# PHD COURSE IN LIFE AND ENVIRONMENTAL SCIENCES

## Report Form for PhD student annual evaluation (XXXVI and XXXVII cycles)

**Name of PhD student:** Savannah Myers

**Title of PhD research:** Lessons from the Past: Understanding past and future climate changes through micropaleontology and geochemistry of anoxic sediment layers deposited in the Mediterranean Sea

**Name of PhD supervisor:** Prof. Dr. Alessandra Negri
**Research lab name:** Stratigraphy, Sedimentology and Paleoecology Laboratory – The PaleoLAB

**Cycle:**
[■] XXXVI
[ ] XXXVII

**PhD Curriculum:**
[ ] Marine biology and ecology
[ ] Biomolecular Sciences
[■] Civil and environmental protection

**DISVA instrumentation labs/infrastructure eventually involved in the project:**
[ ] Actea Mobile Laboratory
[ ] Advanced Instrumentation lab
[ ] Aquarium
[ ] MassSpec lab
[ ] MaSBiC
[ ] Simulation/informatics lab
[ ] Other. Please, indicate: .....

**ABSTRACT (1000 characters, including spaces):**
Paleoclimatology, the study of ancient climates, has become an essential science for trying to understand how human-induced global warming will affect Earth's future. And by studying specific extreme events caused by past climate changes, like what is indicated by Mediterranean sapropel deposits, we can get a glimpse into how ecosystems and environments responded. To do this, we must apply combinations of micropaleontology, geochemistry, and paleoecology using the microfossils, especially calcareous foraminifera, that are preserved in the geologic record throughout the Mediterranean Sea. My PhD research applies these palaeoclimatological techniques (biostratigraphy; foraminiferal paleoecology; Boron & Iodine isotopic analysis) with the overarching goal of better understanding the mechanisms behind the sapropel sedimentation layers by looking at sapropel sequences that are not as well studied from the mid Quaternary and that predate the extreme episode of the Messinian Salinity Crisis.

**Part 1. Scientific case of the PhD Research (2 to 3 pages, including figures)**

**- BACKGROUND**

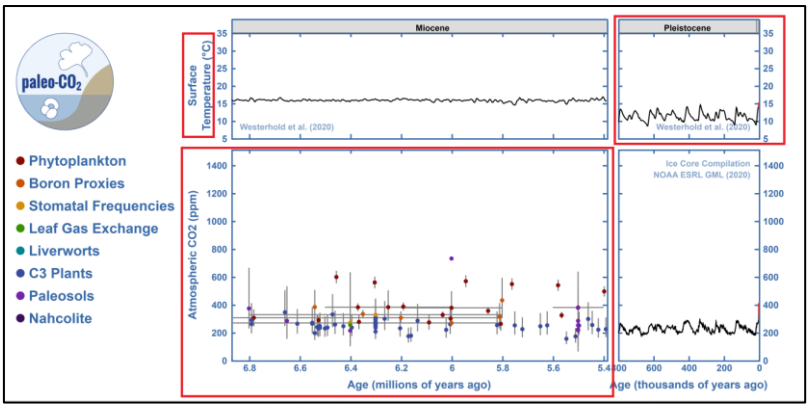
The study of Climatology examines the enormous variability in meteorological conditions across time and space, throughout history; and for ancient climates it is called Paleoclimatology. These fields involve the analysis of Earth's atmosphere, hydrosphere, cryosphere, lithosphere, biosphere, and their various interactions. As global warming is now an undeniable reality, Paleoclimatology has become essential for our comprehension of how the climate system works and to verify the models used to make future projections (Ramstein et al., 2021).

In sedimentary sequences over the last 13.5 Ma, sapropels—discrete, black sedimentation layers rich in organic matter—are found to occur periodically basin-wide throughout the Mediterranean Sea (Rossignol-Strick, 1985; Rohling et al., 2015). The mechanisms behind sapropel deposition are still unresolved but, generally speaking, they occur during conditions of decreased oxygen resulting from global and regional climatic forcing events (Benkovitz et al., 2020); and has been found to correspond with times of astronomically driven maximized summer insolation coinciding with precession (wobble of Earth's axis) minimum (Rohling et al., 2015). As a result of these orbital conditions, North African monsoonal activity increases causing a shutdown of thermohaline ventilation and/or enhanced biological productivity in the Mediterranean leading to the anoxic environments (indicated by sapropel layers) (Ramstein et al., 2021). Fortunately, sedimentary sequences preserve many types of microfossils, like foraminifera, that can reflect the assemblage that once existed at that location and time of deposition. With this, we can apply a type of Paleoecology called synecology, where the ecology of communities of organisms and their relationship with the environment is studied (Saraswati & M.S. Srinivasan, 2016). We can also apply geochemistry to these microfossils as the isotopic content of their anatomy are functions of the physical and chemical parameters of the water masses where they once lived.

