FOSSILS: ENVIRONMENT AND TIME

Lucia Angiolini, Marco Balini, Bottini Cinzia, Erba Elisabetta, Maria Rose Petrizzo

The Research Group comprises specialists of macroinvertebrates (brachiopods and ammonoids) and microfossils (calcareous nannofossils and planktonic foraminifers).

PhD Student will benefit of lab facilities at the Department of Earth Sciences including:

- Micropaleontology Preparation Lab
- Micropaleontology Microscopy Lab
- Macropalaeontology Preparation Lab
- Macropaleontology Microscopy Lab
- Scanning Electron Microscope

Moreover, well-established collaboration with international geoscientists grant the exposure of PhD students to multidisciplinary research experiences at Italian, European and extra-European Institutions.
Presentations/publications (co)authored by PhD are foreseen as part of the planned transfer of knowledge and training in specialized as well as interdisciplinary research.
The Tutors will provide expertise in Taxonomy, Paleoecology, Paleoceanography, Paleoclimatology, Integrated Stratigraphy and Chronostratigraphy. Within the PhD program in Earth Sciences the research topics to be developed are described below.

CURRICULUM "EARTH SYSTEM"

1 - Biota resilience to global change: biomineralization of planktic and benthic calcifiers in the past, present and future (Progetto MIUR- PRIN2017RX9XXY)

Lucia Angiolini, Cinzia Bottini, Elisabetta Erba, Maria Rose Petrizzo

Life on Earth has survived major paleoenvironmental disturbances, causing profound stresses on ecosystems with evidence of variable engineering and ecological resilience. Causes of past climate change are the subject of continuing research, but the trigger for such events was geological in origin, often a period of intense volcanic activity. The rapid rises in atmCO_2 in the last few decades cannot be attributed to any such geological cause. At the present rate of increase, atmCO_2 may reach 600 parts per million (ppm) by the end of this century – a value that appears not to have been typical for at least 24 million years.
A pressing issue is the understanding of the future state of the planet within the context of global change (warming, excessCO_2, ocean acidification, eutrophication, anoxia) to recognize causal or casual links among the Anthropocene CO_2 emissions and associated thermal-stress and ecosystem resilience and adaptive capacity. Given enough time, a resilient ecosystem may be able to fully recover from perturbations and become as diverse and healthy as before. However, continuing stress can severely compromise the resilience and under critical conditions even apparently trivial disturbances can become devastating.
The rate of current atmCO_2 increase far exceeds the speed at which natural feedbacks can restore the system to "normal" conditions. Oceanic uptake of CO_2 inexorably drives acidification, weakening the adaptive capacity of marine calcifying organisms to thermal stress and changing seawater chemistry, with severe shifts in biodiversity in neritic and pelagic settings.
Studies on modern biota are vital for measuring ecosystem resilience at (very) short-term, but the Earth's biological systems should be scrutinized also at medium- and long-term using geological records. Our planet, in fact, has experienced extreme environmental disturbances, with varied tempos and modes of ecosystem resilience, occasionally reaching tipping-points that triggered permanent modification in abundance, diversity and biomineralization processes of marine calcifiers.

We selected geological case-histories including:

(1) END PERMIAN- EARLY TRIASSIC (253-251 Ma);
(2) TOARCIAN OAE (183-182 Ma);
(3) EARLY APTIAN OAE1a(120-119 Ma);
(4) LATEST CENOMANIAN OAE 2 (94-93 Ma).

Moreover, we will develop laboratory experiments on extant coccolithophores and brachiopods to implement current data-sets of marine calcifiers' abundance and biomineralization under perturbed conditions.
The main objectives of the proposed research are to: a) quantify the response of calcareous plankton and benthos to CO_2-induced ocean acidification and global warming at medium- to long-term scale (paleontological record) and short-term (laboratory experiments and extant taxa); b) investigate similarities/differences of the response of planktic and neritic calcifiers to environmental stress; c) verify the synchroneity/diachroneity of responses; d) identify thresholds/tipping points; e) assess the impact and frequency of disturbances that control the resilience of pelagic and neritic ecosystems.
We selected case-histories of past high-CO_2 scenarios with geological evidence of climate change, and environmental stress. The integrated analyses of pelagic and shallow-water carbonates are designed to understand the reactions of calcifiers in both the pelagic and neritic habitats and assess ecosystem resilience and eventually threshold crossing. The comparison of carbonate-secreting planktic and benthic organisms is vital to fully characterize and understand the role of climate change and ocean chemistry on pelagic and neritic ecosystem resilience.
We aim at contributing to the major issues of recent global changes, by investigating geological examples of extreme warmth and ocean acidification to provide guidance as to the response of biota to an abrupt massive CO2 release.

