2nd Symposium On

"Meteoroids, Meteors and Meteorites: Messengers from Space"

25th November, Thursday

Session-IV: Impacts: Shaken and Stirred! Puckered and Smithereens!

Session Chairs: Jayanta K. Pati and Sujoy Ghosh

Abstract #	Time	Speaker	Title of talk
Invited	11.45-12:15	Sujoy K. Ghosh	Formation of High-Pressure Phases in Shocked Chondrite.
S4-01	12.15-12:25	Prosenjit Ghosh	Oxygen isotope constraints on the origin of impact glasses from Lonar Crater, India
S4-02	12:25-12:35	Aryavart Anand	Chromium Isotopes Identify the Type of Impactor Involved in the Formation of Dhala Impact Structure, India
S4-03	12:35-12:45	Kishan Tiwari	Vesicular olivines and pyroxenes in shocked Kamargaon L6 Chondrite: Implications for primary volatiles and its multiple impacts history
S4-04	12:45-12:55	Dipansu Dipayan Behera	Impact shock origin of diamond in an Enstatite chondrite
S4-05	15:15-15:25	V.P. Singh	Cosmic spherules from various terrestrial environments
S4-06	15:25-15:35	Mayank Pandey	Geochemical characterisation of cosmic spherules collected from Central Indian Ocean Basin
S4-07	15:35-15:45	Surendra V Singh	Polypeptide synthesis in hypervelocity impact on amino acid-water ice targets
S4-08	15:45-15:55	Arijit Roy	Shock Induced formation of SiC
S4-09	15:55-16:05	Garima Arora	Chemical dating(U-Th-Pb) of the Asteroidal Impact Craters
S4-10	16:05-16:15	Rajesh Kumar Behera	High-pressure phases in heavily shocked Bori L6 chondrite
S4-11	16:15-16:20	Chetna Sharma	Formation of dust impact signal

Oxygen isotope constraints on the origin of impact glasses from Lonar Crater, India

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Lonar cratering activity around 52000 years or 570 ka BP was unique cratering event on Earth; serve as an analogue for similar events on lunar and Martian surface. Deccan basalt was target rock for the chondritic impactor A comparison of geochemical patterns of immobile elements (trace and REEs) for glass, melt rock and basalt indicates minimal redistribution or partitioning of elements between the target rocks and the impactites. Post-impact hydrothermal alteration is predicted as a factor for driving the abundances of volatile trace elements. We investigated here the target basalt and melt for characterization of 18O values for understanding the presence and absence of meteoric water during melt generation. Laser-extraction oxygen isotope analysis of impact melts from Lonar crater revealed incorporation of meteoric water. In this study, we analysed target basalt and impact melt from the outcrop and observed evidences of signature from meteoric water during melting. The target rocks are Deccan basalt with d18O value with respect to SMOW lying between 6-6.5‰ , consistent with the previous observation. The impact melt characterized by glass and are derived from partial melting of weathered basalt in a basinal setting in presence of meteoric water . This is inferred based on oxygen isotopic composition of the melt registering low d18O values ranging between 4.3 to 5.3t. Our observation suggests melting process in presence of water of meteoric origin available in the basinal settings.

Chromium Isotopes Identify the Type of Impactor Involved in the Formation of Dhala Impact Structure, India

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The ca. 11 km diameter Dhala structure in north-central India is a confirmed complex impact structure of Paleoproterozoic age. The presence of an extraterrestrial component in the impactites from the Dhala structure was recognized through geochemical analyses of the highly siderophile element Ir representing the platinum group elements, moderately siderophile elements (e.g., Ni, Cr, Co) and Re-Os isotopic compositions in different rocks of the impact structure. However, the nature of projectile has remained unidentified [1]. The present study employs Cr isotope systematics for the same suite of rock samples represented in [1] to identify the type of impactor involved in the formation of the Dhala structure.

Dhala impactites/target samples were digested and Cr was purified by a three-step cation-anion exchange chromatography as described in [2]. The purified Cr was loaded onto outgassed Re-filaments with activators and Cr isotopes were measured along with the terrestrial standard NIST SRM 979 on a Thermal Ionization Mass Spectrometer (TIMS) at the University of Bern.

