ENVIRONMENTAL PROCESSES GROUP

Research in the Environmental Processes Group is concerned with climatic change and landscape evolution, and with connections between these and crustal processes, with attention to the chronology and rates of past changes at the Earth's surface. The question of the relative impacts of climatic change and human activities on Earth surface systems is basic to much of the group's research. Work in 2000 was focussed on high resolution variations of climate and sea level in the last 130,000 years, as well as the role of soil carbon in the global carbon cycle, and the chronology of landscape elements and regolith in Australia. Research is underpinned by a variety of laboratory facilities, particularly stable isotope mass spectrometry and various methods of dating surficial deposits, including radiocarbon and, through collaboration with the Environmental Geochemistry and Geochronology Group, luminescence and uranium-series techniques. Measurement of cosmogenic radionuclides, central to determination of erosion rates and exposure ages of rock surfaces, is carried out by accelerator mass spectrometry (AMS) as a collaborative program with the Department of Nuclear Physics (RSPhysSE). Palaeomagnetic measurements of the age of ancient regolith continued in conjunction with the Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRC LEME), using the RSES-AGSO palaeomagnetic facility. The Radiocarbon Laboratory, in keeping with its role in the cross-campus Centre for Archaeologic Research, maintained its program of dating a range of archaeologic sites throughout the southwest Pacific region. As in previous years, the Group’s support staff continued to devote effort beyond the call of duty to sustain a high level of equipment operation and sample processing.

The group's research progressed well in 2000. Dr Gagan, together with Ms McGregor, Ms Abram and new post-doctoral fellow, Tsuyoshi Watanabe, extended their coral-based studies of the past behaviour of El Niño and the Indian Ocean Dipole through the last 8000 years, with materials from northern Papua New Guinea, eastern Indonesia and the Mentawai Islands near Sumatra. Ms Treble examined relationships between weather systems and the isotopic composition of rainfall, thus advancing the basis for palaeoclimatic analysis of limestone cave deposits. Dr Bird further extended his sample array for determining fluxes and residence times of soil carbon with new sites in Australia and overseas, while the ages of pre-Tertiary weathered soil mantles in Western Australia were determined palaeomagnetically by Dr Pillans. By combining cosmogenic nuclides with quartz particle luminescence, Dr Heimsath, Professor Chappell and Mr Rustomji, together with Dr Spooner of the Environmental Geochemistry and Geochronology Group, determined processes and rates of soil production by rock weathering in southeastern Australia. Results of this work were integrated by Dr Braun in the Geodynamics Group into numerical models of soil transport and landform evolution.

^{10}Be determination of erosion and soil production rates throughout Australia

J. Chappell, A. Heimsath, A. Alimanovic and P. Rustomji, K. Fifield[1], M. de Tada[1], P. Hausladen[1] and G. Santos[1]

Rates of erosion in a wide sample of Australian landscapes were assayed using measurements of ^{10}Be, produced in rock outcrops by cosmic rays. The rate of soil production by rock weathering on soil-mantled slopes was determined similarly. Measurements were completed for over 100 samples from sites in the southeastern highlands, the Flinders Ranges, the gibber plains and table-top hills west of the Simpson Desert, the Macdonnell Ranges near Alice Springs, and the rolling downlands of the West Australian wheat belt. Samples from ancient granite domes of Tai Shan in eastern China also were measured.

A theoretical sampling distribution was developed to cover the problem of determining a representative erosion rate for blocky, jointed bedrock surfaces that break up in a stepwise manner. Measurements from samples from precipitous rocky slopes in the Flinders Ranges

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conform to the theoretical distribution and give the same mean rates as talus and coarse sediment derived from these slopes, confirming that representative erosion rates can be obtained even in rugged terrain. Interesting results include the finding that deep, steep valleys in the Flinders Ranges are eroding by slope retreat and downcutting at an average of 7 m per million years in hard quartzite terrain and at about twice this rate in sandstone and mixed limestone terrain. Geomorphologic evidence indicates that these rates probably have been sustained over tens of millions of years and imply that uplift and slow deformation of the ranges is a continuing process.

Cosmogenic determinations of the rate of soil production by rock weathering, initiated by Dr Heimsath before joining the group, were continued at soil-mantled hillslopes in the Bega Valley. Concentrations of cosmogenic nuclides at the surfaces of granite tors, exhumed over the last 100,000 years or so, indicate that the long-term natural loss of soil by downslope transport in this area is in equilibrium with weathering and soil production, the rate of which was found to decrease exponentially as the depth of soil increases, with a maximum under thin soil (less than 10 cm) of ~50 m per million years. This natural rate of soil production is very much less than rates of soil losses induced in many parts of the eastern highlands of Australia by land mismanagement since the establishment of agriculture since the mid-nineteenth century.

Determination of processes and rates of downslope soil transport, using optically stimulated luminescence

A. Heimsath, N. Spooner, J. Chappell and D. Questiaux

The downhill movement of soil, assisted by natural "stirring" caused by treefall and by burrowing animals from ants to wombats, was studied by using optically stimulated luminescence (OSL) measurements of invidual quartz grains from a range of positions within a downslope soil profile. These measurements showed that a large proportion of mineral grains have visited the surface in the past, only to become re-buried in their passage downhill, and that the time elapsed since last visiting the surface increases with soil depth. In addition, the measurements show that the number of grains that have yet to visit the surface also increases with soil depth.

