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NEUTRAL GAS AND ION MEASUREMENTS WITH THE REFLECTRON-TYPE TIME OF FLIGHT MASS SPECTROMETER ROSINA-RTOF

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Introduction: On March 2, 2004 the European Space Agency (ESA) successfully launched the Rosetta spacecraft that will rendezvous with comet 67P/Churyumov-Gerasimenko (C-G) in November 2014. Onboard this spacecraft is, among others, the ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis) instrument package comprising two mass spectrometers, a cometary pressure sensor and a data processing unit [1]. The two mass spectrometers DFMS (Double Focusing Mass Spectrometer) and RTOF (Reflectron-type Time of Flight mass spectrometer) are designed to analyze the volatile material in the vicinity of C-G and to quantify the molecular and isotopic composition of C-G during the conjoint journey towards the Sun and throughout the perihelion passage. Here, we report on RTOF neutral gas measurements from space and the first RTOF ion measurements with a low energy ion source in the lab.

RTOF Characterization: The RTOF sensor consists of four different parts [2]. The first part is the source region, in which two independent ion sources are located. The electron impact ion storage source is used to store ions which are continuously produced from incoming cometary neutrals by electron bombardment. These ions are extracted by a short high-voltage pulse and are further accelerated into the time of flight system. In the second source, the orthogonal extraction ion source, the incoming primary cometary ions are directly pulsed onto the time of flight path, again by means of a high-voltage pulse. The second part of the sensor is the time of flight section, which consists of the field-free drift path (length ~ 1 m) and two ion mirrors facing each other for multiple reflections of the ion trajectories. The RTOF sensor houses two separate MCP (multi channel plate) detectors (third part), one for the cometary neutrals and one for cometary ions. The fourth part of RTOF is the electronic box that houses eight electronic boards.

Discussion: The RTOF sensor complements DFMS with an extended mass range from 1 to > 300 amu/e and a high sensitivity. An advantage of the RTOF sensor is that within 100 μ s a full mass spectrum is recorded over the entire mass range. The recorded mass range is only limited by the signal accumulation memory. The mass resolution in the triple reflection mode is $m/\Delta m > 4500$ at the 50% peak height. During the calibration program we could demonstrate that RTOF has a wide dynamic range. Therefore, in the environment of C-G, RTOF will be able to cope with highly variable outgassing rates and will measure the minor constituents of the volatile material. Species with partial pressure $< 10^{-12}$ mbar are detected. Measurements in the lab with a specially constructed low energy ion source [3] have been performed in order to calibrate the ion measurements of the RTOF sensor. This source has been designed to simulate the cometary ions which have energies well below 20 eV.

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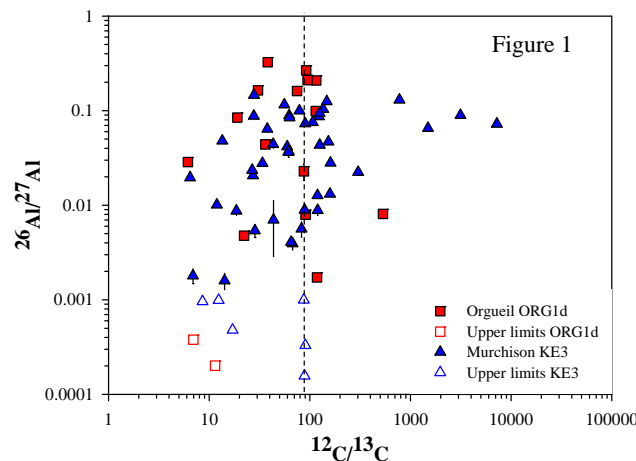
SUPERNOVA GRAPHITE GRAINS FROM ORGUEIL.M. Jadhav¹, S. Amari¹, T. Maruoka^{1*}, and E. Zinner¹.¹Laboratory for Space Sciences, Washington University, St. Louis, MO 63130, USA. E-mail: manavijadhav@wustl.edu.

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Introduction: In previous studies [1-3], some of the graphite grains from the low-density fraction of Orgueil, ORG1d ($\sim 1.75\text{-}1.92\text{ g cm}^{-3}$; grain sizes $> 1\ \mu\text{m}$), were found to have isotopic signatures in N, O, and Si that indicated a supernova (SN) origin. In a continued attempt to better understand SN graphite grains, we isolated ORG1d candidate grains from the large amounts (much larger than in graphite separates from Murchison) of macromolecular carbonaceous material, in which the graphite grains are often found embedded. This was done to reduce contamination from this carbonaceous material and, hence, facilitate the isotopic analyses. Here we present C, N, O, Si and Al-Mg isotopic data obtained with the NanoSIMS, for the grains of this fraction. The same grains will be analyzed for Ti isotopes and, eventually, heavy element isotopes (Sr, Zr, Mo, Ru, Ba) by resonant ionization mass spectrometry (RIMS) with CHARISMA.

Experimental: Spherical, carbonaceous grains identified by X-ray analysis in the SEM were picked with a micromanipulator and deposited on a gold-foil mount. Isotopic analyses of these grains were carried out in the NanoSIMS. Negative secondary ions of ^{12}C , ^{13}C , $^{12}\text{C}^{14}\text{N}$ and $^{12}\text{C}^{15}\text{N}$ (analysis phase 1) and, ^{16}O , ^{18}O , ^{28}Si , ^{29}Si and ^{30}Si (phase 2) produced by bombarding the sample with a Cs^+ primary beam were counted in multidetection mode. In phase 3 of the analysis, positive secondary ions of ^{12}C , ^{24}Mg , ^{25}Mg , ^{26}Mg and ^{27}Al produced with an O^- beam were detected.

Results and Discussion: 18 of the 41 candidate carbonaceous grains were found to be presolar, as indicated by their $^{12}\text{C}/^{13}\text{C}$ ratios that vary from 6 to 910. We found 12 grains that contain ^{18}O excesses, with $^{18}\text{O}/^{16}\text{O}$ ratios of up to 15 times the solar value. 8 of these grains also exhibit ^{15}N excesses and 6 contain ^{28}Si excesses. These signatures indicate a SN origin for these grains [4]. In addition, 17 grains exhibit large $^{26}\text{Al}/^{27}\text{Al}$ ratios (up to 0.33) that were derived from ^{26}Mg excesses. In Figure 1 we compare the $^{26}\text{Al}/^{27}\text{Al}$ ratios of these grains with those of graphite grains from the Murchison KE3 low-density fraction [4]. The high $^{26}\text{Al}/^{27}\text{Al}$ ratios we found now were probably not seen in the previous study of grains from ORG1d [3] because of the large ^{24}Mg and ^{27}Al signals obtained from the contamination present on that mount. All the grains with ^{18}O , ^{15}N and ^{28}Si excesses have high $^{26}\text{Al}/^{27}\text{Al}$ ratios indicating that they are bonafide SN grains.



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U-PB DATA ON CLEAN MINERALS FROM NAKHLITES.

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Introduction: Nakhrites constitute about one-fifth of about 30 known Martian meteorites. Among the finds are the recently in the Antarctica discovered two nakhrites, Y-000593 and Y-000749 from the Yamato mountains [1] and MIL03346 found in the Miller Rang. All nakhrites have basaltic composition and a cumulate texture. From electron microscope (EM) and microprobe imagery the olivine and augite are seen to be zoned in major and trace elements. Our Pb and Nd isotopic results have already been presented at recent LPSC [2, 3], and here we report U-Pb results on ultra-clean mineral separates. Previously determined Rb-Sr and Sm-Nd mineral ages for Nakhla are about 1.3 Ga. A similar ^{238}U - ^{206}Pb age was measured on a baddeleyite-containing residue fraction of the leached meteorite. However, for combined leach and residue fractions have ^{207}Pb - ^{206}Pb ages >2 Ga, and the Pb-Pb isochron plot show considerable scatter [2- 5]. In this study we try to better define the initial Pb isotopic composition of nakhrites. Plagioclase and pyroxene separates were obtained by hand-picking under the binocular microscope. The pyroxene was then further crushed to 50μ , and separated into high-Fe and low-Fe fractions using a magnetic separator. Pyroxene analyses were made on only optically pure grains, and both pyroxene and plagioclase were additionally acid-washed to avoid surface contamination. The same technique was then applied to other nakhrites from the Antarctic NIPR collection and NASA (MIL03346) with similar results, indicating that all nakhrites may have the same age.

Results: An identical initial Pb isotopic composition indicates that all of these meteorites were derived from the same homogeneous source. Moreover, it is strongly suggested by their initial Pb that the “olivine shergottites”, like SaU 005, DaG 476, and Y- 980459, as well as the basaltic shergottite QUE94201 [6], likewise come from this Nakhla source. While “normal” shergottites like Shergotty and Los Angeles for example are from sources having a more evolved Pb isotopic composition. “Olivine shergottites” are clearly younger than nakhrites. Their Sm Nd and Rb Sr isotopic systems are highly disturbed. Analyzing the existing data we favor an age of 800 my for the “olivine shergottites” which is also suggested by Ar-Ar systematic.

The Nakhla reservoir was sampled at least 2 times: at 1300 my (nakhrites) and at 800 my (olivine shergottites). However, the Pb isotopic composition plots close to the Geochrone at a $^{238}\text{U}/^{204}\text{Pb}$ of about 2. This gives interesting implications for the evolution of this reservoir and their parent body.

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SECONDARY FAYALITE IN THE VIGARANO CV3 CARBONACEOUS CHONDRITE: OCCURRENCE AND FORMATION AGE

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Introduction: Vigarano meteorite, classified to reduced subgroup of CV3 chondrite (CV3_{Red}) [1], is one of the most primitive solid materials in the solar system. However, it comes to be known that Vigarano experienced very weak aqueous alteration, which results in formation of secondary fayalite [2]. In the present study, we made detailed characterization of many fayalite grains in Vigarano and then determined formation age of the fayalite based on Mn-Cr system using an ion probe at Kyushu University, in order to constrain the early evolution of a CV3_{Red} Vigarano asteroid.

Results and discussion: The SEM and FE-SEM observation indicates that, among twenty-three chondrules investigated, only four POP chondrules have fayalite-magnetite-troilite veins (~10 x 100 μm in size) that extend from large troilite-magnetite inclusions at chondrule surfaces to exterior matrix. Fayalite grains in the veins are smaller than 20 μm in size. The four POP chondrules having the veins have fine-grained rims around them. The rims and the enclosing chondrules comprise discrete clasts which can be recognized by the boundary lines to Vigarano host by SEM observation. The fayalite-magnetite-troilite veins terminate at the boundary. The mineralogy of the clasts suggests that they are probably Bali-like oxidized material CV3_{OxB} [3, 4].

Within the fayalite grains iron-magnesium zoning is commonly observed: high Fa# at the center and low Fa# at the rim (Fa#=95-72). This indicates that at the early stage of the alteration almost pure fayalite formed and later the rim of the fayalite became enriched in MgO, approaching equilibrium with matrix olivine (Fa₅₀). Ion-probe analysis was performed on an interior portion of the biggest fayalite (10 x 20 μm in size, Fa₉₅ at the center, and high MnO content of 0.6 wt%). The Mn-Cr data for the fayalite defines an initial ⁵³Mn/⁵⁵Mn ratio of (2.19 ± 0.53) × 10⁻⁶. This ratio indicates that Vigarano pure fayalite formed 3 ± 1 Ma before Angrite. An absolute age was also determined to be 4561 ± 1 Ma. The obtained age corresponds to the time of pure fayalite formation induced by early aqueous alteration in a CV asteroid.

CV3_{Red} Vigarano meteorites consist of both CV3_{OxB} and CV3_{Red} materials. This implies that Vigarano is a breccia. The preferential occurrence of fayalites in the clasts of CV3_{OxB} suggests that the fayalite formation did not take place in situ in the present structure of Vigarano: the fayalites had formed in a different location of the Vigarano asteroid or in a different CV asteroid where the alteration was very active. The obtained fayalite formation age of Vigarano is identical within errors to that of CV3_{OxB} Mokoia [5] and CV3_{OxB} Kaba [6]. This identical match indicates that the CV3_{OxB} clasts in the Vigarano CV3_{Red} meteorite formed in the period same as other CV3_{OxB} meteorites.

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TEXTURAL EVIDENCE FOR MELT PROCESSES ON THE PALLASITE PARENT BODY

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Introduction: Pallasites are generally ~50:50 mixtures of iron-nickel metal and olivine; iron sulphides are normally present only as a minor phase. We have recently described [1] a new unusually sulphide-rich pallasite. Irregular distribution of its metal, sulphide and olivine yields clues to the origin and evolution of main group pallasites. It has been suggested [2,3] that cooling and evolving IIIAB iron metallic melt should form two immiscible liquids when the sulphur to phosphorous ratio exceeds 25. We have observed textures that support this view.

Observations: The meteorite has marginal, olivine-rich regions composed of sub-rounded, ~cm-sized crystals forming a granular mosaic. Towards the interior, this gives way to metal-rich or sulphide-rich regions in which the olivines tend to be fragmented, angular and smaller in size. There seems little doubt that where metal is host to angular olivine, the silicate was solid and brittle when enveloped in molten metal [4]. A similar textural relationship exists between olivine and sulphide, but the latter intrudes the olivines as fracture-filling veins <1mm thick that carry sub-rounded to angular sub-mm fragments of olivine. Sulphide veining commonly occurs to the exclusion of metal.

Discussion: The ability of sulphide to have been injected along sub-mm channels indicates that it was more fluid than metal. The tendency for metal and sulphide to be segregated is consistent with their occurrence as two immiscible liquids, as attested by the textural relationship between olivine fragments and metallic or sulphide hosts.

Conclusion: The new pallasite provides strong support for the separation of immiscible metallic and sulphide-rich liquids during pallasite genesis. Such evidence had previously been sought [3], but until now, was lacking.

References: [1] Abstract: Johnson D., Hutchison R., Grady M. M. & Kirk C. (*this volume*). [2] Ülf-Møller F. 1998. *Meteoritics & Planetary Science* 33: 207-220. [3] Ülf-Møller et al. 1998. *Meteoritics & Planetary Science* 33: 221-227. [4] Scott E.R.D. 1977. *Geochimica et Cosmochimica Acta* 47: 693-710.