Unlike the composition of siderophile elements and their inter-element ratios that may get compromised due to the extreme energy generated during an impact event, Cr isotopes retain the composition of the impactor [3, 4]. In the present study, the distinct ε^{54}Cr value of -0.31 ± 0.09 for a Dhala impact melt breccia sample (D6-57) indicates the inheritance from the impactor originating from the non-carbonaceous reservoir, i.e., the inner Solar System [5]. The combined Ni/Cr ratio, Os abundance and Cr isotopic composition of sample D6-57 suggest an ureilite-type impactor for Dhala structure. Binary mixing calculations indicate a contamination of the target rock samples from the Dhala structure by 0.1-0.3 wt.% of material from a ureilite-like impactor. Thus, similar to the earlier identified projectiles that formed El’gygytgyn [6], Zhamanshin [7] and Lonar impact structures [8], the Cr isotopic compositions of the Dhala impactites also argue for a much more diverse source of the objects that collided with the Earth over its geological history than has been supposed previously.

References: [1] Pati et al. (2017) *Meteoritics & Planetary Science*, **52(4)**, 722-736 [2] Anand et al. (2021) *Geochemical Perspectives Letters* **20**, 6-10. [3] Shukolyukov and Lugmair (1998) *Science*,**282(5390)**, 927-930 [4] Trinquier et al. (2006) *Earth and Planetary Science Letters*, **241(3-4)**, 780-788 [5] Warren (2011) *Earth and Planetary Science Letters*, **311(1-2)**, 93-100 [6] Foriel et al. (2013) *Meteoritics & Planetary Science*, **48(7),** 1339-1350 [7] Magna et al. (2017) *Nature Communications*, **8,** 1-8 [8] Mougel et al. (2019) *Meteoritics & Planetary Science*, **54(10),** 2592-2599.

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, segmentation and melting textures displayed by the silicate phases (olivines and pyroxenes) 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 (Fo_{73-74}), low-calcium (Ca) pyroxene ($En_{77–80}Fs_{19–22}Wo_{1–2}$), high-Ca pyroxene ($En_{45–46}Fs_{9–10}Wo_{44–46}$), plagioclase ($Ab_{62–70}An_{18–23}Or_{12–15}$), 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.

Segmented Olivine: Several rounded and coarse-grained olivine fragments (100-200 μm) entrained in the SMV show formation of cellular walls resulting in segmentation texture with individual segments up to ~5 µm in size (Fig. 1a). Two discrete lamellar zones are visible in the middle portion of the segmented olivine grain and are in light grey contrast while the rest of the grain is in dark grey contrast as observed in BSE image (Fig. 1a). EPMA analyses of these two domains show that the light grey lamellar zones are Fe-rich olivine ($Fo_{67–70}$), whereas the dark grey zones are relatively Fe-poor ($Fo_{73–76}$). We propose that the segmentation has developed due to the formation of sub-grain boundaries during the recovery process when grains were subjected to localized shear stress. The olivine grains in and around the SMV experience high temperature but the shock compression suppresses the thermal expansion which results in high thermal stress in the olivine grains. Consequently, high strain energy gets stored in the grains and they become unstable. To ease off this stored strain, as a recovery process, dislocations from different parts of a grain migrate to form a dislocation wall and divide one strained grain into two, relaxed grains with a subgrain boundary between them. Segments showing heterogeneous composition may have formed due to the interdiffusion of Fe-Mg during the segmentation process.

Composite and vesicular grains: Numerous olivine grains entrained in the SMV 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/m^3), 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 SMV 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.

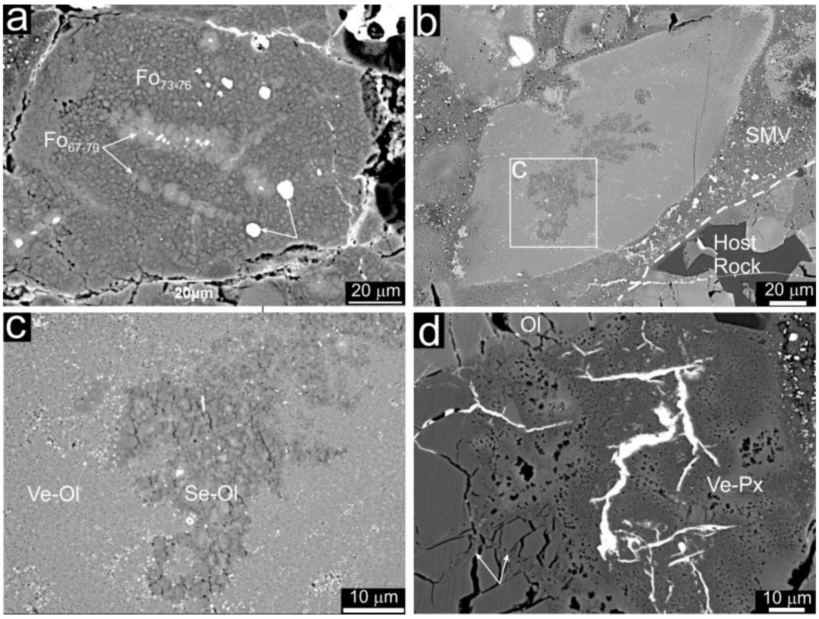

Fig. 1 Different textures present in Kamargaon L6 chondrite.

