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ARGON AND NEON IN GENESIS ALUMINUM-COATED SAPPHIRE COLLECTORS FROM REGIME ARRAYS.

J. C. Mabry¹, A. P. Meshik¹, C. M. Hohenberg¹, Y. Marrocchi¹, O. V. Pravdivtseva¹, J. Allton², R. Bastien², K. McNamara³, E. Stansbery³, and D. Burnett⁴. ¹Washington University, Physics Department, St. Louis, MO, 63130. E-mail: jcmabry@wustl.edu; ²Lockheed Martin c/o NASA/JSC, Mail Code KT, Houston, TX 77058; ³NASA/JSC, Mail Code KA, Houston, TX 77058; ⁴Geology 100-23, Caltech, Pasadena, CA, 91125.

Introduction: Here we report Ar results from the Aluminum on Sapphire (AoS) bulk regime samples, from which Ne results were obtained [1]. Ar measurements from other regimes are in progress.

Regime	²⁰ Ne fluence, 10 ¹² /cm ²	²⁰ Ne/ ²² Ne	²¹ Ne/ ²² Ne
Bulk	1.23 ± .11	13.96 ± .03	.0346 ± .003
IS	.352 ± .032	13.98 ± .04	.0340 ± .004
CME	.271 ± .024	13.93 ± .04	.0336 ± .004
C-H	.362 ± .032	13.94 ± .04	.0345 ± .004

Method: Since elemental and isotopic abundances of light noble gases in solar wind differ substantially from terrestrial air (usually used for calibration), we used specially tailored calibration procedures. For Ar, we lowered the ion source emission to 50 μA, from our typical 150 μA. Using this procedure, mass discrimination was small and reproducible at less than 0.3 %/amu.

The AoS samples were loaded into an extraction cell specially designed to minimize Al sputtering effects which can contribute significantly to the blank and block the view-port. We rastered areas of 4, 10, 15, and 20 mm² for Ar and 1-2 mm² for Ne, using a Q-switched infrared laser, slightly defocused to optimize the surface energy density and the time needed to complete the raster. The corrections for ¹H³⁵Cl⁺ and ¹H³⁷Cl⁺ interferences at A = 36 and 38 were negligible, as was the ⁴⁰Ar blank (< 5 × 10⁻¹⁰ ccSTP) with observed ⁴⁰Ar/³⁶Ar ratios between 3 and 10.

Ar fluences were calibrated using both an air standard and (mg size) Springwater olivine grains, with known amounts of spallogenic ³⁶Ar, ³⁸Ar, ²¹Ne and ²²Ne [2]. These two calibrations differed by about 8%, which should improve by ongoing inter-lab calibrations.

Results: The Ar data from all four rastered areas formed a nearly perfect straight line when the ratios of ³⁶Ar/⁴⁰Ar versus ³⁸Ar/⁴⁰Ar were plotted, indicating a mixing of only two distinct components: solar wind and terrestrial atmosphere, no SEP or HCl effects. We calculated fluences (not corrected for backscatter) of (2.4 ± 0.2) × 10¹⁰ ³⁶Ar /cm⁻² and (4.5 ± 0.4) × 10⁹ ³⁸Ar/cm⁻². All four of our ³⁶Ar/³⁸Ar ratios agree to within 5 per mil.

³⁶ Ar/ ³⁸ Ar ratios (from [3] and this work).	
Terrestrial Air	5.32
Apollo foils	5.3 ± 0.3
Lunar regolith (Zürich)	5.48 ± 0.05
Lunar regolith (Minnesota)	5.80 ± 0.06
SOHO/MTOF	5.5 ± 0.6
Regime bulk (this work, weighted average)	5.467 ± 0.010

Supported by NASA grants NNJO4HI17G & NAG5-12885.

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**STRUCTURAL DOME AT SAO MIGUEL DO TAPUIO,
PIAUI, BRAZIL**

W. D. MacDonald, A. P. Crosta, J. Francolin

About a dozen known or suspected meteorite impact structures (astroblemes) have been suggested for Brazil (Romano & Crósta, 2004). The largest of these is the 40 km diameter Araguainha dome, of about 245 Ma. Among the suspected impact structures is the dome of São Miguel do Tapuio (e.g. Mariano et al., 2004). Field and laboratory investigations of the structure of the dome were undertaken to evaluate its possible origin by meteorite impact. The dome is defined by a pattern of concentric ridges and depressions approximately 21 km diameter, with a center near 5° 37.6' S, 41° 23.3'W. The surrounding country rocks are mainly sandstones of the Cabeças Formation. The dominant lithologies within the structure are quartzose sandstones and quartz-pebble conglomeratic sandstones. Field investigations included several days of examination of outcrops in several transects across and around the structure. Petrographic studies of thin-sections of the sandstones and of quartz pebbles isolated from the conglomeratic sandstones were made. These revealed few planar fractures (PFs) and no planar deformation features (PDFs), following the usage of Grieve et al. (1996). These observations are contra-indicative of an origin by meteorite impact. Consistent with these observations are the 1) the general absence of breccias or breccia-dikes, 2) the absence of shatter-cones, 3) the absence of shock-melt products in outcrop or thin-section, and 4) the absence of other shock-metamorphic indicators. Taken together, the lack of shock features does not support an origin by meteorite impact. Moreover, there are no clear indications of rim-faults or annular half-grabens. What, then, might account for this feature? Although no igneous rocks were found exposed within the structure, evidence of hydrothermal dissolution occurs near the core of the structure. It is possible that heating at depth, perhaps associated with deep-seated intrusion, could mobilize these quartzose strata in a diapiric fashion, resembling that of the Richat structure, Mauritania (Matton et al., 2005), a larger structure at 40 km diameter, for which an association with a deeper alkaline complex has been hypothesized.

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LITHIUM ISOTOPE COMPOSITION OF THE INNER SOLAR SYSTEM MATERIALS

T. Magna^{1,2}, U. Wiechert³ and A.N. Halliday⁴. ¹ETH Zürich, Switzerland. ²University of Genève, Switzerland. E-mail: magna@erdw.ethz.ch. ³Freie Universität Berlin, Germany. ⁴University of Oxford, UK.

Introduction: We present a survey of lithium isotopes in rocks from the Earth, Moon, Mars and Vesta [1]. Spinel lherzolites probably reflect the composition of the upper terrestrial mantle. Olivines contain 80-90% of the Li inventory of spinel lherzolites and thus may be a good first approximation of the Li isotope composition of the Earth's upper mantle. In addition, lunar rocks are analyzed to estimate the lithium isotope composition of the Earth [3].

Results: Terrestrial mantle olivines from a worldwide collection of spinel lherzolites span an extremely narrow range of $\delta^7\text{Li}$ (+3.6 to +3.8‰). $\delta^7\text{Li}$ of pristine whole-rock peridotites is homogeneous at +3.7 to +4.3‰ identical to previously defined $\delta^7\text{Li}$ of the Earth's upper mantle [2]. Lunar mare basalts and picritic glasses show a dramatic variability of $\delta^7\text{Li}$ (+3.4 to +6.4‰) that varies with lithology. A ferroan anorthosite representative of the lunar crust has a $\delta^7\text{Li}$ of +8.9‰ that is not affected by isotopically heavy solar wind due to extremely short exposure (<2Myrs). Two martian meteorites exhibit slightly different $\delta^7\text{Li}$ values (Zagami +3.9‰; Nakhla +5.0‰). Five eucrites, presumed to be impact-excavated material from asteroid 4 Vesta, yield a $\delta^7\text{Li}$ of +3.7‰. Two chondrites, Allende (CV3) and Bruderheim (L6), are isotopically lighter than the estimated bulk composition of planetary bodies in the inner Solar System.

Discussion: Earth's upper mantle seems to have, on average, Li isotope composition of +4.0‰. Three lunar basalts least depleted in Eu (two quartz-normative basalts and a picritic orange glass) constrain a lunar mantle $\delta^7\text{Li}$ mean of $+3.8 \pm 0.4\%$. Other mare basalts and picritic glasses are isotopically heavier and correlate with indices of magmatic differentiation (Li/Yb, Ga/Hf, Eu_N/Eu^*). This likely reflects crystallization of olivine and pyroxenes with imposed Rayleigh fractionation during the lunar magma ocean stage. Zagami, a martian basalt, reflects a source within the martian mantle and has $\delta^7\text{Li}$ indistinguishable from that of the Earth and Moon. The slightly elevated $\delta^7\text{Li}$ of Nakhla (clinopyroxenite) possibly reflects preferential incorporation of ^7Li into clinopyroxene, an observation in accord with equilibrium inter-mineral fractionation of Li isotopes in pristine spinel lherzolites ($\delta^7\text{Li}_{\text{ol}} \approx \delta^7\text{Li}_{\text{opx}} < \delta^7\text{Li}_{\text{cpx}}$). Eucrites give a value identical within error to Earth, Moon and Mars (Zagami).

Conclusions: We provide evidence for homogeneity of mantles of terrestrial planets and a small but significant Li isotope difference between chondrites and planetary bodies in the inner solar system. The difference between primitive and differentiated parent bodies is either established during the planet formation process [4] or reflects water/rock interaction on chondrite parent bodies [5].

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CaS FORMATION FROM A CI COMPOSITION AT HIGH PRESSURE AND TEMPERATURE UNDER LOW OXYGEN FUGACITY.

V. Malavergne^{1,2}, S. Berthet^{1,2} and K. Righter³, ¹Lunar and Planetary Institute, Houston, Texas 77058, USA and ²Université de Marne La Vallée, Laboratoire des Géomatériaux, Champs-sur-Marne, 77454 Cedex, France E-mail: malavergne@lpi.usra.edu.
³NASA Johnson Space Center, Houston, Texas 77058, USA.

Introduction: The cubic monosulfide series with the general formula (Mg,Mn,Ca,Fe)S are common phases in the enstatite chondrite (EH) and aubrite meteorite groups. In the Earth's mantle, sulfide minerals are associated with peridotites and eclogites (e.g. [1]). Study of these sulfide mineral systems is of interest for the mineralogy and petrology of planetary mantles. For example, MgS could occur in the primitive Earth [2] and because it remains a low density phase compared to metal, would stay a separate phase during the core formation process, and thus not segregate to the core. (Mg,Ca,Mn,Fe)S sulphides might thus be important phases even in planetary differentiation processes. The importance of such minerals, and their formation, composition and textural relationships for understanding the genesis of enstatite chondrites and aubrites, has long been recognized [3]. The main objective of this experimental study is to understand the formation and evolution of (Mg,Ca,Mn,Fe)S sulphides, particularly the oldhamite CaS, with pressure, temperature but also with redox conditions because EH and aubrites are meteorites that formed under reduced conditions.

Results: A simplified CI chondritic glass mixed with FeS and Fe-Si alloy were used as starting material. Some trace elements (as U, Nd and transition elements) were also added. Multi-anvil experiments were performed at the Bayerisches Geoinstitut, Bayreuth, Germany using a 1200-ton press, up to 20 GPa and 2200°C. Samples were characterized and analyzed by scanning electron microscopy, Raman spectroscopy and electron microprobe. At 20 GPa and 2200°C, grains of majorite, which are almost FeO-free, are present with a homogeneous Fe-S-Si alloy, small grains of CaS, and SiO₂.

Discussion: Due to the Si added in the starting material, it was possible to reach highly reduced redox conditions during the experiments. We obtain a minimum relative fO₂ value equal to -6.5 log units below the IW buffer. That means that this sample underwent the same range of fO₂ that prevailed during the formation of EH chondrites. Because of these very low fO₂ it was possible to form some CaS likely through the following reaction:

$$2 \text{FeS} + 2 \text{CaSiO}_{3\text{in silicate}} + \text{Si}_{\text{in metal}} \leftrightarrow 2 \text{CaS} + 3 \text{SiO}_2 + 2 \text{Fe} \quad (1)$$

No silicate melting is thus necessary to crystallize some CaS through process (1). The distribution coefficients of U and Nd between metal and CaS have been measured. Our first results indicate that Nd prefers CaS, even stronger than U does. These observations are in agreement with previous observations done on EH [4, 5]. New piston-cylinder experiments are ongoing to constrain (1) at lower pressure and temperature.