HAMBLETON - A NEW SULPHUR RICH PALLASITE

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Introduction: A new pallasite, a single mass of 17.6 kg, was found south of Hambleton, North Yorkshire, by R and I Elliott in August 2005. The mass is composed of ~60 vol % olivine, ~25 vol% metal and ~15 vol% sulphide. The phases are irregularly distributed and highly weathered. There follow the results of a study by optical and analytical scanning electron microscopy.

Observations: Olivine occurs as cm-sized sub-rounded crystals in a granular mosaic. Many contain sub-parallel sets of fractures, some of which are annealed, while others are filled with metal or sulphide. In metal-rich or sulphide-rich areas olivines are fragmented and angular to sub-angular and veined by metal or sulphide respectively. Some regions <5cm in size are composed entirely of olivine crystals enclosed within troilite. Olivine is Fo_{88.3}, and together with the oxygen isotopic ratios: $\delta^{17}\text{O} = +1.383\text{‰}$; $\delta^{18}\text{O} = +3.029\text{‰}$; $\delta^{17}\text{O} = -0.187\text{‰}$, indicate that the meteorite is a main group pallasite. From the olivine-rich exterior, weathering has penetrated for 4-5 cm towards the interior of the mass. The weathered, olivine-rich outer portion is brittle and prone to disintegration. A blue secondary mineral rich in Mg, P and Fe was shown by XRD to be baricite (Mg, Fe)₃(PO₄)₂.8H₂O. Much of the metal has succumbed to terrestrial oxidation, especially low-Ni phases such as kamacite, cloudy taenite or plessite. The sulphide is more susceptible to terrestrial alteration than the metal.

Discussion: Metal rich regions are consistent with the view of Scott [1] that pallasites formed by the injection of metallic liquid into dunite. Evolved metallic melts, related to IIIAB irons, should be sulphur-rich. Paucity of sulphide in pallasites led Uff-Møller et al [2] to suggest that either FeS-rich liquid was lost or formed pallasites that are underrepresented in our samples.

Conclusion: With Phillips County (pallasite), Hambleton is a rare FeS-rich pallasite.

References:

- [1] Scott E.R.D. 1977. *Geochimica et Cosmochimica Acta* 47: 693-710. [2] Uff-Møller et al. 1998. *Meteoritics & Planetary Science* 33: 221-227.

**THE PETROGRAPHY AND GEOCHEMISTRY OF
LUNAR METEORITE REGOLITH BRECCIA MET
01210.**

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Introduction: MET 01210 [1] is an anorthosite bearing basaltic lunar regolith breccia [2] that is dominated by clast and mineral fragments consolidated in a predominately mare region of the Moon [3]. The MWG sections studied in this investigation (MET 01210,21 and MET 01210,27) have vesicular fusion crusts and are composed of an immature breccia sample with rock (<4mm) and mineral fragments (<1mm) fused in a fine grained crystalline and glass matrix.

Analytical Methods: Mineralogical analysis was done at the NHM using a WDS Cameca SX-50A and elemental mapping was performed using a LEO 1455VP EDS SEM fitted with Oxford Instrument's INCA analysis software.

Observations: Mare basalt fragments in MET 01210 have a range of textures. Examples of mare material include rapidly crystallized fine grained clasts that have a distinctive feathery or plumose texture with a low-Ti affinity. Holocrystalline, coarser grained ferro-basalt fragments have large zoned pyroxenes (<500µm $\text{En}_{1-47} \text{Fs}_{27-86} \text{Wo}_{10-30}$), evolved Low-Ti-VLT bulk compositions and some examples include small fractionated mesostasis assemblages (silica, fayalite, K-feldspar, glass, apatite, whitlockite). Additional clasts of very fine grained / granular symplectites of silica, fayalite and hedenbergite are the collective break-down products of pyroxferroite. Mineral fragments in the matrix are predominantly associated with a fractionated mare basalt parentage.

MET 01210 also contains a non-mare anorthositic component including fragments of anorthositic norite, feldspathic metaigneous clasts and granulites with Mg-rich mafic phases. Additional material in our sections includes small fragments of feldspathic impact melt derived rocks, glass beads (20-100 µm: including one with a HASP composition [4, 5]) and small melt veins.

Discussion: The mineralogical and clast assemblage of MET 01210 is dominated by Fe-enriched, low-Ti mare basalt material with a minor anorthositic component. The bulk rock composition was reported by [3] and is similar to typical average mare soils with elevated Al_2O_3 and depleted MgO as a consequence of additional mixing with anorthositic material. Bulk rock Th (0.86ppm [3]) is comparatively low for mare regolith breccia material [7] suggesting that the mare components in MET 01210 did not experience KREEP assimilation and are likely to have been emplaced distally to the PKT.

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A POSSIBLE AD552 COMET SIGHTING IN JAPAN AND ITS PARALLELS WITH COMETARY PHENOMENA ASSOCIATED WITH THE SARASVATI RIVER OF ANCIENT INDIA.

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Introduction: The *Enoshima Engi* (EE) was written in AD1047 by the Japanese monk Kokei. The narrative mentions spectacular phenomena that took place in the early summer of AD552, including dark clouds covering the sea, earthquakes, the appearance of a bright goddess (Benzaiten/Sarasvati) above the clouds, boulders falling from the sky, lightning-bolts, rocks and sand spurting up from the sea, flames on the water, the emergence of an island, and the descent of the goddess onto the island. In 2003 Juhl translated and studied parts of the EE [1].

The Prabhasa-ksetra-mahatmya book (PK) of the Skandapurana contains references to similar phenomena associated with the Sarasvati River. In 2004 Iyengar published an article on comet-related phenomena in the PK [2].

Discussion: Following is a list of possible comet-related parallels in the PK. All parallels with the EE listed below are from Juhl [1].

The PK mentions objects making holes in the ground in association with a smoky demon [3]. The EE parallel is the "dark clouds covering the sea" and "great boulders descending from above the clouds".

In one episode, the Sarasvati River, carrying fire, enters the ocean. Iyengar translates: "With fire in his hand, the ocean lit up... Due to the gases emanating from the sea, the waters overflowed..." [4] The EE parallel is the description "flames flickered amidst the white-tipped waves".

The level of the sea apparently rose and dropped. Iyengar writes: "... after the fire started burning, initially the sea exceeded its boundaries but later the coast started receding... In the 346th chapter, there is reference to large-scale loss of life associated most probably with a ... tsunami" [5]. The EE parallel is the loss of life as the dragon (the floodwaters) invaded the villages.

The PK has a chapter entitled Sarasvati-avatara-mahimavarnanam, meaning "description of the purpose of the avatara (descent) of Sarasvati" [6]. The EE parallel is the descent of Benzaiten from the sky.

Iyengar comments on a related story: "The further verses indicate that a metallic object eventually landed on earth, leading to earthquakes..." [7]. The EE parallel is the earthquakes before the descent of the goddess.

Conclusions: Most of the phenomena described in the EE are similar to phenomena in the PK. However, they are not copies, only similar. The presence of similar phenomena in unrelated Indian and Japanese records suggest that the phenomena actually did take place substantially as described. A fuller account of the parallels is on the Internet [8]. The phenomena may be comet/meteor related and deserve further investigation.

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ION MICROPROBE REE ANALYSES OF THE YAMATO 983885 LUNAR METEORITE

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Introduction: Yamato (Y) 983885 is a polymict regolith breccia derived from the Moon [1]. The meteorite contains various lunar crustal rocks such as Mg-rich rocks and a KREEP basalt, which is first reported among the lunar meteorites [2]. Here we report a preliminary ion microprobe REE data for individual minerals from the Y983885 lunar meteorite and implications for parent melt compositions of the Mg-rich clasts to better understand their connection to KREEP.

Sample and Methods: A polished thin section (PTS) Y983885,59-2 used in this study is described in detail by Arai et al. [2]. Ion microprobe analyses were carried out on the SHRIMP II at the National Institute of Polar Research, Japan. A modified energy filtering technique [3] was used to discriminate against complex molecular interferences.

Results and Discussion: Y983885 contains a variety of clasts consisting of a KREEP basalt, a Mg-rich troctolite/norite, a high-Al basalt, a very low-Ti basalt, and a granulite originated from ferroan anorthosite [2]. In this study, we focus on the Mg-rich troctolite, which is comprised of Ca-rich plagioclase (59.6 vol%), Mg-rich olivine (23.4 vol%), low-Ca pyroxene (15.5 vol%), and other minor/trace phases [2]. Two spots on plagioclase and three spots on pyroxene in the troctolite were analyzed. Plagioclase is LREE-enriched with La $\sim 10 \times$ chondrite and Lu $\sim 0.5 \times$ chondrite and displays a large positive Eu anomaly. Pyroxene is La $\sim 1 \times$ chondrite and Lu $\sim 20 \times$ chondrite with a negative Eu anomaly. These chondrite-normalized REE abundances of each mineral are broadly consistent with previous ion microprobe studies of Apollo samples [4, 5]. Using these REE abundances with appropriate partition coefficients, we can calculate the parent magma compositions, which can demonstrate a connection between Mg-rich rocks and KREEP basalt.

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DEMONSTRATION OF CRYSTAL FORSTERITE AND STALL STATE GRAIN FORMATIONS

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Introduction: Astromineralogy has been started due to the presence of crystalline silicate dust by the Infrared Space Observatory and detection of presolar grains [1]. Some experiments based on gas-solid condensation from Mg-Fe-SiO-H₂-O₂ vapors, yielded various phases without olivine or enstatite crystals [2, 3]. We demonstrated the film condensed from vapor phase of SiO and Mg by co-evaporation from different evaporation sources were not mixed at room temperature [4]. Forsterite crystal grains were produced by dropping SiO powder into MgO flame in a mixture gas of Ar and O₂ [5], and/or the coalescence growth of Mg and SiO smokes [6] or MgO and SiO₂ smokes [7]. In the present paper, we showed that the forsterite crystal and stall state grains were produced by the simultaneous flush evaporation technique of different mixture powders of Mg and SiO, i.e. different mixture ration of Mg and SiO vapor was important factor for the formation of amorphous stall and crystal forsterite formation.

Experiment: Mixtures of Mg and SiO powders of different weight ratios were prepared, i.e., Mg: SiO = 1:1, 1:2, 1:3 and 1:4. These mixture powders were dropped on a heated V-shaped Ta boat at 2000°C in a mixture of Ar (70 Torr) and O₂ (10 Torr) gases. The dropped mixture powders were evaporated before they reached the boat in the mixture gas. Therefore smoke particles were produced.

Results and Discussion: The 1:1 and 1:4 mixture ratio samples showed typical crystal and amorphous grains. Amorphous particles were composed of spherical of 100 nm order. The Mg₂SiO₄ crystal grains showed the polyhedral shape. With the increment of SiO powder, the spherical Mg₂SiO₄ crystal grains were selectively produced. The spherical grains produced from the powder with 1:3 ratio showed the amorphous grains. HRTEM image of this particles showed the existence of micro crystallites with the size of 2 nm order which can be identified as the Mg₂SiO₄ crystallites by HRTEM. The IR spectrum of this sample showed the stall state which was postulated in the paper on the infrared changes observed in magnesium silicates during thermal annealing [8, 9]. The spectrum of 1:3 specimen corresponds to a silicate revolution index (SEI) of 0.78-2.00 of the stall state. The crystalline and amorphous absorption spectra different with the stall state are clearly elucidated.

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THE COSMOCHEMICAL Cs-PROBLEM.

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The alkali elements are relatively abundant and highly incompatible, and therefore useful for studying planetary differentiation. Alkali elements are also both volatile and fluid mobile and hence difficult to constrain. The constituents of primitive chondrites have experienced various degrees of hydrous alteration and thermal processing and it is uncertain whether the measured values of Rb and Cs from bulk meteorites represent the solar system. There are no measurements of the Cs content of the sun and the solar values for Rb are not the same as for CI meteorites [1]. Without a good reference frame from meteorites and solar measurements, it is difficult to model the Rb and Cs abundances in the primitive mantle of the Earth.

A 50% nebular condensation temperature is often used as a measure of volatility for an element. However, condensation temperatures for specific elements are model dependent and can vary a lot. Heating experiments of primitive meteorites show variable fractionations of Rb and Cs so the retentivity of these elements is definitely host dependent and the quantification of volatile behavior is not straight forward. For example, bulk Murchison (CM2) is depleted in volatile elements compared to CIs, but has the same Rb/Cs ratio. The contributions from thermal and aqueous processing in the bulk values are unclear.

To take hydrous alteration out of the equation, olivine-hosted glass inclusions from the Murchison (CM2) meteorite have been analysed with electron microprobe, SHRIMP and LAICPMS, to study the distribution of Rb and Cs and other trace elements in these primitive materials. CI normalised patterns for refractory elements are flat for both glass inclusions and bulk Murchison. Volatile elements Rb, Cs and Pb are depleted in glass inclusions relative to the refractories, with increasing depletion in that order. The Rb/Cs ratios in the glass inclusions are significantly higher than bulk Murchison (and CI), which could either be inherited from the source of the inclusions or possibly caused by thermal volatilisation during formation of the inclusions and their hosts.

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CATHODOLUMINESCENCE AND RAMAN SPECTROSCOPY OF SHOCKED FELDSPAR WITH PDFs

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In some of alkali feldspar and plagioclase samples, short and closely spaced Planar Deformation Features (PDFs) are combined with relatively larger and more widely spaced features (deformation band or albite twinning) to produce a distinctive ladder texture, which occurs as parallel planar optical discontinuities.

Shock-induced PDFs in feldspar have been less studied and less well characterized than those in quartz because of greater optical and structural complexity. Some of PDFs in feldspar are clearly visible in the CL image, but do not appear in SEM and BSE images. Moreover CL image allows more detail observation of PDFs than optical microscope because of high resolution (~1 μm) by the SEM-CL technique. In this study we have characterized PDFs in feldspar using SEM-CL and 3D Raman spectroscopy.

Alkali feldspar and plagioclase with PDFs from Ries Crater were selected in polished thin sections under optical microscope. Experimentally shocked synthetic plagioclase (An40) was employed for a reference sample. CL image and spectra were obtained using a CL scanning electron microscopy (SEM-CL), of which system was comprised of SEM (JEOL: JSM-5410) and a grating monochromator (Oxford: Mono CL2). Raman spectra and 3D Raman map were collected by a micro-Raman spectrometer (Thermo Nicolet: Almega) with CW laser excitation (532 nm).