References: [1] Goswami T.K. et al. (2016) *Curr. Sci.* **110(10)**, 1894. [2] Tiwari K. et al. (2021) *GRL*, **48**:e2021GL093592. [3] Bendix G.K. et al. 2008. *GCA*, **72(9)**, 2417-2428

S4-04

Impact shock origin of diamond in an Enstatite chondrite

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Introduction: The origin of diamonds in meteorites is a highly debated topic. Post discovery of diamonds in meteorite samples, three mechanisms have been suggested to explain the presence of diamonds: Shock-induced transformation of graphite to diamond during an energetic impact [1,2]; Growth by chemical vapor deposition (CVD) of a carbon-rich gas inside a solar nebula [3]; Growth under static high pressure inside a planetary body with size up to Mercury or Mars [4,5]. Here we are studying a unique enstatite chondrite with large carbon-phases in order to understand their origin and formation history.

Sample and methods: Our study is focused on Ramlat Fasad (RaF) 546, an EL3 enstatite chondrite found in Oman containing numerous platy and microcrystalline diamond grains up to 250x45 µm in size. The meteorite is low shock (S1) and one of those rare low-shocked meteorites where large diamond grains are found. The carbon-phases in the meteorite were studied using a HORIBA LabSpec 6 Raman spectrometer (532 nm) with grating of 600 lines/mm, with an acquisition time of 20-40 seconds and with beam energy of <1mW. From the spectra, a linear background from 800-1800 cm^{-1} has been subtracted. Fitting of the peaks has been done using Lorentzian function for G and D bands.

Results and Discussions: The studied sample has distinct, well-formed chondrules with an apparent mean diameter of 0.73 ± 0.39 mm (n=64), with the largest chondrule having a diameter of 3.0 mm. The silicates in the meteorite sample are dominated by enstatite, with minor diopside. Metal grains up to 150 µm are mostly inter-grown with troilite and contain inclusions of the troilite-alabandite-niningerite solid solution up to 50 µm in size. Carbon-phases up to 40 µm is a common phase observed in the meteorite, mainly at the rims of kamacite. Previous, TEM study of the carbon-phases show that they contain nanopolycrystalline diamond with grain sizes ranging from 50-500 nm. Many grains of the diamond show numerous dislocations and defects, giving rise to extra reflections in the diffraction pattern attributed to lonsdaleite. TEM results also show that graphite bands are embedded within diamond crystals. Inclusions of Fe, Ni-metal, FeS, Fe-phosphate, and chromite have been observed as random clusters within the diamond and graphite crystal. The Raman Spectra with characteristic bands of graphite is observed with D-band occurring at around 1342 cm^{-1}, G-Band at around 1575 cm^{-1}, and D'-band at 1608 cm^{-1}. The presence of D-Band and D'-Band suggests that the graphite crystals present in the meteorite sample are disordered and micro-crystalline in nature, with a certain degree of amorphization. The TEM results show that the nano-polycrystalline structure of the diamond shows a pseudo-morphological behavior by retaining the hexagonal crystalline structure of pre-existing parent graphite crystal. Such formations could be the direct consequence of the shock event. The presence of these large diamond-graphite assemblages in a chondritic meteorite clearly shows that such diamond grains did not form under high static pressure inside a large parent body as suggested by [4,5]. The inclusions of metal phases in the diamond crystals can occur during the shock impact events when the Fe and Ni phases are in the molten state and can flow into the interspace of disordered graphite crystal, acting as a catalyst for the transformation of graphite to diamond. The diamond crystals can easily incorporate the iron-nickel complex phases once the crystallization phase is complete. The pseudo-morphological structure of the diamond can occur during the impact shock when the diamond crystals do not get long enough exposure to high temperature and pressure to re-crystallize themselves into cubical crystal structures. The disordered nature of graphite is another proof for an impact shock origin of the diamond grains.

Conclusions: Our study of carbon-phases in an enstatite chondrite show that the diamond grains formed during a large impact event and not under high static pressure. After the formation of the diamond grains the parent body of RaF 546 was subjected to a heating event (e.g. low-energy impact) during which the shock effects in the silicates were annealed.

