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RUSTICLES AND SCIENCE SAMPLING

Dr Laura Machuca Suarez

Corrosion Engineering Industry Centre, Curtin University

Image courtesy Curtin University and WA Museum. © WA Museum

Science Program Researchers

The SKP Expedition presented a unique opportunity to collect samples from 2,500m depth.

Research Groups Involved:

- Curtin Corrosion & Engineering Industry Centre
- WA Organic & Isotope Geochemistry
- Department of Environment & Agriculture
- Department of Spatial Sciences
- Trace & Environmental DNA Laboratory (TREND Lab)
- Centre for Marine Science and Technology



Prof Euan Harvey



Dr Ben Saunders



Dr Laura Machuca Suarez



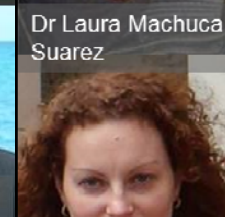
Prof Kliti Grice



Dr Petra Helmholz



Dr Michael Stat



Dr Katerina Lepkova



Assoc Prof Marco Coolen



Dr David Belton



Prof Michael Bunce



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Samples Collected

- Rusticles
- Water
- Sediment
- Biological



Images courtesy Curtin University and WA Museum. © WA Museum



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RUSTICLES

- Rusticles (rust-covered icicles) are mineralized structures, mainly composed of iron oxides and hydroxides and complex microbial consortia.
- Structure and form defined by the surrounding water column, type of steel and microbial activities (extract iron from steel at significant rates)
- Rusticles at shipwrecks continue to grow larger and denser thus indicating continuing deterioration of the wrecks.



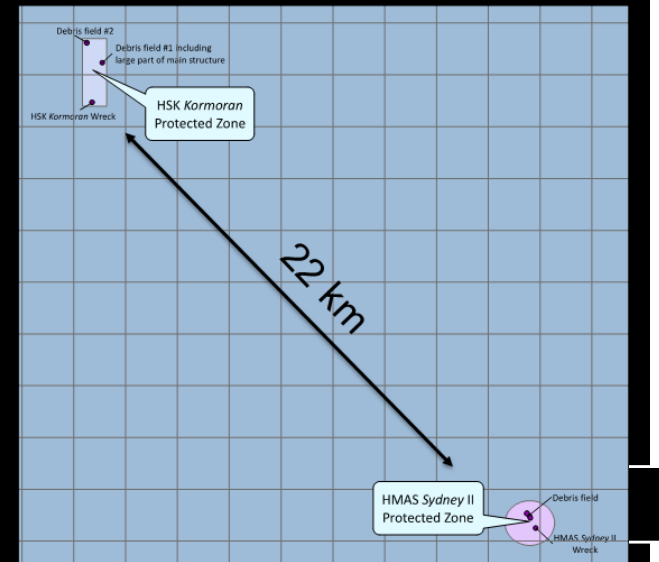
Image courtesy Curtin University and WA Museum. © WA Museum

HMAS Sydney (II) and HSK Kormoran provide unique opportunity to study rusticles from two different types of steel exposed to the same conditions for 74 years.

Samples collected from bows of both shipwrecks.

Conditions of exposure

Temperature	3°C
Dissolved oxygen level	~ 0.5 ppm
Pressure	250 bar
Salinity	3.4-3.5%
pH	7.7
Conductivity	48.2 mS/cm



