ABSTRACTS

AUSTRALIA-NEW ZEALAND GEOMORPHOLOGY GROUP

SIXTH MEETING

30 January - 4 February 1994

Hanmer, North Canterbury

PROGRAMME

AUSTRALIA-NEW ZEALAND GEOMORPHOLOGY GROUP

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Hanmer, North Canterbury

Selkirk, J.	Landslip characteristics on Macquarie Island.
Bourman, R.B.	Coastal landslumping in Pleistocene sediments at Sellicks Beach, South Australia.
Brunsden, D	Future challenges for mass movement studies.

10:30 - 11:00am Tea

11:00am - 12:40pm MASS MOVEMENT 2 (Phil Tonkin)

Chappell, J., Y. Ota and K.Berryman	A 60,000 year record of repeated landslides and coseismic uplift events from Papua New Guinea.
Crozier, M.	Predicting runout behaviour of soil landslides.
Phillips, C.J., M.Marden, and J.C. Ekanayake	Earthflows - a wander through a decade of research on the East Coast of North Island.
Wilkes, S.	Hillslope hydrology - the monitoring of a potential landslide site.
Scheidegger, A.E.	Landslides as singularities in the geomorphic cycle.

12:40 - 1:40pm Lunch

1.40 - 3:20pm QUATERNARY GEOMORPHOLOGY (Jane Soons)

Pillans, B.	Landscape paleomagnetism.
Williams, P.	A 250 ka glacial history from a Fiordland cave.
Fitzsimons, S., M. Pollington and E. Colhoun	Palaeomagnetism of New Zealand glacigenic deposits.
Price, D.M.	Thermoluminescence dating: the good, the bad and the ugly.
Goff, J.	Late Wisconsinan and Holocene sedimentation of Silverhope Valley, British Columbia.

3:20 - 3:50pm Tea

3:50 - 4:50pm GLACIAL AND ALPINE GEOMORPHOLOGY (Eric Colhoun)

Augustinus, P.	Modelling rock stress distribution across glacial valleys: implications for the development of glacial valley cross-profile morphology.
Humphreys, K.	Sediment and landform associations of arid polar glaciers.
Barsch, D.	Rock glaciers indicators for high mountain environments.

4:50 - 5:20 Tea

5:20 - 6:20pm TECTONIC AND REGIONAL GEOMORPHOLOGY (David Price)

Fabel, D.	Some thermal and mechanical consequences of denudation: implications for estimating denudation rates from thermochronological data.
Knuepfer, P. and P.C. Coleman	Tectonic geomorphic domains of the western Southern Alps.
Orr, M.	Morphotectonics of the Endrick River region, New South Wales.

6:30pm Barbecue - Hanmer Lodge

Thursday 3 February

8:00am - 7:00pm NORTH CANTERBURY FIELD TRIP

7.00pm(approx) Dinner - Waipara Springs winery

Friday 4 February

8:30 - 10:30am COASTAL PROCESSES (John Chappell)

Brander, R.	Field investigations on the dynamics of rip currents.
Shen, J.	Suspended sediment characteristics in the surf zone.
Martens, D.	Mega-rip dimensional analyses on the Sydney Coast, Australia.
Single,M. and R. Kirk	Mixed sand and gravel barrier beach response to storms.
Allingham, D.P. and D.T. Neil	The supratidal deposits and effects of coral dredging on Mud Island, Moreton Bay, Southeast Queensland.
Nolan, T.	Beach cusps as sea level indicators.

10:30 - 11:00am Tea

11:00am - 12:40pm ESTUARIES AND COASTAL EVOLUTION (Bob Kirk)

McLean, E., Shi, G.R.and Forsyth, P.W.	Multi-variate analysis of sediment biota distributions in the Pambula R. estuary, New South Wales.
Kotsonis, A.	Eustatic record of the Pliocene: beach ridges of the Parilla Sands, Murray Basin, southeastern Australia.
A. Lawrie and J. Soons	Subsiding Banks Peninsula - myth or reality.
W. Stephenson and J.Shulmeister	Holocene progradation record from Okains Bay, Banks Peninsula, New Zealand.
Masselink, G. and G. Lessa	Barrier stratigraphy of the macrotidal central Queensland coastline.

Sunday 30 January

5:30 pm Rendezvous and registration - Hanmer Springs

Monday 31 January

8:30 - 9:30am Registration

9:45am Welcome

10:00am - 11:20am LAND USE AND SEDIMENT YIELD 1 (Paul Williams)

Gillieson, D., P. Wallbrink and A.Murray	Estimation of wind erosion using the radionuclide caesium-137 on the Nullarbor karst, Australia.
Trustrum, N.A., M.J. Page, J. Wilmshurst, and M. McGlone	Reconstruction of late Holocene storm-induced erosion, sedimentation and vegetation history.
Hoeksma, P.	Application of predictive sediment yield models in resource management - the Karori Reservoir case.
Bowler, J.	Sedimentation of the Upper Mangahao Reservoir.

11:20- 11:50am Tea

11:50am - 1:10pm LAND USE AND SEDIMENT YIELD 2 (David Dunkerley)

Wallbrink, P.J. and A.S. Murray	Measuring soil loss on forest slopes following harvesting - an approach using ^{210}Pb excess to ^{137}Cs inventory ratios.
Olley, J.M., P.J. Wallbrink and A.S. Murray	Determining the sources of sediment on forested hillslopes after partial logging using natural and anthropogenic radioactivity.
Slade, C.J.	Gully initiation and valley floor vegetation on the Southern tablelands of New South Wales.
Slaymaker, O.	Sediment budgets of large drainage basins.

1:10 - 2:10pm Lunch

2:10 - 3:30pm FLUVIAL PROCESSES AND MORPHOLOGY 1 (Gerald Nanson)

Dunkerley, D.	Hydraulic geometry of streams: does it provide an adequate basis for predicting the morphologic response of channels to climate change?
Olive, L.J., A.S. Murray, J. Olley and P.J. Wallbrink	The Murrumbidgee River system - flood sediment and transport.
Tooth, S.	Arid river systems of lowland central Australia: some preliminary findings.
Warner, R.F.	Downstream variations in channel perimeter characteristics and their implications in the Clarence River, New South Wales.

3:30 - 4:00pm Tea

4:00 - 5:00 pm FLUVIAL PROCESSES AND MORPHOLOGY 2 (Rob Warner)

Wende, R.	Drainage and valley asymmetry in the Tertiary hills of Lower Bavaria, Germany.
Ashmore, P.	Morphological measurement of spatially-distributed bedload transport rate in braided streams.
Brizga, S. and D. Fabel	Human impacts on "new" rivers: some observations from Gippsland, Victoria.

5:00 - 5:30pm Tea

5:30 - 6:10pm KARST (Ian Owens)

White, S.	Karst in Cainozoic limestones.
van Beynen, P. and P. Williams	Environmental analysis of speleothems: an historical record.

Tuesday 1 February

8:30 - 9:30am SLOPE PROCESSES AND SOIL EROSION 1 (Noel Trustrum)

Brown, K.	Identifying "runoff producing areas" in erosion studies - an example from an arid western New South Wales catchment.
Goss, H.	Rainfall simulators: do they really simulate rain?
Soufi, M.	Processes and rates of gully erosion in a pine plantation, Bombala, NSW.

9:30 - 10:00am Tea

10:00 - 10:40am SLOPE PROCESSES AND SOIL EROSION 2 (Denys Brunsden)

Mabin, M.	Richter slope development at Radok Lake, Antarctica.
Prosser, I.	Surface wash erosion, channel initiation, and hydraulics of overland flow in hillslope hollows.

11:00am - 5:30pm HANMER BASIN AND WAIAU VALLEY FIELD TRIP

Wednesday 2 February

8:30 - 10:30am MASS MOVEMENT 1 (Mike Crozier)

Tonkin, P.J.	Soil geomorphic models and the interpretation of slope evolution through the processes of mass movement.
Gee, M.	A landslide and debris impact hazard map for Wellington City.
DeRose, R.C.	Relationships between slope morphology, soil properties, and the incidence of shallow landslides in eastern Taranaki hill country.

The supratidal deposits and effects of coral dredging on Mud Island, Moreton Bay, southeast Queensland

D.P. Allingham and D.T. Neil
Department of Geographical Sciences and Planning, The University of Queensland

Mud Island was a 1200 ha coral reef island. Landforms consisted of a seaward sloping open reef flat surrounding a 430 ha inner reef flat area containing a central 2.4 ha terrestrial core, a mangrove intertidal area with creeks and swales, and 33 ha of multiple concentric sand islets formed during the late-Holocene in the eastern, northern, and western inner reef flat quadrants. The islet sediments are coarse sands and generally become better sorted towards the island's core. Mud Island has formed in a relatively exposed location in Moreton Bay and therefore a range of wind/wave energies have influenced its reef top development. Sequential aerial photography shows that coral dredging for cement manufacture has removed about 50% of the total reefal area. An inventory of coral dredging has been constructed. Dredging over a 54 year period has produced shingle ridge spoil with moderately sorted supratidal pebble sized sediment crests which have accumulated on the open reef flat. The ridges have entered parts of the inner reef flat and physically destroyed mangroves. Ridge area has increased by 62% over a 19 year period and they now encompass 75% of the island perimeter. The ridges have transgressed the open reef flat at an average rate of 2.5 m/year, with above average movements on the southern and northern sections. The transgression has decreased over time. The shingle ridges have concentrated tidal flows and sustained water levels during ebb tides resulting in a loss of mangroves via waterlogging and a corresponding expansion of creeks and swales since 1958. The geomorphic characteristics of Mud Island classify it as a "mangrove island", a type of coral reef island found in relatively low energy environments at low latitudes.