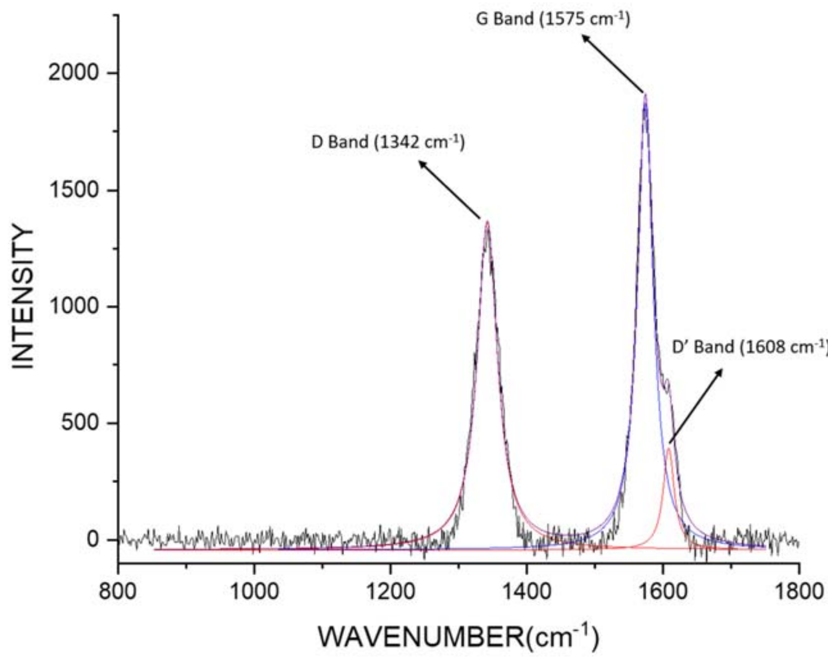

Figure 1- A typical Raman spectra of Ramlat Fasad (RaF) 546

References: [1] Lipschutz M. E. (1964) Science, 143, 1431-1434 [2] Nestola F. et al. (2020) PNAS, 117, 25310-25318. [3] Matsuda J. I. et al. (1995) GCA, 59, 4939-4949. [4] Urey H. C. (1956) ApJ, 124, 623-637. [5] Nabiei F. et al. (2018) Nat. Commun., 9, 1-6.

Cosmic spherules from various terrestrial environments

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Abstract:

Earth's atmosphere is continuously bombarded by the extraterrestrial materials in the various size range from few um-sized dust particles to meter size bodies [1].Tiny um-sized extraterrestrial dust, which survives the hypervelocity impact with the Earth's atmosphere and reaches the Earth's surface, is known as a micrometeorite [2]. Annually, around 40000 tons of cosmic dust bombard the Earth's atmosphere, out of which only approximately 10 percent reaches the Earth's surface and can be collected from various terrestrial environments [3]. Cosmic dustusually originates in interplanetary space by asteroidal collision or sublimation of cometary bodies [4]. When it passes near the Earth, this cosmic dust is attracted by Earth's gravity and enters its atmosphere. Atmospheric frictional heating modifies the chemical and textural nature of the particle during entry [5,6,7]. The degree of atmospheric heating definesthe classification of micrometeorites as melted cosmic spherules, partially melted, and unmelted particles.Further cosmic spherules,based on chemical composition,can be classified as I-type, G-type, and S-type. The textural pattern helps classify S-type as scoriaceous, porphyritic, barred, cryptocrystalline, and glass spherule [8]. Suitable locations for micrometeorite collection are those where the rate of terrestrial dust input and anthropogenic activities are low, like the deep sea and Antarctica or interplanetary dust particles [9,10,11]. We have collected micrometeorites from sediments of the deep Indian Ocean, Antarctica, and from Deccan Intertrappean sediment as our recent collection which can be dated to ~65 Ma. Micrometeorites from deep-sea sediments (age ~50 ka) show a higher degree of etching and dissolution of silicate phases because of harsh conditions. Micrometeorites from Antarctica sediments (<100 yrs) show less modification during their preservation, so they are generally representative of micrometeorites from the Earth's surface. Preliminary investigation of micrometeorite from Deccan Intertrappean shows that cosmic dust around 65 million years ago, the "time of KT extinction," was also bombarding the Earth and represents the cosmic spherules similar to modern times that are preserved and survived indicating the condition during those period.

