NEW DATA ON METEORITIC MATERIAL AT TERRESTRIAL IMPACT CRATERS.

Herbert Palme*), Rainer Wolf and Richard A.F. Grieve**)
Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637
*)present address: Max-Planck-Institut für Chemie, 65 Mainz, F.R. Germany
**)Earth Physics Branch, Department of Energy Mines and Resources, Ottawa, Canada K 1A 0Y3.

Siderophile trace elements such as Ir, Os, Ni etc. have been successfully used as indicators for the presence of meteoritic material in lunar and terrestrial impact craters (1-3). Until recently, only iron or stony-iron meteorites have been identified as projectiles of terrestrial impact craters. Chondritic projectiles of small craters (up to ~ 1km diameter) may be preferentially destroyed in the atmosphere (4). El Goresy and Chao (5) and Morgan et al.(6) have concluded that the Ries crater (23 km diameter) was made by a stony meteorite. Palme et al.(7) showed that the projectile of Clearwater East (20km) was a stony meteorite.

We have now analyzed two more samples from Clearwater East together with samples from Brent (3 km), Manicouagan (65km), Irghizites from the Zhamanshin structure and an Ivory Coast tektite and a Bosumtwi crater sample. All samples have been subject to instrumental and radiochemical neutron activation analysis. The results are given in the Table below.

Clearwater East: Data for sample DCW-63-965 (nominal depth 294 m) essentially confirm earlier measurements (7). The older samples (nominal depth 298.9 and 316.7 m) have also been analyzed for Cr and Co. The mean Ni/Cr ratio for the three samples is 3.1 ± 0.5 (Fig.2). Using the data of Currie (8) for indigenous correction would shift this ratio to 3.3, still too low to match the proposed C1 chondrite (7). If the Ni and Cr contents of sample DCW-2-63-1103 (Table) are of meteoritic origin (there is no suitable country rock available (8)), then some fractionation of the impact melt must have been occurred. A sample 1 m below this sample has 1500 ppm Ni (9). There are also some varia-

Siderophile and Lithophile Elements in Crater Samples

Sample	Description*+	Ir ppb	Os ppb	Re ppb	Ni ppm	Co ppm	Pd ppb	Au ppb	Ge ppb	Se ppb	Cr ppm	Sc ppm	Fe %	Na %
Clearwater East														
DCW-2-63- 965	fi gr melt 294 m depth	38.9	39.0	2.31	739	49.7	58.1	8.1	763	252	287	11.0	3.2	1.8
DCW-2-63-1103	med gr melt 337 m depth	≤0.02	0.038	0.308	80	16.1	≤1.4	0.85	1094	11.2	140	19.0	4.1	2.4
Brent														
B1-59-2758.7	fi gr melt 841 m depth	0.197	0.108	0.105	41	3	≤3.9	0.16	1181	24.2	3.8	8.4	4.0	1.9
B1-59-2773.3	co gr melt 845 m depth	2.68	1.26	0.055	151	10.5	7.8	0.15	1990	62.7	73	12.2	7.2	3.0
B1-59-2800.2	co gr melt 853 m depth	9.57	9.22	0.177	320	21.1	18.1	0.93	1316	119.7	103	12.0	7.0	2.4
B1-59-1503.8	alnoite 458 m depth	≤0.01	≤0.034	0.585	327	88.1	≤4.6	≤0.30	3586	178.7	350	21.7	13.3	0.28
B1-59-2931	bas rock gn 893 m depth	≤0.06	≤0.040	0.021	20	3.2	≤5.3	≤0.26	774	27.7	23	4.8	2.7	2.0
Manicouagan														
WMM-102A-64M	bas rock 75 km from center	≤0.04	≤0.043	0.280	≤10	38	≤5.2	≤0.37	4460	9.45	13	25.2	8.4	3.3
MMG- 74 -74(1)	fi gr melt 25 km from center	≤0.06	≤0.055	0.088	23	27	≤4.8	≤1.1	1176	17.9	97	19.5	5.3	3.0
MMG- 74 -75(5)	me gr melt 25 km from center	≤0.07	≤0.037	0.191	≤50	22	≤6.3	≤0.31	1181	12.1	87	19.0	4.2	3.0
Irghizites														
RZS-76-1.24	acidic ~ 74 % SiO_2	0.14	≤0.08	0.064	1325	86	11.7	0.40	300	12.5	218	10.2	4.6	0.75
RZS-76-1.3	acidic ~ 74 % SiO_2	0.27	≤0.13		983	90	14.4	≤0.44	187	6.6	230	10.6	4.6	0.77
RZS-76-1.15	basic ~ 54 % SiO_2	2.4	≤0.172		≤30	24	≤6.9	1.64	1060	5.3	18	17.1	6.4	2.6
Ivory Coast tektite	IVC-4-64	0.235	0.099	≤0.036	115	25	≤6.9	0.26	301	0.69	225	16.3	5.1	1.4
Bosumtwi crater		≤0.09	≤0.092	≤0.047	94	25	≤7.9	1.98	591	7.9	161	17.8	4.9	2.1
Allende	Split 15, position 23	939	894	81.4	15800	790	784	142.9	15.8	7600	3640	11.5	24.5	0.35

