KEYNOTES

BIOMINERALIZATION & KINETICS

7TH INTERNATIONAL SCLEROCHRONOLOGY CONFERENCE 2026

Microstructure matters!

Sclerochronologists who use molluscan and brachiopod shells as targets rely on having an understanding on how these biocomposites form and also being able to access a common vocabulary of microstructural terms and landmarks in order to be able to compare data and interpretations. Detailed work has been going on for at least 60 years, but it is often mired in bewildering terms with a wide array of different microstructures described, with consequential uncertainties about homology between microstructures and layers within a shell.

In recent years much work has been invested in describing microstructures, using a battery of sophisticated techniques for example, SEM, TEM, EBSD, thermogravimetric analysis and histological studies, in a way that attempts to defines both the crystalline and the organic components, and to understand the similarities and 'genetic' relationships rather than describing everything as 'different'. It is clear that microstructural types and layer arrangements are reasonably distinct and conservative amongst different taxa (hence their value as phylogenetic markers) though with latitude for ecophenotypic or environmental variation in for example organic content or crystal unit size. It is possible to understand the evolution of particular microstructures on geological timescales along particular phylogenetic trajectories. However, it is equally clear that there is a broad spectrum of microstructural types from those which have a very strong biological control, characterised by highly order, hierarchical arrangements with a high organic matrix (inter and intra-crystalline) content and those where, organic content is either very low or non-existent, which are much more reminiscent of inorganic cements.

The classic text-book view suggests that molluscan and brachiopod (assuredly separate phylogenetic entities, and so convergently) secrete shell material by the mantle across a capacious fluid-filled extrapallial space on to the inner surface an organic periostracal sheet. But this view is now challenged on several fronts. For several described microstructures we can now see that mineralization begins within the periostracal sheet not on it, and that the extrapallial space in many of the more highly order molluscan and brachiopod microstructures is nanometric, with a very close association between mantle and forming cells. Furthermore, it is now clear for both molluscs and brachiopods that a single biomineral unit (such as a fibre or plate) may be secreted by the concerted action of more than cell and that a single cell may be simultaneously secreting both organic membranes and calcareous material. Successive shell layers of different microstructure are produced by a zoned mantle with sophisticated proteomic shifts in the basic biomineralization toolkit.

Where does this leave the sclerochronologist? I will attempt to review the relevant changes in our understanding and provide a clear rationale for recognising and describing microstructures and their topological relationships in a way that allows meaningful comparison of data.

Dr. Elizabeth Harper
University of Cambridge

KEYNOTES

PALEOCLIMATES & PALEOENVIRONMENTS

Drivers of Indo-Pacific Oceanic Exchange: Insights from Corals and Ocean Models

The Maritime Continent provides pathways for heat and freshwater transport from the Pacific to the Indian Ocean, serving as an important oceanic teleconnection for Indo-Pacific climate. Yet, the short length of robust observational datasets limits examination of past Maritime Continent and Indo-Pacific Warm Pool variability. Coral proxy records allow insights into variability on seasonal to multi-decadal timescales prior to the period of satellite and in situ observations. In this talk, I will present seasonally resolved coral proxy records (coral $\delta^{18}O$ and $\Delta^{14}C$) and synthesize these records with *in situ* observations and ocean model simulations to explore drivers of seasonal to multi-decadal variations across the Indo Pacific Warm Pool (western Pacific, Maritime Continent and central Indian Ocean). I will discuss the role of key climate modes in driving upper ocean Indo-Pacific variability, including the Interdecadal Pacific Oscillation, El Niño Southern Oscillation and East Asian Monsoon. Such proxy-model comparison is critical for understanding future changes in global heat distribution and Indo-Pacific climate, highlighting the importance of records that resolve climate-ocean interactions beyond recent decades and provide important context for projecting future changes.