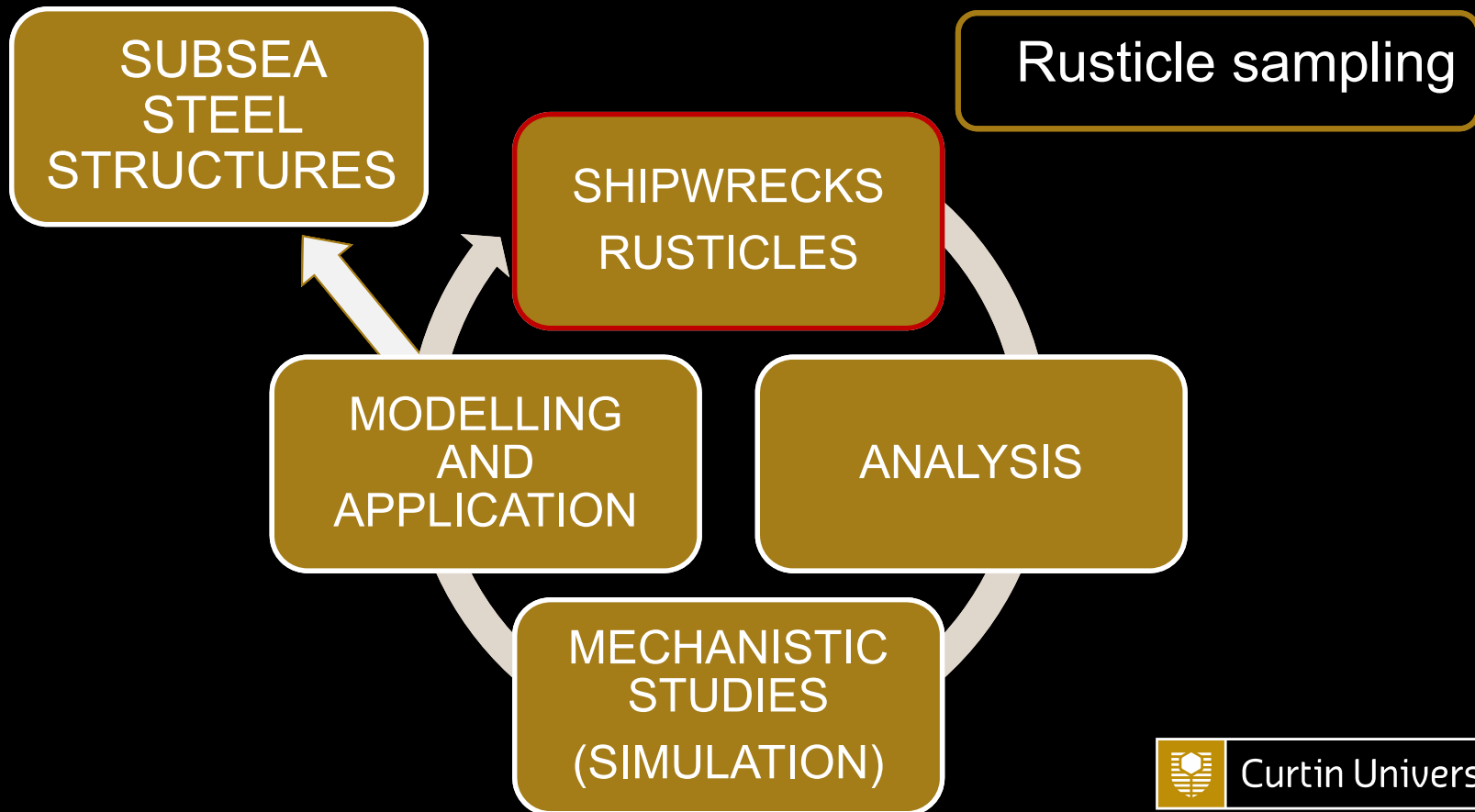
PROJECT AIMS

- Defining rusticle properties and composition. Understanding rusticle formations will allow for predicting deterioration mechanisms of the two ships.
- Modelling of deep water corrosion will be applied to preserve historical artefacts and sustain integrity of subsea steel structures, such as deep-sea oil and gas infrastructure.