As the rapid increase of atmospheric carbon dioxide and other greenhouse gases from anthropogenic emissions continues, increases in snow and ice melt, and increased precipitation lead to enhanced river runoff into our oceans and seas (IPCC, 2021). Even with the limited understanding that we have about sapropel formation, it can be inferred that as global warming persists, sapropelic conditions are foreseen. Therefore, by studying these unique sediment layers using micropaleontology and geochemistry we can better understand Earth's responses to climate changes, its future climate, and its impacts on the society of tomorrow (Ramstein et al., 2021).

**- SCIENTIFIC AIMS**

- Provide insights into the mechanisms behind deposition of sapropel layers across different temporal and spatial scales and their possible relationship with atm $CO_2$ & Dissolved Oxygen fluctuations
- Understand the mechanisms behind Icehouse sapropel S6 and warmer pre-Messinian Salinity Crisis sapropels (see figure below from https://www.paleo-co2.org/)
- Offer fresh perspectives about the conditions that created the Euxinic Shale succession of the Monte dei Corvi section




- Apply a fairly new proxy to better understand the mechanism of deoxygenation leading to sapropels

**- WORKPLAN AND RESEARCH ACTIVITIES**

**WP 1.** **Objective**: Reconstruct the paleoenvironment and paleoclimate of the time corresponding to the glacial sapropel S6 in the Mediterranean Sea (~172 ka) and better constrain the mechanisms behind the deposition of this sapropel

**Methods**:

- Analyse micropaleontological assemblage data (planktonic foraminifera, pollen, dinoflagellate cysts, calcareous nannofossils) using palaeoecological analysis and multivariate statistical procedures, like cluster analysis, principal component analysis, and correspondence analysis.
- Compare micropaleontological assemblage data with the geochemical data
- Gather all already acquired paleoenvironmental data for the time of S6 (SST, Sea Level, pCO2, orbital parameters, etc.)
- Combine my findings with the data and interpretations that are presented in the previously published literature

**Expected/Obtained Results**:

- This interval was a mild/warmer glacial period, and glacial meltwater was the initial trigger for sapropel S6 deposition by preconditioning the basin for a stratification episode.
- Contribution of state-of-the-art information about the paleoenvironment and the unknown climatic mechanisms that occurred in Marine Isotopic Stage 6.5
- Publish this study's results in the Palaeogeography, Palaeoclimatology, Palaeoecology international journal for geo-sciences.

**WP 2. Objective:** Assess the suitability of the well-studied, astronomically tuned Euxinic Shale succession of the Monte dei Corvi outcrop (containing sapropel layers dated back to the Messinian) for the purpose of applying the method that converts isotopic ratio of $^{10}B/^{11}B$ in planktonic foraminifera tests to atmospheric paleo-$CO_2$ reconstructions. If the microfossils are suitable, this will provide important insights about the climate variability that caused these changes in the deep-sea circulation (shown by the sapropels) for a period before the Messinian Salinity Crisis, a dramatic event when the Mediterranean Sea was disconnected from the Atlantic Ocean becoming mostly desiccated (Garcia-Castellanos et al., 2009).

**Methods**:

- Bulk-rock sample collection of each attainable precession cycle located at the targeted section Monte dei Corvi outcrop
- Elaboration of a processing method which allows nearly complete disaggregation of the extremely cemented sediments leading to more accurate results
- Microfossil picking: 400 individuals of the planktonic foraminfer, *Orbulina universa* (which is calibrated for $^{10}B/^{11}B$ analysis), for each sample that this amount is available
- Samples were sent to The Foster Lab at Soton for the oxidative cleaning procedure, trace element analysis, stable isotope analysis, and eventual $^{10}B/^{11}B$ analysis.

**Expected/Obtained Results**:

- The foraminifera were found to be infilled with pyrite or calcite and the B/Ca and Mg/Ca results were not found to be in the expected range. This suggests diagenetic alteration.
- Combining trace element analysis with stable isotope ($d^{13}C$ & $d^{18}O$) analysis will allow us to constrain the extent of the alteration to the foraminifera.
- This study infers that, due to their preservation and condition, samples collected from the Euxinic Shale succession of Monte dei Corvi are unsuitable for B isotope analysis.
- Publish this study's results of the analyses in collaboration with the National Oceanography Centre geochemistry group led by Gavin Foster.

