THE UNIVERSITY OF SYDNEY

Geology & Geophysics Honours Projects

Honours project topics and supervisors available for 2020

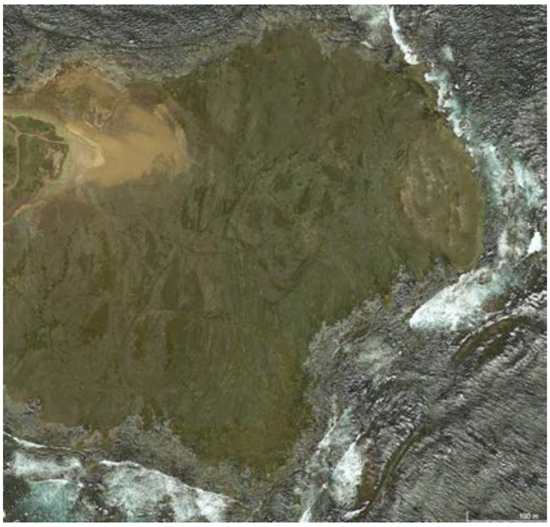
Faculty of Science, School of Geosciences

Contents

1 Honours projects

1.1.1 Earthquake fault mechanics in the Sydney Basin

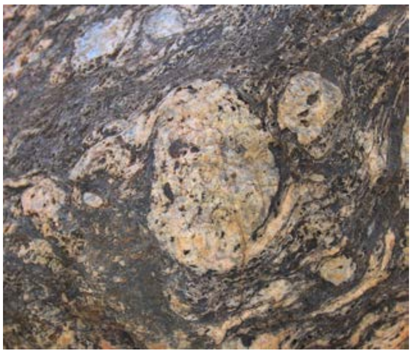
Supervisors: Vasilis Chatzaras vasilieos.chatzaras@sydney.edu.au, Patrice Rey patrice.rey@sydney.edu.au & Martyn Drury (Utrecht University)



Sydney Basin lies within a seismically active area experiencing earthquakes of magnitude 5.5 or greater. The recent discovery that the $300 million nuclear reactor at Lucas Heights is built on ancient faults, has raised public concern. Our limited understanding of earthquake mechanics in such sandstone-hosted faults, hinders quantitative assessment of seismic hazard. The goal of this project is to determine how fault zone architecture, fault rock type, fluid-rock interaction, grain cementation, and deformation mechanisms, influence the frictional strength properties of faults developed in sandstones. The student will perform a multi-scale analysis of fault zone structure, including outcrop scale characterization (cm-m) of faults within the Hawkesbury sandstone, and analysis of deformation processes in the micro-to nanoscale using X-ray and electron microscopy. The student will be part of an international research team from USyd and Utrecht University (NL). The project may include a possible research visit of the student at Utrecht University.

1.1.2 Kinematic evolution of the Redbank thrust zone, Central Australia

Supervisors: Vasilis Chatzaras vasilieos.chatzaras@sydney.edu.au



The Redbank thrust zone is a key structure for understanding intraplate orogeny in central Australia. It comprises a 7-10 km wide and more than 350 km long zone of anastomosing mylonites that has experienced a complex history of multiple reactivation events since the Proterozoic, and accommodated significant intraplate deformation leading to 25 km vertical and 40 km lateral offset of the Moho. This project aims to understand the three-dimensional deformation and kinematic evolution of this major shear-boundary, combining field and microscale (SEM-EBSD, X-ray CT, EPMA) data to reconstruct the tectonic evolution of this major intracontinental structure.

1.1.3 Mineralogical and chemical characterization of a suspected NSW meteorite

Supervisors: Vasilis Chatzaras vasilieos.chatzaras@sydney.edu.au & Geoff Clarke geoffrey.clarke@sydney.edu.au

Meteorites are extra-terrestrial objects that can provide important information for the formation and earlier history of the solar system. In this project, the student will be the first to study a suspected meteorite recently recovered in NSW. The student will conduct detailed characterization of the petrography, chemistry, and structure of the suspected meteorite, combining light microscopy (transmitted and reflected), and beam-based techniques (e.g., scanning electron microscopy, electron probe microanalysis, X-ray computed tomography, and X-ray diffraction). The aim of the project is to validate the first-order identification of the rock as a meteorite and to attempt a classification of the meteorite type.

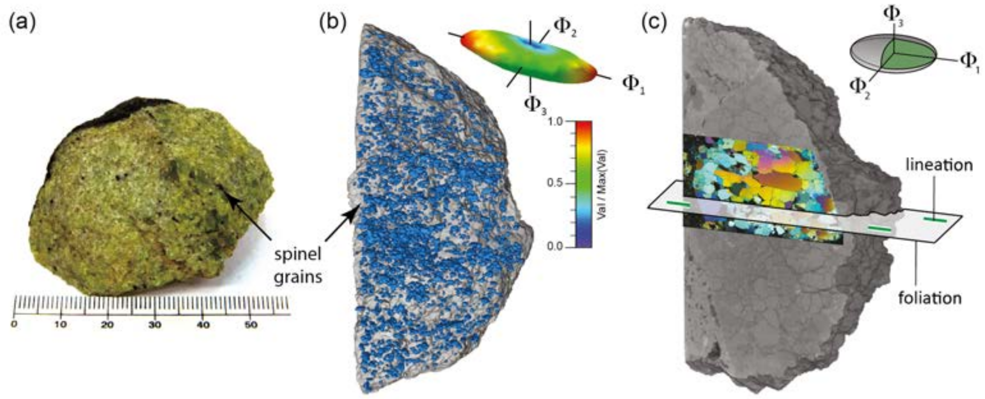
1.1.4 Formation of the mantle-crust transition zone in the New Caledonia forearc ophiolite

Supervisors: Vasilis Chatzaras vasilieos.chatzaras@sydney.edu.au & Derya Gurer (UQ)

The deformation processes during the formation of the mantle-crust transition zone in forearc ophiolites are still poorly understood. In this project the student will analyse rocks from the cumulate sequence of the New Caledonia ophiolite to understand their kinematic evolution, deformation mechanisms, and mechanical heterogeneity. The student will analyse crystal orientation data acquired with the Scanning Electron Microscope - Electron Backscatter Diffraction (SEM-EBSD) technique, to characterize the microstructure and mechanical properties of the rocks comprising the mantle-crust transition zone.

1.1.5 Deformation processes in a mantle shear zone in the Pindos forearc ophiolite, Greece (and a second, co-related project on earthquakes)

Supervisors: Vasilis Chatzaras vasilieos.chatzaras@sydney.edu.au, Basil Tikoff (University of Wisconsin-Madison) & Joshua Davis (Carleton College)

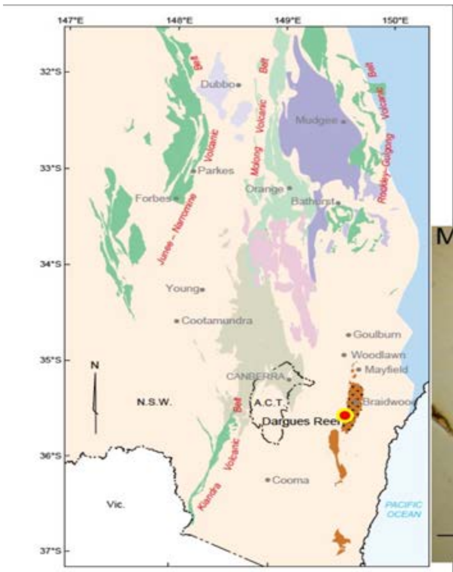


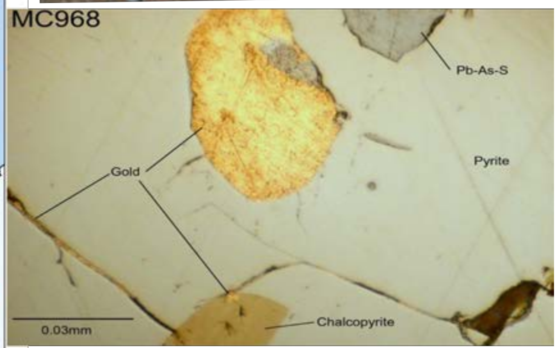
Project 1: One of the aspects of plate tectonics that has not been explored in detail is three-dimensional deformation in the Earth's mantle, particularly along plate boundaries. The aim of this project is to understand the distribution of three-dimensional strain within the oceanic lithosphere that formed in a subduction zone system. The student will use X-ray computed tomography, a non-destructive 3D imaging technique, to analyse the alignment and shape of minerals from rocks that formed in the Earth's oceanic upper mantle. These data will inform models of 3D mantle flow in subduction zones.

Project 2: Major earthquakes that nucleate in the seismogenic layer may cause non-steady state deformation and stress cycles in the Earth's upper mantle. Geological evidence for such earthquake-related episodic deformation in the upper mantle, is not well established. This project aims to identify structures in the microscale that formed during transient deformation events associated with stress change in the upper mantle. The student will analyse crystal orientation data acquired with the Scanning Electron Microscope - Electron Backscatter Diffraction (SEM-EBSD) technique, to characterize microstructures that were generated at different stress conditions in a fault zone that deformed the Earth's oceanic upper mantle. These data will allow us to build a picture of the seismic cycle in the oceanic lithosphere.

1.1.6 Gold in NSW

Supervisor: Derek Wyman derek.wyman@sydney.edu.au

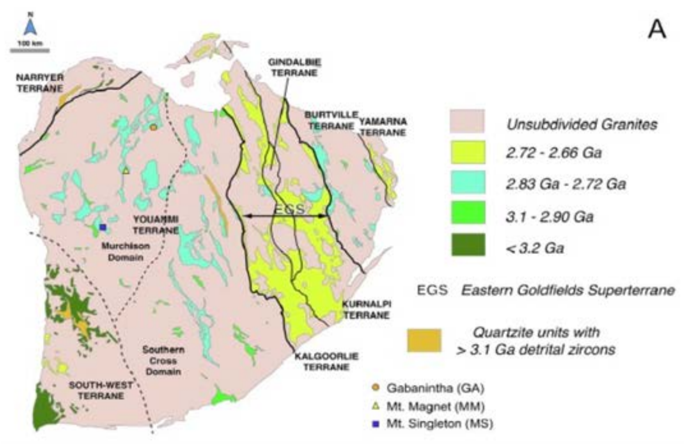




Gold was discovered at Dargues Reef (between Canberra and Batemans Bay) in 1851 and alluvial "pan" mining went on for decades. Now, the source deposit has been identified and will deliver its first gold brick in early 2020. After spending a couple of days on site selecting core, this Honours study will help to resolve questions about the nature of the deposit using geochemical data, petrographic study and microprobe analysis. The deposit is unusual in terms of both age and mineralization style and so will of interest to any students considering a career in the resources industry or other applied geochemistry-related fields.

