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Abstracte

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Title	Microevolutionary dynamics of subseafloor Methanothermococcus populations in high-temperature vent fluids from the Mid-Cayman Rise
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Abstract Text	<p>Understanding the evolution and spread of microbial communities through the deep subsurface is crucial for understanding the role the deep subsurface may have had in life's earliest origins and evolution. Nevertheless, we lack a fundamental understanding of the microevolutionary processes that drive microbial diversification into new ecological niches across the diverse habitats of the deep biosphere. Fundamental questions include: how do selection pressures vary across different habitats of the deep subsurface? What role do biotic and abiotic factors play in driving evolution? How important is the role of horizontal gene transfer in adaptation, and what types of genes are gained or lost? In order to address these questions within the dynamic, gradient-dominated environment of hydrothermal vent systems, we sequenced five single-cell amplified genomes (SAGs), all from the genus Methanothermococcus, sampled from a single hydrothermal fluid sample from the Mid-Cayman Rise. We found that despite being closely related lineages isolated from the same habitat, these Methanothermococcus genomes exhibited differential abundance and expression across different hydrothermal vent habitats. The relative abundance of these genomes correlated with their placement on a phylogenetic tree, and seemed to correlate to the presence or absence of CRISPR loci, indicating that viruses may play an important role in differentiating Methanothermococcus strains. The diversity of CRISPR spacers in Methanothermococcus genomes suggests that archaeal viruses in hydrothermal systems are active and diverse. By harnessing the power of single-cell genomics to conduct population genomics studies of uncultivated microbes, we can begin to gain insight into the evolutionary processes that govern microbial adaptation in the dynamic and diverse habitats of hydrothermal systems.</p>

Title	Tracing Deep Biosphere Methane Cycling with Fully Resolved $^{13}\text{CH}_3\text{D}$ and $^{12}\text{CH}_2\text{D}_2$
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Abstract Text	<p>The balance between methanogenesis and the anaerobic oxidation of methane (AOM) in marine sediments is an important component of the global methane cycle. However, quantifying microbial activity in these deep biosphere systems is challenging. The ability to measure the relative concentrations of at least two doubly-substituted rare isotopologues of gases with biogeochemical relevance provides new constraints on sources and sinks of these gases. Here, we report the first measurements of fully resolved $^{13}\text{CH}_3\text{D}$ and $^{12}\text{CH}_2\text{D}_2$ from natural samples of deep biosphere methane gas.</p> <p>A suite of sedimentary methane samples from Bornholm Basin and Landsort Deep in the Baltic Sea was collected during IODP Exp. 347. Sample depths range from 2-50 meters below seafloor. Methane concentrations decrease with depth, and <i>mcrA</i> (a marker for methanogenesis and methanotrophy) is present throughout. We measure $\Delta^{13}\text{CH}_3\text{D}$, $\Delta^{12}\text{CH}_2\text{D}_2$, $\delta^{13}\text{C}$ and δD and compare our results to porewater chemistry and a multicomponent diagenetic model that estimates rates of methane production, SO_4-AOM and Fe-AOM.</p> <p>$\Delta^{13}\text{CH}_3\text{D}$ and $\Delta^{12}\text{CH}_2\text{D}_2$ vary with depth in response to changing ratios of methanogenesis to methanotrophy. Depths with higher rates of methanogenesis exhibit disequilibrium by up to 2‰ in $\Delta^{13}\text{CH}_3\text{D}$ and 13‰ in $\Delta^{12}\text{CH}_2\text{D}_2$ while depths with higher rates of methanotrophy approach isotopic thermodynamic equilibrium. No isotopic equilibrium between $\delta\text{DH}_2\text{O}$ and δDCH_4 is reached at any depth. While axenic culturing experiments generate methane with large deficits in $^{12}\text{CH}_2\text{D}_2$ (Young et al., 2017), these data from the Baltic Sea demonstrate that isotopic equilibrium can indeed be achieved during microbial recycling of methane.</p> <p>In the absence of $\Delta^{12}\text{CH}_2\text{D}_2$, the $\Delta^{13}\text{CH}_3\text{D}$ values alone could be misinterpreted as representing gradients in temperature due to exothermic organic matter degradation. The combination of both mass-18 rare isotopologues of methane provides the means to distinguish equilibrium from disequilibrium and probe microbial methane cycling even where $\Delta^{13}\text{CH}_3\text{D}$ suggests reasonable temperatures.</p>
References	Young et al., (2017) <i>Geochimica et Cosmochimica Acta</i> 203 15:235-264

Title	Fe ³⁺ /ΣFe and fO ₂ of mantle eclogites reveal highly reducing conditions during formation and recycling of Archaean oceanic crust
Presenting Author	Sonja Aulbach
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Abstract Text	<p>There is considerable uncertainty regarding the oxygen partial pressure (fO₂) of the ambient convecting mantle throughout Earth's history. Archaean mantle eclogite suites have elemental and isotopic compositions indicative of formation of crustal protoliths in oceanic spreading ridges. In order to constrain their redox state and unravel the effects of primary (igneous differentiation) and secondary processes (seawater alteration, metamorphism, metasomatism), we measured Fe³⁺/ΣFe by Mössbauer in garnet from mantle eclogites from the Lace kimberlite (Kaaapvaal craton). The suite comprises compositionally well-characterised samples with melt- and cumulate-like oceanic crustal protoliths that formed ca. 3 Ga ago. Fe³⁺/ΣFe in garnet, corrected to a common jadeite content, shows a broad negative correlation with whole-rock Al₂O₃/TiO₂ and positive correlation with ΣREE, consistent with incompatible behaviour of Fe³⁺ during olivine-plagioclase accumulation (exclusion of TiO₂ and REE) in the protoliths. In contrast, NMORB-normalised Nd/Yb - a proxy of partial melt loss from subducting oceanic crust (<1) and metasomatism by typically LREE-enriched liquids (>1) - shows no relationship with Fe³⁺/ΣFe. Median bulk-rock Fe³⁺/ΣFe is roughly estimated at 0.025, confirming the very reduced nature of the Archaean convecting mantle source to the igneous protoliths of these eclogites, as inferred from V/Sc [1]. Oxygen fugacities (fO₂) relative to the fayalite-magnetite-quartz buffer (ΔFMQ), calculated using a hedenbergite-based oxybarometer [2], range from -1.3 to -4.6 and broadly decrease with increasing pressure, which is ascribed to increasing garnet modes in metabasalts into which Fe³⁺ can be sequestered, reducing its activity. At such low fO₂ and high pressures, methane or anionic carbon species will be stable in dehydration fluids in equilibrium with eclogite, and may result in the crystallisation of diamond upon cooling, volume decrease and/or mixing with other fluids. Diamond formation in reduced oceanic crust may have resulted in a subdued carbon output in Archaean subduction zones.</p>
References	<p>[1] Aulbach S, Viljoen KS (2015) Earth Planet Sci Lett 431:274-286 [2] Vasilyev P (2016) PhD, Research School of Earth Sciences. Australian National University, Canberra, pp 204</p>

Title	A Vision of Global Synthesis of Hydrogen, Methane and Higher Hydrocarbon production and distribution over time constrained via Noble gases
Presenting Author	Chris J Ballentine
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Abstract Text	<p>The production sources and the sinks controlling the concentration, fate and transport of reduced gases such as methane in the Earth's crust over time are complex. These include the production of methane by abiotic organic synthesis [1] and the more well-studied processes of thermogenesis and microbial methanogenesis. Abiotic organic synthesis and our understanding of the subsurface biosphere are developing but, particularly for the Precambrian rocks that make up more than 70% of the Earth's crust by surface area, this remains a frontier research area. As hydrogen provides the feedstock for methanogenesis – whether via abiotic organic synthesis of methane (e.g. Sabatier reactions) or higher hydrocarbons (e.g. Fischer-Tropsch type reactions); or via microbial processes of methanogenesis such as CO₂ reduction [2], estimating hydrogen production rates is an essential first step in constraining the methane cycle. Significant progress has been made constraining hydrogen production and flux from the Precambrian cratons, showing that this accounts for ca 50% of global hydrogen production derived from water-rock reactions [3], the remainder being sourced from the marine lithosphere. Radiogenic noble gases in the Precambrian crystalline systems provide an inert record of both residence time and fluid system competence [4] and hence the reference frame in which the sources and sinks of the methane cycle can be further investigated. We present the critical role of noble gas and hydrogen flux and production rates in constraining the deep carbon cycle and highlight what we know to date through a synthesis of global maps of hydrogen, methane and higher hydrocarbon distributions across Earth's Precambrian continental lithosphere.</p>
References	<p>[1] Sherwood Lollar et al. (2002) Nature 416, 522-524. [2] Sherwood Lollar et al. (2006) Chemical Geology 226:328-339. [3] Sherwood Lollar et al. (2014) Nature 516, 379-382. [4] Holland et al., (2013) Nature 497, 357-363</p>

Title	Biology Meets Subduction: A Collaborative and Multi-disciplinary Deep Carbon Field Initiative
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Abstract Text	<p>Biological processes control the composition of subducted sediments, and thus biology and geology are intimately connected on Earth; however, for many researchers, disciplinary boundaries obscure this connection. Inspired by ongoing multi-disciplinary DCO research, the Biology Meets Subduction project is an effort to understand the complex interplay between volcanic carbon and biology at the Costa Rica convergent margin. In February 2017, nearly 25 scientists from 5 countries conducted fieldwork to quantify the distribution of carbon between Earth's surface and deep reservoirs, with a view towards understanding how the deep carbon cycle is controlled by the dynamic processes of subduction and volcanism. The project brings to bear, for the first time, the diverse expertise and methodology of scientists from all four of DCO's science communities at a single field focus site: the Costa Rica convergent margin. The team is composed entirely of early career scientists, who conducted geochemical, biological, and petrological sampling, a task rarely if ever attempted in a single, coordinated campaign at a convergent margin.</p> <p>In addition to the logistical novelty of the campaign, no one has conducted a comprehensive study separating sources and pathways of biotic vs. abiotic C through a subduction zone. The primary scientific questions we addressed are: (1) What is the influence of biological activity on C ingassing and outgassing at the Costa Rica convergent margin? (2) Can biological signatures be traced through subduction processes and distinguished from shallow biological cycling using isotopic constraints on subducted inputs and volcanic/forearc outputs? Using this information, can we (3) better constrain C sources and fluxes, and (4) improve deep C budget estimates for the Costa Rica convergent margin? This scientific synthesis is bringing together and benefiting scientists from numerous fields, and engaging broader audiences by bringing into focus the complex interplay between biology and geology on Earth.</p>

Title	Surficial Sediment Microbiota Present in Ultra-Deep Convergent Margins
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Abstract Text	<p>Hadal trenches are convergent margin oceanic locations extending from 6,500 m to almost 11,000 m seawater depths. Quantitative analyses of the microbes present in trench sediments are lacking, although these habitats could be home to distinct microbial communities, compared to those at shallower depths, as a result of high hydrostatic pressures, topographical funneling of organic matter, tectonic activity, carbon and energy sources arising from below the seafloor, and biogeographical isolation. We have previously reported on the surprising finding of microbes related to the terrestrial deep biosphere genus <i>Desulforudis</i> present in the bottom waters of the Mariana Trench. Here we characterize the microbial communities present in surficial sediments of the Mariana and Kermadec Trenches, located in the northern and southern hemispheres, respectively, of the western Pacific Ocean, using culture-independent and dependent approaches. Sediment samples were recovered from push cores obtained by the HROV Nereus and from a lander-associated multicorer. Phospholipid fatty acid (PLFA) concentrations were higher in the sediments of the Kermadec Trench than the Mariana Trench. Illumina-tag sequence analyses of the V4-V5 region of the rRNA small subunit gene indicates that the Mariana Trench sediments harbored greater fractions of OTUs belonging to the Thaumarchaeota, whereas the Kermadec Trench harbored higher fractions of Gammaproteobacteria, Cytophagia, Planctomycetia, Flavobacteria, and Nitrospira. These differences likely reflect in part differences in organic matter abundance. Constrained analysis of principal coordinates indicate that the communities are structured by trench, core, water column depth, and sediment depth. In some cases, for example within the Thaumarchaeota, operational taxonomic units (OTUs) showed niche differentiation by trench and sediment depth, likely due to oxygen and organic matter availability. Facultative anaerobic isolates obtained as pure cultures at high pressure were distinct from those obtained at atmospheric pressure, but were similar to OTUs arising during the long-term storage of sediment samples at low temperature and high pressure. These analyses represent a starting point for determining the composition, diversity and distinctive nature of surficial sediment trench microbiota.</p>

Title	Modeling CO ₂ degassing rates across the ocean basins: A comparison of on-axis vs. off-axis fluxes
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Abstract Text	<p>We combine global mantle convection simulations with experimental constraints on carbonate melting to estimate carbon fluxes across the ocean basins. Mantle upwelling and temperature structure are derived from instantaneous calculations of mantle flow driven by a combination of mantle density structure (as inferred from seismic tomography) and surface plate motions [Conrad & Behn, 2010]. Assuming carbon contents inferred for the MORB-source mantle [e.g., Rosenthal et al., 2015; Michael & Graham, 2015; Le Voyer et al., 2017], we use the carbonate melting model of Keller & Katz [2016] to calculate global melt and carbon fluxes. Crustal production rates and CO₂ fluxes from the global mid-ocean ridge system are broadly consistent with previous studies; e.g., ~6 km average crustal thickness and ~1–2 x10¹² mol CO₂/yr. However, unlike silicate melting, which occurs primarily beneath the ridge axes, carbonate melting occurs throughout the ocean basins, driven by large-scale passive upwelling of the mantle in response to subduction. In the depth interval for carbonate melting (100–300 km) off-axis upwelling rates are typically a factor of ~10 smaller than upwelling rates below the ridges, and melting terminates at a greater depth due to the off-axis thickening of the lithosphere. The result is production of low degree, CO₂-rich melts that form pervasively across the ocean basins. The total flux of CO₂ into these melts from the mantle is roughly equivalent to the global mid-ocean ridge CO₂ flux. These melts likely refreeze at the base of the overlying lithosphere and potentially provide an enriched component that can be subducted and later refertilize the Earth's mantle.</p>
References	<p>Conrad CP, Behn MD (2010) <i>Geochem. Geophys. Geosys.</i> 11: Q05W05 doi:10.1029/2009GC002970</p> <p>Keller T, Katz RF (2016) <i>J. Petrology</i>, 57: 1030–1108</p> <p>Le Voyer M, Kelley KA, Cottrell E, Hauri EH (2017) <i>Nature Communications</i> 8: 1–8</p> <p>Michael PJ, Graham DW (2015) <i>Lithos</i> 236-237: 338–351</p> <p>Rosenthal A, Hauri EH, Hirschmann MM (2015) <i>Earth Planet. Sci. Lett.</i> 412: 77–87</p>

Title	Effects of Major Element Phase Transitions on Slab Dynamics and Mass Transfer into the Lower Mantle
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Abstract Text	<p>Carbon is carried into the mantle via subduction of sediments, oceanic crust and lithosphere. Where carbon ends up in the mantle therefore depends on the fate of subducted slabs. Previous models have predicted significant trench retreat, which leads to stagnation of slabs at 660-km due to olivine phase transitions, and slow mass transfer to the lower mantle. Here I present 2D simulations of subduction dynamics showing that more realistic treatment of major element phase transitions leads to more buckling and folding of slabs and oscillations in surface plate speeds, but no slab stagnation in the transition zone. The model tracks compositional layering (crust and harzburgite) and 9 phase transitions for the pyrolite mantle and depleted harzburgite, and crustal layer. We also show that to obtain significant periods of trench retreat (~50%, as observed in nature) it is necessary for ridge push forces from the subducting plate to be balanced by ridge push forces from the overriding plate side. However, even in models which have significant periods of trench retreat, the slab sinks continuously into the lower mantle. None of the models result in any slab stagnation either at the 660-km or deeper. We therefore conclude that previous models assuming olivine composition and only incorporating the two major phase transitions over estimate the resistance to slab sinking: these models therefore significantly underestimate the mass flux into the lower mantle. In addition, the effect of far-field forces on subduction is important for distinguishing which observables are constrained by in situ properties of the subduction zone (e.g., plate age) and which are more readily affected by external processes such as other nearby subduction zones, plumes or mid-ocean ridges. The observation that some slabs do appear to stagnate in the transition zone, may therefore be indicative of larger-scale flow, rather than on phase transitions.</p>

Title	Ultrafast dynamical processes of pure water and solutions under pressure
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Abstract Text	<p>Chemical reactions, structural transformations, solute-solvent interaction are only a few examples of fundamental processes that are generally characterized by techniques not able to access the details of the time evolution of the process. This is particularly true for phenomena driven by pressure changes or occurring under high pressure conditions for the intrinsic difficulties to combine ultrafast detection techniques with the high pressure devices. So far the only way to fill this gap was the combination of experiments with computational methods, but also this approach fails when the phenomena under study occur on a “slow” time scale (hundreds of ns or μs). Within the DCO initiative a facility for the study of ultrafast dynamical processes occurring in samples compressed in diamond anvil cells has been developed at the European Laboratory for Non-linear Spectroscopy in Florence. After having characterized the dynamics of fluid water, unveiling the nature of the low-density – high-density transformation of the pure fluid, we have studied how this dynamics is modified by the presence of a solute, a relevant issue directed to understand the behavior of carbon bearing minerals in aqueous fluids at crustal and upper-Mantle conditions. In addition the dynamics of ice melting has been characterized by coupling the T-jump technique to dynamic Mie scattering from the formation of the liquid nuclei to that of macroscopic fluid regions covering a time interval ranging from 1 ns to tens of ms.</p>

Title	Deep subsurface life in Greenland
Presenting Author	Malin Bomberg
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Abstract Text	<p>The deep cold groundwater of Greenland has surprisingly large microbial communities. In this study, groundwater was collected from two boreholes, DH-GAP01 and DH-GAP04 in the area of Kangerlussuaq, western Greenland in September 2014. DH-GAP01 groundwater originated from 191 m depth. DH-GAP04 was sealed with packers between 600 m and 604 m, and groundwater samples were retrieved from above and below the packers as well as from the packer-sealed fracture zone. The in situ T of the groundwater was 1-2°C. The number of bacteria in the deep, cold groundwater was surprisingly high, 104-106 bacterial 16S rRNA gene copies mL⁻¹. The archaeal community was 100-fold smaller and the concentration of fungal ITS copies was between 5 and 50 mL⁻¹.</p> <p>The majority of the bacteria detected belonged to the sulphate reducing genus <i>Desulfosporosinus</i> (75%). This genus also contain species able of Fe(III) reduction. The archaeal communities contained lineages of Micrarchaea, Parvarchaea and different methanogenic clades. The fungi detected belonged to Ascomycetes and Basidiomycetes. The deep groundwater communities differed greatly from the surface environment (lake, pond, glacier ice, melt water and river) communities, indicating that the water bodied above and below the permafrost layer do not mix. Metagenomes of the microbial communities are presently being analyzed and a near complete genome of the <i>Desulfosporosinus</i> has been assembled.</p>

Title	CO ₂ and H ₂ O under deep lower-mantle conditions and Earth's carbon–hydrogen cycles
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Abstract Text	<p>Carbon dioxide (CO₂) and water (H₂O) play an important role in the Earth's evolution of the Earth as they strongly influence the chemical and physical properties of minerals, melts, and fluids. Distribution and circulation of H₂O and CO₂ between the mantle and the Earth's surface have dominated the evolution of the crust, the oceans, and the atmosphere, controlling many aspects of the Earth's habitability. It is therefore crucial to understand the stability and circulation of hydrous and CO₂-bearing minerals in the Earth's interior. Sedimentary material and altered mafic and ultramafic rocks associated to subducted slabs represent the main source for recycling H₂O and CO₂ as well as other volatiles. Here we present new high pressure experimental results on the effect of CO₂-rich medium on a hydrated iron oxide, goethite at extreme conditions. Our study shows the recombination of oxides into a high-pressure carbon-rich phase and provides new insight on the fate of H₂O and CO₂ at lower mantle conditions.</p>

Title	Size, carbon content and biomolecules of microorganisms in the sub-seafloor
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Abstract Text	<p>The discovery of a microbial ecosystem in ocean sediments has evoked interest in life under extreme energy limitation and its role in global element cycling. However, fundamental parameters such as the size and the cellular content of amino acids, lipids and total carbon of sub-seafloor microbial cells are poorly constrained. Here we provide for the first time measurements of the size and the cellular content of biomolecules in sedimentary microbial cells. We separated intact microbial cells from marine sediment matrices by density centrifugation and fluorescence-activated cell sorting (FACS). To determine their shape and volume, cells were visualized via epifluorescence microscopy (FM) and scanning electron microscopy (SEM). Biomolecules such as amino acids and intact polar membrane lipids (IPLs) were analyzed by high-performance liquid chromatography and mass spectrometry (HPLC-MS).</p> <p>We find that the majority of microbial cells in the sediment have coccoid or slightly elongated morphology. From the sediment surface to the deepest investigated sample (~60 m below the seafloor), the cell volume of both coccoid and elongated cells decreased by an order of magnitude from ~0.05 to 0.005 μm^3. Cells had an average content of amino acids and lipids of 17-38 fg cell⁻¹ and 2.3 fg cell⁻¹, respectively, with an estimated carbon content of 14-31 fg C cell⁻¹. This is at the lower end of previous estimates that were used for global estimates of microbial biomass (Parkes et al., 1994; Whitman et al., 1998; Lipp et al., 2008; Kallmeyer et al., 2012). Our data suggest that microorganisms in the marine deep biosphere grow small cell sizes as adaptation to the long-term subsistence at very low energy availability in the deep biosphere, and the data will improve future global estimates of microbial biomass.</p>
References	<p>Kallmeyer J, Pockalny R, Adhikari RR, Smith DC, D'Hondt S (2012) Global distribution of microbial abundance and biomass in subseafloor sediment. <i>Proc. Natl. Acad. Sci. U.S.A.</i> 109: 16213–16216</p> <p>Lipp JS, Morono Y, Inagaki F, Hinrichs K-U (2008) Significant contribution of archaea to extant biomass in marine subsurface sediments. <i>Nature</i> 454: 991–994</p> <p>Parkes RJ, Cragg BA, Bale SJ, Getliff JM, Goodman K, Rochelle PA, et al. (1994). Deep bacterial biosphere in Pacific Ocean sediments. <i>Nature</i> 371: 410–413</p> <p>Whitman WB, Coleman DC, Wiebe WJ (1998) Prokaryotes: the unseen majority. <i>Proc. Natl. Acad. Sci. U.S.A.</i> 95: 6578–6583</p>

Title	Metagenome-enabled explorations of ecosystems supported by serpentinization
Presenting Author	William J. Brazelton
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Additional Authors	Katrina I. Twing, Matthew O. Schrenk
Abstract Text	<p>The vast majority of all microorganisms on Earth inhabit subsurface environments, but many of these organisms are dormant and awaiting death. However, bacteria and archaea who inhabit environments influenced by serpentinization may represent important hot spots of microbial activity in the subsurface. These environments host a set of extreme conditions characterized by high concentrations of hydrogen gas, methane, and other simple organic compounds that are attractive food and energy sources for microbes. Serpentinization has been occurring on Earth ever since it became cool enough to have liquid water, and it is also expected to occur on other rocky bodies with liquid water such as Mars, Europa, and Enceladus. Therefore, the lessons we learn by studying the weird archaea and bacteria associated with serpentinization are likely to help us understand the origin, distribution, and evolution of life in the solar system. This presentation will provide an update on current efforts to apply metagenomic approaches to a comparative study of several ecosystems supported by serpentinization.</p>

Title	New constraints on volcanic CO ₂ emissions from Java, Indonesia
Presenting Author	Mike Burton
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Additional Authors	Chiarugi A., D'Amato F, Viciani S, Queisser M, Marliyani G, Angarra F, Harijoko A
Abstract Text	<p>One of the main objectives of the ERC-funded CO₂Volc project was the airborne measurement of volcanic gas emissions from volcanoes in Java Indonesia, for whom limited flux information was available. This provides a snapshot of volcanic CO₂ emissions from a large proportion of the Banda-Suna arc, and allows comparison with models of CO₂ subduction and recycling. This airborne campaign required the development of a new suite of volcanic gas instruments, capable of high frequency (2-5 Hz), high precision and high accuracy, whilst measuring multiple gases, including H₂O, CO₂, SO₂, HCl and HF. This development work has been completed successfully, with a suite of four instruments capable of measuring the target gases at the concentrations expected in dilute volcanic plumes. The airborne campaign was conducted in September 2016, following a complex permitting process, using a fixed wing aircraft. gas measurements were conducted on 18 volcanoes and one mud volcano complex. Here we present the results of this survey.</p>
References	http://cordis.europa.eu/result/rcn/179631_en.html

Title	Carbon speciation in pyrolite melts
Presenting Author	Razvan Caracas
Institution/Affiliation	CNRS, Ecole Normale Superieure de Lyon
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Abstract Text	<p>First-principles molecular dynamics calculations on carbon-bearing pyrolite melt show formation of new polymerized carbon species at megabar pressure conditions. Carbon, introduced either as monoxide or as dioxide, shows an increase in coordination by oxygen with pressure. At megabar conditions speciation is dominated by polymerized carbon groups, whose lifetimes depend on the oxygen fugacity. At low-density conditions, at the liquid-vapor coexistence, the vapour is dominated by the carbon species, as expected.</p>

Title	Flux & Fate of Reduced Carbon in a Carbonate-capped, Serpentinizing System: Palawan, Philippines
Presenting Author	Dawn Cardace
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Additional Authors	Meyer-Dombard DR, Woycheese K., Ono S, Arcilla C
Abstract Text	<p>The production, movement, transformation, and fate of methane in ultramafic terrains are of great interest to the DCO Deep Energy Community. Ultramafic rocks host source regions and transfer pathways that transmit deeply sourced, reduced carbon to the hydrosphere and atmosphere (perhaps continuously). In Palawan, Philippines, there is a newly discovered, high pH groundwater flow regime sourced in ophiolite-hosted ultramafics, with pilot boreholes completed by colleagues at the University of the Philippines, National Institute for Geological Sciences (C. Arcilla, UP-NIGS). We propose to study existing cores and sample waters and gas directly from existing boreholes. At this previously undescribed site of continental serpentinization in Palawan, Philippines, our goal is to help resolve two of DE's driving questions, asking "What characteristics of deep Earth control the movements of organic molecules?" and "Did mineral-mediated chemical reactions play a role in life's origins?"</p> <p>We report on initial characterization of serpentinization-influenced waters, gases, and representative country rock. We work to address specific driving questions of DE community, considering the impacts of rock geochemistry/field characteristics of the area on the release/transit of methane and organics from depth, and simultaneously query how similar these sites are to peridotite-hosted vents in the seabed, sites of intense relevance to the origin and early evolution of life on Earth (Sleep et al., 2004; Russell et al., 2010, 2013; Schrenk et al., 2013). The Palawan Ophiolite provides an exciting counterpoint to previously studied sites given high seasonal inputs of typhoon-related rainfall, and potential for vigorous subsurface mixing in subsurface hydrological flow regimes. Initial project outputs will include XRD data for sampled rocks, thin section descriptions, methane emission map of field locality, quantification of gases in groundwater and spring waters, and semi-quantitative country rock bulk geochemistry by handheld XRF.</p>
References	<p>Russell, M.J., Hall, A.J., and Martin, W. (2010). Serpentinization as a source of energy at the origin of life. <i>Geobiology</i> 8, 355-371. doi: 10.1111/j.1472-4669.2010.00249.x.</p> <p>Russell, M.J., Nitschke, W., and Branscomb, E. (2013). The inevitable journey to being. <i>Philosophical Transactions of the Royal Society B-Biological Sciences</i> 368, 20120254-20120254. doi: 10.1098/rstb.2012.0254.</p> <p>Schrenk, M.O., Brazelton, W.J., and Lang, S.Q. (2013). Serpentinization, Carbon, and Deep Life. <i>Reviews in Mineralogy & Geochemistry</i> 75, 575-606. doi: 10.2138/rmg.2013.75.18.</p> <p>Sleep, N.H., Meibom, A., Fridriksson, T., Coleman, R.G., and Bird, D.K. (2004). H₂-rich fluids from serpentinization: Geochemical and biotic implications. <i>Proceedings of the National Academy of Sciences of the United States of America</i> 101, 12818-12823. doi: 10.1073/pnas.0405289101.</p>

Title	A decade of global volcanic SO ₂ emissions measured from space
Presenting Author	Simon A Carn
Institution/Affiliation	Michigan Technological University
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Additional Authors	Fioletov, VE, McLinden, CA, Li, C, Krotkov, NA
Abstract Text	<p>The global flux of sulfur dioxide (SO₂) emitted by passive volcanic degassing is a key parameter that constrains the fluxes of other volcanic gases (including carbon dioxide, CO₂) and toxic trace metals (e.g., mercury). It is also a required input for atmospheric chemistry and climate models, since it impacts the tropospheric burden of sulfate aerosol, a major climate-forcing species. Despite its significance, an inventory of passive volcanic degassing is very difficult to produce, due largely to the patchy spatial and temporal coverage of ground-based SO₂ measurements. We report here the first volcanic SO₂ emissions inventory derived from global, coincident satellite measurements, made by the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite in 2005-2015. The OMI measurements permit estimation of SO₂ emissions from over 90 volcanoes, including new constraints on fluxes from Indonesia, Papua New Guinea, the Aleutian Islands, the Kuril Islands and Kamchatka. On average over the past decade, the volcanic SO₂ sources consistently detected from space have discharged a total of ~63 kt/day SO₂ during passive degassing, or ~23±2 Tg/yr. We find that ~30% of the sources show significant decadal trends in SO₂ emissions, with positive trends observed at multiple volcanoes in some regions including Vanuatu, southern Japan, Peru and Chile. This new volcanic emissions inventory should improve constraints on volcanic CO₂ emissions discharged via passive degassing, and can also be used to prioritize targets for future ground-based CO₂ measurements.</p>
References	<p>Carn, SA, Fioletov, VE, McLinden, CA, Li, C, Krotkov, NA (2017) A decade of global volcanic SO₂ emissions measured from space. <i>Sci. Rep.</i> 7, 44095; doi: 10.1038/srep44095.</p>

