EH6 ENSTATITE CHONDRITES NORTHWEST AFRICA 7976 AND NORTHWEST AFRICA 12945; IMPLICATIONS FOR EH CHONDRITE METAMORPHISM. M. L. Gray[1,3], M. K. Weisberg[1,2,3], D. S. Ebel[1,3], [1]Dept. Earth and Environmental Sci., CUNY Graduate Center, New York, NY 10016. (mgray1@gradcenter.cuny.edu) [2]Dept. Physical Sci., Kingsborough College CUNY, Brooklyn, NY 11235. [3]Dept. Earth and Planetary Sci., American Museum of Natural History, New York, NY 10024.

Introduction: Enstatite (E) chondrites have complex thermal histories, often interpreted to include impact melting and/or shock metamorphism [e.g., 1,2]. We studied two equilibrated E chondrites, Northwest Africa (NWA) 7976 and NWA 12945. These meteorites were previously classified as EH based on a high Si-content of kamacite, and as type 6 based on their recrystallized texture and uniform mineral compositions [3,4]. Only ten EH6 chondrites are known, including one melt-breccia and one anomalous specimen, of which some have not yet been studied. As a result, there is limited information available on the EH6 chondrites and how they fit into the metamorphic history of the EH chondrite group. Studying the properties of EH6 chondrites can elucidate the processes and conditions they have been exposed to, unravelling their thermal histories on the EH parent body.

Amongst the ordinary chondrites, specimens classified as petrologic type 6 are ubiquitous. They are thought to represent the interior, and a large volume, of internally heated (due to decay of short-lived radionuclides) asteroidal parent bodies [e.g., 5], forming the so-called onion-shell structure. This raises the question why E chondrites of petrologic type 6 are relatively rare: Are their parent bodies constructed differently? Are there other processes and/or heat sources responsible for metamorphism of E chondrites? Is the sampling of E chondrites simply not representative of their population? Furthermore, E chondrites are the only class with a direct link to a group of achondrite equivalents, the aubrites, as well as impact-melt rocks.

Methods: Thick and thin sections of NWA 7976 and NWA 12945 were studied in transmitted and reflected light, and backscattered electrons. The electron microprobe was used for collecting element maps and mineral compositions.

Petrography: NWA 7976 and 12945 are both texturally and compositionally equilibrated. They have roughly granoblastic textures dominated by anhedral to subhedral equant crystals of enstatite and plagioclase with minor diopside. Euhedral enstatite grains are absent in these samples.

Relict chondrules are rare; only one was found in our section of NWA 7976 (Fig. 1), as noted in the Meteoritical Bulletin Database (MBDB) [3,4], and several areas in NWA 12945 were interpreted to be relict chondrules (Fig. 2). Enstatite in both meteorites shows undulose extinction in cross-polarized light, suggesting a shock stage S2 resulting from relatively low shock pressures of 5-10 GPa [2].

Mineral compositions. Enstatite compositions are $En_{97.8\pm0.98}Wo_{1.24\pm0.22}$ (N=6) and $En_{98.0\pm0.20}Wo_{1.43\pm0.05}$ (N=18), for NWA 12945 and NWA 7976, respectively. Some of the higher Fe values and range of compositions in the enstatite are likely due to small (sub-micrometer) blebs of Fe-metal observed in some of the enstatite grains, as well as Fe-staining due to weathering. Plagioclase compositions are fairly homogeneous and are, respectively, $Ab_{81.1\pm0.46}An_{14.8\pm0.54}$ and $Ab_{80.8\pm0.69}An_{15.0\pm0.56}$. Similar compositions were reported in the MBDB [3,4].

Kamacite in NWA 7976 has a Ni-content of 2.9±1.6 wt.% with 3.0±2.2 wt.% Si (N=5) [3], and NWA 12945 has a Ni-content of 3.4±0.7 wt.% with 2.5±0.1 wt.% Si (N=3). These numbers are similar to the composition of kamacite in EH3 chondrites [6].

Sulfides present include troilite, daubréelite, niningerite, and oldhamite. The latter is interpreted from presence of Ca-rich regions in veins, since oldhamite is easily weathered in desert finds. In both samples, daubréelite occurs as bands of exsolution lamellae in troilite. Daubréelite exsolves from Cr-bearing troilite below 700˚C [7,8], and likely formed in response to a period of slow cooling from peak metamorphic temperatures.

Weathering. NWA 7976 has been previously assigned weathering grade W4 [3], based on oxidation of metal and troilite. NWA 12945 has a lower weathering grade of W2 [4]. Our sample contains small to large weathering veins throughout.

