Title of the project: Integrated Stratigraphy and Astronomical forcing across the Early Eocene Climatic Optimum

Research Area: SSD GEO/01-GEO/02

Key words: Eocene, carbon cycle, calcareous plankton, cyclostratigraphy.

General presentation of the project and state of the art:

The late Paleocene to early Eocene (~60–50 Ma) experienced the most pronounced long-term warming of the Cenozoic, reaching peak temperatures by ~51 Ma during the early Eocene climatic optimum or EECO (Zachos et al., 2008). Following the EECO, a long-term global cooling led to the emplacement of an ice sheet over Antarctica by 33.6 Ma. The EECO, therefore, represents a major inflection in climate evolution during the Cenozoic. Unfortunately, the widespread occurrence of chert across the corresponding stratigraphic interval makes it often problematic to adequately recover it by ocean drilling. A striking feature of the stable isotope record is a persistent $\delta^{13}C$ shift during the middle part of Magnetochron C23n, which has been interpreted to reflect a major change in carbon cycle dynamics in terms of terrestrial versus marine organic carbon burial and biological pumping efficiency (Hilting et al., 2008). This mode of carbon cycling was replaced in the earliest Eocene by a marine-dominated system, under which decreases in biological pumping efficiency, perhaps driven by enhanced upwelling globally, led to elevated atmospheric pCO_2, warmer climates, higher weathering rates, and enhanced carbonate and organic carbon burial. The carbon isotope shift recorded at the climax of the EECO (early Eocene Carbon Shift or ECCS) reflects a persistent feature of marine $\delta^{13}C$ values and requires a persistent change in the character of the global carbon cycle. For example, a permanent increase in the burial rate of isotopically light organic carbon could explain the positive $\delta^{13}C$ shift, but would also lower atmospheric CO2 and global temperature. However, in the case of the EECS, marine $\delta^{18}O$ values do not support a corresponding cooling (e.g. Kirtland-Turner et al., 2014). Moreover, uncertainty on the tempo and mode of ECCS (Hilting et al., 2008; Westerhold et al., 2018) together with the absence of complete records from a wide spectrum of sedimentary settings and geography, hampers a confident interpretation of the cause(s) and mechanism(s) leading to this important event.

Research Objectives

The main goal of this project is to expand our knowledge of the mechanisms triggering the EECS in the context of the super-greenhouse climate that characterise the EECO interval. The scarcity of well-preserved and continuous marine successions across the EECO has for long time made it difficult to obtaining a high-resolution multisite geochemical record across it. It is now known that the EECO represents a time interval of enhanced sensitivity to orbital forcing. An objective of the proposed research is to derive information on the mechanisms leading to such enhanced sensitivity by comparing records from different sedimentary settings and geographies on an orbital time scale and deriving information on the long-term modulation of higher frequency astronomical forcing parameters. To this end, the project aims at producing an integrated stratigraphic record including micropaleontological and geochemical data.
The project wants to contribute enhancing the stratigraphic resolution of the available records (IODP and ODP Site, and land based sections) across the EECO interval, in order to acquire an orbital or sub-orbital scale resolution (10^4yr) of the Carbon cycle perturbations and the resulting environmental changes studying the $\delta^{13}C$ isotope variance *vs.* the $\delta^{18}O$ isotope and organic geochemical tracers. Ultimately, this exercise is designed to provide insights into the equilibrium climate sensitivity on a long-term period under super-greenhouse conditions.
From a paleobiological point of view, there is evidence for major taxonomic changes in the planktonic foraminifera (Luciani et al., 2016) associated with the EECS. Molecular evidence suggests that in the diatom community might have underwent a major evolutionary turnover in the same interval. Not much is known, however, as far as calcareous nannofossils are concerned.

Hence, an objective of the proposed research is to detect possible evolutionary or taxonomic changes in this group across the EECS.

Methodology and Expected Results

The research will focus on marine sedimentary successions sufficiently expanded to provide a high-resolution record across the EECO interval, from different sedimentary settings and a wide geography. Target sites are ODP Sites 1209 and 577 (Pacific Ocean), ODP Site 1263 (Atlantic Ocean) and several Tethyan land-based sections including, Djebel Kharrauba and Elles sections (Tunisia), the Forada and Facen sections (Belluno Basin, northern Italy) as well the Contessa Road-Bottaccione (Umbria Marche Basin) as a bio-magnetostratigraphic yardstick.

High-resolution stratigraphic analyses will be structured in three main steps:

- Fieldwork (land-based) and sampling, including scouting of further sections, during the first 10 months.
- High resolution integrated stratigraphy: bio- and magnetostratigraphic data, when unavailable, for all the named sections; quantitative micropaleontological (calcareous nannofossils) and geochemical analysis. The latter will include O and C isotopes and, preservation permitting, organic geochemistry for paleothermometry (TEX86).
- Cyclochronology: a spectral analysis of geochemical data will be carried out to detect astronomical periodicities. The resulting cyclochronology will provide a robust intersite correlation tool.

In summary, expected results are:

- Refinement of calcareous plankton biostratigraphy, megnetostratigraphy for the EECO interval.
- Identification of changes in marine microfossil communities across the EECS.
- Enhancement of and oxygen and carbon isotope profiles across the EECO and, in particular the EECS;
- Definition of a cyclochronology and phase relationship between the astronomical forcing and the sedimentological and geochemical signals;

Bibliography

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Description of the research in the three years period (feasibility)

- **First year:** Fieldwork and sampling campaigns;
- **Second year:** Integrated stratigraphy including quantitative micropaleontology and geochemistry.
- **Third year:** Cyclochronology. Intersite comparison and interpretation of the data. Writing the PhD thesis

Geochemistry will require a collaboration with a laboratory that runs organic geochemical analyses. A 6 months stay abroad is therefore included.