THE LOCKNE IMPACT IS NOT RELATED TO THE ORDIVICIAN L-CHONDRITE SHOWER. R. Tagle[1], ([1]VUB Pleinlaan 2, B-1050 Brussels, Belgium, roald.tagle@vub.ac.be), R. T. Schmitt[2] ([2]Museum of Natural History, Invalidenstrasse 43, 10115 Berlin, Germany, ralf-thomas.schmitt@museum.hu-berlin.de) and J. Erzinger[3], ([3]GFZ-Potsdam, 14473 Potsdam, Germany, erz@gfz-potdsam.de).

Introduction: The majority of the impact structures known on Earth formed on continental targets, mostly concentrated on shield areas, but about ~20% were located in marine environments. The Lockne impact structure in central Sweden (14°49´30´´E, 63°00´20´´N) is a relatively well preserved marine impact structure with well exposed resurge deposits. In these resurge deposits, a carbonate breccia member termed "Loftarstone" was found to contain extraterrestrial material derived from the projectile [1]. This study was based on Ir, Ni, Co and Cr analyses and did not allow a refined identification of the projectile component. Further studies on the nature of the projectile concentrated on the extraction and analysis of chromites from the Loftarstone by acid dissolution of the carbonates [2]. The authors propose, based on the composition of the chromite grains, that the projectile was an L-chondrite, and suggest a relation to an Ordovician asteroid shower that is implied to have a direct relation to a major collision of the L-chondrite parent body in the asteroid belt [3, 4]. This study aims to trace and identify the projectile component in the Lockne impactites by analyzing platinum group elements (PGE) in combination with Ni and Cr after the method described by [5, 7].

Samples: A set of 9 impact breccia samples, including six Loftarstone and three Tandsbyn Breccias were selected for this study. The samples were analysed several times to a total of 20 PGE analyses. The Loftarstone samples showed a relative homogenous distribution of clast fragments usually smaller than 2 mm. The three samples of Tandsbyn Breccia represent different clast sizes ranging from 2 mm to < 20 mm. The samples were analyzed for mayor and trace elements by X-ray fluorescence spectroscopy (XRF) on glass beads. Additionally, the elements Ni, Co, and Cr were measured by ICP-MS after acid sample digestion for a precise detection of Ni, Co and Cr. The PGE concentrations were determined after nickel-sulfide fire assay pre-concentration [6, 7]. Sample aliquots of 70 g were used in each analysis. The identification of the projectile component was carried out following the procedure described in [5].

Results: The results of the XRF analyses of the Loftarstone samples revealed that the major and trace element composition is very homogenous, with a $CaCO_3$ content of ~ 40 wt%. The Tandsbyn Breccia, on the other hand, does not contain carbonates. ICP-MS analyses show that the Loftarstone is significantly enriched in Ni, Co, and Cr compared to the Tandsbyn breccia. These results are compatible with those of the PGE analyses, where the concentrations in the Tandsbyn breccia are mostly below the detection limit, whereas PGE concentrations in the Loftarstone samples are significantly higher. Our results support the previous observations on the presence of an extraterrestrial component in the Loftarstone. In Fig. 1, the Cr-Ir trend follows the mixing field between the composition of the continental crust and possible projectile end members.

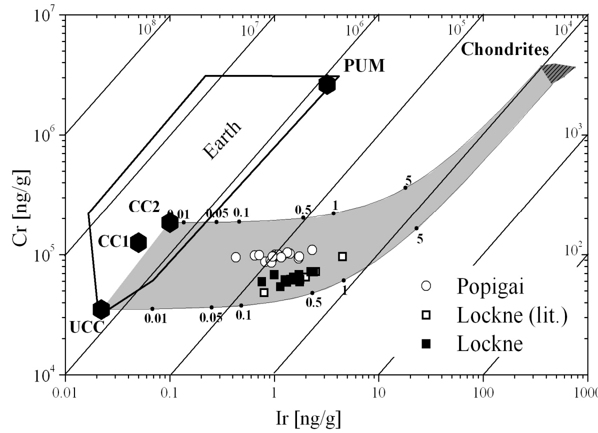

Fig. 1 Double log. plot of the concentrations of Cr vs. Ir of terrestrial lithologies compared to the composition of the Popigai impact melts and the Lockne Loftarstone. The gray field indicates the most likely mixing zones between chondritic projectiles and common terrestrial targets. UCC = upper continental crust, CC = continental crust, PUM = primitive upper mantle. Lockne literature values [1]. Detailed description of the data used for the diagram is given in [5].

