

SAGES Comparative Planetology Forum Research in Progress Meeting

Organised by: Auriol Rae, Jens Barosch, Geoff Bromiley, Iris van Zelst
University of Edinburgh
15th May 2026

Venue

The principal venue of the meeting will be the Elm Lecture Theatre, Nucleus Building, King's Buildings Campus, University of Edinburgh.

Please use Location 38 of the Campus Map below, or alternatively the venue can be found at the following what3words address: [///indeed.both.oval](https://w3w.co/indeed.both.oval) (<https://w3w.co/indeed.both.oval>).

Oral Presentations

Please aim for a 10 minute presentation, with 5 minutes for questions and changeover. If possible, please e-mail your presentation by 5pm on the 14th May to Auriol Rae (auriol.rae@ed.ac.uk). However, if that is not possible then please bring your presentation as a Powerpoint file on a USB stick.

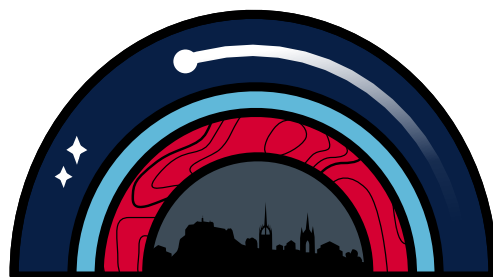
Poster Presentations

Poster boards will be provided at the venue. We recommend that posters are printed A0 in a portrait orientation.

Food and Refreshments

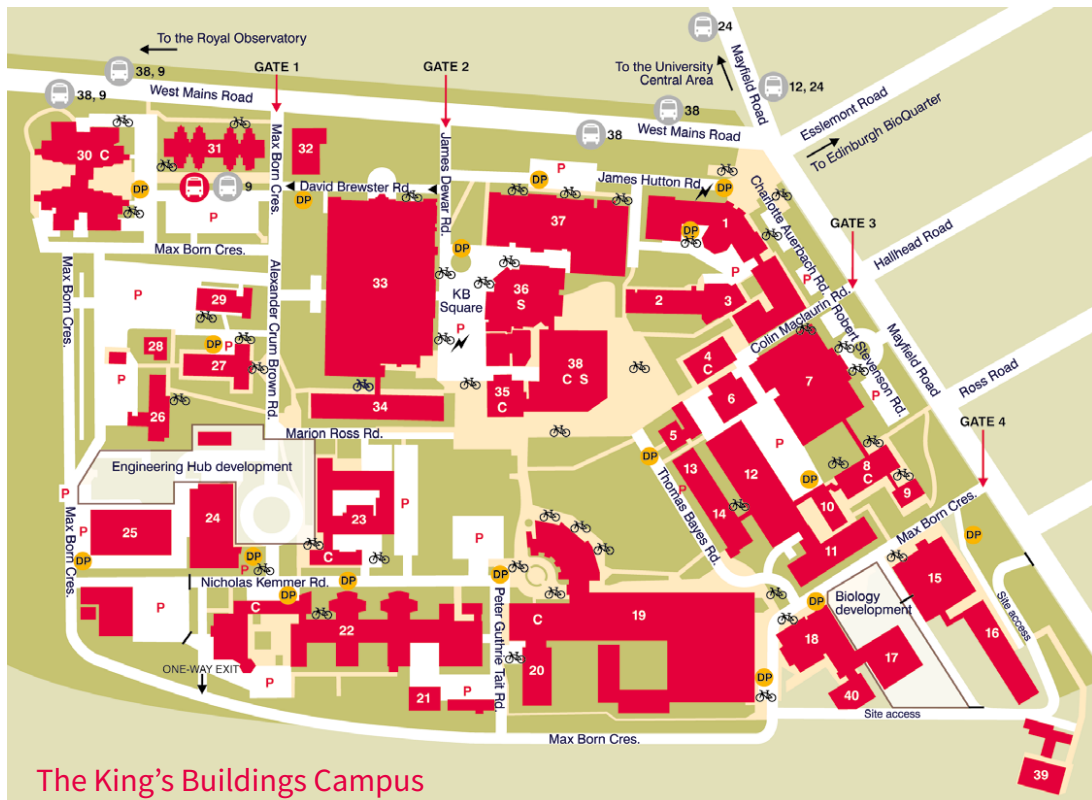
Tea/coffee and lunch are provided throughout the day.

For those who indicated their interest in attending dinner. A table has been booked at the Solti Lounge & Restaurant at 18:30. If you now wish to attend, or are no longer able to attend the dinner, please inform Iris van Zelst (Iris.vanZelst@ed.ac.uk).



