This conference is designed to facilitate communication within the Research School of Earth Sciences and provide valuable experience in research presentation for PhD, Masters and Honours students. In this booklet you will find speaker times and the abstracts for talks and posters. Abstracts are organised in alphabetical order by last name.

This event would not be possible without the generous funding provided by the Research School. We would like to thank in particular our Director, Professor Brian Kennett for such generous support of this conference, and the efforts of the volunteers that have made this event possible. We hope you enjoy it.

Regards,

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NATURAL ANNEALING OF DYNAMICALLY RECRYSTALLISED QUARTZITE FABRICS: EXAMPLE FROM THE CÉVENNES, SE FRENCH MASSIF CENTRAL

Augenstein, C.\(^1\) and Burg, J.-P.\(^2\)

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\(^2\)Geological Institute, ETH Zurich.

In the SW-Cévennes (French Massif Central) quartzite samples have been investigated in order to reveal the effect of static annealing on a previously dynamically recrystallised quartz fabric. Main lithologies in the working area are micaschists divided by the studied, prominent quartzite layer and the St-Guiral granitic intrusion. Foliation, lineation and fold relationships suggest a continuous deformation history: 1. SSW-SW-directed shearing, 2. non-cylindrical drag folding, 3. buckling about open folds, 4. granite intrusion at 1-3kbar -650-700°C associated with minor kinking and flexuring. Recorded crystallographic preferred orientation (CPO) patterns of the dynamically recrystallised quartzite are classified into type I with a monoclinic symmetry and type II with an orthorhombic symmetry. Type I is related to simple-shear-dominated deformation and type II to apparent constriction. These two fabric types are consistent with structural observation that a constrictive coaxial deformation regime controlled the formation of non-cylindrical and refolded folds. In the metamorphic aureole, which essentially produced static annealing, CPO patterns intensify towards the granite until grain growth and spacing between mica bands lead to preferred grain orientation parallel to the mica bands.

Annealing of dynamically recrystallised quartz fabrics reactivates slip systems and so amplifies older patterns. Additionally, fluid and heat during contact metamorphic grain growth and resulting intergranular stress can trigger slip on previously inactive slip systems.
Seismic tomography is used for investigating the internal structure and composition of our planet. The data used basically consist in arrival times of several types of elastic waves which have propagated from an earthquake to a receiver. The speed of the seismic waves is directly linked to physical properties of the Earth. Thus, a seismic wave propagating from an earthquake to a receiver contains information about the Earth structure within its volume of influence. This information obtained is strongly dependent on the location of the earthquakes (most at plate boundaries) and the positions of the receivers, which results in some regions being traversed by many seismic rays and other regions left with poor ray coverage. In order to recover an image of the Earth, one has first to choose a parameterization, that is to “pixelize” the Earth. Hence, the speed of seismic waves within each “pixel” is an unknown in the problem to be solved for. One would like to have small “pixels” where there is a lot of information and large “pixels” where the resolution is poor. I will show that the size of pixels as well as the number of pixels (i.e. the number of unknowns) can be determined by the data and become itself an unknown in the problem.
The Sesia Lanzo Zone (SLZ) records a complex metamorphic history relating to its subduction and subsequent exhumation. Previous studies of the Eclogitic Micaschist (EMS) unit of the SLZ have described a clockwise pressure-temperature-time loop for the EMS [1, 2].

A geochronological and trace element study of zircons from one sample from the EMS yielded an entirely different history. Three zircon overgrowths, distinct in trace element chemistry, yield three different ages. The oldest age is found in dark overgrowths and yields an age of 78.74 ± 0.88 Ma. The REE pattern for these overgrowths suggests HP conditions during this event; Ti in zircon temperature estimates are 640-660°C. An age of 73.7 ± 1.5 Ma is found in zircons with a REE pattern which records the presence of feldspar, and is therefore interpreted as a lower pressure event. The temperature for this zircon overgrowth was 655-675°C. The youngest zircons record the well documented 65 Ma HP event [3], and Ti concentration yields a temperature of 595-615°C. Inclusions in zircon and textural evidence in high pressure assemblages, though scarce, may also provide evidence of this double loop. This P-T-t path, from high pressure to lower pressure and a return to high pressure conditions, has not been observed in the Sesia Lanzo Zone or other eclogite facies rocks worldwide before. The double loop, which occurred within ca. 15 Ma, has important consequences for our understanding of the dynamics of subduction and exhumation of subduction related rocks.


As we begin to understand the origin and evolution of life on Earth and investigate the possibility of extraterrestrial life, the need to scientifically approach fundamental questions such as ‘What is Life?’ increases. In beginning to answer such questions we can look at the ingredients of life on Earth. At the level of chemical elements, the major ingredients are the ‘bulk’ elements oxygen, carbon, hydrogen and nitrogen [96.8 (± 0.1)% by mass]. The remaining mass is made up of phosphorus and sulphur [2.2 (± 0.2)% by mass] along with ‘trace’ elements like potassium, sodium, calcium and other metals such as iron and copper.

The abundance of elements in terrestrial life (humans and bacteria) is positively correlated to devolatilised solar abundances and this supports the idea that 'we are made of star dust'. Correlations between the elemental composition of life and sea water can be interpreted in terms of chemical constraints on metabolic activities and harnessing energy, in an effort to define 'life'.

My PhD research will focus on using analytical technologies such as ICP-AES and Elemental Analysers, to determine elemental compositions of a number of extant species, deeply rooted in the phylogenetic tree of life, for the first time in history, with high enough precision to search for signals that will further our understanding of the origins and evolution of life on Earth.

The coral reef building capability is threatened by the decrease in the aragonite saturation state caused by ocean acidification. A large number of corals reefs are located in coastal areas where they are not only susceptible to the changes in the ocean, but also alterations in terrestrial input. Some of these coastal reefs are affected by river plumes that, in most cases, are acidic relative to the receiving ocean. For most rivers their chemical nature and magnitude of discharge is changing rapidly due to climate change and land-use practices. Here we propose to study the potential change in the coral reef development related to changes in river discharge and ocean conditions during the last 50 yrs. For this purpose we are in the process of skeletal growth parameters (indicators of coral reef growth) and B isotopes (a geochemical tracer for pH) in corals obtained from the Great Barrier Reef along a transect from inshore to offshore of reefs near the Burdekin river.
A NEW RUTILE STANDARD FOR SHRMIP U-Pb DATING
Tanya Ewing and Daniela Rubatto

Rutile frequently occurs as an accessory mineral in moderate- to high-grade metamorphic rocks, and is an appealing target for U-Pb dating as it participates in well-understood metamorphic reactions, allowing age data to be related to the appropriate part of a given metamorphic history.

