PETROGENESIS AND POTENTIAL PAIRING OF THE KUNASHAK AND PARK FOREST CHONDRITES J. K. Dunaway, J. Moersch, and L.A. Taylor, Planetary Geosciences Institute, Dept. of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN 37996, jdunawa1@utk.edu.

Introduction: The Kunashak shocked S4 L6 chondrite from the Chelyabinsk Province of Russia exhibits an unusual dual lithology of light and dark portions. Other papers on such unusual chondrites (e.g., [1-3]) have noted the lack of significant change in overall silicate compositions between these portions, but the darker lithology can show enrichment of volatile gases and different distributions of opaque materials, i.e., metals, sulfides, and oxides. In this paper, a textural and mineralogical description of each portion will be developed, a comparison to the Park Forest chondrite will be made, and an interpretation will be posited as to the petrogeneses of the Kunashak chondrite.

Methodology: Polished thin sections of the light and dark lithologies of the Kunashak meteorite were studied optically using both transmitted and reflected light. A Cameca SX 50 electron microprobe was used to obtain BackScattered Electron (BSE) images and wavelength-dispersive chemical analyses. Operating conditions were 15 kV potential, 20 nA beam current, spot size of 1µm, and count times of 20-40 seconds. In addition, an approximate modal analysis of opaque phases (metals, sulfides) was obtained by "area analysis" using graph paper.

Petrographic Description: Both the light and dark portions of this meteorite consist of poorly defined chondrules with an average of ~ 1.0 mm diameter. The dominant phases are euhedral olivine-pyroxene intergrowths with interstitial feldspar. Barred olivines are in abundance of 20-30%. Chondrules are generally depleted in opaque phases (i.e., FeNi and troilite), but frequently these phases are concentrated along the outer edges in singular small grains and veinlets. The matrix material is difficult to distinguish from potential chondrule fragments because the whole of the specimen is heavily re-crystallized. Total opaque abundance is approximately 4.6% in the dark portion, and 4.8% in the light. *The most significant textural difference is the relative proportion of FeNi and troilite*. The light portion contains 77.9 modal % of troilite, which is significantly greater than dark portion abundance of 43.6 modal %.

Metamorphic alteration and shock effects are apparent. This is evidenced by a lack of appreciable chemical zonation in olivine and pyroxene, an apparent re-crystallization of matrix material, and indistinct chondrules boundaries with euhedral phenocrysts. Abundant fractures, weak mosaicism, and undulatory extinction in many mineral grains represent shock features. Overall, this chondrite is a shocked monomict breccia [2].

Results and Discussion: Mineral compositions, shown by average compositions of olivines, pyroxenes, and feldspars, in Table 1, are not distinctly different between the light portion and the dark portion. No chemical zonations were apparent in individual grains, suggesting equilibrium phases. Metal data show a slight Fe-enrichment of FeNi metals in the dark portion; sulfide data show troilite as the primary phase. It is notable that no significant distinction in mineral compositions appears obvious between light and dark portions of the meteorite. Other studies (e.g., [1-3]) of light versus dark portions of meteorites have also noted similar mineralogies between the two portions.

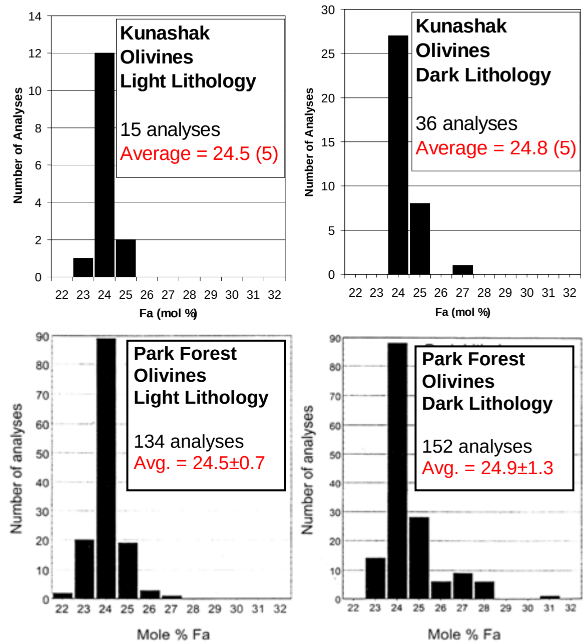

Figure 1: Histograms showing distribution of olivine compositions from the Kunashak (this study) and Park Forest [1] meteorites.

In an examination of other light-dark meteorites, a possible pairing of the Kunashak meteorite was discovered with the Park Lake L6 chondrite. This is particularly obvious with a comparison of the relative frequency of compositions for olivines, as shown in Fig. 1. The similarities are apparent. Pyroxene compositions for both lithologies also display a striking (Fig. 2). The striking similarity between compositional data of the Kunashak and Park Forest meteorites suggest a pairing. Future work should include investigation into whether these chondrites shared a common parent body and impact history.