**Edinburgh Centre for
Planetary Sciences**

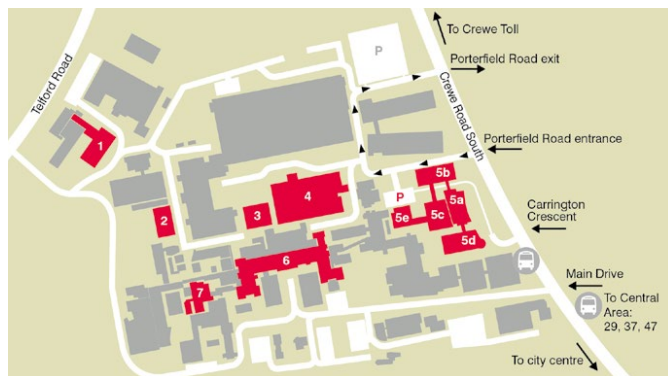
King's Buildings Campus Map



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|-----------------------------------|--|--|---------------------------------|
| 14 Alexander Graham Bell Building | 12 Fleeming Jenkin Building | 40 MEP Building | Bike racks |
| 11 Alrick Building | 25 FloWave Ocean Energy Research Facility | 30 Murchison House | Cafe |
| 32 Arcadia Nursery | 39 Glasshouse | 38 The Nucleus | Disabled permit parking |
| 1 Ashworth Building | 37 Grant Institute | 35 The Noreen and Kenneth Murray Library | Electric car charging point |
| 34 Christina Miller Building | 8 Hudson Beare Building | 22 Peter Wilson Building (SRUC) | Pedestrian area |
| 29 Crew Annex | 9 Hudson Beare Lecture Theatre | 23 Roger Land Building | Permit parking |
| 27 Crew Building | 19 James Clerk Maxwell Building; Learning and Teaching Cluster | 7 Sanderson Building | Public bus |
| 26 Crew Laboratory | 5 John Muir Building | 24 Scottish Microelectronics Centre | Shop |
| 15 Daniel Rutherford Building | 2 John Murray Building | 31 Student accommodation | Shuttle bus to the Central Area |
| 17 Darwin Building | 33 Joseph Black Building | 18 Swann Building | Traffic barrier |
| 6 Engineering Structures Lab | 36 KB House: EUSA | 28 UK Biochar Research Centre | |
| 20 Erskine Williamson Building | 3 March Building | 16 Waddington Building | |
| 21 Estates Hub | 4 Mary Brück Building | 13 William Rankine Building | |
| 10 Faraday Building | | | |
- The timetable for the shuttle bus between the Central Area and the King's Buildings can be viewed at: www.ed.ac.uk/shuttle-bus

Western General Hospital

- | | |
|---|------------|
| 1 Biomedical Research Facility | |
| 2 CJD Surveillance Unit | |
| 6 Clock Tower Building | |
| 5c Institute of Genetics and Cancer Centre | |
| 5a Institute of Genetics and Cancer Centre East and main entrance | |
| 5b Institute of Genetics and Cancer Centre North | |
| 5d Institute of Genetics and Cancer Centre South | |
| 5e Institute of Genetics and Cancer Centre West | |
| 7 Old Metabolic Clinic/Diabetic Clinic | |
| 4 Outpatients Department; Medical Education Centre | |
| 3 Wellcome Trust Clinical Research Facility | |
| P Permit parking | Public bus |
| P Public parking | |



Programme

09:00	09:25	ARRIVAL		
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10:15	10:30	Nicola Capaldi University of Glasgow	The Results are Shocking: Analysis of high-pressure carbon polymorphs and microdiamonds within the Almahata Sitta Meteorite	p.13
10:30	10:45	Auriol Rae University of Edinburgh	Determining Impact Angle from the Spatial Distribution of Shock Metamorphism: A Case Study of the Gosses Bluff (Tnorala) Impact Structure, Australia	p.25
10:45	11:00	Tetsuya Komabayashi University of Edinburgh	Light elements in planetary cores	p.20
11:00	11:30	COFFEE BREAK & POSTERS		
11:30	11:45	Martin Lee University of Glasgow	The 2025 Scottish fireball	p.21
11:45	12:00	Ualisson Bellon University of Edinburgh	(Reliably) Recovering ancient magnetic field signatures from Solar System rocks	p.9
12:00	12:15	Emily Wackan University of Glasgow	A Needle in a Haystack: Applications of Multiscale Techniques to Characterise the Composition of the Cloudy Zone of the Imilac Meteorite	p.26
12:15	12:30	Hyunseong Kim University of Glasgow	Roles of laterally varying tidal heating and surface temperature on Europa's ice shell structure	p.19
12:30	14:00	LUNCH, POSTERS, & LAB TOURS		
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14:45	15:00	Gergely Friss University of Edinburgh	Atmospheric Supply of Hydrogen Cyanide Is Not the Rate-limiting Step for Prebiotic Chemistry across Rocky Exoplanets	p.16
15:00	15:15	Mylaine Holin University of Edinburgh	The supply of organic molecules to the early Earth	p.17
15:15	15:45	COFFEE BREAK & POSTERS		
15:45	16:00	Richard Cannon University of Edinburgh	Contact binary asteroids	p.11
16:00	16:15	Ri Cao University of Leeds	The Stability and Behaviour of Wadalite	p.12
16:15	16:30	Geoffrey Bromiley University of Edinburgh	Diffusion inhibits Zn isotope enrichment during lunar volcanic degassing	p.10
16:30	17:15	Mahesh Anand Open University	High Precision Stable Isotope Measurements in Planetary Samples with the OU NanoSIMS 50L	p.7
17:15	17:20	Martin Lee University of Glasgow	Closing remarks	
18:30	DINNER Solti Lounge & Restaurant			

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From the Nadir to Silverpit Crater: using 3D seismic to test impact origin, dynamics and hazards

Uisdean Nicholson

Impact cratering is the dominant geological process shaping all solid planetary bodies in the Solar System and forms an important geological hazard on Earth. The 1908 Tunguska airblast, which flattened a forest over 2000 km², and the recent close call of Asteroid 2024 YR4 highlight the potential dangers posed by even small-scale collisions. However, impacts with Earth's surface have never been observed in historic timescales, and our understanding of crater formation processes is particularly limited when it comes to larger (>3 km) "complex" craters. This talk focuses on the recent discovery and confirmation of impact origin of two mid-sized complex craters that represent a once per ~100 ky hazard.

