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RESEARCH

Life on Earth – the early days

Novel research coming out of the AMMRF at the University of Western Australia (UWA) is revealing new information about the origin and evolution of life on Earth.

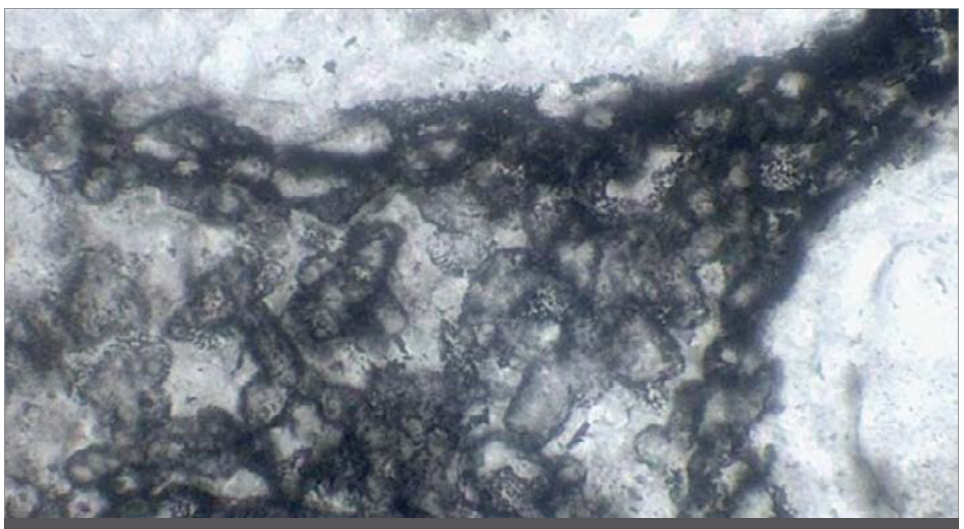
Dr David Wacey, Dr John Cliff, Dr Matt Kilburn and Prof. Martin Saunders, together with Prof. Martin Brasier from Oxford University, report on microfossils from Earth's oldest sandstones in the October issue of *Nature Geoscience*. The microfossils are 3.4 billion years old and come from Strelley Pool, a remote region of the Pilbara about 60 km west of Marble Bar. They consist of remarkably well-preserved carbonaceous cells along with the protective tubes that housed some of these cells.

Proof of life from so long ago is exceedingly rare, because erosion has destroyed most of the evidence of this age. Previously, the earliest uncontroversial fossils that point to early life on Earth were 3.2 billion years old, 200 million years younger than this new find.

The research used multiple complementary microscopy techniques in the AMMRF at both UWA and the University of Adelaide, including light microscopy, scanning and transmission electron microscopy, secondary ion mass spectrosopy (SIMS), nanoSIMS and Raman spectroscopy. This combination was vital, not only to prove the age and biological affinity of these microfossils, but also to show what type of metabolism they were using. By showing the intimate spatial association of these microfossils with the mineral pyrite (FeS_2), the team provided evidence that these early microorganisms employed a sulphur-based metabolism. This ability to essentially 'breathe' sulphur compounds is thought to be one of the earliest stages in the transition from a non-biological to biological world.

When studying such early life-forms, the tricky question always arises: how and where did life first evolve from a mixture of chemicals on the early Earth? Dr Wacey and his Oxford University colleagues, Prof. Brasier, Dr Richard Matthewman and Mr Sean McMahon address this question as well. Publishing in the September issue of Astrobiology, the team present a new hypothesis: that a common, low-density volcanic rock, pumice, was an ideal habitat for the emergence of life over 3.5 billion years ago. Not only does pumice float as rafts on the ocean, but it also has the highest surface-to-volume ratio of any rock. It also has the remarkable ability to adsorb metals, organics and phosphates as well as hosting organic catalysts. During its lifecycle, pumice is potentially exposed to, among other things, lightning associated with volcanic eruptions, oily hydrocarbons and metals produced by hydrothermal vents, and ultraviolet light from the Sun as it floats on water. All these conditions have the potential to host, or even generate, the kind of chemical processes that are thought to have created the first living cells, making pumice ideal for the development of the earliest micro-organisms.

