Geological Magazine

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Discussion

Cite this article: El Goresy A and Schmidt G (2019) Discussion of 'Rare metals on shatter cone surfaces from the Steinheim Basin (SW Germany) – remnants of the impacting body?'. *Geological Magazine* **156**: 1639–1640. https://doi.org/10.1017/S001675681800064X

First published online: 4 June 2019

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CAMBRIDGE UNIVERSITY PRESS

Discussion of 'Rare metals on shatter cone surfaces from the Steinheim Basin (SW Germany) – remnants of the impacting body?'

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A. El Goresy & G. Schmidt comment: We would like to inform the readers of this journal that, in our opinion, in the article by Buchner & Schmieder (2017) inadequate reports are cited and unsubstantiated claims are presented that need to be modified as we will show below.

The authors claimed in Section 3 that 'The very high content in Fe (around 90 wt %; see Table 1, e.g. Fig. 3f) of the coatings of some of the Opalinus Claystone shatter cones and the resultant high conductivity of the surfaces of these shatter cones allows imaging and EDS analyses on uncoated specimens without disturbing charging processes.' It is well known that the conductivity of a material is not a function of high bulk Fe contents but warranted only if Fe and other 3d elements (Ni, Co, Mn, Cr) are in the metallic state and electrically conductive. However, in table 1 the compositions of the elemental concentrations are given as oxides that also contain 0.54 wt % CaO, which unambiguously negates the claimed metal coating. Furthermore, the cited figure 3f shows a shatter cone with brownish Fe_2O_3 coatings but not metallic coating. It is impossible to assign an oxide layer or patina by naked eye inspection 'a meteoritic affinity'. Material that gives the solid impression of being of meteoritic heritage should deliver solid reliable evidence of genetic connection. The word 'affinity' is, in our opinion, erroneous and misleading.

Buchner and Schmieder wrote in the abstract, 'The Opalinus Claystone shatter cone surfaces carry coatings dominated by Fe, Ca, P, S and Al, and are covered by abundant small, finely dispersed microparticles and aggregates of native gold, as well as locally elevated concentrations of Pt.' No information was provided as to how the generally low concentrations of Pt were measured as PtO with a SEM.

In Section 1 the authors stated, 'Similarly, microparticles of meteoritic affinity were recently detected on shatter cones from the structural crater floors of the Ries crater in Germany (Buchner & Schmieder, 2016) . . . ' Since this reference is only an abstract without any supporting evidence for the claims, it is difficult to understand why the authors concluded that the nature of such particles could relate a meteoritic affinity. On the other hand, the works of El Goresy & Chao (1976, 1977) were not cited, who first reported metal veinlets in basement rocks from the floor of the Ries crater of the Nördlingen drill core 1973. Instead, Buchner & Schmieder (2016) cited Schmidt & Pernicka (1994) that 'On the basis of rather high concentrations of Ni, Cr, Co, and Ir in a few of the suevite samples, some authors [e.g., 6] favored an achondritic projectile (aubrite)', but in this paper no high concentrations of Ir in suevite were reported. They, furthermore, claimed to have detected some brecciated Fe–Ni phosphide particles with a chemical composition very close to schreibersite. However, they failed to present any evidence for or analysis of the claimed brecciated Fe–Ni phosphide particles.

In Section 4.b the authors stated that the composition of an unusual, botryoidal oxide flake on the surface of a limestone shatter cone had elevated concentrations of Fe, Ni, Co, Pt, Ga and Ge, and suggested that this flake may represent some sort of meteoritic matter. They also claimed that 'the composition probably does not reflect the primary, but likely altered, element ratios'. The authors further stated the average Ni/Co inter-element ratio of ~7.5 is broadly consistent with the respective whole-rock inter-element ratios of iron meteorites. However, Schmidt, El Goresy & Pernicka (2017) have shown that Ni/Co ratios as fingerprints are not at all conclusive for the identification of impactor traces at the Steinheim and Ries craters. Nickel and Co contents of ultramafic and mafic rocks from the crystalline basement are high, up to 1300 µg/g and 113 µg/g, respectively, and Ni/Co ratios vary between 2.2 and 11.6 (Matthes, Richter & Stettner, 1977), in the range of the ratio for the oxide flake. Therefore, it does not seem appropriate to discuss an iron meteorite as the possible source for the Ni/Co ratios without discussing the Ni/Co ratios of the crystalline basement. Incidentally, Ni/Co ratios of iron meteorites overlap with Ni/Co ratios of chondrites and mantle rocks. But, indeed, rocks from the crystalline basement provide the closest match with the composition of the oxide flake of the shatter cone coating (Fig. 1). For these reasons, an origin of the shatter cone coatings as iron meteorite-derived contamination seems unlikely.

In our opinion, two processes are likely responsible for the generation of these coatings on shatter cones that are characterized by elevated concentrations of Fe, Ni, Co,

https://doi.org/10.1017/S001675681800064X Published online by Cambridge University Press

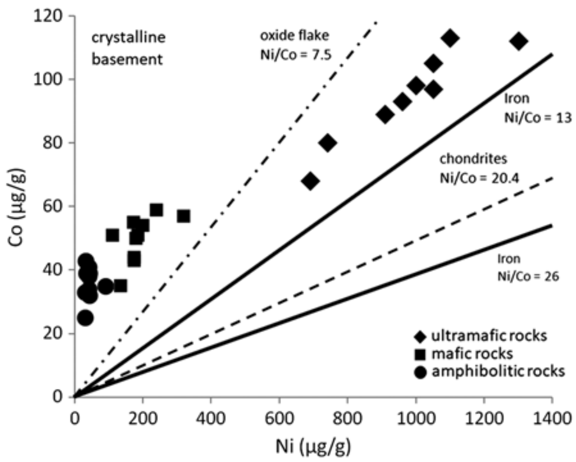

Figure 1. Co versus Ni in various crystalline basement rocks from the Ries drill core (Matthes, Richter & Stettner, 1977) compared with the Ni/Co ratios of chondrites (broken line, Wasson & Kallemeyn, 1988) and iron meteorites. Ni/Co ratios of iron meteorites indicated by lines vary between ~13 and 26 (e.g. Scott, 1972). Also included is the Ni/Co ratio by Buchner & Schmieder (2017) of the oxide flake (dotted line) from the surface of a limestone shatter cone from the Steinheim impact crater. Rocks from the crystalline basement provide the closest match to the ratio of the oxide flake in comparison to chondrites and iron meteorites.

Mn and Cu: (1) weathering from interaction with surface water, and (2) mobilization of elements by water–rock interaction (post-impact hydrothermal activity) involving Middle Jurassic sedimentary rocks (silt- and claystone) and/or the Variscan crystalline basement.

In summary, the most suitable elements as indicators of extraterrestrial materials in rocks from terrestrial craters formed by impacting cosmic projectiles are the platinum group elements (PGE) because of the low PGE contents of the Earth's crust (see e.g. Koeberl, 2014) and the low mobility in particular of Ir, Ru and Rh during water–rock interaction. For these reasons the inter-element ratios of PGE are the best indicators for the identification of extraterrestrial matter and the possible identification of a meteoritic projectile (e.g. Schmidt, 1997; Schmidt, Palme & Kratz, 1997; McDonald, 2002).

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