U-Pb dating of rutile has already attracted significant attention over the past two decades, but dating by in-situ techniques (SHRIMP and LA-ICPMS) has been plagued by difficulties in obtaining an appropriate rutile standard. Although a number of in-situ studies exist [e.g. 1,2,3] a reliable and widely available rutile U-Pb standard is still lacking.

From a suite of rutile-bearing samples from around the world, a rutile megacryst from Wodgina, Western Australia (donated by Western Australian Museum), has been selected as the most appropriate rutile U-Pb standard from the material available to us. Its suitability has been assessed over seven SHRIMP sessions, during which rutile samples from a variety of geological settings were dated against this standard.

The Wodgina rutile contains 160ppm U and has an age of 2843 Ma. Over the seven sessions, the precision obtained on the Pb/U calibration for this standard was between 1.5–4%, depending on the operation of the instrument on the day. These errors represent the limit of precision with which unknowns can be dated, and compare reasonably favourably with the precision typically achieved for zircon standards. However, in many sessions some chips of the standard gave $^{206}\text{Pb}/^{238}\text{U}$ ages that were too old, the reason for which is not yet understood. These analyses had to be excluded to achieve good precision (1.5–4%) on the Pb/U calibration for the standard. Although the presence of such ‘problem’ chips in a standard is not ideal, it has been found that the analyses with spuriously old $^{206}\text{Pb}/^{238}\text{U}$ ages can always be independently identified on a plot of UO/U vs UO$_2$/U [after I.S. Williams, pers. comm.], allowing unbiased exclusion of bad standard analyses. Using this technique, it is possible to date rutile with $\geq$15ppm U by SHRIMP.

A new laboratory study, focused on the damping of seismic waves and modulus changes in upper mantle olivine, is carried out based on several theories proposed during the mid 20th century. The material used is a pre-deformed synthetic fine-grained aggregate to ensure seismic wave attenuation is not affected by other variables such as melts and the presence of water. Previous measurements on the same undeformed material allow for a comparison for the effect of grain size and a correction is made for dislocation density changes that occur at high temperatures over time. The 10% iron-bearing olivine is buffered by the presence of enstatite and is created using a solution-gelation technique. The resulting powder is cold pressed and subsequently fired at 1400°C overnight and hot pressed at 1300°C and 300 MPa Ar confining pressure. The hot pressed sample is then deformed under similar conditions to differential stresses up to 300 MPa (32kN). It is found that the dislocation microstructures in this fine-grained material are typical of those found in natural olivine but that the dislocation kinetics is much less by several orders of magnitude. The attenuation experiments for a sample deformed to 2 cm/m does not show any enhanced attenuation up to temperatures of 1100°C, the chosen limit at which dislocation recovery is still limited for relatively long durations. However, measurements performed on a similar synthetic specimen, deformed to 22 cm/m, show quite significant attenuation above 1000°C. The accompanying increase in dislocation density in this deformed specimen is only ~0.4 orders of magnitude compared to the undeformed specimen. These preliminary results indicate that an actively deformed region in the “solid” upper mantle can yield the same kind of attenuation results than if it were anomalously hot or partially molten.
The main focus of my PhD research is to analyse lunar grains that have been exposed to the solar wind. Of particular interest are metal grains and the composition of oxygen isotopes in them. The first results revealed that oxygen is preserved in them near the surface and therefore they might be suitable collectors of the solar wind [1]. These grains are to be analysed to answer the following questions.

Firstly, we will take a closer look at the oxygen implantation from the solar wind on these grains, and the preservation of oxygen in a metal matrix, through measurements of oxygen abundances and isotopic fractionation. The solar wind, should leave a distinctive composition on the surface of the grains [1], a composition that is representative of the Sun’s, and which reflects the average starting composition of the solar system [2] since the Sun contains more than 99.8% of the known solar system’s material [3]. Moreover, oxygen isotopes show over 30% variation in materials from meteorites which is interpreted as $^{16}$O variability relative to terrestrial mass fractionation line (TFL). Two studies of lunar metal grains show very different results. Analyses by Hashizume & Chaussidon [4] show wide variability but they proposed a solar composition enriched in $^{16}$O by c. 4% on the basis of concentration profiles in metal grains from two-billion-year old regolith breccia. However, these anomalous compositions were extremely deep in the grains requiring implantation energies far in the excess of solar wind, and the compositions are highly fractionated and not on a $^{16}$O mixing line. Ireland et al. [1] found anomalous oxygen near the surface of their grains from recent lunar soil, but the composition is strongly enriched in $^{17}$O and $^{18}$O with an offset from the TFL with $\Delta^{17}$O = $+25.6 \pm 3.2 \text{‰}$. This is, in turn in agreement with solar CO spectral line formation modelling [5]. Last year McKeegan et al. reported that solar wind in the Genesis collectors has a mean $\Delta^{17}$O = $-26.5 \pm 5.6 \text{‰}$ [2]. Finally, Hashizume and Chaussidon [6] report metal grains from a recent soil with elevated $^{17}$O and $^{18}$O at a similar level to [1]. The issues then are, why is the real solar wind not preserved in the metals from lunar soil, and to what is the $^{17}$O,$^{18}$O enriched composition related.

During the work ahead the soon established SHRIMP SI will hopefully give new insights on this matter. Related to this work and SHRIMP SI, the second question of interest will be further measurements on other light elements (H, C, N) implanted in lunar grains, which are dominated by the Sun’s solar wind composition and are preserved on the Moon [7]. This will be followed by analysis on noble gas isotopic and abundances. Up to this point the progress of the research involves an oxygen implantation experiment on steel to determine the diffusion of oxygen through iron. More precisely, various steel samples are polished and gold coated, and then sputtered (and implanted) with an $^{16}$O-beam using SHRIMP I and different implantation periods, from 1min to 30min. For further measurements the samples will undergo oxygen analysis in SHRIMP II, which should provide a depth profile.
SAND DEPOSITS IN THE NORTHERN REGION OF LOWER AUSTRIA (WALDVIERTEL) AND THEIR INFLUENCE ON HISTORICAL GLASS PRODUCTION (FOREST GLASS)