Dr Wacey describes a potential scenario that ties the pumice and microfossil research together: 'The beaching of pumice rafts for long periods of time close to shore, just as is seen around the island of Santorini today, could have provided the cradle for life sometime prior to 3.5 billion years ago, which then evolved into the cellular microfossils that we found in 3.4 billion-year-old beach sandstones at Strelley Pool (left).' ■



Light micrograph showing bacterial and tubular microfossils clustered together around the edges of two quartz grains (top and right). The fossil bacteria are around 20 microns in diameter.

COMMUNITY

AMMRF General Manager Dr Miles Apperley with Ms Patricia Kelly, Deputy Secretary of the Department of Innovation, Industry, Science and Research.

Science and beauty meet in Inner Space

The *Incredible Inner Space* exhibition has opened at Questacon in Canberra. The images for this memorable exhibition have been brought together from all around the AMMRF and highlight how much microscopy matters in providing fundamental data to researchers and in communicating the wonders of science to a wide audience of Australians.

Surrounded by the assembled guests Patricia Kelly, Deputy Secretary of the Department of Innovation, Industry, Science and Research spoke enthusiastically about the exhibition and the AMMRF, emphasising that the images are not only beautiful but the result of real scientific enquiry made possible by the strategic investment in national research infrastructure. Dr Paul Willis, Director of RiAus and former *Catalyst* presenter, then opened the exhibition with an insightful and entertaining talk about the nature of science and the role of the unseen in shaping our vision of the world.

Guests remarked on the beauty and variety of the images on display and were fascinated by the stories behind them. By all accounts, the exhibition is also being extremely well received by visitors to Questacon. This was experienced firsthand by your editor, as a member of the public said to her excitedly after viewing the images, "aren't they just fabulous!"

Incredible Inner Space has also inspired the media, with excellent coverage received in Australia and internationally. ■

RESEARCH

The jaw bone's connected to the ... paw bone

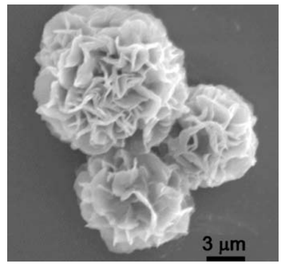
SARF Gum disease and inflammatory (rheumatoid) arthritis are the focus of a recent study by Melissa Cantley, a postgraduate student from the University of Adelaide. Up to 60% of the world's population suffer from gum disease caused by bacterial infection, which leads to inflammation and destruction of the bone that supports the teeth. In an apparently unrelated disease, rheumatoid arthritis, the body's own immune system starts to attack tissues within the joints, resulting in inflammation and crippling pain. However, both conditions are chronic inflammatory diseases that involve destruction of bone.

To investigate the relationship between these two conditions Ms Cantley induced periodontitis in mice, by treating the animals with bacteria known to be involved in human periodontitis. Then, by using X-ray microtomography in the AMMRF at Adelaide, she measured changes in bone volume in the jaws and the paw bones of mice with experimentally induced periodontitis, arthritis or both. She found that bone was lost from both locations, even when mice had only one of the two conditions. Ms Cantley also observed that mice with periodontal disease developed more severe arthritis than those without it.

The results of this study, published in the *Journal of Clinical Periodontology*, suggest a bidirectional relationship between periodontal disease and inflammatory arthritis. Understanding this complex relationship will determine whether treatment of periodontitis has any effect on the clinical features of rheumatoid arthritis.