1.1.7 New Perspectives on Archean Tectonics

Supervisor: Derek Wyman derek.wyman@sydney.edu.au



Western Australia's Yilgarn Craton

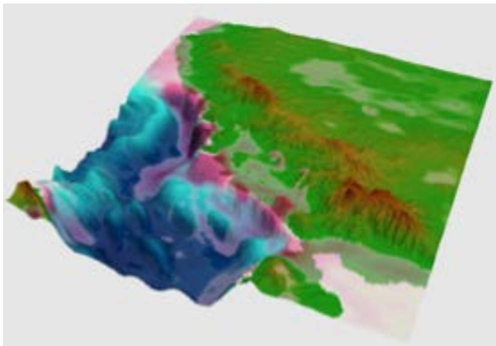
Over the last few years, tectonic models for Western Australia's Yilgarn Craton have been undergoing a dramatic revision. Given the Yilgarn's importance as an example of Earth's Archean proto-continents, these new results have major implications for our understanding of how plate tectonics emerged. The study will combine geochemical and petrographic analysis of 2.8 billion-year-old rocks to contribute to the revised stratigraphic and tectonic framework that is being developed for the western Yilgarn.

2 Honours projects available through the Earthbyte group

2.1.1 How climate and subsidence control the sedimentation along the Norwegian Margin?

Supervisors: Claire Mallard claire.mallard@sydney.edu.au, Tristan Salles tristan.salles@sydney.edu.au, Sabin Zahirovic sabin.zahirovic@sydney.edu.au & John-Are Hansen

The North Sea Basin and associated Norway margins record extensional tectonic events from the Paleozoic to the Early Cretaceous. A major subsidence phase followed this rifting event throughout the Late Cretaceous and Cenozoic, punctuated by basin inversion episodes during the Paleogene. Both complex tectonic and successive glacial episodes make it hard to understand the evolution of the source to sink systems along this margin from pre-rift to the present day.



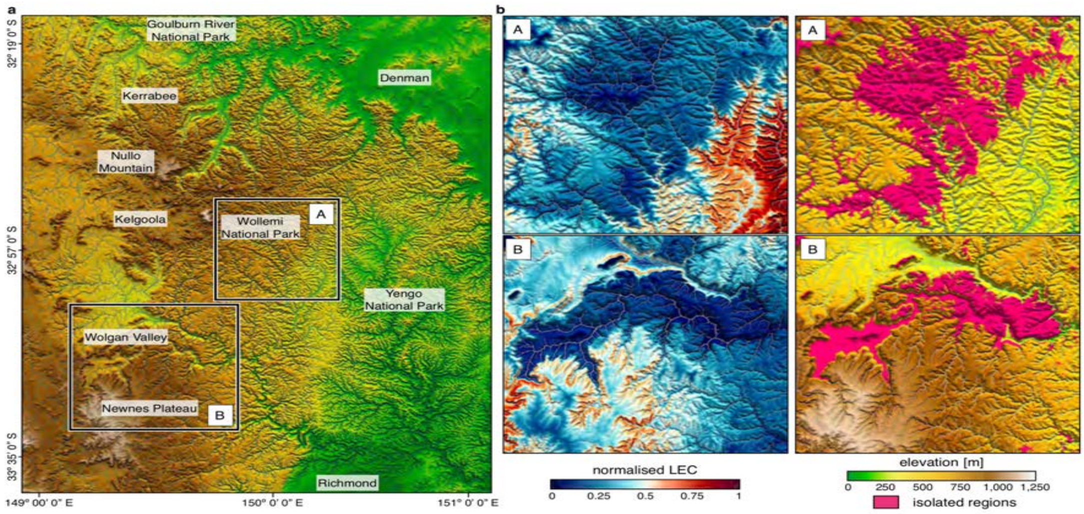
Pre-rift sedimentation is characterized by large Jurassic deltaic systems built out in the sea between Norway and Greenland. Then, in the Late Jurassic and Early Cretaceous, significant continental rifting and crustal thinning events occurred inducing a substantial change of depositional facies from deltaic to deep environments. After break-up, glacial events also affected the region resulting in new changes in depositional environments. A model of passive thermal subsidence enhanced by sediment loading in the central North Sea and marginal uplift of the Norwegian landmasses has been proposed. Nevertheless, the role of continued regional and local tectonic activity on the break-up sedimentation is still debated and the timing of onset of glaciation in the Cenozoic, especially for the Quaternary, remains unclear.

The goal of this project is to characterize the processes providing a fundamental control on the drastic changes of depositional environments and sediment fluxes during the rifting history of the Western Norway margin.The first step is to understand the post-rifting sedimentation and how the latest glacial events affected the succession of depositional environments along the Western Norwegian margin. We will use a regional model of the past 30 Ma to test different climate forcing to determine the most realistic ones. The next investigation will focus on the break-up event and how the delta systems are building out into an epicontinental sea between Norway and Greenland, which evolved into the thick Cretaceous shale units. A range of generic models will be designed to test the subsidence scenarios supported by the literature to determine if they allow the same accumulation and depositional environment evolution than on the actual margin. This project is aligned with the Basin GENESIS Hub and will involve collaboration with the oil company Equinor.

2.1.2 How is landscape complexity driving biodiversity over geological time scales?

Supervisors: Patrice Rey patrice.rey@sydney.edu.au & Tristan Salles tristan.salles@sydney.edu.au

Mountainous landscapes have long been recognized as potential drivers for genetic drift, speciation and ecological resilience. Yet, there is a lack of clarity on the mechanisms and processes linking landscape complexity to biodiversity over geological time scales.



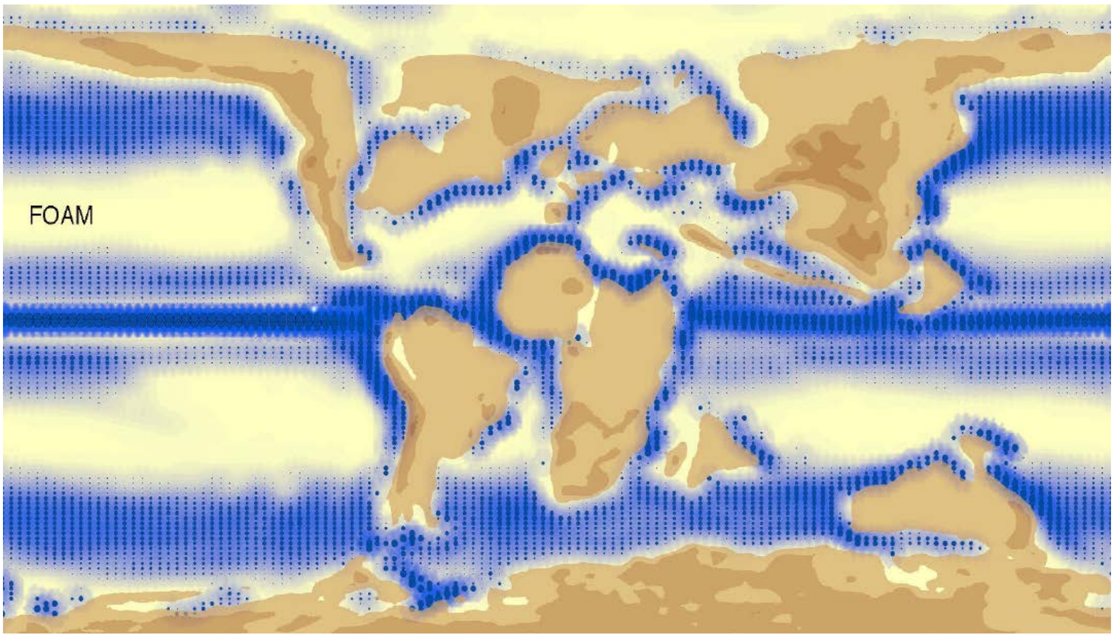
Application of the landscape complexity proxy on the Blue Mountains region (a) highlighting regions of high LEC (i.e. higher biodiversity in b-left) and high isolation (i.e. higher speciation and endemism in b-right).

In most studies, landscape complexity has often been overlooked with species richness evolution only quantified over static landscapes. Consequently, we are still missing a fundamental understanding of how tectonic and surface processes convert landscapes of low elevation and relief, low environmental gradients and continuous habitats, into topographically complex regions of high relief with steep environmental gradients, and fragmented habitats.

Recently a new numerical approach has been proposed to assess and quantify drivers of biodiversity, speciation and endemism over geological time scales. The method is a direct measure of landscape complexity and seems to explain - to the first order - biodiversity in mountainous regions over synthetic landscapes. In this project, we propose to use this new capability (already developed in Badlands) to test its applicability over a range of different mountainous landscapes around the world. From comparisons with available biodiversity dataset, the project will estimate under which conditions this new landscape complexity proxy is a good predictor of species richness. The project outcomes could potentially lead to reassessment of the spatial viability of existing biodiversity conservation sites and could help improve future conservation planning, policy and practice.

2.1.3 Oceanic upwelling and the distribution of deep-sea organic carbon since the Cretaceous Period

Supervisors: Adriana Dutkiewicz adriana.dutkiewicz@sydney.edu.au & Dietmar Müller dietmar.muller@sydney.edu.au



Late Cretaceous upwelling intensity at 90 Ma modelled using the FOAM climate model.

The distribution of sedimentary organic matter in the ocean basins through space and time is of fundamental importance to the global carbon cycle. Deep sea sediments represent an important sink of organic carbon, while subduction of organic carbon contributes to subduction zone degassing of carbon back into the atmosphere. A major challenge is to better constrain the processes that controlled organic carbon production and burial and its consequences for marine biogeochemical cycles. Upwelling of nutrient rich deep water is the primary mechanism driving surface ocean productivity and carbon burial. A secondary process is the influx of terrigenous organic matter to the oceans from the continents. Previous work on organic matter accumulations in deep sea sediments as "black shales" has led to a hypothesis that optimal conditions for black shale deposition should occur where in the outer tropical climate zones and in areas of coastal upwelling with strong forcing by surface winds (Wagner et al., 2013).

