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Misleading projectile determination by Cr/Ni and Ni/Co ratios of Australasian microtektites and impact melt rocks

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Abstract

The identification of meteoritic material in melt rocks from impact craters needs significantly elevated abundances of elements depleted in the Earth's crust and enriched in meteorites. Inter-element ratios of Ni, Co, Cr, and Au are not reliable and misleading for projectile identification in terrestrial impactites. The reasons are (1) high abundances in the Earth crust and (2) mobilisation by secondary processes. The refractory highly siderophile elements Os, Ru, Ir, and Rh (PGE) are abundant in most meteorites but depleted in crustal rocks, less mobile and therefore most reliable elements for projectile identification. Magmatic iron projectiles can be distinguished from non-magmatic iron meteorites by their subchondritic Os/Ir and suprachondritic Ru/Ir ratios (e.g. Sääksjärvi in Finland and Rochechouart in France).

1. Introduction

Approximately 190 impact craters are currently known on Earth. Impact melt rocks are potential carriers of meteoritic material. About 20 iron meteorites and 20 chondrites have been identified as projectiles. The nature of the impactor and the location that generated the Australasian tektite/microtektite strewn field (~15% of the Earth's surface) is unknown [1].

2. Projectile identification

2.1 Australasian tektite strewn field

Recently, an ordinary chondritic impactor signature in Australasian microtektites have been proposed based on variations of Ni, Co and Cr inter-element ratios with concentrations of 680, 50, and up to ~370 µg/g, respectively [2]. High Ni, Co and Cr contents in Australasian microtektites were explained by up to ~5% chondritic impactor contamination [2] corresponding to about 20 ng/g of the refractory siderophile element Ir. However, the Indonesian tektite with high Ni and Cr abundances of 428 and 311 µg/g, respectively, show enrichments of about 4 ng/g Ir [3]. A chondritic impactor contribution appears to be inconsistent with observed Ni, Co, and Cr inter-element ratios. Incidentally, the Ni/Co ratios of chondrites and iron meteorites overlap and are not reliable for projectile identification. In contradiction, the Ni-rich tektite sample exhibit broadly chondrite-relative PGE proportions, although Ru/Ir is about 10% lower [3]. Non-chondritic PGE abundances in tektites with enrichments of Rh were explained by incorporation of IC iron meteorites as impactor [4].

2.2 Sääksjärvi (Finland)

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 [5]. However, detected Cr/Ni, 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 inconsistent with an iron meteoritic projectile.

2.3 Popigai (Siberia)

Concentrations of 98 µg/g for Ni, 26 µg/g for Co, 105 µg/g for Cr, and about 1 ng/g for Ir were measured in impact melt samples from the ~ 100 km diameter Popigai impact crater in Siberia [6]. The observed Cr, Ni and Co inter-element ratios do not support a chondrite as projectile type. At least 75% Cr and ~90% Co have to be subtracted as indigenous contribution to get chondritic Cr/Ni and Cr/Co ratios, an unrealistic scenario. Around 0.2 wt.% meteoritic contamination have been identified in homogeneous impact melt samples based on PGE concentrations (except Os) [6]. An L-chondrite was identified as the most likely Popigai impactor.

2.4 Morokweng (South Africa)

Ni, Co, Cr, and Ir are enriched in melt rock samples from the 70–80 km diameter Morokweng impact structure with average values of 780 µg/g for Ni, 50 µg/g for Co, 440 µg/g for Cr, and 32 ng/g for Ir [7]. However, a chondritic impactor contribution appears to be inconsistent with observed Ni, Co and Cr inter-element ratios. Chromium isotope data have shown that about half of the chromium in the melt rocks is of extraterrestrial origin and consistant with an ordinary chondritic source [8]. Chondrite-normalized PGE abundance pattern of the impact melt rocks are flat and indicate the presence of about 2 to 5 wt% of a chondritic projectile component [7], most likely an L or LL-chondrite [9]. Independent confirmation of the impactor type came from a 25 cm meteorite clast in the impact melt rock of the Morokweng crater [10].

2.5 Clearwater East (Canada)

The 20 km diameter Clearwater East crater is most likely formed by a chondritic projectile based on Ni, Os, Ir [11], Ru, and Rh inter-element ratios. The melt rocks have the highest fraction of extraterrestrial component of any terrestrial impact structure (~7% of a CI-component). The melt samples have high concentrations of 1039 µg/g Ni, 315 µg/g Cr, and 52 µg/g Co [11]. However, from observed Ni, Cr, and Co inter-element ratios a chondritic impactor contribution cannot be identified. At least contents of ≥55 µg/g Cr have to be subtracted from the Ni-rich melt samples to get CI chondritic Cr/Ni and Cr/Co ratios.

3. Summary and Conclusions

The refractory highly siderophile elements Os, Ru, Ir, and Rh are abundant in most meteorites but depleted in Earth's crust, less mobile by secondary processes and therefore most reliable elements for projectile identification. Rh/Ir, Os/Ir, Ru/Ir and Ni/Ir ratios are particularly suitable for distinguishing different types of meteorite projectiles. Even in the case of low meteoritic contamination of about 0.1 wt.% CI chondrite allow the discrimination of the type of impactor, if mantle derived rocks as target rocks can excluded. The identification of the projectile type is quite difficult, if not impossible, if the PGE derived from mantle rocks in impact melts. However, the Ru/Ir ratio of the Earth mantle of about 2 lies significantly above the Ru/Ir ratios of chondrite groups (Ru/Ir = 1.4 to 1.6) and thus the most reliable key ratio for identification [12].

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