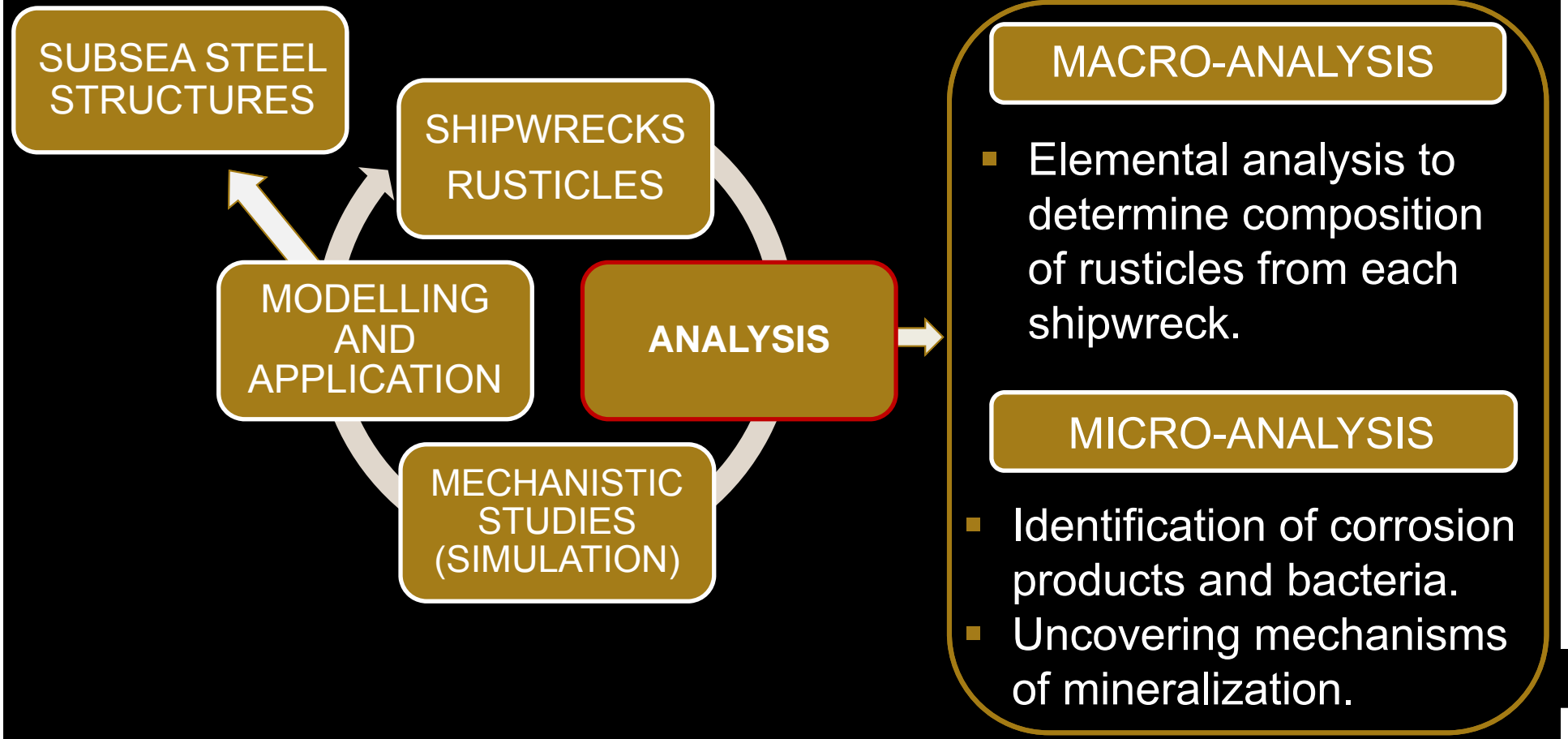
*Rusticle formations
on HMAS Sydney II*

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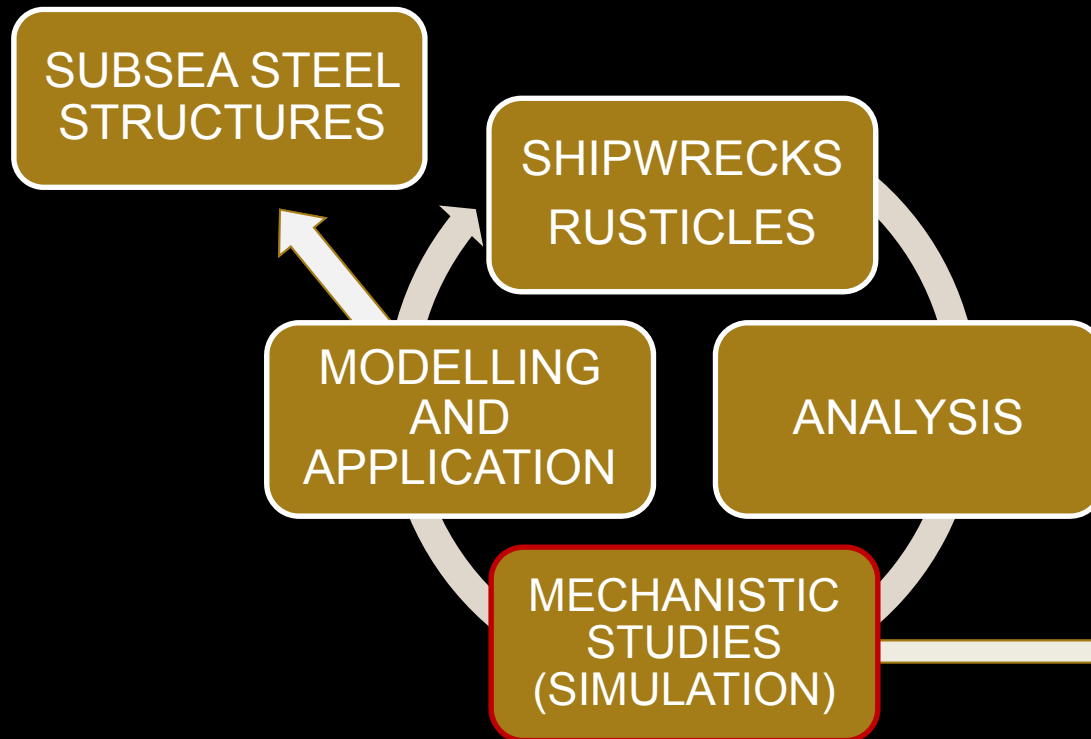