This project is designed to test this hypothesis by combining the outputs of a set of global climate-ocean models run using the Fast Ocean Atmosphere Model (FOAM) with deep-sea sedimentary organic carbon data from ocean drilling sites. Climate model outputs include predicted grids of the past distributions and intensity of upwelling through time as well as water runoff from the continents. The objective is to determine spatio-temporal correlations between total sedimentary organic carbon content with key parameters such as the predicted upwelling intensity and latitude, proximity to continents, including whether continents occur to the west or the east of a given region (upwelling tends to be more pronounced along eastern boundary currents) and regional continental runoff. This will lead to a predictive approach for mapping the reservoir of deep-sea organic carbon through time, as well as its subduction flux. The methodology will build on those developed for oceanic crustal carbon and sedimentary carbonate carbon reconstructions in the EarthByte Group. This project will involve collaboration with Prof Christopher Scotese (Director, Paleomap Project) and assistance with workflow development by Michael Chin, and will lead to further opportunities as part of the Basin Genesis Hub and the EarthByte Group's work on deep carbon and long-term climate change.

References

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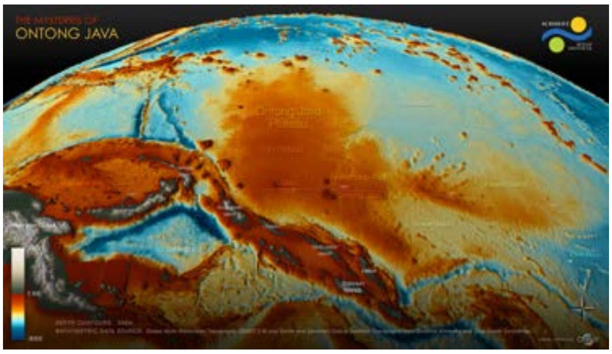
2. Müller, R.D. and Dutkiewicz, A., 2018. Oceanic crustal carbon cycle drives 26-million-year atmospheric carbon dioxide periodicities. Science Advances, 4(2), p.eaaq0500.
3. Wagner, T., Hofmann, P., & Flögel, S., 2013, Marine black shale deposition and Hadley Cell dynamics: A conceptual framework for the Cretaceous Atlantic Ocean. Marine and Petroleum Geology, 43, 222-238.

2.1.4 Vertical motions of the Tasman and Coral Sea: possible link to Ontong Java Plateau collision?

Supervisors: Maria Seton maria.seton@sydney.edu.au & Jody Webster jody.webster@sydney.edu.au



The collision of the world's largest Large Igneous Province, the Ontong Java Plateau (OJP), with the Melanesian Arc is proposed to have caused subduction polarity reversal along the South Solomon Trench, leading to a cascade of events such as a change in direction of the Australian plate, ore-deposit formation along the Melanesian Arc, and possibly a reorganisation of the entire plate-mantle system. Although this major tectonic event is well-recognised in the literature, determining the timing of plateau accretion is difficult as three independent approaches (palaeomagnetics, marine geophysics and onshore geology) yield timings that differ by over 30 million years.

In this project, you will use a novel and multi-disciplinary approach to explore the far-field effect of this collision on the vertical motions of the submarine seamounts and ridges in the Tasman and Coral Seas. You will integrate age and paleo-environment data from recently collected sedimentary samples and construct alternative plate kinematic models of the OJP collision in GPlates. The reconstructions will be fed into geodynamic models of mantle structure and the dynamic topography predictions will be compared to your paleo-environmental data. This project involves collaboration with colleagues from the University of Wollongong.

2.1.5 How has subduction influenced the opening of the Drake Passage?

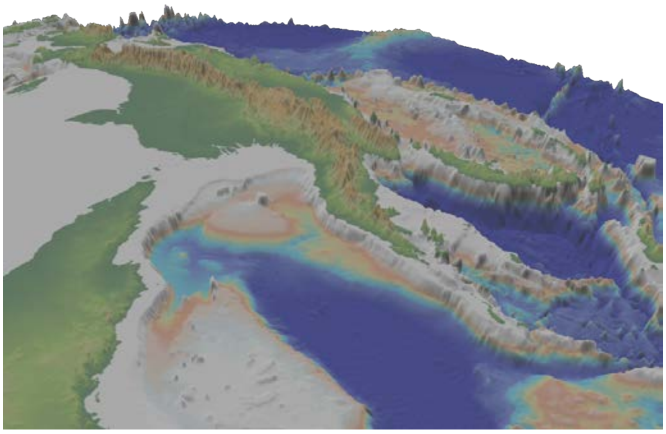
Supervisors: Maria Seton maria.seton@sydney.edu.au & Dietmar Müller dietmar.muller@sydney.edu.au

Oceanic gateways are narrow connections between neighbouring oceans and focal areas for the large-scale exchange of water, heat, salinity and nutrients between ocean basins. Their opening and closure, which is largely driven by plate tectonic processes, is thought to be responsible for abrupt climate shifts by altering ocean circulation leading to a change in the distribution of heat, moisture and CO_2 in the world's oceans and atmosphere. However, understanding the relationship between tectonics and climate is strongly dependent on accurate reconstructions of gateway morphology and their margins, which remain poorly constrained.

In this project, you will explore the relative role of subduction on the Drake Passage and its margins and examine how subduction processes such as back-arc opening and slab window formation may have influenced both the timing of deep-water flow between the Pacific and Atlantic Oceans and the signatures indicating continental separation from the geological record. As part of this project you will develop a new set of plate reconstructions with a particular focus on incorporating the subduction history of southern South America and the Antarctic Peninsula, map the migration of slab windows and create a series of paleobathymetry and palaeoelevation models for the region. You will develop skills in plate tectonic modeling and data synthesis and learn software tools such as *GPlates, ArcGIS* and *GMT*. This project could be a catalyst for further studies in using your results as boundary conditions into paleoclimate modelling software.

2.1.6 The tectonic and surface process evolution of Papua New Guinea

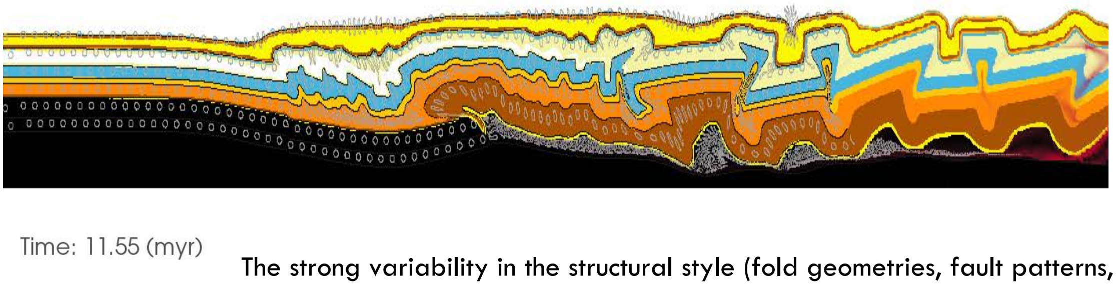
Supervisors: Sabin Zahirovic sabin.zahirovic@sydney.edu.au & Dietmar Müller dietmar.muller@sydney.edu.au



The New Guinea margin has experienced a complex tectonic history due to the convergence between the Indo-Australian, Eurasian and Pacific plates since the breakup of the Pangea supercontinent. The inaccessible terrain in Papua New Guinea, coupled with poor rock exposure due to extreme weathering in the tropical humid belt, result in poorly-constrained models of the regional tectonic and topographic evolution. However, the Papuan Fold and Thrust Belt and the Gulf of Papua host some of the world's most promising energy resources, meaning that the latest modelling approaches must be applied to help demystify the nature and chronology of major tectonic events that have shaped the region. Tectonic reconstructions in *GPlates* that include end-member estimates of lithospheric deformation will be linked to landscape evolution models in *Badlands*, with additional time-evolving boundary conditions applied from *CitcomS* mantle flow models. The timing and magnitude of (Eocene or Oligocene) deformation related to the collision on the Papuan Peninsula, as well as the Late Cretaceous to Eocene rifting in the western Coral Sea, will inform the time-dependent tectonic topography boundary condition applied to the *Badlands* models. The predicted stratigraphy will be compared to interpretations of regional seismic sections with the aim of identifying the most plausible tectonic scenarios, as well as help inform paleogeographic interpretations and resource exploration for the north-eastern margin of the Australian continent. This project is firmly aligned with the Basin GENESIS Hub, and will involve close collaboration with Oil Search who is our key industry partner for the New Guinea region.

2.1.7 The role of mechanical stratigraphy in the structural style and development of fold and thrust belts

Supervisors: Patrice Rey patrice.rey@sydney.edu.au & Luke Mahoney (Oil Search)

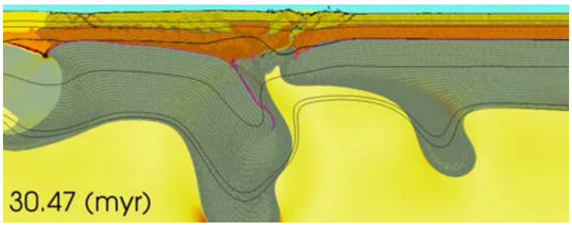


The strong variability in the structural style (fold geometries, fault patterns, etc.) of fold and thrust belts is in large part due to the rheological contrasts that can exist between evaporites, shales, sandstones, limestones and volcanic rocks that accumulate in sedimentary basins. The inversion, via forward modelling, of the structural style imaged through seismic methods, can help constrain the mechanical stratigraphy of basins. In this project, the student will use high-performance computers, and open source numerical codes such as *Underworld*. The aim is to define, via a simple inversion protocol, the mechanical stratigraphy of the fold and thrust belt in Papua New Guinea. This project is a collaboration between the *Basin Genesis Hub* and *Oil Search*, a Sydney-based oil and gas exploration company.