Monte Carlo simulation of simple soil creep, modelled as independent movements of individual grains subjected to random displacements with an overall downhill drift, produces results that compare closely with the OSL data, in terms of mean age-depth relationships, age-variance patterns, and the variation with depth in the proportion of grains that have visited the surface. Combining the results with cosmogenic nuclide determinations of soil production gave a rather complete characterisation of soil flux and particle motion downhill.

Paleomagnetic dating of Phanerozoic weathering imprints, Mount Percy mine, Kalgoorlie, Western Australia

B. Pillans and R. Bateman[2]

Archean basement rocks at Mt Percy mine have been deeply weathered in a tectonically stable, near-surface environment, possibly for much of the Phanerozoic. Secondary iron oxides in the weathered regolith acquired a magnetic remanence in the direction of the Earth's magnetic field at the time they formed. Ages of weathering-induced magnetisation are estimated by comparison with the Australian Apparent Polar Wander Path (AAPWP). Resultant ages confirm, for the first time, that Cainozoic, Mesozoic and probably Paleozoic weathering imprints are recorded in regolith at a single site.

[2] Kalgoorlie Consolidated Gold Mines, Kalgoorlie, WA

Oriented samples of oxidised saprolite were collected in open cut pits at Mt Percy, and subject to stepwise laboratory demagnetisation using both thermal and alternating field techniques; thermal demagnetisation generally yielded more consistent results. Remanences were measured on an ScT 2-axis cryogenic magnetometer. Characteristic Remanent Magnetisations were identified by Principal Component Analysis. Well defined, stable magnetic remanences were isolated at several sites as follows:

1. Ultramafic saprolite from two sites at depths of 15–20 m yielded a combined high temperature (stable to >580°C) remanence direction of decl = 005.7°, incl = -73.3° (N = 20 specimens). The resultant south pole position (115.4°E; 61.3°S; A_{95}= 2.2°) lies on the late Mesozoic/early Tertiary segment of the AAPWP, with an estimated age of 60±10 Ma. This pole is statistically indistinguishable from that of the Morney weathering profile in Eromanga Basin, southwest Queensland.

2. Porphyry saprolite (10–15 m depth) yielded both intermediate (stable to <580°C) and high temperature remanence directions with mean decl = 321.2°, incl = -68.0° (N = 19). The resultant south pole position (164.8°E; 54.7°S; A_{95} = 5.0°) lies close to both the mid-Cretaceous and Jurassic segments of the Mesozoic AAPWP. A mid-Cretaceous age is ruled out because specimens are of both normal and reversed polarities, whereas the mid-Cretaceous is characterised by normal polarity field directions only; a Jurassic age is thus inferred.

3. Porphyry saprolite (35-40 m depth) yielded a high temperature remanence direction of decl = 200.6°, incl = 62.2° (N = 28). The resultant south pole position (076.8°E; 69.4°S; A_{95} = 3.8°) lies on the Carboniferous segment of one of several alternative Paleozoic AAPWP's.

To the south of Kalgoorlie, mid-late Eocene marine sediments occur in paleovalleys cut into older weathered regolith which must therefore be pre-middle Eocene in age. Furthermore, the headwaters of northward-flowing paleovalley drainage networks extend south to, and are truncated by, the present coast. If the headwater regions lay to the south, they must have been in Antarctica prior to the start of continental rifting in the Jurassic. The regolith into which the paleovalleys were incised must therefore be at least as old as Jurassic. The paleomagnetic ages from Mt Percy are consistent with these independent estimates of the extreme antiquity of regolith in eastern Yilgarn

Inventories of carbon and its isotopes in sandy soils

M.I. Bird, Y. Zhou[3], J. Cowley and L. Vellen

As part of research for the CRC for Greenhouse Accounting, Project 3.1 'Inventory Techniques' is developing strategies for the rapid, cost effective sampling of soils in order to determine both the amount of carbon stored in soils and the turnover time of carbon in the soil. The initial targets of the project are sandy soils and to date, over 5,000 soil cores have been taken from such soils from 23 locations of varying climate, in order to develop empirical relationships between climate, soil carbon storage and isotopic composition.

The major problem in sampling soils for carbon is local heterogeneity, particularly with respect to isotopic composition. The approach used in this study is to take many soil cores and then bulk samples collected under woody vegetation, and also away from woody vegetation. In many ecosystems, the distribution of woody vegetation in the landscape plays a major role in determining the distribution and isotopic composition of carbon present in the soil. Cores are collected from 0–5 cm and 0–30 cm depth and the final results are weighted