Morphological measurement of spatially-distributed bedload transport in braided streams

Peter Ashmore
Department of Geography, University of Western Ontario

Existing conventional methods for sampling bedload transport in gravel streams provide detailed point data for measurement of instantaneous rates and short-term (10^3 s) variation. An understanding of the process of bedload transport, and its relation to river hydraulics and morphology requires data on longer-term fluctuations and simultaneous spatial variation. Existing, but little-explored, morphological methods provide a means for doing this, especially in rapidly-changing braided streams in which unsteady transport is a dominant feature. Application of the method requires accurate, rapid bed resurvey and is best accomplished by a combination of photogrammetry and digital survey. However, the appropriate spatial and temporal survey densities require detailed investigation. Difficulties also exist in defining either the mean transfer distance or the input/output to the measured reach. Similarly, the methods remain untested

against the 'true' transport rate, although small-scale modeling provides a solution. Preliminary results from Sunwapta River, Canada show the pattern of bedload movement associated with channel confluences, the temporal and spatial pattern of aggradation and degradation in a reach, the overall correlation between transport rate and total stream discharge and the 'pulsing' of transport independent of discharge fluctuation. Research is continuing to define the optimal survey density for accurate DTM representation, and measure the known errors in the technique.

Modelling Rock Stress Distribution Across Glacial Valleys: Implications For The Development of Glacial Valley Cross-Profile Morphology

Paul C. Augustinus
Department of Physical Sciences, University of Tasmania

The morphology of glacial troughs in the vicinity of the Main Divide of the Southern Alps, New Zealand, is the product of the interaction between Alpine Fault-induced tectonic processes, rock mass strength (RMS) of the uplifted and eroded bedrock, and the processes acting to denude the developing mountains. The magnitude of the effects of glacial erosion on the landscape is directly controlled by the size of the glacier and its physical properties, whilst the form of the trough is a direct consequence of the RMS properties of the slope rock and the *in situ* stress-field. The location of rock failure, and hence the existence of weakened erodible rock, may selectively control the site of preferential glacial and fluvial erosion, hence influencing rock slope inclination and valley morphology. This study has implications for the development and modification of alpine glacial troughs in similar tectonic settings elsewhere.

Coastal landslumping in Pleistocene sediments at Sellicks Beach, South Australia

Robert P. Bourman
School of Applied Science, University of South Australia

A Late Holocene coastal rotational landslump, 350 m long and 50 m wide, occurs at Sellicks Beach, 50 km south of Adelaide. The slump surface at 20 m asl is backed by an arcuate backwall that rises 30 m to an aggradational surface fronting the Willunga escarpment. The slump was identified on the basis of its macro- and micro-morphology; the arcuate backwall is steep, the surface of the slump is stepped downward from the north in four major levels, due to differential settling, and the seaward edge of the slump is marked by irregular and hummocky mounds. The undisturbed Pleistocene sediments dip at 5° N but under the slump, beds have been rotationally tilted and dip 45° E.

The terrestrial Pleistocene sediments consist of six litho-stratigraphic units, and all were involved in the mass failure. Inclusions of masses of older units within the

younger sediments demonstrate considerable fluidity and internal deformation during slumping. At least 15 m of the lower sediments were evacuated by the failure and the rotational movement thrust the upper sediments into an unstable position, from where they flowed down the front edge of the slump, entraining blocks of the older sediment as they did so. At the base of the Pleistocene terrestrial sequence a 3 m thick layer of dark coloured smectitic clays and a marly fossiliferous early Pleistocene limestone probably acted as a relatively impermeable layer and thereby assisted the saturation of the overlying sediments.

The slump appears to be of Holocene age as Late Pleistocene sediments have been disrupted by the failure and there are Mid-Holocene sediments in valleys cut through the slump. There is some evidence for a slightly higher sea level in this locality during the Holocene, which may have increased the effectiveness of coastal erosion and hence the likelihood of a mass failure. The slump is adjacent to the seismically active Willunga Fault and failure of the water-saturated sediments could have been triggered by a seismic event.

Sedimentation of the Upper Mangahao Reservoir

Jarrod Bowler
Research School of Earth Sciences, Victoria University of Wellington

This paper presents a summary of research into sedimentation processes within the Upper Mangahao Reservoir, outlining the controls on the volume of sediment deposited.

The accumulation of sediment behind the dam has reduced the reservoir's capacity by over 65% of its original volume. The rate of sedimentation has declined since the 1950s as a consequence of:

1. revegetation of the upper catchment which has reduced the supply of sediment to the reservoir inflows, and

2. a reduction in the trap efficiency of the dam.

The reservoir sediments have been surveyed and analysed for grain size, to identify the lake conditions which would have existed during their deposition. A depositional history for the reservoir has been developed through the interpretation of stratigraphic profiles, isopach maps, and reconstructed three dimensional images of lake morphology.

Finally this paper:

1. quantifies the volumes of sediment deposited in the reservoir over time,
2. identifies where sedimentation rates are highest,
3. identifies the main controls on sediment distribution, and

4. outlines useful techniques for obtaining, displaying and interpreting volume and sediment data.

Field investigations on the dynamics of rip currents

Robert W. Brander
Coastal Studies Unit, Department of Geography, University of Sydney

An integral component of nearshore circulations along many of the world's beaches is the existence of seaward flowing rip currents. Despite their obvious geomorphological importance, the dynamics and formative mechanisms of rip currents remain poorly understood. Much of the theory which presently exists in the literature remains largely invalidated, due in large part to the lack of satisfactory quantitative measurements required to test available models. In particular there has been a dearth of field measurements made in rip currents over the last decade. This is not surprising given the high energy environment in which rips exist, but it is critical that efforts to obtain such information are undertaken. The purpose of this presentation is to describe a mobile field experimental design developed at the Coastal Studies Unit, University of Sydney in order to obtain continuous, detailed, and high resolution measurements within the logistically challenging rip current environment.

Measurements of horizontal flow velocities, surface water elevations, vertical flow velocity structures, suspended sediment concentrations, and nearshore morphology of *low-energy* rip currents can be obtained with the deployment of multiple instrument stations consisting of Marsh-McBirney (OEM-512) electromagnetic flow meters and/or ducted flow meters, pressure transducers, and optical backscatterance sensors (OBS-1P). These stations must be deployed strategically in the rip feeder, rip neck and rip head components of the rip system and can monitor a particular rip current over both a single 24 hour tidal cycle and an extended time interval following a period of high wave energy. The instruments are hardwired to shore to a real-time display acquisition system housed in a mobile field laboratory. Measurements of *high-energy* rips are restricted to lagrangian methods using drogues, dyes, and tracking techniques. Using both of these approaches, it is possible to successfully monitor rip systems under a wide range of morphodynamic conditions, providing much needed information on the dynamics of rip currents.

Human impacts on "new" rivers: some observations from Gippsland, Victoria

Sandra Brizga and Derek Fabel
School of Environmental Planning, The University of Melbourne

Channel avulsion is a relatively common process on Australian rivers. European settlement is widely thought to have had dramatic impacts on the Australian environment. This paper is concerned with the impacts of European settlement on the behaviour of post-avulsion river channels.

Major avulsions have occurred on two rivers in Gippsland, Victoria, since European settlement: the Tambo (1890s) and the Thomson (1952). Significant differences in channel characteristics and behaviour are apparent between these rivers. The Thomson River is a meandering stream. The pre-avulsion channel has shifted little during the historic period although a wide meander belt featuring many meander cutoffs and oxbow lakes provides evidence of past migration. The post-avulsion channel (known as Rainbow Creek) has migrated considerably in places (eg, 100 m in a 25 year period). Rainbow Creek is a gravel bed stream whereas the pre-avulsion channel of the Thomson River has a gravel bed at its upstream end but a bed of coarse sand at its downstream end. Both the pre- and post-avulsion channels of the Tambo River have sand beds and there is no evidence of extensive lateral migration along either course. Vertical accretion features are prominent on the floodplain: the pre-avulsion course is bordered by high natural levees while extensive sand splays are associated with the post-avulsion channel.

The evolution of the pre-avulsion channels was investigated using evidence from floodplain landforms (eg, palaeochannels, natural levees) and floodplain sediments. The behaviour of the new post-settlement channels was compared with the behaviour of their predecessors at a similar stage in their development.

The impacts of European settlement on the behaviour of the post avulsion channels of the Thomson and Tambo Rivers appear quite different. Comparisons of the behaviour of Rainbow Creek with the behaviour of the pre-avulsion course of the Thomson River at a similar stage of development do not reveal any major qualitative differences in channel behaviour. However, migration rates of Rainbow Creek are likely to have been affected by 1) the general absence of trees and scrub along its course until the late 1970s, and 2) river management works such as concrete block groynes and willow planting. The pre- and post-avulsion courses of the Tambo River differ in terms of the associated floodplain sedimentation. The pre-avulsion course has high natural levees confined to a narrow zone immediately adjacent to the river channel. The new course does not have high natural levees but is associated with broad sand splays. This apparent change in sedimentation may be related to changes in floodplain vegetation. Prior to European settlement, the floodplain was covered in forest and scrub. It is now largely grass and crops. Tree and scrub clearance can be expected to have affected patterns of sedimentation by reducing surface roughness and the degree of flow confinement. Sedimentation rates on the Tambo River may also have increased as the result of nineteenth century gold mining in the catchment.