Title	Diamond oxygen geochemistry
Presenting Author	Pierre Cartigny
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Abstract Text	<p>According to the few, >20 years old, diamond oxygen content would be low, with concentrations below 20 ppm. In order to constrain what are the true levels of oxygen in diamonds, we are building a new vacuum extraction line.</p> <p>There are three scientific motivations driving this new development:</p> <ol style="list-style-type: none"> 1- constraining the speciation of carbon of fluids associated to diamond growth, allowing therefore the oxygen fugacity of mantle fluids to be deduced. 2- constraining the origin of fluids (mantle-derived, subduction-related) leading to diamond. 3- comparing the oxygen isotope geochemistry of diamond and its silicate inclusion <p>The main difficulty consists in oxidizing a diamond without oxygen, and we will use ultra-pure fluorine. We will separate the resulting produced CF₄, NF₃ and O₂ gases which will subsequently be separated using liquid He temperature cryogenic methods and gas-chromatography techniques.</p> <p>The main anticipated difficulty still relies on oxidizing a diamond with low analytical oxygen procedural blanks, (i.e. it would be much more easier if commercially-available high power 5μm laser would exist). Special care is also needed to analyse diamond devoid of nano-sized silicate inclusions, we will therefore try to quantify the amount of released SiF₄ gas.</p> <p>The first test, hopefully undertaken by the end of this year, will therefore be made on a huge (hundred of milligrams) piece of gem-quality diamond heated by an external furnace (i.e. because no high power 5μm heating laser exists).</p>

Title	Influence of carbon on properties of solid iron under extreme conditions: Hidden carbon reservoirs in Earth's core
Presenting Author	Bin Chen
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Abstract Text	<p>Earth's inner core is known to consist of crystalline iron (Fe) alloyed with a considerable amount of nickel (Ni) and lighter elements, but shear wave (S-wave) travels through the inner core at about half the speed expected for most Fe-rich alloys under relevant pressures. The core also exhibits anomalously high Poisson's ratio, but those of most Fe-rich alloys are much lower than observed. Carbon, due to its high cosmic abundance and high solubility in Fe-Ni alloy under the formation and current conditions of outer core, is among the top candidates for the principal light element in the Earth's core. Both iron-carbide phases Fe₃C and Fe₇C₃ have been proposed as components of the inner core, solidifying from a carbon-containing metallic liquids. Here we report new experimental data from Nuclear Resonant Inelastic X-ray scattering measurements up to core pressures on iron carbide Fe₃C, showing that its sound velocities increase with density at a low rate comparable to Fe₇C₃ after going through a pressure-induced spin-pairing transition at 40-50 gigapascals (GPa), as revealed by our X-ray Emission Spectroscopy measurements. Extrapolating to the inner core pressure, we found that the incorporation of carbon in Fe to form Fe₃C and Fe₇C₃ can significantly lower the v_S, but increase the Poisson's ratio to a level close to seismologically observed values of the inner core. The alloying of carbon with solid Fe may account for the anomalous elastic properties of the inner core. Thus, the core may be the largest reservoir of carbon in Earth's deep interiors.</p>

Title	Magmas near the critical degassing pressure drive volcanic unrest toward a critical state
Presenting Author	Giovanni Chiodini
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Additional Authors	Paonita A., Aiuppa A., Costa A., Caliro S., De Martino P., Acocella V., Vandemeulebrouck J.
Abstract Text	<p>During the reawaking of a volcano, magmas migrating through the shallow crust have to pass through hydrothermal fluids and rocks. The resulting magma–hydrothermal interactions are still poorly understood, which impairs the ability to interpret volcano monitoring signals and perform hazard assessments. We used the results of physical and H₂O-CO₂ volatile saturation models to demonstrate that magmatic volatiles released by decompressing magmas at a critical degassing pressure (CDP) can drive volcanic unrest toward a critical state. We show that, at the CDP, the abrupt and voluminous release of H₂O-rich magmatic gases can heat hydrothermal fluids and rocks, triggering an accelerating deformation that can ultimately culminate in rock failure and eruption. We propose that magmas may be approaching the CDP at Campi Flegrei, a volcanic system in the metropolitan area of Naples, one of the most densely inhabited areas in the world, and where accelerating deformation and heating are currently being observed.</p>

Title	Planetary Science and Exploration in the Deep Subsurface: Boulby Mine, UK
Presenting Author	Charles S Cockell
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Abstract Text	<p>Deep subsurface evaporites underlie or are incorporated into a large number of deep subsurface environments. We used culture and culture independent methods to examine the deep subsurface communities associated with fracture zones in a 1 km-deep buried evaporite deposit formed in the Zechstein Sea, a large Permian inland sea. Communities are found in diverse salt types such as sodium chloride and magnesium sulfate dominated brines and 16S rDNA analysis reveals them to be similar across brine types. Metagenomic analysis shows that they primarily subsist on deep subsurface carbon cycling and there is little evidence from metagenomics and culturing analysis for chemolithotrophy or autotrophy. Where brines intersect with certain salts such as magnesium chloride, the water activity is below that required for life and the brines are uninhabited, showing that small deviations in fluid flow make a difference between life and death in deep subsurface evaporites.</p>

Title	Structure and Dynamics of Carbon-bearing Fluids in Nanopores
Presenting Author	David Cole
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Additional Authors	Striolo A, Gautam S
Abstract Text	<p>Complex intermolecular interactions of C-O-H fluids (e.g., H₂O, CO₂, CH₄) result in their unique thermophysical properties, including large deviations in the volumetric properties from ideality, vapor-liquid equilibria, and critical phenomena as these fluids encounter different pressure-temperature-pore network conditions in the crust. Development of a comprehensive understanding of the structures, dynamics, and reactivity at multiple length scales (molecular to macroscopic) over wide ranges of state conditions and composition is foundational to advances in quantifying geochemical processes involving mineral-fluid interfaces. Recently, the importance of nanoporosity (broadly defined as pores with diameters or fractures with apertures less than 100nm) has become better appreciated especially in the context of hydrothermal alteration including serpentinization, hydrocarbon generation/migration associated with burial diagenesis (e.g., tight gas shale), geologic CO₂ sequestration and weathering. The size, distribution and connectivity of these confined geometries dictate how fluids migrate into and through these micro- and nano-environments, wet and react with the solid.</p> <p>This presentation will provide an overview of the application of state-of-the-art experimental and analytical tools (e.g., neutron scattering, NMR) to assess key features of the fluid-matrix interaction. Key results include:</p> <ol style="list-style-type: none"> (1) Even for weak to moderate wetting fluids like the light alkanes and CO₂, respectively, the surface chemistry as well as pore size has a significant impact on changes in fluid density and volume of the adsorbed layer of a pure fluid as pressure and temperature increase. (2) The addition of a second carbon-bearing phase or water has a profound effect on the competition for sorption sites, phase chemistry and the dynamical properties of all phases present in the pore. (3) In addition to pores size, the extent of hydrophilicity (as –OH or H₂O) influences the selectivity of adsorption and associated hydrogen bonding of weakly interacting carbon-bearing species.
References	<p>Ok S, Hoyt D, Andersen, A, Sheets, Welch S, Cole, DR, Mueller, KT and Washton, NM (2017) Surface interactions and confinement of methane: A high pressure magic angle spinning NMR and computational chemistry study. (accepted to Langmuir) doi: 10.1021/acs.langmuir.6b03590</p> <p>Gautam S, Liu T, Patankar S, Tomasko D and Cole D (2016) Location dependent orientational structure and dynamics of ethane in ZSM5. Chem. Phys. Lett. 648, 130-136.</p> <p>Patankar S, Gautam S, Rother G, Podlesnyak A, Ehlers G, Liu T, Sheets J, Cole DR. and Tomasko D (2016) Role of confinement on adsorption and dynamics of ethane-CO₂ in mesoporous CPG silica. J Phys Chem-C 120(9), 4843-4853.</p> <p>Gautam S and Cole, DR (2015) Molecular dynamics simulation study of meso-confined propane in TiO₂. Chem Phys 458, 68-76.</p> <p>Gautam S, Liu T, Rother G, Jalarvo N, Mamontov E, Welch S, Sheets J, Droege M and Cole DR (2015) Dynamics of propane adsorbed in nanoporous silica aerogel: a quasielastic neutron scattering study. J Phys Chem-C 119 (32) 18188-18195.</p>

Title	Quantifying CO ₂ fluxes from diffuse degassing through integration of gas dispersion models and measurements
Presenting Author	Antonio Costa
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Abstract Text	<p>Several non-volcanic sources in Italy emit large amounts of CO₂. Under stable atmospheric conditions, CO₂ concentration, which has a molecular mass greater than that of air, can reach high values that are lethal to humans or animals, especially in topographic depressions.</p> <p>In order to model heavy gas dispersion over complex topographies, accounting for the local meteorology and atmospheric stability, we used a model based on the shallow-layer approach.</p> <p>In areas, like Caldara di Manziana in central Italy, where the gas source can be reasonably estimated (~175 ton/day) we used measurements to validate the model. In other areas, like the Mefite in south Italy, direct measurement of the gas flux is practically impossible because the extremely high CO₂ concentrations near the source. The huge amount of released gas flows along a narrow valley producing a persistent gas river, which can kill people and animals. By integrating the measurements of gas stream velocity, analysis of CO₂ air concentrations, and the physical numerical simulations we were able to estimate a total gas flux of 2000 ton/day, making the Mefite the largest natural emission of low temperature CO₂ rich gases, from non-volcanic environment, ever measured in the Earth. The emission, active at least from thousands of years, is fed by a buried gas reservoir, made up of permeable limestones and covered by clayey sediments, similar to those designed for geological CO₂ sequestration.</p> <p>A similar strategy was used to constrain the CO₂ cloud released during the Lake Nyos limnic eruption, which dispersed up to several kms suffocating wildlife, livestock and humans. We considered various scenarios different for the total amount of the gas and release duration. The scenario involving ~0.5 km³ of gas released in ~3 hours is that better reproduce the observations, reproducing lethal CO₂ concentrations in most of the sites where fatalities occurred.</p>

Title	Persistence of microbial biosignatures with increasing metamorphic grade
Presenting Author	Claire R Cousins
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Additional Authors	Mikhail S, Foucher F, Westall F, Montgomery W, Steele A, Shahar A
Abstract Text	<p>Little is known about the survivability of microbial biosignatures within rock substrates when subject to the high pressures (P) and temperatures (T) typically experienced during rock burial, yet our picture of the early Earth biosphere and microbial evolution over time is based upon the preserved organic and geochemical remnants of such microorganisms. Using a piston cylinder press we exposed a natural microbial biofilm community hosted within a thermal spring carbonate matrix to 6 different PT conditions spanning 500 - 800 MPa and 200 - 550 °C (zeolite - amphibolite) to investigate the persistence of microbial organic material and associated geochemical biosignatures with increasing metamorphic grade. Experimental products were analysed with 2D Raman spectroscopy and FEG SEM mapping to investigate the spatial and geochemical evolution between organic and inorganic phases, and GC-MS to investigate survivability of biomarkers. Microbial biofilms comprising filamentous sulfur oxidising bacteria, cyanobacteria, and diatoms were associated with elevated silica, which mineralised increasingly graphitised organic carbon as temperature and pressure increased. Discrete clusters of sulfur globules associated with the biofilms persisted across all metamorphic facies, becoming morphologically-deformed at the highest PT conditions. At the highest PT conditions, graphitised organic carbon and sulfur globules were completely silicified and eventually preserved within a quartz phase, while the carbonate recrystallised to form the surrounding matrix.</p>

Title	Carbon and sulfur budget of the silicate Earth explained by accretion of differentiated planetary embryos
Presenting Author	Rajdeep Dasgupta
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Abstract Text	<p>The abundances of volatile elements in the Earth's mantle have been attributed to the delivery of volatile-rich material after the main phase of accretion. However, no known meteorites could deliver the volatile elements, such as carbon, nitrogen, hydrogen and sulfur, at the relative abundances observed for the silicate Earth. Alternatively, Earth could have acquired its volatile inventory during accretion and differentiation, but the fate of volatile elements during core formation is known only for a limited set of conditions. Here we present constraints from laboratory experiments on the partitioning of carbon and sulfur between metallic cores and silicate mantles under conditions relevant for rocky planetary bodies. We find that carbon remains more siderophile than sulfur over a range of oxygen fugacities; however, our experiments suggest that in reduced or sulfur-rich bodies, carbon is expelled from the segregating core owing to saturation. Combined with previous constraints, we propose that the ratio of carbon to sulfur in the silicate Earth could have been established by differentiation of a planetary embryo that was then accreted to the proto-Earth. We suggest that the accretion of a Mercury-like (reduced) or a sulfur-rich (oxidized) differentiated body—in which carbon has been preferentially partitioned into the mantle—may explain the Earth's carbon and sulfur budgets. Establishing the sulfur abundance and the C/S ratio requires segregation of sulfide melt after core formation.</p>

Title	Dating individual diamond growth zones: A new methodology for assessing potential temporal changes in the deep carbon cycle.
Presenting Author	Gareth R Davies
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Abstract Text	<p>Diamonds and their inclusions potentially help quantify temporal changes in fluxes in the Earth's deep carbon cycle. The multi-stage growth of many gem quality diamonds, however, requires precise dating of individual diamond growth events before carbon isotope and other geochemical data can be fully interpreted. To this end a methodology has been developed to determine coupled Sm-Nd, Rb-Sr isotope systematics of individual inclusions (> 40 µm) using 1013 Ohm current resistors. Additional characterisation of inclusions for major and trace element contents, and the diamond host for C isotope ratios, N content and aggregation state, allows rigorous assessment of whether inclusions suites are cogenetic.</p> <p>This approach was applied to harzburgitic garnet inclusions from Venetia (SA), where a Sm-Nd Proterozoic age of 2.3 ± 0.04 Ga had been interpreted as diamond formation at ~2 Ga associated with modification of >3 Ga Archaean mantle by Bushveld-related magmas. Garnet inclusions from Venetia are shown to represent two distinct populations with Archaean (2.95 Ga) and Proterozoic (1.15 Ga) Sm-Nd ages. The Archaean diamond suite formed due to relatively cool fluid-dominated metasomatism, whereas the Proterozoic suite formed by melt-dominated metasomatism related to the Umkondo Large Igneous Province.</p> <p>Sm-Nd systematics of E-type diamonds from Botswanan mines support coupled C isotope and N aggregation studies that imply multiple ($n > 6$) diamond growth events at individual mines. Individual diamonds have complex growth zones up to 2 Gyr different in age. The distinct diamond forming events involved carbon derived from 3 different sources interpreted as the asthenosphere and recycled organic-rich and carbonate-rich sediments, the proportion of which varied with time. In both the above studies, diamond growth events can be directly related to regional geological events and hence used to assess the changing tectono-magmatic environment of diamond formation.</p>

Title	A new estimation of volatile flux from the Southern Central American Volcanic Arc
Presenting Author	J. Maarten de Moor
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Additional Authors	Kern C, Aiuppa S, Fischer TP, Avarad G, Muller C, Alvarez J, Ibarra M, Protti M, LaFemina P
Abstract Text	<p>We present an updated estimate of the SO₂ and CO₂ fluxes from the Southern Central American Volcanic Arc (SCAVA) based on an unprecedented dataset covering all of the degassing volcanoes along this 500km arc segment for the period 2015-2016. We find that the SO₂ flux was at least twice that of any previous compilations and that the CO₂ flux was almost an order of magnitude than that reported in previous studies. Our results indicate that either past studies vastly underestimated the volatile flux from SCAVA or that the arc is currently degassing more vigorously than in the past, perhaps in response to two megathrust earthquakes that occurred in 2012. Whereas previous studies relied on limited datasets and extrapolations to conclude that the majority of subducted carbon was transported beyond the volcanic front to the deep mantle, our more complete arc survey indicates that more carbon is degassed by volcanoes than is subducted. These results highlight the crucial need for accurate time series gas flux measurements in order to understand the deep carbon cycle.</p>

Title	Diamond-bearing Marble in Earth's Lower Mantle Down to the Core-Mantle Boundary
Presenting Author	Susannah McGregor Dorfman
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Abstract Text	<p>Carbon storage and flux in the deep Earth are moderated by pressure, temperature, oxygen fugacity and interaction with iron-bearing phases. To understand the fate of carbonates in the lowermost mantle, we have performed experiments on sandwiches of single-crystal $(Ca_{0.6}Mg_{0.4})CO_3$ dolomite and Fe foil in the laser-heated diamond anvil cell at lower mantle conditions of 51-113 GPa and 1800-2500 K. Syntheses were conducted with in situ synchrotron X-ray diffraction to identify phase assemblages. After quench to ambient conditions, samples were sectioned with a focused Ga⁺ ion beam for transmission electron microscopy with energy-dispersive X-ray mapping for composition analysis. At the centers of the heated spots, iron reacted completely to form magnesiowüstite and iron carbide. The corresponding reduction of the carbonate resulted in formation of diamond and ferropericlase, but calcium carbonate remained preserved. While previous studies have suggested that magnesite is more stable than high-pressure calcite polymorphs at high temperatures and in presence of lower mantle silicates, these experiments demonstrate that post-aragonite $CaCO_3$ is more stable than magnesite in a highly reducing, metallic-iron-bearing phase assemblage potentially found in the deep lower mantle or core-mantle boundary.</p>

Title	Synthesis of Deep Carbon Observatory Science
Presenting Author	Marie Edmonds
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Additional Authors	Trew Crist, D.
Abstract Text	<p>The Deep Carbon Observatory ten-year programme has produced a wealth of scientific discoveries, groundbreaking instrumentation and datasets. Between now and the end of 2019, a new focus of the DCO is synthesis, via a range of products and activities. The Synthesis Group 2019 (SG2019) committee, formed in April 2016, is working to integrate research conducted across DCO's four science communities to realize a new understanding of deep carbon science and fully capture DCO's achievements. This synthesis process aims to elevate the collaborative efforts of this global research initiative, making the whole greater than the sum of its parts.</p> <p>Initiatives are broad-based and designed to reach audiences ranging from our scientific peers to the interested public. Many opportunities are available for DCO scientists to participate, ranging from writing review articles and editing special issues, to developing educational materials based on DCO scientific findings, to helping to craft legacy products (e.g. models and databases) that will shape deep carbon scientific research into the future.</p> <p>SG2019 is working to ensure that what has been learned about the role of deep carbon is integrated across DCO's four Science Communities. This cross-community effort has included advancing modeling and visualization (e.g. MELTS and DEW), creating databases and inventories so DCO's work can be integrated into future research, establishing a Gordon Conference series on deep carbon, and funding a number of synthetic projects: seeking to model mineral diversity using novel network tools (Carbon Mineral Evolution), present overarching DCO research in new ways (e.g. Earth in Five Reactions), develop new synergies between communities (e.g. Biology Meets Subduction) among others. The goal is to have this decadal program culminate in 2019 with a sweeping series of scientific contributions unveiled at a science meeting and event to celebrate the creation and solidification of a new field of deep carbon science.</p>

Title	Earth's exhaust pipe: carbon isotope systematics in volcanic arc gases
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Abstract Text	<p>Of the total amount of carbon contained in Earth, the mantle is the largest reservoir. Cycling of carbon between the surface environment and the mantle takes place via carbonate subduction and volcanic outgassing. Imbalance in this cycle has huge significance for atmospheric CO₂ concentration and consequently for atmosphere-ocean temperature over geological timescales. Carbon isotopes, combined with other geochemical tracers, may provide a means to isolate sources and mechanisms of carbon cycling. Carbon in subducting slabs takes the form of organic sediments (with a $\delta^{13}\text{C}$ of -40 to -20‰) and carbonate fixed in the oceanic crust during hydrothermal circulation (with $\delta^{13}\text{C}$ of ~0‰). The $\delta^{13}\text{C}$ composition of the depleted upper mantle has been proposed to be -4±/± 2.5‰. Volcanic gases might be expected to be influenced by these sources, as well as by crustal contamination and interaction with hydrothermal systems. We have created an updated compilation of $\delta^{13}\text{C}$ values of emissions from arc volcanoes, in tandem with He and N isotopic data to provide additional constraint on subduction inputs and crustal contamination. While a small number of arc volcanoes emit gases that fall within typical mantle values, there is a dominance of heavier-than-mantle values in much of the compiled arc volcanic data, particularly when weighted by CO₂ flux. Heavy carbon volcanic outputs, with low ³He/⁴He, are particularly common in continental settings. We propose that whilst the heavy carbon signature of arcs may be influenced by a contribution from subducted inorganic carbon, there is also a strong signature of contamination by carbonate contained within the overriding crust (accreted as carbonate platforms during ocean closure), particularly among volcanic arcs of the Tethyan margin. Observations of modern day volcanic carbon isotope systematics may be used to infer how the volcanic signal might have changed accompanying Wilson cycle supercontinent formation and rifting through the Phanerozoic.</p>

Title	Resources and Partnership Opportunities in Data Science
Presenting Author	Kathleen Fontaine
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Additional Authors	Fox P, Rogers K, Eleish A
Abstract Text	<p>The DCO Data Science Team has a wealth of resources and expertise available to the discerning DCO scientist in these eight areas: Data Management/Curation; Data Rescue; Data Registration; Data Visualization; Data Analytics; Data Papers; Data Linking; and Data Provenance. Each of these areas makes use of a variety of tools, including Jupyter notebooks, available in the DCO Data Portal. Examples of each capability are provided in this poster, along with DCO-specific successes in many areas.</p>

Title	Carbon, sulfur, and halogen fluxes in intraplate mantle lithosphere
Presenting Author	Maria-Luce Frezzotti
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Abstract Text	<p>The balance between carbon being subducted and the degree to which carbon is released from the mantle wedge and from arc volcanoes represents the fundamental process regulating Earth's carbon cycle. In intraplate settings, deep carbon fluxes are considered to originate from "primitive" mantle reservoirs. Here, we present fluid and melt inclusion data in peridotite xenoliths from Ethiopia, Hawaii, and Canary Islands which provide evidence on the nature of mantle fluids in regions of active intraplate and rifting magmatism. Mantle fluids are oxidized, CO₂-rich and contain significant, though variable, amounts of sulfur species (H₂S, SO₂, or sulfates), water, and halogens. Such fluid compositions are unexpected in intraplate continental and oceanic lithosphere (60 – 90 km depth) and show similarities to deeper fluids preserved in kimberlitic diamonds. Data delineate changes in volatile speciation and redox conditions in the lithosphere, and yield improved insights on how hydrous carbonate-rich melts exsolve aqueous-carbonic fluids enriched in halogens and sulfur, on reaction with peridotites. Geochemical characteristics of fluids support an origin that includes recycled crustal sediments and basaltic oceanic crust (paleo-subduction). Natural fluid data suggest that significant amounts of carbon were captured and stored in the upper mantle during Earth's history.</p>

Title	Serpentinization, carbon and life: Preliminary results of drilling the Atlantis Massif (IODP Expedition 357)
Presenting Author	Gretchen L. Früh-Green
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Abstract Text	<p>IODP Expedition 357 successfully used two seabed rock drills to core 16 shallow holes at 8 sites across the Atlantis Massif (Mid-Atlantic Ridge 30°N). A major goal of this expedition was to investigate serpentinization processes and microbial activity in the shallow subsurface of highly altered ultramafic and mafic sequences that have been uplifted to the seafloor along a major detachment fault zone. More than 57 m of core were recovered, with borehole penetration ranging from 1.3 to 16.4 meters below seafloor, and core recovery as high as 75% of total penetration. The cores show highly heterogeneous rock type, bulk rock chemistry and alteration that reflect multiple phases of magmatism, melt-rock interaction, and progressive serpentinization and metasomatism. New technologies were developed and successfully applied for the first time: (1) an in-situ sensor package and water sampling system on each seabed drill measured real-time variations in dissolved methane, oxygen, pH, oxidation reduction potential, temperature, and conductivity during drilling and took water samples after drilling; (2) a borehole plug system to seal the boreholes was successfully deployed at two sites to allow access for future sampling; and (3) chemical tracers were delivered into the drilling fluids for contamination testing. On-going active serpentinization is evident by in situ records of gas release and by elevated concentrations of hydrogen and methane over a number of sites. In addition, preliminary isotopic analyses of fluid inclusions suggest multiple sources of methane. We will provide an overview of the preliminary results of Expedition 357, and highlight the role of serpentinization in carbon cycling and sustaining microbial communities in a region of active serpentinization and low temperature hydrothermal alteration.</p>

Title	Searching for "deep" nitrogen through SIMS analyses of undegassed basaltic glasses
Presenting Author	Evelyn Füre
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Abstract Text	<p>Nitrogen, the main constituent of Earth's atmosphere, is crucial for life and an important component of biological processes, and it represents a potential tool for tracing volatile fluxes between the (near-) surface, shallow-mantle, and deep-mantle reservoirs. However, the study of nitrogen in mantle-derived silicate samples is complicated by its low abundance (ppm levels), which makes this element sensitive to contamination by atmospheric and surface-derived (organic) nitrogen. Consequently, the distribution of nitrogen and its isotopes among the "deep" volatile reservoirs remains a matter of debate. Melt inclusions – potentially undegassed pockets of melt trapped in early-formed minerals – are key for investigating the volatile characteristics of the deep Earth, but current analytical techniques do not allow targeted measurements of nitrogen to be made in these micron-sized samples. Therefore, we have developed a protocol for in situ nitrogen abundance and isotope analyses of silicate samples by secondary ionization mass spectrometry (SIMS). We hold a suite of 14 (C-) N-bearing basaltic glasses, whose nitrogen concentrations and $^{15}\text{N}/^{14}\text{N}$ ratios have been determined by CO_2 laser extraction static mass spectrometry. These glasses are used as standards for nitrogen measurements using the CAMECA IMS 1280 HR2 at the Centre de Recherches Petrographiques et Gochimiques (Nancy, France). Given that this instrument can achieve a very high mass resolving power, potential isobaric interferences on the CN^-, NO^-, AlN^-, and SiN^- signals can be resolved. By targeting these secondary molecular ions, nitrogen abundances can be detected down to the ppm level in both carbon-bearing and carbon-free basaltic glasses. Uncertainties on isotope ratios are on the order of only a few permil for samples containing tens of ppm nitrogen. Thus, this technique will be key for the study of nitrogen in melt inclusions and is expected to provide new insights into the nitrogen (-carbon) characteristics of the deep Earth.</p>

Title	An analysis of the dynamics of Mantle Melting and Outgassing related to deep volatiles
Presenting Author	Fabrice Gaillard
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Abstract Text	<p>Volatile species at mantle depth trigger defects minerals and destabilize solid phases to produce melting. Incipient degrees of melting are produced in response to small amounts of C, O, H, S, Cl species being present in the mantle rocks. Depending on the allocated time, I will tackle various topics related to mantle melting and volatile species that have been considered in the framework of the ElectroLith project:</p> <ul style="list-style-type: none">- The molecular structure of such melts are unconventional in comparison to the canonical basalts and this impacts of their physical and chemical properties.- How and where such melts are produced at depth and how they ascent through the Asthenosphere - Lithosphere boundary- How geodynamics, and in particular, how the secular cooling of the Earth's mantle have modified the dynamics of mantle melting and its impact on the transfer of volatiles to the planetary surface.

