

Vesicular olivines and pyroxenes in shocked Kamargaon L6 Chondrite: Implications for primary volatiles and its multiple impacts history.

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Introduction: The Kamargaon meteorite is a highly shocked L6 chondrite, which was fallen on 13th November 2015 near the town of Kamargaon of the Indian state of Assam [1]. Recently, shock-induced incongruent melting of olivine dissociated into magnesiowüstite and orthoenstatite was reported in a SMV of the Kamargaon L6 chondrite [2]. In this study, we carefully examined shock-melt vein (SMV) of the Kamargaon chondrite in detail to understand dissociation segmented and melting textures displayed by the phases (olivine and pyroxene) present and their formation mechanisms which provide further clues to estimate the shock conditions in the chondrite parent body. Here we found the first occurrence of vesicular olivine and pyroxene in an ordinary chondrite.

Results: The host rock of Kamargaon chondrite consists of olivine (Fo₇₃₋₇₄), low-calcium (Ca) pyroxene (En₇₇₋₈₀Fs₁₉₋₂₂Wo₁₋₂), high-Ca pyroxene (En₄₅₋₄₆Fs₉₋₁₀Wo₄₄₋₄₆), plagioclase (Ab₆₂₋₇₀An₁₈₋₂₃Or₁₂₋₁₅), iron-nickel alloy (kamacite and taenite), troilite plus a minor amount of phosphate and chromite. The host rock shows a pervasive SMV of up to 1.6 mm thickness passing through the middle of the sample [2], enclosing coarse-grained rounded fragments of host minerals in a fine-grained matrix with few irregular shaped metal-sulfide eutectic intergrowths.

Composite and vesicular grains: Numerous olivine grains entrained in the melt vein occur as composite grains displaying the combination of different textures. Such a composite olivine grain present near the vein edge shows heterogeneous texture where core displays segmentation texture (Se-Ol), while the remaining part of the grain shows vesicular texture (Ve-Ol) (Fig. 1b, c). Many enstatite grains show the presence of a large number of vesicles. A grain of such vesicular pyroxene (Ve-Px) is present in Fig. 1d, with the small veinlet offshoots branching from it into the neighbouring grain. Feasibility of three possible mechanisms is discussed for the vesicle formation: (i) liberation of S₂ vapor; (ii) liberation of volatiles such as Na, Mn etc.; (iii) vaporization of olivine and pyroxene. We tested these possible mechanisms by calculating the maximum amount of a chemical species that can be liberated from our sample during vaporization and the amount that is needed for the formation of the observed volume of vesicles. Volume fraction of vesicles in our sample is estimated to be 8-12% using ImageJ software. The mass fraction of gas required to create the estimated volume of vesicles can be calculated using Eq.(1) [3]: $m_g = Pwv_g / (1 - v_g)\rho_{ng}RT$, where m_g , P , w , v_g , ρ_{ng} , R and T are mass fraction of the gas, pressure of vesicle formation (Pa), molecular weight of the gas, volume fraction of the gas, density of the non-gas phase (solid or liquid) (kg/m³), universal gas constant and temperature of vesicle formation (K) respectively. Estimated values of available and required abundance volatiles suggest that all three or any combination of these mechanisms could be responsible for the vesicle formation in the Kamargaon L6 chondrite.

P-T-t path: Based on the pressure stability range of high-pressure phases and its polymorphs and phase equilibrium diagrams, the estimated shock pressure and temperature conditions recorded in the Kamargaon chondrite are 24–25 GPa and ~2433–2633 K, respectively. Calculated impact velocity based on shock pressure estimation is ~2.3 km/s. The calculated crystallization time at the center of the melt vein with a thickness of 1.6 mm is ~50 ms. The shock pulse duration required for back transformation of high-pressure polymorphs is estimated to be ~2 s which implies that the parent body of Kamargaon L6 chondrite is ~6.4 km across in size at least. The panoply of different textures and phases corresponding to contrasting pressure and temperature indicates that our sample has experienced multiple impacts of different magnitudes.

References: [1] Goswami T.K. et al. 2016. *Current Science* 110(10), 1894. [2] Tiwari K. et al. 2021. *Geophysical Research Letters* 48:e2021GL093592. [3] Bendix G.K. et al. 2008. *Geochimica et Cosmochimica Acta*, 72(9), 2417-2428

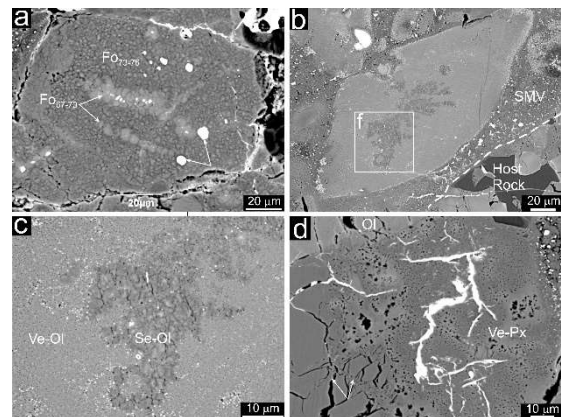


Fig. 1 Different textures present in Kamargaon L6 chondrite