A NON-MAGMATIC IRON METEORITE AS IMPACTOR FOR THE ROCHECHOUART CRATER

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The Rochechouart impact crater in the French Massif Central, has a diameter of 20 - 25 km [1] and an age of 250 my [2]. The cater is deeply eroded, down to the crater floor. Impact melt outcrops can be found in different parts of the crater [3]. The type of impactor that produced Rochechouart crater is still not clear. The first proposal of an IIA iron asteroid was based on the abundance of some platinum group element (PGE) and siderophile elements in the melt and target rocks of the Rochechouart structure [4]. Later, metal veins were reported from the rocks at the bottom crater [5] and interpreted as condensates from the impacting asteroid. From the Ni/Cr ratios of these veins the authors proposed a chondrite body as impactor [5]. On the basis of Cr isotope an ordinary chondrite as impactor was finally proposed by [6].

The goal of the present work was to determine the type of impactor that produced this crater, based on complete analysis of all PGE and Au as well as Ni, Co and Cr. PGE and Au were measure in 26 samples of impact melt rock and melt rich breccia from different localities in the crater using the nickel-sulfide fire assay in combination with ICP-MS, after the procedure of [7]. This method provides reliable precision down to concentration of around 0.06ng/g Ru, 0.02 ng/g Rh, 0.19 ng/g Pd, 0.06 ng/g Ir, 0.07 ng/g Pt and 0.13 ng/g Au and is thus ideal to detect even minute meteoritic contamination. Ni, Co and Cr were analyzed using XRF. PGE have the tendency to concentrate in small nuggets, that can not be homogenized within the sample. This results in a poor reproducibility of the data if a small amounts of sample is used. The nickel sulfide fire assay was carried out in this work using up to 70 g of sample per analysis. For the precise identification the impactor, we used our newly established data base that encompasses the published PGE concentrations of more than 1000 different meteorites. This data is used to determine specific element ratios that characterize each meteorite type. These element ratios were compared to the measured PGE element ratios of the Rochechouart impact melts. Element ratios were determined by linear regression of the element concentrations in the samples, as shown in Fig 2. The same procedure was also successfully applied for the identification of traces of an L-chondrite in the Popigai impact melt by [8].

The results of the analyses of the Rochechouart melt rocks and breccias show a highly inhomogeneous distribution of PGE. Some samples had an Ir concentration of <0.06 ng/g others shows an enrichment up to 7.6ng/g. A relation between the sample location and amount of meteoritic contamination is not observed. The av. concentrations were 2.6 ng/g Ir, 6.6 ng/g Ru, 7.1 ng/g Pt, 1.5 ng/g Rh, 3.7 ng/g Pd. The Ir concentration is much higher than the concentrations found in the gneisses from the target rocks (0.009 ng/g Ir) [4].

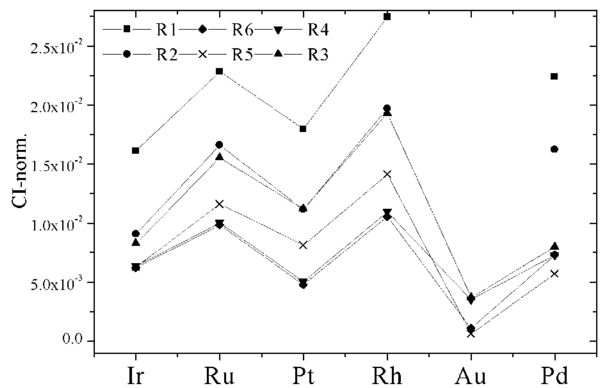

Fig. 1. CI-normalized PGE and Au concentration of some Rochechouart impact melt samples. Patterns are homogenous for all PGE rich samples.

The PGE patterns differ from those in all chondrites types. The Ru and Rh enrichments compared to Ir are common in differentiated iron meteorites but not in chondrites. Ru/Ir ratio in chondrites vary between 1.53 and 1.66 The Ru/Ir ratios for the Rochechouart melt are far from those values (2.8 ± 0.1). The concentrations of the elements Ru and Ir correlate well as shown in (Fig. 2). A good correlation is also observed within all the other elements. No correlation was reported between Ni and Ir for the Rochechouart impact melt [9]. This is interpreted as a product of post impact fractionation. The samples analyzed in this study show a clear correlation between Ni and Ir. The previous lack of correlation might be explained by analytical problems deriving from the nugget effect. Recent studies of PGE as well as Ni and Cr in impact melt from various craters revealed no fractionation between those elements [8,10]. This means that the element ratios of the melt are representative of the composition of the impacting asteroid. The ratios in Table 1 were determined by the same method as illustrated in Fig. 2.