Nadir Crater is an exceptionally well-preserved impact structure situated ~400 km offshore Guinea, West Africa. The crater was identified by chance from a single 2D seismic profile across the Guinea Plateau, that revealed a concave-up crater floor, a distinct central uplift and annular moat surrounded by normal faults, all consistent with a complex crater. Intriguingly, the crater floor was interpreted to be near K-Pg in age, leading to the possibility that this could be genetically related to the Chicxulub impact event (Nicholson et al., 2022).

Serendipity struck again in 2022, when we found out that a seismic company had acquired a new 3D seismic survey directly across the structure. These data (Nicholson et al., 2024) revealed the crater architecture in unprecedented detail, allowing us to reconstruct crater kinematics during the crater modification stage, and to observe evidence of the cascade of environmental consequences that ensued, including liquefaction, tsunami resurge and landslides.

Silverpit Crater was discovered in the North Sea in the early 2000s, but an impact origin was disputed over the subsequent decades. At a famous geological society debate in 2008, the consensus was that this was not an impact structure. However, new 3D seismic data acquired for carbon capture and storage in the early 2020s led to our re-assessment of an impact origin. In combination with petrographic analysis and impact modelling, we demonstrated unequivocally that this is an impact crater—the first such structure in the UK. The new seismic also reveal intriguing evidence for large-scale, catastrophic devolatilization and the first clear evidence of secondary craters by ballistic ejection of target material.

3D seismic data has been critical to the enhanced imaging of these structures, providing crucial constraints on crater kinematics and impact modelling, as well as visually impressive data for public dissemination of scientific results. With Nadir Crater now scheduled to be drilled by IODP3 in 2027, we anticipate that these craters will continue to provide an important contribution to our understanding of planetary impacts for many years to come.

Assessing astrobiogeochemical controls on phosphorus supply and implications for habitability

Eva E. Stüeken

Phosphorus is a critical element for all life as we know it, making it a key parameter for habitability and biogenesis. Some ocean worlds in the outer solar system appear to be phosphorus-enriched, whereas on the modern Earth phosphorus is often a limiting nutrient that restricts biospheric growth. This seminar reviews some of the processes that govern the supply of phosphorus to planetary surfaces, including core formation, meteorite impacts, weathering and secondary mineral formation. New data and models suggest that phosphorus concentrations in Earth's oceans changed markedly over the past 4 billion years, perhaps dictating the pace of biological evolution. An underexplored aspect are spatial gradients and the redox state of phosphorus in different environments through time. Addressing these open questions may enable us to place tighter constraints on planetary habitability across the solar system and beyond.

**High Precision Stable Isotope Measurements in Planetary Samples with the OU
NanoSIMS 50L**
Mahesh Anand

tba

The Edinburgh Ion Microprobe Facility: SIMS analyses to support research in Planetary Sciences

Jens Barosch, Cees-Jan de Hoog, Cristina Talavera

The Ion Microprobe Facility (IMF) at the University of Edinburgh supports academic and commercial services in Secondary Ion Mass Spectrometry (SIMS) for chemical and isotopic analyses of small volumes of solid material. SIMS can achieve detection limits down to parts per billion for many elements and is widely used for applications in Earth and Planetary Sciences.

The Facility hosts two state-of-the-art ion microprobes. The compact Cameca IMS 7f-Geo was commissioned in 2019 and is particularly well suited for the analysis of volatile and light elements, as well as trace element concentrations in both silicate and non-silicate materials. The large-geometry Cameca IMS-1300 HR3 was delivered in November 2025 and is expected to be fully operational by May 2026. It features high secondary ion transmission and multicollection capabilities. It is ideally suited to measure high-precision stable isotope ratios (e.g., H, Li, B, C, N, O, S, Si, Mg), K-Ca and U-Pb geochronology, and the analysis of elements that require extremely high mass resolution such as heavy halogens (Cl, Br, I) and transition metals. Both instruments are supported by comprehensive sample preparation facilities, experienced technical staff, and a wide range of well-characterized standard materials.

The IMF is keen to engage with new and prospective SIMS users from the planetary science research community. This presentation will give a brief overview of SIMS applications in planetary sciences, and highlight the new capabilities of the Edinburgh Ion Microprobe Facility. We invite any interested researchers to contact facility staff (ionprobe@ed.ac.uk) to discuss the needs of your project.

