Meteoritics & Planetary Science 41, Nr 8, Supplement, A243–A246 (2006)
http://meteoritics.org

Toronto, a new Canadian meteorite

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(Received 26 May 2006; revision accepted 31 May 2006)

Abstract–A specimen easily identified as an iron meteorite was first authenticated at the University of Toronto. Although the finder, Karl Heinz, is deceased, it is believed that the meteorite was found on a canoe trip in the Province of Québec. The 2.715 kg main mass is weathered and has no preserved heat-affected zone, although the external shape has a suggestion of regmaglypts, providing evidence that the specimen is a new find. The meteorite is a coarse octahedrite, with kamacite bandwidth 1.64 ± 0.56 mm. Neutron activation analysis yielded Ni 70.4 mg/g, Ge 372 μg/g, Ga 87 μg/g, and Ir 2.55 μg/g, clearly indicating that it is a member of group IAB with composition similar to that of Canyon Diablo. However, of 13 minor and trace elements, As, Au, Ir, Pt, Re, and Sb are more than three standard deviations from well-established Canyon Diablo means, and Ge differs by nearly three standard deviations. The meteorite thus appears to be a new find. The name is in recognition of the University of Toronto, where the meteorite was first examined.

INTRODUCTION

In February 1997, a specimen was brought to the Royal Ontario Museum in Toronto for authentication as a meteorite by its owner, Mrs. Hildegard Weltner of Toronto. She had been given the specimen some years earlier by the widow of the finder, a fellow German immigrant, Karl Heinz. The provenance of the specimen is not known for certain, but the finder arrived in Canada shortly after the Second World War, essentially without possessions. He enjoyed the out-of-doors and spent a good deal of his free time hiking and exploring in Ontario and Québec. He is believed to have found the specimen on a canoe trip in Québec in the 1970s or 1980s.

The Royal Ontario Museum staff passed the specimen on to G. C. Wilson, who subsequently consulted with S. A. Kissin regarding its composition and identity. As discussed below, the specimen was confirmed as an iron meteorite on further examination. As its provenance cannot be established with any certainty, it has been named Toronto after the University of Toronto, where it was first examined. Such naming has its precedents, such as Paneth's Iron (IIIE) and the Kansas University meteorite (L6). It has been reported in the Meteoritical Bulletin (Grossman 1999). The main mass as well as the type specimen (a detached slice of 67 g), total 2570 g, have been acquired by the National Meteorite Collection, Geological Survey of Canada, Ottawa.

DESCRIPTION OF THE SPECIMEN

The meteorite is angular and irregular, with approximate dimensions of 10.0 × 8.0 × 7.5 cm (Fig. 1). The oxidized outer surface exhibits a number of deep pits up to 45 × 30 × 10 mm, which may be remnants of regmaglypts or preexisting troilite nodules. The sample is highly magnetic, the surface oxidation confined to a thin to negligible crust. Two cuts were made to the original specimen, yielding nine small pieces of total mass 4.78 g, from which two polished sections were made, incorporating five of the pieces. Subsequently, a larger 67 g slice was detached for the present study.

The mounts of the chips from the margin of the mass were estimated to contain some 90% (by volume) kamacite, 4% goethite on fractures and a thin surface rind, 4% plessite, 1% schreibersite, and 1% taenite. Plessite occurs as angular masses interstitial to coarse kamacite.

The polished surfaces exhibit the Widmanstätten structure, with generally stubby kamacite lamellae (aspect ratio L:W = 4:1). The kamacite lamellae are separated by very narrow, cloudy taenite lamellae, which are frequently attacked by oxidation. No heat-affected zone is preserved. The kamacite bandwidth, as determined by the method of Frost (1965), is 1.64 ± 0.56 mm. The kamacite lamellae are polygonalized and contain extensively developed Neumann lines. The kamacite showed no gradation in hardness and

Fig. 1. The Toronto IAB iron, ~10 × 8 × 7.5 cm in size, mass 2.715 kg.