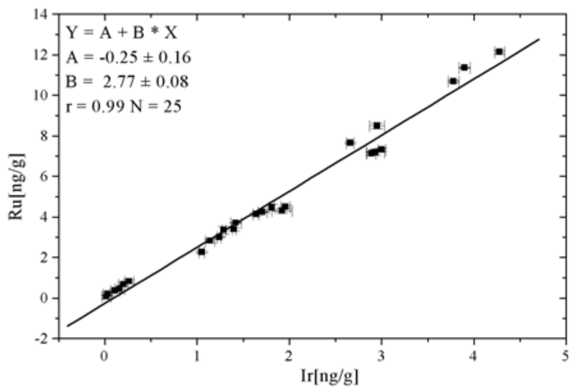

Fig. 2. Correlation between Ru vs. Ir in Rochechouart samples. The slope of the line is the ratio of both elements in the impactor.

Table 1. Inter element ratios in the Rochechouart.

	Ru/Ir	Pt/Ir	Rh/Ir	Pd/Ir	Ni/Ir	Ni/Cr
Rochechouart	2.8±0.1	2.4±0.16	0.61±0.02	1.02±0.05	100±17	2±0.02

Ni/Ir ratio in undifferentiated meteorites such as chondrites vary between 17 and 31. These values are far below those found in the Rochechouart samples (Table 1). The Ir depletion relative to Ni as well as the non-chondritic PGE element ratios points towards a fragment of a differentiated asteroid as impactor. Although being slightly lower, the Ni/Cr ratio is similar to that of chondrites, between 2 and 7. The analyses of the Rochechouart samples shows that the impacting bolide has characteristics of both types, a chondrite and an iron meteorite, which explains the controversy.

Non-magmatic iron meteorites have a very complex formation history. They have similar siderophile elements ratios (Table 2). These meteorites are characterized by a high amount of silicate inclusions. Some of the silicate inclusions have an almost chondritic composition except for the absence of metal [11]. This means that an asteroid with this particular composition contains a combination of an iron meteorite and a partially differentiated silicate (Cr rich) meteorite.

Table 2. Inter element ratios in the iron phase of non-magmatic iron meteorites.

	Ru/Ir	Pt/Ir	Rh/Ir	Pd/Ir	Ni/Ir	Ni/Cr
IA	2.1±0.6	2.6±0.6	0.59±0.07	1.5±0.4	31±10	>3000
IIIC	3.6±1.1	4.5±3.2	1.19±0.4	3.2±1.2	60±40	>3000
IIE	1.5±1	2.4±1.1	0.52±0.2	2.4±1.1	18±7	>4500

Due to the high siderophile character of the PGE are these concentrated metallic phases, which then dictates the PGE signature of the whole meteorite. The comparison of the PGE ratios (Tables 1 and 2) shows great similarities between the Rochechouart samples and the iron phase of non-magmatic iron meteorites. Ni is less siderophile than the PGE, an Cr is a lithophile element. As a result part of the Ni and most of the Cr are in the silicate phase. The Ni/Ir ratio and Ni/Cr ratio in the asteroid depend on the proportion of metallic to non-metallic material. However, it is not possible to quantify these phases. Non-magmatic iron meteorites are only partially fractionated and both phases (iron and silicate) are not widely separated from each other. This results in Ni/Ir ratios for the whole asteroid which are higher than for the metallic phase alone. The Ni/Cr ratios are influenced by the high amount of Cr in the silicate phase. The Ni/Cr ratios may resemble those of chondrite, depending on the proportion of silicate/metal.

These arguments support an hypothesis of a non-magmatic iron meteorite as impactor. These results are not in contradiction with those obtained by [4, 5]. But the interpretation is different. Based on oxygen isotope data, it has been proposed [12] that the parent body of the IAB and IIICD meteorites evolved from a carbonaceous chondrite. The IIE meteorite are more related to ordinary chondrite [11,12]. The Cr isotopes data give important information for discriminating between carbonaceous chondrites and ordinary chondrites. Taking into consideration the results from [6] the impactor is most likely an IIE non-magmatic iron meteorite.

IA iron meteorites are common in the actual meteorite population, IIE are rare. Non-magmatic iron meteorites are also relatively common among the impactors that forms small craters (<1.5 km), e.g. the Barringer crater IAB, Monturaqui IAB or Kaalijärvi IAB [13]. Finding that an asteroid fragment, with non-magmatic composition, larger than 1 km in diameter impacted the Earth has interesting implications on the formation history of those specific meteorites.

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