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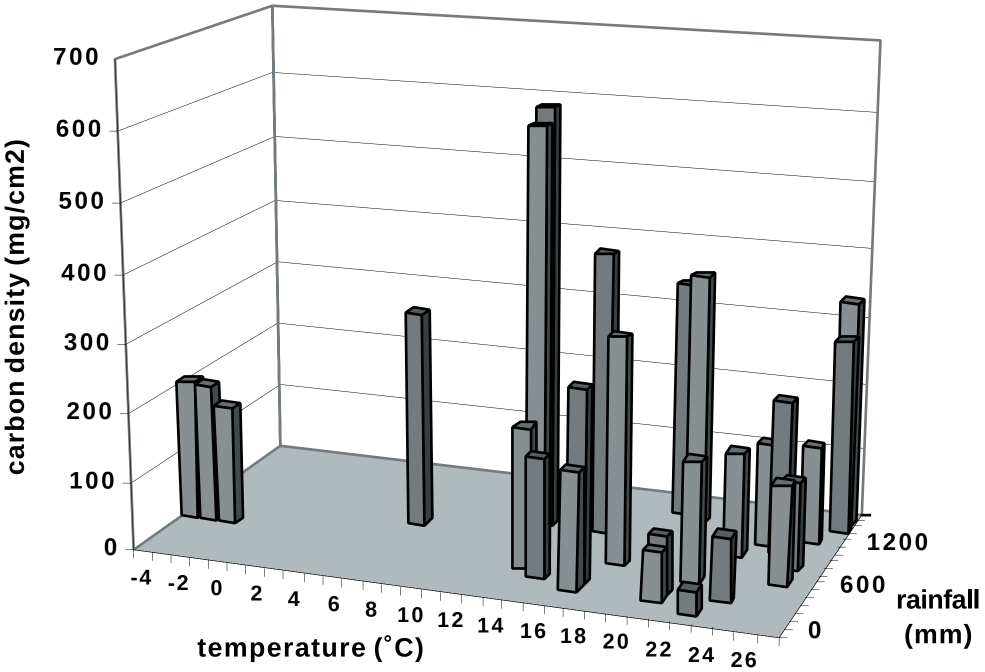

Figure 1: Weighted 0-30cm carbon inventories (mg/cm^2) for sandy soils from contrasting climates.

according to the proportion of woody vegetation present along each of five transects (with five sample sites per transect).

Soil density is measured for each sample in order to be able to calculate carbon densities. Soil densities for the sample localities range from 0.65 – 1.5 g/cm^3, underlining the importance of measuring rather than attempting to estimate soil density when converting measured percent carbon contents to carbon densities. Duplicate samplings suggest that this approach can estimate carbon inventories to better than ±10%.

The resulting weighted carbon inventories from 0–30 cm depth from all the locations for which data is currently available are presented in Figure 1. The weighted carbon inventories range from 36 to 640 mg/cm^2, and vary predictably with climate. Low carbon densities are found in hot dry climates, rising as rainfall increases into wet tropical climates, and rising very dramatically into cool temperate climates before falling again as temperature declines at high latitude. Such inconsistencies as exist in the current data are likely to be the result of differences in the amount of fine soil particles in the samples (the presence of fine particles will increase soil carbon inventories). The quantification of fine particles (<63µm) in the samples is underway, and will ultimately allow the normalization of the data to a uniform fine particle content.

δ^{13}C values are now available for all the sites and vary in a remarkably coherent fashion, in accordance with the known distribution of C3 and C4 plants with climate. Samples from hot, dry climates exhibit the highest δ^{13}C values (up to ~-18‰), with soils under pure C3 vegetation in warm regions having δ^{13}C values <-27‰ and in cold regions δ^{13}C values, generally >-27‰. The measurement of respiration rates for all samples under uniform laboratory conditions is well underway, along with the measurement of δ^{13}C values and radiocarbon content of the respired CO_2. Measurement of the radiocarbon content of the bulk soil is also underway, along with measurements of nitrogen content and extractable K and P. Sampling in the coming year will extend the data set into climatic zones not currently covered, including very wet tropical, very wet temperate, and cold, dry climates.

Progress in low-blank radiocarbon dating

M.I. Bird, L.K. Fifield[1], C.S.M. Turney[4], G.M. Santos[1], P.A. Hausladen[1], M.L. di Tada[1], B. Pillans, J. Chappell, R. Grün, P. Bowman[5], B. Alloway[6], B. David[7]

During the year the operation of the low-blank radiocarbon facility at RSES has become essentially routine, with the application of the techniques developed over the preceding two years to a diverse range of samples and projects with a large number of external collaborators. Samples analysed during the year have included wood, charcoal, ratite eggshell carbonate and organic carbon, lake sediments and mollusc carbonate. The major results have included:

1. measurement of what is probably the oldest 'date' on charcoal, of 61,000 years for charcoal from Border Cave archaeological site in South Africa, and the development of a coherent radiocarbon chronology for the site from 45,000 years to over 50,000 years ago.

2. Development of a new radiocarbon chronology for the Lynch's Crater paleo-environmental record from North Queensland.

3. The measurements of ages >52,000 years for the Nonda archaeological site in North Queensland.

4. Measurement of the oldest radiocarbon dates for the occupation of New Britain (40,000 years) on molluscs from the Buang Merebak archaeological site

5. Measurement of dates of ~50,000 years on ratite eggshell from Lake Eyre.

6. Measurement of an age of 52,000 years on a piece of wood carbonized by an ashflow at Maninjau, Sumatra. A fission track age on the ashflow is in accord with the radiocarbon age.

7. Determination of the deposition age (~43–44,000 years) of the Rotoehu tephra, an important stratigraphic marker in New Zealand.