CL spectra of plagioclase (An50) from Ries Crater have three broad peaks around at 450, 560 and 700 nm, which can be assigned to defect center, Mn^{2+} activation center and Fe^{3+} activation center, respectively. Alkali feldspar (Or70) from Ries Crater shows a broad CL peak at around 460nm attributed to defect center. In CL image, PDFs in both shocked alkali feldspar and plagioclase are observed as thin dark lines superimposed on the more brightly luminescence background of the alkali feldspar and plagioclase grains. The thin dark lines correspond to PDFs, which have been recognized under optical microscope.

Experimentally shocked plagioclase at 40 GPa shows two broad peaks around at 450 and 620 nm related to defect and Mn^{2+} activation centers, respectively, whereas Mn^{2+} center in unshocked one is appeared as a broad peak at around 580 nm. PDFs in shocked plagioclase were observed under optical microscope, and also can be detected in CL image, which is similar to that of shocked plagioclase from Ries Crater.

3D Raman spectral image at 505 cm^{-1} over a sectional area of PDFs in shocked plagioclase from Ries Crater indicates no apparent linear patterns suggesting planar features, whereas experimentally shocked plagioclase at 40 GPa exhibits linear stripe texture in 3D Raman map, which corresponds to that CL image. Such difference in 3D Raman map might be at least partly responsible for heating effect at shock event.

CALIBRATION FOR STARDUST CRATERS IN ALUMINUM FOIL: INTERPRETATION OF COMETARY PARTICLE PROPERTIES BY COMPARISON WITH LABORATORY IMPACTS OF MINERAL, POLYMER, AND GLASS GRAINS.

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Introduction: A unique opportunity to study cometary particles has been provided by successful return of Stardust [1]. It is important to understand original grain size, extent of structural damage and any elemental fractionation suffered by particles during capture, if full interpretation is to be realised. We have simulated impacts on Stardust Al foil, using a suite of mineral powders accelerated by light gas guns [2] to 6.1 kms⁻¹ with perpendicular incidence. Our aim has been to produce an accurate comparison by use of well characterised materials with appropriate grain size and composition.

Experimental and Analytical Techniques: 27 buckshot firings onto Al1100 foil were performed at the University of Kent and NASA/JSC. Soda lime glass bead samples of narrow size dispersion were used for size calibration. Mineral projectiles were selected to reflect likely and possible species in cometary dust [3] and included olivine, ortho- and clino-pyroxenes, calcic feldspar, kamacite, pyrrhotite, magnetite, silicon carbide, corundum, spinel, hibonite, sodalite, calcite, dolomite, breunnerite, gypsum, cronstedtite, lizardite and saponite. Other projectiles included poly-methyl methacrylate, powdered Orgeuil CI chondrite and basalt glass. Soda lime glass craters were measured for a size calibration of cometary dust [4]. Energy dispersive X-ray analyses were performed in situ, and on residue material extracted by focused ion beam microscopy (FIB) techniques [5].

Results and Discussion: The shots yielded thousands of craters on foils. Scanning electron microscopy and FIB revealed abundant residue in the crater interior and rim areas with much of the original projectile retained, mostly melted, yet on occasion preserving some crystalline fragments. Comparison of projectile and residue compositions showed that mineral residues can be identified reliably. Analytical transmission electron microscopy of residue FIB ultrathin sections has shown almost all major elements are retained in substantially original proportions, although there is some depletion of sodium and sulfur. Study of the foil craters will not only provide an accurate measure of flux vs. particle size, but will also complement composition studies of particles in aerogel. Samples of our projectile impacts are available on request for further characterization in other laboratories.

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ANALYSES OF NEAR-IR, SPECTROSCOPIC DATA FOR MEMBERS OF ASTEROID FAMILIES WITH MIXED TAXONOMIES.

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It is generally accepted that large, taxonomically heterogeneous asteroid families, such as the Koronis and Maria families, are “real” or “genetic.” That is, the members of such a family are derived from a common parent body. This is probably a safe assumption for collisionally young families – those that form dense clusters in orbital element space. But the same is not true for collisionally old families, and particularly those with mixed taxonomies. Not only do dynamical family classification systems disagree on the membership and existence of small families, but in the face of taxonomic, or spectroscopic, heterogeneity such clusters are not considered real in a compositional sense. One should keep in mind that taxonomic homogeneity does not automatically mean genetic reality for an asteroid family. For example, the mineralogical diversity within the S-class asteroids effectively rules out a common origin for all of these objects.

Complete differentiation of a parent body with, for example, an ordinary chondrite starting composition could result in an asteroid with a metallic core, an olivine-dominated mantle, and a basaltic crust. The disruptive collision of such an object could yield asteroid family members in the M, A, and S or V taxonomic classes. This may be a relatively easy scenario to accept since meteorite analogs for each of these classes provide evidence of igneous petrogenesis. It is more difficult to imagine a process that would yield a combination of C-, M-, and R-class asteroids as seen in the Budrosa family. However, there are plausible petrogenetic scenarios based on known classes of meteorites that, although beyond the scope of this presentation, could account for the mix of taxonomies (E, F, and M) in the Nysa-Hertha-Polana region of the mainbelt.

In the present study we use low-resolution near infrared spectroscopic data to examine members of three small-to medium-sized asteroid families that contain an odd mix of taxonomies. The Ceres, Eugenia, and Victoria families each contain S- and G/C-class asteroids. Previously unreleased data for asteroids in these families were obtained with the 52-channel double CVF system at the NASA Infrared Telescope Facility. We will compare these “new” data with existing data for asteroids in these families to begin testing their genetic reality.

SURVIVAL OF METHANOGENS DURING PERIODS OF DESICCATION: IMPLICATIONS FOR LIFE ON MARS

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The relatively recent discoveries that liquid water most likely existed on the surface of Mars [1, 2, 3, 4, 5, 6] and that methane currently exists in the Martian atmosphere [7, 8, 9] have fueled the possibility of extant or extinct life on Mars. One possible explanation for the existence of the methane would be the presence of methanogens in the subsurface. Methanogens are microorganisms in the domain Archaea that can metabolize molecular hydrogen as an energy source, carbon dioxide as a carbon source, and produce methane [10]. One factor of importance, and the one that is addressed here, is the arid nature of Mars, at least at the surface. If one is to assume that life exists below the surface, then based on the only example of life that we know, liquid water must be present. Realistically, however, that liquid water may be seasonal just as it is at some locations on our home planet.

Here we report on research designed to determine how long certain species of methanogens can survive desiccation on a Mars soil simulant, JSC Mars-1 [11]. *Methanosarcina barkeri*, *Methanobacterium formicicum* and *Methanothermobacter wolfeii* were grown on JSC Mars-1, transferred to a desiccator within a Coy anaerobic environmental chamber, and maintained there for varying time periods. Following removal from the desiccator and rehydration in anaerobic culture tubes under ideal growth conditions, gas chromatographic measurements of methane production indicated survival for all three organisms for varying time periods, depending on the organism being tested. *M. barkeri* survived desiccation for 10 days, while *M. formicicum* and *M. wolfeii* were able to survive for 25 days. *M. barkeri* and *M. formicicum* showed reduced methane production with increasing desiccation times, while *M. wolfeii* only showed substantially reduced methane initially following 25 days of desiccation. Methane levels increased rapidly with time, achieving the same methane levels as those desiccated for shorter time periods. Even though all three organisms showed some inhibition in methane production at the longest period of desiccation that allowed for survival, substantial amounts of methane were ultimately attained.

If methanogens are able to exist below the surface of Mars, the existence of liquid water is potentially the most important rate-limiting factor. Results reported here indicate that at least two species of methanogens might be able to survive dry periods for close to a month. Another important factor is temperature. The desiccation experiments reported here were maintained at room temperature. Colder temperatures, such as those observed on Mars, but not cold enough to freeze the subsurface water, might slow down the desiccation damage and lead to even longer survival periods.

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THE ANTARCTIC FERRAR DOLERITE AND THE PETROGENESIS OF THE MARTIAN SHERGOTTITES.

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Introduction: The Ferrar dolerite of East Antarctica has been proposed as a terrestrial analog to Mars because of similarities observed on a variety of scales – from surface weathering features at the outcrop scale [e.g., 1-4] to mineral compositions and textures noted in thin section [1, 2]. Previously, we examined mineralogical changes associated with weathering of the Ferrar. For this study, we investigate the possibility of the Ferrar as a planetary-scale analog to the petrogenesis of the martian Shergottites by establishing a more direct comparison between newly acquired Ferrar thin sections and a thin section of the martian meteorite Los Angeles.

Mineralogy: *Previous Work.* Previously, we presented analyses from a suite of Ferrar samples that display a range of weathering styles. These data show that the Ferrar's pyroxene, feldspar, and oxide assemblages provide a satisfactory match to the Shergottites – especially Zagami and Los Angeles – in terms of both range and average composition. However, there are two significant differences: (1) silica and alkaline-feldspars are prevalent in the Ferrar's mesostasis, while nearly absent in most Shergottite lithologies; and (2) the pyroxene-to-feldspar ratio in those Ferrar samples is nearly reversed from that of the Shergottites. Both of these observations suggest the Ferrar samples in hand are relatively evolved when compared to most Shergottites.

New samples. The Shergottites show a range of pyroxene and feldspar compositions representing a range of fractional crystallization stages, with the most evolved samples appear to be Zagami and Los Angeles [5]. Los Angeles, in particular, seems to provide a good comparison for a number of reasons, notably the presence of relatively large (up to 1mm) silica grains [5]. The Ferrar, as a massive sill (several hundred meters thick) also shows a range of fractional crystallization states. We will present results from a direct comparison between Los Angeles and several newly acquired, well-matched Ferrar samples with much higher modal pyroxene.

Petrogenesis: The Ferrar dolerite is a shallow intrusive exposed along the length of the Transantarctic Mountains. Together with its contemporaneous extrusive counterpart in Antarctica (the Kirkpatrick basalt) and coeval lithologies in Australia and South Africa, they represent one of the largest effusive events in planetary history, the breakup of Gondwanaland in the early- to mid-Jurassic [1, 6, 7]. The tectonic extension and rifting associated with this event is typically considered to be a response to significant mantle upwelling beneath an especially large and insulating continental mass [1, 6, 7]. Similar plumes are commonly cited as the driving force behind large volume Martian magmatism in Tharsis and Elysium [1, 8].

A compelling match between these rocks in modal mineralogy and tectonic setting may also infer analogies between the martian mantle beneath Tharsis and the pre-breakup terrestrial mantle beneath Gondwanaland. Some isotopic studies suggest a Ferrar origin from very "fertile" mantle, while others prefer a mantle strongly influenced by incorporation of subducted crust [1, 9]. Further analog studies that incorporate isotope data could help clarify this debate.

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THE INTERSTELLAR GAS-DUST STREAMS AS THE INSTRUMENT OF EXOBIOLOGY

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Gasdust Streams from Double Stars & Lunar Seismicity.

The time series of seismic events were generated as follows: on the ordinate axis the peak amplitudes of events in standard units, on abscissa axis - seismogram durations of the same moonquakes and subsequent time intervals between them were used. Spectrum of the series disclosed time picks on hidden cosmogonical periodicities of lunar seismicity. A part of results (picks) presents orbital periods of double stars nearest to the Solar system. The explanation of that results is existing gas-dust streams from binary stars systems and interacting of it with lunar surface.

Genesis of Life. If the solar system is reached by the gas-dust streams from binary stars, then all bodies in space have particles of star dust on their surfaces and/or atmospheres. Solar system has made 8-10 revolutions around galactic center and thus captured dust from many thousands stars. As these stars caught in turn dust particles from other stars too then probably our solar system has mainly dust samples from all objects of our galaxy. The age of galaxy and old stars is approximately more than 15 billion years and that of the Earth is only ~ 4, 5 Gyr. Genesis of Life for the Earth has not more than 3 billion years. Thus comparative analysis of simple balance of these times shows that the genesis of Life for Earth is the result of galactic processes/objects and not of the solar system of course. After formation of the solar system all old and new captured dust particles are first accumulated in the Oort cloud and then they are carried by comets to planets. The modern state of the Earth exists for more than 3 billion years, so possibilities for appearing Life were always. These processes had happened a few times during this period of the Earth state. The sizes of the universe and galaxies at $\tau_0 < 1$ billion years could be much less than modern estimates (for example, up to ~15 times in diameter), that implies the existence of a common gas-dust exchange. The density of physical fields and radiations at the moment τ_0 was many orders of magnitude higher than the density existing now. Disintegration of neutron substance and nucleus of heavy unstable elements have caused constantly existing streams of left polarized electrons which have determined chirality's asymmetry of original organic molecules and thus the chirality the existing biological world. Some types of radiations functionally could replace enzymes during formation of self-reproducing molecular structures. Man is used only 10 % of the genetic information. It indicates the common total surplus of a genetic material of biosphere of the Earth. Probably, at the moment τ_0 in unique conditions and with sufficient time for creation the universal galactic gene was created which different elements are capable to create biospheres on planets with the widest set of external conditions and for various stages of development of everyone. If the universal uniform galactic genome exists, this universality will appear as redundancy. The universal model of the gene logically contacts the concept of a prediction and designer, hence, the model of occurrence of life and the Creator is logically more proved.

NONLINEAR SEISMIC PROCESSES ON IMPACT CRATERING: INFORMATION CONTENT

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Introduction. Historically, craters were first found out element of structure of a surface of the Moon and many other planets.

Parameters of crater forming processes. Type of an impact body forming a crater may be single or complicated, its density and the form (extent for complicated); speed of a collision for an impact body-surface. Dominant type of seismic waves at the upper structures of heavenly body; Mach numbers M for all stages of wave and integral parameter of nonlinearity of medium and deeper structures.

Seismo-radiative stresses or forces. More correct description of laws of similarity for craters, the conditions of the crater central zone forming demand to account for occurrence and existence of a field of powerful seismo-radiative forces manifesting as acoustic current or pressure in other sections of wave physics. As a result of viscoelastic properties of a crater forming zone and deeper structures instead of acoustic currents it is more correct to consider seismo-radiative forces or pressure (stress). Seismo-radiative stress is proportional to coefficient of nonlinearity n and quadrate of Mach seismic number (M). The record of the stresses was made using radiation of the vibrator for different experimental conditions.