**WP 3. Objective:** Refine the biostratigraphy and perform palaeoecological analysis (in high and ultra-high resolution) of the Euxinic Shale succession of the Monte dei Corvi outcrop which dates precede the Messinian Salinity Crisis.

**Methods**:

- See first 2 bullet points in WP2
- Microfossil picking: ~300 specimens of planktonic foraminifera and ~300 specimens of benthic foraminifera in each sample are identified and recorded into an assemblage dataset
- Compare the biostratigraphic sequence that our data presents, to the biostratigraphic sequence that we expect for this time period (pre-Messinian Salinity Crisis)
- Compare the biostratigraphy findings with that of the predetermined age model for the Euxinic Shale succession
- Evaluate micropaleontological assemblage data using palaeoecological analysis and multivariate statistical procedures, like cluster analysis, principal component analysis, and correspondence analysis.
- Combine my findings with the data and interpretations that are presented in the previously published literature to form conclusions about the paleoenvironment and paleoclimate of this time in the Eastern Mediterranean Sea.
- Collaborate with colleagues at the University of Torino combining my data with their calcareous nannofossil and bulk sediment isotope data

**Expected/Obtained Results**:

- Contribute a new age model for the Euxinic Shale succession of the Monte dei Corvi outcrop formulated from insights of the biostratigraphic sequence
- Fill in the gaps (biostratigraphy & paleoecological data) that are missing to more accurately describe the climatic and oceanographic story behind the deposition of this unique and well-studied succession

**WP 4. Objective:** Test the deoxygenation proxy, I/Ca isotopic ratio analysis, during the transition from bioturbated to sapropel sediments for 1) different outcrop stratigraphic successions across a west-east transect of the Mediterranean Sea on selected precessional cycles that predate the Messinian Salinity Crisis and 2) for a Quaternary interval corresponding to the onsets of sapropels S5, S6, and S7. This will offer the potential to monitor the inception of the deoxygenation that occurs at the time of sapropel deposition (especially at the sapropel base) regarding different spatial and temporal scales.

**Methods**:

- Obtain the samples from stratigraphic sequences that contain sapropels and microfossils, and have well expressed lithology with the availability of high-resolution samples: ODP Leg 160 Core 964 or 967; Monte dei Corvi Euxinic Shale section (cycles 252 – 256) (Husing et al., 2009); Gavdos section (cycle UA22) (Prof. Roveri); Sorbas Basin (cycles UA20 – UA24) (Sierro et al., 2001); Tokhni section (cycles 9 – 13) (Gennari et al., 2018)
- Select species of foraminifera suitable for this geochemical analysis: 1-2 planktonic (upper ocean oxygenation) and 1 benthic (bottom water oxygenation)
- Sample processing: washing and picking
- Analyses to be performed at Syracuse University or Rutgers University to collaborate with Prof. Zunli Lu or Prof. Yair Rosenthal (respectively; major researchers dealing with the I/Ca isotopic ratio) where I plan to use their facilities to carry out the cleaning, mass spectrometer procedure, data interpretation, and stimulating scientific collaboration (April-July 2023)

**Expected/Obtained Results**:

- Semi-quantitative reconstruction of deoxygenation for multiple time intervals and sites containing sapropels throughout the Mediterranean Sea
- Provide useful insights about oxygen level patterns of the sapropel succession in the mid Pleistocene and the one leading up to the Messinian Salinity Crisis and (never done before)

**- REFERENCES**


Benkovitz, A., Matthews, A., Teutsch, N., Poulton, S. W., Bar-Matthews, M., & Almogi-Labin, A. (2020). Tracing water column euxinia in Eastern Mediterranean Sapropels S5 and S7. *Chemical Geology*, *545*, 119627. https://doi.org/10.1016/j.chemgeo.2020.119627

Garcia-Castellanos, D., Estrada, F., Jiménez-Munt, I., Gorini, C., Fernández, M., Vergés, J., & De Vicente, R. (2009). Catastrophic flood of the Mediterranean after the Messinian salinity crisis. *Nature*, *462*(7274), 778-781.

