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We gratefully acknowledge the support of the sponsors for making this meeting possible.

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Oral Presentation Abstracts

Orbis non sufficit: going beyond biogeography in understanding the ecology of deep-sea hydrothermal vents

Jonathan Copley
University of Southampton

Recent exploration has revealed the vent fauna of the Southern Ocean, Arctic, Mid-Cayman Spreading Centre and SW Indian Ridge, refining the global perspective of vent biogeography and enabling an examination of ecological patterns beyond biogeographic distributions. Zonation is a ubiquitous feature at vents, and although taxa differ between biogeographic provinces, there may be a "universal functional zonation" in trophic ecology: (1) holobionts with epsilon-proteobacteria are typically abundant in close proximity to vent fluid exits, where the metabolic flexibility of epsilon-proteobacteria may confer an advantage; (2) holobionts with gamma-proteobacteria are often abundant at greater distances from vent sources, as gamma-proteobacteria may be more restricted to mixing zones by their metabolic requirements; and (3) fauna with trophic modes such as suspension feeding typically dominate peripheral areas, where electron donors for chemosynthesis are more scarce. Within a biogeographic province, species abundance can also vary widely among vent fields, for example along the Mid-Atlantic Ridge where several taxa are abundant at some vent fields but rare or absent at others. Understanding this within-province variation represents a further challenge for vent ecology, requiring a new metric using the "functional zonation" at vents to assess the distinctiveness of faunal assemblages at different vent fields.

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Intimate links between chemosynthetic fauna and their chemical environment: a microhabitat perspective

Nadine Le Bris
Université Pierre et Marie Curie-Paris 6, France

Deep-sea hydrothermal vents have been discovered almost 40 years ago, but the intimate links between vent fauna and their unique mineral environnement are still largely questionned. Deep-sea vent ecosystems rely on carbon fixation by chemolithoautotrophic microbes, which can exploit a wide range of inorganic energy sources made available on the seafloor by the hydrothermal circulation. This talk will shed light on the complex mosaic of habitats shaping communities, both spatially and temporally. It will illustrate how invertebrate species and associated microbes optimize access to these ressources while coping with temperature gradients at mineral-water interfaces and toxic and corrosive properties of fluids. These interactions are also keys to understand species colonisation responses after strong natural disturbances, such as volcanic eruptions, which further add to the remarkable properties of these ecosystems.

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The economic importance of modern seafloor massive sulphide deposits and their ancient analogues

Richard Herrington
Natural History Museum, London

Seafloor massive sulfide deposits are one of the few mineral deposit styles that occur throughout the geological record up to the present day. The oldest know sulfide deposits of this type are located in the pre-3700 million year old Isua group in Greenland, and the youngest are actively forming today in the deep oceans. These deposits have been variously called volcanic-hosted massive sulfide deposits (VHMS), volcanogenic massive sulfide deposits or volcanic-associated massive sulfide deposits (VMS). In both modern and ancient examples, distinctive vent-related faunas are found where the trophic structure of the ecosystem is based on reduced sulfur species venting in the hydrothermal discharge on the ocean floor. These same fluids are responsible for formation of the sulfide minerals from which the deposits are composed.

VMS deposits are an important source for copper and zinc, as well as lead, silver and gold. As a source of mined copper they rank third in importance after porphyry copper and sediment-hosted deposits. The word copper is closely linked to the name of the island of Cyprus, where mining of VMS deposits dates from mankind's earliest use of metals and where some of the best studied Cretaceous VMS deposits are found.

Much is understood about how the deposits formed through detailed studies of modern seafloor hydrothermal systems. The deposits are largely found forming in deep ocean areas where extension is accompanied by submarine volcanism, promoting the circulation of heated seawater that becomes metal-charged and then vents, either at mid-ocean ridges or in volcanic back-arc basins. Rare examples of the deposit type are also known from the relatively shallow water of the Mediterranean. In the geological record, 80% of VMS are found to be hosted in former volcanic arc sequences since mid-ocean ridge environments are generally not preserved as oceanic crust becomes subducted.