Title	Role of faint luminosity of the Sun in the history of biosphere
Presenting Author	Erik Galimov
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Abstract Text	<p>It is known that solar radiation fails to maintain a temperature on the Earth's surface above the freezing point of water. Acceptable for life global temperature is due to presence of greenhouse gases in the atmosphere. Nevertheless from time to time extensive glaciations occurred on Earth. The history of glaciation is complicated. About 2.4 Ga ago enormously deep global glaciation occurred, which lasted almost 200 million years. Then during about 1.5 Ga no glaciation has been registered. Only starting from 0.73 Ga ago a series of glaciations occurred again. The timing of glaciations, in particular, lack of glaciations during 1.5 Ga is considered as an enigma of paleoclimatology. I argue that this is a feature of a dramatic conflict between the role of CO₂ as a greenhouse gas and its role as the base substance for biota creation. Life came into being under the conditions of the highly reduced atmosphere. When molecular oxygen appeared in the atmosphere 2.4 Ga ago, methane stopped playing its role of the main greenhouse gas, while the content of carbon dioxide was not high enough to maintain that role. The ice age was over when CO₂ content in the atmosphere reached the sufficient level. As long as the biota carbon resource was lower than that of the atmospheric CO₂, sporadic increase processes of bioproduction did not result in such outflow of the atmospheric CO₂ that would have any significant impact on the thermal regime. Only by the time of 0.8 Ga ago, when the biota resource became comparable with the atmospheric carbon the periods of glaciation and warm climate became to alternate. With invasion of biota on land the type of interaction changed again. I believe that the aspect of the biosphere history related to the Sun luminosity deserves more detailed study.</p>

Title	Quantification of global volcanic CO ₂ emissions from ground-based remote sensing of SO ₂ and in-situ sampling of volcanic plumes
Presenting Author	Bo Galle
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Additional Authors	Arellano S., Velasquez G., Chacon Z., Burbano V., De Moor M., Muñoz A., Mulina K. and Wallius J.
Abstract Text	<p>DECADE (Deep Earth Carbon Degassing) is a sub-project under "DCO-Reservoirs and Fluxes" aiming at improved quantification of carbon outgassing from the Earth's interior. A significant component of these emissions corresponds to volcanic CO₂, which can be quantified by combining measurements of total SO₂ emission using ScanDOAS remote sensing instruments, with measurements of the CO₂/SO₂ ratio using in-situ MultiGas instruments. This poster presents 3 activities led by Chalmers related to this overall task:</p> <p>NOVAC (Network for Observation of Volcanic and Atmospheric Change) is a global network for ScanDOAS measurements of SO₂ emission from volcanoes. This network is growing and presently comprises 41 volcanoes, including 5 DECADE target volcanoes: Villarrica, Nevado del Ruiz, Galeras, Turrialba and Masaya. Chalmers coordinates this network and an important task is to support the actual volcano observatories with repair and maintenance of the instruments as well as to ensure a timely delivery of validated SO₂ emission data from these NOVAC volcanoes to the DECADE archive. In addition to the abovementioned 5 DECADE/NOVAC volcanoes Chalmers is participating in field-campaigns targeting sparsely monitored volcanoes with expected high gas emissions. As example we show results from a field-campaign conducted on 3 volcanoes in Papua New Guinea in September 2016.</p> <p>An important source of error in the measurement of SO₂ emission from volcanoes using the ScanDOAS technique is caused by atmospheric scattering. Ideally, a ground-based instrument records light from above and transmitted through the volcanic plume, and the amount of gas is evaluated using UV absorption spectroscopy. However, atmospheric scattering from below the plume may add light that has never passed the plume, causing "dilution" of the absorption. We are developing a relatively straight forward approach for the correction of this effect to reduce the error in current and past estimations of the volcanic SO₂ and CO₂ emission.</p>
References	<p>Galle, B., M. Johansson, C. Rivera, Y. Zhang, M. Kihlman, C. Kern, T. Lehmann, U. Platt, S. Arellano, and S. Hidalgo (2010), <i>J. Geophys. Res.</i>, 115, D05304,</p> <p>Conde V., P. Robidoux, G. Avard, B. Galle, A. Aiuppa, A. Muñoz and G. Giudice. . (2014), <i>International Journal of Earth Sciences</i>, 103 (8) s. 2349. ISSN 1437-3254.</p> <p>Aiuppa A.,P. Robidoux, G. Tamburello, V. Conde, B. Galle, G. Avard, E. Bagnato, M. De Moor, M. Martinez, A. Muñoz, (2014), <i>Earth and Planetary Science Letters</i>, 407, 134-147.</p> <p>De Moor, J., Aiuppa, A., Avard, G., Wehrmann, H., Dunbar, N., Muller, C., Tamburello, G., Giudice, G., Liuzzo, M., Moretti, R., Conde, V. and Galle, B. (2016), <i>Journal of Geophysical Research-Solid Earth</i> (2169-9313). Vol. 121 (2016), 8, p. 5761-5775.</p> <p>Galle B., Conde V., Arellano S., Pfeffer M., Barsotti S., Stefansdottir G., Bergsson B., Bergsson B., Ingvarsson T. and Weber K., (2016), <i>Geophysical Research Abstracts</i>, Vol. 18, EGU2016.</p> <p>Arellano S., Galle B. and Wallius J. (2017), <i>Internal DCO-report</i>, February 2017</p>

Title	Quantification of global serpentinisation and hydrogen production at mid-ocean spreading plate boundaries: 250 Ma to Present
Presenting Author	Pablo Garcia del Real
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Abstract Text	<p>Serpentinisation of ultramafic rocks at mid-ocean spreading plate boundaries contributes to global fluxes and transformation of molecular oxygen, carbon and hydrogen. In these vast tectonic provinces, serpentinisation provides a pathway for elemental hydrogen production (H₂), reduction of carbon (e.g. CH₄) and abiotic synthesis of organic compounds. Global quantification of serpentinisation rates requires a physiochemical and temporal description of plate tectonic configuration over geologic time. In this work, we employ broadly applicable geochemical parameters, plate reconstruction and kinematic models spanning the Triassic (250 Ma) to the Present (0 Ma)(1–4) to quantify progressive responses in serpentinisation and concurrent hydrogen production at mid-ocean spreading plate boundaries. Our models aim to capture the systematic relationships among seafloor spreading, serpentinisation and H₂ production during major tectonic events. Using the GPlates(1–4) infrastructure, we calculate the applicable reactive lengths in 1 Ma intervals for: (a) the global plate boundary, which includes interconnected spreading and transform components; (b) spreading centers only; and (c) slow and ultraslow segments. These three scenarios (a,b,c) indicate that the fragmentation of Pangea and formation of the Pacific plate starting 200 Ma ago substantially increased the length of mid-ocean ridges and generation of young oceanic crust, which resulted in H₂ production exceeding $\sim 10^{13}$ mol/yr starting at ~ 160 Ma. This value is one order of magnitude higher compared to rates in the Late Mesozoic (<160 Ma). From 160 Ma to Present, the coupled opening of the Atlantic and Indian oceans as well as variation in spreading rates maintained H₂ production in the $\sim 10^{13}$ mol/yr level, which is one to three orders of magnitude higher than previous estimates(5–13). Compared to other geologically active environments with vigorous H₂ production (e.g. hot basaltic vents, arc volcanoes)(13), serpentinisation at mid-ocean plate boundaries appears to be the largest source of elemental hydrogen on Earth.</p>
References	<ol style="list-style-type: none"> 1. Matthews KJ, et al. (2016) Global plate boundary evolution and kinematics since the late Paleozoic. <i>Glob Planet Change</i> 146:226–250. 2. Müller RD, et al. (2016) Ocean basin evolution and global-scale reorganization events since Pangea breakup. <i>Annu Rev Earth Planet Sci Lett</i> (April):107–138. 3. Cannon J, Lau E, Müller RD (2014) Plate tectonic raster reconstruction in GPlates. <i>Solid Earth</i> 5(2):741–755. 4. Boyden JA, et al. (2011) Next-generation plate-tectonic reconstructions using GPlates. <i>Geoinformatics; Cyberinfrastructure Solid Earth Sci</i>:95–114. 5. Worman SL, Pratson LF, Karson JA, Klein EM (2016) Global rate and distribution of H₂ gas produced by serpentinization within oceanic lithosphere. <i>Geophys Res Lett</i> (43):6435–6443. 6. Keir RS (2010) A note on the fluxes of abiogenic methane and hydrogen from mid-ocean ridges. <i>Geophys Res Lett</i> 37(24):1–5 7. Cannat M, Fontaine F, Escartin J (2013) Serpentinization and Associated Hydrogen and Methane Fluxes at Slow Spreading Ridges. <i>Diversity of Hydrothermal Systems on Slow Spreading Ocean Ridges</i> (American Geophysical Union), pp 241–264. <i>Geophysica</i>. 8. Emmanuel S, Ague JJ (2007) Implications of present-day abiogenic methane fluxes for the early Archean atmosphere. <i>Geophys Res Lett</i> 34(April):1–5. 9. Sorokhtin OG, Lein AY, Balanyuk IE (2001) Thermodynamics of oceanic hydrothermal systems and abiogenic methane generation. <i>Oceanology</i> 41(6):861–872. 10. Kasting JF, Catling D (2003) Evolution of a Habitable Planet. <i>Annu Rev Astron & Astrophysics</i> 41:429. 11. Canfield DE, Rosing MT, Bjerrum C (2006) Early anaerobic metabolisms. <i>Philos Trans R Soc Lond B Biol Sci</i> 361(1474):1819–1834–1836. 12. Welhan JA, Craig H (1983) Methane, hydrogen and helium in hydrothermal fluids at 21 °C on the East Pacific Rise. <i>Hydrothermal Processes at Seafloor Spreading Centers</i>, eds Rona P, Borstrom K, Laubier L, Smith KLJ (Springer), pp 391–409. 13. Sleep NH, Bird DK (2007) Niches of the pre-photosynthetic biosphere and geologic preservation of Earth's earliest ecology. <i>Geobiology</i> (5):101–117.

Title	ENKI: A Jupyter notebook platform that delivers essential modeling tools to the Extreme Physics and Chemistry and the Reservoirs and Fluxes DCO communities
Presenting Author	Mark S. Ghiorso
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Abstract Text	<p>Computational thermodynamics (CT) and computational fluid dynamics (CFD) are two essential modeling tools of the Extreme Physics and Chemistry (EPC) and the Reservoirs and Fluxes (RF) communities within the Deep Carbon Observatory. We are developing ENKI to address modeling needs of EPC and RF and to encourage broad participation in the creative use and interoperability of CT and CFD models. ENKI provides a common browser-based platform for interacting with software tools in CT and CFD, utilizing both Python- and R-based Jupyter notebooks running locally or in client-server configuration. The ENKI platform supports development and access to thermochemical models of Earth materials and establishes a standard infrastructure of web services and libraries that permit these models to be integrated into fluid dynamical transport codes. ENKI allows scientific questions to be answered by quantitative simulations that are presently difficult to impossible because of the lack of interoperable software frameworks and because of the burdensome need to write, port, and modify existing software for local usage. ENKI modernizes how thermodynamic and fluid dynamic models are used by the DCO and broader Earth science community in five fundamental ways: (1) provenance tracking enables automatic documentation of model development and execution workflows, addressing modern reproducible science objectives, (2) novel software tools assist users in updating thermochemical models as new data become available, with the ability to merge these data and models into existing repositories and frameworks, (3) automated code generation eliminates the need for users to manually code web services and library modules, (4) visualization tools and standard test suites facilitate validation of model outcomes against observational data, and (5) collaborative networks enable sharing and archiving of models and modeling workflows with associated provenance for publication. ENKI is being developed on DCO data science servers and will utilize the EPC compute cluster.</p>

Title	The carbon puzzle is missing a piece: shallow-water hydrothermal vents
Presenting Author	Donato Giovannelli
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Abstract Text	<p>Recent estimates of global carbon budgets have benefited from the inclusion of new measurements of diffuse degassing and previously unrecognized CO₂ source and sinks. Despite this the carbon puzzle could be missing an important piece: shallow-water hydrothermal venting.</p> <p>Shallow-water vents are ubiquitous but poorly studied geothermal environments. Located worldwide between the intertidal zone and 200 meters depth, the simultaneous presence of light and geothermally reduced compounds makes shallow-water hydrothermal systems high-energy environments where photosynthesis and chemosynthesis co-occur. Given their distribution and characteristics, shallow-water hydrothermal vents may play a significant role in global biogeochemistry, potentially influencing global CO₂ fluxes. They also harbor a large fraction of microbial diversity fueled by volatiles and reduced species originating from subsurface environments. Despite this, only a small number of shallow-water hydrothermal vents have been investigated in detail, and a large number of vents remain uncharted. We estimate the total number of shallow-water venting sites could be far greater than previously recognized. First order estimates suggest that shallow-water vents could contribute a significant fraction of CO₂ degassing globally. Microbiological studies at shallow vents suggest that the community is highly diverse, and only partially overlapping with deep-sea vents. Moreover, a large fraction of the dominant microbial groups remain uncultured, leading to major challenges in understanding the role for biology in the alteration and removal of volatiles and chemical species released into the water column and atmosphere.</p> <p>In this talk I will briefly summarize current knowledge and recent data collected in shallow-water hydrothermal vents worldwide, highlighting gaps on our understanding of this phenomena. I will argue that shallow vents represent unique environments for investigating the interplay of biological, chemical, and physical processes, potentially influencing carbon cycling at a global scale.</p>

Title	Self-Assembly of Prebiotic Organic Materials from Impact Events of Amino Acid Solutions
Presenting Author	Nir Goldman
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Abstract Text	<p>Proteinogenic amino acids can be produced on or delivered to a planet via abiotic sources and were consequently likely present before the emergence of life on early Earth [1,2]. Dipeptides of proteinogenic amino acids have been produced in the laboratory in interstellar ice models [3]. Shock synthesis of amino acids has also been observed in both computational and experimental studies [4]. Shock compression in astrophysical ices can induce the formation of extended C-N bonded networks similar to peptide chains [5]. However, the role that these materials played in the emergence of life remains an open question, in part because little is known about the survivability and reactivity of astrophysical prebiotic compounds upon impact with a planetary surface. Potential life building synthesis derived from amino acids and peptide activating agents would depend heavily on their fate during extreme pressures and temperatures.</p> <p>To this end, we have used a novel quantum simulation method in development in our group [6], to study oblique impacts of aqueous glycine solutions at conditions of up to 40 GPa and 3000 K. We find that these elevated conditions induce the formation of glycine-oligomeric structures with a number of different chemical moieties such as hydroxyl and amine groups diffusing on and off the C-N backbones. The C-N backbones of these structures generally remain stable during cooling and expansion, yielding relatively large three-dimensional molecules that contain a number of different functional groups and embedded bonded regions akin to peptide chains. Our results help determine the role of comets and other celestial bodies in both the delivery and synthesis of polypeptides and homochirality to early Earth. This will help guide future experimentation by providing both a possible synthetic mechanism as well as a catalogue of possible chemical products to be investigated.</p>
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Title	Chemistry of carbon in carbonates at extreme pressure-temperature conditions
Presenting Author	Alexander F Goncharov
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Abstract Text	<p>Carbonates play a major role in the return of carbon into the mantle, but are very reactive and prone to pressure-induced phase transitions. Of particular importance are the theoretically predicted phase transitions from structures with trigonally-coordinated (sp²) to tetrahedrally-coordinated (sp³) carbon, as these may promote carbon solubility in the mantle and lead to contrasting carbonate chemical and physical behavior with depth. Despite the importance, experimental evidence for the stability of sp³-carbonates at lower mantle conditions has been incomplete. Here we use laser-heated diamond anvil cells combined with synchrotron x-ray diffraction (XRD), Raman spectroscopy, and first-principles calculations to identify phase transitions in CaCO₃ at high pressure. As we show that post-aragonite CaCO₃ transforms to P21/c-CaCO₃ with sp³-hybridized carbon at 105 GPa, this support a crossover to Ca-rich carbonates in the lowermost mantle, which may contribute to the seismic complexity of the region. We have also studied the Mg-carbonate – Fe interactions using synchrotron XRD. This study demonstrates the interaction of carbonates with Fe or Fe-bearing materials that produces Fe-carbide and excessive diamond, which can be accumulated near the core-mantle boundary depending on the balance between carbon and Fe.</p>

Title	Modeling anaerobic oxidation of methane in dynamic methane hydrate-bearing sediments
Presenting Author	Michael F Graw
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Abstract Text	<p>Anaerobic oxidation of methane (AOM) mediated by consortia of anaerobic methanotrophic archaea and sulfate-reducing bacteria (ANME-SRB consortia) accounts for the oxidation of more than 90% of dissolved methane fluxing through methane hydrate-bearing marine continental margin sediments. Despite the biogeochemical significance of AOM, little is known about the cellular-level function of ANME-SRB consortia or the response of these consortia to changes in methane flux. Obtaining a deeper understanding is particularly important at the moment since warming caused by global climate change is expected to gradually induce methane hydrate instability, thereby increasing the flux of dissolved methane through hydrate-bearing continental margin sediments.</p> <p>We are developing a coupled metabolic model of an ANME-SRB consortium in order to elucidate intercellular interactions between microbial partners within the consortium and predictively analyze how these consortia respond to changes in sediment methane flux. We have performed whole-genome shotgun sequencing on environmental isolates and metatranscriptomic sequencing of sediments experiencing a range of methane flux regimes. Combined with geochemical measurements, these datasets are being combined to develop a novel metabolic model calibration technique. We anticipate that our model will demonstrate a novel application of –omics datasets and open the way for metabolic modeling of a range of environmental microorganisms, including those involved in carbon, nutrient, and contaminant cycling.</p>
References	Knittel K, and Boetius A (2009) Annual Review of Microbiology, 63:311-334.

Title	Survival by any means necessary? Insights from the methanogenic archaea-associated oxidation of NH ₄ ⁺ to N ₂ O in three sulfide-mineral systems
Presenting Author	Omar R Harvey
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Abstract Text	<p>The presence of archaea in deep geologic systems is well known. However, the role archaeamineral associations play in archaeal survival mechanisms and ecology are not widely studied. We report, to our knowledge, is the first evidence for archaea-mediated N₂O production in methanogenic environments; its enhanced production in the presence of different sulfide minerals and the possible implications for understanding survival mechanisms of archaea in deep geologic systems. Experiments were conducted with the model methanogenic archaea, <i>Methanococcus maripaludis</i> in the presence and absence of different nitrogen sources and sulfide minerals. Highest N₂O production was observed at the lowest rate of methane production and was much enhanced in methanogenic treatments containing sulfide minerals; indicative of the involvement of archaea-mineral interactions. Among the minerals studied, N₂O production followed the trend pyrite.</p>

Title	IODP Expedition 370: Temperature Limit of the Deep Biosphere off Muroto (T-Limit)
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Abstract Text	<p>Expedition 370 of the International Ocean Discovery Program (IODP) aimed to explore the limits of life in the deep seafloor biosphere at a location where temperature increases with depth at a higher-than-average rate and exceeds the known temperature maximum of microbial life (~120°C) at the sediment/basement interface. Such conditions are met in the protothrust zone of the Nankai Trough off Cape Muroto, Japan, where Site C0023 was established in the vicinity of ODP Sites 808 and 1174 at a water depth of 4776 m using the drilling vessel DV Chikyu. Hole C0023A was advanced across the sediment/basement interface down to a total depth of 1180 meters below seafloor, 112 cores were retrieved, and long-term temperature observations were started. The offshore sampling and research was combined with simultaneous shore-based investigations at the Kochi Core Center (KCC), which is located within helicopter-distance of the drill site, during September 10 – November 23, 2016 (Heuer et al., 2017).</p> <p>The primary scientific objectives of Expedition 370 are (a) to detect and investigate the presence or absence of life and biological processes at the biotic-abiotic transition of the deep seafloor with unprecedented analytical sensitivity and precision; (b) to comprehensively study the factors that control biomass, activity, and diversity of microbial communities; and (c) to elucidate if continuous or episodic flow of fluids containing thermogenic and/or geogenic nutrients and energy substrates support seafloor microbial communities in the Nankai Trough accretionary complex (Hinrichs et al., 2016).</p> <p>This contribution will highlight the scientific approach of our field-work and present preliminary shipboard and shorebased results of Expedition 370.</p>
References	<p>Hinrichs K-U, Inagaki F, Heuer VB, Kinoshita M, Morono Y, Kubo Y (2016) Expedition 370 Scientific Prospectus: T-Limit of the Deep Biosphere off Muroto (T-Limit). International Ocean Discovery Program. http://dx.doi.org/10.14379/iodp.sp.370.2016</p> <p>Heuer VB, Inagaki F, Morono Y, Kubo Y, Maeda L, the Expedition 370 Scientists (2017) Expedition 370 Preliminary Report: Temperature Limit of the Deep Biosphere off Muroto. International Ocean Discovery Program. http://dx.doi.org/10.14379/iodp.pr.370.2017</p>

Title	MetaSeek: A Sequencing Data Discovery Platform
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Abstract Text	<p>There has been an explosion in studies producing sequencing data in recent years. This data resource represents a significant opportunity to undertake large-scale meta-analyses with integrated sequencing data. However, aggregating the vast amount of available data, often spread across multiple repositories and not easily searchable, into an integrated dataset that meets the user's requirements is often a prohibitive obstacle. MetaSeek brings together sequencing metadata from multiple data repositories, and provides a rich, easy to use web application to quickly and easily search, filter, and curate integrated sequencing datasets from widely distributed sources. Using the MetaSeek tool, we curated a global soil whole-metagenomic sequencing dataset that will be used to create a soil-specific gene reference catalog. Future modeling efforts will use this dataset to model global patterns in soil microbial carbon cycling capacities using a semi-supervised topic modeling approach. We are currently looking for beta-testers willing to explore and give input on the application.</p>

Title	Redox equilibria involving chromium minerals in aqueous fluids under subduction zone conditions
Presenting Author	Jingyi Huang
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Abstract Text	<p>Diamonds are often associated with inclusions of garnet that are characteristically Cr-rich and Ca-poor, suggesting metasomatic reactions involving fluids(1). To investigate these reactions we developed a thermodynamic characterization of Cr-bearing minerals and aqueous species. We retrieved thermodynamic properties of eskolaite (Cr₂O₃), picrochromite (MgCr₂O₄), and knorringite (Mg₃Cr₂Si₃O₁₂) consistent with minerals in the Berman database(2). Owing to a lack of heat capacity data for knorringite, we made estimations based on the assumption that the heat capacity of the reaction Cr-Grt + Al₂O₃ = Al-Grt + Cr₂O₃ equals zero. Using SUPCRT92b, we retrieved the Gibbs free energy of picrochromite and knorringite from the P-T equilibria involving the reactions MgCr₂O₄ + SiO₂ = Cr₂O₃ + MgSiO₃(3) and MgCr₂O₄ + 4MgSiO₃ = Mg₃Cr₂Si₃O₁₂ + Mg₂SiO₄(4), respectively.</p> <p>At 5.0 GPa from 600°C to 1000°C, the prediction of the reactions of eskolaite and knorringite in equilibrium with Cr₂⁺ indicate that the stable logfO₂ of Cr(III) minerals increases with increasing temperature, decreasing pH, and decreasing Cr₂⁺ activity; while knorringite and forsterite are stable at more reducing conditions than eskolaite. We replaced the Cr₂⁺ in the previous reactions with CrCl₂⁺ from a low Cl concentration to high Cl concentration and found that complexes of Cr₂⁺ and Cl⁻ could increase the solubility of chromium minerals. High temperature and pressure fluids containing Cr complexes might promote the mobility of chromium and be involved in metasomatic reactions and diamond formation.</p>
References	<p>[1] Klemme S., et al. (2009) <i>Lithos</i> 112: 986-991</p> <p>[2] Berman R G. (1988) <i>Journal of Petrology</i> 29: 445-522</p> <p>[3] Klemme S, O'Neill H S C. (1997) <i>Contributions to Mineralogy and Petrology</i> 130: 59-65</p> <p>[4] Klemme S. (2004) <i>Lithos</i> 77: 639-646</p>

Title	The Carbon Mineral Challenge: A worldwide search for undiscovered minerals
Presenting Author	Daniel Robert Hummer
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Additional Authors	Hazen RM, Downs RT, Hystad G, Golden JJ
Abstract Text	<p>The emerging field of mineral ecology examines the distributions and relationships of minerals in the natural world. Using statistical methods normally applied to biological ecosystems, Hazen et al. (2015) and Hystad et al. (2015) demonstrated that terrestrial minerals, and subsets of minerals, conform to a Large Number of Rare Events (LNRE) statistical distribution. The analysis led to the surprising conclusion that at least 1563 mineral species remain undiscovered. Later, Hazen et al. (2016) used this same technique to calculate that at least 145 mineral species with the crucial element carbon remain undiscovered, and also made specific predictions about the possible identities and localities of these “missing” carbon minerals. To test these predictions, a unique, worldwide endeavor called the “Carbon Mineral Challenge” was launched. The challenge unites scientists, collectors, and enthusiasts from every part of the world to conduct a targeted search for Earth’s missing carbon minerals. The challenge will end in September of 2019, and rules for success are governed by the standards of the International Mineralogical Association (IMA). During the first year of the challenge, eight new carbon minerals have been approved by the IMA, and two of these were minerals specifically predicted by Hazen et al. (2016). The new minerals include both carbonates and organic mineral species from several regions of the world, and represent a promising outlook for the project.</p>
References	<p>Hazen RM, Hystad G, Downs RT, Golden JJ, Pires A, Grew ES. (2015) <i>American Mineralogist</i> 100: 2344-2347.</p> <p>Hystad G, Downs RT, Hazen RM. (2015) <i>Mathematical Geosciences</i> 47: 647-661.</p> <p>Hazen RM, Hummer DR, Hystad G, Downs RT, Golden JJ. (2016) <i>American Mineralogist</i> 101: 889-906.</p>

Title	The global biogeography of subseafloor sedimentary microbiomes
Presenting Author	Fumio Inagaki
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Additional Authors	Hoshino T, Wömer L, Morono Y, D'Hondt S, Hinrichs K-U
Abstract Text	<p>Over the past decades, scientific ocean drilling has explored subseafloor environments at various oceanographic and geological settings and expanded our knowledge of the deep biosphere. Accumulating geochemical and microbiological evidence from sediment core samples demonstrated that the deep subseafloor biosphere principally consists of aerobic and anaerobic microbial ecosystems and contributes to the global biogeochemical cycles of carbon and other elements by their energy respirations over geological time. In this study, we extracted DNA from over 300 deep-frozen sediment core samples using consistent molecular techniques and laboratory conditions, and sequenced and quantified some key genes using Miseq and microfluidic digital PCR techniques. Comparing those ecological data to various environmental factors of cores, the global biogeographical distribution of subseafloor microbial communities is visualized in a quantitative manner, providing fundamental new insights into the factors that constrain the population size, diversity, metabolic functions, and community structure of the global deep subseafloor biosphere.</p>

Title	Insights into diamond formation from polycrystalline diamond aggregates
Presenting Author	Dorrit Jacob
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Abstract Text	<p>Polycrystalline diamond aggregates (diamondites) are produced by rapid crystal nucleation caused by extreme carbon supersaturation in mantle fluids. They may form episodically and under variable chemical conditions, providing snapshots of diamond formation in the Earth's mantle. Diamondites, thus, represent an extreme end member of diamond formation mechanisms, while forming via the same processes and ingredients as the gem-sized diamonds.</p> <p>We present here results on a large suite of diamondites from the Venetia mine (South Africa), comprising a complete characterisation of the diamonds and their silicate inclusions and intergrowths. The highlighted characteristic of this sample suite is its remarkable heterogeneity in all aspects, from affiliated silicate composition to diamond composition and texture of the diamond aggregates.</p> <p>The diamond grains in the samples are intergrown with silicates (garnets, clinopyroxenes, phlogopites) comprising a websteritic-eclogitic and a peridotitic-pyroxenitic suite of minerals. Diamonds, regardless of their affiliation based on their silicate phases, overlap in carbon and nitrogen composition and have $\delta^{13}\text{C}$ values between -28 and -8 ‰, $\delta^{15}\text{N}$ values of 0.8 to 16.3 ‰ and nitrogen contents of 4 to 2329 ppm. The entire range of carbon and nitrogen variability of the suite is also reflected in some individual samples. Cathodoluminescence imaging visualizes different zones in the samples that can be interpreted as different growth events with differing nitrogen contents in line with the variability of nitrogen aggregation states. Electron backscatter diffraction analyses identify an original texture of randomly intergrown diamond grains that is partly changed by deformation and newly grown smaller diamond grains.</p> <p>The large overall variability suggesting episodic formation of diamondite sampled by the Venetia kimberlite and possible scenarios will be discussed.</p>

Title	The Shinas and Mandoos hydrothermal vent systems in the Samail Ophiolite, Oman
Presenting Author	Ana PM Jesus
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Additional Authors	Jesus AP, Cravinho A, Moreira BB, Mateus A, Pracejus B, Figueiras, Benoit M, Vermond D
Abstract Text	<p>Ophiolites upper crustal sections allow reconstructing the path of hydrothermal circulation in oceanic spreading ridges, often related to the development of Volcanic Massive Sulphide (VMS) accumulations. Some studies on the Samail Ophiolite mineralizing hydrothermal systems focused on deposits located at the horizon between the lower V1 (Geotimes) and upper V2 (Lasail, followed by Alley and Boninitic Alley) volcanic units. Recent volcano-stratigraphic studies suggest that the Mandoos and Shinas deposits are hosted within the Alley Unit, which geochemistry is consistent with a supra subduction setting (Gilgen et al., 2014). Mandoos is amongst the largest deposits found in the Samail Ophiolite (8 Mt @ 1.8 wt% Cu). It comprises a cluster of 1-90 m thick massive sulphide lenses featuring pyritic-sandy breccias where primary vent morphologies and tube worm burrows are locally preserved. The smaller Shinas deposit (1.4 Mt @2 wt% Cu) should be located at a higher stratigraphic position within the Alley Unit. It comprises ca. 15 m thick silica-sulphide ore lenses grading towards a siliceous cap. The hanging-wall of both deposits shows intense (clay/)chlorite-quartz-sulphide alteration. Ill-developed stockwork features at Mandoos contrast with >100 m of breccias cemented and veined by a polyphasic (jasper/)silica-sulphide assemblage at Shinas, suggesting significant differences during the evolving hydrothermal alteration stages and sea-floor venting. This cross-disciplinary work builds upon ongoing research characterizing the geology, mineralogy and whole rock geochemistry of the Mandoos and Shinas sulphide ores and host rocks, and seeking for further isotopic work to elucidate on: i) how sulphide lenses formed in ancient hydrothermal vents record major geodynamic changings as inferred by host lavas geochemistry; ii) the thermal and redox conditions during ore deposition; iii) the compositional variations experienced by hydrothermal fluids involved in ore-forming systems at different volcano stratigraphic levels; and iv) the role of organic matter in the development of these sulphide ores.</p>
References	Gilgen, SA, Diamond LW, Mercogli I, Al-Tobi K, Maidment DW, Close R, Al-Towaya A (2014). Volcanostratigraphic controls on the occurrence of massive sulfide deposits in the Semail Ophiolite, Oman. <i>Economic Geology</i> , 109: 1585-1610.

