EEES Project Proposal Form – 2023 entry

Project Title	Developing microanalytical tool for trace element measurements for Earth Science applications
Key words	
Supervisory team (including email address	**PI: Pallavi Anand** **Co-I: Frances Jenner (OU), Katrina Nilsson-Kerr (University of Bergen)**
Is the PhD suitable for part time study?	Yes ☒ No ☐

Project Highlights:

- Develop laser ablation technique for measuring trace elements in natural archives
- Training in analytical technique in collaboration with the laser manufacturer
- Application of new technique in addressing Earth and Environmental Science applications.

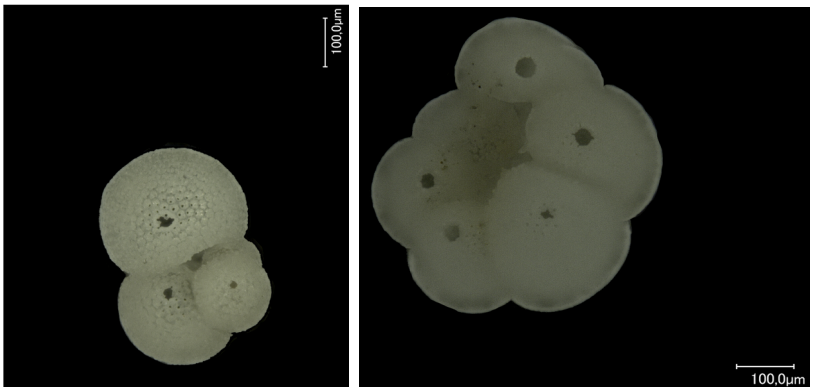
Overview:

This project aims to advance microanalytical technique (laser ablation), by improving laser spot size, for measuring trace elements on a small sample size for a wide variety of materials. The current laser technique is limited by the laser spot size (~30-40μm) [1] and bulk of the atoms are lost at the plasma interface even after all the ablated materials reaches to the plasma. Therefore, there is huge potential for improvement of the laser technique that can help improve the sensitivity and the signal from the ablated material. This project will involve collaborative working with the laser and ICP-MS manufacturers to improve signal acquisition and sensitivity so that analysis at smaller spot sizes can be achieved. The improved technique will open possibilities for measuring small sample size for understanding Earth and Environmental Sciences for example application in biogeochemistry and climatology.

Our climate is changing, and oceans are playing a key role in regulating the system as phytoplankton and zooplankton lock away carbon in their soft tissues and shells. The preserved calcareous and siliceous shells also lock away environmental signal in their chemistry capturing events at daily (e.g., molluscs) to weekly (e.g., coccolithophore) to monthly (e.g., foraminifera) resolution. Accumulation of these shells in sediments allow for extensive and detailed historical climate records to be reconstructed to understand mean state signal [2] which can be further explored using microanalytical techniques to improve understanding of seasonal/extreme events and processes responsible for these events [3] and/or in exploring new geochemical tools (e.g., distribution of U, Nd and Mn in shells for reconstructing river runoff [4]) of environmental significance. New technique will be applied to modern samples where the environmental information is known (using materials grown in culture and or collected from plankton net/sediment trap) to test the fidelity of signal. Further, the technique will be applied to extract climate signal from well dated marine samples to reconstruct seasonal signal and extreme events across Earth history and understand the nature, frequency and magnitude of such extremes. Full potential of the technique could be achieved by extracting chemical information from archives (such as coccolithophore of 5-10 μm in size) that is currently not possible.

This project will further explore application of newly developed technique of the laser ablation inductively coupled plasma mass spectrometer (LA-ICPMS) across Earth and Environmental Science applications using natural archives (such as calcareous shells, pollen, and/or mineral grains).

Figure 1: Pictures of two planktic foraminifera species showing laser ablation pits using 40um laser spot size.



Alt-text: Two images of laser ablated shells of planktonic foraminifera showing holes in chambers of foraminifera (post laser ablation analysis). Both foraminifera tests are off white in colour with a black background and are approximately 250 -400 µm in size. The laser holes are of approximately 40µm in size and appear on all visible chambers of both tests on the apertural side. There is a scale bar of 100µm shown on both images.

