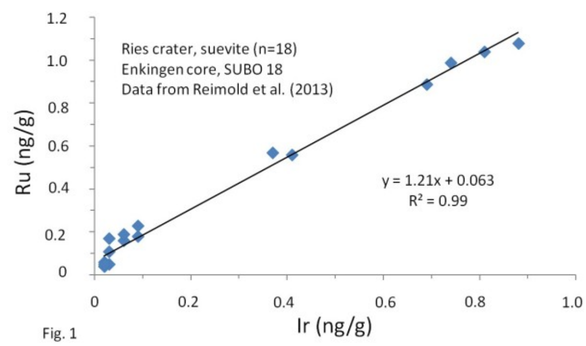


**Fig. 1.** Ru vs Ir correlation diagram of suevite from the Enkingen drill core. Ideally, all samples should lie on a straight line of slope equal to the Ru/Ir ratio in the projectile, and of zero intercept [8].

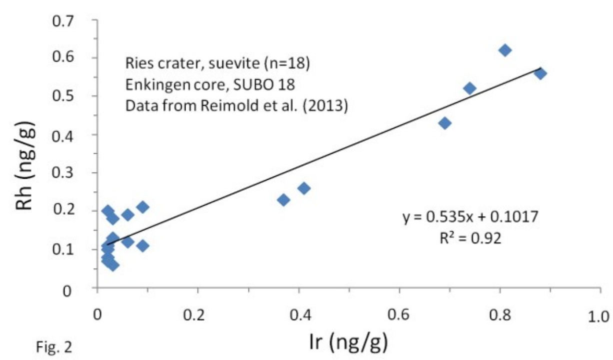


**Fig. 2.** Rh vs Ir of suevites from the Enkingen drill core. Rhodium in suevite is largely a meteoritic inheritance, as shown by its correlation with Ir and its non-correlation with Cr, Co, and Ni. For comparison, rocks from the Earth's mantle (peridotites) have Rh and Ir contents of about 1 ng/g and 3 ng/g, respectively.

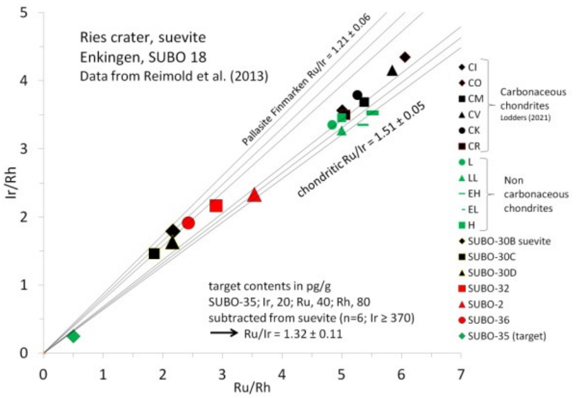


**Fig. 3.** Ru/Rh vs Ir/Rh of suevites with Ir contents of 0.37 ng/g (SUBO-2, altered suevite) to 0.88 ng/g (SUBO-30B, melt-rich suevite) from the SUBO 18 Enkingen drill core (data from [6]) compared to chondrites [9]. The contents of sample SUBO-35 (suevite, clast-rich, felsic-silicate dominated) were used as estimate of the target contents (0.02 ng/g Ir; 0.04 ng/g Ru; 0.08 ng/g Rh). Subtracting these values yields a mean Ru/Ir ratio for suevites (n=6) of 1.32 ± 0.11 compared to the chondritic ratio of 1.51 ± 0.05. For sample SUBO-30, data from three splits (B-D) were used. Suevites from the Enkingen drill core have subchondritic Ir/Rh, Ru/Rh and Ru/Ir mass ratios (except sample SUBO-2).