Title	The hydrothermal transformations of carboxylic acids in the presence of spinel-type mineral surfaces
Presenting Author	Kristin Nicole Johnson
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Abstract Text	<p>Minerals in contact with organic compounds can activate new organic reactions. This study focused on carboxylic acids which are a major component of amino acids, lipids, oil field brines, lignin and low-grade coal. Understanding the transformations of carboxylic acids in the presence of minerals allows us to understand available reactions in carbon-rich environments. We performed experiments under hydrothermal conditions (300 °C and 1 kbar) with the purpose of investigating the effect of minerals on carboxylic acids. Previous studies of carboxylic acid reactivity with minerals have focused on simple molecules such as acetic acid and valeric acid [1, 2]. Phenylacetic acid, a phenyl carboxylic acid, allows us to explore mechanistic pathways for product formation, a method employed in the investigation of other functional groups by members of our laboratory [3, 4, 5]. By holding the crystal structure of the minerals constant, we can investigate the mineralogical properties that govern organic reactions. In hydrothermal experiments without minerals, phenylacetic acid (C₆H₅CH₂COOH) decarboxylates to yield toluene and CO₂ [6]. For experiments in the presence of spinel (MgAl₂O₄), decarboxylation (C₆H₅CH₂COOH → C₆H₅CH₃ + CO₂) remained the dominant pathway but the formation of a symmetrical ketone structure indicated the activation of additional product pathways in the presence of a mineral surface. Once formed, the ketone became a reactant as observed previously [4]. In the presence of magnetite (Fe₃O₄), the rate of decarboxylation was not enhanced but the formation of ketones, diphenyl alkanes and alkenes were activated. Benzoic acid was formed and rapidly consumed as a reactant through decarboxylation and the formation of an asymmetrical ketone product.</p> <p>Spinel and magnetite both activate the formation of larger products from phenylacetic acid. Both minerals facilitated the formation of a ketone structure, but magnetite, with its smaller band gap and potential redox states, was capable of activating the formation of more products.</p>
References	<p>[1] Bell JLS, Palmer DA, Barnes HL, Drummond SE (1994) <i>Geochim Cosmochim Acta</i> 58:4155-4177</p> <p>[2] McCollom TM and Seewald JS (2003) <i>Geochim Cosmochim Acta</i> 19:3645-3664</p> <p>[3] Shipp J et al (2013) <i>Geochim Cosmochim Acta</i> 104:194-209</p> <p>[4] Yang Z et al (2012) <i>Geochim Cosmochim Acta</i> 98:48-65</p> <p>[5] Shock EL et al (2013) <i>Reviews in Mineralogy and Geochemistry</i> 76:311-350</p> <p>[6] Glein CR (2012) PhD Dissertation, Arizona State University</p>

Title	Biogeochemistry and geomicrobiology of sediments from ferruginous and ultraoligotrophic Lake Towuti
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Additional Authors	Friese A, Vuillemin A, Simister R, Bauer K, Crowe SA, Nomosatryo S, Henny C, Dianto A, the ICDP Towuti Drilling Project Science Team
Abstract Text	<p>Lake Towuti is a tropical 200m deep tectonic lake, its catchment is mainly composed of ophiolitic rocks and lateritic soils (1), leading to a high flux of iron (oxy)hydroxides into the lake, thereby scavenging most of the bioavailable phosphorus and driving the lake toward oligotrophic conditions (2). The water column is anoxic below 130m water depth (3) and has high concentrations of dissolved iron, leading to the biological and abiotic formation of authigenic iron minerals in the water column and the sediment. These minerals have the potential to record paleoclimate and diagenesis as well as providing a unique opportunity to develop a better understanding of metabolic diversity and activity of microbial communities in metal-rich subsurface sedimentary environments. From May to July 2015, International Continental Drilling Program (ICDP) sediment cores from three drill sites (1), including a 114 m long core for geomicrobiological studies (TDP-1A) drilled with a contamination tracer (4).</p> <p>We analyzed pore water concentrations of dissolved ions and quantified total microbial abundance. Additionally, authigenic minerals like siderite (FeCO_3) and vivianite ($\text{Fe}_2[\text{PO}_4]_2 \cdot 8\text{H}_2\text{O}$) were recovered from 50 distinct layers and investigated to infer mineral formation and recording of microbial processes.</p> <p>SEM and TEM imaging of the siderites show that they grow from micritic phases into mosaic monocrystals with increasing burial depth. Green rust and magnetites (Fe_3O_4) are interlaced within siderites, suggesting successive diagenetic phases related to iron reduction. The concomitance of vivianites argues for accumulation of dissolved iron and potentially methane in the anoxic bottom water. We observe contrasting siderite-rich intervals that lack vivianite, which point toward bottom water oxygenation with increased burial of amorphous Fe^{3+}. Our results show that the lake has experienced significant changes in bottom water oxygenation and a complex diagenetic history.</p>
References	<ol style="list-style-type: none"> 1. Russell JM, et al. (2016) The Towuti Drilling Project: paleoenvironments, biological evolution, and geomicrobiology of a tropical Pacific lake. <i>Sci. Dril.</i> 21:29-40. 2. Crowe SA, et al. (2008) The biogeochemistry of tropical lakes: A case study from Lake Matano, Indonesia. <i>Limnology and Oceanography</i> 53(1):319-331. 3. Vuillemin A, et al. (2016) Geomicrobiological features of ferruginous sediments from Lake Towuti, Indonesia. <i>Frontiers in Microbiology</i> 7. 4. Friese A, et al. (2017) A simple and inexpensive technique for assessing contamination during drilling operations. <i>Limnology and Oceanography: Methods</i>.

Title	Solid Earth--climate coupling at inter/glacial timescales?
Presenting Author	Richard F Katz
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Additional Authors	Burley J, Huybers P
Abstract Text	<p>Volcanoes transmit large amounts of CO₂ and other volatiles from the mantle reservoir into the ocean/atmosphere system. The geological record documents a link between glacial/interglacial cycles and volcanic eruptions subaerially [1] and, potentially, at mid-ocean ridges [2]. Hence there is a possibility of solid Earth—climate interaction during glacial cycles. This may explain the mid-Pleistocene transition, when the dominant period of glacial cycles changed from 40ka to ~100ka. It is broadly accepted that the 40ka glacial cycles were driven by obliquity cycles. However, this does not explain the ~100ka cycles. Here we investigate the hypothesis that variations in volcanic CO₂ emissions can cause the mid-Pleistocene.</p> <p>Any proposed mechanism for ~100 ka glacial cycles must give the Earth's climate system a memory of O(10⁴) years. This timescale is difficult to achieve for surface processes. Recent work suggests that there could be a ~50ka delay in the MOR response to sea-level change [3]. This lagged response could drive glacial cycles from 40ka cycles to an integer multiple of the forcing period. Under what conditions could the climate system admit such a response?</p> <p>To address this, we use a simplified climate model modified from [4]. Our version comprises three component models for energy balance, ice sheet growth and atmospheric CO₂ concentration. The model is driven by insolation alone with other components varying according to a system of coupled, differential equations.</p> <p>We obtain a switch from 40 ka to ~100 ka cycles as the volcanic CO₂ response to glacial cycles is increased. These ~100 ka cycles are phase-locked to obliquity, lasting 80 or 120ka. Whilst the MOR response required (in this model) is larger than plausible estimates based on [2], it illustrates the potential of MOR CO₂ feedbacks to generate ~100 ka glacial cycles, consistent with an even simpler climate model [5].</p>
References	<p>[1] Huybers, P., & Langmuir, C. (2009). EPSL, doi: 10.1016/j.epsl.2009.07.014</p> <p>[2] Crowley, J. W., Katz, R. F., Huybers, P. J., Langmuir, C. H., & Park, S.-H. (2014). Science, doi: 10.1126/science.1261508</p> <p>[3] Burley, J. M. A., & Katz, R. F. (2015). EPSL, doi: 10.1016/j.epsl.2015.06.031</p> <p>[4] Huybers & Tziperman, (2008), Paleoceanography, doi: 10.1029/2007PA001463</p> <p>[5] Huybers, P., & Langmuir, C. H. (2017). EPSL, doi: 10.1016/j.epsl.2016.09.021</p>

Title	Carbonation & decarbonation of oceanic plates and the mantle wedge: Implications for the subduction zone carbon cycle
Presenting Author	Peter Kelemen
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Abstract Text	<p>Characterization of peridotite carbonation during hydrothermal alteration and weathering in ophiolite and seafloor environments indicates that rates are rapid, and uptake extensive, when carbon is available (transport limited). We combined this information with literature data on carbonation of oceanic crust, extent of seafloor composed of peridotite (mainly, at slow spreading ridges) and the extent of alteration of mantle peridotite at the “outer rise” just before subduction, to estimate inputs of carbon in subducting oceanic plates. We also adopted prior estimates of carbon subduction in sediments, with minor modification, to estimate carbon subduction fluxes.</p> <p>Inspired by observations of 100% carbonated peridotite in the hanging wall along the basal thrust of the Samail ophiolite in Oman (e.g., Falk & Kelemen GCA 2015), we wondered how much carbon might be stored in the mantle lithosphere, as a result of recycling from subduction zones. Thus, we reviewed estimates for carbon removal from subducting oceanic plates via dewatering, dehydration and dissolution of carbon-bearing minerals, metamorphic decarbonation reactions, partial melting, and transport of chemically buoyant metasediments via diapirs. These data, taken together, are consistent with approximately 30 to 99.9% recycling of subducting carbon, out of subducting plates and back into the overlying mantle and crust within five to ten million years. Because the high-end estimate is relatively new and exciting, we’ve focused on this, though of course it remains highly uncertain.</p> <p>Current estimates of fluxes of carbon from fore-arcs and arcs are substantially smaller than the flux of subducting carbon. Thus, if >> 50% of subducting carbon is recycled into the mantle lithosphere, crust, oceans and atmosphere (the lithosphere plus the “exosphere”), then much of it must be stored in the tectonic plates. Aside from carbon-bearing sedimentary rocks, the carbon content of the crystalline continental crust seems to be fairly low. Thus, we propose that the continental lithospheric mantle may be an important reservoir for stored carbon recycled from subduction zones. Data on the carbon content of lithospheric mantle are few. Xenoliths must lose CO₂ during high temperature decompression from source to surface, and so provide few constraints. It will be important to gather data on carbon concentration and mineralogy in more slowly exhumed mantle massifs and various flavors of alpine peridotites, particularly those in ultra-high-pressure metamorphic terrains. In turn, it is important to seek constraints on the timing of carbon introduction into such samples.</p>
References	<p>Falk ES, Kelemen P (2015) Geochemistry and petrology of listvenite in the Samail ophiolite, Sultanate of Oman: Complete carbonation of peridotite during ophiolite emplacement. <i>Geochimica et Cosmochimica Acta</i> 160:70-90</p> <p>Kelemen P, Manning C (2015) Reevaluating carbon fluxes in subduction zones, what goes down, mostly comes up. <i>Proceedings of the National Academy of Sciences</i> 112(30):E3997-E4006</p>

Title	Volatiles beneath mid-ocean ridges: deep melting, channelised transport, focusing, and metasomatism
Presenting Author	Tobias Keller
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Abstract Text	<p>The deep CO₂ cycle is the result of fluxes between near-surface and mantle reservoirs. Outgassing from mid-ocean ridges is one of the primary fluxes of CO₂ from the asthenosphere into the ocean-atmosphere reservoir. Focusing of partial melt to the ridge axis crucially controls this flux. However, the role of volatiles, including CO₂ and H₂O, on melt transport processes beneath ridges remains poorly understood. We investigate this transport using numerical simulations of two-phase, multi-component magma/mantle dynamics. The phases are solid mantle and liquid magma; the components are dunite, MORB, hydrated MORB & carbonated MORB. These effective components capture accepted features of mantle melting with volatiles. The fluid-dynamical model is McKenzie's formulation [1] while melting and reactive transport use the R_DMC method [2,3].</p> <p>Our results indicate that volatiles cause channelized melt transport, which leads to significant variability in volume and composition of focused melt. The volatile-induced expansion of the melting regime at depth, however, has no influence on melt focusing; distal volatile-rich melts are not focused to the axis. Up to 50% of these melts are instead emplaced along the oceanic LAB. There, crystallization of accumulated melt leads to enrichment of CO₂ in the deep lithosphere, which has implications for carbon recycling by subduction. Results from a suite of simulations, constrained by cataloged observational data [4,5,6] enable prediction of global MOR CO₂ output. By combining observational constraints with self-consistent numerical simulations we obtain a range of CO₂ output from the global ridge system of 50–56 Mt CO₂/yr.</p>
References	<p>[1] McKenzie (1984), doi:10.1093/petrology/25.3.713. [2] Rudge, Bercovici & Spiegelman (2011), doi:10.1111/j.1365-246X.2010.04870.x. [3] Keller & Katz (2016), doi:10.1093/petrology/egw030. [4] Dalton, Langmuir & Gale (2014), doi:10.1126/science.1249466. [5] Gale, Langmuir & Dalton (2014), doi:10.1093/petrology/egu017. [6] White et al. (2001), doi:10.1093/petrology/42.6.1171.</p>

Title	A reservoir model for the evolution of deep carbon through deep time
Presenting Author	Louise Helen Kellogg
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Abstract Text	<p>Carbon is one of the most important elements in the Earth, but the mass distribution and temporal evolution remain poorly understood. We present models for the time-dependent evolution of the masses of carbon in the major reservoirs for carbon through Earth history. At the present, major reservoirs for carbon are the core, the mantle, and the continental crust. Early in Earth history, the atmosphere was also a major reservoir for carbon. The smaller reservoirs for carbon, the oceans, the present atmosphere, and organic materials, contain at least a factor of 3 orders of magnitude less carbon than the major reservoirs; thus transport between the large and small reservoirs can influence the mass of carbon in the small reservoirs, but do not substantially alter the masses of carbon in the large reservoirs. With 4.5×10^9 Gt of carbon, the largest reservoir for carbon is in the core. This carbon entered the core at the time of its formation, and there is no evidence of significant flux of carbon between the core and the mantle since that time. The second largest reservoir for carbon is in the mantle. Using the flux of carbon out of the mantle at mid-ocean ridges, we estimate that the mantle contains 2×10^8 Gt of carbon and argue that this has not changed significantly in the last 3 Ga. The third largest reservoir for carbon is the continental crust, primarily carbonates. It has been estimated that this mass of carbon in the continental crust is 4.2×10^7 Gt. A large fraction of this carbon was likely extracted from the atmosphere prior to 3 Ga and the mass of carbon in this reservoir has remained relatively constant since. We note that Venus currently has a large concentration of CO₂ in its atmosphere; scaling this to Earth would yield the equivalent of 1.57×10^8 Gt of carbon in Earth's atmosphere. This is close to the mass of carbon in Earth's mantle reservoir. Sleep and Zahnle (2001) suggest that after the moon-forming giant impact at about 4.4 Ga, the carbon in the Earth's atmosphere was transferred into the mantle reservoir. We further suggest that the volcanic flux of carbon out of the mantle was responsible for the carbon concentrations in the surficial reservoirs today. In this scenario, carbon accumulated in the deep ocean until the carbon flux into the mantle via subduction balanced the carbon flux out of the mantle via volcanism.</p>

Title	The relative abundances of resolved $^{12}\text{CH}_2\text{D}_2$ and $^{13}\text{CH}_3\text{D}$ and mechanisms controlling isotopic bond ordering in abiotic and biotic methane gases
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Abstract Text	<p>The ability to resolve $^{12}\text{CH}_2\text{D}_2$ from $^{13}\text{CH}_3\text{D}$ provides unprecedented insights into the origin and evolution of CH_4 (Young et al. 2017). In general, we see intramolecular isotopic equilibrium in abiotic gasses produced at $T > 100^\circ\text{C}$. In such cases, concordant $\Delta^{12}\text{CH}_2\text{D}_2$ and $\Delta^{13}\text{CH}_3\text{D}$ temperatures can be used reliably for thermometry. Concordant temperatures do not always match previous hypotheses based on indirect estimates of temperature of formation nor temperatures derived from CH_4/H_2 -D/H equilibrium with water, underscoring the importance of reliable thermometry based on the CH_4 molecules themselves. Where coupled $\Delta^{12}\text{CH}_2\text{D}_2$ and $\Delta^{13}\text{CH}_3\text{D}$ values are inconsistent with thermodynamic equilibrium, temperatures of formation derived from either of these species can be spurious and potentially misleading. However, disequilibrium mass-18 isotopologue abundances may provide the means for differentiating between methane produced by abiotic synthesis versus biological processes. Measured deficits in $^{12}\text{CH}_2\text{D}_2$ and $^{13}\text{CH}_3\text{D}$ compared with equilibrium values for CH_4 gas made by surface-catalyzed abiotic reactions in the laboratory are large enough to suggest a quantum tunneling origin. While some degree of tunneling may be present in microbially produced samples based on culture experiments, it does not approach the magnitude of the effect measured in abiotic reactions. This tunneling signature may prove to be an important tracer of abiotic methane formation, unless low temperature abiotic equilibration proves possible, as suggested by some bulk isotope compositions. So far, this seems unlikely as CH_4 from deep mine environments is dominated by tunneling signatures. These environments also show that isotopologue signatures of abiotic methane production can be erased by infiltration of microbial communities, and $(\Delta\text{MEAS}-\Delta\text{EQ})^{12}\text{CH}_2\text{D}_2 = \Delta^{12}\text{CH}_2\text{D}_2(\text{measured}) - \Delta^{12}\text{CH}_2\text{D}_2(\text{equilibrium})$ values are key tracers of microbial recycling of CH_4. This recycling process could be mediated by microbial communities, both producing and consuming CH_4 with potentially small impacts on the bulk isotopic composition resulting from intra-cellular enzymatic back reactions.</p>
References	Young ED, et al. (2017) <i>Geochimica et Cosmochimica Acta</i> 203:235-264.

Title	DEEP HYDROCARBON CYCLE
Presenting Author	Vladimir Kutcherov
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Abstract Text	<p>The deep carbon cycle describes the circulation of carbon into and out of the crust, mantle, and core. In hydrocarbon form deep carbon provides the main energy resource for mankind. Experimental results and theoretical considerations published recently give us the possibility to introduce the concept of deep hydrocarbon cycle as a part of the deep carbon cycle.</p> <p>The concept of deep hydrocarbon cycle is based on the following considerations and experimental data. Organic matter including hydrocarbon deposits accumulated in the Earth's crust could eventually be transported with the slab below the crust of the Earth during subduction. Until the depth of 50-60 km hydrocarbon systems At certain depths organic substances can react with ferrous iron-bearing minerals and form carbides, which in turn can form hydrocarbon-aqueous fluids by reaction with available in asthenosphere water. According to the ideas of the great Russian chemist Dmitri Mendeleev carbides could be precursors for the synthesis of hydrocarbons in the depths of the Earth. Therefore, iron carbide, as a donor of carbon (alongside with carbonates and pure carbon) can react with hydrogen donors (water, hydroxyl groups of some minerals, existing in asthenosphere) and form hydrocarbons. Hydrocarbons from asthenosphere can migrate to the crust through deep faults and form accumulations of oil and gas. Deep hydrocarbon cycle is completed.</p>

Title	Exploring Ecological Patterns of Earth's Subsurface Life
Presenting Author	Joshua Ladau
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Additional Authors	Joshua Ladau, Cara Magnabosco, S. Emil Ruff, Frederick Colwell, Steven D'Hondt, Eric Gaidos, Sharon Grim, Tom Kieft, Rosa Leon Zayas, Karen Lloyd, T.C. Onstott, Brandi Kiel Reese, Karyn Rogers, Matt Schrenk, Barbara Sherwood-Lollar, Andre Soares, Mitch Sogin
Abstract Text	<p>Much of the planet's poorly known microbiota occurs in the deep Earth. Patterns framing our understanding of this life have emerged but the most fundamental elements of this underworld remain enigmatic. Constructing the theoretical framework for the location, quantity, and diversity of deep life is central to developing the ecological rules for the deep biosphere. We hypothesize that subsurface communities widely result from a winnowing of surface communities. This hypothesis predicts that deep communities will bear the fingerprints of (i) surface dispersal limitation and selection, (ii) historical contingency on both the surface and the subsurface, and (iii) subsurface selective filters, particularly the availability of reduced inorganic compounds, availability of electron acceptors, and hydrogeological constraints (i.e., whether a site is controlled by advection-diffusive transport, or by fracture flow). We will test these predictions by comparing subsurface community composition and function in subsurface fluids of different provenance (e.g., recent recharge, versus paleometeoric water recharged in the past, versus deep fluids dominated by geothermal reactions or low temperature long-term water-rock reaction) to surface community composition and function, and assessing which historical and contemporary environmental factors predict subsurface community composition and function. The investigation involves computational analysis of 16S rRNA marker gene data for 1,200 globally distributed deep subsurface microbial communities acquired through the Census of Deep Life developed through the Deep Carbon Observatory. We expect to detect patterns in microbial diversity and correlations between community structure and contextual parameters (i.e., sample depth, residence time, propensity for H₂ production, hydrogeologic parameters) and correlations between microorganisms. Our initial meta-analysis has diagnosed differences between the subseafloor and subterrestrial microbes and H₂ presence in these systems may be one determinant of community structure. Modeling and computational analyses will be used at global spatial scales and long temporal scales, where experimentation and sampling are impractical.</p>

Title	Microbial community zonation across a natural organic matter gradient spanning the Namibian shelf
Presenting Author	Lorenzo Lagostina
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Additional Authors	Arndt S, Lomstein B, Evans T, Pancost R, Sales De Freitas F, Lever MA
Abstract Text	<p>Despite tremendous advances in the study of microbial biogeography in subsurface marine sediments, little is known about the factors determining community structure or the metabolism of the majority of subsurface microbes. In particular, the relationship between organic matter (OM) composition and microbial community structure is poorly understood. Since OM can differ considerably in terms of chemical composition depending on age, source and sedimentary settings, we hypothesize that the macromolecular composition of buried OM is a key factor shaping seafloor microbial communities. To address our hypothesis, we characterized microbial community composition on a transect spanning from the continental shelf to the abyssal plain across one of the most productive marine ecosystems on Earth, the Benguela Upwelling System. Preliminary results show vertical and lateral zonation of communities: within the first meter typical surface sediment groups (Proteobacteria, Thaumarchaeota) progressively decrease and are replaced by characteristic subsurface taxa (Atribacteria, Chloroflexi, Bathyarchaeota and Lokiarchaeota). Coastal non-bioturbated sites show dominance of Thermoplasmata and absence of Thaumarchaeota, opposite of what is observed approaching the abyssal plain. To further elucidate how microbial metabolic potential is changing across the continental margin we analyzed – supported by CoDL - the metagenomes of three subsurface samples representative of different sedimentary settings: inner shelf, depositional center and continental rise. Parallel to the microbial community and metagenome analyses, detailed characterization of the OM present in the transect will be performed. Predominant macromolecular building blocks of the OM will be determined by GC-pyrolysis. The diagenetic status of the OM will be inferred using amino-acid nitrogen to total nitrogen ratios and amino-acid composition-based indicators. Biomarker analysis (GDGTs, alkenones, alcohols) will elucidate the origins of the OM. This extensive organic geochemical dataset will be related to the genetic information through multivariate statistical analysis to test whether certain phylogenetic groups are associated with specific OM fingerprints.</p>

Title	Direct access to the serpentinite subsurface: a biogeochemical investigation to characterize a unique habitat
Presenting Author	Susan Q. Lang
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Additional Authors	Marvin D. Lilley, Gretchen L. Früh-Green, Beth N. Orcutt
Abstract Text	<p>The circulation of ocean water through ultramafic rocks generates hydrogen and methane that can sustain microbial communities. The ultramafic subsurface was the target of the International Ocean Discovery Program (IODP)'s first hard rock expedition specifically devoted to identifying subsurface life. Expedition 357 successfully recovered 17 cores along an east-west profile across the top of the Atlantis Massif, the ocean core complex that hosts the serpentinite-dominated Lost City hydrothermal field. In addition to the recovery of 57 m of core, multiple types of fluid samples were collected before, after, and during drilling to characterize the biogeochemical signatures of water that passes through the rocky subsurface.</p> <p>Here we present results focused on using organic molecules in the recovered rocks and fluids to identify subsurface life and metabolism. The concentrations of these molecules can reveal the spatial distribution of microbial communities while the isotopes can provide constraints on the metabolisms and carbon sources that these communities employ. These signatures are compared to elevated concentrations of hydrogen and methane in co-registered samples that demonstrate active serpentinization is widespread across the Atlantis Massif. Ultimately, the goal of this work is to relate physical and geochemical processes, such as detachment faulting, hydrothermal circulation, and water-rock reactions, to zones of microbial activity.</p>

Title	Microbial syntrophy: implications on diversity, stability, biogeography and evolution of the deep biosphere
Presenting Author	Maggie C.Y. Lau
Institution/Affiliation	Princeton University
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Abstract Text	<p>Subsurface Lithoautotrophic Microbial Ecosystems (SLiMEs) under oligotrophic conditions are energy-deficient, which limit the growth of microbial inhabitants, the variety of biochemical reactions that can take place and hence the overall biodiversity. Recent studies of microbial DNA using next-generation sequencing technologies showed that the deep biosphere actually harbors taxonomically and functionally diverse communities. These results inspired further investigations to find out which of these organisms and pathways are indeed active in situ at the deep subsurface. In this talk, I will give an overview of the metabolic landscape (i.e. a functional network populated with taxonomic groups) that was constructed for the first time for SLiMEs [1]. This metabolic landscape reveals (i) the dominance of sulfur-driven autotrophic denitrification over other H₂-utilization processes, (ii) an apparent “inverted biomass pyramid”, and notably, (iii) the importance of microbial syntrophy for thriving in the deep subsurface. These findings motivate us to consider how microbial interaction and cooperation affect the diversity, stability, biogeography and evolution of deep life.</p>
References	<p>1. Lau, M.C.Y., T.L. Kieft, O. Kuloyo, B. Linage-Alvarez, E. van Heerden, M.R. Lindsay, C. Magnabosco, W. Wang, J.B. Wiggins, L. Guo, D.H. Perlman, S. Kyin, H.H. Shwe, R.L. Harris, Y. Oh, M.J. Yi, R. Purtschert, G.F. Slater, S. Ono, S. Wei, L. Li, B. Sherwood Lollar and T.C. Onstott (2016) An oligotrophic deep subsurface community dependent on syntrophy is dominated by sulfur-driven autotrophic denitrifiers. <i>Proceedings of the National Academy of Sciences (USA)</i> 113: E7927–E7936, doi: 10.1073/pnas.1612244113</p>

Title	The uncultivated phylum TA06
Presenting Author	Maggie CY Lau
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Additional Authors	Becraft E, Cason E, Borgonie G, Kieft TL, Li L, van Heerdeen E, Jarett J, Woyke T, Stepanauskas R and Onstott TC
Abstract Text	<p>Enabled by next-generation sequencing, our knowledge on biodiversity, spatial distribution and biogeochemical roles of the deep biosphere has been growing at an unprecedented pace over the past decade. However, the metabolic and ecological traits of Microbial Dark Matter (MDM) – the uncultivated phyla – in the deep subsurface remain largely unexplored. We employed “Genomes from Metagenomics” and single-cell genomics to investigate the phenotypic and functional features of the MDM TA06 that accounted for 13% of the community. The fracture fluid analyzed was collected from borehole DR5IPC, which is located at 1 km depth at the Driefontein gold mine, Carletonville, South Africa (S2626'05”, E2730'14”) [1,2]. The 70%-complete pan-genome of TA06 from DR5IPC indicated that this gram-negative, motile bacterium possesses dissimilatory sulfite reductase genes (<i>dsrAB</i>) for respiring sulfate. The near-complete collection of genes for Wood-Ljungdahl pathway and genes for partial pentose phosphate pathway, glycolysis and tricarboxylic acid cycle suggested that TA06 could be supported by a mixotrophic life style. Ongoing analyses aimed to elucidate (i) the phylogenetic placement of TA06; (ii) genome-wide and gene-specific variations between this subsurface TA06 pan-genome, single-cell amplified genomes from our deep subsurface sites and other genomes of TA06 and sulfate reducers reported in the literature; and (iii) the core and accessory genes of TA06.</p>
References	<ol style="list-style-type: none"> 1. Lau MCY, Cameron C, Magnabosco C, Brown CT, Schilkey F, Grim S, Hendrickson S, Pullin M, Sherwood Lollar B, van Heerden E, Kieft TL and Onstott TC (2014) <i>Frontiers in Microbiology</i> 5: 531 2. Magnabosco C, Tekere M, Lau MCY, Linage B, Kuloyo O, Erasmus M, Cason E, van Heerden E, Borgonie G, Kieft TL, Olivier J and Onstott TC (2014) <i>Frontiers in Microbiology</i> 5: 679

Title	Microbial community composition and function in the Tonga Trench: from 400m below the sea surface to 9100m water depth and from 0 to 2 m below the seafloor
Presenting Author	Rosa Leon-Zayas
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Abstract Text	<p>Exploration of the deep ocean has expanded our understanding of oceanic ecosystems including continental margins and mid-ocean ridges, but little is known about the deepest sites on Earth, oceanic trenches. In this study, sediment and water samples were collected from the Tonga Trench at 9100m below sea level. These include four water column samples at depths of 400m, 3000m, 5000m and ~9100m, and sediment samples at 0, 1, and 2 meter below the seafloor (mbsf). The analysis of the sediment samples provided a new perspective of life in the deep ocean. The data for microbial community composition and metabolic profiles at 0 mbsf suggest that microbes are present and taxonomically similar to the deep water column microbes, and perform varied aerobic as well as anaerobic metabolisms, including degradation of organic carbon, oxidative phosphorylation, fermentation, nitrate reduction and sulfur oxidation. On the other hand, at 1 and 2 mbsf, the microbial community has diminished richness and diversity when compared to 0 mbsf and are potentially environmentally degraded due to rapid sedimentary deposition. The water samples varied from Archaea dominated at 400m, to over 90% Bacteria at 9000m. The 400m sample displays low oxygen metabolic signatures, while the mid water samples are the most similar to each other and possess aerobic metabolic signatures including archaeal ammonia oxidation. To our knowledge these are the deepest metagenomes analyzed to date, allowing for an unprecedented look of an understudied section of our planet.</p>

