EARLY FORMED SOLIDS IN THE SOLAR SYSTEM: SHOCK METAMORPHISM, THERMAL IMPACT HISTORY, AND CHONDRULE DIVERSITY OF THE DERGAON H5 ORDINARY CHONDRITE.

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Introduction: Ordinary chondrite meteorites (OCs) are the most abundant meteorites comprising ~80% of all falls. These meteorites which are largely composed of silicate phases such as olivine and low-Ca pyroxene, have been subdivided into three main groups (H, L and LL) based on their bulk chemistry, e.g. molecular ratios of FeO / (FeO+MgO) in silicate minerals, and the ratio of Fe metal to total Fe content [1-3]. Amongst the ordinary chondrites, the H chondrites are the most reduced OCs, with the highest total Fe content and highest Fe/Si ratio, with most iron being present in reduced form. Investigation of variations in textures, along with mineralogical and geochemical analyses can be used to understand the conditions of thermal metamorphism of these meteorites. Brecciation along with other shock features are considered to be common features in many ordinary chondrites (~30%), and may provide critical insight into the collisional history and regolith formation in the parent bodies of these meteorites [1,4]. Fall of an undifferentiated meteorite occurred in Dergaon, Assam, India (26°41' N, 93°52' E) on March 2, 2001 (16:40 IST), and on the basis of geochemical and isotope analysis it was classified as an H-chondrite (H5) with relatively low K-content [5-7]. A comprehensive investigation of the textural variation in chondrules, shock induced features of the H5 Dergaon ordinary chondrite, along with detailed mineralogical and geochemical analysis is still needed to understand its formation environment, and the nature of the parent body.

Objective and Approach: This work attempts to understand the thermal evolution and impact history of the Dergaon H5 chondrite. Using optical microscopy, SEM, EPMA and Raman spectroscopy techniques, a detailed mineralogical and geochemical characterization of the bulk sample as well as the diverse range of chondrules present within the studied section, textural study, along with an investigation of the shock features present in the Dergaon H5 chondrite was performed. In the analysed sample, the chondrule to matrix ratio is visibly high because of the relatively large number of chondrules that are found to be present (Fig.1).

Results: The observed silicate phases are olivine, orthopyroxene, sodic plagioclase with accessory chromite and apatite phases, while kamacite, taenite and troilite comprise the metallic phases. Chondrules have been classified based on two different classification parameters.

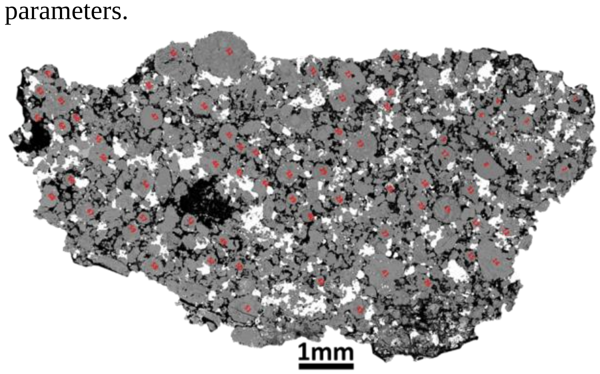

Fig.1. Back Scattered Electron (BSE) image of the polished section of a sample of the Dergaon H5 chondrite (numbered red points are chondrules).

The first is based on mineralogical characteristics (Fig.2.) namely, porphyritic olivine pyroxene (POP), barred olivine (BO), porphyritic olivine (PO), porphyritic pyroxene (PP), radial pyroxene (RP), porphyritic olivine pyroxene (ROP) and cryptocrystalline chondrules (C). Abundance of porphyritic (especially POP) chondrules is found to be high relative to the non-porphyritic chondrules. The other classification is based on the shape and presence of fractures, and based on these chondrules have been classified as pristine, mechanically deformed and partially melted chondrules respectively. Nearly 40 vol% are partially melted with serrated and degraded boundaries indicating thermal metamorphism.

Previous studies [5] suggested that there is not enough supporting evidence of thermal or shock metamorphism in these chondrites but our observations based on the detailed analysis of the Dergaon chondrite sample suggested otherwise. The observed presence of features such as radial cracks, irregular fractures, planar deformational features (PDFs), cataclastic texture, silicate melt veins, metal melt veins and veinlets (Fig.3.), indicate that the possible source of heat generated for this metamorphism could be via mild impacts. Additionally, based on various shock and impact features, moderately shocked (S4) shock stage has been assigned, where corresponding pressure would have been 30-35 GPa, contrary to S2-S3 (very weakly to weakly shocked) shock stage suggested by previous studies with corresponding pressure 5-20 GPa [5].

