TERRESTRIAL AND EXTRATERRESTRIAL MAFIC SILICATES FROM THE P-T BOUNDARY CLAYSTONE BRECCIA OF GRAPHITE PEAK, ANTARCTICA: EVIDENCE FROM OXYGEN ISOTOPES AND MINERAL CHEMISTRY. M. I. Petaev[1,2] , K. Nagashima[3], A. N. Krot[3], R. Chakrabarti[2], S. B. Jacobsen[2], L. Becker[4], and A. R. Basu[5]. [1]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA (mpetaev@cfa.harvard.edu); [2]Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA; [3]HIGP/SOEST, University of Hawai'i at Manoa, Honolulu, HI 96822, USA; [4]Institute for Crustal Studies, Department of Geological Sciences, University of California, Santa Barbara, CA 93106, USA; [5]Department of Earth and Environmental Sciences, University of Rochester, Rochester, NY 14627, USA.

Introduction: Among the proposed causes of the P-T mass extinction a catastrophic collision of Earth with a celestial body is expected to leave behind a suite of distinct tracers. Therefore, identification of extraterrestrial materials/signatures at P-T boundary would support such a hypothesis. Recently we reported the discovery of abundant meteoritic fragments, Fe,Mn-metal grains, and impact magnetite-silicate spherules in magnetic separates of P-T boundary samples from Graphite Peak, Antarctica [1-3] that is consistent with the earlier reports of a ^{3}He-rich magnetic component with solar-type gases in P-T boundary samples [4,5]. Among the questions which still remained unanswered, the most important ones may be why and how highly unstable forsteritic olivine and Fe-rich metal have survived in the hostile subsurface conditions for ~250 million years. In an attempt to answer these questions [6] have searched for similar objects in magnetic separates of new samples collected in November 2003 by the field team that included R. Chakrabarti and L. Becker. The samples studied included two different lithologies – a whitish-gray sedimentary rock with clear bedding (sample #1) and a massive light-colored breccia with large whitish and greenish polygonal patches (sample #2) – from the ~2 m claystone breccia boundary interval [1] and a relatively dense rock with irregular greenish and brownish areas with smooth boundaries (sample #3) from the bottom of the last Gondwana coal layer. A detailed description of these samples was given in [6]. The mafic silicates were found only in the sample #2. Here we report chemistry and mineralogy of mafic silicates and associated minerals and oxygen isotopic compositions of olivine and orthopyroxene from selected fragments.

Separation and analytical techniques: The bulk samples received from UCSB as single pieces were divided into several sub-samples at Harvard. Each step was carefully documented and all splits were photographed. Sample #2 was fragile enough to be split into several pieces by bare hands. Two different magnets – a rather weak cylindrical AlNiCo magnet inserted into a silica test tube and a strong Nd-Fe-B square magnet wrapped into a plastic film – were used in magnetic separations. Further details of the separation procedure are described in [6].

The collected magnetic fractions or parts of them were embedded into an epoxy resin. The polished sections were then examined by optical microscopy and studied by SEM and EPMA at Harvard using traditional analytical routines. The oxygen isotopic compositions of olivine and orthopyroxene were measured with the University of Hawai'i Cameca ims 1280 ion microprobe by rastering ~7 μm beam over 10×10 μm areas. Analytical details were the same as in [7]. The San Carlos olivine and a synthetic enstatite were used to correct for instrumental mass fractionation.

Results and discussion: About a dozen of olivine and orthopyroxene fragments and three polycrystalline clasts were identified in magnetic separates. One orthopyroxene fragment (Fig. 1) contains a dumbbell-shaped metal inclusion with 7.6 wt. % Ni and 0.55 % Co, characteristic of chondritic metal. Its high concentrations of Al_2O_3 (0.65 wt. %), Cr_2O_3 (1.2 – 1.3 %), MnO (0.48 – 0.50 %), and CaO (3.36 – 3.45 %) are also consistent with chondritic origin. Many individual olivine fragments contain numerous inclusions of low-Ni metal or Fe oxides similar to olivine grains from the clast shown in Fig. 3.