Dr. Sujata Murty
University of Albany, SUNY

KEYNOTES

PALEOCLIMATES & PALEOENVIRONMENTS

7TH INTERNATIONAL SCLEROCHRONOLOGY CONFERENCE 2026

Utilizing a network of Arctica islandica records and model simulations to investigate past regional ocean dynamics in the rapidly warming western North Atlantic

The complex changes occurring in modern day oceans require an understanding of long-term regional processes to contextualize current observations and guide future projections. As sclerochronology continues to grow in the field of paleoclimatology, the ability to build networks of shell-based, hydrographic reconstructions has become critical to understanding complex oceanic regions in the past. This comprehension is particularly critical in areas like the rapidly warming western North Atlantic, where the confluence of multiple major ocean currents and water masses create a complex hydrodynamic system. This presentation will discuss efforts to build a network of six shell-based hydrographic reconstructions on the continental shelf off the eastern coast of the United States, ranging from the southern Mid-Atlantic Bight to the northern Gulf of Maine. Reconstructions utilize annually- to decadally-resolved oxygen isotope records from Arctica islandica shells and vary in length from ~60 years to over 300 years. At some sites, radiocarbon and nitrogen isotope records have also been developed. Reconstructions reveal both coherent warming within the last ~50 years as well as deviations in variability between sites farther back in time, likely indicating multiple oceanographic processes affecting these different regions. Such variability was further investigated using a hierarchy of numerical model simulations, including a fully coupled, global climate model (Community Earth System Model – Last Millennium Ensemble) and a high-resolution ocean model (VIKING20X). Combining sclerochronological records with model simulations enables a more thorough investigation and interpretation of past regional oceanic changes in order to contextualize the rapid changes observed today.

Dr. Nina M. Whitney
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KEYNOTES

PROXY DEVELOPMENT & OPTIMIZATION

Utilizing a network of Arctica islandica records and model simulations to investigate past regional ocean dynamics in the rapidly warming western North Atlantic

Climate variability happens at a wide range of timescales but, due to the scarcity of suitable archives for hourly to decadal scale variability, we know very little about the behaviour of the climate system on these short timescales in the geological past. Mollusc shells present themselves as unique archives to fill this gap in our understanding, if we can read climate information them. In this presentation, I will expose some of the tools we use to understand how shell mineralization happens on short timescales. I will show how we can select the best-preserved fossil shell material to characterize ancient climates. I will discuss how information from those climates can teach us how Earth's climate changes in response to different forcings, and hold clues for our future climate. I will show some results of the high-resolution climate reconstructions we can do when we successfully decode the diaries of ancient molluscs. Finally, I will provide an outlook into an emerging application for sclerochronology: The reconstruction of paleo-weather patterns.

Dr. Niels de Winter
Vrije Universiteit

KEYNOTES

IMPACTS ON ECOSYSTEMS & POLLUTION

Ecosystem and biodiversity reconstructions from molluscan bivalve sclerochronologies

Over the past 25 years, much of the motivation for research in molluscan bivalve sclerochronology has been in reconstructions of the ambient external physical environment. This motivation has been stimulated by 1. the need to provide enhanced understanding of the role of the ocean in climate change and 2. the realisation that the chronological precision, replication and fidelity of these annually-resolved timeseries from long-lived species such as *Arctica islandica* and *Glycymeris glycymeris* can reveal histories of toxicity and pollution that are consistent with the timescales of the human activity generating these impacts. When appropriately calibrated with instrumental data and crossdated, growth increment series, stable oxygen and carbon isotope, and radiocarbon, data enable reconstructions of seawater temperature and density, ocean circulation, and the marine Suess effect (Butler et al. 2009; Wanamaker et al. 2012; Reynolds et al. 2016). Annual resolution enables precise temporal correlation between series facilitating large spatial scale network analyses that reveal basin-scale modes of climate variability (Reynolds et al. 2018) and the identification of systemic tipping points (Arellano-Nava et al. 2025). These data provide long-term series that extend beyond the duration of instrumental series and even prior to significant human perturbation of the climate system; these records are therefore invaluable for assessing climate model ensembles and contribute to the identification of forcing mechanisms (Halloran et al. 2020).