GO flowers

SARF Carbon-based nanostructures have been emerging as novel and versatile systems for a wide variety of applications. Dr Andrew Vogt and collaborating researchers in the AMMRF at Flinders University have developed fast and effective new methods of manipulating these materials to form flower-shaped nanostructures made of graphene oxide (GO). Carbon nanotubes are first unzipped by using ultrasonication in N-methylpyrrolidone and the resulting sheets are self-assembled onto a silicon base. Through volume-controlled growth, intricate, high-order nanoarchitectures form on glass or silicon substrates. These flower-shaped assemblies, or GO flowers, have very large surface-to-volume ratios, giving them potential for catalytic or scaffolding applications. The fact that they were found to exhibit blue photoluminescence and photovoltaic activity could also make them suitable for sophisticated optical and electronic applications, such as advanced photovoltaic devices and organic light-emitting diodes (LEDs).



International study on premature birth

UWA Each August an international team of researchers congregates in Perth for three weeks to study the inflammatory responses of preterm sheep with the aim of improving our understanding of preterm labour and premature birth in humans. Chorioamnionitis and other perinatal infections that cause inflammation of the foetal membranes and umbilical cord are often associated with preterm labour. Prof. John Newnham from the University of Western Australia (UWA) and Prof. Alan Jobe from Cincinnati Children's Hospital Medical Center in Ohio, USA, started the highly successful global collaboration 21 years ago. The group has more recently expanded to include Prof. Suhas Kallapur from Cincinnati, Prof. Boris Kramer from Maastricht University, Netherlands, and Dr Matthew Kemp from UWA.

Perth is the only feasible location in which to do this research project because of the juxtaposition of expertise and instrumentation with a well co-ordinated local source of large numbers of high-quality sheep. Precision breeding is required for the team to have pregnant ewes at exact gestational ages on specified days throughout the three-week period. The farm consultants manage the entire timed-breeding operation.


Photo: C. Goodwin

This collaboration is also unique because of the significant and long-standing expertise of the team in multi-disciplinary domains, including foetal physiology, developmental biology, foetal immunology, and maternal and foetal medicine. They are able to obtain a great deal of high-quality flow-cytometry data in this very short period of time through the contributions of Asst/Prof. Kathy Heel and Ms Tracey Lee-Pullen at the AMMRF at UWA to the design and execution of the experiments.

The team is showing that specific components of the inflammatory response to bacterial infection affect the health of the preterm lambs. This research work is translational in nature and is crucial to understanding the mechanisms of lung disease and foetal systemic inflammation in infants. It is bringing the team closer to their long-term goal of finding better therapies for premature infants.

EXECUTIVE DIRECTOR'S COLUMN

The 3,300 users of the AMMRF and our terrific staff would no doubt have been extremely interested in the announcement last month that Daniel Shechtman had been awarded the 2011 Nobel Prize for Chemistry. In a celebration of fundamental discovery research using electron microscopy, the Nobel Committee awarded the prize to Shechtman for his discovery of quasicrystals. It is said that Shechtman uttered the phrase 'There can be no such creature' when he first observed the unusual symmetries in his electron diffraction patterns. And, it took many years for his peers to accept that this man and his electron microscopy were blazing an entirely new trail in crystallography. A scary campaign was perpetrated against Shechtman by none other than dual Nobel Prize winner Linus Pauling. Shechtman's endurance under this campaign, and in the face of the request from the head of his research group that Shechtman leave the Technion Institute in Haifa is an indication of his courage. As a result of his work, we now accept that crystals can exist that possess regular patterns that never repeat.

I take several inspirations from Shechtman's 2011 Nobel Prize. Firstly, it reminds me of the tremendous power of the transmission electron microscope (TEM). This remarkable instrument has proven to be a true platform for discovery – over and over again. Little wonder that the AMMRF records over 20,000 hours of usage across our impressive fleet of TEMs. There are so many fascinating secrets in the physical, chemical or biological materials, studied in the AMMRF, that we need to be prepared to be surprised – and then to rigorously follow up that surprise with careful checking and validation. Now undoubtedly, modelling and simulation are also crucial parts of the scientific approach and many of us routinely use these approaches in our work. However, in considering Shechtman's success, I am also reminded that, in many areas of frontier science and engineering research, what is urgently needed is a foundation of observations that will provide a phenomenological basis for an eventual trip to the whiteboard to try to model and/or simulate the observed behaviour.

