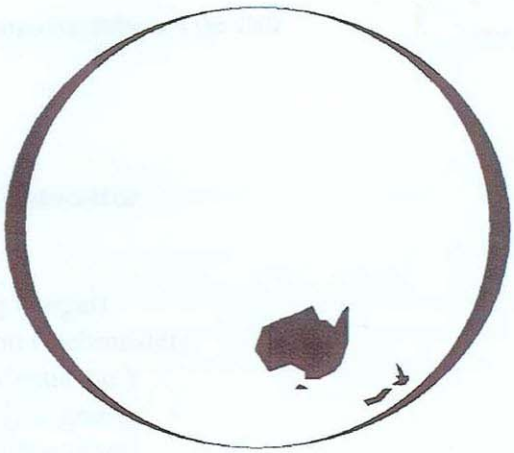
Australia and New Zealand Geomorphology Group



KALGOORLIE, AUSTRALIA

30 September - 4 October 2002

Conference Program

Abstracts and Participants

KALGOORLIE
AND THE WA GOLDFIELDS

10th Conference - 2002

Organising Committee

Mike Craig (Legal)
Andrew McMahon (Webmaster)
Colin Pain (Venue etc.)
Brad Pillans (Program)
Lisa Worrall (President)
and
Derek Fabel, John Webb, Jon Clarke (Fieldtrips)

Venue

WMC Conference Centre

Contents

Program vi

Almond, Peter; Roering, Josh; Tonkin, Philip; McKean, Jim 1
Processes and rates of soil creep on hillslopes: calibration of a soil transport model using tephra stratigraphy and dispersion

Anderson, Ian; Clarke, Jonathan D.A. (Poster) 2
Regolith mapping and the search for groundwater in a karst terrain, Balladonia, Western Australia

Atlhopheng, Julius; Chivas, Allan R. (keynote) 3
The ages of deep weathering in the Yilgarn Craton

Baker, Robert G.V.; Haworth, Robert J.; Flood, Peter G. 4
Global marine events on Rottnest Island, Western Australia?

Bourke, M.C. 5
Aeolian-fluvial interaction at paleoflood termini in central Australia

Brizga, S.O.; Craigie, N.M.;Clark, S.Q. 6
The use of hydraulic modelling in fluvial geomorphology - examples of the application of one- and two-dimensional models in Victorian river systems

Jonathan Brown 7
Late Quaternary landscape processes in the east Victorian highlands, with reference to Caledonia Fen, Bennison High Plains, Victoria

Chan, Roslyn 8
Regolith and landform evolution processes in the north-western Lachlan Fold Belt, NSW

Chappell, John (Keynote) 9
Cosmogenic isotopes and long term Australian landform evolution

Clark, Dan; Leonard, Mark; Collins, Clive (Poster) 10
Multi-disciplinary neotectonics research in Australia: developing an improved basis for seismic hazard assessment

Clark, Dan; Sandiford, Mike; Dentith, Mike 11
Longevity and significance of Australian seismic geomorphology: a hazard perspective

Clarke, Jonathan D.A. 12
Jarntimarra-1: selecting Australia's Mars analogue research site

Clarke Jonathan D.A.; Hou, Bouhong (Poster) 13
Eocene coastal barrier evolution in the Eucla Basin

Clarke, Jonathan D.A.; Worrall, Lisa; Pillans, Brad (Keynote) 14
Evolution of an ancient landscape, Kalgoorlie region, Eastern Goldfields, Western Australia

Crozier, M. J.; Hardenbicker, U.; Boyens, N. 15
Use of the jetstream hydraulic erosion device for determining erodibility of hillslope material - initial results

Davies, R.R.; Doerr, S.H.; Pulford, A. 16
Has speleogenesis beneath the Nullarbor Plain been underestimated? - evidence from microgravity measurements and geomorphological observations

Doerr, S.H.; Smart, P.L.; Beddows, P.; Smith, S.; Whitaker, F.F. 17
Investigating the hydro-geomorphology of the Worlds' largest submerged cave systems using novel underwater research techniques in the Yucatan, Mexico

Dunkerley, David 18
Canopy interception losses in dryland plant communities: why are they important, and how can we measure them?

Dunkerley, David (Keynote) 19
Do the little things matter? Recent work on the behaviour of shallow overland flows.

Fabel, Derek 20
Surviving glaciation: complex exposure modelling and the preservation of glacial landscapes

Fanning, Trish 21
Jobs for geomorphologists!: A new geoarchaeology of aboriginal stone artefact scatters in western NSW, Australia

Giles, Philip T. 22
Relict foredune plains in the Gulf of St. Lawrence, Canada

Hardenbicker, U.; Pott, A.; Crozier, M. J. 23
The influence of rainfall, soil hydrology and pipe network characteristics on slope drainage in steep pasture-covered hill country.

Hawke, R.M.; McConchie, J.A. 24
A geomorphic history of the dune system in the Otaki-Te Horo area

Hawke, R.M.; McConchie, J.A.; Toleman, I.E.J. 25
Discharge, velocity, and erosion within the Waikato River channel

Hemmingsen, Maree 26
The role of abrasion in coastal stability on the mixed sand and gravel beaches of the Canterbury Bight, South Island, New Zealand

Hesse, P.P.; Olley, J. 27
The encircling lunette at old harbour, nsw: implications for atmospheric circulation patterns during the Late Pleistocene

Hesse, P.P.; Pearce, B.; Ralph, T.; Yonge, D. 28
Origin and structure of riverine wetlands in the Murray-Darling Basin: the example of the Macquarie Marshes

Jansen, John D.; Nanson, Gerald C. 29
Anabranching rivers & maximum flow efficiency

Joyce, E.B. 30
Geomorphology and landscape history of a young volcanic province: the western plains of Victoria

Kennedy, David M.; Armour, Rachel (Poster) 31
Holocene estuarine infill and vegetation history of Whanganui inlet, New Zealand: preliminary findings

Lawrence, Ruth 32
Geomorphology as tourism: case study of Samoa

Neave, Mel 33
The development of soil crusts on a semiarid bajada

Orr, Meredith; Grindrod, John; Brown, Jonathan; Marsh, Dru; Peel, Matthew; Delaney, Andrea 34
Revised dune and soil history of northern King Island, Bass Straight

Outhet, David; Young, Carolyn (Poster) 35
Reference reach database for river geomorphic types in NSW

Pain, Colin 36

The RED scheme and other colourful regolith-landscape interpretations

Pickard, John; Fanning, Patricia; Gore , Damian; Crighton, Paula; Adamson, Don....37
Post-european landscape change in semi-arid New South Wales: a review of evidence from process monitoring, absolute dating and artefacts

Pillans, Brad; Spooner, NigeL; Chappell, John....38
The dynamics of soils in north Queensland: rates of mixing by termites determined by single grain luminescence dating

Ralph, Tim; Hesse, Paul....39
The mechanism and history of channel avulsion in a floodplain wetland, Macquarie Marshes, N.S.W.

Rayburg, Scott C. 40
Three dimensional morphologic characteristics of pool-riffle sequences

Richards, Danette T.W. 41
Geomorphological studies on the development of karst, north-west Nelson, New Zealand

Saynor, M.J.; Erskine, W.D.; Evans, K.G.; Moliere, D.; Eliot, I. 42
Channel stability in a sand-bed stream in the seasonally wet tropics

Schmidt, Jochen 43
Soil-landscape modelling in New Zealand: from qualitative, knowledge-based approaches to quantitative models

Schmidt, Jochen & Dikau, Richard (Poster) 44
Modelling climatic variability and its effects on slope stability: a case study from Bonn, Germany

Shulmeister, James; Thackray, Glenn; Fink, David; Augustinus, Paul C. 45
Geomorphic evidence for a piedmont glaciation in N.W. Nelson, New Zealand, at the last glacial maximum

Taylor, Anna 46
Wave processes on a shore platform, Kaikoura, South Island, New Zealand.

Terry, James P. 47
Interpreting anomalous drainage and geomorphology of the Navua River, Fiji

Tokarev, Victor; Gostin, Vic....48
Morphotectonic evolution of the western portion of the Mt Lofty Ranges

Webb, John....49
The origin and evolution of the Nullarbor Karst

Wilkinson, Marshall; Humphreys, Geoff; Smith, Bart; Chappell, John 50
Soil production in heath and forest, Blue Mountains, NSW

Williams, Frances; Williams, Martin; Gibson, Ian; Aumento, Fabrizio 51
A dividing continent: tectonism, volcanism and crustal spreading rates in the Ethiopian and Afar rifts.

Williams, Paul (Keynote)....52
Interpreting environmental change from cave deposits

Worrall, Lisa; Lane, Richard....53
Airborne electromagnetics, geomorphology and mineral exploration, Gawler Craton, South Australia

Yonge, D.; Hesse, P ....
Holocene evolution of the lower Macquarie riverine plain, central western New South Wales

Participants 54

Program

Time/Day	Monday 30th	Tuesday 1st	Thursday 3rd	Friday 4th
0845-0900	Welcome			
0900-0940	Chappell keynote	Clarke keynote	P. Williams keynote	Dunkerley keynote
0940-1005	Fabel	Clark	Hesse	Neave
1005-1030	Shulmeister	M. Williams	Brown	Crozier
1030-1100		MORNING TEA		
1100-1125	Pain	Worrall & Lane	Webb	Almond
1125-1150	Chan	Yonge	Davies	Pillans
1150-1215	Tokarev&Gostin	Hesse	Doerr	Wilkinson
1215-1240	Joyce	Ralph	Richards	Hardenbicker
1240-1340		LUNCH		
1340-1405	Lawrence	Brizga	Giles	Schmidt
1405-1430	Terry	Hawke	Orr	Pickard
1430-1455	POSTERS	Rayburg	Hawke	Dunkerley
1455-1525		AFTERNOON TEA		
1525-1550	Clarke	Saynor	Baker	ANZGG
1550-1615	Fanning	Jansen	Taylor	MEETING
1615-1640	Chivas keynote	Bourke	Hemmingson	
			DINNER	

Processes and rates of soil creep on hillslopes: calibration of a soil transport model using tephra stratigraphy and dispersion

Peter Almond[1], Josh Roering[2], Philip Tonkin[1] and Jim McKean[3]

[1]Lincoln University, [2]University of Oregon, [3]University of Canterbury

The piedmont on the east coast of the South Island of New Zealand is dominated by fluvial landforms of Pleistocene age. The post-depositional evolution of these landforms is most strongly influenced by tectonically induced base level lowering. A common sequence of landform evolution is: (1) alluvial fan or terrace, (2) loess-mantled terrace, (3) dissected loess-mantled terrace, (4) loess-mantled downland, (5) loess-free ridge and valley terrain. Relief development appears to take place episodically. Climatically controlled loess accumulation and stream downcutting increase local relief by raising interfluves and lowering channels, respectively. At some point drainage density and slope morphometry reach a critical state, after which erosion rate exceeds time-averaged loess deposition rate and the transition between loess-mantled downland and loess-free ridge and valley terrain takes place.

The aims of this study were to: (1) characterize and model processes of soil transport on slopes in a loess-mantled downland, and (2) use the model to predict loess distribution in the landscape.

The Charwell River in Southern Marlborough has a sequence of fluvial terraces with members representative of the stages of terrace evolution listed above. A penultimate glaciation fluvial gravel has a developing downland form and is mantled by three loess sheets (L1 to L3 youngest to oldest) with total thickness up to 7 m. On uneroded interfluves L1 incorporates a 26.5 ka tephra from Central North Island at about 85 cm depth. We surveyed and documented loess and tephra stratigraphy along a 90 m rectilinear slope transect from interfluve to gully floor. The upper slope segment has a convex form indicating a slope-dependent transport mechanism (soil creep). Convexity increases non-linearly downslope to the footslope. Over the first 40 m of the slope from the interfluve, depth to primary tephra decreases from about 85 cm to 60 cm in parallel with the increasing slope convexity. Beyond 40 m the tephra is mixed uniformly within the upper 50 cm of soil. This depth coincides with the rooting depth of the podocarp and beech trees that occupied the site throughout the Holocene until about 700 yr ago. Therefore, we concluded that bioturbation associated with root growth and tree overturn was the main mode of disturbance contributing to soil transport (creep). Assuming a linear slope-dependent transport model, differences in surface lowering relative to Kawakawa tephra datum and differences in slope convexity between pairs of sample points on the slope were used to estimate the diffusivity parameter K. The average value for K calculated in this way, assuming 9 ka of erosion, is 0.012 □ 0.008 m^2yr^{-1}.

As an independent approach to deriving K we used the tephra as a tracer and developed a coupled model for transport of soil and tracer particles (glass grains). Coupled transport was modeled as an advective process. Glass grains are incorporated into the mobile layer and passively transported once surface lowering brings primary tephra within 50 cm of the soil surface, i.e. within range of the soil disturbance process. Variation in tracer concentration in a slope increment over an interval of time is dependent on exhumation of available primary tephra and advective transport into and out of the slope increment. We invoked the model to simulate slope evolution and tephra dispersion from the early Holocene to the present. Initial slope form was derived by draping the maximum observed thickness of L1 (1.8 m) on the surface of L2. Our model was calibrated by varying K so that at the end of the simulation the pattern of glass concentration along the slope matched our field observation. The best-fit value of K was 0.014 □ 0.005, a value indistinguishable from that derived from our slope curvature/tephra exhumation analysis.

We applied the calibrated model to another more convex slope transect on the downland and with similar assumptions of initial loess thickness and erosion interval the model successfully predicted absence of loess.

Regolith mapping and the search for groundwater in a karst terrain, Balladonia, Western Australia (Poster)

Ian Anderson and Jonathan D. A. Clarke
CRC LEME, Department of Geology, Australian National University, Canberra, ACT 0200

Balladonia lies on the western margin of the Eucla Basin. The area is under pastoral lease and numerous exploration licences have been issued in the past, especially for lignite, gold, uranium, and mineral sands. Potable groundwater is a major limiting factor in the region, hypersaline water can be obtained from the palaeovalleys peripheral to the Eucla Basin. At present potable water can only be obtained from diverting runoff from areas of granite outcrop. The search for potable groundwater in the Balladonia region has been ongoing for over 130 years, without success.

The stratigraphy of the western margins of the Eucla Basin extends consists largely of Eocene and Miocene sediments. Stratigraphic architecture is modified by proximity to the granitic Albany-Fraser Range, with more clastic sedimentation close to the margins of the basin and around granite inselbergs. In this western embayment we find white chalky bryozoan limestone Eocene Wilson Bluff Limestone on the seaward side of a line of granitic highs grading into the coeval biosiliceous clays, silts, and sands of the Pallinup Formation behind the barrier. These overlie carbonaceous silts and sands of the Pidinga Formation along the extreme western margin, and are overlain through much of the area by the Miocene Nullarbor Limestone.

The Balladonia region is made up of several landforms. The eastern region consists of a karst plain with a series of indurated or calcreted rises. Intervening depositional regions are large karst depressions filled with a mixture of limestone floaters, colluvium from the flanks of residual rises and stratified alluvial and aeolian sands, silts and clays. Calcrete in this region is slabby and massive, with pedogenic carbonate pisoliths accumulating in the generally thin soil horizons.

The western margin is dominated by a low relief scarp, approximated by the 170m contour on the DEM, cut into Eocene sediments. This elevation is equivalent to the Miocene highstand, with calcreted Eocene sediments having thick accumulations of pisolithic calcrete. The region is punctuated by a series of inliers of Precambrian crystalline basement or granite inselbergs. These out cropping granites are generally surrounded by benches of indurated limestone, and many were probably islands or shallow reefs during the last major transgression in the Miocene. Unconsolidated cover materials appear to have a more complex mineralogy than in the eastern regions, the sources include granitic materials from the Fraser complex and amorphous silica, possibly from spicular sediments.

Vegetation associations are a key to mapping the regolith landforms in this region, as on the karst plain stands of trees are found exclusively on the topographic highs of the calcreted residual limestone rises, with depositional depressions giving way to mainly low relief salt bush and blue bush. The terrace of Eocene sediments also well covered by trees. Large native trees are also absent around outcropping granites, and in regions where crystalline basement is close to the surface.

The Ages of Deep Weathering in the Yilgarn Craton (Keynote)

Julius Atlhopheng and Allan R. Chivas
School of Geosciences, University of Wollongong NSW 2522

The oxygen-isotope values of minerals formed at the Earth's surface during weathering depend on their temperature of formation and the isotopic composition of the contemporaneous soil water or groundwater. Several minerals (eg. carbonates) have a high degree of temperature sensitivity (0.23˚/$_{00}$ per ˚C temperature change), whereas others (e.g. clay minerals) do not. The latter minerals are ideal for tracing past climates by calculating the past isotopic composition of meteoric (=unevaporated atmospheric) water, which is dependent upon air-tempaerature, and is largely a function of (palaeo) latitute, and less so (palaeo) altitude. Australia's northwest drift over 40˚ of latitude since the late Cretaceous, also permits clays from weathering profiles to be dated using oxygen isotopes.

Using a calibrated-age method for the 0-18/0-16 values of weathering-related kaolinites, previously established for eastern and central Australia, by Bird and Chivas (1988, 1989, 1993) and Chivas and Bird (1994), we have made an extensive investigation of weathering in the Yilgarn Craton.

More than 100 samples from breakaways, drill-core and mine-pit exposures have been analysed. The majority of samples are indicative of a Late Tertiary weathering event, although there are several areas, largely in the northern and eastern Yilgarn, that show evidence of earlier weathering events, both Early Tertiary and late Mesozoic. There are parallel age patterns with the palaeomagnetic results for hematite produced by Brad Pillans. In detail, where both techniques were co-sampled from the same exposures (typically in mine-pit profiles), they show similar ages, but not necessarily at the scale of individual samples.

A few exposures provide evidence for multiple weathering events within single profiles. Importantly, the 0-18/0-16 results indicate older weathering events to be overlain by younger kaolinisation, which was unexpected, indicating overprinting of weathering events, rather than a continuously younging downwards weathering front.

The 0-18/0-16 values of several goethite samples from Yilgarn weathering profiles indicate a consistent $\Delta^{18}0$ kaolinite-goethite value (+10.2 to +11.4 per mil), meaning that the goethite formed in oxygen-isotope equilibrium with the kaolinite, and broadly at the same time. The pilot study on goethite is worth extending to investigate weathering profiles where the upper iron-rich portion may be of different ages to the underlying pallid-zone kaolinite-rich material. Such time differences would be readily distinguished using oxygen isotopes. The way is now also open to investigate, more broadly, the 0-18/0-16 systematics of several iron-oxide minerals from the regolith, now that their oxygen-isotope stability in the surficial environment has been demonstrated on time spans of over 100 Ma.

Bird, M.I. and Chivas, A.R. (1988) Oxygen isotope dating of the Australian regolith. *Nature*, **331**:513-516; **332**:568.

Bird, M.I. and Chivas, A.R. (1989) Stable-isotope geochronology of the Australian regolith. *Geochimica et Cosmochimica Acta*, **53:**3239-3256.

Bird, M.I. and Chivas, A.R. (1993) Geomorphic and palaeoclimatic implications of an oxygen-isotope chronology for Australian deeply weathered profiles. *Australian Journal of Earth Sciences*, **40**:345-358.

Chivas, A.R. and Bird, M.I. (1994) Palaeoclimate from Gondwanaland clays. In: Churchman, J., Fitzpatrick, R. and Eggleton, R.A. (Eds), Clays: Controlling the Environment. Proceedings 10th International Clay Conference, Adelaide 1993, CSIRO Publishing, Melbourne, 331-336.

Global marine events on Rottnest Island, Western Australia?

*Robert G.V. Baker[1], Robert. J. Haworth[1] and Peter. G Flood [2]
[1] School of Human and Environment Studies
[2] Faculty of the Sciences, University of New England, Armidale, N.S.W. 2351 (Australia)

There is a strong coincidence in the mid to late Holocene sea-level change record observed at Rottnest Island, in Western Australia and previously published sites along the eastern coast of Australia. New dates are presented from Rottnest Island and the environmental history there is re-interpreted. An east-west Australian coastal comparison indicates a common mid- to late-Holocene fluctuating relative sea-level c. two metre higher-than-present with approximately one metre falls and cooling at ~5200, ~3800 and ~1400 cal yr B.P. These oscillations appear also to be associated with both rising sea levels and warmer-than-present sea surface temperatures at ~4200 and ~6500 cal yr B.P. These mid-latitude fluctuations and environmental changes on the Australian coastline are similar to eustatic event horizons and temperature shifts over the same period in Antarctica. and southern Brazil. These three southern continents display a coincidence in the periodicity and rapidity of the changes, suggesting a possible regular quasi-periodic global forcing function that broadly corresponds to events in the North Atlantic.