References: [1] Sharp 1996 *Nature*, 211, 402-403. [2] Siebert et al., 2004, *Phys. Earth Planet. Int.*, 144, 421-432. [3] Keil, 1989 *Meteoritics*, 24: 195-208. [4] Furst et al. 1982 *Geophys. Research Lett.* 9, 41-44. [5] Murrell and Burnett 1982 *Geochim. Cosmochim. Acta* 46, 2453-2460.

**A COMPARISON OF AN ISLAMIC
CONTEMPORARY COMET REFERENCE AND
THE ANGLO-SAXON CHRONICLE
CONTEMPORARY COMET REFERENCE TO
HALLEY'S COMET OF 1066 AD.**

A. A. Mardon^{1, 2}; ¹Antarctic Institute of Canada,
²Honourary Professor Penza State Pedagogical Uni-
versity (PO Box 1223, Main PO, Edmonton, Alberta,
CANADA T5J 2M4 amardon@shaw.ca).

Introduction: The following are two different contemporary written references to Halley's Comet of 1066A.D. one from England and one from the Islamic world. Other comparisons between the Anglo-Saxon Chronicles records of cometary sightings give the substantiation that the ASC has historical veracity.

Textual References: "in the first tenth of Jumada I if this year a great comet with a long tail appeared in the east. Its width was around three yards and it stretched to the middle of the sky. It stayed until the twenty seventh and then disappeared. Then there appeared at the end of the same month at sunset a heavenly body with light that surrounded it like that of the moon. People were frightened. When the night fell, the heavenly body developed a tail pointing south. It stayed for ten days and then disappeared" Textual Contemporary Reference from the Islamic Medieval source Ibn al-Jawzi.[1]

العشر الأول من جمادى الأولى ظهر كوكب كبير له ذؤابة طويلة يف
بناحية المشرق عرضها نحو ثلاث أذرع وهي ممتدة إلى وسط السماء
ويبقى إلى السابع والعشرين من الشهر وغاب ثم ظهر أيضاً آخر الشهر
هليلج هرون رادتسا دق بأكوك سمشلا بورغ دنع روكذملا
هل راص ليللا ملظاً املو اوج عزن او سانلا اعتراف رمقلالك
لحمضا مئ مأي أقرشع يقبو بونجل وحن بئ اوذ

"Then was over all England such a token seen as no man ever saw before. Some men said that it was the comet-star, which others denominate the long-hair'd star. It appeared first on the eve called "Litania major", that is, on the eighth before the calends of May; and so shone all the week." Textual Contemporary Reference from the Anglo-Saxon Chronicle.

References: [1] http://islamiccoins.ancients.info/comets_and_meteorites.htm.

Acknowledgements: The support of F. Barrage & the Maskukat Collection of Islamic Coins.

POSSIBLE PLEISTOCENE METEORITE PLACER DEPOSITS ON THE CANADIAN PRAIRIES SIMILAR TO ANTARCTIC METEORITE PLACERS.

A. A. Mardon¹, M. Zalcik², J. A. Greenspon³ & E. G. Mardon¹;

¹Antarctic Institute of Canada (amardon@shaw.ca), & ²Noctilucent Cloud Canadian-American Network (bluegrama@shaw.ca)

³Stargate Research Lab,

(jon.a.greenspon@stargateresearch.com)

Introduction: In 1988[1], [2] the first author predicted the possibility that meteorite placer zones might have occurred in North America during the last glaciation. It is possible that similar concentrations of meteorites may be found in North America similar to those that have been found in the Antarctic. In Late 2005 it was proposed in the media that the rapid recovery of several meteorites near Winnipeg, Manitoba, Canada may mean that meteorites could be concentrated there through the same processes that occurred in Antarctica[3], [4].

Analogues to Antarctic Meteorites: Over the later part of the 20th Century and the first part of the 21st Century approximately 30,000 separate meteorites have been recovered in the Antarctic by various nations. Is it possible that in formerly glaciated portions of North America there might be meteorite placer deposits that are similar to what has been found in the Antarctic. It should be noted that the author was a junior member of the 1986-1987 USARP team which recovered over 700 separate meteorites in the area of the Antarctic Polar Plateau and the Lewis Cliff Ice Tongue. This area near the source of the Beardmore Glacier has been called from the time of R. F. Scott of the Antarctic as the *Highway to the Pole*. Heavily traversed and overflowed substantially for most of the 20th Century, meteorites were not found until W. A. Cassidy led a team to the Lewis Cliff Ice Tongue in the 1980's. We propose that other placers might exist in the Northern Hemisphere specifically in North America in areas that had similar characteristics of glaciation. Meteorite concentrations in the last glacial period may be similar to the abundance of precious meteorites that have been found in the Antarctic.

Further Research: Other locales around the world in formerly glaciated regions such as Northern Europe and parts of Asiatic Russia should have similar potential Pleistocene deposits to those found in the Antarctic by various nations Antarctic Meteorite Recovery Programs.[1] Scientists searching for meteorites may not be looking in locations with analogue glacial characteristics to those meteorite placers that have been found in the Antarctic.[5] If the authors are correct, it might be possible that Pleistocene meteorite placers could be found in North America in the future. Finds on the Canadian Prairies might indicate potential meteorites that may be recovered in the future.

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TRACE ELEMENTS IN PRESOLAR SiC GRAINS: CONDENSATION Vs IMPLANTATION

K. K. Marhas^{1,2}, P. Hoppe² and U. Ott². ¹Laboratory for Space Sciences and Physics Department, Washington University, St. Louis, MO 63130, USA. E-mail: kmarhas@wuphys.wustl.edu. ²MPI für Chemie, Becherweg 27, D-55128 Mainz, Germany.

Introduction: Trace elements in various individual presolar grains serve as a tool to understand the chemical and physical conditions during the formation of presolar grains (in expanding envelope/ejecta of stars). Two scenarios that have been discussed to incorporate trace elements within the forming presolar SiC grains are: (a) condensation of trace elements as solid solutions [1, 2]. The abundances will be a function of C/O ratio, pressure, volatility and crystal structure; and (b) ion implantation of trace elements into the SiC grains. In this case abundances depend on the ionization potential of the respective element [3]. Noble gas data for presolar SiC grains indicate that ion implantation plays an important role. Quantifying the fraction of implanted trace elements might give a better idea on the physical conditions under which SiC condensation takes place.

Experimental: We have measured 32 individual mainstream SiC grains, 7 SiC-agglomerates and 17 single X-grains from the Murchison and Murray meteorites using the NanoSIMS at Max-Planck-Institute for Chemistry at Mainz for Ba isotopes (except ¹³⁰Ba, ¹³²Ba) along with the most abundant isotopes of selected trace elements (Sr, Zr, Cs, La and Ce) [4].

Results: The trace element characteristics (normalized to Si and CI) can be summarized as follows: (1) There is a spread of two orders of magnitude for the concentrations of all trace elements, except for Cs which varies by 7 orders of magnitude. The data obtained for bulk samples of Murchison KJA-KJG grains [1] for Ce, La, Sr, Zr are compatible with those of the mainstream grains analyzed in this work. (2) There is no systematic difference between the trace element concentrations of the 17 X grain and single mainstream grains and the agglomerates. (3) Normalized Sr abundances are on average lower than Ba by an order of magnitude. (4) Except for Cs and Zr, correlations exist between Ba and the other trace elements, that is, [Ba]-[La], [Ba]-[Ce] and [Ba]-[Sr]. (5) Zr, La, Ba and Ce are enriched relative to Si and CI, whereas most of the SiC grains are depleted in Sr. (6) There is a rough negative correlation between concentrations of Ce, Ba, La, and Sr and grain size. This trend even extends to the larger KJH grains (3.4-5.9 microns) studied by [1].

The existence of a negative correlation between grain size and trace element concentration implies that at least some fraction of the Ba and other trace elements were implanted into the mainstream SiC grains. It has been proposed that 60 % of the Ba in SiC was trapped by ion implantation [3] and that the rest co-condensed into the SiC grains. The ion implantation scenario is also favored by trace element data from ICPMS measurements on bulk SiC [5]. Clearly, more theoretical work needs to be done in order to get a better understanding on how the trace elements were incorporated in presolar SiC grains.

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CHRONOMETRY AND REDOX STATE OF THE ANGRITE PARENT BODY AS INFERRED FROM Hf-W ISOTOPIC DATA. A. Markowski¹, G. Quitté¹, T. Kleine¹, M. Bizzarro², A. J. Irving³, A.N. Halliday⁴. ¹Inst. for Isotope Geochemistry & Mineral Resources, ETH-Zürich, Switzerland. E-mail: markowski@erdw.ethz.ch. ²Geological Inst., Univ. of Copenhagen, Denmark, ³Dept. of Earth and Space Sciences, Univ. of Washington, Seattle, USA, ⁴Dept. of Earth Sciences, Univ. of Oxford, UK

Introduction: The ¹⁸²Hf-¹⁸²W isotopic system is commonly used to date early planetesimal metal-silicate differentiation because it has an appropriate half-life of 8.9 Myr and Hf and W are strongly fractionated during differentiation. Hafnium is strongly lithophile, whereas W is moderately siderophile in a reducing environment. However, the chemical properties of W are different under oxidizing conditions and W becomes more lithophile. According to ²⁶Al-²⁶Mg and U-Pb data [1, 2] angrites are very ancient basaltic achondrites that have differentiated ~3 Myr after CAIs formation. These achondrites can potentially be used to intercalibrate different chronometers based on short- and long-lived radionuclides [e.g. 3], because they cooled quickly. They can also be used to study the redox conditions of early planetesimal formation. After a first report on this topic [3], we further investigated the Hf-W isotopic systematics in mineral separates from Sahara 99555 and are in the process of generating pure mineral separates from Northwest Africa 2999.

Chronology: In addition to our previous measurements of Sahara 99555, we obtained Hf-W data for a >230 m fraction which is enriched in feldspars, for fines, and for an acid-washed 80-150 m fraction. We also analyzed a whole rock and fines from another piece of Sahara 99555. All data plot on an isochron with an initial ¹⁸²Hf/¹⁸⁰Hf of ~7.3 · 10⁻⁵ and an initial ω of ca. -2.1. The difference in slopes of Sahara 99555 and Allende CAIs isochrons [4] yields a time interval of ~5 Myr, in good agreement with the ²⁶Al-²⁶Mg age obtained for mineral separates for Sahara 99555 [2,5,6], but slightly younger than ²⁶Al-²⁶Mg model ages inferred from whole-rock angrite samples [2]. Average Hf/W ratios obtained for whole-rocks from Sahara 99555 and Northwest Africa 2999 are ~5 and ~3.5, respectively. We thus inferred from Sahara 99555 a model dependent core formation age for the angrite parent body between 1.7 and 2.8 Myr after Allende CAIs.

Redox conditions: Using similarity in the bulk silicate solid/liquid distribution coefficients for Th and W, we recalculated the Hf/W ratios of the silicate reservoirs of D'Orbigny (~8), Sahara 99555 (~5), Angra dos Reis (~2), Northwest Africa 2999 (~2) [7, unpublished data]. These Hf/W ratios are lower than those calculated by Halliday [8] for the eucrite parent body, the Earth and the Moon, suggesting that oxidizing conditions may have prevailed for at least some early planetesimals during core-mantle segregation.

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INVESTIGATING RECOIL LOSS FROM ^{22}Na DECAY WITHIN NANOGRAINS.

E. Marosits and U. Ott. Max-Planck-Institut für Chemie, Abteilung Geochemie, Becherweg 27, D-55128 Mainz, Germany. E-mail: marosits@mpch-mainz.mpg.de.

Introduction: Recoil effects may be of importance in the study of presolar grains in a variety of ways. It is essential, e.g., to understand recoil losses in spallation reactions in order to determine presolar cosmic ray exposure ages [1]. Recoil does also occur in radioactive decay, however. For β -decays it is usually a negligible effect, but the situation may be different for grains that are of nm-size such as the presolar nanodiamonds, where the expected evidence for the former presence of now extinct ^{26}Al and ^{44}Ti has not been found [2]. We have started a set of experiments in order to determine whether loss due to recoil may be an explanation for this lack [3].

