SEARCH FOR PROJECTILE TRACES IN MELT ROCKS OF THE CHARLEVOIX AND DELLEN IMPACT STRUCTURES. R. Tagle[1] ([1]VUB, Pleinlaan 2, B-1050 Brussels, Belgium, Roald.Tagle@vub.ac.be), J. G. Spray[2], ([2]Planetary and Space Science Centre, University of New Brunswick, Fredericton, NB E3B5A3, Canada, jgs@unb.ca), and R. T. Schmitt[3] ([3]Museum of Natural History, Invalidenstrasse 43, 10115 Berlin, Germany, ralf-thomas.schmitt@museum.hu-berlin.de).

Introduction: The identification of projectile components is an important goal of impact crater research. The first studies that addressed this issue in the 1970s involved lunar impact melt (IM) rocks, e.g., [1, 2]; only later work focused on terrestrial impact structures. It is remarkable, however, that despite almost 40 years of projectile research, the number of craters for which a projectile is precisely known remains small [3 and ref. therein]. Precise identification of projectile components by geochemical techniques has only been accomplished in the past 10 years. Projectile identification in lunar materials is, in principle, easier than in terrestrial rocks because the projectile contamination (reflected by Ir concentration), is usually significantly higher than in most impact melt rocks of terrestrial craters, where the proportion of projectile is usually less than 1%. Here, we present the results of investigations into two terrestrial impact structures: Charlevoix, Canada, and Dellen, Sweden.

Charlevoix: The impact structure (47°32´N/70°18´W) is located ~100 km northeast of Quebec City. The ~54 km complex crater structure is topographically well expressed. The impact event was dated by K/Ar to 357 ± 15 Ma [5], but newer Ar-Ar laser fusion suggests later ages between 460-470 Ma [4]. However, further studies are required for a better age constraint of this structure. For this study, a set of 22 impact melt rock samples was selected for analysis. The samples were collected at three IM localities. One sample was collected near to an in-situ outcrop Im1 (± 30 m), a set of 9 samples from an outcrop of glacier reworked material ~ 1 km from the first location (outcrop Im1 and Im2 described by [5]), and 12 samples from an outcrop near to the central peak at Mt. des Eboulements.

Dellen: This 19 km diameter impact structure is located at N 61°48'/E16°48'. Dating by Ar-Ar and Rb-Sr give an age of 89.2±2.7 Ma [6]. A set of 15 IM samples and one Suevite of glacially reworked material from two localities were studied for projectile traces.

Methods: Major, minor and selected trace elements of the IM samples were determined by XRF. Ni, Co and Cr were measured by ICP-MS after acid dissolution to obtain a better resolution. PGE were analyzed after the procedure of [7] by NiS-fire assay in combination with ICP-MS. In the case of Charlevoix, only 3 samples from Im2 were analyzed for PGE because of the homogenous composition of these samples indicated by the XRF and ICP-MS data. A total of 16 PGE analyses of the Charlevoix samples were performed. For Dellen, all samples were used several times for a total of 20 analyses. For each sample, relatively large (40 and 80 g) masses were used in order to minimize background effects.

Results: The XRF and ICP-MS analyses reveal a homogenous composition of the IM rocks for the three localities sampled within the Charlevoix crater, as well as a relative low concentration of Co, Ni and Cr. The same is observed for the Dellen IM rocks (Table 1). This low concentration of Ni and Cr suggests that, if present in the IM, the proportion of extraterrestrial material is extremely low.

Table 1. Composition of the impact melt rocks

	Charlevoix					Dellen		
	Ave. IM1	Ave. IM2	s	Ave. ME	s	Ave. IM	s	suevite
wt.%								
SiO2	60.2	61.4	0.4	62.5	4.4	66.3	2.6	65.0
TiO2	1.01	1.04	0.10	0.97	0.33	0.59	0.08	0.66
Al2O3	14.7	14.6	0.2	14.6	0.9	15.1	1.2	14.2
Fe_2O_3*	7.25	6.91	0.40	7.03	1.93	4.79	0.63	5.47
MnO	0.09	0.09	0.01	0.07	0.03	0.05	0.01	0.04
MgO	2.15	2.15	0.43	2.12	1.07	1.21	0.30	1.45
CaO	4.12	3.26	0.54	2.31	1.15	2.97	1.06	2.89
Na_2O	3.38	2.15	0.24	3.15	0.90	3.06	0.34	1.92
K2O	2.45	4.95	0.16	4.05	2.04	4.22	0.81	4.88
P_2O_5	0.29	0.28	0.05	0.18	0.05	0.14	0.02	0.16
SO_3	<0.1	<0.1		<0.1		<0.1		<0.1
LOI	4.2	2.9	0.6	2.6	0.7	1.1	0.6	2.7
total	99.8	99.7		99.6		99.6		99.4
µg/g								
Ba	850	1171	114	712	511	589	68	719
Ce	147	85	18	119	28	86	12	90
Cu	42	50	11	34	1			<30
Rb	139	158	5	138	63	198	35	210
Sr	349	327	49	201	141	177	66	231
Th	12	12		16	3	20	4	16
V	86	84	10	81	40	52	10	57
Y	57	58	6	75	22	65	3	68
Zn	97	96	23	86	42	63	7	77
Zr	535	512	65	462	273	319	49	359
Co	17	17	2	16	7	8	2	n.d.
Cr	37	39	9	32	17	18	4	n.d.
Ni	25	26	4	22	12	12	3	n.d.
ng/g								
Ru	0.12	0.12		0.23		0.22		0.06
Rh	< 0.01	0.01		0.60		0.07		0.01
Pd	< 0.13	< 0.13		0.38		0.37		< 0.13
Ir	< 0.04	< 0.04		0.11		0.23		< 0.04
Pt	0.06	0.10		0.26		0.56		0.07