* Corresponding author
Contact email: rbaker1@metz.une.edu.au
Fax 61 2 67733030
Ph. 61 2 67733030

Aeolian-fluvial interaction at paleoflood termini in central Australia

M. C. Bourke
School of Geography and the Environment, University of Oxford, OX1 3TB, UK, mary.bourke@geog.ox.ac.uk

The physical boundary between geomorphic systems is dynamic. Along desert margins where fluvial and aeolian systems interact, the location of the boundary and the assembledge of surface landforms may rapidly change. The shifting position is controlled by climate change and/or extreme fluvial events. This paper presents data across four scales of fluvial-aeolian interaction using examples from the termini of the Todd, Hale and Finke Rivers in Australia.

In central Australia, Late Pleistocene and Holocene floods have strongly influenced the assemblage of fluvial, aeolian and lacustrine landforms along the desert margin. A series of high magnitude floods eroded longitudinal dunes, emplaced sandy-gravel bars and splays and formed clay pans in inter-dune areas. Aeolian processes have reworked the abandoned flood channels. Pre-existing linear dunes were nourished and new climbing dunes formed along bedrock ridges. New linear dune fields have reformed across the paleoflood channel. Some dunes extend from the flood-truncated dunes while others are initiated in inter-dune areas, often on low gravel bars. Despite an increase in sediment supply and change in prevailing wind direction, the dune form and orientation are strikingly similar to the older dune field. This suggests that boundary layer dynamics set up by the older linear dune field, located upwind, has influenced the formation of the younger dune field. However, dune size and the crest height to wavelength relationship are significantly different when compared with the older dune field. A comparison of preliminary data from dunes developed on paleoflood channels aged 13 ka and 5 ka suggest that time may be an important control on dune dimension in the study area.

These adjustments in aeolian landform to fluvial events provide key geomorphic signatures of pulsed high-energy climatic events. Aeolian dunes located proximal to fluvial systems are therefore useful repositories of information on past episodes of fluvial activity. However, the development of a dune field proximal to an alluvial basin may not be a reliable indicator of climate change (e.g. increasing aridity/windiness) rather it may reflect the development (by fluvial erosion) of a new accommodation space for linear dune development associated with a new/replenished sediment source.

The use of hydraulic modelling in fluvial geomorphology – examples of the application of one- and two-dimensional models in Victorian river systems

S.O. Brizga[1], N.M. Craigie[2] & S.Q. Clark[3]
[1] S. Brizga & Associates Pty Ltd, PO Box 68, Clifton Hill Vic. 3068, Australia;
sbrizga@ozemail.com.au
[2] Neil M. Craigie Pty Ltd, Melbourne, Australia
[3] Water Technology Pty Ltd, Melbourne, Australia

Streamflow hydraulics are a key determinant of erosion and sedimentation processes in rivers. Developments in numerical hydraulic modelling and increases in computer power have enabled the simulation of hydraulic processes in sufficient detail to assist geomorphological explanation and prediction. This paper discusses two case studies that provide examples of the application of one- and two-dimensional modelling in a geomorphological context.

One-dimensional model – Glenelg River

One-dimensional models represent longitudinal variations in the hydraulic properties of flow. A one-dimensional model of the Glenelg River was used in conjunction with more conventional geomorphological analyses to assess sand transport process along this river. This work was carried out in response to concerns regarding sedimentation risks in the middle and lower reaches resulting from fluvial transport of sand liberated by historical catchment erosion. The modelling successfully simulated areas of high and low sediment transport efficiency identified from geomorphic evidence. It was found that a major hydraulic discontinuity effectively separates the river channel within the study area into two discrete sediment transport systems.

Two dimensional model – Tambo River

Two-dimensional models represent both longitudinal and lateral variations in the hydraulic properties of flow. Rivers or floodplains are represented by a grid of levels describing the terrain. In June 1998, the Tambo River experienced its largest flood of the twentieth century. Flood flows in the Bruthen area resulted in catastrophic erosion, large-scale sedimentation and extensive damage to public and private assets. A detailed geomorphological investigation was initiated by the East Gippsland Catchment Management Authority to develop appropriate and effective management strategies for the Tambo River. In order to quantify river processes and assist in identifying likely future changes, full two-dimensional hydraulic modelling and more conventional fluvial geomorphological analyses were undertaken. The hydraulic model successfully simulated the hydraulic conditions underlying the erosion and deposition observed during the June 1998 flood, and was used to examine future geomorphological trends including possible avulsion threats.

Acknowledgments

The work presented in this paper was funded by the East Gippsland and Glenelg Hopkins Catchment Management Authorities. We would particularly like to thank Mr Rex Candy (East Gippsland Catchment Management Authority) for his support.

Late Quaternary landscape processes in the east Victorian highlands, with reference to Caledonia Fen, Bennison High Plains, Victoria

Jonathan Brown
School of Geography and Environmental Science, Monash University, Clayton, Victoria, 3800

Caledonia Fen is a small alpine bog located at an altitude of 1280 m, on the western edge of the Bennison High Plains in the Australian Alps. There is a paucity of long-term records of palaeoenvironments in the mainland Australian Alpine region. Caledonia Fen has been subject to continuous sediment accumulation for a period representing at least one full glacial cycle. For this reason alone the record should be invaluable for comparison of landscape processes operating during the last glacial cycle outside the relatively small region of the Kosciuszko Massif. The site has been subjected to a previous (and ongoing) palynological study by Dr Merna McKenzie at Monash University and a preliminary study of the sediment physical properties has shown significant variation in the nature and composition of the sediment.

This presentation outlines research currently being undertaken on sediment physical properties including mineral magnetics particle size analysis, and mineralogy. Identification of depositional environments will lead to greater understanding of landscape processes operating in the catchment during the late Quaternary. Preliminary findings suggest that the site has been subjected to a number of depositional processes throughout the sequence. Specifically, particle size distributions suggest that periods of sediment settling, channelised flow and colluvial deposits (possibly representative of periglacial activity) have occurred.

A strong chronostratigraphy is being compiled using OSL dating of the sequence. Preliminary work in this area suggests that the sediments contain a well-preserved OSL signal, with no indication of partial bleaching. The relatively high dose rates of the sediment however, suggest that the saturation limit of traditional OSL may be reached before the base of the sequence. Detailed comparative analysis between OSL and AMS for a 2 metre section of the record suggest that the OSL record matched well the AMS dates, suggesting that a firm chronology of the last glacial cycle in the Australian Alps can be derived from the site.

Regolith and landform evolution processes in the north-western Lachlan Fold Belt, NSW

Roslyn Chan
Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) Geoscience Australia

The CRC LEME Girilambone Project is developing a regolith framework for the Lachlan Fold Belt east of Cobar in New South Wales. This framework aims to assist mineral exploration to interpret geochemical anomalies, identify weathered bedrocks, guide sampling strategies, and predict mineralisation pathways. To date, regolith studies have been carried out in the Sussex-Coolabah area (Chan et al., 2001) and the Hermidale area (Chan et al., 2002). This region of mainly plains (<9 m relief) and rises (9-30 m relief) drains both to the east into the north flowing Bogan River and to the north into the southwest flowing Darling River. The basement geology is dominantly composed of metasediments of the Ordovician Girilambone Group with slivers of Early Devonian Cobar Supergroup, and isolated acid volcanics and mafic to ultramafic intrusives.

Sediments are widespread and their landform associations indicate a wide range of depositional processes. Sheetwash colluvium extensively drapes depositional and erosional plains and rises. Depths of colluvium of 1-2 m on slopes of rises gradually increase through erosional plains to 1-5 m on depositional plains. Alluvial sediments are common and also occur beneath colluvium. Networks of erosional depressions with minimal alluvium drain the sheetwash plains and rises. The density of these networks increases below a plateau in the Sussex-Coolabah area. They merge into a few depositional plains, but mainly directly into alluvial plains and channels with 5-40 m of alluvium associated with the main drainage lines. Stagnant alluvial plains occur in the Hermidale area on the margin of the Lachlan Fold Belt. Airborne magnetics and aircore drilling have delineated palaeovalleys with sediments containing maghemite. Palynological dating of some of these sediments indicates a Late Miocene to Early Pliocene age of sedimentation (Chan et al., 2002). Analysis of regolith materials from drilling indicates extensive magnetic as well as non-magnetic palaeosediments. These palaeosediments infill and, in places, bury a palaeotopography with a greater relief than the present topography. A ubiquitous 0.5 - 3 m thick parna layer coats the landsurface. Silt-sized clay aggregates of aeolian dust impregnate surface colluvium, alluvium, palaeosediments and saprolite. High values of Na and Ca carbonates occur to at least 5 m depth in places, indicating the calcareous dust was blown in and then leached out of the parna and deposited lower in the profile.

Weathering has largely oxidised the palaeosediments above the water table, with the water table shallowing towards the eastern margin of the Lachlan Fold Belt with the Surat Basin. Weathered bedrocks mainly occur beneath the sediments; there is very little saprolite and saprock outcrop in the region. Mafic dykes weathered to kaolinite were detected by Portable Infrared Mineral Analyser (PIMA) and their high Cr and low K contents (Chan et al., 2001). Siliceous induration and ferruginous induration, mottling and Fe staining are locally apparent. Bleached saprolite zones are commonly associated with the base of palaeovalleys, some of whose palaeosediments have been completely eroded away. Erosional processes due to base level changes are dominant in the region presently, other than on the depositional margin of the Lachlan Fold Belt.

Chan R.A., Greene R.S.B., de Souza Kovacs N., Maly B.E.R., McQueen K.G. & Scott K.M. 2001. Regolith, geomorphology, geochemistry and mineralisation of the Sussex-Coolabah area in the Cobar-Girilambone region, northwestern Lachlan Fold Belt, NSW. CRC LEME Report **166**.

Chan R.A., Greene, R.S.B., Hicks, M., Maly B.E.R., McQueen K.G. & Scott K.M. 2002. Regolith architecture and geochemistry of the Hermidale area of the Girilambone region, northwestern Lachlan Fold Belt, NSW. CRC LEME Report **179**.

Erosion, Soil Production and Sustainability: Cosmogenic Assessment (Keynote)

John Chappell
Research School of Earth Sciences, Australian National University

Whether soil production, transport and loss were in balance before Europeans arrived in Australia, or indeed whether these processes were in balance at any time since the arrival of humans ~50,000 years ago, are issues that influence our assessment of the development of Australia's ecosystems and their sustainability.

Long-term rates of soil production are measured using cosmogenic nuclides that form *in situ* at soil base and rock surfaces, although present techniques assume that soil production and transport are in balance. Methods are presented for examining this assumption, using combined measurements from soil base, rock outcrops, bedrock tors and small-catchment sediments. At humid temperate lowland sites, results indicate that there is a steady-state balance between production and transport. At other sites, including areas in the eastern highlands of NSW and the Western Australian wheat belt, cosmogenic data indicate that present soils are not in balance with transport and were generated relatively rapidly after the change from Late Pleistocene cold and arid climate, to warmer, wetter and more stable Holocene conditions.

Cosmogenic nuclides must be combined with other methods to assess denudation by chemical weathering, and to determine the process of soil creep and its contribution to total transport. The combined use of trace-elements and cosmogenic nuclides is discussed, and it is shown how creep processes have been determined by combined cosmogenic and single-grain optical dating.

Multi-disciplinary neotectonics research in Australia: developing an improved basis for seismic hazard assessment

Dan Clark, Mark Leonard & Clive Collins
Geoscience Australia, GPO Box 378, Canberra, ACT, dan.clark@ga.gov.au

In most intraplate regions, such as Australia, there is a general lack of understanding of why earthquakes occur where they do, or even why they occur at all. Estimates of seismic hazard are necessarily based upon the assumption that the past distribution of epicentres is indicative of where future seismic activity will occur. However, this approach has been demonstrated to be less than ideal as calculations based on instrumental recordings of seismicity can't predict the location of the larger, less frequent earthquakes with any accuracy. A better basis for earthquake hazard assessment could be gained by enhancing probabilistic models for seismicity with geologic data that includes stress and strain conditions, the number and distribution of potentially seismogenic faults, and on better knowledge of patterns in the long- and short-term behaviour of intraplate faults.

We present our methodology and preliminary results from ongoing multi-disciplinary and multi-organisational research in the Southwest Seismic Zone (SWSZ) of Western Australia aimed at addressing this challenge. Techniques employed to date in this test-area include stress tensor reconstruction using earthquake focal mechanisms, strain field characterisation using repeat campaign GPS surveying, earthquake epicentre mapping, failure surface mapping using high-precision epicentral determinations from earthquake aftershock sequences and swarms, fault mapping/imaging using geophysics, trenching investigations of fault scarps, and dating of materials recovered from fault scarp colluvial wedges.

This study in the SWSZ is complemented by similar collaborative research in other seismically active regions of Australia, including the Flinders Rangers and the eastern highlands. The data will be compiled into Geoscience Australia's Neotectonics database, which is a dynamic and evolving research resource soon to be obtainable from the authors. The database is currently populated with over 60 potential and actual seismic sources from around Australia. The bulk of the data comprise faults on which Quaternary movement has been demonstrated or is suspected. We are currently building in the facility to include other categories of entry such as instrumentally defined fault planes (seismic fault plane mapping), and geophysically defined potential seismic sources.

Geoscience Australia acknowledges the contribution of our collaborative partners working towards bettering our understanding of the intraplate seismicity in Western Australia: the University of Western Australia, Curtin University of Technology, DOLA, and IGNS of New Zealand.

Longevity and significance of Australian seismic geomorphology: a hazard perspective

Dan Clark[1], Mike Sandiford[2] & Mike Dentith[3]
1. Geoscience Australia, GPO Box 378, Canberra, ACT, dan.clark@ga.gov.au
2. School of Earth Sciences, University of Melbourne, VIC, 3010, mikes@unimelb.edu.au
3. Dept. of Geology & Geophysics, University of Western Australia, WA, 6009, mdentith@geol.uwa.edu.au

In most intraplate regions, such as Australia, there is a general lack of understanding of why earthquakes occur where they do, or even why they occur at all. The lack of a definitive model, at any scale, describing Australian seismicity imposes significant limitations upon the methodologies that can be employed to estimate earthquake hazard. To better understand the infrequent large earthquakes that present the greatest risk to population and infrastructure, and to develop realistic models of seismicity that account for them, we must turn to the record of earthquake activity preserved in the landscape (neotectonic geomorphology).

Observations in the South West Seismic Zone and in the Hyden region of Western Australia lend support to the notion that strain is distributed amongst a family of suitably oriented faults within a region. Relief is typically only preserved relating to one or two events on structures inferred to be the most recently active in the family. Interaction between faults belonging to the main set and other faults trending at high angles appears to be important in shutting down activity on individual structures after one or two large events, causing seismicity to migrate elsewhere. Geomorphic expressions on individual faults tend to be subdued, or absent altogether, suggesting that time-averaged recurrence rates cannot compete with the local rates of erosion. It is debatable in this instance whether the concept of recurrence interval on individual structures is strictly applicable. However, circumstantial evidence from Hyden suggests that a locked fault system may become active again after a prolonged period (>>100Kyr) (Crone et al., 2002). In terms of seismic hazard, recurrence may be better applied to fault families. An important implication of this model for hazard estimation is that the greatest levels of seismic hazard may be posed by faults that preserve no history of activity and are presently aseismic.

In contrast to Western Australia, the rugged and youthful topography of the Mt Lofty-Flinders Ranges of South Australia, and to a lesser extent the highlands in south eastern Australia, preserve evidence for a very different style of seismicity. Here, rates of slip on a handful of controlling structures are far in excess of rates of erosion (Sandiford, 2002). Large offsets on individual structures are demonstrably the sum of many individual movements. Although individual events are typically of indeterminate magnitude and timing, time-averaged slip rates are recoverable from an abundance of offset or fault related datums (e.g. strata, marine strandlines, riverine terraces, sag ponds, drainage diversion etc). The main topography controlling structures are in this instance the most significant for hazard estimation purposes.

There are surprisingly rich and varied neotectonic records emerging from several seismogenic regions of Australia, many of which are only just beginning to be analysed. This talk focuses on a selection of such areas, each characterised by a unique geomorphic response to geologically recent pre-historic seismicity, and each providing different insight relevant to the development of realistic and workable Australian seismicity models.

CRONE A., DE MARTINI P., MACHETTE M., OKUMURA K. & PRESCOTT J. 2002. Palaeoseismicity of aseismic Quaternary faults in Australia – implications for fault behaviour in stable continental regions. *Bulletin of the Seismological Society of America*, submitted.

SANDIFORD M. 2002, Neotectonics of southeastern Australia: linking the Quaternary faulting record with seismicity and in situ stress, eds Hillis, R.R. Muller, D., *Evolution and dynamics of the Australian Plate*, G.S.Australia and G.S.America, Joint Special Publication. In press.

Jarntimarra-1: selecting Australia's Mars analogue research site

Jonathan D. A. Clarke
Department of Geology, Australian National University, ACT 0200

In October-November 2001 the Mars Society Australia (MSA) carried out a study to select areas with Mars analogue research potential. Electronic discussion between members of the MSA highlighted a number of these, especially in South Australia and the Northern Territory. Sites were nominated on the basis of scientific relevance, range of terrain types, and visual resemblance to Mars. The preferred site would be where the Mars Analogue Research Stations (MARS-OZ) would be located.

The survey team filled in a database information sheet at each site, recording information of the site name, date visited, coordinates, ownership, access, risks, maps, geology, climate, flora/fauna, history, analogue value and references. These provided for factual entries in the Jarntimarra database. Comparative judgements with respect to MSA's specific needs were made on a separate assessment sheet with a list of 9 scientific, 8 engineering, 7 logistic, and 8 visual criteria.

The expedition noted that most of the assessed sites fell within the boundaries of only six 200-km diameter circles. These circles are equivalent to the region that could be easily explored of a simulated Mars base, given a vehicle capable of extended traverses. MSA's Starchaser Marsupial Rover is such a vehicle. Each region was rated on 5-point scale according to the above specific characteristics with engineering and science factors being given double weighting. Moon Plain, Woomera and Arkaroola regions achieved equal ranking as the most attractive sites.

Further examination led to the Arkaroola region in the North Flinders Ranges being selected because its international scientific reputation and history of Mars analogue research. Previous specific Mars analogue research in Arkaroola region has been three-fold, focusing on aeolian landforms, extremophiles, and remote sensing of hydrothermal systems. Studies of aeolian landforms compared Martian dunes at Nili Petra with terrestrial dunes at Gurra Gurra Waterhole in the Strzelecki Desert. The extremophile work found radiation-resistant thermophiles in the Paralana hot spring which is characterised by high levels of radon gas. The area has been used in remote sensing experiments comparing hyperspectral imagery from the alteration halo surrounding the Mount Painter fossil hydrothermal system with ground truth from a hand-held spectrometer. This last study is particularly relevant to detecting the presence of such systems on Mars, which are believed to be good localities to search for microfossils. Potential Mars analogue geoscience research in the area may include palaeontology, geomorphology and regolith studies. The Proterozoic sediments of the area are known to host silicified microfossils and the sinters of the Mt. Gee fossil hydrothermal system show potential for microfossil preservation. Geomorphological and regolith studies include evolution of the alluvial fans on the eastern flank of the Flinders Ranges, nature of mound springs of Lake Frome, and landscape evolution of the northern Flinders Ranges, where uplift has led to partial exhumation and dissection of ancient land surfaces buried beneath Cretaceous cover. Finally, the area includes a wide range of surfaces, including boulder-strewn stream beds, gibber plains, salt lakes, sand dunes, gorges and very rugged hills, providing an ideal testing ground for rovers and other hardware.

An ideal site for the habitat was found on the gravel plains to the east of the Arkaroola zone's central point, between the eastern side of the northern Flinders Ranges and Lake Frome. This will allow easy access to sites in the Flinders Ranges proper as well as on the plains that surround Lake Frome. Any landing site for a crewed expedition to Mars will similarly be located in safe flat terrain, but with a wide range of interesting sites nearby. The exact site for the MARS-OZ complex will be decided during the Jarntimarra-2 expedition, probably in 2003.

Eocene coastal barrier evolution in the Eucla Basin (Poster)

Jonathan D. A. Clarke and Bouhong Hou
[1] CRC LEME, Department of Geology, Australian National University, ACT 0200
[2] Department of Primary Industry South Australia , Adelaide, SA 5000

A range of shoreline features occurs along the northern and eastern margins of the Eucla Basin include coastal scarps, barriers, lagoons, and estuaries. These were deposited during the latest Eocene transgression of the Eucla Basin. The complex geometry of these features and their scale (they extend along a 600 km front and are up to 200 km wide, the barrier sands reach a thickness of 100 m) strongly suggest that these features formed in more than one transgressive episode. This poster presents a testable suggestion as to how the Eocene coast barrier system evolved.