2.1.8 Lithospheric mechanical layering and mountain building processes

Supervisors: Patrice Rey patrice.rey@sydney.edu.au & Vasilis Chatzaras vasilieos.chatzaras@sydney.edu.au

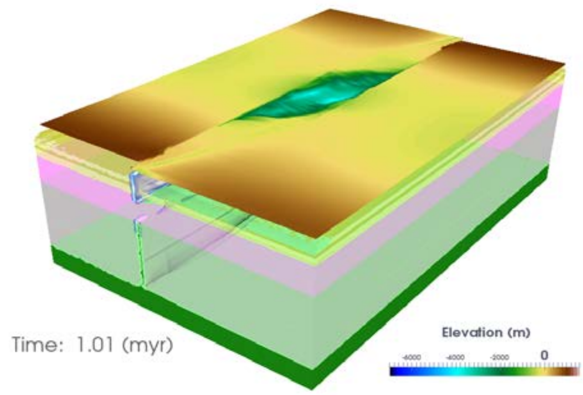
The topography of continents is the expression of geodynamic and tectonic processes deforming the continental lithosphere. How the continents deform depends on their mechanical properties and their thermal state. A number of rheological models have been proposed for the continental lithosphere varying from the "crème brulée" model, in which the strong upper crust stands above a much weaker lower crust and weaker mantle, to the "jelly sandwich" model, in which a much weaker lower crust separates the stronger upper mantle from the stronger upper crust. In this project, we propose to explore the role of the lithospheric mechanical layering on collisional processes. The candidate will design, run, analyse and compare simulations of continental collision involving a range of rheological layering. Results will be compared to a number of orogens including the Himalayas-Tibet and central Anatolia.



2.1.9 Effect of mechanical layering on lithospheric coupling in strike-slip fault systems

Supervisors: Patrice Rey patrice.rey@sydney.edu.au & Vasilis Chatzaras vasilieos.chatzaras@sydney.edu.au

Major strike-slip faults extend through the crust, offsetting the Moho, and may even offset the lithosphere-asthenosphere boundary. As such, these structures require some type of mechanical communication between crust and mantle. In this project we propose to explore the effect of the rheological structure of strike-slip fault zones on the mechanical interaction and degree of coupling between the different lithospheric layers (i.e. upper crust, lower crust, and upper mantle). You will run numerical models of deformation in lithospheric-scale strike-slip faults using a range of mechanical stratifications. You will compare the results of the simulations with observations from major strike-slip faults, such as the San Andreas fault (USA) and the North Anatolian fault (Turkey). High-performance computers, and open source numerical codes such as Underworld will be used to run the simulations. In this project you will develop skills in: 1) geodynamic modelling, and 2) analysis of deformation in transform settings.



Relevant literature

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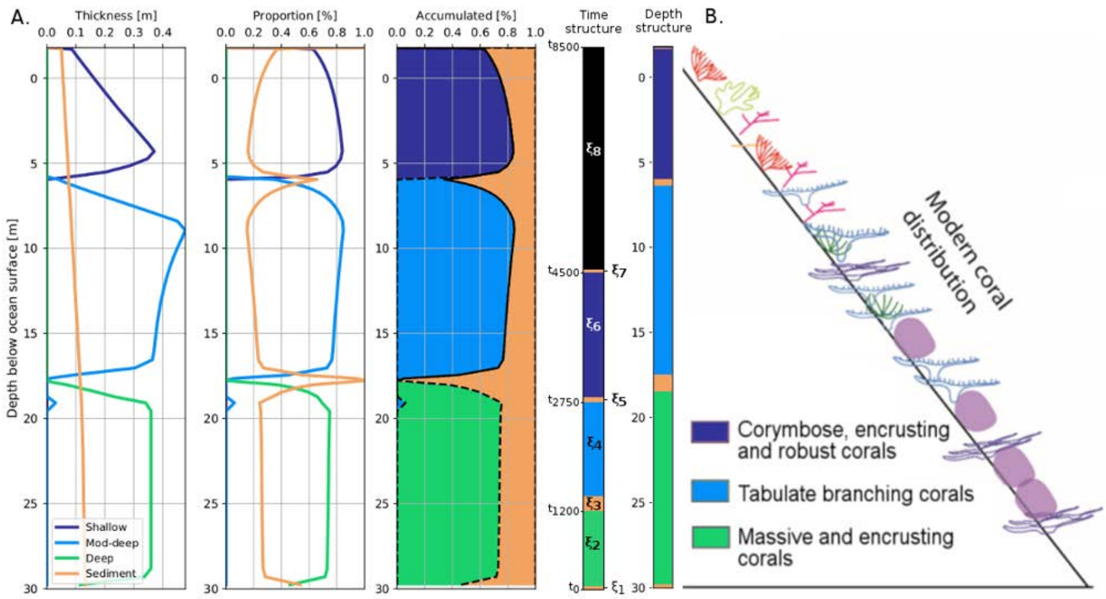
- Rey, P. F., Mondy, L., Duclaux, G., Teyssier, C., Whitney, D.L., Bocher, M. and Prigent, C., 2017. The origin of contractional structures in extensional gneiss domes. Geology, v.45, DOI: 10.1130/G38595.1.

2.1.10 Multi-core parallel tempering for extending BayesReef for modelling reef growth on geological timescales

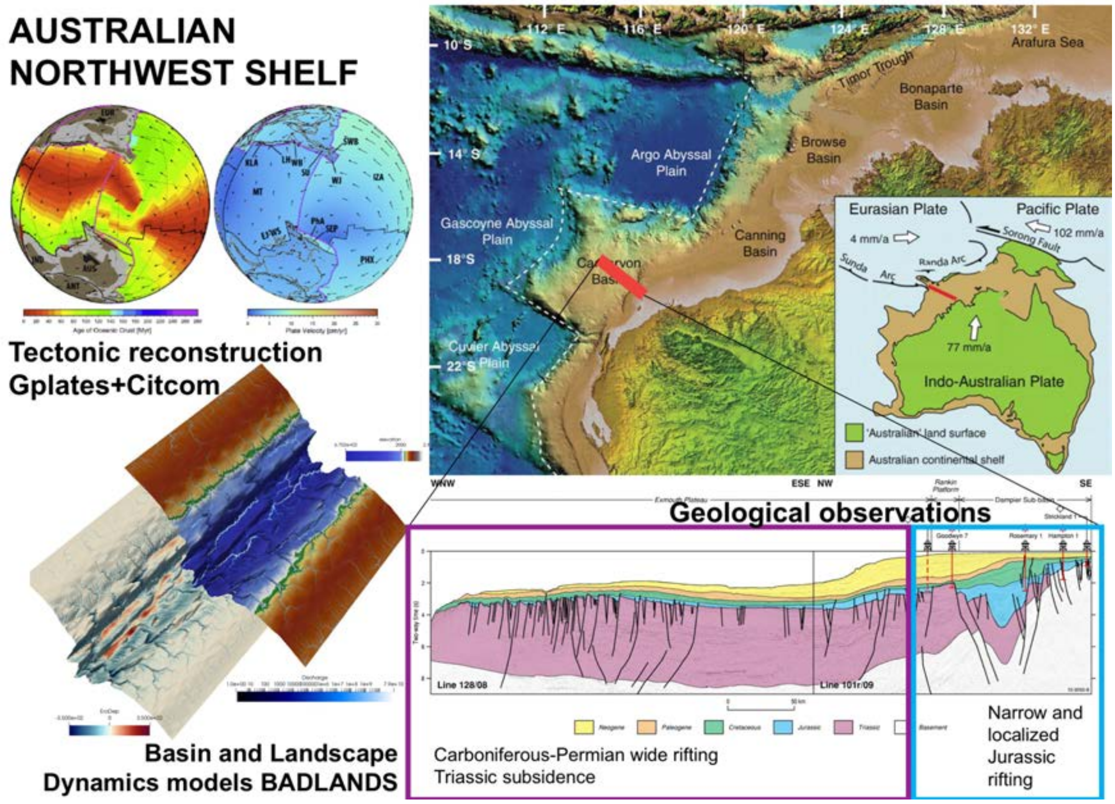
Supervisors: Rohitash Chandra rohitash.chandra@sydney.edu.au & Jody Webster jody.webster@sydney.edu.au



Estimating the impact of environmental processes on vertical reef development in geological timescales is a very challenging task. This is due to complex models and data with missing information. py-Reef Core is a vertical reef growth simulation model for geological timescales. BayesReef has been proposed to estimate and provide uncertainty quantification for py-Reef Core which features environmental condition parameters. BayesReef features limitations when the size of the problem increases due to computational requirements in sampling and hence only a few parameters were estimated. Parallel tempering (PT) is an advanced MCMC method suited for irregular and multi-modal distributions. Moreover, PT is more suitable for multi-core implementations that can speed up computationally expensive geophysical models. The Honours research project extends Bayeslands using parallel tempering to estimate dozens of parameters on a synthetic reef core dataset.

2.1.11 Understanding the link between plate tectonics and landscape-basin evolution

Supervisors: Sara Morón sara.moronpolanco@sydney.edu.au, Sabin Zahirovic sabin.zahirovic@sydney.edu.au, Tristan Salles tristan.salles@sydney.edu.au & Chris Elders (Curtin University)



Sedimentary basins capture the Earth's tectonic and landscape history and host a range of resources of critical importance for the continued functioning of modern society.

The sedimentary basins of the North West Shelf (NWS) of Australia contain an exceptional record of multiple phases of rifting associated with supercontinental breakup. These multiple rift phases which span from the Permian to Cretaceous exhibit contrasting structural and stratigraphic styles. This contrasting record offers an excellent opportunity to investigate the link between plate tectonics and landscape-basin evolution. This project will use a combination of (i) plate tectonic reconstructions, (ii) basin and landscape dynamics numerical models and (iii) a synthesis of geological observations to unravel the link between plate tectonics and landscape-basin evolution. Models will allow exploring (i) how temporal structural changes can be associated to changes in the direction of rifting, (ii) how variations in the stratigraphic record are the result of variations in the flux of sediments from the continent interior to the continental margin and (iii) the interaction between plate tectonics and landscape-basin evolution. This project provides an extraordinary opportunity to learn about tectonics and surface processes with cutting-edge software tools, which will give students a valuable set of skills that are important for both academia and industry.