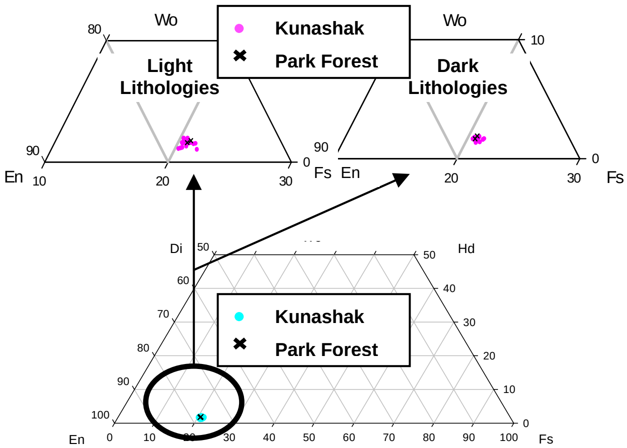

Figure 2: Ternary plots showing distinct similarity of pyroxene compositions for Kunashak and Park Forest.

Origin of Light and Dark Lithologies: The origin and formation of the light and dark textures in the Kunashak meteorite have received considerable debate over the years [1-7]. Evidence from the present study suggests that dark lithologies may have originally been the outer exposed layer of a homogenous regolith/parent body, thus exposed to irradiation, while the light lithologies represent deeper (and more pristine) layers, shielded from irradiation. Sulfur is ultimately depleted in this outer (dark) layer. which agrees with data from various studies (e.g. [6], [7]). Thus, the dark lithologies were derived from the primary light lithologies. With subsequent impacts, the surface and subsurface volumes are shattered and mixing of lithologies occurs; sulfur mobilization occurred via the shock metamorphism. The proceeding agglomeration resulted in the formation of chondritic breccias with dual lithologies.

The above scenario is in agreement with evidence from previous studies [e.g., 3] where it was discovered that although the dual portions do not differ in mineralogy, enrichment in volatile/mobile trace elements has been manifest in the dark lithologies. The most popular explanations include mobilization (of volatiles) during metamorphism, with the dark lithologies being derived from light lithologies [1] [3]. Shock metamorphism is typically used as the mobilization mechanism. Brearly and Jones [4] extended this idea by stating the volatile gases were "probably implanted during irradiation by an ancient solar wind, in a regolith environment," and Dhingra et al. [5] described noble gas abundances in terms of shielding depth from irradiation. Furthermore, sulfur mobilization must have been an important part of the shock-process history. Indeed, sulfur has been found to be depleted on the surface of asteroids and the Moon (asteroid mean bulk compositions correlate well to that of ordinary chondrites), with mobilization of sulfur due to various processes [6]. The sulfide mineral (troilite) abundance in the Kunashak chondrite (i.e., total sulfur content) is enriched in the light portion relative to the dark. A complete synthesis of all these ideas is lacking in any one study. In general, our scheme of events, presented above, has integrated concepts and results from these earlier studies into a scenario that can explain the origin and formation of light and dark lithology chondrites.

Summary: The Kunashak chondrite displays no major textural differences between light and dark lithologies, with the exception that the light portion is more enriched in troilite with respect to the dark. Chemical analysis data also demonstrate no differences in mineral chemistry between the portions. With regards to the petrogenesis resulting in dual lithologies, studies have hypothesized that such dual lithologies arise from metamorphic effects, and dark lithologies have developed from light. As an expansion and synthesis of these ideas, this paper suggests that the dual lithologies were native to the parent body as a function of exposure to irradiation and shock metamorphism. Subsequent impacts effectively mixed these lithologies into the dual-lithology chondritic meteorites found today.

(mol %)	Light	Dark
Olivine		
Fa	**24.5 ±0.5**	**24.8 ±0.3**
Pyroxene		
Wo	**1.55 ±0.30**	**1.63 ±0.15**
En	**77.7 ±0.4**	**77.5 ±0.3**
Fs	**20.7 ±0.4**	**20.9 ±0.3**
Feldspar		
Ab	**83.5 ±1.6**	**84.4 ±1.0**
An	**10.7 ±0.4**	**10.7 ±0.5**
Or	**5.83 ±1.80**	**4.93 ±0.84**

Table 1: Average compositions of olivine, pyroxene, and feldspar in light and dark portions of Kunashak.

References: [1] Simon et al. (2004) *Met. & Plan. Sci., 39*, 625-634. [2] Lipshutz et al. (1983) *GCA, 47*, 169-179. [3] Fredriksson & Kiel (1963) *GCA, 27*, 717-739. [4] Brearly & Jones (1998) in Min. Soc. of Am., Rev. in Min., 36. [5] Dhingra et al. (2004) *Met & Plan Sci, 39, Sup.*, A121-A132. [6] Killen (2003) *Met & Plan Sci, 38*, 383-388. [7] McCoy et al. (2005) *Lunar & Plan. Sci. Conf., 36*.