Stratigraphy

Two third order Eocene transgressions reached this far inland. These were the Middle Eocene Tortachila and the Late Eocene Tuketja transgressions. The Tortachila is represented in the area by the Middle Eocene marine limestones of the Paling Member of the Wilsons Bluff Formation. The spicular Kharsta Member of the Hampton Formation, which everywhere occurs as the highest Eocene unit, overlies it.

Tortachila Transgression

The highstand is characterised by development of the Ooldea Range, which forms a coast barrier. A northwest-southeast trending basement high may have provided a site on which the barrier originally nucleated. Sand was supplied by the 5 major palaeorivers to the west of the Ooldea Range, and by the 8 palaeorivers directly landward of the barrier. Lagoonal sediments included low energy brackish water facies of the Pidinga, high-energy brackish facies of the Hampton, and marine facies of the glauconitic and calcareous Paling Member. Multiple beach ridges in the Ooldea Range suggest a fourth order control on barrier accretion.

Erosion of the much of the upper part of the lagoonal succession is likely during the subsequent regression. This would have removed much of the Hampton and Paling from the lagoonal area. Existing tidal channels would have been enlarged as palaeorivers extended out across the former sea floor.

Tuketja Transgression

In WA the Tuketja transgression reached an elevation some 20-m higher than the Tortachila (Clarke 1994) and we assume a similar figures applies in the eastern Eucla Basin. Consequently the shoreline extended much further inland at this time. An erosional scarp marks the shoreline position. A new barrier system developed, forming the Barton Range. The Ooldea Range formed a chain of offshore sand islands. A J-shaped barrier (the Paling Range) formed late in the evolution of the barrier complex. This tied the Ooldea Range to the Barton Range.

Lagoonal sediments between the Ooldea and Barton Ranges and landward of the Barton Range during the Tuketja transgression consisted of estuarine sands and clays (Pidinga Formation) and spicular marine sands (Kharsta Member of the Hampton Formation. The lagoonal and barrier facies are widely preserved owing to the shift of to more arid conditions following the terminal Eocene transgression.

Implications

Much of the stratigraphy of these units occurs in the subsurface (Figure 5), however the proposed model makes a number of predictions that can be tested by stratigraphic drilling.. It specifically predicts that the Ooldea Formation (recognisably more angular than the Hampton and lacking marine fossils) of the Ooldea Range should overlie Hampton containing sparse calcareous fossils (Paling Member equivalent). On the landward side of the Ooldea Range the spicular Kharsta Member should overlie the Ooldea Formation, but the Ooldea Formation of the Barton and Paling range should overlie the Kharsta Member.

Evolution of the Kalgoorlie landscape, Eastern Goldfields region, Western Australia

Jonathan Clarke, Lisa Worrall, and Brad Pillans

Kalgoorlie is located in the Eastern Goldfields Region of Western Australia. The landscape and associated regolith contain evidence for evolution over at least 250 million years. Aridity has been present for only the last 5 million years. The landscape of the region is a palimpsest of processes that include those of glacial, marine, temperate, savannah, and arid environments.

The Eastern Goldfields are located on the Yilgarn Craton, which was stabilised by the end of the Archean. Archean gold, which is currently being mined in the Kalgoorlie area, was emplaced around 5 kilometres below the surface. This suggests that less than 5 kilometres of rock have been eroded from the Craton in last 2500 Ma. The oldest datable landforms in the Eastern Goldfields were formed during the Permo-Carboniferous glaciation. Traces of fluvial glacial and glacial Permian cover and valley fills are locally preserved, especially in the north and east. The climate in the Late Permian and through the Triassic remained cool and humid, and there is some palaeomagnetic evidence for deep weathering. Drainage direction is unclear but is probably predominantly to the north and east, with the head-waters in Antarctica.

The inception of rifting along the southern margin of Australia during the Jurassic resulted in extensive drainage reorganisation and incision, removing most of the Permian regolith. The eroded sediment formed thick Jurassic to Eocene clastic successions along the Australian southern margin. Both terrestrial and marine biotas indicate temperate conditions during this time. Paleomagnetic dating indicates a widespread episode of deep oxidative weathering during the Paleocene. Renewed, though limited, incision of the palaeodrainage system during the early Tertiary resulted in formation of inset valley profiles and isolation of terrace deposits on the flanks of the palaeovalleys. Eocene transgressions into the lower reaches of the palaeovalleys formed an irregular coastline of estuaries and embayments. The high base levels established during these transgressions resulted in extensive infill of the palaeovalley systems, mostly with fine-grained marine, estuarine, and coastal plain sediments. Coarser sediments were deposited in the steeper tributary valleys.

Extensive aggradation smoothed the topography in the Kalgoorlie landscape and lowered relief. Relief is still low because pre transgression base levels are yet to be re-established. This process has been slowed by the post Eocene shift to a drier climate. Local relief continued to lower as unconfined flow processes, predominantly sheetwash and sheetflood processes, shaped extensive plains in the head-waters and proximal reaches of the palaeodrainage net. Playa lakes developed over groundwater sumps associated with more distal reaches of the drainage net. Fine-grained clastic sediments and with minor carbonates were deposited in these lakes. Most of these sediments are strongly oxidised, indicating shallow, well-mixed water. Rare deposits of organic-rich lacustrine sediments indicate the occasional presence of deeper and/or stratified water. Regolith architecture, radiometric ages, and palaeomagnetic dating show that deep weathering processes continued through this period, at least where oxidised groundwaters were able to flow through the regolith. Most of the iron duricrusts and segregations in the regolith are shown by palaeomagnetic and radiometric techniques to be Oligo-Miocene in age, as are local silcrete occurrences.

Further increases in aridity by the Early Pliocene to Pleistocene led to sulphate deposition in the lakes, increased aeolian activity, and the predominance of groundwater discharge over runoff in most of the palaeovalley lakes. Chains of boinkas dominated the palaeovalleys, comprising complex groundwater discharge landforms characterised by inset playa lakes, sand dunes, and sapping. These boinkas are the source of calcareous dust which mantles much of the surrounding landscape. The larger lakes still intercept significant surface runoff, forming hybrid discharge and runoff systems. Under arid and semi-arid conditions since the Pliocene regolith processes are characterised by formation of pedogenic and groundwater calcrete and gypsum with only very limited iron mobility.

Use of the jetstream hydraulic erosion device for determining erodibility of hillslope material - initial results

Crozier, M. J., Hardenbicker, U. and Boyens, N.
School of Earth Science, Victoria University, P O Box 600, Wellington

Several different methods have been developed in the past for characterising erodibility of material with respect to running water. These involve either laboratory or *in situ* field tests generally applied to rill, gully or channel surfaces. Channel erosion is generally expressed as a relationship between the erosion rate and the effective stress in excess of some critical stress:

$$E = k (te – tc)$$

Where:

k = erodibility coefficient (cm^3/ N-s)

te = effective stress on the soil boundary (N/cm^2)

tc = critical stress (N/cm^2)

E = erosion rate (cm/sec)- expressed as a volume per unit area /time when the dimensions of the affected surface are taken into account.

The jetstream hydraulic erosion device developed by Hanson (1991) and described in this paper provides a measure of erodibility (k), the 'jet index', that is more physically based than the commonly used erodibility indices. The device is designed to produce a scour hole in the soil surface through the application of a water jet. Jet velocity is controlled by the nozzle diameter, reservoir head, and height of nozzle above the ground surface. During the one test, successive measurements are taken of scour depth development, until steady state is achieved. The jet index is a measure of the relationship of the rate of scour development to jet velocity, corrected for reduction in velocity from scour-hole wall friction with increasing time (depth).

In this study the jet stream device has been used to assess the erodibility of loess with respect to subsurface soil tunnelling. The use of the device in a hillslope setting as opposed to the stream channel environment is a novel application and presents a number of operational problems.

The results indicate that the device, while not representing true piping, satisfactorily simulates conduit development through tunnel scour. The jet index is clearly sensitive to soil properties, however, macropores, such as vertical loess joints, can produce a wide range of values in the one material.

Hanson G. J., 1991. Development of a jet index to characterise erosion resistance of soils in earthen spillways. *Transactions of the American Society of Agricultural Engineers* 34(5): 2015-2020

Has speleogenesis beneath the Nullarbor Plain been underestimated? - evidence from microgravity measurements and geomorphological observations

R.R. Davies[1*], S.H. Doerr[1,2], and A. Pulford[3]
[1]Department of Geography, University of Wales Swansea, Swansea, SA2 8PP, UK; *r.r.davies@swan.ac.uk
[2]School of Ecology and Environment, Deakin University, Warrnambool, Victoria, AU
[3]School of Earth Sciences, Victoria University, Wellington, NZ

The limestone of the Nullarbor Plain covers a large area (>200,000 km^2), but known karst features, although sometimes of impressive scale, are relatively scarce. The most conspicuous are about 150 collapse dolines, about 20 of which give access to large passages close to the water table. Since the size of known caves is at odds with their paucity, the question of their origin and true extent is contentious. The present climate is too arid for cave formation and speleothem dating suggests a minimum age of 780,000 years. Because large caves and collapses are few and mostly located within 100 km of the coast, it has been suggested that the dry climate has inhibited widespread speleogenesis, especially away from the somewhat wetter coastal region. However, ancient river channels can be traced for large distances far from the coast, suggesting much wetter conditions in the past and morphological evidence from Weebubbie and Cocklebiddy caves implies that they served as phreatic conduits for water flowing toward the coast under pressure.

Subdued topography and uniformity of cave and rock structure makes the Nullarbor a uniquely favorable environment for mapping caves with microgravity. A survey was undertaken around the entrance of Cocklebiddy cave (WA) to examine whether microgravity could locate the known cave from the surface, and also to attempt mapping of any unexplored passages in the area. Three negative anomalies were found to radiate from the entrance doline and are interpreted as being due to voids. A north-trending one agrees with the modelled gravity effect of the explored passage. A second anomaly extends southwest of the doline, presumably the coastward continuation. A third runs northeast from the doline, suggesting that the cave entrance is due to collapse at the weak intersection of two large passages.

On reflection, the detection of new cave passage is unsurprising. Cocklebiddy cave has been explored inland for ~6 km but nowhere does roof collapse approach the surface. Similarly, Mullamullang cave has about 40 major rockpiles along its 5 km length, but only one entrance. That no large Nullarbor cave has two or more entrances is highly significant because it implies that cave development is generally too deep for collapses to have reached the surface - the vast majority of cave systems presumably have no entrance at all. Furthermore, the coastal distribution of dolines may not indicate the extent of speleogenesis as generally accepted. Instead, we suggest that surface collapses are less likely where caves are situated deeper, where the water table is higher and where passages are smaller. All these three conditions are more likely to be met inland. The spatially homogeneous nature of the Nullarbor limestone makes it seem improbable that conditions could have favoured very localised development of a few large conduits. It is much more likely that passages are relatively frequent, but collapse entrances are very scarce. The strong barometric draughts at thousands of small blow-holes would be consistent with pressure equalisation of large reservoirs of "ground" air. Whether these originate from large caves, as opposed to microfractures and connected pore spaces, could readily be resolved by microgravity surveys. By applying this technique over larger areas, it would be possible to reveal the true extent of Nullarbor cave development.

Investigating the hydro-geomorphology of the Worlds' largest submerged cave systems using novel underwater research techniques in the Yucatan, Mexico

S.H. Doerr[1], P.L. Smart[2], P. Beddows[2], S. Smith[2], F.F. Whitaker[2]
[1]Department of Geography, University of Wales Swansea, Swansea, SA2 8PP, UK; s.doerr@swan.ac.uk
[2]School of Geographical Sciences, University of Bristol, Bristol BS8 1SS, UK

Our understanding of speleogenesis is largely derived from studies of continental carbonate terrains with diagenetically mature carbonates of low primary porosity, where an often significant relief provides the main drive for circulation of meteoric waters. Caves form from recharge points towards the lowest outlet, with individual passage directions determined by the nature, attitude and distribution of host fractures. Progressive elimination of relief and the resulting isostatic compensation give lowering of base level and abandonment of the initial network, with development of newer systems at depth.

Speleogenesis in low-lying and diagenetically less mature carbonate platforms is less well understood. Here primary porosity and permeability are high and fractures related to burial and tectonism, are unlikely to have developed. For coastal platforms, exposure results from relatively small (<10's m) changes in sea-level rather than uplift and the exposed carbonates remain in contact with marine waters at the platform margin. Meteoric recharge forms a freshwater lens over saline groundwaters below and significant carbonate dissolution results from the mixing of saline groundwaters entrained by meteoric groundwater flow. A model for cave formation under these conditions is the flank margin model: isolated spongiform mixing chambers form along the seaward margin of the exposed carbonates, with blind passages developing headward into the interior fed by intergranular diffuse flow. These caves are localised where undersaturation results from mixing, and thus differ from the often much larger continental caves, on which much of our understanding of karstification is based. In contrast to continental caves, they develop headwards, with speleogenesis occurring in progressively younger rocks as subsidence occurs.

Whilst the flank-margin model is useful, it is based almost wholly on observations in caves of limited extent developed in small isolated islands during the last interglacial high-stand, which are now subaerial and thus readily accessible. Its use in explaining the laterally continuous submerged cave systems that exist in the Yucatan Peninsula, Mexico may thus be rather limited. These systems, which include the worlds' longest submerged cave (Sistema Ox Bel Ha, >80km), have much greater dimensions, complexity and antiquity than the simple one-phase caves that have been the focus of most previous studies. Their detailed investigation has been limited since they require specialised cave diving techniques for access. Over the last the last few years, we employed such techniques for combined morphological mapping, hydrological observation and geochemical characterisation of groundwaters to develop an understanding of the genesis of these extensive underwater caves. This study presents an overview of the techniques used and summarises some preliminary findings on the genesis of these systems.

Techniques used include (i) conventional underwater mapping supplemented by digital video recording for subsequent detailed passage interpretation, (ii) short-term and multi-seasonal discharge measurements and salinity profiling, (iii) rock and water sampling for bio-geochemical analysis and (iv) speleothem collection for uranium series dating. Preliminary findings indicate that the Yucatan cave systems represent an important intermediate type between flank margin and epigenetic continental caves, with large meteoric groundwater flows and enhanced saline circulation through older cave passages at depth, while currently very active headward dissolution of anastomosing conduits occurs in a shallower zone sloping landward along the fresh- saltwater interface. This style of karst development may provide a more useful model than the conventional continental model for, for example, palaeokarst carbonate reservoirs where the elapsed time between deposition of the host carbonate and exposure is quite short.

Canopy interception losses in dryland plant communities: why are they important, and how can we measure them?

David Dunkerley
School of Geography and Environmental Science, PO Box 11A Monash University Victoria 3800

Only small amounts of water – typically the equivalent of a few mm of rainfall – can be held on plant canopies. The continued arrival of water in storms larger than this exceeds the *canopy storage capacity* (CSC) and the surplus passes downward through the canopy as released throughfall derived from leaf or branch drip, or as stemflow. Through the course of a period such as a season or a year, the amount of water returned to the atmosphere by evaporation from the wet plant canopy is a function of storm properties, the canopy storage capacity, and external meteorological conditions (humidity, wind speed, surface net radiation). In forests of the humid zone, from 15% to 25% of the annual rainfall may be intercepted and returned to the atmosphere. This local moisture source may be crucial to sustained rainfall downwind (in the process of *precipitation recycling*). For plant communities of the Australian drylands, there are no available data on annualised water losses arising from canopy interception. This is partly because such annualised water losses are far harder to measure than the CSC, which can be determined by weight gain when a specimen of foliage is wetted-up until freely dripping.

A knowledge of canopy interception losses in dryland vegetation is significant for several reasons. We know that certain dryland plants (like the mulga, *Acacia aneura*) have a leaf and branch architecture that efficiently funnels intercepted water to especially permeable soil close to the stem, and this is inferred to augment the water resource of the plant. But while there are some field measurements of the stemflow volume in relation to rainfall on the storm-period timescale, it has not been demonstrated that when annualised, a net benefit arises. Furthermore, intergrove runoff may itself augment the plant water supply adequately. Thus, although stemflow has been recorded, its fate (direct use by the plant? loss by percolation to depths beyond the root zone?) has not been experimentally revealed. For widespread Australian dryland plants such as bluebushes and saltbushes, there are few good estimates of CSC and none at all for annualised interception loss. Consequently, we lack the data to enquire to what extent the dense canopy of a shrub like the black bluebush *Maireana pyramidata* or of a tussock grass such as the Mitchell grass *Astrebla pectinata* acts to deprive the plant of significant water, or about what implications such deprivation might have for root architecture and plant spacing within a vegetation community, and hence for erosion processes like splash and surface entrainment. The widely-adopted view that individual or small groups of such shrubs or grasses constitute 'resource islands' might be true for nutrients but may not be true in terms of water availability.

The dryland communities in which the required data could be sought are relatively remote, and rain events are infrequent. Furthermore, there may be a range of plant forms and ages, so that to derive an estimate of annualised canopy interception loss for a vegetation *community* might require observations on many individuals. Clearly, therefore, any method for field recording of water losses must be capable of operating over long periods of time (in order to record an adequate sample of storms, both small and large) and sufficiently cheap that multiple individuals can be instrumented. A new approach to this task has been developed, which involves a low-cost form of chemical integration. Tablets of a soluble substance are set out both in the open and beneath the canopy. These lose weight in proportion to the depth (volume) of water to which they are exposed. These losses are tracked by periodic weighing, and are calibrated against total rainfalls recorded at a nearby gauge. The tablets in the open provide a calibration in mg mm^{-1}, and this is used to derive an estimate of the water depth that had passed across the sub-canopy tablets. Funnel collectors of varying size can be used to integrate across sub-canopy areas of varying size. For relatively short study periods, tablets having a higher solubility can be employed, and for long-term monitoring, a material of lesser solubility would be selected. Preliminary field results will be presented.

Do the little things matter? Recent work on the behaviour of shallow overland flows

David Dunkerley
School of Geography and Environmental Science, PO Box 11A Monash University Victoria 3800

On many dryland surfaces, as elsewhere, surface runoff begins as shallow, non-channelised interrill flow. In these same flows, raindrop impacts generate the forces needed to dislodge and entrain sediment particles. Owing to the patchiness characteristic of many drylands, and the resulting short runoff fetch before an absorbing shrub or grass microenvironment is encountered, these flows may be the dominant form of runoff across many broad, low-gradient landscapes. The interrill flows are shallow (often just a few mm), and without the effects of droplet impact, would be laminar, often with $Re << 500$. In view of these properties, the flows seem susceptible to modification by seemingly minor surface features – loose or embedded stones, the stems of plants, and loose organic litter. Soil surface features (grain roughness, amplitude and form of microtopography) likewise probably take on a heightened significance for flow properties, friction coefficients, and flow speeds.

If we are to understand the origins of surface runoff and the initial entrainment of sediments, these flows must be researched. Doing so would assist in the ranking of surface features (such as areal litter loadings) subject to human modification but of key significance in the operation of environmental processes. Additionally, the refinement of exploratory hydrologic and erosion models cannot progress until relevant parameterisation of surface features has been achieved, and values for key parameters (such as flow friction coefficients) have been derived.

Recent experimental work has targeted some of these areas of need. *Flow depth* is a key parameter that relates both to the intensity of drop splash and to the surface drag affecting shallow flows, and one that enters into determination of the Darcy-Weisbach friction coefficient. However, flow depth is not determined solely by kinematics, but is additionally influenced by the volumetric displacement of obstacles like stones or litter lying on the soil surface. A correction for volumetric displacement results in higher friction coefficients, but perhaps more importantly, coefficients that change with flow depth or flow intensity in ways not suggested by kinematics. These changes result from the profile of obstacle volume lying above the surface. Mean flow depths may be reduced by > 200% once the effects of volumetric displacement are eliminated. *Surface tension forces* become significant in shallow flows, especially where large aggregate edge lengths (such as from scattered small litter particles) are available to support the formation of menisci. These can generate local flanking flows up to 7 mm wide, that are 100-300% deeper than nearby free-field flow, and in which flow speeds are > 40% faster. Though not yet explored, these meniscus zones may form avenues where particle mobility is enhanced. *Obstacles within the flow* have the potential to generate additional frictional drag. The dominant view has been that this arises from a direct obstruction of flow paths proportional to the aggregate upslope-projected wetted area of the obstacles. However, surface microtopography steers flow threads along particular tracks, as does the exclusion of some potential tracks by obstacles. Resulting flow threads may carry > 40% of the flow in < 20% of the flow width, and maintain speeds > 2 x the flow-field mean. These *flow filaments* thus seem to provide another potential key avenue for enhanced particle mobility.

Findings like those just outlined suggest that an understanding of the detailed mechanics of shallow flows has the potential to contribute significantly to our ability to describe soil surfaces meaningfully, to measure relevant flow properties, and to begin to parameterise soil surfaces in ways relevant to hydrologic and erosion modelling. A less reductionist (more 'black-box') approach to understanding what takes place on experimental plots may be expedient in some contexts, but is much less suitable for generating the detailed level of understanding of surface processes that ought to be one of the foundations of a scientifically-based process geomorphology.