Barbara Frasl

The northern Waldviertel has been part of the bohemian glasshouse region since 14th century. The original glass production always followed the raw materials; wood and quartz. The wood was burned to ash to providing potash as flux. Quartz was either gathered in stone quarries or sands pits close to the glasshouses. Due to impurity of the quartz and sands the glasses had a greenish colour, which was mostly corrected by the use of manganese which has a decolourizing effect. So the name forest glasshouse did not only originate from their placement in the woods, but their characteristically greenish glass [1]. Within this work different glasses from various ages and places in the described region were taken. The sands that had potential for use as raw material in the glass production were analysed. The investigated region belongs to the Southbohemian Batholith (360 – 350Ma) in the Bohemian Massif. In detail it is part of the Eisgarn Pluton (two-mica bearing granite) with relicts of the sediment cover of the Klikov and Lipnice formation [2]. The sands were classified into four groups; river sediments, tertiary fluviatile sands, soil samples, and weathering samples of granites. The first step was a sieve analysis of the sands carried out by wet sieving, followed by chemical analysis of the different sand fractions and glasses. The samples were prepared with hydrofluoric acid and perchloric acid for the Atomic Absorption Analysis (AAS). Here the samples were tested for the concentration of the elements K, Na, Mg, Ca, Fe and Al. Additionally the glasses were tested for Co, Cu, Ni, Cr and Mn. Furthermore thin sections of representative sediment samples were made to examine the microscopic texture and composition. The chemical analyses gave plausible results when comparing the data from the sediments data with data from the glass samples. The content of CaO, Na₂O and K₂O in the glasses are slightly higher, which is in agreement with the addition of ash as flux during the glass production. The higher values of MgO and CaO, can be easily explained by adding limestone and dolomite, a quite common procedure. Even the FeO concentration matches in both, sediments and glasses with an average value of almost 1%, and an anomaly of a small group of almost 5% FeO. Finally the Al₂O₃ concentration demonstrates at best the selection of raw materials necessary for glass production, since only the more mature sands and the quartzes are a possible choice based on their Al₂O₃ value in comparison to the glasses. In conclusion, a selective choice of the sands and quartzes of the northern Waldviertel were definitively worthy raw materials for historically coloured glasses, more specifically “forest glass”. But time did not only change the demands in quality, but also in quantity, which might be an equal problem considering future mining of the sands for any glass production in this region, keeping in mind the limited sizes of the quarries.

SALT OF THE EARTH OR IS THAT SALT OF THE SEA? PERHAPS SALT OF THE RAIN…

Julia Jasonsmith

Imagine you’re in a beautiful river valley, surrounded by high sandstone cliffs. The sandstone in these cliffs, and the mudstone and coal lying deep beneath them, were deposited over millions of years by massive rivers draining towering mountains, long before the dinosaurs. Water has been seeping through this yellow sandstone since it formed, leaching it of the minerals and solutions which were originally contained within it.

The valley is far from the sea, and has a river fed by groundwater which flows even during high drought, into a larger river that eventually drains to the sea. With a parched throat, on a hot summers day, drinking of the mineral groundwater burbling in the river sounds like a wonderful experience, doesn’t it? Except, the problem is, the river is too salty to drink. It’s saltier than almost any of the other rivers draining the surrounding area, and saltier by far than the nearby rivers which drain rocks that were formed under the sea.

So, where does the salt come from and why does it occur in this valley? Could it come from outside the catchment, as dust blown in from Australia’s salty interior or instead dissolved within rain formed from the sea? Could it flow into the valley, dissolved in groundwater deep below the Earth’s surface, seeping through the cracks and fissures in the sandstone, from a saltier region nearby? My research aims at finding out, using variations in the type of salts, their concentrations, and their isotopes as well as using hydrological measurements such as water flow. Not only will this research contribute to a better scientific understanding of how salts move on a catchment scale, the knowledge of how to mitigate and even stop salt movement into the valley will also result, allowing for healthier plants and soil, more productive farms, and maybe even a river with water fresh enough to drink.
2800 km² of plutonic rocks of Carboniferous age are present in the most north-eastern part of the Lachlan Fold Belt (LFB). The Carboniferous granites are not only regionally but also chemically and isotopically restricted. They are all I-type granites (ASI < 1.2) containing low CaO and Y and high K₂O, P₂O₅, Rb and Sr (Chappell, unpublished data) relative to pre-Carboniferous granites of the LFB. The initial ⁸⁷Sr/⁸⁶Sr ratios of the Carboniferous granites of the LFB range from 0.7039 to 0.7067 (Shaw and Flood, unpublished data), which are close to the inferred Sr ratio of the mantle.

The Carboniferous granites of the LFB can be divided into three batholiths (Gulgong, Bathurst and Oberon batholiths) and two supersuites (Bathurst and Oberon supersuites), from which samples were collected to cover the whole area of those granites. Zircons (Th/U ratio: 0.2–1.5) were dated using SHRIMP II for 13 granite samples. Their ages range from 328 to 341 Ma, which are not distinctive between each batholith. We also find out different age patterns of inheritance between southern and northern parts of study area, which might be Oberon, and Bathurst and Gulgong batholiths, respectively.

For more detail information, Sm-Nd whole rock analyses and O and Hf isotopic analyses for dated zircon grains are in progress now.
Australia today is widely regarded as a hot, dry place; a continent composed mostly of desert, fringed with trees. It was not always so: faunal and sedimentary evidence indicate that during the Tertiary, Australia’s climate was humid-subtropical [1]. Increased sea surface temperatures in the Late Tertiary raised the temperature and lowered the humidity of air masses penetrating the Australian continent, and Australia began to dry out. However, these changes did not affect all parts of the continent equally; moreover, they were accelerated by the onset of glaciation during the Pleistocene. In order to reconstruct the nature and extent of the changes that occurred with the onset of aridity on the Australian continent, we require multiple lines of evidence from diverse locations. Since Australia is an erosional continent however, well-preserved continental sedimentary successions covering the last 200,000 years are sparse. As a new approach, we study lipid biomarkers preserved in sediments of playa lakes and use them as proxies to reconstruct regional climatic variation in southeastern Australia through the mid- to late-Pleistocene. This period of time includes arguably “the greatest environmental transformation of the last 20 million years.” [2]

Lipid biomarkers are chemical fossils that are diagnostic of the organisms that produced them and that are stable in rocks and sediments over geologic timescales. As such, they are indicative of the presence and, to an extent, the relative abundance of organisms within a paleo-community. By extrapolation, environmental parameters required for these organisms’ survival in the present day can be used to reconstruct the conditions at the time when the biomarkers were deposited. Thus, biomarker data can be integrated with palynological, sedimentological and isotopic studies to refine climate reconstructions on a regional level, and also to provide information about the types of organisms that inhabited the region through time. However, as with macrofossils, the presence of indigenous biomarkers is dependent on the conditions encountered during deposition and diagenesis. Dry, oxic conditions are not conducive to biomarker preservation; unfortunately, playa lakes are intermittently dry, and desiccation cracks in the lakebed promote oxidation of sediments to depth. Therefore, it was necessary to test whether these environments would contain extractable quantities of indigenous biomarkers in deeply buried sediments.