One of the clasts (Fig. 2 of [6]) is mineralogically and chemically similar to the chondritic fragments described in [1]. Two others are rather unusual.

The homogeneous Opx fragment (Fig. 2) is partially surrounded by a fine-grained material which contains forsteritic olivine, albite, K-feldspar, and phlogopite. This assemblage is atypical of meteorites and more likely of terrestrial origin, consistent with the orthopyroxene O isotopic compositions which are plotted on the terrestrial fractionation line (TFL in Fig. 4).

A rather large irregular rock fragment (Fig. 3) consists of clastic grains of olivine, orthopyroxene, labradorite, albite, and rare metal particles embedded in a fine-grained Al,Si-rich matrix material. Some olivine grains contain numerous inclusions of Ni-poor metal (white specs) often replaced by Ni-bearing Fe oxides, mainly magnetite. Such grains are reminiscent of meteoritic 'dusty' olivines. The O isotopic composition of the olivine grain #1 is slightly enriched in ^{16}O and clearly resolved from the TFL, consistent with an extraterrestrial nature of this clast. Given the unusual mineralogy of the clast, its affinity to known meteorite groups is difficult to access because of the highly 'crowded' nature of that portion of the O three-isotope diagram.

The nature of individual olivine and orthopyroxene fragments can be accessed from their Cr_2O_3 and MnO contents (Fig. 5) which are usually high in meteoritic minerals and low in terrestrial analogues. It appears that all Ol and most Opx grains are extraterrestrial, but a few terrestrial Opx grains are also present.

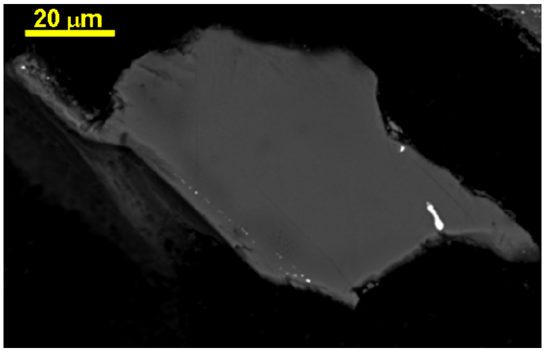

Fig. 1. BSE image of an Opx grain (gray) with the inclusion of Fe,Ni metal (white). Black is epoxy.

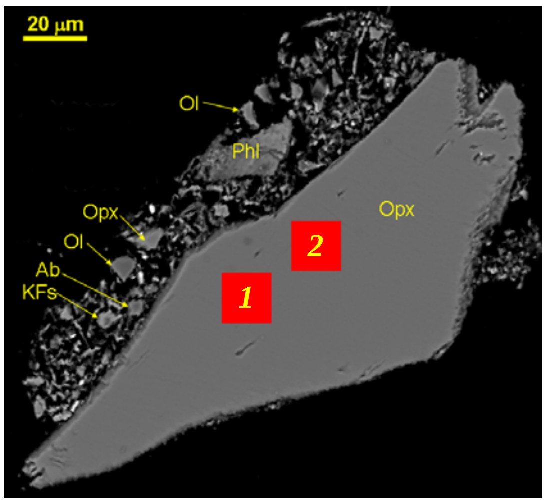

Fig. 2. BSE image of a large clastic grain of low-Ca pyroxene (Opx) partially embedded in a fine-grained matrix containing forsteritic olivine (Ol), Opx, albite (Ab), K-feldspar (KFs), and phlogopite (Phl). Red squares show O-isotope spots.