NOTES

Ecology and biogeography of cold seep fauna, with insights from the Northeast Atlantic

Marina Cunha
Universidade de Aveiro, Portugal

Cold seeps include a diversity of seascapes and multiple habitats where fluids rich in chemically reduced compounds, linked to the presence of hydrocarbon reservoirs, are released from the sea floor. Most cold seeps sustain highly productive and specialized biological assemblages; remarkable symbiont-bearing invertebrates exploit the abundant chemical energy of seeps and other unique life forms cope with elevated concentrations of chemical compounds, low oxygen levels and other harsh conditions.

During the last decade, the scientific exploration of the deep-sea using submersibles and in situ video and photography greatly increased the rate of discovery of new cold seep sites and revealed that these ecosystems are more widespread along the continental margins than previously thought. Nevertheless, the ecological specificities of the fauna, their intimate relationship to the geochemical heterogeneities of the environment and the often long distances between similar habitats are challenging conditions for the dispersal and settlement of cold-seep organisms. Along the European margin every seep region (e.g. Nordic Margin, Gulf of Cadiz, Alboran Sea, Western Mediterranean, Marmara Sea) is different in terms of community composition and biodiversity, and some faunal groups exhibit high diversity even within regions. However, speciation and other evolutionary mechanisms leading to these biogeographic patterns remain largely unresolved.

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Biogeochemical processes at ancient and modern methane-seeps

Jörn Peckmann
Department of Geodynamics and Sedimentology, University of Vienna, 1090 Vienna, Austria

The chemosynthesis-based macrofauna and mineral formation at marine methane-seeps have in common that they are sustained by the oxidation of reduced compounds by chemotrophic prokaryotes. Anaerobic oxidation of methane (AOM) induces carbonate precipitation, but also produces hydrogen sulphide, another 'geofuel' utilised by chemotrophs. Unlike much of the macrofauna, no or very little body fossil evidence of prokaryotes is preserved in the rock record. Molecular fossils, however, provide the means to reconstruct biogeochemical processes at the base of the food web at ancient seeps. These fossils are molecules (lipid biomarkers) that can be assigned to source biota and are stable on geologic time scales. The analysis of molecular fossils significantly contributed to unravelling the process of AOM, which was shown to involve archaea as well as sulphate-reducing bacteria. Since AOM is inducing carbonate formation, the archaeal and bacterial fossils are preserved in a product of their own metabolic activity, favouring excellent preservation. The reconstruction of biogeochemical processes at ancient seeps benefits from a natural tracer experiment based on the fact that methane is strongly depleted in the ^{13}C isotope. The biomass of organisms metabolising methane or carbonate ions resulting from its oxidation reflect this ^{13}C-depletion. Molecular fossils of AOM-performing prokaryotes and methane-derived carbonates are consequently typified by an extraordinary ^{13}C-depletion.

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Chemosynthetic symbioses at vents and seeps: tapping dark energy in the deep sea.

Jillian Petersen
Symbosis Department, Max Planck Institute for Marine Microbiology, Bremen, Germany

Life at hydrothermal vents and cold seeps is powered by chemosynthetic primary production. In contrast to photosynthesis, which is powered by sunlight, chemosynthesis is powered by the energy locked in chemicals such as sulfide, methane and hydrogen. Fluids rich in these compounds gush from the sea floor at vents and seeps, fuelling dense ‘oases of life’. Since animals cannot do chemosynthesis, the key to their success in these hostile habitats is a symbiotic association with chemosynthetic bacteria that provide them with nutrition. The first chemosynthetic symbiosis with sulfur-oxidizing bacteria was discovered in the giant *Riftia* tubeworms 1981. Shortly after, the first methane-based symbiosis was discovered. Thirty years after their initial discovery, sulfide and methane were still the only two compounds known to power chemosynthetic symbioses. We recently discovered hydrogen-powered symbioses at hydrothermal vents in the Atlantic ocean. Some of these vents have the highest hydrogen concentrations ever measured in nature. Using ship-board incubation experiments, the latest *in situ* hybridization techniques and genome sequencing, we showed that the sulfur-oxidizing symbionts of *Bathymodiolus* mussels can use hydrogen to power primary production. Moreover, using state-of-the-art deep-sea technology, we could measure hydrogen consumption by a population of mussels 3000 m below the sea surface. We now know that hydrogen use is widespread; even the symbionts of *Riftia*, the first chemosynthetic symbionts discovered, can use this rich energy source.

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Chemosymbiotic bivalves from the intertidal to deep sea – multiple origins, diversity and evolution.