Identifying "runoff producing areas" in erosion studies - an example from an arid western New South Wales catchment

Kate Brown
Department of Geography and Environmental Science, Monash University

Many investigators of catchment erosion like to identify "runoff producing areas" so that they can provide a value for sediment loss over space and time (ie units such as kg ha^{-1} $year^{-1}$). Usually, these investigators provide no insight into how such values have been derived, and I would argue that the assignment of such values is completely arbitrary (except in cases where erosion plots have been used). If one is attempting to measure erosion on a hillslope site over a period of time, it is impossible to suggest that the site is simple enough to respond in exactly the same way during each event; for example, rainfalls of different intensities and/or different durations will produce different "source areas" for sampling sites. Also, owing to the complex micro-topography of these hillslopes (and I would argue all hillslopes), it is impossible to confine the area of runoff within an imaginary square, rectangle or diamond. It would appear that this technique has been developed to provide values for catchment sediment loss for engineering purposes, but instead it has been readily adopted by geomorphologists. One must step back and ask what these values really mean. Some may argue that the values at least provide an average amount of sediment loss, but an average value may have little or no resemblance to the actual values of sediment movement. Instead I would argue that it is only possible to identify the amount of sediment moving across a contour over a period of time.

Data collected from a sediment transport monitoring programme established in a small arid zone catchment are presented to illustrate these ideas.

Some new approaches to landslide studies

Denys Brunsden
Department of Geography, King's College, London

If we are to go boldly where no one has gone before, we will need to concentrate on the conceptual approaches of geomorphology; new attitudes to community response, new mapping and monitoring techniques, a better understanding of mechanisms and patterns at all scales, and attention to lessons of the past. The lecture will illustrate new mapping techniques, including analytical photogrammetry, remote warning systems, GPS, video field systems, and autosubs for submarine research. Anything to do with description, remote sensing or other boring approaches is ignored.

A 60,000-year record of repeated landslides and coseismic uplift events from Papua New Guinea

John Chappell, Department of Biogeography and Geomorphology,
Australian National University,
Yoko Ota and Kelvin Berryman

The Huon Peninsula of Papua New Guinea parallels a major plate boundary and is tectonically highly active, with average late Quaternary uplift rates exceeding 3 $m.ka^{-1}$. Late Quaternary raised coral terraces on the northeast of the Peninsula have been extensively dated by $^{230}Th/^{234}U$ and other methods, in a series of studies over the last 20 years. This staircase landscape has a large number of landslides; 26 which occurred within the last 60 ka are dated either by morphostratigraphic relationships to the dated terraces, or directly by ^{14}C ages from materials in or bracketing their flow deposits. Although age-limits are about ± 10 ka for many of the late Pleistocene events, occurrence of these landslides appears to have been statistically uniform through the last 60 ka. There are two groups of major landslides at Huon Peninsula. Type I slides have negligible debris flows, although they can be large, and principally involve rocks of the coral terraces. Type II slides have substantial debris flows and penetrate beneath the coral terraces into relatively incompetent tuffaceous sandstones and muddy conglomerates. The percentage area affected by Types I and II landslides in sampling quadrats, each about 25 km^2, ranges from <1% to 30%, increasing with tectonic uplift rate and topographic gradient. Type II landslides are confined to high uplift regions where coral limestone of the terraces is discontinuous or locally thin (<10 m).

Tectonic uplift in the area is dominantly coseismic. Dating of coseismic terraces shows that the recurrence interval of major uplift events has been about 1 ka during the last 6 ka, and was statistically similar between 30 and 52 ka in late Pleistocene times. The average magnitude of coseismic uplifts is about 3 to 4 m where the uplift rate is about 3 $m.ka^{-1}$ and is less where uplift rate is lower. Small scale coseismic uplift occurs: a magnitude 7.2 earthquake in May 1992 produced 0.1-0.3 m uplift, and generated local landslides. Field evidence clearly shows that the large uplifts of several metres are discrete events. By ^{14}C dating we show that some large landslides occur close to large uplifts but we have not recognised landslides associated with every large uplift event. This may imply that not all very large earthquakes produce large landslides in this geomorphologically unstable region. Although further field work is required to complete the analysis, this is the most detailed record, covering some 60 ka, of landslides and coseismic uplift events known to us.

Predicting runout behaviour of soil landslides

M. J. Crozier
Research School of Earth Sciences, Victoria University of Wellington

Prediction of landslide runout distance is an important component of landslide hazard assessment and a useful aspect of sediment routing analysis. The

development of empirical runout models has been attempted in the past for more catastrophic failures such as rock slides but little work has been done on regolith landslides such as debris flows and rapid earthflows.

This paper presents a conceptual model for approaching the problem. Aspects of this are tested by correlating runout behaviour with landslide charcteristics including: slide volume, pathway slope angles, and material properties. The tests are limited to shallow, rapid earthflows that occurred on Tertiary sandstone and mudstone in Wairarapa and Rangitikei during the winter of 1992.

Relationships between slope morphology, soil properties and the incidence of shallow landslides in eastern Taranaki hill country

R.C. DeRose
Landcare Research, Landcare Research - Manaaki Whenua, Palmerston North

Research is being conducted into the inter-relationships between slope morphology, soil properties, and the incidence of shallow landslides in a steepland landscape in the North Island of New Zealand. Eastern Taranaki hill country is characterised by a dendritic drainage pattern which has formed in consolidated Tertiary sandstone over a period of in excess of 600,000 years. Hillslope evolution is by the gradual colluvial infilling and periodic evacuation of 0-order basins. Residence times of soil and regolith decrease from greater than 26,000 years on gentle uneroding hillslopes to less than 1000 years on the steepest hillslopes. On slopes less than 31°, airfall deposits of andesitic and rhyolitic tephra within soil profiles indicate stability throughout the Holocene. On steeper hillslopes recurrent landsliding has generally removed these tephra and soils have developed in weathered bedrock or colluvial slope deposits.

Mapping of soils and landforms in this region is complicated by the extreme short-scale variation in surface form and associated soil properties. For example, there is poor correlation between soil depth to bedrock and slope angle over short measurement distances (<10 m), but in general there is a decrease in depth with increasing slope angle. Correlation can be greatly improved by spatially averaging depth and slope measurements over larger areas. The density of shallow landslides increases with increasing slope angle above a threshold slope of 28°. In addition, the spatial distribution of landslide scars depends on relative storm size. The threshold slope for landslides increases and the density of landslides decreases with decreasing relative storm size. Maps showing the spatial distribution of slope for areas of 600 m^2 to 10,000 m^2 in size are a useful tool to map soil properties and landslide hazard in eastern Taranaki hill country.

Hydraulic geometry of streams: does it provide an adequate basis for predicting the morphologic response of channels to climate change?

David Dunkerley
Department of Geography and Environmental Science, Monash University

It has recently been suggested that hydraulic geometry data will permit the response of streams to altered discharge, possible under enhanced Greenhouse climates, to be forecast for river management purposes.

There are many barriers to such prediction. In particular, the procedure would ignore the probability that some streams are close to a threshold of morphologic change. Catchment-derived sediment loads would alter in parallel with discharge, and could induce a fundamental adjustment of stream channel style (metamorphosis). Nor can it be assumed that the parameters employed in conventional hydraulic geometry (mean channel depth, mean annual discharge, etc) are sufficient descriptors of stream form and process. Bank erosion processes and degradation and aggradation in response to climate change involve other complex factors. Seasonality of flow regime, changes in hydrograph character, and changes in riparian and in-channel vegetation would also be overlooked in any extrapolation of contemporary hydraulic geometry. It is suggested that more sophisticated models, linking channel form to catchment parameters and not simply to discharge as the supposed controlling factor, are essential for progress in this area.

Some Thermal and Mechanical consequences of Denudation: implications for estimating denudation rates from thermochronological data

Derek Fabel
Department of Geography, University of Melbourne

The use of thermochronological data to derive denudation rates requires that the information about the variation of temperature with time be transformed into information about the variation of depth with time. This transformation depends on knowing or making reasonable assumptions about the variation of temperature with depth within the crust, specifically at the time that cooling was recorded by the thermochronological technique being used. The two major sources of uncertainty in estimating denudation rates in this way are the difficulty in constraining palaeo-geothermal gradients and the relationship between the process of denudation and the thermal structure of the crust. An assumption commonly made either explicitly or implicitly by most interpretations of thermochronological data is that the geotherm is not significantly affected by the denudation responsible for the cooling episode being measured. It is shown here that denudation directly affects the spatial distribution of temperature within the crust because heat is transported upwards by the process of advection.

To assess the significance of the effects of denudation with regard to using thermochronological data to document denudation rates, the thermal effects of

denudation are quantitatively examined using a simple one-dimensional thermal model. Model results show that errors well in excess of 1 km can be introduced into the estimation of depth of denudation if advection is ignored.

The results also indicate the need to consider both the rate and duration of the denudation episode when deciding on what represents an appropriate threshold rate of denudation below which the effects of advection can be disregarded.

Palaeomagnetism of New Zealand glacigenic deposits

Sean Fitzsimons
Department of Geography, University of Otago
Michael Pollington
Department of Geography and Environmental Studies, University of Tasmania
Eric Colhoun
Department of Geography, University of Newcastle

In Tasmania and South America palaeomagnetic studies of glacial deposits have proven to be a useful means of identifying Early Pleistocene deposits on the basis of polarity of glaciolacustrine sediments. These studies stimulated a pilot project that was designed to test the existing New Zealand stratigraphic model by examining the polarity of glaciolacustrine sediments. Sets of specimens were collected from 16 sites that represent major periods of glaciation in the South Island. NRM of the specimens was measured using an ScT cryogenic magnetometer in the AGSO/ANU Black Mountain Laboratory. Representative specimens were selected from each sample site and step-wise demagnetized using an alternating field demagnetizer. On the basis of the demagnetization results the remainder of the specimens from each sample site were demagnetized at one or two steps between 10 and 30 mT. Three groups of specimens can be distinguished on the basis of demagnetization behaviour. Group I sediments are distinguished by high stability magnetic remanences that decay linearly to the origin on Zijderveld diagrams and plot as tight clusters on equal area nets. These sediments are of highest quality data. Group II sediments are distinguished by poorly defined characteristic magnetization mostly confined to a single quadrant of the equal area plot. Group III sediments show an unstable characteristic demagnetization that does not permit an evaluation of the polarity. The results show that valuable stratigraphic information can be obtained from discontinuous terrestrial sequences. Perhaps more importantly, the results demonstrate that palaeomagnetic data, used together with other dating techniques and field mapping can generate important questions and lines of enquiry that are not otherwise obvious.