Recent interannual extremes in groundwater transport of CO_2 to the Great Barrier Reef

M.K. Gagan, L.K. Ayliffe[8], D. Hopley[9], H. Scott-Gagan, J. Cowley, B.N. Opdyke[10] and M.T. McCulloch

Submarine groundwater discharge to coastal marine ecosystems has not been generally recognised, and direct measurements in the field are rare. On the other hand, long continuous records of freshwater input to coral reefs can be made by proxy from precise, tandem measurements of Sr/Ca and $^{18}O/^{16}O$ ratios in corals, which make it possible to determine uniquely the past oxygen isotopic composition of seawater. Here we produce a comparative history of the magnitude and interannual variability of groundwater discharge to a mid-Holocene (~6170 y) palaeo-reef fringing Orpheus Island, one of many island fringing reefs on the inner sector of the central Great Barrier Reef continental shelf.

The new high-resolution measurements shown in Figure 2 reveal that the submarine flux of ^{18}O-depleted groundwater has increased and become more variable since the mid-Holocene

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[7] School of Geography and Environmental Science, Monash University
[8] Laboratoire des Sciences du Climat et de l'Environnement, Unite Mixte de Recherche, Cedex, France
[9] Coastal and Marine Consultancies Pty Ltd, Townsville, Qld
[10] Department of Geology, ANU

(see figure caption). Oxygen isotope mass-balance calculations show that mixing of ~3% groundwater with the coastal ocean is all that is required to produce the 0.18‰ offset in seawater $\delta^{18}O$ following wet summers. The enhanced groundwater discharge to the coastal ocean is probably a result of recent decreases in evapotranspiration and twentieth century deforestation for agriculture, leading to higher land-sea hydraulic gradients.

Analysis of the groundwater shows that it is acidic (pH~6.3) and has a CO_2 partial-pressure (PCO_2) of ~47,000 µatm, which is more than two orders of magnitude higher than the mean PCO_2 of surface seawater. Therefore, introduction of ~3% groundwater could raise coastal seawater PCO_2 to ~430 µatm following active summer monsoons. According to the inverse relationship maintained between PCO_2 and CO_3^{2-} via the reaction $H_2O + (CO_2)_{aq} + CO_3^{2-} \leftrightarrow 2HCO_3^-$, the submarine influx of CO_2-enriched groundwater could have important implications for both aragonite saturation, and coral calcification. The natural rise and post-industrial increase in atmospheric CO_2 since the mid-Holocene already should have reduced coral calcification by ~20%. According to our calculations, this decrease in calcification could be periodically doubled (~40%) where nearshore coral reefs are exposed to groundwater discharge maxima.

Our results provide new evidence for a recent rise and pronounced interannual variability in groundwater discharge to the coastal ocean, which leads us to suggest that the impact of CO_2 on coral reefs may be greater, and more variable, than previously suspected. We estimate that ~60% of the world's coral reefs lie in nearshore environments exposed to CO_2–enriched groundwater inflow. Like the Orpheus Island reefs, many of these may have evolved from relatively stable, low CO_2 oceanic settings, and recent decreases in coral calcification driven by groundwater influx could help explain their recent degradation. Pursuit of this issue will require careful integration of coral palaeoenvironmental reconstructions and, where possible, real-time records of the relationship between groundwater discharge and PCO_2 in the coastal ocean.

Environmental evolution and OSL chronology in central Australia

P. English, N.A. Spooner, J.Chappell, D.G. Questiaux and N.G. Hill

Late Quaternary lacustrine, aeolian and fluvial deposits in Lake Lewis basin, Northern Territory, have been dated by optically stimulated luminescence (OSL). Lying at the furthest point from Australia's coastline, the study area has maximum "continentality" and lies near the southern edge of the Australian monsoon regime where the Macdonnell Ranges intercept moist air masses that sporadically penetrate this semi-arid region.

A longer period of wetter conditions during most of the Pleistocene is represented by thick uniform lacustrine clay that underlies the present playa of Lake Lewis and extends beyond it, grading into alluvial and piedmont sediments. A change to drier climatic regimes led to hydrologic closure of the basin, resulting in more heterogeneous lacustrine sediments, including deflated playa salts. Large volumes of calcrete and gypsum were deposited around the basin centre together with gypseous lake-shore dunes during wetter phases in the progression towards aridity, while longitudinal dune fields represent drier phases. OSL results show that aeolian dunes began to accumulate before 95,000 years ago, when the lake was shallow and saline, and peaked around 21–23,000 years ago. OSL ages of palaeo-flood deposits from the centripetal array of creeks feeding the lake indicate a change in the last 20,000 years to a regime of episodic flood events that continues to dominate the hydrology and sedimentary processes in central Australia today.

