PHYSICS OF THE EARTH HONOURS PROGRAM
RESEARCH SCHOOL OF EARTH SCIENCES
THE AUSTRALIAN NATIONAL UNIVERSITY
RESEARCH PROJECTS FOR 2004
(Research projects and supervision by RSES staff are also available to students undertaking Honours in Physics, Mathematics, Geology, Computational Sciences and Engineering at the ANU)

To obtain more information on the Physics of the Earth Honours Program, contact Jean Braun (Jean.Braun@anu.edu.au) or visit our web site (http://rses.anu.edu.au/PhysEarth). To find out about a particular project, do not hesitate to contact the potential supervisor directly.

ADAPTIVE NON-LINEAR INVERSION OF SEISMIC DATA FOR EARTH STRUCTURE

In recent times, tomographic imaging techniques have enabled seismologists to produce detailed three-dimensional maps of Earth structure from large seismic datasets. Traditional methods of seismic tomography often rely on iterative non-linear inversion schemes and represent structure by a regular grid of parameters. However, iterative inversion schemes may converge to local minima and regular parameterizations are inconsistent with non-uniform distributions of data. The aim of this project is to introduce a suite of new computational tools to seismic tomography in order to overcome these problems. The important requirement of defining a continuous medium from an irregular distribution of nodes placed only where they are required by the data can be satisfied using natural neighbour interpolation. We envisage the use of a fully non-linear search technique to solve the inverse problem, e.g. the locally developed neighbourhood algorithm. Finally, the forward problem of calculating model predictions can be rapidly solved using grid-based wavefront tracking schemes such as the fast marching method. The use of direct search methods in seismic tomography is computationally expensive, but the project will have ready access to a powerful 128-node supercomputer. A background in computational mathematics is recommended.

Contact: Nick Rawlinson (nick@rses.anu.edu.au) or Malcolm Sambridge (malcolm@rses.anu.edu.au)

Want to know more?

(1) Natural neighbour interpolation: http://rses.anu.edu.au/geodynamics/nn/nn.html
(2) Neighbourhood algorithm: http://rses.anu.edu.au/~malcolm/na/na.html
(3) Fast marching method: http://rses.anu.edu.au/~nick/waves.html
(4) Tomography with irregular parameterization:
http://rses.anu.edu.au/seismology/projects/tireg/tomo.html

STRUCTURAL CONTROL ON LANDFORM EVOLUTION IN SOUTH ISLAND, NEW ZEALAND

As part of a large ARC-funded project on the tectonic and geomorphic evolution of the Southern Alps, New Zealand, we are looking for a motivated Honours student to help with the collection of structural and thermochronological data from the central part of the orogen, near Mount Cook and its interpretation using state-of-the-art computer modelling tools. We have been working for many years now to try to understand the coupling between erosion and tectonics in active mountain belts. The

continental collision between the Australian and Pacific plates across the South Island of New Zealand is an ideal location to study these interactions. The strong asymmetry in precipitation between the two sides of the orogen (resulting from the rain-shadow effect caused by the high local relief and the dominant westerly winds) is thought to be responsible, in part, for the strong asymmetry in exhumation on either side of the divide. This orogen is commonly regarded as a clear example of the strong feedback between tectonics and erosion. We are now interested in investigating the importance of lateral advection of the landform by horizontal tectonic movement across the main divide. Deeply incised, U-shaped, glacial valleys that seem to develop along pre-existing structures characterize the region east of the divide. The region west of the divide has most of the characteristics of a landform that is dominated by hill-slope processes (landsliding) and fluvial incision and transport, where valleys have formed across the structural grain. We would like to (a) to evaluate the degree of structural control on the main features of the landscape (b) to estimate how much of the glacial landform in the east is advected across the divide and (c) quantify its potential influence on the formation of the fluvial landform to the west. This project requires a good training in Earth Sciences, with a keen interest in fieldwork, as well as the will to use computational methods, like a landscape evolution model, to quantify the processes under study.
Contact/Supervisor: Jean Braun (Jean.Braun@rses.anu.edu.au)

DYNAMICS OF EARLY CRUST
The Earth's earliest crust was probably a thick basalt layer, the base of which would have been prone to transforming to dense "eclogite" at high pressures and temperatures. This may have caused it to founder episodically, which could have important implications for mantle convection, mantle chemistry and the early crustal record. The project is to adapt an existing numerical convection code to this problem, and to explore the influence on dynamical behaviour of the phase transformation, including whether it is controlled by pressure or by temperature.
Contact/Supervisor: Geoff Davies (Geoff.Davies@anu.edu.au)

PLUME DRIFT AND POLAR WANDER
Recent two-dimensional numerical models of mantle convection show episodes of relative horizontal motion between the lithosphere and the high-viscosity lower mantle. This would be manifest in the real mantle as ``true polar wander'', in which the hotspots collectively move relative to the rotation pole. The effect seems to be controlled in the models by the way subducted lithosphere couples the two layers. The project is to quantify the amount of ``drift'' in the 2-D models, to determine its dependence on lithosphere viscosity and dip angle, and to compare the results with observed episodes of polar wander.
Contact/Supervisor: Geoff Davies (Geoff.Davies@anu.edu.au)

CONTROLS ON MANTLE PLUME HEADS AND TAILS
The sizes and temperatures of plume heads and plume tails in numerical models are controlled by properties of the deep mantle. Existing models do not adequately reproduce the sharp contrast in volume between flood basalt volcanism (from melting plume heads) and hotspot volcanism (from melting plume tails). The project is to vary the relevant deep mantle properties to see if the observed eruption rates can be accounted for with reasonable mantle properties.
Contact/Supervisor: Geoff Davies (Geoff.Davies@anu.edu.au)

THE DYNAMICS OF CONVECTIVE EXCHANGE IN BUILDINGS

Fluid dynamics experiments will be used to understand the processes that control turbulent flow and heat transfer between chambers in a building. These flows are of vital importance in the architectural design of modern buildings that use natural ventilation. The project will involve experiments with a convection tank divided into two chambers connected by a smaller passage and forced by a variety of boundary conditions.