John Taylor
Natural History Museum, London

Bivalves are the most diverse group of marine animals possessing chemosymbiosis with sulphide-oxidising and methanotrophic bacteria housed in the gills. The association is now documented in 9 separate families of bivalves and including around 800 living species. For some families, Solemyidae, Nucinellidae, Lucinidae and Vesicomyidae the symbiosis is obligate and possessed by all species but both asymbiotic and symbiotic species are found within Mytilidae, Thyasiridae, Montacutidae, Saxicavellidae and Teredinidae. Although early discoveries focussed on deep-water hydrothermal vents and hydrocarbon seeps, chemosymbiotic bivalves are now known to be widespread from intertidal to hadal depths and occupying a wide range of habitats. Molecular phylogenetic analysis demonstrates that the chemosymbiotic lifestyle has evolved independently in at least 7 lineages. By far the most diverse family is the Lucinidae with around 400 living species and recent discoveries indicate their ubiquity from intertidal to bathyal depths in the tropical Indo-West Pacific, particularly at sites with organic enrichment. Some features of bivalve anatomy and biology that may have facilitated the symbiosis will be briefly reviewed. Evidence from fossils suggests that at least two of the bivalve families Solemyidae and Lucinidae possessed the chemosymbiotic mode of life early in the Palaeozoic but for others a later Mesozoic and Cenozoic acquisition is likely.

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Chemosynthesis at whale-falls and their role in driving the speciation and evolution of annelids in the deep sea

Adrian Glover
Natural History Museum, London

For most of human history, the fate of large dead whales in the ocean was not something that concerned anyone. This was despite large whales being perhaps one of the most celebrated, romanticised, fought-over, discussed, hunted, exploited and finally regulated of nature's ocean wonders. The 1987 chance discovery of a large dead whale on the seabed off California, its oily bones fuelling a chemosynthetic ecosystem akin to that at hydrothermal vents, opened our eyes to another type of deep-sea ecosystem, just as the vent discoveries did a decade earlier. And researchers speculated that the scattered remains of whales on the seafloor, termed 'whale-falls' could act as stepping-stones for the dispersal of chemosynthetic fauna over the vast distances of the deep seafloor. In this talk, I will review evidence for this in four different lineages of annelids, one of the most abundant and diverse groups at both vents and whale-falls.

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Chemosynthetic Ecosystems through Earth history

Steffen Kiel
Universität Göttingen, Germany

Hydrothermal vents and methane seeps in the deep sea harbor unique ecosystems dominated by animals relying on geochemical energy sources, mainly sulfides and methane, rather than photosynthesis, as used by earth surface ecosystems. Due to the extreme environments they inhabit and their *in situ* food source, the adaptational pathways, origin, and evolutionary history of these faunas are the matter of controversial debates. The fossil record provides direct evidence for the history of these faunas and recent paleontologic work has improved the dating of the origin of many of the modern groups that inhabit these ecosystems. And not only that; it shows that Paleozoic and Mesozoic seeps were dominated by giant brachiopods with as-yet unknown lifestyles, what types of substrates the bone-eating worm *Osedax* colonized in the past, and the geologic record might even provide insights into the causes of major evolutionary events in the history of chemosynthetic ecosystems.

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Astrobiological Implications of Chemosynthesis

Monica Grady
The Open University

For many decades, it was understood that all life on Earth relied on the mechanism of photosynthesis to provide the energy needed for growth. This picture changed with the discovery of the rich fauna that exists in the deep ocean, basing its energy requirements on chemosynthesis. It is now possible to envisage environments in other locations where chemosynthesis is the basis of life. These environments are not restricted to the Earth – although there are interesting prospects for the potential for life to arise deep inside the Earth's Lithosphere – it is perhaps more exciting to consider where, beyond Earth, a chemosynthesis-based "ecology" might evolve. Whilst the Jovian and Saturnian satellite systems provide possible habitats within the Solar System, the growing catalogue of exoplanets also suggests that life, at least at the microbial level, might be much more abundant than would have been considered even as recently as two decades ago.

NOTES

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Lecture Theatre
Exit at front of theatre (by screen) onto Courtyard or via side door out to Piccadilly entrance or via the doors that link to the Lower Library and to the staff entrance.
Main Piccadilly Entrance
Straight out door and walk around to the Courtyard.