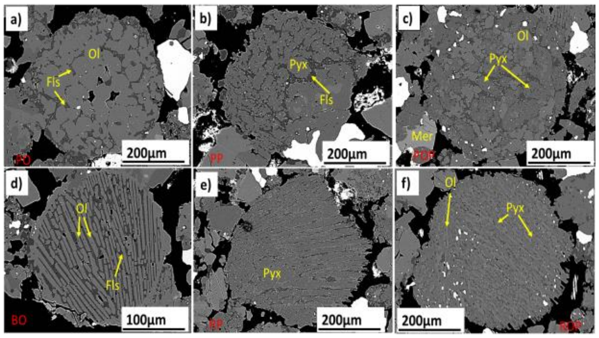

Fig.2. BSE image showing classification of chondrules a) porphyritic olivine (PO), b) porphyritic pyroxene (PP), c) porphyritic olivine pyroxene (POP), d) barred olivine (BO), e) radial pyroxene (RP), f) radial olivine pyroxene (ROP). Mer-merrillite.

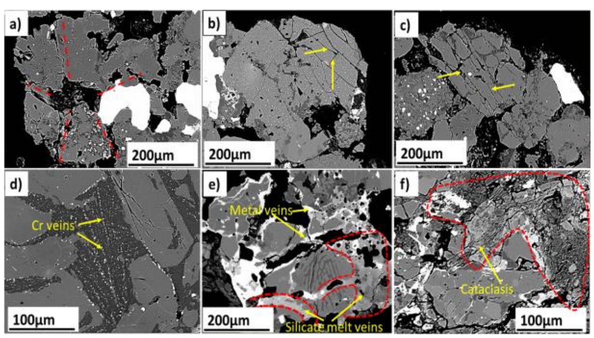

Fig.3. BSE image showing evidences of shock metamorphism a) radial cracks, b) irregular fractures, c) planar deformational fractures (PDFs) in mechanically deformed chondrules, d) chromite veins indicative of shock metamorphism [8], e) silicate melt veins and metal melt veins f) cataclasis near the chondrule.

Discussion and conclusions: This work presents a comprehensive mineralogical and geochemical characterization of the H5 Dergaon meteorite, classification of the wide variety of chondrules found to be present, textural study, and an investigation of the shock features present in the Dergaon H5 chondrite, and also proposes a basic conceptual model for the thermal impact history of the ordinary chondrites.

Porphyritic chondrules (1650°C) formed at temperature difference of 100°C with respect to non-porphyritic chondrules (1590°C) in reducing nebular environment [7], as is suggested by the crystallization of olivine and pyroxene mineral phases in the chondrules. Subsequently, these chondrules along with the fine-grained matrix and dark inclusions would have accreted to form the asteroidal parent body from which these meteorites originated from. This stage was possibly followed by the parent body experiencing an impact event resulting in shock metamorphism and in the ejection of Dergaon H5 chondrite. This is also supported by the observed presence of the radial cracks, PDFs and melt veins which assign them S4 shock stage with corresponding pressure 30-35 GPa. The presence of different mineral phases established from the Raman spectroscopy analyses of the sample, further confirm the high pressure S4 shock stage. It was observed that the silicate melt veins composition with olivine (Fa 42-43), at some places within the studied section was different from the olivine of nearby matrix and chondrules (Fa 18-19). The results of the geochemical analysis interpreted from ternary and bivariate plots, show that the average compositional range of pyroxene, olivine and feldspar are $Wo_{0.40-7.04}$ $En_{74.98-84.37}$ $Fs_{14.32-17.92}$; $Fo_{79.41-81.05}$ $Fa_{18.63-19.94}$ $Te_{0.02-0.71}$, and $An_{6.93-39.01}$ $Ab_{36.22-91.51}$ $Or_{1.56-8.01}$ respectively, which clearly implies that the sample lies well within the H-chondritic compositional range [1,3,5]. Post shock pressure release may have favoured the loss of K and other volatiles, as evident from the relatively low K-content found in this meteorite [6].

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