Surviving glaciation: complex exposure modelling and the preservation of glacial landscapes

Derek Fabel
Research School of Earth Sciences, ANU, Canberra

Some areas within former ice sheet boundaries retain landforms that appear unmodified by glacial erosion. These relict areas have either remained ice-free islands (nunataks), or were preserved under ice. Differentiating between these alternatives has significant implications for palaeoenvironment, ice sheet surface elevation, and ice volume reconstructions. Here we show that in the northern Swedish mountains in situ cosmogenic ^{10}Be and ^{26}Al concentrations from erratics on relict surfaces, and glacially eroded bedrock adjacent to these surfaces, provide consistent last deglaciation exposure ages (~8-13 kyr), confirming ice sheet overriding as opposed to ice free conditions. Apparent exposure ages of 34 kyr to 61 kyr on bedrock surfaces in these same relict areas demonstrate cosmogenic nuclide inheritance. This inheritance has to be derived from previous exposure (ice-free) periods during interstadial and interglacial times. The existence of the inherited cosmogenic nuclides today indicates that these relict areas have not been significantly eroded (< 2 m) during the last glaciation, probably as a result of cold-based conditions.

Complex exposure modelling based on the relative decay of ^{26}Al and ^{10}Be the measured nuclide concentrations in several of the relict bedrock surfaces suggests that they remained largely unmodified during multiple ice sheet growth and decay phases. The results indicate that boundaries between glacially sculpted and preserved landscapes should not automatically be interpreted as former ice limits in palaeoclimatic and palaeoglaciological reconstructions. Relict areas need to be accounted for as frozen bed patches in basal boundary conditions for ice sheet models, and in landscape development models.

Jobs for geomorphologists! A new geoarchaeology of aboriginal stone artefact scatters in western NSW, Australia.

Trish Fanning
Graduate School of the Environment, Macquarie University, Sydney.

Surface scatters of stone artefacts are the most ubiquitous feature of the Australian Aboriginal archaeological record, yet the most underutilized by archaeologists in developing models of Aboriginal prehistory. Among the many reasons for this are the lack of understanding of geomorphic processes that have exposed the artefacts, and the lack of a suitable chronological framework for investigating Aboriginal 'use of place'.

In arid western NSW, erosion and deposition accelerated as a result of the introduction of sheep grazing in the mid 1800s has resulted in exposure of artefact scatters in some areas, burial in others, and complete removal in those parts of the landscape subject to concentrated flood flows. The result is a patchwork of artefact scatters exhibiting various degrees of preservation, exposure and visibility. My research at Stud Creek, in Sturt National Park in far western NSW, develops artefact and landscape survey protocols to accommodate this dynamic geomorphic setting. A sampling strategy stratified on the basis of landscape morphodynamics is presented that allows archaeologists to target areas of maximum artefact exposure and minimum post-discard disturbance. Differential artefact visibility at the time of the survey is accommodated by incorporating measures of surface cover which quantify the effects of various ephemeral environmental processes, such as deposition of sediments, vegetation growth, and bioturbation, on artefact count.

While surface stone artefact scatters lack the stratigraphy usually considered necessary for establishing the timing of Aboriginal occupation, a combination of radiocarbon determinations on associated heat-retainer ovens, and stratigraphic analysis and dating of the valley fills which underlie the scatters, allows a two-stage chronology for hunter-gatherer activity to be developed. At Stud Creek, dating of the valley fill by OSL established a maximum age of 2,040±100 y for surface artefact scatters. The heat-retainer ovens ranged in age from 1630±30 y BP to 220±55 y BP. Furthermore, a gap in oven building between about 800 and 1100 years ago was evident. Environmental explanations for this gap were explored, but the palaeoenvironmental record for this part of the Australian arid zone is too sparse and too coarse to provide explanations of human behaviour on time scales of just a few hundred years.

To test this model of episodic landscape change and its effects on preservation of the archaeological record, three locations on Fowlers Gap Station with distinct geomorphic histories were investigated. A record of just a few hundred years was obtained from sites located on channel margins and low terraces, while the longest record thus far of around 5,000 years was obtained from high terrace surfaces more remote from active channel incision. But even here, the record is not continuous, and like Stud Creek, the gaps are interpreted to indicate that Aboriginal people moved into and out of these places intermittently throughout the mid to late Holocene.

Episodic nonequilibrium (*sensu* Renwick 1992) characterizes the geomorphic history of these arid landscapes, with impacts on the preservation of the archaeological record. Dating of both archaeological and landform features shows that the landscape, and the archaeological record it preserves, are both spatially and temporally disjointed. Models of Aboriginal hunter-gatherer behaviour and settlement patterns must take account of these discontinuities in an archaeological record that is largely shaped by geomorphic activity.

Renwick, W.H. (1992). Equilibrium, disequilibrium and nonequilibrium landforms in the landscape. *Geomorphology* 5, 265-276.

Relict foredune plains in the Gulf of St. Lawrence, Canada

Philip T. Giles
Department of Geography, Saint Mary's University, Halifax, Nova Scotia,
Canada B3M 2K9 (Philip.Giles@stmarys.ca)

Introduction

Three Holocene relict foredune plains in the Gulf of St. Lawrence, Canada, have been studied and cross-sectional profiles are compared and contrasted. A relict foredune plain is a series of former foredune ridges built seawards by progradation and oriented approximately parallel to one another. Except closest to the shore, the dunes tend to be stabilized with mature vegetation and a soil profile, or covered by a bog. The hypothesis being tested in this research is that relative sea level history during development is manifested in the cross-sectional morphology of the foredune plain.

Regional setting

The Gulf of St. Lawrence is a mesotidal, semi-enclosed sea. The region was isostatically depressed during the last glacial period by the Laurentide ice sheet. Relative sea level history at a locale reflects a combination of factors: regional isostatic rebound (greater towards the north), northward migration of a crustal forebulge associated with ice sheet retreat, and eustatic sea level rise.

Examples of relict foredune plains

Two relict foredune plains on Iles de la Madeleine, in the centre of the Gulf, exhibit contrasting morphologies. Both plains are east-facing, on the more protected coast of the island-tombolo chain. Ridges and swales comprising Les Sillons on Dune du Sud rise steadily in the seaward direction and are flooded on the lagoon side (Giles and King, 2001). Approximately 25km to the southwest, the ridges of Dune de l'Est have a flatter trend, even with a shallow dip in the middle of the plain. It is hypothesized that these two plains developed at different times under different relative sea level conditions. Dune de l'Est ridges may have developed earlier during a relative sea level lowstand (minimum around 6000 BP) in the lee of a bedrock island, Ile du Havre Aubert. In contrast, Dune du Sud developed later during relative sea level rise after the Dune du Nord tombolo on the west-facing coast had extended to provide a sheltered depositional environment. The third relict foredune plain studied, at Basin Head on Prince Edward Island, is located on the Northumberland Strait 125km south of Iles de la Madeleine (Giles, 2002). Palmer (1978) used diatom stratigraphy to document Holocene sea level rise at Basin Head. Its cross-sectional morphology is similar to Les Sillons (Dune du Sud) in that there is a steady rise in ridge and swale elevation from lagoon to shore. Les Sillons and Basin Head were able to prograde and rise during a period of rising sea level because of a high sediment supply in the post-glacial environment.

Present transgression

All three relict foredune plains are presently undergoing transgression in response to continued sea level rise of (currently ~0.35m/century in the region) and reduced sediment supply. The seaward stabilized dunes are now eroding and becoming reactivated. Les Sillons and Basin Head are most affected by transgression while the more protected wave environment adjacent to Dune de l'Est appears to be limiting its rate of transgression.

GILES, P.T. and KING, M.C. 2001. 'Les Sillons': A relict foredune plain. *The Canadian Geographer* **45**, 437-441. (Canadian Landform Example – 42)

GILES, P.T. 2002. Historical Coastline Adjustment at MacVanes Pond Inlet, Eastern Prince Edward Island. *The Canadian Geographer* **46**, 6-16.

PALMER, A.J.M. 1978. Diatom stratigraphy of Basin Head Harbour, Prince Edward Island. *Proceedings of the Nova Scotian Institute of Science* **28**, 201-215.

The influence of rainfall, soil hydrology and pipe network characteristics on slope drainage in steep pasture-covered hill country

Hardenbicker, U., Pott, A. and Crozier, M. J.
School of Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand

Preferential sub surface stormflow provides a mechanism for rapid hillslope runoff. Underestimates of stormflow in surface streams have occurred in the past as a result of assuming hillslope runoff as a function solely of soil matrix flow. This study attempts to establish some real time measurements of stormflow occurring in soil pipes. The ultimate aim of the study is to measure pipeflow runoff characteristics, determine which factors control flow behaviour, and estimate the role of pipeflow in hillslope drainage.

The study area is a 4500 m^2 pasture-covered, hillslope of the Tutira catchment, Hawke's Bay, east coast North Island, New Zealand. The soils are highly permeable intergrades between yellow-brown pumice soils and yellow brown loams, mantling relatively low permeability Pliocene marine mudstones, sandstones and occasional limestone bands, to a depth of about 1.2 m. The study area is serviced by an automatic climate station and five nearby sites are equipped to measure soil tension and soil moisture (at depths of 25, 50, and 100cm) as well as porewater pressure throughout the profile.

The alignment of shafts in the soil surface indicates the presence of at least three pipeflow networks. The largest of these is estimated to have a catchment area of 1219 M2 and exits the base of study slope just upslope of a landslide scar. A thin-walled, 20 degree 'v'-notch weir has been installed at the pipe exit with water depth recorded by a pressure transducer / data logger system.

Pipeflow is ephemeral with twenty-nine discrete pipeflow events being recorded between July 2000 and November 2001 associated with rainfall events ranging in total between 5.4mm and 296 mm. The flow events are generally very small with volumes ranging from less than one litre to 70,000 litres. The five largest events have total volumes ranging from 168 – 70,356 litres with maximum discharges recorded at one-minute intervals ranging from 965 – 83,264 ml/min.

In all cases pipeflow commenced several hours before soil moisture began to rise at the position in the soil where pipes were located (50cm depth). This suggests that pipeflow is not the result of the wetting front from matrix flow intersecting the pipe. For the twenty-nine events, the median delay between the onset of rain and pipeflow was 135 minutes while the median delay between the onset of rainfall and a measurable soil moisture response was nearly 19 hours. In addition, the median lag time between the peak of rainfall and the peak of the flow event was 13 minutes. These results indicate that bypass flow rather than matrix flow contributes to pipeflow.

Correlation analysis shows close significant relationships between pipeflow discharge parameters and total event rainfall as well as between pipeflow response times and rainfall intensity. Conversely measures of antecedent soil moisture and magnitude of soil moisture change during events were not related to pipeflow behaviour. Clearly the influence of rainfall on pipeflow is little modified by soil moisture conditions and suggests that water contributes to pipeflow through direct contact with the surface, via crack and surface openings.

The pipe network monitored in this study appears to make a significant contribution to hillslope storm runoff only in extreme events.

A geomorphic history of the dune system in the Otaki-Te Horo area

R.M. Hawke and J.A McConchie
School of Earth Sciences, Victoria University of Wellington, New Zealand

An extensive complex of dunes, sand plains, and peaty swamps borders the west coast of the southern half of the North Island, New Zealand. This complex extends from Paekakariki north for 200km to Patea and is up to 20km wide. A number of previous authors have identified and discussed phases of dune-building in this general area (Cowie, 1963; Fleming, 1972). However, the majority of previous work has been further north in the lower Manawatu (Hesp and Shepherd 1978; Hesp, 2001).

In the vicinity of the Otaki River the coast has been prograding at approximately 0.5m/y during the Holocene, with the present shoreline 3km west from the last interglacial sea cliff (6000-6500 B.P.). Parabolic dunes are aligned transverse to the coast and their distinctive clustering suggests that they formed during distinct phases. These phases, in order of increasing age, have been named Waitarere, Motuiti, Foxton, and Swamp Rd. Previous estimates of the ages of the dune phases have been largely on the basis of their geographic position, the occurrence of Taupo pumice (1800 B.P.), and some radiocarbon age determinations. A thermoluminesence date at a site near the Manawatu River yielded a date of 3000±500 for a Foxton dune that had migrated over a peaty paleosol (Shepherd and Price, 1990).

This paper uses sedimentological data and optical luminescence dating to provide a chronology for the development of the Holocene dunes and the coastal plain in the area around the mouth of the Otaki River. While in many respects the dunes in this area are similar to those described to the north (Muckersie and Shepherd, 1995; Hesp, 2001) there are also distinctive differences, such as the occurrence of the Swamp Rd dunes.

Sediment samples were taken from the crests of seven dunes from each dune phase along three transects (106 samples in total). In addition, eight samples were collected for OSL dating: one from each of the Waitarere and Motuiti phases, four from the Foxton phase (to allow both vertical and horizontal variability to be quantified), and two from the Swamp Rd phase. The distinctive soil profiles observed for each dune phase suggest either episodic dune development or coastal progradation. The sedimentological characteristics suggest a similar sediment source and depositional history for each of the Foxton, Motuiti, and Waitarere dune phases. Both the sedimentological and magnetic composition data suggest the Swamp Rd dunes are distinctly different from the other phases. There is also strong evidence that significant differences in energy conditions, and hence sediment character, occur at sites depending on their position relative to the Otaki River mouth. The combination of OSL dates and sedimentological data allows a geomorphic history of the area to be constructed.

Cowie, J. 1963: Dune-building phases in the Manawatu district, New Zealand. *New Zealand Journal of Geology and Geophysics,* 6(2): 268-280.

Fleming, C. 1972: The contribution of C14 dates to the Quaternary geology of the 'golden coast', Western Wellington. *Tuatara,* 19: 61-69.

Hesp, P. 2001: The Manawatu dunefield: environmental change and human impacts. *New Zealand Geographer*, 57(2): 33-40.

Hesp, P. and Shepherd, M. 1978: Some aspects of the late Quaternary geomorphology of the lower Manawatu valley, New Zealand. *New Zealand Journal of Geology and Geophysics,* 21(3): 403-412.

Muckersie, C. and Shepherd, M. 1995: Dune phases as time-transgressive phenomena, Manawatu, New Zealand. *Quaternary International*, 26: 61-67.

Shepherd, M. and Price, D. 1990: Thermoluminescence dating of late Quaternary dune sand, Manawatu-Horowhenua area, New Zealand: a comparison with 14C determinations. *New Zealand Journal of Geology and Geophysics,* 33: 535-539.

Discharge, velocity, and erosion within the Waikato River channel

R.M. Hawke; J.A McConchie; I.E.J. Toleman
School of Earth Sciences, Victoria University of Wellington, New Zealand

At 425km the Waikato River is the longest river in New Zealand. It also drains the North Island's largest catchment with an area of over 14,000km^2, and carries the North Island's largest mean annual flow. In falling 350m from Lake Taupo to the sea at Waikato Heads a considerable amount of energy is dissipated within the eight hydroelectric power stations, and their associated tailraces; however, some energy is also dissipated on the bed and banks of the river. As part of the current resource consent renewal process considerable research has been undertaken to quantify the natural geomorphic processes and the effects of flow augmentation and regulation associated with hydro-electricity generation.

The effect of flow regulation has been to alter the natural flow regime, both the average conditions and the flow variability, of the river. At the Lake Taupo outlet the mean flow is 161m^3/s. By Karapiro this has increased by over 50% to 247m^3/s. By Mercer the flow of the Waikato River is over 2.5 times that at the Lake Taupo outlet (mean 421m^3/s). Despite flow regulation large floods still occur, for example, in the July 1998 event the maximum discharge was 1488m^3/s at Ngaruawahia (McConchie, 2001).

Given the significance of within-channel and bank erosion processes in affecting the geomorphic character of the Waikato River a detailed study was designed to: quantify the effect of variations in flow and river level on near-bank velocity profiles; quantify the effect of variations in flow and river level on erosion and sediment entrainment; to quantify the effect of vegetation cover, land use and other anthropogenic factors on the above. Field measurements were undertaken at a number of locations along the length of the Waikato River. These locations were chosen to reflect the variations in lithology and/or processes along the river, and areas where erosion is active currently. At each location matched pairs of measurement sites, vegetated and un-vegetated, were chosen and sampled under both high and low flow conditions (McConchie, 2001).

While an increase in flow, for example from 150m^3/s to 400m^3/s, resulted in a considerable increase in flow depth this was not always correlated with an increase in near-bank velocity. At a number of sites the effectiveness of vegetation in reducing near-bank flow velocities was demonstrated. In addition, the nature of the bank profile had an important effect on the way the velocity profiles changed with varying discharge. Overall, the majority of the observed near-bank velocities were lower than the entrainment threshold of the bank material. These results were complemented with flow gauging records that showed increasing the discharge over the range affected by flow regulation for power generation leads to significant increases in velocity within the centre of the channel rather than at the banks.

In addition to the measurements of velocity suspended sediment data were collected. While the highest sediment concentrations were recorded close to the bank there was no strong correlation with either distance from the bank, or mean velocity. Rather, sediment concentration was largely a function of site characteristics, including the bed and bank material and the geometry of the bank. For example, in situations where low flows expose fine sandy material sediment concentrations tend to increase while higher flows that cover grassed or vegetated slopes often lead to lower concentrations (Toleman, 2002).

McConchie, J.A. 2001: Waikato River geomorphic processes. Report prepared for Mighty River Power Ltd. 248p.

Toleman, I.E.J. 2002: Stream bank sensitivity to physical and anthropogenic factors: an analysis of the Waikato River. Unpublished MSc thesis, School of Earth Sciences, Victoria University of Wellington, 211p.

The role of abrasion in coastal stability on the mixed sand and gravel beaches of the Canterbury Bight, South Island, New Zealand

Maree Hemmingsen
Department of Geography, University of Canterbury, Private Bag 4800, Christchurch, New Zealand (maree@geog.canterbury.ac.nz)

The coastline of the Canterbury Bight between Timaru and the southern end of Kaitorete Barrier at Taumutu is in long term erosion. Paradoxically, several large, braided rivers drain from the rapidly eroding Southern Alps into the Canterbury Bight transporting sands and gravels derived from the indurated sandstone of the Torlesse Super Group or "greywacke" to the coast. Griffiths (1981) states that catchment-specific sediment yields average 1856± 261t km^2yr^{-1} compared with the world average of 182t km^2yr^{-1} and are among the highest known specific sediment yields. However, the large sediment loads from these Canterbury rivers are comprised of predominantly fine sediments in suspended load (more than 90%) and only a small amount of coarse bedload (less than 10%). This is reflected in the nature of the mixed sand and gravel beaches. The Canterbury Bight coastline is then apparently abundantly supplied with sediment which is subsequently transported northward ultimately forming Kaitorete Barrier. Yet, historically there has been very little accumulation of sediment against Banks Peninsula at the downdrift end. Previous research has suggested that the missing sediment is lost from the beaches due to abrasion and is carried offshore.

The work presented here is a step towards deriving a more precise measure of abrasion for input to the sediment budget of the mixed sand and gravel beaches of the Canterbury Bight. Tumbler experiments were carried out using a concrete mixer. Samples were collected along the coastal zone of the Canterbury Bight. Results have shown a consistency of method between sites. However, the results have also highlighted differences between sediments from different sites. In addition to lithological variations identified between sites, variations in abrasion rates can also be attributed to the sediment sizes within samples, the amount of weathering of sediments and the shape of sediments. The results clearly show that no single value can adequately represent the abrasion behaviour of greywacke sediments from mixed sand and gravel beaches. The experiments do however, confirm abrasion as the main sediment loss mechanism from the beaches along the Canterbury Bight.

The encircling lunette at Old Harbour, NSW: Implications for atmospheric circulation patterns during the Late Pleistocene

Hesse, P.P. & Olley, J.*
Dept. Physical Geography, Macquarie University, Sydney
*CSIRO Land and Water, Canberra

Old Harbour, near Dubbo, New South Wales, boasts a lunette dune which encircles the lake floor except where a small creek enters. The lake (1.5 x 1 km) is fed by a small catchment (11 km^2) of low hills on the boundary between the Macquarie and Castlereagh catchments. In the late 20th century the lake has been ephemeral, filling for several years during each of the major La Nina events of the 1950s, 1970s and late 1990s. The lake maintains a dense stand of juncus on the clay floor during dry and wet periods alike and dense stands of river red gum around the shore. The lunette is vegetated with a mixed Callitris/Eucalyptus/Allocasuarina woodland with a sparse understorey of grasses and other species. Currently the shoreline and lunette are stable while the lake bed may be receiving a small amount of fine sediment from the creek.