The mapping of planet internal structure into structures of craters and astroblems. Conditions of effective mapping are determined by several factors. The following concern to the most essential. An extent and spatial distribution of bodies of crushing impactor, forming one or several long wave train-packages of flat seismic waves with number of Mach $M \approx 10^{-2}$ under surface impact. Occurrence of a piston mode of wave trains - bunches of high-frequency seismic waves in an impact zone. For this wave bunch the subsequent preservation of wave train form and conditions $10^{-3} < M < 10^{-2}$ after passage and/or its reflection from geological border of a planet (minus losses). As a direction of vectors of seismo-radiative stresses and a gradient of density of the geological medium are opposite, the occurrence of the central hill is the elementary consequence of this fact. Diameter of the crater with such hill corresponds to the minimal cross section of a wave bunch at a piston mode radiation of seismic waves. Reflected from the removed borders of a planet the wave bunch tests to geometrical divergence because a reflecting surface has a spheroid form. Accordingly under day surface output seismo-radiative stress or force of wave packages of the reflected beam operates on the area with diameter exceeding an initial crater, and forms an external ring. Thus, the geomorphology of impacted craters and astroblems contains the information about an internal structure of a planet.

FE-NI METAL AND SULFIDES IN ACFER 094: THERMAL HISTORY OF THE MOST PRIMITIVE CHONDRITE.

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Introduction: Acfer 094 is a unique carbonaceous chondrite, with properties similar to CO and CM chondrites [1]. The matrix mineralogy [2], abundant presolar grains [1], and primitive features of refractory inclusions [3] indicate that Acfer 094 preserves primordial features that were not modified on the parent body [e.g., 1]. Recently we showed that Fe-Ni metal is one of the most useful indicators for distinguishing the most primitive chondrites [4]. Here we report the characteristic features of Fe-Ni metal and sulfides in Acfer 094, in order to explore the primitive nature and thermal history of this remarkable chondrite.

Fe-Ni metal and sulfides: Fe-Ni metal is fairly abundant in the chondrules and matrix. The texture of Fe-Ni metal in Acfer 094 is almost homogeneous in all occurrences, and shows little plessitic intergrowth. This is in contrast to metal in Semarkona (LL3.00), which typically shows plessitic texture [4]. In the other type 3 chondrites, Fe-Ni metal generally shows an intergrowth of coarse-grained kamacite and Ni-rich metal [4]. The latter texture is extremely rare in Acfer 094.

The composition of Fe-Ni metal in Acfer 094 depends on the occurrence of the grain: chondrule metal has 4.0-7.4% Ni and 0.16-0.44% Co, whereas matrix metal has 3.8-39.5% Ni and 0.10-1.8% Co. The Ni/Co ratio is generally solar in all occurrences.

Sulfide minerals generally occur as spherical to irregular-shaped grains in the matrix. They generally consist of troilite with pentlandite. Pentlandite contains 16-26% Ni and 0.3-1.8% Co, with solar Co/Ni ratio.

Discussion: Acfer 094 is one of the least metamorphosed chondrites, based on the Cr distribution in olivine [5]. We [4] suggested that the classification of metamorphic grade based on Fe-Ni metal features, especially the texture of plessite, is consistent with the classification by olivine [5]. However, Acfer 094 metal does not show plessitic texture. Alternatively, we suggest that most of Fe-Ni metal in Acfer 094 is martensite, based on texture and Ni content. The metal should have been quenched from high temperature conditions, higher than ~600°C.

Martensite should transform to plessite during parent body metamorphism under low-temperature conditions [6]. Therefore, presence of martensite strongly indicates that Acfer 094 was hardly subjected to metamorphism on the parent body, and that Acfer 094 seems to be more primitive than Semarkona.

The troilite and pentlandite assemblage may have formed through sulfidation of Fe-Ni metal under low temperatures. The solar Co/Ni ratio of pentlandite supports this idea.

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VARIETY OF REFRACTORY OXIDE GRAINS DEPEND ON FORMATION ENVIRONMENTS.

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Introduction: Almost four decades ago, a 10- μm feature was discovered in evolved stars and silicate grains were suggested as the material responsible [1,2]. Subsequently, the 10- μm feature has been observed from objects of almost all evolutionary stages, from stars (even some carbon-rich stars) and comets and is still attributed to silicate grains. Condensation mechanisms for silica and silicate grains have been investigated in both laboratory nucleation experiments and via theoretical calculations. A wide array of grain synthesis experiments have been carried out by several groups [e.g. 3-5]. IR spectra of both amorphous and crystalline silica and silicate grains with various components have been widely observed. The spectral changes in the shape of the 10- μm feature due to thermal annealing of the grains was also investigated as a function of temperature and time. Constraints on the astrophysical environments and formation conditions of circumstellar, interstellar and interplanetary dust particles have been provided based on comparisons of the observational and laboratory spectra.

Although the correlation between IR spectra and thermal effects has been extensively studied, experiments to observe the effects of changing formation environments are lacking. For example, only a few grain growth experiments have been attempted in magnetic and plasma fields [6,7]. We assume that their environment can affect grains during formation and growth. Accordingly, it should be important to demonstrate the effects of formation environment during grain formation on the resultant IR spectra. Here we report the IR spectra of iron silicate, iron and silicon oxide particles produced in both electrical discharge and UV irradiation experiments. The average character of the grains will be also presented as analyzed using a transmission electron microscope.

Initial Results: FeSiO particles produced from mixtures of Fe(CO)₅, SiH₄ and O₂ using electrical discharge or UV radiation in flowing H₂ gas have a uniform composition within a probable error of 2% as reflected in their ambient gas atmosphere. SiO and FeO grains have not been observed so far. In contrast, when FeSiO grains were produced by the thermal decomposition of Fe(CO)₅ and SiH₄ within a furnace, the grains were classified into three distinct groups with specific atomic ratios [8].

Silica grains produced by UV irradiation display a very intense feature at 11.3 μm attributed to Si₂O₃. The intensity is as strong as 15% of the simultaneously observed 9.2 μm feature, as compared to the typical intensity of the well-known Si₂O₃ spectrum where the 11.2- μm feature seldom exceeds 5% of the intensity of the strong 9.2- μm peak. These experiments are still progressing. We will show further results and discussion that may provide additional constraints concerning silicate formation conditions.

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OXYGEN ISOTOPES IN MAFIC AND FELDSPATHIC CLASTS FROM POLYMIC T UREILITES.

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Introduction: Polymict ureilites DaG 165 and DaG 319 contain a wide variety of igneous clasts that might be derived from basaltic complements to the ultramafic monomict ureilites [1-2]. In a previous ion microprobe oxygen isotopic study of clasts from DaG 319, most plagioclase bearing clasts were found to plot along the CCAM-line and thus their origin from the ureilite parent body (UPB) was confirmed [1]. However, because of the small number of samples and limited precision of the analyses ($\Delta^{17}\text{O} \sim 1\%$), oxygen isotopic systematics among these clasts is not well understood. In this study, the new ion microprobe IMS-1280 [3] was used to perform a systematic survey of 28 new clasts (described by [2,4]) in DaG 165 and 319, including 20 plagioclase bearing clasts similar to those studied by [1]. In addition, two unusual mafic clasts (olivine with chromite exsolution, and Fe-rich pigeonite containing a melt inclusion) described by [4] and several of the olivine-augite feldspathic clasts described by [2] were studied to clarify their origin.

Ion Microprobe analyses: The sample was sputtered with focused Cs⁺ primary ions (2-7nA, 10-15 μm diameter) and oxygen three isotopes were analyzed by 3 Faraday Cup detectors combining mono and multi-collection systems [3]. At least 4-6 repeated analyses were made for each clast in order to obtain <0.3‰ precisions in $\delta^{18}\text{O}$, $\delta^{17}\text{O}$ and $\Delta^{17}\text{O}$. Olivine, pyroxene, and plagioclase standards with matching chemical compositions were used for correction of instrumental mass fractionation.

Results and Discussion: All but one of the feldspathic clasts plot along the CCAM line in the same region as ferroan monomict ureilites ($\Delta^{17}\text{O} = -0.5$ to -1.4%). One albitic plagioclase fragment plots on the TF line at $\delta^{18}\text{O} \sim 6\%$, similar to enstatite meteorites. The two unusual mafic clasts plot on or slightly above the TF line at $\delta^{18}\text{O} \sim 3\%$, indicating a possible link to primitive achondrites or ordinary chondrites. Four olivine-augite bearing feldspathic clasts plot along CCAM, confirming their UPB origin. None of the samples plot in the range of magnesian ureilites ($\Delta^{17}\text{O} \sim -2\%$ on CCAM), consistent with the previous study [1]. If smelting determined mg#s of monomict ureilites and the UPB had a correlation of $\Delta^{17}\text{O}$ with depth [4], our results indicate a bias toward materials from the deeper source regions (in contrast to the interpretation of [4] that the dominant feldspathic clasts were derived from the shallowest depths). This is likely due to mingling of melts during fractional melt extraction [6], a process that was not recognized in the modeling of [4]. Calcic clasts (An>30) show slightly higher $\Delta^{17}\text{O}$ than albitic clasts (An<30) by 0.3‰. Low degree melts enriched in alkali and other trace elements generated at depth might migrate into shallower region where isotopic mixing with lower $\Delta^{17}\text{O}$ could occur. This is consistent with recent UPB models suggesting that Al-rich melt containing live ²⁶Al concentrated at shallower depths on the UPB [5,6].

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HF-W AGES FOR THE ACCRETION OF ORDINARY CHONDRITE PARENT BODIES.

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Introduction: Key issues regarding the early evolution of the solar system include the timescales of accretion, differentiation and thermal metamorphism of planetesimals. Many of these processes involved metal-silicate fractionations (e.g., core formation, metal formation in ordinary chondrites) and can be dated using ¹⁸²Hf-¹⁸²W chronometry. Hafnium is lithophile whereas W is siderophile, such that metals have Hf/W~0 and preserve the W isotope composition acquired at the time of their formation. The W isotope compositions of magmatic iron meteorites indicate that their parent bodies differentiated in less than ~1.5 Myr after formation of Allende CAIs [1-3]. Here we present W isotope data for metals from ordinary chondrites to constrain formation intervals between metal segregation in iron meteorite parent bodies and the accretion of ordinary chondrite parent bodies.

Results: Metals from 10 L and 2 H ordinary chondrites were separated and their W concentrations and W isotope compositions determined using methods of [4]. Tungsten contents in the metals continuously increase (with increasing petrologic type) from ~0.3-0.4 ppm in type 3 up to ~1-1.4 ppm in type 6 ordinary chondrites. This range in W concentrations is consistent with results from earlier studies [5]. Despite these variations in W content, all ordinary chondrite metals analyzed so far have similar W isotope compositions ranging from ~-3 to ~-2.5 ε_W (where ε_W is the deviation of ¹⁸²W/¹⁸⁴W from the terrestrial standard value in parts per 10,000). There are no resolvable ε_W differences among metals from type 3, 4, and 5 ordinary chondrites and only type 6 metals appear to be slightly more radiogenic.

Discussion: The increasing W content of metals with increasing petrological type indicates a continuous transfer of W from silicates into metal during thermal metamorphism. This transfer must have occurred rapidly, as indicated by the similarity in W isotope compositions of metals from type 3-5 ordinary chondrites. Thus, W isotopes in metal from type 3 and 4 ordinary chondrites constrain the timing of parent body accretion. Based on the W isotope compositions of metals from Julesburg (L3), Mezö-Madaras (L3), and Saratov (L4) accretion of the L chondrite parent body occurred 3-5 Myr after core formation in the parent bodies of magmatic iron meteorites. Accretion of the H chondrite parent body (based on Hf-W systematics of Ste. Marguerite [6]) would have occurred at 2-4 Myr. These data confirm results that suggested that accretion of chondrite parent bodies postdates differentiation in some asteroids [1, 7]. Additional data, especially for metals from the most primitive ordinary chondrites, are needed to better constrain the effects of parent body processes on the W isotope composition of metals in type 3 ordinary chondrites.

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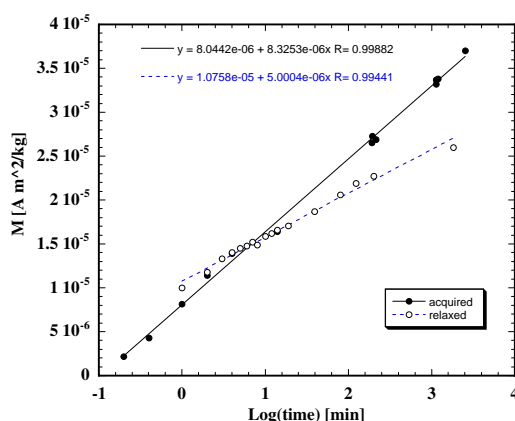
PROTOCOL FOR FIRST ORDER PALEOFIELDS ESTIMATION

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Examination Protocol: Our experience from application of normalizing technique to the Murchison and Bjurböle meteorites allows us to develop a list of steps that have to be performed when examining magnetism of an extraterrestrial object.

Protocol for first order paleofield estimation requires decisions in respect to following questions: Was the sample exposed to geomagnetic field? Does the measurement device produce measurable magnetic field that can partially magnetize the sample (>0.05 mT)? Is the NRM above the noise level of the instrument? Does the REM (NRM/SIRM ratio for all AF steps) curve has significant positive/negative AF slope after the full AF demagnetization of both NRM and saturation isothermal remanent magnetization (SIRM)? Is remanence less than 50% of NRM after sample has been exposed to fields exceeding 0.05 mT? Is there a time dependence of magnetization after putting sample in magnetic vacuum and low temperature (e.g. 77K). Is NRM after low temperature exposure less than 50%? Do sub-samples of meteorite pass conglomerate test?

An example of unusual property of meteorites not often considered is illustrated on Murchison meteorite. The effect of geomagnetic field exposure and shielding is illustrated in Figure 1, where the acquired/relaxed component is shown to increase linearly with the logarithm of time. This property is independent of further demagnetization and/or acquisition and thus must be considered when deciphering the extraterrestrial magnetization signature.



THE 2005 ICDP-USGS DEEP COREHOLE IN THE CHESAPEAKE BAY IMPACT STRUCTURE. C. Koeberl¹, G.S. Gohn², W.U. Reimold³, and K.G. Miller⁴, ¹University of Vienna, Dept. Geological Sciences, A-1090 Vienna, Austria (christian.koeberl@univie.ac.at); ²U.S. Geological Survey, Reston, VA 20192, USA; ³Univ. Witwatersrand, Impact Cratering Research Group, Johannesburg, South Africa & Humboldt University (Mineralogy), Invalidenstrasse 43, D-10115 Berlin, Germany; ⁴Rutgers University, Dept. Geol. Sci., Piscataway, NJ 08854, USA.