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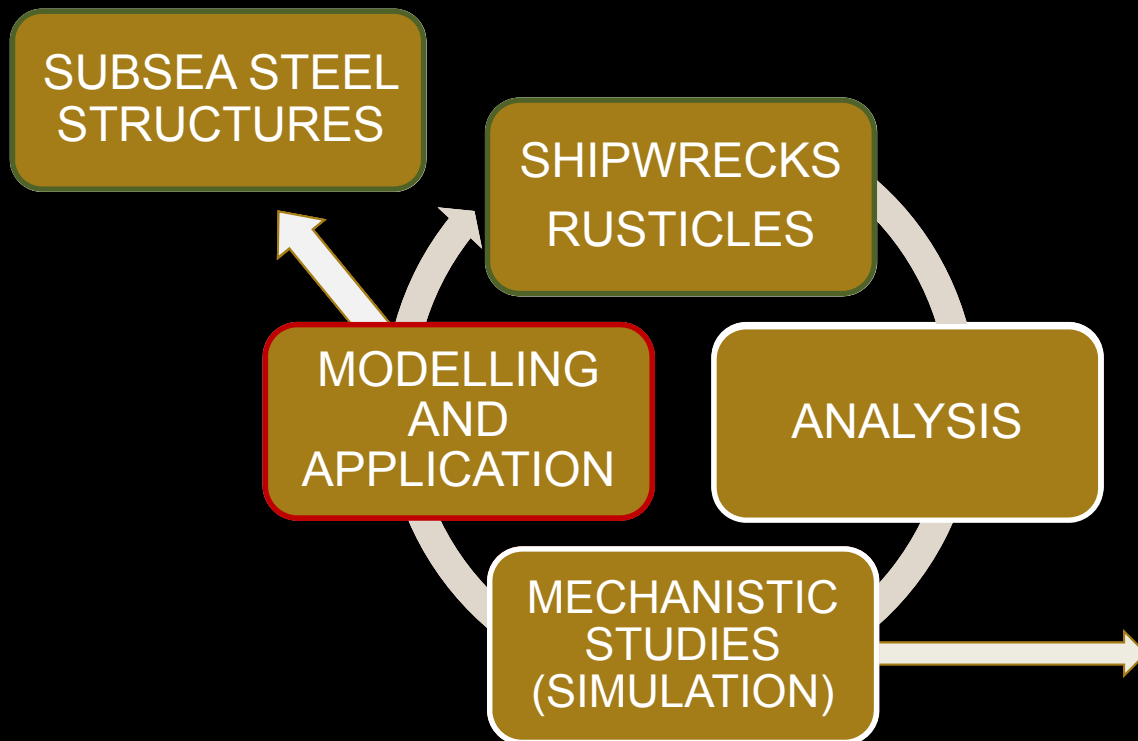