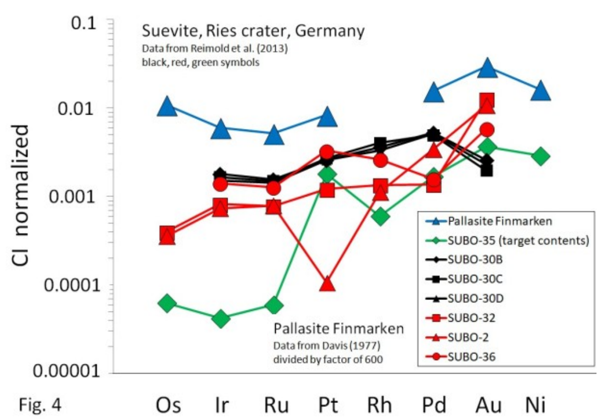


**Fig. 4.** Semi-log comparison of Os, Ir, Ru, Pt, Pd, Au, and Ni of suevites from the Ries crater (data from [6]) and the pallasite Finmarken, Norway (data from [10]) normalized to CI chondrite [9]. The concentrations of sample SUBO-35 (suevite, clast-rich, felsic-silicate dominated) were used as estimate of the target contents (0.03 ng/g Os; 0.02 ng/g Ir; 0.04 ng/g Ru; 1.69 ng/g Pt; 0.08 ng/g Rh; 0.94 ng/g Pd) and subtracted from Ir-enriched samples. The Ru/Ir ratio of the pallasite Finmarken of 1.21 (radiochemical data [10]) agrees with that of the suevite of Enkingen. Unfortunately, no Rh data are available for Finmarken. The contribution of pallasitic components can be estimated up to 0.05 wt% (Ir, Ru, Pt, Pd) in suevite sample SUBO-30 from Enkingen. However, Reimold et al. [6] concluded on page 1565 "The PGE patterns are consistent with admixture of 0.1 - 0.2% chondritic material to the target rocks. This is most obvious for the Ru/Ir ratio (Table 5),which is most useful for distinguishing.."

**Ries impactor:** Stöffler et al. [11] calculated in their models on the Ries-Steinheim impact event with a projectile density of 2.5 g/cm$^3$ and reported on page 1898: "The trajectories of the two bodies, whose sizes are similar to the Ries and Steinheim impactors (~1000 and 100 m, respectively), were followed for different impact angles and impact velocities, to determine how far they could separate upon reaching the Earth's surface. We used a typical density of 2.5 g/cm$^3$ for the two bodies, although we also explored how a lower density (2 g/cm$^3$) for the larger (Ries-size) body would affect the results." However, the bulk density of pallasites is 4.76 ± 0.10 g/cm$^3$ [12], and thus much higher. Pallasites also show little porosity compared to chondrites. The models for the Ries event would therefore have to be revised. Compositional data for metal from the main-group pallasites (PMG) indicate that these meteorites were formed at the core–mantle interface between a crystallizing metallic magma and the surrounding solid mantle of the IIIAB asteroid [13,14].

**Conclusions:** Ir-enriched samples from Enkingen exclude a chondritic projectile for the Ries crater based on diagnostic and subchondritic Ir/Rh, Ru/Rh and Ru/Ir mass ratios. The PGE pattern of the pallasite Finmarken agrees with that of the suevite of Enkingen (Fig. 4). The contribution of pallasitic components can be estimated up to 0.05 wt% in suevite sample SUBO-30. It is interesting to note that [3] excluded already chondrites and most irons as likely projectile material.

**References:** [1] O'Keefe J.D. and Ahrens T.J. (1977) *8th Proc. Lunar Sci. Conf.* 3357 - 3374. [2] El Goresy A. and Chao E.C.T. (1976). *Earth and Planetary Science Letters 31*, 330-340. [3] Morgan J.W. et al. (1979) *Geochimica et Cosmochimica Acta 43*, 803-815. [4] Pernicka E. et al. (1987) *Earth and Planetary Science Letters 86*, 113-121. [5] Schmidt G. and Pernicka E. (1994) *Geochimica et Cosmochimica Acta 58,* 5083-5090. [6] Reimold W.U. et al. (2013) *Meteoritics & Planetary Science 48,* 1531-1571. [7] Rudnick R. L. and Gao S. (2014) In *Treatise on Geochemistry*, 1-51. [8] Gros J. et al. (1976) In *Lunar and Planetary Science Conference Proceedings* 7, 2403-2425. [9] Lodders K. (2021) *Space Science Reviews 217(3),* 1-33. [10] Davis A.M. (1977) PhD thesis, Yale University. [11] Stöffler D. et al. (2002) *Meteoritics & Planetary Science 37*, 1893–1907. [12] Britt D. T. and Consolmagno G. J. (2004) In *Lunar and Planetary Science Conference,* p. 2108. [13] Scott E.R.D. (1977) *GCA 41,* 693–710. [14] Wasson J.T. and Choi B.-G. (2003) *GCA 67*, 3079–3096.