CALCIUM-ALUMINUM-RICH (CAI) AND SODIUM-ALUMINUM-RICH (NAI) INCLUSIONS IN THE PAT 91546 CH CHONDRITE. M. K. Weisberg[1,2,3] J. N. Bigolski[1,2,3] and D. S. Ebel[2,3,4]. [1]Dept. Phys. Sci., Kingsborough College, City University of New York, Brooklyn, NY 11235. (mweisberg@kbcc.cuny.edu) [2]Earth and Env. Sci., Graduate Center, CUNY, NY, NY 10016. [3]Dept. Earth Planet. Sci., American Museum Natural History, NY, NY 10024. [4]Lamont-Doherty Observatory, Columbia University, NY, NY, USA.

Introduction: CH chondrites are closely related to CB and CR chondrites [1,2] and are among the most primitive and most controversial chondrite groups. They contain a relatively high amount of metal (> 20 vol. %), no interstitial matrix and their chondrules are small and dominated by cryptocrystalline textures [3-5]. These unusual characteristics, as well as the relatively young Pb-Pb ages of their chondrules, have led to the interpretation that CH chondrules formed as molten droplets in an impact plume produced during a planetesimal-scale collision [e.g., 6-8]. However, CH chondrites have refractory inclusions with ^{16}O-rich compositions that are generally interpreted to be primitive relicts that survived the impact event [e.g., 9-13].

Here we present the first results of our study of CAIs in the PAT 91546 CH chondrite. We also identified inclusions rich in Na and Al (referred to as NAIs). Our initial goal is to study the micro-distribution of refractory and volatile elements in the CH chondrites and decipher the origin of the refractory inclusions and their relationship to the chondrules and other CH components. We are particularly interested in the compositional and textural range of objects in CH chondrites.

Methods and Results: Using the SX100 electron probe at the AMNH we collected x-ray elemental maps of 100 mm^2 of PAT 91546, 11. The maps were used to locate Ti-, Al- and Ca-rich hot spots leading to discovery of 15 refractory inclusions and 3 Na-Al-rich inclusions (NAIs). Mineral assemblages of all inclusions were studied in detail using the JEOL JSM-6390 SEM at Kingsborough College.

The inclusions range from 15 to 200 µm, similar in size to the chondrules and other components in the meteorite and suggesting a close relationship between the components in CH chondrites. Most appear irregular in shape; some are spherical and apparently melted.

Refractory Inclusions: Ca-*Pyroxene-rich Barred Olivine.* One inclusion (CAI 1) is a remarkable barred olivine (BO) chondrule-like object dominated by Ti-, Al-rich Ca-pyroxene enclosing minor olivine bars and Mg-Al spinel grains (Fig. 1a). This is in contrast to typical BOs in which the olivine is surrounded by a feldspathic glass and/or low-Ca pyroxene [e.g., 14]. *Amoeboid olivine aggregate (AOA).* We found an AOA consisting of 2 refractory nodules of perovskite, surrounded by melilite followed by diopside and rimmed by forsterite (Fig. 1b). The forsterite encloses small (2-4 µm) Fe-Ni grains. The mineral assemblage and nodular structure of the AOA are similar to those of AOAs in other C chondrites [e.g., 15] and suggest the object is an unmelted accretion of refractory nodules. *Melilite-rich Inclusions.* Six inclusions are dominated by melilite containing varying amounts of Mg-Al spinel ± Ca-pyroxene ± perovskite (e.g., Fig. 1c). Some of these have concentric structures with perovskite surrounded by spinel followed by melilite and Ca-pyroxene. Some of these inclusions are similar to type A CAIs that are present in other C chondrites [16] but the ones in PAT 91546 are generally smaller. -*rich Inclusions*. Two grossite-rich inclusions were identified. One is composed of grossite and perovskite surrounded by melilite (Fig. 1d). The other contains grossite intergrown with hibonite, Mg-Al spinel and perovskite, surrounded by melilite. *Ca-pyroxene-rich Inclusions.* Five of the inclusions are dominated by Ti-, Al-rich Ca-pyroxene. One of these is a fine-grained fluffy object containing Mg-Al spinel. One is a Ca-pyroxene fragment and one is a spherical object rimmed by forsterite. Two of these inclusions have a concentric structure with perovskite – melilite – anorthite and an outer layer of Ti-, Al-rich Ca-pyroxene. **NAIs:** These inclusions are dominated by albitic plagioclase. One is dominated by albitic glass with small skeletal diopside and tiny (~1 µm) FeNi and FeS (Fig. 1e), one is an isolated albitic feldspar fragment ($Ab_{\sim 90}$) and the third is an assemblage of albite, diopside and enstatite (Fig. 1f). Albitic feldspar from PAT 91546 was previously interpreted to be fragments from a differentiated body [17]. The assemblage of albite with enstatite and diopside is also found in some enstatite meteorites.