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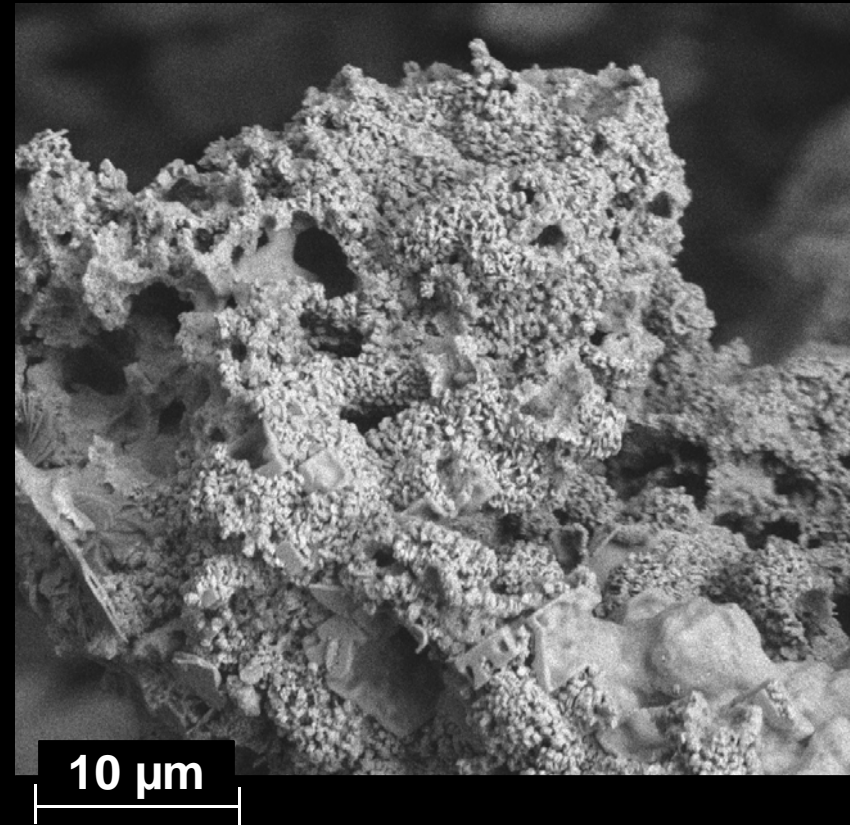
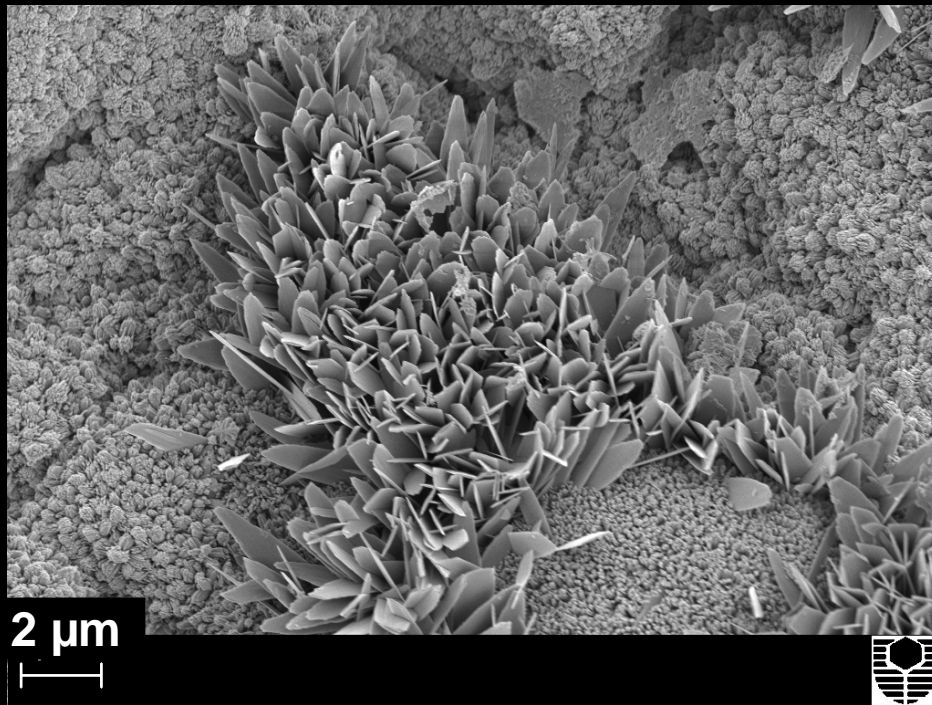
- Systematic study of corrosion processes under controlled conditions at laboratory scale.
- Simulating range of depths, from deep sea to shallow waters and in the presence of bacteria.

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RUSTICLE MICROANALYSIS



Corrosion products in rusticles of the HMAS Sydney II,
Machuca and Lepkova, 2015 (unpublished data)