As we head towards the festive season for 2011, I wish all users and staff of the AMMRF a happy and safe Christmas holiday period, and I also hope that you will find unexpected scientific surprises lurking in your samples!

Simon Ringer Executive Director & CEO

AWARDS AND PRIZES

2011 Life Scientist of the Year

USyd A/Prof. Min Chen, an AMMRF user from the University of Sydney, has been awarded the Science Minister's Prize for 2011 Life Scientist of the Year for her work on chlorophylls. A/Prof. Chen is a world expert on chlorophyll d, a light-capturing molecule found in cyanobacteria living in low-light conditions on the Great Barrier Reef. She was searching for chlorophyll d in cyanobacteria from stromatolites in Shark Bay in Western Australia when she discovered a new type of chlorophyll, chlorophyll f. Her work on this newly discovered molecule was published in *Science* last year and shows how chlorophyll f can capture the energy from particularly low energy, far-red light.

A/Prof. Chen used cryo transmission electron microscopy in the AMMRF at the University of Queensland to determine the detailed structure and arrangement of phycobiliprotein molecules in the photosynthetic membranes of cyanobacteria. Phycobiliprotein works in conjunction with chlorophyll d to capture additional wavelengths of light to optimise energy collected by these bacteria in difficult, low-light conditions.

Chlorophylls, and their associated light-capturing proteins, particularly those that can capture low levels of light efficiently, are highly significant to technological developments, not only in agriculture. but also in biofuels and solar industries more widely.


Photo: Prime Minister's Science Prizes/Bearcage

Young Tall Poppy

USyd Dr Peter Liddicoat, the AMMRF's Atom Probe Scientist, has been doubly recognised for his significant research achievements, resulting from his atom probe analysis of nanostructural hierarchies in super-strong, light, aluminum alloys. On 3 November, at a ceremony at the Powerhouse Museum, Prof. Jill Trewhella, Deputy Vice Chancellor (Research) from the University of Sydney, presented Dr Liddicoat with a 2011 NSW Young Tall Poppy Science Award. In a separate ceremony on October 28 the University of Sydney recognised him as a finalist for the Rita and John Cornforth Medal for excellence in his PhD. His postgraduate research was published last year in *Nature Communications*. Dr Liddicoat has also just heard of his success in the inaugural Discovery Early Career Researcher Awards. His new three-year project is entitled 'Enabling a new generation of advanced high-strength aluminium alloys through materials design'

Eureka Prizes

UQ The Eureka prize for Research by an Interdisciplinary Team was won by Prof. Mark Kendall (right) and the engineers, mathematicians, materials scientists and immunologists of his team. They use the AMMRF at the University of Queensland to develop and optimise their revolutionary Nanopatch technology, featured in the previous issue of the *AMMRF News*.

Prof. Jian-Xin Zhao, Director of the Radiogenic Isotope Facility in the AMMRF at the University of Queensland, won the Inaugural Eureka Prize for Outstanding Mentor of Young Researchers. Frank Howarth, Director of the Australian Museum, said of him, "Dr Zhao is hailed by students and younger colleagues for his outstanding science, his professional guidance and his leadership both in and out of the lab.


Photo: One Ventures

ANNOUNCEMENTS

AMMRF Staff Workshop 2012

A staff workshop will be held in Brisbane in 2012, more information is coming soon.

Register for ACMM22/ ICONN2012/ APMC10

A combined conference taking place in the Perth Convention & Exhibition Centre, WA, 5–9 February 2012. Info and registration at: microscopy.org.au/ACMM-22

Prof. Rob Parton awarded the ANZSCDB President's medal

UQ Prof. Rob Parton from the Institute for Molecular Bioscience, and Deputy Director of the AMMRF at the University of Queensland, has been chosen as the 2011 recipient of the President's Medal, awarded by the Australia and New Zealand Society for Cell and Developmental Biology. It is the highest honour that the Society bestows and is in recognition of Prof. Parton's research and expertise on microdomains of the plasma membrane and, in particular, his focus on caveolae and caveolins. Prof. Parton presented the ANZSCDB President's Medal plenary lecture at the ComBio2011 meeting in Cairns during September.