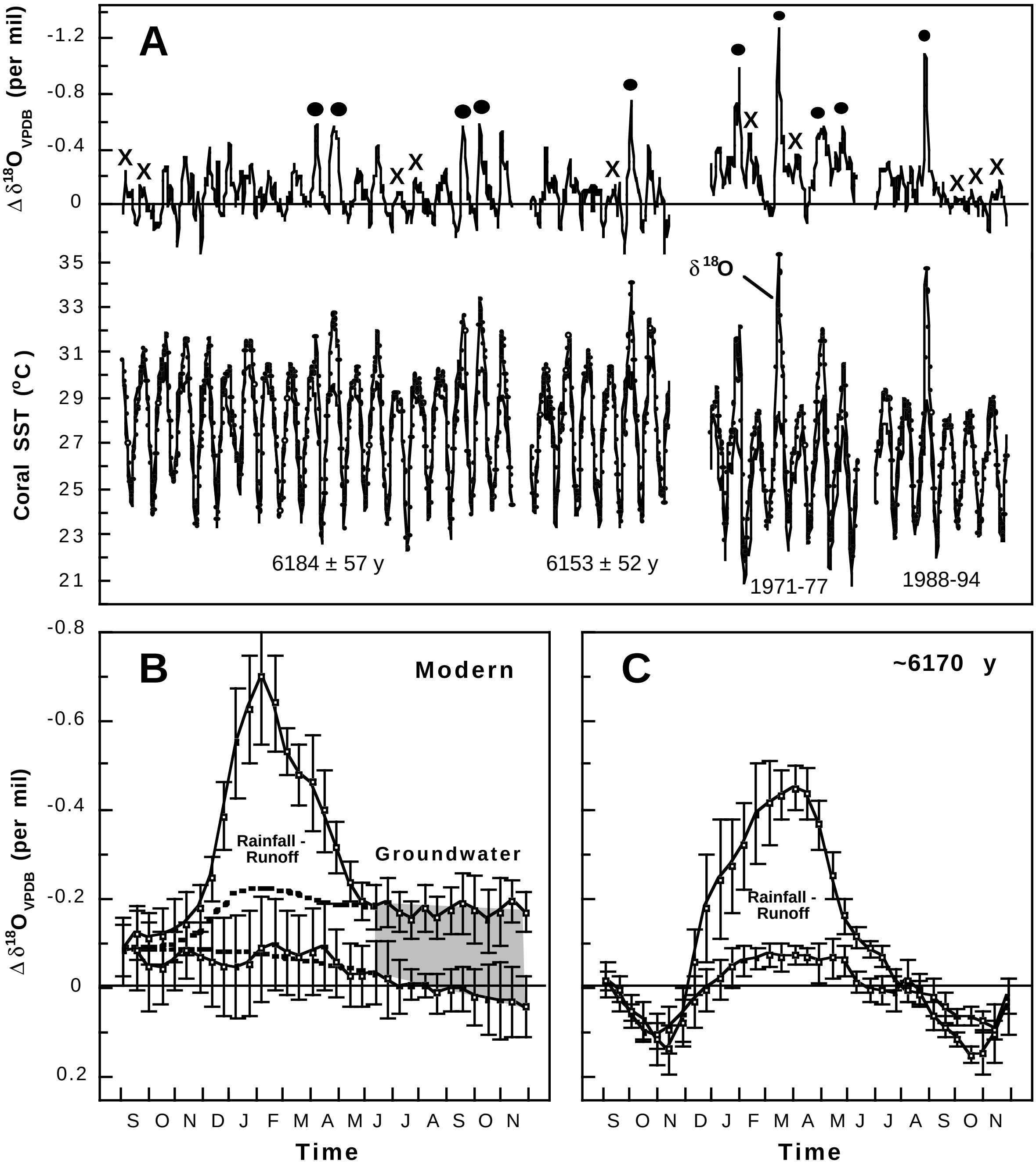

Figure 2: (A) Comparison of coral Sr/Ca (lower solid curves) and $\delta^{18}O$ (curves with circles) temperatures calculated for modern and mid-Holocene (^{230}Th ages) Porites from Orpheus Island, central Great Barrier Reef (18°45'S, 146°29'E). Upper solid curves show changes in the $\delta^{18}O$ of seawater ($\Delta\delta^{18}O$), after subtracting the temperature component of the coral $\delta^{18}O$ signal. Negative $\Delta\delta^{18}O$ values define relative freshening of the ocean surface by ^{18}O-depleted monsoonal rainfall and groundwater, whereas positive $\Delta\delta^{18}O$ values reflect evaporative ^{18}O-enrichment of the surface ocean in spring. (B, C) Comparison of the mean annual cycle of freshwater fluxes ($\Delta\delta^{18}O$) for the five wettest years (upper curves) and five driest years (lower curves) recorded by the modern (B) and mid-Holocene (C) coral records (vertical bars indicate standard error). The major difference between the mid-Holocene and modern $\Delta\delta^{18}O$ records is that, following wet years, the negative $\Delta\delta^{18}O$ signal in the modern coral record does not return to dry-year values during the June-November dry season. Groundwater inflow (indicated by shaded area) is the likely source of ^{18}O-depleted water following wet years. The dashed lines in (B) illustrate the probable contribution of groundwater to the $\Delta\delta^{18}O$ signal during dry and wet years.

Abrupt shift in mid-Holocene climate from coral proxy records in the western Pacific warm pool

H.V. McGregor, M.K. Gagan, M.T. McCulloch and J. Chappell

One of the major challenges for climate researchers is the prediction of human-induced greenhouse warming and how the tropics, through the El Niño southern oscillation, will respond. The El Niño southern oscillation is responsible for major climate fluctuations, which, through atmospheric teleconnections, can have far reaching impacts on climate around the globe. This study uses coral climate reconstructions from the Western Pacific warm pool to investigate the origins of the El Niño southern oscillation, the nature of the El Niño southern oscillation during the mid-Holocene (~6,000 years ago) and how the Western Pacific warm pool interacts with the monsoon systems.

Modern and fossil *Porites sp.* corals were drilled from Koil and Muschu Islands located within the flood plume of the Sepik River, Papua New Guinea in the Western Pacific warm pool core region. Here, El Niño events are manifest by reduced rainfall and cooler sea surface temperature. Changes in these parameters are reflected in coral skeletal oxygen isotope ($\delta^{18}O$) and Sr/Ca ratios, which thus can be used to reconstruct climate in the past.

