UBIQUITOUS FeO-RICH PYROXENES IN ENSTATITE CHONDRITES: IMPLICATIONS FOR METAMORPHISM AND BRECCIATION; David Lusby, Edward R.D. Scott, and Klaus Keil, Institute of Meteoritics and Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131.

Introduction. Nearly all pyroxene in enstatite chondrites contains 0.1 - 1.5 mol.% Fs [1,2], but some grains have Fs 5-20 [3-8]. Detailed descriptions of only 5 FeO-rich objects have been published, with microprobe analyses of 11 FeO-rich pyroxenes [3]. While studying ALHA77295 for regolith features [9], we found FeO-rich objects to be much more common than previous reports suggest. We have studied these FeO-rich objects with SEM, electron probe and optical microscope to elucidate their origin and to delineate the extent and timing of brecciation in E chondrites. Our survey of three EH3 chondrites (one section of each), revealed 325 objects >10μm in size that contain pyroxene with Fs 5-25 (0.4 vol.%). Two EH4-5 chondrites were found to contain only two objects with Fs > 5, but 89 objects contain pyroxene with Fs 1-5 that are morphologically similar to some of the FeO-rich objects in EH3 chondrites. Most FeO-rich objects comprise single grains with partial or complete rims of enstatite, and cannot have been derived directly from unmetamorphosed chondrules or aggregates. They must have experienced metamorphism and breakage outside what is now their host rock.

Results. We found the EH3-5 chondrites to contain three compositional types of pyroxene: FeO-rich (Fs 5-25), and pure and impure enstatite. Most FeO-rich pyroxene contains Fs 8-16 and 0.3-0.6 wt.% MnO, 0.5-1.0% Cr_2O_3, 0.2-0.6% Al_2O_3 and 0.2-1.0% CaO. Impure enstatite is typically Fs 1-3 with 0.3-0.5% MnO, 0.3-1.0% Cr_2O_3, 1-2% Al_2O_3 and 1-3% CaO, and comprises 90% of the silicates in the rock. Pure enstatite (≅ blue-luminescing enstatite [2]) is Fs 0.1-0.5 with <0.04% MnO, Cr_2O_3 and CaO, and 0.03-0.07% Al_2O_3. In Abee and St. Marks, only four FeO-rich pyroxenes were found with Fs 5-6. However, pyroxenes with cloudy cores of Fs 1-5 and pure enstatite rims are abundant. All FeO-rich pyroxenes contain narrow (2μm) veins of enstatite and low-Ni metal, usually oriented crystallographically, and lacking SiO_2; these are similar to veins described by [3]. About two thirds of these pyroxenes appear cloudy or opaque because of abundant metal blebs . Many FeO-rich pyroxenes also contain wider (2-20μm) irregularly oriented veins containing only pure enstatite, which appear to have formed in preexisting cracks. Olivines with >2% Fa were not found. Five types of objects with FeO-rich pyroxene were found (Table 1). A) Chondrules. One chondrule contains irregular, dusty bronzite, like a chondrule described by [4], surrounded by impure enstatite, some of which nucleated on bronzite. Other chondrules contain clear, euhedral bronzite rimmed by pure enstatite. B) Aggregates, (which lack mesostasis) and contain all three pyroxene types. C) Crystals of FeO-rich pyroxene with pure enstatite regions. D) Crystals of FeO-rich pyroxene with partial or complete rims of pure and/or impure enstatite. Cores average 60-70μm diameter with rims 2-10μm thick in EH3's; in EH4-5's, cores with Fs 1-6 average 50 μm diameter, and rims are 10-40 μm thick. E) Unzoned single crystals, lacking rims or regions of enstatite.

Origins. Some chondrules contain many large, euhedral FeO-rich pyroxenes, which must have crystallized from a melt. Others contain irregular bronzite which either crystallized from a melt and were corroded after a change in fO_2, or fell in while the chondrule was molten. In any

case, E chondrites, like CM2 and unmetamorphosed C3 chondrites [10,13] contain chondrules that are largely reduced, with an admixture of chondrules that experienced more oxidizing conditions and formed in different nebular locations. Morphological and chemical data are consistent with derivation of isolated grains from chondrules or aggregates, but some may have separate origins [6], especially the rimmed objects. Alteration. The wide, unoriented veins of pure enstatite may have been produced by reduction or Fe-Mg exchange along cracks. Since no metal or SiO_2 is observed in these veins, we favor Fe-Mg exchange, which has been invoked to explain unoriented, Fe-rich veins in olivine from metamorphosed CO3 chondrites [11]. The rims on single grains may have been produced by growth from liquid, gas or solid states, or by reduction or exchange in the nebula or on the parent body. In the EH4-5's, asteroidal metamorphic processes clearly formed the wide rims. Because of the textural and chemical similarities of rims in EH3 and EH4-5 chondrites, we favor parent body metamorphism, consistent with arguments for the growth of pure enstatite during planetary metamorphism [12]. Brecciation. If in fact the rims were produced by planetary metamorphism, we infer that the EH3's discussed herein are post-metamorphic fragmental breccias.

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Table 1. Objects Containing Pyroxene With Fs 5-25

	ALHA 77295 EH3	Kota-Kota EH3	Qing-zhen EH3	St. Marks EH5	Abee EH4	Hvit-tis EL6
A) Chondrules	4	1	6	0	0	0
B) Aggregates	25	11	12	0	0	0
Pyroxene Crystals:						
C) With Associated Enstatite	17	27	1	0	0	0
D) With Partial Enstatite Rims	27	32	12	0	0	0
With Complete Rims	38	40	21	0 (42*)	2 (47*)	0
E) Lacking Enstatite Rims or Regions	18	9	24	0	0	0
Total Number Found	129	120	76	0	2	0

*These objects are Fs 1-5.