The late Eocene Chesapeake Bay impact structure is among the largest and best preserved of the known impact structures on Earth, e.g. [1]. In 2004, a multidisciplinary drilling project for this crater, by a research team from 10 countries, had been accepted by the International Continental Scientific Drilling Program (ICDP). Drilling of the joint ICDP and U.S. Geological Survey (USGS) deep corehole into the Chesapeake Bay impact crater began during September 2005 and was completed in early December 2005. This was followed by geophysical logging in the borehole. The drill site is located at Eyreville farm, Northampton Co., Va., USA, above the near-circular moat structure that surrounds the central uplift of this impact structure. Post-impact marine sediments were cored (starting at 125 m depth) above the crater-fill impactite section, which consists (with depth) of sediment-clast breccia, sediment megablocks, a large granitic megablock, smaller sediment blocks, suevite and lithic impact breccia, and a section of only locally brecciated mica schist and pegmatites with rare veining of suevitic and lithic breccia. Overall, core recovery was good to excellent. However, trapped drill rods severely limited the geophysical logging program. Also, a second corehole, 5001-1-B (733 to 1,766 m), had to be drilled because the drill bit deviated from the original hole, 5001-1-A (0 to 941 m), during reaming.

Matrix-supported sediment-clast breccia constitutes the uppermost part of the impactite section. This breccia (known from other coreholes in the area and termed "Exmore Breccia") overlies thick sections of Cretaceous sands and clays that probably represent slumped megablocks. An unexpected 275-m-thick section of only weakly deformed granitoid underlies the sediment megablocks and probably represents a megablock of target material. The suevitic breccias are coherent, well lithified, and contain clasts of probable impact-melt rock, and fragments of cataclastically deformed metamorphic and igneous target rocks, in an apparently unsorted matrix of similar but finer-grained material. Lithic impact breccias are polymict and resemble the suevite except for a lack of evident impact-melt clasts. The suevitic breccias are underlain by mica schist and granite-pegmatite of the basement. About two dozen scientific teams are working on various geological, mineralogical, geochemical, and geophysical aspects of the borehole and the core samples.

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APPLICATIONS OF THE METEORITE PHYSICAL PROPERTIES DATA OBTAINED USING MOBILE LABORATORY FACILITY.

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Introduction: Physical properties of meteorites provide valuable information about the meteorite history and the meteorite parent bodies - asteroids. Meteorites represent valuable rare material and it is difficult to bring meteorites directly to the laboratory for scientific studies. Thus the *mobile laboratory facility* was established The Division of Geophysics, University of Helsinki in order to make a research tour over the museums and collections in Europe and to measure the physical properties of meteorites in the presence of the curator using *harmless, non-destructive methods*.

The 2005 European meteorite research tour: The tour was conducted in October 2005 using the mobile laboratory facility. During the tour the 6 member team visited 13 institutions in 8 countries across Europe and measured around 200 individual meteorite samples.

Instruments and methods: During the meteorite research tour the measurement of bulk physical parameters (magnetic susceptibility, bulk and grain density, porosity and magnetic remanence) of meteorites was performed.

The Hämäläinen TH-1 portable susceptibility meter with large (12 cm) coil was used for susceptibility measurements of bulk samples. For bulk volume measurements the chemically inert tiny glass beads (20 – 50 micrometer in diameter) were used to replace liquids used in traditional Archimedean method. The grain volume was measured by Notari portable air pycnometer working at low pressures. The mass was determined using digital balance always calibrated prior the measurements. The magnetic remanence was measured using portable Schoenstedt PSM-1 remanence meter.

Data application: The results of the project are used to enhance existing database of physical properties of meteorites.

The magnetic susceptibility and density show characteristic values for different meteorite classes and can be used for (1) rapid meteorite classification [1], (2) identification of mislabeled samples and (3) pairing the samples from meteorite showers.

The porosity data shows wide scatter even among meteorites of the same class. There is a trend in porosity showing decrease with the increasing metamorphic degree as well as with level of terrestrial weathering.

The other applications include Solar System history studies, data interpretation of planetary and asteroid space missions, future sample return research and asteroid mitigation efforts.

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AMOEBOID OLIVINE AGGREGATES IN YAMATO-86009 CV CHONDRITE: EVIDENCE FOR IN SITU AQUEOUS ALTERATION.

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Introduction: Amoeboid olivine aggregates (AOAs) are important refractory components of carbonaceous chondrites (except CH and CB chondrites) and have been interpreted to represent solar nebular condensates that experienced high-temperature annealing, but largely escaped melting [1]. Because AOAs in primitive chondrites are composed of fine-grained minerals that are easily modified during postcrystallization alteration, the mineralogy of AOAs can be used as a sensitive indicator of metamorphic or alteration processes. In order to understand the alteration history of the CV3 chondrites, we performed mineralogical studies of AOAs in the Yamato-86009 CV carbonaceous chondrite.

Samples and analytical procedure: Two polished thin sections of Y-86009, 51-1 and 51-2, were studied using optical microscopy, SEM+EDS, and EPMA.

Results and discussion: AOAs in Y-86009 are irregularly-shaped objects, 50-750 μm in size, composed of forsteritic olivine ($\text{Fo}_{>88}$), high-Ca pyroxene, anorthite \pm spinel ($\text{FeO} < 1 \text{ wt.}\%$). Forsteritic olivine typically shows enrichment in FeO along the cracks and grain boundaries. Anorthite is partly or completely replaced by fine-grained Al-rich phyllosilicates; nepheline is minor. Anhedral grains of hedenbergite occur along grain boundaries in direct contact with phyllosilicates. Euhedral fayalitic olivine grains (Fa_{63-71}) overgrow forsterite and occasionally show inverse compositional zoning. Some forsterite grains are overgrown by euhedral pyroxene ($\text{Wo}_{41}\text{En}_{56}\text{Fs}_3$, $< 10 \mu\text{m}$ in size) along the rim of AOAs. In some cases, enstatite ($\text{Wo}_5\text{En}_{94}$) occurs around the metal-magnetite nodules.

Based on our petrographic observations and the previously reported ^{16}O -rich compositions of olivine in the Y-86009 AOAs [2], we infer that these AOAs were originally similar to AOAs in the reduced CVs [3] and subsequently experienced low-temperature aqueous alteration. The observed alteration features in Y-86009 are similar to those in CAIs, chondrules, and matrices of the Bali-like oxidized CVs (CV_{oxB}) [4], however, there are some important mineralogical differences as well. The common presence of anorthite in AOAs and rarity of Fa_{100} implies that the degree of aqueous alteration is lower than other CV_{oxB} chondrites. In addition, secondary fayalite in Kaba (CV_{oxB}) rarely shows inverse compositionally zoning and approaches nearly pure fayalite. The presence of nepheline, sodalite and lath-shaped fayalitic olivine in matrix implies that Y-86009 also experienced higher temperature, and possibly more prolonged aqueous alteration than Kaba. We infer that Y-86009, like MET00430 [5], is intermediate between CV_{oxA} and CV_{oxB} . Indeed, inverse chemical zoning of individual ferrous olivines are similar to those in MET00430 [5], suggesting the dissolution of ferrous olivine and precipitation of more forsteritic olivine from a fluid phase during the late-stage thermal metamorphism.

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L CHONDRITE ASTEROID BREAKUP TIED TO ORDOVICIAN METEORITE SHOWER BY MULTIPLE ISOCHRON ^{40}Ar - ^{39}Ar DATING.

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Radiochronometry of L chondritic meteorites yields a rough age estimate for a major collision in the asteroid belt ~500 Ma ago [e.g., 1,2,3]. Fossil meteorites from Sweden indicate a highly increased influx of extraterrestrial matter in the middle Ordovician ~480 Ma ago [4]. An association to the L chondrite parent body event was suggested, however, a definite link is precluded by the lack of more precise radiometric ages of L chondrites. Here we report a high precision age value of the L chondrite asteroid breakup obtained by improved ^{40}Ar - ^{39}Ar dating.

High resolution ^{40}Ar - ^{39}Ar dating of the L5 chondrite Ghubara (host, chondritic xenolith, impact melt) demonstrated the presence of distinct excess argon components. We identified distinct trapped argon components with lower than terrestrial $^{40}\text{Ar}/^{36}\text{Ar}$ ratios at medium-high temperature extractions, proving their extraterrestrial origin. In particular, correcting the Ghubara melt age spectrum for trapped excess argon results in an age plateau comprising 24 temperature extractions (~95% ^{39}Ar release) with an age of 465 ± 4 Ma. This is to our knowledge the first report of non-terrestrial excess argon in asteroidal meteoritic samples identified and corrected for by a multiple isochron approach. Several circumstances favoured our discovery: sample selection, high resolution ^{40}Ar - ^{39}Ar analyses and measures to minimize neutron-induced ^{38}Ar from Cl (Cd shielding, relatively short irradiation time).

We found multiple isochrons also for L chondrite data of a previous study from the Heidelberg ^{40}Ar - ^{39}Ar laboratories [5]. The slightly revised ages are consistent, indicating a single asteroid breakup event. The weighted average of the individual results from five L chondrites (Ghubara, Paranaiba, Mbale, Taiban, Bluff) of 469.6 ± 5.4 Ma is in perfect agreement with a refined age estimate of the middle Ordovician meteorite shower at 467.3 ± 1.6 Ma [6]. Our results link these fossil meteorites directly to the L chondrite asteroid destruction, rapidly transferred from the asteroid belt and are consistent with the recently demonstrated short transfer time of fossil meteorites [7]. The new age value for the L chondrite event of 469.6 ± 5.4 Ma serves as a precise time marker to calculate the cratering rate before and afterwards, demonstrating that the terrestrial impact crater base [8] displays a significantly increased cratering rate by at least a factor of 4-5.

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SELENIUM AS POSSIBLE INDICATOR OF ASTEROIDAL DIFFERENTIATION.

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Magmatic iron meteorites are thought to have originated by fractional crystallization of the metallic cores of differentiated asteroids. The crystallization path of a metallic Fe,Ni liquid depends strongly on the initial concentration of non-metals, particularly sulfur. However, the initial sulfur content of the parental melts is poorly constrained. Previous methods have relied on modelling the behavior of metallic trace elements (Ge, Ir, As, etc.) whose partition coefficients are sensitive to melt composition. Here I outline a different way in which the initial sulfur content of the melt might be estimated.

The Se/S ratio of chondritic meteorites is, with few exceptions, remarkably constant [1]. Most magmatic iron meteorites originated in parent bodies that were probably roughly chondritic in bulk composition, e.g., siderophile element abundances in IIIAB irons are similar to those in ordinary chondrites. It can therefore be assumed that the parent bodies of most magmatic iron meteorites had a chondritic Se/S ratio.

Selenium has rarely been determined in the troilite of magmatic irons, but the few analyses that do exist show a Se/S ratio ~30% lower than in chondrites [2]. The abundance of daubréelite, which has a higher Se/S ratio than troilite, is insufficient to account for the missing Se. It is plausible that the remaining Se is present in the metal phase. This is because S behaves as major element and is saturated in the metallic phase, whereas Se behaves as a dilute solute in both liquid and solid. Hence during fractional crystallization of the core it obeys, at least approximately, Henry's Law. The exact solubility of Se in γ -Fe is not known, but it is sufficiently high to form a $\gamma \leftrightarrow \alpha + \text{FeSe}$ eutectoid at 885°C, 13° below the α/γ transformation temperature of pure Fe. The Se partition coefficient between melt and solid γ -(Fe,Ni) is likely to be small but not zero.

If the bulk Se content of both sulfide and metal phase can be determined, and a chondritic overall Se/S ratio is assumed, a simple mass balance calculation would yield the relative amounts of sulfide and metal in the original core. Sufficiently precise determination of Se in the metal phase is difficult, especially since a large α/γ segregation is expected from the phase diagram. However, with current analytical methods it should be possible to constrain the S content of the parent melt to within a factor of 2 or less.

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DISCOVERY OF THE SUDBURY IMPACT LAYER IN MICHIGAN, USA.

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Introduction: We have discovered deposits that contain probable distal ejecta from the 1,850 Ma Sudbury impact event in northern Michigan, about 500 km from the center of the impact structure in Ontario. They occur in marine sediments of the Michigamme Formation in the upper Baraga Group of the Marquette Range Supergroup and resemble deposits previously described in Ontario and Minnesota [1]. We are investigating material from five localities in northern Michigan, described here as the Baraga basin, West Dead River, East Dead River, Marenisco, and Republic sites [2]. All of these sites are at or within a few hundred meters above the base of the Baraga Group at a comparable stratigraphic horizon to the Ontario ejecta.

Results: At the Baraga basin site, a 1-2 m thick layer in the lower 10 m of the Michigamme Formation contains well developed accretionary lapilli, chert breccia, and quartz grains that contain single and multiple sets of planar zones of inclusions interpreted to be the metamorphosed relicts of shock-induced planar deformation features (PDFs). The West Dead River site consists of an isolated outcrop of material at least 2 m thick and probably at least 100 m above the base of the Michigamme Formation; it is rich in accretionary lapilli, contains angular chert fragments to about 1 m diameter, and shows strong carbonate replacement. The East Dead River locality is a bed of polymict breccia, about 30 m thick, which contains abundant chert clasts as well as volcanic-like fragments, including sparse accretionary lapilli and relict glass shards that have been replaced by chlorite. The bed is crudely graded with the coarsest clasts at the base. It lies about 300 m above the base of the Michigamme Formation, where it is underlain by banded iron formation and overlain by black pyritic slate. At the Marenisco locality, a 2-m thick bed of coarse sand and conglomerate near the base of the Copps Formation (Michigamme equivalent) contains abundant clasts of Archean granite, less abundant slabs of chert to about 2 m diameter, and quartz grains having possible relict PDFs; it shows strong carbonate replacement. The Republic site is a gravel pit in glacial till, where boulders rich in accretionary lapilli are thought to be locally derived.

Discussion: At this early stage of investigation, we have found accretionary lapilli similar to those at the Ontario locality at five sites. Probable metamorphosed relicts of PDFs are present in quartz at the Baraga basin site and can be found within the cores of lapilli, accreted shells of material, and interstitial matrix. Lapilli are up to 2 cm diameter, are sometimes concentrically zoned, and, rarely, contain lithic cores. Except for the PDFs and the very broad (200-400 km) geographic distribution of the lapilli, they are similar to volcanic lapilli formed in clouds with 15-25 wt.% water. The lapilli appear to have been produced in a vapor-charged cloud of impact ejecta that was deposited with sufficient energy, or subsequently reworked, to rip up local lithologies.