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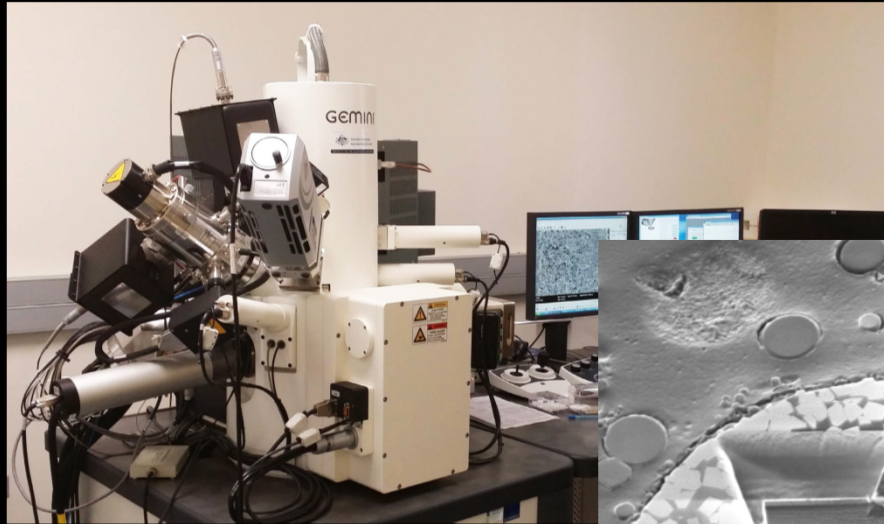
RUSTICLE ANALYSIS

Surface analysis techniques to identify corrosion products and understand mineralization processes:

- Electron microscopy with X-ray microanalysis
- Infrared spectroscopy
- Raman spectroscopy
- X-ray diffraction spectroscopy
- Focused ion beam spectroscopy
- Transmission electron microscopy

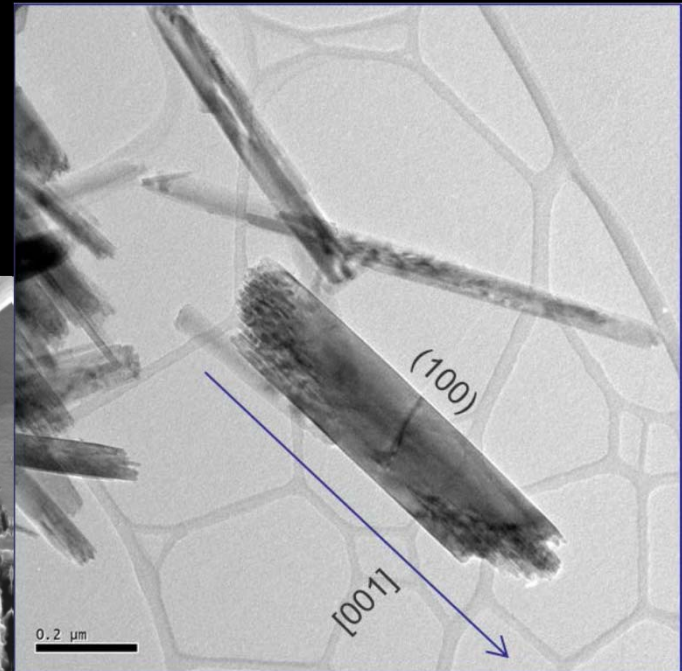
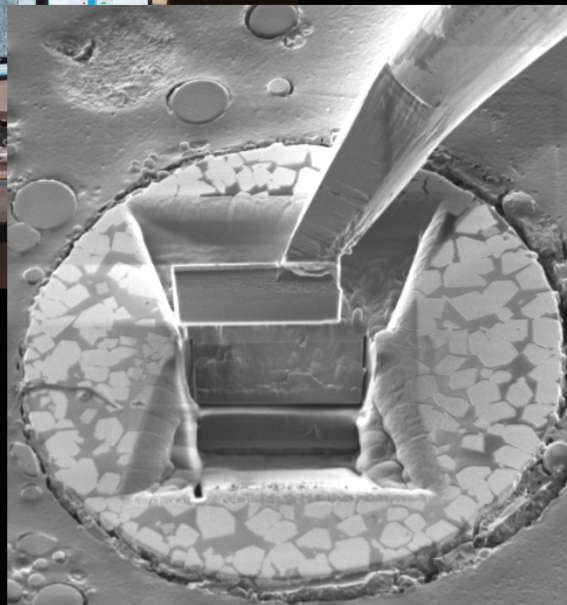


CORROSION PRODUCT PROPERTIES



Zeiss Neon 40EsB FIBSEM

Example of FIB-milled surface. Preparation of ultra-thin plates for TEM analysis.



Bright field image of a geothite crystallite growing along the c-axis.

Images from John de Laeter Centre, Curtin University.