*Bas = basement; co = coarse; fi = fine; gn = gneiss, gr = grained, med = medium.

+Sample sources: Canadian crater samples: R.A.F. Grieve, Dept. of Energy, Mines and Resources, Ottawa, Canada. Bosumtwi crater sample and Ivory Coast tektite: E. C. T. Chao, U.S.G.S., Reston, Irghizites: K. Fredriksson, Smithsonian Institution, Washington.

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tions in the Ni/Ir ratio (Fig. 2), indicating that Ni is somewhat decoupled from other siderophiles. Obviously, some more samples are needed to get a better defined average Ni/Cr ratio. Table 1 and Fig.2 indicate that Se in the Clearwater East samples is probably of meteoritic origin, which is to be expected if the projectile was a chondrite.

Brent: One Brent sample (845 m) has a relatively flat pattern of siderophiles and Cr (Fig. 2). The low Re and Au contents are probably due to weathering,which has affected Brent samples much more than Clearwater East samples. From the limited information available, it appears that Re and Au are most easiest susceptible to weathering (10,11). Like in Clearwater East there is a Ni-Cr correlation. Fig.1 includes various data from the Canadian Geological Survey. Grieve (12) has calculated an average Ni/Cr ratio of 2.85 ± 0.4 from these data. Average country rock analyses from inside and outside the crater (13), would not change this ratio significantly. Furthermore, Se is enriched parallel to Cr (Table, Fig. 2). Thus, there should be little doubt that the Brent crater was made by a chondrite; eventually an L-chondrite (Figs. 1&2).There is a source of Ni, Cr and Se at Brent (although with still too low Ni/Cr) (Table), which would provide these elements. The contribution of the alnoite to the impact melts is, however, in most cases insignificant.

Manicouagan: Still no enrichment in siderophiles has been found in a sample from this crater (7). Curiously, the two impact melts have relatively high Cr concentrations compared to a basement rock (grnt-pyx-bt-gneiss (14)).An achondritic projectile would provide Cr but no siderophiles.

Irghizites: The high Ni and Co concentrations of the Irghizites already observed by Ehmann et al.(15) is puzzling. The enriched Ir suggests a meteoritic component. However, the basic variety has much higher Ir content, but is very