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PHASE RELATIONS IN NA-RICH CHONDRULES.

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Introduction: Chondrules are believed to have formed by a brief but intense heating and melting event in the early solar system. We describe two Na- and Al-rich chondrules [1] from UOCs Dar al Gani 369 and 378 [2,3]. Both chondrules contain *ol* and glassy mesostasis with <1 wt.% MgO and CaO, ~10 wt.% Na₂O. Both chondrules are low in FeO [2,4]. We discuss phase relations and with implications for concepts of chondrule precursors and nebular and parent body metasomatism.

Results and Discussion: Crystallization of *fo* as only liquid phase in CMAS decreases the MgO-content of the residual melt [7], but can only occur in melts containing >12 wt.% MgO. Therefore *fo* crystallization cannot lead to MgO-contents of <1 wt.% as observed in the Na-rich *ol*-chondrules [4]. Addition of Na₂O to the CMAS system expands the *fo* stability field towards lower MgO-concentrations in the residual liquid and can explain low MgO in alkali-rich mesostasis. The low MgO values could also be explained by metastable *ol* crystallization into the *fsp* or *px* stability fields or by a combination of presence of alkalis and rapid crystallization.

Dynamic crystallization experiments will be conducted in order to show if metastable *fo*-crystallization in the *fo-ab-an*-system can account for the observed low MgO contents.

Low Ca in the chondrules (<1 wt.%) may be explained in terms of a precursor that was mainly composed of *fo* and *ab*, which would be in agreement with presence of alkalis during chondrule melting and initial chondrule compositions close to the *fo-ab* eutectic composition. This implies a very brief melting event and/or an environment with high alkali activity. The alkali-rich and Ca-depleted precursor component may have formed by fractional condensation of alkali feldspar at <1000 K [5] or by recycling of Na-rich mesostasis from a previous generation of chondrules [6].

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REFRACTORY INCLUSIONS IN THE METAL-RICH CARBONACEOUS CHONDRITE ISHEYEVO.

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Introduction: Ca,Al-rich inclusions (CAIs) in the metal-rich CH and CB carbonaceous chondrites are characterized by a number of unique mineralogical and isotopic characteristics. For example, CB CAIs analyzed so far are uniformly ¹⁶O-depleted [1] and lack ²⁶Mg* [2]. CH CAIs show a bi-modal distribution of O- and Mg isotope compositions: (i) most CAIs are ¹⁶O-enriched; some igneous CAIs are ¹⁶O-depleted [3,4]; (ii) very refractory, grossite- and hibonite-rich CAIs lack ²⁶Mg*; the inferred ²⁶Al/²⁷Al ratio in less refractory, melilite-rich CAIs is $\sim 5 \times 10^{-5}$ [5-7]. Here we describe mineralogy and petrography of CAIs and amoeboid olivine aggregates (AOAs) in the recently discovered metal-rich chondrite Isheyevo [8]; oxygen and magnesium isotope studies of these CAIs are in progress.

Results: Isheyevo contains several lithologies which show mineralogical and chemical affinities to the CH and CB chondrites [8]. Based on the major mineralogy, 159 refractory inclusions found in ~ 10 cm² of X-ray mapped area of Isheyevo can be divided into hibonite±pyroxene±melilite (37%), grossite-rich (18%), melilite-rich (23%), spinel-rich (16%), pyroxene-anorthite-rich (5%) CAIs, and AOAs (1%). The CAIs and AOAs show no evidence for thermal metamorphism, Fe-alkali metasomatic or aqueous alteration; they are texturally and mineralogically similar to those in the previously studied CH (Acfer 182, ALH85085, PCA91467, PAT91546, NWA 470, 739, and 770) and to a lesser degree to those in CB_b (Hammadah al Hamra 237, QUE94411) chondrites. As a population of refractory objects, they are distinct from those in CR, CM, CV, CK, CO, and ungrouped carbonaceous chondrites Acfer 094, Adelaide, MAC87300, and MAC88107. Most Isheyevo CAIs are very refractory (hibonite- or grossite-rich), rounded or ellipsoidal objects, 20-240 μm in apparent diameter, which appear to have crystallized from rapidly cooling melts and escaped significant interaction with high-temperature nebular gas after solidification (secondary anorthite and Wark-Lovering rims are typically absent), suggesting a short residence time in the high-temperature condensation region. Less refractory CAIs (melilite- and pyroxene-anorthite-rich) and AOAs, 40-300 μm in apparent diameter, appear to have experienced more extensive high-temperature alteration resulting in replacement of melilite and spinel by anorthite and diopside, and formation of Wark-Lovering rims; some CAIs were melted prior to and during chondrule formation. We infer that there are two populations of refractory inclusions in Isheyevo that experienced different thermal histories.

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DIFFERENCES IN CHONDRULE FORMING ENVIRONMENTS BETWEEN LL AND CO CHONDRITES.

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The difference in the chondrule forming environments between ordinary (OC) and carbonaceous (CC) chondrites should be investigated in order to clarify the origin of chemical group of chondrites. Petrology of common ferromagnesian chondrules in the least metamorphosed OCs have been well studied [1-3]. Although petrological and isotopic observations on the least metamorphosed CCs have been vigorously carried out recently, systematic investigations of the primitive CCs are limited. Here, we report bulk chemical compositions of individual ferromagnesian chondrules in from CO3.0 Yamato-81020, and compare them to those from LL3.1 Bishunpur and LL3.1 Krymka [4-5].

Bulk major elemental abundances of chondrules measured by EPMA show that elements more refractory than Si are unfractionated for both CO and LL Type I chondrules, and volatile elements decrease with volatility. In particular, CO Type I chondrules are more depleted in volatiles than LL Type I chondrules (average Na abundance; CO 0.11, LL 0.50). Type II chondrules are basically unfractionated for both CO and LL. The bulk compositions of chondrules, CAI and matrix in Y-81020 normalized to those of the bulk chondrite suggest that Type I and II chondrules and matrix are depleted and CAIs are enriched in refractory elements, and Type Is are richer in refractories than Type IIs. Regarding volatiles, Type Is are depleted, whereas Type IIs are enriched and matrix is more volatile rich. These diversities of chondrules between OC and CC were established in spatially separated regions in the protoplanetary disk, and not by different time, because chondrules of both CO and LL were formed contemporaneously, except CO Type IIs [6]. These observations along with non-fractionated pattern of Type IIs suggest the following scenario: (1) refractory elements were fractionated at the early stage, of which residues became precursor of chondrules, and (2) Type Is were formed from precursor with composition close to Type II through evaporative loss of volatile components, and the evaporated fraction added to matrix. In this scenario, matrix is pristine but volatiles were enriched during chondrule formation. As the distribution of Fe is only incompatible with the other volatile elements, we also estimated total Fe abundance in Type I and IIs. Type Is in both CO and LL contain less total Fe abundance (3-15wt%). On the other hand, Type IIs in CO have higher Fe abundance (20-27wt%) than those of LL (12-15wt%). The significant enrichment of in Type II in CO is not explained by only volatility-controlled processes, and another explanation is needed, that is, difference in their precursors which might regard metal/sulfide and silicate fractionation during chondrule formations.

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A NEBULAR ORIGIN OF CHLORAPATITE AND SILICATE GLASS IN THE GUIN (UNGR) IRON.

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Silicate inclusions in iron meteorites [e.g., 1] are believed to sample primitive (chondritic) as well as chemically fractionated parent bodies [2]. Inclusions in IIE irons have extreme fractionations, which are commonly considered to be due to impact melting and mixing of feldspars and silica from the surface of a highly differentiated parent body [e.g., 3, 4]. Studies of IIE iron-like inclusions from the Guin (ungr) iron show that they record nebular rather than planetary fractionation processes.

Large silicate inclusions in Guin are common [5] and consist of devitrified siliceous glass with or without augite and phosphates. We investigated an elongated oval (2 x 0.5 cm²) devitrified glass inclusion consisting of a fine-grained intergrowth of albite, silica and low-Ca pyroxene with accessory ilmenite, rutile, FeNi metal, FeS, Cl-apatite and whitlockite. Albite dominates the chemical composition with (in wt%) 70.3 SiO₂, 16.8 Al₂O₃, 0.04 MgO, 1.4 FeO, 1.3 CaO, 8.5 Na₂O, 0.7 K₂O and 0.17 P₂O₅. Trace element (TE) contents are low (~0.1×CI) except for Ti, Sr, Zr and Nb (~10×CI) and Sc (~1×CI). The REE contents are also low (<0.1×CI) and decreasing from La to Gd (~0.02×CI) and increasing again towards Lu (~0.1×CI). Eu and Yb have positive anomalies. A chlorapatite co-existing with the devitrified glass has low Ti, V, Zr and Nb (<0.1×CI) and high Sr (~20×CI), REE and Y (~70-80×CI) contents with a flat abundance pattern and negative anomalies in Eu and Yb. The complementary TE patterns of Cl-apatite and glass suggest an igneous origin. However, compared to experimental distribution coefficients of TE between apatite and a siliceous liquid [6], the Guin assemblage is far out of equilibrium (e.g., La K_d ~12, but La_[ap]/La_[gl] ~750!), except for Sr. In addition, the REE abundance pattern of apatite does not follow the distribution coefficients but rather is flat and resembles the group III-pattern of CAIs [7] but at an abundance similar to that in hibonites [e.g., 8] and oldhamites [e.g., 9, 10]. The pattern and abundance level suggest a TE-rich precursor phase for the apatite, oldhamite?, that formed by condensation from nebular gas at low fO₂ [11].

The very low TE content of the glass is similar to those of glasses from other IIE irons [e.g., 4, 12, 13] and does not support a derivation from albite as is widely advertised [3, 4] because it is unfractionated. The positive anomalies of Eu and Yb make the pattern very similar to one reported for a glass from the Colomera IIE iron [12] where the anomalies were considered to be due to "...melting of silicates under highly reducing conditions, similar to those for enstatite chondrites". However, to us the TE pattern of the Guin glass suggests derivation from a nebular reservoir strongly depleted in refractory TE (and Mg!) but not in Eu and Yb. Chlorapatite and devitrified glass in Guin appear to be genetically related but not via an igneous system but via the solar nebula. The precursors could have been oldhamite and a siliceous liquid which subsequently experienced oxidizing conditions that turned oldhamite into chlorapatite [e.g., 14, 15]. Metal trapped the products and preserved this primitive matter [see also 16].

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DETERMINATION OF ^{26}Al CONTENTS FOR ANTARCTIC METEORITES USING EXTREMELY LOW BACKGROUND γ -RAY COUNTING SYSTEM OF ICRR, UNIVERSITY OF TOKYO.

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Introduction: Determination of terrestrial ages of Antarctic meteorites supplies useful informations for the frequency of meteorite fall, mechanism of accumulation of meteorites and the age of ice. ^{26}Al ($T_{1/2} = 7.17 \times 10^5\text{y}$) is a useful tool for the dating of terrestrial age of meteorite.

Samples and Experimental: ^{26}Al contents in Yamato-791199, -791192 and -791962 meteorites have been determined non-destructively by extremely low background γ -ray counting system of Institute for Cosmic Ray Research, University of Tokyo. The counting system consists of a well type of large volume high pure Ge detector. Absolute counting efficiency of the detector was 1.76% at 1809keV γ -ray of ^{26}Al . 1.73 to 1.78g of crushed samples were packed in plastic vials prior to put into the well of detector.

Results and Discussion: The determination results are shown in Table 1 with the sample weight for determination and the count length. The results are generally consistent with those of previous work [1-3].

Usually, determinations of ^{26}Al contents for more than 100g of samples are performed by γ -ray count non-destructively. However, those for small samples such as less than 20g are very difficult. Recently, accelerator mass spectrometry (AMS) analysis has been applied to determination of ^{26}Al in meteorites. Although the sample amount of AMS analysis is small, this analysis is destructive.

For small size of meteorites which original weights are less than 2g, non-destructive determination of ^{26}Al content using extremely low background γ -ray counting system has a great advantage, because we can get other informations such as chemical, petrological and mineralogical informations from the same samples after ^{26}Al determination.

Table 1. ^{26}Al contents in Antarctic meteorites

sample	weight (g)	count length (days)	^{26}Al content (dpm/kg)
Y-791199 (Anorthosite)	1.78	180	55 ± 4
Y-791192 (Eucrite, polymict texture)	1.73	124	94 ± 5
Y-791962 (Eucrite)	1.73	181	89 ± 4

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METEORITIC MICROFOSSILS IN ELTANIN IMPACT DEPOSITS.

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Introduction: We report the unique occurrence of microfossils composed largely of meteoritic ejecta particles from the late Pliocene (2.5 Ma) Eltanin impact event. These deposits are unique, recording the only known km-sized asteroid impact into a deep-ocean (5 km) basin. First discovered as an Ir anomaly in sediment cores that were collected in 1965, the deposits contain mm-sized shock-melted asteroidal material, unmelted meteorite fragments (named the Eltanin meteorite), and trace impact spherules. Two oceanographic expeditions by the FS Polarstern in 1995 and 2001 explored ~80,000 km² of the impact region, mapping the distribution of meteoritic ejecta, disturbance of seafloor sediments by the impact, and collected 20 new cores with impact deposits in the vicinity of the Freeden Seamounts (57.3°S, 90.5°W). Analyses of sediment cores show that the impact disrupted sediments on the ocean floor, redepositing them as a chaotic jumble of sediment fragments overlain by a sequence of laminated sands, silts and clays deposited from the water column. Overprinted on this is a pulse of meteoritic ejecta, likely transported ballistically, then settled through the water column. At some localities, meteoritic ejecta was as much as 0.4 to 2.8 g/cm². This is the most meteorite-rich locality known on Earth.