(Reliably) Recovering ancient magnetic field signatures from Solar System rocks

Ualisson Bellon; Wyn Williams, Adrian Muxworthy

When magnetic minerals form in rocks, some can align their magnetic moments with the ambient magnetic field. As the rock cools, this information may become locked in and preserved for billions of years, provided the rock is not reheated above the Curie temperature, exposed to magnetic fields stronger than their coercivities, or significantly altered by chemical or physical processes. These remanent magnetisations offer a rare window into ancient planetary magnetic fields in both differentiated and undifferentiated bodies, helping constrain dynamo intensity, core processes, and even the presence or absence of tectonic activity. The challenge is that not all magnetic minerals are reliable recorders. Only the smallest grains, typically in single-domain or vortex states, are sufficiently stable over geological timescales. Natural rocks, however, contain a wide distribution of grain sizes, shapes, and magnetic states, many of which are unstable and can overprint or obscure the original signal. As a result, traditional paleomagnetic studies often require hundreds of centimeter-scale samples and extensive statistical treatment. For planetary returned samples, such quantities are rarely available. My work addresses this limitation by going to the microscale. Using quantum diamond microscopy, we measure the magnetic fields of individual particles and particle clusters, then apply numerical inversion methods to recover their magnetic moments. Combined with high-resolution tomography and state-of-the-art three-dimensional micromagnetic modeling, this approach allows us to identify which grains are stable recorders and which are not. The result is (we hope) a more detailed, precise, and accurate reconstruction of ancient planetary magnetic fields from extremely limited material. In this talk, I will briefly present the current development of this methodology, how I have been applying it in practice, and why it is likely the only approach currently suited to the study of precious space-returned samples.

Diffusion inhibits Zn isotope enrichment during lunar volcanic degassing.

Geoffrey Bromiley, Siobhan Kingham, Paul Savage, Matthew Varnam, Lee Saper

Volatile depletion, and heavy isotope enrichment of moderately volatile elements (MVEs), in lunar material have been interpreted as signatures of high-temperature degassing during formation of the Moon, during lunar magma ocean solidification, and/or during later volcanism. However, our ability to interpret these geochemical signatures is currently constrained by limited understanding of magmatic degassing mechanisms. Here, we describe results from high-temperature experiments which constrain mechanisms for Zn degassing from analogue lunar magmas. Effective evaporative loss of MVEs (Cl, Zn) in lunar systems is controlled by both evaporation rate and diffusivity within magmas. However, Zn degassing is effectively decoupled from loss of other elements, and strongly dependent on oxygen fugacity, fO_2 . As a consequence, under reducing lunar conditions Zn is significantly more volatile than Cl, and Zn loss is strongly diffusion limited. Zn evaporation results in mass-dependent fractionation in lunar magmas. However, our results demonstrate that fractionation is strongly inhibited by diffusion, even over limited length scales of pyroclastic eruptions and lunar volcanic glass bead formation. Interpretation of geochemical signatures of volcanic degassing in lunar (and other planetary) material is non-trivial for many metals due to this diffusion control, as degassing processes and magmatic fO_2 both (variably) influence mass loss and isotope fractionation. For lunar material, heavy isotope enrichment of Zn is, however, more likely to evidence volatile loss during Moon formation, rather than during later volcanism.

Contact Binary Asteroids

Richard Cannon, Agata Rozek, Colin Snodgrass

Contact binary asteroids - those that appear to be two objects stuck together - are found throughout the solar system in both asteroid and comet populations, with ground-based observations finding that up to 30% of near-Earth asteroids (radar estimate) and 50% of trans-Neptunian objects (optical estimate) are bilobate in shape. By combining ground-based radar and optical observations, we can create shape models for these objects, of which there are currently 20 that have been published, 16 of which are NEAs that have been observed with radar. Contact binaries of note are the comet 67P, visited by ESA Rosetta, and Selam and Donaldjohanson, visited by the NASA Lucy mission. Even the limited number of contact binary models show a wide variety in how a bilobate structure can present itself, with both trends and outliers evident. We present some small number statistics and discussion on these variations and similarities to investigate potential shared formation and evolutionary pathways in the solar system.

The Stability and Behaviour of Wadalite

Ri Cao, Muhammad Jawad Ahmed, Alan Whittington, Min Zou, Gavin G. B. Stenning, Yunguo Li, Geoff Bromiley, Theodore Hanein

The mineral wadalite ($\text{Ca}_6\text{Al}_5\text{Si}_2\text{O}_{16}\text{Cl}_3$) was first discovered in a skarn xenolith[1], but has excited interest due to its presence in a carbonaceous chondrite asteroid meteorite, where it evidences reactions with Cl-rich fluids[2]. Wadalite can also act as a weakly-hydraulic Cl-carrier in calcium-sulfo-aluminate-based cements[3]. Wadalite forms a solid solution with Cl-mayenite ($\text{Ca}_{12}\text{Al}_{14}\text{O}_{32}\text{Cl}_2$), in which tetrahedral Si^{4+} is replaced by Al^{3+} and a vacancy cage replaces Cl-. Determining the crystal structure and thermodynamic properties of wadalite and its solid solution is crucial to volcanology, planetary science and cement communities. To investigate the thermodynamic properties, we synthesised pure wadalite and Cl-mayenite by the acid-catalysed sol-gel method at 820 °C, with a 5-6 hour dwell time. We then measured thermodynamic properties (e.g., heat capacity, entropy, and enthalpy) of wadalite using a Quantum Design physical property measurements system (PPMS) at ISIS, Diamond Light Source, Oxford, from 0 to 300 K, and a Netzsch Differential Scanning Calorimeter from 300K to 1873 K at the University of Texas at San Antonio. Thermodynamic data were then combined with the enthalpy of formation results from Density Functional Theory (DFT) and previous experiments to model the thermodynamic properties of wadalite using the 3rd generation CALPHAD function. Our Rietveld quantification phase analysis shows that the synthesised wadalite and Cl-mayenite are ~98% pure with grain sizes of ~78 nm. The pure phase required some atomic occupancy refinement to fit the diffractogram, which impacts the centrosymmetric nature of wadalite crystals. The BSE (back-scatter) image of powder wadalite grains showed small grains growing on the tops of large grains due to Ostwald Ripening. The heat capacity of wadalite shows an onset of melting at 1150 °C, followed by phase transformations to mayenite, alinite, and Cl-mayenite from 1200 to 1550 °C, with complete melting at ~1600 °C. This study sheds light on the stability and potential behaviour of wadalite and its solid solutions, providing new thermodynamic information needed to model processes on planetary surfaces and in the cement industry.

