

UNUSUAL ACHONDRITE-LIKE FIND IN SOOKE BASIN: RESULTS OF FIRST ANALYSES.

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Introduction: The achondrite-like stone examined here was discovered by Craig Ebrahimi during diving in Sooke Basin with JW Pulse 8X induction metal detector. The stone was at 12 m depth and under 3 m of anoxic mud, about 100 m from east shore of Sooke Basin, a 10 km² body of sea water connected to the Juan de Fuca Strait at the Southern tip of Vancouver Island. This area was populated long time ago by the T'sou-ke Nation of the Coast Salish. The Juan de Fuca Ice Lobe of the Cordilleran Ice Sheet advanced and receded many times until ~15,000 years BP and likely deposited meteorites from the glacier. The find weighs ~13 kg, attracts a magnet, and is up to 70% covered by black fusion crust about 0.5 to 1 mm thick.



Fig. 1. Photograph of the find, without a cut section.

Analyses:

Chemistry: Using fusion ICP and Na₂O₂ techniques, Actlabs in Ancaster, Ontario, determined LOF=3.45% and elements in proportions characteristic of achondrites - likely from Mars or 4 Vesta. In the Korotev's plots our data in wt% vs. Fe₂O₃+MgO=29.55 are all located in achondrite areas: 45.95 SiO₂ in lunar, HED or Mars; 17.90 MgO and 1.5 MgO/Fe₂O₃ above HED and Mars; 5.30 Al₂O₃ in Mars; 14.74 CaO in lunar, Mars or other; 2.78 CaO/Al₂O₃ in Mars or other; 11.65 Fe₂O₃ below lunar, HED and Mars; Fe₂O₃/MnO=77.7 in lunar and other; 0.36 Na₂O in lunar, HED and near Mars; 0.08 K₂O in lunar, HED and Mars, and 940 ppm Cr as in Mars. Low amount of Na₂O+K₂O=0.44 vs. 45.95 SiO₂ places our find in the left corner of SNC meteorites area [5]. There are also 0.43 wt% TiO₂, and in ppm 227 V, 100 Co, 240 Ni and 50 Zn. REE's were found at lower concentrations than in Martian meteorites, but in a range of 1 ppm observed in many stony achondrites (e.g. aubrites). La/Lu fractionation ratio is ~9 with linear decline between La and Lu and no Eu and Er anomalies.

Petrography: Thin sections that were examined showed some similarities to the NASA study of Alan

Hill 84001. Minerals were identified in the following volume fractions and main crystal size ranges: pyroxene 55-60%, 1-3 mm; olivine 35-40%, 0.5-2 mm locally up to 5 mm crystals partly altered to serpentine-magnetite ~1%, 0.3-0.7 mm particles. Pyroxene formed irregular crystals in the spaces between olivine crystals slowly formed during cooling.

Mössbauer spectra: The spectrum in Fig. 2 illustrates close similarity of our Mössbauer data and NASA data for Martian tephrite meteorite MIL 03346 [1]. Mössbauer spectra of stony meteorites usually consist of three doublets due to paramagnetic Fe²⁺ present in olivine and pyroxene [2] and two sextets due to magnetically ordered iron in magnetite. In our samples Fe²⁺ is in M1 and M2 sites of clinopyroxene (ferric diopside CaMgFeSi₂O₆) and in olivine (fayalite (Mg,Fe)₂SiO₄). The average values of quadrupole splitting for Fe²⁺ in 12 spectra analyzed vs. depth were: 2.59 mm/s in M1 site and 2.02 mm/s in M2 site of clinopyroxene; and 2.89 mm/s in fayalite.

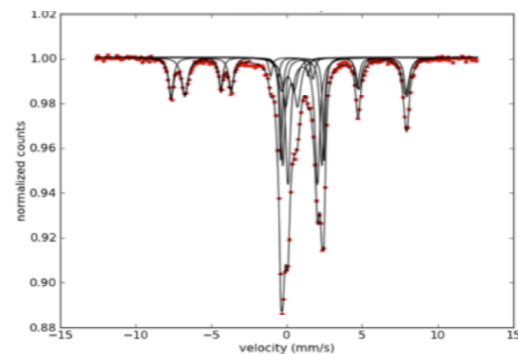


Fig. 2. Mössbauer spectrum of 15-mm deep sample.

With the depth of samples from crust to ~20 mm inside the total fraction of Fe in cpx M1 and M2 sites increased from 20% to 40% and in fayalite from 10 to 15%; in magnetite it decreased from 65% to 15%, while the fraction of Fe³⁺, likely in a form of amphibole increased from 15% to 40%, see Fig. 3.

