The geochemistry of chert fossils in deep time

Supervisors: Dr Russell Garwood, Dr Romain Tartese, Prof Roy Wogelius, Dr Brian O'Driscoll, Prof Ray Burgess, Dr Bart Van Dongen.

Primary Contact Name and Email: Dr Russell Garwood (russell.garwood@manchester.ac.uk)

Introduction:

Chert is a key lithology for the preservation of Precambrian life. These rocks, which are composed primarily of microcrystalline silica, host a myriad of important remains of early life. The lithology is so important due to the high fidelity preservation of fossils and the chemical traces of life that result from its fine grain size and high resistance to weathering and metamorphic alteration. This is coupled with modes of formation that are often found in near surface environments. Cherts host key fossil deposits including: the earliest putative morphological fossils from the Apex Chert (3.46 Ga), Strelley Pool Formation (3.4 Ga), and Farrel Quartzite (3.0 Ga) of the Pilbara craton, Australia; the renowned Gunflint Chert, Ontario (1.88 Ga) which has been suggested as a benchmark for the preservation of early ecosystems; the Bitter Springs Formation, Australia (850 Ma) home to a diverse assemblage of Proterozoic fossils; and the Devonian Rhynie chert, Scotland (400 Ma) which yields key insights into the interactions of early life on land. It is a key rock type for understanding the first three billion years of evolution, but highly variable, as it may result from the silicification of diverse protoliths. This project uses an array of techniques to characterise the petrology of chert and the taphonomy of the associated fossils, to better understand life on Earth in deep time. This project forms part of a thriving cross-disciplinary research area at the University of Manchester. A large group of academic staff and associated researchers are addressing evolutionary and palaeobiology questions through studying ancient life, supported by Manchester's Interdisciplinary Centre for Ancient Life (http://www.ical.manchester.ac.uk/) and the Computational Biology group in the Evolution, Systems and Genomics Domain (https://www.bmh.manchester.ac.uk/research/domains/evolution-systems-genomics/).

Project Summary (max 700 words inc introduction):

This project will reassess a number of important chert-hosted fossil deposits, assessing the geochemistry and three-dimensional structure of the rocks and fossils, and the petrology of the matrix. Recent research has demonstrated that multidisciplinary approaches to the imaging and analysis of fossils can provide key insights into understanding the preservation process and original biology of long-extinct organisms. Trace-metal inventories and related organic compounds can survive through geological time, and many three-dimensionally preserved fossils can be reconstructed using scanning technologies and digital visualisation. A number of such approaches will be used to understand chert-hosted fossils from throughout the geological record.

This project stands at the interface between palaeontology, biology and geosciences and will involve diverse analytical techniques, using facilities at the University of Manchester, which include: Fourier Transform InfraRed (FTIR) imaging and spectroscopy; numerous forms of mass spectrometry for both organic and inorganic compounds; X-ray micro- and nanotomography; and confocal and scanning electron microscopy. In addition to these approaches, the project will exploit synchrotron facilities, including Diamond Light source (DLS) and the Stanford Synchrotron Radiation Lightsource. This will include tomography, and chemical imaging, (e.g. Synchrotron X-ray Fluorescence (SXRF), scanning transmission X-ray microscopy (STXM), and X-ray Absorption Spectroscopy (XAS). This multidisciplinary approach will improve our understanding of the metabolism and biology of ancient organisms in life. Potential aspects of this study will include: assessing the geology and biogenicity of structures in Archean Cherts; mapping metal concentrations associated with photosynthesis (iron, manganese, magnesium, and copper); constraining the distribution and concentration of elements such as boron which were potentially important in early Earth synthesis of RNA and common in chert-hosted phases such as tourmaline; and imaging at high enough resolutions to potentially differentiate cellular organelles to study the origin of Eukaryotes.

This is an unparallelled opportunity to receive training in a wide range of analytical techniques, and develop a clearer understanding of the mode of formation of a range of important cherts. It will help clarify the taphonomy of the fossils by better understanding their chemistry and microstructure - and in key deposits help confirm whether the observed structures are biogenic. It is anticipated that the proposed work will pave the way for such multi-disciplinary approaches to be applied to a wide range of other early fossils, creating a more a holistic understanding of the interactions between life and the Earth through geological time.