2.1.12 Fingerprinting the closure of the Central American Seaway

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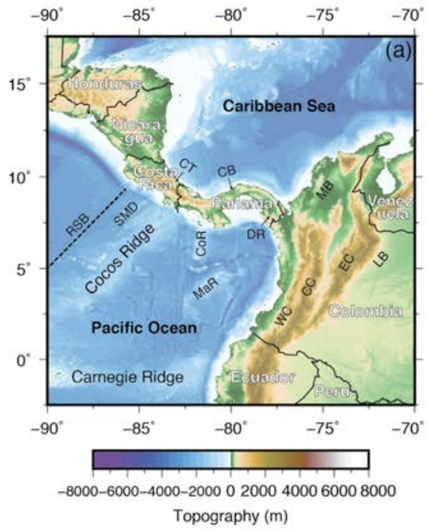
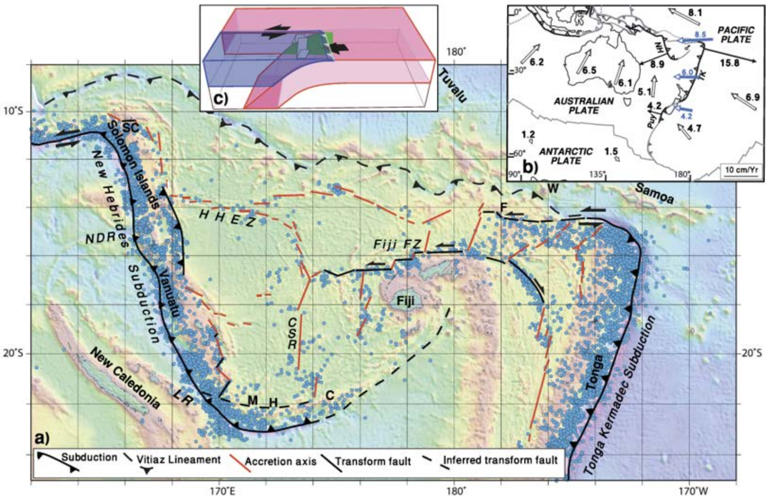


The Central American Seaway facilitated the exchange of water, heat, salinity and biota between the Pacific and Atlantic oceans. The closure of this oceanic gateway, at the Isthmus of Panama, has been attributed to the onset of northern hemisphere glaciation, the formation of North Atlantic Deep Water and the great biotic exchange between North and South America during the Pliocene. However, the timing of gateway closure is controversial with ages ranging from Paleocene-Eocene through to the Pliocene, requiring a rethink of our understanding of global ocean circulation patterns and biotic exchange through this gateway. You will attempt to address this controversy by comparing mapped fluvial systems from southern North America and northern South America with results from landscape evolution software, Badlands. You will acquire a wide variety of skills in data synthesis and numerical modelling (GPlates, Badlands, GMT). This project forms part of the ARC-funded Basin Genesis Hub.

2.1.13 A newly discovered plate boundary in the North Fiji Basin - why is it there ?

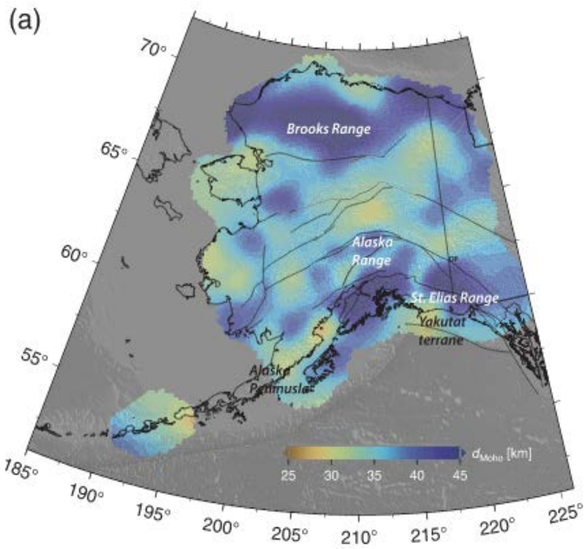
Supervisors: Maria Seton maria.seton@sydney.edu.au & Julian Giodmai



The most complex arrangement of mid-ocean ridges on Earth exists in the late Miocene-present North Fiji Basin. While many of the spreading centres have been mapped through a combination of earthquake focal mechanisms, high-resolution geophysical data, and direct sampling, others have been inferred. One such example is an accretionary axis close to the New Hebrides subduction zone. In this project, you will interpret newly collected marine geophysical data from the North Fiji Basin to map a newly discovered plate boundary and then use numerical experiments using Underworld to explore whether the collision of the Loyalty Ridge could led to the arrangements of plate boundaries we currently observe in the southwest North Fiji Basin. The results of the experiments will help inform on the dynamics of arc collision and overriding plate deformation. As part of this project, you will acquire skills in marine geophysical data analysis, GIS and numerical modeling. These skills will help prepare you for working in the exploration industry, consulting firms, government agencies or universities. This project will involve close collaboration with colleagues from the University of Melbourne.

2.1.14 Coupling pyGPlates with thermal diffusion models: a case study on how subduction rates impact the thermal regime in Alaska.

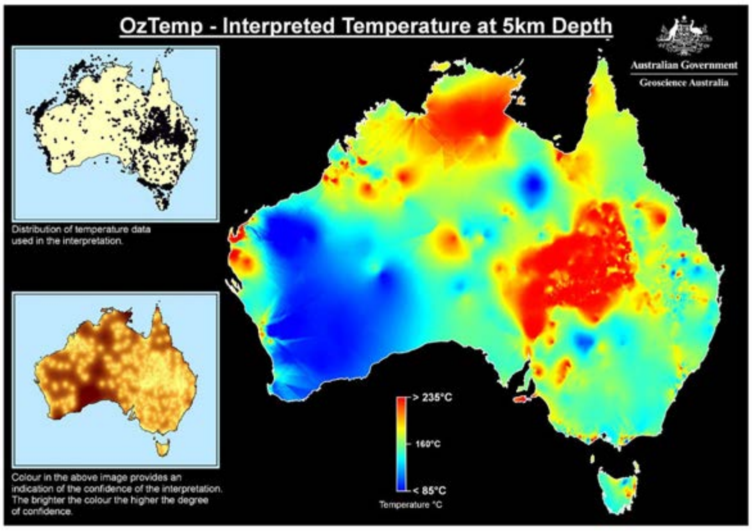
Supervisors: Ben Mather ben.mather@sydney.edu.au & Dietmar Müller dietmar.muller@sydney.edu.au



The present-day temperature distribution of the Earth's lithosphere inherits geological processes that have occurred tens of millions of years ago. Recent seismic data acquired in Alaska capture two horizons that obscure the Moho, which is probably related to interference with the eastward-subducting slab. In this project, the candidate will use pyGPlates to interrogate the position and velocity of the subducting slab through the last 80 million years and couple a simplified model of thermal diffusion to simulate the thermal evolution of the lithosphere. The region is currently thermally active, as shown by the presence of numerous hot springs, but very little is known about the composition of the lithosphere in Alaska. By merging pyGPlates with a model of thermal diffusion that assimilates multiple observations related to temperature (e.g. Curie depth, heat flow measurements, crustal thickness) the candidate will be able to quantify the present-day thermal regime to some degree of uncertainty. The project will develop the candidate's skills in the Python programming language and Bayesian inference. This project will be undertaken in close collaboration with researchers at the Australian National University in Canberra.

2.1.15 Inverting the present-day temperature distribution in Australian crust at unprecedented resolution.

Supervisors: Ben Mather ben.mather@sydney.edu.au & Dietmar Müller
dietmar.muller@sydney.edu.au



Understanding the thermal structure of the crust is key to informing regions that are desirable for geothermal exploration or hydrocarbon maturity. Furthermore, temperature is a requirement to ascertain the rheology of the crust to identify regions that are more susceptible to deformation. Despite there being numerous attempts to characterise the temperature distribution in Australia, the thermal structure of the crust in Australia is relatively unknown. Most temperature maps ignore the geological complexity of different terranes and sedimentary basins within Australia and focus only in the top 5km of the crust. In this project, the honours candidate will invert the temperature of Australia's crust using high performance computing (HPC) infrastructure. The project will leverage an in-house Python code developed to efficiently find an optimal temperature solution, subject to available data, which also produces uncertainty estimates. This project will develop the candidate's skills in the Python programming language and Bayesian inference. This project will be undertaken in close collaboration with researchers at the Australian National University in Canberra.

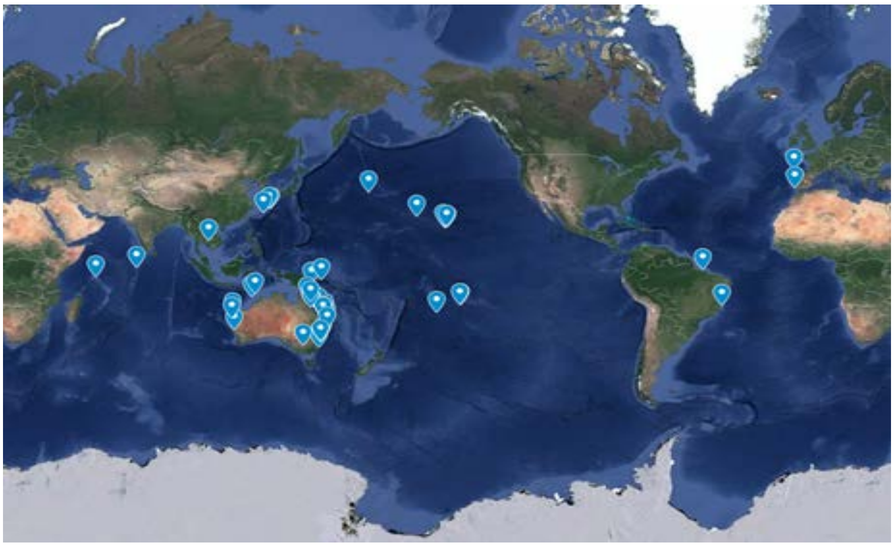
3 Honours projects available through the Geocoastal Research Group (GRG)

This is a non-exhaustive list of possible research projects in the Geocoastal Research Group (GRG). Please note that most projects can be tailored to suit your passion, expertise and research program (i.e., Honours, Master's, Phd), and that we might be happy to supervise you on a different project. Come and talk with us if you are interested in any specific project or other broad research theme.
By undertaking a research project with us, you will become a member of the GRG, while also interacting with other research groups within and outside of the school as relevant to your project. Our research students participate in our numerous field campaigns each year. Therefore, even if your project does not specifically include fieldwork, you will have plenty of optional opportunities to go to the field. In the last few years, we have had students participating in fieldwork campaigns in temperate and tropical coasts around Australia and the world.

Marine Science is a multidisciplinary research area, which at The University of Sydney mostly comprises Marine Biology and Marine Geosciences. Many of our projects on marine geosciences link directly with marine biology so your bio/geo background might be a strength!
Most importantly, with our research projects you can choose to learn a set of skills to suit your future and those include fieldwork skills, numerical modelling, coding, GIS.