Discussion: Thermal histories and heat sources for metamorphism have been controversial for E chondrites, as well as for other chondrite groups. Many metamorphosed EH and EL chondrites have been interpreted to be heavily shocked and some are considered impact-melt breccias [1,2,9]. Previously, it was determined that collisional heating seems to be the primary process responsible for the metamorphism of EH6 chondrites [9]. Several E7 chondrites are interpreted to be impact-melt rocks [9].

However, it cannot be excluded that certain E chondrites, that exhibit few shock characteristics, have been heated and metamorphosed by alternative processes. Besides (1) shock induced heating from an impact event, metamorphism might have been caused by (2) internal heating due to decay of short-lived radionuclides and/or residual heat of accretion, or (3) heat derived from impact-melt sheets, analogous to contact metamorphism.

Neither of the EH6 samples seem to contain evidence of high pressures, and thus significant shock. No evidence of impact-melt has been observed, such as melt veins found in other E chondrites [9]. We, therefore, find (1) unlikely. Distinguishing between (2) and (3) is difficult. The relatively low abundance of EH6 chondrites may suggest that metamorphism was a more local process, consistent with (3). Additionally, the ubiquitous occurrence of impact features and impact-melt rocks among the E chondrites makes this an appealing hypothesis.

Alternatively, [10] modeled the EL chondrite parent body with EL6 chondrites forming in the interior of an onion shell body (2). The EL6 chondrites were buried at a depth of 12-20 km, consisting of a <1 km layer. If the EH6 chondrites stem from a similarly small onion shell body, that might also explain their scarcity.

Conclusion: NWA 7976 and NWA 12945 are recrystallized, homogenous metamorphic E chondrites. They lack evidence of having experienced significant shock, leaving internal heating processes or contact metamorphism from impact-melt sheets as potential heat sources causing their metamorphism. If internally heated, the EH chondrite parent body may have been a relatively small onion-shell-structured asteroid.

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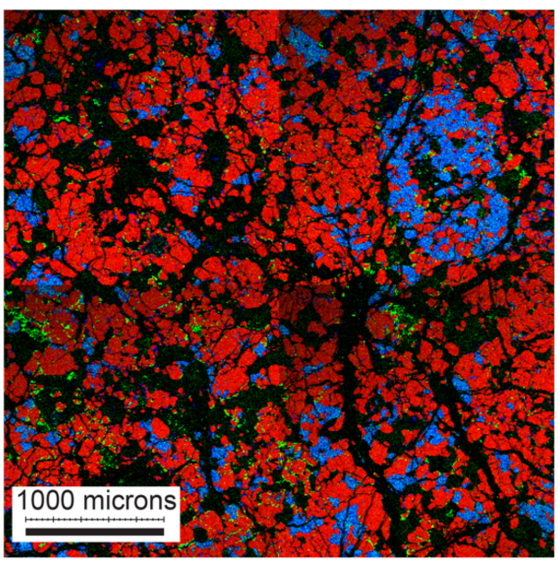

Figure 1. Section of combined elemental map of NWA 7976 in Mg (red), Ca (green) and Al (blue). Enstatite is the dominant red phase, plagioclase is blue, (weathered) oldhamite is green, FeNi metal is black. The upper-right corner shows a relict chondrule in blue. The shaded upper-left corners of individual tiles are caused by a slight tilt of the sample.

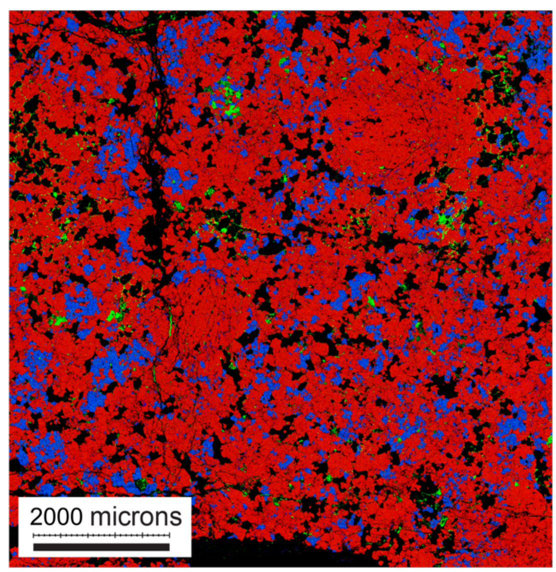

Figure 2. Section of combined elemental map of NWA 7976 in Mg (red), Ca (green) and Al (blue). Enstatite is the dominant red phase, plagioclase is blue, (weathered) oldhamite is green, FeNi metal is black. This section shows two relict chondrules and weathering veins.