Experimental: As the next step in our series of investigations we have implanted radioactive ^{22}Na into both terrestrial detonation nanodiamonds ("K2" supplied by A.P. Koscheev; cf. also [4]) as well as meteoritic nanodiamonds extracted from the Allende and Murchison meteorites using procedures similar to those of [5]. For the implantation radioactive ^{22}Na as NaCl solution was diluted with stable Na for a $^{22}\text{Na}/^{23}\text{Na}$ ratio of $\sim 10^{-3}$. Approx. 0.2 μl solution were put onto a Pt filament together with silica gel, from which they were thermally ionized, accelerated to 1 keV energy and implanted into a nanodiamond layer (~ 1 mg) deposited on a Cu ribbon. After implantation the diamonds were recovered from the Cu ribbon, washed with HCl to remove surficial Na and kept in NH_3 solution in order to avoid reimplantation of daughter nuclei into neighboring grains. Effective implantation yields were determined by counting the activity of the recovered and washed diamonds and were found to be on the order of 1% ($\sim 6 \times 10^{10}$ atoms) for the terrestrial and ~ 1 % ($\sim 5 \times 10^9$ atoms) for the meteoritic diamonds.

Decay and Recoil: Determining recoil loss requires checking the content of the decay product ^{22}Ne contained in the diamonds after sufficient decays have occurred. First results for the K2 detonation diamonds will be available by the time of the Conference. Results for the Allende and Murchison diamonds will become available later: more complete decay is required because of the smaller amount of implanted ^{22}Na as well as the rather high background of Ne-HL (cf. [6]).

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INDUCTION HEATING IN ASTEROIDS PART 2: EXPERIMENTAL ANALOGS C. A. Marsh, D. N. Della-Giustina, J. Giacalone, and D. S. Lauretta, University of Arizona, Lunar and Planetary Laboratory, Tucson, AZ 85721, USA (ce-linda@lpl.arizona.edu).

Introduction: The theoretical background of induction heating of asteroids, as well as recent observations and models of magnetic field strengths are discussed in [1]. We have established a laboratory in which samples can be subjected to magnetic fields and thermal response can be measured. We have conducted a series of experiments to test the effect of induction heating on asteroidal materials. Here we take the parameters from Favata et al. (2005) and compare them to our experimental operating procedure and results.

Experimental Methods: The materials used in our experiments are pellets of cutting dust from the Fukang pallasite [3], controlled mixtures of olivine and metal, and pure metal reference materials. Grain sizes and composition are measured in control samples in all cases through optical microscopy and electron microprobe analysis.

Our procedure consists of placing samples in vacuum-sealed silica tubes and heating them using an Ameritherm HotShot radio frequency (RF) induction heating station. This device is designed to heat small objects using frequencies from 150 to 400 kHz with up to 2 kW of power. The calculated maximum magnetic field strength for our experimental configuration is 24 Gauss. Temperature is monitored throughout the experiment using either an Omega IR2 two-color pyrometer or an Omega OS37-10-K pyrometer and DPi32 temperature logging system.

Sample	Gauss	Temperature
Fukang Powder	24 (max)	500 C
Fe Powder	24 (max)	650 C
Fe Foil	24 (max)	750 C

Table 1. Results of induction furnace experiments. Gauss is the magnetic field strength produced by the HotShot.

Conclusions: The results obtained thus far show the dependence of peak temperature reached to both composition and grain size. Considerable heat has been generated at a magnetic field strength below those modeled by [2] as having reached the circumstellar disk. Thus far, we have been able to reproduce the temperatures experienced by type-4 and type-5 ordinary chondrites. We are performing additional experiments on a wide range of asteroidal samples. Additional factors, such as frequency, object size and duration of heating are needed to extrapolate the experimental system to induction heating on asteroids. As this series of experiments continues, it will provide a critical quantitative constraint on the extent and efficacy of induction heating in asteroids in the early solar system.

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ISOTOPIC ANALYSIS OF NUCLEOBASES IN THE MURCHISON METEORITE

Z. Martins¹, O. Botta², M. L. Fogel³, M. A. Sephton⁴, D. P. Glavin², J. S. Watson⁵, J. P. Dworkin², A. W. Schwartz⁶ and P. Ehrenfreund^{1,6}. ¹Astrobiology Laboratory, Leiden Institute of Chemistry, Einsteinweg 55, 2300 RA Leiden, The Netherlands. E-mail: z.martins@chem.leidenuniv.nl ²NASA Goddard Space Flight Center, Goddard Center for Astrobiology, Greenbelt, MD, USA. ³GL, Carnegie Institution of Washington, Washington DC, USA. ⁴Impacts and Astromaterials Research Centre, Department of Earth Science and Engineering, South Kensington Campus, Imperial College, London, UK. ⁵Planetary and Space Sciences Research Institute, The Open University, Walton Hall, Milton Keynes, UK. ⁶Radboud University Nijmegen, Nijmegen, The Netherlands.

Nucleobases are important compounds in modern terrestrial biochemistry, because they are key components of nucleic acids (DNA and RNA), which are the central biopolymers used in the storage, transcription and translation of genetic information.

Nucleobases have been detected in carbonaceous chondrites by several research groups [1-5]. Because of the fact that significant quantitative and qualitative differences were observed (even within the same meteorite), confirmation of the extraterrestrial origin of these nucleobases is still open to question. In order to address this crucial question, we have performed an extensive analysis that included formic acid extraction of samples of the Murchison meteorite [6], followed by an extensive purification procedure, analysis and quantification by high-performance liquid chromatography with UV absorption detection and gas chromatography-mass spectrometry. We obtained results that were qualitatively consistent with previous results [3,4], but showed some significant quantitative differences. Compound specific carbon isotope values for xantine and uracil were obtained, using gas chromatography-combustion-isotope ratio mass spectrometry. We also analyzed a soil sample that was collected in the proximity of the Murchison meteorite fall site, subjecting it to the same extraction, purification and analysis procedure.

Stable carbon isotope measurements unambiguously confirm that the nucleobases in the Murchison meteorite are indigenous to the meteorite, and clearly differ from the values determined for the terrestrial nucleobases measured in the surrounding fall site soil. These results support the hypothesis that nucleobases were exogenously delivered to the early Earth, contributing to a feed-stock of molecules crucial for the origin of life on our planet.

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SIMULATION OF COSMOGENIC NUCLIDE PRODUCTION IN STONY AND IRON METEORITES. J. Masarik, , Department of Nuclear Physics, Komensky University, Mlynska dolina F/1, Sk-842 48 Bratislava, Slovakia,; Masarik@fmph.uniba.sk;

Introduction: Development in the understanding of primary cosmic-ray spectra in the last decade and development in the numerical codes used for simulations of their interaction with matter leads to the changes in theoretical estimates of production rates in meteorites. Influence of these changes on production rates of cosmogenic nuclides is reviewed in this paper. The numerical simulation cosmic-ray particles interactions with matter was done with the LAHET Code System (LCS) [1], GEANT [2], and MCNPX [3]. The investigated objects were spheres with various radii that were divided into spherical layers. We used the spectrum of the galactic-cosmic-ray particles corresponding to their long-term averaged value [4]. Two different shapes of differential primary spectra [5,6] were used in our simulations..

The production rates of nuclides were calculated by integrating over energy the product of these fluxes and cross sections for the nuclear reactions making the investigated nuclide. For cross sections, we relied on the values evaluated by us and tested by earlier calculations [e.g., 4].

Results and Discussion: These spectra depend on the shielding of the sample, i.e., its location inside the object, the object's size, and its chemical composition. The differences in particle fluxes obtained by various codes are minor. There are significant differences between production rate depth profiles in stony and iron meteorites caused by the presence of heavy elements in iron meteorites in much higher concentrations. We found that there are also substantial differences between capture rates for stony and iron meteorites. They are independent of primary spectra. Generally, higher iron content results in lower fluxes of thermal neutrons and therefore also lower capture rates and vice versa.

We can compare our calculations with some cosmogenic nuclide measurements for well studied meteorite, as for example Knyahinya. [7]. This study is in progress, and will be presented.

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CONTINUED SEARCH FOR Q IN DIFFERENT TYPES OF METEORITES BY THE PHYSICAL SEPARATION METHOD.

J. Matsuda¹, Y. Matsuo¹, C. Nishimura¹ and S. Amari².
¹Department of Earth and Space Science, Graduate School of Science, Osaka University, Toyonaka, Osaka 560-0043, Japan (matsuda@ess.sci.osaka-u.ac.jp). ²Laboratory for Space Sciences and the Physics Department, Washington University, St. Louis, MO 63130, U.S.A.

Introduction: Meteoritic separates that are enriched in the Q-gases have usually been prepared by the chemical procedure [1]. With Allende (CV3), Matsuda et al. [2] have shown that material that floats on the surface of the water (“floating fraction”) during the freeze-thaw disaggregation exhibits the similar isotopic and elemental abundances to those of residues treated with HF-HCl. This method has been applied for a few fragments of Allende and floating fractions enriched in the Q-gases have always been recovered [3, 4].

This physical separation method was also applied for two ordinary chondrites (H/L3.2 and L4~6) [5]. The floating fractions from the two meteorites comprise 0.046 wt% and 0.0057 wt% of the bulk meteorite, respectively. Concentrations of the heavy noble gases (Ar, Kr and Xe) in the floating fraction from the H/L3.2 meteorite are similar to those of the bulk meteorite, indicating noble gases are not enriched in the floating fraction. Excesses in the heavy noble gases (1- 3 orders of magnitude of the bulk meteorite) are observed in the floating fraction of the L4-6 chondrite. However, Xe isotopic ratios of the fraction are identical to those of the air. Obviously, the physical separation method is not applicable to ordinary chondrites to concentrate the fraction enriched in noble gases.

In this study, we applied the physical separation method to Murchison (CM2), a carbonaceous chondrite in a different petrologic type from Allende (CV3).

Results and discussion: We started from 648.48 mg of a fragment of Murchison. After 120 cycles of the freeze-thaw disaggregation, 0.26 mg of the floating fraction was recovered. This yield (0.004%) is much smaller than the yield (0.068%) obtained after 216 cycles [4], however it is equivalent to the yield (0.004%) after ~120 cycles for Allende [3].

Elemental and isotopic abundances of noble gases in the floating fraction have been analyzed as well as elemental abundances of noble gases in the bulk Murchison. Pronounced enrichment of the heavy noble gases was not observed in the floating fraction from Murchison. Thus, Q in Murchison does not preferentially float on the surface, behaving the same way as the rest of constituents of the meteorite. EDX analysis of the floating fraction with scanning electron microscopy indicates most grains are silicates. This is consistent with the noble gas result and yet illuminates another difference from the Allende floating fractions, where many of the grains are carbonaceous.

It remains to be seen why the physical separation method can be successfully applied only to Allende: a make-up of carbonaceous matter in Allende may favor a preferential separation of Q (and presolar diamond) during the freeze-thaw disaggregation.

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CATHODOLUMINESCE STUDY OF THE NAKHLITE METEORITES FROM ANTARCTICA

N. Matsuda¹, H. Nishido¹, A. Gucsik², T. Okumura¹, M. Kayama¹ and K. Ninagawa³, ¹Research Institute of Natural Sciences, Okayama University of Science, 1-1 Ridai-cho, Okayama 700-0005, Japan. E-mail: matsuda@rins.ous.ac.jp. ²University of West Hungary, Bajcsy-Zs. E. u. 4., Sopron, H-9400, Hungary. ³Dept. Applied Physics, Okayama University of Science, 1-1 Ridai-cho, Okayama 700-0005, Japan.

Introduction The recent discovery of nakhlite among numerous specimens of the meteorites collected from Antarctica has made many important contributions to its mineralogy, crystallization differentiation, accumulation process and thermal history. It is noteworthy that hydrated alteration of this meteorite could be estimated from the existence of clay-like materials. In this study we focus on the cathodoluminescence (CL) emitted from the minerals in the nakhlite to investigate their crystal chemistry concerning to lattice defect and trace impurity.

Samples and Methods Two polished thin sections of Yamato 000593 and Yamato 000749, which are possibly paired, supplied from the National Institute of Polar Research (NIPR) were employed for CL measurements. These meteorites belong to the nakhlite subgroup of the SNC. CL image, which can be compared to optical image under a petrographic microscope, was obtained using a cold-cathode type "Luminoscope" at 15 kV with a cooled CCD camera. CL image at high magnification and CL spectra were collected using a scanning electron microscope-cathodoluminescence (SEM-CL) composed of SEM: JEOL 5410LV with a grating monochromator: Oxford Mono CL2, where EDS system can be used in combination with SEM-CL. A scanning electron beam of energy 15 kV and current 1.0 nA was adopted in CL analysis.