Come join us on our quest to undertake Marine Geoscience all around the world!

http://grgusyd.org/



GRG's fieldwork sites around the world

3.1.1 Constraining the size of tsunami generated by the Wide Bay Submarine Landslide

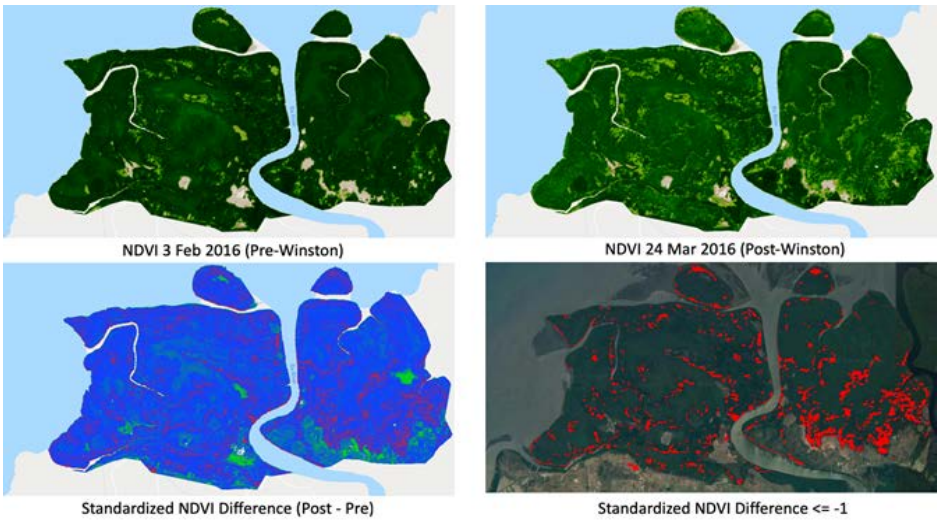
Supervisors: Tom Hubble tom.hubble@sydney.edu.au

Constraining the size of tsunami generated by the Wide Bay Submarine Landslide (Mid-Year start post-RV Investigator July-2020 cruise).

3.2 BLUE CARBON

3.2.1 Spatio-temporal patterns of coastal slatmarsh and mangrove biomass

Supervisors: Eleanor Bruce eleanor.bruce@sydney.edu.au & Kevin Davies kevin.davies@sydney.edu.au



Mangroves and saltmarshes are major sources of organic carbon that are important for global strategies to mitigate global warning. Global degradation and loss of these critical ecosystems have reduced organic carbon stocks potentially increasing release of CO_2 into the atmosphere. In addition, the ability of tidal communities, such as mangroves, to transgress inland under changing sea levels, will also impact on these environments. In urban environments, such as Sydney, coastal squeeze resulting from development pressures reduces the lateral space (accommodation space) for transgression of mangroves and other intertidal ecosystems. Assessing above ground carbon in mangrove and saltmarsh areas requires fine scale measurement of biomass. In the absence of detailed systematic field surveys, satellite and UAV borne sensors can be used to characterise patterns of aboveground biomass.

Current understanding of how saltmarsh and mangrove biomass varies across fine spatial and temporal scales and the drivers behind these trends is limited. This research project would contribute to methods for characterising spatio-temporal variability in biomass estimates in saltmarsh and mangrove communities in the Sydney Harbour and Parramatta River using ultra high-resolution UAV data, broader scale satellite imagery and field survey. This project presents an opportunity to work closely with industry partners involved in UAV and satellite data capture (Arbour Carbon) and other marine research institutes.

Research partners: ARC Training Centre for Cubesats, UAVs and Their Applications (CUAVA), Arbor Carbon, UWA Oceans Institute & Australian Institute of Marine Science (AIMS)

http://www.cuava.com.au/

3.2.2 Coastal ecosystem services, Tonga

Supervisors: Eleanor Bruce eleanor.bruce@sydney.edu.au, Kevin Davies kevin.davies@sydney.edu.au & John Duncan

Susceptibility to climate variability and extremes is acutely felt by many natural resource-dependent coastal communities of the South Pacific. Livelihood and food security in these environments are inextricably linked with coastal ecosystem health. Focused on mangrove ecosystems, this project would involve the use of Earth observation data to examine the influence of biophysical interactions operating in inter-tidal environments on local livelihood and food security in Tongan coastal communities. This would potentially involve integrating remotely sensed indicators of ecosystem status and qualitative information on subsistence usage patterns, fishing activities and land use practices, to investigate key socio-ecological system interlinkages and beneficiaries of coastal ecosystem services.

Funding is available to support field travel.
https://livelihoodsandlandscapes.com/fiji-and-tonga/

3.2.3 Mapping coastal seagrass ecosystems using high resolution remote sensing

Supervisors: Eleanor Bruce eleanor.bruce@sydney.edu.au, Kevin Davies kevin.davies@sydney.edu.au & John Duncan

Extensive meadows of seagrass in shallow coastal waters provide important ecosystem services that directly or indirectly benefit human needs, particularly in the stabilisation of nearshore sediments and as nursery grounds for commercial fish species. Previous research has shown that the spatial patterning and species present within seagrass meadows can influence the ecosystem service flows from these environments. For example, do well established meadows vs. areas comprising smaller colonising species provide habitat characteristics that support commercially important fish or stabilise sediments? There has been no systematic review of seagrass ecosystem service provision in the South Pacific. High resolution bathymetric (LiDAR) data and satellite imagery (Digital Globe) are available that cover extensive seagrass meadows in the nearshore area of Tongatapu, Tonga. Spatial modelling and remote sensing-based research on these coastal seagrasses can provide valuable insight on species composition, benthic substrates and other variables that influence the ecosystem service contributions for local communities.

Funding is available to support field travel.

3.3.1 Unravelling the trace element signatures of rare CO_2 traps

Supervisors: Bree Morgan bree.morgan@sydney.edu.au, Jessica Hamilton (ANSTO) & Siobhan Wilson (U Alberta)

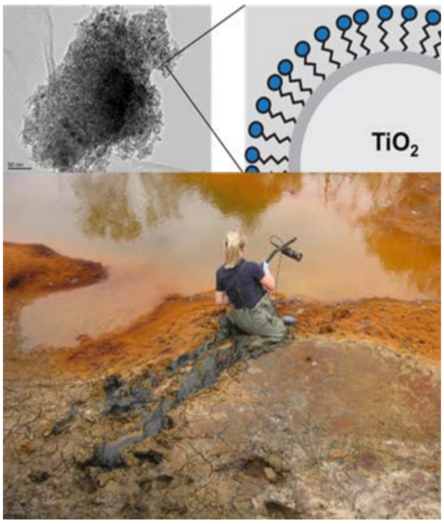
Highly-stable Mg-carbonate minerals, such as magnesite (MgCO3) and dolomite (CaMg(CO3)2), are ideal safe and permanent sinks for CO2, but their formation is kinetically restrained under Earth's surface conditions. Despite this, they are found as rare modern precipitates in ephemeral playa lake sediments in Australia and Canada. Their occurrence in both environments despite the extreme contrasts between geochemical, lithological, topographic and climatic conditions, provides the ideal natural settings to unravel the underlying mechanisms driving their formation.

Accumulation and fractionation of trace elements (including the rare earth elements) can provide powerful insights into biogeochemical processes and conditions impacting coastal sediments. In this Honors project, trace element signatures will be mapped in modern sediments containing both dolomite and magnesite, along with fringing microbialites, collected from the Coorong Lakes in South Australia, and the Cariboo in British Columbia. The aim will be to build on our fundamental understanding of biogeochemical conditions that drive the safe and permanent capture of CO2 in environmentally friendly minerals. This will be critical for innovating efficient and affordable carbon capture and storage strategies to mitigate the impacts of CO2 pollution and global warming. Additionally, this fundamental knowledge will substantially build our scientific understanding of carbonate sediments as a CO2 sink over geologic timescales.

3.4 COASTAL REMEDIATION, CHEMISTRY

3.4.1 Mining wastewaters and remediating coastal metalliferous drainage using synthetic sorption materials

Supervisors: Bree Morgan bree.morgan@sydney.edu.au & Jessica Veliscek-Carolan (ANSTO)



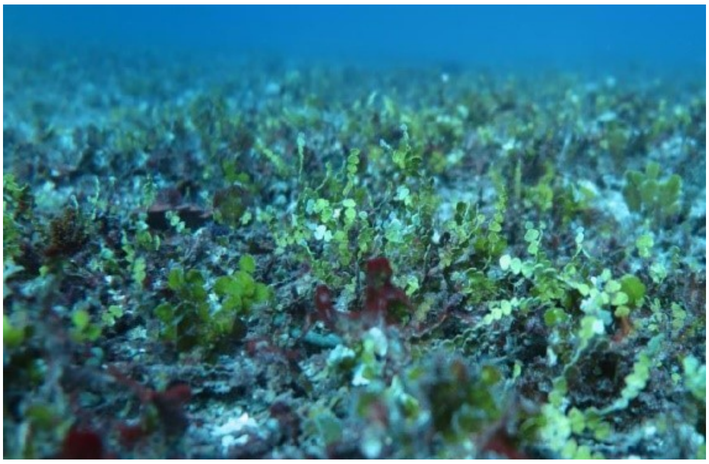
Acidic drainage from acid sulfate soils and mining activities is a considerable source of trace metal pollution to sensitive coastal ecosystems. Ideally, the treatment of metalliferous drainage would not only prevent the release of toxic metals to downstream environments, but would also recover and recycle them as a valuable resource for use in other industries. While materials have been developed for removal of toxic heavy metals from environmental waters based on polymers or silica, they are often unstable in the presence of acid. On the other hand, titanium dioxide (TiO2) is known to have a high affinity for trace metals when coated with specific ligands, and its stability over a range of pH conditions makes it a potentially ideal candidate for remediation of acidic metalliferous drainage. However, behaviour of this material in complex natural systems is poorly understood, and optimisation for metal uptake under a wide range of environmental conditions needs to be achieved. This project will combine laboratory and field experimentation to optimise functionalised titania as a stable trap for trace metals in drainage from acutely acidified coastal landscapes in Northern NSW. Research will be undertaken collaboratively between the University of Sydney and ANSTO (the Australian Nuclear Science and Technology Organisation). Interested students must be willing to travel to ANSTO, Lucas Heights, to conduct their laboratory work.

Project laboratory work will be conducted at ANSTO, Lucas Heights.
Possible AINSE $5,000 stipend available through competitive application.

3.5 CORAL REEF GEOMORPHOLOGY

3.5.1 HALO - Halimeda bioherm Origins, function and fate in the northern Great Barrier Reef

Supervisors: Jody Webster jody.webster@sydney.edu.au, Luke Nothdurft (QLD University of Technology) & Robin Beanab (UQLD)



Calcareous green macroalgae genus Halimeda

Calcareous green alga Halimeda is a major contributor to coral reef shelf sediments and is found along the entire Great Barrier Reef (GBR), Australia. Previous studies of extensive Halimeda deposits, or bioherms, show they represent important inter-reef habitats and potential carbon sinks in the GBR Marine Park, covering ~26% of the northern shelf, equal to the modern coral reef system. Pioneering work in 70-80s indicate the bioherms are in depths of ~20-40 m forming linear ridges and flat-topped mounds ~20 m thick.