Title	Recent developments in the use of perfluorocarbon tracers for contamination monitoring in ocean drilling
Presenting Author	Mark Alexander Lever
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Additional Authors	Eickenbusch P, Torti A, Hoshino T, Inagaki F, Jørgensen BB, Kevorkian RT, Liu C, Marshall IPG & IODP Expeditions 337, 347, and 366 Scientists
Abstract Text	<p>For the past 30 years, perfluorocarbon compounds have been added to drilling fluids during terrestrial and ocean drilling operations to quantify drilling fluid contamination of soil, sediment, and rock cores used for microbiological and geochemical investigations. During ocean drilling operations, perfluoromethylcyclohexane has been the perfluorocarbon compound of choice, with recent applications including riserless and riser drilling on JOIDES Resolution, Chikyu, mission-specific platforms, and seabed drills. Extensive methodological tests during and after drilling expeditions have shown that tracer recovery with established extraction protocols can be incomplete, resulting in underestimation of drilling fluid intrusion into cores. Furthermore, tests reveal that assumed target concentrations of tracers are typically not reached within drilling fluids, further contributing to an underestimation of drilling fluid contamination. This poster presents improved methods and sampling strategies that enable scientists to more reliably extract and quantify drilling fluid intrusion into cores based on PMCH measurements. Comparisons of PMCH-based core contamination are made across different drilling vessels and drilling methods, and PMCH-based drilling fluid intrusion estimates compared to those obtained with a second perfluorocarbon tracer (perfluoromethyldecaline).</p>
References	<p>Lever MA, Alperin MJ, Engelen B, Inagaki F, Nakagawa S, Steinsbu B, Teske A (2006) Trends in basalt and sediment core contamination during IODP Expedition 301. <i>Geomicrobiol J</i> 23:517- 530.</p> <p>Inagaki F, Hinrichs K-U, Kubo Y, & Expedition 337 Scientists (2013) <i>Proc IODP 337: Tokyo, Japan (IODP)</i>.</p> <p>Andr�n T, Jørgensen BB, Cotterill C & Expedition 347 Scientists (2015) <i>Proc IODP 347: College Station, TX, USA (IODP)</i>.</p>

Title	Earth in Five Reactions: A Deep Carbon Perspective
Presenting Author	Jie Li
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Additional Authors	Simon Redfern
Abstract Text	<p>“Earth in Five Reactions (5R)” is a synthesis project that aims to identify and use the five most important reactions that govern the transformation and movement of carbon in Earth as the central themes to synthesize and disseminate deep carbon knowledge and findings of the ten-year Deep Carbon Observatory. The project is designed to accomplish the following objectives: 1) Introduce the concept of “Earth in Five Reactions” as a unique and effective framework for synthesis to the broad DCO community; 2) Motivate a select group of scientists to review and integrate recent findings through the lens of the top five reactions and to explain the role the reactions play in the big picture of carbon storage and cycling; 3) Curate deep carbon research accomplishments through scholarly publications featuring the top five reactions; 4) Disseminate knowledge about deep carbon science to the scientific community and broader audiences using the 5R framework.</p>

Title	Crystallization of water mediated by carbon
Presenting Author	Tianshu Li
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Additional Authors	Bi Y, Cao B, Cabriolu R, Porras A
Abstract Text	<p>Carbon is known to influence the crystallization of water in a variety of different ways. An intriguing question is thus how the crystallization of water is initiated and controlled by the fundamental level interaction between carbon and water. By advanced molecular modeling, we attempted to address this question at both the thermodynamic and molecular levels. Remarkably, we find that ice nucleation appears rather “classical” at a thermodynamic level, but can also be surprisingly complex at a molecular level. On one hand, we found ice nucleation, when either occurs homogeneously(1) or heterogeneously on carbon surface(2), appears to follow a pathway that can be quantitatively described by classical nucleation theory. On the other hand, at a molecular level, we also discovered that ice nucleation is dictated by the subtle interplay among different molecular details of surface. For example, surface crystallinity of graphitic carbon is found strongly coupled with surface hydrophilicity, which yields a non-monotonic, wide range of ice nucleation behaviors(3). The geometry of carbon surface, when matching either the crystalline ordering or a topological defect of ice, is also found to significantly enhance ice nucleation(4).</p> <p>Carbon, in the form of small hydrocarbons such as methane, can also directly participate in the crystallization of water, which then leads to the formation of clathrate hydrate. To this end, we developed advanced molecular simulation strategy to understand the nucleation mechanism of gas hydrate(5). Hydrate nucleation, on average, was found to proceed through two-step, non-classical pathways. Strikingly, our study also showed the free energy profile of such non-classical nucleation pathways could be fit well against classical nucleation theory. We reconcile this seeming contradictory by proposing a new perspective: Hydrate nucleation can be an entropically driven, kinetic process, which proceeds via multiple pathways that are nearly degenerate in free energy landscape(6).</p>
References	<ol style="list-style-type: none"> 1. Li T, Donadio D, Galli G (2013) Ice nucleation at the nanoscale probes no man’s land of water. <i>Nat Commun</i> 4:1887. 2. Cabriolu R, Li T (2015) Ice nucleation on carbon surface supports the classical theory for heterogeneous nucleation. <i>Physical Review E</i> 91:052402. 3. Bi Y, Cabriolu R, Li T (2016) Heterogeneous Ice Nucleation Controlled by the Coupling of Surface Crystallinity and Surface Hydrophilicity. <i>J Phys Chem C</i> 120(3):1507–1514. 4. Bi Y, Cao B, Li T (2017) Enhanced heterogeneous ice nucleation by special surface geometry. under review. 5. Bi Y, Li T (2014) Probing Methane Hydrate Nucleation through the Forward Flux Sampling Method. <i>J Phys Chem B</i> 118(47):13324–13332. 6. Bi Y, Porras A, Li T (2016) Free energy landscape and molecular pathways of gas hydrate nucleation. <i>J Chem Phys</i> 145(21):211909.

Title	Characterization of methane hydrate reservoirs in the Gulf of Mexico
Presenting Author	Afu Lin
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Additional Authors	Dong T, Flemings PB, Polito PJ
Abstract Text	<p>We will present our recent research efforts on an interdisciplinary multi-scale investigation of the physics and chemistry of methane hydrate reservoirs through pore-scale and physical properties characterization of natural samples from the Gulf of Mexico. The research project funded by DOE, “Deep water methane hydrate characterization in the Gulf of Mexico: scientific assessment and production potential” (“GOM2”), aims for recovery of natural methane hydrate samples from GOM2 expeditions in 2017 and 2018 in the Gulf of Mexico. Our recent research initiative with ExxonMobil and UT Energy Institute allows us to take advantage of the mini-PCATS technology to manipulate, characterize and analyze natural methane hydrate samples. We focus on pore-scale experiments to characterize physical and chemical properties of synthetic and natural gas hydrate samples using micro-Raman spectroscopy and X-ray tomography under relevant to methane hydrate reservoirs in the Northern Gulf of Mexico (e.g., methane hydrate chemistry and distribution, salinity, porous medium - sand grain sizes and cement type). In this presentation, we will report results using micro Raman spectroscopy and dynamic modeling to monitor methane hydrate samples at The University of Texas Hydrate Core Analysis Facility and Mineral Physics Laboratory for studying physics, chemistry, and kinetics of gas hydrate samples as a function of pressure, temperature, composition/salinity, and time relevant to their natural environments and extraction processes. We aim to use these experimental data to understand how methane and ethane gases are formed and then released from the nano-pores of the core samples to the extraction well and how the gas diffuses within the hydrate and migrates into the bounding units and reservoirs.</p>
References	<p>[1] Xiaoli Liu and Peter B Flemings. Passing gas through the hydrate stabilityzone at southern hydrate ridge, offshore oregon. <i>Earth and Planetary Science Letters</i>, 241(1):211–226, 2006.</p> <p>[2] Alberto Malinverno. Marine gas hydrates in thin sand layers that soak up microbial methane. <i>Earth and Planetary Science Letters</i>, 292(3):399–408, 2010.</p> <p>[3] Mark Maslin, Matthew Owen, Richard Betts, Simon Day, Tom Dunkley Jones, and Andrew Ridgwell. Gas hydrates: past and future geohazard? <i>Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences</i>, 368(1919):2369–2393, 2010.</p> <p>[4] Wenyue Xu and Carolyn Ruppel. Predicting the occurrence, distribution, and evolution of methane gas hydrate in porous marine sediments. <i>Journal of Geophysical Research: Solid Earth</i>, 104(B3):5081–5095, 1999.</p> <p>[5] Kehua You, Timothy J Kneafsey, Peter B Flemings, Peter Polito, and Steven L Bryant. Salinity-buffered methane hydrate formation and dissociation in gas-rich systems. <i>Journal of Geophysical Research: Solid Earth</i>, 120(2):643–661, 2015.</p>

Title	Viral dynamics and global estimates for the biomass and biodiversity of the subsurface
Presenting Author	Cara Magnabosco
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Additional Authors	Bradley J, Onstott TC
Abstract Text	<p>This poster will explore the themes of "global biomass", biodiversity, and virus-host dynamics in the subsurface through modeling. Combining a database of 3700 cellular concentration measurements from cores and water samples with global heat flux and mean annual temperature maps we have estimated that the continental subsurface biosphere is comprised of $\sim 10^{30}$ cells down to a depth equivalent of 85C to 120C. From a collection of over 300 HT-16S rDNA datasets, we find that lithology is significantly correlated to community composition. Finally, we provide a framework to model viral-host interactions with parameterizations based on previously published data.</p>

Title	Formation of reduced Carbon compounds using natural catalysts in hydrothermal experiments
Presenting Author	Isabelle Martinez
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Additional Authors	Vacquand C, Kularatne K, Sissmann O, Brunet F, Recham N
Abstract Text	<p>The alteration of peridotites leads to the production of H₂ and thus propagates low oxygen fugacity conditions in the fluids which may in turn favor the reduction of CO₂. This reduction reaction is invoked for the production of methane and other reduced carbon molecules (e.g. carboxylic acids, formic acid, methanol) observed in hydrothermal fluids circulating through the oceanic lithosphere. Even though it is admitted that such reactions are promoted by some catalysts, those catalysts have not been clearly identified in such environments. We thus carried on an experimental work to study the catalytic properties of some spinel-structure phases (magnetite and chromite) and sulfides (Fe, Cu-sulfides) which are suspected to play some role in these FTT processes. Hydrothermal batch experiments were performed using the potential catalysts (spinels, sulfides) added in relatively small amounts to nano-olivine and run in gold capsule at P=200 bars –T=200 °C, together with a bicarbonate solution. After experiments, the gold capsule was pierced under vacuum to analyse the gaseous phases (H₂, n-alkanes, CO, CO₂); the solid phase was subsequently recovered for identification using electronic microscopy. We will compare the production of C-reduced phases to a blank experiment, and discuss the possibility of FTT reactions for each catalyst.</p>

Title	The origin of terrestrial volatiles including carbon in light of the recent results from the Rosetta mission
Presenting Author	Bernard Marty
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Additional Authors	K. Altwegg, M. Rubin, and the Rosina team
Abstract Text	<p>The potential contribution of comets to terrestrial volatiles is a long-standing problem that was central in the definition of the ESA Rosetta mission exploring Comet 67P/Churyumov-Gerasimenko (67P/C-G). The Rosina mass spectrometer on board of the spacecraft analyzed volatiles emitted by the comet during 2 years. Among them, noble gases are key tracers for the origin(s) and processing of volatile elements in the nascent solar system and in planetary atmospheres. The analysis of argon and xenon in Comet 67P/C-G permits for the first time to set stringent constraints on the origins of volatiles including carbon on Earth.</p>

Title	The influence of structure on CO ₂ degassing and past volcanism in the Main Ethiopian Rift.
Presenting Author	Tamsin A. Mather
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Additional Authors	Hunt JA, Pyle DM, Zafu A
Abstract Text	<p>Volcanism in the Main Ethiopian Rift takes a variety of forms and represents a largely unquantified risk for the country's growing population. Distributed volcanic fields, active during the Quaternary, are aligned along bands of normal faults. Recent extension is focussed along these bands, significantly accommodated by magmatism. Large, peralkaline volcanoes are distributed along the axis of the rift - some show present unrest (e.g. Aluto, Corbetti - deformation, hydrothermal activity) whilst others are likely extinct.</p> <p>Diffuse CO₂ surveys have been used to investigate areas of high flux in an attempt to quantify net emissions and characterise the pattern of degassing along the rift. Previous work suggests a huge contribution from rifts - we find that degassing is concentrated in localised areas and only specific faults, probably determined by magma storage. We therefore expect a lower (but significant) net flux from the rift, and warn of the ongoing risk from regional and distributed volcanism.</p> <p>Digital elevation models of several peralkaline volcanoes have been generated. These are being used to characterise past volcanic events and assess the importance of pre-existing structures to vent location and eruption style. Results will have implications for hazard management and our understanding of rift-related volcanism.</p>

Title	Spotlight on carbonates under pressure
Presenting Author	Catherine McCammon
Institution/Affiliation	Bayerisches Geoinstitut, University of Bayreuth
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Additional Authors	Winkler B
Abstract Text	<p>What happens when a geographically diverse group of scientists get curious about the fate of carbonates at high pressure and high temperature? If the scientists are in Germany and funding decisions are positive, then CarboPaT happens. So what is CarboPaT? It's a Research Unit funded by the German Science Foundation that enables topics to be tackled that are beyond the resources of a single lab or University. We focussed our spotlight on what happens to carbonates at extreme conditions with a two pronged approach, first to develop new state-of-the-art equipment and techniques and second to apply these methods to carbonates, with the added value of sample and young scientist exchange between participants. The presentation will showcase some highlights of the first funding period, including the discovery of new high-pressure tetrarbonates, elastic properties through the high- to low-spin transition of iron-bearing carbonates and the electronic structure of carbonates from multifaceted spectroscopic studies.</p>

Title	Pathways for Abiotic Carbon Reduction During Serpentinization
Presenting Author	Tom M McCollom
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E-mail	mccollom@lasp.colorado.edu
Abstract Text	<p>Abiotic reduction of inorganic carbon during serpentinization has substantial implications for the support of chemolithotrophic microbial communities and carbon cycling in the oceanic lithosphere. While there is considerable evidence for the presence of abiotic methane and other organic compounds in serpentinizing systems, the processes responsible for the formation of these compounds remain uncertain. A series of recently completed experimental studies performed in my lab indicate that methane synthesis during serpentinization may be much more sluggish than previously thought, particularly at temperatures below 300 °C (McCollom, 2016; McCollom and Donaldson, 2016). Ongoing work is investigating the possibility that carbon reduction during serpentinization may extend to the formation of more complex, macromolecular carbon compounds. Solid carbonaceous materials have been observed in several of our laboratory experiments and are predicted to occur by thermodynamic models (Milesi et al., 2016), but the composition of these materials and pathways for their formation have not been determined. Preliminary results also suggest that interaction of dissolved inorganic carbon with these materials may provide a novel pathway for methane synthesis, but this remains to be tested. We are currently conducting new experiments to investigate the formation of macromolecular materials during serpentinization, and are working with colleagues to characterize their composition.</p>
References	<p>McCollom TM (2016) PNAS 113:13965-13970 McCollom TM, Donaldson C (2016) Astrobiology 16:389-406 Milesi V, McCollom TM, Guyot F (2016) Geochimica et Cosmochimica Acta 189:391-403</p>

Title	Ubiquity of condensed carbonaceous matter in the hydrated oceanic lithosphere: implications for the deep biosphere and elemental cycles of this unaccounted fraction so far
Presenting Author	Benedicte MENEZ
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Additional Authors	Brunelli D, Richard L, Sforza MC, Pisapia C, Pasini V, Seyler M, Trias R, Gérard E
Abstract Text	<p>We review here natural occurrences of condensed phases of carbonaceous matter in oceanic serpentinites and ophiolites and discuss its chemical nature and structure. This overview, supported by petrological and thermodynamical constraints, allows providing a first general understanding of its formation modes and associated conditions. Special attention is paid to hydrogarnets shown to be a major player in the abiotic formation of condensed carbonaceous matter (CCM) and hence, a proxy of such processes. Although often closely associated with the presence of acknowledged metallic catalysts, we show that endogenic accumulations of organic carbon can also solely derive from mineralogical alteration reactions. Strikingly, variable contents in heteroatoms including O and N as functional groups or heterocycles along with unsaturated aliphatic chains mixed with aromatic moieties provides high reactivity to the CCM with likely consequences for deep life sustenance. We hence evaluate the potential of CCM as representing a valuable carbon source for the deep ecosystems, based on the metabolic capabilities recently depicted for the microbial communities inhabiting those environments.</p>
References	<p>Trias R, Ménez B, le Campion P, Zivanovic Y, Lecourt L, Schmitt-Kopplin P, Uhl J, Gíslason SR, Alfreðsson HA, Mesfin KG, Snæbjörnsdóttir SÓ, Aradóttir ES, Gunnarsson I, Matter J, Stutte M, Oelkers E, Gérard E - High reactivity of deep biota under anthropogenic CO₂ injection into basalt - Nat. Comm., under revision.</p> <p>Pisapia C, Gérard E, Gérard M, Lecourt L, Lang SQ, Pelletier B, Payri CE, Monnin C, Guentas L, Postec A, Quéméneur M, Erauso G, Ménez B (2017) Mineralizing filamentous bacteria from the Prony bay Hydrothermal Field open new perspectives for serpentinization-based deep ecosystems. <i>Front. Microbiol.</i>, 8:57. doi: 10.3389/fmicb.2017.00057.</p> <p>Sforza MC, Brunelli D, Pasini V, Pisapia C, Ménez B (2016) Multiple carbon reduction pathways within serpentinized peridotites from the South-Western Indian Ridge and Northern Apennines Ophiolites. <i>Goldschmidt 2016</i>: 2809.</p> <p>Pasini V, Brunelli D, Dumas P, Sandt C, Frederick J, Benzerara K, Bernard S, Ménez B (2013) Low temperature hydrothermal oil and associated biological precursors in serpentinites from Mid-Ocean Ridge. <i>Lithos</i> 178: 84-95.</p> <p>Ménez B, Pasini V, Brunelli D (2012) Life in the hydrated suboceanic mantle. <i>Nat. Geosc.</i> 5: 133-137.</p>

Title	Candidate carbonate phases in the Earth: experimental X-ray diffraction studies
Presenting Author	Marco Merlini
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Abstract Text	<p>With the current state of art of experimental facilities, we conducted studies on carbonates at the variable pressures and temperatures existing from the Earth's crust to the mantle/core region conditions. The quality of the diffraction data (single crystal and powder) allow full structural analysis for all the phases encountered. We present an updated overview of all the possible candidate carbonate phases in the inner Earth, based on model carbonate system and on most-likely composition in the ternary diagram CaCO₃-MgCO₃-FeCO₃. The model BaCO₃ studied at high temperatures and high pressures present the sequence of transition from aragonite-type phase to disorder-calcite phase and finally NaCl structure. At high pressure, the aragonite-type transform into the post-aragonite above 8 GPa. A similar scenario is observed in CaCO₃, but new high-pressure polymorphs denser than aragonite are present above 15 GPa. Dolomite, previously considered unstable at mantle conditions, is demonstrated to be stable above 30 GPa at the high pressures and temperatures existing in the Earth's interior up to the mantle/core boundary. It transforms to dense polymorphs based on distorted calcite-type structure at intermediate pressures, and, above the Mbar, transforms into new polymorphs featuring ring-carbonate C₃O₉ groups. This structure is likely the candidate phase for carbon storage in a carbonate in the Earth's mantle, and may form complete solid solution with CaCO₃ and MgCO₃. Fe-magnesite, stabilized at high pressures and temperatures, undergoes complex red-ox reactions, with the formation of Fe³⁺ bearing carbonates with stoichiometry different from ABO₃.</p>
References	<p>Merlini M, Hanfland M, Salamat A, Petitgirard S, Muller H (2015) The crystal structures of Mg₂Fe₂C₄O₁₃, with tetrahedrally coordinated carbon, and Fe₁₃O₁₉, synthesized at deep mantle conditions. <i>American Mineralogist</i>, 100:2001-2004</p> <p>Merlini M, Sapelli F, Fumagalli P, Gatta GD, Lotti P, Tumiati S Abdellatif M, Lausi A, Plaisier J, Hanfland M, Crichton W, Chantel J, Guignard J, Meneghini C, Pavese A, Poli S (2016) High-temperature and high-pressure behavior of carbonates in the ternary diagram CaCO₃-MgCO₃-FeCO₃. <i>American Mineralogist</i> 101, 1423-1430.</p>

Title	The use of Venusian data to constrain the origin of Earth's carbon
Presenting Author	Sami Mikhail
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Additional Authors	Heap MJ, Forgan D
Abstract Text	<p>Carbon is part of a group. This group includes the other elements vital for life (H-N-S) and the noble gases (He-Xe). Collectively, these elements are known as the volatiles (characterized by their low-boiling points). Therefore, the origin of Earth's carbon is intimately linked to the origin of the other volatiles. One consequence of their low-boiling points is that they're easily converted to gaseous form and lost pre-, syn-, and post-planetary accretion. For example, they're depleted in chondrites relative to solar abundances. This complexity inhibits an easy mass balance calculation for the bulk silicate Earth versus chondrites to constrain their core abundances (as is the case for elements like Ni and Co), and makes it very difficult to constrain Earth's bulk carbon abundance. Here we consider Earth's evil twin, Venus, as an opportunity. These two planets represent an ideal natural experiment to constrain the origin of Earth's volatiles (i.e. carbon) because both planets share a similar mass, composition, and position within the Solar System. However, their contrasting volcanology, atmospheric mass and chemistry, climate, and geomorphology are striking. Nonetheless, the relative abundances of the primordial noble gases of argon and neon are similar, as are their isotopic ratios - implying a shared origin for these volatile elements. The quandary here is that the Venusian atmosphere is roughly 2-orders of magnitude more volatile-rich in terms of nitrogen carbon, and the primordial noble gases. In the simplest sense, this implies one of two things: [1] Venus received more volatiles during accretion, or [2] Earth lost more of its volatiles following accretion. We will present the results of astronomical modelling to constrain the relative impact flux received by both planets, and tie this in with geological processing (volcanism, tectonics, and weathering) to provide a new insight on the origin of Earth's volatiles, including carbon.</p>

Title	Carbon from Crust to Core: a history of deep carbon science
Presenting Author	Simon Mitton
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Abstract Text	<p>What happened before 2009? And what happened next? To answer these questions I am researching the history of the discovery of the interior working of our dynamic planet. I am preparing a book that will be a showcase for the history of deep carbon science. Key discoveries will be highlighted and documented. The impact of new knowledge will be explored the roles of deep carbon scientists and their institutions. This innovative book will present the engaging human story of the remarkable scientists from whom we have learned about Earth's interior. The fascinating story of carbon in Earth is centre stage in a narrative that describes the discovery of the physical, chemical and biological aspects of the element carbon in the Earth's interior. This history and philosophy of science project will add to the literature of the history of geosciences. My poster has a list of Remarkable Deep Carbon Scientists from William Gilbert (1494-1555) to Claude ZoBell (1904-1989). Come along and add more researchers: tell me about the pioneers from history, promote your colleagues, or be very daring and add a "selfie!" As a historian and biographer, I am keen to add researchers who have been overlooked in the standard histories where each generation assumes the mantle of its predecessors. I am on the lookout for standout stories and personal recollections. I will be at the meeting equipped to do oral history interviews. So, what's your story? Cambridge University Press will publish the book in 2019. Whom do you want to see in the Index? And what keywords should be in that Index? That's what my poster is all about.</p>

Title	Microbially mediated alteration of crystalline basalts as identified from analogical reactive percolation experiments
Presenting Author	Rachael Leigh Moore
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Additional Authors	Ménez B, Stéphant S, Dupraz S, Ranchou-Peyruse M, Ranchou-Peyruse A, Gérard E
Abstract Text	<p>Alteration in the ocean crust through fluid circulation is an ongoing process affecting the first kilometers and at low temperatures some alteration may be microbially mediated. Hydrothermal activity through the hard rock basement supports diverse microbial communities within the rock by providing nutrient and energy sources. Currently, the impact of basement hosted microbial communities on alteration is poorly understood. In order to identify and quantify the nature of microbially mediated alteration two reactive percolation experiments mimicking circulation of CO₂ enriched ground water were performed at 35 °C and 30 bar for 21 days each. The experiments were performed using a crystalline basalt substrate from an earlier drilled deep Icelandic aquifer. One experiment was conducted on sterile rock while the other was conducted with the addition of a microbial inoculate derived from groundwater enrichment cultures obtained from the same aquifer. μCT on the experimental basaltic substrate before and after the reactive percolation experiment along with synchrotron radiation x-ray tomographic microscopy and the mineralogical characterization of resulting material allows for the comparative volumetric quantification of dissolution and precipitation. The unique design of this experiment allows for the identification of alteration which occurs solely abiotically and of microbially mediated alteration. Experimental results are compared to natural basaltic cores from Iceland retrieved following a large field CO₂ injection experiment that stimulated microbial activity at depth.</p>

Title	Low-biomass communities at the deep-biosphere extremes: Why and how do we care?
Presenting Author	Yuki Morono
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Additional Authors	Inagaki F
Abstract Text	<p>Over the past decades, scientific ocean drilling has explored the deep seafloor biosphere at various oceanographic settings and demonstrated that remarkable numbers of microorganisms are present in the seafloor biosphere. Rigorous efforts on cell counts showed so far that microbial communities are logarithmically decreased with increasing sediment depth, despite the bottom of the deep biosphere still remain uncertain. In order to explore low-biomass communities living close to the life-less lithosphere, quality assessment and quality control (QA/QC) for sampling and subsequent experimental procedures will be crucial; furthermore, some innovative technologies to investigate single cells living on the edge would be required. We recently developed a fluorescence color-based cell detection and enumeration method, enabling discriminative cell recognition in geologic samples. This technique results in objective and statistically mean cell numbers with higher precision. Also, a new protocol for effective cell separation from core samples using a multi-gradient density centrifugation has been standardized, making our cell counting more fast, sensitive, and precise than before, even for very low-biomass sediment samples. By applying these techniques, we are currently studying low-biomass community samples obtained from the Integrated Ocean Discovery Program (IODP) Expeditions 357 (Atlantis Massif Serpentinization and Life) and 370 (T-Limit of the Deep Biosphere off Muroto), providing unprecedented opportunities to expand our knowledge of the limits of life and the deep biosphere. Under the strict QA/QC using super-clean facilities, our current minimum quantification limit of microbial cells approaches a few to few-tens cells/cm³ of sediment. Cell separation and sorting techniques can also be applicable for single cell-genomic and isotopic studies; e.g., the separated cells can be concentrated and placed at few hundreds micrometer-region, and then each single cell can be analyzed with nano-scale secondary ion mass spectrometry (NanoSIMS) for probing cellular activity to incorporate stable isotope-labeled substrates.</p>

Title	Network analysis applications to carbon mineral systems
Presenting Authors	Shaunna M Morrison, Ahmed A Eleish, Daniel R Hummer
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Additional Authors	Liu C, Prabhu A, Zhong H, Fox P, Ralph J, Golden JJ, Downs RT, Hystad G, Meyer M, Hazen RM
Abstract Text	<p>Recent studies in carbon mineral ecology and evolution focus on the spatial and temporal distribution of Earth's more than 500 known and predicted carbon-bearing mineral species. We enlist "big data" resources, statistical analyses, and varied visualization methods to reveal previously hidden patterns in planetary mineralogy. In this context, network analysis provides an especially powerful approach to exploring the co-evolving geosphere and biosphere.</p> <p>Mineral network analysis (Liu et al., 2017; Morrison et al., 2017) utilizes the visualization and statistical network analysis techniques (Kolaczyk, 2009; Newman, 2013) previously applied to other complex, multi-dimensional systems, such as paleogeography (Costanzo et al., 2016), terrorist networks (Abraham et al., 2010), and civil engineering (Hwang and Houghtalen, 1996). Utilizing extensive mineral data resources (e.g. RRUFF.info/IMA, mindat.org), we are assembling a large database of mineralogical information, such as co-occurrence, locality, age, chemistry, and physical properties, for the purpose of characterizing previously unknown trends (chemical, tectonic, geographic, temporal, etc.), comparing mineral, rock, and planetary systems, and developing predictive statistical models of mineral formation, diversity, and distribution.</p> <p>Recent mineral ecology studies have begun applying network and cluster analysis techniques to vanadium, chromium, and copper minerals, as well as igneous minerals from Johannsen's (1932-1938) exhaustive petrologic compilations of igneous rocks. Network diagrams (including force-directed and bipartite networks through deep time), clustering, and network metrics (including density, betweenness centrality, and degree centrality) for the above mineral systems will be compared to that of carbon minerals. We will explore additional statistical tools, such as the Cochran-Mantel-Haenszel statistical analyses of 3-element mineral correlations, to further examine chemical and geologic trends in the C mineral system.</p>
References	<p>Abraham A et al. (2010) New York: Springer Costanzo M et al. (2016) Science 353(6306):1381 Hwang N and Houghtalen R (1996) Prentice Hall Johannsen A (1948–1963) Chicago, IL: University of Chicago Press Kolaczyk ED (2009) New York: Springer Liu C et al. (2017) (in review) Morrison SM et al. (2017) (in review) Newman MEJ (2013) New York: Oxford University Press</p>

Title	Copper mineral ecology and network analysis through deep time
Presenting Author	Shaunna M Morrison
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Additional Authors	Eleish A, Liu C, Prabhu A, Zhong H, Fox P, Golden JJ, Ralph J, Downs RT, Hystad G, Meyer M, Hummer DR, Hazen RM
Abstract Text	<p>Introduction: Network analysis techniques (Kolaczyk, 2009; Newman, 2013) have been applied to the evaluation, characterization, and visualization of many complex, multi-dimensional systems, including biology (Costanzo, 2016), sociology (Abraham, 2010), technology (Pagani and Aiello, 2013), and, recently, mineral ecology (Liu et al., 2017; Morrison et al., 2017). In this study, we utilize network analysis statistical and visualization techniques to further examine the chemical, geological, and temporal trends in Cu mineral occurrence on Earth's surface.</p> <p>Methods: We have compiled a database of Cu mineral co-occurrence, locality, age, chemistry, and physical properties from literature and open-source databases (mindat.org; ruff.info). These data can be visualized with network diagrams, where each mineral is represented by a node and co-occurrence of two minerals is shown as a link between nodes. The color, size, length, shape, etc. of nodes and links can represent a data parameter, such as chemical composition, oxidation state, age, or frequency of co-occurrence. Moreover, bipartite diagrams have two distinct sets of nodes and display the connectivity between sets. Network diagram flexibility allows us to display multi-dimensional data in a way that the viewer can recognize trends that are not apparent in the data alone or from traditional two-dimensional graphs. In addition to powerful visualizations, we also utilize statistical metrics to quantitatively evaluate and compare mineral networks.</p> <p>Copper: Cu minerals form distinct clusters as a function of anion or anion complex, particularly as sulfides, sulfates and oxides, and also by deposit type, such as hydrothermal sulfide veins and fumarole deposits, illustrating the chemical and geological connectivity of mineral co-occurrence. Furthermore, bipartite graphs of mineral and locality relationships for geologic time intervals illustrate the evolution of Cu minerals diversity and distribution through deep time, highlighting the prominence of reduced Cu phases early in Earth's history and the transition to higher proportions of oxidized phases post-GOE.</p>
References	<p>Abraham A et al. (2010) New York: Springer Costanzo M et al. (2016) Science 353(6306):1381 Kolaczyk ED (2009) New York: Springer Liu C et al. (2017) (in review) Morrison SM et al. (2017) (in review) Newman MEJ (2013) New York: Oxford University Press Pagani GA and Aiello M (2013) Physica A 392</p>

Title	A snapshot of volatile degassing at the scale of an entire subduction zone; the “Trail by Fire” expedition.
Presenting Author	Yves Moussallam
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Abstract Text	Quantifying the total flux of volatiles, including carbon, emitted by active volcanoes is a community-wide endeavour with the double aim of (i) Understanding volatile cycling at the planetary scale and (ii) Improving current global climate models. Here I'll present preliminary results from the Trail by Fire expedition that took place between 2015 and 2017. The expedition aimed at providing a snapshot of volatile degassing at the scale of the entire Nazca plate subduction zone by providing remote and direct measurements at nearly twenty actively degassing volcanoes along the arc. Secondary objectives of the expedition were (i) to acquire $\delta^{13}\text{C}$ measurements in volcanic plumes by Isotope Ratio Infrared Spectroscopy (IRIS), (ii) to acquire simultaneous ground and satellite-based observations and (iii) to perform UAV-based measurements in volcanic plume.