COMMUNITY

National Characterisation Roadshows

The AMMRF, the Australian Synchrotron, the National Deuteration Facility and the National Imaging Facility again joined forces to spread awareness of collaborative infrastructure available to frontline researchers around the country. This year's roadshows visited the University of Western Sydney (UWS) Campbelltown campus and the Australian National University in Canberra on 27 and 28 October. Presenters from each organisation introduced their capabilities, access arrangements and applications in a number of case studies.

Audio-visual capture of the UWS talks will soon be uploaded to the National Characterisation Council website so they can be viewed 24/7 by all researchers whether in regional or major centres.

FROM THE NODES

High-profile visitors to the AMMRF

The AMMRF at the University of Sydney has recently hosted several important visitors. The Hon. Tanya Plibersek MP, Member for Sydney and the Hon. Carmel Tebbutt MP, Member for Marrickville, both toured the facility to see how we support Australian research. Both were clearly fascinated and impressed by what they discovered.

Prof. Roger Tsien, who won the Nobel Prize for Chemistry in 2008, also visited the Sydney node after a five-year interval and was mightily impressed with its progress since then.

Dop Brzesowsky, Leica International Vice President, Sales and Service, also dropped in to check progress of the recently acquired Leica multiphoton instrument, a $2.2 million investment in cutting-edge laser microscopy.

Back in August, Director of the Science and Technology Equipment Centre (STEC) at Silkaporn University in Thailand, Prof. Thanit Pewnim, was in Sydney to learn about national research facilities such as the AMMRF so he can implement best practice in the establishment of their new centre in Thailand.

AMMRF CEO Prof. Simon Ringer with Prof. Jill Trewhella DVC-R, the University of Sydney, and the Hon. Tanya Plibersek MP

The AMMRF at the University of Adelaide also hosted visitors. In September the newly appointed Chief Scientist for South Australia, Prof. Don Bursill, visited. It was clear to him that the facility has a direct impact on the strategic directions of the state government, those being mining, defence industries, manufacturing, horticulture and agriculture. Prof. Bursill went away ready to brief the incoming South Australian Premier, Jay Weatherill.

In October, the Hon. John Hill MP, Minister for Health in the South Australian Government also visited. He was able to see clearly the positive effect that engagement of Adelaide Microscopy with the AMMRF has had on the facility and was pleased by the applications of their technology to many fields of research.

As part of a scoping exercise to develop a register of microscopy and microanalysis suppliers in South Australia, Mr Terry Dwyer, Senior Advisor in the South Australian Department of Trade and Economic Development, also visited. The SA Government intends to encourage industry to source these services locally. Mr Dwyer was impressed with the portfolio of instrumentation offered by the AMMRF. He plans to bring all the senior managers in his department to visit the facility – an important opportunity to build stakeholder engagement with the SA government. ■

STAFF NEWS

UNSW

Ms Leah Koloadin has joined the AMMRF at the University of New South Wales as a technical officer. Leah holds a Bachelor of Biotechnology degree from the University of Newcastle and is currently completing a Masters of Applied Science in Microscopy and Microanalysis at the University of Sydney, where she dedicated much of her research time to various projects on seed morphology. Leah also has a Diploma in Laboratory Technology majoring in bio/environmental testing. Leah brings with her over five years experience in maintaining research laboratories in Calvary Mater, Newcastle University and Johnson & Johnson Research.

CAPABILITY

Laser ablation system brings new capability

SARF

October saw the installation of a new RESOlution M50 193nm excimer laser ablation system in the AMMRF at the University of Adelaide. The system made by Resonetics uses a coherent excimer laser coupled to a unique ablation cell developed by Mike Shelley, formerly of the Australian National University. The system, together with a new-generation Agilent 7700 inductively coupled plasma mass spectrometer (ICPMS), was purchased with funds from a successful Premier's Science and Research Fund grant from the South Australian Government.