A landslide and debris impact hazard map for Wellington City

Michael Gee
Wellington

Landslides in the Wellington area, broadly, are of two types: those originating from fill or cut rock batters, and those originating from natural hillslopes. This second type, shallow regolith movements best described as debris avalanches or debris flows, tend to be larger than the first type and, from an emergency management perspective, pose a greater hazard to life and property. Developed urban areas in Wellington City immediately at the bases of undeveloped hillslopes are at risk from shallow regolith landslides from the slopes above during rare, intense rainstorms. At greater risk, however, are developed areas adjacent to the exits of small streams and gullies that drain undeveloped hillslopes. Such sites may be inundated by landslide and flood debris. Previous studies of historical landsliding in Wellington have identified the rainfall required to trigger landsliding and have quantified the relative landslide susceptibility of different natural hillslopes. From these data a landslide and debris impact hazard map has been constructed using a 1:50,000 scale topographic map supplemented by field checking. Although simple and quick to produce, the map provides the relevant information in a form that is of immediate use to an emergency manager. The manager, knowing the approximate frequency, magnitude and consequences of the hazard impact event, can set priorities in relation to other hazard types that also have the potential to create mass emergencies. It is possible that similar simple maps could be produced at little cost for areas other than Wellington.

Estimation of wind erosion using the radionuclide caesium-137 on the Nullarbor Plain karst, Australia

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The Nullarbor Plain is the largest karst area in Australia (220,000 km^2) and one of the largest in the world. The landscape is divided into extensive closed karstic depressions or dongas separated by low rocky ridges, and the dominant vegetation types are varieties of chenopod shrubland. This study integrates GIS modelling providing estimates of the extent of potential erosion with long-term erosion rate estimates using fallout radionuclides. Seasonal wind drift potential is moderate while soil transport is controlled by vegetation cover with a threshold at around 15% projected foliage cover. Wind erosion is dominant around stock watering points where grazing by sheep and rabbits bares the soil. During droughts, loss of annual plant cover extends potential wind erosion to other open shrubland vegetation. A partial sediment budget using caesium-137 inventories reveals a pattern of soil movement around this landscape. There is a net movment of soil from open sites to

mounds that accumulate beneath the adjacent chenopod shrubs, presumably due to wind trapping effects. Soil also appears to move from the donga depressions up to the ridgelines, and is thought to result from wind transport of soil bared around stock watering points or by overgrazing. The combined average of ^{137}Cs inventories from these sites was equal to the 'reference' ^{137}Cs value determined for this landscape, within uncertainties, and confirms that net soil loss from this landscape is negligible although moderate redistribution does occur on a local scale within the karst depressions themselves.

Late Wisconsinan and Holocene sedimentation of Silverhope Valley, British Columbia, Canada

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Late Wisconsinan evidence suggests that during the downwasting and retreat of the Cordilleran Ice Sheet between approximately 11 500 and 11 000 years BP, there was one minor readvance and two small oscillations in the valley. During deglaciation a dead ice-dammed lake formed in front of the retreating ice mass. Partial lake drainage occurred initially by catastrophic flooding through dead ice into the contiguous Chilliwack valley over a low pass. Subsequent lake levels were controlled by dead ice decay, hummocky terrain, ice marginal drainage and height of the retreating ice mass.

Burial of Mazama tephra found in periglacial alluvial fans suggests that following deglaciation, meltwater reworking of glacial sediments was more rapid on the west side of the drainage basin.

More recently, landslide-damming (probably seismic-generated) of Silver Lake appears to have taken place around 1100 AD. Radiocarbon ages indicate that sedimentation in the lake occurred at a rate of about 0.14 cm a^{-1} until 1946, with Silverhope Creek forming a delta into the southwest side of the lake. In 1946, diverted flows built a new delta into the southeast side of Silver Lake at the commencement of major logging activity and road construction around and to the south of Silver Lake. Caesium-137 traces indicate that post-1946 sedimentation rates have increased to approximately 2.75 cm a^{-1}. Rates do not appear to have declined significantly in the last twenty to thirty years.

Rainfall simulators: Do they really simulate rain?

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Rainfall simulators have been developed to control the intensity, frequency and duration of rainfall events, while conducting erosion/runoff experiments. Raindrop

size and fall height determine kinetic energy of rain and consequently its erosive power. Therefore, ideally raindrops produced by rainfall simulators should mimic the size of real raindrops and deliver comparable energy to the ground. Similarly, raindrop impact flow detachment and transportation should simulate natural processes.

But can rainfall simulators simulate rain?

Using results from rainfall experiments in Arnhem Land, Northern Territory, the advantages and disadvantages of using the Colorado State University rainfall simulator system in erosion/runoff experiments is discussed.

Application of predictive sediment yield models in resource management - the Karori Reservoir case

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The Upper Karori Reservoir, Wellington, New Zealand has recently been decommissioned as a water storage reservoir for the Wellington Regional Council. The sediments deposited over the life of the dam (some eighty years) provide an excellent record of sedimentation and erosion history for the catchment. This presents an opportunity to test the actual yield of the catchment against predictive models of catchment sediment yield.

This paper presents the results of a comparison of pre-deposition and post-deposition land surfaces, surveyed in 1908 and in 1992-93 in order to test three models of catchment sediment yield. The original survey data from Wellington Regional Council survey plans were digitised into computer format in order to run modelling programs in TECHBASE. 1992-93 survey data were also entered into the program and modelled in the same way, the resultant surfaces were then compared using cells to determine the thickness of sediment between the two surfaces.

This method presents problems such as accounting for the density of sediments, the amount of bedload material and the organic content of the sediment. Comparison of two differing sets of data is difficult as the original datums no longer exist. New datums need to be established, shifting the area of comparison. The three models tested against the actual suspended sediment yield of the Karori Reservoir are: McSaveney (1978), Griffiths (1982) and Streeter (1982).

A preliminary estimate of 348 $t/km^2/yr$ for the catchment erosion rate (figure still under revision) compares reasonably well with calculated rates given by empirical formulae by Streeter (1982) 295 $t/km^2/yr$, McSaveney (1978) 230 $t/km^2/yr$, and Griffiths (1982) 256 $t/km^2/yr$.

This figure is high when compared to other catchments within the Wellington Region, for example Morton dam 27 $t/km^2/yr$; Pauatahanui 98 $t/km^2/yr$ and

Pauatahanui (Curry 1981) 37 t/km^2/yr. The reasons for some of these differences may stem from the methods of yield calculation, catchment size (and storage potential) and frequency, intensity and spatial distribution of sediment producing storms.

Results indicate that the predictive models tested should be used only as a general indication of the probable rate of erosion in the catchment concerned, rather than the actual rate of erosion, as there are many other factors involved in the production of sediment from a catchment apart from its climatic character.

Sediment and landform associations of arid polar glaciers

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The features of many glacial landscapes have been recognised as being organised into three-dimensional patterns depending on the nature of the glacier, and these patterns have been termed sediment and landform associations. While associations are well established for temperate and polythermal glaciers, the depositional mechanisms of polar glaciers are not well defined. It has been proposed that because of their frozen beds and lack of meltwater, these glaciers form distinctive depositional sequences. This proposition was tested by attempting to develop a depositional model for dry based alpine glaciers in the Dry valleys, Antarctica. The elements of the model were determined by examining the contemporary depositional processes around the margin and the ice-marginal sediments and landforms. The model shows that the alpine polar glaciers do have distinctive ice and sediment characteristics but the deposited sediments and landforms are not significantly different to those of polythermal glaciers. The glaciers have a very low debris concentration and the sediments undergo little englacial comminution, generally remaining subangular with very little silt. Where the glaciers reach the valley floor, their terminus cliffs expose entrained blocks of lacustrine or fluvial sediments and basal debris bands and some deposits include lenses of similarly sorted material. The moraines formed have asymmetrical profiles and show evidence of fluvial erosion and mass wasting. Some of the larger glaciers, which have proglacial lakes, have thrust block moraines of lacustrine sediments similar to polythermal glaciers. These findings show the importance of climate, thermal regime, and bed morphology to the geomorphology of glacial deposits and have important implications for the interpretation of glacial sediments elsewhere.

Tectonic Geomorphic Domains of the Western Southern Alps, New Zealand

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Tectonic geomorphic analysis of active range fronts typically is designed to demonstrate along-strike differences in landscape assemblages that relate to relative differences in uplift rates along the range-bounding fault. Most past studies have presupposed that sections or segments of the range front having different tectonic histories are already known to exist; tectonic geomorphic analysis then is used to quantify relative differences in range-front activity. Here we use new methods of analyzing parameters such as sinuosity and axial ratios of drainage basins to obtain objective estimates of boundaries between distinct domains of similar landscape character along the western margin of the Southern Alps, avoiding reliance on a priori definitions of mountain-front segments. Four geomorphic domains are defined between the Taramakau and Cascade rivers. The northern domain is characterized by a narrow range with a very steep rise from the range front and relatively smoothly steep rivers. The north-central domain encompasses two large basins that also rise steeply at the range front and have more irregular river long profiles. The transition to the south-central domain occurs in the area of the Waiho and Fox rivers. Here the range becomes especially narrow, yet much of the relief occurs in the headwaters of the basins. The south-central domain is dominated by the anomalous Haast-Landsborough river system, which may in part have advected (been captured) from the east side of the Southern Alps, diverting the range crest eastward. The southern domain begins at the Haast River and is characterized by rivers and basins elongate along structures within the Haast Schist.