* total Fe = Fe2O3; IM1, 2 = outcrop IM1 and IM2; ME = Mt. des Eboulements; n.d. not determined

The PGE concentrations in the IM rocks of both structures are very low (Table 1). A significant proportion of the samples show results below the detection limit of the method. The highest Ir concentration in one Charlevoix sample (Ir 0.25 ng/g) coincides with this being the only sample with more Ni than Cr. In the case of Dellen, the average PGE concentration was higher and two samples showed Ir concentrations of 0.73 ng/g and 0.54 ng/g.

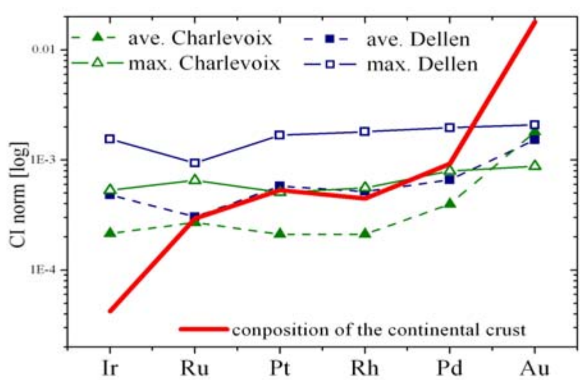

Fig.1. CI-chondrite norm. PGE patterns of the impact melt rocks of Charlevoix and Dellen (average and maximum values) compared to the average composition of the continental crust [see 7].

PGE patterns of the two IM sample suites are plotted in Fig. 1. This reveals a relatively flat CI-normalized trend for the average composition, as well as for samples with the maximum concentration. The element patterns differ from the continental crust by an enrichment of Ir and Ru. This suggests the possibility of a chondritic projectile or a mantle source for the PGE. For further characterization of the projectile, assuming a chondritic PGE source, it is necessary to determine the projectile elemental ratios [3]. Two examples, one for Charlevoix and one for Dellen are shown in Fig. 2.

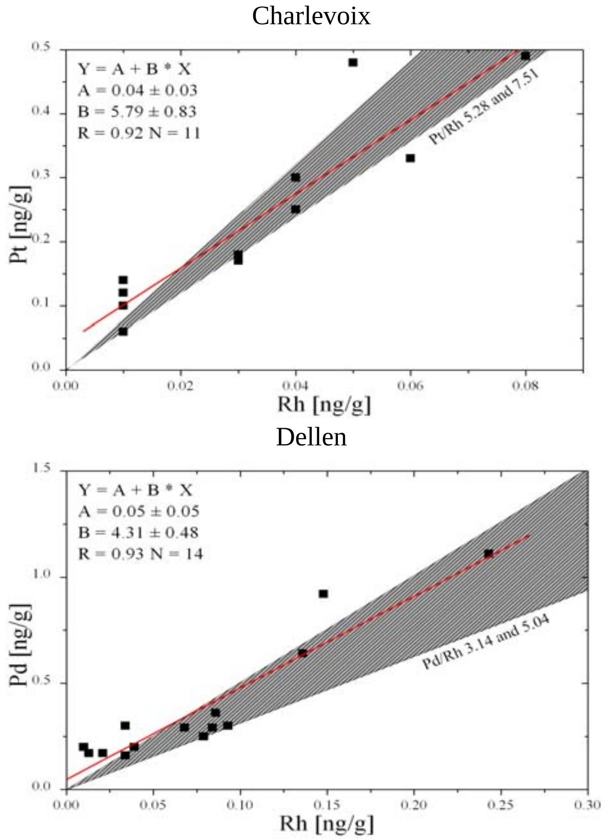

Fig. 2. Determination of projectile element ratios by calculation of the slope (B). The spread of the ratios in chondrities is given as a gray field. The values are shown below (data from [8]).