References

1. Brownlee, D. E. (1985), Cosmic dust: Collection and research, Annu. Rev. Earth Planet. Sci., 13, 147–173.
2. A.E. Rubin, J.N. Grossman, (2010). Meteorite and meteoroid: new comprehensive definitions Meteorit. Planet. Sci., 45, pp. 114-122.
3. Love SG and Brownlee DE (1993). A direct measurement of the terrestrial mass accretion rate of cosmic dust. Science, 256: 550-553.
4. Dohnanyi J. S. (1976). Sources of interplanetary dust: Asteroids. In. Interplanetary dust and zodiacal light, edited by ElsasserH.Berlin: Springer-Verlag. Pp. 569–639.
5. Vondrak T., Plane J. M. C., Broadley S., and Janches D.,(2008). A chemical model of meteoric ablation. Atmos. Chem. Phys., 8, 7015–7031.
6. Love S. G. And Brownlee D. E., (1991). Heating and thermal transformation of micrometeoroids entering the Earth's atmosphere. ICARUS 89, 26-43.
7. N. G. Rudraswami, M. ShyamPrasad, S. Dey, J. M. C. Plane, W. Feng, S. Taylor. (2015). Evaluating changes in the elemental composition of micrometeorites during entry into the Earth's atmosphere. Astrophys. J., vol.814.
8. Genge M. J., Engrand C., Gounelle M., and Taylor S., (2008). The classification of micrometeorites. Meteoritics and Planetary Science 43:497-515.
9. Parashar, K., M. S. Prasad, and S. S. S. Chauhan (2010), Investigations on a large collection of cosmic dust from the central Indian Ocean, Earth Moon Planets, 107, 197–217, doi:10.1007/s11038-010-9362-3.
10. Taylor S., Lever JH., Harvey RP (2000) Number, types and compositions of an unbiased collection of cosmic spherules. Meteoritics and Planetary Science, 35: 651-666.
11. Rudraswami N G, Fernandes D and Pandey M 2020 Probing the nature of extraterrestrial dust reaching the Earth's surface collected from the Maitri station, Antarctica; Meteorit. Planet. Sci. 55 22562266.

Geochemical characterisation of cosmic spherules collected from Central Indian Ocean Basin

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Large quantity of extraterrestrial material received by the earth comes in the form of dust and sample in size range of ten's of um to few hundred um, with a wider range of precursors in contrast to known meteorites. Atmosphere acts as a filter and significant portion of incoming dust is ablated while remaining portion reaching to the Earth's surface are termed as Micrometeorites. The degree of heating while entering into atmosphere is mainly governed by entry velocity, entry angle and size of particle, chemical composition which in turn leads alteration of pre-existing mineralogy and texture [1]. Deep-sea region with low sedimentation rates facilitates concentration of cosmic dust and offer a unique opportunity for the collection of micrometeorites. In the present work geochemical characterisation of few hundred cosmic spherules recovered from deep sea sediments of Central Indian Ocean Basin (water depth > 5200m) is carried out based upon their major elemental concentrations. Further 239 porphyritic olivines (PO) and 42 relict olivines are also analysed to depict their textural and compositional development during atmospheric entry. Attempt has been taken to relate these cosmic spherules to their perspective precursor on the basis of their elemental ratios considering atmospheric ablative losses of elements. The composition of these spherules suggest that they are dominantly sourced from carbonaceous chondrites. Most of the recent collections have been carried out in Polar region because of better preservation conditions in comparison to the ocean, as sea water interacts with spherules and cause dissolution. However, dissolution of extraterrestrial dust can be important phenomenon which regulates climate by providing bioavailable iron to phytoplankton enhancing primary productivity [2]. Thus, interaction of these spherules with sea water is also discussed succinctly.

References:

[1] Rudraswami, N. G., Prasad, M. S., Dey, S., Plane, J. M. C., Feng, W., & Taylor, S. (2015). *The Astrophysical Journal*, **814(1)**, 78.

[2] Rudraswami, N. G., Pandey, M., Genge, M. J., & Fernandes, D. (2021). *Meteoritics & Planetary Science*, **56(12)**, 2175-2190.

Polypeptide synthesis in hypervelocity impact on amino acid-water ice targets

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Impacts are prevalent in the solar system and have played a profound role in the evolution of the solar system bodies. The delivery of prebiotic compounds through impact events is one of the crucial steps in developing habitable conditions on a planetary surface and is therefore significant in our understanding of the origins of life on Earth or elsewhere. Previous studies have reported the role of the impact process in the abiotic synthesis of building blocks of life such as amino acids [1,2] and peptides [3,4]. Here, we present synthesis of polypeptides in the ejecta of simulated impacts carried out in the laboratory on an icy mixture of amino acids. Various batches of amino acid mixtures (glycine, glutamine, glycine & glutamine) within water ice targets, mimicking the icy bodies (140 K), were prepared and impacted over impact speed of approximately 5 km s^{-1} using the light gas gun facility at the University of Kent. A pressure of 10's of gigapascals is achieved with a very short time scale as expected to be achieved in impact-induced shock conditions. After the impact, the ejected material from the target was collected and analyzed. When this ejecta was subjected to SEM analysis, they revealed ordered structures with interesting morphology consisting of dendritic patterns. While LCMS analysis of theses ejecta showed presence of lone polypeptide chains. These results provide significant elucidation of our understanding of the role played by complex molecules and impact events in the origins of life.