Title	Reconstructing the variability in mantle carbon contents underneath mid-ocean ridges.
Presenting Author	Sujoy Mukhopadhyay
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Abstract Text	<p>Most Mid Ocean Ridge Basalts (MORBs) extensively degas CO₂ prior to eruption onto the seafloor. As a result, mantle carbon concentration, or the carbon flux from the mantle cannot be reconstructed directly through measurements of most MORBs. The CO₂/3He ratio in MORBs, combined with the 3He flux into the ocean, is often used to quantify the carbon flux out of the mantle. Since degassing can modify the CO₂/3He ratio, measured CO₂/3He ratios are corrected for degassing using an equilibrium degassing model based on measured 4He/40Ar* ratios (where * refers to the radiogenic abundance of an isotope; e.g., Marty and Tolstikhin, 1998). Such an approach leads to CO₂ flux of around 5×10¹³ g/year out of mid-ocean ridges. However, the average carbon flux out of the mantle does not provide insights into variations in mantle carbon content.</p> <p>Using global MORB data, we demonstrate that 4He*/21Ne*, 4He*/40Ar*, and 4He*/136Xe*U ratios do not simultaneously conform to any equilibrium degassing model, questioning the validity of these models for correcting ratios involving C. We will present a simple new model of disequilibrium degassing that can quantitatively reconstruct pre-degassing volatile contents in individual MORB samples through combined carbon-noble gas measurements. Reconstructed initial magmatic CO₂ contents from a suite of Mid Atlantic and Southwest Indian Ridge basalts vary from 900 to 2500 ppm with a median value of 1700 ppm. The reconstructed CO₂ contents correlate with the Ba content and the median CO₂ contents imply an global CO₂ flux of 1.2×10¹⁴ g/year out of mid-ocean ridges, higher than estimates based on CO₂/3He ratios but consistent with recent estimates from Michael and Graham (2015) based on CO₂ measurements in volatile undersaturated MORBs. Thus, combined carbon-noble gas measurements in conjunction with our disequilibrium degassing model provide a framework for mapping the variation in mantle carbon contents.</p>
References	Marty B, Tokstikhin IN (1998) Chemical Geology, 145, 233-248; Michael PJ, Graham D. W. (2015) Lithos, 236, 338-351.

Title	Data2Paper: A stakeholder-driven solution to data publication and citation challenges
Presenting Author	Fiona Murphy
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Abstract Text	<p>Data, and especially open data, are valuable to the community but can also be valuable to the researcher. Data papers are a clear and open way to publicize and contextualize your data in a way that is citable and aids both reproducibility and efficiency in scholarly endeavour. However, this is not yet a format that is well understood or proliferating amongst the mainstream research community.</p> <p>Part of the Jisc Data Spring Initiative, a team of stakeholders (publishers, data repository managers, coders) have been developing a simple 'one-click' process where data, metadata and methods detail are transferred from a data repository (via a SWORD-based API and a cloud-based helper app based on the Fedora/Hydra platform) to a relevant publisher platform for publication as a data paper. Relying on automated processes: using ORCIDs to authenticate and pre-populate article templates and building on the DOI infrastructure to encourage provenance and citation, the app seeks to drive the deposit of data in repositories and encourage the growth of data papers by simplifying the process through the removal of redundant metadata entry and streamlining publisher submissions into a single consistent workflow.</p> <p>This poster will explain the underlying rationale and evidence gathering, development, partnerships, governance and other progress that this project has so far achieved. It will outline some key learning opportunities, challenges and drivers and explore the next steps.</p>

Title	Crystallographic orientations between diamond and its mineral inclusions: new insights into the syngensis/protogenesis relationships
Presenting Author	Fabrizio Nestola
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Abstract Text	<p>The growth mechanism relationships between diamond and its mineral inclusions are not trivial. Most of the works in literature assumed the so-called “syngensis”, i.e. diamond and its mineral inclusions simultaneously growth in contact and from the same chemical reaction. However, a series of works are in contrast with the syngensis assumption and definitively propose instead that diamond crystallizes on pre-existing mantle minerals, i.e. the inclusions are defined as “protogenetic” (i.e. Spetsius et al. 2002; Taylor et al. 2003; Thomassot et al. 2009; Jacob et al. 2016). Here, the syngensis versus protogenesis is discussed for lithospheric diamonds by using crystallographic orientations between diamond and its mineral inclusions obtained by single-crystal X-ray diffraction following the same experimental approach as in Nestola et al. (2014) and Milani et al. (2016).</p>
References	<p>Jacob DE, Piazzolo S, Schreiber A, Trimby P (2016) Nature Communications 7: 11891.</p> <p>Milani S, Nestola F, Angel RJ, Nimis P, Harris JW (2016) Lithos 265: 312-316.</p> <p>Nestola F, Nimis P, Angel RJ, Milani S, Bruno M, Prencipe M, Harris JW (2014) International Geology Review 56: 1658–1667.</p> <p>Spetsius ZV, Belousova EA, Griffin WL, O'Reilly SY, Pearson NJ (2002) Earth and Planetary Science Letters 199: 111-126.</p> <p>Taylor LA, Anand M, Promprated P (2003) Eighth International Kimberlite Conference, Long Abstract, Volume, Victoria, Canada.</p> <p>Thomassot E, Cartigny P, Harris JW, Lorand JP, Rollion-Bard C, Chaussidon M. (2009) Earth and Planetary Science Letters 282: 79 – 90.</p>

Title	In situ measurements using space instrumentation proves Ni isotopes as reliable biomarkers in microfossils.
Presenting Author	Anna Neubeck
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Abstract Text	<p>Investigating isotopic fractionation patterns in situ in microfossils is critical for site-specific ascribed isotopic signals that are needed to differentiate between abiotic and biologic microstructures. Stable isotopes of nickel have been proposed a suitable biomarker due to experimentally proven microbial preferential uptake of the lighter isotope. It has until now been unknown if such fractionation signals can be preserved and analyzed in fossilized microorganisms in rocks. We have conducted in situ analyses of micrometer sized deep subsurface seafloor fossils using a miniaturized laser ablation mass spectrometer (LMS) developed for space research to investigate the preservation and fractionation patterns of stable nickel isotopes. Biologic negative delta values of nickel isotopic signals measured in fossils and abiotic, positive signals measured in abiotic rock samples strongly suggest that nickel isotopes can be used as a reliable biomarker for ancient and well as extraterrestrial life. Our results also proves that the instrumentation used for the measurements is sensitive enough to extract trace amounts of an element but precise enough to omit noise. Such an instrument combined with the new method of using nickel isotopes as biomarkers opens up new possibilities in space and early Earth research.</p>

Title	Guar gum stimulates biogenic sulfide production at elevated pressures: Implications for shale gas extraction
Presenting Author	Sophie Nixon
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Additional Authors	Walker L, Streets M, Boothman C, Eden B, Taylor K, Lloyd J
Abstract Text	<p>Biogenic sulfide production is a common problem in the oil industry, and can lead to costly hydrocarbon processing and corrosion of extraction infrastructure. The same phenomenon has recently been identified in shale gas extraction by hydraulic fracturing, and organic additives in fracturing fluid have been hypothesised to stimulate this process. Constraining the relative effects of the numerous organic additives on microbial metabolism in situ is, however, extremely challenging.</p> <p>Using a bespoke bioreactor system we sought to assess the potential for guar gum, the most commonly used gelling agent in fracturing fluids, to stimulate biogenic sulfide production by sulfate-reducing microorganisms at elevated pressure. Two pressurised bioreactors were fed with either sulfate-amended freshwater medium, or low-sulfate natural surface water, in addition to guar gum (0.05 w/v%) and an inoculum of sulfate-reducing bacteria for a period of 77 days. Sulfide production was observed in both bioreactors, even when the sulfate concentration was low. Guar gum was degraded into bioavailable volatile fatty acids acetate and propionate. Analysis of 16S rRNA gene sequences indicate that heterotrophic bacteria closely associated with the genera <i>Brevundimonas</i> and <i>Acinetobacter</i> became enriched early in the bioreactor experiments, followed by an increase in relative abundance of 16S rRNA genes associated with sulfate-reducing bacteria (<i>Desulfosporosinus</i> and <i>Desulfobacteraceae</i>) at later time points.</p> <p>Results demonstrate that guar gum can stimulate acid- and sulfide-producing microorganisms at elevated pressure, and may have implications for microbially-induced corrosion during hydraulic fracturing operations. Our laboratory approach can be tailored to better simulate deep subsurface conditions in order to probe the role of other fracturing fluid additives and downhole parameters on microbial metabolisms observed in these systems. Such baseline studies will prove essential for effective future development of shale gas worldwide.</p>

Title	Microbial activity in the serpentinizing subsurface of Atlantis Massif: Initial Results from IODP Expedition 357
Presenting Author	Beth N Orcutt
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Abstract Text	<p>In late 2015, Integrated Ocean Drilling Program (IODP) Expedition 357 drilled the southern wall of the ocean core complex Atlantis Massif on the western flank of the Mid-Atlantic Ridge with a goal of studying the connection of deep life with serpentinization. As part of this goal, we established incubation experiments with seafloor rocks to examine microbial activity. Here, we will present initial results on extracellular enzyme activity measured in these incubations, and compare these with recent results from other deep biosphere environments to assess the contribution of global seafloor microbial activity. We will also present initial results from newly developed cell sorting procedures for sorting growing cells from enrichment and whole rock samples for genomic analysis.</p>

Title	Fate of MgCO ₃ in subducting slabs and formation of superdeep diamonds and oxidizing zone in the deep lower mantle
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Abstract Text	<p>The stability of MgCO₃ at high pressure and temperature has been studied by experiments and ab initio calculations [1,2]. Although these previous studies revealed that MgCO₃ changes its structure from magnesite to its high-pressure polymorphs [1,2], the phase change behaviors of MgCO₃ bearing multicomponent systems including under the lower mantle conditions are not well understood yet.</p> <p>We have conducted high pressure and temperature experiments on a reaction between MgCO₃ and SiO₂ under the whole mantle conditions using a double sided-laser heated diamond anvil cell combined with the synchrotron X-ray diffraction technique at the beamline of BL10XU, DPring-8. We have focused on the MgCO₃-SiO₂ reaction which is a simplified model of the carbonated slab material descending into the lower mantle [3].</p> <p>The phase transition of magnesite to MgCO₃ II, a high-pressure polymorph of magnesite, was observed at around 80 GPa and 1800 K. Under the same pressure and temperature conditions, diamond was formed by the reaction of MgCO₃ and SiO₂. We describe the phase diagram of the MgCO₃-SiO₂ system under the whole mantle conditions. The phase diagram shows that MgCO₃ and SiO₂ do not react with each other down to the 2000 km depth of the lower mantle in cold subducting slabs. The reaction of formation of diamond and oxygen occurs at the depths greater than 2000 km in the lower mantle. The reaction of MgCO₃ and SiO₂ may explain diamond originating in the deep lower mantle [4,5]. The diamond forming reaction generates oxygen, which could provide high fO₂ conditions in the deep lower mantle.</p>
References	[1] Isshiki et al. (2004) <i>Nature</i> 427, 60-63. [2] Oganov et al. (2008) <i>Earth Planet. Sci. Lett.</i> 273, 38-47. [3] Seto et al. (2008) <i>Phys. Chem. Miner.</i> 35, 223-229. [4] Hayman et al. (2005) <i>Contrib. Mineral. Petrol.</i> 149, 430-445. [5] Wirth et al. (2014) <i>Earth Planet. Sci. Lett.</i> 404, 365-375.

Title	Deep methane cycles
Presenting Author	Shuhei Ono
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Abstract Text	<p>In deep subsurface environments, the abundance of a doubly substituted methane isotopologue, $^{13}\text{CH}_3\text{D}$, encodes information about the temperature at which methane is generated or equilibrated. We will discuss how this isotopologue thermometer can be translated to the generation depth of methane, and ultimately used to generate a 1-D, 2-D or 3-D map of deep methane cycles.</p> <p>Methane isotopologue temperatures for methane hydrates from the western African coast and the Black Sea ranges from 10 to 70 °C (with peak at 35 °C), with higher temperatures (100 to 160 °C) measured for methane from mud volcanoes. Given a geothermal gradient of 26 °C/km, we estimate the mean generation depth of methane in methane hydrate to be 1.0 ± 0.5 km below seafloor. Degradation of organic materials in sediments deeper than the sulfate reduction zone is limited to fermentation, methanogenesis, and thermal diagenesis. The interpreted average depth of methane sources in these two regions suggests rate-limiting process is likely fermentation (and hydrolysis), and this process is favored at warmer temperatures. Higher temperatures, up to 160 °C, measured in mud volcano gas samples indicate more deeply-sourced (>3 km below seafloor) thermogenic methane. The deep-sourced methane is pushed upwards due to sediment compaction and lateral compression forces and migrates upwards through local fault systems.</p>

Title	First-principles Raman spectroscopy of dissolved carbon in water under extreme conditions
Presenting Author	Ding Pan
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Abstract Text	<p>The aqueous properties of dissolved carbon at extreme conditions are of great importance to the carbon cycle in the deep Earth, which substantially influences the carbon budget near the Earth's surface, and in turn global climate change.</p> <p>We carried out first-principles simulations that showed that, contrary to the assumptions of many geochemical models, carbon dissolved in water-rich fluids at the bottom of the Earth's upper mantle is not in the form of CO₂(aq) but rather in carbonate and bicarbonate ions [1]. We also calculated the Raman spectra of (bi)carbonate aqueous solutions at supercritical conditions, and obtained the Raman scattering cross sections of carbon species at high pressures and high temperatures from first principles. We will discuss how to use our results to interpret and guide spectroscopic measurements.</p>
References	Pan D. and Galli G.(2016) Sci. Adv. 2: e1601278

Title	Constraints on mantle carbon speciation through deep time – the diamond perspective
Presenting Author	Graham Pearson
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Abstract Text	<p>Diamonds offer a unique deep-time perspective on the evolution of mantle carbon because of their large range in formation ages and their physical and chemical robustness. Because diamonds are widely believed to be of metasomatic origin, those containing included minerals have the potential to constrain the speciation of carbon-bearing mantle fluids in terms of depth (lithosphere, transition zone or lower mantle), host rock (peridotite or eclogite) and time. Only diamond can provide this range of information.</p> <p>Diamond occurrences where the formation age of specific parageneses had previously been determined were selected for SIMS analysis. From these localities, fragments of inclusion-bearing diamonds are imaged with CL and analyzed along “core-rim” transects for variations in $\delta^{13}\text{C}$ and N-content. Our current data set reveals that $\delta^{13}\text{C}$ overall is a fairly poor tracer of diamond forming processes: $\delta^{13}\text{C}$ only shows significant evolution (beyond the analytical uncertainty of $\sim 0.2\%$) in very dilute (carbon poor) diamond-forming fluids or for large degrees of diamond crystallization in fluid-limited systems. For most diamonds on which analytical transects were conducted so far, systematic co-variations between $\delta^{13}\text{C}$ and N-content are absent. The few examples where a growth mode can be identified are equally split between diamond precipitation from carbonate-bearing or near-water maximum fluids and reduced fluids (e.g., CH_4 and C_2H_6) and occurred in diamonds of both lherzolitic and eclogitic paragenesis.</p> <p>Conclusions so far: Diamonds forming in the lithospheric mantle document no discernable temporal trend in mantle carbon speciation over 2.5 Ga. The transition zone appears to store predominantly recycled C and N, forming diamonds from both “oxidised” and “reduced” fluids, although the signal is currently biased towards the eclogitic paragenesis.</p>

Title	Sedimentary Carbon Input and Recycling at Subduction Zones
Presenting Author	Terry Plank
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Abstract Text	<p>Seafloor sediments approach active subduction zones with both organic and inorganic carbon loads, and this constitutes a significant flux over geological time with respect to the size, isotopic composition and electron balance of the carbosphere. In order to quantify the flux of organic carbon into subduction zones, we have examined carbon concentration and density measurements provided by drilling for cores that sample sedimentary sections near deep sea trenches. An interpolation scheme compensates for sparse or non-uniform analyses, and a weighted bulk concentration and subduction flux is calculated for organic carbon (OC) and inorganic carbonate (IC) for each site. Sites with the greatest concentration of OC include those that pass beneath regions of high biological productivity (such as the Eastern Equatorial Pacific) and those that receive terrigenous turbidites (e.g., Indus and Begal Fans, Gulf of Alaska). Together, terrigenous turbidites make up about 60% of the global subducted sediment (GLOSS), and thus have a strong control on the concentration of OC in GLOSS. Sites dominated by terrigenous turbidites have 0.3 wt% OC on average (1sd = 0.1 wt%), and GLOSS is very similar, yielding about 5 MtC/yr OC subducted globally. This flux is enough to subduct the entire surface pool of OC every 3 Ga, which if not returned, or returned in a more oxidized form, could contribute to a significant rise in oxygen at the surface of the Earth. The IC concentration in subducting sediments is also very heterogeneously distributed, with much of the north Pacific devoid of carbonate sediment, and local concentrations in equatorial regions (Eastern Pacific) and on plateaux (Hikurangi in New Zealand). Globally, carbonate (IC) dominates OC by a factor of 4. The subducted IC flux appears to control the CO₂/S flux emitted from arc volcanoes, and the OC/IC ratio may control the isotopic composition of volcanic gases.</p>

Title	IDENTIFICATION OF INFLOW OF FRESH LIGHT HYDROCARBONS IN THE OIL RESERVOIR THROUGH THE STUDY OF THE COMPOSITION OF OIL
Presenting Author	Irina N. Plotnikova
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Abstract Text	<p>This presentation is devoted to a study of the characteristic features of the composition and structure of crude oils from terrigenous Devonian producing deposits in the Minnibaevskii section of the Romashkino and Pervomai fields. Using the SynOil program, we identified the features of the molecular weight distribution of n-paraffins, cyclohexanes, and monoalkylbenzenes associated with the formation and transformation conditions in the crude oil deposits.</p> <p>Geochemical parameters based on the composition of aliphatic and aromatic hydrocarbons are traditionally used to establish the composition and structure of crude oils. They can answer several important questions regarding the solution of engineering and geological problems. However, some of the questions remain unanswered. In particular, both the formation stage of oil and gas deposits and their preservation conditions in nature are unresolved. A new methodical approach and set of required parameters are required in order to solve these problems. In the present work, one solution to these problems that examines the molecular-weight distribution (MWD) of aliphatic and aromatic C₁₂+ hydrocarbons is presented using crude oils from the Minnibaevskii section of the Romashkino and Pervomai fields as examples.</p> <p>Thus, the study of crude oils from Romashkino and Pervomai fields using simulated separation of n-paraffins, ACH, and AB according to the SynOil program showed that the crude oils were formed in complicated conditions. The presence or absence of one group of low-molecular-weight compounds or another in the crude oils was indicative of their natural storage conditions.</p> <p>The presence of condensate components in crude oils indicates different stages of introduction of hydrocarbons in the formations. The high content of condensate components in petroleum migration indicates its character and the introduction of new light hydrocarbons. Light condensate components are not connected to the source rocks, but have a different, presumably deep source of generation.</p>

Title	DCO Engagement: Telling the Deep Carbon Story
Presenting Author	Robert Pockalny
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Abstract Text	<p>The Deep Carbon Observatory is approaching the end of its decade-long quest to explore and define the quantities, movement, forms, and origins of carbon in Earth. Its extensive, collaborative network of 1,000 scientists in 45 nations has made many scientific discoveries, which are increasing understanding of how Earth works. DCO's Engagement Team is charged with telling these stories to a variety of audiences. To this end, the Team undertakes a broad range of activities, ensuring the science network flourishes and sharing its achievements both in and outside of the network. The team's activities—everything from a robust web presence on deepcarbon.net, to an active social media presence, to sharing DCO news with the broader research communities and interested public—comprise the public face of DCO. To accurately and appropriately represent DCO, we work hand-in-hand with DCO's leadership, its four Science Communities, Engagement Advisory Committee, Secretariat, and Data Science Teams. Our collective goal is to share timely, accurate, and interesting information to keep the community and broader audiences informed about the rapidly growing field of deep carbon science.</p> <p>As 2019 approaches, the Engagement Team will continue promoting DCO science, expanding its geographic and cultural boundaries. It will also work across DCO communities to develop DCO-wide materials, with an eye towards making them relevant, easily digested, and visually interesting across many digital and print platforms for wide dissemination and use. The Team is also working to improve deep carbon science content on Wikipedia and other public platforms, recording DCO's legacy and contributions to scientific understanding.</p>

Title	Hydrous carbonatitic liquids generated by subducted pelagic carbonates
Presenting Author	Stefano Poli
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Abstract Text	<p>Pelagic limestones, hundred meters in thickness, are subducted today in a variety of subduction zones worldwide (Colombia, New Zealand, Vanuatu). Impure marbles constitute large tectonometamorphic units in mountain belts (e.g. Alps) testifying to their lithological and geochemical identity throughout the orogenic cycle. Despite the geochemical relevance of systems enriched in CaCO₃, experimental investigation mostly focused on carbonated pelites, characterized by low Ca/(Ca+Mg+Fe) ratio. Here we study the composition and the condition of formation of liquids formed in the model system CaO-Al₂O₃-SiO₂-H₂O-CO₂, profiting of phase relationships in the subsystem CaO-H₂O-CO₂ (CHC) where continuous transition between a high-density „vapor“ and a carbonated hydrous „melt“ was suggested to occur close to a second critical endpoint at temperatures as low as 530 °C, and approximately 4 GPa (Wyllie and Boettcher, 1969).</p> <p>Multianvil experiments were performed at 4.2 and 6.0 GPa on three bulk compositions, where zoisite and/or Al₂SiO₅ saturation prevents the formation of portlandite and dellaite, experimentally recorded on eutectic melting in CHC, but barely found in nature. H₂O contents vary from 6 to 21 wt%.</p> <p>Aragonite + kyanite + fluid, and minor lawsonite form at 700 °C, replaced by zoisite at 800 °C. Between 850 °C and 950 °C, a complex sequence of textural features is observed upon quenching of single volatile-rich liquid phase formed at run conditions. Precipitates include dendritic CaCO₃, silicate glass and Al-rich whiskers. The bulk composition of such hydrous carbonatitic liquids is retrieved by image analysis on X-ray maps, showing Ca:Al:Si ratios up to 6:1:3.</p> <p>Hydrous Ca-carbonatitic are efficient media for scavenging volatiles from subducted crustal material and for metasomatizing the mantle wedge.</p>
References	Wyllie PJ, Boettcher AL (1969) Am J Sci 267-A: 489-508

Title	Synthesizing Deep Carbon - Distillation and Dissemination in Five Reactions
Presenting Author	Simon A T Redfern
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Abstract Text	<p>As the DCO project, in its current guise, approaches its completion, thoughts turn to synthesizing outputs, achievements and advances. Attempting to do this under the theme of the five most important reactions on/in Earth involving carbon is a challenge that demands the attention of all the DCO communities. But why bother? Who will listen? What are the audiences and why might we want to reach them? Some (at least) of these questions will be addressed as we reflect on the work of the DCO since its inception.</p>

Title	Coupled geodynamic models of flow and transport in subduction zones
Presenting Author	David William Rees Jones
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Additional Authors	Katz RF, May D, Rudge JR, Tian M
Abstract Text	<p>Subduction-zone processes control the chemical composition of the continental crust, the refertilization of the upper mantle, and the sequestration of volatile species in the deep mantle. As such, they play an uncertain but potentially large role in the deep carbon cycle [1,2], which we aim to quantitatively understand. Previous geodynamic modelling of subduction zones has largely decoupled the solid velocity and thermal calculations from the liquid velocity calculations [3]. Transport by the liquid phase is likely to be significant, especially for volatile species such as carbon, which are highly incompatible. We are developing new software in which the equations governing conservation of mass, momentum, energy and chemical species are solved in a coupled fashion, leveraging the PETSc library to deliver high performance, scalable solutions. We present preliminary calculations that illustrate coupled two-phase flow in subduction zones.</p> <p>We demonstrate the significance of solving the conservation equations in a coupled fashion by considering the impact of magmatism on the thermal structure of subduction zones [4]. A range of geochemical and heat flow evidence has recently converged to indicate that subduction zones are hotter than predicted by models of solid-state mantle creep [5,6,7]. We show that magmatic transport locally alters the thermal structure of canonical models by ~200–300 K. We find the advection of sensible heat to be significantly larger than the deposition of latent heat. Based on these results, we suggest that magmatism could significantly affect the location, extent and chemical composition of arc volcanism. The thermal structure of the wedge may also rheologically influence the transport of volatile-rich liquids in the wedge, and so in turn influence the degree to which volatile species are sequestered into the deep mantle or retained in the shallow mantle or lithosphere.</p>
References	<p>[1] Dasgupta R, Hirschmann MM (2010) The deep carbon cycle and melting in Earth's interior. <i>EPSL</i>, doi:10.1016/j.epsl.2010.06.039.</p> <p>[2] Kelemen PB, Manning CE (2015) Reevaluating carbon fluxes in subduction zones, what goes down, mostly comes up. <i>EPSL</i>, doi:10.1073/pnas.1507889112.</p> <p>[3] Wilson CR, Spiegelman M, van Keken PE, Hacker BR (2014) Fluid flow in subduction zones: The role of solid rheology and compaction pressure. <i>EPSL</i>, doi:10.1016/j.epsl.2014.05.052.</p> <p>[4] Rees Jones DW, Katz RF, Tian M, Rudge JF (under review) Thermal impact of magmatism in subduction zones. <i>arXiv version</i>, arxiv.org/abs/1701.02550.</p> <p>[5] Kelemen PB, Rilling JL, Parmentier EM, Mehl L, Hacker BR (2003) Thermal structure due to solid-state flow in the mantle wedge beneath arcs. <i>Geophysical Monograph Series</i> 138, 293–311.</p> <p>[6] Perrin A, Goes S, Prytulak J, Davies DR, Wilson C, Kramer S (2016) Reconciling mantle wedge thermal structure with arc lava thermobarometric determinations in oceanic subduction zones. <i>Geochemistry, Geophysics, Geosystems</i>, doi:10.1002/2016GC006527.</p> <p>[7] Manga M et al (2012) Heat flow in the Lesser Antilles island arc and adjacent back arc Grenada basin. <i>Geochemistry, Geophysics, Geosystems</i>, doi:10.1029/2012GC004260.</p>

Title	Sampling Microbes in the Subsurface: A cautionary tale
Presenting Author	Brandi Kiel Reese
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Abstract Text	<p>Sampling low biomass systems for microbes and the subsequent analysis of the communities is fraught with issues related to potential contamination. Sources of contaminating microbes may come from the sampling process, lab handling, extraction or sequencing reagents. Putative contaminants commonly identified are associated with humans or drilling fluids, but unlikely to be present in the subsurface, and may be easily identified and removed from a database. However, other microbes may be more enigmatic and could represent either a contaminant or native residents of subsurface environments (e.g., <i>Ralstonia</i> spp.). Our objectives are: 1) summarize best practices for sample collection that minimizes contamination, 2) identify typical contaminants, and 3) establish best practices for contamination removal. In the future, ribosomal databases (e.g., Census of Deep Life) sourced from low biomass environments can be rendered suitable for examination by minimizing inclusion of known non-subsurface microbes. During sample collection and handling, equipment cleanliness, contamination tracers, and administrative procedures (e.g., handling or shipping blanks) may be essential for obtaining uncompromised materials. Additionally, using extraction blanks during nucleic acid extraction is crucial to determining source of contamination (e.g., sampling, extraction kits or sequencing reagents). As a final step after sequencing, <i>in silico</i> contaminant removal may involve selectively removing suspect sequences from the dataset. <i>In silico</i> approaches also include eliminating OTUs that are most likely contaminants on a case-by-case basis, using a probability-based analysis of contaminant likelihood, or using sequence oligotypes to detect the fine-scale OTU relatedness. Oligotyping can also be useful in identifying the source of contamination. A combination of routines used to “sanitize” a community dataset may be required to ensure interpretations of results are accurate. Broad adoption and development of these methods are necessary to effectively characterize subsurface communities and will extend to other low biomass research environments (e.g., examination of samples from other planets).</p>