Coral Sr/Ca ratios at 7900 calibrated years before present indicate cooler than present sea surface temperatures, warming to modern conditions between 6900 and 6100 calibrated years before present (Figure 3B). Around 5700 calibrated years before present, Sr/Ca measurements show that the sea surface temperature peaked at ~1.5°C higher than today, while fossil corals from 7900 to 5700 calibrated years before present show higher $\delta^{18}O$ values than the modern corals, implying higher salinity (Figure 3C). Between 5700 and 5400 calibrated years before present the Sr/Ca ratios and $\delta^{18}O$ values suggest a rapid transition to lower sea surface temperature and lower $\delta^{18}O$ (lower salinity). By 1800 calibrated years before present, modern conditions were established. Furthermore, interannual variability of $\delta^{18}O$ values was 30% lower than today, from 7900 to 5400 calibrated years before present, suggesting that El Niño events were weaker at that time (Figure 3A).

The Western Pacific warm pool today is a region of high sea surface temperature and low salinity leading to a deep, stable thermocline, reduced ocean mixing, with convergence of moist air above the Western Pacific warm pool. The resulting atmospheric convection above the warm pool forms the ascending arm of the Asian-Australian-African monsoon system. The results for 7900 to 5700 calibrated years before present suggest more saline and/or drier conditions in the Western Pacific warm pool region, effectively the opposite of the present situation, which could reflect stronger windfields and reduced atmospheric convergence at the warm pool. The shift to cooler and wetter conditions between 5700 and 5400 calibrated years before present is interpreted as a rapid initiation of convergence at the Western Pacific warm pool, perhaps leading to establishment of modern warm pool conditions. Interestingly, dust records from Africa also show a shift to modern conditions, around 5500 calibrated years before present (Figure 3D). Considering the interaction between the Western Pacific warm pool and the Asian-Australian-African monsoon systems today, it is possible that the rapid climate shift observed in the two records represents a reorganisation of the ocean-atmosphere-land system in the tropics.