Results: Two cores were taken in a basin near the top of the Freeden Seamounts at a water depth of 2.7 km. Sediments in this shallow basin are compositionally different than those at all other sites as they contain abundant calcareous microfossils. In deeper water sites (4 to >5 km depth), higher pressures and CO₂ concentrations cause dissolution of calcite and sediments contain siliceous (opal) microfossils or are barren. An exception to this is a few sites in the immediate vicinity of the seamounts that contain calcareous sediments that flowed off the seamounts after being disturbed by the impact. At the top of the seamounts, sediments with meteoritic ejecta are bioturbated by burrowing organisms. Microfossils of one of these organisms are truly remarkable. These "agglutinated" foraminiferans are unicellular, live in the sediment, and construct their shells from mineral grains in the sediment, which they bind together with an organic cement. The microfossils occur as tubes (up to 7 mm x 3 mm), with a central cavity that the foraminifer inhabited. Interestingly, this particular species of foram is known as a "disaster" species that is quick to re-inhabit an environment after a devastating event, such as a volcanic eruption, or, as we now know, an asteroid impact. On the Freeden seamounts, the most abundant "mineral" grains in these sediments, other than calcareous microfossils, are fragments of meteoritic ejecta. Point counting of 283 grains (25 to 250 μm) examined by microprobe EDS and WDS in one specimen revealed that 70% of the particles are meteoritic ejecta, primarily vesicular melt rock with lesser pyroxenes and anorthite from the Eltanin meteorite. The other 30% is terrestrial quartz, feldspars, unclassified grains (probably mostly basaltic glass fragments), and a few lithic grains and microfossils.

THE STUDY OF SCHREIBERSITE AND MICRORHABDITE EXTRACTED FROM SIKHOTE-ALIN METEORITE.

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Introduction: Iron meteorites contain iron nickel phosphides (Fe,Ni)₃P in the forms of schreibersite and rhabdite. Schreibersite and rhabdite are formed as a result of heterogeneous and homogeneous nucleation mechanisms, respectively [1]. The differences of these phosphides morphology and crystal structure are of interest and, therefore, were studied using various techniques.

Methods: The sample of schreibersite was prepared as a powder using mechanically extracted massive schreibersite from Sikhote–Alin (IIB) meteorite that was treated with HCl to remove kamacite residue. The microrhabdite crystals were extracted electrochemically from Sikhote–Alin (IIB) meteorite. Mössbauer spectra were measured at room temperature using spectrometer SM–2201 with high accuracy, stability and sensitivity in transmission geometry. X–ray diffraction study of microrhabdite and schreibersite was performed with STADI-P diffractometer and VEPP-3 synchrotron equipped by MAR 3450 detector. The Fe, Ni and P concentrations in extracted phosphide crystals were measured by SEM Philips 30-XL with EDX.

Results and discussion: The schreibersites with size up to 30 μm were located in α - α grain boundary of Sikhote-Alin meteorite. The extracted microrhabdite look like thin plates about 150 μm in length and prismatic crystals about 5 μm in cross section. Mössbauer spectra of schreibersite and microrhabdite samples were different [2]. Mössbauer spectrum of schreibersite was complicated and consisted of at least several magnetic sextets and several quadrupole doublets. Mössbauer spectrum of microrhabdite demonstrated the presence of unresolved magnetic sextet and possibly quadrupole doublet. The unresolved magnetic sextet may be a result of the relaxation processes or fuzzy magnetic phase transition in the sample at room temperature as well as a result of superparamagnetic behavior of microrhabdite particles. X–ray diffraction study of phosphides showed the following parameters of the unit cell: $a_{sch} = 9.049(8) \text{ \AA}$, $c_{sch} = 4.461(8)$, and $a_{rhab} = 9.029(3) \text{ \AA}$, $c_{rhab} = 4.461(5)$ for schreibersite and microrhabdite, respectively. The Fe content in schreibersite and microrhabdite was approximately 50 and 38 wt. %, respectively, while Ni content was 30 wt. % in schreibersite and 40 wt. % in microrhabdite. Skala [3] demonstrated that nickel and iron atoms are not distributed equally over three crystallographically non-equal sites of the structure. These results demonstrated the differences of the hyperfine interactions, structural parameters and Fe/Ni content in schreibersite and microrhabdite. It is possible that Ni content increase in microrhabdite correlates with value decrease of unit cell parameter a_{rhab} [4]. Further studies are required to analyze structure, chemistry, and hyperfine parameters mutual relationships for phosphides with different morphologies.

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DEVELOPMENT OF A NEW RESONANCE IONIZATION MASS SPECTROMETER FOR THE ISOTOPIC ANALYSIS OF KR AND XE

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A new spectrometer has been built for measuring very small Kr and Xe abundances. This instrument consists of a resonant ionization ion source, a cryogenic sample concentrator and a time-of-flight mass analyzer. It is based on a similar design than the instrument developed at IRIM, Knoxville, University of Tennessee [1,2] or than the “RELAX” spectrometer working at University of Manchester [3,4]. Initially designed for Kr measurements, this new instrument allows Xe analyses by simply tuning the wavelength for ionization. A two-photon excitation, followed by one-photon ionization at the same wavelength (“2+1” transition) is used. A Kr atom resonantly absorbs two photons with 216.7 nm wavelength, resulting in the electron transition from ground state to $5p[5/2]_2$ state, and then the excited atom subsequently absorbs another photon non resonantly, exceeding the ionization energy level. For Xe, ionization can be achieved following a similar procedure but using a 217.1 nm wavelength ($7d[1/2]_0$ state). Ultra-violet beams are generated by mixing third harmonic of a Nd:YAG laser (1.6J, 10Hz) with a dye laser pumped by the second harmonic of the Nd:YAG laser. Atoms of Kr in the instrument are condensed on a cold trap at 25-35°K and released after heating by a pulse of an IR NdYAG laser (50 mJ). Ionization and heating lasers are delayed in order to obtain the maximum ionized atoms in the source of the Time Of Flight spectrometer. For now, the detection limit is about several thousands of Kr atoms. Measurements with this new instrument are in progress to determine CRE of iron meteorites by using ^{81}Kr -Kr dating [4]. Cosmic ray exposure dating in iron meteorites is an important tool for studying variations of galactic cosmic ray in the past and complex irradiation histories of meteorites [5].

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TOF-SIMS ANALYSIS OF CRATER RESIDUES FROM PROJECTILES SHOT ONTO ALUMINUM FOIL.

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Introduction: Samples from the *Stardust* mission offer the first opportunity to analyze cometary matter collected under controlled conditions [1, 2]. In addition to aerogel, Al foils were exposed to the comet as well. These foils were used to facilitate the removal of the aerogel blocks from the collector trays [2].

In this ongoing study [3–5], time-of-flight secondary ion mass spectrometry (TOF-SIMS) is being used for the analysis of crater residues on Al foils from laboratory impacts that employed a variety of well characterized projectile materials. The major goal of this investigation is to evaluate how well the chemical composition of the projectiles can be reproduced by TOF-SIMS.

Samples and Experimental Procedures: Powdered materials were fired into *Stardust*-type Al foils with impact velocities ranging from 4.2 to 6.1 km/s. Due to fragmentation in the launch process, a wide range of crater diameters was observed. Initial analyses of projectile residues used powdered CV3 chondrite Allende [3–5], hornblende and coal standards [5]; the present, investigations extended this work to a set of well characterized minerals, including olivine, diopside, pyrrhotite, and bytownite.

After necessary sputter cleaning through Ar ion bombardment, individual craters were rastered with a 0.2 μm $^{69}\text{Ga}^+$ primary ion beam. From the distribution of secondary ions from major elements, regions of interest were selected for the generation of mass spectra and calculation of element ratios using relative SIMS sensitivity factors derived from glass standards [6].

Results and Discussion: Geometric mean values of most element ratios relative to Si for nearly all examined Allende residues are close to CV element ratios and fit well within the range of ratios observed for Allende chondrules [7].

Due to their greater homogeneity, element ratios in the hornblende residues show significantly less deviations from reference data [8] than the Allende data, as most ratios are within a factor of 1.5 identical to literature values.

Analysis of the coal residues was focused on the behavior of complex molecules. Although Ar sputter cleaning destroys some of the hydrocarbons, they still could be detected in the craters [5].

The analysis of olivine, diopside, pyrrhotite, and bytownite residues is still in progress.

Conclusions: The first results show clearly that rocky material impinging on Al foil at ~6 km/s can be identified by TOF-SIMS analysis. Furthermore, even complex molecules can survive the impact on Al foils under these conditions.

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AMORPHOUS SILICATE HYDRATION IN THE PROTOPLANETARY DISK: AN EXPERIMENTAL APPROACH.

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Introduction: In the inner region of the protoplanetary disc, water is found in form of vapour. If this vapor interacted with silicates, at locations where the inner planets and parent bodies of meteorites formed, it could be of a primary importance to their evolution [e.g., 1]. Silicates are good candidate to carry on water, in form of hydroxyl bonds. Earlier works showed that hydration of silicates was not kinetically possible on nebular timescales with crystalline silicates as the solid reservoir [2]. However ISO spectra showed that interstellar silicates are amorphous [e.g., 3], probably irradiated within interstellar shockwaves [4]. Since the protoplanetary disk was formed by interstellar materials, the hydration behaviour of amorphous silicates precursors must be examined.

Experimental procedure: Hydration experiments were performed from room temperature to 200°C for various reaction times, at 1 atmosphere and saturated water vapour pressure. The silicate materials used were amorphous thin films having a composition close to olivine. The thin films were studied by optical microscopy, scanning electron microscopy (SEM), atomic force microscopy (AFM) and transmission electron microscopy (TEM).

Results: The first modification that appeared in the amorphous thin films consists of extended patches, well visible by optical microscopy. Crystallization of hydrated minerals occurs within these patches, in form of extended needles, nano-scale fibrous texture and well faceted crystals, depending on the experimental conditions. TEM characterization showed that the amorphous phase converted into phyllosilicates, mainly composed of talc, frequently associated with brucite. Kinetics strongly depends on temperature but also on the thin film thickness.

Conclusion: Phyllosilicates are present in the most primitive materials from our solar system (IDPs, micrometeorites, carbonaceous chondrites). In carbonaceous chondrites they display clear evidences for aqueous alteration but the original materials from which they are formed is still largely debated. Recently it was proposed that phyllosilicates can be nebular products [5]. This hypothesis is supported by hydration experiments on magnesiosilica smokes [6]. Our preliminary results confirm that phyllosilicates can be formed from amorphous precursors that simulate interstellar silicates, in interaction with water, at relatively low temperature.

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TITANIUM ISOTOPES IN SOLAR SYSTEM OBJECTS.

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Introduction: Isotopic anomalies in solar system objects provide powerful constraints on the origin and evolution of the early solar system. Of particular importance are titanium isotopes in refractory inclusions from primitive meteorites because *i*) titanium isotopes are important indicators of nucleosynthetic processes contributing to iron group elements and *ii*) titanium isotopes may also serve as an indicator of possible irradiation processes in the early solar system. Variations in titanium isotopes have been reported for refractory inclusions from Allende (CV3), whereas the type of the anomalies was not well characterized, e.g. [1,2,3]. However, while all earlier studies agreed that virtually every Ca-Al-rich refractory inclusion from Allende contains anomalous titanium, the titanium isotopic composition of other meteoritic constituents is still not completely characterized with respect to their nature and extent. Here we present a detailed and consistent database for the titanium isotopic composition in various solar system objects.

Experimental: Sample preparation, chemical separation, and data reduction followed the procedures described by [4,5]. Measurements of isotopic ratios were performed with the high resolution MC-ICP-MS (Nu 1700) at ETH Zürich.

Results: After correcting for *i*) mass fractionation (internally via ⁴⁹Ti/⁴⁷Ti), *ii*) external and plasma specific interferences, and *iii*) blanks the external reproducibility (2σ) obtained from repeated measurements of terrestrial basalts is 0.36ε, 0.38ε, and 0.28ε, for ⁵⁰Ti/⁴⁷Ti, ⁴⁸Ti/⁴⁷Ti, and ⁴⁶Ti/⁴⁷Ti, respectively. Comparing our data obtained for various standard solutions (synthetic solutions and terrestrial basalts) with literature data clearly indicate that the terrestrial titanium isotopic composition is not well defined. The “standard ratios” used by different groups for normalization differ by up to 15ε-units, making titanium the element with the least known atomic weight among all elements [6].

An unexpected result is the detection of anomalous titanium in ilmenite separates from lunar rocks. New model calculations will enable us to check whether such anomalies are real or whether the effect is simply caused by interactions with galactic cosmic-rays. Most of the meteoritic material analyzed display a normal titanium isotopic composition. For Allende CAIs we confirm an excess of ~10ε in ⁵⁰Ti/⁴⁷Ti. In contrast to earlier studies we found excess ⁵⁰Ti in Allende bulk material (~3ε). Significant anomalies were also found in troilites from Estacado (H6) and in leachates from Allende and Murchison. The new database will be discussed with respect to galactic cosmic-ray interactions, nucleosynthetic processes, and a possible early solar system local irradiation scenario.

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OLIVINES IN MAGNESIAN PORPHYRITIC CHONDRULES: MANTLE MATERIAL OF EARLIER GENERATIONS OF DIFFERENTIATED PLANETESIMALS?

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Libourel and Krot [1] reported the discovery of lithic clasts having granoblastic texture and composed of forsterite and Fe,Ni-metal within Type I chondrules from the CV carbonaceous chondrite Vigarano. They suggested that Type I chondrules consist of an inherited, relict component, mainly forsteritic olivine and \pm Fe,Ni-metal, originated from olivine-dominated (dunite-like) mantle material of earlier generations of differentiated planetesimals, and an igneous component equilibrated with nebular gas – glass, low-Ca pyroxene, high-Ca pyroxene, and \pm silica phase. In this scenario, the olivine lithic fragments predate formation of Type I chondrules. The chondrule mesostasis, low-Ca and high-Ca pyroxenes are the result of a reprocessing of these olivine clasts in the nebular gas followed by melt infiltration and progressive partial dissolution of the olivines along grain boundaries. The variability in chemical composition observed in the glassy mesostases of Type I chondrules results from the progressive addition of a volatile-rich component from the nebular gas [1-3]. If this interpretation is correct, detailed studies of these olivine-rich granoblastic aggregates can help to constrain the main characteristics of these olivine-dominated (dunite-like) mantle material of earlier generations of differentiated planetesimals. We therefore extend our survey to other CV carbonaceous chondrites, including Allende, Efremovka, Leoville, Mokoia and Vigarano.