It is now recognised that these molluscan sclerochronological series register changes in the ecological environment in addition to the physical system. Correlations between different annually resolved biological archives (bivalve, tree-ring, fish otolith; Black et al. 2014) that reveal large-scale ecosystem shifts, often in response to climate change, can be termed extrinsic reconstructions. Intrinsic reconstructions involve the interpretation of data from within bivalve growth increments that facilitate the interpretation of changes in the biodiversity and functioning of the ambient ecosystem. Examples of these intrinsic data include environmental DNA preserved in shell carbonate (der Sarkissian et al., 2017) enabling biodiversity assessment, the interpretation of changes to fish stocks via $\delta^{13}C$ series (Estrella Martinez et al. 2019) and Ba trace element data revealing changes in primary productivity (Fröhlich et al., 2022). Stable bulk $\delta^{13}C$ and $\delta^{15}N$ analyses of the organic fraction of shell carbonate (Schöne & Huang 2021) are now being complemented by data revealed by novel technical developments in compound specific $\delta^{13}C$ and $\delta^{15}N$ (CSIA) analyses of amino acids in bound organic matter as part of the ERC SEACHANGE Project (Huang et al. 2023). For example, changes in baseline source amino acid, $\delta^{15}N$ phenyalanine, in *Arctica* shell, a primary consumer, enable CSIA data of coeval higher trophic level fish bone to discriminate between environmental and human-induced changes (i.e. trophic cascade vs. feeding down forced by human exploitation of fish stocks).

The ability to reconstruct long parallel timeseries of both the physical and ecological system from the same material is invaluable since it facilitates the impact of the physical system on biodiversity and ecosystem changes, and the discrimination of human induced vs. external environmental/climatic forcings.

Dr. James Scourse
University of Exeter

KEYNOTES

Fisheries Ecology, Management & Conservation

Soft skeletons, tough sclerochronology? Elasmobranch tissues for historical data

Sclerochronology is a staple of fisheries management for teleosts and bivalves. However, directly applying concepts used for those taxa to one of the other largest and most conservation-dependent groups in fisheries, elasmobranchs, can be problematic. While vertebrae, which are used to age elasmobranchs, appear analogous to fish otoliths, many studies including my own have challenged the validity of this concept. Here I will discuss the complexities of using elasmobranch tissues for sclerochronology, with a deep dive into vertebral formation, elemental profiling, growth interpretation, inter-specific differences and the use of other alternative tissues.

DR. Vincent Raoult
Griffith University

KEYNOTES

SCLEROCHRONOLOGY IN DEEP TIME

Shells through time: challenges and opportunities of the fossil bivalve archive

Bivalve shells are excellent archives of environmental proxies, providing a rich source of information for reconstructing Earth's deep and recent past. Abundant in the benthic fossil record and spanning more than 500 million years of evolutionary history, they represent an invaluable archive for understanding their palaeobiology and reconstructing evolution and palaeoecology. Their accretionary shells record the physical and chemical conditions of the environment in which they lived, making them particularly suitable for sclerochronological and geochemical analyses.

Despite their great potential, the sclerochronological study of fossil bivalves presents a number of fundamental challenges. Diagenetic alteration can obscure original growth patterns and modify shell mineralogy, microstructure, and geochemical signals, requiring rigorous screening and preservation assessment prior to analysis.

Here, the main challenges associated with sclerochronological analyses of fossil bivalve shells are explored through case studies from different stratigraphic contexts, ranging from the Jurassic to the Holocene. Key issues encountered when using fossil biotic archives include: (a) the absence of modern analogues for extinct taxa, as exemplified by Lower Jurassic aberrant bivalves such as lithiotids from Italy; (b) uncertainties related to assumptions about ancient seawater $\delta^{18}O$ values and stable isotope interpretations in settings affected by salinity variations, as observed in Lower Pleistocene bivalves from the Arda section (Italy); and (c) species selection and thermal alteration induced by anthropogenic activities, as documented in Holocene bivalves from archaeological contexts in Oman.