The lunette is highly unusual because it entirely circles the lake bed. The stratigraphy of the eastern and western lunettes is remarkably similar: the clay-rich lunette contains several strata of variable clay content and sand size and is cemented by at least three fragipans which appear to drape the dune and may represent separate soil forming episodes. This clay lunette is largest on the western side but nearly as high in the northeastern sector. A sand dune covers the crest of the western lunette and a similar, but shallower, sand body is also present on the crest in the eastern and northern sectors. The youngest stratigraphic unit is a beach and foredune unit which occurs all around the lake. In the south and east the beach is inset into a notch eroded in the base of the clay lunette. A 1-1.5m cliff is still preserved beneath the sand. On the west and north the sands appear to overlie the clay lunette conformably.

The similarity of the stratigraphy on the eastern and western sides (with at least two wetting and drying cycles preserved) suggests synchronous deposition. If this is the case then it indicates a seasonal change in wind direction such as is experienced today. A small number of OSL dates from the western and southern portions of the lunette date the clay lunette to >40ka, the dune to around 30 ka and the beach to around 20 ka. Further dates will allow us to test the hypothesis that during the period up to 20 ka the seasonal wind pattern in this area was essentially the same as the Holocene. The obvious implication would be that during the LGM there was no significant change in the latitude of the major wind systems in this region.

Origin and structure of riverine wetlands in the Murray-Darling Basin: the example of the Macquarie Marshes

Hesse, P.P., Pearce, B., Ralph, T. & Yonge, D.
Department of Physical Geography, Macquarie University, Sydney

John Oxley sailed down the Macquarie River in 1818 until it disappeared into a sea of reeds. He insisted that only the impassable reeds separated him from the inland sea he sought.

The Macquarie Marshes, on the Macquarie River of northern New South Wales, are representative of riverine wetlands (marshes) found on many rivers of the Murray-Darling basin. Their widespread distribution and characteristic fluvial forms seem to have escaped notice and previous explanations for the origins of individual marsh systems concentrate on local causes. These mostly rely on damming mechanisms; in the case of the Barmah Forest damming of the Murray River is known to have occurred through fault movement and the Great Cumbung Swamp on the Lachlan River may be the result of trunk stream alluviation and damming (by the Murrumbidgee). By contrast, the fluvial wetlands of the Loddon, mid-Lachlan, Macquarie, Castlereagh, Namoi and Gwydir (and many more smaller streams) share characteristics which cannot be explained by the chance occurrence of local external mechanisms but indicate a common response to hydrological conditions of the Holocene.

The Macqaurie Marshes, like other fluvial wetlands of the MDB, result from channel breakdown on a river which suffers downstream decreases in discharge and sediment calibre but a perennial (if erratic) flow. Floodplain wetlands form where 'breakaways' (crevasses) deliver water from the main channel on its alluvial ridge to the floodplain. The attenuated discharges of the lower reaches of the river cause these breakaways to be active almost continuously, giving rise to lush wetlands. Some of these breakaways result in avulsion of the main channel, but others seem to exist as minor distributories for decades. These floodplain marshes neighbouring a continuous trunk stream are only a precursor to the eventual complete breakdown of the channel into a semi-perrenial wetland without continuous channels. This pattern appears to be a response to three factors, (1) the predisposition of the channels to form breakaways and avulsions (anastomosis), (2) the greater expanse of low-lying plain allowing dispersal of the distributaries and their flow and (3) the near-perennial flows lead to vegetation clogging channels and trapping sediment.

The Macquarie River undergoes at least four scales of breakdown at a range of temporal and spatial scales. The main area of marsh occurs where the confining palaeochannel tracts diverge leaving a low-lying plain up to 30 km wide. Only the smallest scale of breakdown leads to complete channel breakdown however these account eventually for the whole discharge of the river. These individual marsh areas have a deltaic form and are themselves arranged in series; breakdown is followed by convergence of flows, channel development, breakdown and so on. Sediment trapped by vegetation in breakdowns may be (in part) re-entrained by the reformed channels. One of the curious features of these riverine wetlands, with their total channel breakdown, is that they are not terminal. All the rivers reform into single channels. The stability of these downstream channels may rely on the retention of suspended sediment in the marshes.

Anabranching rivers & maximum flow efficiency

John D. Jansen, Gerald C. Nanson
School of Geosciences, University of Wollongong, 2522, New South Wales

In this field - and laboratory-based study, we demonstrate that the development of anabranching channels in some rivers increases the conveyance of sediment and water, compared with a single channel at the same flow discharge. That is, under certain conditions, anabranching channels exhibit greater sediment transporting capacity per unit available stream power.

Anabranching is a globally widespread river pattern noted in diverse physiographic, hydrologic and sedimentologic environments, and recent efforts have sought to unravel controls on their origin and maintenance. It is widely held that most rivers form a single-channel in order to minimise boundary roughness while conveying water and sediment, but do all rivers show a tendency to develop a single channel? And if so, what factors lead to long-term anabranching?

The observation that anabranching commonly develops in environments where water and sediment conveyance is maintained with little or no recourse to increasing energy slope prompted the hypothesis that rivers may adopt a multiple channel pattern in order to optimise their efficiency where they cannot otherwise increase slope. It is reasoned that development of a system of multiple channels reduces total flow width and raises mean flow depth, thereby maximising sediment transport per unit area of the channel bed and maintaining or enhancing water and sediment throughput. In testing the hypothesis we present: (1) results of a field experiment in which hydraulic variables and bedload discharge are measured and compared for single-channel versus multichannel reaches of the same river (Magela Creek, northern Australia); (2) comparison of these field results with bedload transport modelling via well known bedload equations; and (3) results of an experimental flume study comparing hydraulic variables and sediment flux in single-channel versus divided flow.

Magela Creek is representative of several anabranching systems draining the Alligators Rivers Region of monsoonal northern Australia. We investigate the dynamics of flows up to four-times bankfull discharge and find that at high flowstage hydraulic variables interact in a complicated manner that precludes conventional hydraulic geometry analytical methods. The complex trends among hydraulic variables reflect the differential and stage-dependent interactions between bank vegetation and channel roughness. Abrupt decline in overbank velocity promotes proximal sedimentation in the form of vertically-accreting islands, levées and sand splays—mechanisms of sediment sequestration that may eventually lead to channel avulsion and creation of new channels.

Just as different equilibrium states are expected to exist in braiding, meandering and straight rivers, we anticipate that other anabranching rivers may differ in their efficiency. Moreover, the development of sediment and water flux imbalances between anabranches is a highly likely outcome of their independent functioning. Channel atrophy coupled with in-channel sedimentation lies at the heart of channel avulsion and abandonment processes and therefore is central to the anabranching pattern.

The world's largest rivers all feature divided flow around large alluvial islands, yet ironically, anabranching was long regarded as unusual and therefore peripheral to the fluvial trinity of braiding, meandering and straight channel patterns. The five largest rivers (i.e. Amazonas, Congo, Orinoco, Chang Jiang, and Padma-Jamuna-Brahmaputra) all constitute anabranching over the majority of their alluvial tracts. In total, these rivers feature anabranching along 92 % of their total alluvial length. Given that river pattern reveals much about river dynamics, the prevalence of anabranching—particularly among the world's largest rivers—invites the speculation that a fundamental physical principle may underpin the widespread adoption of anabranching; it may be the most efficient means of transmitting large water and sediment discharges in alluvial rivers.

Geomorphology and landscape history of a young volcanic province: the Western Plains of Victoria

E. B. Joyce
School of Earth Sciences, The University of Melbourne, VIC 3010, ebj@unimelb.edu.au

The Western Plains sub-province is a part of the Newer Volcanic Province of Southeastern Australia, which includes the Mt Gambier sub-province in southeastern South Australia, and the Western Uplands sub-province in Victoria. In the late Tertiary, a shallow sea reached to the southern margin of the Western Uplands, the east-west spine of Western Victoria. The retreat of this sea exposed for the first time marine deposits of sand, clay and marl, with many parallel ridges marking successive shorelines. Most of these shorelines ridges have only just been recognised on new radiometric, magnetic and digital terrain imagery. As the sea retreated, rivers in the Uplands gradually extended southwards, reworking and partly covering the marine surface with thin alluvial deposits.

About the same time both the Uplands and the Plains gave birth to a new volcanic province, and over the last 5 Ma nearly 400 small, monogenetic, Strombolian/Hawaiian scoria cones, maars and lava shields have been built up, with fluid basalt flows spreading laterally around vents, and often southwards for many kilometres down stream valleys. Where the lava has blocked drainage, lakes and swamps have formed, and on the plateau-like flow surfaces collapse depressions have produced further lakes and swamps.

Some lava flows have been dated by K/Ar and radiocarbon, and changes in landforms, drainage, and soil and regolith development, using new airborne geophysical imagery, can be used to build up a detailed chronosequence of lava flows through the Quaternary. The youngest dated eruption is that of Mt Gambier in nearby southeastern South Australia, at 4000-4300 B.P. by radiocarbon, and perhaps a dozen volcanoes may eventually be found to have erupted within the last 20,000 to 30,000 years. Along a line from Port Fairy to Colac, near the southern limit of volcanic activity, groundwater has interacted with rising magma to cause phreatomagmatic explosions, reaming out some 40 or so deep maar craters and building up rims of ash or tuff. Rain and groundwater have filled many of these craters, and sediment, pollen and microfauna accumulated in the lakes record changing climate during the latter part of the Quaternary.

Many hundreds of small lakes and swamps can also be found on the widespread flat to undulating clay plains, with duplex soils and gilgai, which have developed on lava flows erupted between 3 and 1 Ma ago. On areas of exposed Tertiary marine sediments between the flows larger lakes have built up lunette complexes by deflation; in what is possibly a tectonic depression, Lake Corangamite and nearby lakes make up a major lake-lunette complex. Megafaunal remains were first discovered last century in a number of maar craters and lunette-bounded swamps. Further evidence of neotectonics is found in faults and monoclines affecting lava flows, and the warping of sandy Tertiary shoreline ridges; broad uplifted blocks of Tertiary sediments are associated with several volcanic complexes as at Staughtons Hill.

Regolith-landform mapping of flows, studies of the changing morphology of cones, craters and flows though time, and most recently the recognition and dating of neotectonic activity are providing further details of the history of the development of this striking landscape.

Holocene estuarine infill and vegetation history of Whanganui Inlet, New Zealand: preliminary findings (Poster)

David M Kennedy and Rachel Armour
School of Earth Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand

The coastline of New Zealand is a tectonically active environment related to the collision of the Australian and Pacific plates. Coastal landform evolution is therefore related to tectno-isostacy characterized by uplifted terraces and coarse sediment loads. Only a few areas can be considered stable over the Holocene. The north-western tip of the South Island lies in a fulcrum between the subsiding Marlborough Sounds and the uplifting West Coast and appears to have remained relatively stable over the past few thousand years. Whanganui (Westhaven) Inlet is located in this region and therefore has the potential to provide a unique record of climate and sedimentological change in New Zealand.

Whanganui Inlet is located at the northern end of the South Island 19 km southwest of Farewell Spit. The inlet is a drowned river valley approximately 13 km long and 1 – 2 km wide, with a total area of 2600 hectares. There is presently little vertical accommodation space with broad tidal flats being exposed at low tide throughout the inlet. These flats extend up the streams that drain the hinterland, which is composed of native forest dominated by kahikatea, pukatea, rata, beech, rimu and nikau palm species.

A series of seven vibrocores were taken from the southern half of the inlet. The cores penetrated to a maximum depth of 5 m and are dominated by fine mud with alternating coarse shell and sand layers, most probably related to tidal channel migration across the flats. Preliminary analysis suggests that sediments are predominantly sourced from the local catchment. Radiocarbon dating indicates that little sediment accumulation has occurred during the Holocene with shell material dating at around 7 ka 2 m below the surface. More rapid sediment accumulation has occurred in peat swamps to the south of the inlet where *in situ* organic material was cored to 7 m depth. The base of this core dated at 5700 year BP. Well preserved pollen is found in both the estuary and swamp cores and has the potential to provide a record of coastal vegetation change since the warmer early-mid Holocene. There appears to be a marked change in the local vegetation with a marked reduction in ferns being associated with an increase in beech species.

Geomorphology as tourism: case study of Samoa

Ruth Lawrence

The Independent State of Samoa is located in the South Pacific region immediately east of the International Date Line. It is a country with limited natural resources and the economy is somewhat dependent on tourism. The people largely live in a traditional village manner and have started to engage in village-based tourism enterprises. This paper describes sites of geomorphological interest that tourists visit, assesses the effectiveness of the geomorphological interpretation, and suggests alternative methods of approaching village-based geotourism.

The development of soil crusts on a semiarid bajada

Mel Neave
School of Geosciences, University of Sydney

This study undertakes a preliminary investigation of the influence of rainfall and surface type on the formation of soil crusts. The study was performed on a semiarid bajada in the American southwest. The soils of this bajada are predominantly sandy loams and commonly exhibit well developed surface crusts (compacted soil layers typically about 3 to 5 mm thick). Previous work suggests that these crusts play a major role in the generation of runoff and sediment from the bajada and yet, to date, the mechanics of their formation are still not well understood.

The objectives of this study include making a preliminary assessment of the role of rainfall in the process of crust development, investigating the influence of surface type on crust formation and assessing variations in sediment and water movement from surfaces exhibiting different stages of crust formation. To achieve these objectives, repeated rainfall simulation experiments were performed on paired runoff plots from three surface types on the bajada. The runoff plots were initially disturbed to allow for the progressive development of crusts throughout the study. For each simulation event, one runoff plot was left bare while the other was covered with a fine mesh to limit the direct impact of raindrops on the soil. This paper reports on the findings of comparisons made between the covered and uncovered plots and between the three surface types.

Revised dune and soil history of northern King Island, Bass Strait

Meredith Orr, John Grindrod, Jonathan Brown, Dru Marsh, Matthew Peel and Andrea Delaney
School of Geography and Environmental Science, Monash University, Clayton. Vic 3800

Northern King Island has a variety of sand dunes and sheets that differ in topographic form, sediment composition and particle size, and soil development degree. The history of the aeolian landscape is complementary to palynological work undertaken on the island (eg D'Costa 1993) and together they provide a broader view of environmental change in the region. Yet, unexpected dates determined for the coastal dune sequences require a revision of the aeolian history and the broader framework of environmental change.

Jennings (1959) categorised the northern King Island coastal dunes into two systems known as the "Old Dunes" and "New Dunes". He argued that these systems developed during the Last Interglacial and Holocene high sea level stands respectively, based on differences in weathering degrees and dune relief between the two systems. D'Costa et al. (1993) accepted these tentative ages as a factor in their interpretation of the age of Egg Lagoon sediments on northern King Island, as the Old Dunes were believed to have impeded drainage that led to the lagoon development. An inferred Last Interglacial age for much of the Egg Lagoon sequence led to its inclusion with a number of sites that suggest marked environmental differences between the last and present interglacial stages (Kershaw et al. 2000).

New OSL dates reveal that both dune systems are largely Holocene in age. The results, though unexpected, are consistent with the degree of soil formation in the dunes. Soil profiles are not strongly developed in the west coast Old Dunes and calcium carbonate content, though variable, is still relatively high here in the soil zone.

The development of B horizons is uncommon in the calcareous west coast Old Dunes, and a sample taken from the C horizon below one of these B horizons has a dated age of 10,174 ± 733 years B.P. An Old Dune, with A horizon development only, is dated to 8,703 ± 870 years B.P. A sample from below a groundwater-induced coffee rock horizon, underneath the base of an Old Dune, is dated at 10,774 ± 1002 years B.P. The base of the overlying Old Dune at this site has a dated age of 8,359 ± 746 years B.P.

The inland edge of a west coast New Dune is dated at 2,503 ± 246 years B.P., similar to the age of a reddish-brown and apparently wind blown sediment deposited in the swales of the Old Dunes, dated at 2,416 ± 208 years B.P. Sand sheets inland of the dunes systems produced near-surface ages of 47,932 ± 6128 and 51,036 ± 3837 years B.P, above and below B horizons respectively.

A more detailed Holocene environmental history can be now determined for northern King Island on the basis of these results. Aspects such as vegetation cover, wind regimes and weathering rates are being revised in the context of this new temporal framework.

D'costa D.M., Grindrod J. and Ogden R. 1993. Preliminary environmental reconstructions from late Quaternary pollen and mollusc assemblages at Egg Lagoon, King Island, Bass Strait. *Australian Journal of Ecology* **18**: 351-366.

Jennings J. 1959. The coastal geomorphology of King Island, Bass Strait, in relation to changes in the relative level of land and sea. *Rec. Queen Vict. Mus.* **11**.

Kershaw P., Quilty P.G., David B., Van Huet S. AND McMinn A. 2000. Palaeobiogeography of the Quaternary of Australasia. *Memoir of the Association of Australasian Palaeontologists* **23**: 471-516.

Reference reach database for river geomorphic types in NSW

David Outhet and Carolyn Young
Centre for Natural Resources, NSW Dept. Land and Water Conservation
douthet@dlwc.nsw.gov.au cyoung@dlwc.nsw.gov.au

Management and assessment of rivers in NSW starts with determining their geomorphic types, condition and recovery potential (Brierley et al., 2002). This information then forms the platform for activities such as ecological assessment, rehabilitation design, funding prioritisation, policy development and legislation implementation. The determination of geomorphic condition is also required to help determine the physical 'health' of rivers for audit and management purposes. For example, the natural condition reference reach approach is being used in the Sustainable Rivers Audit being conducted by the Murray Darling Basin Commission (Whittington et al., 2001).

To improve the science of determining geomorphic condition, the DLWC has commenced a project to find and describe natural condition reference reaches for all of the 26 geomorphic types of rivers found in NSW so far.

It is anticipated that the reference reach database will be made available on the DLWC Internet site in a format similar to the existing GIS-linked SPADE database for soils (http://spade.dlwc.nsw.gov.au/jsp/spade.jsp).

The river geomorphic type reference reach database is primarily intended for use by geomorphologists wishing to determine the geomorphic condition of a particular reach of river. One way that this can be done is to compare the condition indicators for the reach in question with the indicators for the nearest natural condition reference reach (Brierley and Fryirs, 2002). These are reaches that have fully adjusted to prevailing catchment boundary conditions.

Many of the reference reach descriptions are being obtained from the published literature. They are also being obtained from internal DLWC reports/archives on the geomorphology of rivers in NSW. Additional fieldwork is being done to fill in gaps and to check the quality of the data.

Although historical data are analysed for the database, it is hoped that future funding will be obtained to monitor the reference reaches to determine their dynamic range over time.

Each river geomorphic type has its own unique suite of relevant condition indicators. For example, there is no bank erosion rate indicator for the bedrock types. Many of the indicators are visual and produce a category (eg geomorphic unit pattern). Others are measured (eg width/depth ratio). The indicators for each geomorphic river type are grouped in the database according to the three degrees of freedom: channel geometry; river planform; and bed material character/organisation.

There are still many gaps in the database, especially for the alluvial river geomorphic types so DLWC would welcome all contributions. If you or your organisation has unpublished geomorphic data on good condition river reaches in NSW and you wish to share it with your colleagues, please contact the authors.

Brierley, G., Fryirs, K., Outhet, D. & Massey, C. 2002. Application of the River Styles framework as a basis for river management in New South Wales, Australia. *Applied Geography* 22, 91-122.

Brierley, G., & Fryirs, K. 2002. *The River Styles® Framework: The Short Course Conceptual Book,* Macquarie University, 147p.

Whittington, J., Coysh, J., Davies, P., Dyer, F., Gawne, B., Lawrence, L., Liston, P., Norris, R., Robinson, W. & Thoms, M. 2001. *Development of a Framework for the Sustainable Rivers Audit*, CRC for Freshwater Ecology, Tech. Rep. 8/2001. CDROM.

The RED scheme, and other colourful regolith-landscape interpretations

Colin Pain, CRC LEME

Geology maps show the distribution of rocks at the surface. Geological map units are grouped by age in a legend, and the criteria for geological units can be used anywhere. Geology maps are not linked to any specific model of Earth evolution

Regolith maps should show the distribution of regolith materials at the surface, with 3D information where available. Regolith map units should be grouped according to a "factual" classification. However, unlike geology maps, age is not suitable for grouping regolith units. As with geology map units, the criteria for regolith map units should be applicable anywhere. Moreover, regolith maps should not be linked to any specific model of landscape evolution

There are three main contenders for regolith mapping schemes:
The RED scheme (CSIRO)
Named regolith-landform units (BMR)
Regolith-landform "fact maps" (AGSO/GA)

The RED scheme maps Relict, Erosional and Depositional regimes (Anand and Smith 1993). *Residual regimes* are areas characterised by widespread preservation of lateritic weathering profiles. *Erosional regimes* consist of terrain within which varying degrees of erosion of the lateritic weathering profile has occurred, exposing lower zones in the weathering profile. *Depositional regimes* are areas of terrestrial deposits that commonly conceal extensive areas of complete or nearly complete lateritic weathering profiles. The RED scheme assumes that an extensive and complete lateritic weathering profile formerly covered the whole landscape. The RED scheme is therefore applicable only to areas with lateritic weathering profiles and associated landscapes. It is not applicable to much of Australia, or to most of the rest of the world. Variations on the RED scheme have been used in Western Australia, South Australia and Queensland, at scales from 1:10,000 to 1:250,000.