References:

[1] Bar-Nun A., et al. (1970) *Science*, 168, 470. [2] Martins Z. et al. (2013) Nature *Geoscience*, 6, 1045. [3] Sugahara H. and Mimura K. (2014) *Geochemical Journal*, 48(1), 51. [4] Sugahara, H. and K. Mimura (2015) Icarus, 257, 103.

Shock Induced formation of SiC

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SiC has always been a topic of discussion for the meteorite community. It is one of the most studied and 2nd most abundant carbonaceous grains after nanodiamonds detected as presolar grains in the meteorite [1]. The presence of SiC in space has been known for decades, even before its 1st signature was detected in the Murry carbonaceous chondrites [2.3]. The combined effort of IR spectroscopic observations at different parts of the interstellar medium (ISM) and the lab-based isotopic analysis of the presolar grains suggest that most of the SiC are produced at the envelope of the carbon-rich Asymptotic Giant branch (AGB) stars [1,4]. These grains are injected into the ISM and exposed to extreme energetic processing. This leads to forming different carbonaceous dust and molecules, especially fullerene and carbon nanotubes [5]. Also presence of SiC in ISM catalyzed the PAH formation through the etching of graphene on its surface [6].

Despite its importance in interstellar chemistry, the formation of SiC in ISM is still poorly understood. Shock-induced energetic processing of dust enriches the chemical complexity of ISM. Low velocity shock waves (3-10 M) detected around Mira Variable can process the dust thermally and produce new molecular species [7]. These low-velocity shock waves can be created in the lab using a shock tube. In this experiment, we used a mixture of amorphous carbon (C) and silicon (Si) (2:1) in H_2 environment and processed it using the shock of Mach 5.6, 7300 K produced in High-Intensity Shock Tube for Astrochemistry (HISTA) housed at PRL. The processed samples were then examined using XRD, FTIR Spectroscopy and HR TEM imaging technique. Here we present the first results from the preliminary experiments carried out by shock processing of the mixture of C and Si nanopowder in hydrogen.

References

[1] Ott, U. 2010, in Astromineralogy, ed. T. Henning (Lecture Notes in Physics,Vol. 815; Berlin: Springer), 277 [2] Speck, A. K., Barlow, M. J., & Skinner, C. J. 1996, NASCP, 3343, 61. [3] Bernatowicz, T., Fraundorf, G., Ming, T., et al. 1987, Natur, 330, 728.[4] Bernatowicz, T. J., Akande, O. W., Croat, T. K., & Cowsik, R. 2005, ApJ,631, 988. [5] Bernal, J. J., et al (2022). *The Journal of Physical Chemistry A*, *126*(34), 5761-5767. [6] Merino, P., et al. *Nature Communications* 5.1 (2014): 1-9. [7] Rudnitskij, G. M. *Astrophysics and Space Science* 251.1 (1997): 259-262.

Chemical dating(U-Th-Pb) of the Asteroidal Impact Craters

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Impact cratering is one of the fundamental processes that modify surfaces of planets, satellites and asteroid bodies in our solar system (French, 1998). Precise and accurate dating of impact craters (e.g. Jourdan et al. 2012) allows the correlation of impact structure formation with other geological events (e.g. the Chicxulub crater associated with the Cretaceous-Paleogene mass extinction; Schulate et al. 2010), and in some cases, the determination of the influence of impact cratering on human civilization (e.g. Masse 2007; Hmacher and Goldsmith 2013). Additionally, the dating of impact craters is crucial to determine the impact flux on Earth (e.g., Bland and Artemieva 2006).

Chemical dating of Th/U rich minerals by electron probe microanalysis (EPMA) has been proved to be a powerful and fast technique (Suzuki and Adachi 1991, Montel *et al.* 1996, Rhede *et al.* 1996, Vlach *et al.* 1999) in the last few years. The high spatial resolution of the EPMA beam gives information about complex mineral zoning and overgrowths down to a few mm and users are also able to see exactly what they are analyzing. These are very important features, as different textural generations of a Th-U mineral in a rock, or even domains within a single grain, can preserve chemical and isotopic signatures related to contrasting geological events. The method is non-destructive, sample preparation and analytical procedures are relatively easy and inexpensive and dating can be undertaken in a normal EPMA work procedure.