We have extracted lipid biomarkers from a 13 m core taken at the north end of Lake Tyrrell, an ephemeral salt lake in northwestern Victoria, where conditions through the mid-Pleistocene are less well characterized [3]. Despite variable oxidizing and reducing conditions through the core,
extractable biomarkers occur in clay-rich sediments deposited when the lake was fresh more than 500,000 years ago, and in evaporite-rich sediments deposited during the last 120,000 years. We have correlated biomarker suites to mineral assemblages for two subsamples from our core, and have confirmed biomarker syngeneity and the viability of paleoenvironmental reconstruction at the site. Sterol, isoprenoid and triterpenoid biomarker lipids have yielded the most specific information, indicating the existence and variability of populations of bacterivorous ciliates, gymnodinoid dinoflagellates, halophilic archaea and green algae within the lake throughout its more saline period. Ongoing work involves quantitative analysis of the correlation between biomarker suites and mineral assemblages through the core; the ultimate goal is to construct a record of the effects of changing salinity and aridity on communities of organisms living within and around the lake.

Further work includes the use of stable carbon isotopic signatures of n-alkanes to determine the relative dominance of C3 to C4 plants in the area through time, possible use of long chain alkenones and $\delta^{18}$O signatures in diatom tests for paleotemperature reconstructions, the description of additional lipid biomarkers not amenable to traditional analytical methods and compound specific radiocarbon dating of indigenous lipids combined with optically stimulated luminescence dating of quartz sands [4] from the core to constrain the timing of environmental change at Lake Tyrrell from the Pleistocene through to the present.

The Willandra Lakes are a dry lake system consisting of a number of ancient lakes in the western region of the Murray basin. The area has significant scientific value, providing detailed palaeoenvironmental and palaeoclimatic records of arid, ice-age Australia as well as a rich and unique archaeological record. Lake Mungo, resting place of Australia’s oldest dated aboriginal remains, has been a popular lake for study, while Lake Mulurulu, the northern-most lake in the system, is relatively understudied, despite its abounding potential. The aim of the current study is to combine isotope palaeoecology, geochronology, stratigraphy and sedimentological techniques to study the Mulurulu Lake lunette, thus creating a detailed geomorphological and palaeoenvironmental history of the lake, putting the aboriginal occupation of the area into an environmental context. Fieldwork conducted during 2007 and 2008 resulted in the collection of a variety of samples for archaeometric laboratory studies, including stable isotope analysis and geochronological techniques, which are currently underway.
SECONDARY MINERAL ASSEMBLAGES IN ECLOGITE XENOLITHS 
AND CONSTRAINTS ON THEIR ORIGIN.

Ekaterina S. Kiseeva, Gregory M. Yaxley, Vadim S. Kamenetsky

Despite the large amount of work done on eclogite xenoliths, the origin of the secondary mineral assemblage is still not understood. Alteration of even well preserved eclogite xenoliths is evident. We can observe mechanical balling and partial melting, which result in a rounded shape of xenoliths, as well as chemical alteration inside the xenolith. Grains of primary minerals of eclogite xenoliths, mainly garnet and clinopyroxene, but also kyanite, rutile and sulfides are rarely in contact but commonly have a rim, which is often large, of secondary minerals around them.

The possible origin of the secondary mineralization is as follows:

- metasomatic alteration either by transient mantle fluids,
- interaction with kimberlite magma,
- partial melting of the eclogite itself

or a combination of these.

Here I present a study of six natural eclogite xenoliths from Jericho (Canada) and Roberts Victor (South Africa) kimberlite pipes. I examine their primary and secondary mineral assemblages with the trace and REE patterns of these alteration assemblages and try to develop constraints on the composition and possible nature of melts or fluids from which these secondary minerals have crystallised.
Salinity and salinisation in Australia are two current and significant environmental issues because of the loss of arable land and declining availability of freshwater. Understanding salinisation in past ecosystems opens the possibility to understand the present state and trajectory of salinisation on the Australian continent. However, there is currently a paucity of reliable sedimentary proxies that can be used to estimate aqueous salinities in past hypersaline environments. While good salinity estimates can be obtained from fossil diatoms [1] and ostracods [2] living at defined salinity ranges, the tests of these organisms are rarely well-preserved in sediments of Australian salt lakes. Therefore, in this study, we aim to create a new proxy for hypersaline conditions based on biomarker molecules that can be extracted from sediments of recent salt lakes and million-year-old sedimentary rocks that were deposited in ancient hypersaline environments.

Previous studies that also utilise biomarkers as molecular indicators for determining salinity have studied pristane \( (nC_{17}, \text{Pr})/ \) phytane \( (nC_{18}, \text{Ph}) \) ratios, gammacerane indices, and chromanes and their derivatives for assessing lacustrine salinity [3]. However, these proxies are only characteristic of lower salinities of around 10 – 15% and even within these limits, they are unreliable and imprecise. In the case of chromanes not even the biological precursors are known [4]. This study focuses on the use of the halophilic archaeal carotenoid, bacterioruberin, to estimate minimum salt levels in sediments deposited under extremely hypersaline conditions.

Bacterioruberin is a red-pink \( C_{50} \) carotenoid pigment biosynthesised by halophilic archaea as well as some non-halophilic bacteria, and it is a characteristic pigment of extremely hypersaline archaeal communities. It is produced by archaea only under specific salt conditions, giving it the potential to become a biomarker proxy for salinity. Biomarkers, which are the molecular fossils of natural products that can be preserved over geological time in the sedimentary record, have become an important method to compliment more conventional paleontological studies (e.g. fossils). Biomarkers are able to link molecules to biological sources; therefore if an environment does not favour fossil preservation, the hydrocarbon skeleton of biogenic compounds may still remain in the sediment.

For this study, we aim to isolate and extract the pigment bacterioruberin from water filtrates of saline Lake Tyrrell in outback Victoria, synthesise its hydrocarbon equivalent, bacterioruberane, and perform various temperature-controlled hydrous pyrolysis experiments on both compounds. Following hydrous pyrolysis, we expect to obtain smaller breakdown fragments of the original
compound that are identical to the putative natural degradation products of this pigment and that should have unique and diagnostic structures. The ultimate goal will be to look for the distribution of these fragments in sedimentary rocks up to 800 Ma old that were deposited in ancient hypersaline ecosystems. Our sample suite are shale evaporites composed of anhydrite and dolomite, originating from the Gillen member of the Bitter Springs Formation in the Amadeus Basin, Central Australia. If molecular fossils of bacterioruberin can be found in these ancient samples, it will represent the first and oldest evidence for hyperhalophilic organisms and Haloarchaea in the geological record.

