Mineralogy, petrology and cosmogenic radionuclide chemistry of the Buzzard Coulee H4 chondrite.

Walton E. L.[1], Herd C. D. K.[1] and Duke M.J.M.[2] [1]Dept. of Earth & Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2E3, Canada, ewalton@ualberta.ca. [2]SLOWPOKE Nuclear Reactor Facility, 3126 Dentistry / Pharmacy, University of Alberta, Edmonton, AB, T6G 2N8 Canada.

Introduction: The Buzzard Coulee meteorite was collected as fragments from a fireball witnessed at 17:26.43 MST on November 20, 2008 by thousands of residents across the Canadian prairies. The total weight of the fall is currently unknown, but may range into the hundreds of kg. Three samples were made available to this study; two samples each measuring 3.5 cm in the longest dimension and weighing 34 and 37 g, and one 151.7 g sample measuring 7.5 cm in longest dimension (Fig. 1). In hand specimen, the stones are partially to completely covered by black fusion crust. The meteorite interior has a light grey color, with chondrules and metal grains readily visible on the broken surface. The 34 g sample was used to prepare a polished thin section. The 151.7 g sample was used to measure cosmogenic radionuclides. Here, we report a detailed study of the petrography, mineralogy, and cosmogenic radionuclide chemistry of this new meteorite fall.

Figure 1. Photograph of the 151.7 g sample of the Buzzard Coulee meteorite showing fusion crust and the broken edge.

Density: A NextEngine Desktop 3D laser scanner was used to capture and preserve the morphology of the meteorite specimens prior to any further sample processing. This method also provides an estimate of the volume of the sample, which was used to determine a bulk density of 3.5 g/cm^3, comparable to the densities of H chondrites reported previously [1].

Petrography: Detailed microtextures were characterized using backscattered electron (BSE) and secondary electron (SE) images at the University of Alberta using a JEOL 6301F Field Emission SEM, using an 8 mm working distance and an accelerating voltage of 20 kV. Mineral and glass compositions, and X-ray maps were collected using a Cameca SX-100 electron microprobe at the University of Alberta.

The overall texture is massive, with chondrules embedded in a fine-grained matrix with coarser Fe-Ni metals (Fig. 2). Major minerals / phases include low-Ca pyroxene, olivine, devitrified alkali-rich glass, troilite, kamacite and taenite with minor chromite, merrillite, pentlandite, augite, and rare spinel (s.s.) and silica glass.

Matrix: In plane light the matrix appears dark brown. Detailed BSE investigation shows that the matrix texture is variable – some areas exhibit recrystallization textures, with 120^{o} triple junctions between minerals, others, small mineral fragments (~5 – 15 μm); dendritic textures of low-Ca pyroxene in glass has also been observed. Metal grains range in size from small disseminated grains 10's of microns in size to larger (500 – 800 μm) grains. In the larger grains kamacite, taenite and Fe-rich sulfide are observed both as discrete grains and as symplectic intergrowths. Inclusions of pyroxene and chromite are enclosed by the larger grains of FeNi metal.

Chondrules: A variety of chondrule types including, but not limited to, barred olivine, porphyritic olivine, porphyritic pyroxene, porphyritic olivine-pyroxene, cryptocrystalline pyroxene, radial pyroxene, metal-rich and Al-rich are present in the thin section (Fig. 3). The Al-rich chondrule contains skeletal grains of olivine in devitrified alkali-rich glass with euhedral spinel (s.s.) zoned to chromite near the chondrule rim. Chondrule size is variable, ranging from 1400 μm (porphyritic pyroxene-olivine) to 150 μm (cryptocrystalline pyroxene). In general, the cryptocrystalline pyroxene chondrules are the best preserved with sharply defined edges; the barred olivine chondrules have suffered the greatest degree of textural equilibration with the matrix. Primary glass forming the chondrule matrices is now present as a devitrified glass that is brown-colored in plane transmitted light.

Shock Metamorphism: The sample is not brecciated but is highly fractured. Olivine exhibits straight to undulose extinction with irregular fractures; some grains contain planar fractures. Thin glassy veins of impact melt material, commonly observed in other ordinary chondrites, have not been observed in our samples. Troilite however, exhibits local melting and infilling of cracks and fractures in neighboring minerals. These melts are restricted to grain boundaries and we note that preferential melting of pyrrhotite is well documented from ordinary chrondites as a result of its compressible crystal structure, thereby absorbing shock wave energy [2].

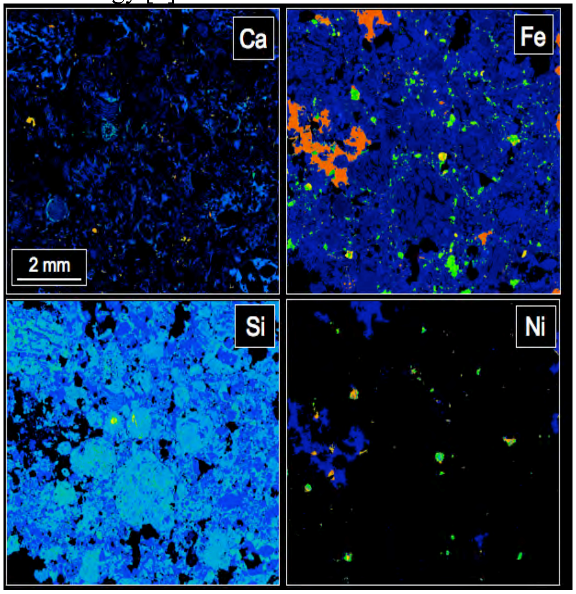


Figure 2. Elemental X-ray maps showing the overall texture of Buzzard Coulee.