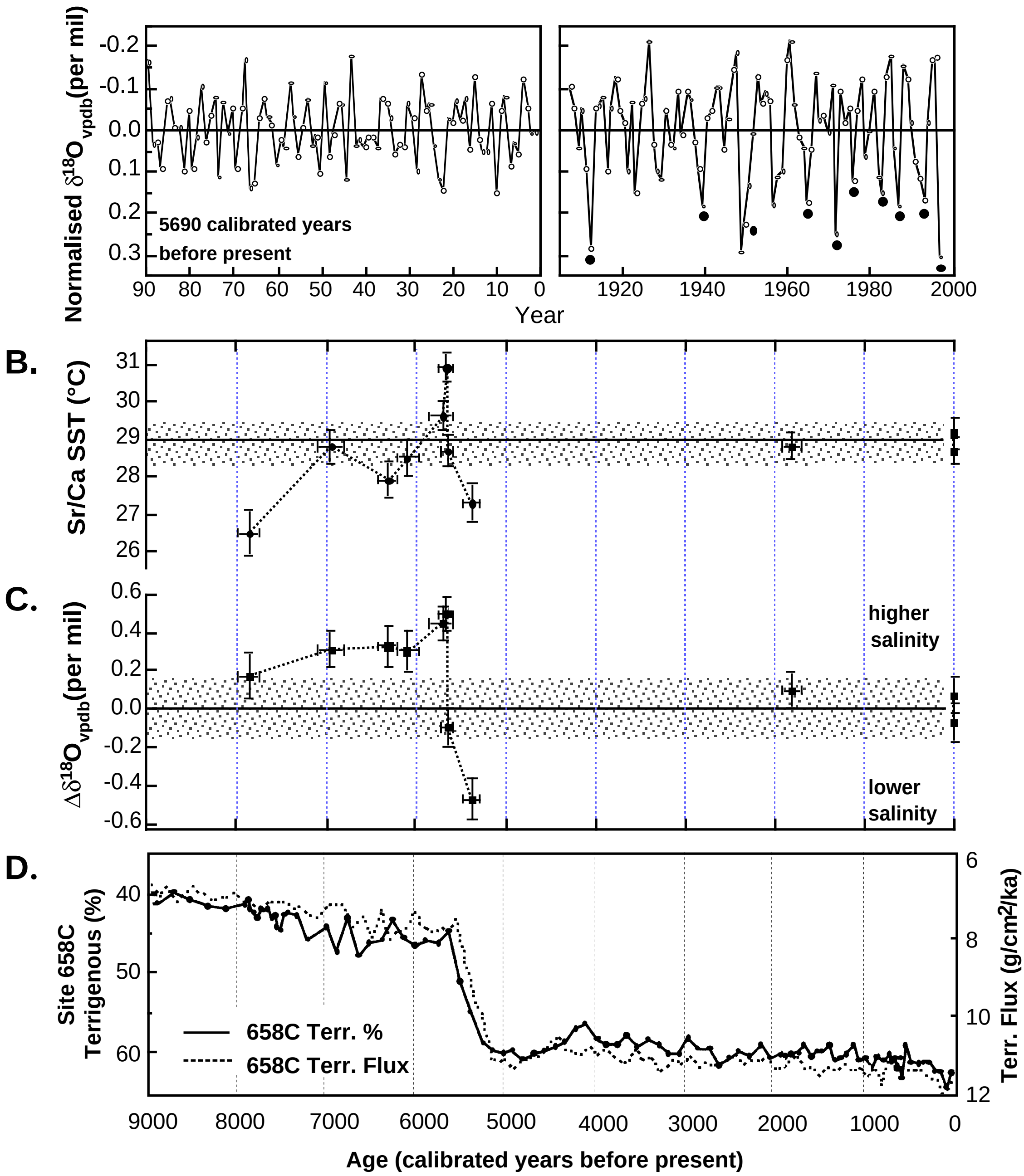

Figure 3: (A) Normalised annual δ^{18}O values for the modern and 5690 calibrated years before present corals from Muschu Island. A filter was used to remove non- El Niño-Southern Oscillation variability. Black dots on the modern record mark El Niño years. (B, C) Summary of mean annual Sr/Ca sea surface temperatures and $\Delta\delta^{18}$O values calculated for modern and fossil corals. Vertical bars indicate the standard error, horizontal bars indicate the 1σ range in the calibrated radiocarbon age. (D) Deep-sea core site 658C aeolian dust record from the literature. Abrupt onset and termination of the African Humid Period: rapid climate responses to gradual insolation forcing.

Coral records of the Indian Ocean Dipole

N.J. Abram, M.K. Gagan and W.S. Hantoro[11]

The Indian Ocean dipole is a recently discovered inter-annual climate oscillation which occurs in the tropical Indian Ocean region. Sea surface temperature variations off the south-western coast of Sumatra, Indonesia (Figure 4A) play a key role in driving the Indian Ocean dipole, which results in severe rainfall and drought events in Eastern Africa, Indonesia and Australia. During late 1997 the strongest dipole in recorded history occurred in the Indian Ocean and led to massive fires throughout Indonesia, as well as widespread death of the Mentawai Island reef ecosystem. Reconstructions of past events are essential in order to better understand the natural dynamics and effects of the Indian Ocean dipole, and how it interacts with other aspects of world climate such as the Asian monsoon and El Niño southern oscillation.

