THE METEORITIC COMPONENT OF IMPACT MELTS FROM EUROPEAN IMPACT CRATERS.

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Impact melt samples from 5 European craters (Lappajärvi, Sääksjärvi, Mien, Dellen and Rochechouart) have been analysed for siderophile elements by using a new analytical technique. The neutron irradiated samples are equilibrated with metal at high temperatures. The metal is then physically separated, dissolved and counted on a Ge(Li)-detector (1). This allows rapid analyses of siderophiles at only moderate neutron fluxes. Results are presented in Table 1. All impact melt samples contain at least 1 ppb Ir. Iridium concentrations of basement rocks at Lappajärvi and Sääksjärvi are much lower than this (2,Tab.1). Since the composition of impact melts at the 4 craters in the Fennoscandian shield are rather similar (3), we conclude that there is a meteoritic contribution in the impact melt of all 4 craters. A significant meteoritic contribution to Rochechouart melts has already been demonstrated (4).

Lappajärvi: The melt at Lappajärvi is chemically homogeneous with respect to meteoritic as well as non-meteoritic elements (5,6). Iridium concentrations do not exceed variations of about a factor of two (6,2,Table 1). The high Re concentrations of two impact melts (2) have also been found in three additional samples (Table 1). We have not found the source of the Re excess among the three types of basement rocks (7). The well defined mean Ni/Ir ratio of 5 samples (Table 2) is very near to the Orgueil value, but also within the range of H-chondrites. From the available evidence: Ni/Ir (Table 2), Co/Cr between H- and C-chondrites (5),large volatile element concentrations, e.g. Se (2), we infer a carbonaceous chondritic projectile, perhaps with a high Re/Ir ratio,however, at present we cannot completely exclude an H-chondrite.

Sääksjärvi: There is clear enrichment of Ir, Ni, Co and Cr in the 5 samples analysed. This would suggest a chondritic projectile. However, the Ni/Ir ratio is significantly higher than any chondritic ratio (Table 2, Fig. 1).

The chemical similarity of Lappajärvi and Sääksjärvi impact melts suggests that the high Ni/Ir ratios are not due to excessively high Ni concentrations in a basement rock. Since Cr is simultaneously enriched in Sääksjärvi melts (Table 1)(although the Ni/Cr ratio is not very well defined, because of the fairly high indigenous Cr) an iron meteorite is ruled out. The remaining

Siderophile elements and Cr in impact melts from five European craters.

Table 1

	Ir ppb	Re ppb	Au ppb	Ni ppm	Co ppm	Cu ppm	As ppm	Sb ppb	W ppm	Fe ppm	Cr ppm
LAPPAJÄRVI											
impact melts											
L 2 - 2	7.6	3.5	2.8	240	22.6	22.0	0.50	19	0.55	3.87	93
L 15/2	8.4	2.8	1.7	250	23.5	43.0	0.54	22	0.42	3.44	
L 1/14	4.8	2.2	2.4	177	16.6	36.5	0.95	2010	0.60	3.70	109
basement											
L5 gra.-peg.		<1.1	0.3	5	0.2	1.3	0.62	45	0.20	0.90	
L7 amph.	<0.2	<0.4	3.0	58	40.0	116.0	0.91	215	0.44	8.90	
SÄÄKSJÄRVI											
impact melts											
S 7/1-1	3.8		4.9	370	30.2	71.5	1.62	20	1.02	3.67	204
S 9 - 2	4.6		1.4	330	27.0	29.0	0.29	11	1.10	4.10	145
S 6 - 3	3.6		1.6	341	37.3	33.0	0.47	7	0.74	3.25	165
S 5/2-4	3.9		1.5	333	59.5	59.0	0.23	16	0.51	4.00	132
S 5/2-1	5.5		2.0	310	47.3	43.0	0.36	38	0.71	3.88	167
basement											
S 14 grano	<0.4		<0.5	22	12.8	0.6	0.13		0.23	4.40	109
MIEN											
impact melt											
Mi 4	1.2		1.1	58	8.3	12.5	0.38	190	1.56	2.11	52
DELLEN											
impact melt											
De 7	1.0		1.1	56	8.8	13.4	0.26	40	0.35	2.85	21
ROCHECHOUART											
impact melts											
V 1	10.8		0.4	347	24.4	45	14.8	117	16.8	2.12	204
VR 2	12.2		0.8	205	29.0	97	9.3	93	6.5	4.32	
VR 1	15.2			252	25.5		10.2	353	17.2	4.80	301
2 - F2	10.4		0.5	202	9.3	46	29.4	199	28.5	1.29	228
3 - F2	1.2			66	1.9	43	22.5	360	18.0	1.21	123
LA 1	1.1		0.5	41	5.4	24	2.2	130	3.3	1.03	60
1 - B2	0.5		0.5	36	10.2	31	17.6	190	112.0	5.4	44

