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Re-investigation of projectile types from terrestrial impact craters – Hiawatha (Greenland), Popigai (Siberia), Clearwater East, Brent, Wanapitei (Canada), Gardnos (Norway), Rochechouart (France), Ries (Germany)

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Abstract

Nebular processes and fractional crystallization during core formation of planets have produced some compositional variation in the platinum group element (PGE) chemistry of stony meteorites and irons. This compositional variation makes it possible to identify projectiles from impact craters. The refractory metals Os, Ir, Ru, Pt, and Rh (T_C > 1360 K) are abundant in most meteorites but depleted in crustal rocks. For Ir and Os, there is a difference of four orders of magnitude, and Rh three orders of magnitude between their meteoritic and crustal abundances. The Ir/Rh, Ru/Rh and Os/Ir mass ratios are particularly suitable for distinguishing different types of projectiles. In this study I review diagnostic element ratios for specific impactor compositions of Greenland, Popigai, Clearwater East, Brent, Wanapitei, Gardnos, Rochechouart, Ries and Boltysh impact craters.

1. Introduction

The Moon can provide insight into the early development of the Earth, where the direct record of early evolution was destroyed by geological activity. During solidification of the Earth's crust the surface was exposed to a similar flux of impacting asteroids as the Moon. In 1991 about 130 terrestrial impact craters were known. The Earth Impact Database comprises a list of currently about 190 confirmed impact structures (http://www.passc.net). Impact melt rocks are potential carriers of meteoritic material. The chemical composition of impacting asteroids can be obtained from relative abundances of platinum group elements (PGE) in impact melts. The determination of these elements is a difficult challenge because of the low contents in the pg/g to ng/g range. Today there are still few data on Rh, mainly because of the low concentrations in upper crustal rocks of about 60 pg/g and difficulties with analysis. However, high quality data especially of Rh and Ir might answer fundamental questions of cosmochemistry [1]. Studying the nature of impactors is crucial to understand the characteristics and origin of material delivered to planets.

2. Projectile types

2.1 Hiawatha Glacier (Greenland)

Recently a 31 km large impact crater beneath Hiawatha Glacier in northwest Greenland was discovered [2]. The assumption of a "fractionated iron asteroid with more than a kilometer in diameter" as impactor is based on concentrations of Ni, Co, Cr, PGE, and Au in glaciofluvial sediment samples [2]. However, Cr, Co, Os and Au mass ratios are not suitable as fingerprints of the Greenland projectile because of their mobility in aqueous environments. As an example, the Co content of glaciofluvial sediment sample (HW21) is lower than the upper crustal Co content. Cr is ~60% enhanced. However, as with Au, Pd and Pt are mobile in the earth's crust. Ru/Rh vs Ir/Rh mass ratios show that an iron projectile similar to the Boltysh impactor in Ukraine not sampled in meteorite collections is possible. A mixture of crust and a Duchesne iron meteorite component however do not match ratios determined in Greenland sediments.

2.2 Popigai (Siberia)

Up to 2.31 ng/g Ir were measured in impact melt samples from the ~ 100 km diameter Popigai impact crater in Siberia, one of the largest craters on Earth [3]. Around 0.2 wt.% meteoritic contamination have been identified in homogeneous impact melt samples based on PGE concentrations (except Os). An L chondrite was identified as the most likely impactor. However, element ratios in Popigai impactites match also EL chondrites and iron meteorites.

2.3 Gardnos (Norway)

The Gardnos impact structure of about 5 km in diameter was likely produced by a ~200 m diameter fragment of a non-magmatic iron projectile, most likely similar to members of the IA or IIIC irons reported by the authors [4]. However, Ru/Ir, Ru/Rh and Pt/Rh mass ratios of six samples with highest PGE contents overlap with ordinary chondrites.

2.4 Clearwater East, Brent, Wanapitei (Canada)

Impact melts from Clearwater East crater with a diameter of ~22 km have the highest fraction of a extraterrestrial component of any terrestrial impact structure. The crater was probably formed by a chondrite (e.g., [5] [6]). However, element ratios of the iron meteorite Gibeon [7] agree with melt samples [8]. Based on PGE, Au, Re and Ni excesses up to ~1.2 wt.% of a Gibeon-like component or about 7 wt.% of a member of an unidentified chondrite group, which is not present in meteorite collections (H. Palme, pers. communication) is contained in melt samples. Ir/Rh and Ru/Rh literature data from Brent and Wanapitei samples match irons.

2.5 Rochechouart (France)

Ru/Rh and Ir/Rh from Rochechouart samples [9] match IA, IIC and IVA irons and melt rocks from the Apollo 16 landing site [10].

3. Summary and Conclusions

(1) The identification of an iron asteroid as impactor for the impact crater beneath Hiawatha Glacier based on Ni, Cr, Co and Au is impossible. Ru/Rh and Ir/Rh point to an iron projectile. (2) The Popigai impactor could also be an EL chondrite or even an iron meteorite. (3) Melt rocks from Clearwater East have similar PGE, Re, Au and Ni inter-element ratios than the iron meteorite Gibeon. (4) A non-magmatic iron projectile for the Gardnos impact structure is questionable since Ru/Ir, Ru/Rh and Pt/Rh mass ratios overlap with ordinary chondrites. (5) Provided the PGE contents in suevite from the Ries crater (Enkingen core) in Germany are of extraterrestrial origin, the non-chondritic Ru/Rh and Ir/Rh would exclude a chondritic projectile. (6) Subchondritic Os/Ir and supra-chondritic Ru/Ir ratios are consistent with an unidentified iron projectile type as impactor for the 24 km diameter Boltysh impact structure.

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