PORPHYRITIC OLIVINE-PYROXENE CLAST IN KAIDUN: FIRST DISCOVERY OF AN ORDINARY CHONDRITE CLAST? T. Mikouchi[1], J. Makishima[1], E. Koizumi[1], M. E. Zolensky[2], [1]Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan (mikouchi@eps.s.u-tokyo.ac.jp), [2]Mail Code KT, NASA Johnson Space Center, Houston, TX 77058, USA.

Introduction: Kaidun is an enigmatic meteorite showing a micro-brecciated texture composed of variable kinds of lithic clasts and mineral fragments [1]. The constituent components range from primitive chondritic materials to differentiated achondritic materials, and thus believed to have originated from a large parent body accumulating materials from many different bodies in the asteroid belt [1]. One of the interesting observations is that no ordinary chondrite component has been found yet, although C and E chondrites components are abundant. In this abstract, we report mineralogy of the clast (Kaidun #15415-01.3.13a) showing a porphyritic olivine-pyroxene chondrule-like texture similar to those found in unequilibrated ordinary chondrites [2,3].

Petrography: The clast studied (*ca*. 4 x 3 mm) shows a porphyritic texture mainly composed of pyroxenes and olivine set in the glassy mesostasis (Fig. 1). The grain sizes of pyroxenes and olivine are up to 0.5 mm and both minerals are usually euhedral. The pyroxene abundance is slightly larger than that of olivine (45% pyroxenes, 41% olivine, 13% mesostasis, 1% opaque minerals). Polysynthetic twinning is common for pyroxenes. The edges of pyroxene grains are terminated by euhedral olivine edges in many cases, suggesting prior olivine crystallization. Fe-Ni metal spherules (~200 µm) surrounded by Fe-Ni sulfide rims are scattered. The interstitial glass is nearly crystal-free. There is little evidence for shock because optical microscopy shows sharp extinction of olivine and pyroxene.

Mineral chemistry: Pyroxenes show a progressive zoning sequence from the orthopyroxene core to the thin augite rim (usually a few tens of µm thick) via pigeonite composition (Fig. 2). The most Mg-rich orthopyroxene composition is $En_{82}Wo_1$. Minor elements range 0.2-3 wt% Al_2O_3, 0-0.8 wt% TiO_2, 0-0.3 wt% Na_2O, and 0.5-1 wt% Cr_2O_3, all of which are positively correlated with *fe#* of pyroxenes. Olivine is also extensively zoned from the Mg-rich core to the Fe-rich rim (Fig. 2). The most Mg-rich olivine core is Fo_{91} and the typical core ranges Fo_{90-80}. The Fe-rich rim compositions vary depending upon what phases they are adjacent to, but usually ranging Fa_{30-45}. The CaO content is positively correlated with the Fa content of olivine (0.05-0.3 wt%), but the zoning pattern of Ca is steeper at the rims than that of Fa. The Cr_2O_3 content is 0.2-0.5 wt%. There are a few olivine grains showing reverse chemical zoning in major and minor elements (Fig. 3). These olivine grains show dusty appearance at the core-rim boundaries (Fig. 3). The composition of the mesostasis glass is slightly heterogeneous ranging 54-61 wt% SiO_2, 15-21 wt% Al_2O_3, 5-8 wt% CaO, 4-12 wt% FeO, 3-6 wt% Na_2O, and 0.5-2 wt% P_2O_5.

Discussion: Although many kinds of lithologies have been described in Kaidun, no similar lithologies to this clast (#15415-01.3.13a) were found so far [1].

The clear igneous texture of this Kaidun clast suggests that it is an achondrite fragment. However, the porphyritic texture composed of pyroxene and olivine is rare in achondrites, and only known in angrites [4], lunar mare basalts [5], and Martian meteorites [6]. In angrites, pyroxenes are Ca-, Al-rich diopside (fassaite) and there are abundant calcic plagioclases ($An_{>99.5}$), which is clearly different from the Kaidun clast. In lunar mare basalts, pyroxenes are usually more Fe-rich ($Fs_{>30}$) and the mesostasis (or plagioclase) is much more alkali-poor than the Kaidun clast, probably ruling out a lunar origin for this clast. In Martian meteorites, several samples show porphyritic textures composed of pyroxene and olivine set in the glassy mesostasis. All the nakhlites are texturally very similar to the Kaidun clast [7], but the nakhlite pyroxenes are augite and more Fe-rich ($Fs_{>20}$) than the Kaidun clast. The nakhlite olivine is also much more Fe-rich ($Fa_{>55}$). Y980459 is the most Mg-rich Martian meteorite known to date and composed of olivine and pyroxene [8], whose compositions are similar to those of the Kaidun clast. However, the presence of Fe-Ni metal in the Kaidun clast suggests crystallization under reducing condition, and thus does not support a Martian origin. Therefore, there are no achondrites similar to the Kaidun clast.