Title	Homogeneous reduction of CO ₂ under hydrothermal conditions: effects of temperature and dissolved sulfide
Presenting Author	Eoghan Reeves
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Abstract Text	<p>Abiotic synthesis of CH₄ in hydrothermal fluids is presumed to involve catalytic minerals. Stepwise aqueous reduction of CO₂ may be an alternate pathway, with production potentially regulated by the abundances of the metastable single carbon reaction intermediates. Here we examine the role of CH₃OH as a temperature-dependent metastable species, and additionally the effect of reduced sulfur (H₂S) via the formation of the analogous organosulfur intermediate, methanethiol (CH₃SH). ¹³C-labeled HCOOH solutions were heated (300-325 °C, 35 MPa) in a gold-TiO₂ apparatus without minerals, generating CO₂ and H₂, and concentrations of carbon compounds were monitored over several years. ¹³C-labelled CH₄ and CH₃OH were produced at 325 °C, despite low overall conversion of CO₂ to CH₄ (<0.7% in 2.6 yr). CH₄ production varied in proportion to CH₃OH concentration at 325 °C. Cooling to 300 °C increased CH₃OH via re-equilibration with CO₂ and H₂, resulting in faster CH₄ production. Overall, this demonstrates aqueous formation of CH₄ from CO₂ is limited by the concentration of the CH₃OH intermediate, the stability of which depends on dissolved H₂ and temperature. Injection of H₂S and additional H¹³COOH at 300 °C resulted in rapid formation of ¹³C-labelled CH₃SH, which decomposed to CH₄ without attaining equilibrium with CO₂, H₂ and H₂S. Consistent with observations from seafloor hydrothermal fluids, direct reduction of CO₂ to CH₃SH was not evident, implying CH₃SH does not fulfill the same role as CH₃OH in regulating homogeneous CH₄ formation. Our observations indicate that aqueous synthesis of CH₄ from CO₂ can proceed on timescales of years under H₂-rich, moderate temperature hydrothermal conditions in the absence of heterogeneous catalysts. Although unlikely on timescales of circulating hydrothermal fluids, aqueous reduction is a potential CH₄ source in moderate temperature settings with long residence times, e.g. mineral-hosted fluid inclusions in oceanic crust, deep fracture fluids in igneous basement, subduction zone fluids, as well as laboratory serpentinization experiments.</p>

Title	High-pressure microbial growth in the deep biosphere
Presenting Author	Karyn Rogers
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Abstract Text	<p>A majority of Earth's prokaryotes reside in the deep biosphere where elevated pressures can impact microbial cell growth and survival. In subsurface habitats, increasing pressure can impact biomolecule stability, membrane fluidity, metabolic energy yields, and the solubility of toxic metabolic products. In an effort to understand the myriad effects elevated pressure can have on microbial communities, we have been growing two marine sulfate reducers, <i>Desulfovibrio salexigens</i> and <i>Archaeoglobus fulgidus</i>, at pressures that reflect subsurface conditions. Both strains can grow at elevated pressures, and only marginal decreases in growth rates were observed in the lower half of the pressure range for each strain. <i>D. salexigens</i> continued exponential growth up to 20 MPa and <i>A. fulgidus</i> showed increased cell densities relative to initial conditions up to 60 MPa. Stress-induced biofilm formation in <i>A. fulgidus</i>, initially observed at elevated pressures, appears to be a function of aqueous sulfide concentrations, and not a direct effect of elevated pressure. Nonetheless, the absence of a gas phase during growth contributes to the buildup of aqueous sulfide and triggers this negative stress response. While the sensitivity to sulfide was not observed in <i>D. salexigens</i>, cell viability did decrease following successive decompression at 30-50 MPa. However, experiments conducted in the DCO PUSH device, which negates the need for decompression during growth, showed no such impact on cell viability and cell numbers even increased at 30 MPa, thus expanding the growth range of this strain. These results emphasize the importance of exploring both the physiological and metabolic effects of pressure on microbial survival. Furthermore, our preliminary results indicate that decompression can reduce cell viability, and suggest that traditional decompressive sampling techniques could limit our ability to retrieve obligate piezophiles from the deep subsurface.</p>

Title	Submarine mud volcanoes: Microbial life and carbon flux at the interface between seafloor and subsurface
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Abstract Text	<p>Marine mud volcanoes are dynamic geological systems that erupt subsurface gases along with sediments and deep biosphere life. Active mud volcanoes around all continental margins are an important source of methane to the hydrosphere and eventually also the atmosphere. Here we investigated the biogeochemistry, diversity and metabolic potential of microbial communities after a series of eruptions of Håkon Mosby mud volcano. We show that freshly erupted material had the microbial signature of the deep subsurface, but the communities and functions changed substantially with increasing exposure to surface conditions. Clades typically found in the subsurface, such as Atribacteria and Bathyarchaeota disappeared in the exposed sediments, while methanotrophic communities established. Aerobic methanotrophs were found within less than a year, followed by anaerobic methanotrophs, sulfate reducers and thiotrophs. Our data indicate that it may take decades for the development of complex microbial communities that efficiently remove the rising methane. The observed turnover of communities and functions provided key insights on the establishment of microbial life at the interface of marine realms.</p>

Title	Shear anisotropy in textured ferromagnesite in subducting slabs
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Abstract Text	<p>Constraining the amount of carbon that is reintroduced into the mantle via subduction is a critical parameter to quantify the deep carbon cycle. Ferromagnesian carbonates are the main hosts of carbon in subducted oceanic crust and their stability to lower mantle depths has been documented by experiments and thermodynamic models (e.g., Kerrick and Connolly, 1991; Isshiki et al., 2004). Therefore, a better knowledge of their physical properties (namely seismic velocities and anisotropy) is required for the detection of carbonated lithologies by geophysical methods and to constrain the extent of carbon recycling at depth. Previous sound velocity measurements in Mg-Fe carbonates concluded that the seismic contrast between carbonated and non-carbonated lithologies is within the resolution of seismic methods (Sanchez-Valle et al., 2011; Yang et al., 2014), although it could be enhanced further by velocity anomalies associated to spin transitions in Fe²⁺ in ferromagnesite (Liu et al., 2014). Alternatively, the large shear anisotropy displayed by Mg-Fe carbonates (35%) is likely the best diagnostic feature to identify carbonated region at depth (Sanchez-Valle et al., 2011), but the effect of textures on the propagation of seismic waves remains unknown. In this contribution, we present results from plastic deformation studies of Ferromagnesite (Fe_{0.66}Mg_{0.33})CO₃ up to 55 GPa conducted in a diamond anvil cell using radial X-ray diffraction at beamline ID9 of ESRF. The results show the development of strong textures upon compression that preserves anisotropy in the deformed polycrystalline aggregates. The observed slip systems active in axial compression and the effect of textures on the propagation of shear waves will be applied to assess the detectability of carbonated region at depth.</p>
References	<p>Isshiki M, Irifune T, Hirose K, Ono S, Ohishi Y, Watanuki T, Nishibori E, Takata M, Sakata M (2004) <i>Nature</i> 427:60- 63. Kerrick DM, Connolly JAD (2001) <i>Nature</i> 411:293-296. Liu J, Lin J-F, Mao Z, Prakapenka VB (2014) <i>Am Miner</i> 99:84-93. Sanchez-Valle C, Ghosh S, Rosa AD (2011) <i>Geophys Res Lett</i> 38: L24315. Yang J, Mao Z, Lin J-F, Prakapenka VB (2014) <i>Earth Planet Sci Lett</i> 392:292–299.</p>

Title	Exploring the archaeobacterial communities in deep terrestrial crustal system underneath Deccan traps, India
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Abstract Text	<p>Despite the significance of understanding evolution, adaptation and functioning of life within deep subsurface, knowledge on structure and functioning of microbial ecosystems within deep terrestrial igneous provinces remained largely elusive. Recent deep drilling initiative at Deccan traps at Koyna, India provided a unique opportunity to study deep (~1400 mbs) terrestrial life within such environment. The present report highlights result of a metagenome-based investigation on archaeobacterial communities residing within the basaltic (~65 Mya) and granitic (>2.5 Bya) horizons of/underneath Deccan. High-throughput archaeobacterial 16S rRNA gene amplicon sequencing revealed that members of Euryarchaeota and Thaumarchaeota predominate these igneous provinces.</p> <p>Massive basalts from varied depths were characterized with conspicuous presence of Euryarchaeota (class Thermoplasmata) along with uneven distribution of Thaumarchaeota, followed by less abundant Crenarchaeota. Granitic samples, in contrast, showed a unique composition with significantly higher proportions of Thaumarchaeota followed by uneven distribution of Euryarchaeota. Methanobacteria although present in nearly all samples, distinct abundance of hydrogenotrophic methanogens in basalts was observed. It is noteworthy that Thaumarchaeota members represented mainly by SAGMCG-1 and MCG not only emerged as a signature group in granitic bedrock but the relative abundance of SAGMCG correlated strongly with depth. Comparatively higher abundance of Sulfolobaceae in amygdaloidal basalts and methanogenic Methanobacteria in massive basalts corroborated well with sulphate rich microenvironment in amygdaloids or relatively higher organic carbon in respective rock types.</p> <p>Increased abundance of ammonia oxidizing Thaumarchaeota known to have a 'hot loving ancestor' within the deeper strata of granitic basement and chemolithotrophic, Fe²⁺ oxidizing Ferroplasmaceae in basalts could be a glimpse of yet to be explored microbial planet residing deep within terrestrial crustal system at Deccan. The study deserves a thorough investigation to unravel the complex and possibly yet to be known role of subterranean archaeal communities in global carbon and other nutrient cycling.</p>

Title	The Deep Carbon Observatory: A ten-year quest to study carbon in Earth
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Abstract Text	<p>The Deep Carbon Observatory (DCO) is an ambitious, international, ten-year scientific quest to explore the quantities, movements, forms, and origins of carbon in Earth's deep interior. DCO is a global community of scientists, whose work crosses traditional disciplinary boundaries and who have collectively forged a new, integrative field of deep carbon science. By combining field expeditions, laboratory experiments, and computational simulations, DCO is fundamentally changing our understanding of Earth's deep carbon, which may include more than 90% of the planet's total carbon. DCO's overarching mission is to understand Earth's deep carbon cycle—beyond the atmosphere, oceans, and shallow crustal environments, which have drawn most previous research attention. DCO addresses its mission through four Science Communities (Extreme Physics and Chemistry, Reservoirs and Fluxes, Deep Energy, and Deep Life) and four crosscutting initiatives (instrumentation, field studies, data science, and modeling and visualization). The DCO Secretariat, located at the Geophysical Laboratory of the Carnegie Institution for Science, serves as headquarters for the program and provides program management, oversight, and coordination.</p> <p>After seven years of research and discovery seeded with support from the Alfred P. Sloan Foundation, DCO's nearly 1,000 scientists in 45 countries are bringing their scientific findings together, painting a new picture of carbon in Earth. A concerted effort is underway to synthesize knowledge within and across DCO's Science Communities so that the whole is greater than the sum of its parts. Leading up to the culmination of the decadal program in 2019, DCO is sharing what has learned and what remains unknown, and perhaps unknowable, about the quantities, movements, forms, and origins of carbon in Earth. DCO is also exploring options for fostering deep carbon science after 2019, by identifying structures and organizations that will keep the DCO legacy alive and proposing new ventures capitalizing on DCO's international network of scientists.</p>

Title	The Microbiology of Serpentinizing Ultramafic Intrusions: Insights from the Kirkland Lake Kimberlites
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Abstract Text	<p>To date, a majority of studies relating serpentinization to microbial activities have focused upon the aqueous alteration of ophiolites, or upon hydrothermal systems near mid-ocean ridges. The alteration of ultramafic intrusions in continental settings represents an additional, distinct type of environment that may sustain biogeochemical process related to serpentinization and play important roles in controlling the exchange of carbon and reducing power between the deep Earth and the surface biosphere. Serpentinizing diamondiferous kimberlite intrusions represent a geographically and contextually distinct system to explore the relationship between serpentinization, carbon, and life. A series of deep, ultrabasic wells were sampled near Kirkland Lake, Ontario, Canada in 2012 and 2013 for coupled geochemical and microbiological analyses. The wells were high pH (between 9 and 12) and contained elevated concentrations of H₂ and hydrocarbon gases. However, the wells exhibited methane isotopic signatures distinct from one another, which reflect different sources and/or processing mechanisms for the resulting gas. Parallel analyses of microbial abundances and community composition provided insight into the biogeochemistry of these ecosystems. While hydrogen-driven chemolithoautotrophy appeared to be common across all of the wells based upon the predominance of Betaproteobacteria in tag sequencing analyses of 16S rRNA genes, sequences associated with known methanogens were partitioned between the wells. Shotgun metagenomics data from 4 of the wells allowed us to document the potential substrates utilized for microbial methanogenesis, and highlighted relationships between putative acetogens and methanogens in the groundwater ecosystem. These results are in stark contrast to existing data on continental serpentinites, which have provided relatively scant evidence for biological methane cycling. These data are significant in that they provide insight into microbial activities and biogeochemical signatures in serpentinizing environments associated with ultramafic intrusions, which may be a prominent setting in extraterrestrial environments without active plate tectonics.</p>

Title	15-years degassing activity of Miyakejima volcano, Japan
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Abstract Text	<p>Miyakejima volcano, Japan started a gigantic degassing in 2000 with the peak SO₂ flux of 50 kt/d at the end of 2000, then the flux continuously decreased gradually. Here, we report a summary of the 15 years monitoring results of the Miyakejima degassing activity and discusses the mechanism of the large scale degassing and their changes (Shinohara et al., 2017).</p> <p>A basaltic island volcano Miyakejima started the gigantic degassing activity in the mid 2000 after formation of a caldera of 1.6 km diameter and 450 m deep, which was caused by depression of a magma chamber due to magma outflow to a dyke to the northwest of the island. The SO₂ emission rate decreased almost linearly on a log scale to 5 kt/d by 2003. During the early degassing period, the volcanic gas composition was constant with the CO₂/SO₂ = 0.8 (mol ratio) and H₂O/SO₂ = 35. The SO₂ emission rate further decreased gradually to 0.2 kt/d by 2015 and the gas composition also changed gradually to CO₂/SO₂ = 1.5 and H₂O/SO₂ = 150. The compositional changes are not likely caused by changes in degassing pressure or volatile heterogeneity of a magma chamber but are likely attributed to an increase of hydrothermal scrubbing caused by large decrease of the volcanic gas emission rate, suggesting a supply of gases with constant composition during the 15 years. During the 15 years from 2000 to 2015, Miyakejima volcano discharged 25.5 Mt of SO₂, which required degassing of 3 km³ of basaltic magma. The intensive degassing was modeled based on degassing of a convecting magma conduit (Shinohara, 2008). The gradual SO₂ emission rate decrease without changes in volcanic gas composition is attributed to a reduction of diameter of the convecting magma conduit.</p>
References	<p>Shinohara H, Geshi N, Matsushima N, Saito G, Kazahaya R (2017) Bull. Volcanol. (accepted)</p> <p>Shinohara H (2008) Rev. Geophys. 46: RG4005, doi:10.1029/2007RG000244.</p>

Title	Superdeep diamonds with metal inclusions: confirmation of an ancient, reduced, recycled C reservoir in the mantle transition zone
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Abstract Text	<p>Diamonds are the premier container for minerals from the deep mantle —effectively isolating them perfectly from reactions with fluids and magmas. A special class of diamond, comprising less than 2% of diamonds mined from kimberlite, derives from hundreds of kilometers below the lithospheric mantle. These so-called "superdeep" diamonds carry distinctive retrograded mineral assemblages that give a valuable look at deep mantle mineralogy not attainable in any other way.</p> <p>Recent work shows a recurring set of inclusions in large, high-quality, predominantly Type IIa diamonds, distinct from those of more familiar lithospheric/sublithospheric diamonds. The most abundant inclusion is a metallic, Fe-Ni-C-S multi-phase (cohenite + Fe-Ni alloy + pyrrhotite) assemblage with a surrounding fluid jacket of H₂ and CH₄. The second most abundant inclusion is former CaSiO₃ perovskite, now retrogressed to lower-pressure minerals but also associated with metal, H₂, and CH₄. Trapping CaSiO₃ perovskite inclusions constrains the minimum depth of formation to ~360 km. Two additional Cullinan-like Type IIa diamonds were found to have inclusions of low-Cr majoritic garnet, also indicative of a sublithospheric origin. Overall, the inclusions suggest that these diamonds originate in reduced regions of the mantle where they crystallize from Fe-Ni-C-S metallic liquids. The deep mantle below ~250 km has long been thought capable of precipitating metallic iron but physical confirmation from deep mantle samples has been lacking.</p> <p>Taken collectively, recent studies of microscopic mineral inclusions extracted from superdeep diamond hosts support the recycling of surface-derived constituents to the top of the lower mantle [1], a measurably high water content for nominally anhydrous high-pressure minerals [2], a mantle that gets progressively reduced with depth yet harbors distinct oxidized and reduced regions [3] that may be long-lived. The newly-discovered metallic Fe-Ni-C-S liquids constitute a discrete, reduced reservoir for C and S in the deep mantle that may be ancient.</p>
References	<p>[1] Walter M et al. (2011) Science 334: 54-57. [2] Pearson DG et al. (2014) Nature 507: 221-224; Hauri et al. unpub data and ms in prep. [3] Smith EM et al. (2016) Science 354: 1403-1406.</p>

Title	Deep Organic Geochemistry and Metastability
Presenting Author	Everett Shock
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Abstract Text	<p>When organic compounds react in aqueous fluids at high pressures and temperatures, they commonly reach relative abundances indicative of metastable equilibrium states. These states are local energy minima in a vast landscape of reaction progress that stretches among stable equilibrium states in the C-H-O-N system. The normal condition of deep organic geochemistry will be dominated by metastable states. The existence and composition of metastable states, and the mechanistic pathways that bring them into existence, can be accessed through hydrothermal experiments. Those that include minerals show greater diversity of reaction mechanisms than those without, pointing to the essential involvement of aqueous-organic-surface interactions in determining energy and material flow across the reaction progress landscape. Recent results show reversible reactions among amines (Robinson), hydrothermal dehydration of alcohols (Bockisch), ketonic decarboxylation of acids at oxide surfaces (Johnson), and surface-catalyzed transformations of aldehydes (Fecteau). Each is an example of how water and mineral surfaces guide the reactivity of organic compounds throughout the Earth.</p>

Title	The solid Earth's involvement in oxygen cycling: Observations and theory
Presenting Author	Oliver Shorttle
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Abstract Text	<p>Interactions between the hydrosphere, atmosphere, and silicate portion of Earth regulate atmospheric oxygen. Whilst oxygen is produced by photosynthesis, its buildup in the atmosphere is regulated by oxidation of organic matter, reduced volcanic gasses, and the ferrous iron in silicates. We focus on this latter part of the abiotic oxygen cycle, and interrogate with new observations and modelling the long term cycling of oxygen between the mantle and atmosphere via ocean crust formation, oxidation, subduction, and its eventual inclusion in the source regions of hotspots.</p> <p>We present new Fe-XANES measurements on basalts from three localities: two mid-ocean ridges (MOR) free from hotspot influence, Juan de Fuca and the South East Indian Ridges; and one plume locality exhibiting significant geochemical heterogeneity, Iceland. These samples constrain the redox heterogeneity of their respective mantle source regions and the processes involved in ferric iron transfer from the mantle into basalts. The MORs erupt basalts with very uniform ferric iron proportions, despite their exhibiting large changes in ridge axial depth and geochemical variability. In contrast, Icelandic basalts vary widely in their ferric iron proportions, and are systematically more oxidised than MOR basalts by 0.8 log units. We find that the Icelandic mantle contains oxidised domains with the major element, trace element, and isotopic signatures of recycled basalt components. These geochemical characteristics support a model in which alteration of oceanic crust provides a long-term sink for oxygen in the deep mantle.</p> <p>We also perform thermodynamic calculations characterising the behaviour of ferric iron during melting. These models identify what aspects of basalt ferric iron systematics are attributable to melting processes as opposed to source composition. The models' prediction of basalt ferric iron contents decreasing with increasing mantle potential temperature is not realised in our MOR dataset, suggesting that Fe-mineral equilibria may be being buffered during melting.</p>

Title	Insights into the Archean deep carbon cycle revealed by >3 Ga placer diamonds
Presenting Author	Katie A Smart
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Abstract Text	<p>Diamonds are effective monitors of Earth's secular deep carbon cycle [1]. While the oldest ages determined from diamond mineral inclusions exceed 3 Ga, it remains contentious if these ages reflect the timing of either diamond crystallization or inclusion formation [2]. In order to gain unequivocal insight in to the ancient deep carbon cycle, three "confirmed" Archean diamonds were investigated from the 2.8 – 3.0 Ga Witwatersrand Supergroup, located in the Kaapvaal craton, South Africa. Estimated mantle residence times of 10 – 400 Myr for the diamonds, coupled with ca. 2.8 – 3.0 Ga Ma depositional ages, indicate diamond formation within the mantle from 3.0-3.5 Ga. Hence, these Archean placer diamonds provide unparalleled constraints on the cycling and character of volatiles on early Earth [3]. Detailed SIMS analyses of [N]-$\delta^{15}\text{N}$-$\delta^{13}\text{C}$ in core-to-rim transects were conducted on the Witwatersrand diamonds. Elevated nitrogen contents (max. 1231 at. ppm) and positive $\delta^{15}\text{N}$ values (between -0.5 and 2.7 ‰) have similarities to Archean sediments [4], in contrast to the nitrogen-poor and isotopically depleted mantle [5]. If sedimentary nitrogen was involved in < 3.5 Ga Witwatersrand diamond genesis, then recycled crustal components were present within the mantle, which is best explained by the operation of plate tectonics during the Paleoproterozoic. The carbon isotope composition ($\delta^{13}\text{C}$: -5.7 to -3.0 ‰) of the Witwatersrand diamonds is mantle-like, but nonetheless compatible with an isotopic mixing model between mantle-derived carbon and crustal sediments. Significantly, core-to-rim increases in $\delta^{13}\text{C}$ values indicate the Witwatersrand diamonds crystallized from oxidized (CO_2 or carbonate-bearing) fluids/melts within the early Archean mantle. The first identification of oxidized components in the Paleoproterozoic mantle is noteworthy given the uncertainties that surround the redox state of the Archean mantle, the evolution of mantle redox composition, and finally, the absence of oxidized CO_2-rich magmatism near Earth's surface before 3 Ga [6].</p>
References	<p>1] Shirey SB et al. (2013) <i>Rev. Min. Geochem.</i> 75: 355–421. [2] Cartigny P et al. (2014) <i>Annu. Rev. Earth Planet. Sci.</i> 42: 699–732. [3] Smart KA et al. (2016) <i>Nature Geoscience</i> 47(3): 303–322 [4] Thomazo C. and Papineau D. (2013) <i>Elements</i> 9: 345–351 [5] Cartigny P and Marty B (2013) <i>Elements</i> 9: 359–366 [6] Tappe S et al. (2014) <i>J Petrol</i> 55: 2003-2041</p>

Title	Reduced volatiles in the deep Earth: Raman evidence from lithospheric and sub-lithospheric diamonds
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Abstract Text	<p>There is abundant thermodynamic and other indirect evidence for CH₄ along with other reduced hydrocarbons in the mantle, however only rarely has there been direct observation of mantle CH₄ that can provide evidence of its behaviour deep in the Earth's mantle. Sampling of mantle-derived CH₄ is rare, since it must avoid being oxidised in the shallow mantle and crust on the way to the Earth's surface. Here we present CH₄ detected in diamond samples from both the lithospheric and sub-lithospheric mantle. Diamond is the ideal carrier, since it shields any trapped reduced volatiles from oxygen exchange during its rapid transport to the surface. Analyses of reduced volatiles, along with any co-existing phases and the host diamonds, provide an opportunity to better understand their storage and transport into the deep Earth. Specifically, these studies can help evaluate whether methanogenesis occurs in the mantle, or whether mantle CH₄ has a subducted origin. Lithospheric diamonds (depths < 200 km) from Zimbabwe contain abundant CH₄ micro-inclusions that occur in association with graphite [1]. Both phases are evenly distributed, a syngenetic texture that suggests that they co-crystallised from the same C-O-H fluid. Positive δ¹⁵N values for the host diamonds require that the carbon-bearing source fluids originated in the oceanic crust that was subsequently emplaced into the diamond stability field (depths >120 km) likely through subduction. Sub-lithospheric gem-quality diamonds from depths between 360 and 750 km have recently been found to contain inclusions with reduced volatile budgets [2]. Specifically, iron-nickel rich metallic inclusions are consistently found trapped along with CH₄ (and H₂) in large gem-quality diamonds. This suggests that C-O-H fluids in metal-saturated regions of the deep mantle are buffered to reduced compositions, either dissolved into metallic liquids or existing as CH₄-rich fluids.</p>
References	<p>[1] Smit et al. (2016) <i>Lithos</i> 265:68-81 [2] Smith et al. (2016) <i>Science</i>, 354:6318,1403-1405</p>

Title	COMPOSITION OF VOLATILE COMPONENTS IN DIAMONDS AND GARNETS FROM UNIQUE DIAMONDIFEROUS PERIDOTITE OF THE UDACHNAYA PIPE, YAKUTIA, RUSSIA
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Abstract Text	<p>A unique diamondiferous garnet peridotite xenolith was recovered from Udachnaya mine consisting of enstatite and Iherzolite garnet with lesser olivine. The modal abundances of the minerals are (in vol.%): diamonds (9.5); enstatite (38); pyrope (35); sulfides (4, pentlandite and djerfisherite) and the remainder being alteration products along with the majority of diamonds. This 10.5 g peridotite contains > 30.000 colorless, octahedral microdiamonds with sizes of 10 to 700 micrometers, many occurring in clusters (1). This is absolute highest of diamonds over in a mantle xenoliths – 106 cts/tonne. The $\delta^{13}\text{C}$ of diamonds is -22.9‰ which is not characteristic of the mantle ($\delta^{13}\text{C} - 2$ to 8‰) (2, 3). Diamonds with such light isotopic carbon are considered as indicative of subduction of oceanic crust (4). The diamonds are Type IIa. Volatile components of diamond and garnet inclusions were analyzed by combined gas chromatography mass-spectrometry. They are represented by paraffins, olefins, naphthenes, arenes, alcohols, aldehydes, ketones, carboxylic acids, polycyclic aromatic hydrocarbons, furans, esters, ethers, CO_2, H_2O, nitrogenated and sulfonated compounds have been found in the composition of the gas phase of the diamonds and garnets (5). Methane-heptadecane series (10.1%) in diamond and methane octadecane (8.7%) in garnet are saturated hydrocarbons. Unsaturated hydrocarbons are contained as ethylene-7-pentadecyne (4.8%) in diamond and ethylene-1-undecene (9.9%) in garnet. The content of oxygenated hydrocarbons in diamond is 55.7% and in garnet – 43.0%. Tetradecanenitrile in diamonds (1.8%) and 4-piperidone (0.55%) in garnet prevailed among nitrogenated compounds. Sulfur dioxide dominated in the composition of sulfonated compounds both in diamond and garnet (0.9 and 2.6%, respectively). CO_2 content in diamonds and garnets is 0.33 and 9.5% and H_2O -11.5% and 13.9%, respectively. The non mantle $\delta^{13}\text{C}$ values of countless diamonds are considered as supporting evidence for their formation from metasomatic fluids with crustal signatures (6).</p>
References	<ol style="list-style-type: none"> 1. Logvinova AM, Taylor LA, Fedorova EN, et al. (2015) Russ Geol Geophys 56:306-320 2. Sobolev NV, Galimov EM, Ivanovskaya IN, et al. (1979) Dokl Akad Nauk SSSR 249:1217-1220 3. Cartigny P (2005) Elements 1:79-84 4. Sobolev VS, Sobolev NV (1980) Dokl Akad Nauk SSSR 250:683-685 5. Tomilenko AA, Chepurov AI, Sonin VM, et al. (2015) High Temp.-High Press 6:451-465 6. Taylor LA, Spetsius ZV, Wiesli R, et al. (2005) Russ Geol Geophys 46:1176-1184

Title	An experimental study on the origin and emplacement of carbonate-rich melts through time
Presenting Author	Vincenzo Stagno
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Abstract Text	<p>Carbonatitic and carbonate-silicate magmas are representative of mantle-derived melts that form by redox partial melting of diamond-bearing peridotite and eclogite rocks at depths greater than 60 km in the Earth's interior. The composition of near-solidus carbonatitic melts are expected to contain 1-5 wt% SiO₂, however, their chemistry mainly varies as result of the pressure effect and mantle redox state, with the SiO₂ content increasing up to 10-30 wt%. This variation in composition is expected to cause significant changes in the physical properties (e.g. viscosity and melt structure) of these magmas with important implications for their migration rate.</p> <p>The aim of this study is to determine the viscosity and structure of CO₂-rich melts with variable SiO₂ content representative of carbonatitic to carbonate-silicate natural melts. The starting materials consisted of both synthetic glasses and natural ultrabasic rock powders with known CO₂ content. Synthetic glasses with 5 wt%, 18wt% and 36wt% SiO₂ were employed for viscosity measurements conducted with the falling-sphere method using the Paris-Edinburg type large volume apparatus at pressures between 1.5-6 GPa and temperatures of 1100-1500 °C. The falling velocity of a platinum sphere through the CO₂-bearing melts was measured by ultrafast X-ray radiography using a high-speed camera with a 500-1000 fps recording rate. The viscosity was, then, calculated using the Stokes equation including the correction factors for the effect of the wall and the end effect. Structural measurements of the liquid at high temperature were also performed using multi-angle energy dispersive X-ray diffraction technique.</p> <p>Preliminary results from this study are used to determine the migration rate as function of pressure, temperature and mantle redox state during up welling in the asthenospheric mantle from the Archaean to the present.</p>

