EXTRATERRESTRIAL PLATINUM GROUP ELEMENTS IN IMPACTITES AND MISLEADING NI/CR, NI/CO AND CR/CO ELEMENT RATIOS FOR PROJECTILE IDENTIFICATION.

G. Schmidt[1], A. El Goresy[2] and H. Palme[3], [1]Institut für Geowissenschaften der Universität, Im Neuenheimer Feld 234–236, D-69120 Heidelberg, Germany (Gerhard.Schmidt@geow.uni-heidelberg.de), [2]Bayerisches Geoinstitut der Universität, D-95440 Bayreuth, Germany (Ahmed.ElGoresy@uni-bayreuth.de), [3]Forschungsinstitut und Naturmuseum Senckenberg, Senckenberganlage 25, D-60325 Frankfurt am Main, Germany (PalmeHerbert@gmail.com).

Introduction: Approximately 190 impact craters are currently known on Earth. It is well known that impact melt rocks are potential carriers of meteoritic material. About 20 iron meteorites and 20 chondrites have been identified as projectiles. From 150 impact craters the projectile types are unknown. The identification of meteoritic material in melt rocks needs significantly elevated abundances of elements depleted in the Earth's crust and enriched in meteorites. Low or absent platinum group element (PGE) signals indicate that either the projectiles had low PGE contents or the velocity of the impacting object was very high, leading to almost complete vaporisation of the impactor and/or producing such a large amount of melt that the concentrations of dissolved PGE are below the detection limit [1]. The elements Co, Cr, and Au are not reliable for projectile identification in terrestrial impactites. The reasons are (1) high abundances in the Earth mantle and crust, and (2) mobilisation by secondary processes.

Three examples of misleading Ni/Cr, Ni/Co, and Cr/Co for projectile identification:

Clearwater East. The 20 km diameter Clearwater East crater in Canada is most likely formed by a chondritic projectile since Os/Ir (1.07 ± 0.01), Ru/Ir (1.51 ± 0.04), Ru/Rh, and Ni/Ir element ratios are similar to those from chondrites [2,3,4]. Clearwater melt samples are high in Ni (1039 µg/g Ni, 315 µg/g Cr, 52 µg/g Co) [5]. The Ni-rich samples exhibit chondrite-relative highly siderophile element proportions. From observed Ni/Cr, Ni/Co, and Cr/Co ratios a chondritic impactor contribution appears to be misleading. At least 55 µg/g Cr (crustal contribution) have to be subtracted from the Ni-rich melt samples to get CI chondritic Cr/Ni and Cr/Co ratios. Clearwater East melt rocks have the highest fraction of extraterrestrial component of any terrestrial impact structure (~7% of a CI-component). It is also the only impact crater with chondritic Cr/Ni and Cr/Co ratios in melt samples after subtraction of a realistic crustal contribution of Cr.

Sääksjärvi. The 5 km diameter impact crater in Finland is most likely formed by a magmatic iron meteorite, based on subchondritic Os/Ir and suprachondritic Ru/Ir ratios [6]. However, the observed Ni/Cr, Ni/Co, and Cr/Co ratios of the melt samples are much higher than those from iron meteorites with very low Cr/Ni $<<0.1$ and Cr/Co $<< 0.1$ and would not support an iron meteorite as projectile type derived from PGE ratios.

Nördlinger Ries. Recently an iron (or stony-iron) meteoritic projectile was proposed for the Ries crater based on interelement ratios between Fe, Ni, Cr and Co from fracture surfaces of shattered belemnites [7]. This speculation is unsupported by Cr/Ni and Cr/Co ratios [8]. Ackerman et al. [9] reported that a detectable addition of meteoritic material in moldavites, derived from the Ries crater can be observed through co-variations between Os and Ir, Ni and low $^{187}Os/^{188}Os$, although the measured low contents of Os, Ir, and Ni in moldavites are typical for upper crustal rocks [2]. As noted already in Koeberl [10] geochemical data from impact craters are vulnerable to overinterpretation and wishful thinking.

Refractory highly siderophile elements Os, Ru, Ir, and Rh: The refractory highly siderophile elements Os, Ru, Ir, and Rh are abundant in most meteorites but depleted in crustal rocks and therefore most reliable elements for projectile identification (e.g. [11]). The Rh/Ir, Os/Ir and Ru/Ir ratios are particularly suitable for distinguishing different types of meteorite projectiles. For example, magmatic iron meteorites can be distinguished from non-magmatic iron meteorites by their lower Os/Ir ratios (Sääksjärvi and Rochechouart in France). However, meteorite/target ratios are low if target rocks consist of mantle rocks. In this case PGE may enriched in impactites due to the relatively high abundances (ng/g level) in target rocks to make the identification of the projectile type quite difficult, if not impossible. The well established Ru/Ir ratio of the Earth mantle is about 2 and significantly above the Ru/Ir ratios (1.4 to 1.6) of different chondrite groups. The Ru/Ir ratio in impactites is thus the most reliable key ratio that rules out Earth upper mantle derived refractory highly siderophile element components in impactites [12].

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