Results and discussion Two samples exhibit a similar petrographic texture with unbrecciated cumuli of mineral grains consisting abundant augite with less olivine, mesostasis and minor hydrated alteration materials. The texture and mineral paragenesis coincide with the previous description. A systematic survey of all area by CL imaging reveals that CL emissions with blue, pale pink, yellow and dark violet colors are apparent in the mesostasis and hydrated alteration zone, whereas narrow streaks of faint emission are recognized in augite and olivine grains. Based on the EDS analysis the outstanding CL of bright blue is emitted only from pure silica grains, which are distributed in the mesostasis with lath-shaped plagioclase or exist as an isolated round shape. CL spectra of these grains indicate a broad peak at around 415 nm, which can be assigned to recombination of self-trapped exciton (STE) and/or E' center characteristic to silica minerals. Usually ordinary quartz shows red to violet CL emission, but not so bright at ambient temperature, with the spectral peak in red color region from 600 to 650 nm. Therefore, the silica minerals with bright blue CL emission might not be identified to quartz. We have been investigating to clarify them using a micro-Raman spectroscopy. Most plagioclase (An₃₀₋₄₀), which are abundant in the mesostasis, exhibits pale pink CL, of which spectra shows three broad peaks around at 400, 570 and 760 nm corresponding to lattice defect and trace impurities of Mn²⁺ and Fe³⁺, respectively. Yellow and dark violet CL can be detected in glassy "maskelynite" and possibly hydrated alternated zone, but a rare case. In this way a CL method presents unique perspective casting new light on the study of the meteorite.

COMETARY PETROLEUM IN HADEAN TIME?

M.Maurette¹ and A. Brack². ¹CSNSM, Bat. 104, 91405 Orsay-Campus, France, maurette@csnsm.in2p3.fr. ²CBM, Rue Charles Sadron, 45071 Orleans Cedex 2, France.

Introduction. Kerogens are abundant by-products of incomplete combustion, pyrolysis and radiation reprocessing of almost any kinds of organic precursors. In the absence of microorganisms, kerogen is one of the most durable and insoluble organic materials. On Earth, important substances are derived from some parent kerogen. They include petroleum and varieties of activated carbon. We question below whether the constituent kerogen of large unmelted Antarctic micrometeorites (AMMs), which was identified from C/N ratios measured with a nuclear microprobe [1] might have been involved in the making of abiogenic crude oil in Hadean times, prior to ~4 Ga. As AMMs are probably cometary dust particles [2, 3], this petroleum would have a "cometary" origin.

Delivery of micrometeorite kerogen to the Hadean oceanic crust. We predict that a huge mass (~5 × 10²⁴ g) of juvenile micrometeorites (JMMs) was accreted by the Earth, during the first ~200 Ma of the post-lunar period – see Ref. 2. Recent AMMs flux measurements [4] show that at least ~20 wt.% of the micrometeorites survive unmelted upon atmospheric entry [4]. As their kerogen represents about 2.5 wt.% of carbon, this amounts to a total mass of kerogen on the early Earth's surface (~2.5 × 10²²g) equivalent to a ~40 m thick global layer. A large fraction of the unmelted JMMs were deposited on the early oceanic crust, which was formed very soon after the formation of the Moon around ~4.4 Ga ago.

A slow burial in deep sea sediments that mimics that of dead plankton. On the Earth, bitumen- and kerogen-rich shales are the source rocks of petroleum. In the biogenic scenario most petroleum exploited today was derived from tiny plants and organisms (i.e., plankton) that thrived in the top layers of the oceans during the Jurassic. When they die they accumulate on the sea floor (like kerogen-rich unmelted micrometeorites), where they get steadily buried in sediments. At depths larger than a few hundreds meters, their residual organics yield kerogen whereas sea sediments are transformed into shales. Then, at larger depths in the "oil window" (between ~0.5–5 km), the heat and pressure break down kerogen to form petroleum.

Surprisingly, kerogen-rich micrometeorites would have followed an abiogenic fate that surprisingly well mimics the biogenic fate of dead plankton. This led to the abiogenic formation of crude oils at a time of intense impact fracturing, prior to ~4 Ga ago. This likely led to some giant spills of the abiogenic petroleum that could have formed kinds of gigantic mega-films of oil on the oceans, which did capture unmelted micrometeorites and various micrometeoritic "smoke" particles released upon atmospheric entry. Did this "dusty black tide" cosmic machinery open new reaction channels in the prebiotic chemistry of life?

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MISSING "CARROTS" IN THE STARDUST AEROGEL.

M. Maurette¹ and G. Kurat². ¹CSNSM, Bat. 104, 91406 Orsay-Campus, France, maurette@csnsm.in2p3.fr. ²Institut für Geologische Wissenschaften, Universität Wien, Althanstrasse 14, 1090 Vienna, Austria.

Introduction: Stardust apparently produced exciting results – as can be deduced from the scarce data available (e.g., NASA Stardust Web site). The conclusions drawn, however, seem to reflect a certain degree of confusion among investigators who either reach the grand conclusion that “...*the Stardust minerals may have crystallized from melts near other stars...*” and “...*at least some comets may have included materials ejected by the early sun to the far reaches of the solar system*”. There is no grand surprise with the mineralogical findings on Wild 2 particles (W2s) as they can be expected from what we know from meteorites, Antarctic micrometeorites (AMMs) and stratospheric IDPs [e.g., 1]. We discuss here our earlier prediction of a possible link between cometary matter and AMMs [2].

Bulbs against carrots: The W2s recovered at the terminus of about 20 well visible tracks in the aerogel (with length of up to 12 mm) are made of refractory minerals (forsterite, enstatite, diopside, spinel, anorthite). These tracks have a "bulb" shape very different from the "carrot" shape observed for all projectiles fired into aerogels at speeds similar to that of the W2s (~6 km/s), as to assess their survival during aerogel capture [4]. These spectacular "bulbs" are sprayed with tiny shell-splinters tracks. This bulb shape probably is the result of a powerful microscopic explosion ignited along the track of the W2s.

Saponite rich chondrites without chondrules: Saponite is the dominant hydrous silicate of IDPs and AMMs. Suppose that it is also the dominant hydrous phase of the W2s before their impact into the aerogel. This mineral contains structural water that starts to be released at a low temperature of ~100 °C. In contrast, the artificially accelerated projectiles included: – anhydrous minerals, such as those found in chondrules; – fragments of the "dry" Allende chondrite; – a mineral of the serpentine group (lizardite); – fragments of the Orgueil and Murchison chondrites, where serpentine is the dominant hydrous silicate.

Serpentine-rich projectiles yielded carrot-shaped tracks, probably because serpentine only contains OH groups that are released at a temperature of ~600 °C. Therefore, the dominant bulb shape of the W2s tracks would reflect the explosive release of the constituent water of the W2s saponite as well as a strong depletion of chondrules in the W2s flux. Only the largest refractory phases of the W2 "shrapnel" could continue and form a long track beyond the "bulb". Surprisingly, the missing raw carrots alone would reveal two major similarities between IDPs, AMMs and the W2s (i.e., the existence of saponite and a depletion of chondrules). In this case, the chemical and isotopic compositions of the AMMs and W2s olivines should be similar [4].

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THE UNBRECCIATED EUCRITES: VESTA'S COMPLEX CRUST.

R. G. Mayne¹, A. Gale², T. J. McCoy², H. Y. McSween Jr.¹, and J. M. Sunshine³. ¹Dept. of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996-1410. E-mail: rmayne@utk.edu. ²Dept. of Mineral Sciences, Smithsonian Institution, Washington DC, 20560-0119 ³Dept. of Astronomy, University of Maryland, College Park, MD 20742

Introduction: 4 Vesta is the largest differentiated asteroid and is critical to understanding the processes that contributed to the evolution of planets in the early solar system history. Gaffey [1] utilized sub-hemispheric color and spectral variations on the surface of Vesta to produce a lithologic map; however, regolith material blanketing the surface obscured smaller-scale details of the basaltic crust. By examining petrologic and spectral variations in eucrites, we can draw conclusions about the smaller-scale lithologic variations that exist in the upper basaltic crust.

Methodology: Unbrecciated eucrites were selected for study to avoid spectral mixing of different lithologies. The mineral abundances and distributions of 31 thin sections were mapped using the SEM and mineral chemistries analyzed with the electron microprobe. Eleven samples represent the petrologic diversity in the entire group, and their VISNIR spectra were collected at RELAB and modeled using MGM [2,3].

Discussion: Our ultimate goal is to distinguish different lithologic units, as sampled by eucrites, using their spectra. We must first identify such units petrologically – in terms of textures, mineral chemistries, modes, grain sizes, and cooling rates – and then explore the extent to which they can be spectrally distinguished.

The unbrecciated eucrites are a diverse group of meteorites. To date, we have defined four distinct lithologies for the unbrecciated eucrites using their petrologic characteristics. These units, with an example of each, are: cumulate/slowly cooled (Moore County), partial-cumulate/Mg-rich partial melt (EET 87520), granoblastic (Ibitira), and quenched/quickly-cooled (ALH A81001). The primary difference between these is their depth of formation in the crust. The spectra for these types show variations in spectral contrast, band centers, and band widths [4]. Preliminary MGM analyses can distinguish cumulate/slowly-cooled from quenched/quickly-cooled eucrites. This is possible primarily because quickly-cooled eucrites contain only one pyroxene, whereas those that cooled slowly have two. Refined models will test if all four units can be defined by their spectra.

Implications: The basaltic crust on Vesta is complex and eucrites represent our best tool for understanding its formation and diversity, but we require both coordinated spectral/petrologic studies of the lithologic diversity and higher-resolution spectral data for the crust. In addition to continuing our study of eucrites, we intend to apply our laboratory data to the spectra of V-type asteroids [5]. These asteroids are thought to represent km+-size fragments of the crust of Vesta and, hence, can provide a constraint on the approximate size of lithologic provinces that may occur on Vesta. Ultimately, the *DAWN* mission will provide the best opportunity to map the basaltic crust of Vesta at the highest spatial resolution.

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FROM GASEOUS GIANTS TO ROCKY PLANETS

M. Mayor, Observatoire de Geneve, CH-1290 Sauverny, Switzerland

In the last eleven years, about 200 exoplanets have been detected. Most of these detections have been made by Doppler spectroscopy, looking for the variation of the stellar velocity induced by the gravitational influence of planetary companions. A dozen of exoplanets have also been detected by the presence of transits or gravitational microlensing events.

These discoveries have revealed an impressive diversity of exoplanet orbital properties with periods as short as 1.2 days for example or orbital eccentricities as large as 0.93. Systems with several planets orbiting the same stars are more and more frequently found, some of them with planets on resonant orbits. Several statistical properties are already emerging and help constraining the formation mechanisms of these systems.[1,2] These observed statistical properties not only concerns the orbital parameters of planets but also the chemical composition of host stars [3].

The past ten years have also witnessed a remarkable improvement of the precision of radial velocity measurements with a gain of about a factor 100. A precision of the order of 0.5 m/s or better has been achieved (relative Doppler shift of one part in a billion). Planets with masses as small as a few Earth-masses have been detected. The most exceptional system recently discovered includes three Neptune type planets orbiting a solar type star with an asteroid belt! [4]. The two inner planets have been shown to be mostly rocky by models of planetary formation. [5]

Is it possible to expect further significant progresses of Doppler measurements? Such a possibility could be of interest to permit radial velocity follow-up measurements of planetary transit candidates expected from the COROT and KEPLER space missions, the goal being to get a precise determination of mass-radius relations from terrestrial planets to brown dwarfs.

A radial velocity precision at the level of 0.1 m/s does not seem out of reach. With an observing strategy adapted to minimize the influence of the stellar intrinsic variability (magnetic activity, acoustic modes) we should be in position to explore statistical properties of terrestrial planetary systems.

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LAP 04840: AN AMPHIBOLE-BEARING R-CHONDRITE.

M. C. McCanta¹, A. H. Treiman¹, and E. Essene². ¹Lunar and Planetary Institute, Houston, TX 77058. ²Dept. Geosciences, Univ. Michigan, Ann Arbor, MI.

Introduction: The LaPaz Ice Field 04840 (LAP04840) meteorite is an R chondrite of petrographic grade 6 [1]. It is unique among meteorites, in containing abundant amphibole, and has the second meteoritic occurrence of biotite. If the amphibole is hydrous (as it appears), LAP 04840 must come from deep within a water-rich chondritic asteroid.