2 - Biomineralization

Lucia Angiolini, Cinzia Bottini, Elisabetta Erba

Biologically-mediated biomineralization is the controlled production of mineralized tissues resulting from biological activity. Biomineralizing organisms are able to produce a hierarchically organized organic–inorganic composite material at low cost and with exceptional properties, mainly for support and protection, but also for more specialized functions (storage, optical, magnetic) and for survival in changing environmental and climate conditions. In this process, the organisms exert a strong control over the composition, morphology, and orientation of the biominerals and the resulting hard tissues have a hierarchical architecture which is functional and advantageous for the organisms. These biomineral architectures have evolved through millions of years of evolutionary history. Understanding the principles at the base of the biomineralization processes is primary in the design of biomimetic materials and in material science in general. However, fundamental to this is the comprehension of the different types of biomineralizing systems (from the intracellular system of coccolithophorids to the extracellullar system of brachiopods, mollusks and foraminifera) and the evolution of biomineralization strategies, from the start and diversification of metazoans biomineralization in the Cambrian.
The research includes the study of coccolithophores, brachiopods and mollusks.
Coccolithophores are studied to understand the effects of altered environmental conditions, including toxic metals and biolimiting elements, on the calcification process. The approach sees dedicated culture experiments on extant species as well as the study of the fossil records from the Mesozoic. Selected species are analyzed through morphometric analyses and via nanoscale investigations of the composition and structure of the coccoliths (SEM, TEM, AFM, XANES, XRF). The analyses aim at identifying the factor/s which alter the calcification process, the strategies used by coccolithophore to survive, determine the tipping points and define the effects on coccolith morphology, composition and structure to implement the use of coccoliths ad paleoenvironmental tracers.
The investigation of brachiopods and mollusks aims at unraveling the main controlling factors on biomineral production (from the vital effect to abiotic factors as temperature, pressure and pH); reconstructing the evolution of carbonate biominerals during the Phanerozoic and inferring the main biological mineralization strategies. The overarching aim of the project is to understand the biomineral architectures and the genetic processes which had the greatest success during the Phanerozoic and are still and widely produced in different environments today. The main objectives of this research are: 1) to apply different methodologies at the micro and nanoscale (SEM, TEM, AFM, EBSD) to define and quantify the hierarchically organized biominerals of brachiopods and mollusks.

3 - Triassic ammonoid chronostratigraphy, from regional scales to global standards

Marco Balini

During the Triassic the ammonoids show an extraordinary evolutionary flexibility, with superfast recovery rates with high speciation rates, as well as sudden extinctions. Therefore, the ammonoids are considered the reference group for building a high-resolution chronostratigraphic scale of the Triassic.
Some Triassic intervals are characterized by low paleobioprovincialism (e.g. Late Ladinian and Norian), while some other intervals (e.g. Anisian and Early Ladinian) are characterized by increased paleobioprovincialism, especially as regard the North America and the western Tethys. This complex combination results in the development of different ammonoid lineages and different biozonations, with significant problem for the long-distance correlations.

The planned research is focused in two main topics:

- Middle-Late Anisian correlations between Nevada and western Tethys. Aim of this research is to calibrate the correlations of the two scales, thus far lacking any calibration.
- Norian subdivisions and correlations between Nevada and western Tethys. The zonation of the Norian is presently best defined in Canada and the aim of this research is to improve the resolution of the correlation of the Canadian scale with the low paleolatitude successions.

4 - Revision and updating of the Jurassic-Cretaceous planktonic foraminifera and calcareous nannofossil integrated biozonation and potential revision of Timescales.

Elisabetta Erba, Maria Rose Petrizzo, Cinzia Bottini

Thanks to the acknowledged expertise in biostratigraphy of calcareous plankton, the research group is deeply involved in the international scientific effort aimed at sequencing Earth history through an integrated geochronologic and stratigraphic approach. Ongoing and planned research include:

- Updated calcareous nannofossil biostratigraphy of the Jurassic and Cretaceous
- Updated planktonic foraminifera biostratigraphy of the Cretaceous

CURRICULUM "GEORESOUCES"

5 – Chronostratigraphy and paleoceanography of organic-rich facies based on calcareous plankton: Jurassic and Cretaceous Oceanic anoxic events.

Elisabetta Erba, Maria Rose Petrizzo, Cinzia Bottini

Black shales strongly enriched in organic carbon (mostly laminated, rich in pyrite and trace metals) have excellent potential to generate hydrocarbon at appropriate thermal maturity. A focal point for unique time periods in the Mesozoic is the Oceanic Anoxic Events (OAE)s which represent major perturbations in the global climate and ocean system. The causes and effects of these events are still not fully constrained, mainly because of the lack of high-resolution oceanic records.
Ongoing research comprises investigation of calcareous nannofossils, planktonic and benthic foraminifera. Semiquantitative analyses of planktonic foraminifera and calcareous nannofossils are used to improve the biostratigraphic framework defining biozones and the identification of intervals characterized by specific nannofossil and foraminiferal assemblages for regional to global correlations. Quantitative analyses of calcareous nannofossils, planktonic and benthic foraminifera are aimed at reconstructions of surface and bottom water conditions. Specifically:

- Absolute and relative abundances of calcareous nannofossil assemblages to derive paleoecological nannofossil indices of paleofertility and paleotemperature (surface water conditions);
- Absolute and relative abundance of planktonic foraminiferal assemblages to complement and extend paleoecological indices of paleofertility and paleotemperature (surface water conditions);
- Absolute and relative abundances of benthic foraminiferal assemblages to derive paleoecological indices of oxygen at the seafloor, organic matter fluxes to bottom waters and pale-water depths.