MICROSTRUCTURAL ANALYSIS OF SHEAR ZONES IN THE LESSER HIMALAYA, NW INDIA

Jia-Urn Lee, Marnie Forster

The Lesser Himalaya is one of the major thrust sheets within the Himalayan orogen. Smaller-scale, intra-continental thrust sheets exist within the Lesser Himalaya, juxtaposed by shear zones. Understanding the evolution of these internal thrust sheets is vital to understanding the evolution of the orogen itself. The structurally highest of these internal thrust sheets is the Jutogh Formation, thrust upon the underlying stratigraphic formations by the Jutogh Thrust. The tectonic events and their relative duration in this complex terrane have been reassessed using Tectonic Sequence Diagrams (TSDs) with important results essential for future geochronology work.

The colonization of Remote Oceania and where the colonizing population of Lapita originated has been a source of speculation in Pacific archaeology because of the previous lack of prehistoric human remains. The use of strontium isotope ratios to track the degree of mobility in prehistoric populations in continental settings has become a common technique in archaeometry. The method matches the bioavailable $^{87}$Sr/$^{86}$Sr ratios in sediment, rock, and plant materials with the strontium isotope ratios of human and faunal teeth from archaeological sites. Various projects have applied the technique to select regions in the Pacific Islands associated with Lapita with positive results. Samples from the major geological units of Vanuatu have been collected and will be analysed resulting in the construction of a bio-available strontium isotope map. The map will then be used to compare the values obtained from the Teouma site, the largest collection of Lapita age skeletal remains, to provide further details on the degree and direction of mobility in the Lapita colonization.
THE BORON ISOTOPE COMPOSITION OF BIOGENIC SILICA

Andrea de Leon, Martin Wille, Stephen Eggins, Michael Ellwood

The Southern Ocean is widely regarded as playing a key role in influencing atmospheric pCO₂ over glacial-interglacial timescales; the mechanism by which this influence is exerted is, however, poorly constrained. A better understanding of changes in the surface and deep water carbonate system (e.g. pH, alkalinity) would provide invaluable insight into the driver(s) of millennial scale climate change.

The boron isotope composition of biogenic carbonate has been demonstrated to be a useful proxy for seawater pH, and has been used to reconstruct pH and pCO₂ records over time. Unfortunately, the paucity of biogenic carbonate in Southern Ocean sediments means similar reconstructions have not been made in this region. To overcome this problem, the boron isotope composition of biogenic silica, which is abundant in Southern Ocean sediments, is being investigated as a potential seawater pH proxy.

Analysis of siliceous sponges collected from the continental shelves off Tasmania and Antarctica is being conducted in order to investigate the relationship between the boron isotope signature of biogenic silica and seawater pH and nutrient composition.
WATER ISOTOPE RECORDS OF PALAEOMONSOON DYNAMICS OVER THE LAST ~30 kyr

Sophie Lewis, Michael Gagan, Linda Ayliffe, Allegra LeGrande, Maxwell Kelley, Gavin Schmidt

We present high-resolution, uranium-series dated stable isotope records from multiple speleothems from southern Indonesia (8°S, 120°E) spanning the last ~30 kyr. Speleothem δ¹⁸O variability at this site largely reflects changes in precipitation brought about by large-scale shifts in the position of ITCZ.

The speleothem δ¹⁸O record shows pronounced variability over the last ~30 kyr and demonstrates distinct differences from late Quaternary speleothem-based climate reconstructions of the Northern Hemisphere (Borneo and China). In addition, fast-growing Indonesian stalagmites are near-annually banded and provide the opportunity for multi-proxy annual- and seasonal-scale rainfall δ¹⁸O reconstructions during MIS3.

Although water isotope records provide some of the most extensive evidence of past climate change, interpreting their variability into climatic change requires applying a relationship between water isotopes and climate, usually inferred from modern variability. We improve this estimate for the relationship between water isotopes and climate through multiple simulations of past and present climate using the GISS ModelE-R, a fully coupled atmosphere-ocean GCM equipped with water isotope tracers. In addition, we tag water isotope variability due to alterations in source through the addition of 144 tracers that allow us to explicitly track the precipitation source distribution for individual sites.

Model results support the interpretation of isotopic variability in tropical speleothem records and allow a greater understanding of late Quaternary changes in precipitation. In southern Indonesia, speleothem δ¹⁸O variability is caused by changes in local precipitation amount and shifts in oceanic source region through time.
EXPERIMENTAL CONSTRAINTS ON CHLORINE BEHAVIOR IN SUBDUCTED SEDIMENTS

Huijuan Li, Joerg Hermann.

The phase and melting relations in subducted pelites have been investigated experimentally at 660-800°C, 25kb and 35kb. The starting material contains 6.6% water with the ratio of water to Cl content at 30, which is similar to the water to Cl ratio in the olivine-hosted melt inclusions found in arc lavas. Amphibole contains detectable amounts of Cl (400-500ppm). At 800°C, 25kb and 35kb, Cl content in Phengite(200 ppm) is just above the detection limit, while it reaches 700ppm at 750°C, 35kb. Biotite contains around 0.1% Cl at 760°C, 25kb. Apatite is the favorite hydrous mineral in which Cl is found residing. Cl content in Apatite increases with increasing temperature from 0.35% at 660°C, 25kb to 1.2% at 800°C, 25kb; and from 0.15% at 700°C, 35kb to 0.65% at 800°C, 35kb. Meanwhile the Cl content in the melt decreases with increasing temperature from 0.17% at 690°C, 25kb to 0.08% at 800°C, 25kb; and from 0.29% at 750°C, 35kb to 0.08% at 800°C, 35kb.
PETROLOGY OF THE MANTLE WEDGE IN THE NEW BRITAIN ARC

Sarlae McAlpine

This presentation will detail my direction in this early stage of my PhD study.

During the West Bismarck Vents Expedition research voyage of the Marine National Facility, a large collection of peridotite- and gabbro-cored basalt bombs were dredged from three cones in the vicinity of Ritter Volcano. Ritter is the first active volcano located to the west of New Britain. The Ritter suite represents the first global occurrence of peridotites from an active volcanic arc front volcano, hosted by subalkaline basalt. Wedge-derived peridotites are extremely rare even in well-explored subaerial arcs.