This system provides the latest laser ablation (LA) technology for LA-ICPMS and allows users to navigate around their samples by using any previously acquired sample images, e.g. backscatter electron, secondary electron, cathodoluminescence or optical images. The Laurin Technic ablation cell provides rapid washout in between ablation events, making the instrument uniquely suited to mapping and imaging by LA-ICPMS. ■

QUT goes UHV

QUT

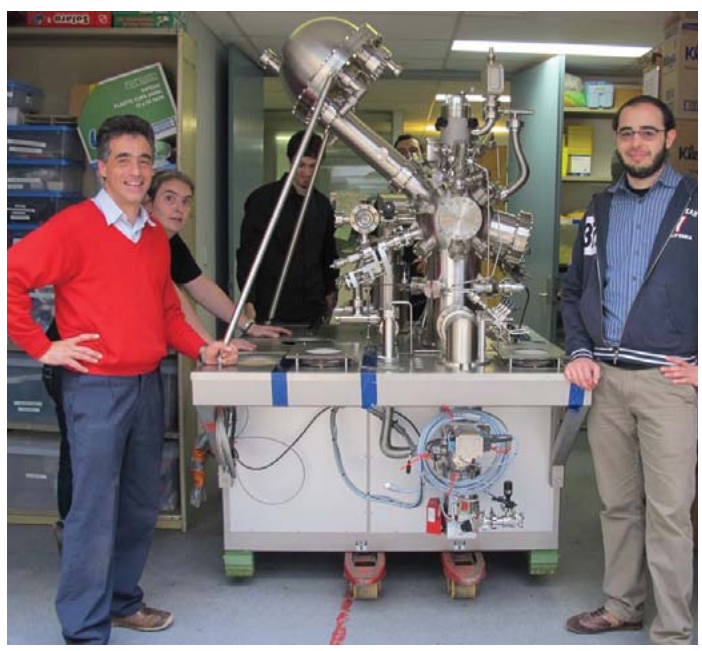
In August, the AMMRF Linked Lab at the Queensland University of Technology (QUT) installed an Omicron Multiscan Lab system – the first of its kind in an Australian multi-user microscopy facility. As an ultra-high vacuum (UHV) instrument, it offers researchers the ability to prepare, manipulate, image and analyse atomically clean surfaces. Even in the high-vacuum of an electron microscope, a monolayer of contamination can form in less than a second. This takes many hours in a UHV system. The argon ion-sputtering gun, atomic hydrogen source and sample heating to 1500K, all help engineer the sample's surface.

At the heart of the instrument is Omicron's scanning probe microscope (SPM). A piezo-actuated tip scans the specimen surface with feedback from either tunneling current (STM) or atomic force microscopy (AFM). A broad range of techniques probe the physical and electronic properties of the sample down to the atomic level. SPM experiments are possible at temperatures from 25 to 600K and it is possible to image progressive processes such as epitaxial growth, quantum dot formation and single-molecule interactions with the surface.

A second chamber is for analysis, including a scanning electron microscope. Excitation is either by X-ray (XPS) or SEM electron beam (Auger), with the resulting signal resolved by a sensitive spectrometer. These techniques are highly surface sensitive, and provide scanning elemental analysis and bonding-state information.

LIEF-bid leader Prof. Nunzio Motta says: "The system is designed for flexibility, so that many different experiments can be performed with it. Our scanning probes are capable of atomic resolution and tunnelling spectroscopy at the same time, enabling collection of atomically resolved images of insulators, such as metal oxides, diamond or polymers. Capability to measure current–voltage characteristics of single nanostructures is also available".

Initial research is being driven by nanosensor applications and other experiments include studies of molecular film growth, counter electrodes for dye-sensitised solar cells and studies of two-dimensional nanosheets for photocatalysis. ■



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