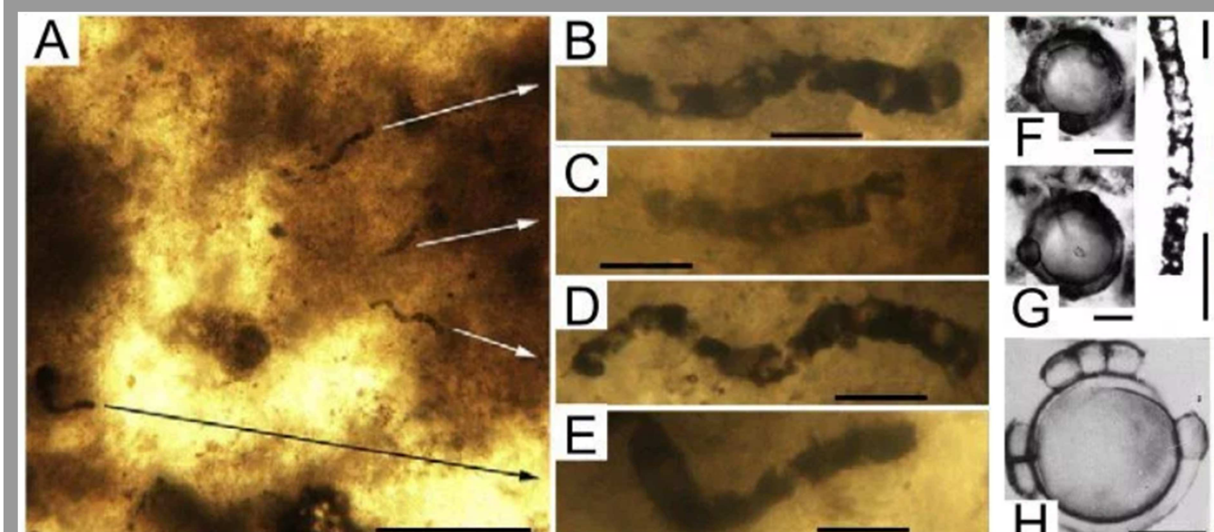

Figure 1: Cherts associated with studies of ancient life. A–E: Examples of possible microfossils from the Apex Chert. If they are biological in origin, they are contenders for the earliest known fossils. Modified from this source. F–I: The earliest universally accepted fossils, from the Gunflint Chert. Modified from this source. Scale bar in panel A: 100 micrometres. All others 10 micrometres. *From: Garwood, Russell J. 2012. Patterns In Palaeontology: The first 3 billion years of evolution. Palaeontology Online, Volume 2, Article 11, 1-14*

References

Wogelius, R. A., Manning, P. L. Larson, P. L., Barden, H., Edwards, N. P., Webb, S. M., Sellers, W. I., Taylor, K. G., Dodson, P., You, H., Da-qing L. and Bergmann, U. 2011. Trace metals as biomarkers for eumelanin pigment in the fossil record, Science, DOI: 10.1126/science.1205748.

Manning, P. L., Morris, P. M., McMahon, A., Jones, E., Gize, A., Macquaker, J. H. S., Marshall, J., Lyson, T., Wolff, G., Buckley, M. van Dongen, B.E. and Wogelius, R. A. 2009. Preserved soft tissue structures and organic molecules in a mummified hadrosaur dinosaur from the Hell Creek Formation, North Dakota (USA). Proceedings of the Royal Society Series B., 276 (1672), 3429- 3437.

Garwood, R. J. 2012. Patterns In Palaeontology: The first 3 billion years of evolution. Palaeontology Online, Volume 2, Article 11, 1-14

Edwards, N. P., Barden, H. E, van Dongen, B. E., Manning. P. L., Bergman, U., Sellers, W. I., and Wogelius, R. A. 2011. Infra-Red mapping resolves soft-tissue preservation in 50 Million year old reptile skin. Proceedings of the Royal Society, Series B., doi: 10.1098/rspb.2011.0135

Brasier, M. D., Antcliffe, J., Saunders, M., & Wacey, D. (2015). Changing the picture of Earth's earliest fossils (3.5–1.9 Ga) with new approaches and new discoveries. Proceedings of the National Academy of Sciences, 112(16), 4859-4864.