The determination of the projectile component based on PGE element ratios calculated from the slope does not reveal a definitive answer on the nature of the projectiles for Dellen or Charlevoix (see Fig 3). Whereas for Dellen the arguments for a chondritic projectile (without further classification) appear consistent, the arguments in the case of Charlevoix are not fully convincing because the PGE values for some elements, including Pd and Ir, can be below the detection limit. Therefore, a calculation of the projectile element ratios is sometimes reduced to only 4 points, which accounts for a very poor statistic.

Conclusions: PGE elemental ratios in the IM rocks of Charlevoix and Dellen are extremely diluted, which hampers the precise identification of the projectile. However, no superior technique of projectile identification for these impact melts is available at present. Compared to other techniques, neither Os-isotopes nor Cr-isotopes promise better results. Os-isotopes would suffer from the same problems of low PGE concentrations, in addition to the fact that the information output is minimal for a projectile identification [3]. In the case of Cr-isotopes with significantly more information on projectile nature, the indigenous Cr influences the limit of determination of extraterrestrial Cr isotopes. For example, according to [9], 50 µg/g Cr in the target requires 0.7 wt.% of chondritic material to allow detection of the extraterestrial component. Taking the highest values measured for Charlevoix and Dellen and assuming a CI projectile with ~471 ng/g Ir [98], the amount of CI-normative projectile would be ~0.05 wt.% for Charlevoix and ~0.15 wt.% for Dellen. These values are far below those required for a Cr-isotopic study.

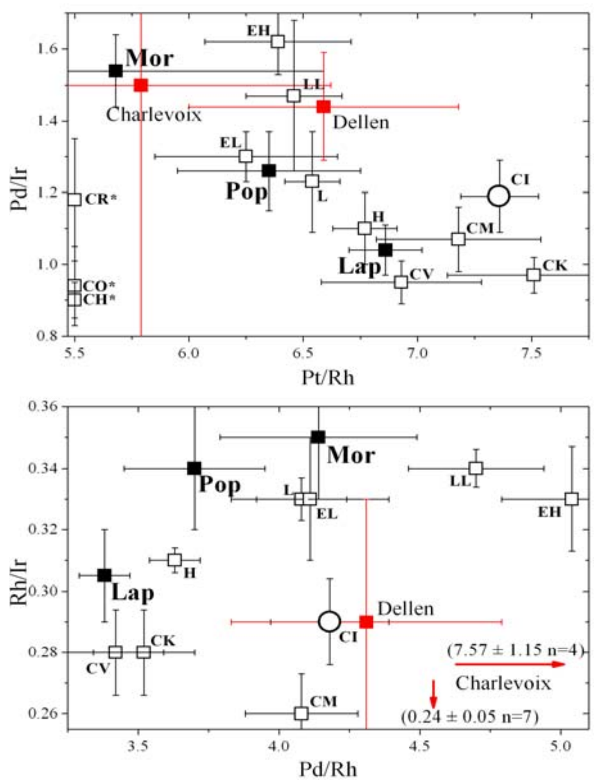

Fig. 3. Comparison of the element ratios calculated for the projectiles for Dellen and Charlevoix, with the composition of the possible chondritic projectiles as well as the results for Morokweng [10], Popigai [11] and Lappajärvi [8]. Note that for Charlevoix the values for Rh/Ir and Pd/Rh are out of the chondritic range.

Outlook: For a more precise determination of the projectile material in these two impact structures, further studies are required. A highly sensitive PGE determination still offers the best opportunity to find the most conclusive answer, especially in combination with a larger survey of samples by XRF for high Ni values.

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References: [1] Hertogen et al. (1977) Proc. Lunar Sci. Conf. 8th, 17-45. [2] Janssens et al. (1978) Proc. Lunar Sci. Conf. 9th, 1537-1550; [3] Tagle & Hecht (2006) MAPS 41, 1721-1735; [4] Whitehead et al. (2003) Large Met. Impact Nödlinen, abst. #4084; [5] Rondot (1971) J. Geophy. Res. 76, 5414-5423; [6] Deutsch et al. (1991) Tectonophisics 216, 205-518 [7] Tagle et al. (in press) MAPS; [8] Tagle and Berlin (in press) MAPS; [9] Frei and Rosing (2005) EPSL 236, 28-40; [10] McDonald et al. (2002) 65, 299-309; [11] Tagle & Claeys (2005) GCA 69, 2877-2889.