Methodology: The method development for this project will be achieved by working with the lead researcher of the laser manufacturer. The existing LAICPMS methodology operational at the OU will be enhanced through upgrade of custom cell, high resolution optics and optimisation to the ICP interface. These methodological improvements have potential to increase application of the LAICPMS in measuring small samples and elements that are currently not possible. In case there are challenges in achieving technical advancements to its fullest potential, the improved technique could still be applied to address scientific objectives such as past climate (temperature, rainfall/runoff seasonality) reconstructions using well dated IODP samples.

Training and skills:

The student will receive specific training on LA-ICPMS from Dr Jenner (and lab support from Dr Kunz) and from a researcher working in laser manufacturing industry and foraminifera specific knowledge from Drs Anand and Nilsson-Kerr.

The student will also receive skills training. OU offers a diverse set of training courses throughout their PhD.

Specific skills that will be acquired during this project include:

- Developing cutting edge geochemical techniques
- Data handling and interpretation from a wide variety of sources
- Scientific communication through writing, poster and oral presentations to academic and non-academic audiences
- Co-supervision on your own devised OU's master's project and teaching research methods to A level Nuffield funded summer students.

Partners and collaboration: This project will benefit from a wide range of collaboration from industry to international scientific community. In particular, there will be collaboration with

scientists working on individual foraminifera analysis Ed Hathorne (GEOMAR) and other researchers (UK/US/India) with modern culture and plankton tow samples.

Possible timeline:

Year 1: Obtain training in sample processing on laser ablation sample preparation and existing methodology. Develop technique for improving laser spot size on standards and small samples. Present data at TMSOC annual meeting.

Year 2: Apply newly developed technique on modern samples and international standards to test the fidelity of technique and signal measured for environmental applications. Measure natural samples using new technique for wider Earth and Environmental Science applications. Write a manuscript on technical advancement.

Year 3: Finish remaining analytical work, data analyses, and present results at an international conference and write up thesis and manuscripts.

Further reading:

1. Richey, J. N., Fehrenbacher, J. S., Reynolds, C. E., Davis, C. V. and Spero, H. J. (2022) Barium enrichment in the non-spinose planktic foraminifera, *Globorotalia truncatulinoides*. Geochimica et Cosmochimica Acta, 333, 184-199, doi.org/10.1016/j.gca.2022.07.006.
2. Groeneveld, J., Ho, S. L., Mackensen, A., Mohtadi, M., & Laepple, T. (2019) Deciphering the Variability in Mg/Ca and Stable Oxygen Isotopes of Individual Foraminifera. *Paleoceanography and Paleoclimatology*, *34*(5), 755–773. https://doi.org/10.1029/2018PA003533
3. Brinkmann, I., Barras, C., Jilbert, T., Mareike Paul, K., Schweizer, M., and Fillipsson, H. L., (2022) Drought recorded by Ba/Ca in coastal benthic foraminifera, Biogeosciences, 19, 2523-2535, doi.org/10.5194/bg-19-2523-2022.
4. Nilsson-Kerr, K., Anand, P., Sexton, P. F., Leng, M. J., Misra, S., Clemens, S.C. and Hammond, S.J. (2019) Inter-hemispheric climate controls on late Pleistocene Asian summer monsoon subsystems, *Nature Geoscience*, 12, pp. 290-295.

Further details:

Please contact Supervisor (pallavi.anand@open.ac.uk) for further information and informal discussion about this project.

Applications should include:

- A covering letter that includes:
    - Your motivation to study for a PhD in general
    - Your interest in this project in particular
    - The project-specific skills, aptitude and experience you bring to the project
- an academic CV containing contact details of three references, one of whom should be able to comment on your academic abilities.
- and an Open University application form.
    - If you are living in the UK and have residency rights then use the Home form
    - If you are living abroad then use the International form

Applications should be sent to **STEM-EEES-PHD@open.ac.uk** **by the end of the day on Wednesday 11th January 2023.**