When we hypothesize that this Kaidun clast is chondritic material, we find a better match. The porphyritic olivine and pyroxene (POP) chondrule is very similar to the Kaidun clast in texture [9]. POP chondrules are one of the major chondrule types and found in many chondrite groups. The known chondrite lithologies in Kaidun include CM1-2, CV3, E, and R chondrites plus new C1 and C2 type lithologies [1], and this clast could be one of these chondrite types except for petrologic type 1 samples that do not contain chondrules. Because the most Mg-rich olivine and pyroxene compositions are Fa_9 and Fs_{18}, respectively, this Kaidun clast appears most similar to a type II POP chondrule [9]. The highly Mg-rich nature of E chondrites is clearly different from the Kaidun clast. In contrast, R chondrites contain Fe-rich homogeneous olivine (Fa_{37-40}), which is also different from the Kaidun clast. CM2 and CV3 chondrites contain type II POP chondrules, and their olivine and pyroxene compositions are generally similar to those of the Kaidun clast [9]. However, the following mineralogical properties of the Kaidun clast suggest a closer relationship to type II POP chondrules in unequilibrated ordinary chondrites (UOC) [9]. (1) A chondrule larger than 4 mm in size is more characteristic of type II chondrules in UOCs (especially, L and LL chondrites, though some are found in C chondrites) [2]. (2) Olivine, pyroxene and mesostasis glass compositions from type II POP chondrule in UOCs match those of the Kaidun clast [9] (Fig. 2); Pyroxene mineralogy (large enstatite cores with thin augite rims) in particular is remarkably similar. (3) The presence of reverse-zoned olivine with dirty areas is common in type II POP chondrules in UOCs [3], suggesting chondrule recycling. Also, Fe-Ni metal grains with sulfide rims are common in UOCs [9]. The crystal-free nature of the mesostasis indicates that this clast is close to petrologic type 3.0 (if it is really chondritic material).

Conclusion: Kaidun clast (#15415-01.3.13a) shows the closest match to type II POP chondrules in UOC in terms of mineralogy. If this is indeed the case, it is the first discovery of an ordinary chondrite component in Kaidun. Since Kaidun is believed to have originated from a large asteroid accumulating materials from many different bodies [1], discovery of ordinary chondrite material is no surprise. Otherwise, this object is an unknown achondritic clast showing a very similar mineralogy to a type II POP chondrule. Because it is difficult to classify the meteorite type in such a complex breccia only by mineralogy, oxygen isotope analysis must (and will) be performed.

References: [1] Zolensky M. E. and Ivanov A. (2003) *Chem. Erde Geochem*., *63*, 185-246. [2] Jones R. H. (1996) *GCA, 60*, 3115-3138. [3] Jones R. H. (1994) *GCA, 58*, 5325-5340. [4] Mikouchi T. et al. (1996) *Proc. NIPR Symp. Antarct. Meteorites*, *9*, 174-188. [5] Papike J. J. et al. (1976) *Rev. Geophys. Space Phys*., *14*, 475-540. [6] McSween H. Y. Jr. (2002) *Meteoritics & Planet. Sci.*, *37*, 7-25. [7] Mikouchi T. et al. (2003) *Antarct. Meteorite Res*., *16*, 34-57. [8] Mikouchi T. et al. (2004) *Antarct. Meteorite Res*., *17* (in press). [9] Brearley A. J. and Jones R. H. (1998) *Rev. in Mineral.*, *36*, Chapt. 3.

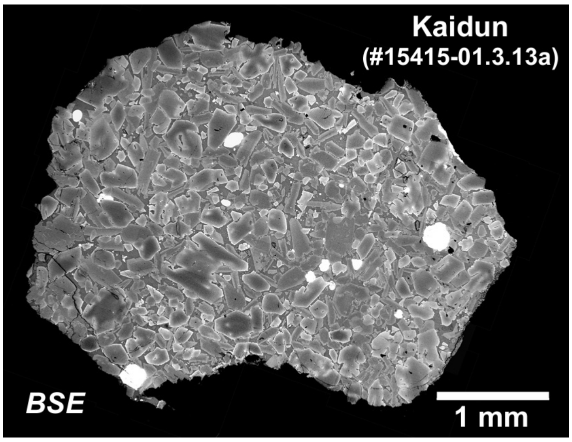

Fig.1. Backscattered electron image of the #15415-01.3.13a clast in Kaidun, showing a porphyritic texture composed of zoned pyroxenes and olivine.

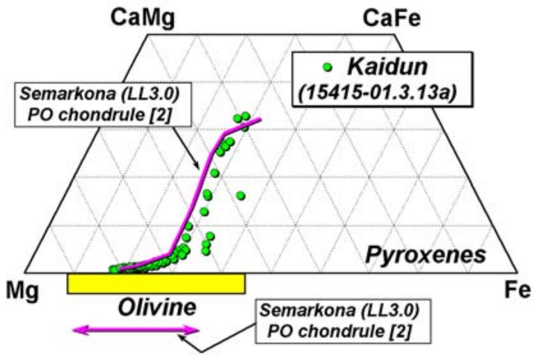

Fig. 2. Pyroxene and olivine compositions of the Kaidun clast. For comparison PO chondrule olivine and pyroxenes from Semarkona (LL3.0) are shown.

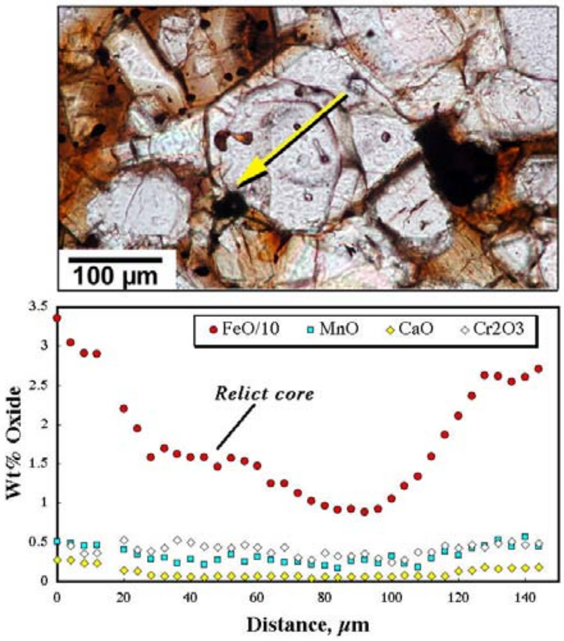

Fig. 3. Olivine grain showing reverse zoning. There are dirty appearance areas at the core-rim boundary.