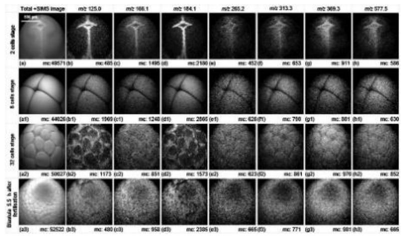
PROJECT TITLE: Mass spectroscopic mapping of organically preserved fossils
DTP Research Theme(s): Solid Earth, Living World
Lead Institution: University of Bristol
Lead Supervisor: Jakob Vinther, School of Earth Sciences, University of Bristol
Co-Supervisor: Ian Bull, School of Chemistry, University of Bristol
Co-Supervisor: (name, institution, school / department)
Project Enquiries: jakob.vinther@bristol.ac.uk
Project keywords: palaeobiology, taphonomy, materials science, mass spectroscopy

The J105 SIMS. https://www.ionoptika.com



Example of how it is possible to map secondary molecular ions across a surface with marked relief using the J105 SIMS. This is a frog embryo and different lipids are characterised across a spherical surface. From Tian et al. 2014 http://www.jlr.org/content/55/9/1970.full

Project Background

The fossil record holds crucial evidence for the nature and evolution of the biosphere. Exceptionally preserved fossils hold crucial cues to the nature of extinct organisms, but due to their rarity they are precious and difficult to probe. There are still major conceptual gaps in our understanding of fossilisation processes: What processes lead to preservation and what original biomolecules are retained and how are they altered during diagenesis?

Together with IONOPTIKA this PhD project will allow the candidate to develop a new and promising analytical instrument for fossils analysis. Their new and groundbreaking J105 can not only analyse rough surfaces with perfect mass resolution, but with novel primary ion sources, mor. TOF SIMS allow researchers to collect mass spectroscopic data in a minimally destructive fashion and furthermore being able to spatially map the composition across a surface.

Project Aims and Methods

The project includes 3 main components

1. **Optimising the J105 for analysing smaller and larger rock samples**

Due to the nature of fossil samples that need to be evacuated and the potential of these to charge under the high current, it is necessary to develop the experimental protocol and understand the best practice for sample preparation and machine configuration for different samples

2. **Develop standard spectra from extant and experimentally fossilised organic compounds.**

The use of different primary ion sources changes the spectral composition of molecular fragments that the machine collect. In order to compare spectra and diagnose compounds, it is necessary to collect data from extant samples as well as artificially matured samples (cooked under high pressure and temperature) in order to develop a reference library.

3. **Demonstrate the utility of J105 in fossil analysis, developing integrative research projects and answer scientific questions (taphonomic, ecological, evolutionary).**

The last component provide the student to develop their own research project (s) and with the knowledge from 1. and 2. to answer novel and important palaebiological questions.

Methods

Mass spectroscopy. The mass spectroscopic data will be collected on the J105 TOF SIMS. Other mass spectroscopic facilities can be implemented for comparative and validatory purposes. TOF SIMS data provide secondary ion spectra from individual data points across a larger area. These can be investigated by mapping individual secondary ions across a specimen. **Experimental taphonomy**. Organic materials undergo transformations during geological burial which ultimately may transform the compound into a volatiles, or into graphite. However, in the interim the molecule may retain aspects of its diagnostic structure. In order to accurately diagnose fossil materials it is powerful to subject organic molecules to experimental maturation, which mimic the diagenetic fossilisation processes. Decay can also be experimentally performed to understand their importance. **Chemical extraction and purification of molecules.** Several compounds are not available commercially. A great part of this project therefore entails purifying organic molecules using organic chemistry and molecular biological procedures.

Candidate Requirements

The candidate can have either a chemistry, materials science or geology/biology background. The key aspect for a successful candidate will be to be willing to develop and expand their repertoire of transferrable skills.

CASE Partner

IONOPTIKA developed the J105 TOF SIMS, which is the most innovative TOF SIMS developed in the last 20 years. Its potential in materials science, medicine as well as in palaeontology are still largely untapped. Therefore, the unique opportunity to work closely with IONOPTIKA sets this project apart as a unique opportunity for the candidate to obtain exclusive expertise and research.

Training

The student will get training in mass spectroscopic analysis, operating a TOF SIMS, experimental taphonomy, electron microscopy as well as several disciplines within palaebiology. This project not only equip a student for different directions within the private sector, but is also a possibility for becoming an integrative researcher and teacher within academia.

Background reading list

Colleary, C., A. Dolocan, J. Gardner, S. Singh, M. Wuttke, R. Rabenstein, J. Habersetzer, S. Schaal, M. Feseha, M. Clemens, B. F. Jacobs, E. D. Currano, L. L. Jacobs, R. L. Sylvestersen, S. E. Gabbott and J. Vinther (2015). "Chemical, experimental, and morphological evidence for diagenetically altered melanin in exceptionally preserved fossils." Proceedings of the National Academy of Sciences.Gabbott, S. E., P. C. Donoghue, R. S. Sansom, J. Vinther, A. Dolocan and M. A. Purnell (2016). Pigmented anatomy in Carboniferous cyclostomes and the evolution of the vertebrate eye. Proc. R. Soc. B, The Royal Society. Lindgren, J., P. Uvdal, P. Sjovall, D. E. Nilsson, A. Engdahl, B. P. Schultz and V. Thiel (2012). "Molecular preservation of the pigment melanin in fossil melanosomes." Nature Communications **3**. Siljeström, S., T. Hode, J. Lausmaa, P. Sjövall, J. Toporski and V. Thiel (2009). "Detection of organic biomarkers in crude oils using ToF-SIMS." Organic Geochemistry **40**(1): 135-143. Thiel, V. and P. Sjövall (2011). "Using time-of-flight secondary ion mass spectrometry to study biomarkers." Annual Review of Earth and Planetary Sciences **39**: 125-156. Tian, H., J. S. Fletcher, R. Thuret, A. Henderson, N. Papalopulu, J. C. Vickerman and N. P. Lockyer (2014). "Spatiotemporal lipid profiling during early embryo development of Xenopus laevis using dynamic time-of-flight secondary ion mass spectrometry (ToF-SIMS) imaging." Journal of lipid research: jlr. D048660. Vinther, J. (2015). "A guide to the field of palaeo colour: Melanin and other pigments can fossilise: Reconstructing colour patterns from ancient organisms can give new insights to ecology and behaviour." Bioessays **37**(6): 643-656.

Links:

School URL – http://www.bristol.ac.uk/earthsciences/courses/postgraduate/
NERC GW4+ DTP Website: http://nercgw4plus.ac.uk/

Bristol NERC GW4+ DTP Prospectus:
http://www.bristol.ac.uk/study/postgraduate/2020/doctoral/phd-great-western-four-dtp/

How to apply to the University of Bristol:
http://www.bristol.ac.uk/study/postgraduate/apply/
http://www.bristol.ac.uk/earthsciences/courses/postgraduate/

General Enquiries:
Bristol NERC GW4+ DTP Administrator
Email: bristol-nercgw4plusdtp-admin@bristol.ac.uk