I propose a detailed mineralogical, petrological and isotopic study of these samples. The prime aims of the research will be to unravel the petrological history of the wedge from formation of the harzburgites (likely through melt extraction) through to metasomatic veining of the material, possibly through subducted slab-derived fluid ingress.

This presentation will cover the geographical and geological locations of my samples, previous research, initial aims and why the Ritter suite offers a unique window into the mantle wedge underlying the New Britain Arc.
A PRECISE Mn-Cr PSEUDO-ISOCRHN FOR THE BRENHAM PALLASITE METEORITE

Seann McKibbin

Pallasite meteorites are mixtures of Mg-rich olivine and Fe-Ni metal, interpreted as rocks derived from the core-mantle boundary of a differentiated asteroid, or mixtures of mantle and core material formed during a magmatic intrusion or the destruction of one or more differentiated asteroids (for a short review, see [1]). Olivine is generally homogeneous in Mg# but is zoned for some minor and trace elements, including Cr, Ca, Al, V, Ti, Ni and Mn [2, 3]. Crystal rims have high Mn/Cr ratios, making them potentially suitable for Mn-Cr isotope dating ($^{53}\text{Mn} \rightarrow ^{53}\text{Cr}$, $t_{1/2}$ 3.7 Ma) through measurement of $^{53}\text{Cr}/^{52}\text{Cr}$ and $^{55}\text{Mn}/^{52}\text{Cr}$ by SHRIMP ion-probe. There is a hint of excess $^{53}\text{Cr}$ in pallasite olivine rims [4], but the magnitude of the anomaly has not been precisely determined and may not be significantly higher than that found by thermal ionisation mass spectrometry (TIMS) of bulk olivine grains [5, 6].

Olivine from the Brenham Pallasite was recently analysed by SHRIMP-RG. Results show excesses of $^{53}\text{Cr}$ of up to ~5 ‰ that are correlated with $^{55}\text{Mn}^{53}\text{Cr}$ which ranges from 15 to 50. This looks very much like a Mn-Cr isochron, with an inferred initial $^{53}\text{Mn}/^{55}\text{Mn}$ ratio of ~2-3 × 10^{-5}. This initial abundance is an order of magnitude higher than that inferred for other achondrites with well determined Mn-Cr ages [e.g. 6] and higher than reported by those using the TIMS method [5, 6]. Rather than a chronological interpretation, a diffusive process is preferred to explain the excess of $^{53}\text{Cr}$. It is possible that the source of the anomalous Cr is Mn-rich phosphate with high $^{53}\text{Cr}$ (identified in pallasites [7] and IIIAB iron meteorites [8] that may come from the same asteroid), with Cr migrating into the outer parts of olivine crystals. Another possibility is that diffusion may give rise to unusual isotopic effects in cases where cooling occurs over a timescale similar to that of $^{53}\text{Mn}$ decay [similar to that modelled in 8].

STROMTNIUM ISOTOPE TRACING OF HUMAN MIGRATIONS IN THE LEVANT

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The use of strontium isotope ratios to track the degree of mobility of prehistoric populations has become a common technique in archaeometry. This method aims to match the bioavailable Sr\textsuperscript{87}/Sr\textsuperscript{86} ratios in soil, rock and plant material with the strontium isotope composition of human and faunal teeth from archaeological sites. A substantial database of contemporary strontium values in soil, rock and plant samples has been collected from all major geological units in Israel. These are being used to construct a map of bioavailable strontium which will be compared to the strontium isotope composition of samples of faunal materials from key archaeological sites including Amud, Kebera, Qafzeh, Skhul, Sefunim and Tabun. The results of this analysis will provide new data on the distance and direction of migrations by early anatomically modern humans and Neanderthals in the Levant.
The Boggy Plain zoned pluton is composed of a wide range of rock types from gabbro, through granodiorite and granite to aplite. It is thought to be formed by the convective fractionation from relatively homogeneous high temperature magma [1]. Fourteen samples from the Boggy Plain zoned pluton have been analyzed for Re, Au and platinum group elements. The aim of this study was to investigate the PGE geochemistry of the fractionating high temperature I-type magma and their relationship with other chalcophile element such as Cu, Au and Re.

The PGE concentrations of the Boggy Plain rocks generally decrease from mafic to felsic, but the trend is not linear. The decreases in the abundances of PGE are slow in the gabbro and outer granodiorite, but are rapid through granite to aplite and there is a distinctive depletion in the inner granodiorite. When the data are plotted on mantle-normalized diagrams, the PGE patterns for the all rock types are sub-parallel over a range of ~100 times for Pd and Pt and ~ 40 times for Ru and Ir. Pd/Ir ratios for gabbros and granodiorites are from 41 to 191 and from 86 to 339 and increase with increased fractionation. Pd/Ir ratios for granite and aplite, on the other hand, markedly drop with the range from 28 to 52. Re and Cu behaves differently from PGE. They show peaks at SiO$_2$ 58 wt %. It suggests that the abundance of PGE, Re and Cu are controlled by different mineral assemblages. The subparallel PGE patterns exclude the depletion of PGE by the magma chamber scale sulfide fractionation. The clear explanation for the Cu-Re-Au-PGE pattern of the Boggy Plain rocks requires the further study.

EXPERIMENTAL EVIDENCE FOR HIGH-PRESSURE Na-AMPHIBOLE IN SUB-ARC ENVIRONMENTS AND IMPLICATIONS FOR THE SUBDUCTION FACTORY.

Cassian Pirard

In arc environment, fluids which are leaving the subducted slab are interacting with the mantle to finally form magmas when partial melting conditions are met under arc volcanoes. One of these fluid-mantle interactions is characterized by porous flow behavior which leads to the formation of hydrous peridotites.

The formation of hydrous peridotite is based on the presence of hydrated phases in the mantle, which can be talc, chlorites, serpentines, amphiboles and micas. At P-T conditions where slab fluid-mantle interactions are likely to take place (700°C-35kbar), most of these hydrous phases are no longer stable and will have broken down, releasing fluids in the mantle or forming other water-bearing phases. In those conditions, only trioctahedral micas (phlogopite) and rare amphiboles (K-richterite) remain. Although micas are important reservoirs for both water and incompatible elements, the crystal structure doesn’t allow the storage of large amounts of REE, Na and transition elements. Ultra high pressure amphiboles such as K-richterite would be likely to retain trace elements such as rare earths, however, it is unable to host large amount of important major elements such as sodium.