The purpose of the present study is to establish a protocol for trace element concentration measurement and quantify the conditions of monazite dating using JEOL EPMA. These include optimized measurement conditions like accelerating voltage, probe current, beam diameter and counting time etc. We have applied this method for monazite dating of impact melt samples from the Araguainha impact crater, Brazil. The 40 km-wide Araguainha impact structure is the largest impact crater in South America. It was excavated in the flat lying sediments of the northern parts of the Parana Basin in central Brazil.

Thin sections of the impact melt sample from Araguainha crater were coated with gold for electron probe microanalyses using JEOL JXA-8530F Plus EPMA at Physical Research Laboratory, Ahmedabad. Monazite grains of a few micron size were identified, BSE imaging was done and concentration of elements such as Si, Ca, P, Th, U, Pb, Y, REEs etc. were measured. The chemical ages were calculated using the Monazite Age dating software incorporated with the JEOL EPMA. The impact occurred around 250 Ma ago and the results obtained are in conformity with the age determined by SHRIMP dating of same monazite samples by Tohver et al. (2012) which also confirms the reliability of the protocol developed at PRL for the U–Th–total Pb chemical age dating of monazite. It will also be corroborated with LA-ICPMS studies in the future. Further, the mineral chemical data integrated with the XRD and Raman data could be useful for fine-grained mineralogy and infer structural architecture in the future planetary exploration missions.

High-pressure phases in heavily shocked Bori L6 chondrite

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Introduction: Chondritic meteorites are undifferentiated planetary bodies that provide clues to the origin of the solar system. Shocked meteorites are those which have experienced high pressure and temperature conditions due to the collision between celestial bodies in space. These collisions cause deformation and fracturing. The friction along these fractures results in high-temperature conditions and subsequent melting. Such fractures are known as shock melt veins. The minerals that are present in and around the shock melt vein are transformed into their high-pressure polymorphs as a result of high pressure and temperature. These high-pressure phases are rare in terrestrial rocks but are abundant in the Earth's mantle. Hence the study of the high-pressure phases found in the meteorites provides clues about phase transformation processes that are occurring in the planetary interiors. Here we report different shock-induced textures and high-pressure phases in heavily shocked Bori L6 chondrite. The Bori meteorite fell in 1894 in Bori village, Madhya Pradesh, India.

Significance of the work: The significance of the study is to substantiate the understanding of the phase transformation mechanisms and to find out the effects of pressure, temperature, and shock duration and also the role of kinetic rate in the phase transformation mechanisms. We will describe in detail the mineralogy and microtextures of the high-pressure phases which are formed by the transformation of host rock pieces inside the melt vein.

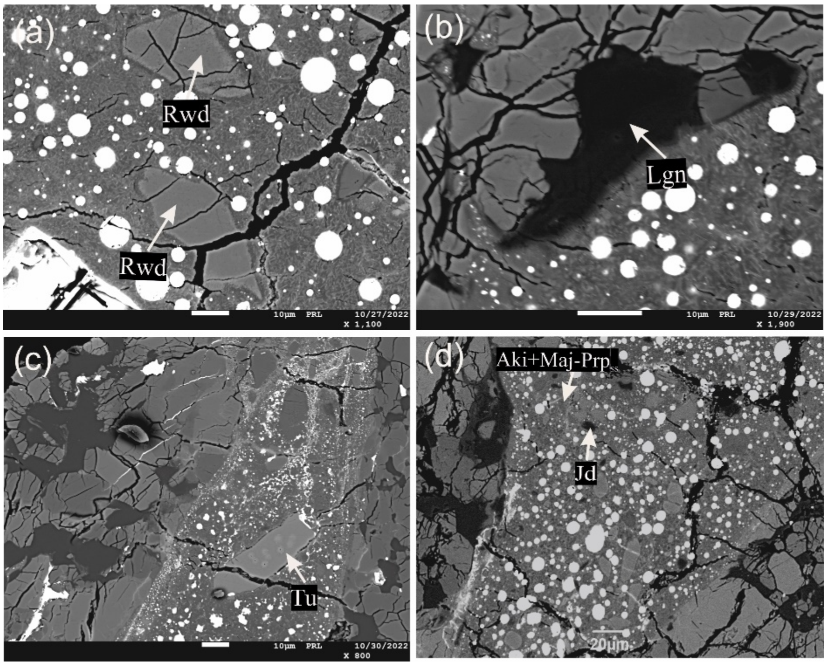

Fig. 1. Back-scattered electron images of Bori L6 chondrite. (a) Ringwoodite (Rwd) grains inside the melt vein, (b) Lingunite (Lgn) grain at the boundary of the melt vein, (c) Tuite (Tu) inside the melt vein, (d) Akimotoite (Aki) , majorite pyrope$_{ss}$ (Maj-Prp$_{ss}$) and jadeite (Jd) present in the matrix portion.