Despite these challenges, which must be carefully considered but can often be overcome, fossil bivalves remain among the most powerful archives for high-resolution reconstructions of past oceanic conditions, offering multiple opportunities to explore the Earth's past. Moreover, sclerochronological analyses of fossil shells also provide valuable insights into the growth rates, life spans and palaeobiology of extinct species, contributing to a better understanding of the evolution of marine ecosystems and organisms that inhabited our planet in the past.

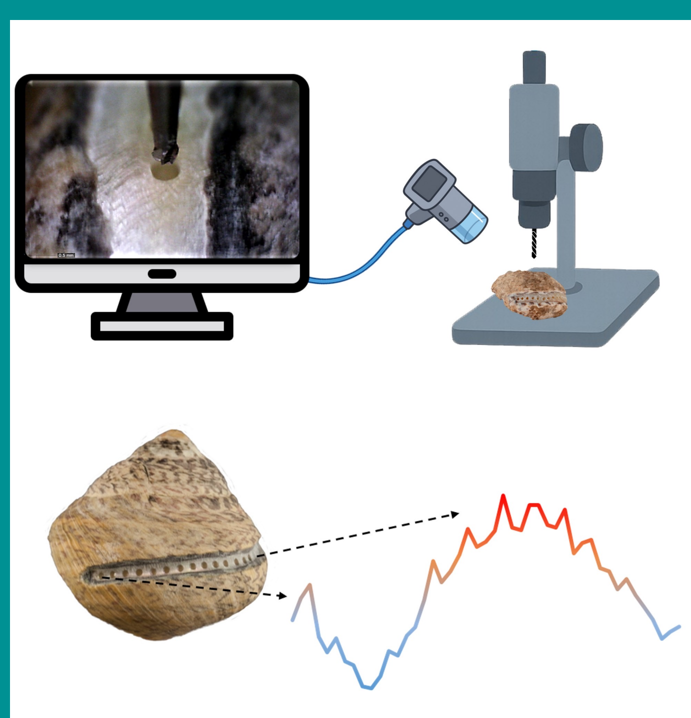
Dr. Gaia Crippa
Università degli Studi di Milano

KEYNOTES

ARCHAEOLOGY

Sclerochronology in archaeology: Inferring seasonality of mollusc collection and past climate conditions

The application of sclerochronological approaches in archaeology has notably increased over the last decades. Stable oxygen isotope ($\delta^{18}O$) and trace element ratio values from mollusc shell remains have become powerful tools for determining the season or seasons during which shellfish were harvested by past hominin populations, as well as for evaluating the role of intertidal resources in their annual subsistence strategies. Moreover, $\delta^{18}O$ and element ratio values have frequently been used to infer past sea surface temperatures and to assess the impact of climate changes on human ecology. In this paper, three case studies from archaeological sites dated to the Mesolithic and Middle Palaeolithic in Europe, and pre-Columbian period in Bolivia are presented to highlight the insights gained from applying $\delta^{18}O$ analyses to marine and terrestrial gastropods. $\delta^{18}O$ values from *Phorcus lineatus* topshells recovered from the Mesolithic shell midden at El Mazo (N Spain) and *Phorcus turbinatus* species from the Middle Palaeolithic site of Los Aviones (S Spain) have shown that both anatomically modern humans (AMH) and Neanderthals inhabiting coastal areas of the Iberian Peninsula developed complex seasonal strategies for collecting marine molluscs, maximising meat yield from coastal resources while minimising health risks. Additionally, sclerochronological analyses of freshwater *Pomacea* spp. from the forest island of Los Chuchíos (Bolivia) have revealed, for the first time, how pre-Columbian populations adapted to the Amazonian savannah, which was seasonally inundated for several months each year.



Dr. Asier García-Escárzaga

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