From a detailed characterization of the mineralogy and chemistry of these lithic clasts we confirm the occurrence of coarse-grained forsteritic clasts with equilibrium textures inside Type I chondrules in all the studied CV chondrites. From their oxygen isotopic composition, we infer that these igneous objects, which are ¹⁶O-enriched [see also 4, 5] in a similar manner as refractory forsterites [6], may be derived from planetesimals that were disrupted (they have a common $\Delta^{17}\text{O}$ signature). However, if olivines in the CV magnesian chondrules studied are lithic fragments of pre-existing planetesimals, their $\Delta^{17}\text{O}$ values indicate that these planetesimals may not have been sampled yet, since differentiated meteorites have ¹⁷O values $>-3\text{‰}$ [7], at the exception of olivines from a few pallasites such as Eagle Station with $\Delta^{17}\text{O} = -4.8\text{‰}$ [8].

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RECOVERY OF 5354 METEORITES IN GROVE MOUNTAINS, ANTARCTICA, BY THE 22ND CHINESE ANTARCTIC RESEARCH EXPEDITION

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Introduction: The Grove Mountains is one of the most meteorite-enriched regions in Antarctica, as demonstrated by discovery of a total of 4480 specimens by the 15th, 16th and 19th Chinese Antarctic Research Expeditions (CHINARE) during 1998-1999, 1999-2000 and 2002-2003 austral summer seasons, respectively^[1-3]. In 2005-2006 season, another field party of 11 members explored Grove Mountains again, and found a total of 5354 fragments of meteorites.

Results: Grove Mountains locate east to Amery ice sheet and about 400 km south to the Zhongshan station of China, eastern Antarctica. There are 64 nunataks in this region, and altitude of the ice fields ranges from 1850m to 2060m. On the eastern side, the Gale Escarpment ridge, consisting of three parts, ranges about 50 km in length and in direction of NNE. It blocks the ice sheet flowing from east, with most meteorites stranding along the downstream side of the ridge.

The field party departed from Zhongshan station on Dec. 23, 2005, and returned back on Feb. 18, 2006. It took 17 days on the way, and we had only 41 days on the ice fields in Grove Mountains. Most of the meteorites were collected in the first 20 days, and the rest of time was mainly used for other fieldworks, including geological survey, mapping, and remote sensing flow of the ice sheet.

In the southern part of Gale Escarpment, there was no moraine. All 21 meteorites were found on blue ice, with a total mass of 61g. 2438 specimens (15.9kg) were collected in the middle part, and 2144 of them are small fragments found in moraines. These small fragments are heavily weathered, with little fusion crust remained. They are probably fragments from much less number of meteorites. The northern part of Gale Escarpment is the most meteorite-concentrated area in Grove Mountains, with a total of 2847 meteorites (44.2kg in weight) found in this expedition. Although more than half of the specimens are less than 1g, many of them have complete fusion crusts and are not fragments broken by weathering. Distribution of meteorites in this area was continuous from moraines to blue ice without clear cutoff. The meteorite collection sites nearly overlaps with those in the 19th CHINARE, indicating continuous coming up of meteorites onto the surface of ice fields.

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OXYGEN ISOTOPIC COMPOSITIONS IN CM HIBONITE: IMPLICATIONS FOR SOLAR NEBULA HETEROGENEITY.

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Introduction: CM hibonite crystals are known to preserve isotope anomalies of large magnitude in Ca, Ti and O [1-7]. A recent study has also confirmed the existence of apparent deficits in ²⁶Mg in a population of platy hibonite crystals [8]. Unlike the correlation between ⁴⁸Ca, ⁵⁰Ti, and ²⁶Al, oxygen anomalies seem to be independent of hibonite chemistry and morphology [1-7]. We have determined the oxygen isotopic compositions in a suite of Murchison hibonite grains that have been characterized for Mg isotopes [8] in an attempt to better understand the distribution of O isotopic reservoirs in the solar nebula.

Results and Discussion: Oxygen isotope mass spectrometry was performed with the UCLA CAMECA 1270 ion microprobe using the procedures described in [9]. In this session, 6 platy-crystals (PLACs), 6 spinel-hibonite spherules (SHIBs) and 1 blue-aggregate (BAG) were measured. All samples are enriched in ¹⁶O relative to terrestrial values with ¹⁷O ranging from ~ -15‰ to -25‰, and one extraordinary BAG hibonite with ¹⁷O = -38‰. While our results are broadly similar to those found previously [2,5,7], the new data show a tendency for PLACs to sample larger oxygen variations than SHIBs. This would be consistent with larger isotopic anomalies generally being associated with PLACs, however there is no apparent quantitative correlation between ⁴⁸Ca or ⁵⁰Ti or the presence of Mg isotope anomalies (²⁶Mg* deficits) and the magnitude of the observed ¹⁶O excesses.

Among all the samples, the aggregate ANU-Hib1 is of special interest because it exhibits very heterogeneous Mg isotopic compositions (²⁶Mg* = 0‰ and -6‰ in 2 spots). Two different spots differ by ~50‰ in both ¹⁷O and ¹⁸O, and plot on a slope 1 trajectory, offset from the CCAM line by ~15‰. If we assume that the primary oxygen isotope composition of the most ¹⁶O-rich ANU-Hib1 spot evolved off the CCAM line by mass fractionation, similar to what is observed in FUN inclusions [10], we infer a starting composition of (¹⁸O = -81‰, ¹⁷O = -80‰), which is consistent with the most ¹⁶O-rich composition yet observed [11]. Since ANU-Hib1 is an aggregate, the large internal heterogeneity may be ascribed to preservation of distinct oxygen isotope compositions in different hibonite laths. This implies that there must be multiple oxygen reservoirs present in the solar nebula during hibonite formation, although the poorly understood chronology of hibonite formation precludes conclusions regarding possible evolution of those reservoirs.

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DIGGING DEEP IN THE SUPERNOVA: TiC AND Fe METAL COMPOSITES IN PRESOLAR GRAPHITE.

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Introduction: Micron-size presolar graphite of type II supernova (SN) origin can contain numerous inclusions of TiC and Fe,Ni-metal up to several hundred nm in size [1]. In most instances, metal is directly attached to TiC subgrains, which [1] interpreted by TiC and metal condensation prior to graphite. Graphite condensation requires a C-rich environment with $C/O > 1$ but a typical condensation sequence at $C/O > 1$ in an otherwise solar composition gas is TiC-graphite-SiC-FeSi. So FeSi condenses instead of metal and neither SiC nor FeSi were found in the grains described by [1]. Hence the question how did the TiC-metal-bearing graphites form in SN ejecta?

Condensates in SN Zones were calculated for a 25 solar mass SN using averaged zone compositions from [2]. None of the individual SN zones returns the observed condensate sequence for the grains. Zone compositions with $C/O < 1$ can be excluded because they yield oxides and silicates. The He-C zone with $C/O > 1$ favors TiC and graphite, but in addition SiC and FeSi condense. The inner C- and O-poor Si-S and Ni-zones yield metals, sulfides, and exotic refractory silicides for *averaged* compositions. These exotic condensates appear irrelevant to the observed assemblage; but only the Si-S and Ni zones produce ^{44}Ti and ^{49}V whose decay products are seen in presolar SN graphites.

Digging Deeper: The ejecta composition of the Ni-zone is quite variable as it depends on the mass-cut and fall back from the SN explosion. A check of the condensates along the compositional gradient of the Ni-zone ejecta shows that titanides such as Ti_5Si_3 and $(\text{Fe,Ni})_2\text{Ti}$ also appear. Formation of refractory $(\text{Fe,Ni})_2\text{Ti}$ is especially favored if Si and S abundances are reduced. This can be achieved at the innermost ejecta by complete Si-burning with α -rich freeze-out also responsible for ^{44}Ti .

Formation of $(\text{Fe,Ni})_2\text{Ti}$ is the key to the presolar grain observations [3]. If the Si and S-poor ejecta make it to the C-rich He-C zone, carburization via $(\text{Fe,Ni})_2\text{Ti} + \text{C} = \text{TiC} + 2(\text{Fe,Ni})$ can explain the observed TiC-metal grains in the presolar graphite. However, the Ni-zone ejecta must cross the Si-S zone and the O-rich O-Si, O-Ne, and O-C zones without mixing before reaching the He-C zone. This may not be a problem if the products of α -rich freeze-out are ejected from the core in bipolar jets, which are known to be associated with asymmetric core-collapse SN.

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GERMANIUM ISOTOPIC VARIATIONS IN IRON METEORITES

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Introduction: Magmatic and nonmagmatic iron meteorites have been thought to represent distinct portion of planetesimals, core and outer part of differentiated bodies, respectively. However, processes by which the nonmagmatic irons (IAB-IICD and IIE groups) are generated, near-surface impact-melt model [1] vs. deep origin [2] remain unsolved, especially for the IIE groups. In this respect, Germanium which is the most volatile siderophile element is sensitive to processes linked to core formation, such as metal-silicate diffusion and redox process, and to evaporation processes [3]. Ge elemental distribution and Ge isotopic ratios can thus provide informations on the mechanisms of formation and origin of iron meteorites. We present additional Ge isotope data of IAB, IIIAB, IIC magmatic and IAB-IICD, IIE nonmagmatic iron meteorites, on samples covering a broad range of Ge concentrations.

Methods: Ge isotopes are measured using the Isoprobe Multi-Collector ICP-MS (CRPG-Nancy) with a precision better than 0.06‰ per amu (2σ total external reproducibility on 11 total replicate analyses of the Magura IAB meteorite, including chemistry, in 7 sessions during 4 years)(‰ $\delta^x\text{Ge} = ((^{x}\text{Ge}/^{70}\text{Ge})_{\text{sa}} / (^{x}\text{Ge}/^{70}\text{Ge})_{\text{JMC Std}} - 1) * 1000$). Germanium was perfectly isolated from the matrix by liquid-liquid chromatography [4,5].

Results-Discussion: In comparison to previous results, the variations of Ge isotopic ratios have been extended, with a total range of $\delta^{74}\text{Ge}$ from -0.22 to 1.86‰, defining a single mass fractionation line similar to the TMFL [5]. The $\delta^{74}\text{Ge}$ data show a remarkable distinction between magmatic and nonmagmatic groups, without any inter-group correlations with Ge, Ir, Ni contents:

- *magmatic groups* have similar and high $\delta^{74}\text{Ge}$ values ($\delta^{74}\text{Ge} = +1,35$ to $+1,86$ ‰) for distinct Ge contents. The precision of data even allows distinction between IIA ($\delta^{74}\text{Ge} = 1,77 \pm 0,17$ ‰) and IIB ($\delta^{74}\text{Ge} = 1,35$ ‰) samples.

- *nonmagmatic groups* have low $\delta^{74}\text{Ge}$ values: high Ge IAB-IICD samples have clustered values around $1,15 \pm 0,19$ ‰; low Ge IIE samples have lower values with distinction between the Miles group ($-0,22$ to $+0,43$ ‰) and Watson (1,4‰).

Whatever the complex history of magmatic and nonmagmatic irons leading to their Ge-Ir-Ni geochemical trends (e.g. fractional crystallization, trapped liquid, impact melt mixing; [1,2,6]), it does not govern the isotopic fractionation of Germanium. The data will be discussed as follows: (1) isotopic fractionation in the early stage of formation of these irons, and reflecting the specific redox state of Germanium: either by core segregation for magmatic iron (Ge reduction in metal form, diffusion/reequilibration) or impact melt/gas for nonmagmatic group (formation of volatile Ge oxides enriched in ^{70}Ge); (2) more likely, they can also reflect the isotopic composition of their parent body and thus their degree of redox state. In this way, the correlation between $\delta^{74}\text{Ge}$ of a given group of iron (this work) and $\Delta^{17}\text{O}$ of their silicate inclusions and chondritic parent bodies [7] will be discussed.

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Rb-Sr ISOTOPE DATA FOR CORE SAMPLES OF THE ICDP BOSUMTWI SCIENTIFIC DRILLING PROJECT, GHANA.

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Introduction: The 1.07 Ma old Bosumtwi impact structure, Ghana (06°32'N, 01°25'W) is a young and excellent preserved complex crater. As part of the Bosumtwi Core Drilling Project (BCDP) two cores were drilled into impactites (BCDP-7A: annular moat, BCDP-8A: central uplift). In contrast to the broad spectrum of target and impact lithologies found on the crater rim, the drill cores mainly consist of meta-greywackes, phyllites and impact breccias [1, 2]. The goal of this isotope study is to constrain the precursor lithologies of Bosumtwi-related impact glasses (Ivory Coast tektites [IVC] and microtektites).

Samples: We investigated (1) six breccias of cores 7A and 8A, (2) two meta-greywackes (7A), and (3) two shales (7A). (1) consist of mineral (mainly quartz, feldspar, and calcite) and lithic fragments (meta-greywacke and a variety of shales to phyllite) ranging in diameter from 0.1 to 10 cm. The fine grained matrix additionally contains sheet silicates. To estimate the influence of clasts to the whole rock isotope systematics different parts of breccias were separated, i.e. (i) domains exclusively consisting of matrix and clasts ≤ 0.5 cm, (ii) such with matrix and clasts mainly larger than 1 cm, and (iii) single large meta-greywacke clasts (≥ 5 cm). (2) one meta-greywacke is medium grained, the other one phyllitic; (3) the shales are grey to dark grey, very fine grained, and display a foliation; they have a powdery consistency.

Rb-Sr isotope data: The breccias from core 8A have $^{87}\text{Sr}/^{86}\text{Sr}$ ratios between 0.703350 ± 14 (2σ) and 0.708955 ± 12 , those of core 7A higher values from 0.720310 ± 13 to 0.72581 ± 10 . The breccia domains (i), (ii), and (iii) don't display large variation indicating the absence of not yet sampled target lithologies (e.g., granitoids) in the matrix. Two shales of 7A show much higher present day $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (0.728310 ± 13 and 0.750205 ± 14) which is within the range published by [3] for shales, greywackes, and phyllites collected at the rim and in the vicinity of the crater. Reflecting the lower content of micas, greywackes of core 7A yield relatively low $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (0.716423 ± 14 and 0.718968 ± 14), in accordance with our earlier results of core 8A [4]. Respective regression line calculations using the different lithologies result in rather low initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of 0.7107 (7A) and 0.7027 (8A); the correspondent age values do not date a so far documented event, their geological relevance is questionable.

Outlook: The current set of isotope data does not allow to correlate specific target rocks with IVC. Therefore further isotope studies (Rb-Sr, Sm-Nd) as well as SEM analyses are in progress.

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