However, new bathymetry data reveals a completely different picture of their morphology, characterised by complex reticulate (honeycomb-like) shapes and covering an area >3X original estimates. These new findings confirm the Halimeda bioherms are much larger and more complex than previously thought – challenging existing paradigms as to their origin, development and significance. We will study these enigmatic features, building directly on a recently funded (US$2.5 mill) RV Investigator cruise scheduled for May-June 2020. We will conduct high-resolution multibeam mapping, subbottom profiling, sediment coring and innovative seabed/habitat imaging (AUVs, ASV, ROV). This will increase our understanding of the fundamental processes that control bioherm development, and have direct implications for environmental managers tasked with predicting how these poorly studied inter-reef environments might respond to future climate change.

Note: multiple opportunities exist to join the voyage on the RV Investigator next year and then undertake post cruise research on the data and samples as part of your hons, Mphil or PhD project(s). The HALO project is also funded by an $150,000 grant from the Ian Potter Foundation to support pre- and post cruise activities and science.

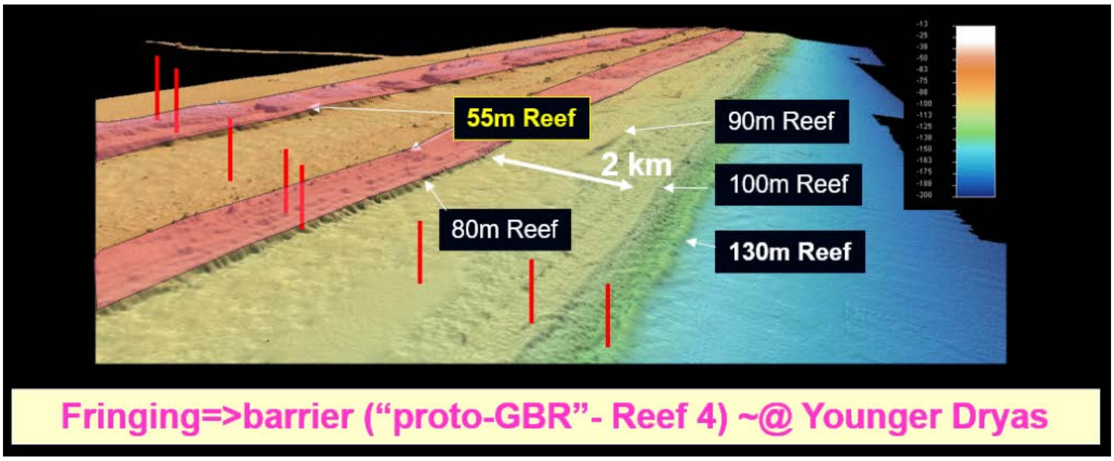
3.5.2 Morphologic evolution of the rubble cays at One Tree Reef

Supervisors: Ana Vila-Concejo ana.vilaconcejo@sydney.edu.au & Tristan Salles tristan.salles@sydney.edu.au

One Tree Reef in the Southern Great Barrier Reef has two rubble cays: One Tree Island is located on its SE corner, and Two Tree Island is located on its NE flank. They are both composed of unconsolidated sediment that is deposited under high energy conditions. We have a collection of remotely sensed images that can be used to determine the decadal evolution of the islands; we also have some annual measurements taken over the last few years using state-of-art techniques such as real time kinematic positioning systems and structure from movement remote sensing using kites. This project encompasses analysing the decadal and annual evolution of One Tree Island in relation with the wave climate and cylonic events.

3.5.3 Death by a thousand cuts: understanding the role of paleowater quality (high sediment & nutrient flux) in the growth and demise of the Great Barrier Reef over the past 30,000 years

Supervisors: Jody Webster jody.webster@sydney.edu.au, Dirk Erler (Southerb Cross University) & Greg Webb (UQLD)



Exp. 325 revealed that the Great Barrier Reef (GBR) had a complex and dynamic history of reef growth and demise over the past 30 kyr, characterized by five distinct reef sequences. Reef death occurred in two ways: subaerial exposure caused by sea-level fall or due to rapid sealevel rise and associated environmental changes. Previous work highlighted the importance of high sediment flux and poor water quality, rather than abrupt sea-level rise alone, in ultimately determining reef demise. The objective of this project is to investigate the role of paleowater quality (sediment and nutrient flux) had in controlling the evolution of the GBR over the past 30 ky. We will investigate fossil coral reef material for IODP Expedition 325 (Great Barrier Reef Environmental Changes) to: (1) reconstruct a unique, high-resolution record of sediment and nutrient flux to the reef using a suite of geochemical proxies (major trace and rare earth elements, nitrogen isotopes); and (2) relate the changes in paleowater quality to changes in reef communitie s, accretion and bioerosion, that ultimately led to reef demise. This project will greatly improve our understanding of the critical environmental thresholds that led to reef demise in the past and how reefs recovered after disturbances on different spatio-temporal scales.

Note: this project is funded by new ANZIC IODP Legacy grant to support analyses on the fossil core reefs cores.

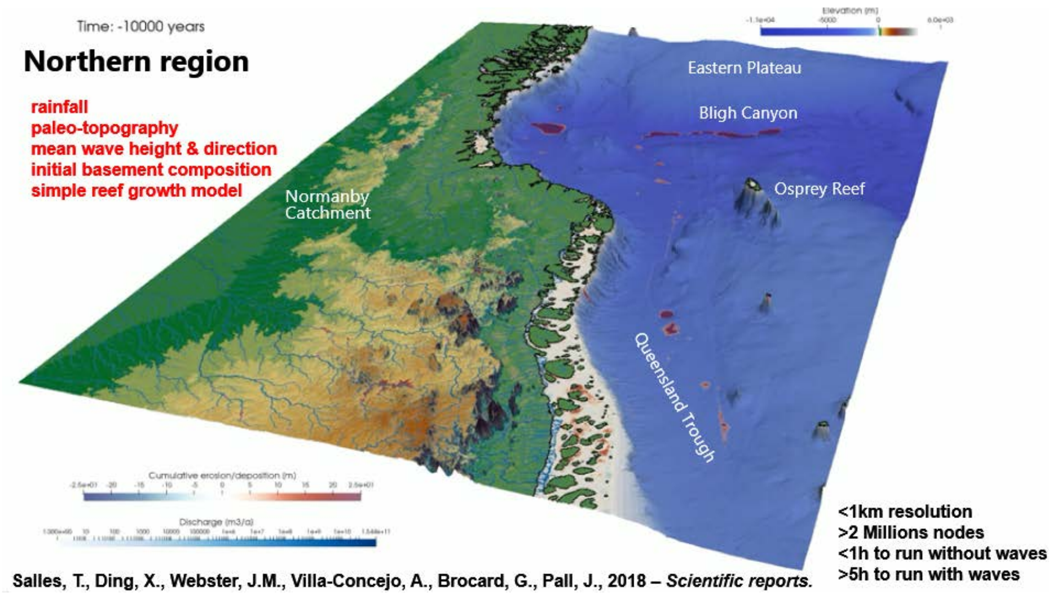
3.5.4 The origin of the Great Barrier Reef – when, where and why?

Supervisors: Jody Webster jody.webster@sydney.edu.au & Greg Webb (UQLD)

The origin of the Great Barrier Reef is still shrouded in mystery. The when, where and why of how this iconic reef system turned-on is still very poorly understood. You will integrate new and existing sedimentologic, biologic, geochemical, and chronological data sets from a unique suite of fossil reef cores from the GBR (Ribbon Reef 5, Boulder Reef) to explore the past evolution of the GBR in response to major global climate and environmental changes. Using a suite cutting edge analytical techniques, combined with a quantitative paleoecologic approach, will test a range of hypotheses put forward to explain the turn-on of the GBR (sea level, SST, sediment influx, upwelling etc). This will provide new insights into how the GBR ecosystem evolved over past 700 ka.

3.5.5 The lives and deaths of the Great Barrier Reef – combining data & models to understand the evolution of Australia's iconic reef

Supervisors: Jody Webster & Tristan Salles

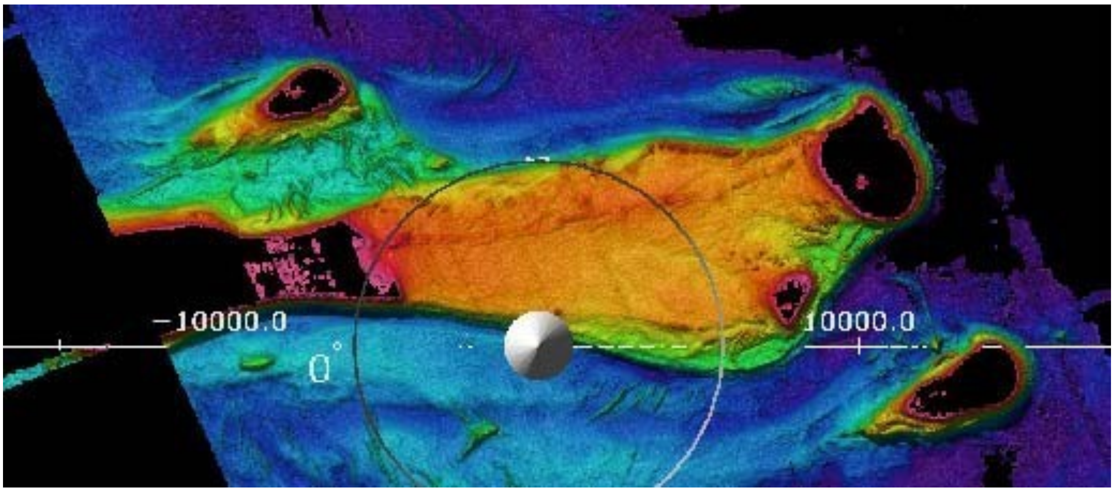


Predicting how the Great Barrier Reef (GBR) will respond in the face of future global climate changes is both poorly constrained and controversial. This relates to our incomplete understanding of how reef systems respond to environmental changes but also the lack of baseline data — particularly on centennial to millennial time scales. The study of the evolution of the GBR over past 500-600 ka can provide unique insights about how this iconic reef system responded to abrupt and major environmental changes over a range of spatio-temporal scales. In this project, you will integrate existing sedimentologic, biologic, geochemical, and chronological data sets from a unique suite of fossil reef cores from the GBR. Then you will use sophisticated modelling software (pyReef-Core) that predicts core stratigraphy, facies, and reef communities, in combination with innovative data sciences tools (BayesReef - bayesian inference computational algorithm) to optimize model inputs/parameters, to explore the past evolution of the GBR in response to major global climate and environmental changes.