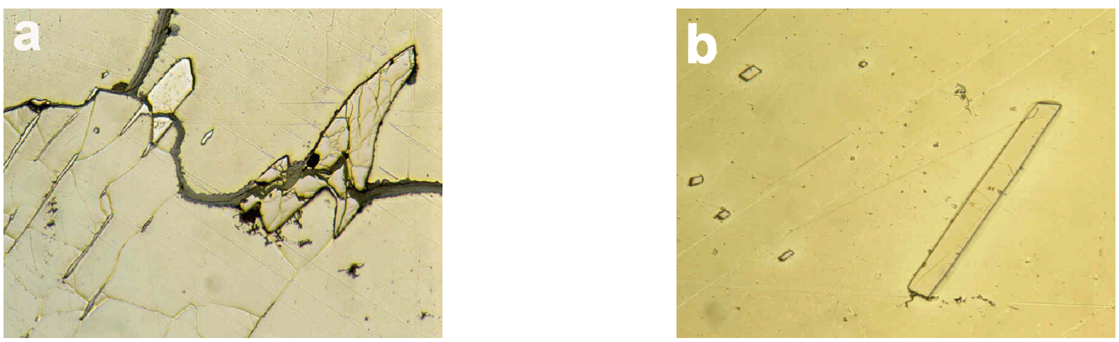

Fig. 2. Textures in reflected, plane-polarized light, on polished but unetched surfaces. a) Host kamacite plus exsolution features along grain boundaries and fractures. The latter include various scales of white, high-relief taenite, including a tooth-like grain near center of field of view, and a larger, darker schreibersite showing a characteristic fracture pattern; 80× magnification, long-axis field-of-view 1.2 mm. b) A relatively coarse, euhedral schreibersite crystal, 330 × 30 m, in kamacite host; 160× magnification, long-axis field-of-view 0.6 mm.

measurement yielded VHN = 176 (mean of three), consistent with moderate cosmic shock. Plessite displays moderate development in the form of comb or net structures.

The meteorite is relatively rich in phosphorus, as seen in the abundance of schreibersite (Figs. 2a and 2b) in the form of copious rhabdites, some of which are distinctly elongated (L:W as much as 10:1); relatively short lamellae (L:W = 10:1); and small, globular masses. Exceptionally, the phosphide is visible in sections as long and elongate as 400 × 8 µm (L:W = 50). Phosphides form by exsolution of P from metal during cooling. It has been estimated that massive grains form at >850 °C, rhabdite at ≈600 °C, and some partitioning of elements has been observed according to crystal habit and size (Jochum et al. 1980). Toronto may well be a good iron in which to study this further.

Electron microprobe on the polished mounts confirmed the major phases as kamacite averaging 6.22 ± 0.86 wt% Ni ($2\sigma_{n-1}$, n = 13), taenite (≈30% Ni), schreibersite (≈35% Ni), plessite, and secondary Fe oxide (goethite).

ANALYTICAL METHODS

Two parallel cuts to one corner of the mass generated eight small fragments, which split along oxide-lined, hairline fractures. The total area of the sawn face on the mass is 3.5 cm^2, maximum axes ≈25 × 20 mm. The main mass was reweighed at ≈2703 g. Two polished mounts were prepared, incorporating five chips (total weight 4.29 g, area ≈2.1 cm^2), leaving two epoxy-mounted offcuts for additional metallography (areas ≈1.9 cm^2).

Table 1. Analytical data for Toronto in comparison with those from Canyon Diablo and Odessa.

	As μg/g	Au μg/g	Co mg/g	Cr μg/g	Cu μg/g	Ga μg/g	Ge μg/g	Ir μg/g	Ni mg/g	Pt μg/g	Re ng/g	Sb ng/g	W ng/g
Canyon Diablo mean (21) (Wasson and Ouyang 1990)	12.7	1.57	4.68	24	148	83.8	322	2.17	69.2	6.3	228	295	990
Standard deviation	0.7	0.11	0.15	6	6	3.4	19	0.07	1.7	0.8	27	38	129
Toronto, this work	15.8	1.91	4.81	14	136	87	372	2.55	70.4	11.2	315	420	947
Toronto, first 70-mg aliquot	14	1.8	4.5	n.d.	150	127	n.d.	n.d.	63	n.d.	n.d.	n.d.	n.d.
Odessa, this work	14.7	n.d.	4.63	27	142	76	n.d.	n.d.	68.6	n.d.	n.d.	350	908
Odessa mean (30) (Choi et al. 1995)	14.4	1.65	4.73	30	130	75.6	283	2.40	71.9	6.2	240	310	1270
Standard deviation	0.8	0.11	0.15	7	5	3.0	17	0.07	1.7	0.8	29	40	165

Initial determination of the bulk chemistry was achieved by qualitative, energy-dispersive electron microprobe examination and by instrumental neutron activation (INAA) of small chips (0.07 g) in a Slowpoke reactor in Toronto. Although the sample was very small, the INAA result was quite close to the official best estimate which came later, using a larger sample (Table 1). The identification continued with a modest number of quantitative, wavelength-dispersive electron microprobe analyses. The estimated bulk Ni content derived from the estimated mode and the microprobe data is ≈7.1 wt%, just 1% higher than the best estimate by INAA.