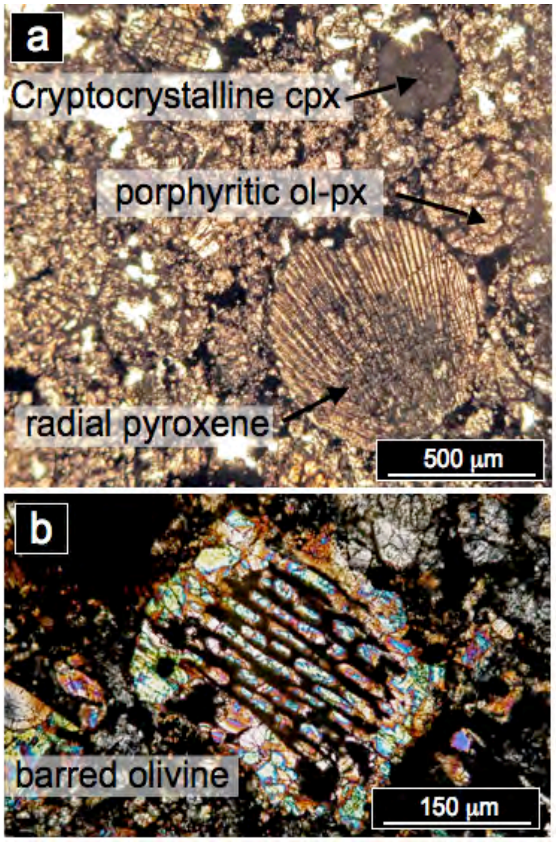
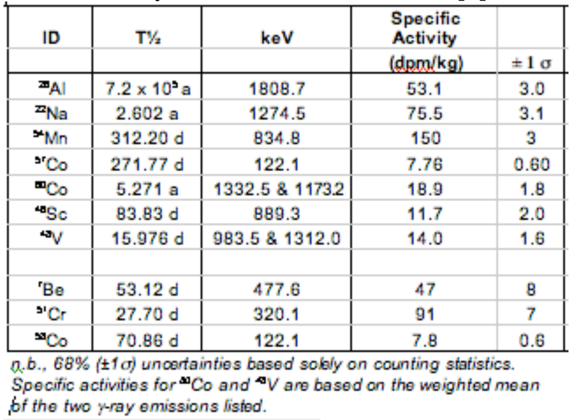


Figure 3. Plane (a) and crossed polarized (b) light photographs showing the main chondrule types.

Composition: The average composition of olivine in chondrules overlaps with that of matrix olivine (average $Fa_{17.7}$; range $Fa_{15.9-20.5}$). The average composition of pyroxenes are: low-Ca pyroxene $Fs_{15.8}Wo_{1.0}$ (range $Fs_{15-17.8}Wo_{0.17-3.2}$), pigeonite $Fs_{12.9}Wo_{14.6}$ (range $Fs_{11.7-14.3}Wo_{11.2-19.4}$) and augite $Fs_{5.2}Wo_{46.0}$ (range $Fs_{4.9-5.6}Wo_{44.6-46.6}$). Co in kamacite ranges from 0.19 to 0.49 wt% Co (average 0.34 wt%); much greater than Co contents measured from taenite (avg 0.06 wt%; range b.d. – 0.17 wt%). The Ni content of taenite is quite variable (20.93 – 53.35 wt%). Ni contents in troilite range from 0.01 to 0.82 wt%.

Cosmogenic Radionuclides: The 151.7 g sample was counted for 606 kS (slightly over 7 days) using a 40% efficient hyperpure, high resolution, Ge detector (Ortec GEM FX Profile) with carbon window, housed in a ~15 cm Pb cave. The measurement commenced 10 days 23½ hours following the fall of the meteorite. The specific activities of the measured cosmogenic radionuclides are listed in Table 1 (*n.b.*, the specific activities have not been corrected for decay since time of fall, however decay corrections would only be relevant to ^{48}V, ^{51}Cr and possibly ^{7}Be specific activities). The measured specific activities of radionuclides (^{26}Al and ^{22}Na, for example) are in good agreement with those commonly determined for chondrites [3].



ID	T½	keV	Specific Activity	
			(dpm/kg)	±1 σ
^{26}Al	7.2×10^{5} a	1808.7	53.1	3.0
^{22}Na	2.602 a	1274.5	75.5	3.1
^{54}Mn	312.20 d	834.8	150	3
^{57}Co	271.77 d	122.1	7.76	0.60
^{60}Co	5.271 a	1332.5 & 1173.2	18.9	1.8
^{46}Sc	83.83 d	889.3	11.7	2.0
^{48}V	15.976 d	983.5 & 1312.0	14.0	1.6
^{7}Be	53.12 d	477.6	47	8
^{51}Cr	27.70 d	320.1	91	7
^{58}Co	70.86 d	122.1	7.8	0.6

n.b., 68% (±1σ) uncertainties based solely on counting statistics. Specific activities for ^{60}Co and ^{48}V are based on the weighted mean of the two γ-ray emissions listed.

Table 1. Cosmogenic radionuclides determined for the Buzzard Coulee H4 chondrite.

References: [1] Britt D.T. and Consolmagno G.J. (2003) *MAPS*, *38,* 1161-1180. [2] Stöffler D. et al. (1991) *GCA*, *55,* 3845-3867. [3] Evans et al. (1982) *J. Geophys. Res.*, *87,* 5577-5591.

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