Contact/Supervisor: Ross Griffiths (Ross.Griffiths@anu.edu.au)

DEFORMATION IN YIELD-STRENGTH FLOWS

The dynamics of mud and lava flows having a yield strength have been studied in experiments with slurries. In order to determine the history of strain and deformation within these flows, and to predict the distribution of material from sequential inputs, we will use tracers in slow extrusions onto horizontal and sloping planes. The flows will be frozen and dissected to measure tracer distributions, which can be compared to simple theoretical predictions.

Contact/Supervisor: Ross Griffiths (Ross.Griffiths@anu.edu.au)

SEISMIC ATTENUATION AND ANISOTROPY IN THE UPPER MANTLE BENEATH AUSTRALIA

The project will be directed at the analysis of seismic body waves (both P and S) to delineate 3-D variations in seismic properties using refracted waves and multiple reflected phases. Attenuation will be extracted from the spectral ratio of P and S arrivals and anisotropy form time differences in the polarisation of shear waves.

Contact/Supervisor: Professor B.L.N. Kennett (Brian.Kennett@anu.edu.au)

MANTLE FABRICS FROM SLOW SPREADING MID-OCEAN RIDGES: IMPLICATIONS FOR TECTONIC PROCESSES

The project will involve examining core drilled from the Mid-Atlantic Ridge by the Ocean Drilling Program Leg 209 by electron microscopy (imaging, analysis and Electron Backscatter Diffraction) to determine olivine lattice preferred orientations and relate them to models for slow spreading ridges and ophiolites. A background in structural geology, geophysics or physics/math with interest in geophysics is highly desirable.

Contact/Supervisor: Uli Faul (Uli.Faul@anu.edu.au)

TOPOLOGY OF SIMPLE FLUID NETWORKS.

Percolation of liquids through aggregates of solid grains is a field of considerable practical importance in engineered materials and in geological materials where silicate melts can flow in grain-scale networks through granular rocks. Using the X-ray microtomography facility in Dept Applied Maths, data has been collected to characterise the three-dimensional character of (solidified) partially melted material. This computational project aims to process this data, analyse the topology of simple fluid networks, compare these with published data from other natural and synthetic rocks, and simulate bulk-materials properties. Background and skills needed can be developed during the project but would suit a student interested in 3-d computation/visualisation.

Contact/Supervisors: John Fitzgerald (john.fitzgerald@anu.edu.au), Tim Senden (tim.senden@anu.edu.au) and Uli Faul (uli.faul@anu.edu.au)

SEA LEVEL CHANGE IN AUSTRALIAN REGION SINCE THE LAST GLACIAL MAXIMUM 20,000 YEARS AGO.

The project will be concerned with a literature survey of evidence of sea level change, with the mathematical modelling of the change caused by the melting of the last great polar ice sheets and with the interpretation of results. A background in sedimentology is desirable as is some experience with Unix operating system.

Contact/Supervisor: Kurt Lambeck (Kurt.Lambeck@anu.edu.au) and Tony Purcell (Anthony.Purcell@anu.edu.au).

PRESENT DAY SEA LEVEL CHANGE. WHAT ARE ITS CAUSES?

This project will start with the IPCC report and examine and evaluate some of the physical processes contributing to present-day sea level change. Are the ice sheets melting or growing? What is the effect of the melting of mountain glaciers? What are the human influences? Some scientific programming and computational mathematics experience is desirable.

Contact/Supervisor: Kurt Lambeck (Kurt.Lambeck@anu.edu.au) and Tony Purcell (Anthony.Purcell@anu.edu.au).

REMOTE SENSING OF THE ATMOSPHERE IN ANTARCTICA USING GPS OBSERVATIONS.

This honours project will use GPS and environmental data collected at four remote sites in the Prince Charles Mountains, Antarctica, to generate for the first time a record of present-day precipitable water vapour along a transect of sites from the coast to up to 600 km inland. The research will involve some GPS data analysis, utilisation and modification of water vapour estimation software and interpretation of the resulting time series of estimates of water vapour.

Contact/Supervisor: Paul Tregoning (pault@rses.anu.edu.au)

INFLUENCE OF SECULAR VARIATION OF THE GEOMAGNETIC FIELD ON PRODUCTION RATES OF TERRESTRIAL COSMOGENIC NUCLIDES.

Terrestrial cosmogenic nuclides (TCN) are produced in rocks and sediment exposed near the Earth's surface as a result of the interaction between minerals and high energy cosmic rays. They are used to model the age of landscape elements and the rates of geomorphic processes in a variety of geomorphological and geographical settings. To improve the accuracy of the models it is necessary to improve our understanding of the influence of the effective geomagnetic field on the cosmic ray flux. This project aims to determine the influence of the known variations in intensity and position of the dipole and non-dipole field of the Earth on the cosmic ray flux responsible for TCN production, and hence improve the accuracy of current TCN models.

Contact/Supervisor: Derek Fabel (Derek.Fabel@anu.edu.au)