One question remains: What type of projectile caused the enrichment? The inter-element-correlations including Ni are neither coherent with the values from this study nor with those from the work by [1] as this element appears to be affected by weathering. In contrast, Cr and PGE correlate well and thus allow projectile recognition. The correlation of Cr vs. Ir (Fig. 2) shows that their ratios are outside of the range of chondrites (gray field) and significantly higher than the values in L chondrites.

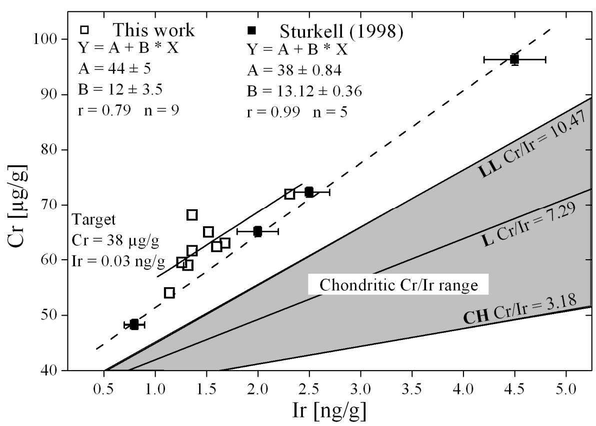

Fig. 2 Correlation of Cr vs. Ir including data from this work and [1]. The samples analysed by [1] show a wider range of concentrations allowing a better determination of the slope ***B****.*

The results for the PGE show a similar picture: Their element patterns are not chondritic and the ratios are significantly outside of the chondritic range (Fig. 3). Figure 4 shows the average PGE element pattern of Lockne compared to those obtained from the Gardnos impact structure [8].

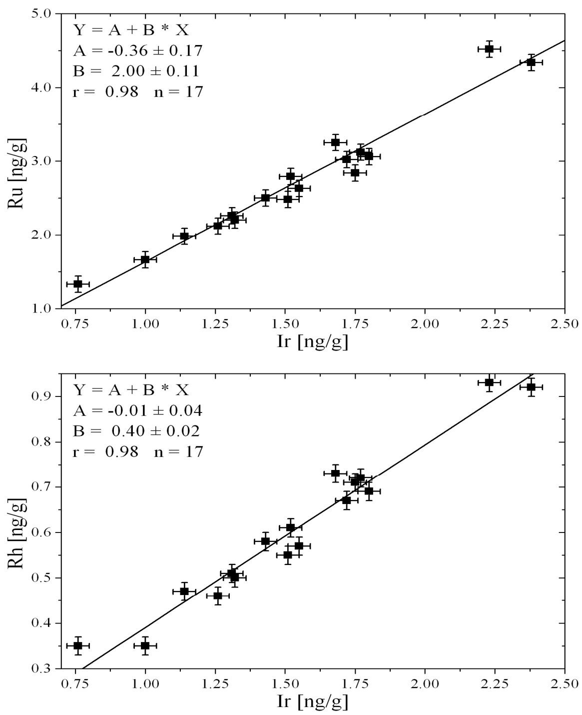

*Fig. 3: Regression analyses of Ru and Rh vs. Ir. The slope **r** represents the projectile elemental ratio. The Ru/Ir and Rh/Ir ratios in chondrites vary between 1.42 and 1.62 and 0.26 and 0.34 respectively [12]. **B** represent the element ratios in the projectile*

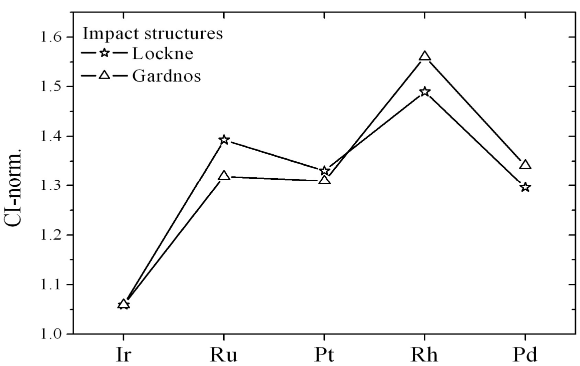

Fig. 4: The element patterns of Lockne compared to those from Gardnos (data from [8]).