A mapping scheme using named regolith-landform units was introduced in the Bureau of Mineral Resources (now Geoscience Australia) in the early 1980s, and is based on Cliff Ollier's experience with land system mapping. A regolith-landform unit consists of one or, more usually, several recurring landscape elements and their associated underlying regolith packages that together form a distinct regolith landform entity. Geoscience Australia produced maps at 1:500,000 scale, and regolith-landform maps using this scheme have been published by the Victorian Geological Survey at 1:100,000.

Regolith-landform "fact maps" show units based on regolith types such as residual sand, saprolite, alluvium and colluvium. Landforms are used to compile mapping units because there is generally a close relationship between regolith materials and landforms in local to regional areas. Maps of this kind have been produced at scales from 1:25,000 to 1:250,000. The regolith and landform characteristics of each mapping unit are recorded and then stored in RTMAP, the national regolith database maintained by Geoscience Australia. The classification of regolith used in RTMAP is largely genetic at higher levels, and based on regolith characteristics at lower levels. Mapping units can be grouped on the basis of regional associations of regolith types – these regolith-landform associations are similar to the mapping units used in the named regolith-landform units initially used in early BMR maps. This "fact-map" system has been adopted by the Victorian Geological Survey, and also by CRCLEME.

Geological maps have named formations and groups, among other formal designations. In pedology soils are classed by profile form, and soil map units are named soil series, with an implied common origin, but no implied age. There is no equivalent in regolith, and it is uncertain yet whether such a system can be used in regolith mapping. Some weathering profiles have been given formal names in Australia, but there are problems with their assumed correlation and age relationships. At present it seems better to stay with "fact-maps", until more information has been gathered. We have to remember that regolith mapping began about 20 years ago, and only a small part of Australia, let alone other parts of the world, has been mapped.

Post-European landscape change in semi-arid New South Wales: a review of evidence from process monitoring, absolute dating and artefacts

John Pickard [1,2], Patricia Fanning [1], Damian Gore [3], Paula Crighton [3] and Don Adamson [4]

1 Graduate School of the Environment, Macquarie University NSW 2109
2 Present address: PO Box 793, Dubbo NSW 2830 (john.pickard@bigpond.com)
3 Department of Physical Geography, Macquarie University NSW 2109
4 School of Biological Sciences, Macquarie University NSW 2109

Considerable landscape change followed settlement of European pastoralists in semi-arid and arid rangelands of NSW, Australia in the mid to late 19th century. The cause was the change from indigenous hunter-gathering to sheep and cattle grazing. In this paper we review evidence from widely spaced sites and over varied time-scales. Age control is provided by radiocarbon dating of charcoal from Aboriginal heat retainer hearths, OSL dating of sediments, burial of fences and other European artefacts, and direct measurement over days, years and decades.

Stratigraphic analysis of upland valley fills shows that sediments derived from erosion of topsoils on the slopes were initially deposited across valley floors forming a distinctive unit termed post-European material (PEM). This was followed by a shift from relatively shallow, single or multi-thread channels to the wide, flat-bottomed valley floor gullies characteristic of the region today. Downstream, the systems are characterised by rapid sedimentation, channel avulsion and floodout formation.

Monitoring of erosion and sedimentation at *Fowlers Gap* in the Barrier Ranges (31^0 04'S 141^0 41'E) over the last 20 y indicates that erosion rates outside stream channels may exceed 200 t ha^{-1} y^{-1}, and that channel enlargement and knickpoint retreat through the upland stream systems are continuing to destabilise valley floors. Buried fences record sedimentation over the period 1907 to 1995 in Faulkanhagan Creek on *Polpah Station* (30^0 50'S 143^0 12'E). Mean overall rates are approximately 0.01 m y^{-1}, but more likely much higher following intense rainfall. Buried fences and abandoned dams indicate that the channels of ephemeral creeks here have migrated laterally at rates of 1-2 m y^{-1} since 1883, and are associated with channel down-cutting of 0.06 m y^{-1} over the same period. Such lateral migration may be the result of the propensity of these streams for avulsion whenever channels are impeded by obstructions as minor as a few tree branches. Rates of down-cutting and knickpoint retreat observed during a single intense storm at *Mutawintji* in December 1992 exceeded 1 m day^{-1} and 3 m h^{-1} . By comparison Wasson & Galloway found post-European sediment yields at Umberumberka (31^0 49'S 141^0 12'E) to be 50-90 times higher than Holocene rates, but that there was considerable decadal variation in the post-European rates.

The range of rates presents challenges to integrating localised data into a more coherent regional picture. Mean long-term rates conflate brief periods of intense activity with far longer periods of little change. A major difficulty is the lack of reliable and comparable information on paddock-scale stocking rates of domestic animals, and rainfall during locally intense storms. However, the end result of the erosion is a redistribution of soil from the more susceptible parts of the landscape to sediment sinks.

We dedicate this paper to the memory of Don Adamson who died on 5 May 2002. Don was the consummate geomorphologist and interpreter of landscapes in a wide range of environments in Australia, Antarctica and Africa. He was a supportive friend with a generous spirit, a challenging mentor and colleague, and a wonderful field companion. His legacy lives with us in our research and our daily lives.

The dynamics of soils in North Queensland: Rates of mixing by termites determined by single grain luminescence dating

Brad Pillans, Nigel Spooner & John Chappell
Research School of Earth Sciences, ANU, Canberra

Charles Darwin drew attention to the role of earthworms in the formation of the upper, organic-rich horizons of soils. He concluded (Darwin (1837) that progressive slow burial of objects, originally at the surface, could be explained by "the large quantity of fine earth continually brought up to the surface by worms in the form of castings". Darwin (1881) calculated rates of surface accumulation by weighing worm casts that accumulated in small areas (typically about 1 m^2) over a year, and also by measuring the burial depth of objects, originally at the surface, over periods of up to 30 years. Calculated rates of surface accumulation were 2 to 5 mm/year.

Since that time, the role of soil biota in soil mixing has become well established, particularly the role of termites (e.g. Lee & Wood 1971). Mixing, or turnover of soils by biota (usually referred to as bioturbation) plays a key role in nutrient cycling. Coventry *et al.* (1988) estimated that rates of surface soil accumulation, averaged over the building and erosion of one generation of termite mounds in the Charters Towers area of north Queensland, were in the range of 0.018 to 0.025 mm/year. Somewhat higher rates (0.05 to 0.4 mm/year) were reported by Lee & Wood (1971) and Williams (1968), from sites in the Northern Territory. In this study we use Optically Stimulated Luminescence (OSL) dating of individual quartz grains to determine long-term rates of soil mixing, principally by termites, near Hughenden in north Queensland.

Two broad groups of soils, developed on Quaternary and Late Tertiary basaltic lava flows, were studied: Black soils (Vertisols), dominated by smectite clays, which occur in areas of impeded drainage and show evidence of shrink-swell activity, and red soils (Lithic and Oxic Ustropepts), dominated by kaolinite clays, that are typical of well drained sites, and are extensively colonised by mound-building termites. Paleomagnetic data show that lower parts of the red soil profiles have reversed polarity; indicating that termite activity is depth-limited (about 60 to 80 cm). In contrast, the black soils have normal polarity throughout, with shrink-swell mixing extending to the base of the profile. The soils contain allochthonous quartz grains derived from adjacent Mesozoic sedimentary rocks. In four red soil profiles and one black soil profile, mean luminescence ages of quartz grains increase with depth (up to 44.7 ka in the red soils and 11.3 ka in the black soil at 80 cm depth); standard deviation of mean age also increases with depth.

In the simplest (Darwinian) model of bioturbation, soil particles are brought to the surface by termites to construct mounds, which are subsequently eroded and the material spread evenly across the surface. Exposure at the surface resets the luminescence signal in individual grains, which then undergo slow, progressive burial, by later mound-derived material. The results of a Monte Carlo simulation model of bioturbation will be discussed in the light of our OSL data.

Coventry, R.J., Holt, J.A. & Sinclair, D.F. 1988. Nutrient cycling by mound-building termites in low-fertility soils of semi-arid tropical Australia. *Australian Journal of Soil Research*, **26**, 375-390.

Darwin, C. 1837. On the formation of mould. *Transactions of the Geological Society of London*, **5**, 505.

Darwin, C. 1881. *The Formation of Vegetable Mould through the Action of Worms*. J. Murray, London.

Lee, K.E. & Wood, T.G. 1971. Physical and chemical effects on soils of some Australian termites, and their pedological significance. *Pedobiologia*, **11**, 376-409.

Williams, M.A.J. 1968. Termites and soil development near Brocks Creek, Northern Territory. *Australian Journal of Science*, **31**, 153-154.

The mechanism and history of channel avulsion in a floodplain wetland, Macquarie Marshes, NSW

Tim Ralph and Paul Hesse
Department of Physical Geography, Macquarie University, N.S.W. 2109, Australia.
Email: tralph@laurel.ocs.mq.edu.au, phesse@laurel.ocs.mq.edu.au

The Macquarie River is one of several large inland rivers of south-eastern Australia which experience channel breakdown and distributary development on their lower reaches, forming extensive floodplain wetlands and at times losing all channel definition as flows enter swamps or marshes. Channel breakdown and marsh formation is characteristic of the Holocene drainage systems of lowland interior-flowing Australian rivers that have lower discharges and are mainly dominated by suspended sediment loads. These marsh areas appear to be very dynamic and undergo both frequent growth and abandonment, principally through a process known as avulsion (the sudden abandonment and formation of new channels). These morpho-dynamics continue to have profound effects on the marsh ecosystems and are currently a cause of concern for habitat management and conservation. In order to understand the mechanism and history of avulsion in an inland fluvial wetland system, ^{210}Pb and AMS ^{14}C dating were used in conjunction with sedimentological analysis to document the rate and distribution of sedimentation adjacent to Buckiinguy Break, a distributary marsh feeder channel in the southern Macquarie Marshes. The rates of sedimentation determined from the ^{210}Pb analysis of six sediment cores show significant trends in the spatial distribution of recent sedimentation in the Buckiinguy marsh system. Recent sedimentation was greatest near the channel margin and decreased with distance across the floodplain, leading to the formation of contemporary levees on the channel margin. Results show that avulsion in this system is related to extensive in-channel and overbank deposition resulting in the formation of an alluvial ridge, which elevates the channel above the surrounding floodbasin. A gradient advantage is thereby created between the channel and floodplain, providing favourable conditions for avulsion and subsequent channel abandonment if flows are preferentially diverted to the lower surrounding floodplain. Differences between the contemporary and long-term sedimentation rates and historical evidence indicates a recent change in sedimentation regime, which is related to avulsion of Buckiinguy Break 70 to 90 years ago, rather than to catchment-scale post-European influences. In-channel and floodplain vegetation promotes sediment deposition out of suspension and therefore also plays a critical role in the avulsion processes observed.

Three dimensional morphologic characteristics of pool-riffle sequences

Scott C. Rayburg
Department of Geography, University of Buffalo, Buffalo, NY 14222, USA

Pool-riffle structures have been extensively researched with studies focusing on formation and maintenance, sedimentology and transport, structural and hydrologic characteristics and scale relationships. However, several key aspects of pool-riffle form and function have been neglected. Firstly, pools and riffles are three dimensional bedforms which experience three dimensional flow and transport, yet most treatments deal with these bedforms in only one or two dimensions. Secondly, the evolution of pool-riffle morphology following channelization has been largely ignored. Finally, a comprehensive attempt to relate pool-riffle form to reach and planform scales is lacking. These shortcomings in the literature inhibit our ability to make generalizations that could aid restoration and channelization efforts where accurate predictions of stable bedforms are essential. This study will begin to address these issues using survey and sediment data collected from two vastly different rivers in central and eastern USA.

The objectives of this study are: 1) to examine the three-dimensionality of pool-riffle form. Specifically, the evolution of bed structure through time is investigated in the Embarras River, Illinois, USA. This river is a low gradient, mixed sand and gravel bed agricultural stream that is particularly well suited to this task because closely spaced individual channel reaches have experienced diverse channelization histories; 2) to compare morphologic characteristics from the Embarras River to those found in the gravel and cobble bedded Cattaraugas Creek, New York, USA. This portion of the study seeks to define common structural elements found in pools and riffles from significantly different rivers. Common morphologic features found in both rivers may illuminate the controls on pool-riffle form; 3) to relate pool-riffle form characteristics to reach and planform variables in an effort to provide detailed scale relationships between bedforms and the larger channel.

Geomorphological studies on the development of karst, northwest Nelson, New Zealand

Danette T W Richards
Geological Sciences, University of Canterbury, Christchurch, New Zealand (d.richards@geol.canterbury.ac.nz)

The study area is situated between the Takaka and Riwaka Valleys near Nelson in the north of the South Island, New Zealand. The initial objectives of the research, which are reported here, are to develop a geomorphic inventory of landforms in the Ordovician Arthur Marble and Oligocene Takaka Limestone and to determine the geomorphological evolution of the karst terrain. The research comprises part of a broader research project (in progress) assessing environmental impacts on the karst as a result of increasing development and human activities.

Detailed geomorphological mapping at 1:7500 scale together with morphological classification has identified 8 major geomorphological zones. Characteristics such as observed doline and karren type, soil cover and hydrology, and measured fracture frequency were used to define the landform assemblage zones. Analysis of lithological properties such as porosity and compositional purity will be used to further define the geomorphology in each area. The zones are grouped here on the basis of the sedimentary cover and are termed covered or bare karst.

The two bare karst zones are characterised by autogenic drainage, solutional and collapse dolines, rillenkarren/rinnenkarren, and well developed calcareous topsoil profiles where soil is present. These features are interpreted to have developed in the absence of significant long-term allogenic drainage and as a result of the lack of surficial cover. The Takaka Walkway Zone, is located immediately adjacent to a large fault, and has limited solutional doline development due to the high fracture frequency and associated secondary permeability. The brecciated nature of the karst in the Takaka Walkway Zone appears to favour the development of collapse dolines (locally known as tomos). In the Plateau Zone, the secondary permeability is controlled by solutional development on masters joint sets, and as a consequence has well formed solutional dolines and numerous uvalas.

The covered karst zones are typified by the presence of allogenic drainage, paleo-drainage features such as dry and blind valleys, karren indicative of covered development and non-calcareous soils. The East Takaka Zone occurs on a fault escarpment with ~1km vertical displacement and has well formed v-shaped karst canyons, marble scree slopes and limited doline development. These features occur as a result of the allogenic drainage arising from the nearby non-karst terrain and rapid uplift along the fault escarpment. The Kairuru Karst Zone displays evidence of the inheritance of paleo-allogenic drainage, and also has limited doline development. The Canaan North, Canaan South and Smith-Walker Karst zones have numerous dry or blind valleys and are characterised by the predominance of alluvial dolines relative to other doline types. The Smith-Walker Karst Zone has extensive sedimentary cover and relatively little outcrop. The Takaka Limestone Zone has yet to be assessed.

The present karst landforms are predominantly a reflection of the karstification occurring post-uplift on the fault escarpment. Studies to date indicate movement on the fault is constrained to the late Miocene but further work is required to confirm younger deformation. The information collated from assessing the geomorphology and geomorphological evolution of the zones will be used to help distinguish human induced impact from natural environmental change and to identify those karst features or zones that are most vulnerable to impacts from land use, water management and discharge practices.

Channel stability in a sand-bed stream in the seasonally wet tropics

M.J. Saynor[1 & 3], W.D. Erskine[2], K.G. Evans[1], D. Moliere[1] & I. Eliot[3]

1 Environmental Resarch Institute of the Supervising Scientist, Locked Bag 2 Jabiru, NT, 0886
2 Office of the Supervising Scientist, Darwin, NT, 0801
3 Department of Geography University of Western Australia, Nedlands, WA, 6907

Swift Creek (Ngarradj) is a sand bed stream in Kakadu National Park, Northern Territory. The stream, located in the seasonally wet tropics, flows for approximately half of the year during and immediately after the wet season. In 1998, 51 permanently marked cross sections were installed to monitor the amount of bed sediment storage and/or large scale erosion at three gauging stations. These cross sections have been surveyed annually during each dry season since installation. These survey data provide information about the changes in sediment storage that have occurred between each dry season. Between 1998 and 1999, aggradation of between 0.1 and 0.2 m occurred at each of the three sites but between 1999 and 2000, this sand level remained constant.

The gauging stations were visited weekly during the wet season when the creeks are flowing to obtain hydrological and sediment load (suspended sediment and bedload) information. A velocity-area gauging is completed at station to construct a discharge rating curve. The gauging cross sectional information is used to investigate the within wet season changes. Scour and fill of up to 0.6 m and a shifting thalweg have been identified. Maximum scour is limited by the exposure of a root mat material or a more resistant bed material layer at the sites.

A total of 36 metal scour chains were installed in the Swift Creek catchment to measure scour and fill during the 1998/1999, 1999/2000 and 2000/2001 Wet seasons. Mean scour ranging from a minimum of 50 $\pm$ 34 mm on Tributary North during the 1999/2000 Wet season to a maximum of 332 $\pm$ 93 mm at the Swift Creek gauge during the 2000/2001 Wet season were recorded. Mean fill ranging from a minimum of 56 $\pm$ 18 mm on Tributary North during the 2000/2001 Wet season to a maximum of 391 $\pm$ 43 mm at Swift Creek during the 1998/1999 Wet season were also recorded.

Three years of erosion pin measurements in the Swift Creek catchment established that substantial bank erosion occurred during the Wet season on the western tributaries by rapid lateral migration (up to 100 ± 24 mm/yr) and by erosion of gully sidewalls (up to 27 ± 18 mm/yr) by a combination of within-gully flows and overland flow plunging over the sidewalls. Bank erosion also occurred during the Dry season (up to 26 ± 14 mm/yr) by desiccation and loss of cohesion of the sandy sediments, by faunal activity and by dry flow processes. Channels with dense riparian vegetation do not generate significant amounts of sediment by bank erosion (average of 4 ± 4 mm/yr). As found elsewhere by others, deposition (up to - 28 ± 14 mm/yr) was also locally significant, despite the sandy bank sediments.

In general, the between wet season changes are considerably smaller than the within wet season changes. Although there are large amounts of sand movement during the wet season, channel cross sections return to pre-wet season profiles during recessional flow. This indicates that the stream channel cross sections usually reach equilibrium on the flow recession.

Soil-landscape modeling in New Zealand: from qualitative, knowledge-based approaches to quantitative models

Jochen Schmidt
Landcare Research, Lincoln, New Zealand (schmidtj@landcareresearch.co.nz)

The development and application of soil-landscape models has a long history in New Zealand. The relationships of soil attributes and soil types to other environmental factors, e.g. terrain position, vegetation type, and climate, have been heavily used in soil surveying and land resource mapping at various scales. Most of these approaches have been conceptual and descriptive. Therefore, they are not directly applicable for quantitative soil-landscape modelling using GIS. This study presents an approach to quantitative soil-landscape modelling on different scales based on existing qualitative models. The objectives are to (1) rationalise existing soil-landscape models in order to allow their application within a GIS framework, and (2) to derive explanatory environmental parameters and rules for soil-landscape modelling at different scales. The land systems approach was used as a general conceptual framework for this study.

Land system modelling

For the South Island, the New Zealand soil map and the New Zealand Land Resource Inventory (NZLRI) model spatial patterns of soil sets and soil associations at the land systems scale, based on the terrain type and spatial variations of environmental drivers, including precipitation, bedrock, and land cover. The mapped soil units are therefore strongly related to patterns of land systems. To assess the 'hidden' rationale behind these maps, statistical procedures were applied to model the explanatory value of several environmental variables in relation to the mapped land systems. Tree models lead to (1) rule sets for the occurrence of land systems, and (2) probability maps of land systems in relation to environmental drivers.

Land element modelling

Many studies have been carried out at the land component scale to derive spatial patterns of soil series within specific land systems. Landscape components and land elements have been used as the dominant predictor variables for soil units at this scale. A new morphometric model for determination of land elements is presented and applied to a variety of land systems. The results show that land element and component characterisation based on local landform is possible for a variety of hill and steepland land systems.

Conclusions

The study shows that the land systems approach provides a valuable framework for soil-landscape modelling at different scales. An attempt at rationalising and quantifying the concepts behind land systems for New Zealand on different scales was presented. Land systems are strongly related to the geomorphology of a landscape and are therefore applicable to other spatial problems, which are related to form, material, and geomorphologic history of landscape units (e.g. parent material, loess distribution). Therefore, this approach can lead to better tools for quick land resource mapping using spatial information technologies.