[1] Tsukimura et al. (1993) *Acta Crystallographica*, C49, 205-207

[2] Ishii et al. (2010) *American Mineralogist*

[3] Simoni et al. (2021) *CCR*.

The Results are Shocking: Analysis of high-pressure carbon polymorphs and microdiamonds within the Almahata Sitta Meteorite

Nicola Capaldi, Luke Daly, Liene Spruzeniece, Shriyar Tariq, Lydia Hallis, Emily Wackan, James Gilgannon

Ureilites are achondrite meteorites thought to be derived from a disrupted protoplanet, the ureilite parent body (UPB) (Patzner, 2024), which was destroyed early in the Solar Systems history by a collision with another protoplanet (Bischoff, 2010; Andrew G. Tomkins, 2022; Nestola, 2020). Almahata Sitta is a brecciated ureilite meteorite fragment (Bischoff, 2010; Goodrich, 2015). This meteorite is composed primarily of olivine and pyroxene with minor phases of carbonaceous material, low Ni-Fe metal, and sulphides (Nestola, 2020; Loehle, 2017; Abdu, 2023). The interstitial carbonaceous material within Almahata Sitta hosts microdiamonds which are uniquely large relative to that of other ureilite meteorites (Mittlefehldt, 1998; Miyahara, 2015).

There are three main theories surrounding the mechanism(s) responsible for diamond formation in the ureilites: growth under high static pressures (Miyahara, 2015), formation in the solar nebula through chemical vapour deposition (CVD) (Fukunaga, 1987), and shock-induced transformation of graphite to diamond (Ross, 2011). This research aims to provide evidence which satisfies one theory for ureilite diamond formation through analysis of Almahata Sittas carbon phases using Energy Dispersive X-ray Spectroscopy (EDS), Electron Backscatter Diffraction (EBSD), and Transmission Electron Microscopy (TEM). Three electron transparent lamellae have been prepared, TEM analysis is planned and results will be presented at the meeting.

EBSD data shows that these cubic diamond grains exhibit a strong orientation around the $\{111\}$ plane with grains rotating around this $\{111\}$ plane of cubic diamond. A crystallographic relationship between graphite and cubic diamond has also been identified, with the orientation of the basal $\{0001\}$ plane of graphite matching the orientation of the $\{111\}$ plane of neighboring cubic diamonds. This presentation will discuss the implications of these results in line with the existing theories surrounding diamond formation in the ureilites.

The NC-CC Chondrite Dichotomy

Sterling Davis, Paul Savage, Robert Steele

A fundamental question in cosmochemistry asks how our solar system and planets formed and evolved. We can attempt to answer such questions through the isotopic analyses of chondrites, which can be grouped based on their distinct isotopic compositions, correlating with the inner (noncarbonaceous) and outer (carbonaceous) solar system (1-4). This--the NC/CC dichotomy--is crucial insight for constraining the origin of terrestrial planet building blocks and volatiles, and has been garnered through the discovery of nucleosynthetic isotope anomalies across a range of elements, those of zinc being particularly relevant to this study due to its volatile nature among the iron-peak elements. Three ordinary chondrites, spanning a range of alteration grades, will be the focus of this study: Julesburg (L3.6), Saratov (L4) and New Concord (L6). These chondrites will be processed by way of column chemistry, acid leaching experiments, and subsequent analysis using mass spectrometry. Preliminary elemental analysis of the leachates from Julesburg and New Concord reveal that zinc is most concentrated in the steps targeting metals, silicates, and refractory phases. If we can better constrain the phases where the anomalous Zn reservoir is stored in meteorites, and how these anomalies can be redistributed about parent asteroids as a function of alteration, a clearer picture will emerge as to how the iron-peak anomalies were generated in the early solar system.

1. Tissot, F. L., Burkhardt, C., Kuznetsova, A., Pack, A., Schiller, M., Spitzer, F., ... & Yap, T. E. (2025). Infall and disk processes--the message from meteorites. *Space Science Reviews*, 221(7), 1-50.
2. Trinquier, A., Birck, J. L., & Allegre, C. J. (2007). Widespread ^{54}Cr heterogeneity in the inner solar system. *The Astrophysical Journal*, 655(2), 1179.
3. Trinquier, A., Elliott, T., Ulfbeck, D., Coath, C., Krot, A. N., & Bizzarro, M. (2009). Origin of nucleosynthetic isotope heterogeneity in the solar protoplanetary disk. *Science*, 324(5925), 374-376.
4. Warren, P. H. (2011). Stable-isotopic anomalies and the accretionary assemblage of the Earth and Mars: A subordinate role for carbonaceous chondrites. *Earth and Planetary Science Letters*, 311(1-2), 93-100.