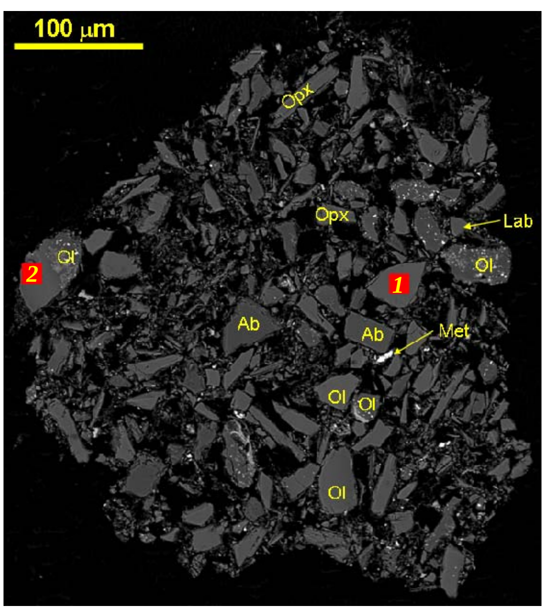

Fig. 3. BSE image of an irregular rock fragment containing clastic grains of olivine (Ol), low-Ca pyroxene (Opx), labradorite (Lab), albite (Ab), and rare metal (Met) embedded in the fine-grained Al,Si-rich matrix material. Note that some olivine grains contain numerous inclusions of Ni-poor metal (white specs) often replaced by Ni-bearing Fe oxides, mainly magnetite. Red squares show O-isotope spots. The spot #2 slightly overlapped the epoxy so its composition is not shown in Fig. 5.

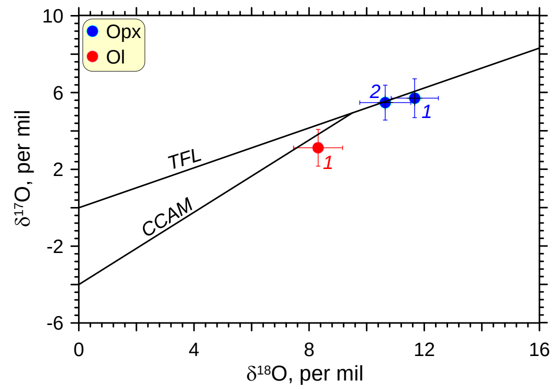

Fig. 4. Oxygen isotopic compositions of Opx (blue) and Ol (red). Error bars are 2σ. The spots analyzed are shown in Figs. 2 and 3, respectively. The terrestrial fractionation (TFL) and carbonaceous chondrite anhydrous mineral (CCAM) lines are shown for reference.

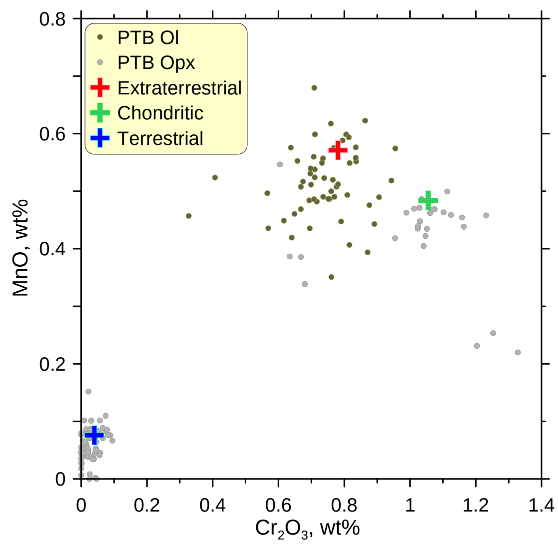

Fig. 5. MnO-Cr_2O_3 systematics of olivine (olive circles) and orthopyroxene (gray circles) separated from sample#2 (including multiple analyses of large grains). The crosses show a chondritic orthopyroxene (green, imaged in Fig. 1), a terrestrial orthopyroxene (blue, Fig. 2), and extraterrestrial olivine (red, Fig.3).

References: [1] Basu A. R. et al. (2003) *Science, 302*, 1388-1392. [2] Petaev M. I. et al. (2004) *LPS XXXV*, #1216. [3] Shukolyukov A. Yu. et al. (2004) *LPS XXXV*, #1875. [4] Becker L. et al. (2001) *Science, 291*, 1530-1533. [5] Poreda R. J. and Becker L. (2003) *Astrobiolgy, 3*, 75-90 [6] Petaev M. I. et al. (2006) *LPS XXXV*, #2309. [7] Makide K. et al. (2009) *GCA, 73*, 5018-5050.