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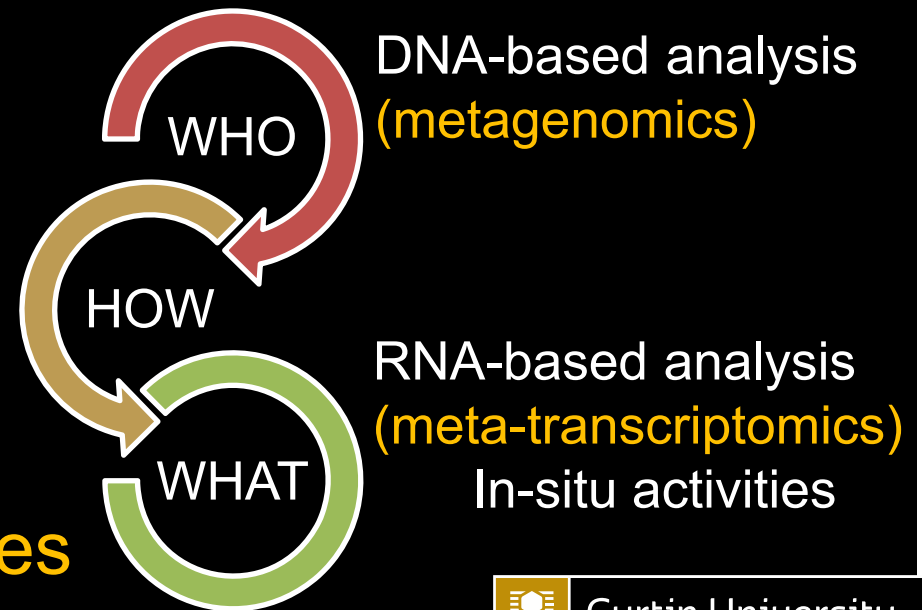
RUSTICLES: Microbiological analysis

Cultivation of microbes

- Cultivation of deep-water microbes for corrosion tests
- Isolation: Novel species?
- Characterization of species

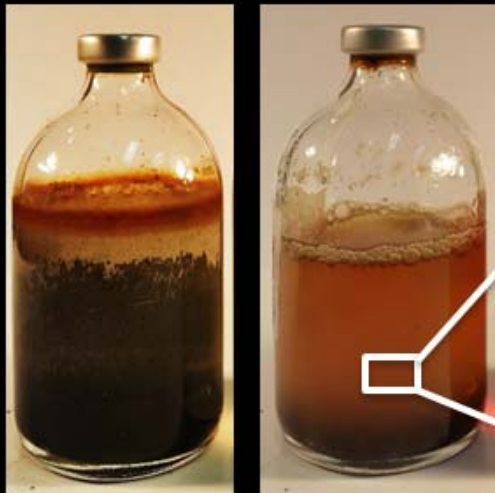
Imaging and High-Res studies

Genetic analysis

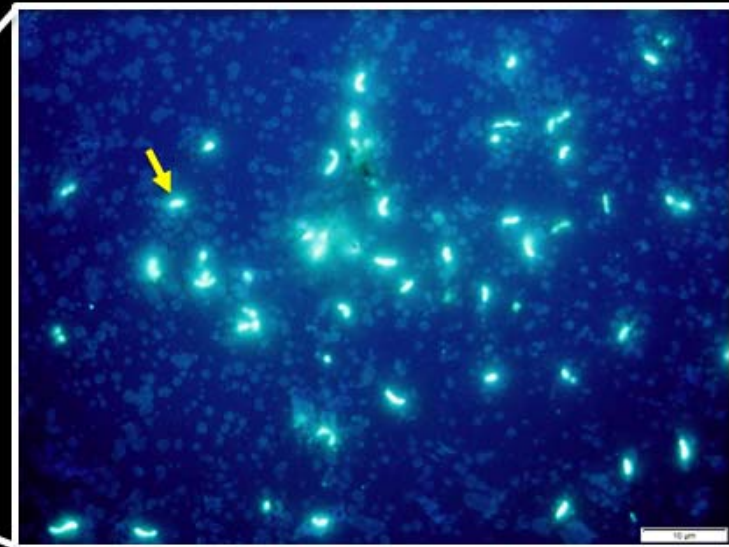


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Cultivation of microorganisms from rusticles at the Curtin Corrosion Engineering Industry Centre



Microbial cultures at 3 °C and 20 °C



Microbial cells stained with DAPI DNA fluorescent stain and imaged using fluorescence microscopy