Modelling climatic variability and its effects on slope stability: a case study from Bonn, Germany

Jochen Schmidt* & Richard Dikau
Department of Geography, University of Bonn, Germany

* now at: Landcare Research, Lincoln, New Zealand (schmidtj@landcareresearch.co.nz)

One important issue in recent climate impact research is the assessment of effects of climatic variability and climate change on geomorphic processes and hazards, such as landslides. Hillslopes in central Germany are heavily affected by landslides. Field experiments and archive analysis for the area around Bonn showed that precipitation-induced groundwater rises are a major contribution to slope instabilities and a dominant cause for failures in that region. However, little is known about the history of landslides and about the impact of climate change on landslide processes. This study presents a scenario model for historical variations in climate and slope stability for the Bonn area. It is the objective to assess the stability of hillslopes around Bonn in relation to different landforms and lithologies, and changing climate. Therefore, a new approach was developed, by coupling proxy-derived climate scenarios with a model for groundwater-controlled slope stability.

Method

A model for climate variability for the study area was developed on the basis of seasonal temperature and rainfall proxy data. The statistical procedure modelled past climate scenarios by typical annual cycles for the study area. A process-based, spatio-temporal model for groundwater variations and slope stability was developed using the GIS environment of the software PCRaster (Utrecht, The Netherlands). The model was applied to assess the effects of the different climate scenarios on slope stability for three different hillslopes in the Bonn area.

Results

The findings indicate that past climate is highly variable, but also shows distinct trends. Three climatic phases with different annual characteristics of temperature and precipitation were derived based on proxy data and weather records. The groundwater / slope stability modelling results show that a climatic scenario representing instable climatic conditions of a transition from more humid little Ice Age conditions to dryer recent conditions produces the highest instabilities for all spatial scenarios. The intensity of this impact, however, varies with the sensitivity of the specific geomorphic system, i.e. the specific landform and lithology, and is not related to the stability of a specific hillslope.

Conclusions

The study showed that proxy data can be used to generate historical climate scenarios for a specific region and to assess changing patterns in geomorphic activity, in this case slope stability, using mechanistic models. A more unstable area is not necessarily more sensitive to climatic changes: the location of permeable layers (prone to groundwater rise) in relation to sensitive layers (lower strength) and higher-gradient areas (higher stress) influences the sensitivity of a site with respect to climate changes. The applied method is capable of modelling landscape sensitivity to climate change with respect to groundwater controlled landslides.

Geomorphic evidence for a piedmont glaciation in NW Nelson, New Zealand, at the last glacial maximum

James Shulmeister[1], Glenn Thackray[2], David Fink[3] and Paul C. Augustinus[4]

[1] Department of Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch, New Zealand

[2] Department of Geosciences, Idaho State University, Pocatello, ID 83209-8072, USA

[3] AMS-ANTARES, ANSTO, Private Bag 1, Menai 2234, Sydney, Australia

[4] Departments of Geography and Geology, University of Auckland, Private Bag 92019, Auckland, New Zealand

We present evidence for greatly expanded glaciation at the last glacial maximum (LGM) in the Cobb-Takaka valley system, NW Nelson, New Zealand. Shulmeister et al. (2001) outlined the then existing evidence for glaciation in the Cobb Valley. They identified a LGM advance which, they argued, terminated at the head of the Cobb Reservoir, 19 km upstream of the main Takaka Valley. Nested over 100 m above and several kilometres downstream of these deposits, were a series of high level glacial features, including basal tills, provisionally attributed to a Late Pliocene to mid-Quaternary advance. A new series of twenty one matched ^{10}Be and ^{26}Al ages from the Cobb System, dismantled the model of two widely separated glaciations, as all samples collected within and beyond the putative LGM limits yielded LGM to deglaciation ages. These results clearly implied much more extensive ice in the Cobb and adjacent Takaka river systems at the LGM.

Glacial mapping has consequently been extended onto the main Takaka valley floor, well beyond the recognised limits of Late Quaternary glaciation. Geomorphic evidence for glaciation includes a variety of glacial deposits and landforms, with weathering and degradation characteristics consistent with a LGM age. The findings may be summarised as follows;

1. Outcrops of till are plastered onto bedrock obstructions and terraces edges on the western side of the main Takaka valley, 20 km downstream of the Cobb Reservoir.

2. End moraines and kame terraces associated with ice debouching from the Cobb-Takaka valley are recognised on the western side of the Takaka valley as far north as Uruwhenua (c. 25 km beyond the Cobb Reservoir).

3. Ice also advanced down the Anatoki river system constructing moraines at the confluence with the lower Takaka Valley. The ice breached a low divide with the Waingaro River at Go Ahead Creek, where a small lateral moraine and putative kame terrace complex is preserved.

In order to accommodate this ice in the Cobb-Takaka and Anatoki systems we map a piedmont ice cap over the whole of the NW Nelson ranges at the LGM. This piedmont cap was the second largest ice cap in New Zealand at the LGM. Its recognition increases the known area of glaciation by about 7%.

Shulmeister, J., McKay, R. Singer, C. & McLea, W. (2001) Glacial geology of the Cobb Valley, north-west Nelson. *New Zealand Journal of Geology and Geophysics.* **44**,55-62.

Wave processes on a shore platform, Kaikoura, South Island, New Zealand.

Anna Taylor
Department of Geography, University of Canterbury, Private Bag 4800, Christchurch, New Zealand.
(taylora@geog.canterbury.ac.nz)

This paper presents a description of the flow regime of waves as they move onto and across a shore platform on the Kaikoura Peninsula, New Zealand. It has been asserted in the literature that waves are of fundamental importance in the formation of shore platforms. For example Sunamura (1992) presented a model that showed platform development occurred when the assailing force of the waves (F_w) was greater than the resisting force of the rocks (F_r). It is therefore important that the flow regime on the platform, which is the expression of the wave assailing force, is documented and understood. To date no such detailed analysis has been presented.

Simultaneous measurement of deepwater wave conditions and water velocity at three locations across an intertidal shore platform were made. Deepwater wave measurements were conducted in conjunction with National Institute of Water and Atmosphere (NIWA) and the Zoology Department, University of Canterbury, using a non-directional deepwater wave buoy. Onshore flows were measured in 18 minute bursts every hour, on the hour, while tidal waters covered the platform, using two electromagnetic current metres and one acoustic Doppler velocity metre.

A comparison of deepwater and onshore wave height, flow velocity, energy and energy flux is presented. As waves moved from deepwater onto the shore platform wave height decreased by more than 68% and wave energy and energy flux reduced more than 90% in a non-linear manner. All but the smallest waves had broken before they reached the platform and waves flowed over the platform as turbulent bores. There was significant lateral flow along the platform and velocities consistently varied across the platform. Relatively uniform flows of greater average magnitude occurred near the centre of the platform compared with flows measured closer to either the seaward or landward cliffs. Maximum flows of 2.54 $m.s^{-1}$ and average flows of between 0.22 – 0.72 $m.s^{-1}$ were recorded.

These findings mean that use of deepwater wave energy as an indicator of onshore wave assailing force should be used with caution.

Interpreting anomalous drainage and geomorphology of the Navua River, Fiji

James P. Terry[1], Clifford D. Ollier[2], and Colin F. Pain[3]

[1]Department of Geography, University of the South Pacific, PO Box 1168, Suva, Fiji.
[2]Geography Department, University of Western Australia, Nedlands, WA, Australia.
[3] CRC LEME, c/o Geoscience Australia, GPO Box 378, Canberra, ACT 2601 Australia

The Navua river on the main island of Fiji has anomalous features of drainage and fluvial geomorphology. The river course has a right-angled bend, beyond which it flows through a narrow gorge cut into hard volcanic rocks. Several tributaries enter the gorge as high cascades from hanging valleys. It is proposed that the former course of the palaeo-Navua river flowed in a straight line along the modern Waidina river, and eventually discharged into Fiji's largest Rewa river system. Evidence for this is another gorge without an occupying river (a wind gap) at the head of the Waidina river. Previous ideas of river capture fail to explain the evolution of the local fluvial geomorphology. Instead, tectonic uplift probably dammed the palaeo-Navua and diverted it to its present short course to the sea. This new hypothesis provides a more plausible, simultaneous account for all the major features of fluvial geomorphology, their geographical distribution and their relationship with geology in the Navua region.

(key words: river diversion, gorges, Fiji Islands)

Morphotectonic evolution of the western portion of the Mt Lofty Ranges

Victor Tokarev and Vic Gostin
Adelaide University, Adelaide, SA 5005

The present landscape is a result of long-term interactions between tectonics, changes of sea-level, climate and vegetation, weathering and erosion. Three principal tectonic stages are proposed in the formation of the Mount Lofty Ranges and its flanking basins.

Middle Eocene-Miocene extensional stage: During this initial extensional stage, a high-standing pre-Middle Eocene palaeoplain (~200m above present sea level) was segmented by subsidence of the St. Vincent and western Murray Basins. South-westward down-tilting of the palaeoplain formed the asymmetric shape of the Mount Lofty Ranges. Crustal segmentation resulted in the formation of several local depocentres and embayments bounded by synsedimentary normal faults. The major river network was directed south-westward to the St. Vincent and eastward to Murray Basins and was thus superimposed onto the basement structure and lithology. Absence of fluvial sediments in the Middle and Late Tertiary indicates a minimal sedimentary supply from the source area and therefore a low and subdued landscape in the Mount Lofty Ranges.

Middle Miocene to Early Pleistocene transitional tectonic stage: During this time, the preceding extensional style of tectonic movements changed to a Quaternary compressional regime. This involved transformation of normal fault movements into reverse motions and significant reduction of the sedimentary accommodation space in the flanking basins. This transformation was slow and involved southward tilting of 3-5^{o} that locally deformed the early Tertiary sedimentary package. Tectonic quiescence resulted in a mature and subdued state of the pre-Pleistocene landscape. Deep weathered planation surfaces and wide shallow valleys of such a landscape are still evident and recognised around the major watershed. Late Pliocene marine inundation of the St. Vincent Basin left widespread thin, fine-grained calcareous sediments is additional evidence of relative tectonic quiescence and restricted sedimentary supply. This process of transformation took approximately 10-12Ma and generally ceased in the Pleistocene.

Pleistocene to modern compressional tectonic stage: Prominent fault scarps of the Para, Eden-Burnside, Clarendon and Willunga Faults were created as a result of relatively rapid compressive uplift of the western portion of the Mount Lofty Ranges. Youthful and well-dissected western slopes and dramatic changes to stream profiles with gorges, waterfalls and knick-points are direct geomorphological evidence of Pleistocene uplift. The sedimentary succession of the terrigenous Hindmarsh Clay preserves evidence of Early and Middle Pleistocene morphotectonics. This formation is generally only 10s of meters thick but increases locally to over 100m. It is widespread in the eastern part of the St. Vincent Basin including the currently uplifted Para Block. It was deposited as several alluvial fans leading down to wide plains and swamps. Despite general climatic aridisation, streams deeply eroded the western slopes of the Ranges delivering a significant amount of gravel, sand, silt and clay in a short time-interval. Both the sediments and geomorphology responded to the Pleistocene uplift. This included the Para Block in the Adelaide area that affected the River Torrens drainage and its sedimentary discharge.

In the history of the Mt Lofty Ranges, the early Tertiary extensional stage saw the segmentation of the pre-Middle Eocene palaeoplain, and development of the superimposed drainage system on a gently tilted surface. During the middle Tertiary transition, the tectonic regime changed to compression that resulted in Pleistocene uplift of the western portion of the Mount Lofty Ranges that continues today.

The origin and evolution of the Nullarbor karst

John Webb
Department of Earth Sciences, La Trobe University, Victoria 3086 (john.webb@latrobe.edu.au)

The Nullarbor Plain, with an area of ~200,000 km^2, is one of the largest outcrops of limestone in the world. It is astoundingly flat, mostly treeless, with at present a semi-arid to very arid climate. More than 150 collapse dolines and 100 significant caves are present in the flat-lying Middle Eocene-Middle Miocene limestone, mostly within 60 km of the coast; given the vast size of the Nullarbor, there are relatively few of these features. The caves have suffered extensive collapse, because the limestone is poorly cemented and structurally weak, and the arid climate promotes salt weathering. However, some of the deeper caves contain original phreatic passages. For example, Old Homestead Cave has about 30 km of horizontal phreatic passages lying up to 70 m below the plain, and Cocklebiddy Cave consists largely of a water-filled subcircular phreatic tube, up to 40 m across and 30 m high.

Decoration in the caves is largely composed of gypsum and halite, reflecting the current arid climate. The shallower caves also contain abundant dark brown to black calcite speleothems, >400,000 years old, and currently being broken down by salt crystallisation. The black colour is due to organic compounds, and may indicate the presence of swamps on the plain during calcite deposition, perhaps during a relatively wet climatic phase between 3 and 5 million years ago.

There is some cave formation on the Nullarbor occurring at present, as periodic collapses and minor dissolution due to mixing corrosion. However, the main phase of cave formation probably started after the last retreat of the sea and uplift of the Nullarbor Plain around 14 million years ago. Since then, for most of the time the climate was warm with a strongly seasonal rainfall (similar to that in northern Australia today); the present level of dryness was reached only about 1 million years ago. Given the long time period and relatively humid climate, why are there so few caves and dolines?

It is postulated here that flat plains of porous limestone cannot readily develop extensive underground karst features, no matter what the climate. Although groundwater flow is concentrated along a few joints which become caves, there is still substantial flow through the porous limestone itself. Caves on the Nullarbor developed predominantly where old river courses sank into the porous limestone. For example, Old Homestead Cave lies south of an old river channel which represents the southerly extension of a palaeochannel cut into the basement to the north. The larger caves closer to the coast may represent trunk systems that had several tributaries of the size of Old Homestead Cave.

The occurrence of most caves and dolines within 60 km of the coast probably reflects the influence of salt spray, blown a more or less uniform distance inland. Salt crystallisation opens entrances into caves in the coastal region through collapse. There may be many caves further from the coast, but they lack entrances.

Soil production in heath and forest, Blue Mountains, NSW

Marshall Wilkinson[1], Geoff Humphreys[1], Bart Smith[2] & John Chappell[3]

1. Department of Physical Geography, Division of Environmental and Life Sciences, Macquarie University, NSW 2109.
2. Luminescence Laboratory, Earth Sciences, Melbourne University, VIC 3010.
3. Research School of Earth Sciences, Australian National University, ACT 0200.

Heath distribution on spur noses in the western Blue Mountains, NSW, appears to be related to geomorphic processes rather than microclimatically controlled exposure (Wilkinson and Humphreys, in review). While nutrient levels in 'nose heath' and adjacent forest on proximal spur ends are not significantly different, soil mantles are significantly thinner in heath than forest (28 and 66 cm respectively, p= 0.000). The vegetation and soil depth transition are both sharp and nose heath is composed of alternating bands of closed heath and rock outcrop. One of these patterns may be an artefact of the soil production function operating. If a humped function applies, similar to that proposed by Gilbert (1877), maximum production occurs at a non-zero soil depth, d_m. This implies that mantles thinner than d_m are unstable and tend toward d_m or zero which may either explain the transition from forest to heath or the bands of heath. However an inverse exponential function (Heimsath et al., 1999) may operate at our study site at Marrangaroo Creek. We evaluate two humped models and one inverse exponential model in light of vegetation and soil depth patterns, OSL ages from pits in heath and forest, and imminent cosmogenic ^{26}Al and ^{10}Be data from our site.

A humped function with d_m= 66 cm may explain the sharp vegetation boundary. However OSL results suggest bioturbation, and hence biogenic soil production is minimised at this depth. Furthermore spur morphology is inconsistent with bedrock lowering implications of this model. A humped function with d_m=28 cm may explains the alternating bands of rock and heath on spur noses and is consistent with spur morphology. However, an inverse exponential function is also consistent with morphology though the alternating bands of heath and rock remain unaccounted for. The transition from deeply mantled proximal spur to shallow-soiled nose heath may be due to incremental movement of the mantle by rainwash processes (Paton et al., 1995), influenced by spur curvature. Heath bands on noses may not be static thereby explaining lack of relief between bands of heath and rock and inferred differential lowering rate.

While both humped and inverse exponential functions have been demonstrated elsewhere (e.g. Heimsath et al., 1999; Small et al., 1999), the incorporation of exposure data from small inselbergs (tors) is inconsistent and represents a conceptual dilemma. Furthermore, Marrangaroo Creek exhibits small inselbergs (pagodas) and rock outcrops with little relief (rock bands), suggesting outcrops may be weathering at significantly different rates, and that a bifurcation of the soil production function at shallow and zero soil depths may need to be considered.

Gilbert, G.K. (1877) *Report on the Geology of the Henry Mountains (Utah)*, United States Geographical and Geological Survey, Washington. D. C.

Heimsath, A.M., Dietrich, W.E., Nishiizumi, K. and Finkel, R.C. (1999) Cosmogenic nuclides, topography, and the spatial variation of soil depth. *Geomorphology*. **27**, 151-172.

Paton, T.R., Humphreys, G.S. and Mitchell, P.B. (1995) *Soils: a new global view*, UCL Press Limited, London.

Small, E.E., Anderson, R.S. and Hancock, G.S. (1999) Estimates of the rate of regolith production using 10Be and 26Al from an alpine hillslope. *Geomorphology*. **27**, 131-150.

Wilkinson, M.T. and Humphreys, G.S. (in review) The limited role of modelled exposure and aspect on the distribution of heath on the northern Newnes Plateau, Blue Mountains, NSW. *Austral Ecology*. .

A dividing continent: tectonism, volcanism and crustal spreading rates in the Ethiopian and Afar Rifts

[1]Williams, Frances, [2]Williams, Martin, [3]Gibson, Ian and [4]Aumento, Fabrizio

[1]Department of Geology and Geophysics, University of Adelaide, SA 5005, Australia
[2]Department of Geography and Environmental Studies and Department of Geology and Geophysics, University of Adelaide, SA 5005, Australia
[3] University of Otago, Dunedin, Otago, New Zealand
[4]Department of Environmental Sciences, La Tuscia University, Viterbo, Italy

Many attempts have been make to quantify plate movements and crustal extension in the complex region of the Main Ethiopian Rift, the Afar Depression, the Red Sea and the Gulf of Aden. We present here a geological contribution based on field measurement of tensional fissures in the northern part of the Main Ethiopian Rift, combined with radiometric and radiocarbon dating of the rift floor materials that they dissect.

The Main Ethiopian Rift is the northern segment of the African Rift System. It runs approximately SSW – NNE through Ethiopia, opening at latitude 10°N into the Afar Triangle. Afar is a region of complex tectonics and recent and current volcanism resulting from the movements of the Arabian, African and Somali Plates. The Main Ethiopian Rift itself is seismically and tectonically active, and has been volcanically active throughout the Quaternary. It is believed to represent an incipient stage of continental break-up.

Although the Rift itself is some 80 km wide, tectonic and volcanic activity appear to concentrate within a 20 – 30 km wide zone known as the Wonji Fault Belt. Although this belt is not physically axial to the Rift it may be regarded as its tectonic axis. Few faults, earthquake epicentres or sites of volcanic eruption occur between it and the main Rift Margins. It is not a continuous belt but is formed of a series of offset segments, each consisting of short and often closely spaced normal faults and fissures arranged *en échelon*. Although the component segments of the Wonji Fault Belt more or less parallel the Rift margins, the faults themselves generally do not. Their orientation ranges from about N40°E to N-S. A series of Quaternary central silicic volcanoes along the Belt is often located at offsets. These volcanoes are pantelleritic (highly alkaline) in composition, and some have collapsed into summit calderas with the accompaniment of voluminous ash flow tuffs. These, together with lacustrine sediments, volcanic ash fall deposits and fissure basalts form the covering of the Rift floor.

The Red Sea probably commenced opening about 25 my ago and the Gulf of Aden somewhat earlier. Recent work has shown that the Red Sea is currently widening at a rate (from north to south) of 0.8 – 1.7 cm/yr and the Gulf of Aden at 1.5 – 2.5 cm/yr as a result of sea floor spreading. The onset of rifting in the Main Ethiopian Rift commenced about 10 my ago, with initial downwarping at about 15 my, and has continued in several stages until the present. The Wonji Fault Belt was probably initiated about 1.6 my ago and a major impulse in volcanic and tectonic activity occurred within it at 0.25 my. Methods of determining crustal extension rates can be divided into three groups: geodetic, plate tectonic modelling (kinematic) on a regional or global scale, and geological. Two groups of open tensional fissures occur in proximity to two caldera complexes at the northern end of the Main Ethiopian Rift. We have surveyed the fissures and dated the formations they dissect. The results suggest that rift extension in this region has been relatively intense over the past few thousand years and confined to a narrow zone, following a period of inactivity lasting over 150,000 years.