Eustatic record of the Pliocene: beach ridges of the Parilla Sands, Murray Basin, southeastern Australia

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The dunefields of the Cainozoic Murray Basin are underlain by predominantly Tertiary marine sequences, the uppermost marine unit being the Parilla Sand of Late Miocene to Plio-Pleistocene age, a siliceous sand deposited under shallow-marginal marine to beach-barrier environments.

In western Victoria and adjacent areas of South Australia and New South Wales, the upper surface of the Parilla Sand comprises partly buried, topographically subdued, sub-parallel curvilinear ridges that trend north-west to westerly and extend for tens of kilometres. These curvilinear features represent coastal beach-barrier ridges, which run parallel to the large calcareous ridges of the Bridgewater Formation and the Coorong along the coast. They vary internally from marginal marine beach and off-shore barrier-bar. This composite beach-ridge strandplain, resulting from fluctuations in sea level associated with changes in polar ice volumes, permits definition of a sea level curve for the Pliocene, the precursor of the large-scale

glaciations of the Quaternary. Correlatives could be drawn between the continental record of sea level changes with those of the deep sea oxygen isotope curves which reflect Milankovitch-type changes in the ice budget of the world, and eustatic sea level changes can be approximated. The accuracy of the sea level approximations is constrained by local tectonic uplift along the Pinnaroo Block during the Late Pliocene to Pleistocene simultaneous with marine regression.

Because of the subdued expression of the ridges, conventional topographic and air photo analysis has been complemented by NOAA-AVHRR satellite imagery in the thermal wavelengths (10.3-11.3 μm and 11.5-12.5 μm respectively) with surprising success. The application of this tool, primarily used in the past for meteorological observations, has far reaching applications for regional geomorphic mapping of subtle landscape features.

Subsiding Banks Peninsula - myth or reality?

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Banks Peninsula is a late Tertiary volcanic complex linked to the South Island by the coalescing fans of the Canterbury Plains. It has been successfully shown that the Plains have subsided and this has led to the assumption by many that the Peninsula is also subsiding, although no conclusive evidence has been presented. Evidence to the contrary has, however, been presented in the form of observations of relict marine platforms on the peninsula adjacent to Lake Ellesmere at elevations of several metres. The higher of two sets of platforms is at an elevation of around 8 m. These platforms extend under a thick loess deposit to a buried cliff feature. The higher platforms are thus proxy dated as pre-last glaciation. Sea level is not likely to have been higher than 8 m in the past and therefore the presence of marine features at this elevation indicates that Banks Peninsula has not subsided in the last 120 000 years.

Slope development at Radok Lake, Antarctica

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Radok Lake (70° 50' S, 68° 00' E), which occupies a 10km long by up to 2.5km wide basin in the Prince Charles Mountains, is Antarctica's deepest lake (~350 m). It is surrounded by steep slopes rising 150 m-400 m above the frozen lake surface, which is at 7 m above sea level. A 5 km stretch of the eastern shore is the focus of this paper. Here, slopes 100 m-150 m high are formed in arkosic sandstones and

siltstones that exhibit remarkably uniform lithology, overall dip and strike, and rock mass strength. Despite this uniformity of underlying structure, three quite distinct slope forms occur along the shoreline (from N-S): a northern section of debris mantled slopes (max slope angle ~30°) with numerous shallow gullies; a central section of debris mantled slopes (max slope angle ~36°) with free-face elements; a southern section of cliffs with richter slopes (slope angle 37°) at the base. The northern slopes appear to be undergoing slope decline, the central section slope replacement, while the southern section is showing parallel retreat slope development. These differences are believed to represent subtle variations in the balance of slope processes and conditions above and below the steep slopes. The overall form of the slopes suggests that in these conditions slope decline is a more rapid development style than slope replacement, and parallel retreat is the slowest form of slope development.

Mega-rip dimensional analyses on the Sydney coast, Australia

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Mega-rips are large-scale erosive rip currents that occur by definition under high wave conditions ($H_b \approx > 3$ m) on embayed coasts where topography prevents the dissipative beach-state. These currents remain relatively unstudied but are thought to significantly contribute towards nearshore sediment dynamics. Currently, mega-rips are omitted from beach-state models and are viewed as a 'separate case'.

Data, in the form of oblique aerial photographs, for 23 mega-rips on the Sydney coast were rectified to the vertical using an image processing system (IDRISI) so that real measurements of mega-rip and embayment dimensions could be made. Two mega-rip systems were identified: (1) single-celled, where only one longshore feeder current existed and a single mega-rip was topographically arrested at one of the headlands, and (2) multi-celled, where the mega-rip was fed by two or more (in the case of > 1 mega-rip) longshore feeder currents. Single-celled mega-rips occurred in embayments < 2.5 km in length and multi-celled mega-rips occurred for embayments 2.5-5.0 km long. Longer embayments tended towards the dissipative beach-state.

The influence of topography on mega-rip occurrence and beach-state is quantified by a proposed non-dimensional embayment scaling parameter, δ'. When $\delta' > 19$, the existing accepted beach-state model based on Ω (dimensionless fall velocity) operates. When $\delta' \leq 19$, the influence of topography on beach-state becomes significant with 'transitional' beaches occurring when $8 < \delta' \leq 19$ and 'cellular' beaches (single lateral circulation cell) occurring for $\delta' \leq 8$. A revised beach-state model based on Ω and δ' is presented. Using these non-dimensional parameters it is shown that the two mega-rip types may occur as modal beach-states termed 'Cellular Mega-rip' for single-celled systems and 'Super-rhythmic' for multi-celled systems. A predictive model for the occurrence and size of mega-rips based on H_b

and embayment size is given. This may be used to determine the seaward extent of offshore sediment transport during mega-rips.

Barrier stratigraphy of the macrotidal central Queensland coastline

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The central Queensland coastline represents a macrotidal, fetch-limited and low wave energy environment with a low gradient continental shelf. Offshore sediment and seismic data indicate an inner-shelf depleted of holocenic sediments, with a pre-Holocene substratum outcropping in many places. The character of the coastline is controlled by the dominance of either waves or tides and varies along the coast due to the differences in exposure to the waves. The dominance of one over the other is strongly influenced by the alignment of the coast to the predominant southeasterly wind and wave direction. Wide intertidal flats characterise areas sheltered from wave activity whereas sandy barrier systems occur in areas not sheltered from the waves.

The morphostratigraphy of two of these barrier systems was investigated. The studied barriers have many characteristics in common with the more extensively studied microtidal barrier systems and may be classified as progradational barriers with transgressive and regressive sequences. The transgressive sequence formed during the Holocene transgression and evolved according to the classic mechanism of "shoreface retreat" as evidenced by the basal mud layer underlying the barrier. The regressive sequence formed under a falling sea level, and, for the barrier systems north of the mouth of the Pioneer River, an abundance of fluvial and continental shelf sediment supply. The thickness of the macrotidal barrier sequences is around 10 m, and the limited vertical extent of the barriers is ascribed to the gentle gradient of the continental shelf (1/1000) off the central Queensland coastline.

The morphostratigraphies of the barrier systems indicate sea level was at least 2 m higher than present at the maximum PMT. This is in general agreement with models of isostatic rebound and field evidence from northern Queensland. In addition, the variation in the thickness of the two beach stratigraphic units identified in one of the profiles suggest the occurrence of a high energy window (associated with higher wave energy) and a tidal window (associated with small tidal ranges) close to the maximum PMT.

The character of the sediments contained in the barriers and the prevailing northward littoral and nearshore drift within the study area suggests that the barriers south of the Pioneer River are predominantly supplied by the continental shelf whereas the barrier systems north of the river mouth are composed of sediments derived from both the Pioneer River and the continental shelf.

Multivariate analysis of sediment-biota distributions in the Pambula Estuary, N.S.W.

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Sampling of the surface sediments and invertebrate fauna of the Pambula Estuary has been undertaken to study the relationship between measurable sediment parameters and the invertebrate population. Multivariate analysis techniques (cluster analysis and ordination) have been used to identify possible boundaries between populations and comparisons with the hydrodynamic pattern have been made in order to delineate habitats related to salinity and velocity distributions in the estuary.

The pattern of invertebrate fauna was dominated by mollusca and polychaeta. In the tidal entrance channel sandy sediments and gastropods form the correlated populations. Polychaetes, although distributed throughout the rest of the estuary, are most obvious in the muddy sediments in the back of the lake. The tidal river channels exhibit a range of fauna which appears dependent on the substrate properties which range through gravels, sands and muds.

Beach cusps as sea-level indicators

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The elevation of a set of beach cusps on a mixed sand and gravel beach type exposed to an East Coast Swell environment was found to be related to relative sea-level. A relationship between beach cusp interhorn spacing and the elevation of the horn on the beachface is described and has been related to relative sea-level. This relationship has been used to predict the elevations of a series of relict cusps preserved on a series of regressive beach ridges inland of the present day Leithfield Beach. A discrepancy was found between the elevations predicted by the relationship, and the measured elevation of the cusps. The measured elevation of the ridges is 0.6 to 1.0 m higher than the heights predicted by the relationship. This difference in elevation is interpreted as being the result of a combination of tectonic uplift and a eustatic fall in sea-level, with there being insufficient information to separate the influences of the two.

The Murrumbidgee River system - flood sediment transport

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The Murrumbidgee River is essentially a controlled river where the flow regime has been completely altered to supply irrigation waters for the Murrumbidgee and Colleambally irrigation areas. This control is exerted by two major storage dams in the upper river and a series of weirs downstream. During flood events there is little regulation and the river behaves as a more natural fluvial system. This paper examines two floods in the system in July/August 1991 and October/November 1992. The 1991 flood was generated by water from Burrinjuck Dam and downstream tributaries while in 1992 the discharge was from Blowering Dam and downstream tributaries.