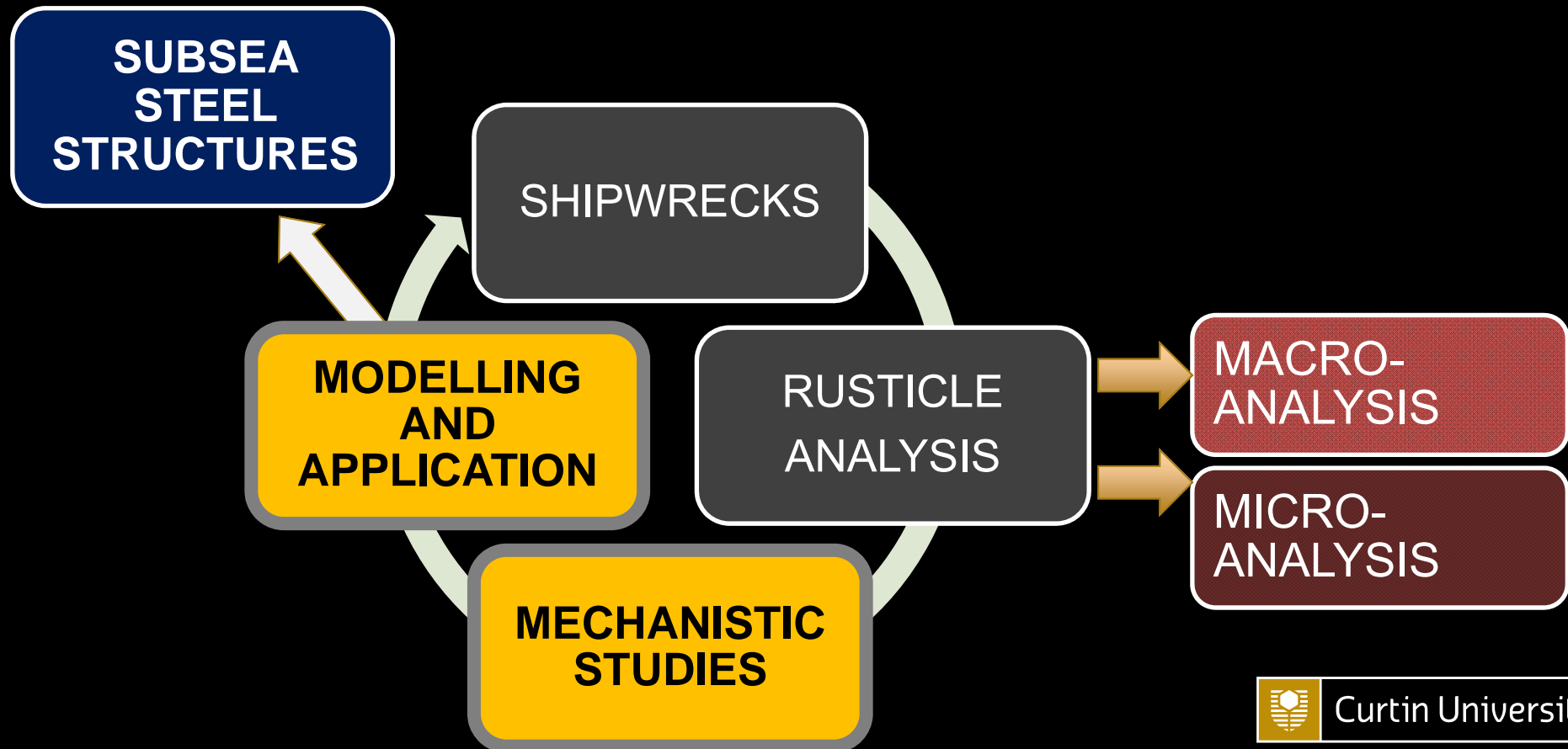
Genetic analysis

Microbial diversity in rusticles

- Around 100 different species of microorganisms have been identified in rusticles from the HMAS Sydney and HSK Kormoran
- Several uncultured unknown species
- The microbial consortium is different for the two shipwrecks



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Researchers – Rusticle Program

Dr. Laura Machuca Suarez, Microbiologist, Curtin Corrosion Eng. Industry Centre

Dr. Kateřina Lepková, Electrochemist, Curtin Corrosion Eng. Industry Centre

Prof. Brian Kinsella, Chemist/corrosion specialist, Curtin Corrosion Eng. Industry Centre

Dr. Ian MacLeod, Electrochemist/conservation Scientist, Executive Director, WA Museum

E/Prof. Wilhelm van Bronswijk, Department of Chemistry, Curtin University

Dr. William Rickard, Science leader, Curtin Microscopy and Microanalysis

Prof. Elizabeth Watkin, Environmental Microbiologist, Curtin Biosciences Research Precinct

Dr. Kylie Munyard, Molecular geneticist, Curtin Biosciences Research Precinct



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