Texture: LAP 04840 contains chondrules, chondrule fragments, and mineral grains in a finely crystalline matrix. Chondrules are up to ~3 mm diam., and include barred olivine, porphyritic olivine, and porphyritic pyroxene varieties. Many are surrounded by rims of finely crystalline material (~20 μm grain size), which lack larger mineral grains. Matrix among the chondrules and fragments is composed of anhedral grains, also ~20 μm diameter, in a granulitic, metamorphic texture. Section ,30 shows no signs of deformation or shock after this metamorphism.

Mineralogy: The larger mineral grains (> 50 μm) in LAP 04840 are olivine, orthopyroxene, plagioclase, amphibole, Cr-magnetite, and sulfides. Olivine occurs in chondrules and as isolated grains. It is compositionally homogeneous ($\text{Fo}_{61}\text{Fa}_{39}$) throughout the meteorite – the same in all analyzed chondrules and mineral grains. The only pyroxene identified is orthopyroxene, which contains abundant inclusions of opaques and other minerals. It has the same composition ($\text{Wo}_{01}\text{En}_{68}\text{Fs}_{31}$), throughout the meteorite. Amphibole is abundant, ~ 15%; it is pleochroic in foxy brown colors, and shows strong cleavage at 120° angles. It is magnesiohornblende [1,2], of nearly constant composition throughout. The amphibole contains little F or Cl, suggesting it is either hydrous or oxy-amphibole. Much of its iron is Fe^{3+} (by normalization). LAP contains no metal. Cr-magnetite is scattered throughout the meteorite, but the largest grains occur with the sulfide phases (pyrrhotite and pentlandite) [1]. It is commonly associated with Cl-bearing apatite. Mg-rich biotite (phlogopite), with little F or Cl, occurs rarely with amphibole, Cr-magnetite, and sulfides.

Metamorphism: The amphibole in LAP04840 is metamorphic, occurring as anhedral and euhedral scattered through the rock and as replacements of material (glass?) among olivines and pyroxenes in chondrules. By analogy with terrestrial metamorphics, the LAP mineral assemblage (ol-opx-amph) and mineral compositions (e.g., Al in amphibole) suggest upper amphibolite facies conditions: ~600°C < T < 800°C, and $P(\text{H}_2\text{O}) > 1$ kbar [3,4]. With this temperature range, olivine-orthopyroxene-spinel equilibria yield f_{O_2} of QFM+0.6(± 0.5) log units, consistent with the high oxidation states of R chondrites and the absence of Fe metal. Pressure of metamorphism is poorly constrained at present. However, water-pressure must be high to stabilize this Ti-poor hornblende. For LAP 04840, one must infer that it was metamorphosed deep in a chondritic asteroid, under water-rich conditions.

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PYROCLASTIC VOLCANISM ON THE AUBRITE PARENT BODY: EVIDENCE FROM AN Fe,Ni-FeS CLAST IN LAR 04316.

T.J. McCoy and A. Gale. ¹Dept. of Mineral Sciences, Smithsonian Institution, Washington DC 20560-0119 USA.

Introduction: A long-standing problem in aubrite petrogenesis has been the absence of basaltic and Fe,Ni-FeS melts, presumed to form during melting of an enstatite chondrite-like protolith, complementary to the enstatite-rich aubrites. A possible solution [1] is that early partial melts were volatile-rich, producing eruption velocities that exceed the escape velocity for asteroids less than ~100 km in radius, and causing these melts to be lost. Pyroclasts produced during such eruptions would range from ~30 μm to ~4 mm in diameter [2]. Samples of these pyroclasts have proven elusive, compromising our ability to fully understand their formation.

Results: LAR 04316 is an 1163 g aubrite dominated by a typical enstatite-rich matrix, but containing two cm-sized clasts apparently joined by an igneous contact. One is composed of enstatite+forsterite+glass, similar in size and mineralogy to those described by [3] and interpreted as basaltic vitrophyres extracted at ~1500°C and “quenched” at 1070-1350°C. The other is a quench-textured Fe,Ni-FeS clast previously unknown from aubrites. The clast consists of ~60:40 Fe,Ni:FeS by volume (~50:50 by mass) with minor alabandite as grains up to 0.5 mm, corresponding to a metal-sulfide partial melt extracted at ~1300-1350°C. Fe,Ni forms a dendritic or cellular structure with arm/cell spacings of ~30 microns, implying cooling at 25-30°C/sec [4-6].

Discussion: The co-occurrence of a vitrophyric basaltic clast and an Fe,Ni-FeS clast can provide critical information about the physical setting of formation.

The 25-30°C/sec cooling rate of the Fe,Ni-FeS clast is consistent with “quenching” invoked for the silicate clasts [3]. It was unclear whether cooling occurred during a pyroclastic phase, in a lava flow, or in a conduit. Our cooling rate is consistent with formation of μm to dm-sized clasts by radiation into space [5,6] as molten droplets during a pyroclastic phase. Further, they are at the upper range of calculated pyroclast sizes [2], perhaps suggesting agglomeration of smaller pyroclasts during flight. Only their large size allowed retention on the parent body.

It is less clear how the silicate and metal-sulfide clasts came together in the first place. Both would require extraction from a chondritic source at a range of temperatures ~350-550°C above the onset of partial melting (~950°C). It is possible that they were produced essentially contemporaneously at different places in the parent body and were transported together in a complex dike system. Alternatively, they may have only come together during the pyroclastic eruption. If the latter occurred, it is puzzling that these two clasts apparently survived together through 4.5 Ga of impact gardening, suggesting that LAR 04316 might be a particularly ancient regolith breccia.

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ISOTOPIC COMPOSITIONS OF COMETARY MATTER RETURNED BY THE STARDUST MISSION.

K. McKeegan¹, J. Aleon², C. Alexander³, J. Bradley², D. Brownlee⁴, P. Burnard⁵, A. Butterworth⁶, M. Chaussidon⁵, A. Davis⁷, C. Floss⁸, J. Gilmour⁹, Y. Guan¹⁰, C. Hohenberg⁸, P. Hoppe¹¹, I. Hutcheon², M. Ito¹², S. Jacobsen¹³, L. Leshin¹⁴, I. Lyon⁹, K. Marhas⁸, B. Marty⁵, A. Meibom¹⁵, A. Meshik⁸, S. Messenger¹², K. Nakamura¹², L. Nittler³, R. Palma¹⁶, M. Pellin¹⁷, R. Pepin¹⁶, P. Tsou¹⁸, F. Robert¹⁵, D. Schlutter¹⁶, F. Stadermann⁸, R. Stroud¹⁹, A. Westphal⁶, E. Young¹, K. Ziegler¹, E. Zinner⁸. ¹Dept. of Earth & Space Sciences, UCLA (kdm@ess.ucla.edu). ²IGPP, LLNL. ³DTM, Carnegie Inst Wash. ⁴Univ. Washington. ⁵CRPG. ⁶UC Berkeley. ⁷Univ. Chicago. ⁸Washington Univ. ⁹Univ. Manchester. ¹⁰Caltech. ¹¹MPI, Mainz. ¹²NASA JSC. ¹³Harvard Univ. ¹⁴NASA GSFC. ¹⁵Mus. D'Hist. Nat., Paris. ¹⁶U. Minn. ¹⁷ANL. ¹⁸NASA JPL. ¹⁹NRL.

Introduction: The STARDUST spacecraft flew through the coma of comet 81P/Wild2 on Jan. 2, 2004, at a distance of ~236km and a relative velocity of ~6.1 km/s [1]. Dust particles, which were released from the comet hours before the encounter, were captured in silica aerogel and successfully returned to the Earth on Jan. 15, 2006. Cometary debris was also retained in small impact craters on Al-foil strips adjacent to the aerogel collector cells. A preliminary examination team (PET) of ~150 scientists has been engaged in studying the mineralogy/petrology, chemistry, optical properties, organic materials, fluence, and isotopic compositions of a subset of the returned cometary materials [2,3]. This report will summarize what has been learned regarding isotopic compositions of select elements by the PET during its 6 month investigation.

Goals of PET Isotope Analysis: The PET is designed to provide an initial characterization of the isotope properties of Wild2 samples, concentrating primarily on major isotope systems (e.g., C, H, O, N) that permit comparison to a larger database of isotope reservoirs found in primitive solar system materials (meteorites and IDPs) and in individual presolar grains. It is hoped that isotopic abundances can help ascertain whether comets are merely mechanical agglomerations of unprocessed presolar materials, or whether their constituents were processed and mixed with other materials in the solar accretion disk. Even if most Wild2 materials are not distinguishable from solar system matter on the basis of their isotope abundances, it is still possible that the comet could provide an enhanced reservoir of presolar grains with distinct nucleosynthetic histories (i.e., 'stardust') which, in principle, could be different than the populations so far identified in meteorites. Coordination with other investigations, especially mineralogy/petrology and organics, can also help decide the nature of specific materials collected by the mission. Additional isotope analyses will be undertaken opportunistically on grains with appropriate mineralogy, e.g., Mg isotopes in refractory grains.

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**RECOGNITION OF ALKALINE ROCKS ON MARS:
BASALTS FROM GUSEV CRATER AND NAKHLITES.**

H. Y. McSween Jr.¹, K. R. Stockstill², and the Athena Science Team. ¹Department of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN 37996, USA, E-mail: mcsween@utk.edu, ²Hawaii Institute of Geophysics and Planology, University of Hawaii at Manoa, Honolulu, HI 96822, USA.

Introduction: Igneous rocks analyzed by the Spirit rover in Gusev crater [1] include picritic basaltic flows (Adirondack class) on the Plains, a complex variety of float rocks (here we consider only the Wishstone, Backstay, and Irvine classes) on the north face of Husband Hill, olivine-rich outcrops (Algonquin class) on the south face, and volcanoclastic deposits with associated scoria at Home Plate within the Inner Basin. The compositions of all these rocks are mildly alkaline – Gusev volcanics constitute the first alkalic province recognized on Mars. However, re-evaluation of nakhlites suggests that they also formed from alkaline parental magma.

Petrogenesis of Gusev rocks: Highly vesiculated lavas and pyroclastic rocks in Gusev suggest high volatile contents. Calculated liquid lines of descent using MELTS for Adirondack class rocks with 0.5 wt.% H₂O at appropriate redox states suggest that the other lithologies encountered in Gusev could have formed by fractional crystallization of the Adirondack class magma at varying depths corresponding to pressures of 0.1-1.0 GPa. This seems plausible because experiments on Adirondack class basalt composition suggest that it is a primitive magma formed by melting the putative Mars mantle assemblage at ~1.0 GPa [2].

Alkaline nakhlites: A calculated liquid line of descent for the Nakhla parent magma estimated from rehomogenized melt inclusions [3] is also mildly alkaline and resembles low-pressure melts from Gusev. Interstitial liquid compositions in the MIL 03346 nakhlite [4] also demonstrate its alkaline character.

Significance of alkaline rocks: In hindsight, it should not be surprising that alkaline igneous rocks occur on Mars. Models for the Martian mantle are enriched in volatiles (including Na₂O and K₂O), and melting of this primitive mantle could produce alkaline magmas. However, SNC meteorites have always been described as subalkaline, as have Mars crustal compositions inferred from orbital remote sensing data. Depleted mantle – the source for most young SNC magmas, had already lost alkalis before these magmas formed, but older magmas such as the nakhlites and Gusev basalts are more likely to have formed from relatively undepleted mantle sources. Small degrees of melting and high pressures have also likely played a role in generating alkaline magmas on Mars [5].

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THE DEEP IMPACT EXPERIMENT: A SMALL-SCALE MOLDAVITE SIMULATION?

H. J. Melosh¹ Lunar and Planetary Lab, University of Arizona, Tucson AZ 85721 USA and Bayerisches Geoinstitut, Universität Bayreuth, Bayreuth, DE: jmelosh@lpl.arizona.edu

Introduction: On July 4, 2005 the Deep Impact experiment collided a 370 kg spacecraft with comet Tempel 1 at a speed of 10.2 km/sec and an impact angle of about 30° from the horizontal [1]. During the first half-second the Medium Resolution Imaging (MRI) system recorded the rapid expansion of a glowing cloud of molten silicate droplets. Although the Tempel 1 droplets were only about 200 microns in diameter, and probably of mafic composition, the physical circumstances of their formation is a close analog of the formation of Moldavite tektites from the Ries, Germany impact 22 million years ago.