Bacterial transformation of organic matter and the effects on gas exchange suppression in oceanic environments

Nair Eguibar, Bischoff, Wagner, Norouzi, Rickard, Pereira

The oceanic microbiome is responsible for the transformation of organic matter in the ocean, and that directly mediates the rate of gas exchange (k_w) between the atmosphere and the sea. The composition of the organic matter is crucial in this process. k_w is controlled by spatial and temporal variability of near surface turbulence which is in part controlled by enrichments biologically derived surfactants in the surface microlayer (SML). While broad scale relationships between ocean primary productivity and surfactant abundance in the SML have been identified there are notable uncertainties in lead-lag relationships between biological uptake and release of organic matter components that mediate relative gas exchange rates across the SML.

To elucidate the role of the microbial community on dissolved organic matter (DOM) composition, the surfactant production and the surfactant suppression effect (SSE) of *Alcanivorax borkumensis*, a marine bacterium capable of surfactant production, was investigated. The experiment was cultivated using ONR7a medium supplemented with sodium pyruvate as the sole carbon source. Total surfactant Activity (SA) throughout the experiment was quantified using AC voltammetry, and DOM composition was determined using size exclusion liquid chromatography with a carbon and a nitrogen detector (LC-OCD-OND). The rate of gas exchange suppression was measured with our custom-built gas exchange tank (GETCO₂). Our results show that as organism growth progressed, pyruvate was consumed while low molecular weight neutrals and acid compounds were produced. At the same time, increased SA was observed at key growth phases with relative impacts on k_w , which, can in turn impede gas transfer of climate active gases across the ocean-atmosphere interface.

Atmospheric Supply of Hydrogen Cyanide Is Not the Rate-limiting Step for Prebiotic Chemistry across Rocky Exoplanets

Gergely Friss, Paul I. Palmer, Marrick Braam, Ken Rice

Hydrogen cyanide (HCN) is crucial for the RNA World hypothesis, forming biomolecules essential for early life. Life likely emerged around 4 billion yr ago during the early Archean Eon, a period on Earth with a fainter Sun, frequent impacts, and a weakly reducing atmosphere. Warm little ponds (WLPs) are hypothetical protective aqueous environments that help explain the emergence and evolution of fragile prebiotic chemistry in such a hostile environment. WLPs need to undergo cycles of evaporation and rehydration, concentrating prebiotic molecules that increase the likelihood of (de-)polymerisation and forming early RNA molecules. We use a 1D model of atmospheric chemistry to compare atmospheric HCN delivery to WLPs with exogenous sources. Using early Archean Earth as our baseline, we examine the sensitivity of atmospheric HCN delivery to the atmospheric C/O ratio, semimajor axis, assumed stellar host type, and methane budget, exploring conditions across rocky exoplanets. We find that atmospheric HCN delivery is sensitive to these parameters, but its values generally exceed those of meteoritic delivery and our baseline Archean Earth. Planetary atmospheres with higher C/O ratios within the habitable zones of G stars and those closely orbiting M-dwarfs deliver the most atmospheric HCN. We find that atmospheric HCN delivery is remarkably robust, so this molecule is likely not the rate-limiting step for the emergence of prebiotic chemistry on rocky exoplanets. This finding, with important caveats, potentially increases the probability of life emerging on other worlds.

The supply of organic molecules to the early Earth

Mylaine Holin, Sean McMahon, Inge Loes ten Kate, Thomas Sanders, Auriol Rae, Richard Anslow

In 1992, Christopher Chyba and Carl Sagan published "Endogenous production, exogenous delivery and impact-shock synthesis of organic molecules: an inventory for the origins of life"[1]. This paper established an inventory of the sources of organic carbon on the Hadean–Archean Earth and made a quantitative assessment of the prebiotic organic matter available on Earth from 4.4 to 3 Gyr ago. Those sources are divided into three categories: intact delivery by extraterrestrial objects, synthesis by impact shocks, and endogenous sources.

Taking into account the discoveries made since this publication, we present an update on carbon inventory during the Early Earth. In particular, we include an estimate of the contribution from hydrothermal vents to the endogenous delivery[2]. We also reassess the contribution of meteorites to the exogenous delivery, using recent simulation of atmospheric entry of impactors in Earth's atmosphere[3].

[1] Christopher F. Chyba and Carl E. Sagan. Endogenous production, exogenous delivery and impact-shock synthesis of organic molecules: an inventory for the origins of life. *Nature*, 355:125–132, 1992.

[2] McDermott, J.M., Seewald, J.S., German, C.R., Sylva, S.P. Pathways for abiotic organic synthesis at submarine hydrothermal fields. *Proc Natl Acad Sci U S A*. 112(25):7668-72. (2015) doi: 10.1073/pnas.1506295112.

[3] Richard J Anslow, Amy Bonsor, Zoe R Todd, Robin Wordsworth, Auriol S P Rae, Catriona H McDonald, Paul B Rimmer, The atmospheric entry of cometary impactors, *Monthly Notices of the Royal Astronomical Society*, Volume 539, Issue 1, May 2025, Pages 376–392, <https://doi.org/10.1093/mnras/staf507>

Preparing for the Habitable Worlds Observatory: Mapping clay mineralogy of NE Iceland

Tanja Holc, Beth Biller, Sean McMahon

The Habitable Worlds Observatory (HWO) is being planned to directly image potentially habitable exoplanets in reflected light, gaining insight into their surface composition as well as atmosphere. One approach to preparing for these future observations is treating Earth as an exoplanet and using remote observations to study its surface. Using infrared surface reflectance observations with the Harmonized Landsat and Sentinel-2 satellite, we generated a map of clay mineral coverage of Northeast Iceland. We used this to identify areas with presumed clay abundance and collected 11 samples. We are in the process of analysing their composition and obtaining sample reflectance spectra to be compared to the remote data. Since Iceland is a good spectral analogue for the early Earth or habitable Mars surface, our data will be used to model an exoplanet with a global Iceland-like surface, and simulate HWO observations of such a planet.