Note: this project is part of the new DARE ARC ITTC and fully funded PhD scholarships are available to suitable candidates.

3.5.6 The last coral reef frontier - quantitative geomorphology of the modern Coral Sea reefs

Supervisors: Jody Webster jody.webster@sydney.edu.au & Tristan Salles tristan.salles@sydney.edu.au



High-resolution LADS bathymetry data from southern Great Barrier Reef showing reef and inter-reef areas (data source http://www.hyrdro.gov.au/aboutus/lads/lads.htm*)*

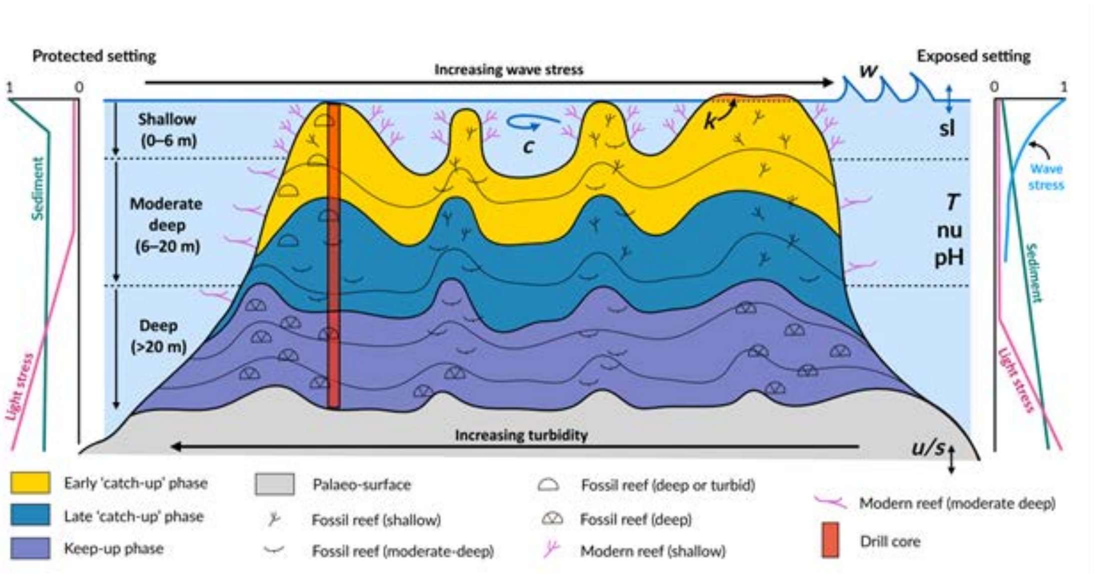
The project will investigate new and existing high-resolution remote sensing data (LIDAR & multibeam bathymetry data, aerial photographic imagery) to understand the main processes controlling the geomorphic variation of reef and associated environments in the largely unexplored reefs of the Coral Sea. Using advanced GIS and 3D visualization tools, we will develop a new quantitative morphologic characterisation of the reef and inter-reef areas (ie. terraces, banks, sediment wedges, channels, shoals, sand wave/dunes). We will also explore the relationships between the benthic habitats/sedimentary facies, the quantitative geomorphic data and physical processes operating in the Coral Sea. This project could also incorporate sophisticated new numerical reef model tools (pyBadlands, pyReef) under development by the GRG. The project will have implications for improving our understanding modern reef environments and processes as well enhancing our knowledge of ancient carbonate platforms.

3.5.7 Controls on the Holocene evolution of the Great Barrier Reef: linking 4D numerical model ing and observational data

Supervisors: Jody Webster jody.webster@sydney.edu.au & Tristan Salles tristan.salles@sydney.edu.au

This project will investigate the relationship between biological and geological processes controlling the evolution (stratigraphic ages, residence times and geometries ('architecture') of coral reef systems. We will construct new 4D numerical models using state of the art software (eg.,pyBadlands, pyReef) and compare them against observational reef data sets from the Great Barrier Reef that grew during the Holocene (9,000 years to now). We aim to assess the sensitivity of coral reef systems to various environmental stresses (eg. sea-level rise, subsidence and sediment flux) acting on different timescales, magnitudes and rates. The project may also involve field work to One Tree Reef in the southern GBR to calibrate model parameters and processes against real world sedimentary and biological examples.

Note: this project is part of the new DARE ARC ITTC and fully funded PhD scholarships are available to suitable candidates.

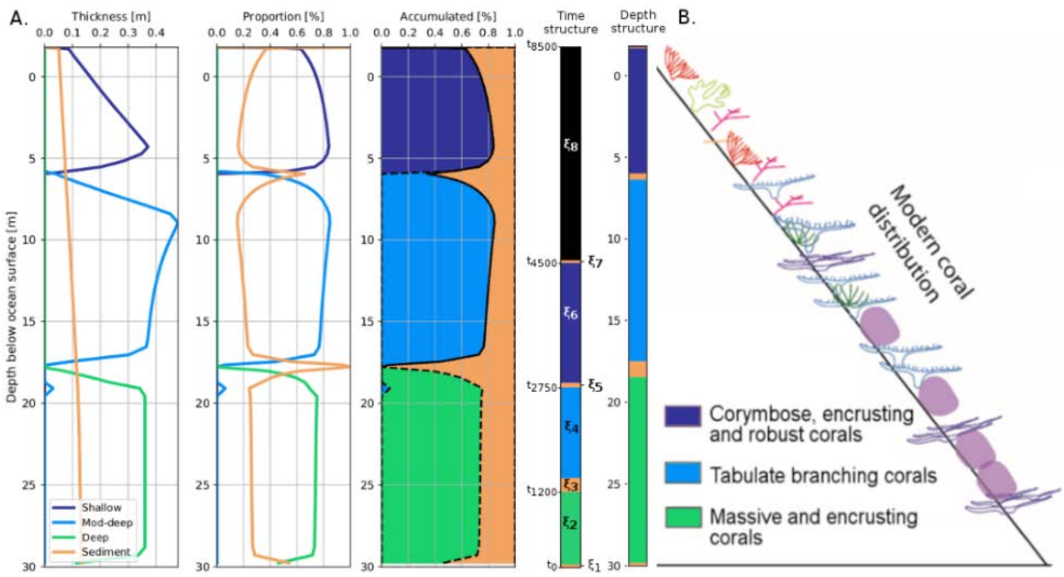


Modeling of One Tree Reef using pyReef and pyReef core (Salles et al,. 2018)

3.5.8 Multi-core parallel tempering for extending BayesReef for modelling reef growth on geological timescales

Supervisors: Rohitash Chandra rohitash.chandra@sydney.edu.au, Tristan Salles tristan.salles@sydney.edu.au & Jody Webster jody.webster@sydney.edu.au

Estimating the impact of environmental processes on vertical reef development in geological timescales is a very challenging task. This is due to complex models and data with missing information. py-Reef Core is a vertical reef growth simulation model for geological timescales. BayesReef has been proposed to estimate and provide uncertainty quantification for py-Reef Core which features environmental condition parameters. BayesReef features limitations when the size of the problem increases due to computational requirements in sampling and hence only a few parameters were estimated. Parallel tempering (PT) is an advanced MCMC method suited for irregular and multi-modal distributions. Moreover, PT is more suitable for multi-core implementations that can speed up computationally expensive geophysical models. The Honours research project extends Bayeslands using parallel tempering to estimate dozens of parameters on a synthetic reef core dataset.



Note: this project is part of the new DARE ARC ITTC and fully funded PhD scholarships are available to suitable candidates.

3.6 MORPHODYNAMICS OF TEMPERATE COASTS

3.6.1 What is special about beaches in estuaries and bays?

Supervisors: Ana Vila-Concejo ana.vilaconcejo@sydney.edu.au & Shari Gallop (U Waikato, NZ)

Despite the ubiquitous distribution of beaches in estuaries and bays, little is known of the short to long term morphodynamics of these systems when compared to open coast environments. The fact is that they are often taken as small-scale versions of their oceanic counterparts. However, recent research shows that they behave in different ways and that the key to their behaviour seems to reside on the ratios of the different types of energy (swell waves; wind waves; infragravity energy; tidal currents) that they receive. In this project, the student will survey the hydrodynamics and topography of estuarine beaches in the Sydney region, including Sydney Harbour, Botany Bay and/or the Pittwater estuaries, and will determine the processes inciting geomorphic change and evolution of these systems.

3.6.2 What will happen to Sydney's beaches with climate change? How can we prepare?

Supervisors: Ana Vila-Concejo **ana.vilaconcejo@sydney.edu.au** & Shari Gallop (U Waikato, NZ)

This project involves monitoring of beaches on selected Sydney Eastern suburbs including Bondi Beach. The student will measure the topography of selected beaches monthly and after storms. One question relevant to 2019 is why do the beaches have so much sand? The students will analyse topographic and video data from 2015 until present to quantify the processes that control sediment deposition. Analyses of longer data series of wave climate will allow to compare those years with past erosive states like, for example 2011. Where is the sand coming from? Where will it go? And what are the conditions that will trigger erosion again? Most importantly, this research aims to quantify sand management approaches to adapt to climate change.

3.6.3 Estuarine beaches of Sydney Harbour: what's going on in Rose Bay?

Supervisors: Ana Vila-Concejo ana.vilaconcejo@sydney.edu.au & Tristan Sallles tristan.salles@sydney.edu.au

Natural oyster reefs were extinct from NSW estuaries in the late 20th century. But some of them survived and are still going. While scientists still don't understand why some reefs have survived, we suspect that the physical and sedimentary processes exert some control in whether they survive or not. Oysters are being used all over the world to remediate contaminated estuaries. With our research we want to understand the following:

- What ranges of physical and sedimentary processes, allow oyster reefs to thrive
- What are the effects that oyster reefs have on the sediments
- What are the effects that oyster reefs have on physical processes such as wave and current attenuation

This research is part of collaborative research with Marine Biology. This is a new, interdisciplinary, line of research that started in 2018.

Rose bay photo, Google Earth