Title	Some Effects of Confinement on Fluid Behavior and Reactivity
Presenting Author	Alberto Striolo
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Abstract Text	<p>It has been shown, by numerous experimental and computational techniques that the properties of fluids strongly depend on nature of pore or fracture confinement. One of our major focus areas is the assessment of preferential adsorption of C-O-H bearing species in pores that differ in size, surface chemistry, shape and connectivity. We have shown that: (1) the structure of fluids under confinement is markedly different compared to bulk properties for the same fluids (e.g., Cole et al. 2013), which provides a connection between the Deep Energy and both the Extreme Physics and Chemistry and the Deep Life Communities of the DCO, and (2) that a strong relationship exists between the structure of the confined fluids and the transport of each (e.g., Le et al. 2015; Phan et al., 2016), which provides a link between the Deep Energy and the Reservoir and Fluxes Communities.</p> <p>In this presentation we will summarize key insights provided by our effort, which include the realization that fluids in some nanoporous systems exhibit faster surface diffusion than 'pore' diffusion (Phan et al., 2014), whereas for others the contrary holds true and the specie adsorbed on the surface behaves as a molecular lubricant to enhance the transport of the least adsorbed specie (e.g., Gautam et al., 2015, Le et al., 2015). We will also discuss how water can control the transport of non-polar fluids such as methane, which is of relevance for quantifying the fluxes of hydrocarbons in the subsurface (Phan et al., 2016). Finally, we will discuss how confinement effects could affect the thermodynamic equilibrium of reactions of importance to the DCO community, with particular emphasis on the facilitation of the thermal synthesis of hydrocarbons.</p>
References	<p>Cole, D. R., Ok, S., Striolo, A. and Phan, A. (2013) Chapter 19. Hydrocarbon behavior at nanoscale interfaces. In: Carbon in the Earth (Eds. R. Hazen, R. Hemley, A. Jones, J. Baross) Rev. Mineral. Geochem. 75, 495-545.</p> <p>Gautam, S., Liu, T., Rother, G., Jalarvo, N., Mamontov, E., Welch, S., Sheets, J., Droege, M. and Cole, D. R. (2015) Dynamics of propane adsorbed in nanoporous silica aerogel: a quasielastic neutron scattering study. J Phys Chem-C 119 (32) 18188-18195.</p> <p>Le, T., Striolo, A., and Cole, D.R., (2015) CO₂-C₄H₁₀ Mixtures Simulated in Silica Slit Pores: Relation between Structure and Dynamics, J. Chem. Phys. C 119 (27) 15274-15284.</p> <p>Phan, A., D.R. Cole, G. Weiss, J. Dzubiella, A. Striolo, (2016) Confined water determines transport properties of guest molecules in narrow pores. ACS Nano 10 (8) 7646-7656.</p>

Title	Deep Earth water maintains the long-term habitability of our planet
Presenting Author	Dimitri Alexander Sverjensky
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Abstract Text	<p>Earth's plate tectonic cycle links the near-surface environment to the deep Earth. During the subduction of plates, the dehydration of hydrous mineral assemblages results in the release of volatile-rich fluids which can be involved in mantle metasomatism and partial melting of the upper mantle. It has long been suggested that an oxidizing signature is imparted to the melts by the fluids, manifested by the eruption of oxidized lavas and the release of CO₂, N₂, and SO₂ into the atmosphere. Overall this process helps to maintain an atmosphere consistent with the habitability of our planet over billions of years. However, the origin of the oxidizing nature of the fluids has been mysterious. Based on recent observations of dehydrated serpentinites containing hematite-magnetite, it has been hypothesized that highly-oxidizing fluids might be generated during the breakdown of the serpentine mineral antigorite¹. Advances in theoretical and experimental aqueous geochemistry now enable quantitative testing of the antigorite serpentinite breakdown hypothesis. Using the Deep Earth Water (DEW) model², we calculated equilibrium constants enabling aqueous speciation and chemical mass transfer modeling of antigorite serpentinite breakdown to investigate its potential to liberate highly oxidizing fluids in subduction zones. Our results strongly support the hypothesis that the dehydration of serpentinites in subduction zones takes place at high fO₂. The calculations also indicate that Fe is not a significant element in the transport of the oxidizing signature, instead CO₂ and SO₄²⁻ species are the likely candidates. Overall, the generation of highly oxidized fluids in subduction zones may be an inevitable consequence of plate tectonic activity. In this way, water in the deep Earth has played a vital role in maintaining the long-term habitability of our planet.</p>
References	[1] Debret et al. (2015) <i>Contrib. Mineral. Petrol.</i> 169:1-18; [2] Sverjensky et al. <i>Geochim. Cosmochim. Acta</i> : 129:125-145.

Title	Expression of metabolic pathways in microbial communities from a tropical serpentinizing environment
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Abstract Text	<p>Serpentinization is the hydrous alteration of mafic rocks in the ocean crust to form serpentine minerals. The set of reactions that constitutes serpentinization result in extremely high pH of surrounding fluids, an abundance of H₂, methane, abiotically generated organic molecules, and depletion of dissolved inorganic carbon. As a geochemical, abiotic source of organic molecules, serpentinization has implications for the subsurface carbon cycling.</p> <p>While serpentinization generally takes place within ocean crust, continental sites of serpentinization are found where the seafloor is obducted onto continental crust, making the process more accessible to study. Sites of continental serpentinization around the world have been the topic of recent studies [1,2,3] and have displayed consistently low microbial diversity and a surprising similarity in community composition among sites, namely a dominance of the classes Betaproteobacteria and Clostridia [1,2,3].</p> <p>Recent studies have assessed the metabolic potential of continental serpentinization through analysis of shotgun metagenomic datasets, identifying genes involved in hydrogen [4,5], methane [6,7], and acetate [5] metabolisms as being key to biogeochemical cycling in these environments. However, to date, no published studies have directly assessed the activity of microbial communities in continental serpentinite environments through the use of metatranscriptomics.</p> <p>The Santa Elena Ophiolite (SEO) is a site of continental serpentinization located in northwestern Costa Rica that experiences seasonal weather extremes of wet (May-Nov.) and dry (Dec.-April) seasons [8]. Sequences related to hydrogen and methane cycling organisms have been detected at SEO, as have genes involved in methanogenesis [7,8]. However, similar to other sites of serpentinization, microbial activity has not yet been assessed.</p> <p>This study will identify what metabolic pathways are expressed in serpentinite fluids at SEO by analyzing metagenomic (metabolic potential) and metatranscriptomic (expression) data. These data will be analyzed in tandem with geophysical and environmental parameters to help define biogeochemical relationships within the serpentinite subsurface system. This study will help advance our understanding of microbial ecology and the cycling of subsurface carbon.</p>
References	<p>[1] Brazelton W. J. et al. (2013) <i>Appl. Environ. Microbiol.</i>, 79, 3906-3916. [2] Suzuki S. et al. (2013) [3] Tiago I., Verissimo A. (2013) <i>Appl. Environ. Microbiol.</i> 70, 1687-1706. [4] Brazelton W. J. et al. (2012) <i>Front. Microbiol.</i>, 2, 268. [5] Twing K. I. et al. (2017) <i>Front. Microbiol.</i> [6] Brazelton W. J. et al. (2017) <i>PeerJ</i>. [7] Crespo-Medina M. et al. (In Revision) <i>Front. Microbiol.</i> [8] Sanchez-Murillo R. et al. (2014) <i>Geochem. Geophys. Geosyst.</i>, 15, 1783-1800.</p>

Title	Exploring ways to assess abundance, diversity and viability of endospores in low biomass sub-seafloor sediments of the Nankai Trough Accretionary Complex
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Abstract Text	<p>Bacterial endospores are a potentially important and overlooked component of the deep biosphere (Lomstein et al., 2012). Sporulation is a survival strategy of bacteria in the phylum Firmicutes employed to face e.g. low energy and nutrient conditions or high temperatures. IODP Expedition 370 (Site C00023 aimed to explore the upper temperature limit of life in the Nankai Trough Accretionary Complex (Heuer et al., 2017 and thus represents an ideal place to study the adaptations of microbial communities to high temperatures, in particular endospores. Preliminary cell counts were in the 105 cells cm⁻³ range at 300 mbsf, and decreasing to 102 cells cm⁻³ between 400 to 600 mbsf. If endospores are roughly as abundant as counted cells at site C00023 in the Nankai Trough (Lomstein et al., 2012, it will be very challenging to detect and quantify them, as they are close or below the current detection limit of the biomarker-based approach, using dipicolinic acid as an endospore specific molecule for quantifying endospore abundance. Furthermore, the DNA extraction efficiency of endospores is typically low and they are not detected by conventional cell counting due to poor intrusion of dyes into the cells. To circumvent these obstacles we plan to (i) improve the current dipicolinic acid method for low biomass sedimentary samples (ii) use special DNA extraction protocols for endospores and endospore-forming Firmicutes and (iii) enrich samples for endospores before performing incubation experiments under varying substrate additions. As a result we aim to get a well constrained, high resolution estimate of endospore abundance, diversity and viability from mesophilic to hyperthermophilic sediments and down into the basement of the Nankai Trough Accretionary Complex.</p>
References	<p>Lomstein BA, Langerhuus AT, D'Hondt S, Jørgensen BB, Spivack AJ (2012) Endospore abundance, microbial growth and necromass turnover in deep sub-seafloor sediment. <i>Nature</i>, 484(7392):101-104.</p> <p>Heuer VB, Inagaki F, Morono Y, Kubo Y, Maeda L, Expedition 370 Scientists (2017) Expedition 370 Pre-liminary Report: Temperature Limit of the Deep Biosphere off Muroto. International Ocean Discovery Program. http://dx.doi.org/10.14379/iodp.pr.370.2017</p>

Title	High-pressure serpentinisation and abiotic methanogenesis
Presenting Author	Alberto Vitale Brovarone
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Abstract Text	<p>Serpentinisation is a well established process at the origin of abiotic methane in shallow environments such as the seafloor and obducted ophiolites. These conditions, however, correspond to the shallowest part of the stability field of serpentine minerals, which can also form down to about 150km depth under thermal regimes typical of subduction zones. The study of Lanzo Massif, a subducted ultramafic body now exposed in the Italian Western Alps, indicates that high-pressure serpentinisation promotes abiotic methanogenic processes similar to the ones observed at shallow conditions, but with substantial differences (Vitale Brovarone et al., 2017).</p> <p>The aim of this presentation is to discuss the geological conditions favouring high-pressure abiotic methanogenesis in subduction zones, as well as the identified production processes, fluxes and fate of these reduced gases at depth.</p>
References	<p>Vitale Brovarone, A., Martinez, I., Elmaleh, A., Compagnoni, R., Chaduteau, C., Ferraris, C., Esteve, I., 2017. Massive production of abiotic methane during subduction evidenced in metamorphosed ophicarbonates from the Italian Alps. Nature Communications. DOI: 10.1038/ncomms14134.</p>

Title	The stability of carbonate in deeply subducted oceanic crust
Presenting Author	Michael J Walter
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Additional Authors	Drewitt, J., Zhang, H., Thomson, A., McMahon, S., Lord, O.
Abstract Text	<p>Recycling of carbon by subduction of carbonated oceanic crust may be a primary mechanism for transport and long-term storage of carbon in the deep mantle. Some proportion, possibly most, of subducted carbonate is released from subducting oceanic crust during progressive dehydration due to the high solubility of calcite in aqueous fluids, and is cycled back to the surface by volcanic outgassing [1]. However, inclusions of carbonate in sublithospheric diamonds, as well as indirect evidence for the role of carbonate melts in inclusion and diamond formation, provide ample evidence that some carbonate makes it at least as far as the transition zone [2, 3]. Carbonate that survives beyond the dehydration front will occur primarily as magnesite in oceanic crust, but depending on the bulk composition, both aragonite or Na-carbonate may also stabilize in the sub-solidus. Melting of carbonated oceanic crust that includes both magnesite and Na-carbonate involves a deep solidus depression between about 300 and 500 km and nearly all subduction geotherms will intersect the carbonated basalt solidus, providing a plausible explanation for the preponderance of sublithospheric diamonds from this depth range [4]. However, carbonate may bypass the solidus ledge if bulk compositions are sufficiently calcic, or geotherms sufficiently cool, and carbonate may subduct into the lower mantle. Recent experiments indicate another mechanism for diamond formation deeper in the lower mantle due to decarbonation of magnesite, forming diamond and releasing oxygen [5]. Here we will review the phase equilibrium of carbonated eclogite at transition zone and lower mantle conditions, and present new results from our experimental investigations of carbonate stability in the lower mantle in the systems CaO-MgO-SiO₂-CO₂ and FeO-MgO-SiO₂-CO₂ conducted in the laser heated diamond anvil cell.</p>
References	<p>[1] Kelemen, P. and Manning, C. (2015) PNAS 112: E3997–E4006 [2] Brenker, F. et al (2007) EPSL 260: 1-9 [3] Walter, M. et al (2008), Nature 424: 622-626 [4] Thomson, A. et al (2016), Nature 529: 76-79 [5] Maeda et al (2017), Scientific Reports, DOI: 10.1038/srep40602.</p>

Title	A visual guide to the interpretation of methane stable isotopologue data - application to deep carbon cycles
Presenting Author	David T. Wang
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Abstract Text	This poster illustrates how data on the relative abundances of $^{12}\text{CH}_4$, $^{13}\text{CH}_4$, $^{12}\text{CH}_3\text{D}$, $^{13}\text{CH}_3\text{D}$, and $^{12}\text{CH}_2\text{D}_2$ can be used in several geological applications, including geothermometry of high-temperature crustal fluids and tracing of interactions between aqueous and hydrocarbon fluids. We will also graphically depict trajectories of methane isotopologue ratios during several biological and non-biological processes as predicted or observed in recent studies (1-9), and show how stable isotopologue ratios depend on or inform predictions from thermodynamics and kinetics of (bio)geochemical reactions in the crust.
References	<ol style="list-style-type: none"> 1. Stolper DA, et al. (2014) <i>Science</i>, 344, 1500. 2. Wang DT, et al. (2015) <i>Science</i>, 348, 428. 3. Stolper DA, et al. (2015) <i>Geochim. Cosmochim. Acta</i>, 161, 219. 4. Inagaki F, et al. (2015) <i>Science</i>, 349, 420. 5. Lopes J, et al. (2016) <i>J. Dairy Sci.</i>, 99, 5335. 6. Douglas PMJ, et al. (2016) <i>Geochim. Cosmochim. Acta</i>, 188, 163. 7. Wang DT, et al. (2016) <i>Geochim. Cosmochim. Acta</i>, 192, 186. 8. Whitehill AR, et al. (2017) <i>Geochim. Cosmochim. Acta</i>, 196, 307. 9. Young ED, et al. (2017) <i>Geochim. Cosmochim. Acta</i>, 203, 235.

Title	Roles of archaea in organic matter degradation in marine sediments
Presenting Author	Fengping Wang
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Abstract Text	<p>Marine sediment contains Earth's largest pool of organic carbon. Microbial transformation of carbon is considered as the key process influencing the flow of carbon in the sediment, sediment-water interface, which ultimately regulate the atmospheric oxygen and carbon dioxide concentrations. Our current knowledge on the microbial mediated organic matter transformation in marine sediments still remains poor, in particular the roles of archaea in the carbon cycling is at the beginning stage to be understood. Here, I'll report our recent investigations on the roles of uncultivated archaea (the novel archaeal Phylum Bathyarchaeota as the representative) on carbon cycling using a combination of geochemical, genomics, and cultivation approaches. We propose that many of the uncultivated archaea in marine sediments take part in the transformation of recalcitrant organic matters, play a key role in the carbon cycling in marine sediments.</p>

Title	The role of noble gases in interpreting deep carbon-rich systems in the crystalline basement
Presenting Author	Oliver Warr
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Additional Authors	Sherwood Lollar B, Fellowes J, Sutcliffe CN, McDermott JM, Holland G, Mabry JC, Ballentine CJ
Abstract Text	<p>The crystalline basement, which represents over 70% of the continental crust, has recently been discovered to produce H₂ through water-rock interaction on a comparable scale to the marine lithosphere [1]. These same environments are also known to generate significant quantities of both biogenic and abiogenic hydrocarbons [2]. Accordingly these systems are expected play a significant role in global distributions and cycling of carbon. However, despite up to 30% of all groundwater residing in fractures within this crystalline basement, little is known about fluid residence ages, rates of methanogenesis, preservation and proliferation of life, or the degree and timing of communication with external systems.</p> <p>Noble gases are the ideal tool for constraining these key variables and better understanding fluid residence times within these deep carbon-rich systems. We present noble gas data from fracture fluids sourced from two locations in the Canadian Shield; Kidd Creek (KC) and Sudbury. KC, which was initially studied in 2013 [3], was resampled 80 months later at 2.4 km depth and new samples were taken 2.9 km depth while two new mines were sampled from the Sudbury Basin at 1.7 and 1.4 km depth. At KC 2.9 km the most radiogenic signals ever measured in free fluids are observed with ⁴⁰Ar/³⁶Ar ratios exceeding 125,000 alongside a ¹³⁶Xe excess of 90%. These excesses correspond to an average residence age of 1.7 Ga. Meanwhile, the resampled upper level indicates a reduction in the average fracture fluid residence age to 0.4 Ga which is consistent with our model which predicts the inclusion of less ancient fluids over time. The radiogenic excess is lower in both Sudbury mines 1 & 2 than initial KC values with mean residence ages of 0.3 and 0.5 Ga respectively.</p>
References	<p>[1] Sherwood Lollar B, Onstott TC, Lacrampe-Couloume G, Ballentine CJ (2014). Nature 516, 379-382</p> <p>[2] Sherwood Lollar B, Westgate TD, Ward JA, Slater GF, Lacrampe-Couloume G (2002). Nature 416, 522–524</p> <p>[3] Holland G, Sherwood Lollar B, Li L, Lacrampe-Couloume G, Slater GF. Ballentine CJ (2013). Nature 497, 357-360</p>

Title	Novel laser-based instrumentation for field measurement of gaseous emissions
Presenting Author	Damien Weidmann
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Abstract Text	<p>As gas sensing technologies advance, novel opportunities to develop instrumentation with enhanced capabilities arise. The advent and maturation of mid-infrared tunable lasers, and associated novel laser spectrometer concepts now allows the development of high-precision instrumentation suitable for field deployment, and delivering high sensitivity, high selectivity, and real-time analysis. The development of associated optical integration offers a roadmap to miniaturization and ruggedization that ought to benefit Earth sciences and geochemistry. We will present two instrument concepts as well as their first results gathered during field campaigns. The first is an in-situ laser isotope ratio-meter ($^{12}\text{CO}_2/^{13}\text{CO}_2$) based on extractive sampling that has been deployed at the Solfatara volcanic field for demonstration of fumarole release measurements. The isotope ratio-meter achieves a precision of 0.1 per mil in ~30s integration time, and was demonstrated to be robust enough to measure unfiltered sample from the Bocca Nuova fumarole. In the second, two long open-path laser dispersion spectrometers measure $\text{CH}_4/\text{C}_2\text{H}_6$ for thermogenic/biogenic methane discrimination, and CO_2, respectively. These systems have been deployed for atmospheric background measurements (up to 500 m open path so far) and demonstrate excellent immunity to atmospheric turbidity and transmission change owing to the fundamental characteristics of molecular dispersion measurements compared to “traditional” absorption. Prospects to deploy these systems for large area emission mapping (localization and quantification) will be discussed.</p>

Title	Quantifying CO ₂ degassing from volcanoes – Recent advancements and future challenges
Presenting Author	Cynthia Anne Werner
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Abstract Text	<p>The quantitative understanding of CO₂ output from volcanic and magmatic sources on Earth has progressed dramatically in the last 15 years with advances in technology and new initiatives. However, unique challenges exist for measurement of CO₂ emissions from active volcanic and magmatic regions due to the large areas of degassing sources, relatively low volcanic CO₂ concentrations in ambient air, and the remoteness of many volcanoes. CO₂ degassing from active volcanoes is a major component for most global budget studies and getting more continuous measurements from Earth's most active volcanoes has been a focus of the Deep Carbon Observatory's DECADE initiative. These studies typically pair continuous remote measurements of SO₂ with direct plume measurements of C/S ratios and are particularly important for quantifying CO₂ degassing from open-system volcanoes where CO₂ degassing can change dramatically over short time periods. CO₂ degassing at volcanoes with little SO₂ emission could be equally important, but is a lot more challenging to quantify. Here we present recent examples of C-rich pre-eruptive, or deep degassing, at active volcanoes to emphasize the importance of this invisible and subtle source. We also look at the significance of diffuse CO₂ degassing at inactive volcanoes over multi-decadal timescales in comparison to volcanoes that have regular eruptive cycles. Through these examples we demonstrate how the subtle sources of CO₂ must not be overlooked and offer a vision for future opportunities.</p>

Title	Understanding the depositional conditions of the Union Springs and Oatka Creek members of the Marcellus Formation: Are they different?
Presenting Author	Jeremy Christopher Williams
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Abstract Text	<p>The Marcellus Formation is one of the largest shale play areas in the US that is currently exploited for hydrocarbon resources. Despite the success of the shale gas “revolution,” the average recovery from shale play areas is about 25% for gas and less than 10% for tight oil. Although there are issues with the recovery of natural gas from shale play areas, there is an insufficient understanding of the paleoenvironments of the Marcellus Formation. Currently, we are investigating the origin of total organic carbon (TOC) in the Marcellus Formation through the assessment of carbon (C)-nitrogen (N)-sulfur (S) systematics of the depositional environment. We observe different variations in geochemistry between Union Springs and Oatka Creek black shale members. The Union Springs formation is characterized by higher concentrations of transitional metals, and higher TOC content (9-12%), and a heavier stable isotopic composition ($\delta^{13}\text{C}_{\text{org}} \sim 26\text{‰}$); whereas Oatka Creek has higher incompatible element concentrations, lower TOC content ($\sim 1\text{-}4\%$) and lighter isotopic composition ($\delta^{13}\text{C}_{\text{org}} \sim 33\text{‰}$). We suggest that the difference between the geochemistry of the two members may be caused by basin flexing of the Acadian orogenic belt, instead of basin filling (e.g. Black Sea Model). In the basin flex model, we propose Union Springs was deposited in a shallower environment and further away from the orogenic belt than the Oatka Creek member yielding higher TOC values. Due to basin flexing, the Acadian orogenic belt created a deeper depositional environment for Oatka Creek, lowering TOC preservation due to higher dissolution from deepening the basin and higher sedimentation rates.</p>

Title	Something new from something old? Identifying factors that constrain life 2,500 meters below the surface
Presenting Author	Kelly C Wrighton
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Abstract Text	<p>The deep terrestrial biosphere is one of the least explored and understood ecosystems on Earth. Here, we leverage analysis of pristine shale cores prior to energy extraction, and subsequent analysis of fluids collected during energy production, to understand how hydraulic fracturing alters the biogeochemistry in the deep subsurface. In contrast to prior reports from other shale formations, our combined microbial biomarker analyses failed to identify signatures for active microbial life in Marcellus shales prior to energy extraction. Instead, we show that hydraulic fracturing injects surface-derived microorganisms 2,500 meters deep, exposing organisms to high pressures and brine-level salinities. Here we use an integrated meta-omic platform to identify microbial adaptations to this new environment. We confirm microorganisms adapt to increased salinity via the production of osmoprotectants, and these metabolites introduced into extracellular fluids fuels an interconnected methylamine network, ultimately yielding biogenic methane. Microorganisms participating in this food web (osmoprotectant synthesis, fermentation, and methanogenesis) are core members in Appalachian Basin shale wells, suggesting this metabolic network is critical to life in deep shales. In addition to Bacteria and Archaea, viruses act as critical top-down and bottom-up controllers in this newly created shale ecosystem. Extensive CRISPR links between viruses and hosts, as well as new spacer incorporation in host genomes, suggest active ongoing viral predation. In the laboratory, we demonstrated that prophage are induced by known environmental stressors in the fractured shale environment, with viral lysis representing a mechanism for osmoprotectant release. Collectively this research highlights the resilience of microbial life to adapt to and colonize a new habitat structured by abiotic and biotic stressors far different than their origin.</p>
References	Daly R, et al (2016) Nature Microbiology: 16146 http://www.nature.com/articles/nmicrobiol2016146

Title	How Thermococcus eurythermalis A501 live in deep biosphere with concise genome?
Presenting Author	Xiang Xiao
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Additional Authors	Zhao WS, Leng Hao, Wang H, Liu XX, Jian HH, Ma XP, Zhang Y, Li J
Abstract Text	<p>How archaea live in deep biosphere including both extreme and ordinary environments? Under chronic energy stress, most archaea have concise genomes but may have to tolerate dramatic environmental fluctuations. However, the underlying mechanisms remain unclear. We selected the archaea strain Thermococcus eurythermalis A501, isolated from a deep sea hydrothermal vent, with a genome of only 2.1 Mb and growth at a wide range of temperatures (50-100°C), pH values (4-9) and pressures (0.1-70 MPa), to study adaptation to multiple stresses. Global quantitative proteomic analysis with 79.8% complete genome coverage demonstrated that approximately 61% of the significant differentially expressed proteins (DEPs) responded to multiple stresses. The responses to extremes of pH, temperature, salinity and high hydrostatic pressure (HHP) were closely correlated, but the responses to low temperature and high salinity were the most distinct. In total, 732 genes constituting 33.5% of the predicted protein-encoding genes in the complete genome were found to be in common response processes, while only 159 genes (7.3%) were identified in other stress response processes. Conclusion: Firstly, Sodium-dependent energy conversion endows T. eurythermalis A501 capability to live in a wide ranges for pH, temperature and pressure but narrow salinity range; Secondly, a common adaptation strategy to different stresses was developed in its concised genome. Our results proved the existence of common adaptation strategy under different environmental stresses. And we try to test the limits of life via cross-stress response. Using our deep sea simulating system, an obligated pieophile community was enriched with optimal growth pressure at about 150MPa. Another 42-days temperature fluctuation (80-130°C) experiment enriched a community dominated by Thermodiscus, Thermococcus and Geoglobas, which can survive and regrowth after stay in 130°C for at least 5 hours each day.</p>

Title	Experimental investigation of the carbonation of antigorite under the fore-arc region in subduction zones.
Presenting Author	Gregory Mark Yaxley
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Abstract Text	<p>Thermodynamic modelling and experimental studies have shown that carbonate may be retained in the subducting slab under typical slab geotherms and potentially subducted deep into the mantle. However, externally derived, aqueous fluids released from pore-water or by breakdown of hydrous minerals (e.g. lawsonite) deep in the subducting slab may infiltrate the overlying carbonate-bearing lithologies (e.g. sediments, meta-basalts), promoting decarbonation. The resultant CO₂+H₂O-fluids may infiltrate overlying ultramafic, partially serpentinised wedge beneath the fore-arc region.</p> <p>We have experimentally modelled carbonation of antigorite in the mantle wedge by CO₂+H₂O bearing fluids derived from dehydration and decarbonation of subducting crust under pressure-temperature conditions of the mantle wedge under the fore-arc. We directly analysed the compositions of the experimental fluids by gas chromatography, using a recently developed system that allows recovery of the gas phase from quenched, experimental run products and direct measurement of the mole fractions of CO₂, H₂O and alkanes in the gas present in the capsule after the experiment.</p> <p>Carbonation of serpentinite is a highly efficient process, rapidly consuming CO₂ from the fluid. At 1-2 GPa and 500-650 °C, with progressive carbonation and decreasing mole fraction of CO₂ in the fluid, the formation of assemblages of magnesite+quartz, magnesite+quartz+talc+chlorite and magnesite+antigorite+chlorite was observed. At temperatures above antigorite stability magnesite+chlorite+enstatite±talc±olivine formed. The specific mineral assemblage depends on the mole fraction of CO₂ in the fluid and bulk CO₂ at given pressure and temperature. The volatile compositions in the experimental fluids analysed by gas chromatography compare very well to those calculated using thermodynamic models.</p> <p>These experimentally demonstrated fluid + serpentine reactions may influence how much subducted carbonate is sequestered in shallow mantle reservoirs, how much is returned to the exosphere via subduction-related volcanism, and how much is subducted into the deeper mantle.</p>

Title	Intercalation of Solid Hydrogen in Graphite
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Abstract Text	<p>We present the Raman and X-ray diffraction evidences of pressure-induced intercalation of solid hydrogen into graphite to 60 GPa. The intercalation is evident by the emergence of two characteristic Raman bands of intercalated hydrogen (ν_{o1} and ν_{o2}), as well as the abrupt expansion of the c-axis of host graphite lattice, both of which occur upon the solidification of hydrogen. The ν_{o1} and ν_{o2} frequencies of intercalated hydrogen are substantially higher than the ν_o of bulk hydrogen, indicating the presence of strong repulsive interactions between intercalated hydrogen molecules and graphite layers. The intensity of the intercalated hydrogen bands decreases with increasing pressure and eventually disappears as all sp^2-hybridized graphitic carbons convert to sp^3-hybridized carbons at 57 GPa. These results provide important constraints for high-pressure or low-temperature storage of solid hydrogen in graphite, as well as fundamental carbon reduction processes to hydrocarbon polymers and low-dimensional hetero-layered structures.</p>