Both floods showed similar response patterns. Transmission time of the flood pulse through the system is in the order of 25-30 days with a marked reduction in the flood peak and attenuation of the hydrograph downstream. At Balranald on the lower river there was no discernible discharge pulse. Sediment concentration showed similar trends but the pulse was still clearly defined at Balranald and the transmission time was considerably less at 18 days. The sediment pulse leads that of discharge with the lead increasing downstream.

Water and sediment budgets were also determined for the two floods. Discharge peaked around Wagga and then there was a progressive downstream transmission loss with the flow at Hay, the lowest point on the river where the pulse could be detected, approximately 50% that of Wagga. Sediment loads peaked at Wagga and then decreased rapidly to Narrandera where it was approximately 40% of the Wagga load. Only 10% of the Wagga load was delivered at Balranald. It appears that most of the sediment is derived from the tributaries between the storage dams and Wagga but it is deposited in the reach between Wagga and Narrandera where the river enters the riverine plain.

Determining the sources of sediment on forested hillslopes after partial logging using natural and anthropogenic radioactivity

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Measurements of the lithogenic radionuclides ^{226}Ra and ^{228}Ra are used to demonstrate that no single source dominates the sediment moving in a partially logged, forested catchment (76.9 ha), located in the Yambulla State Forest near Eden, New South Wales, Australia. Point sources in the catchment were found to have different $^{226}Ra/^{228}Ra$ ratios, resulting from both the redistribution of radium during weathering and the marked difference in the half-lives of the radium isotopes (1600

year and 5.8 years respectively). Sediment present in the drainage lines had ratios ranging from 0.52 to 1.8. Such variations indicate that the sediments have been derived from numerous small point sources and are not dominated by material from the upper logged slopes of the catchment. This conclusion is also supported by ^{137}CS concentrations in the stream bed material which indicate that while surface soil is entering the channel from the upper catchment it is being diluted by erosion of subsoil material exposed along the channel banks.

Morphotectonics of the Endrick River region, New South Wales

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Eocene basalts at the Endrick River in south-eastern New South Wales were deposited within a valley that had at least 150 m of relief (Young & McDougall, 1985). Young and McDougall (1985) suggested that uplift of the Eastern Highlands must have caused this erosion by the time the basalts were deposited.

The drainage controlling the erosion, however, flowed north-west *towards* the Great Divide. The results of this study show that the major earth movements shaping the topography occurred east of the Endrick River basalts, not in the west near the Divide.

Lineaments, fracture alignments and drainage network patterns in the east indicate a NNE-oriented axis of subsidence at the edge of the Clyde River basin. Fissure basalt eruptions followed the subsidence. In the west the preservation of the NW-flowing basalt valley and pebble imbrication of Eocene sediments west of the Shoalhaven River indicate stability of drainage directions since at least the Eocene. A dendritic drainage net has been traced from these results. This drained the position of the present continental margin.

Cretaceous intrusions of monzonite and essexite occur at this location of the present margin. Veevers (1986) used these to indicate the location of a magnetic arc with associated uplift of a margin range prior to the breakup of the Tasman Rift. The subsequent subsidence of this margin range accounts for nearly the entire height from the level of the Divide to the coastal plains. These results indicate that uplift may not be the only process that shaped the Eastern Highlands of Australia.

References:

Veevers, J.J. 1986 *Phanerozoic Earth History of Australia.* Oxford: Clarendon.
Young, R.W. & McDougall, I. 1985 The age, extent and geomorphological significance of the Sassafras basalt, south-eastern New South Wales. *Aust. J. Earth Sci.* 32:323-331.

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Earthflows - a wander through a decade or so of research on the East Coast of North Island

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Earthflows and their complexes are a common landform of the eastern flanks of the Raukumara Peninsula. Landcare Research (formerly Forest Research Institute) have been studying earthflows since the late 1970s. Research initially concentrated on the nature and distribution of earthflows then moved towards determining the spatial and temporal activity of selected earthflows. Much of the earlier work was carried out on grassed earthflows and involved stake array surveys and simple experimental methods. In latter years, our need to understand the nature of the internal deformation of these feature and the role that trees play in modifying movement lead to development of new instrumentation. Our recent efforts have been to understand the nature and distribution of pore water pressure and how this relates to strength-strain behaviour of materials. This paper will review what we currently know about earthflows and will highlight where we think research should head.

Landscape palaeomagnetism

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The history of past changes of the Earth's magnetic field (palaeomagnetism) is commonly used by geologists for correlation and dating of rocks. Broadly, there are three main approaches - secular variation, magnetic reversals, and apparent polar wander - on timescales of 10^2–10^4, 10^4–10^8 and $>10^6$ years respectively. In this paper I will give examples of the application of palaeomagnetism to geomorphology, using the history of magnetic reversals (magnetostratigraphy).

A Natural Remanent Magnetisation (NRM) may be acquired by rocks in any one of three main ways: (1) Thermal Remanent Magnetism (TRM) is an NRM acquired when magnetic minerals in igneous and metamorphic rocks cool below their Curie points (several hundred degrees C). (2) Detrital Remanent Magnetisation (DRM) is acquired by sediments when fine grained magnetic minerals settle through air or water and become aligned with the contemporary geomagnetic field. Further re-alignment of grains may occur during sediment compaction, and this is referred to as Post-Depositional Remanent Magnetisation (PDRM). (3) Chemical Remanent Magnetisation (CRM) is acquired during the low temperature formation of secondary iron oxides by weathering processes. In each case, the acquired NRM provides a record of the magnetic field at the time of cooling/deposition/ weathering.

In geomorphology, CRMs can provide important clues to landscape history, including rates of soil formation, erosion and tectonic uplift. The examples I will discuss include basalt soils in eastern Australia, alluvial fan sediments in South Australia, and weathered greywacke in Wellington, New Zealand.

Thermoluminescence dating: the good, the bad and the ugly

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Thermoluminescence (TL) dating has successfully found wide application on the Australian continent. At the Wollongong University laboratory the method has been extensively applied in the age determination of sediments ranging from as recent as five hundred years and it has been demonstrated that it is possible to measure the depositional age of samples back as far as one million years. TL has been successfully applied to sediments of an extremely diverse nature ranging from alluvial, aeolian, coastal and lacustrine sediments to tsunami deposits and off-shore marine sediments. In the main, TL is well suited to the age determination of Australian sedimentary deposits. Australian sediments generally consist of a high percentage of quartz which is both TL sensitive and able to store the accumulated TL in a stable fashion over extremely long periods of time. Additionally, frequently long sediment transport distances are involved before final deposition and high levels of the sun's ultra-violet radiation are likely to be encountered prior to final deposition. All of these factors contribute to the suitability of a sediment for the application of the TL dating method and to an accurate TL chronology. For all this, the method is not without its problems and these may quite easily lead to an incorrect age determination in the laboratory. Substantial errors can arise from several sources such as incomplete removal of the previously acquired TL signal prior to the last deposition, incorrect estimation of the palaeo-moisture content and the removal of the radioactive salts from the sediment by leaching. Bioturbation may also provide a further source of error.

The strengths and weaknesses of TL as applied to sedimentary dating are discussed giving examples of some of the problem areas encountered and how these might be recognized in the field prior to sample collection. As with other dating techniques poor samples generally lead to misleading sample ages and this situation is not often redeemable in the laboratory. Finally comparisons are given of sample ages derived for the same sedimentary sequences using differing dating techniques with those determined from TL analysis as well as inter-laboratory and TL methodology comparisons.

Surface wash erosion, channel initiation, and hydraulics of overland flow in hillslope hollows

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Our understanding of the hydraulics of overland flow comes mainly from laboratory studies and simulated rainfall experiments. Little work has been conducted on well vegetated natural surfaces, particularly at the high Reynolds numbers of concentrated flow in hollows. I report results of flume experiments conducted over natural grassland in the Coast Range of Northern California. Flow resistance, boundary shear stress, and sediment yield were investigated under undisturbed and clipped grass conditions.

Results show that with progressive clipping of grass the Darcy-Weisbach friction factor becomes increasingly less sensitive to Reynolds number, and at low Reynolds numbers, flow resistance due to vegetation dominates over form and grain resistance. Velocity measurements suggest that the vertical velocity distribution does not conform to either logarithmic or parabolic forms, but has a more complex structure influenced by vegetation cover. Under these conditions boundary shear stress may be insensitive to changes in discharge.

Initial sediment transport can be related to boundary shear stress in excess of a critical value, but continued sediment transport is limited by availability, so that channel initiation in hollows requires a much greater boundary shear stress to enable incision into the root mat. Implications of these results for hollow development and modelling channel networks will be discussed.

Landslides as singularities in the geomorphic cycle

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The development of landscapes can be described phenomenologically as the outcome of the operation of a few simple fundamental principles amongst which the Antagonism Principle is the most fundamental one. It states that there are two types of processes active in the formation of a landscape at the same time: the endogenic (tectonic) and the exogenic (meteoric) processes. These two processes have a fundamentally different stochastic nature: Endogenic processes are essentially non-random, exogenic ones essentially random. Generally, these two processes more or less balance each other; thus the actual aspect of a landscape corresponds to the instantaneous dynamic equilibrium between them. If one of the external parameters is changed, the equilibrium is re-established by a corresponding continuous change of the other parameters (process-response theory). However, it is well known that the dependences between various landscape parameters may become multivalued at junctions, cusps etc.; in that case, small random perturbations can send the system from one branch of the process-response curve to another branch: a natural disaster

occurs. Applied to slopes this implies a suddenly occurring instability which expresses itself in a landslide. Such landslides are part and parcel of the geomorphic cycle, inasmuch as the continuously occurring tectonic uplift has to be balanced by a corresponding removal of mass.