The Deep Impact "poof": Within 150 milliseconds after the initial contact, a high velocity, parachute-shaped arc of glowing debris emerged from the impact site. The arc expanded at about 3 km/sec in width and 4.5 km/sec in length, projected on the sky. This plume passed through the slit of the IR instrument, which recorded a spectrum of water vapor, CO₂, HCN and organic material in emission at temperatures between 1,000-2,000 K. The clear-filter (0.4 to 1.0 micron) visible MRI images show a bright cloud that cooled in a characteristic log-time cooling curve with a 1/e cooling time of 80 milliseconds, indicating radiation cooling of droplets in the size range of 200 microns. The initial temperature was in the range of 2500-3000 K, where Forsterite is molten, but with a low enough vapor pressure that the droplet lifetime against evaporation exceeded the observation time.

Moldavite formation: Moldavites, in common with other tektites, were created during the impact of a large high speed meteoroid with the Earth's surface. Tektites are typically high in SiO₂, although more mafic varieties of microtektites are found in deep sea cores. The sizes of typical tektites are 1 to 10 cm, with some larger types known. From their distances from their source areas, they were ejected at speeds of a few km/sec and traveled ballistically above the atmosphere before being emplaced down-range of the impact. Many contain vesicles that preserve vacuum, indicated that they cooled in flight, high above the Earth's atmosphere.

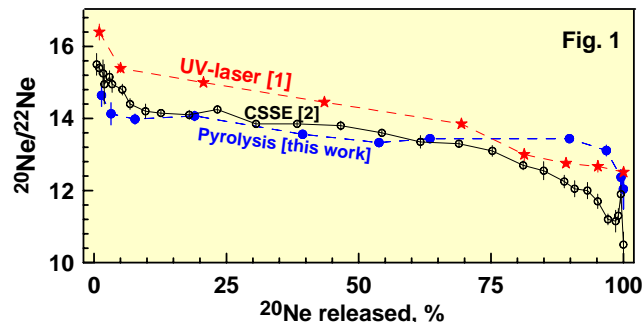
Deep Impact as a Moldavite Analog?: Both the surface of Tempel 1 and the Moldavite source rocks were probably highly porous accumulations of silicate particles. Most tektites seem to require a target material such as loess, one that is particularly susceptible to melting by shock compression. Tempel 1's bulk density is only about 0.4 gm/cm³, a mixture of silicate and ice dust that is also highly susceptible to melting by shock compression. Modeling of the equations of state of these materials indicate that compression yields hot, molten silicate and vapor that travels at high speed away from the impact site. The difference in scale between typical tektites and the Deep Impact melt droplets may be accounted for by the factor of 100 difference in scales between the two events and the resultant reduction in pressure gradients that tend to reduce melt to small droplets.

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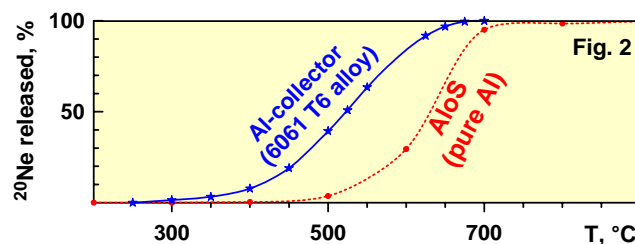
SOLAR NEON RELEASED FROM GENESIS ALUMINUM COLLECTOR DURING STEPPED UV-LASER EXTRACTION AND STEP-WISE PYROLYSIS.

A. Meshik¹, Y. Marrocchi¹, C. Hohenberg¹, O. Pravdivtseva¹, J. Mabry¹, J. Allton², R. Bastien², K. McNamara³, E. Stansbery³, and D. Burnett⁴. ¹Washington University, St. Louis, MO 63130 (am@physics.wustl.edu), ²Lockheed Martin c/o NASA/Johnson Space Center, Mail Code KT, Houston, TX 77058, ³NASA/JSC, Mail Code KA, Houston, TX 77058, ⁴Geology 100-23, CalTech, Pasadena, CA 91125.

Earlier this year we reported results of UV-laser stepped raster extractions of Ne and He from Genesis Al-collector [1]. Since then, using pyrolysis of a 0.005 cm² fragment of this material left from the earlier study, we have estimated the efficiency of the UV-laser extraction to be at least 95%. We also analyzed Ne released from the Al-collector by means of stepped pyrolysis. Here we compare these new data with stepped UV-laser extraction and the CSSE results [2]. Fig. 1 shows ²⁰Ne/²²Ne ratio extracted from Genesis collectors using these three techniques.



The common feature in these different extraction methods is the profile of the ²⁰Ne/²²Ne ratios. In the beginning the ratios are elevated, then relatively flat in the middle, and lowest at the end of the extractions. This pattern seems to be due to the different implantation depths for ²⁰Ne and ²²Ne and agrees with isotopic fractionation expected from SRIM calculations [3].



Comparison of Ne release profiles from Al-collector and pure Al-coated sapphire (AlO₃, [4]) reveals significant differences between these materials (Fig. 2), suggesting that AlO₃ may retain noble gases better than the Al-collector. This may explain slightly higher Ne and He fluxes observed in bulk AlO₃ collector [5] relative to those measured in Al-collector [1].

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LIFE AFTER SHOCK: THE MISSION FROM MARS TO EARTH.

C. Meyer¹, D. Stöffler¹, J. Fritz¹, G. Horneck², R. Möller², C. S. Cockell³, J. P. de Vera⁴, and U. Hornemann⁵. ¹Museum f. Natural History (Mineralogy), Humboldt-University, Invalidenstr. 43, 10115 Berlin, Germany. E-mail: cornelia.meyer@museum.huberlin.de. ²DLR, Institute for Aerospace Medicine, Köln. ³Open University, Milton Keynes, UK, ⁴Institute of Botany, Heinrich-Heine-University Düsseldorf, ⁵Ernst-Mach-Institute, Freiburg i. Breisgau.

Introduction: In view of the geological and climatological development of planet Mars, the origin and evolution of life in the first 1.5 billion years of martian history appears possible. There is also convincing evidence that a significant amount of surface material was ejected from Mars by impact processes and a substantial portion of that transferred to Earth. The minerals of the Martian meteorites collected so far indicate an exposure to shock waves in the pressure range of 5 to 55 GPa [1]. As terrestrial rocks are frequently inhabited by microbial communities, rocks ejected from a planet by impact processes may carry with them endolithic microorganisms, if microbial life existed/exists on this planet.

Experiment: We produced planar shock waves by an explosive device, which accelerates a planar flyer plate. The plate impacted an Armco iron container, in which the sample, an assemblage of different kinds of microorganisms and rock, was placed parallel to the shock front. Independently of the peak shock pressure predetermined by the dimensions and material properties of the experimental set-up, the actual peak shock pressure of the recovered shocked material was controlled by measurement of the refractive indices of plagioclase, based on accurate calibration for shock pressure [e.g., 2].

Based on the experience with shock recovery experiments at an ambient temperature of 293 K [3], we performed a new set of experiments to extend the temperature conditions to 233 K and 193 K, respectively, in order to better simulate the Martian temperature environment (147 to 290 K). Considering the detailed knowledge about the composition and constitution of Martian surface rocks and the well-known relation between shock pressure and post-shock temperature for various types of rocks, we used dunite (corresponding to the Martian chassignite meteorites) on the one hand, and sedimentary rock (sandstone) saturated with water and salt on the other hand, as an extension of our earlier work with gabbro [3]. Dunite is the rock of choice because of a relatively low increase of shock and post-shock temperature after shock loading [1]. Sandstone served as an analogue of the Martian water-saturated regolith.

Conclusion: The aim of these experiments was to determine the temperature or pressure as the limiting factor for the survival rate of microorganisms during shock loading and to better understand the underlying molecular mechanisms of the survival of microorganisms in an impact and ejection scenario.

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POST-SHOCK COOLING HISTORY OF DHOFAR 378 SHERGOTTITE.

T. Mikouchi¹, G. McKay² and E. Koizumi¹, ¹Dept. of Earth and Planet. Science, University of Tokyo, Hongo, Tokyo 113-0033, Japan, ²KR, NASA Johnson Space Center, Houston, TX 77058, USA, E-mail: mikouchi@eps.s.u-tokyo.ac.jp.

Although plagioclase in shergottites is “maskelynite”, Dhofar 378 plagioclase is present as fibrous crystalline phases, which is considered as recrystallization from shock plagioclase melt [1]. Thus, Dhofar 378 is important for assessing a “shock” age of shergottites. This abstract reports results of a mineralogical study of the Dhofar 378 chip that was also used for chronological studies [2,3], and discusses shock heating and subsequent cooling of Dhofar 378.

Petrography and mineral compositions of the Dhofar 378 sections studied are generally similar to the section that we previously studied [1]. Plagioclase grains are composed of fibrous minute crystalline needles (~100 μm long and <10 μm wide) of An₅₈Or₁ to An₄₀Or₇. Thin K-, Na-rich glass areas (K₂O: 0.5-6.5 wt%, Na₂O: 5-11 wt%) are present near the center of grains. The shock textures of the previously studied section are more extensive than those of sections studied this time, suggesting heterogeneous shock metamorphism even in a small meteorite (15 g total recovered mass).

The presence of both recrystallizing plagioclase rims and the inner K-rich feldspathic glass areas is similar to heated “maskelynite” in Zagami at 900 °C [4]. We performed additional experiments at 1000 and 1100 °C, and found that Dhofar 378 is most similar to the sample heated at 1000 °C for 1-24 hours. The sample heated at 1100 °C contains partial melt between pyroxene and plagioclase. Ca phosphates are absent, and plagioclase grains are clear brown in the sample heated for 24 hours. Thus, the peak temperature of Dhofar 378 during shock would be lower than 1100 °C, probably ~1000 °C. The cooling rate of Dhofar 378 after the shock is difficult to estimate from our present results. However, crystallization experiment of Los Angeles [5], which is nearly identical to Dhofar 378 except for shock degree [1], shows that 2.5 °C/hour cooling could produce similar fayalite textures in Dhofar 378. This cooling rate is comparable to the experimental recrystallization of plagioclase with only small amounts of K-rich glass left, but is very slow for shock environment. We plan to perform cooling experiments of Zagami from 1000 °C and 1100 °C to constrain a post-shock cooling rate of Dhofar 378.

The Ar-Ar age obtained from the same rock chip used for this study gave ~143 Myr, which is interpreted as an earlier impact event rather than the ejection event from Mars [2]. The Sm-Nd result also shows a similar age of 157 Myr [3]. The strong shock metamorphism and slow post-shock cooling observed in Dhofar 378 may record this ~143 Myr event.

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**YOUNG RADIOMETRIC AGES OF SHERGOTTITES:
IMPLICATIONS FOR AQUEOUS ALTERATION ON THE
MARTIAN SURFACE**

K. Misawa¹, H. Kaiden¹ and T. Noguchi². ¹Antarctic Meteorite Research Center, National Institute of Polar Research, Tokyo 173-8515, Japan. E-mail: misawa@nipr.ac.jp. ²Ibaraki University, Mito, Ibaraki 310-8512, Japan.

Introduction: Bouvier et al. [1] argued that most radiometric ages of shergottites including lherzolitic were reset recently (i.e., ~180 Ma) by acidic aqueous solutions percolating throughout the Martian surface. Detailed mechanisms of aqueous alteration on the Martian surface are still not well-understood. Grady et al. [2] suggested different flows of water: surface water in contact with Martian atmosphere might be percolating downward from above and precipitation of salts could have occurred. On the other hand, groundwater from melted ice could be circulating from below and alteration of silicates could have occurred.

Results and Discussion: During aqueous alteration elemental fractionations of lithophile trace elements could have occurred. For example, U and Th have similar chemical properties and show tetravalent oxidation state with similar ionic radii. Under oxidizing condition, U forms the uranyl ion which forms compounds easily soluble in water. Therefore, U becomes a mobile element and could be separated from Th which exists only tetravalent state and whose compounds are generally insoluble in water. Large elemental fractionations between U and Th were sometimes observed during acid treatment in laboratories [3-5]. The $^{232}\text{Th}/^{238}\text{U}$ ($\equiv \kappa$) ratios for whole-rock samples of ALH-77005, LEW 88516 and Y-793605 determined by IDMS are constant, i.e., $\kappa = 3.8\text{-}4.0$ [3-5].