Our experimental studies on the porous flow interaction between slab-related fluid and mantle have revealed the presence of a new stable sodium-rich hydroxyamphibole in the range of 35kbar where other similar amphiboles would breakdown at much lower pressure (25kbar). This amphibole has a chemical composition close to a magnesiokatophorite \( \text{Na}_2\text{Ca}_5\text{Mg}_2\text{Al}[(\text{Si}_2\text{O}_5)(\text{OH})_2] \), with a very low calcium content, Na/K ratio around 10:1 and an Mg-number with mantle values. Such amphibole, in equilibrium with olivine, orthopyroxene and biotite, shows a stability range spreading from less than 800°C up to 950°C at 35kbar when it breaks down into a highly sodic melt. The major element composition offers a good counter part to micas by hosting most of the sodium released by slab fluids. Moreover, amphiboles and micas have an efficient job-sharing behavior as recipient for trace elements carried by the slab fluids. The amphibole crystal structure has a good aptitude to host REE but also group 3 and group 4 elements whereas micas are more likely to contain LILE and U and Th. In consequence, the breakdown of such assemblage of hydrous phases at sub-arc conditions could have a potential key-role in understanding the subduction factory and the transmission of the slab signature to the lavas occurring in arc settings.
EXPLORING THE MELTING BEHAVIOUR OF THE EARTH’S HETEROGENEOUS UPPER MANTLE

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High pressure phase relations and melting behaviour of heterogeneous mantle comprised of mixed lithologies (e.g. discrete bodies of mafic eclogite or pyroxenites and diverse types of metasomatised, re-fertilised or depleted mantle) are poorly constrained, yet this information is essential for understanding the observed geochemical diversity of primitive magmas on Earth. My project aims to provide a systematic high-pressure experimental framework for understanding the phase and melting relations in upwelling heterogeneous upper mantle. The phase relations thus determined control minor and trace element behaviour during partial melting and will be essential constraints on models of isotope evolution and mixing used to explain the chemical and isotopic heterogeneity of mantle-derived magmas.

One part of this study is designed to reveal systematically the variations in solidus temperatures, phase relations, and partial melt compositions during decompression melting of residual garnet-bearing pyroxenites with variable Na/Ca ratios and SiO2 contents.

An essential component of the project is also to search for evidence of processes of heterogeneous melting, melt migration and mantle refertilisation in natural mantle samples. Accessible for such investigation due to tectonic emplacement from upper mantle into the crust are the peridotite and pyroxenite massifs of the Western Gneiss Region (WGR) of Norway. At Almklovdalen, orthopyroxene rich lithologies line contacts between refractory eclogitic lenses surrounded by garnet peridotite. The eclogitic pyroxene compositions are consistent with loss of a partial melt fraction, whereas the peridotite clinopyroxene compositions and orthopyroxene layers indicate reaction and enrichment during metasomatic influx of a siliceous melt. This may be a natural analogue for the reaction experiments of Yaxley and Green (1998) [1] in which silicic partial melts of eclogite layers reacted with adjacent peridotite, producing orthopyroxene-rich layers at the eclogite/peridotite interface.

This study of rocks at Almklovdalen will compliment the high pressure experimental studies of eclogite melting by enabling investigation of migration of melt in the upper mantle, and reaction processes at the lithological interface in natural mantle samples. We are also searching for links
between partial melting of heterogeneous mantle and deformation, and how this bears on melt segregation and migration and reaction in upwelling mantle.

MOLECULAR CHARACTERIZATION OF A NEOPROTEROZOIC HYPERSALINE ECOSYSTEM

Richard Schinteie, Jochen J. Brocks

We present a detailed molecular investigation of the biotic composition and biogeochemistry of an evaporitic, hypersaline environment from the mid-Neoproterozoic (~0.8-0.7 Ga). The discovery of evaporite deposits on Mars highlights the need to understand their capacities as biological archives. Biomarkers were analyzed from evaporitic sediments of the Neoproterozoic Bitter Springs Formation, Amadeus Basin, central Australia. Due to the broad shallow nature of the Amadeus Basin and a tenuous connection with the ocean, the water was characterized by elevated salinity levels during that time. As a result, very thick (100 m to >2000 m) evaporite units were deposited [1].

We extracted biomarkers from evaporitic sediments composed of dolomite, anhydrite and/or halite. The evaporites are often composed of numerous microbial mat-like formations that exhibit roll-up structures and tearing. Full scans (gas chromatography - mass spectroscopy, GCMS) of the saturate fraction revealed high ratios of mono- and dimethyl alkanes relative to \( n \)-alkanes. Such patterns are typical of Precambrian and Cambrian samples and observed in a number of facies settings. An outstanding characteristic are several pseudohomologous series of both regular (to \( C_{25} \)) and irregular (to \( C_{40} \)) acyclic isoprenoids. These isoprenoids are present in high concentrations and have never before been reported in the Precambrian. The presence and relative concentrations of these compounds vary with regards to the sedimentology of the host rock. Hopanes and steranes are often present in low concentrations or are absent.

Based on these results, we present an ancient and extreme, saline environment dominated by prokaryotes – with potentially the oldest evidence of haloarchaea in the geologic record. The presence of exceptionally well preserved biomarkers in anhydrite, despite the fact that sulfate and biomarkers are thermodynamically not stable together, raises the prospect of finding biomarkers in sulfate deposits on Mars.

A NUMERICAL MODEL OF MANGANESE DIFFUSION IN GARNET AND ITS APPLICATIONS TO GEOSPEEDOMETRY

Iona R. Stenhouse, Gordon S. Lister, Daniel Viete, Hugh St.C. O’Neill

The determination of time-scales of thermal pulses can constrain in part the P-T-t history of a rock unit. The geospeedometry method allows for the determination of timescales of thermal events by measurement of diffusional modification of element concentration profiles in minerals. Lasaga (1983) introduced the new geospeedometry method as an extension to geothermometry to obtain rates of cooling and exhumation of metamorphic rocks. The term is now used for various diffusion modelling studies on metamorphic rocks, despite not all methods returning a rate but rather a time-scale for thermal events. The diffusive exchange of iron and manganese between garnet and ilmenite has the potential to be a useful tool due to the temperature dependence of the partition coefficient (Pownceby et al. 1987). At temperatures higher than the growth temperature ilmenite will act as a diffusive sink for Mn. On the cooling path however the ilmenite inclusion will expel Mn into the garnet host. This effect has the potential to produce a “moat” in the Mn concentration surrounding an ilmenite inclusion in the garnet host. This “moat” when measured, due to the quadratic relation between length of diffusion profiles and timescales, has the potential to constrain timescales on the prograde and retrograde path. This phenomenon predicted theoretically was observed in natural garnets and simulated using a numerical model.