Landslip characteristics on Macquarie Island

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The surface of much of Macquarie Island (54°30'S 153°57'E) is peat. Landslips are common occurrences on both high and low angled slopes. The characteristics of a total of nine slips on a range of slopes were investigated. Heavy rain appears to be an important triggering mechanism; tectonic activity may also be a contributing factor. The slip plane of landslips on high angled slopes has a characteristic surface layer.

Mixed sand and gravel barrier beach response to storms

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Breaching of the mixed sand and gravel barrier beach system near Wainono Lagoon in South Canterbury, South Island, New Zealand has caused significant damage due to widespread saltwater flooding. Determination of the processes and morphological factors that result in breaching can help to predict likely breach positions so that an attempt can be made to reduce the hazard. The short term effects of four storm events were examined and are described. Most of the foreshore adjustment occurs in the middle and upper foreshore during high energy events. The antecedent condition of the foreshore is an important control on the type of beach response. Profiles with foreshore volumes over 130 $m^3.m^{-1}$ of beach, and foreshore widths greater than 35 metres sustained less damage to the barrier crest than those with lesser dimensions. The responses do not necessarily result in net erosion to the beach profile. Instead, they are a complex reflection of the unique morphological characteristics of mixed sediment beaches.

Gully initiation and valley floor vegetation on the Southern Tablelands of New South Wales

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Dramatic gully erosion has accompanied the introduction of agriculture in many parts of the world. Historical gully erosion on the Southern Tablelands of New South Wales has been associated with European settlement of the district. Holocene gully erosion has been discussed in terms of climatic change and intrinsic instability leading to channel incision. However, the causes of gully erosion have usually been considered in qualitative terms, and few studies have attempted to quantify the forces of erosion and the resistance to erosion that lead to channel incision.

In order to quantify the resistance to flow on a vegetated valley floor, experiments were conducted on a swampy meadow using a large flume to determine the Darcy-Weisbach friction factor and Reynolds number for a variety of vegetation covers. Measurements of the critical shear stress for scour were also taken.

Results from the flume experiments indicate that historical gully erosion has been caused by changes to the vegetation on the valley floor and is insensitive to increases in discharge that result from climatic or land use changes.

Sediment Budgets of Large Drainage Basins

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The sediment budget is defined as a formal procedure of accounting for the production, erosion, transportation and deposition of sediment and solutes at a site, over a landform or through a drainage basin. The equation $I + \Delta S = O$, where I is input, S is storage and O is output, may apply over short time periods for mesoscale landforms. For large drainage basins, S is large and the time period of integration is very long. The sediment budget of such basins must therefore be extended through time to allow interpretation of Holocene landform evolution. The sediment budget of the Lillooet River basin in British Columbia (3,150 km^2) is developed to exemplify this methodology. Sediment and solute transport processes in Holocene time are identified and quantified. The budget is demonstrated to be severely unbalanced. Historical events and transient response to those events are implicated. A minimum of four time scales of integration - geological, Pleistocene, Holocene and contemporary - are proposed, and the role and status of the components of the sediment budget are examined. Storage sites and solute links, linkages among sediment and solute transport processes, the role of biotic factors, weathering, stratigraphic evidence and the hydrologic balance are individually reviewed. Spatial scale considerations provide a way of interpreting and aggregating the above complex factors. In general, there appears to be no spatial scale at which sediment and solute supply from the slopes is in balance with storage change and yield over

specified time periods. The importance of landforms composed of stored sediments, their mapping, dating and interpretation is thereby emphasised.

Processes and rates of gully erosion in a pine plantation, Bombala, NSW

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Softwood forestry is a contentious landuse in eastern Australia and its future will depend partly upon an ability to limit land degradation processes such as gully erosion and accelerated sediment supply to streams. Development of the Kapunda pine plantation, south of Bombala, in 1988 resulted in rapid development of discontinuous valley side gullies. This has led to forestry management problems for the NSW forestry commission. Firstly the gullies continue to erode and limit forestry operations. Secondly there is the possibility of increased sediment delivery to streams.

A project has begun to: (i) determine the importance of particular hydrological processes in gully development; (ii) measure and predict rates of gully erosion; and (iii) construct a sediment budget focusing on the sources of sediment and sediment delivery to streams. Therefore hydrological and erosional processes will be monitored over the next two years. Overland flow and seepage processes will be monitored separately using piezometers, runoff plots, pluviometers, seepage traps and erosion pin networks. Repeated surveys of gully erosion and alluvial fan deposition will be used to determine sediment delivery to streams. Methods, potential causes of gully erosion and preliminary results will be reported.

Holocene progradation record from Okains Bay, Banks Peninsula, Canterbury, New Zealand: work in progress

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An investigation of a coastal progradation sequence from Okains Bay, Banks Peninsula, Canterbury, New Zealand is currently under way. In all, 60 ridges of mixed aeolian and marine sediments have been identified behind the modern coast. These ridges may be divided into five major groups on the basis of morphology and orientation. The groups are believed to represent variation of supply during the mid to late Holocene. Terrestrial input of sediments into Okains Bay is small and it is known that the sediments in the modern beach are derived from a sand bank on the Canterbury Shelf. This sand bank in turn is fed by material swept around the end of Banks Peninsula and is originally derived from the erosional South

Canterbury coast. As such, the ridges preserved in Okains Bay may provide a proxy record of coastal erosion in South Canterbury.

The current investigation is attempting to determine whether a signal of coastal erosion and/or climate change can be extracted from the sedimentary sequence. To this end, the sequence is being dated using TL and radiocarbon and the stratigraphy and sedimentology of the ridges are being deciphered. This study will provide a useful insight into the long-term sediment budget of the Canterbury Shelf.

Soil geomorphic models and the interpretation of slope evolution through the processes of mass movement

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An adaptation of Butler's K cycle model is presented and applied to the evolution of slopes at the scale of bedrock hollows to low order drainage basins. In the model, slope evolution proceeds in repeating cycles, each comprising a period of regolith production (**recovery time**), a period of minimal slope modification and maximum slope stability and soil development (**residence time**), and a period of soil and regolith removal by one or many individual mass movements (**evacuation time**). Slopes in recovery time are characterised by areas of exposed debris mantle or bedrock on upper slopes, and accretionary and composite soils within the aggrading debris mantle wedge on lower slopes and in hollows. Slopes currently in residence time are characterised by a virtual absence of exposed bedrock and the evolution of soil catenas which developed in response to hydrological gradients within the debris mantle. The debris mantle may represent a single lithological unit or may contain multiple soil stratigraphic units indicating the incomplete removal of the debris mantle during previous evacuation times. Slopes in evacuation time are indicated by the progressive and continued removal of soil and debris mantle from hollows and sideslopes until a new stability is attained by either the exposure of more resistant bedrock or by the progressive accumulation of a colluvial wedge of transported soil and debris in hollows and on footslopes. Case studies from the eastern front range of the South Island provide examples of bedrock hollows and low order drainage basins in recovery time and residence time, and case studies from Taranaki and northern Hawkes Bay in North Island provide examples of drainage basins in evacuation time.

Arid river systems of lowland central Australia: some preliminary findings

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Most previous studies of Australia's fluvial systems have focused on the relatively well-watered southeastern region and to date, little research has been carried out in

the arid and semi-arid areas of the continent. Recent fieldwork on the arid plains of central Australia has revealed a number of interesting fluvial features, most of which have received little attention in the literature. For example, a series of narrow, tree-covered alluvial ridges aligned parallel to the channel banks have created a multichannel planform in some reaches, with similarities to those observed in the monsoon tropics of northern Australia. Other features such as channelized splays, intermediate and terminal floodouts and unchannelled floodplains appear to be characteristic of the distal reaches of these arid river systems and also pose interesting questions as to the controls on their formation and development.

Reconstruction of Late Holocene storm-induced erosion, sedimentation and vegetation history

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The impacts of natural and man-induced forest clearance and pastoral land use on the erosion-sedimentation behaviour of a soft-rock hill country watershed was reconstructed by analysis of the sedimentary record. Extensive coring of the sediments of Lake Tutira and environs, located in a landslide-prone area of the east coast of the North Island, New Zealand, has provided a record of historic and late Holocene storm-induced erosion and sedimentation. Pulses of sediment representing individual storms can be distinguished by graded bedding in the cores. The chronostratigraphy of the cores has been determined using tephrochronology, pollen and diatom analysis, paleomagnetism, caesium 137 and radio-carbon dating, together with reference to historical documents including rainfall records.

Analysis of the historic record (European era) has allowed characterisation of erosion-sedimentation dynamics under pasture land use. Sediment pulses have been dated by matching with the rainfall record, and correlated spatially to determine their magnitude. Magnitude-frequency relationships for both rainfall and erosion-sedimentation have been established, and rainfall thresholds for significant sedimentation have been identified. A sediment budget (including identification and quantification of sediment source areas) has been constructed for the most recent major erosion event (Cyclone Bola), to link off-site (sedimentation) and on-site (erosion) processes.

Pollen analysis has been used to document vegetation changes between undisturbed podocarp/hardwood forest, bracken/scrubland following fire or volcanic disturbance, and pasture dominated systems of the European era. The pollen record has been compared with the sedimentary record of storm pulses and tephra layers of known age to determine the relative importance of natural events and anthropogenic fire and clearance.

Preliminary results indicate that even during pre-Polynesian times (800-1200 y BP) volcanic eruptions and drought episodes led to outbreaks of fire within the watershed that burnt considerable areas of forest. Burning practised by the Polynesians led to a predominantly scrub-bracken vegetation for several hundred years before European arrival in the 1870s. After Europeans arrived, there was widespread clearance by fire of the remaining forest and bracken, which was replaced by pasture and introduced plants. Sedimentation rates were relatively unchanged under the predominantly bracken and scrub cover induced by Polynesian settlement. However, with conversion to pasture, sedimentation rates have increased about seven-fold.