Roles of laterally varying tidal heating and surface temperature on Europa's ice shell structure

Hyunseong Kim, Antoniette Greta Grima, Luke Daly

Observations from past missions indicate that Europa hosts active ice tectonics and a subsurface ocean, suggesting ongoing material recycling within its ice shell and potential exchange with the ocean below which are the key processes for habitability. Constraining the internal structure of Europa's ice shell is therefore a primary goal of NASA's Europa Clipper mission, as this structure governs the efficiency of surface–ocean exchange. However, the processes controlling mass transport and internal structure within the ice shell remain uncertain. These processes are likely affected by the spatial distribution of heat sources: insolation elevates surface temperatures at the equator, whereas tidal heating is expected to peak toward the poles. Because these heat sources display opposing latitudinal gradients, their combined influence may either amplify or diminish lateral heterogeneity within the shell. To explore this interplay, we developed numerical models of Europa's ice shell that incorporate laterally varying tidal heating and surface temperature, coupled with visco-elasto-plastic deformation and composite ice rheology. We examine how these heat sources affect convective behavior across a range of plausible ice shell thicknesses and assess their impact on global patterns of heat flow, stress distribution, and surface topography. Our results provide new insights into lateral variations in ice shell structure and the evolution of surface deformation, with implications for tectonics and surface–interior coupling in the ice shell.

Light elements in planetary cores

Tetsuya Komabayashi

Any of the rocky planets in the solar system has an Fe-rich metallic core which is believed to contain light impurities such as sulphur, silicon, and oxygen. If we can identify the kinds and amounts of the light elements in the core, that will place constraints on the origin and evolution of a planet because those impurities should have been included during core formation. We are trying to identify the core composition for the Earth by developing thermodynamic models for iron alloy systems, which can be compared with geophysical observations such as the density of the core. I will present our most recent model composition for Earth's core.

The 2025 Scottish fireball

Martin Lee, Aine O'Brien, Luke Daly

In the early hours of 3 July 2025, a fireball and sonic boom were recorded across Scotland. The fireball was observed by members of the public, and captured by dedicated cameras of the UK Fireball Alliance. The sonic boom was also registered by several of the British Geological Survey's seismometers. Later that day, accounts and videos of the fireball were circulated widely in national newspapers and on social media. The fireball should have dropped meteorites in the central highlands, but despite intensive searches no fragments have yet been found. Here we will describe some of the records of the event and their implications for understanding the meteor's origins and properties. We will also consider what the media reactions can tell us about how fireballs are perceived by the public.

The Internal Structure and Composition of Ice Giants: Insights from the H₂O-NH₃ binary system

David Lewis, Andreas Hermann, Tetsuya Komabayashi

The bulk composition of planetary atmospheres is intrinsically linked to which species can and cannot be sequestered into the interior. Recent observations of the Ice Giants, Uranus and Neptune, indicate a higher atmospheric abundance of H₂S than NH₃. This suggests either; preferential accretion of sulphur over nitrogen during planet formation, or that nitrogen (in the form of NH₃) is trapped in the interior of the planet. In this work we study the H₂O-NH₃ binary system, including the ammonia hydrates (H₂O)_x(NH₃)_y, at high pressure and temperature. Using density functional theory and molecular dynamics simulations we characterise the range of phases, including fluid and superionic states, which arise in the H₂O-NH₃ system. From these simulations we begin to calculate absolute free energies using coupling-constant integration. This will allow us to build a first-principles binary phase diagram to understand miscibility in the H₂O-NH₃ system at planetary interior conditions which will provide better constraints on the global budget of H₂O and NH₃ in ice giants.

Anthropocene Cosmographies

James Lowder

In recent decades, outer space has increasingly featured as a topic of investigation for social scientists, including human geographers. At the same time, social scientists have sought to better integrate physical science into social science theories, including to acknowledge interactions between the Earth and the wider Solar System. Despite the rising popularity of these themes, there remains a lack of social science engagement with planetary science and related fields, particularly meteoritics. Drawing upon my doctoral research in human geography, and recently published monograph 'Anthropocene Cosmographies', this poster presents findings from one of the first social science engagements with the field of meteoritics and discusses possible future research directions. My examination of meteoritics highlights the social dimensions of scientific practice, the advances offered by modern technologies and the global networks that enable cutting-edge research, including the importance of dedicated camera networks and the significance of Antarctic expeditions. Findings also reveal the capacity of extraterrestrial geology to produce philosophical insights, including how understanding meteorites sheds light on the Solar System's deep past and a shared corporeal heritage that is rooted in 'stardust'. In looking forward, this poster also explores planetary science's entry into an era of sample-return, including the successes of the Hayabusa and OSIRIS-REx missions, as well as the implications of schemes like the UK Space Frontiers 2035 initiative. Overall, this research works to bridge the gap between planetary thought and planetary science, while demonstrating how extraterrestrial material touches human experience in a multitude of ways.