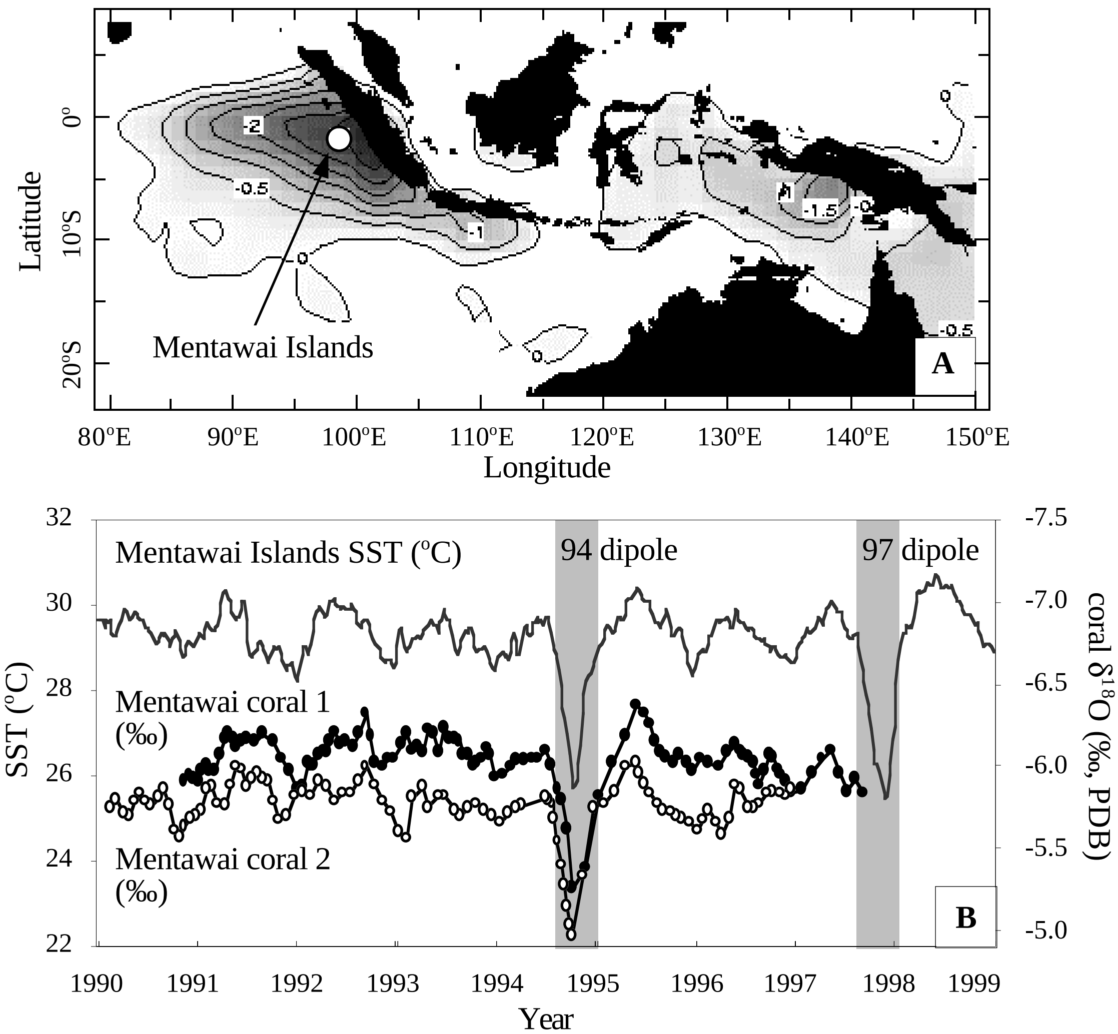

Figure 4: (A) Sea surface temperature anomaly map for November 1997. The strong negative anomaly in the Mentawai Islands region is the result of ocean upwelling associated with the Indian Ocean dipole. (B) Plot showing sea surface temperature in the Mentawai Islands and the corresponding $\delta^{18}O$ records of two modern corals from this region. The coral records clearly preserve the cool anomaly of the 1994 Indian Ocean dipole event.

[11] Research and Development Centre for Geotechnology, Indonesian Institute of Sciences

The oxygen isotope composition of two modern *Porites* corals from the Mentawai Islands have been analysed and demonstrate that corals from this area can be used to reconstruct dipole events (Figure 4B). Trace element analysis of these coral dipole records will be used in conjunction with the oxygen isotope signals to characterise the temperature, salinity, upwelling and productivity signatures of dipole events. Abundant and well preserved fossil reefs in the Mentawai Islands also will be used to reconstruct the Holocene history of climate and the dipole in the Indian Ocean. This research will contribute to the accurate prediction of future climate change as well as improved long range forecasts of flood and drought events in Africa, Indonesia and Australia.

Planetary evolution and the early carbon isotope record: evidence from Western Australia

J. Lindsay and M. Brasier[12]

The Late Archaean to Early Palaeoproterozoic basins of Western Australia contain a stratigraphic record covering the time interval between 2.7 and 1.8 Ga (= billion years ago) when the earth's atmosphere and biosphere were evolving rapidly. Carbonate rocks are well preserved throughout the succession where they form the upper parts of eustatically-controlled sequences. Stable isotope data from these rocks provide insights into factors controlling evolution of the arly atmosphere and biosphere.

The secular curve of $\delta^{13}C$ in carbonates is flat at ~2.6 Ga but from 2.6 to 1.9 Ga the curve is much more dynamic, showing significant positive and negative excursions. A major positive excursion between 2.2 and 2.3 Ga correlates with a similar event recognised in Africa, Europe and North America, the so-called Lomagundi Event. From 1.8 Ga, carbonates in overlying rocks suggest that the curve then is flat for the following billion years, until the Neoproterozoic. Stratigraphic data from these regions indicate that the Lomagundi Event coincides with cratonic convergence, supercontinent assembly and the initiation of major crustal subduction.

These data imply that carbon was sequestered in the mantle during ocean closure, as organic-rich passive-margin sediments containing isotopically light carbon were subducted. Atmospheric oxygen levels appear to have risen at the same time. The pattern appears to have been repeated in the Neoproterozoic when the supercontinent, Rodinia, was assembled, immediately before the appearance of multicellular life and the evolutionary "big bang", suggesting that evolution of life was modulated by plate tectonic evolution of the planet.

Calibration of speleothem oxygen isotopic records

P.C. Treble

Oxygen isotopes preserved in speleothem records have the potential to contribute significantly to the reconstruction of past climates. However, the climatic variables driving these speleothem records remain uncertain, particularly for records from Tasmania where isotopic trends over glacial to interglacial timescales suggest that rainfall effects dominate the isotopic signal. This situation raises an interesting problem as speleothem records from New Zealand (which also lies in the same mid-latitude westerly weather system as Tasmania) has earlier been shown to be driven by temperature, the isotopic effect of which is opposite in sign to the rainfall effect.

Since rainfall effects appear to dominate Tasmanian records it is necessary to investigate the oxygen isotopic composition of rainfall in this region. Monthly data from Tasmania published by the International Atomic Energy Association are inadequate because isotopic variations at the scale of synoptic weather patterns, which can be substantial, are smoothed out. However, several years of oxygen isotopic measurements of Hobart rainfall for individual

[12] Earth Science Department, Oxford University

rainfall events, kindly made available by Professor W. Budd of the University of Tasmania, have been correlated with synoptic weather patterns and show that the trajectory and origin of the rain-bearing moisture mass has a significant effect on rainfall oxygen isotopes. Hence, six rainfall collection sites (four in Tasmania, one in south-west Western Australia and one in South Island New Zealand) have been set-up to monitor the oxygen isotopic composition of rainfall produced by the dominant rain-bearing westerly frontal system.

Analysis of data obtained so far has shown that the frontal trajectory of mid-latitude moist air masses are governed by the latitude of the subtropical high which in turn influences the passage of the frontal system, and significantly affects the oxygen isotopic composition of rainfall across southern Australia. It is hypothesised that northwards migration of the subtropical high during glacial times would have enhanced these distillation effects, delivering isotopically lighter rainfall to Tasmania and so producing the observed shift in Tasmanian speleothem records, while the absence of such a landmass in the pathway of the fronts reaching New Zealand means that rainfall reaching New Zealand in glacial times was not similarly affected.