amph. - amphibolite; gra.-peg. - granite-pegmatite; grano. - granodiorite.
Rochechouart melts: V - Valette; F - F. Cêverane; LA - L'Ajoux; B - Babaudu.
Rochechouart samples: W. Horn and A. El Goresy.

possibility is a stony-iron meteorite. Fig.1 shows that in general pallasites have much too high Ni/Ir ratios, while mesosiderites have too low ratios, however, marginally reaching the Sääksjärvi ratios. More basement rocks will be analysed to clarify these points.

Mien and Dellen: Because only one sample has been analysed so far from these craters not much can be said. The concentrations of the first 6 elements of Table 1 are surprisingly similar in Mien and Dellen. From the data of the other craters on the Fennoscandian shield one must conclude that 1 ppb Ir indicates the presence of a meteoritic component. The Ni, Co and Cr values are, however, in the range of the basement of the other craters. More analyses are needed to demonstrate Ni, Co and Cr excesses.

Rouchechouart: The six impact melt samples (Table 1) come from 4 different localities within the crater. Janssens et al.(4) have already found large enrichments of siderophile elements in Rochechouart melts. However, interelement ratios among siderophile meteoritic elements are heavily disturbed, presumably due to weathering. This makes the assignment of the projectile to a certain meteoritic group rather complicated. Janssens et al.(4) have suggested a IIA-iron meteorite as the most plausible choice for the projectile. However, the data of Table 1 do not confirm this assignment, they rather support the finding of Horn and El Goresy (8), who suggest that the projectile was a chondrite not an iron meteorite:

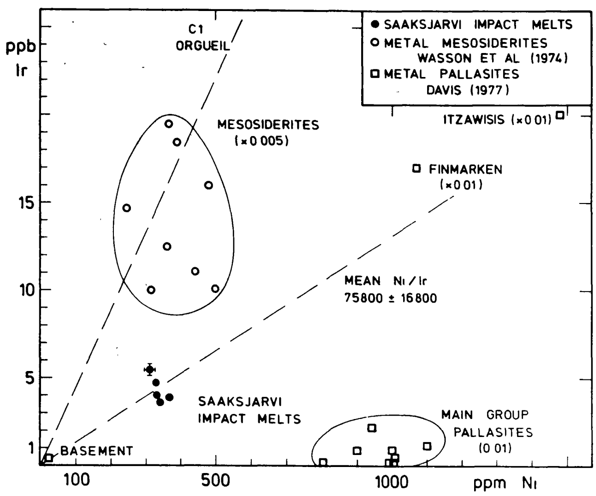
1.) The Ni-Cr relationship (Fig.2) shows a rough correlation of Ni and Cr in the melt samples. The Ni/Cr ratios lie between the ratios of the small metallic particles (8) and chondritic ratios.

Mean Ni/Ir ratios in samples form 4 terrestrial impacr craters.

	Number of samples	Ni/Ir (corrected for indign.Ni)	Literature
Clearwater East	12	24 800 ± 4 100	(11)
Lappajärvi	5	23 400 ± 910	(2),Table1
Rochechouart	7	30 930 ± 15 900	Table 1
Sääksjärvi	5	71 700 ± 13 800	Table 1
Orgueil (C1)		22 670	this lab.
C 2-chondrites	7	21 330 ± 7 300	this lab.
H -chondrites	18	24 200 ± 1 400	(16)
L -chondrites	17	28 360 ± 2 300	(16)
LL -chondrites	9	30 670 ± 5 480	(16)