Discussion: The CH chondrites contain an array of objects ranging from refractory (Ca-Al-rich) to the cryptocrystalline chondrules to the NAIs to unmelted hydrated clasts [18, 19]. Additionally, thermally metamorphosed objects have been reported [17]. These observations led [17] to conclude that CH chondrites accreted diverse types of materials and are accretionary breccias that sampled the protoplanetary disk. Fractional condensation of a solar gas has also been invoked to explain the range of CH materials [e.g., 20]. Interestingly, the refractory lithophile abundances (normalized to Mg) of CH chondrites are ~1 x solar [4] suggesting some degree of complementarity and a ge-

netic relationship of their disparate components.

The refractory inclusions in the CH chondrites have textural, compositional and isotopic similarities to those in other C chondrite groups. However, they are smaller in size (similar in size to the CH chondrules) and the abundances of inclusion types are unique to CH chondrites with some varieties that differ from those in other chondrites groups. This suggests local formation for the inclusions in the same environment as the chondrules or could be the result of efficient size sorting of materials.

The origin of objects with Na-rich compositions is particularly perplexing since retention of Na in chondrule melts requires conditions of dust enrichments and total pressures that are not predicted for the solar nebula [e.g., 21], possibly supporting a planetary origin. Based on the high Al/Mg ratio in the Ab-rich grains in PAT 91546 and the observation of antiperthite texture and pyroxene exsolution in one albite grain, [17] suggested relatively slow cooling for the albite, proposing that the albite grains represent fragments of a differentiated body. We explore 3 hypotheses for origin of the albite-rich NAIs: (1) fragments of chondrule mesostasis, (2) fragments of a differentiated planetesimal [17] and (3) products of fractional condensation [20]. The origin of these objects from breakage of chondrules seems unlikely since they are similar in size to the chondrules, most mesostasis in CH chondrules is Na-poor, and large crystalline albite (Fig. 1f) is rare in CH chondrules. An origin as fragments from a differentiated body seems equally unlikely and unconstrained since other evidence of such a body is lacking. Additionally, this interpretation is partly based on textural evidence of slow cooling for some plagioclase grains [17]. However, some NAIs (e.g., Fig. 1e) are glassy with skeletal Ca-pyroxene suggesting rapid cooling and a different origin from the plagioclase grains. Fractional condensation has been proposed to explain silica-bearing objects in CH chondrites and the wide compositional range of CH materials [20]. However, as discussed above, retention of Na would be problematic under nebular conditions. Further work on these mineral assemblages in more NAIs combined with oxygen isotope analysis may help to resolve their origin. CH chondrites appear to have a wider mixture of materials than in other chondrites, comparable to that in Comet Wild 2 [22].

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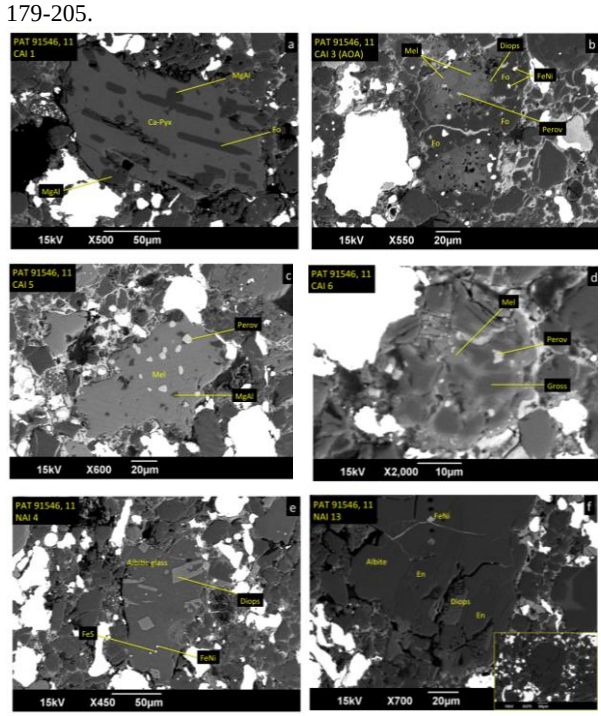

Figure 1. Backscattered electron images of objects from PAT 91546. (a) Barred olivine containing Mg-Al spinel, in which the olivine and spinel are enclosed by Ti-, Al-rich Ca pyroxene. (b) AOA with forsterite surrounding nodules of perovskite, melilite and dipside. The olivine contains small blebs of FeNi. (c) Melilite-rich inclusion containing Mg-Al spinel and perovskite enclosed by melilite. (d) Grossite-rich inclusion with grossite, perovskite and melilite. (e) NAI dominated by albitic glass with minor skeletal diopside and tiny blebs of Fe-Ni metal and FeS. (f) NAI dominated by albite with minor low-Ca pyroxene and diopside. (Mel-melilite, Perov-perovskite, Fo-forsterite, En-enstatite, MgAl-spinel, Diops-diopside, Gross-grossite).