For purposes of formal classification, a sawn piece of fresh metal of approximately 0.4 g and 3.2 mm thick was analyzed by INAA at Activation Laboratories (Ancaster, Ontario) for 13 elements, according to the methods of Wasson et al. (1998). NBS 809B was the standard for As, Au, Co, Cr, Cu, Ga, Ni, Pt, Sb, and W using the data of Wasson et al. (1998) and Odessa was the standard for Ge, Ir, and Re (Choi et al. 1995). Samples were encapsulated in metal-free polyethylene vials and irradiated together with the standards at a thermal flux of 7×10^{12} N $\cdot$ cm^{-2} s^{-1} for 30 min. The samples were counted after 12 h with a high-resolution Ge detector for 2000 s for Cu, Ga, Ge, Re, and W. The remaining elements were counted after 5 d for 1000 s.

CHEMISTRY

The results of neutron activation analysis for 13 minor and trace elements in the Toronto iron are presented in Table 1, together with the mean of 21 analyses and their standard deviations of Canyon Diablo (Wasson and Ouyang 1990), the mean of 30 analyses and their standard deviations of Odessa (Choi et al. 1995), and elements other than Au, Ge, Ir, Pt, and Re in Odessa as analyzed in this study. The Odessa data are included in order to demonstrate the accuracy of the analyses in this study. Our Odessa results for eight elements are all within three standard deviations of the Choi et al. Odessa means.

As the composition resembles that of Canyon Diablo, and Canyon Diablo and Odessa specimens are both abundant and are known to have been transported within North America, a detailed comparison of the composition of Toronto with these meteorites was made. As can be determined from Table 1, the composition of Toronto differs by more than three standard deviations from the means of Canyon Diablo trace elements As, Au, Ir, Pt, Re, and Sb, and nearly three standard deviation in Ge. Toronto is thus compositionally distinct from Canyon Diablo, notwithstanding complexities noted previously by examination of large numbers of analyses, such as a bimodal distribution of Ir with peaks at 2.17 and 2.34 ppm (Wasson and Ouyang 1990).

The composition is also similar to that of Odessa, but differs by more than three standard deviations from the means of Ge and Re and almost three standard deviations from the mean for Re. The point that emerges is that the population of group IAB members with Ni content of ~70 mg/g is high, and the various meteorites have similar minor and trace element concentrations.

Acknowledgments–The mass was sawn by Shawn McConville at the Geology Department of the University of Toronto, in consultation with John Rucklidge. L. A. (Larry) Pavlish kindly analyzed the first sawn fragment of the iron using the now-closed Slowpoke reactor facility on the St. George campus. George Taylor prepared the polished mounts, and Karyn Gorra took the hand-specimen photograph. Microprobe analysis was facilitated by Claudio Cermignani. Anne Hammond of Lakehead University prepared the samples for NAA.

Editorial Handling—Dr. A. J. Timothy Jull

REFERENCES

Choi B.-G., Ouyang X., and Wasson J. T. 1995. Classification and origin of IAB and IIICD iron meteorites. *Geochimica et Cosmochimica Acta* 59:593–612.

Frost M. T. 1965. Kamacite plate width estimation in octahedrites. *Mineralogical Magazine* 35:640–642.

Grossman J. N. 1999. The Meteoritical Bulletin, No. 83, 1999 July. *Meteoritics & Planetary Science* 34:A169–186.

Jochum K. P., Seufert M., and Begemann F. 1980. On the distribution of major and trace elements between metal and phosphide phases of some iron meteorites. *Zeitschrift für Naturforschung A* 35:57–63.

Wasson J. T. and Ouyang X. 1990. Compositional range in the Canyon Diablo meteoroid. *Geochimica et Cosmochimica Acta* 54:3175–3183.

Wasson J. T., Choi B.-G., Jerde E. A., and Ulff-Møller F. 1998. Chemical classification of iron meteorites: XII. New members of the magmatic groups. *Geochimica et Cosmochimica Acta* 62: 715–724.