Numerical modelling of impact-induced hydrothermal systems

Annemarie Pickersgill, Tobias Keller

Hypervelocity impact structures are known to result in post-impact hydrothermal systems that have been tied to the origins of life. Despite the importance of impact-induced hydrothermal activity in the development of habitable environments, the duration and structure of fluid flow in such systems is poorly constrained. Here we present a custom-made numerical model implemented in Matlab designed specifically to accommodate the unique hydro-geological conditions generated by hypervelocity impact, and to include variable salinity resulting in double diffusive convection.

The model solves the Darcy equation for an incompressible pore fluid percolating through a non-reactive, non-deforming matrix; the equations are discretised by finite differences on a regular, square, staggered grid; material transport is modelled using the 5th-order WENO advection scheme; numerical solutions are obtained using a pseudo-transient iterative approach. We assume an incompressible fluid composed of mostly H₂O and variable salinity (concentration by weight of NaCl) occupies and percolates through the saturated porosity of a perfectly rigid rock matrix. We assume that fluid and matrix are in local thermal equilibrium and that there is no dissolution or precipitation of halite. For simplicity, we neglect phase changes in the H₂O-NaCl system which may become important when water is boiling or entering supercritical state from impact heat or where halite precipitates to clog pore space.

Here we compare the development of a hydrothermal system in impact craters with: 1) a saline lake (3.5% NaCl) and 2) a freshwater lake. The water layer representing the crater lake is set to have temperature and salinity evolve over time, and to undergo temperature exchange with the overlying air. Water is treated as a high-permeability medium allowing exchange flow with underlying lithologies, and with a spatially uniform temperature and salinity.

Determining Impact Angle from the Spatial Distribution of Shock Metamorphism: A Case Study of the Gosses Bluff (Tnorala) Impact Structure, Australia

Auriol Rae, Eloise Matthews, Thomas Kenkmann, Nicholas Timms, Aaron Cavosie, Marian Holness

Impact angle is a key parameter controlling the impact cratering process, affecting crater morphology, ejecta patterns, shock pressures, and the volumes of melt and vapour produced — all of which have major implications for planetary surface evolution and the environmental effects of an impact. The majority of planetary impacts occur at oblique angles, yet constraining impact angle and direction in eroded terrestrial craters remains challenging.

In this study, we investigate the potential of asymmetries in shock metamorphism to act as a quantitative constraint on the direction and angle of impact at the Gosses Bluff structure in Northern Territory, Australia. We measured the frequency of specific orientations of planar deformation features in quartz from samples around the central uplift and compared the spatial asymmetries in observed peak shock conditions with predictions from new three-dimensional numerical impact simulations of the formation of the Gosses Bluff structure. This comparison indicates formation by an impact along an approximately north-to-south trajectory at an angle of $52^\circ \pm 10^\circ$. Alongside a trend of an increase in shock pressure recorded by down-range target rocks, we also observe a marked increase in shock metamorphism in the cross-range direction at Gosses Bluff. We attribute this pattern to the movement of faults in the central uplift during crater modification, displacing and dissecting the originally smooth distribution of shock metamorphism. This study provides new guidance for identifying and quantifying oblique impacts in the rock record, applicable to a large range of impact angles and crater sizes, and offers a framework for interpreting the geological signatures of oblique impacts across the Solar System.

A Needle in a Haystack: Applications of Multiscale Techniques to Characterise the Composition of the Cloudy Zone of the Imilac Meteorite

Emily Wackan, Trevor Almeida, Liene Spruženiece, Andrew Matzen, William Smith, Shriyar Tariq, Claire Nichols, Paul Bagot, Luke Daly, Joshua Franz Einsle

Iron-nickel meteorites contain microstructures formed under extreme Pressure/temperature conditions and long durations. A unique structure observed in iron-nickel meteorites is the cloudy zone (CZ). This structure forms after the crystallisation of kamacite grains, which exclude nickel during their formation and growth producing rims around kamacite grains that are enriched in nickel. During subsequent slow cooling and spinodal decomposition allows for the formation of a binary phase comprised of nanoscale tetrataenite islands (with $\text{Fe}_{0.5}\text{Ni}_{0.5}$ composition and an ordered L10 structure) surrounded by an Fe-rich matrix in these rims. This unusual nanoscale structure gives rise to strong magnetic properties comparable to current rare earth element (REE) permanent magnets. Research efforts in planetary sciences have focussed on understanding the paleomagnetic remanence of the CZ as a record of dynamo formation on planetesimal bodies in the early Solar System. More recently, CZ has been analysed in the field of materials science and engineering in response to the growing demand for REE magnets from the energy sector; if synthesised appropriately, the high natural magnetic coercivity of this material would provide a sustainable, cost-effective, REE-free permanent magnets with the same required functional properties. Various factors are likely to influence the formation rate of CZ including the presence of trace elements.

Here we show analysis of the Imilac meteorite (a stony iron meteorite from the main group pallasite group), conducted using several characterisation techniques. These include Scanning Electron Microscopy-Energy Dispersive X-ray Spectrometry (SEM-EDS), Electron Probe Micro Analysis (EPMA), and Atom Probe Tomography (APT). We will discuss how the results from these different techniques can be compared to strengthen our understanding of CZ trace element chemistry as well as the challenges that have arisen in analysing these materials.