Results: Bori L6 chondrite consists of a melt vein that cross cut the sample. Few melt pockets are also present in the host rock. The mineral phases present in the host rock are olivine, high- Ca pyroxene, low Ca-pyroxene, plagioclase, chromite, apatite, Fe-Ni and troilite. Host rock fragments entrained in the SMV have transformed into high-pressure polymorphs. The high-pressure phases that are present in Bori L6 chondrite are ringwoodite, jadeite, lingunite, tuite, xieite. The matrix portion of the melt vein consists of fine-grain assemblage of silicates with metals and sulfides. The high-pressure phases present in the matrix portion are akimotoite and majorite-pyrope solid solution. The small grains of olivine fragments are completely transformed into ringwoodite grains.

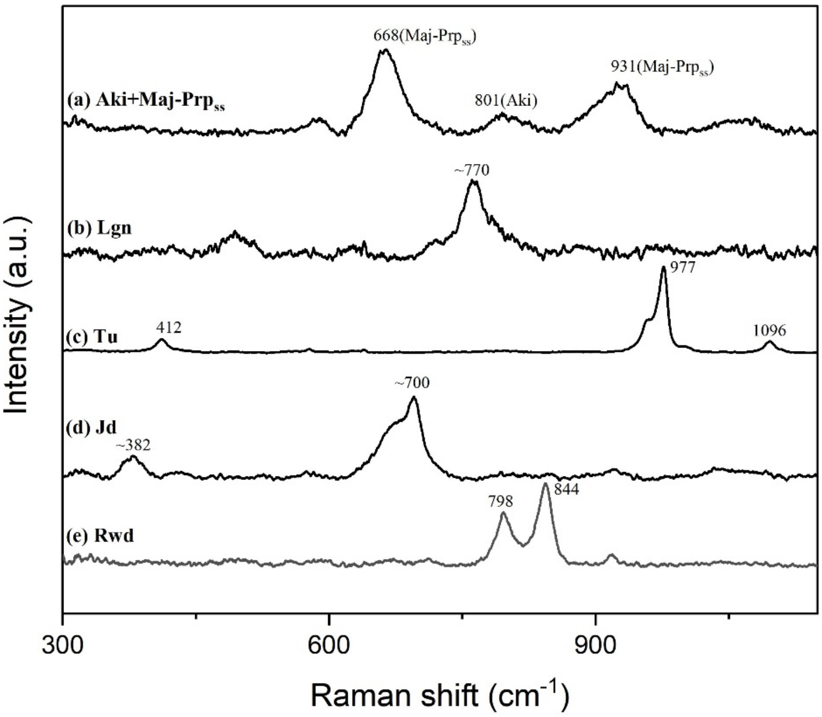

Fig. 2. Raman spectra of different high-pressure phases entrained in shock melt veins.

Future work: Transmitted electron microscope (TEM) studies will be carried out for a detailed study of different phases on submicron scale.

References: [1] Miyahara M. et al. (2010) *EPSL* 295.1-2 : 321-327. [2] Zhang A. et al. (2006) EJM 18.6 : 719-726. [3] Ohtani E. et al .(2017) JMPS : 170329. [4] Xie X. et al. (2003) EJM 15.6 : 1001-1005. [5] Chen M. et al . (2008) CSB 53.21 : 3341-3345.

Formation of dust impact signal

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When interplanetary dust particles hit the spacecraft or detector surface, impact ionization takes place. When a micro particle hits a spacecraft, its kinetic energy gets converted into ionization energy and dense but small plasma cloud is generated. [1] Free charges in form of electrons and positive ions are formed. After impact ionization recombination takes place and residual ionization appears in form of charge Q. The dust impact signal that is observed is formed by combination of four stages –spacecraft at equilibrium potential, electron escape, ion escape and finally relaxation. [2] We have estimated target or spacecraft potential difference developed due to impact process for the case of dust measurements towards Mars by MAVEN's Langmuir Probe and Waves (LPW) instrument by using relationship between pulse rise time and potential difference involving various other parameters.

References: [1] Hew et al. (2018), International Journal of Impact Engineering, **121**, 1–11. [2] Mann et al. (2019), Ann. Geophys., **37**, 1121–1140