Gennari, R., Lozar, F., Turco, E., Dela Pierre, F., Lugli, S., Manzi, V., Natalicchio, M., Roveri, M., Schreiber, B. C., & Taviani, M. (2018). Integrated stratigraphy and paleoceanographic evolution of the pre-evaporitic phase of the Messinian salinity crisis in the Eastern Mediterranean as recorded in the Tokhni section (Cyprus island). Newsletters on Stratigraphy, 51(1), 33–55. https://doi.org/10.1127/nos/2017/0350

Hüsing, S. K., Kuiper, K. F., Link, W., Hilgen, F. J., & Krijgsman, W. (2009). The upper Tortonian–lower Messinian at Monte dei Corvi (Northern Apennines, Italy): Completing a Mediterranean reference section for the Tortonian Stage. *Earth and Planetary Science Letters*, *282*(1), 140–157. https://doi.org/10.1016/j.epsl.2009.03.010

IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3-24, doi:10.1017/9781009157940.001.

Lu, W., Dickson, A. J., Thomas, E., Rickaby, R. E. M., Chapman, P., & Lu, Z. (2020). Refining the planktic foraminiferal I/Ca proxy: Results from the Southeast Atlantic Ocean. *Geochimica et Cosmochimica Acta*, *287*, 318–327. https://doi.org/10.1016/j.gca.2019.10.025

Ramstein, G., Landais, A., Bouttes, N., Sepulchre, P., & Govin, A. (2021). Paleoclimatology. https://doi.org/10.1007/978-3-030-24982-3

Rohling, E. J., Marino, G., & Grant, K. M. (2015). Mediterranean climate and oceanography, and the periodic development of anoxic events (sapropels). *Earth-Science Reviews*, *143*, 62–97. https://doi.org/10.1016/j.earscirev.2015.01.008

Rossignol-Strick, M. (1985). Mediterranean Quaternary sapropels, an immediate response of the African monsoon to variation of insolation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *49*(3), 237–263. https://doi.org/10.1016/0031-0182(85)90056-2

Saraswati, P. K., & Srinivasan, M. S. (2015). Micropaleontology: Principles and applications. Springer.

Sierro, F. J., Hilgen, F. J., Krijgsman, W., & Flores, J. A. (2001). The Abad composite (SE Spain): A Messinian reference section for the Mediterranean and the APTS. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *168*(1), 141–169. https://doi.org/10.1016/S0031-0182(00)00253-4


**Part 2. PhD student information on the overall year activity (courses/seminars/schools, mobility periods, participation to conferences)**

***List of attended courses/seminars/schools***

1) Seminar: “Quaternary paleoenvironments and paleoclimate in the Mediterranean area”
    - Hosted by Dr. Adele Bertini at the Università di Firenze

- 14/12/2021 – 16/12/2021

2) Course/School: "Past Climate Reconstruction and Modelling Techniques" organized by the Urbino Summer School in Paleoclimatology
    - Hosted by Dr. Simone Galeotti at the University of Urbino
    - 7/7/2022 – 20/7/2022
3) Course: Italian Language – Base Level
    - 3/2022 – 7/2022 (2 classes / week)

***List of periods spent abroad***

N/A

***List of conferences/workshops attended and of contributions eventually presented***

1) Urbino Summer School in Paleoclimatology Conference

**Part 3. PhD student information on publications**

*If not yet published, please indicate the publication status (submitted, accepted, in preparation...)*

***List of publications on international journals***

J1. Multi-proxy paleoceanographic reconstruction of the Mediterranean Sea during sapropel S6 deposition (172 kaBP) – IN PREPARATION (CLOSE TO BEING SUBMITTED)

J2. Oligo-monospecific assemblage of calcareous nannoplankton in response to the Messinian paleoceanographic setting: insight from Monte dei Corvi section (Central Italy) – IN PREPARATION – in collaboration with Dr. Alan Mancini (Università di Torino)

J3. Biostratigraphic and paleoecological interpretation of the precession-driven Euxinic Shale succession from the Monte dei Corvi outcrop (Central Italy) – IN PREPARATION

J4. A test to assess the Monte dei Corvi outcrop (Central Italy) for the use of atmospheric paleo-$CO_2$ reconstruction using the isotopic ratio of $^{10}B/^{11}B$ in planktonic foraminifera – IN PREPARATION

***List of publications on conference proceedings***

Oligo-monospecific assemblage of calcareous nannoplankton in response to the Messinian paleoceanographic setting: insight from Monte dei Corvi section (Central Italy)

- 18th International Nannoplankton Association meeting (2022) – Co-author

***List of other publications (books, book chapters, patents)***

N/A

*[14/10/2022]*

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