Interpreting environmental change from cave deposits

Paul Williams
School of Geography & Environmental Science, University of Auckland

Caves are superb natural repositories for deposits that shed light on past environmental conditions. Caves act as shelters, dens and pitfall traps and so yield archaeological and palaeontological remains of great significance with ancestral hominid lines traced to 3.3 Ma. Caves sediments have yielded dateable evidence used to elucidate major events in regional geomorphology to at least the Pliocene. Speleothems provide detailed archives of terrestrial climate change that can be dated with great precision to 0.5 Ma and can sometimes be interpolated to annual resolution.

Caves have long been recognised as containing important repositories of natural history, but relative inaccessibility and inadequate scientific techniques have prevented their full potential from being realised. A raft of new techniques is now changing that and so caves will soon be our best continental source of easily and precisely dateable palaeoenvironmental information. Magnetic sector inductively coupled plasma mass spectrometry (ICP-MS) is superseding TIMS uranium series dating of speleothems, by allowing smaller sample sizes and higher sample throughput, and so is set to make uranium series dating cheaper and more accessible. Cosmogenic ^{26}Al and ^{10}Be dating of cave sediments permit geochronology reconstruction from clastic cave fills into the Pliocene. Trace element analysis using Secondary Ionising Mass Spectrometry (SIMS) and laser ablation techniques for stable isotopes means it is now possible to obtain palaeoenvironmental data of annual resolution. But such information is still only proxy data and so relies on correct interpretation to be of value. This is a major challenge that must be overcome before the full potential of the new data stream can be realised.

Speleothems have been used since Hendy's pioneering work at Waitomo in the 1960s to reconstruct climatic change. Attention focused first on their $\delta^{18}O$ and $\delta^{13}C$ records. Later work drew attention to the significance of fluctuating episodes of speleothem growth over time. And recently attention has been given to variations in luminescence and trace element characteristics. Interpretation of the proxy data has sometimes appeared to be contradictory, for example:

1) Episodes of abundant speleothem growth have been interpreted in terms of glacial-interglacial oscillation with matches demonstrated to the SPECMAP curve from the marine isotope record. Thus in Europe, increased speleothem growth is associated with *warm* periods. But in Australia, increased speleothem growth has been associated with *wet* periods. Can we have it both ways?

2) Delta ^{18}O is usually interpreted as a proxy for temperature but has been shown in Israel to be correlated with rainfall. Can we have it both ways?

3) Thermodynamic considerations indicate $\delta^{18}O$ to be *inversely* related to temperature, yet in some places (Vancouver Is, Ireland, Tasmania, New Zealand) it has been demonstrated empirically to vary *directly* with temperature. Both relationships can hold, but under what circumstances?

The separation of the influences of T and P on speleothem $\delta^{18}O$ remains a challenge. Attempts have been made to generate terrestrial palaeotemperature time series using speleothem $\delta^{18}O$, but both calibration and the definition of confidence limits remain difficult. The full potential of the $\delta^{13}C$ signal has barely been touched.

Airborne electromagnetics, geomorphology and mineral exploration, Gawler Craton, South Australia

Lisa Worrall & Richard Lane
Geoscience Australia

The mineralised Archaean to Mesoproterozoic basement of the Gawler Craton (Drexel et al., 1993) is obscured by sedimentary basins and regolith cover that have hindered both geological mapping and mineral exploration. Mineral exploration has proceeded largely by geochemical prospecting, however the effective design and interpretation of geochemical surveys is dependant on a good understanding of the craton's post mineralisation geomorphic history. Unfortunately this understanding is poorly developed. This is largely because conventional methods of mapping regolith volumes, as a preliminary to reconstructing geomorphic history, are slow and expensive.

In this presentation we discuss the fruits of a Geoscience Australia/ South Australian Department of Primary Industry and Resources/ Cooperative Research Centre for Landscape Environment and Mineral Exploration project that has demonstrated that Airborne ElectroMagnetic (AEM) systems are capable of rapid and cost effective reconnaissance mapping of regolith volumes at regional scales on the Gawler Craton. The areas flown are in the vicinity of Moonta-Wallaroo on the Yorke Peninsula in the eastern Gawler, over the Tunkillia prospect in the central Gawler, over the Challenger deposit in the central northwestern Gawler and in the Lake Harris District, also in the central Gawler. We show how the demonstration datasets were used to construct a preliminary understanding of the geomorphic history of these terrains, and indicate how this understanding could have saved the relevant exploration companies many millions of dollars.

Drexel, J.F., Preiss, W.V., and Parker, A.J., 1993, The geology of South Australia: South Australia Geological Survey Bulletin 54.

Holocene evolution of the lower Macquarie riverine plain, central western New South Wales

Yonge, D & Hesse, P.
Department of Physical Geography, Macquarie University, Sydney

The contemporary channel system of the lower Macquarie River riverine plain in central western NSW is characterised by the breakdown of a sinuous single channelled form into an extensive network of discontinuous anabranching and distributary streams. In contrast, relics of continuous meandering palaeochannels are evident on the surface of the alluvial plain indicating a change in fluvial character in the recent geological past.

In the modern fluvial system, single channel reaches develop into fan-shaped distributary deltas that prograde into extensive wetlands dominated by sheetflow processes. The floodplain accretes in a series of depositional lobes produced as the deltas mature and relocate through avulsion. A reduction in flow velocity resulting from flow separation & increasing in-channel vegetation occurs at the channel breakdown. Suspended load data indicates these environments are extremely effective in inducing deposition of available sediment.

Data obtained through stratigraphic drilling indicates the contemporary channel and floodplain sequences consist almost entirely of clays to a depth of approximately 2.8m, and are underlain by oxidised alluvium with a grain size distribution comprised of a higher proportion of silts and sands. The boundary between the two units is sharp, indicating a rapid change in depositional style. Morphological and sedimentological evidence suggests the discontinuous, multiple channel network became established approximately 5 ka. The transition in drainage pattern from continuous meandering streams to the modern form is likely to have occurred between approximately 5 ka and 8 ka. An episode of floodplain denudation is believed to have preceded the development of the contemporary system, producing a topographic basin in which the contemporary channel network is located. Average accumulation rates in the contemporary system are extremely low (<1 mm/yr), especially given its depositional efficiency. Low rates of sediment availability within the catchment are proposed from at least the mid Holocene.

Participants

a

Almond, Peter

Full Name: Dr. Peter Almond
Company: Lincoln University
Soil and Physical Sciences Group
PO Box 84
Lincoln University
Canterbury
NEW ZEALAND
Bus: 0064 3 3252811 x8209
Bus Fax: 0064 3 3253607
E-mail: almondp@lincoln.ac.nz

Anand, Ravi

Full Name: Dr Ravi Anand
Company: CRCLEME|CSIRO
ARPC
26 Dick Perry Avenue
Technology Park
Kensington WA 6150
Bus: 08 6436 8672
Bus Fax: 08 64368560
E-mail: ravi.anand@csiro.au

b

Bourke, Mary

Full Name: Dr. Mary Bourke
Company: University of Oxford
School of Geography
Mansfield Road
Oxford UK OX1 3TB
Bus: 44 1865 271915
Bus Fax: 44 1865 271929
E-mail: mary.bourke@geog.ox.ac.uk

Boyens, Nick

Full Name: Nick Boyens
Company: School of Earth Sciences, Victoria University of Wellington
PO Box 600
Wellington
NEW ZEALAND
Bus: 64 4 463 6118
Bus Fax: 64 4 4635186
E-mail: nick.boyens@vuw.ac.nz

Brizga, Sandra

Full Name: Dr. Sandra Brizga
Company: S.Brizga & Associates Pty Ltd
Po Box 68
Clifton Hill VIC 3068
Bus: 03 9859 7403
Bus Fax: 03 9859 7403
E-mail: sbrizga@ozemail.com.au

Brown, Jonathan

Full Name: Mr. Jonathan Brown
Company: Monash University
43 Crow Street
East Burwood VIC 3151
Bus: 03 9803 3966
Mobile: 0438 456 243
E-mail: jonathan.brown@arts.monash.edu.au

c

Chan, Rosyln

Full Name: Ms. Rosyln Chan
Company: CRCLEME
Geoscinec Australia
GPO Box 378
Canberra ACT 2601
Bus: 02 6249 9371
Bus Fax: 02 6249 9930
E-mail: rosyln.chan@ga.gov.au

Chappell, John

Full Name: Prof. John Chappell
Company: Australian National University
Research School of Earth Sciences
Canberra ACT 0200
Bus: 02 6125 8113
E-mail: john.chappell@anu.edu.au

Chivas, Allan

Full Name: Prof. Allan Chivas
Company: University of Wollongong
School fo Geosciences
Wollongong NSW 2522
Bus: 02 4221 3263
Bus Fax: 02 4221 5703
E-mail: toschi@uow.edu.au

Clark, Dan

Full Name: Dr. Dan Clark
Company: Geoscience Australia
GPO Box 378
Canberra ACT 2601
Bus: 02 6249 9606
Bus Fax: 02 6249 9969
E-mail: _dan.clark@ga.gov.au

Clarke, Jon

Full Name: Dr Jon Clarke
Company: ANU
Dept of Geology
Australian National University
Canberra ACT 0200
Bus: 02 6125 8322
Bus Fax: 02 6125 3544
E-mail: jdac@alphalink.com.au

Crozier, Mike

Full Name: Prof. Mike Crozier
Company: Victoria University of Wellington
Institute of Geography
School of Earth Sciences
PO Box 600
Wellington
NEW ZEALAND
Bus: 64 4 463 5279
E-mail: Michael.Crozier@vuw.ac.nz

d

Doerr, Stefan

Full Name: Dr. Stefan Doerr
Company: Deakin University
School of Ecology and Environment
PO Box 423
Warrnambool VIC 3280
Bus: 03 5563 3138
Bus Fax: 03 5563 3143
E-mail: s.doerr@swansea.ac.uk

Dunkerley, David

Full Name: David Dunkerley
Company: Monash University
School of Geography and Environmental Science
Monash University
VIC 3800
Bus: 03 9905 2914
Bus Fax: 03 9905 2948
E-mail: david.dunkerley@arts.monash.edu.au

e

Ellaway, Mark

Full Name: Dr. Mark Ellaway
Company: Geography, University of Melbourne
School of Anthropology, Gegraphy & Environmental Studies
University of Melbourne
VIC 3010
Bus: 03 83447101
Bus Fax: 03 83444972
E-mail: edwardme@unimelb.edu.au

f

Fabel, Derek

Full Name: Dr. Derek Fabel
Company: Research School of Earth Sciences
Australian National University
Canberra ACT 0200
Bus: 02 6125 5518
Bus Fax: 02 6125 5443
E-mail: derek.fabel@anu.edu.au

Fanning, Trish

Full Name: Trish Fanning
Company: Macquarie University
Graduate School of the Environment
Sydney NSW 2109
Bus: 02 98507979
Bus Fax: 02 9850 7972
E-mail: pfanning@gse.mq.edu.au

g

Giles, Philip

Full Name: Dr. Philip Giles
Company: Saint Mary's University
Department of Geography
Halifax, Nova Scotia B3H 3C3
CANADA
Bus: 1 902 420 5740
Bus Fax: 1 902 496 8213
E-mail: Philip.Giles@stmarys.ca

Gostin, Vic

Full Name: Dr. Vic Gostin
Company: Adelaide University
Dept of Geology and Geophysics
Adeliade SA 5005
Bus: 08 8303 4039
Bus Fax: 08 8303 4347
E-mail: victor.gostin@adelaide.edu.au

h

Hardenbicker, Ulrike

Full Name: Dr. Ulrike Hardenbicker
Company: Victoria University of Wellington
PO Box 600
Wellington
NEW ZEALAND
E-mail: Ulrike.Hardenbicker@vuw.ac.nz

Hawke, Richard

Full Name: Richard Hawke
Company: Victoria University of Wellington
School of Earth Sciences
Wellington
NEW ZEALAND
Bus: 64 4 463 5844
Bus Fax: 64 4 4635186
E-mail: Richard.Hawke@vuw.ac.nz

Haworth, Robert

Full Name: Dr. Robert Haworth
Company: University of New England
Armidale NSW 2351
Bus: 02 6773 2006
Bus Fax: 02 6773 3030
E-mail: Rhaworth@metz.enu.edu.au

Hemmingsen, Maree

Full Name: Maree Hemmingsen
Company: University of Canterbury
Department of Geography
Christchurch
NEW ZEALAND
Bus: 64 3 364 2987
Bus Fax: 64 3 364 2907
E-mail: maree@geog.canterbury.ac.nz

h

Hesse, Paul

Full Name: Dr. Paul Hesse
Company: Macquarie University
Department of Physical Geography
NSW 2109
Bus: 02 9850 8384
Bus Fax: 02 9850 8420
E-mail: phesse@laurel.ocs.mq.edu.au

Ho, Lih-Der

Full Name: Mr. Lih-Der Ho
Company: University of Melbourne
Department of Geography and Environmental Studies
VIC 3010
Mobile: 0421 494 614
E-mail: l.ho2@pgrad.unimelb.edu.au

j

James, Patrick

Full Name: Assoc Prof. Patrick James
Company: CRCLEME
Geology and Geophysics
School of Earth and Environmental Sciences
Adelaide University
Adeliade SA 5005
Bus: 08 8303 5254
Bus Fax: 08 8303 4347
E-mail: patrick.james@adelaide.edu.au

Jansen, John

Full Name: Dr. John Jansen
Company: University of Wollongong
Wollongong, NSW 2522
Bus: 02 4221 4441
Bus Fax: 02 4221 4250
E-mail: jansen@uow.edu.au

Joyce, Bernie

Full Name: Mr. Bernie Joyce
Company: University of Melbourne, The
School of Earth Sciences
VIC 3010
Bus: 03 8344 6521
Bus Fax: 03 8344 7761
E-mail: ebj@unimelb.edu.au

k

Kennedy, David

Full Name: Dr. David Kennedy
Company: Victoria University of Wellington
School of Earth Sciences
PO Box 600
Wellington
NEW ZEALAND
Bus: 64 4 463 6159
Bus Fax: 64 4 463 5186
E-mail: David.Kennedy@vuw.ac.nz

Kiernan, Kevin

Full Name: Dr. Kevin Kiernan
Company: Forest Practices Board, Tasmania
Forest Practices Board, Tasmania
30 Patrick Street
Hobart TAS 7000
Bus: 03 62337716
Bus Fax: 03 6233 7954
E-mail: kevink@fpb.tas.gov.au

l

Lawrence, Ruth

Full Name: Dr. Ruth Lawrence
Company: La Trobe University
Outdoor Education & Nature Tourism
PO Box 199
Bendigo VIC 3550
Mobile: 0427 421 425
E-mail: r.Lawrence@bendigo.latrobe.edu.au

Lee, Pei-Jung

Full Name: Mrs. Pei-Jung Lee
4 Vernon Street
Huntingdale VIC 3166
Mobile: 0421 494614
E-mail: paypei917@hotmail.com

n

Neave, Mel

Full Name: Mel Neave
Company: University of Sydney
School of Geosciences
University of Sydney
Madsen Building (F09)
Sydney NSW 2006
Bus: 02 9351 6463
E-mail: mneave@geography.usyd.edu.au

o

Ollier, Cliff

Full Name: Prof. Cliff Ollier
Company: UWA
Geography
University of Western Australia
Crawley WA 6009
Bus: 08 9380 2664
Bus Fax: 08 9380 1054
E-mail: cliffol@geog.uwa.edu.au

Orr, Meredith

Full Name: Dr. Meredith Orr
Company: Monash University
School of Geography and Environmental Science
Vic 3800
Bus: 03 9905 4617
Bus Fax: 03 9950 2948
E-mail: Meredith.Orr@arts.monash.edu.au

o

Outhet, David

Full Name: Dr. David Outhet
Company: NSW Dept Land and Water Conservation
PO Box 3720
Parramatta NSW 2124
Bus: 02 9895 7816
Bus Fax: 02 9895 7867
E-mail: douthet@dlwc.nsw.gov.au

p

Pain, Colin

Full Name: Dr. Colin Pain
CRCLEME
c/o Geoscience Australia
GPO Box 378
Canberra ACT 2601
Bus: 02 6249 9469
Bus Fax: 02 6249 9930
E-mail: Pain Colin

Pickard, John

Full Name: Dr. John Pickard
Company: Macquarie University
PO Box 793
Dubbo NSW 2830
Bus: 02 6882 0034
E-mail: john.pickard@bigpond.com

Pillans, Brad

Full Name: Dr Brad Pillans
Company: ANU
Australian National University
Canberra ACT 0200
Bus: 02 6249 1507
E-mail: brad.pillans@anu.edu.au

r

Ralph, Timothy

Full Name: Mr. Timothy Ralph
Company: Macquarie University
Department of Physical Geography
Syndey NSW 2109
Bus: 02 9850 8318
Bus Fax: 02 9850 8420
E-mail: tralph@laurel.ocs.mq.edu.au

Rayburg, Scott

Full Name: Scott Rayburg
Company: SUNY Buffalo
3/22-24 Terrace Road
Dulwich Hill NSW 2203
Bus: 02 9558 6436
E-mail: srayburg@acsu.buffalo.edu.au

Richards, Danette

Full Name: Miss Danette Richards
Company: University of Canterbury
Finleys Road
West Melton, R. D. 1.
Christchurch
NEW ZEALAND
Bus: 64 3 3477 123
E-mail: d.richards@geol.canterbury.ac.nz

s

Schmidt, Jochen

Full Name: Dr. Jochen Schmidt
Company: Landacre Research NZ Ltd
PO Box 69
Lincoln
NEW ZEALAND
Bus: 64 3 325 6701 x3805
Bus Fax: 64 3 325 2418
E-mail: schmidtj@landcareresearch.co.nz

Shulmeister, James

Full Name: James Shulmeister
Company: University of Canterbury
Dept of Geological Sciences
Private Bag 4800
Christchurch
NEW ZEALAND
Bus: 64 3 3642762
Bus Fax: 64 3 3642764
E-mail: j.shulmeister@geol.canterbury.ac.nz

Smith, Barton

Full Name: Mr. Barton Smith
Company: University of Melbourne
School of Earth Sciences
Parkville VIC 3010
Bus: 03 8344 3898
Bus Fax: 03 8344 7761
E-mail: barton@unimelb.edu.au

t

Taylor, Anna

Full Name: Anna Taylor
Company: University of Canterbury
124 Jeffreys Road
Christchurch
NEW ZEALAND
Bus: 64 3 3516943
E-mail: taylora@geog.canterbury.ac.nz

Terry, James

Full Name: Dr. James Terry
Company: University of the South Pacific
Department of Geography
Suva
FIJI
Bus: 679 321 2549
Bus Fax: 679 330 1487
E-mail: terry_J@usp.ac.fj

t

Tomkins, Kerrie

Full Name: Ms. Kerrie Tomkins
Company: Dept of Land and Water Conservation
Sustainable Farming Systems Branch
59 Swift Street
Wellington NSW 2820
Bus: 02 6840 0911
Bus Fax: 02 6840 0940
E-mail: ktomkins@dlwc.nsw.gov.au

w

Webb, John

Full Name: John Webb
Company: La Trobe University
Dept of Earth Sciences
VIC 3086
Bus: 03 9479 1273
Bus Fax: 03 9479 1272
E-mail: john.webb@latrobe.edu.au

Wilkinson, Marshall

Full Name: Marshall Wilkinson
Company: Macquarie University
35 Braeside Street
Blackheath NSW 2785
Bus: 02 4787 8482
Mobile: 0407350388
E-mail: marshwilko@ozemail.com.au

Williams, Martin

Full Name: Prof. Martin Williams
Company: University of Adelaide
Department of Geographical and Environmental Studies
Adelaide SA 5005
Bus: 08 83034170
Bus Fax: 08 83034383
E-mail: martin.williams@adelaide.edu.au

Williams, Paul

Full Name: Paul Williams
Company: University of Auckland
School of Geography and Environmental Science PB 92019
Auckland
NEW ZEALAND
Bus: 64 9 3737 599 x8459
Bus Fax: 64 9 373 7434
E-mail: p.williams@auckland.ac.nz

Worrall, Lisa

Full Name: Lisa Worrall
Company: Geoscience Australia
Geoscience Australia
GPO Box 378
Canberra ACT 2601
Bus: 02 6249 9192
Bus Fax: 02 6249 9965
E-mail: Worrall Lisa

y

Yonge, David

Full Name: David Yonge
Company: Macquarie University
1/27 Currie Road
Forestville NSW 2087
Bus: 02 9453 0336
E-mail: cuthbt@yahoo.com

Young, Carolyn

Full Name: Ms. Carolyn Young
Company: Dept of Land and Water Conservation
PO Box 189
Queanbeyan NSW 2620
Bus: 02 6298 4020
Bus Fax: 02 6299 6619
E-mail: cyoung@dlwc.nsw.gov.au