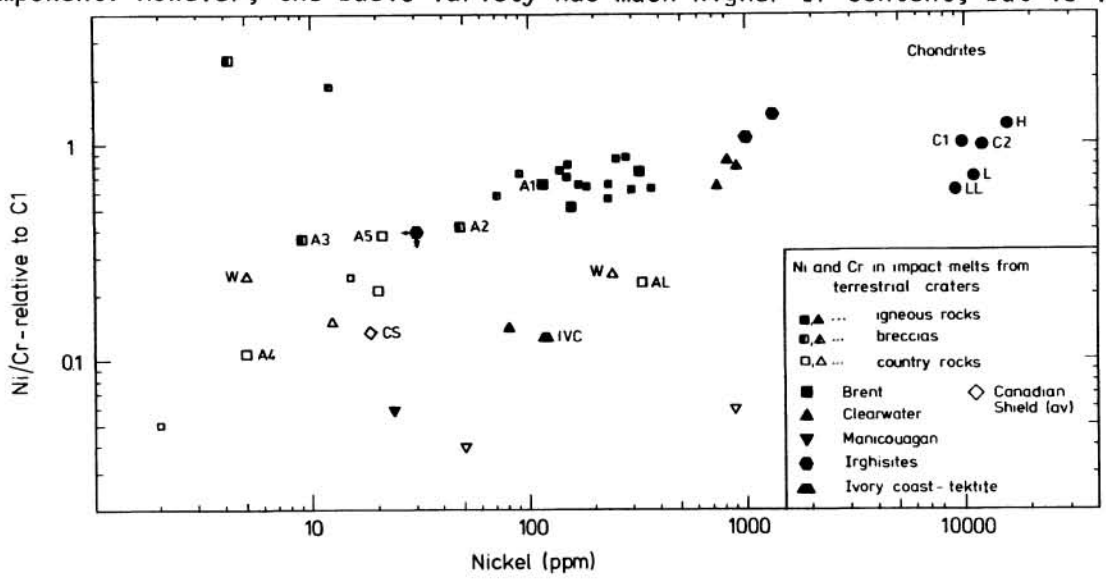

Fig.1; A1-A5 average: melt, glass-rich and glass-poor breccias, country rock inside and outside the crater (13); W-Clearwater West, CS-average Canadian Shield (17), Al-Alnoite (Brent), small symbols: individual analyses Geological Survey Canada (9).

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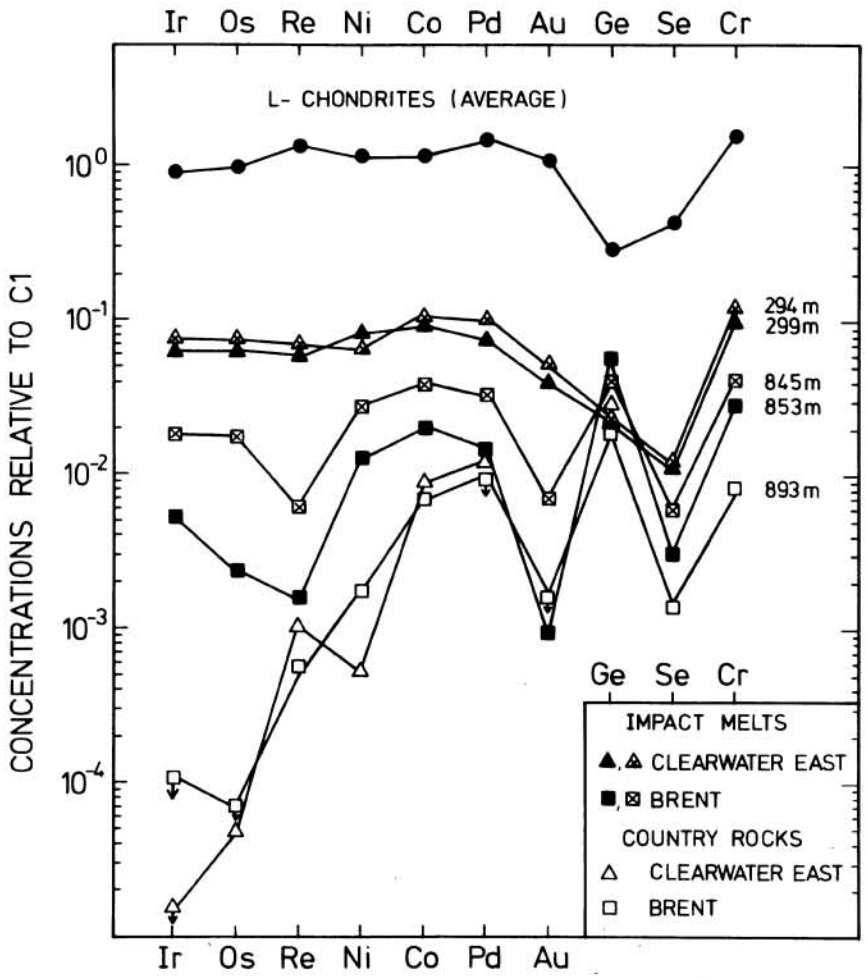

Fig.2; Clearwater East 299 m and Clearwater East country rock (7).

low in Ni. If the two types of Irghizites (16) are produced by the same projectile, severe fractionation of the meteoritic component must have accompanied the formation of these tektites. Maybe Ni and Ir were already in different phases in the impacting meteorite.

Ivory Coast tektite: Ir, Os, and Ni are slightly lower than in the previous analysis (7). The Ni/Cr ratio is far below the chondritic value (Fig. 1), in contrast to the acidic Irghizites. Thus the suggestion of Palme et al.(7) that the impacting body was probably an iron meteorite is confirmed. The Bosumtwi crater sample related to the Ivory Coast tektite does not show a significant enrichment in siderophiles.

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