Lherzolitic shergottites are extremely sensitive to addition of mobile lithophile elements (e.g., LREE, Ba and Sr) during alteration. Variations of Ba/La and Sr/Eu ratios for whole-rock samples of ALH-77005, LEW 88516, Y-793605 and NWA 1950 are small [6-9]. The REE patterns of phosphates and whole-rock samples of ALH-77005, LEW 88516 and GRV 99027 are consistent with closed-system crystallization [10,11]. Moreover, Ce anomalies, which are recognized as products of aqueous alteration, are not observed.

These facts suggest that abundances of lithophile trace elements were not disturbed, and that the young Rb-Sr, Sm-Nd and U-Pb ages so far reported could represent crystallization events.

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GEOCHEMISTRY OF PALLASITE OLIVINES AND THE ORIGIN OF MAIN-GROUP PALLASITES.

D. W. Mittlefehldt¹ and D. Rumble III². ¹NASA/Johnson Space Center. (david.w.mittlefehldt@nasa.gov) ²Geophysical Laboratory, Carnegie Institution of Washington.

Main-group pallasites (PMG) are mixtures of iron-nickel metal and magnesian olivine thought to have been formed at the core-mantle boundary of an asteroid [1]. Some have anomalous metal compositions (PMG-am) and a few have atypically ferroan olivines (PMG-as) [2]. PMG metal is consistent with an origin as a late fractionate of the IIIAB iron core [2]. Most PMG olivines have very similar Fe/Mg ratios, likely due to subsolidus redox reaction with the metal [3]. In contrast, minor and trace elements show substantial variation, which may be explained by either: (i) PMG were formed at a range of depths in the parent asteroid; the element variations reflect variations in igneous evolution with depth, (ii) the pallasite parent asteroid was chemically heterogeneous; the heterogeneity partially survived igneous processing, or (iii) PMG represent the core-mantle boundaries of several distinct parent asteroids [4, 5]. We have continued doing major, minor and trace elements by EMPA and INAA on a wider suite of PMG olivines, and have begun doing precise oxygen isotope analyses to test these hypotheses.

Manganese is homologous with Fe²⁺, and can be used to distinguish between magmatic and redox processes as causes for Fe/Mg variations. PMG olivines have a range in molar 1000*Mn/Mg of 2.3-4.6 indicating substantial igneous fractionation in olivines with very similar Fe/Mg (0.138-0.148). The Mg-Mn-Fe distributions can be explained by a fractional crystallization-reduction model; higher Mn/Mg ratios reflect more evolved olivines while Fe/Mg is buffered by redox reactions with the metal. There is a positive association between Mn/Mg and Sc content that is consistent with igneous fractionation. However, most PMG olivines fall within a narrow Mn/Mg range (3.0-3.6), but these show a substantial range in Sc (1.00-2.29 µg/g). Assuming fractional crystallization, this Sc range could have resulted from ~65% crystallization of an ultramafic magma. This is inconsistent with formation at the core-mantle boundary of a single asteroid [4].

One alternative is that the PMG are fragments of several asteroids, and these could have had different initial Sc contents, Mn/Mg and differences in igneous history. Our preliminary O isotope data and those of [6, 7] do not support this, although the coverage of PMG olivines is incomplete.

The PMG-as Springwater is not easily fit in any scenario. Its olivine has among the highest Mn/Mg suggesting it is one of the most evolved, but the lowest Sc content suggesting it is the least evolved. The O isotopic composition of Springwater olivine is the same as that of other PMG. Thus there is no indication that it represents a distinct parent asteroid.

Our preliminary O isotopic data favor a single PMG parent asteroid. In this case, the olivines are more likely melt-residues, and that the parent asteroid was initially heterogeneous in chemical, but not isotopic, composition.

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**FERRIC IRON IN AL-BEARING AKIMOTOITE
COEXISTING WITH IRON-NICKEL METAL IN A
SHOCKED L-6 CHONDRITE.**

N. Miyajima¹, A. El Goresy¹, C. Dupas², F. Seifert¹, D. Rubie¹, M. Chen³ and X. Xie³. ¹Bayerisches Geoinstitut, Universität Bayreuth, D-95440 Bayreuth, Germany. E-mail: nobuyoshi.miyajima@uni-bayreuth.de. ²Universite des Sciences et Technologies de Lille, Bat C6 F-59655 Villeneuve d'Ascq Cedex, France. ³Guangzhou Institute of Geochemistry, CAS, Wushan, Guangzhou 510640, China.

Introduction: Melt veins in many shocked L-6 chondrites contain complex assemblages indicative of formation at high-pressures and temperatures during dynamic events on parent asteroids [1-2]. These assemblages include ringwoodite and majorite formed by solid-state phase transformation in addition to the liquidus pair majorite-pyrope_{ss} + magnesiowüstite indicative of crystallization at $P < 23$ GPa and $T \leq 2000^\circ$ C [1-2]. Akimotoite, the ilmenite-structured dense polymorph of $(\text{Mg,Fe})\text{SiO}_3$ pyroxene newly described in shocked chondrites was found to contain variable amounts of Al_2O_3 [3-4]. This raises a question of the possibility of the presence Fe^{3+} to maintain the charge balance. In order to explore the presence of Fe^{3+} , we have examined a shock-melt vein in the Sixiangkou meteorite having high concentrations of akimotoite, using an analytical TEM equipped with electron energy-loss spectrometer (EELS).

Results: In addition to aluminous akimotoite, the vein contains majorite-pyrope_{ss}, ringwoodite, FeNi metal, troilite and a silicate glass. The glass domains have compositions that are similar to those of synthetic $(\text{Mg,Fe})\text{SiO}_3$ perovskites, low in Al_2O_3 . In contrast, the rim of the domains mainly consists of aluminous majoritic garnets [2]. The akimotoite grains far from the domains have appreciable Al-contents (1-5 mol % Al_2O_3) and about 5 mol% FeO. The electron energy-loss near-edge structures (ELNES) demonstrate that aluminous akimotoite has high proportions of Fe^{3+} with Fe^{3+} / total Fe ratio of 0.30-0.50(5), although it coexists with FeNi metal. This is the first report of Fe^{3+} in natural or synthetic akimotoite. In contrast, the coexisting Fe-rich ringwoodite (Fa_{25-40}), is enriched in Fe^{2+} with the Fe^{3+} / total Fe ratio of 0.05(5). The above-mentioned amorphous domains are inferred to be silicate perovskite.

Conclusions: Aluminous akimotoite could contain significant amount of Fe^{3+} , even under reducing conditions prevailed during their crystallization. The bulk composition of the melt vein is chondritic[2]. The MgSiO_3 glass (perovskite?)-majorite-akimotoite-ringwoodite assemblages are not predicted as a stable liquidus assemblage deduced from high-pressure experiments of chondritic bulk composition[1]. The texture is, however suggestive of resulting from crystallization of a melt and its partial reaction with olivine- and pyroxene-fragments at pressures expected in static high-pressure experiments.

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EVOLUTIONARY TRENDS OF ACAPULCOITES: NEW EVIDENCES FROM CHEMICAL, MINERALOGICAL AND PETROLOGIC DATA ON PRIMITIVE, TYPICAL AND TRANSITIONAL ACAPULCOITES.

V. Moggi-Cecchi¹, G. Pratesi^{2,3}, and L.Mancini¹, ¹Museo di Scienze Planetarie, Provincia di Prato, Via Galcianese, 20/h, I-59100 Prato, Italy, e-mail: v.moggi@pratoricerche.it, ²Museo di Storia Naturale, Università degli Studi di Firenze, I-50121 Florence, Italy, ³Dipartimento di Scienze della Terra, Università di Firenze, Via La Pira, 4, I-50121, Florence, Italy, e-mail: gpratesi@unifi.it

Introduction: NWA 1052 and NWA 1054 are two primitive acapulcoites whose main masses weigh 22 and 86 g, respectively [1, 2]. Dho 290 is a typical acapulcoite with a main mass of 62 g [3]. NWA 3008 is a transitional acapulcoite with a main mass of 157 g [4]. The NWA3008 and Dho290 thin sections have been kindly provided by J. Schlüter (Mineralogical Museum, University of Hamburg) and by M.Nazarov (Vernadsky Institute of Moscow).

Description: NWA 1052 and 1054 display a granular fine-grained texture with olivine and orthopyroxene phenocrysts and relic RP and POP/PP chondrules ranging in size from 400 to 1400 μm set in a feldspathic matrix. Dho 290 has a granoblastic texture with ipidiomorphic crystals of silicates (ranging from 100 to 300 μm in size), chromite and phosphates (<100 μm) mixed with troilite and metal (both >200 μm). NWA 3008 has a granoblastic texture with grains in the range 100-300 μm . The areal distributions of silicates, metal and troilite have been measured in all the samples with a Zeiss Axioplan 2 optical microscope equipped with the Axiovision 4.1 software: NWA 1052 and NWA 1054 show a finer-grained texture, (91 and 86 % of silicates in the 0-25000 μm^2 range), while Dho 290 and NWA 3008 display a more coarse-grained texture (63 and 66 % of silicates in the 0-25000 μm^2 range). The comparative study of the modal mineralogy of these samples showed a decreasing amount of opaque phases (troilite and metal) going from NWA 1052 - NWA 1054 (15% of the total volume) to Dho 290 (12%) and NWA 3008 (10%). For what concerns the chemical characteristics both Na and Cr contents of diopside and Fo - Fs molar contents of olivine and orthopyroxene have been detected by EMPA in all the samples. The increasing Cr contents and Fo - Fs distributions suggest a trend going from NWA1052 to NWA3008 (Figure 1).

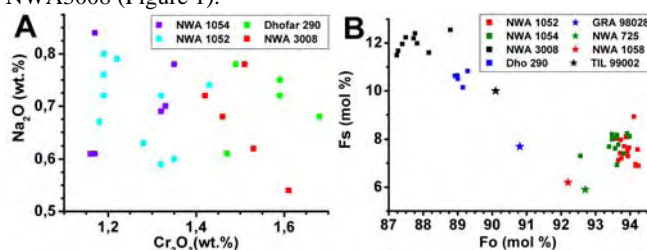


FIG. 1 (A) plot of Na vs Cr contents of diopside in NWA1052, NWA1054, Dho290 and NWA3008; (B) plot of Fs vs Fo contents of olivine and orthopyroxene for the same samples compared with literature data (★) from [5].

Conclusions: Both textural, mineralogical and chemical data suggest a rather clear and coherent evolutionary trend going from the more primitive NWA 1052 and NWA 1054 acapulcoites to the more evolved ones Dho 290 and NWA 3008, in good agreement with the trend indicated by [6].

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STUDY OF NORTHWEST AFRICA 4269 : A METAL-RICH LIKE “EUCRITE” BASALTIC ACHONDRITE

B.N. Moine¹, A. Seddiki², C. Renac¹, J. Bascou¹ and J.Y. Cottin¹
¹Laboratoire de Pétrologie-Géochimie UMR CNRS 6524 “Magmas et Volcans”, Université Jean Monnet, Saint-Etienne 42023. France. moineb@univ-st-etienne.fr. ²Laboratoire de Magmatisme et Géodynamique des Bassins Algériens, Université d’Oran Es-senia, Oran 31000, Algérie

NWA4269 is a highly metamorphic basaltic monomict breccia from southern Algeria. This meteorite presents microstructure variations characterized by both coarse-grained regions with magmatic relict (subophitic texture) constituted by pigeonite and plagioclase minerals and fine grained recrystallized regions, which contain α -quartz, low- and high-Ca pyroxenes, plagioclase, troilite, Fe metal, with Ca-phosphate ilmenite, spinel in minor proportion. Pyroxenes (low-Ca: Fs₆₃₋₆₆, high-Ca: Fs₃₁₋₃₃) in recrystallized regions are equilibrated at 900°C. The mean FeO/MnO atomic ratio in pyroxenes is 28 with very low variations. Fe-metal is abundant in this sample (more than 1%). Metal display a low Ni content (<0.1wt%) and is located only in recrystallized regions in small inclusions in low-Ca pyroxene or in/around quartz grains. However, it can also occur as millimetric elongated grains. Sulfide is abundant and is only low-Ni pyrrhotite. Metal abundance in eucrite is often interpreted as reduction of Fe-rich orthopyroxene during thermal event by reaction with sulphide like described in Camel Donga eucrite or in some lunar rocks.

