EXPERIMENTAL STUDY OF UNGROUPED ACHONDRITE ERG CHECH 002. M. F. Balemian-Spencer[1], M. J. Krawczynski[1], P. K. Carpenter[1], and R. C. Ogliore[2]. [1]Department of Earth and Planetary Sciences, Washington University in St. Louis, Campus Box 1169, 1 Brookings Drive, St. Louis, MO 63130-4899. [2]Department of Physics, Washington University in St. Louis. (b.forest@wustl.edu).

Introduction: Erg Chech 002 (EC 002) is the oldest found meteorite in our solar system, having crystallized between 1.46 – 2.18 Myr after the formation of CAIs [1,2]. It has distinguishable pyroxene megacrysts with Mg-rich cores (Avg Mg# = 78.35; Mg# = Mg/(Mg+Fe)*100) that measure up to 9 cm in length, as reported by [3], a groundmass composed of Fe-rich pigeonite and highly sodic plagioclase (Avg Ab# = 83.68; Ab# = Na/(Na+Ca+K)*100) (Figure 1), and various other minor minerals. EC 002 is chemically classified as andesitic [3,4] and challenges the current perception of the early solar system, which was shaped by mafic achondrite meteorite classes such as eucrites and angrites [5,6]. The introduction of EC 002 to the meteorite collection extends the timing of silica-rich material production into the dawn of the solar system and highlights the importance of diverse igneous processes on planetesimals during this time.

Through a series of crystallization experiments and comparison with natural mineralogy, this study aims to assess the primitive melt nature of EC 002 as well as compares experimental liquid lines of descent (LLD) to H, LL, and CI partial melts. Overlapping trends in LLD and chondritic partial melts may suggest similar building blocks between these meteorites.

Experimental Methods:

Experimental set up. The starting material composition (Mix #80) was synthesized from several high purity reagent-grade oxide powders and reflects an average of natural data reported by [3] and [4]. In addition, a derivative composition (Mix #85) was synthesized in response to the occurrence of non-equilibrium textures. Mix #85 is the average glass composition of the experiment conducted at 1086°C with corrections made for Na_2O, K_2O, and P_2O_5 loss (Table 1). Oxide powders were pressed into ~60 mg pellets and fused onto a Re loop before being attached to a Pt quench wire at the bottom of a sample holder rod. The selection of Re wire was made to minimize Fe-loss during the experiment [7]. Crystallization experiments were performed in Deltech 1-atm vertical gas-mixing tube furnaces at isothermal conditions, using temperatures between 980-1243°C, and approximately isobaric oxygen fugacity (fO_2) at IW-1, which was controlled by continuous H_2-CO_2 gas flow into the furnace.

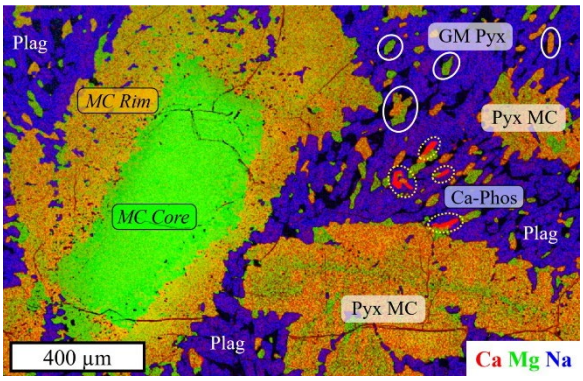

Figure 1: X-ray map of EC 002. Pyx MC = pyroxene megacryst; MC Core = megacryst core; MC Rim = megacryst rim; GM Pyx (white solid circles) = groundmass pyroxene; Plag = plagioclase; and Ca-Phos (yellow dotted circles) = Ca-phosphate.

Analytical conditions. Major and minor element concentrations of experimental and natural sample phases were analyzed using the JEOL JXA-8200 electron microprobe at Washington University in St. Louis. All analyses were performed at 15 kV and 25 nA probe current, with the exception of experimental glasses, which were analyzed at 10 nA. A focused beam was used for all phases except for glasses which were measured using a defocused beam. Defocused beam analysis was used for pyroxenes with sub-micron exsolution lamellae.

Results: Experiments produced glass, high-Ca pyroxene, low-Ca pyroxene, sodic plagioclase,

Oxides	Mix #80	Mix #85
SiO_2	58.22	65.95
TiO_2	0.38	0.49
Al_2O_3	9.01	14.12
Cr_2O_3	0.50	0.07
FeO	11.09	7.26
MnO	0.47	0.27
MgO	7.65	1.53
CaO	8.03	3.30
Na_2O	3.91	5.97
K_2O	0.47	0.92
P_2O_5	0.09	0.12
Total	*99.79*	*100.00*

Table 1: Experimental starting materials. Mix #80 is an average of compositions reported by [3] and [4], while Mix #85 is the derivative mix synthesized from experimental glass. Mix #85 simulates fractional crystallization.