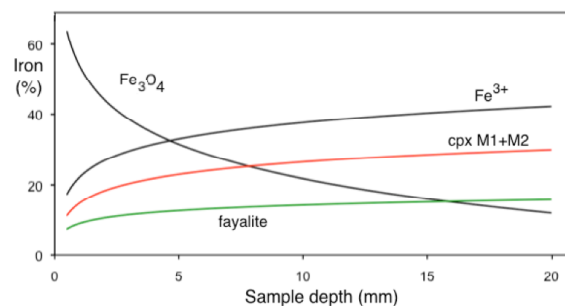


Fig. 3. Dependence of Fe fractions on sample depth.

X-ray diffraction: Peaks in diffractogram of sample taken from ~15 mm inside the rock were assigned to ferroan diopside, sodium-tremolite i.e. amphibole richterite $(\text{NaCa})\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$ and magnetite, in accord with Mössbauer spectra. Abundance of tremolite resembles that in Almahata Sata meteorite of asteroid origin. Remaining three diffraction peaks were ascribed to oxidized and reduced graphene.

Raman spectra: Taken with 532, 633 and 785 nm laser beams focussed to a 2 μm spots showed mostly bands of clinopyroxene P at 320, 660 and 1020 cm^{-1} , some bands of tremolite T, and likely very weak broad bands at 400 and 600 cm^{-1} of maskelynite from the impact.

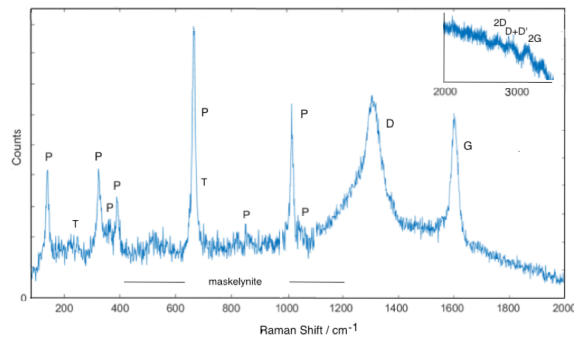


Fig. 4. Raman spectra of the general area and of white feature shown in photograph below.



Fig 5. The photograph of the 2x3 cm polished area.

The white area in Fig. 5 showed prominent bands of nanodiamonds: D at ~1330 cm^{-1} due to structural defects and sp^3 bonds and G at ~1600 cm^{-1} from in plane vibrations of sp^2 bonded carbon atoms in graphene. Minor bands seen in top right corner of Fig. 4 between 2500 and 3300 cm^{-1} , are ascribed to the combinations of inelastic scattering bands observed in the first-order region [3]. The nanodiamonds as small as 2-7 nm were previously observed in carbonaceous meteorites, e.g., Allende. Such particles can be formed by CVD process or shocks at 1000-2300 K and 30-40 GPa.

Oxygen isotopes: The $\delta^{17}\text{O}$ and $\delta^{18}\text{O}$ values obtained for 3 samples taken near crust are close to terrestrial fractionation line at 0.523, but also close to the data for

lunar and 4 Vesta samples, whereas $\Delta^{17}\text{O}$ values are similar to those in angrites as shown below.

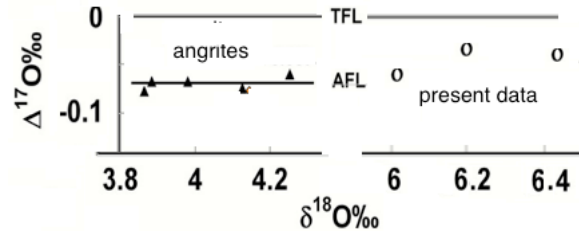


Fig. 6. Oxygen isotopes data compared with angrites.

However, as the oxygen isotopes near the surface of meteorites after long exposure to ^{18}O -rich sea water become closer to terrestrial [4] even small correction for $\delta^{18}\text{O}$ of -1‰ could relocate our data to the Martian area in $\delta^{17}\text{O}$ vs. $\delta^{18}\text{O}$ plot. Further analyses of bulk samples and separates from deep interior for comparison in particular with NWA 7035 data [5],[6] are necessary.

SEM-EDS and TEM: are being used now to identify CAI inclusions, C-N-P elements overlaps, graphite whiskers, iron veins and other microscopic features.

Conclusions: Analyses suggest that we have encountered a very interesting, differentiated, carbonaceous extraterrestrial object with nanodiamond including features. This could be the third largest Martian and largest not fractionated basaltic shergottite-type of trachlite-like meteorites ever found, possibly from celestial watery bodies [7],[8] or carbonaceous asteroids [9],[10],[11]. As the research in astrogeology and biochemistry of Martian and asteroid meteorites, rocks and soil and space missions intensify, we trust that this find can be quite significant and deserves further more thorough investigations.

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