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Assemble in the Courtyard in front of the Royal Academy, outside the Royal Astronomical Society.

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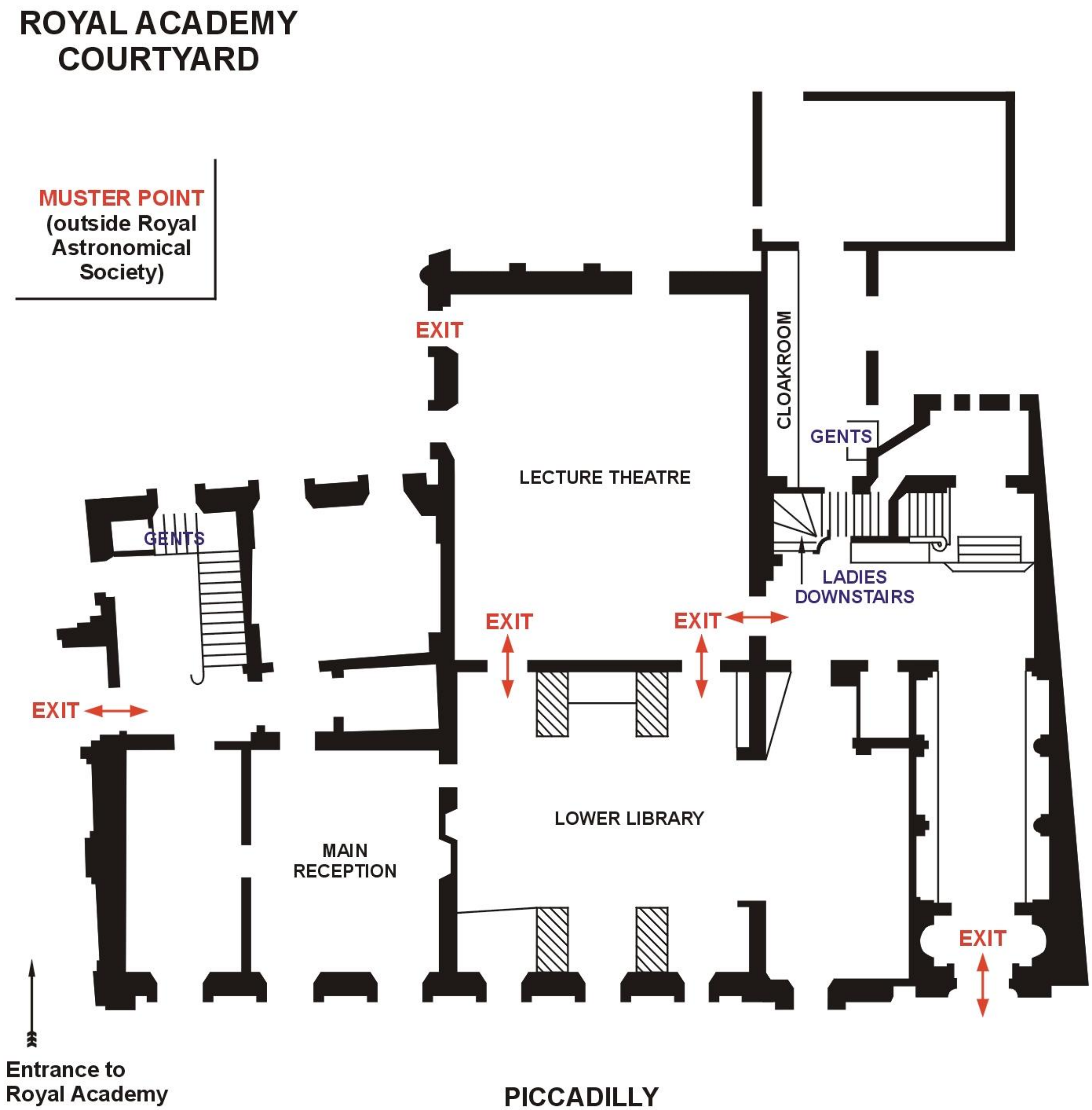
The Gents toilets are situated on the ground floor in the corridor leading to the Arthur Holmes Room.

The cloakroom is located along the corridor to the Arthur Holmes Room.

Ground Floor Plan of the Geological Society, Burlington House, Piccadilly



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