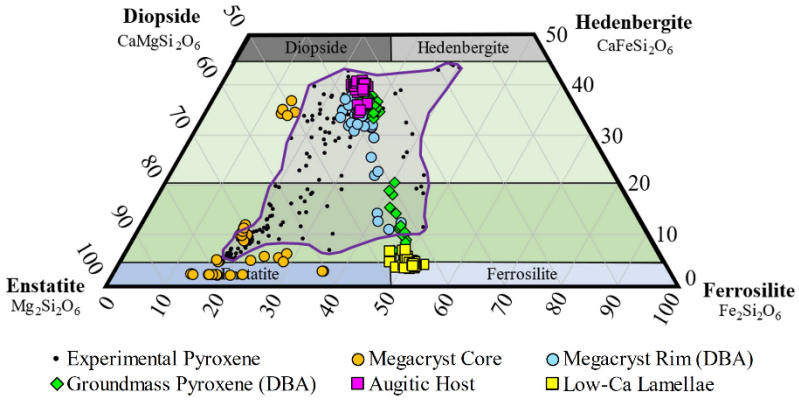

Figure 2: Pyroxene quadrilateral with experimental and natural data. DBA = Defocused Beam Analyses (25 μm beam diameter). Purple boundary is hand drawn to highlight the approximate compositional region of experimental pyroxene. Megacryst core compositions overlap high-temperature experiments while DBA analyses of groundmass pyroxene are intermediate to synthetic pyroxene crystallized between 1028 and 1099°C, suggesting crystallization at this temperature.

chromite, and a silica phase. Mass balance calculations show that experiments exhibit a loss of volatile elements, such as Na and K, due to open system behavior, and Fe loss to the Re wire loop. Phases identified in EC 002 samples include high-Na plagioclase, exsolved pyroxene groundmass with low-Ca lamellae and augitic host material, pyroxene megacrysts with high-Mg cores and rim compositions similar to groundmass pyroxene, Ti-bearing chromite, ilmenite, troilite, Ca-phosphate, silica, and Fe-metal (Figure 1, Figure 2).

Discussion:

Contextualizing experimental results. Synthetic mineralogy does not deviate from natural meteorite samples in that there are no observed crystalline phases that are not present in EC 002. However, experiments lack other observed phases such as ilmenite ($FeTiO_3$), troilite (FeS), Ca-bearing phosphate, and Fe-metal. Absence of troilite is a direct result of S not being present in the starting material. Fe-bearing phases such as ilmenite and Fe-metal are possibly missing due to Fe-loss during experiments that reduces the concentration of Fe in the experimental charges. However, at lower temperatures these phases are likely to crystallize.

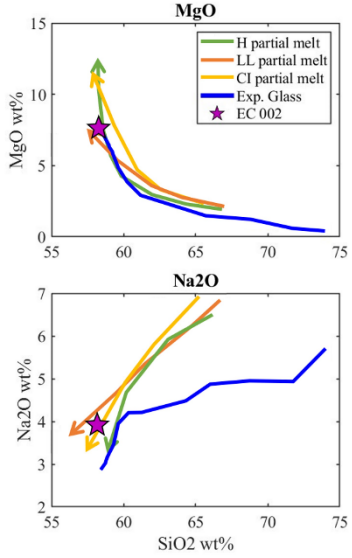

Figure 3: Partial melt trends and experimental LLD. EC 002 bulk composition is marked with purple star and the experimental LLD is determined from glass analyses. Na concentrations are true to experimental values, which reflect loss from volatilization.

Consistency between synthetic and natural mineralogy suggests that the bulk composition of EC 002 is reflective of the melt from which the meteorite is derived from. That is, it can be assumed to be a primitive melt composition, rather than a cumulate or residual solid.

Forming in tandem with chondrites. Establishing the EC 002 bulk composition as a primitive melt is an important first step in understanding its origins. EC 002 is peculiar because its high-Mg content suggests formation at high temperature, but its high-Na content is not readily consistent with this interpretation. However, comparison to H, LL, and CI chondritic partial melt studies, such as those by [8] and [9], provide evidence for the possibility of high-Mg high-Na compositions to be achieved (Figure 3), suggesting that EC 002 may have formed with some of the same building blocks as these meteorites.

Acknowledgements: This research is made possible by support from the NSF Graduate Research Fellowship Program (DGE-2139839 and DGE-1745038). Data from the Meteorite Deep Zoom database was used in this work. We would also like to thank Tony Irving (University of Washington, WA) for sharing a sample of EC 002 for this study.

References: [1] A. Anand, et al. (2022) *Meteorit. Planet. Sci., 57,* 2003-2016. [2] Fang, et al. (2022) *PNAS, 119.* [3] J.A. Barrat, et al. (2021) *PNAS, 118.* [4] P. K. Carpenter, et al. (2021) *52nd LPSC,* Abstract #2548. [5] K. Keil (2012) *Geochem. J., 72,* 191-218. [6] Zhou, et al. (2013) *Geochim. Cosmochim. Acta, 110,* 152-175. [7] A. Borisov and J.H. Jones (1999) *Am. Min., 84,* 1528-1534. [8] M. Collinet and T.L. Grove (2020a), *Geochim. Cosmochim. Acta, 277,* 358-376. [9] M. Collinet and T.L. Grove (2020b), *Geochim. Cosmochim. Acta, 277,* 334-357.