Environmental analysis of speleothems: an historical record from Auckland

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Microscopic luminescence banding in speleothems viewed under UV radiation has been reported by Shopov et al. (1989), who suggested that it may be related to variations in solar activity, particularly sunspots. Genty (1992) found speleothem banding when viewed under plain light in a 42 year old specimen from Belgium to be annual, with darker bands associated with drier years in the meteorological record. Baker et al. (1993) found microscopic luminescence banding in speleothems from the UK to be annual in parts of only 5 out of 43 samples.

The research reported here provides results of the analysis of a 65 year old speleothem from a tunnel in the Waitakere Hills near Auckland. It was photographed under both UV and plain light, data on banding being extracted by laser densitometry of the negatives, with an average of one reading per 10 days over the entire period.

Densitometer readings were compared to a range of environmental data for the same period (1925-1990), including a satellite-based estimate of solar radiation (ACRIM), temperature, rainfall, water balance, Southern Oscillation Index, and tree ring index. A significant relationship was found between plain light banding and solar radiation, cross-correlation clearly showing a sunspot cycle effect (10.7 year cycle). Luminescence banding showed the same relationship but less clearly. Thus Shopov et al.'s hypothesis is proven.

Spectral analysis of banding showed the sunspot peak and in addition a 5.33-5.41 year cycle, which may be a harmonic (0.5 sunspot cycle) or alternatively a reflection of the Southern Oscillation. The plain light spectra also showed a strong annual peak, but annual bands could not be clearly counted by eye.

None of the other relationships explored was unequivocally significant, but when cross-correlation data are compared similar cycles are frequently observed. In particular here is a suggestion that dark bands and low luminescence are associated with drier periods, as indicated by Genty (1992). Auckland has a very moist

environment, so extremes of rainfall are rather narrow; hence it is not the best location to explore a possible rainfall effect. However, when older speleothems from Waitomo, that experienced glacial changes in climate, are examined, it is evident that darkening of bands occurs prior to growth hiatuses; presumably a consequence of drying trends that culminated during glacial advances when growth sometimes stopped.

Evidence is therefore mounting that, in addition to proxy solar radiation data and the well known paleo-temperature record (from oxygen isotopes) that can be derived from speleothems, there is potential for a paleo-moisture record, partly from colour banding, but also from growth rates.

References

Baker, A. et al. 1993: Nature 364: 518-520
Genty, D. 1992: Speleochronos 4: 3-29
Shopov, Y. et al. 1989: Proc 10th Internat Congress Speleol (Hungary): 95-97

Measuring soil loss on forest slopes following harvesting - an approach using ^{210}Pbexcess to ^{137}Cs inventory ratios

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Measurements of the anthropogenic nuclide ^{137}Cs have been routinely used to measure soil movement and loss from hillslopes. It is proposed that a new method, which combines ^{137}Cs and fallout ^{210}Pb, offers an improvement in sensitivity over using ^{137}Cs alone. This technique assumes that the two nuclides have different penetration characteristics and involves using the changes in the core inventory ratio with depth. This change in ratio is first determined at a control location at which no soil loss is believed to have occurred. A number of soil cores are then obtained from the disturbed location and the average inventory ratio of these is calculated. The amount or volume of soil that has been removed from the disturbed site can then be calculated by the extent of depletion of this ratio compared with the ratio curve from the control site. This method has been applied to two harvested forests in N.E. Tasmania. These forests were subject to different harvesting procedures; Slope 2 had severe logging with multiple passes from snigging vehicles and complete crown and stem removal; Slope 3 had a 'sensitive' approach that involved low mechanical input and tree crowns being left on the site. The results indicate that an average depth of 41 mm of soil had been removed from slope 2 and that 16 mm of soil had been removed from slope 3. These are equivalent to a nett soil loss of 450 ± 50 and 165 ± 30 t/ha respectively from these slopes. The calculated soil loss for these slopes using this approach are then compared to values derived from applying the ^{137}Cs technique alone. Advantages and limitations of the ^{210}Pbexcess/^{137}Cs inventory method are also discussed.

Downstream variations in channel perimeter characteristics and their implications in the Clarence River, New South Wales

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The Clarence River has one of the largest catchments in the coastal rivers of New South Wales (29,000 km^2); it is also devoid of significant regulation. Like most coastal streams it was affected by a major regime shift in the late 1940s, as well as earlier in accordance with other adjacent systems. This paper briefly reviews the evidence for such changes but it concentrates on downstream variations in perimeter characteristics like: width, maximum and mean depth, cross-section areas and channel capacities. It also looks at perimeter responses to the present regime where historical data are available for comparison. Above Grafton, the limit of research, the channel is laterally confined, often with very long pools and bedrock riffles. These, together with frequent shifts from hard Palaeozoic to softer Mesozoic formations and back, help to explain some of channel variations and perhaps the lower rates of adjustment to the present regime found in several places.

Drainage and valley asymmetry in the Tertiary Hills of Lower Bavaria, Germany

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Valley asymmetry with steeper west facing valley sides is a common feature in the Tertiary Hills of Lower Bavaria. In most previous studies this has been attributed to microclimatic differences under periglacial conditions prevailing in the Pleistocene glacials. In contrast to the asymmetric valleys in this area, little attention has been given to the drainage networks which show asymmetry in length and number of tributaries on either side of the main stream. In meridional-trending catchments, extension of the drainage was apparently favoured in westerly directions, coincident with valley asymmetry. The asymmetric drainage development causes differences in slope dimensions and an imbalance in run-off and sediment supply on opposite valley sides, and is a possible explanation for many valley asymmetries. The asymmetric drainage is probably the result of the Pliocene initial conditions and the development and evolution of the networks in competitive situations.

Karst in Cainozoic limestones

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Karstification is a complex process controlled by the nature of the lithology, tectonic structure and climatic conditions. In particular, the variety of lithological characteristics can be very important in the degree to which karstification occurs.

Porosity, chemical composition and strength are extremely variable in limestones. Whereas massive, well jointed and relatively chemically pure limestones are traditionally perceived as having the best karst development, but on the other hand, the extensive Cainozoic limestones in Australia offer opportunities to understand karst processes in the softer, less compact limestones. Speleogenesis in Tertiary marine limestones and Pleistocene aeolianites can be discussed in terms of extent of limestones, degree and nature of karstification and the processes involved. Examples will be given from a range of sites in southern Australia.

Hillslope hydrology - the monitoring of a potential landslide site

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A climate station, soil moisture sensors and groundwater piezometers have been installed on a potential landslide site in Belmont Regional Park near Wellington.

Rainfall data and soil properties were obtained in order to make predictions of soil moisture response to rainfall through utilising the SWIM model.

The TECHBASE model is being utilised to manipulate and present data.

The climate station uses a Campbell CR10 datalogger to record the following climatic variables:

- solar radiation
- temperature
- relative humidity
- rainfall
- wind speed
- wind direction

Groundwater is measured using Dataflow 692 recorders, soil moisture sensors and piezometers.

Installation of the climate station was completed in February 1993. While awaiting the arrival of groundwater instrumentation, manual groundwater levels have been recorded following rainstorm events using an electronic probe.

Preliminary results have shown that the groundwater response to rainfall occurs as peaks and that these 'peaks' in groundwater rise and fall rapidly. The reasons for this most probably lie in the fact that Wellington has experienced a very dry winter and that most rainfall is contributing to recharge and consequently there is little or no build up of groundwater, and any corresponding increase in pore water pressures is minimal. It is hoped that the winter of 1994 will be considerably wetter than that of 1993, resulting in some conclusive data.

At the time of writing SWIM results are unavailable. The study is on-going.

A 250 ka record of glacial and interglacial events from the Aurora Cave System, Fiordland, New Zealand

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Suggate (1990) and Pillans (1991) have recently reviewed evidence for glaciations and climatic change in New Zealand during the past 2.5 Ma. The glacial record in the South Island contains many outstanding problems: (1) glaciations beyond the range of radiocarbon are poorly dated; (2) evidence has been revealed for fewer glaciations than evidently occurred if the deep-sea record is correctly interpreted; (3) the status and duration of intervals between known glacial advances is unclear; (4) the number of major advances in each glaciation is not well known; and (5) inadequate dating control makes it impossible to confirm proposed correlations of glacial advances across the Southern Alps and between South and North Island chronologies.

The research reported here sheds light on several of these issues by interpreting the stratigraphy in the Aurora Cave System near Te Anau, a cave that was repeatedly overrun by Pleistocene glaciers. Twenty-seven uranium series dates on speleothem accumulations associated with glacifluvial sediments constrain the record. Seven glacial advances are recognised in the last 230 ka. The dates below indicate the intervals within which the events occurred, although the older glacial advances occupied only a part of the intervals concerned.

Glacial Advance	Non-glacial Interval	Date (ka BP)
	Post-glacial	
Aurora 1		12-14
	Interstadial 1	14-17
Aurora 2		16-17
	Interstadial 2	17-18
Aurora 3		18-20
	Interstadial 3	20-37
Aurora 4		37-41
	Interstadial 4	40-41
Aurora 5		41-47
	Interstadial 5	47-66
Aurora 6		66-92 (66-70?)
	Last Interglacial	
Aurora 7		92-227
	Penultimate Interglacial	

Rapid melting occurred after 13.8 ka BP, but there is possible evidence for an advance (Aurora 1) just after this date. The Otira Glaciation comprised 5 glacial advances (Aurora 2-6 inclusive). Advances 2 and 3 occurred in the interval 15.2-20.4 ka BP, but dating errors overlap; so precise separation is not yet possible. The earliest advance of the Otiran (Aurora 6) occurred between 66-92 ka BP, evidence from a North Island speleothem indicating probably 66-70 ka BP. Since the cave extends only to 469 m asl, but kame terraces occur to 900 m and erratics to 1130 m, there is ample evidence for considerably older glaciations in the region.