MINERALS OF REE, Th AND U IN HIGH PRESSURE AND ULTRAHIGH PRESSURE (DIAMOND GRADE) METAMORPHIC ROCKS (KOKCHETAV MASSIF, NORTHERN KAZAKHSTAN).

Stepanov AS, Korsakov AV, Rubatto D, Hermann J

The Kokchetav metamorphic complex in Kazakhstan is famous for metasedimentary rocks that experienced diamond-grade UHP metamorphism. We investigated the Kokchetav rocks by SEM targeting REE, U and Th minerals to trace the fate of these geochemically important elements during subduction. Most of studied samples are from the Barchikol lake area and some from Kumdy-Kol lake. Samples can be classified as schists and gneisses, with the schists being the precursors of the gneisses, which most likely represent restites after melting of metapelites [1,2].

The studied pelitic schists contain monazite as main REE and Th bearing mineral. In sample B01-3 xenotime is present as small inclusions in garnet but is absent in matrix. Content of Y decreases significantly in rim garnet thus the xenotime in matrix was consumed during the garnet growth. Sample BVV contains monazite enclosed by allanite.

Gneisses have complicated REE mineralogy. In general the gneisses have lower content of REE minerals than the pelitic schists. In a number of samples the following REE, Th, U minerals were found:

- Sample B48-04 – large grain of allanite in rock’s matrix.
- Sample B94-118 – in matrix observed large grain of U mineral (probably UCO3).
- Sample B29-04 – large kyanite crystal contains abundant monazite inclusions as well as microdiamond, graphite, rutile and zircon.

Complex associations of REE, U, Th minerals were also found:

- Sample B118-50 – contains pseudomorph after allanite composed of ThSiO₄, monazite and sericite. Large grain of rutile contains inclusion of U,Th mineral (U, Th carbonate?) and surrounded by simplectite with Nd-monazite.
- Sample B94-333 – contains garnet with inclusions of monazite, and replacement of monazite by apatite with formation of Th-rich mineral.

Concluding remarks

In the medium grade rocks of the Kokchetav, REE, U, Th are mainly hosted in monazite and allanite. On the other hand, the high grade rocks contain REE mineral associations, which are not typical for medium pressure granulites. In a number of samples the REE, Th and U are decoupled – they form distinct minerals. Some of these minerals appear to have formed during decompression (ThSiO₄, Nd-monazite, synchysite) and for other minerals formation on decompression possible as well. The
reported results rise a number of questions for further studies: (1) what minerals contained REE, U, Th in diamond-grade metamorphic rocks during prograde ultrahigh pressure metamorphism? (2) what portion of REE, Th and U were extracted from the metapelites during the melting process?

[1] Hermann J, Rubatto D, Korsakov A, Shatsky VS, 2001 Multiple zircon growth during fast exhumation of diamondiferous, deeply subducted continental crust (Kokchetav Massif, Kazakhstan), Contributions To Mineralogy And Petrology, 141, 1, 66-82.

Non-uniform buoyancy forcing along a horizontal boundary of a fluid-filled volume establishes a fundamentally unique circulation known as horizontal convection. Horizontal convection has a number of features in common with the overturning circulation in the oceans, and has been a powerful means of gaining insight into the role that surface buoyancy fluxes might play in the latter. We build on previous work and turn our attention to understanding the influence submarine topography (ridges, marginal seas, continental shelves, etc.) has on the circulation. In addition to this, we look at the effect external sources of mechanical mixing (winds and tides) have on the oceanic transport of heat. We do this by introducing these effects into idealised and controllable laboratory experiments and numerical simulations of horizontal convection, through which we aim to generate greater physical insight into the dynamics of the overturning circulation in the oceans.
THE EPISODIC SIGNATURE OF MAGMATISM IN THE LADAKH BATHOLITH, NW INDIAN HIMALAYA

Lloyd White¹, Talat Ahmad², Gordon Lister¹, Trevor Ireland¹, Marnie Forster¹

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The Ladakh Batholith is part of the Andean-type Trans-Himalayan Plutonic Belt that spans the length of the Himalayan mountain belt [1]. The Ladakh Batholith is thought to have formed as the result of north-directed subduction of the Tethyan oceanic crust below an island arc situated along the southern margin of Eurasia during the Cretaceous to early Tertiary [2]. The batholith shows evidence of multiple phases of magmatism, where the relative timing of magmatism can be understood through cross-cutting relationships that are observed in the field. The episodic nature of magmatism is also supported by various absolute geochronological methods that suggest magmatism occurred at ~distinct phases at ~100, 70, 60-58 and 49.8 Ma [1-4]. Much of this geochronological work has focused on trying to understand the youngest phase of magmatism in this part of the Himalaya, as it is thought to indirectly date the timing of the accretion of the Indian plate to the Eurasian plate (e.g. [3]). However, most of this work has relied on various statistical methods that average and smooth the resultant data (e.g. [3]; [5]).

Our work attempts to resolve the timing of magmatic events in the Ladakh Batholith by applying SHRIMP U-Pb dating to the sequence of cross-cutting magmatic events that are established in the field. We are also investigating the timing of magmatic events in the Karakorum Batholith / Metamorphic Complex, that are found to the north of the Ladakh Batholith / Shyok Suture Zone. These rocks also show a complex magmatic history that spans over 100 million years ([5-6]).

Our preliminary results indicate that the magmatic history of this part of the Himalaya is much more complex than it was previously considered. They also show that the results that are considered as outliers by other workers are often confirmed as zircon crystallisation ages through a more comprehensive dating strategy. Our preliminary results also indicate that magmatism was episodic throughout the Himalayan Orogeny.

These initial results lead to further questions about the tectonic history of the Himalaya, the timing of granite emplacement during orogeny and the interpretation of geochronological data in general. How does the production of magma/granite vary before and after tectonic mode switches? Collins [7] suggests magma is emplaced during the extensional regime of a tectonic mode switch. If this were the case, our results would suggest that extension plays a significant role during the Himalaya Orogeny. However, other mechanisms (passive emplacement/diaprism, or stoping etc.) may be more applicable. Another interesting result is that the episodic signature of magmatism in the Himalaya also seems to
be consistent with the timing of other major tectonic events observed along the length of the Alpine-Himalayan orogenic belt [8]. These are thought to be the result of tectonic mode switches [8].