Conclusions: Based on the results for Cr and the PGE, the extraterrestrial component in the impactites from Lockne is not chondritic. The similarity to the element pattern obtained for the Gradnos impact structure in Norway suggests that a similar type of projectile is responsible for these two impact structures. The "M-like" shape of the PGE is similar to the element pattern found for the Rochechouart and the Sääksjärvi impact structures, which are suggested to be produced by non-magmatic iron meteorites (NMI) [10]. This is in contrast to the findings of [2], who identified an L-chondrite projectile based on the similarity of SEM-EDX analyses of chromite grains extracted from Loftarstone samples with chromite grains from ordinary chondrites. However, the results of [2] do not convincingly overlap the compositions of chromites from ordinary chondrites or chromites from Kinnekulle (Sweden) that are linked to the Ordovician L-chondrite shower (Fig. 5).

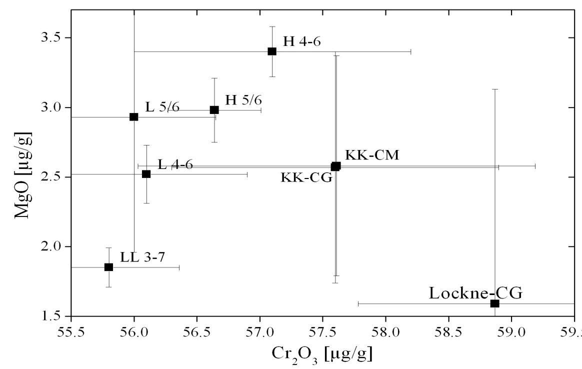

Fig. 5: Comparison of the composition of the Lockne chromite grains with the composition of the Kinnekulle chromite grains (KKCG) as well as the chromites from the fossil meteorites (KKCM) with chromites from LL, L and H ordinary chondrites. Data extracted from [2].

Summary: Here, we show that the projectile responsible for Lockne is not a chondrite and therefore not directly related to the Ordovician event, if this is linked to the disruption of an L-chondrite parent body. Instead, it might be a random impact of a common projectile type. Based on size frequency distribution, a ~7.5 km impact crater on Earth occurs every 100.000 years [9]. These types of projectiles, probably related to the NMI meteorites (Fig. 6) are besides chondrites the most common type of material impacting Earth which is possibly linked to some S-type asteroids from the inner part of the asteroid belt [10].

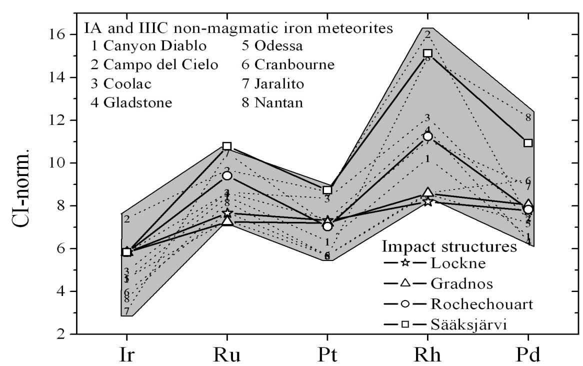

Fig. 6: Comparison of the PGE element pattern of Lockne with those found for Gardnos, Rochechouart and Sääksjärvi (values escalated for a better comparison). Data from [10]. The composition of these projectiles is compared to the patterns of the PGE in the metal phase of NMI meteorites (IA and IIIC), including Canyon Diablo, the projectile for the Barringer crater.

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References: [1] Sturkell (1998) GFF 120, 333-336. [2] Alwmark and Schmitz (2007) EPSL 253, 291-303.. [3] Heck et al. (2004) Nature 430, 323-325; [4] Korochantseva et al. (2007) MAPS 42, 113-130; [5] Tagle and Hecht (2006) MAPS 41, 1721-1735; [6] Plessen and Erzinger (1998) Geostand. Newsletter 22, 187-194. [7] Tagle and Claeys (2005) GCA 69, 2877-2889. [8] Goderis et al. (2006) GSA Vol. 38 Abstract #111141; [9] Chapman (2004) EPSL 222, 1-15. [10] Tagle et al. (2007) LPSC, abstr. # 2216.