Table 2

Fig.2



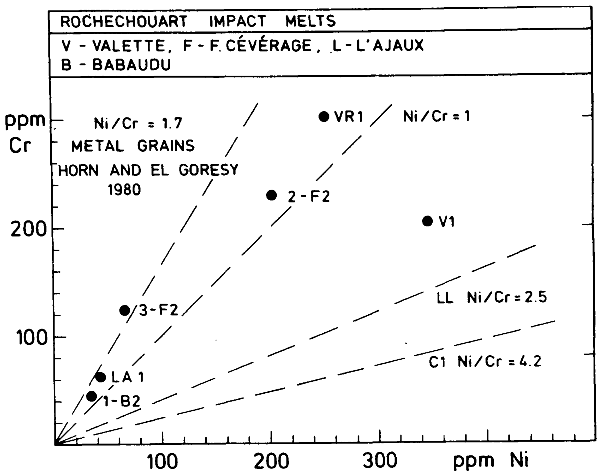
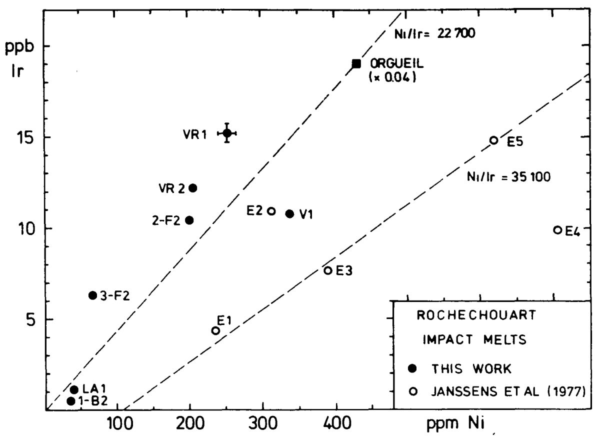


Fig.3 ↑ Fig.4 ↓



2.) Ni-Ir ratios in melt samples are so variable that a chondritic Ni/Ir ratio cannot be excluded (Fig.3). In fact, our data come much closer to the chondritic ratio than those of Janssens et al.(4). Figs.2 and 3 indicate that some bias may arise by taking only samples from one place. Since weathering may have caused the large scatter in interelement ratios, rocks from each locality may have their characteristic imprint of weathering.

3.) Not only the low Au but also the low Os concentrations (Table1,(4))may be caused by weathering. One heavily weathered Brent sample shows depletion in Os and Au (10).

Summary: This and earlier results have clearly shown the dominant role of impact melt as the main carrier of meteoritic material at large terrestrial impact craters:

1.) The coherent melt sheet, if present, always has the highest concentrations of siderophile elements. This has been observed at Clearwater East (10), Lappajärvi (5,6), Sääksjärvi (Table 1), Brent (12) and Rochechouart (4).

2.) The meteoritic component seems to be fairly homogeneously distributed within the melt sheet. This corresponds to the chemical homogeneity of the melt. Since siderophile meteoritic elements are usually concentrated in very minor phases (FeNi,FeNiS) some inhomogeneity may arise from local concentrations of these elements. This is best demonstrated at Clearwater East where one part of the melt is practically free of Ir, while the meteoritic Cr is only slightly lower than in the bulk melt (11). Secondary alteration is another source of inhomogeneous distribution of meteoritic elements (4,9). Both processes can lead to distortions of meteoritic element ratios.

Melt bearing mixed breccias (suevitic melt) have been found to be free of meteoritic component in Brent and Lappajärvi samples (12,5).

3.) The fraction of meteorite in impact melts may be as large as 10 % (11). The assumption that the meteorite is "dissolved" in the impact melt, together with estimates for the amount of melt, allows to calculate impact velocities (13). The obtained velocities are reasonable (10).

4.) So far 5 chondrites have been found as projectiles of large terrestrial craters with coherent melt sheets: Clearwater East (10), Brent (9), Lappajärvi (5,2), Rochechouart (8) and Wanapitei (14); perhaps one stony-iron (Sääksjärvi) and one achondrite (Nicholson Lake (14)) have been identified by enrichments of meteoritic elements in impact melts.

Impact melt sheets without a meteoritic signature (e.g. Mistastin (15,10), Manicouagan (10) may be produced by achondrites. There is, however, the possibility that large parts of the impact melt sheet remains uncontaminated by meteoritic material. The problem is especially obvious at Clearwater West (10). The evidence for iron meteorites is more circumstantial (14).

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Fig.2: Wasson,J.T. et al.(1974) GCA 38, 135; Davis, A.M. (1977) PhD. Thesis.