Trace element pattern of whole-rock normalized to CI is flat (15xCI) except for highly volatile element (Rb, Pb) that are depleted and for Ba, U and Nb that show slight enrichment. In situ trace element analyses of pyroxene and plagioclase obtained by laser ablation coupled with an ICP-MS also display similar La/Y and Sm/Yb ratio with highly metamorphosed non cumulate eucrites.

Petrographic, petrologic and geochemical characteristics of this meteorite are very similar with metamorphosed non cumulate eucrite and Ibitira achondrite, however oxygen stable isotope composition measured on this sample shows a higher $\Delta^{17}\text{O}$ (0.136, $\delta^{18}\text{O}=3.27$ and $\delta^{17}\text{O}=1.84$) than this of HED group and nearby from $\Delta^{17}\text{O}$ of Ibitira.

This $\Delta^{17}\text{O}$ deviation from HED group could reflect intrinsic heterogeneities in the HED parent body due to incomplete mixing at an early stage, or, it is conceivable that there was more than one parent body for like “eucrite” basaltic achondrites.

DUST FROM COLLISIONS IN CIRCUMSTELLAR DISKS: SIMILARITIES TO METEORITIC MATERIALS ?

A. Morlok^{1,2}, M. Köhler³, M. Anand⁴, C. Kirk² and M. M. Grady⁴. ¹Department of Earth and Planetary Sciences, Kobe University, Nada, Kobe 657-8501, Japan <morlok70@kobe-u.ac.jp>, ²The Natural History Museum, Cromwell Road, SW7 5BD, London, UK ³Institut für Planetologie, Wilhelm-Klemm Str. 10, 48149 Münster, Germany. ⁴The Open University, Walton Hall, Milton Keynes MK7 6AA, UK

Introduction: There is growing evidence from astronomical observations that dust is produced in later stages of circumstellar disks by collisions of larger bodies or planetesimals [e.g. 1,2]. The bodies involved probably have similar characteristics like the planetesimals in our own young Solar System. In the form of meteorites we have remnants of these bodies available for measurements. For the interpretation of astronomical infrared spectra of dust, a comparison with infrared spectra of material from such meteorites should be useful.

Samples and Techniques: Material from matrix and CAI was separated from polished samples, powdered to a sub-micron powder and measured using a Perkin Elmer AutoImage FTIR microscope [e.g. 3]. For chondrules and bulk measurements of achondrites and martian samples, infrared spectra were obtained from KBr pellets using the Perkin Elmer Spectrum One workbench [e.g. 4]. For the comparisons and calculations here, all transmission/absorption spectra were calculated to a spectral resolution of 4cm^{-1} in the range from 8 to $16\ \mu\text{m}$.

Discussion: If the population of planetesimals collided in the observed circumstellar discs is as diverse as in our own solar system, the astronomical infrared spectra show probably a mixture of many types of sources, both primitive and differentiated. Thus also mixtures of laboratory meteorite spectra were calculated and compared with typical astronomical spectra of circumstellar disks, where accretion (and thus collisions) possibly already took place. First preliminary results are presented below.

Single Meteorite Samples: Matrix material from Kakangari (K3) has very similar band positions to HD179218 (~1.25My [5]) and Hen3-600 (1-10My [5]), although with different relative band intensities. Material from bulk Ureilites (Hajmah-A) is similar to that of HD100546 (>10My [5]) [4].

Meteorite Mixtures: Spectra like that of Herbig stars HD142527 (~1My [5]) and HD104237 (~2 My [5]) can be reproduced with a 1:2 mixture of olivine rich matrix from a CO chondrite (Ornans) and tektite (representing impact melt glasses). A 3:3:5 mixture of Ureilites, chondrules and tektite also shows a good similarity, like a 1:2 mixture of Kakangari matrix and olivine-rich chondrules.

The spectra of Herbig star HD163296 (~5My [5]) has similarity to a 1:2:1.5 mixture of CII (Alais) matrix, olivine-rich chondrules and HED bulk material. Also a mixture of chondrule material and tektites gives good results.

Some results make more sense in an early Solar System environment than others. This will be discussed in the presentation

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DETERMINING THE EFFECTS OF AQUEOUS ALTERATION ON THE DISTRIBUTION OF OXYGEN ISOTOPES IN CARBONACEOUS CHONDRITES.

A. A. Morris, I. A. Franchi, L. Baker, J. Watson and I. P. Wright. Planetary and Space Sciences Research Institute, The Open University, Milton Keynes, MK7 6AA. E-mail: a.a.morris@open.ac.uk.

Background: Carbonaceous chondrites (particularly the CI, CM and CR meteorites) have the most diverse range of high and low temperature mineral phases, and display the widest range of oxygen-isotopic compositions [1,2]. There are then inherent problems when trying to interpret early Solar System history. One is identifying the isotopic signature of oxygen from specific component compounds in a complex mixture of materials that existed in the solar nebular, and deconvoluting this from signatures developed during parent body processing, of which aqueous alteration is the most wide spread. Models to account for the variations in oxygen-isotopic compositions in carbonaceous chondrites e.g. [3,4] generally involve mixing of a solid anhydrous silicate component, with an isotopic composition enriched in ^{16}O , with liquid water depleted in ^{16}O along with mass-dependent isotopic fraction between various phases at low temperature [5]. Isotopic evolution of the fluids involved in these reactions would be expected to lead to significant isotopic heterogeneity within the components e.g. [4].

Research: We have employed a number of approaches to better determine the distribution of oxygen isotopic components within these complex meteorites. Much of our work has been involved with characterizing the products from artificial hydrothermal alteration of olivine. Olivine was reacted with neutral, acidic and alkaline solutions at 330°C and 50 bar pressure with the aim of producing phyllosilicates of serpentine composition (lizardite, chrysotile and antigorite); the products were characterised using Raman spectroscopy, SEM, XRD and thermal analysis. Stepped heating extraction to liberate water and structural (OH) $^-$ has also been undertaken [6]; this technique permits isotopic measurements of resolved components, the identification of which has been established by detailed study of the thermal release temperature of water (OH) $^-$ components and a range of terrestrial analogues. This method has been used to trace the location of different oxygen reservoirs as alteration proceeds in further artificial hydrothermal alteration reactions of olivine using isotopically labeled water. Stepped heating extraction of water and (OH) $^-$ have also been used to characterise the oxygen isotopic composition of liberated, indigenous, water (OH) $^-$ from a range of carbonaceous chondrites (CI, CM2, CR2).

Summary: The initial stepped heating experiments for carbonaceous chondrites revealed considerable variation in $\delta^{18}\text{O}$ [5]. Much of our new work has been aimed at determining the extent of isotopic fractionation associated with the formation of the common phyllosilicates found in meteorites, and identifying the specific minerals liberating (OH) $^-$ at each temperature. This will be used ultimately to better constrain the isotopic composition of the fluids involved in the alteration process on carbonaceous chondrite parent bodies.

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**SPATIAL DISTRIBUTION OF DEUTERIUM HOT-SPOTS
IN THE INSOLUBLE ORGANIC MATTER: A NANOSIMS
STUDY**

S Mostefaoui¹, F. Robert¹, S. Derenne², A. Meibom¹ ⁽¹⁾LEME,
CNRS-Muséum, Paris, France (robert@mnhn.fr). ⁽²⁾LCBOP-
BioEMCo, CNRS-ENSCParis, France

Introduction: Because of a systematic enrichment in deuterium, the insoluble organic molecules (IOM) of the carbonaceous meteorites are generally considered to represent interstellar materials. However, the D/H ratios in IOM remain much lower than those measured by spectroscopy in the organic molecules of the interstellar gas phase (ISM). Since no plausible process has been proposed to account for this discrepancy, a straight heritage of the IOM from ISM remains uncertain. Recently, NanoSIMS data have yielded new information that may provide a solution to this pending issue.

The heterogeneous distribution of Deuterium in IOM: It has been recently shown [1,2] that, organic species with low C/H ratio (1.2 ± 0.2) are embedded in the IOM and exhibit much higher δD values (δD up to +7000‰) than the bulk IOM value ($\delta D = +1000 \pm 200$ ‰). This “material” (*D hot-spots*) exhibits highly variable D/H ratios, compared with the more invariable D/H ratio of the enclosing IOM. Based on a correlation between the D/H ratio and the binding energy of the organic H [3], it was proposed that the radical-rich regions of the IOM are the carriers of these *D hot-spots* [4]. Indeed, the presence of paramagnetic organic radicals (with unpaired electron orbitals) has been observed by EPR spectroscopy in the IOM [5]. Micrometer regions of the IOM are characterized by high concentration of free radicals. These radical-rich regions must be regarded as “survivals” of the parent body hydrothermalism, likely because they were embedded in minerals or too deeply embedded in the bulk IOM to be reached and destroyed by circulating water.

Testing the hypothesis: According to EPR data, the abundances of these free radicals relative to bulk IOM, vary from Murchison to Orgueil to Takish-Lake; that is : 4%, 17%, et 50% , respectively. Thus, if the deuterium is indeed concentrated in free radicals rich regions, it should be possible to correlate the surface density of *D hot-spots* obtained through NanoSims image analyses with the relative abundances of free radicals. We will present these new results along with IOM extracted from an unequilibrium Enstatite meteorite.

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NITROGEN IN INDIVIDUAL CHONDRULES FROM ORDINARY, ENSTATITE AND CARBONACEOUS CHONDRITES.

S.V.S. Murty and J.P. Das, Physical Research Laboratory, Ahmedabad 380009, India

Introduction: Isotopic composition of nitrogen ($\delta^{15}\text{N}$) shows distinct grouping for ordinary (O), enstatite (E) and carbonaceous (C) chondrites, similar to $\Delta^{17}\text{O}$ values that are due to differences in their formation environment [1,2]. On the other hand, the differences between $\Delta^{17}\text{O}$ of chondrules from their respective parent chondrites signify the precursor differences [3]. A systematic investigation of trapped nitrogen and noble gases in individual chondrules from O, E and C chondrites has been undertaken with the objective of understanding the nature of chondrule precursors as well as the chondrule formation environment and processes.

Samples: We have only selected petrologic class 3 and 4 for OC, 3 for EC and 2 and 3 for C chondrites, to minimize effect of parent body processes. We have analysed a total of 77 chondrules coming from 10 chondrites belonging to O (6), E (2) and C (2). Splits for 27 of these chondrules that are >1 mg have been analysed by EPMA for chemical and mineralogical characterization. FeO contents suggest that 13 of these belong to type I, while 14 are from type II. N and noble gases have been analysed by laser heating gas extraction [4]. $\delta^{15}\text{N}$ of total measured N has been corrected for cosmogenic contribution, based on ^{21}Ne [5], to derive $\delta^{15}\text{N}$ of trapped N.

Results and discussion: Among ordinary chondrites, while the N contents are comparable or higher, the $\delta^{15}\text{N}$ of individual chondrules show a wide range (generally more positive) as against the narrow range for bulk UOC. The trend for individual chondrites (Dhajala and Bjürbole from which a large number of chondrules have been analysed) is same as that for all UOC together. Among C chondrites, though the N contents in chondrules are very low as compared to the parent chondrite, the $\delta^{15}\text{N}$ values are more positive, similar to the trend in OC. However, for E chondrites the $\delta^{15}\text{N}$ of chondrules overlap those of bulk chondrites. These observations possibly suggest that EC chondrules formed from same precursors as their parent chondrites.

Among chondrules from all chondrites, the spread in $\delta^{15}\text{N}$ is more among type II (FeO rich) chondrules as compared to type I (FeO poor). When only UOC are considered, the same trend is clearly displayed. The process by which, type I chondrules are derived from type II [6], results in homogenization of $\delta^{15}\text{N}$. There is narrowing in the range of $\delta^{15}\text{N}$ as the % melt (represented by feldspar content) increases. $\delta^{15}\text{N}$ variations among individual chondrules are mostly of primary nature, but in some cases, could have been modified by secondary processes (both nebular and parent body origin). Those of primary origin indicate the differences in precursor materials. The narrowing in the $\delta^{15}\text{N}$ with lower FeO and higher melt proportion suggest that the melting which brought about these changes is due to a secondary heating event in the nebula, resulting in the homogenization of N components from an ensemble of precursors making up the primary chondrule.

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